

भारतीय मानक

IS 1893 (Part 5) : 2025

Indian Standard

**डिज़ाइन भूकंपीय जोखिम और संरचनाओं के
भूकम्परोधी डिज़ाइन के मानदंड — रीति
संहिता**

भाग 5 भवन

(सातवां पुनरीक्षण)

**Design Earthquake Hazard
and Criteria for Earthquake-Resistant
Design of Structures — Code of
Practice**

Part 5 Buildings

(Seventh Revision)

ICS 91.120.25

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Earthquake Engineering Sectional Committee, CED 39

FOREWORD

This Indian Standard (Part 5) (Seventh Revision) was adopted by Bureau of Indian Standards, after the draft finalized by the Earthquake Engineering Sectional Committee had been approved by the Civil Engineering Division Council.

About 61 percent of India's land area (with over 75 percent of its population living in it) is prone to moderate to strong earthquake shaking intensities (*see* Annex B of IS 1893 (Part 1) for MSK 1964 intensity scale for earthquake ground shaking). Hence, earthquake-resistant design and construction is essential.

This was first published in 1962 with the title 'Recommendations for earthquake-resistant design of structures', and revised in 1966, 1970, 1975 and 1984. In the revision, IS 1893 was decided to be published in parts. Part 1 'General provisions and buildings' was then published in the year 2002 and revised again in 2016. The significant changes in the 2016 version were: definition of design spectra for natural period up to 6 s; use of same design spectra for all buildings (irrespective of material of construction); intermediate importance category of buildings; flat slab buildings; clarity on dealing with the irregularity in structural systems; inclusion of effect of masonry infill walls in analysis and design; introduction of method for estimating the natural period of buildings with basements, step back buildings and buildings on hill slopes; and simplified method for liquefaction potential analysis. The other parts of IS 1893 which have been published are:

- Part 2 Liquid retaining tanks
- Part 3 Bridges
- Part 4 Industrial structures and stack-like structures
- Part 6 Base-isolated buildings

In the seventh revision of IS 1893 (Part 1), the Committee decided to present the provisions related to buildings in a separate part considering buildings as one of the type of structure and to keep abreast with rapid developments and extensive research carried out in earthquake-resistant design of buildings. In this revision, the Committee decided to present the provisions for different types of structures in separate parts, to keep abreast with rapid developments and extensive research carried out in earthquake-resistant design of different types of structures. The parts of this series are:

- Part 1 General provisions
- Part 2 Liquid-retaining structures
- Part 3 Bridges
- Part 4 Industrial structures
- Part 5 Buildings
- Part 6 Base-isolated buildings
- Part 7 Long-distance pipelines
- Part 8 Steel towers (*under preparation*)
- Part 9 Coastal structures (*under preparation*)
- Part 10 Tunnels (*under preparation*)
- Part 11 Earthen embankments and earth-retaining structures (*under preparation*)

This standard contains provisions specific to earthquake-resistant design of buildings, in addition the general provisions laid down in IS 1893 (Part 1). The provisions of this standard are presented in 4 sections, namely:

- Section 1 Additional criteria for all buildings

Section 2 Additional criteria for masonry buildings

Section 3 Additional criteria for concrete buildings

Section 4 Additional criteria for steel buildings

For adobe buildings, IS 13827 and IS 13828 shall be referred to, and for other building typologies, specialist literature may be referred.

In this standard, the provisions related to earthquake-resistant design of buildings had been subsumed from IS 1893 (Part 1) : 2016 with the following major changes:

Section 1: Additional Criteria for All Buildings

- a) 'Response reduction factor' has been renamed as 'elastic force reduction factor' with its values provided for more structural systems and revised for some structural systems;
- b) Importance factors have been adjusted in view of the revision in the hazard levels;
- c) Provisions on design for torsion about the vertical axis have been improved;
- d) Provisions on buildings have been harmonized from relevant provisions given in IS 4326;
- e) Additional provisions have been added for earthquake-resistant design of critical buildings; and
- f) Requirements for serviceability check under the effects of earthquake loads are dispensed with in the design of buildings.

Section 2: Additional Criteria for Masonry Buildings

- a) Provisions on buildings have been harmonized from IS 4326;
- b) Admissibility of different masonry structural systems in the earthquake zones is clarified; and
- c) Provisions of IS 17848 are subsumed in this standard, and hence IS 17848 will stand withdrawn after the publication of this standard.

Section 3: Additional Criteria for Concrete Buildings

- a) Expression for approximate fundamental natural period of buildings is revised;
- b) Admissibility of different structural systems in the earthquake zones is clarified; and
- c) Variation of the structural plan density of the structural walls with the earthquake zone and category of the building is provided.

Section 4: Additional Criteria for Steel Buildings

- a) Admissibility of different steel structural systems in the earthquake zones is clarified;
- b) Provisions on design of braces in moment-resisting frames with open storey(s) at any; and
- c) Provisions of IS 18168 are subsumed in this standard, and hence IS 18168 will stand withdrawn after the publication of this standard.

In the formulation of this standard, effort has been made to coordinate with standards and practices prevailing in different countries in addition to relating it to the practices in the field in this country. Assistance has particularly been derived from the following publications:

- a) ASCE/SEI 7-22, Minimum design loads for buildings and other structures, American Society of Civil Engineers, USA, 2022;
- b) IBC 2021, International Building Code, International Code Council, USA, 2021;

- c) NEHRP 2020, NEHRP Recommended Seismic Provisions for New Buildings and Other Structures, Volume I: Part 1 Provisions, Part 2 Commentary, Report No. FEMA P2082-1, Federal Emergency Management Agency, Washington, DC, USA, September 2020;
- d) NZS 1170.5: 2016, Structural Design Actions, Part 5: Earthquake Actions – New Zealand, Standards New Zealand, Wellington, New Zealand, 2016; and
- e) JICA, Specifications for Highway Bridges, Part IV, Japan International Cooperation Agency, 1994.

This standard contributes to the following United Nations Sustainable Development Goals:

- a) Goal 9 Industry, innovation and infrastructure towards building resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation; and
- b) Goal 11 Sustainable cities and communities towards making cities and human settlements inclusive, safe, resilient, and sustainable.

Also, considerable assistance has been given by Indian Institute of Technology Madras, Indian Institute of Technology Bombay, Geological Survey of India, India Meteorological Department, National Center for Seismology, Institute for Seismological Research, CSIR National Geophysical Research Institute, CSIR Central Building Research Institute, National Thermal Power Corporation, VMS Consulting Engineers Private Limited, R. S. Mandrekar and Associates, PVS Structech, PCR Structural Consultants, K and G Consultants, and several other organisations.

The composition of the Committee responsible for the revision of this standard is given in [Annex B](#).

For deciding whether a particular requirement of this standard is complied with, the final value observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 2022 'Rules for rounding off numerical values (*second revision*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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Indian Standard

**DESIGN EARTHQUAKE HAZARD AND CRITERIA FOR
EARTHQUAKE-RESISTANT DESIGN OF STRUCTURES —
CODE OF PRACTICE**

PART 5 BUILDINGS

(Seventh Revision)

1 SCOPE

The provisions of this standard (Part 5) are additional criteria specific to earthquake-resistant design of buildings, beyond those specified for all structures in IS 1893 (Part 1).

1.1 Masonry Buildings

1.1.1 Section 2 of this standard deals with the selection of materials, special aspects related to design and construction of new earthquake-resistant masonry buildings, including masonry buildings using rectangular masonry units with cast in-situ or prefabricated flooring and roofing elements.

1.1.2 Guidelines for earthquake-resistant design of buildings constructed using masonry of low strength and earthen buildings are covered in IS 13827 and IS 13828.

1.2 Concrete Buildings

1.2.1 Section 3 of this standard deals with the selection of materials and special aspects related to design and construction for cast in-situ earthquake-resistant reinforced concrete (RC) buildings.

1.2.2 The provisions of this standard are not applicable to design of buildings which are composed of:

- a) Only structural walls and slabs, with no beams and columns; and
- b) Structural walls, slabs, and beams, with beams oriented perpendicular to the minor axis of the thin structural walls without a boundary element at the interface of the walls and these beams.

1.3 Steel Buildings

Section 4 of this standard deals with the selection of materials, special aspects related to design and construction for earthquake-resistant steel buildings.

1.4 All Buildings

The provisions of this standard shall be used only in conjunction with the provisions of respective parts

of IS 1893, IS 13920 and IS 13935, and not with requirements of other standards that are based on design principles different from that adopted in this standard.

2 REFERENCES

The standards listed in [Annex A](#) contain provisions which through reference in this standard, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent edition of these standards.

3 TERMINOLOGY

The definitions given below shall apply for the purpose of earthquake-resistant design of buildings, in addition to those provided in IS 1893 (Part 1).

3.1 All Buildings — For buildings referred to in this standard, the definitions provided hereunder shall apply.

3.1.1 Base — The level at which inertia forces generated in the building are transferred to the ground through the foundation. In buildings with:

- a) No basements, the base is taken at the top of:
 - 1) the pile cap, when resting on pile foundations;
 - 2) the raft, when resting on raft foundations; and
 - 3) the footing, when resting on footings.
- b) Basement(s), the base is taken at:
 - 1) the bottom of the basements, if basement walls are neither connected to the floor slabs (including the ground floor slabs) nor fitted between the building columns in the basement storey(s); and
 - 2) the top of the basements, if basement walls are connected to the floor slabs (including the ground floor slabs), or

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fitted between the building columns in the basement storeys.

- c) Combined types of foundation, it is taken at the bottom-most level of the bases of the constituent individual foundations.

3.1.2 Base Dimension (*d*) — Dimension of the building just above its base along a direction of shaking.

3.1.3 Beam — Member (generally in horizontal direction) resisting loads primarily through bending and shearing actions.

3.1.4 Building — A structure built using any material to support and enclose space, whether intended for human habitation or other functions.

3.1.4.1 Concrete buildings — Buildings whose vertical and horizontal members are made with reinforced concrete; the spaces between beams, columns and walls may be filled with masonry walls.

3.1.4.2 Masonry buildings — Buildings whose vertical members are made with masonry units and mortar.

3.1.4.3 Steel buildings — Buildings whose vertical and horizontal members are made with structural steel; the spaces between beams, columns and braces may be filled with masonry walls.

3.1.5 Centre of Mass (*CM*) — The point on the floor of a building through which the resultant of the inertia force at the floor is considered to act during earthquake shaking. Unless otherwise stated, this force is considered as that associated with the horizontal shaking of the building.

3.1.6 Centre of Resistance (*CR*)

3.1.6.1 Single storey buildings — The point on the roof of a building through which when a lateral load is applied, the building undergoes:

- a) pure translation in the horizontal direction; and
- b) no twist about vertical axis passing through it.

In buildings with sloping roofs, this point should be located within the inclined part of the roof above the eaves level.

3.1.6.2 Multi storey buildings — The points on the horizontal floors of a multi-storey building at which when a lateral load is applied, the floor undergoes:

- a) pure translation in the horizontal direction; and

- b) no twist about vertical axis passing through this point.

3.1.7 Column — A member (generally in vertical direction) resisting loads primarily through axial, bending and shearing actions.

3.1.8 Concrete Grade — The 28-day compressive strength (in MPa) of concrete cubes of 150 mm size admissible in design of concrete buildings as per IS 456.

3.1.9 Core Structural Walls, Perimeter Columns, Outriggers and Belt Truss System — A structural system comprising of a core structural wall and perimeter columns, resisting the vertical and lateral loads, with:

- a) the core structural wall connected to select perimeter column element(s) (often termed outrigger columns) by deep beam elements, known as outrigger, at discrete locations along the height of the building; and
- b) the outrigger columns connected by deep beam elements (often known as belt truss), typically at the same level as the outriggers.

3.1.10 Earthquake Base Force — The total horizontal lateral force in the considered direction of earthquake shaking at the base of the building.

3.1.10.1 Design earthquake base force — The earthquake base force V_{BD} that shall be considered in the design of the building.

3.1.10.2 Overstrength earthquake base force — The earthquake base force $V_{B\Omega}$ that shall be considered in the design of select elements of the building, which are not expected to sustain damage during design earthquake shaking.

3.1.11 Diaphragm — A horizontal or nearly horizontal structural system (for example, reinforced concrete floors including their collectors and horizontal bracing systems), which transmits lateral forces to vertical elements of the lateral force-resisting system connected to it.

3.1.11.1 Diaphragm collector — The structural member in the direction of considered earthquake shaking, which transfers lateral forces from the diaphragm to the vertical elements of the lateral force-resisting system.

3.1.12 Earthquake Zone — Zone into which the land of the site under consideration is classified as per 6.2.1 of IS 1893 (Part 1).

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3.1.13 Eccentricity

3.1.13.1 Design eccentricity — The distance e_{di} between center of mass (CM) and center of resistance (CR) of floor i to be used in estimation of design torsion effects.

3.1.13.2 Static eccentricity — The distance e_{si} between center of mass (CM) and center of resistance (CR) of floor i .

3.1.14 Floating Vertical Member — A vertical structural element that rests on a horizontal structural element at its bottom (starting level).

3.1.14.1 Floating column — A column that rests on a beam or slab at its bottom (starting level).

3.1.14.2 Floating structural wall — A structural wall that rests on a beam or slab at its bottom (starting level).

3.1.15 Gravity Column — A column that is not a part of the designated lateral force-resisting system, and is designed to resist:

- a) gravity loads; and
- b) force effects due to displacement compatibility induced by the roof and floor slabs during earthquakes through axial, bending and shearing actions.

3.1.16 Height of Building — The height H of building from its base to top of roof level. In step-back buildings, it shall be taken as the average of heights of all steps from the base, weighted with their corresponding floor areas. In buildings founded on hill slopes, it shall be taken as the height of the roof from the top of the highest footing level or pile cap level.

3.1.17 Height of Floor — The vertical elevation difference H_i between the base of the building and the top of floor i of the building.

3.1.18 Height of Storey — The vertical elevation difference between the tops of two consecutive floors, which constitute that storey.

3.1.19 Horizontal Bracing System — A horizontal truss system that serves the same function as a diaphragm.

3.1.20 Joint — The portion of the column that is common to beams, which frame into the column.

3.1.21 Lateral Force-Resisting System (LFRS) — The arrangement of members, which consists of all structural members that resist most of the lateral load actions induced or imposed on the building, especially the inertia forces induced in it during earthquake shaking; it is part of the overall structural system of the building.

3.1.22 Load Path — The sequence of adjoining

structural elements along which the forces are transmitted from their origin to the foundation of the building.

3.1.23 Moment-Resisting Frame (MRF) — An assembly of interconnected beams and columns (without structural walls and inclined brace members) functioning as a complete self-contained unit with or without the aid of horizontal diaphragms of floor bracing system, which resists load actions induced and imposed primarily by axial and flexural actions.

3.1.23.1 Ordinary moment resisting frame (OMRF) — An MRF designed and detailed as per IS 456 or IS 800, but not meeting special design and detailing requirements given in IS 13920.

3.1.23.2 Special moment-resisting frame (SMRF) — An MRF whose members are designed and detailed specially to provide ductile behaviour to the building and meet basic design requirements given in IS 456 or IS 800, and special design and detailing requirements given in IS 13920.

3.1.24 Moment-Resisting Frame with Structural Walls — An MRF with structural walls distributed in one or more bays or along both plan directions of the building.

3.1.25 Number of Storeys — The number N of levels of a building above the base at which mass is present in substantive amounts. This:

- a) excludes the basement storeys, where basement walls are connected to the ground floor deck or fitted between the building columns; and
- b) includes the basement storeys, when they are not so connected.

3.1.26 Principal Plan Axes — Two mutually perpendicular horizontal directions in the plan of a building along which the geometry of the building is oriented.

3.1.27 RC Structural Wall — A planar member (generally vertical) that is provided along the height of the RC building, which is designed to resist forces in its own plane by axial, flexural and shearing actions.

3.1.27.1 Ordinary RC structural wall — An RC structural wall designed and detailed as per IS 456, but not meeting special design and detailing requirements for ductile behaviour as per IS 13920.

3.1.27.2 Special RC structural wall — An RC structural wall designed and detailed as per IS 13920, and meeting special design and detailing requirements for ductile behaviour as per IS 13920.

3.1.28 Storey — The space between two consecutive floors of a building, or between the roof slab and the

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slab below it.

3.1.28.1 Soft storey — A storey whose lateral translational stiffness in a considered principal plan direction is substantially less than that of the storey above.

3.1.28.2 Weak storey — A storey whose lateral strength in a considered principal plan direction is substantially less than that of the storey above.

3.1.29 Storey Drift — The relative lateral displacement (including the effects of torsion) between the floor slabs above and below the storey under consideration.

3.1.30 Storey Lateral Shear Strength (S_i) — The sum of the design shear force capacities of all vertical elements in the considered storey of the building in a principal plan direction.

3.1.31 Storey Lateral Translational Stiffness (K_i) — The effective lateral translational stiffness offered by all earthquake lateral force resisting elements in the considered storey in a principal plan direction.

3.1.32 Storey Shear (V_{Di}) — The sum of design lateral forces at all levels above the storey i under consideration.

3.1.33 Tall Building — As defined in IS 16700.

3.2 Masonry Buildings

For masonry buildings referred to in this standard, the additional definitions given hereunder shall apply.

3.2.1 Band — A reinforced concrete or reinforced brick runner provided in the walls to tie them together and to impart horizontal bending strength in them.

3.2.2 Box System — A bearing wall structure without a space frame, the horizontal forces being resisted by the walls that act as structural walls.

3.2.3 Separation Section — A gap of specified width between adjacent buildings or parts of the same building either left uncovered or covered suitably to permit movement to avoid pounding due to earthquake.

3.2.3.1 Crumple Section — A separation section filled with appropriate material that crumples or fractures in the event of an earthquake.

3.2.4 Space Frame — A three-dimensional system of interconnected members, without structural walls, that functions as a complete self-contained unit with

or without the aid of horizontal diaphragms or floor bracing systems.

3.3 Concrete Buildings

For concrete buildings referred to in this standard, the additional definitions given hereunder shall apply.

3.3.1 Beam-Column Joint — The portion of an RC MRF at the junction of beams and columns. It consists of the reinforcement from the beams and columns, with or without stirrups around the longitudinal steel bars of the column or beam.

3.3.2 Masonry Infill — The masonry material placed between the beams and columns after the construction of the MRF.

3.3.3 Structural Plan Density (ρ_{SPD}) — The gross cross-sectional area of columns and structural walls at the considered storey of the building, expressed as percentage of total structural plan area at bottom of the storey being considered.

3.3.3.1 Structural plan density (ρ_{CC}) of columns — The gross cross-sectional area of RC columns alone at the considered storey of the building, expressed as a percentage of total structural plan area at the bottom of the storey being considered.

3.3.3.2 Structural plan density (ρ_{SW}) of structural walls — The gross cross-sectional area of RC structural walls alone at the gross considered storey of the building, expressed as a percentage of total structural plan area at the bottom of the storey being considered.

3.3.3.3 Structural plan density (ρ_{MW}) of masonry walls — The gross cross-sectional area of masonry infill walls alone at the gross considered storey of the building, expressed as a percentage of total structural plan area at the bottom of the storey being considered.

3.4 Steel Buildings

For steel buildings referred to in this standard, the additional definitions given hereunder shall apply:

3.4.1 Brace — A member (generally inclined) resisting loads through axial actions.

3.4.2 Connection — The assembly of fasteners, including plates, bolts and welds, that are used to join two members.

3.4.3 Concentrically Braced Frame (CBF) — An LFRS composed of interconnected beams and columns with inclined members as braces, which function as a complete self-contained unit with or without the aid of horizontal diaphragms of floor

bracing systems, in which the system resists gravity and lateral force effects primarily by axial actions.

3.4.3.1 Special concentrically braced frame (SCBF) — A CBF whose members are designed and detailed specially as per the requirements given in IS 13920 to provide ductile behaviour to the building.

3.4.4 Eccentrically Braced Frame (EBF) — An LFRS composed of interconnected beams and columns with inclined members as braces that has at least one end connected to a beam through a link with a defined eccentricity from another beam-to-brace connection or a beam to column connection, which functions as a complete self-contained unit with or without the aid of horizontal diaphragms of floor bracing systems, in which the system resist gravity and lateral force effects primarily by axial action in the braces and shearing and flexural actions in the links. Its members are designed and detailed specially as per the requirements given in IS 13920 to provide ductile behaviour to the building.

3.4.5 Joint Panel Zone — The part of the column that is adjoining the beam, and consists of the column web, column flanges, and continuity plates in line with the flanges of beams that connect to the column.

3.4.6 Link — The segment of a beam that is located between the ends of the connections of two diagonal braces in EBFs. The length of the link is the clear distance between the ends of two diagonal braces or between the diagonal brace and the column face.

