Impact of Draft IS 1893-2023 Code Provisions on Building Design

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On 26th April, 2023, the BIS released the 7th draft of the codes for seismic analysis of structures, namely, IS 1893:2023 (WC) Part 1&2, [1,2] for wide circulation. The final form of the to-be released revision of the IS 1893 codes are expected to be more of less the same as the IS 1893:2023 (WC) codes, except that some values or some specifications may get modified. Hence, a brief review of the draft code provisions are discussed, especially the most prominent changes.

The major change in the code is the determination of the zone factors based on the Probabilistic Seismic Hazard Assessment (PSHA), compared with the Deterministic Seismic Hazard Assessment approach (DSHA) followed in the previous versions of the code. The use of PSHA could lead to either unsafe or overly conservative engineering design (Wang, 2010; and Krinitzsky, 1995). Comparison of the zone factors of the draft code with the 2016 edition of the code reveals that, these values are always on the higher side (for all the zones), in spite of the fact that the controversial load factor of 1.5 for earthquake loads has been corrected as 1.0 in the draft code.

The zone map of India has also been changed, with an additional zone. The Acceleration Response Spectra have been defined up to natural period of 10s. The importance factor in the draft code has lost its relevance as it is assumed as 1.0 in most of the cases. The zone factor, Z, applicable to a given building is now different for strength design and serviceability checks. There is a slight adjustment in the Response Reduction Factor R (which is unnecessarily renamed as elastic force reduction factor). One welcome addition is the improved provisions on torsion. The permissible drift limits are made stringent for higher zones. The draft code suggests structural systems to be adopted for RC buildings in different zones, along with minimum Structural Plan Density (SPD) of structural walls. This may curb the creativity of architects and engineers.

Overall the code has now become more conservative and may result in increased size of members and the subsequent cost of buildings. Usually, tall buildings will be governed by wind loads rather than earthquake loads. But the provisions of this code may make the earthquake code as the critical load for many tall buildings.

Introduction to the Codes

Part 1 of the IS 1893:2016 [3] code deals with the general parameters of seismic design (like Zonal map and details of Response Spectrum Curve) as well as parameters pertaining to design of buildings (like Response Reduction factors, 'R' and Importance Factors, 'I'). However, in the IS 1893:2023 (WC) codes, these have been designated as separate parts, numbered 1 and 2 respectively – referred together in this article as 'draft code', while the IS 1893:2016 is referred to as the 'current code'. It may be of interest to note that the future IS 1893 Parts 3 to 11, dealing with tanks to tunnels and everything in between, are expected to be released in due course of time.

Before going into the intricacies of the draft codes, the concept of the "level of earthquake" based on "probability of occurrence" needs to be understood. Simply put, earthquakes (or rather earthquake intensities) can be categorised as frequent, occasional, rare and so on. Obviously, a devastating earthquake is a very rare incident, while very mild tremors are relatively frequent occurrences. It also needs to be noted that an occasionally occurring earthquake in the Himalayas is expected to be much stronger in intensity than an occasionally occurring earthquake in Bengaluru.

So, although an earthquake being, say, strong on one hand, and correspondingly being rare on the other are closely correlated, the actual intensity conveyed by the terms frequent, occasional, rare and so on, differs depending on the geographical location in question. These probabilities of occurrences are expressed as percentage of exceedance for a fixed number of years – the number of years being usually 50 or 100, with 50 usually being selected, assuming the life of a structure to be closer to it – for example, the probability of occurrence of a very rare earthquake is 2% in 50 years (represented as 2%/50y). Inversely, it also represents a "level of confidence" of 98% that a structure designed for this level of earthquake would withstand a strong probable earthquake likely to occur within the next 50 years. This percentage probability can be used to reverse calculate and obtain what is known as the Return Period, T_{RP} (also known as "mean recurrence interval") of the earthquake. For the 2%/50y earthquake, the T_{RP} is 2,475 years. However, it is not to say that an event of that level of earthquake will surely occur once in 2,475 years. It is only a probable future predictive likelihood, expressed either as a percentage or as Return Period.

