SEISMIC DESIGN CONSIDERATIONS IN HIGH RISE BUILDINGS – A STANDARD'S PERSPECTIVE

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INTRODUCTION

Due to rapid urbanization, shortage of land and continuous growth of population, there has been significant rise in the construction of tall buildings, especially in the urban areas to cater to the associated need for shelter spaces, office spaces and other commercial spaces. Tall buildings are designed not only by considering structural safety criteria but also ensuring the required serviceability aspects, especially under the conditions of lateral loads such as wind and earthquakes.

Although, design of tall buildings in mainly governed by wind loads, in regions of higher seismic zones earthquake loads become prominent which needs to be considered in the planning and design of buildings before construction. In order to ensure safety as well as serviceability aspects of tall buildings, Bureau of Indian Standards (BIS) had formulated an indigenous standard, IS 16700: Criteria for Structural Safety of Tall Concrete Buildings, which provides prescriptive requirements for the design and construction of RC tall buildings in the country. As far as earthquake resistant design of tall buildings is considered, IS 16700 should be read in conjunction with IS 1893 (Part 1) which lays down general provisions and guidelines for design of all buildings.

OVERVIEW OF THE STANDARD

IS 16700 covers the design aspects of RC buildings of height greater than 50 m and less than or equal to 250 m. This standard is applicable only for buildings with equal to or less than 20,000 occupants inhabiting the building. The standard covers various design aspects of tall buildings such as selection of appropriate structural systems, geometric proportioning, integrity of structural system, resistance to wind and earthquake effects and other special considerations related to tall buildings. The standard also provides general procedure to be adopted to proportion, analyze, design, detail and gain approval for construction of buildings that do not conform to the requirements prescribed in the standard. This standard provides additional requirements to be used in the design of tall buildings in addition to the ones prescribed by other Indian Standards used for structural design of buildings.

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For buildings that do not conform to the prescriptive requirements of IS 16700, the general guidelines to proportion, analyze, design, detail, gain approval and construct such buildings as given in Annex A of IS 16700 should be adopted. Performance objectives or procedures are more stringent than those specified in Annex A may be specified by the client and/or owner of the building or by the tall building committee appointed by the local authority administering the building project.

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GENERAL REQUIREMENTS FOR TALL BUILDINGS

IS 16700 provides various limitation on different structural parameters based upon the seismic zones [as in IS 1893 (Part 1)] in which the buildings are located.

a) The maximum building height (in m) is one such parameter which should not exceed the values given in Table 1 for buildings with different structural systems.

Table 1: Maximum Values of Height H above Top of Base Level of Buildings with different Structural Systems, in m

Sl No.	Seismic Zones	Structural System				
		Moment Frame	Structural Wall Well Distributed[1]	Structural Wall + Moment Frame	Structural Wall + Perimeter Frame	Structural Wall + Framed Tube
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	V	NA	120	150	150	180
ii)	IV	NA	150	200	200	225
Iii)	III	60	200	225	225	250
iv)	II	80	250	250	250	250

[1] Structural walls are considered to be well-distributed when structural walls that are outside of the core are capable of carrying at least 25 percent of the lateral loads.

b) Slenderness of buildings is another important parameter whose maximum value (the ratio of height to minimum base width) shall not exceed the values given in Table 2.

Table 2: Maximum Slenderness Ratio

Sl No.	Seismic Zones	Structural System				
		Moment Frame	Structural Wall Well Distributed	Structural Wall + Moment Frame	Structural Wall + Perimeter Frame	Structural Wall + Framed Tube
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	V	NA	8	8	9	9
ii)	IV	NA	8	8	9	9
Iii)	III	4	8	8	9	10
iv)	II	5	9	9	10	10

c) Building plans to preferably be rectangular (including square) or elliptical (including circular) to enable the structural members participate efficiently in resisting lateral loads without causing additional effects arising out of re-entrant corners and others. The plan aspect ratio has a critical limit which should be adhered.

d) For design earthquake force, the maximum inter-storey drift shall be $h_i / 250$ where h_i is inter-storey height of i^{th} floor in the building.

e) Cast in-situ floor slabs are preferable. Where precast floor systems are used, a minimum structural topping of 75 mm concrete with reinforcing mesh is essential in Seismic Zones III, IV and V, which can be reduced to 50 mm in Seismic Zone II.

f) The minimum grade of structural concrete shall be M30 while the suggested maximum grade is M70. However, higher grades are permitted, wherein; the designer shall ensure through experimentation that such concretes shall have at least a minimum crushing strain in compression of 0.002.

g) Specific reinforcing steel as per IS 1786:2008 and conforming to the provisions of IS 13920 are to be used.

h) All the load combinations shall be taken in accordance with IS 875 (Parts 1 to 5), IS 1893 (Part 1), IS 456 and IS 13920.

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EFFECTS OF EARTHQUAKE FORCES TO BE CONSIDERED IN DESIGN

As per IS 1893 (Part 1), the four main desirable attributes of an earthquake resistant building are:

a) Robust structural configuration,
b) At least a minimum elastic lateral stiffness,
c) At least a minimum lateral strength, and
d) Adequate ductility.