4 SYMBOLS AND ABBREVIATIONS

4.1 The symbols and notations given below shall apply to the provisions of this standard:

A_{col}	Total area of all RC columns at any storey of the building
$A_{HD,k}$	Design horizontal PSA using natural period of oscillation T_k of mode k obtained from free vibration analysis
$A_{HD}(T_H)$	Design horizontal acceleration coefficient along any horizontal direction of a building, which is a function of the natural period T_H of the building
$A_H(T_H)$	Elastic maximum horizontal PSA depending on the natural period T_H of the building of horizontal translational mode, corresponding to the return period T_R and the category of building

specified in Table 1 of IS 1893 (Part 1) for the limit state design of concrete or steel buildings or working stress design of masonry buildings

$A_{VD}(T_V)$	Design vertical acceleration coefficient along vertical direction of a building, which is a function of the natural period T_V of the building
$A_V(T_V)$	Elastic maximum vertical PSA depending on the natural period T_V of the building of horizontal translational mode, corresponding to the return period T_R and the category of building specified in Table 1 of IS 1893 (Part 1) for the limit state design of concrete and steel buildings or working stress design of masonry buildings
$A_{a,e}$	Effective axial area of the cross-section of a member
$A_{a,gross}$	Gross axial area of the cross-section of a member
A_o	Area of openings in the slab
$A_{opening}$	Area of opening in unreinforced masonry infill walls in elevation
A_s	Full area of the floor slab
$A_{s,e}$	Effective shear area of the cross-section of a member
$A_{s,gross}$	Gross shear area of the cross-section of a member
A_{SW}	Total effective area of structural walls at any storey of the building
A_{SWi}	Effective cross-sectional area of structural wall i at the base of the building
A_{wall}	Total area of a unreinforced masonry wall panel in elevation
B	Outer dimension of the building along the direction perpendicular to the considered direction of shaking
b_i	Floor plan dimension of floor i , perpendicular to the considered direction of earthquake shaking

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DL	Dead load	H_w	Height of RC structural wall
d	Base dimension of the building at the plinth level along the considered direction of earthquake shaking	h_w	Clear height of unreinforced masonry infill wall
E	Modulus of elasticity	I	Importance Factor that reflects the relative importance within each category of the building
E_b	Modulus of elasticity of clay brick masonry	I_c	Second moment of area of the column adjoining the infill
E_c	Modulus of elasticity of concrete	I_e	Effective second moment of area of the cross-section of a member
E_m	Modulus of elasticity of masonry	I_{gross}	Gross second moment of area of the cross-section of a member
EL	Earthquake load	IL	Imposed load
e_{di}	Design eccentricity to be used at floor i	$I_{VEi,j}$	Seismic mass moment of inertial of vertical element j at storey i about the axis passing perpendicular to the CG of its cross-section
e_K	Stiffness eccentricity of the building taken as distance in plan between CM and CR	K_{xi}	Translational stiffness of storey i of the building
e_{Ki}	Stiffness eccentricity at floor i of the building measured perpendicular to the direction of shaking	$K_{\theta i}$	Torsional stiffness of storey i of the building
e_{si}	Static eccentricity at floor i defined as the distance between CM and CR	L	Horizontal dimension of the lateral force resisting system at the base of the building, or overall plan dimension of the building at the base of the building
F_i	Design lateral force at level of floor i	L_{ds}	Length of the diagonal strut formed in the unreinforced masonry infill wall panel
F_{roof}	Design lateral force at roof level	L_o	Offset length of the structural wall in plan
f_b	Compressive strength of brick	L_{pX}	Projected dimension in plan of the building oriented along X-direction beyond the core
f_{ck}	Characteristic compressive strength of concrete	L_{pY}	Projected dimension in plan of the building oriented along Y-direction beyond the core
f_m	Compressive strength of masonry prism	L_w	Length of the structural wall in plan
f_{mo}	Compressive strength of mortar	L_{wi}	Length of structural wall i in first storey in the considered direction of lateral forces
g	Acceleration due to gravity		
H	Height of the building		
H_{DC}	Design lateral shear force at top of column c in any storey of the building		
H_i	Height of floor i measured from the base		
h_{storey}	Height of storey		

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L_X	Overall dimension in plan of the building oriented along X-direction		resisting structural system employed along X-direction
L_Y	Overall dimension in plan of the building oriented along Y-direction	R_{XB}	Elastic force reduction factor of the building B for the lateral load resisting structural system employed along X-direction
L_W	Clear length of the unreinforced masonry infill wall panel		
l	Clear length of the unreinforced masonry infill wall between the vertical RC elements (columns, walls, or a combination thereof) between which it spans	R_Y	Elastic force reduction factor of the building for the lateral load resisting structural system employed along Y-direction
M	Seismic mass of the building	R_{YA}	Elastic force reduction factor of the building A for the lateral load resisting structural system employed along Y-direction
M_k	Modal mass of mode k of oscillation of the building	R_{YB}	Elastic force reduction factor of the building B for the lateral load resisting structural system employed along Y-direction
$m_{i,j}$	Seismic mass that is lumped at node j at storey i of the building		
N	Number of storeys in building, at which masses are located	R_1	Elastic force reduction factor of the building 1 or unit 1 of the same building
N_w	Number of walls in the considered direction of earthquake shaking	R_2	Elastic force reduction factor of the building 2 or unit 2 of the same building
P_{Dc}	Design axial load in column c at any storey of the building		
P_k	Mode participation factor of mode k of oscillation of the building	r_i	Translational radius of gyration of the mass of the building at the floor level i
$Q_{Di,H}$	Design storey lateral force at top of storey i	r_j	Translational radius of gyration of the mass of the building at the floor level j
$Q_{Di,V}$	Design storey vertical force in storey i	$r_{K\theta i}$	Torsional radius of gyration of the mass of the building at the floor level i
$Q_{Dik,H}$	Design storey lateral force at floor i in mode k of oscillation of the building	S_i	Lateral strength of storey i of the building
Q_S	Stability index at any storey	T_a	Approximate fundamental translational natural period of oscillation estimated by empirical expressions
R	Elastic force reduction factor of the building corresponding to the structural systems of the building	T_H	Natural period corresponding to the fundamental lateral oscillation of the building
R_X	Elastic force reduction factor of the building for the lateral load resisting structural system employed along X-direction	T_k	Natural period of mode k of oscillation of the building
R_{XA}	Elastic force reduction factor of the building A for the lateral load		

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T_V	Natural period corresponding to the fundamental vertical oscillation of the building	$V_{Di,H}$	Design lateral storey shear force in storey i
T_X	Natural period of the fundamental translational modes of oscillation of the building along plan direction X	$V_{Dik,H}$	Design peak shear force acting in storey i in mode k of oscillation of the building
T_Y	Natural period of the fundamental translational modes of oscillation of the building along plan direction Y	$V_{Di,V}$	Design vertical shear force in storey i
T_θ	Natural period of the fundamental torsional modes of oscillation of the building	VE_i	Total number of vertical elements in storey i
t	Thickness of infill masonry wall in building	$VE_{i,j}$	Vertical element j in storey i
t_{ds}	Thickness of the diagonal strut formed in the unreinforced masonry infill panel	V_i	Shear force in the building at storey i
$V_{BD,H}$	Design horizontal base shear force along any principal horizontal direction of a building	V_{roof}	Shear force in the building in the top storey
$V_{BD,V}$	Design vertical base shear force along vertical direction of a building	W	Seismic weight of the building
$V_{BD,H,min}$	Minimum design horizontal earthquake base shear force	W_i	Seismic weight of floor i of the building
V_{BDX}	Design base shear force for earthquake shaking considered along X-direction in plan	w_{ds}	Width of equivalent diagonal strut generated in URM infill wall without any opening
V_{BDY}	Design base shear force for earthquake shaking considered along Y-direction in plan	w_s	Width of equivalent diagonal strut generated in URM infill wall with an opening
$\bar{V}_{BDX}$	Design base shear force for earthquake shaking considered along X-direction in plan, which is estimated using the empirical expression given in this standard for approximate fundamental natural period of buildings	Z	Earthquake zone factor, which reflects the mean horizontal peak ground acceleration (PGA) corresponding to return period T_R (in years) and the earthquake zone in which the building lies
$\bar{V}_{BDY}$	Design base shear force for earthquake shaking considered along Y-direction in plan, which is estimated using the empirical expression given in this standard for approximate fundamental natural period of buildings	α_h	Stiffness parameter related to diagonal strut of URM infill wall
$V_{B\Omega}$	Overstrength base shear force of the building	Δ	Drift ratio specified for buildings
		Δ_{avg}	Average displacement between the ends of the diaphragm
		Δ_{DC}	Lateral deflection at the top of column c with respect to its bottom in any storey
		Δ_{max}	Largest horizontal displacement of the floor slab in plan of a building in the direction of the lateral force at one end of the floor slab

Δ_{mid}	Lateral displacement at the center of the diaphragm (measured from the undeformed position of the slab)	Δ_{YA2}	Design displacements along Y direction of building A at height h_2 at level 2 from its base
Δ_{min}	Smallest horizontal displacement of the floor slab in plan of a building in the same direction of the lateral force at the other end of the same floor slab than that where the displacement is the largest	Δ_{YB1}	Design displacements along Y direction of building B at height h_1 at level 1 from its base
$\Delta_{X,min}$	Minimum deformation capacity to be provided between the ends of a displacement-sensitive AEU for earthquake shaking considered along X-direction	Δ_{YB2}	Design displacements along Y direction of building B at height h_2 at level 2 from its base
Δ_{X1}	Design displacements along X direction of the building at height h_1 at level 1 from its base	Δ_1	Storey lateral displacement of the building 1 or unit 1 of a building
Δ_{X2}	Design displacements along X direction of the building at height h_2 at level 2 from its base	Δ_2	Storey lateral displacement of the building 2 or unit 2 of a building
Δ_{XA1}	Design displacements along X direction of building A at height h_1 at level 1 from its base	δ	Inter-storey drift limit
Δ_{XA2}	Design displacements along X direction of building A at height h_2 at level 2 from its base	δ_{storey}	Inter-storey drift
Δ_{XB1}	Design displacements along X direction of building B at height h_1 at level 1 from its base	ϕ_{ik}	Mode shape coefficient at floor i in mode k of oscillation of the building
Δ_{XB2}	Design displacements along X direction of building B at height h_2 at level 2 from its base	$\phi_{X,i}$	Mode shape coefficient of fundamental translational mode along X-direction at storey i
$\Delta_{Y,min}$	Minimum deformation capacity to be provided between the ends of a displacement-sensitive AEU for earthquake shaking considered along Y-direction	$\phi_{\theta,i}$	Mode shape coefficient of fundamental torsional mode about Z-axis at storey i
Δ_{Y1}	Design displacements along Y direction of the building at height h_1 at level 1 from its base	θ	Angle of the diagonal strut with the horizontal
Δ_{Y2}	Design displacements along Y direction of the building at height h_2 at level 2 from its base	ξ	Damping ratio
Δ_{YA1}	Design displacements along Y direction of building A at height h_1 at level 1 from its base	ρ_c	Structural plan density of columns at the considered storey of the building
		ρ_{MW}	Structural plan density of masonry walls at the considered storey of the building
		ρ_{SPD}	Structural plan density of columns and structural walls at the considered storey of the building
		ρ_{SW}	Structural plan density of structural walls at the considered storey of the building
		τ	Ratio of natural periods of fundamental torsional and fundamental translational modes of oscillation of the building

ψ_i	Torsional flexibility factor of a building at storey i
Ω	Overstrength factor, reflecting the ratio of the maximum lateral resistance offered by the building and the design lateral force
Ω_v	Overstrength shear force amplification factor in the structural wall of the building

When other symbols are used, they are explained at the appropriate place. Unless otherwise specified, all dimensions are in millimeters (mm), force in Newton (N), stresses in Mega Pascal (MPa) and time in seconds (s).

4.2 The abbreviations given below apply to this standard:

<i>Abbreviation</i>	<i>Full Expanded Form</i>
<i>BE</i>	Boundary element
<i>CBF</i>	Concentrically braced frame
<i>CM</i>	Center of mass
<i>CMW</i>	Confined masonry wall
<i>CR</i>	Center of resistance
<i>DS</i>	Dual system
<i>EBF</i>	Eccentrically braced frame
<i>FS</i>	Flat slab

<i>Abbreviation</i>	<i>Full Expanded Form</i>
<i>LFRS</i>	Lateral force-resisting system
<i>LSM</i>	Limit state method of design
<i>MRF</i>	Moment-resisting frame
<i>MWB</i>	Masonry wall with bands
<i>MWBR</i>	Masonry wall with bands, and horizontal and vertical reinforcement
<i>NBE</i>	No boundary element
<i>OCBF</i>	Ordinary concentrically braced frame
<i>OMRF</i>	Ordinary moment-resisting frame
<i>OSW</i>	Ordinary structural wall
<i>PSA</i>	Pseudo-spectral acceleration
<i>RC</i>	Reinforced concrete
<i>RMW</i>	Reinforced masonry wall
<i>SCBF</i>	Special concentrically braced frame
<i>SMRF</i>	Special moment-resisting frame
<i>SW</i>	Structural wall
<i>SSW</i>	Special structural wall
<i>URM</i>	Unreinforced masonry wall
<i>WSM</i>	Working stress method of design

SECTION 1 CRITERIA FOR ALL BUILDINGS

5 GENERAL PRINCIPLES

5.1 Site Selection

The selection of the site of a building shall be considered as per **5.1** of IS 1893 (Part 1).

5.2 Ground Motions

The ground motions and ground shaking shall be considered as per **5.2** of IS 1893 (Part 1).

5.3 Earthquake Effects on Buildings

The design forces, inelastic behaviour and earthquake response of floors shall be considered as per **5.3** of IS 1893 (Part 1).

5.4 Soil-Structure Interaction

The soil-structure interaction shall be considered as

per **5.4** of IS 1893 (Part 1).

5.5 Classification of Buildings

Buildings are classified into four categories, based on the relative severity of the negative consequences (that is, losses of life and livestock, losses of property and harm to natural environment) in the event of their failure.

5.5.1 Categories of Buildings

Buildings shall be classified into the following four categories (see [Table 1](#)):

- Normal buildings,
- Important buildings,
- Critical buildings, and
- Special buildings.

Table 1 Categories of Buildings

(Clauses [5.5.1](#) and [8.2.4](#))

SI No.	Building Category	Return Period (years)	Description
(1)	(2)	(3)	(4)
i)	Special Buildings	4 975 for LSM and 975 for WSM	Buildings of Strategic Importance Buildings that control and operate special liquid-retaining structures Buildings that control and operate special bridges Buildings in special industrial structures Buildings identified by Statutory Authorities having jurisdiction to be of special category Special base-isolated buildings Buildings that control and operate special long-distance pipelines Buildings that control and operate special dams Buildings that control and operate special steel towers Buildings that control and operate special coastal structures Buildings that control and operate special tunnels
ii)	Critical Buildings	2 475 for LSM and 475 for WSM	Buildings that control and operate critical liquid retaining structures Buildings that control and operate critical bridges Buildings in critical industrial structures Buildings identified by Statutory Authorities having jurisdiction to be critical for governance or disaster management Hospital buildings that are required to be functional in the aftermath of earthquakes, or service the functions of a hospital that are required in the aftermath of earthquakes Places of worship Buildings that house the control or operations of utilities (like water, power, and sewage disposal), and lifeline (like communication and transportation facilities) structures Critical base-isolated buildings Buildings that control and operate critical long-distance pipelines Buildings that control and operate critical dams Buildings that control and operate critical steel towers Buildings that control and operate critical coastal structures Buildings that control and operate critical tunnels Buildings related to critical space applications Buildings that control and operate critical telecommunication and IT-related systems

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Table 1 (Concluded)

SI No.	Building Category	Return Period (years)	Description
(1)	(2)	(3)	(4)
iii)	Important Buildings	975 for LSM and 275 for WSM	Buildings that control and operate important liquid-retaining structures Buildings that control and operate important bridges Buildings in important industrial structures Residential or commercial buildings with occupancy more than 100 persons Tall buildings Educational buildings Public buildings Hospital Buildings that are not critical to the functioning of hospitals in the aftermath of earthquakes Buildings that control and operate important long-distance pipelines Buildings that control and operate important dams Buildings that control and operate important telecommunication and IT-related systems
iv)	Normal Buildings	475 for LSM and 175 for WSM	Buildings that control and operate normal bridges Buildings in normal industrial structures Residential or commercial buildings with occupancy less than 100 persons Buildings that control and operate normal liquid-retaining structures Buildings that control and operate normal long-distance pipelines Buildings that control and operate normal dams Buildings not covered in special, critical, and important buildings

5.6 Performance Expectation

5.6.1 Provisions of **5.6** of IS 1893 (Part 1) shall be considered depending on the level of damage admitted and structural integrity required in buildings under the design earthquake hazard specified in [6](#).

5.6.2 In buildings designed as per this standard and expected to sustain structural damage during design earthquake ground shaking specified in [6](#), the requirements given in this standard, in IS 1893 (Part 1), IS 13920 (Part 1) and IS 13920 (Part 5) for the earthquake-resistant design shall be the minimum to be complied with.

6 DESIGN EARTHQUAKE HAZARD

For the design of buildings, earthquake ground shaking, design earthquake hazard and site-specific

earthquake hazard shall be considered as specified in **6** of IS 1893 (Part 1).

7 CRITERIA FOR EARTHQUAKE-RESISTANT DESIGN OF ALL BUILDINGS

The four main desirable attributes of an earthquake-resistant building are:

- Robust structural configuration;
- At least a minimum initial elastic lateral stiffness;
- At least a minimum overall lateral strength; and
- Adequate ductility.

The provisions to achieve each of these attributes are specified in this standard.

7.1 Structural Configuration

7.1.1 Components and Lateral Force Resisting Planes

The inertia forces induced in buildings during earthquake shaking shall be transferred to the underlying soil strata through slabs, beams, columns and/or structural walls, foundations, and through the associated joints and connections (namely between slabs and beams, beams and columns, columns and foundations, slabs and walls, and walls and foundations). Load paths shall be identified along which the flow of these forces is the large. The combinations of beams, columns, structural walls and foundations in a plane along each of the two principal plan directions play vital role of transferring these inertia forces induced, and are called the Lateral Force Resisting Planes.

7.1.1.1 At least two lateral force-resisting planes shall be provided along each principal plan direction of a building.

7.1.1.2 The lateral force-resisting planes shall be provided along each principal plan direction of a building, such that they do not induce twisting in the building about its vertical axis.

7.1.2 Earthquake Zone-wise Admissible Structural Systems

The structural systems that are admissible in different earthquake zones for buildings made of masonry, reinforced concrete and structural steel, shall be taken as per [12.1](#), [14.1](#) and [16.1](#), respectively.

7.1.3 Irregularities

Buildings shall be simple and regular in geometry and have uniformly distributed mass and stiffness in plan and in elevation, to ensure that they suffer much less damage, than buildings with irregular configurations. A building shall be considered as irregular for the purposes of this standard, if any of the conditions specified in [7.1.3.1](#) to [7.1.3.5](#) are met. Also, [7.1.3.1](#) to [7.1.3.5](#) specify requirements to identify the irregularities and to address them, when permitted. The irregularities considered in this standard are presented in [Table 2](#). All efforts shall be made to eliminate irregularities by modifying architectural planning and structural configurations.

Table 2 Irregularities in Buildings

([Clauses 7.1.3](#))

Sl No.	Type of Irregularity	In Plan	In Elevation
(1)	(2)	(3)	(4)
i)	Geometry	Re-entrant corners	Vertical geometric irregularity
ii)	Mass	Horizontal mass irregularity	Vertical mass irregularity
iii)	Stiffness	a) Non-parallel lateral force resisting system	a) Soft storey
		b) In-plane stiffness discontinuity in floor slab-beam system	b) In-plane discontinuity in vertical elements resisting lateral force
		c) Out-of-plane offsets in vertical elements resisting lateral force	c) Floating columns and floating structural walls
iv)	Strength	–	Weak storey
v)	Behaviour	a) Torsional flexibility	
		b) Flexible floor diaphragm	
		c) Closely spaced modes of vibration	
		d) Irregular modes of oscillation in two principal plan directions	

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7.1.3.1 Geometry of structural system

a) Irregularity in plan

1) Re-entrant corners

A building is said to have a re-entrant corner in any plan direction, when its structural system in plan has a projection of size greater than 15 percent of its overall plan dimension in that direction (see Fig. 1).

In buildings with re-entrant corners, three-dimensional dynamic analysis method shall be adopted considering the flexibility of floor diaphragms to capture the concentration of forces generated in the re-entrant corners especially in the floor diaphragm and special elements adjoining the re-entrant corner.

b) Irregularity in elevation

1) Vertical geometric irregularity

A building is said to have vertical geometric irregularity, when:

- i) the horizontal length of the lateral force resisting system in adjacent storeys differs as mentioned hereunder:
 - aa) When there is gradual reduction on one-side of the building, the total

reduction is more than 25 percent on the side of reduction (see Fig. 2A), and when there is abrupt reduction on one-side of the building, the total reduction is more than 20 percent on the side of the reduction;

- bb) Between adjacent storeys, the maximum total reduction is more than 10 percent in a storey, or the total reduction along the height of the building is more than 20 percent (see Fig. 2A);

- cc) When there is reduction on both edges of the building, the maximum total reduction is more than 10 percent on each side (see Fig. 2B); and

- ii) the horizontal projected overhang of the irregular part of the lateral force resisting system is more than 6.25 percent of the overall horizontal dimension L at the base of the (see Fig. 2C).

In buildings with vertical geometric irregularity and located in earthquake Zones III, IV, V and VI, the earthquake effects shall be estimated by linear dynamic analysis (as per 8.3.3.2 and 8.3.3.3).