This approach reminds one, of the performance level matrix followed in Performance Based Design,[4] where the levels of earthquakes are categorised as 'frequent', 'rare' and 'very rare', and the expected performance of buildings are classified as 'Operational Level' (OL, i.e., fully functional), 'Immediate Occupancy' (IO), 'Life Safety' (LS, i.e., limited damage) and 'Collapse-Prevention' (CP, i.e., near collapse). With these two parameters, the expected performance of each building type is defined; for e.g., an ordinary building should have an LS performance for a rare earthquake.

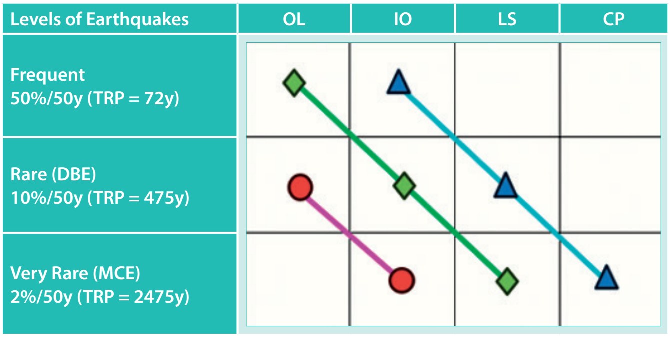

Fig. 1: Performance Level Matrix, [4] *where Δ=Ordinary Structures, ◊=Essential Structures and O=Critical Structures*

At the same time, the same building should satisfy IO level in a frequent, and CP at its worst (i.e., should not collapse) in a very rare one.

Such sets of multiple grades of expected performance are defined for other building categories as well (Fig. 1). In fact, the actual design is usually for the rare level of earthquake, followed by checking and fine tuning the design for satisfactory performance in the frequent and very rare levels. Although the performance level matrix (explained above) is adopted in many codes in the west, the approach of the draft code is quite different – similar but alternate approach. However, the use of separate earthquake levels for design and for serviceability seems to have been influenced by this matrix.

Basic Changes – Zones, I, R & Response Spectrum Curves

Having grasped a basic idea of the concept of probability of occurrences and Return Periods, we shall look into the draft codes Part 1&2. Firstly, the zone map of India has been modified (Fig. 2a):

