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Comprehensive Analysis of Modifications in the Draft Code IS1893 (WC) 2023 for RC Buildings

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Abstract - *The latest draft of the building code IS 1893 (WC) Part1 & Part 2, issued by the Bureau of Indian Standards (BIS) in April 2023, introduces significant alterations and provisions necessitating careful scrutiny before enforcement. Key changes include the transition from Deterministic Seismic Hazard Assessment (DSHA) to Probabilistic Earthquake Hazard Assessment (PEHA) methodology for seismic zone factor determination, leading to substantial increase in peak ground accelerations and distinct seismic zone factors for strength design and serviceability checks within the same structure. This exodus hints a substantial shift towards performance-based seismic design practices. Moreover, adjustments to the horizontal response spectrum curve, expansion of soil site classification based on shear wave velocity, and modifications in load combinations, minimum design horizontal base shear force, lateral storey drift limits, and allowable structural systems in reinforced concrete (RC) buildings have been implemented. Furthermore, the draft code introduces novel criteria for assessing building irregularities, with a specific focus on torsion, and mandates consideration of soil flexibility in structural analysis. It also incorporates provisions for analyzing Architectural Elements and Utilities (AEU), addresses small residential structure design, and delineates torsional analysis criteria for rectangular regular buildings. While these revisions aim to enhance seismic design methodologies, challenges such as comprehending return periods and adapting to new methodologies may arise. Therefore, the provision of clear explanations within the code and educational resources is imperative to facilitate understanding and implementation. This research paper conducts a comprehensive analysis of the revisions introduced in the draft code, particularly focusing on their implications for RC buildings.*

***Key Words*: Draft building code IS 1893 (WC) part 1 & part 2, peak ground accelerations, Probabilistic Earthquake Hazard Assessment, shear wave velocity**

1. INTRODUCTION

The latest draft of the building code IS 1893 (WC) Part1 & Part 2 released by BIS in April 2023 [1] [2] have brought substantial changes and provisions that warrant thorough review. While the final version of the revision is anticipated to closely resemble this draft, it's essential to acknowledge the possibility of modifications in values or specifications before its implementation. It's worth noting that the imminent release of IS 1893 Parts 3 to 11, which encompass topics ranging from tanks to tunnels and more, is anticipated in the near future.

Part 1: General provisions
Part 2: Buildings
Part 3: Liquid retaining tanks
Part 4: Bridges and retaining walls
Part 5: Industrial structures
Part 6: Base isolated buildings
Part 7: Pipelines
Part 8: Dams and embankments (to be formulated)
Part 9: Coastal structures (to be formulated)
Part 10: Steel towers (to be formulated)
Part 11: Tunnels (to be formulated)
Some noteworthy changes outlined in the draft of the building code IS 1893 (WC) Part1 & Part 2 are presented here.

1.1 Interpreting part 1 & part 2 together

The existing IS 1893-2016 Part 1 encompasses general provisions and guidelines for seismic design of buildings, while IS 1893 (WC) Part 1 and Part 2 serve as complementary sections to be interpreted together. Part 1 typically addresses general provisions, while Part 2 specifically focuses on seismic design considerations for buildings. It could potentially introduce confusion or make the code less user-friendly if essential provisions for seismic design are spread across multiple parts. Consolidating all pertinent information into Part 1 of the code would likely streamline the design process and facilitate easier reference for practitioners. This approach ensures that critical seismic design considerations are readily accessible within a single document, enhancing clarity and usability.

1.2 Symbols & Notations

The majority of symbols and notations in IS 1893 (WC) Part 1 and Part 2, are newly introduced and causing confusion compared to the previous version of the code, highlighting a significant usability issue.

1.3 Seismic zone factor

The cornerstone of the alterations in the code is the methodology used to determine zone factors. The new seismic map of India is based on Probabilistic Earthquake Hazard Assessment (PEHA) [3] method with an additional zone – Zone VI. Previous versions relied on the Deterministic Seismic Hazard Assessment (DSHA) approach. The design earthquake zone factor Z, indicative of the mean horizontal peak ground acceleration, now varies based on different return periods - T_{RP} (years) for various structure categories within each zone. Peak ground accelerations have substantially increased compared to existing values. Additionally, separate zone factors are now applicable for strength design and serviceability checks to the same building. This shift represents a momentous exodus from earlier practice, hinting a step towards performance based seismic design of structures. The method for specifying the zone factors Z in the draft code involves referencing two tables: Table 1 for obtaining the return period (T_{RP}) applicable to each building category (differentiating between Design and Serviceability), and Table 2 for determining the corresponding zone factor Z based on the T_{RP} and the seismic zone of the location. Appendix G of the draft code part 1 gives a brief of the process.