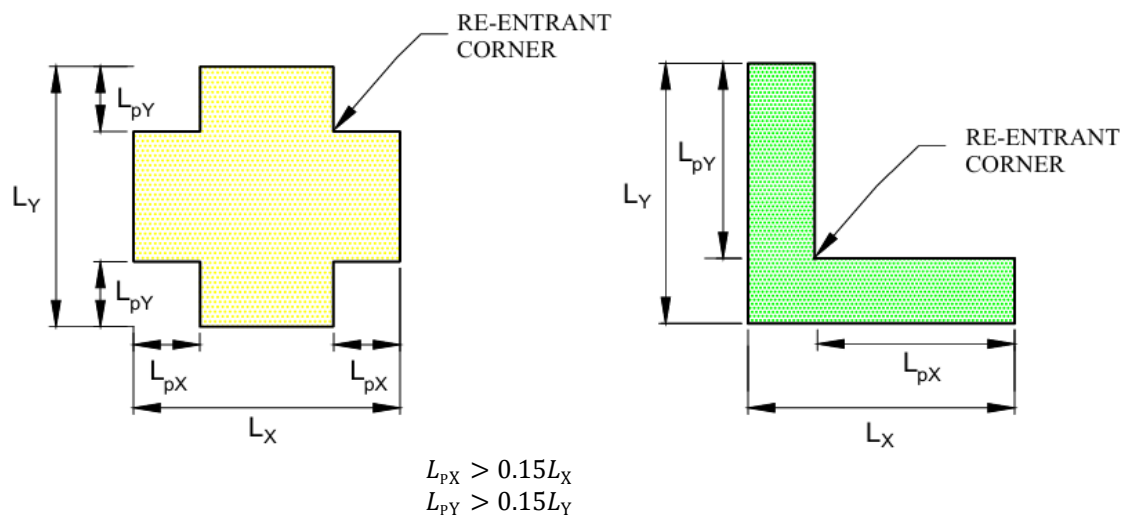


FIG. 1 GEOMETRIC IRREGULARITY IN PLAN – RE-ENTRANT CORNERS

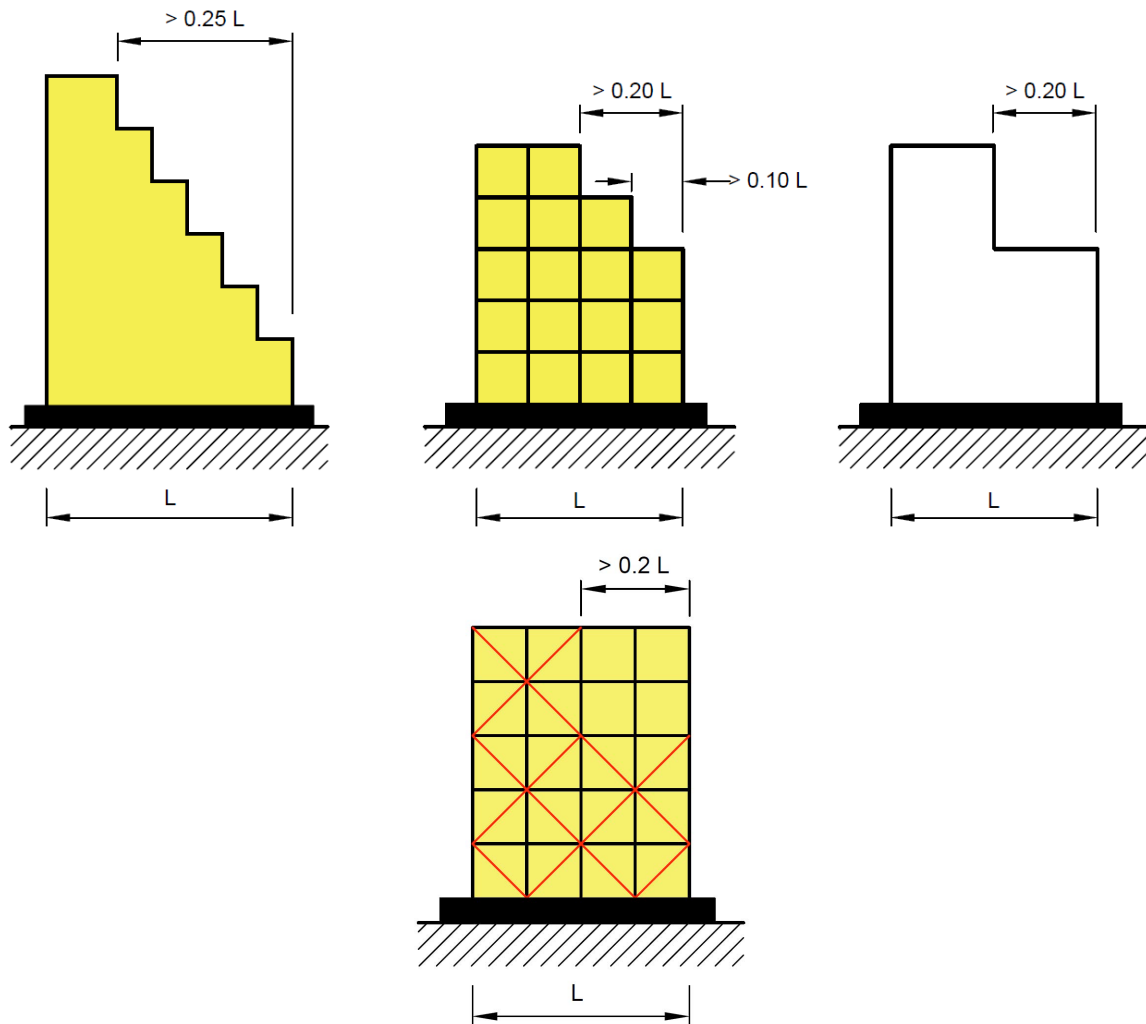
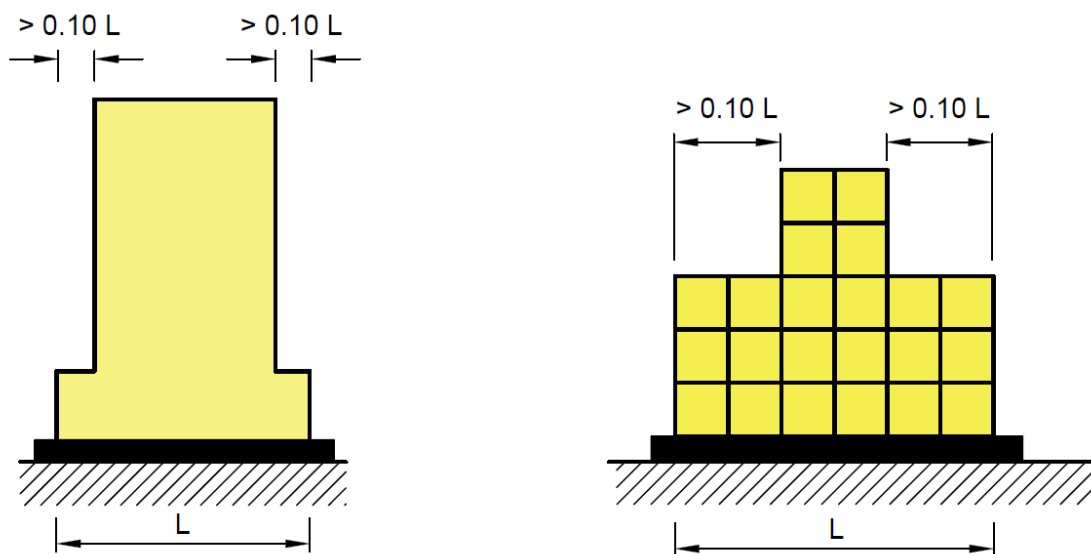


FIG. 2A REDUCTION ON ONE SIDE



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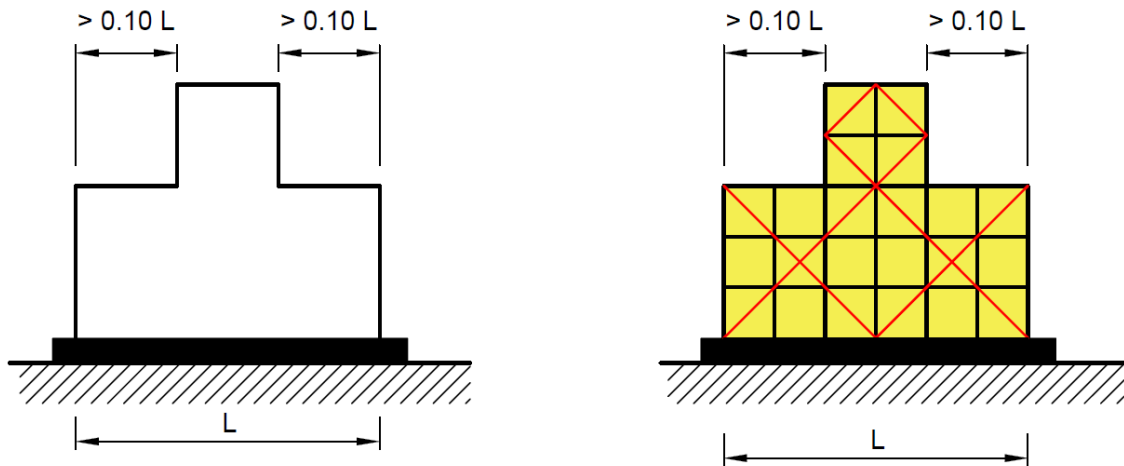


FIG. 2B REDUCTION ON BOTH SIDES

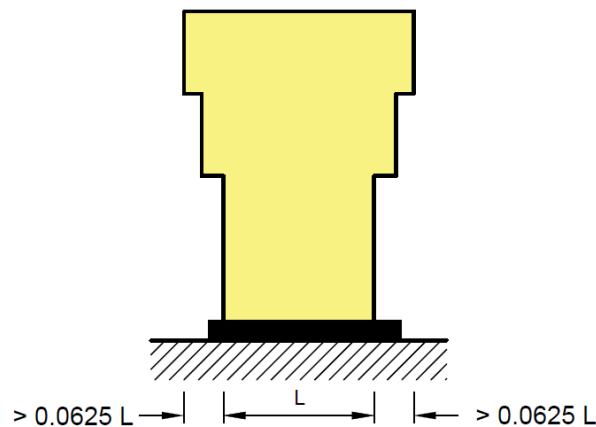


FIG. 2C INCREASE ON BOTH SIDES

FIG. 2 GEOMETRIC IRREGULARITY IN ELEVATION OF BUILDINGS

7.1.3.2 Mass

a) Irregularity in plan

1) Horizontal mass irregularity

The mass irregularity in plan is addressed through the design eccentricity at each floor in [8.2.4.6\(a\)](#), which accounts for both mass and stiffness irregularity in plan at each floor level.

b) Irregularity in elevation

1) Vertical mass irregularity

A building is said to have vertical mass

irregularity, when the seismic weight (as per [8.2.1](#)) at any floor level is more than 1.5 times than that of the storey immediately above or below it (see [Fig. 3](#)). This irregularity need not be considered at the roof level, if the seismic weight at the roof level is less than that at the level below.

In buildings with mass irregularity and located in earthquake Zones III, IV, V or VI, the earthquake effects shall be estimated by dynamic analysis (as per [8.3.3.2](#) and [8.3.3.3](#)).

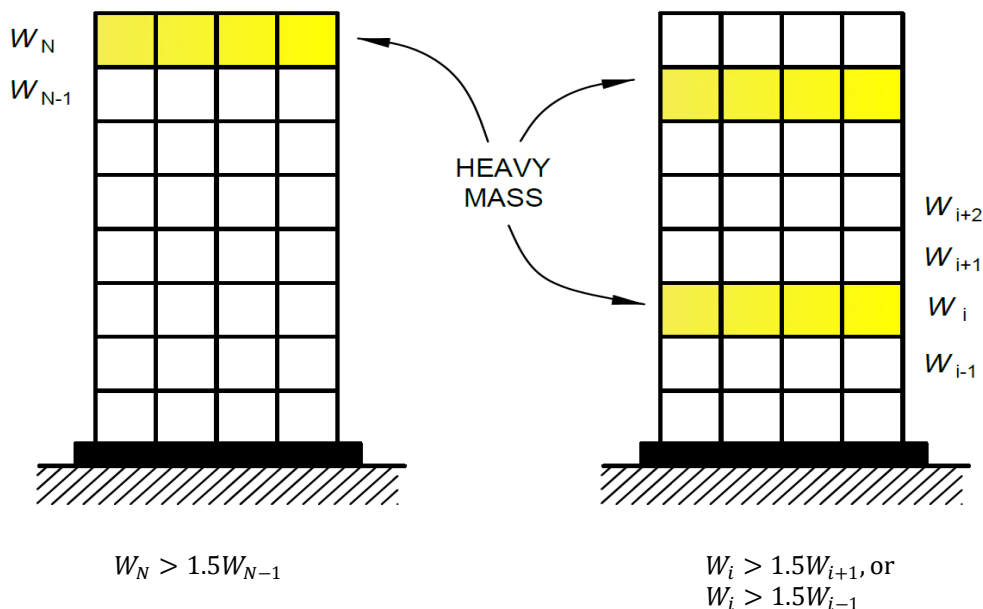


FIG. 3 MASS IRREGULARITY IN ELEVATION

7.1.3.3 Stiffness

a) Irregularities in plan

1) Non-parallel lateral force resisting system

A building is said to have non-parallel LFRS when the vertical structural elements resisting the lateral loads are not oriented along the two principal orthogonal axes in plan (see Fig. 4).

In buildings with non-parallel LFRS, the effects of earthquake shaking shall be estimated by dynamic analysis as per 8.3.3.2 or 8.3.3.3 and load combinations as per 8.4.3.2 of IS 1893 (Part 1).

2) In-plane stiffness discontinuity in floor slab – beam system

A floor slab-beam system of a building is said to have discontinuity in its in-plane stiffness in the plan of the floor slab, when

(see Fig. 5):

- i) Cut-outs or openings in floor slab-beam system have area (A_o) of more than 25 percent of the full area A_s of the floor slab-beam system in openings not close to its perimeter (whose edge distance is more than 15 percent of the building dimension in both directions); or more than 10 percent in openings close to the perimeter (whose edge distance is less than 15 percent of the building dimension in any direction); or
- ii) There is a change in the stiffness of the diaphragm of more than 50 percent between two adjacent storeys.

In buildings with floor slab-beam system having excessive cut-outs or openings, the floor slab-beam system shall be modelled using flexible in-plane slab in structural analysis of the building.

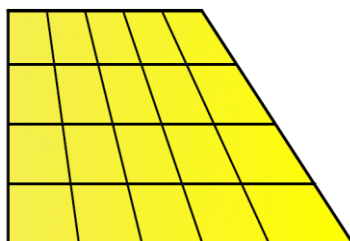


FIG. 4A MOMENT RESISTING FRAME BUILDING

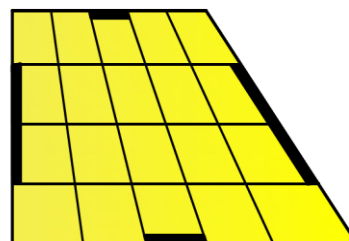


FIG. 4B MOMENT RESISTING FRAME BUILDING WITH STRUCTURAL WALLS

FIG. 4 NON-PARALLEL LATERAL FORCE RESISTING SYSTEM

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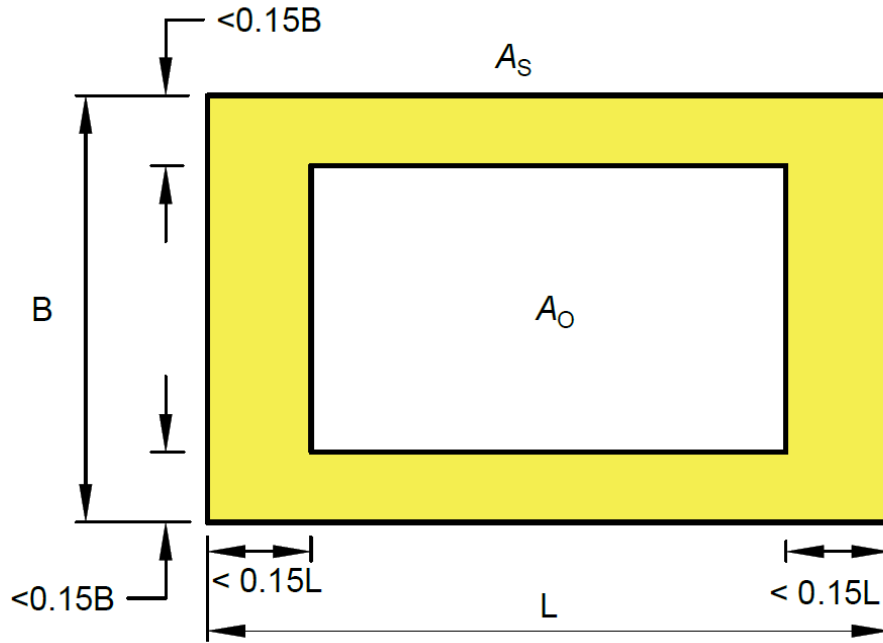


FIG. 5A OPENING LOCATED AWAY FROM EDGE OF THE SLAB — BEAM SYSTEM

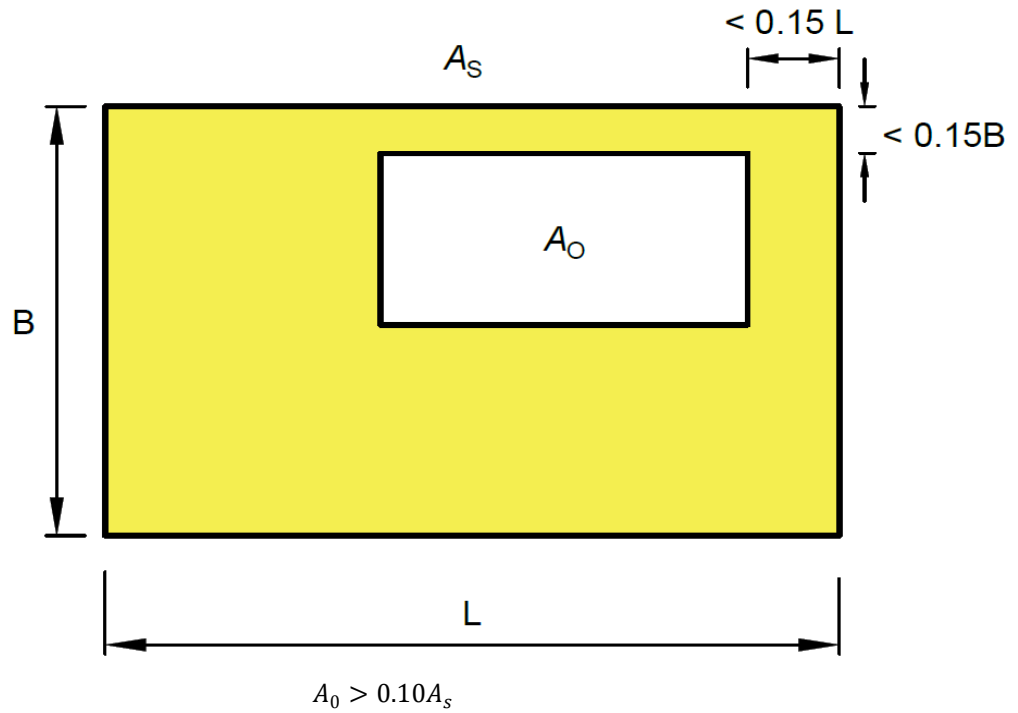


FIG. 5B OPENING LOCATED CLOSE TO THE EDGE OF THE SLAB – BEAM SYSTEM

FIG. 5 PLANS OF FLOOR SLAB – BEAM SYSTEM SHOWING EXCESSIVE CUT-OUTS AND OPENINGS

3) *Out-of-plane offsets in vertical elements resisting lateral force*

A building is said to have out-of-plane offset in vertical elements, when structural walls, braces or moment frames are moved out of their plane at any level along the height of the building (see Fig. 6).

In buildings with out-of-plane offsets in the lateral load-resisting elements and located in:

- i) earthquake Zone II, both the following conditions shall be satisfied:
 - a) The forces and moments due to earthquake effects in the elements

connecting the vertical elements with out-of-plane offset elements, the vertical element supporting the offset, and its connections and their foundations shall be designed for earthquake effects enhanced by a factor of at least the overstrength factor Ω ; and

- b) Lateral drift shall be less than 0.2 percent of the storey height in the storey having the offset, and in all storeys below it.

- ii) earthquake zones III, IV, V or VI, the said irregularity shall not be permitted.