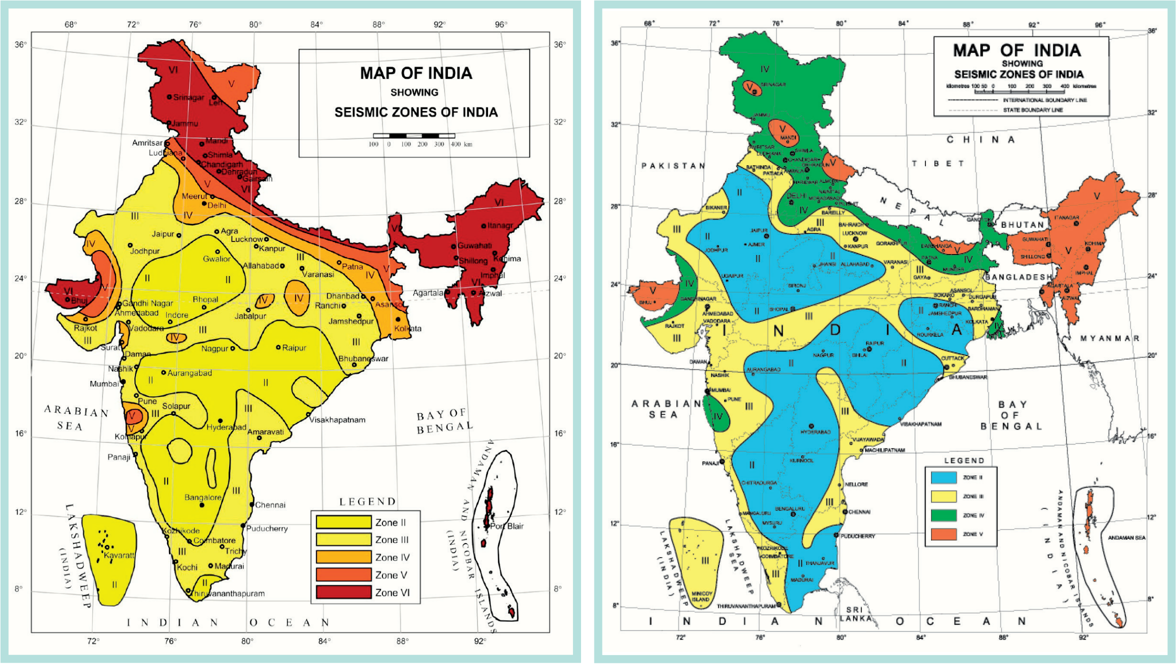

Fig. 2: Zone Map of India: (a) in the Draft Code and (b) in the Current Code

One, the boundaries of each zone has been redrawn, and two, a new zone, namely zone VI, has been introduced – both have contributed to some towns switching zones, in the current code: for example, while Madurai had to switch from zone II to III, Roorkee jumped two zones from IV to VI. Secondly, the definition of seismic intensity as Maximum Considered Earthquake (MCE) and Design Basis Earthquake (DBE), [5] represented by the absence and presence respectively of the '2' in the denominator of the basic equation for horizontal acceleration in the current code, has been replaced with the probability based approach in the draft codes. Thus, it has the same formula for A_h, but without the '2' in place. (Eq. 1)

$$A_h = \frac{ZI}{R}\left(\frac{Sa}{g}\right) \tag{1}$$

Due to this change, the designers will not know the level of earthquake forces for which the structure is being designed.

The draft is said to be a hybrid of the DSHA (Deterministic Seismic Hazard Assessment – on which the current and earlier codes were based on) and PSHA (Probabilistic Seismic Hazard Assessment) approaches. The key documents, on detailed PSHA studies of the subcontinent that have laid the foundations to this draft code can be found in the net (one of them being ref.[6]), while Appendix G of the draft code Part 1 [1] gives a short description of the process. Thirdly, the zone factor, Z, applicable to a given building is now different for strength design and serviceability checks.

The method of specifying the different zone factors, Z, are also different: the T_{RP} applicable for each building category (again different for Design and Serviceability) are provided in one table (Table 1), and the T_{RP} read off from this table is to be looked up in a second table (Table 2) in order to obtain the Z value against the zone of the location of the proposed building. Although the value of Z from the draft appears to be less than its corresponding value from the current code, the MCE values in the current code have to be halved for conversion to DBE (thus taken as Z/2) for a fair comparison.

Table 1: Table of T_{RP} for Different Building Categories

Category of Structures	Return Period T_{RP} (Years) for	
	Strength Design	Serviceability Check
Normal (Set 1)	475	73
Important (Set 2)	975	225
Critical/Lifeline (Set 3)	2475	475
Special (Set 4)	4995	975

Table 2: Table of Zone Factors for Various T_{RP}, against each Earthquake Zone

Earthquake Zone	Design Earthquake Zone Factor Z for Different Return Periods, T_{RP} (Years)						
	73	225	475	975	2475	4975	9975
II	0.0375	0.050	0.075	0.10	0.15	0.2000	0.250
III	0.0750	0.100	0.150	0.20	0.30	0.4000	0.500
IV	0.1800	0.225	0.300	0.36	0.45	0.5400	0.675
V	0.2400	0.300	0.400	0.48	0.60	0.7500	0.900
VI	0.3000	0.375	0.500	0.60	0.75	0.9375	1.125

On the other hand, it also needs to be taken into consideration that in the draft codes, the structural load combinations are as follows (where DL and LL represent Dead Load and Live Load, and EQ_D and EQ_S represent Earthquake loads for Design and Serviceability, respectively):