In addition to the above, the other aspects to be considered for resisting the effects of lateral forces due to an earthquake as laid down in IS 16700 are given as under:

a) Vertical shaking shall be considered simultaneously with horizontal shaking for tall buildings in Seismic Zone V.
b) For buildings in Seismic Zone V, deterministic site-specific design spectra may preferably be estimated and used in design. When site-specific investigations result in higher hazard estimation, site-specific investigation results shall be used.
c) Design base shear coefficient of a building under design lateral forces, shall not be taken less than that given in Table 3.

Table 3: Minimum Design Base Shear Coefficient (Percent of Seismic Weight)

Sl No.	Building Height, *H*	Seismic Zone II	III	IV	V
(1)	(2)	(3)	(4)	(5)	(6)
i)	$H \leq 120$ m	0.7	1.1	1.6	2.4
ii)	$H \geq 200$ m	0.5	0.75	1.25	1.75

NOTE – For buildings of intermediate height in the range 120 m – 200 m, linear interpolation shall be used.

d) For buildings of height 50 m and more, the fundamental Period T (in second) for a structure shall be determined by accounting for all structural properties and inherent stiffness of the building through rigorously validated structural analysis procedures. The fundamental period shall however not exceed the value obtained from the approximate fundamental translational natural period Ta (in second) of oscillation, estimated by following expression:

$$Ta = 0.0644H^{0.9}$$

for concrete moment resisting frame systems, and

$$Ta = 0.0672H^{0.75}$$

for all other concrete structural systems

STRUCTURAL DESIGN CONSIDERATIONS

The design of the following structural systems falling under different seismic zones should be done in accordance with the provisions of IS 16700 in addition to the requirements given in IS 1893 (Part 1) and IS 13920.

a) Framed Buildings
b) Moment Frame - Structural Wall Systems
c) Structural Wall Systems
d) Flat Slab – Structural Wall Systems
e) Framed Tube System, Tube-IN-Tube System and Multiple Tube System

Buildings with simple regular geometry and uniformly distributed mass and stiffness in plan and in elevation, suffer much less damage, than buildings with irregular configurations. All efforts shall be made to eliminate irregularities by modifying architectural planning and structural configurations. Limits on irregularities for Seismic Zones III, IV and V and special requirements are given in Tables 5 and 6 of IS 1893 (Part 1).

Earthquake resistant design of tall buildings shall be performed using Dynamic Analysis Method as given in IS 1893 (Part 1). Dynamic analysis may be performed by either Time History Method or Response Spectrum Method. IS 16700 also provides recommendations

> **Earthquake resistant design of tall buildings shall be performed using Dynamic Analysis Method as given in IS 1893 (Part 1).**

for design of Non-Structural Elements (NSEs) in both new as well as existing buildings. Also, for monitoring deformations in buildings, all tall buildings in Seismic Zone V and tall buildings exceeding 150 m in Seismic Zone III and IV shall be instrumented with tri-axial accelerometers to capture translational and twisting behaviour of buildings during strong earthquake shaking.

NATIONAL PERSPECTIVE

The basic tools for land and building development rely very much on the Building Bye-laws which are evolved basically out of another premium publication of BIS, namely the National Building Code of India 2016 (NBC 2016) which in turn refer copiously to over 1,000 Indian Standards as accepted standards and good practices. Part 6 of NBC 2016 provides the guidelines for structural design of buildings.

Various other related Indian Standards including those under development should also be considered for implementation such as: IS 1893 (Part 6):2022 Criteria for earthquake resistant design of structures: Part 6 Base isolated buildings; Part 4 'Fire and life safety' of NBC 2016; IS/ISO 15392:2019 Sustainability in buildings and civil engineering works — General principles (first revision); Doc: CED 43 (21409) on 'Design and Construction of Combined Piled Raft Foundation'; ultrafine materials in concrete such as [silicafume (IS 15388:2003), metakaolin (IS 16354:2015), ultrafine GGBFS (IS 16715:2018), ultrafine flyash [Doc: CED 2 (17395)] towards ensuring that apart from the structural safety aspects, fire safety, life safety and public safety aspects are also addressed in achieving disaster resilient tall buildings in the country.

CONCLUSION

In India, land development and building construction is mainly regulated by the local building authorities or municipal corporation, who can incorporate the guidelines of Part 6 Structural Design of NBC 2016 in their building byelaws, which in turn cross refers to the other Indian Standards for ensuring earthquake safety of the buildings. Part 2 'Administration' of NBC 2016 also stipulates periodic audit for structural sufficiency of special buildings including high rise (> 15m) buildings. Thus, it is expected that all important buildings and structures are to be periodically verified, particularly against the standard used for the initial design. This will help in achieving safe, sustainable, robust and reliable design of the buildings.

REFERENCES

1. IS 16700: 2017 Criteria for structural safety of tall concrete buildings, Bureau of Indian Standards, New Delhi, India
2. National Building Code of India 2016, NBC 2016.
3. IS 1893 (Part 1) Criteria for earthquake resistant design of structures Part 1 General Provisions and Buildings

TWO-DAY ONLINE WORKSHOP ON "SUSTAINABLE CONSTRUCTION FOR DISASTER MITIGATION" held on **23rd and 24th March '23.**