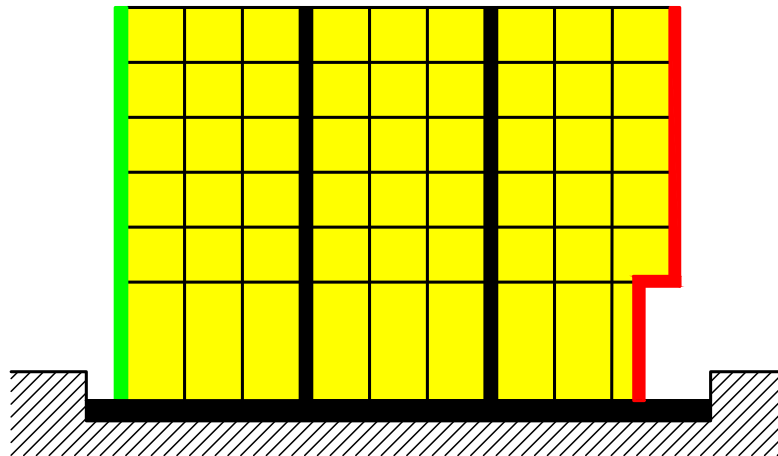


FIG. 6A PARTIAL-BAY OFFSET

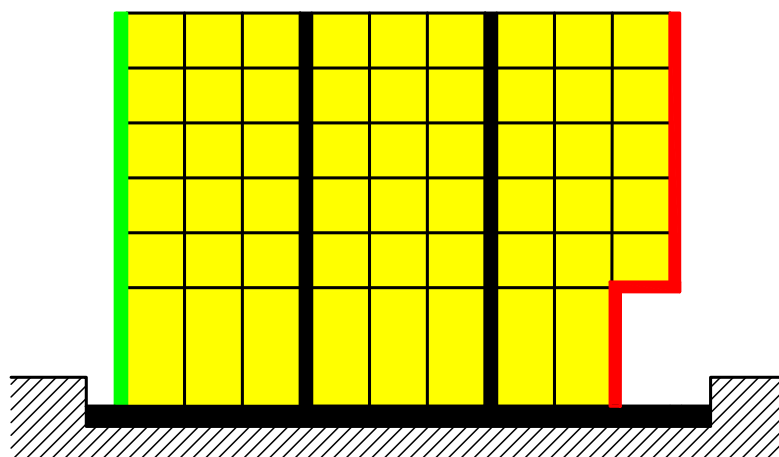


FIG. 6B FULL-BAY OFFSETS

FIG. 6 BUILDING WITH OUT-OF-PLANE OFFSETS IN LATERAL LOAD RESISTING ELEMENTS

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b) *Irregularities in elevation*

1) *Soft storey*

A building is said to have a soft storey, when lateral stiffness of a storey is less than 70 percent of lateral stiffness of the storey above or less than 80 percent of the average lateral stiffness of the three storeys above (see Fig. 7).

In buildings with URM infills, when structural plan density (ρ_{MW}) of masonry infills exceeds 20 percent, the effect of URM infills shall be considered by explicitly modeling the same in structural analysis as per 15.2.3.

Buildings with soft storeys shall not be permitted in earthquake zones III, IV, V and VI. In buildings with soft storeys in earthquake zone II, the following shall be complied with:

- i) Dynamic analysis shall be employed to capture the actual distribution of lateral stiffness along the height of the building; and
- ii) The drift in the soft storey and the storeys below it shall be limited to 0.2 percent.

2) *In-plane discontinuity in vertical elements resisting lateral force*

A building is said to have an in-plane discontinuity in its lateral force resisting system, when in-plane offset of this system is more than 20 percent of the plan length of the respective structural walls (see Fig. 8).

In buildings with in-plane discontinuity and located in earthquake zone II,

- i) the storey drift in any storey shall be limited to 0.2 percents;
- ii) the irregular distribution of the in-plane forces arising out of the discontinuity in the floor slab shall be considered in design; and
- iii) the in-plane offset shall not be more than 50 percent of the plan length of the lateral force resisting system.

Buildings with in-plane discontinuity shall not be permitted in earthquake zones III, IV, V and VI.

3) *Floating columns and floating structural walls*

A building is said to have a floating column or a floating structural wall, when any column or structural wall terminates on a main or secondary beam at an elevation above the base level of the building (see Fig. 9).

Buildings with floating columns and floating structural walls shall not be permitted, if the total lateral force carried by the planar MRFs and MRF with SWs containing the floating columns or floating structural walls, together carry at the point of discontinuity more than 10 percent of the design lateral force along each principal plan direction.

7.1.3.4 Strength

a) *Irregularities in elevation*

1) *Weak storey*

A building is said to have weak storey, when the lateral shear strength of a storey is less than that of the storey above (see Fig. 10).

In buildings with weak storeys:

- i) in earthquake zones II and III, all elements below the level of weak storey, their connections and their foundations shall be designed for the effects arising from additional load combinations specified in 14.4 or 16.4, as applicable;
- ii) in earthquake zones IV, V and VI, buildings with weak storeys shall not be permitted; and
- iii) arising because of URM infills, provisions of 15.2.3 shall be followed.

This requirement is not applicable to the top storey.

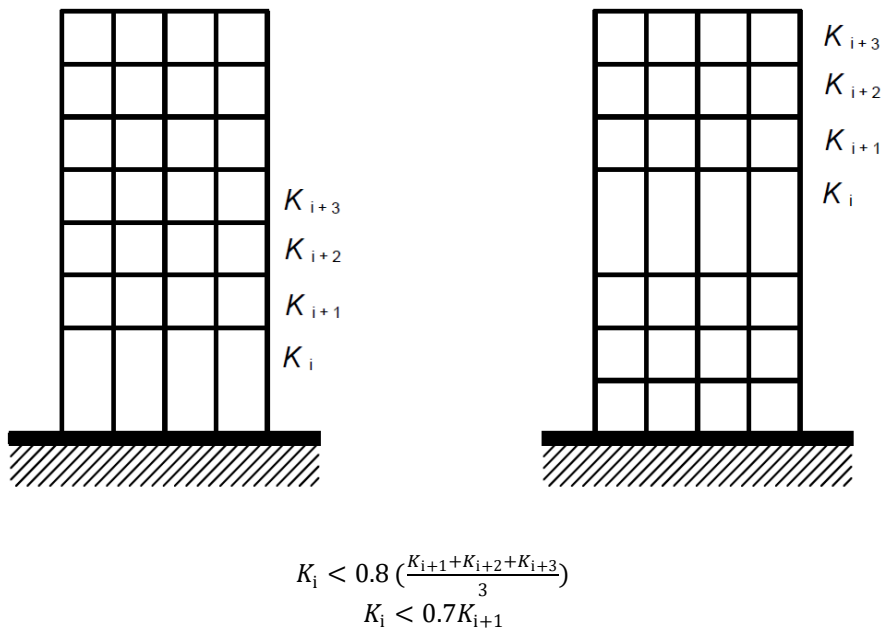


FIG. 7 SOFT STOREY IN BUILDINGS

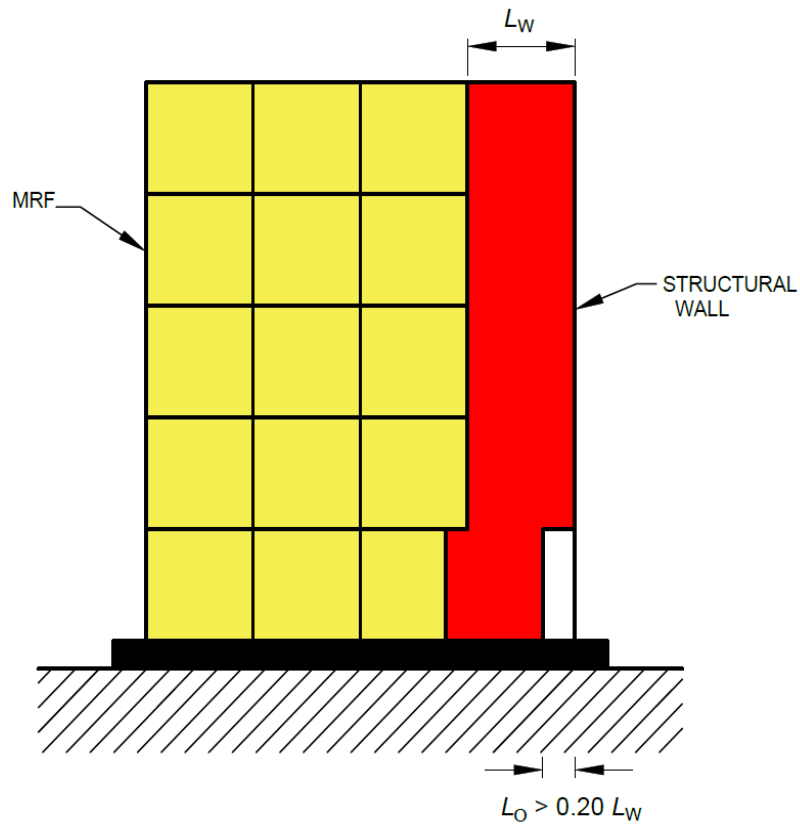


FIG. 8 IN-PLANE DISCONTINUITY IN VERTICAL ELEMENTS RESISTING LATERAL FORCES IN BUILDING

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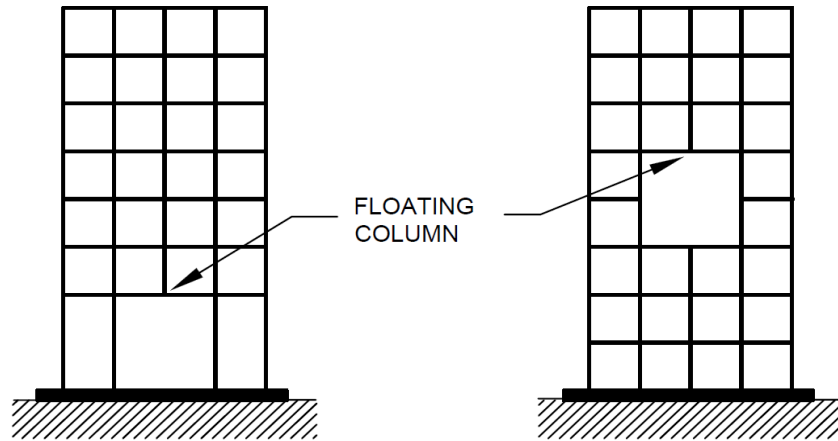


FIG. 9A FLOATING COLUMNS IN BUILDINGS

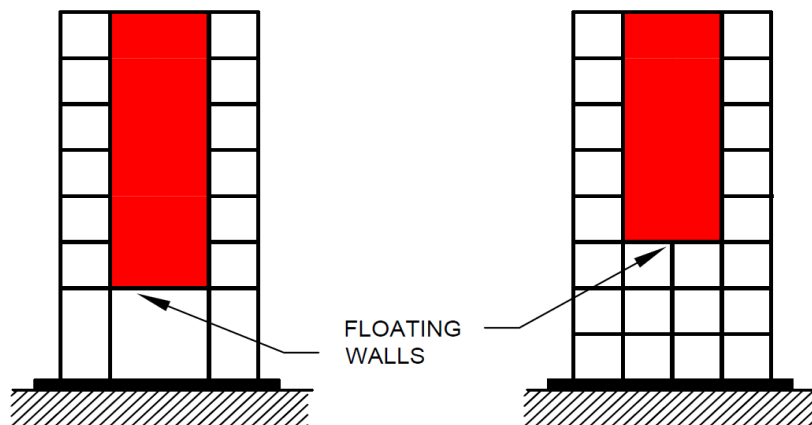
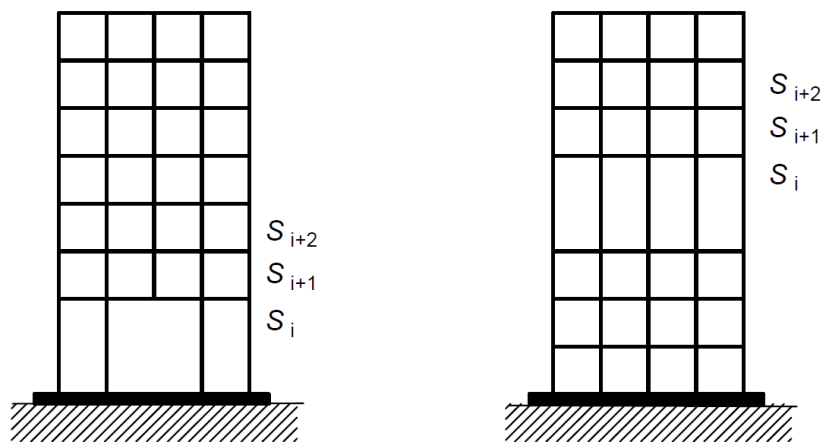


FIG. 9B FLOATING STRUCTURAL WALLS IN BUILDINGS

FIG 9. FLOATING COLUMNS AND FLOATING STRUCTURAL WALLS



$$S_{i+1} < S_{i+2}$$

$$S_i < S_{i+1}$$

FIG. 10 WEAK STOREY IN BUILDINGS

7.1.3.5 Behaviour

a) Torsional flexibility

A building is said to have torsional flexibility, when the fundamental torsional natural period is more than the fundamental translational natural period along each principal plan direction.

Buildings with torsional flexibility shall not be permitted. The stiffness of the structural elements of the building shall be revised to ensure that the fundamental torsional natural period is smaller than the fundamental translational natural period along each principal plan direction, that is, the first two modes of the building are the fundamental translational modes along the two principal plan directions.

b) Flexible floor diaphragm

A building is said to have a flexible floor diaphragm, when under the action of earthquake loads specified in 8.2.4 its floor diaphragm deforms such that the lateral displacement at the center of the diaphragm Δ_{mid} (measured from the undeformed position of the slab) is more than $1.2 \Delta_{avg}$ (see Fig. 11), where

$$\Delta_{avg} = \frac{\Delta_{min} + \Delta_{max}}{2}$$

where

Δ_{min} = smallest horizontal displacement of the floor slab in plan of a

building in the same direction of the lateral force at one end of a floor slab; and

Δ_{max} = largest horizontal displacement of the floor slab in plan of a building in the same direction of the lateral force at the other end of the same floor slab

In buildings with flexible floor diaphragm, the following shall be complied with:

- 1) When Δ_{max} is in the range of $1.2\Delta_{avg}$ to $1.4\Delta_{avg}$,
 - i) dynamic response history analysis shall be performed using three-dimensional analytical model considering the in-plane flexibility of the floor diaphragms; and
 - ii) structural elements (including the floor diaphragms) shall be designed for the effects of earthquake loads induced in them owing to the effects of diaphragm flexibility.
- 2) When Δ_{max} is more than $1.4\Delta_{avg}$, the structural configuration shall be revised to mitigate the flexible floor diaphragm irregularity.

This requirement need not be met, if the fundamental lateral translational natural period of the building is 0.1 s or less.

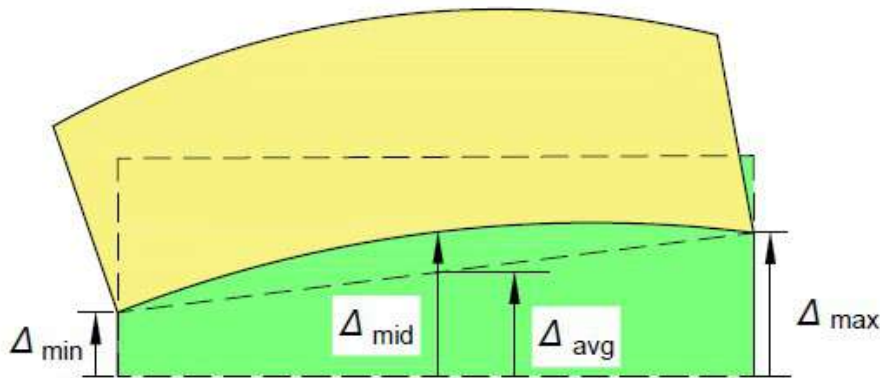


FIG. 11 TORSIONAL IRREGULARITY IN BUILDINGS (IN PLAN)

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c) *Closely-spaced modes of vibration*

A building is said to have closely-spaced modes of vibration, when fundamental translational natural periods of the building in the two principal plan directions are within 10 percent of the larger of the two translational natural periods.

Buildings with closely-spaced modes of vibration shall not be permitted. The stiffness of the structural elements of the building shall be revised to separate the two closely-spaced modes.

d) *Irregular modes of oscillation in two principal plan directions*

A building is said to have irregular modes of oscillation in a principal plan direction, if:

- 1) The first three lateral translational modes in that principal plan direction together contribute less than 65 percent mass participation; or
- 2) The building has closely-spaced modes as per [7.1.3.5\(d\)](#).

In a building with lateral irregular modes of oscillation along any of its two principal plan directions, and located in:

- a) earthquake Zones II and III, it shall be ensured that the first three lateral translational modes of the building together account for at least 65 percent of the seismic mass in each principal plan direction.
- b) earthquake Zones IV, V and VI, it shall be ensured that:
 - 1) the first three lateral translational modes of the building in each principal plan direction together contribute at least 65 percent of the seismic mass in that direction,
 - 2) the fundamental lateral translational natural period of the building in each principal plan direction is more than that of the first torsional mode, and
 - 3) the fundamental lateral translational natural periods of the building in the two principal plan directions are away

from each other by at least 10 percent of the larger value.

In buildings with significant share of its mass contributed by its basements or podiums, recourse should be sought through missing mass correction [as per [8.3.3.2\(e\)\(3\)](#) in IS 1893 (Part 1)] to account for at least 90 percent of the seismic mass in each principal plan direction.

7.2 Initial Lateral Stiffness

The deformation of buildings under the design load combinations (involving earthquake load EL) specified in [8.4.1](#), [8.4.2](#) and [8.4.3](#) of IS 1893 (Part 1) shall be obtained by structural analysis using a structural model with section properties as specified in [7.2.1](#).

7.2.1 Effective Section Properties

The section properties of members input to a structural model shall be taken as specified in [Table 3](#).

7.2.2 Storey Drift Limit

7.2.2.1 The storey drifts in buildings, under the load combinations specified in [8.4](#) of IS 1893 (Part 1), shall not exceed the values given in [Table 4](#).

7.2.2.2 The storey drifts shall be estimated by linear structural analysis, by the equivalent static method, the response spectrum method and the response history method mentioned in [8.3.3.1](#), [8.3.3.2](#) and [8.3.3.3](#) of IS 1893 (Part 1), respectively.

7.2.2.3 When response spectrum method or the response history method is used, the displacement responses need not be amplified by the ratio mentioned in [8.3.3.2\(e\)\(4\)](#) and [8.3.3.3\(d\)\(4\)](#) of IS 1893 (Part 1) for stress-resultants.

7.3 Lateral Strength

The design horizontal earthquake base shear forces for design shall be considered as per [8](#).

7.4 Ductility

Buildings designed and detailed as per IS 13920 (Part 1) and IS 13920 (Part 5) shall be deemed to have the overall lateral displacement ductility required to resist the effects of design earthquake shaking.

**Table 3 Normalized Effective Section Properties of Members to be
Used in Structural Analysis of Buildings**
(Clauses 7.2.1 7.5 and 12.3.1.3)

SI No.	Structural Members of Buildings	Effective Axial Area $A_{a,e}/A_{a,gross}$	Effective Shear Area $A_{s,e}/A_{s,gross}$	Effective Second Moment of Area I_e/I_{gross}
(1)	(2)	(3)	(4)	(5)
A. RC Slabs				
i)	Masonry buildings	1.0	0.4	0.5 out-of-plane 1.0 in-plane
ii)	Concrete buildings	1.0	0.2	0.25 out-of-plane 1.0 in-plane
iii)	Steel buildings	1.0	0.2	0.25 out-of-plane 1.0 in-plane
B. Beams				
i)	Masonry buildings	1.0	0.4	0.35 major axis 1.0 minor axis
ii)	Concrete buildings	1.0	0.4	0.35 major axis 1.0 minor axis
iii)	Steel buildings	1.0	5/6 (area of web only)	1.0 major axis 1.0 minor axis
C. Columns				
i)	Masonry buildings	1.0	0.4	0.35 major axis 0.35 minor axis
ii)	Concrete buildings	1.0	0.7	0.7 major axis 0.7 minor axis
iii)	Steel buildings (including braces)	1.0	5/6 (area of web only)	1.0 major axis 1.0 minor axis
D. Structural Walls				
i)	Masonry buildings	1.0	0.4	0.35 out-of-plane 0.35 in-plane
ii)	Concrete buildings	1.0	0.7	0.7 out-of-plane 0.7 in-plane
iii)	Steel buildings	1.0	5/6 (area of web only)	1.0 out-of-plane 1.0 in-plane
E. Others				
i)	RC transfer girders	1.0	5/6 (area of web only)	1.0 major axis 1.0 minor axis
ii)	RC transfer slabs	1.0	5/6 (area of web only)	1.0 out-of-plane 1.0 in-plane
iii)	RC joints	1.0	1.0	1.0
iv)	Steel joints	1.0	1.0	1.0

Table 4 Limit on Lateral Storey Drifts in Buildings

(Clauses 7.2.2, 10.5.2.1 and 10.5.2.2)

SI No.	Earthquake Zone	Lateral Storey Drift $\delta_{storey}/h_{storey}$
(1)	(2)	(3)
i)	VI	0.004
ii)	V	0.004
iii)	IV	0.004
iv)	III	0.004
v)	II	0.004

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7.5 Relative Displacement Capability

Two adjoining buildings or two adjoining units of the same building shall be separated (with a seismic joint between them) by a distance equal to:

- $(\Delta_1 R_1 + \Delta_2 R_2)$ when the floor levels of the adjoining units of a building or of adjoining buildings are at different levels; and
- $(\Delta_1 R_1 + \Delta_2 R_2)/2$ when floor levels of the adjoining units of a building or of adjoining buildings are at the same level.

where

- Δ_1 = storey lateral displacement of building 1 or unit 1 of the same building;
- Δ_2 = storey lateral displacement of building 2 or unit 2 of the same building;
- R_1 = elastic force reduction factor of building 1 or unit 1 of the same building; and
- R_2 = elastic force reduction factor of building 2 or unit 2 of the same building.