$$1.5\ DL + 1.5\ LL \tag{2a}$$

$$1.2\ DL + 1.2\ LL \pm EQ_D \tag{2b}$$

$$1.5\ DL \pm EQ_D \tag{2c}$$

$$0.9\ DL \pm EQ_D \tag{2d}$$

$$1.0\ DL + 1.0\ LL \tag{3a}$$

$$1.0\ DL + 0.8\ LL \pm EQ_S \tag{3b}$$

$$1.0\ DL \pm EQ_S \tag{3c}$$

$$0.9\ DL \pm EQ_S \tag{3d}$$

with partial load factor of 1.0 for earthquake loads, for both design (Eq. 2) and serviceability combinations (Eq. 3), as opposed to the load factor of 1.5 in the current code. This is said to be due to the careful selection of T_{RP}, which accounts for the uncertainties that the partial safety factors stand for. Table 3 compares the values of Z of the draft code to Z/2 of the current code for 'Normal' structures. It has to be noted that in the last two columns of Table 3, the change in partial load factor in the draft code has been considered.

The table assumes that the spectral acceleration value obtained from the Response Spectrum curve is the same for both the current and the draft codes – which usually happens when time period, T, of the building is less than 0.4s. The table does not reflect the effect on buildings in locations that switched to higher zones in the draft code. However, there is now leniency in the Response Reduction factor R (but obviously with higher responsibility on the designers to ensure ductility), in cases involving special RC walls, where the value of R has been increased from 4.0 in the current code, to 5.0 and 4.5 in the draft code (depending on whether the walls provided are with and without boundary elements respectively).

For dual systems, it has been increased from 5.0, to 6.0 and 5.5 respectively (for the same criteria). These changes are expected to provide some savings in the case of tall buildings.

Table 3: Comparison of Zone Factors of the Draft and Present Code

Zone	Zone Factors		Ratio of $Z_{Draft}/Z_{Current}$	Percent increase in Zone Factor	
	Z (Draft code)	Z/2 (Current code)		for Load Combination (2b)*	for Load Combination (2c)*
II	0.075	0.05	1.50	25%	0%
III	0.150	0.08	1.88	56%	25%
IV	0.300	0.12	2.50	108%	67%
V	0.400	0.18	2.22	85%	48%
VI	0.500	N/A	N/A	N/A	N/A

* refers to the equation labels in the text

The function of the Importance factor, 'I', is now served by specifying different Z values, for each building category (as shown in Table 1), while the 'I' in the formula (Eq. (1)) is kept only for 'namesake'. It is given a value of 1.0, in general, but suggested as 1.15 in buildings with occupancy of 100-200 persons.

Apart from the basic three categories of importance of structures in the current code (represented by 'I', having values of 1.0, 1.2 and 1.5), one more category termed "Special Structures (Set 4)" has been introduced in the draft code.

An additional category for nuclear and related structures is also included (Set 5), for which applicable parameters are not provided, but meant to be specified by the appropriate statutory authorities.

Despite the 'I' factor being present only as namesake, one can, for comparative purpose, calculate the apparent 'I' values corresponding to the values in the current code as the ratios of Z's, for example, $I_{Critical} = Z_{Critical}/Z_{Normal}$ for critical structures (Table 4). It can be seen that for zones IV, V and VI, the 'apparent I' values are same as in the current code, but for zones II and III, they are higher.

Table 4: Apparent I Value of Draft Code and I Value from Current Code

Zone	Normal	Important	Critical/Lifeline	Special
II	1.00	1.33	2.00	2.67
III	1.00	1.33	2.00	2.67
IV	1.00	1.20	1.50	1.80
V	1.00	1.20	1.50	1.88
VI	1.00	1.20	1.50	1.88
Current code	1.0	1.2	1.5	N/A

The Response Spectrum (RS) curve also has notable modifications. While the RS curve in the current code has the download sloped curve portion up to 4s and flat thereafter, the draft code presents a new RS curve definition that has the download sloped curve portion up to 6s, followed by a second downward sloped curve thereafter (known as the constant displacement range) up to 10s (Fig. 3), making it look more like, for example, the one in the Eurocode. [7] Thus, buildings, especially the tall ones, with fundamental frequency greater than 4 sec. are now covered.