In the current code, seismic intensity is defined using two distinct categories: Maximum Considered Earthquake (MCE) and Design Basis Earthquake (DBE) [4]. Zone factor Z represents MCE and the Design Basis Earthquake is taken as 50% of MCE i.e. Z/2. Not everyone may be familiar with the concept of return periods in seismic design. Return periods represent the average interval of time between occurrences of a specific seismic event with a certain magnitude at a given location. To address this knowledge gap, it's important for seismic design codes to provide clear explanations and context regarding return periods. This could include definitions within the code itself, as well as educational materials or references to resources where users can learn more about seismic terminology and concepts. Additionally, code committee could consider providing practical examples or guidance on how return periods are used in seismic design calculations. This can help users understand the significance of return periods and how they influence design decisions without requiring specialized expertise in seismology.

Table -1: Return Period T_{RP} (years) for Strength Design and Serviceability [1]

Category of Structures	Return Period TRP (years)	
	Strength Design	Serviceability Check
Normal structures	475	73
Important structures	975	225
Critical / lifeline structures	2475	475
Special structures	4975	975
Nuclear power plant structures	To be specified by Atomic Energy Regulatory Board (AERB), GoI	To be specified by Atomic Energy Regulatory Board (AERB), GoI

Table -2: Earthquake Zone Factor Z for Different Return Periods T_{RP} in Different Earthquake Zones [2]

Seismic Zone	Design Earthquake Zone Factor Z for different Return Periods T_{RP} (years)						
	73	225	475	975	2475	4975	9975
II	0.038	0.050	0.075	0.100	0.150	0.200	0.250
III	0.075	0.100	0.150	0.200	0.300	0.400	0.500
IV	0.180	0.225	0.300	0.360	0.450	0.540	0.675
V	0.240	0.300	0.400	0.480	0.600	0.750	0.900
VI	0.300	0.375	0.500	0.600	0.750	0.9375	1.125

Table -3: Earthquake Zone Factor Z (MCE) [4]

Seismic Zone	Zone factor Z
II	0.10
III	0.16
IV	0.24
V	0.36

Earthquake levels are categorized based on their probability of occurrence as frequent, occasional, rare, very rare and so on. A frequent earthquake has 50% chance of occurrence in 50 years with a return period-T_{RP} of 72 years. It is known as serviceability earthquake as per existing code. All types of structures are designed to remain fully operational and functional under the expected levels of shaking associated with these earthquakes. A rare earthquake has 10% chance of occurrence in 50 years with a return period-T_{RP} of 475 years. It is known as design earthquake as per existing code. Critical infrastructure and important structures are designed to remain operational and functional under the expected levels of shaking associated with these earthquakes. A very rare earthquake has 2% chance of occurrence in 50 years with a return period-T_{RP} of 2475 years. It is known as maximum considered earthquake as per existing code. This level of seismic event serves as a benchmark for ensuring the safety and resilience of critical and lifeline facilities. This typology hints the shift towards performance based seismic design as per Fig-1.

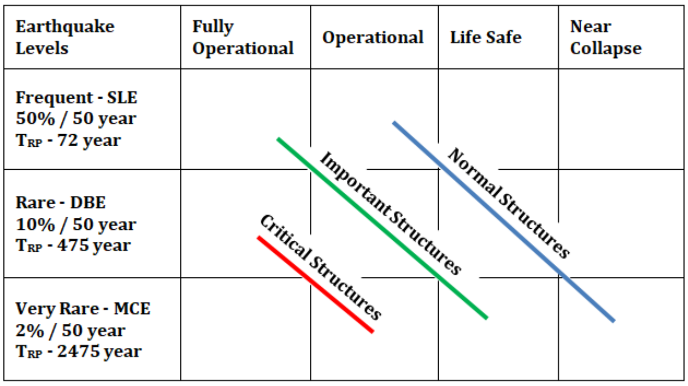


Fig -1: Performance Based Seismic Design (PBSD)- SEAOC Vision 2000 Committee (1995) [5]

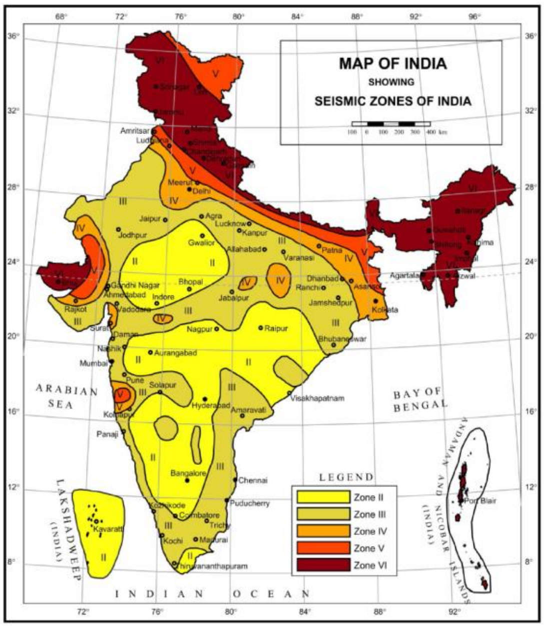
The comparison of zone factors for design strength as per category of structure given in draft code is shown in Table 4 and compared with the zone factor of the current code.