Here, Δ_1 and Δ_2 shall be estimated using the load combinations specified in 8.4 of IS 1893 (Part 1) and reduced cross-section properties specified in Table 3.

8 EARTHQUAKE DEMAND

8.1 Assumptions

The effect of in-plane stiffness of unreinforced masonry (URM) infill walls, if any, shall be considered as per 15.2.3.

8.2 Design Earthquake Forces

8.2.1 Seismic Weight

- Seismic weight W of each floor shall be taken as its full dead load (including superimposed dead load) plus appropriate amount of imposed load specified in IS 875 (Part 2) and as specified in Table 5. This seismic weight shall
- be converted into seismic mass and used in the three-dimensional dynamic analysis of the building. Further,

- While computing the seismic weight of each floor, the weight of columns and walls in any storey shall be appropriately apportioned to the floors above and below the storey;
- In the estimation of seismic weight, the reduction allowed in imposed load as per Table 5 alone shall be admissible, and not that allowed by IS 875 (Part 2);
- In the calculation of design earthquake forces of buildings, imposed load need not be considered on roofs only when they are inaccessible. But, weights of equipment and other permanently fixed facilities on roof shall be considered, and the reductions of imposed loads mentioned in Table 5 shall not be applicable to that part of the load;
- Snow loads and dust storm loads shall be considered appropriately. In regions of severe snow loads and sand storms exceeding intensity of 1.5 kN/m², 20 percent of uniform design snow load or sand load respectively, shall be included in the estimation of seismic weight; these values shall not be lesser than those given in IS 875; and
- The seismic weight of partitions on floors shall be included in the estimation of seismic weight; it shall not be less than that:
 - Arising from a uniform loading on the floor of 0.5 kN/m²; and
 - Specified for partitions in IS 875 (Part 2).

- Seismic mass M of each floor shall be taken as its seismic weight W divided by acceleration due to gravity g , as:

$$M = \frac{W}{g}$$

Table 5 Imposed Load to be Considered in Estimation of Seismic Weight

(Clause 8.2.1)

Sl No.	Design Imposed Loads Distributed Uniformly on Floors (kN/m ²)	Imposed Load (percent)
(1)	(2)	(3)
i)	Up to and including 3.0	25
ii)	Above 3.0	50

8.2.2 Importance Factor

In estimating design horizontal and vertical elastic PSA of buildings as per 6.2 or 6.3 of IS 1893 (Part 1), the importance factor (I) of buildings shall be taken as per Table 6. Further,

- a) Owners and design engineers of buildings may choose values of importance factor (I) higher than those specified in Table 6. But, in such cases, the product of ZI of the building shall not exceed the value of Z specified in Table 3 of IS 1893 (Part 1) for the next higher category of buildings; if it does exceed, the building shall be categorised to be of the higher category;
- b) In Table 6, the occupancy size shall be for each of the structurally independent units

of the building, when a building is composed of more than one structurally independent unit; and

- c) In buildings with mixed occupancies, wherein different factors are applicable for the respective occupancies, larger of the applicable importance factors shall be used for estimating the design earthquake force of the building.

8.2.3 Elastic Force Reduction Factors

The elastic force reduction factor of buildings with different structural systems shall be taken as per Table 7.

Table 6 Importance Factor I of Different Buildings of the Four Categories

(Clause 8.2.2)

SI No.	Category of Buildings	Importance Factor I
(1)	(2)	(3)
Concrete and Steel Buildings		
i)	Special Buildings	1.0
ii)	Critical Buildings	1.0
iii)	Important Buildings	1.0
iv)	Normal Buildings	1.0
Masonry Buildings		
i)	Special Buildings	1.0
ii)	Critical Buildings	1.0
iii)	Important Buildings	1.0
iv)	Normal Buildings	1.0

Table 7 Elastic Force Reduction Factor R for Buildings with Different Structural Systems

(Clauses 8.2.3 and 8.2.4)

SI No.	Structural System	R
(1)	(2)	(3)
i)	Buildings with Moment Frames	
a)	RC buildings with ordinary moment resisting frames (OMRFs) designed and detailed as per IS 456	3.0
b)	RC buildings with special moment resisting frames (SMRFs) designed and detailed as per IS 13920 (Part 5)	5.0
c)	Steel buildings with ordinary moment resisting frames (OMRFs) designed and detailed as per IS 800	3.0
d)	Steel buildings with special moment resisting frames (SMRFs) designed and detailed as per IS 13920 (Part 5)	5.0

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Table 7 (Concluded)

SI No.	Structural System	R
(1)	(2)	(3)
ii)	Buildings with Braced Frames	
	a) Steel buildings with ordinary concentrically braced frames (OCBFs) designed and detailed as per IS 800	3.0
	b) Steel buildings with special concentrically braced frames (SCBFs) designed and detailed as per IS 13920 (Part 5)	4.5
	c) Steel buildings with eccentrically braced frames (EBFs) designed and detailed as per IS 13920 (Part 5)	5.0
iii)	Buildings with Load Bearing Masonry Walls	
	a) Unreinforced masonry walls designed and detailed as per IS 13920 (Part 5) and provided with horizontal RC earthquake bands	1.5
	b) Unreinforced masonry walls designed and detailed as per IS 13920 (Part 5) and provided with horizontal RC earthquake bands and vertical reinforcements	2.5
	c) Confined masonry walls designed and detailed as per IS 13920 (Part 5)	3.0
	d) Reinforced masonry walls	3.0
iv)	Buildings with RC Structural Walls	
	a) Ordinary RC structural walls (OSWs-RC) designed and detailed as per IS 456	3.0
	b) Special RC structural walls without boundary elements (SSWs-RC-NBE) designed and detailed as per IS 13920 (Part 5)	4.5
	c) Special RC structural walls with boundary elements (SSWs-RC-BE) designed and detailed as per IS 13920 (Part 5)	5.0
v)	Buildings with RC Moment Frames and RC Structural Walls	
	a) OSWs-RC and OMRFs-RC both designed and detailed as per IS 456	3.0
	b) SSWs-RC-NBE and SMRFs-RC both designed and detailed as per IS 13920 (Part 5)	4.0
	c) SSWs-RC-BE (single SW, or coupled SW) and SMRFs-RC both designed and detailed as per IS 13920 (Part 5)	4.5
vi)	Buildings with RC Dual Structural System	
	a) SSWs-RC-BE and SMRFs-RC both designed and detailed as per IS 13920 (Part 5)	5.0
vii)	RC Buildings with RC Flat Slab and Special RC Moment Frames and Special RC Structural Walls	3.0
	a) RC SMRF+SSW+FS1 or SMRF+SSW+FS2 building with features given below:	
	1) SSWs-RC designed to resist 100 percent of design horizontal base shear force,	
	2) Perimeter SMRFs-RC designed to resist independently 25 percent of design lateral force), and	
	3) A system connecting SSWs-RC and perimeter SMRFs-RC (for example, outrigger belt-truss system)	

8.2.4 Design Earthquake Forces

In the design of a building, the design horizontal acceleration coefficient $A_{HD}(T_H)$ along any principal plan direction of a building and the design vertical acceleration coefficient $A_{VD}(T_V)$ shall be estimated as:

$$A_{HD}(T_H) = \frac{A_H(T_H)}{R}; \text{ and}$$

$$A_{VD}(T_V) = A_V(T_V)$$

where

$A_H(T_H)$ = Elastic maximum horizontal PSA depending on the natural period T_H of the fundamental horizontal translational mode of the building [as per 6.2 or 6.3 of IS 1893 (Part 1)], corresponding to the return period T_R and the category of building specified in Table 1 of IS 1893 (Part 1) and category specified in [Table 1](#);

$A_V(T_V)$ = Elastic maximum vertical PSA depending on the natural period T_V of the fundamental vertical translational mode of the building [as per 6.2 or 6.3 of IS 1893 (Part 1)] corresponding to the return period T_R and the category of building specified in Table 1 of IS 1893 (Part 1) and category specified in [Table 1](#);

R = Elastic force reduction factor of buildings with different structural systems shall be taken as per [Table 7](#). These values shall be used for design of buildings with said structural systems, but not for their design when these structural systems are built in isolation. Structural systems referred to in [Table 7](#) shall be as per Sections 2, 3 and 4;

T_H = Natural period corresponding to the fundamental lateral mode of oscillation of the building when equivalent static analysis method is adopted (and is taken as T_a given by [8.2.4.3](#)), and corresponding to the modal natural period of the building when response spectrum method is adopted; and

T_V = Natural period corresponding to the fundamental vertical mode of oscillation of the building, obtained from modal analysis.

And, in the design of a building, the design horizontal base force $V_{BD,H}$ [as per 6.2 or 6.3 of IS 1893 (Part 1)] along any principal plan direction and design vertical base force $V_{BD,V}$ shall be estimated as:

$$V_{BD,H} = A_{HD}(T_H) W \text{ and}$$

$$V_{BD,V} = A_{VD}(T_H) W$$

where

W = seismic weight of the building as per [8.2.1](#).

8.2.4.1 Structural systems of buildings

a) Buildings with regular structural systems

When the structural system of the building is regular (see [Fig. 12](#)) as per [7.1.3.1](#), the design earthquake base force shall be estimated for the whole building.

b) Buildings with irregular structural systems

When the structural system of the building is irregular (like buildings with podiums having stiff basements walls including when the stiff walls are placed in the basement either symmetrically in one or both plan directions, or unsymmetrically along one or both plan directions) (see [Fig. 13](#)) and buildings with transfer slabs or girders as per [7.1.3.1](#), the design earthquake base force shall be estimated in two parts, namely for the portion A and for the portion B separately.

1) The design earthquake base forces for the two portions shall be estimated as below:

i) For portion A, estimate $V_{BD,A}$ using the seismic weight of portion A alone, the design horizontal acceleration $A_{HD}(T)$ corresponding to approximate fundamental natural period specified in [8.2.4.3](#); and

ii) For portion B, estimate $V_{BD,B}$ using the seismic weight of portion B alone, and the design horizontal acceleration $A_{HD}(T)$ and the design vertical acceleration $A_{VD}(T)$ a taken as:

$$A_{HD}(T) = \frac{2.5ZI}{R}; \text{ and}$$

$$A_{VD}(T) = 2.5ZI.$$

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- 2) These forces shall be distributed along the height of the building as specified below:
 - i) For Portion A, $V_{BD,A}$ shall be distributed as per [8.2.4.5](#) using heights measured from the top of Portion B to the floor levels in Portion A; and
 - ii) For Portion B, $V_{BD,B}$ shall be distributed as per [8.2.4.5](#) using heights measured from the bottom of Portion B to the floor levels in Portion B.

The structural analysis of the whole building with all loads distributed shall be performed as per **8.3.3** of IS 1893 (Part 1).

8.2.4.2 Damping ratio

The value of damping ratio shall be taken as 5 percent of critical damping for the purposes of estimating design horizontal and vertical elastic PSA of buildings [as per **6.2** or **6.3** of IS 1893 (Part 1)].

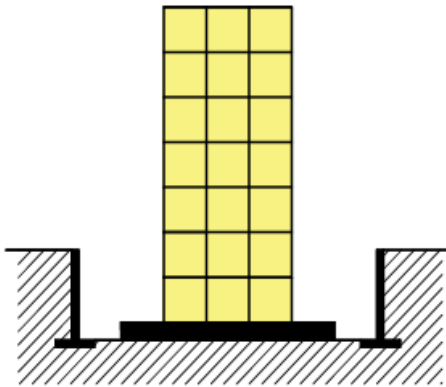


FIG. 12A FLAT ROOF BUILDING WITH BASEMENT RETAINING WALLS NOT CONNECTED TO BUILDING FRAME

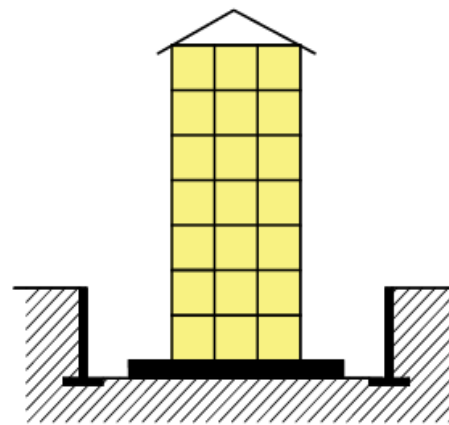


FIG. 12B SLOPED ROOF BUILDING WITH BASEMENT RETAINING WALLS NOT CONNECTED TO BUILDING FRAME

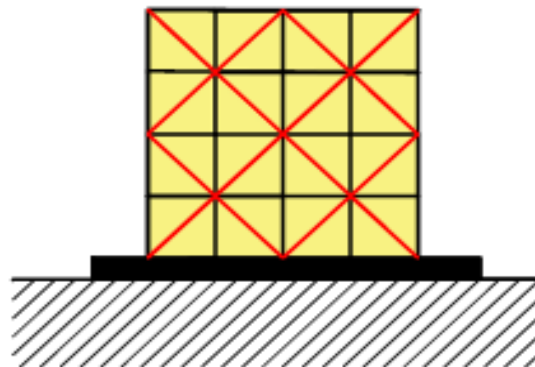


FIG. 12C BUILDING WITH CONCENTRIC BRACES AND NO BASEMENTS

FIG. 12 BUILDINGS WITH REGULAR STRUCTURAL SYSTEMS

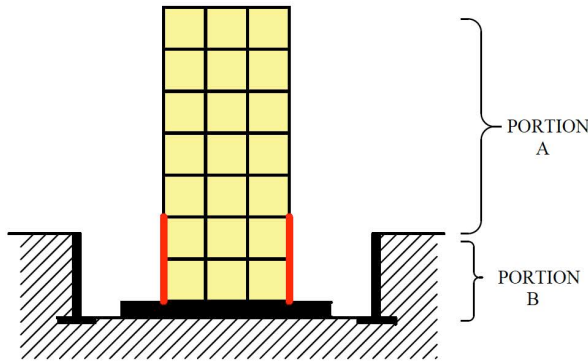


FIG. 13A MRF BUILDING WITH RETAINING WALL IN BASEMENT CONNECTED

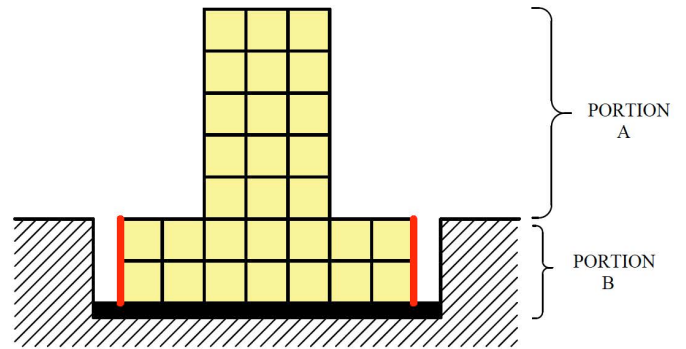


FIG. 13B MRF PODIUM BUILDING WITH PODIUM STOREYS BELOW GROUND LEVEL WITH RETAINING WALL IN BASEMENT CONNECTED

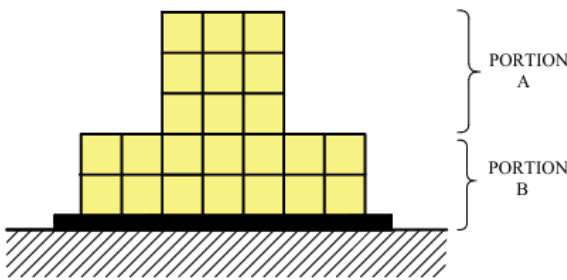


FIG. 13C MRF PODIUM BUILDING WITH PODIUM STOREYS ABOVE GROUND

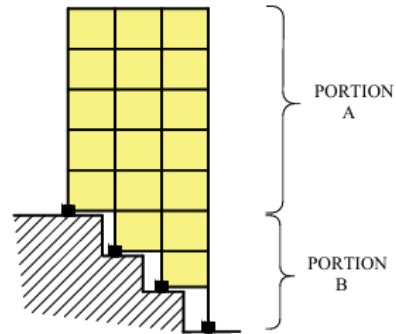


FIG. 13D BUILDING ON HILL SLOPE

FIG. 13 BUILDINGS WITH IRREGULAR STRUCTURAL SYSTEMS

8.2.4.3 Approximate fundamental translational natural period T_a

The approximate fundamental translational natural period T_a (s) of oscillation of buildings less than 50 m in height along a considered principle horizontal direction of shaking shall be estimated by the following expressions:

- a) Buildings with RC MRFs with or without RC structural walls and with or without URM infills:

$$T_a = \frac{0.075H^{0.75}}{\sqrt{1 + 0.2\rho_{CC} + \sum_{i=1}^{N_{CSW}} [\rho_{CSWi} \{0.2 + (\frac{L_{CSWi}}{H})^2\}] + 0.02\rho_{MW}}}$$

where

- H = height (in m) of the building (see Fig. 14);
- ρ_{CC} = structural plan density (percent) of all concrete

columns at the base of the building;

N_{CSW} = number of concrete structural walls;

ρ_{CSWi} = structural plan density (percent) of concrete structural wall i alone at the base of the building in the considered direction of shaking;

L_{CSWi} = length of the concrete structural wall i at the base of the building; and

ρ_{MW} = structural plan density (percent) of masonry infill walls alone at the base of the building in the considered direction of shaking, where masonry infill walls are made with material whose density is more than 12 kN/m³.

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- b) Steel buildings without braces and without masonry infills:

$$T_a =$$

$$\begin{cases} 0.080H^{0.75} & \text{RC-Steel composite MRF buildings} \\ 0.085H^{0.75} & \text{Steel MRF buildings} \end{cases}$$

- c) Buildings other than buildings with RC MRFs with or without RC structural walls and with or without URM infills:

$$T_a = \frac{0.09 H}{\sqrt{d}}$$

where

d = dimension (m) of the building at the base along the considered direction of earthquake shaking, that is the plan distance between the extreme vertical members on the perimeter of the building.

The approximate natural periods of buildings taller than 50 m shall be taken as per IS 16700.

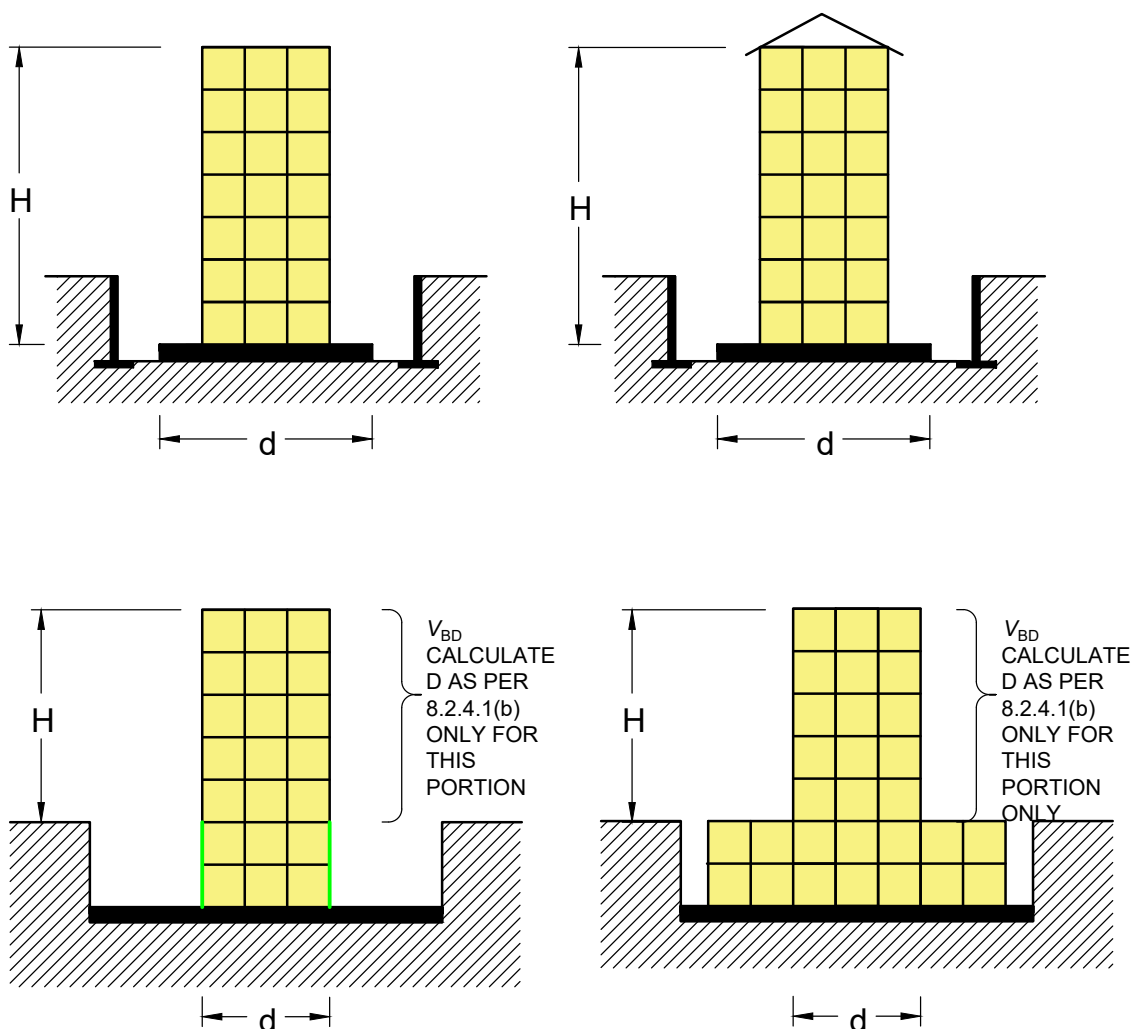


FIG. 14 HEIGHT H OF BUILDING TO BE CONSIDERED IN ESTIMATION OF T_a

8.2.4.4 Lower limit of design horizontal base shear force

a) Equivalent static method

For buildings of height less than 50 m, the design horizontal earthquake base shear force $V_{BD,H}$ obtained from 8.2.4 for the design shall not be taken less than $V_{BD,H,min}$ given by:

$$V_{BD,H,min} = 0.625 \left(\frac{ZI}{R} \right) W \geq 0.015 W$$

b) Response spectrum method

The design base shear forces V_{BDX} and V_{BDY} estimated by response spectrum method shall not be less than the corresponding design base shear forces $\overline{V_{BDX}}$ and $\overline{V_{BDY}}$ and estimated by equivalent static method (using approximate fundamental natural period T_a estimated as per 8.2.4.3).