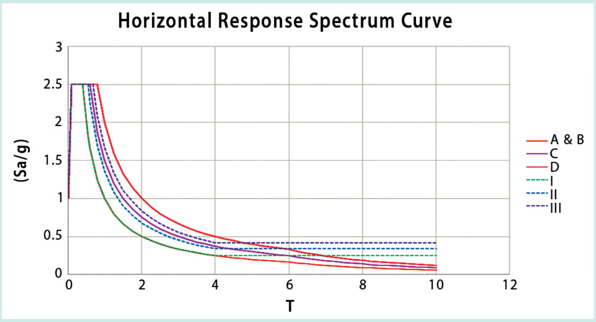

Fig. 3: Horizontal Spectrum Curves from the Draft Code (Solid Lines, Curves A to D) and Current Code (Dotted Line, Curves I to III)

The classification of Type of soil for selecting the appropriate RS curve has also been modified – while the current code relies on the SPT value of soil for classification, in the draft code, it is based on the Shear Velocity of soil, V_s (Table 5, where values from UBC-97 [8] are also included for comparison).

In view of the difficulty in assessing V_s by field test, empirical formulae have also been provided for calculating them from soil SPT.

However, no RS curve has been defined for Site Class E (which overlaps some of the site locations in Type III and few in Type II of the current code), stipulating that it be proceeded with site specific assessments.

The formula for RS curve for vertical earthquake has been modified and presented (Fig. 4) which now varies with T, as against the mere flat one with an S_a/g value of 2.5 of the current code (although the flat line effectively represents an S_a/g value of 0.83, being equal to (2/3)×2.5×(1/2), where the (1/2) is for MCE to DBE conversion).

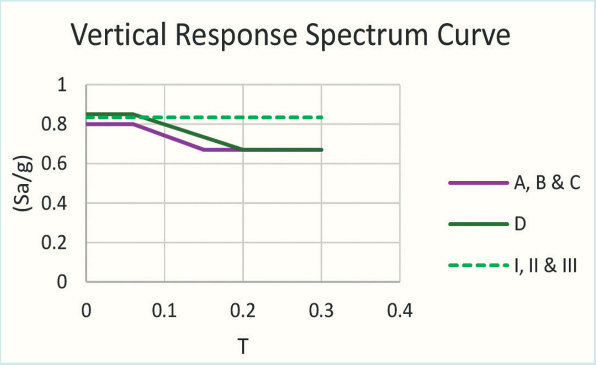

Fig. 4: Vertical Spectrum Curves Plotted as per Draft Code (Solid Lines) and Current Code (Dotted Line)

Table 5: Comparison of Site Class of Draft Code to that in Present Code

Shear Velocity (m/s)	SPT Value (UBC-97)	Site Class	
		Draft Code/ UBC-97 [8]	Current Code (Soil Type)
$V_s > 1500$	--	A	I
$760 < V_s < 1500$	--	B	I
$360 < V_s < 760$	$N > 50$	C	I
$180 < V_s < 360$	$50 \geq N \geq 15$	D	Partly I & partly II
$V_s < 180$	$15 > N$	E	Partly II & partly III

Miscellaneous Changes

There are many other changes in the code that are too numerous to be covered here: like permissible drift limits (to be obtained from Z for Serviceability) being tapered down for higher zones (Table 6) making it stringent for higher zones – how the drift limits are influenced by the different Z's for service and the updated drift limits for each zone, in comparison to the current code, is also indicated in the Table. The structural systems allowable for RC buildings are also presented (Table 7), keeping in mind that moment frames alone are not expected to perform well in higher zones. This Table 7 is to be interpreted with respect to the minimum Structural Plan Density (SPD) of Structural Walls in RC Buildings (Table 8), again the specified limits being specific for each zone. One of the notable specifications is one concerning providing shear walls in buildings on slope (Fig. 5, Table 9), to avoid torsional tendencies in such buildings.

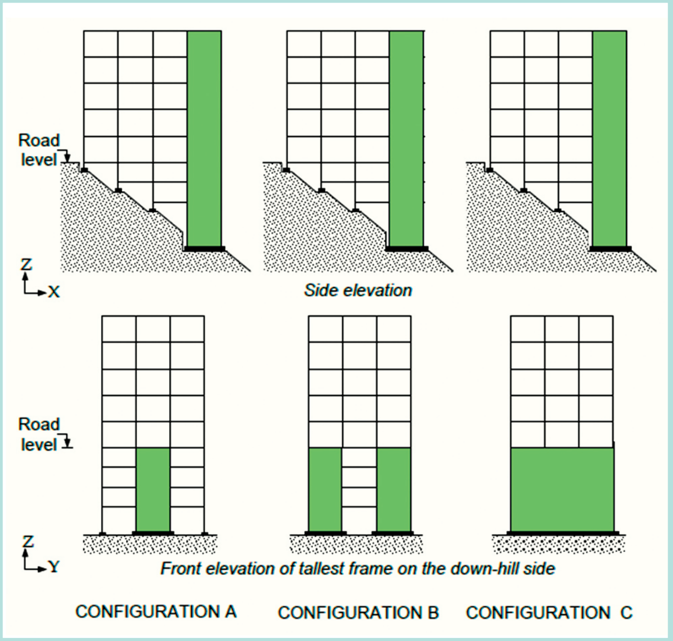

Fig. 5: Shear Wall Configurations for Buildings on Slope [2] (Table 9)

Table 6: Inter-storey Drift Limits, with Comparisons with those in the Present Code

Zone	Drift Limit	Whether the Draft Code is more Stringent than the Current Code		
		Normal Building	Important Building	Critical Building
II	0.004	No	No	No
III	0.004	No	Yes	Yes
IV	0.003	Yes	Yes	Yes
V	0.0025	Yes	Yes	Yes
VI	0.002	NA	NA	NA

Table 7: Allowable Structural Systems for RC Buildings (OMRS = Ordinary Moment Resisting Frames, SMRF = Special Moment Resisting Frames and SMRF+SSW = Special Moment Resisting Frames with Special Structural Walls)

Zone	Building Category		
	Normal	Important	Critical/Lifeline
II	OMRF SMRF SMRF+SSW Dual-System	SMRF SMRF+SSW Dual-System	SMRF+SSW Dual-System
III	SMRF SMRF+SSW Dual-System	SMRF SMRF+SSW Dual-System	SMRF+SSW Dual-System
IV	SMRF+SSW Dual-System	SMRF+SSW Dual-System	Dual-System
V	Dual-System	Dual-System	Dual-System
VI	Dual-System	Dual-System	Dual-System

Where, OMRS = Ordinary Moment Resisting Frames, SMRF = Special Moment Resisting Frames, and SMRF+SSW = Special Moment Resisting Frames with Special Structural Walls

Table 8: Minimum Structural Plan Density Limits for Walls

Earthquake Zone	SPD
II	1.0%
III	1.5%
IV	2.0%
V	2.5%
VI	2.5%

Table 9: Prescription of Configuration to be used (Fig. 5) based on Building Parameters, for Buildings on Slope

Difference between Highest and Lowest Column Base Levels	Wall Configuration
≤ 10 m	A
10-15 m	B
> 15 m	C

The draft code has been lenient on design of small residential framed structures up to two storeys where Equivalent Static Method of analysis is considered sufficient. But in zones II and III, it should be at least SMRF with infill walls in minimum 90% of the bays; and in zones III and IV, it should be at least SMRF (with in-fills) with SSW with minimum 1.5% SPD in each principal plan direction (Table 7 for abbreviations).

The code has now prescribed that soil flexibility should be considered for all cases (requiring building analysis models to have their supports assigned with calculated springs instead of just fixed or pinned), except those in site classes A and B, and buildings up to five stories.

A major addition to the code is the introduction of analysis for Architectural Elements and Utilities (AEU) – prescriptions often seen only in NDMA guidelines, but now incorporated into the draft code itself. AEU's includes all appendages from partition walls and storage cabinets to electrical and mechanical equipment. The AEU's are classified as acceleration-sensitive and displacement-sensitive, with the latter further classified as being fixed at different building levels or to the same level. Methods of analysis for each are elaborated with dedicated tables for Importance, Acceleration Amplification and Response Reduction factors to refer to.