When V_{BDX} is less than $\overline{V_{BDX}}$ along X-direction in plan, then:

- 1) The stress resultants in all members, storey shear forces and base reactions, arising from the earthquake shaking along the X-direction in plan alone, shall be amplified by the ratio $\overline{V_{BDX}} / V_{BDX}$; and
- 2) The deformations at all points in the building, arising from the earthquake shaking along the X-direction in plan alone, need not be amplified by the said ratio.

Similarly, when V_{BDY} is less than $\overline{V_{BDY}}$ along Y-direction in plan, then:

- 1) The stress resultants in all members, storey shear forces and base reactions, arising from the earthquake shaking along the Y-direction in plan alone, shall be amplified by the ratio $\overline{V_{BDY}} / V_{BDY}$; and
- 2) The deformations at all points in the building, arising from the earthquake shaking along the Y-direction in plan alone, need not be amplified by the said ratio.

The said scaling need not be applied when $V_{BDX} > \overline{V_{BDX}}$ or $V_{BDY} > \overline{V_{BDY}}$ along X- and Y-directions in plan, respectively.

c) Response history method

The provision of 8.2.4.4(b) shall apply to the design base shear forces V_{BDX} and V_{BDY} estimated by response history method also.

8.2.4.5 Distribution of earthquake forces

a) Design horizontal base shear force

The design horizontal earthquake base shear force $V_{BD,H}$ obtained from 8.2.4 shall be distributed along the height of the building and in plan at each floor level as specified hereunder.

1) Distribution of base shear forces as floor lateral forces at different floor levels

The design floor lateral force $Q_{Di,H}$ at floor i shall be estimated as:

$$Q_{Di,H} = \left(\frac{W_i H_i^2}{\sum_{j=1}^N W_j H_j^2} \right) V_{BD,H}$$

where

- W_i = seismic weight of floor i ;
- H_i = height of floor i measured from base; and
- N = number of storeys in building, that is levels at which masses are located.

2) Estimation of storey shear forces

The design storey shear force $V_{Di,H}$ in storey i shall be estimated as:

$$V_{Di,H} = \sum_{j=i}^N Q_{Dj,H}$$

3) Distribution of storey shear forces at each storey to vertical members in that storey

- i) In buildings whose floors can provide rigid horizontal diaphragm action in their own plane, $V_{Di,H}$ shall be distributed to the various vertical structural elements in proportion to their lateral stiffness; and
- ii) In buildings whose floors are not capable of providing rigid horizontal diaphragm action in

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their own plane, $V_{Di,H}$ shall be distributed to the various vertical structural elements in proportion to the masses from tributary floor areas. Alternatively, the flexible floor shall be modelled as a flexible diaphragm.

b) Design vertical base force

The design vertical earthquake base force $V_{BD,V}$ obtained from [8.2.4](#) shall be distributed along the height of the building and in plan at each floor level as specified hereunder.

1) Distribution of vertical base force to different floor levels

The total design vertical force $Q_{Di,V}$ in storey i shall be estimated as:

$$Q_{Di,V} = \left(\frac{w_i}{\sum_{j=1}^N w_j} \right) V_{BD,V}$$

The design vertical force $V_{Di,V}$ in storey i shall be estimated as:

$$V_{Di,V} = \sum_{j=1}^N Q_{Dj,V}$$

2) Distribution of total vertical force at each storey to vertical elements in that storey

$V_{Di,V}$ shall be distributed to all vertical structural elements (including those that are not part of the lateral load resisting system) in proportion to their axial stiffness.

8.2.4.6 Torsion

Provision shall be made in all buildings for increase in shear forces on the lateral force resisting elements resulting from twisting about the vertical axis of the building, arising due to eccentricity between the center of mass (CM) and center of resistance (CR) at the floor levels. The design floor lateral forces $Q_{Dj,H}$ calculated as in [8.2.4.5\(a\)\(1\)](#) at each floor shall be applied at the location of the CM specified hereunder.

a) Design eccentricity

While performing structural analysis for design, the design eccentricity e_{di} from CR

to CM at floor i shall be taken as one of the following two values, whichever gives the more severe effect on lateral force resisting elements:

$$e_{di} =$$

$$\begin{cases} \begin{cases} 1.8e_{si} + 0.05 b_i \\ e_{si} - 0.05 b_i \end{cases} & \text{Equivalent static method} \\ \begin{cases} 1.8e_{si} + 0.05 b_i \\ e_{si} - 0.05 b_i \end{cases} & \text{Response spectrum method} \\ \begin{cases} e_{si} + 0.05 b_i \\ e_{si} - 0.05 b_i \end{cases} & \text{Response history method} \end{cases}$$

where

e_{si} = static eccentricity at floor i , which is the distance between center of mass and center of resistance; and

b_i = floor plan dimension of floor i , perpendicular to the direction of force.

b) Torsional flexibility

For buildings less than 50 m in height, the torsional flexibility factor ψ of a building at storey i shall be estimated as:

$$\psi_i = \left(\frac{e_{ki}}{B} \right) \left(\frac{B}{r_i} \right)^2 (\tau^2)$$

where

e_{ki} = static stiffness eccentricity e_{si} at floor level i taken as plan distance between CM and CR at the floor level measured perpendicular to the considered direction of shaking;

B = outer dimension of the floor above the said storey perpendicular to the considered direction of shaking;

τ = ratio of fundamental torsional natural period T_θ and fundamental translational natural periods T_X and T_Y modes of oscillation of the building for earthquake shaking considered along the X- and Y- directions, respectively;

r_i = translational radius of gyration of the mass at the floor above the said storey about the CM

$$= \sqrt{\frac{I_i^m}{m_i}}$$

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where

I_i^m = seismic mass moment of inertia of storey i

$$= \sum_{j=1}^{N_{VE,i}} (I_{VE,i,j}^M) + \sum_{j=1}^{N_{LM,i}} (m_{i,j} r_{i,j}^2)$$

m_i = seismic mass of storey i

$$= \sum_{j=1}^{N_{LM,i}} (m_{i,j})$$

where

$I_{VE,i,j}^M$ = seismic mass moment of inertia of vertical element j at storey i about its CG;

$m_{i,j}$ = seismic mass lumped at node j at storey i ;

$r_{i,j}$ = distance from CM of the seismic mass lumped at node j at storey i ;

$N_{LM,i}$ = number of seismic lumped mass at storey i ; and

$N_{VE,i}$ = number of vertical elements at storey i .

If $\psi_i < 0.4$ at any storey i of the building, then the building is said to be torsionally stiff, else torsionally flexible.

1) *Buildings with $\psi_i < 0.4$*

In torsionally stiff buildings, the analysis using the design eccentricity specified in [8.2.4.6\(a\)](#) shall suffice, provided the values of τ and (e_{Ki}/B) at each storey i are within the range specified in [Table 8](#), else the structural configuration of the building shall be revised.

2) *Buildings with $\psi_i \geq 0.4$*

In torsionally flexible buildings, the structural configuration of the building shall be revised to ensure that $\psi_i < 0.4$.

Table 8 Design Limit for e_K/B and τ for Rectangular Regular Buildings

[Clause [8.2.4.6\(b\)\(1\)](#)]

SI No.	Ratio τ of Natural Periods, T_θ/T_X or T_θ/T_Y	Total Torsional Eccentricity (e_K/B)				
		$e_K/B \leq 0.05$	$0.05 < e_K/B \leq 0.07$	$0.07 < e_K/B \leq 0.10$	$0.10 < e_K/B \leq 0.125$	$0.125 < e_K/B$
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	$\tau \leq 0.6$	Perform torsional analysis as per 8.2.4.6(a)				Revise structural configuration to reduce e_K/B
ii)	$0.6 < \tau \leq 0.7$	Perform torsional analysis as per 8.2.4.6(a)			Revise structural configuration to ensure $\tau \leq 0.6$	
iii)	$0.7 < \tau \leq 0.8$	Perform torsional analysis as per 8.2.4.6(a)		Revise structural configuration to ensure $\tau \leq 0.7$		
iv)	$0.8 < \tau \leq 0.9$	Perform torsional analysis as per 8.2.4.6(a)	Revise structural configuration to ensure $\tau \leq 0.8$			
v)	$\tau \geq 0.9$	Not permitted				

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8.3 Earthquake Analysis

8.3.1 Analytical Model

The provisions given in **8.3.1** of IS 1893 (Part 1) shall apply.

8.3.2 Modal Analysis

The provisions given in **8.3.2** of IS 1893 (Part 1) shall apply.

8.3.3 Methods of Earthquake Analysis

The effects of design earthquake loads on buildings can be assessed by the following methods of linear structural analysis:

- Static analysis by the equivalent static method;
- Dynamic analysis by the response spectrum method; and
- Dynamic analysis by the response history method.

8.3.3.1 Equivalent static method

The provisions given in **8.3.3.1** of IS 1893 (Part 1) shall apply to perform equivalent static method of analysis of buildings. In addition:

- The design base force V_{BD} shall be computed for the building. Then, it shall be distributed to the various floor levels at the corresponding centers of mass and, finally, this design earthquake force at each floor level shall be distributed to individual lateral load resisting elements through structural analysis considering the applicable floor diaphragm behaviour;
- Linearized $P - \Delta$ analysis shall be performed for buildings where the stability index Q_s at any storey of the building exceeds 0.04, where:

$$Q_s = \frac{\sum_{c=1}^{N_{CS}} (P_{DC} \Delta_{DC})}{[\sum_{c=1}^{N_{CS}} (H_{DC})] h_s}$$

where

- P_{DC} = design axial force in column c in the storey considered;
- Δ_{DC} = lateral deflection at top of column c with respect to its bottom, in the storey considered along the principal plan direction considered;
- N_{CS} = number of columns in the storeys considered;
- H_{DC} = design lateral shear force at top of column c in the storey considered along the principal

plan direction considered; and

h_s = height of storey considered.

In the above, P_{DC} , Δ_{DC} and H_{DC} are based on results from linear elastic analysis under the action of loads combined as per **8.4** of IS 1893 (Part 1).

8.3.3.2 Response spectrum method

The provisions given in **8.3.3.2** of IS 1893 (Part 1) shall apply to perform *response spectrum method* of analysis of buildings. In addition:

- When a building has none of the irregularities specified in **7.1.3**, then it can be modelled using a simplified analytical model as specified hereunder:

Buildings may be analyzed as a system of masses lumped at the floor levels with each mass having one degree of freedom, that of lateral displacement in the principal plan direction under consideration. In such cases, the expressions given below can be used.

1) Modal mass

Modal mass M_k of mode k shall be estimated as:

$$M_k = \frac{\{ \sum_{i=1}^N (W_i \varphi_{ik}) \}^2}{g \sum_{j=1}^N \{ W_j (\varphi_{jk})^2 \}}$$

where

- N = number of floors of the building;
- W_i = seismic weight of floor i of the building;
- φ_{ik} = mode shape coefficient at floor i in mode k ; and
- g = acceleration due to gravity.

2) Modal participation factor

Mode participation factor P_k of mode k shall be estimated as:

$$P_k = \frac{\sum_{i=1}^N W_i \varphi_{ik}}{\sum_{j=1}^N \{ W_j (\varphi_{jk})^2 \}}$$

3) Design peak lateral force at each floor in each mode

Design peak lateral force $Q_{Di,k,H}$ at floor i in mode k shall be estimated as:

$$Q_{Di,k,H} = A_{HD,k} \varphi_{ik} P_k W_i,$$

where

$A_{HD,k}$ = design horizontal elastic PSA as per **6.2.3.4** or **6.3**

of IS 1893 (Part 1) using natural period of oscillation T_k of mode k obtained from modal analysis.

4) *Design peak storey shear forces in each mode*

Design peak shear force $V_{Dik,H}$ acting in storey i in mode k shall be estimated as:

$$V_{Dik,H} = \sum_{j=i+1}^N Q_{Djk,H}$$

5) *Design peak storey shear force due to all modes considered*

Design peak storey shear force Q_i in storey i due to all modes considered shall be obtained by combining those due to each mode in accordance with **8.3.3.2(e)(2)** of IS 1893 (Part 1).

6) *Design lateral forces at each storey due to all modes considered*

Design lateral forces F_{roof} at roof level and F_i at level of floor i shall be obtained as:

$$F_{\text{roof}} = V_{\text{roof}}; \text{ and} \\ F_i = V_i - V_{i+1}.$$

7) *Structural analysis*

The stress resultants (namely axial forces, shear forces, bending moments, and torsional moments) in the members of the building shall be estimated by equivalent static analysis method as per **8.3.3.1** with the lateral forces estimated from **8.3.3.2(a)(6)** applied at the CM as per the torsional analysis mentioned in **8.2.4.6**.

- b) When a building has any of the irregularities specified in **7.1.3**, then it shall be analysed as a specified in **8.3.3.2** of IS 1893 (Part 1).

8.3.3.3 Response history method

The provisions given in **8.3.3.3** of IS 1893 (Part 1) shall apply to perform *response history method* of analysis of buildings.

8.3.3.4 Applicability of methods

The applicability of these methods shall be as per **Table 9**. Further:

- a) Response spectrum method can be adopted even when buildings are regular; and
b) Response history method can be adopted even in buildings of normal or important category.

Table 9 Methods of Linear Structural Analysis Applicable for Different Buildings

(*Clause 8.3.3.4*)

Sl No.	Method of Analysis	Earthquake Zone	Building Category	Building Configuration	Approximate Natural Period T_a
(1)	(2)	(3)	(4)	(5)	(6)
i)	Static analysis				
	a) Equivalent static method	See 13.1 , 15.1 and 17.1	All	All	All
ii)	Dynamic analysis				
	a) Response spectrum method	All zones	All	Recommended for Irregular Buildings	Recommended for buildings with natural period more than 0.4 s
	b) Response history method	All zones	Recommended for Critical and Special Buildings except for Critical and Special Small Buildings as defined in 13.1 and 16.1		

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8.4 Load Combinations

8.4.1 Basic Load Combinations

The provisions given in **8.4.1** of IS 1893 (Part 1) shall apply.

8.4.2 Additional Load Combinations

Additional load combinations other than those specified in [8.4.1](#) shall be:

- a) None for masonry buildings;
- b) as per [14.4](#) for Concrete buildings; and
- c) as per [16.4](#) for steel buildings.

8.4.3 Multi-Directional Earthquake Shaking

The provisions given in **8.4.3** of IS 1893 (Part 1) shall apply.

8.5 Design Demand

8.5.1 Designing for Effects from Earthquake Load Combinations

The provisions given in **8.5.1** of IS 1893 (Part 1) shall apply.

8.5.2 Designing for Effects from Non-Earthquake Load Combinations

The provisions given in **8.5.2** of IS 1893 (Part 1) shall apply.

9 GEOTECHNICAL ASPECTS

9.1 Soil Properties

The provisions given in **9.1** of IS 1893 (Part 1) shall apply.

9.2 Liquefaction

The provisions given in **9.2** of IS 1893 (Part 1) shall apply.

10 ARCHITECTURAL ELEMENTS AND UTILITIES

10.1 Classification of AEUs

The provisions given in **10.1** of IS 1893 (Part 1) shall apply.

10.2 Protection of AEUs

The provisions given in **10.2** of IS 1893 (Part 1) shall apply.

10.3 Load Effects for Design of System to Protect AEUs

The provisions given in **10.3** of IS 1893 (Part 1) shall apply.

10.4 Earthquake Analysis

The provisions given in **10.4** of IS 1893 (Part 1) shall apply.

10.5 Earthquake Demands on AEUs

10.5.1 Acceleration-Sensitive AEUs

The provisions given in **10.5.1** of IS 1893 (Part 1) shall apply.

10.5.2 Displacement-Sensitive AEUs

The design relative displacements Δ_X and Δ_Y along plan directions X and Y, respectively, at the two ends of a D-AEU in buildings estimated in **10.5.2** of IS 1893 (Part 1) shall not be less than those specified hereunder.

10.5.2.1 Displacement-sensitive AEU on same building

When the D-AEU is supported consecutively at two levels of the same building, one at height h_1 and the other at height h_2 from base of the building:

a) *Static analysis*

$$\Delta_{X,\min} = \max [1.2R_X(\Delta_{X1} - \Delta_{X2}); R_X\delta(h_1 - h_2)] ; \text{ and}$$

$$\Delta_{Y,\min} = \max [1.2R_Y(\Delta_{Y1} - \Delta_{Y2}); R_Y\delta(h_1 - h_2)]$$

b) *Dynamic analysis*

$$\Delta_{X,\min} = \max [R_X(\Delta_{X1} - \Delta_{X2}); R_X\delta(h_1 - h_2)]; \text{ and}$$

$$\Delta_{Y,\min} = \max [R_Y(\Delta_{Y1} - \Delta_{Y2}); R_Y\delta(h_1 - h_2)]$$

where

- R_X = elastic force reduction factor of building for the lateral load resisting structural system employed along X-direction;
- R_Y = elastic force reduction factor of building for the lateral load resisting structural system employed along Y-direction;
- Δ_{X1} and Δ_{Y1} = design displacements along X and Y directions, respectively, of the building at height H_1 at level 1 from its base;
- Δ_{X2} and Δ_{Y2} = design displacements along X and Y directions, respectively, of the building at height H_2 at level 2 from its base, or of the ground; and
- δ = drift limit specified for buildings in [Table 4](#) and [7.2.2](#).

10.5.2.2 Displacement-sensitive AEU on different buildings or supports

When the D-AEU is supported:

- a) At two levels of two different buildings (A and B, say, even if one of them is an electric pole, or a communication antenna tower), or at two levels of two adjoining parts (A and B, say) of the same building separated by a separation joint on which the AEU is supported, that is, at height h_1 on Building A and at height h_2 on Building B from bases of the respective buildings; and

1) *Equivalent static method*

$$\Delta_{X,\min} = \max [(1.2R_{XA}\Delta_{XA1} + |1.2R_{XB}\Delta_{XB2}|); (R_{XA}\delta h_1 + R_{XB}\delta h_2)]; \text{ and}$$

$$\Delta_{Y,\min} = \max [(1.2R_{YA}\Delta_{YA1} + |1.2R_{YB}\Delta_{YB2}|); (R_{YA}\delta h_1 + R_{YB}\delta h_2)],$$

2) *Response spectrum method and response history method*

$$\Delta_{X,\min} = \max [(|R_{XA}\Delta_{XA1}| + |R_{XB}\Delta_{XB2}|); (R_{XA}\delta h_1 + R_{XB}\delta h_2)]; \text{ and}$$

$$\Delta_{Y,\min} = \max [(|R_{YA}\Delta_{YA1}| + |R_{YB}\Delta_{YB2}|); (R_{YA}\delta h_1 + R_{YB}\delta h_2)],$$

- b) One end at a level on a building and another on the adjoining ground:

1) *Equivalent static method*

$$\Delta_{X,\min} = \max [(1.2R_{XA}\Delta_{XA1} + |1.2\Delta_{gX}|); (R_{XA}\delta h_1 + R_{XB}\delta h_2)]; \text{ and}$$

$$\Delta_{Y,\min} = \max [(1.2R_{YA}\Delta_{YA1} + |1.2\Delta_{gY}|); (R_{YA}\delta h_1 + R_{YB}\delta h_2)],$$

2) *Response spectrum method and response history method*

$$\Delta_{X,\min} = \max [(|R_{XA}\Delta_{XA1}| + |1.2\Delta_{gX}|); (R_{XA}\delta h_1 + |1.2\Delta_{gX}|)] \text{ and}$$

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$$\Delta_{Y,min} = \max [(|R_{YA} \Delta_{YA1}| + |1.2 \Delta_{gY}|); (R_{YA} \delta h_1 + |1.2 \Delta_{gY}|)],$$

where

- Δ_{XA1} and Δ_{YA1} = design displacements along X-directions and Y-directions, respectively, of building A at height h_1 at level 1 from its base;
- Δ_{XB2} and Δ_{YB2} = design displacements along X-directions and Y-directions, respectively, of building B at height h_2 at level 2 from its base, or of the ground;
- R_{XA} and R_{XB} = elastic force reduction factor of building for the lateral load resisting structural system employed along X-direction of buildings A and B, respectively;
- R_{YA} and R_{YB} = elastic force reduction factor of building for the lateral load resisting structural system employed along Y-direction of buildings A and B, respectively;
- δ = drift limit specified for buildings in [Table 4](#) and [7.2.2](#);
- h_1 and h_2 = elevations of levels 1 and 2 from the base of the building, respectively; and
- Δ_{gX} and Δ_{gY} = design displacements along X- directions and Y-directions, respectively, of the ground adjacent to the building.