Torsional Irregularity

Concerning irregularities of buildings, especially critical for tall buildings, is the updated criterion for torsion. Apart from the already existing criteria based on ratio of maximum floor edge displacement to its minimum (which labels a building as torsionally irregular when that Δmax is more than 1.5 times Δmin – see Fig. 6), a new criterion involving calculating the influences of three aspects that contribute to torsional tendencies of the building, (combined to obtain the Torsional Flexibility Factor, ψ) has been put forth

$$\psi = \left(\frac{e_K}{B}\right)\left(\frac{B}{r}\right)^2\left(\frac{T_\theta}{T_t}\right)^2 \qquad (4)$$

where B is the outer dimension of building, e_K is the eccentricity of centre of mass from centre of rigidity, r is the mass radius of gyration of the floor, T_θ and T_t are time periods of torsional mode, and translational (T_X or T_Y) modes. The three aspects are represented by the terms seen in the three separate brackets in Eq. 4, pertaining respectively to torsional eccentricity (based on eccentricity of the centres of mass and rigidity), rotational flexibility (based on the radius of mass gyration of mass – obtainable from tabular outputs of analysis packages) and torsional flexibility (based on ratio of the T's).

For rectangular regular plan buildings, whether to do a torsional analysis or a revision of structural configuration is to be done, is decided based on the torsional eccentricity and the ratio of the T's (Table 10). For buildings with non-rectangular irregular plan geometry, it has to be confirmed that ψ is less than 0.4, or else, revise the structural configuration – this is, in effect, the same as what is conveyed in Fig. 6, but adopted for irregular buildings: the following relation clarifies it.

$$\frac{\Delta_{\max}}{\Delta_{\min}} = \left(\frac{1+\dfrac{\psi}{2}}{1-\dfrac{\psi}{2}}\right) \qquad (5)$$

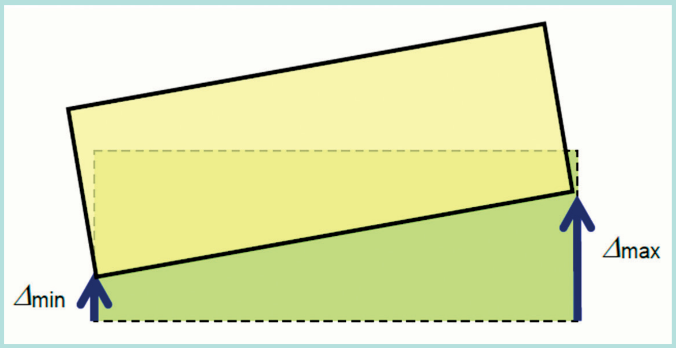

Fig. 6: Torsional Irregularity in Buildings (Plan View) [2]

Table 10: Criteria for the Selection between Torsional Analysis and Structural Configuration Revision for Torsional Buildings (τ = (T_θ/ T_X) or (T_θ/T_Y), as the Case may be)

Ranges of τ	**Ranges of e_K/B**				
	≤ 0.05	**0.05-0.07**	**0.07-0.1**	**0.1-0.125**	**>0.125**
τ ≤ 0.6					
0.6 < τ < 0.7		Perform Torsional Analysis			
0.7 < τ < 0.8				Revise Structural Configuration	
0.8 < τ < 0.9					
τ ≥ 0.9			Not permitted		

Summary and Conclusions

The important provisions in the recently released Draft 7th revision of the code, IS 1893-Parts I and II, as compared with the present 2016 edition are discussed. It is seen that in the draft code the zone factors are based on the Probabilistic Seismic Hazard Assessment (PSHA), compared with the Deterministic Seismic Hazard Assessment approach (DSHA) followed in the previous versions of the code. According to Wang (2010) the use of PSHA could lead to either unsafe or overly conservative engineering design or public policy, each of which has dire consequences to society. Krinitzsky (1995) also argues that PSHA is a defective procedure.

> *"It is seen that in the draft code the zone factors are based on the PSHA, compared with the DSHA approach followed in the previous versions of the code."*

The concept of Maximum Considered Earthquake (MCE) and Design Basis Earthquake (DBE), which has been well understood by structural engineers, is considered in a convoluted manner in the code, by removing the factor '2' in the expression for A_h. (Eq. 1)

Hence, the structural engineers will not know whether they are designing for the actual earthquake forces or for the reduced values. The importance factor 'I' is also not important as per the code, as its value is generally taken as 1.0 in the draft code. The load factor for earthquake, which was mistakenly taken as 1.5 in the earlier versions, is considered correctly as 1.0. While the current code relies on the SPT value of soil for classification, in the draft code, it is based on the shear velocity of soil, V_s. The permissible drift limits are stringent, especially for the higher zones.

The draft code suggests structural systems to be adopted for RC buildings in different zones, along with minimum Structural Plan Density (SPD) of structural walls. It may be difficult to adopt them especially in severe zones. Moreover, such specifications may restrict the creativity of architects and engineers.

One notable specification is concerned with providing shear walls in buildings on slope, to avoid torsional tendencies in such buildings. A new provision has been introduced to calculate Torsional Flexibility Factor, in order to reduce torsional irregularity of the building.

In this connection, It is interesting to note that the team that developed FEMA P-2012 performed collapse analysis for variety of buildings with/without irregularities and found that the Equivalent Lateral Force (ELF) method provides more conservative results than Response-Spectrum Analysis (RSA), and provides force results closer to the Nonlinear Time-History Analysis. Based on these observations ELF method is suggested in the current ASCE 7-22, without many restrictions. Overall, the draft code provisions are found to be overly conservative.

References

1. *CED 39(22343)WC, "Draft Indian Standard Criteria for Earthquake Resistant Design of Structures Part 1 General Provisions [Seventh Revision of IS 1893 (Part 1)] (ICS No. 91.120.25)" Bureau of Indian Standards, New Delhi (2023) (https://www.services.bis.gov.in/tmp/WCCED21022343_26042023_2.pdf)*
2. *CED 39(22345)WC, "Draft Indian Standard Criteria for Earthquake Resistant Design of Structures Part 2 Buildings [Seventh revision of IS 1893 (Part 1) (ICS No. 91.120.25)" Bureau of Indian Standards, New Delhi (2023) (https://www.services.bis.gov.in/tmp/WCCED21022345_26042023_1.pdf)*
3. *IS 1893 (Part 1):2016, "Indian Standard Criteria for Earthquake Resistant Design of Structures, Part 1: General Provision and Buildings", Bureau of Indian Standards, New Delhi (2016)*
4. *SEAOC, "Vision2000, Performance Based Seismic Engineering of Buildings, Vols. I and II: Conceptual Framework", Structural Engineers Association of California, USA (2000).*
5. *IS 1893 (part 1): 2002, "Indian Standard Criteria for Earthquake Resistant Design of Structures, Part 1: General Provisions and Buildings (Fifth Revision)", Bureau of Indian Standards, New Delhi (2002)*
6. *NDMA Technical report, "Development of Probabilistic Seismic Hazard Map of India", National Disaster Management Authority, India (2010) (https://www.ndma.gov.in/sites/default/files/PDF/Technical%20Documents/Indiapshafinalreport.pdf)*
7. *BS EN 1998-1: 2004: "Eurocode 8: Design of structures for earthquake resistance- Part 1: General rules, seismic actions and rules for buildings", European Committee for Standardization, Belgium (2004).*
8. *Krinitzsky, E.L. (1995) "Deterministic versus probabilistic seismic hazard analysis for critical structures", Engineering Geology, Vol. 40, pp. I-7*
9. *UBC 97, Uniform Building Code, International Conference of Building Officials, California, U.S.A. (1997)*
10. *Wang, Z. (2010) "Seismic Hazard Assessment: Issues and Alternatives", Pure and Applied Geophysics, 15pp. DOI 10.1007/s00024-010-0148-3*
11. *ASCE/SEI 7(2022) Minimum Design Loads and Associated Criteria for Buildings and Other Structures, American Society of Civil Engineers, Reston, Virginia.*
12. *FEMA P-2012 (Sept. 2018) Assessing Seismic Performance of Buildings with Configuration Irregularities-Calibrating Current Standards and Practices, prepared by the Applied Technology Council for the Federal Emergency Management Agency, Washington, D.C, 366 pp.*