11 MISCELLANEOUS

11.1 Buildings on Sloping Ground

Before the provisions given hereunder are applied, the hill slope shall be examined to be stable from geophysical and geotechnical considerations.

- a) RC buildings on sloping ground (*see* [Fig. 15](#)) shall be provided with RC structural walls as specified in (b) and (c) below, which are oriented along both principal plan directions, to minimize torsional irregularity;
- b) RC structural walls (*see* [Fig. 16](#)):
 - 1) perpendicular to the road shall be provided in the tallest bay on the downhill side of the two exterior frames from the lowest column base level up to the highest column base level (that is, the road level); and
 - 2) parallel to the road shall be provided, in the tallest frame on the down-hill side from the lowest column base level up to the highest column base level (that is, the road level), and meet the following:
 - i) These RC structural walls shall have configuration A, B or C ([Table 10](#)); and
 - ii) These RC structural walls have a total cross-sectional area, such that the maximum horizontal displacement of the tallest frame at any floor, including roof, under the action of design horizontal force in the direction parallel to the road, is not more than 1.05 times that at the same floor in the shortest frame.
- c) The design and detailing of the RC structural walls shall conform to the provisions of special structural walls in IS 13920 (Part 5).

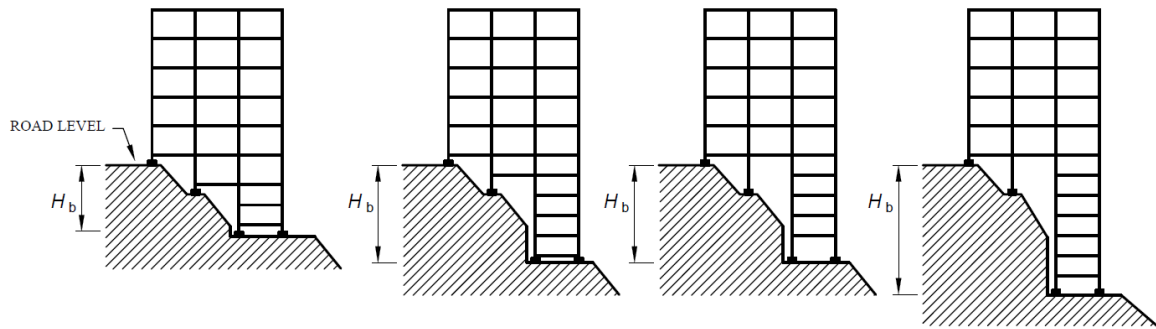
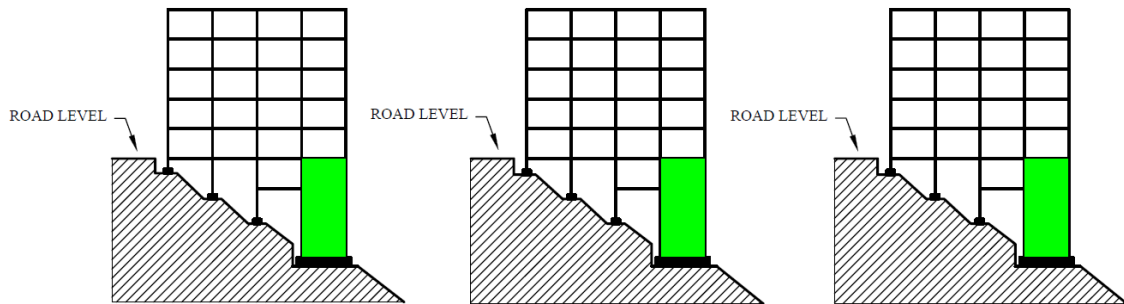


FIG. 15(A) SHALLOW SLOPE

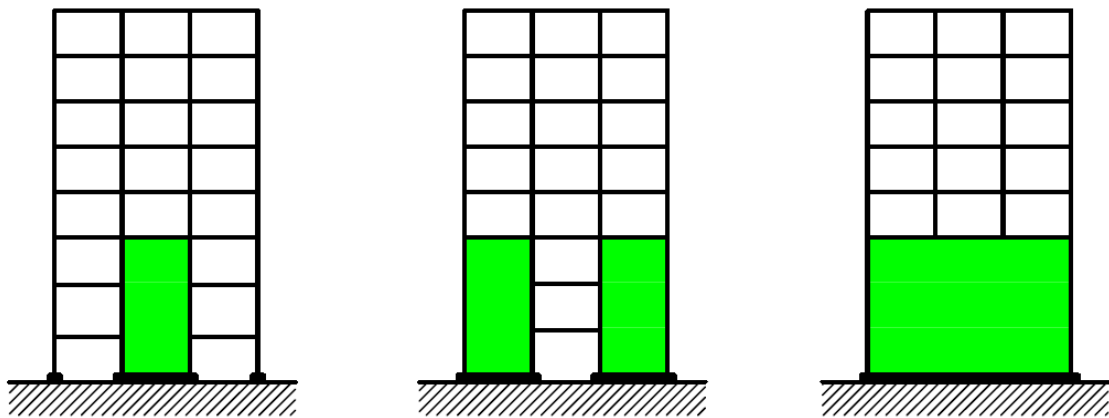
FIG. 15(B) MODERATE SLOPE

FIG. 15(C) STEEP SLOPE

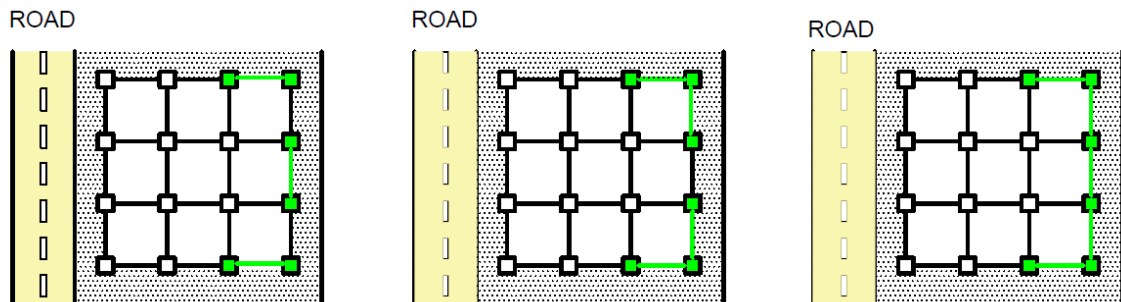
FIG. 15 ELEVATION OF TYPICAL STEP-BACK BUILDINGS RESTED ON SLOPPING GROUND



SIDE ELEVATION



FRONT ELEVATION OF TALLEST FRAME ON THE DOWN-HILL SIDE



PLAN (AT ROAD LEVEL)

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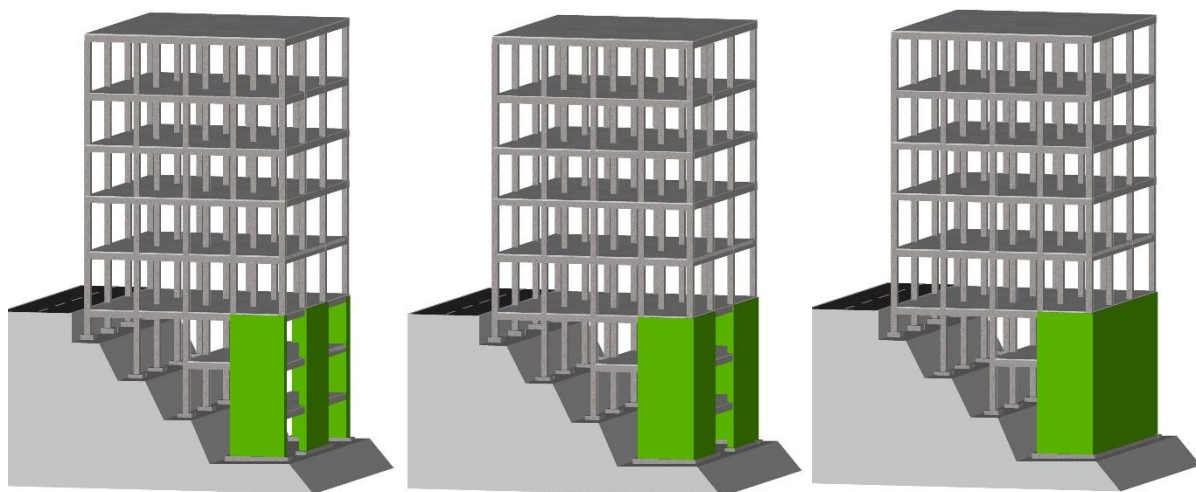


FIG. 16(A) CONFIGURATION A

FIG. 16(B) CONFIGURATION B

FIG. 16(C) CONFIGURATION C

FIG. 16 RC STRUCTURAL WALL CONFIGURATIONS OF BUILDINGS ON HILL SLOPES

Table 10 RC Structural Wall Configurations in Step-Back Buildings on Hill Slopes

[Clause 11.1(b)]

Sl No.	Difference in Height H_b between Base Levels of Highest and Lowest Column	Wall Configuration
(1)	(2)	(3)
i)	≤ 10 m	A (see Fig. 16A)
ii)	10 m to 15 m	B (see Fig. 16B)
iii)	> 15 m	C (see Fig. 16C)

11.2 Foundations

Foundations shall be designed for the stress-resultants imposed by the superstructure under the action of loads combined as per combinations given in 8.4 of IS 1893 (Part 1). In the estimation of the stress-resultants, the inertia of the foundations shall be considered as provided hereunder:

Individual footings and rafts resting on ground	: None;
Individual footings and rafts resting on piles	: Full inertia of footings and rafts; and
Pile and well foundations	: Inertia of piles and wells above ground level.

These inertia forces of foundation elements shall be considered along with the base force of the superstructure of the building applied at the top of the foundation.

11.2.1 Soil Flexibility

The soil flexibility need not be modelled in buildings (other than critical and special buildings) with the elevation aspect ratio 3 or less along the smaller plan dimension.

11.2.2 Use of foundations vulnerable to significant differential settlement due to ground shaking shall be avoided in buildings located in earthquake zones III, IV, V and VI.

11.2.3 Isolated RC footings without tie-beams or unreinforced strip foundations shall not be rested on soils of Site Class D.

11.2.4 In buildings located in earthquake zones IV, V and VI, individual footings or pile caps shall be inter-connected with ties, except when individual spread footings are rested directly on rock. Under all load combinations, these ties shall be capable of carrying axial tensile and axial compressive forces equal to $0.25A_{HD} (T_H)$ times the larger of the column or pile cap load, in addition to resisting the stress-resultants arising from load combinations specified in 8.4, subject to a minimum of 5 percent

of larger of column compressive forces, where $A_{HD}(T_H)$ is as per 8.2.4.

11.2.5 Piles shall be designed and constructed to withstand maximum deformations imposed on them by the response of the structure owing to earthquake ground shaking. Design of anchorage of piles into the pile cap shall consider combined effects, including those of axial forces due to uplift of piles and bending moments arising in them owing to fixity to pile cap.

11.3 Cantilever Projections

Only the projecting parts and their connections with the building (and not the building) shall be designed for the design forces based on increased elastic maximum PSA specified hereunder.

11.3.1 Vertical Projections

Small-sized facilities (like towers, tanks, parapets, smoke stacks/chimneys) and other vertical cantilever projections attached to buildings and projecting vertically above the roof, but not a part of the structural system of the building, shall be designed and checked for stability for R times the design horizontal acceleration coefficient $A_{HD}(T_H)$ (as per 8.2.4) for that building. In the analysis of the building, weights of these projecting elements shall be lumped with the roof weight.

11.3.2 Horizontal Projections

All horizontal projections of buildings (like cantilever structural members at the porch level or higher) or attached to buildings (like brackets, cornices, and balconies) shall be designed for the design vertical acceleration coefficient $A_{VD}(T_V)$ (as per 8.2.4) for that building.

11.4 Compound Walls

Compound walls shall be designed for the design horizontal force given by seismic weight of the compound wall multiplied by R times the design horizontal acceleration coefficient $A_{HD}(T)$ (as per 8.2.4) of the building it is surrounding. When a compound wall surrounds many buildings, the largest value of $A_{HD}(T)$ among all buildings and its R value shall be considered.

SECTION 2 ADDITIONAL CRITERIA FOR MASONRY BUILDINGS

12 EARTHQUAKE DEMAND

12.1 Structural Systems

12.1.1 Available Structural Systems

The following structural systems shall be available in masonry buildings to resist effects of earthquake

shaking:

- a) Building with masonry walls with bands (MWB);
- b) Building with masonry walls with bands, and horizontal and vertical reinforcements (MWBR);
- c) Building with confined masonry walls (CMW); and
- d) Building with reinforced masonry walls (RMW).

12.1.1.1 Building with masonry walls with bands

These are buildings with masonry walls with bands (MWB) comprising of unreinforced masonry conforming to geometrical requirements specified in IS 1905, not designed for stress-resultant and deformation demands based on principles of structural engineering, but provided with horizontal bands only, and conforming to requirements of IS 13920 (Part 5).

12.1.1.2 Building with masonry walls with bands and horizontal and vertical reinforcements

These are buildings with masonry walls with bands and horizontal and vertical reinforcements (MWBR) comprising of unreinforced masonry conforming to geometrical requirements specified in IS 1905, not designed for stress-resultant and deformation demands based on principles of structural engineering, but provided with horizontal bands and horizontal and vertical reinforcements, and conforming to requirements of IS 13920 (Part 5).

12.1.1.3 Building with confined masonry walls

These are buildings with confined masonry walls (CMW) comprising of unreinforced masonry walls conforming to geometrical requirements specified in IS 1905, with the load-bearing walls having reinforced concrete horizontal (that is tie-beams) and vertical (that is, tie-columns) confining concrete members built on all four edges of the masonry wall panel, and conforming to requirements of IS 13920 (Part 5).

12.1.1.4 Building with reinforced masonry walls

These are buildings with reinforced masonry walls (RMW) comprising of masonry walls conforming to geometrical requirements specified in IS 1905, with the load-bearing masonry walls provided with vertical and horizontal reinforcements, and conforming to requirements of IS 13920 (Part 5).

12.1.2 Admissible Structural Systems

12.1.2.1 Masonry buildings required to resist earthquake ground shaking shall have a structural system admissible as per Table 11 depending the earthquake zone and category of the building.

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Table 11 Structural Systems Admissible in Different Earthquake Zones in Masonry Buildings of Different Categories
([Clause 12.1.2.1](#))

SI No.	Earthquake Zone	Building Category		
		Normal	Important	Critical and Special
(1)	(2)	(3)	(4)	(5)
i)	VI	RMW CMW MWBR	RMW CMW	RMW
ii)	V	RMW CMW MWBR	RMW CMW	RMW
iii)	IV	RMW CMW MWBR	RMW CMW	RMW
iv)	III	RMW CMW MWBR MWB	RMW CMW MWBR	RMW CMW
v)	II	RMW CMW MWBR MWB	RMW CMW MWBR	RMW CMW

12.1.2.2 The same type of LFRS shall be used along both principal plan directions.

12.2 Design Earthquake Force

12.2.1 Design Base Force

The total design force earthquake base force at the base of the building shall be estimated as per [8.2.4](#).

The following shall be used in the estimation of the design horizontal and vertical earthquake forces of masonry buildings:

- Seismic weight shall be taken as per [8.2.1](#);
- Importance Factor shall be taken as per [8.2.2](#);
- Damping ratio shall be taken as 5 percent of the critical damping as per [8.2.4.2](#); and
- Elastic force reduction factor R shall be taken as per Table 7.

12.2.2 Distribution of Design Base Force

12.2.2.1 Distribution in elevation

The design base force shall be distributed along the height of the building as per [8.2.4.5](#).

12.2.2.2 Distribution in plan

The in-plan distribution of design lateral force at floor i to different walls shall be estimated based on their relative stiffness.

12.2.3 Torsion

12.2.3.1 Design eccentricity

Provision given in [8.2.4.6\(a\)](#) shall be modified as specified hereunder for masonry buildings. While performing structural analysis by any method, the design eccentricity e_{di} to be used at floor i shall be taken as one of the following two values, whichever gives the more severe effect on lateral force resisting elements:

$$e_{di} = \begin{cases} e_{si} + 0.05b_i \\ e_{si} - 0.05b_i \end{cases}$$

where

e_{si} = static eccentricity at floor i , which is the distance between center of mass and center of resistance in the direction perpendicular to the direction of force; and

b_i = floor plan dimension of floor i , perpendicular to the direction of force.

This requirement shall be applicable when any of the three methods of analysis is employed, namely equivalent static method, response spectrum method, and response history method.

12.3 Earthquake Analysis

- The provisions given in **8.3** of IS 1893 (Part 1) shall apply in general; and

- b) Simple structural models based on hand calculations and/or more sophisticated computer models can be employed to perform structural analysis, obtain demands on masonry walls, and perform demand-to-capacity verification under all earthquake load combinations as per 8.4 of IS 1893 (Part 1).

12.3.1 Modelling

Structural analysis by hand calculations is permitted in buildings with single-storied simple configurations that are regular in plan and in elevation with minimum torsional eccentricity (e_K/B) less than or equal to 0.05. For other masonry buildings, the following methods of structural analysis may be used:

- Equivalent frame model; or
- Finite element model.

Linear elastic models shall be adopted with homogenized or smeared material properties for idealizing the composite masonry (that is masonry unit and mortar). Floor and roof diaphragms shall be provided with diaphragm constraints only where the floor and roof slabs are classified as rigid.

12.3.1.1 Equivalent frame model

- The masonry walls shall be discretized into equivalent vertical (piers) and horizontal (spandrel) elements. The masonry piers and spandrels shall be idealized as beam-column frame elements capable of resisting axial loads, bending moments and shear forces. Appropriate boundary conditions shall be assigned to these frame elements; and
- In masonry walls (with window and door openings), the masonry piers and spandrels shall be connected through rigid nodes. A masonry wall without openings shall be discretized only as a single masonry pier.

12.3.1.2 Finite element model

All masonry elements shall be discretized as planar or three-dimensional elements, and these elements shall be assigned appropriate material properties.

12.3.1.3 Section properties

When equivalent frame model is adopted, the masonry piers and spandrels shall be assigned effective section properties, namely area of cross section and second moment of area, as per [Table 3](#).

12.3.1.4 Material properties

- The modulus of elasticity E_m (in MPa) of masonry shall be taken as:

$$E_m = \begin{cases} 550f_m & \text{Clay brick masonry} \\ 750f_m & \text{Concrete block masonry} \end{cases}$$

where

f_m = compressive strength (in MPa) of masonry prism as per IS 1905.

- The Poisson's ratio ν of clay brick masonry shall be taken as per [Table 12](#) depending on the proportion of cement mortar mix.

13 SPECIFIC BUILDINGS

13.1 Small Buildings

In single-storied residential buildings with less than 50 m² of built-up area, with load-bearing walls oriented along both principal plan directions to minimize torsional irregularity, structural plan density not less than 15 percent, and laterally supported wall lengths not more than 3.0 m, structural analysis is not required in:

- earthquake zones II and III, if masonry walls are provided with bands (MWB); and
- earthquake zones IV, V and VI, if masonry walls are provided with bands, and horizontal and vertical reinforcements (MWBR).

Table 12 Poisson's Ratio of Masonry

([Clause 12.3.1.4](#))

Sl No.	Mortar Mix	Poisson's Ratio, ν	
		Clay Brick Masonry	Concrete Block Masonry
(1)	(2)	(3)	(4)
i)	1 : 3	0.15	0.15
ii)	1 : 4		
iii)	1 : 6	0.12	
iv)	1 : 8		

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SECTION 3 ADDITIONAL CRITERIA FOR CONCRETE BUILDINGS

14 EARTHQUAKE DEMAND

14.1 Structural Systems

14.1.1 Available Structural Systems

The following structural systems are available in concrete buildings to resist effects of earthquake shaking:

- a) Buildings with ordinary moment resisting frames (OMRF);
- b) Buildings with ordinary moment resisting frames and ordinary structural walls (OMRF + OSW);
- c) Buildings with ordinary structural walls (OSW);
- d) Buildings with special moment resisting frames (SMRF);
- e) Buildings with special structural walls (SSW);
- f) Buildings with SMRFs, SSWs and flat slabs (SMRFs + SSWs + FS);
- g) Buildings with special moment resisting frames with special structural walls (SMRF + SSW); and
- h) Buildings with dual system (DS).

14.1.1.1 Buildings with ordinary moment resisting frames (OMRF)

These are buildings with ordinary MRF and their members designed and detailed as per IS 456.

14.1.1.2 Buildings with ordinary moment resisting frames and ordinary structural walls (OMRF + OSW)

These are buildings with ordinary SWs and ordinary MRFs designed and detailed as per IS 456.

14.1.1.3 Buildings with ordinary structural walls (OSW)

These are buildings with ordinary SWs and beams, if any, designed and detailed as per IS 456.

14.1.1.4 Buildings with special moment resisting frames (SMRF)

These are buildings with special MRF and their members designed and detailed as per IS 13920.

14.1.1.5 Buildings with special structural walls (SSW)

These are buildings with special SWs and beams, if any, designed and detailed as per IS 13920 (Part 5).

a) Buildings with SSWs with boundary elements (BE)

The SSWs are designed and detailed as per IS 13920, when boundary elements are required as per IS 13920 (Part 5).

b) Buildings with SSWs with no boundary elements (NBE)

The SSWs are designed and detailed as per IS 13920, when boundary elements are not required along the full or partial height of the building as per IS 13920 (Part 5).

14.1.1.6 Buildings with SMRFs, SSWs and flat slabs

a) These are buildings with SMRFs, SSWs and flat slabs:

- 1) SMRFs designed as per IS 13920 (Part 5), and SSWs designed and detailed as per IS 13920 (Part 5);
- 2) SMRFs or SMRFs with SSWs provided along the perimeter of the building;
- 3) Punching shear failure eliminated under load combinations for design;
- 4) Storey drift under lateral force does not exceed 0.1 percent, where lateral drift shall be estimated:
 - i) Using 3-dimensional building models, and considering total lateral displacement, including torsional effects, arising from 3-dimensional dynamic analysis; and
 - ii) Without scaling of displacement response quantities, as mentioned in [8.2.4.4\(b\)](#) and [8.2.4.4\(c\)](#);
- 5) Effects of creep and shrinkage on vertical and horizontal members accounted for in the structural design; and
- 6) Three-dimensional earthquake ground shaking considered.

b) These buildings with flat slabs, which comply with the requirements in [14.1.1.6](#),

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are classified as:

- 1) Buildings with SMRF + SSW + FS1:
There are no intermediate columns between the concrete core and perimeter column (without a perimeter frame) over which the slab rests; and
- 2) Buildings with SMRF + SSW + FS2:
There are intermediate columns between the concrete core and perimeter frame over which the slab rests.

14.1.1.7 Buildings with special moment resisting frames with special structural walls (SMRF + SSW)

These are buildings with SMRFs with SSWs and their members designed and detailed as per IS 13920. Additionally, RC SWs shall be provided such that:

- a) The RC SSWs in a building are well distributed in the plan along the two principal plan directions reflecting the plan geometry with a view to eliminate fundamental torsional mode as any of first two modes;
- b) The total structural plan density $\rho_{SPD} = 100(A_{SW} + A_{Col})/BL$ of the RC SSWs and RC SMRFs at any storey along both plan directions together is at least that given by:

$$\rho_{SPD} = [2 - 0.75 \left(\frac{f_{ck} - 25}{40} \right)] N A_{HD}(T_H)$$

where

A_{SW}	=	area of structural walls;
A_{Col}	=	area of columns;
B	=	breadth of the building in plan at the storey considered;
L	=	length of the building in plan at the storey considered;
f_{ck}	=	characteristic strength of concrete in the range 25 MPa to 65 MPa;

N = number of storeys of the building above the storey being considered; and

$A_{HD}(T_H)$ = larger of the two horizontal design acceleration coefficients estimated as per [8.2.4](#);

- c) The cross-sectional area of RC SSWs alone provided along each principal plan direction at any storey is not less than 1.0 percent of the plinth area of buildings in earthquake Zones IV, V and VI.

14.1.1.8 Buildings with dual system (DS)

These are buildings which comply with the provisions given in [14.1.1.7](#) and consist of:

- a) SMRFs and SSWs in different principal plan directions designed and detailed as per IS 13920; or
- b) SMRFs and SSWs in the same principal plan direction but in different vertical planes, such that both of the following conditions are valid:
 - 1) Special SWs and special MRFs are designed to resist total design lateral force in proportion to their lateral stiffness, considering interaction of two systems at all floor levels; and
 - 2) Special MRFs are designed to resist independently at least 25 percent of the design horizontal base shear force.

Buildings with SMRFs and SSWs in the same principal plan direction in a single vertical plane are not considered as Buildings with Dual Systems.

14.1.2 Admissible Structural Systems

14.1.2.1 Concrete buildings required to resist earthquake ground shaking shall have a structural systems admissible as per [Table 13](#) depending the earthquake zone and category of the building.

14.1.2.2 The same type of LFRS shall be used along any principal plan direction, but different structural systems may be used along the other principal plan direction.

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**Table 13 Structural Systems Admissible in Different Earthquake Zones
in Concrete of Different Categories**
([Clause 14.1.2.1](#))

Sl No.	Earthquake Zone	Building Category		
		Normal	Important	Critical and Special
(1)	(2)	(3)	(4)	(5)
i)	VI	DS SMRF + SSW	DS SMRF + SSW	DS
ii)	V	DS SMRF + SSW	DS SMRF + SSW	DS
iii)	IV	DS SMRF + SSW SMRF + SSW + FS2	DS SMRF + SSW SMRF + SSW + FS2	DS
iv)	III	DS SMRF + SSW SMRF + SSW + FS2 SMRF + SSW + FS1 SSW SMRF	DS SMRF + SSW SMRF + SSW + FS2 SSW	DS SMRF + SSW
v)	II	DS SMRF + SSW SMRF + SSW + FS2 SMRF + SSW + FS1 SSSW SMRF OSW OMRF + OSW OMRF	DS SMRF + SSW SMRF + SSW + FS2 SMRF + SSW + FS1 SSSW SMRF	DS SMRF + SSW

14.2 Design Earthquake Forces

The provisions given in [8.2](#) shall apply.

14.3 Earthquake Analysis

The provisions given in [8.3](#) shall apply.

14.4 Additional Load Combinations

14.4.1 The following additional load combination shall be considered in buildings located in earthquake zones III, IV, V and VI, in which inelastic effects are admitted in structural elements of lateral force resisting system, to address the effects of overstrength in buildings:

$$DL + IL \pm \Omega EL$$

Here, EL shall be considered as per **8.4.3** of IS 1893 (Part 1).

14.4.2 The load combination specified in [14.4.1](#) shall be considered in the design of the following members in concrete buildings:

- Columns in buildings with SMRFs,

- Beam-to-column and beam-to-wall joints, which are part of SMRFs and SSWs, and

- Structural members in foundations,

with overstrength factor Ω taken as 2.0.

14.4.3 The shear force design of SSWs shall be performed by amplifying the shear force induced by earthquake shaking (corresponding to EL_X or EL_Y) with overstrength factor Ω_V taken as:

$$\Omega_V = \begin{cases} 3.0 & H_W/L_W \geq 2 \\ 2.5 & 1 > H_W/L_W > 1 \\ 2.0 & 1 \geq H_W/L_W \end{cases}$$

14.4.4 The axial force, shear force and bending moment demands on the said members (specified in [14.4.2](#)) from the said load combination (specified in [14.4.1](#)) need not exceed those obtained by considering the overstrength plastic hinges in the adjoining elements.

14.4.5 When the effects of additional load combinations specified in [14.4.1](#) are considered, the allowable bearing pressure in soil may be increased by 33 percent.

15 SPECIFIC BUILDINGS

15.1 Small Buildings

In residential buildings up to 2-storeys (including basement) and plan area less than 200 m², and located in:

- a) earthquake zones II and III:
 - 1) Equivalent static analysis is permitted; and
 - 2) The structural system shall be at least SMRFs with infill walls in at least 60 percent of the bays; and
- b) earthquake zones IV, V and VI:
 - 1) Equivalent static analysis is permitted; and
 - 2) The structural system shall be at least SMRFs (with infills) with SSWs with at least 0.75 percent structural plan density in each principal plan direction.

15.2 Frame Buildings with Open Storeys

RC moment frame buildings, which have open storey(s) at any level, such as due to discontinuation of URM infill walls or of structural walls, are known to have flexible and weak storeys as per [7.1.3](#). In such buildings, measures, such as RC structural walls or braced frames (in select bays of the building) shall be provided along both plan directions as per the requirements specified hereunder, to increase both stiffness and strength to the required level in the open storey and the storeys below. This provision shall be applicable to buildings in all earthquake zones.

15.2.1 Structural Walls

When RC structural walls are provided:

- a) They shall be:
 - 1) Founded on properly designed foundations;
 - 2) Continuous over the full height of the building; and
 - 3) Connected monolithically to the moment resisting frame of the building through slabs and beams.
- b) they shall be designed such that:
 - 1) They do not introduce additional torsional irregularity in plan than that already present in the building,

- 2) Lateral stiffness of the open storey(s) is not less than 90 percent of that of the storey above, and
 - 3) Lateral strength of the open storey(s) is not less than 95 percent of that of the storey above, and
- c) structural walls of this measure may be adopted even in regular buildings that do not have open storey(s).

15.2.2 Braces

When steel braces are provided, provisions of [16.1.1.3](#) shall be complied with.

15.2.3 Unreinforced Masonry Infill Walls

15.2.3.1 In RC MRF buildings and URM infill walls, effect of in-plane stiffness and strength of URM infill walls shall be considered on storey stiffness and storey strength of the building (along the height), when

$$h_w/t_w < 12, \text{ and } L_w/t_w < 12$$

or

$$\rho_{MW} \geq 20$$

where

- h_w = clear height of URM infill wall between the top beam and bottom floor slab;
- L_w = clear length of the URM infill walls between the vertical RC elements (columns, walls or a combination thereof) between which it spans; and
- ρ_{MW} = structural plan density (percent) of masonry walls or URM infills (see [8.2.4.3](#)).

Irregularities due to storey stiffness and storey strength shall be addressed as per [7.1.3](#).

15.2.3.2 Members and beam-column joints of RC MRFs shall be designed for the more severe of the combinations of stress resultants arising from the following two structural analyses with:

- a) Bare RC MRF building; and
- b) RC MRF building with URM infills.

15.2.3.3 The estimation of in-plane stiffness and strength of URM infill walls shall be based on the following:

- a) The modulus of elasticity E_m (in MPa) of masonry infill wall shall be taken as per [12.3.1.4](#). Alternately, for clay brick masonry, it may be estimated considering:

$$f_m = 0.6 f_b^{0.5} f_{m0}^{0.3},$$

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where

f_b = compressive strength (in MPa) of brick; and

f_{m0} = compressive strength (in MPa) of mortar.

b) URM infill walls shall be modelled (using equivalent diagonal struts resisting only compressive axial forces) as below:

1) Ends of diagonal struts shall be pin-jointed in the RC frame; and

2) For URM infill walls without any opening, width w_s of equivalent diagonal strut (see Fig. 17) shall be estimated as:

$$w_s = 0.175 \alpha_h^{-0.4} L_{ds}$$

where

$$\alpha_h = h \sqrt[4]{\frac{E_m t \sin 2\theta}{4 E_c I_c h}}$$

where

L_{ds} = length of diagonal strut;

h = clear height of the column;

E_m and E_c = moduli of elasticity of URM infill and concrete;

t = thickness of the infill wall;

θ = angle of the diagonal

strut with the horizontal; and

I_c = smaller of the second moment of area of the adjoining columns.

c) The width of the equivalent diagonal strut formed in the URM infill wall with opening shall be estimated as:

$$w_{ds} = w_s \left(1 - \frac{2.5 A_{\text{opening}}}{A_{\text{wall}}}\right)$$

where

A_{opening} = the area of the opening in the infill wall in elevation; and

A_{wall} = the total area of the infill wall panel in elevation.

d) Thickness t_{ds} of the equivalent diagonal strut shall be taken as thickness t of the URM infill wall.

e) The area A_s of the equivalent diagonal strut shall be taken as:

$$A_s = \begin{cases} t_{ds} w_s & \text{walls without openings} \\ t_{ds} w_{ds} & \text{walls with openings} \end{cases}$$

f) The strength of the diagonal masonry infill walls shall be estimated as the strength corresponding to their horizontal sliding along the mortar joints at the most critical level along the height of the infill wall panel.

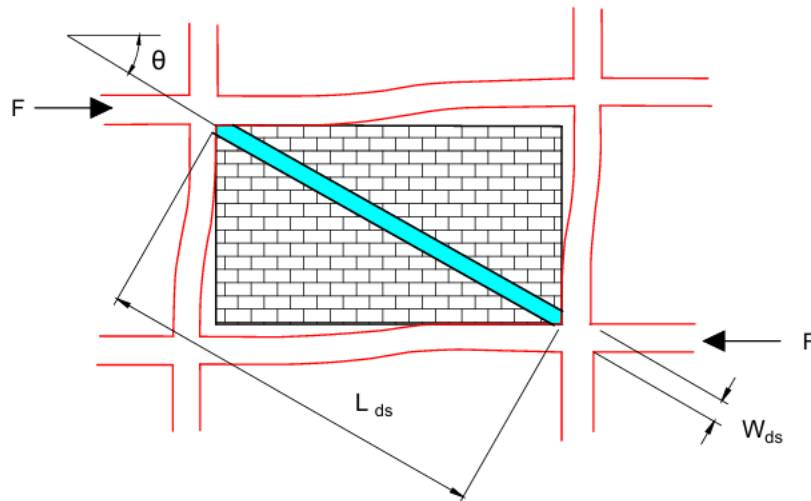


FIG. 17 EQUIVALENT DIAGONAL STRUT OF THE URM INFILL WALL WITHOUT OPENINGS

15.3 Buildings with Post-Tensioned Slabs

15.3.1 In earthquake zones V and VI, RC buildings with post-tensioned slabs shall not be permitted.

15.3.2 In earthquake zones II, III and IV, RC buildings with post-tensioned slabs shall comply with the following:

- a) Effects of elastic shortening arising out of prestressing (either pre-tensioning or post-tensioning), if any, of the horizontal members (namely beams and slabs) shall be accounted in the structural analysis, especially on the vertical members; and
- b) This structural system shall not be adopted when reversal of stresses occurs in prestressed members under horizontal and vertical earthquake shaking.

SECTION 4 ADDITIONAL CRITERIA FOR STEEL BUILDINGS

16 EARTHQUAKE DEMAND

16.1 Structural Systems

16.1.1 Available Structural Systems

The following structural systems are available in steel buildings to resist effects of earthquake shaking:

- a) Buildings with ordinary moment resisting frame (OMRF);
- b) Buildings with ordinary concentrically braced frame (OCBF);
- c) Buildings with special concentrically braced frames (SCBFs);
- d) Buildings with special moment resisting frames (SMRF); and
- e) Buildings with eccentrically braced frames (EBFs).

16.1.1.1 Ordinary moment resisting frame (OMRF)

These are buildings with ordinary MRFs designed and detailed as per IS 800.

16.1.1.2 Ordinary concentrically braced frame (OCBFs)

These are buildings with Ordinary CBFs designed and detailed as per IS 800.

16.1.1.3 Special concentrically braced frames (SCBFs)

These are buildings with Special CBFs designed and

detailed as per IS 13920 (Part 5).

16.1.1.4 Special moment resisting frames (SMRFs)

These are buildings with Special MRFs designed and detailed as per IS 13920 (Part 5).

16.1.1.5 Eccentrically braced frames (EBFs)

These are buildings with eccentrically braced frames designed and detailed as per IS 13920 (Part 5).

16.1.2 Admissible Structural Systems

16.1.2.1 Steel buildings required to resist earthquake ground shaking shall have a structural systems admissible as per [Table 14](#) depending the earthquake zone and category of the building.

16.1.2.2 The same type of LFRS shall be used along any principal plan direction, but different structural systems may be used along the other principal plan direction.

16.2 Design Earthquake Forces

The provisions given in [8.2](#) shall apply.

16.3 Earthquake Analysis

The provisions given in [8.3](#) shall apply.

16.4 Additional Load Combinations

16.4.1 The following additional load combination shall be considered in buildings located in earthquake zones III, IV, V and VI, in which inelastic effects are admitted in structural elements of lateral force resisting system, to address the effects of overstrength in buildings:

$$DL + IL \pm \Omega EL$$

Here, EL shall be considered as per **8.4.3** of IS 1893 (Part 1).

16.4.2 The load combination specified in [16.4.1](#) shall be considered in the design of:

- a) columns in SMRFs, SCBFs and EBFs,
- b) beams in SCBFs and EBFs,
- c) braces in EBFs,
- d) structural members in foundations of columns, and
- e) all connections and/or joints, which are parts of SMRFs, SCBF and EBFs in steel buildings,

with overstrength factor Ω taken as 2.0.

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**Table 14 Structural Systems Admissible in Different Earthquake Zones
in Steel of Different Categories**
(Clauses [16.1.2.1](#) and [11.2](#))

Sl No.	Earthquake Zone	Building Category		
		Normal	Important	Critical and Special
(1)	(2)	(3)	(4)	(5)
i)	VI	EBF	EBF	EBF
ii)	V	EBF	EBF	EBF
iii)	IV	EBF SMRF	EBF SMRF	EBF SMRF
iv)	III	EBF SMRF SCBF	EBF SMRF SCBF	EBF SMRF SCBF
v)	II	EBF SMRF SCBF OCBF OMRF	EBF SMRF SCBF	EBF SMRF SCBF

16.4.3 The axial force, shear force and bending moment demands on the said members (specified in [16.4.2](#)) from the said load combination (specified in [16.4.1](#)) need not exceed those obtained by considering the overstrength plastic hinges in the adjoining elements.

16.4.4 When the effects of additional load combinations specified in [16.4.1](#) are considered, the allowable bearing pressure in soil may be increased by 33 percent.

17 SPECIFIC BUILDINGS

17.1 Small Buildings

In residential buildings up to 2-storeys (including basement) and plan area less than 200 m², and located in:

- a) Earthquake Zones II and III;
 - 1) Equivalent static analysis is permitted; and
 - 2) The structural system shall be at least SCBFs with infill walls in at least 60 percent of the bays; and
- b) Earthquake Zones IV, V and VI;
 - 1) Equivalent static analysis is permitted; and

- 2) The structural system shall be SCBFs (with infills) and EBFs (with infills) in each principal plan direction as per [Table 14](#).

17.2 Steel Buildings with Open Storeys

Steel moment resisting frame buildings, which have open storey(s) at any level, such as due to discontinuation of URM infill walls or of braces, are known to have flexible and weak storeys as per [7.1.3](#). In such buildings, measures, such as steel braces or RC structural walls in select bays of the building, shall be provided along both plan directions as per the requirements specified hereunder, to increase both stiffness and strength to the required level in the open storey and the storeys below. This provision shall be applicable to buildings in all earthquake zones.

17.2.1 Braces

- a) When steel braces are provided, they shall be:
 - 1) continuous over the full height of the building; and
 - 2) connected to the moment resisting frame of the building.

- b) They shall be designed such that:
- 1) they do not introduce additional torsional irregularity in plan than that already present in the building;
 - 2) Lateral stiffness of the open storey(s) is not less than 80 percent of that of the storey above; and
 - 3) Lateral strength of the open storey(s) is not less than 90 percent of that of the storey above.
- c) Steel braces of this measure may be adopted even in regular buildings that do not have open storey(s).

17.2.2 Structural walls

When RC structural walls are provided, provisions of [15.2.1](#) shall be complied with.

17.2.3 Unreinforced Masonry Infill Walls

In steel buildings with URM infill walls, the effect of in-plane stiffness of URM infill walls on storey stiffness of the building (along the height), shall be considered as per [15.2.3](#).

18 EARTHEN RETAINING WALLS AND EARTHEN EMBANKMENTS

18.1 Retaining Walls

The provisions given in **18.1** of IS 1893 (Part 3) shall apply.

18.2 Earthen Embankments

The provisions given in **18.2** of IS 1893 (Part 3) shall apply.

IS 1893 (Part 5) : 2025

ANNEX A

(Clause 2)

LIST OF REFERRED STANDARDS

<i>IS No.</i>	<i>Title</i>	<i>IS No.</i>	<i>Title</i>
IS 456 : 2000	Plain and reinforced concrete — Code of practice (<i>fourth revision</i>)	IS 13828 : 1993	Improving earthquake resistance of low strength masonry buildings — Guidelines
IS 800 : 2007	General construction in steel — Code of practice (<i>third revision</i>)	IS 13920	Earthquake resistant design and detailing of structures — Code of practice:
IS 1893	Design earthquake hazard and criteria for earthquake resistant design of structures — Code of practice:	(Part 1) : 2025	General provisions (<i>second revision</i>)
(Part 1) : 2025	General provisions (<i>seventh revision</i>)	(Part 5) : 2025	Buildings
IS 1905 : 1987	Code of practice for structural use of unreinforced masonry (<i>third revision</i>)	IS 13935	Assessment and retrofit of structures for earthquake safety — Code of practice:
IS 13827 : 1993	Improving earthquake resistance of earthen buildings — Guidelines	(Part 1) : 2025	General provisions (<i>second revision</i>)
		(Part 5) : 2025	Buildings

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ANNEX B

(Foreword)

COMMITTEE COMPOSITION

Earthquake Engineering Sectional Committee, CED 39

<i>Organization</i>	<i>Representative(s)</i>
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Central Public Works Department, New Delhi	SHRI DINESH KUMAR UJJAINIA
Central Water Commission, New Delhi	DIRECTOR, CMDD (E&NE) DIRECTOR, EMBANKMENT (NW&S) (<i>Alternate</i>)
Creative Design Consultants Pvt Ltd, Ghaziabad	SHRI AMAN DEEP SHRI BARJINDER (<i>Alternate</i>)
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IS 1893 (Part 5) : 2025

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SCIENTIST 'E'/DIRECTOR

AND

SHRI JITENDRA KUMAR CHAUDHARY
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