Table -4: Zone Factor comparison for design strength (current code and draft code)

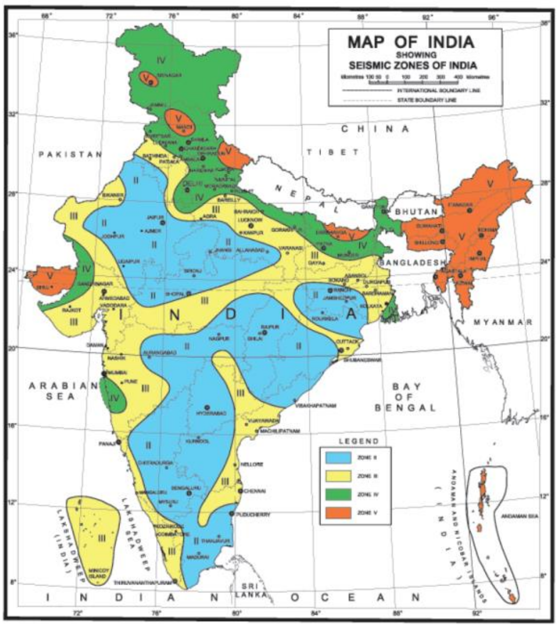
Seismic Zone	Design zone factor as per current code Z/2	Normal Structures Design T_{RP} - 475 years Z	Important Structures Design T_{RP} - 975 years Z	Critical / Lifeline Structures Design T_{RP} - 2475 years Z	Special Structures Design T_{RP} - 4975 years Z	Nuclear power plant structures
II	0.05	0.075	0.100	0.150	0.200	To be specified by AERB, Government of India
III	0.08	0.150	0.200	0.300	0.400	
IV	0.12	0.300	0.360	0.450	0.540	
V	0.18	0.400	0.480	0.600	0.750	
VI	-	0.500	0.600	0.750	0.9375	

2. SEISMICITY AND IMPORTANCE

The seismic zone map of India has been modified in the draft code with additional zone – zone VI as shown in Fig. 2. Due to change in boundaries, many cities have shifted from previous zone to higher zone. Shimla, Chandigarh, Roorkee and Dehradun shifted from zone IV to VI. Madurai and Trichy shifted from zone II to III. The entire north east belt, northern part and Himalayan region along with west Gujarat is shifted to new zone VI [2].



Seismic zone map India - draft code



Seismic zone map India - current code

Fig-2: Seismic zone map India - draft code & current code

2.1 Importance factor I

In the draft code, the importance factor I vary depending on the category of structures and the associated design return period. The current code provides three basic values for importance factor. Table below shows the comparison of importance factor I as per current code and draft code.

Table -5: Importance factor I

Category of structures	Current code	Draft code
Normal structures	1.0	1.0
Residential / commercial buildings with occupancy 100 – 200 persons	1.0	1.15
Residential / commercial buildings with occupancy more than 200 persons	1.2	1.0 (Important structure category)
Important structures	1.5	1.0
Critical / lifeline structures	1.5	1.0
Special structures	-	1.0
Nuclear power plant structures	-	To be specified by Atomic Energy Regulatory Board (AERB), Government of India

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2.2 Response reduction factor R

In the draft code, the response reduction factor is termed as elastic force reduction factor R. For building systems, it is more or less same as current code except at few places. Table 6 below highlights the difference in value of R as per current code and draft code. From the table it is observed that the draft code has provided different value of R for ductile structural walls without boundary elements and with boundary elements. Additionally, for dual structural system the increase in R value from 5.0 to 5.5 and 6.0 could potentially lead to cost savings by allowing for more efficient design and construction of high-rise buildings.

Table -6: Response reduction factor R

Structural system	Current code	Draft code
Building with Ordinary Braced Frames (OBF) having concentric braces	4.0	3.0
Building with Special Braced Frames (SBF) having eccentric braces	5.0	5.5
Unreinforced masonry (designed and detailed as per IS 1905) and provided with horizontal RC seismic bands	2.0	1.5
Buildings with ductile RC Structural Walls without boundary elements	4.0	4.5
Buildings with ductile RC Structural Walls with boundary elements	4.0	5.0
Dual system - Buildings with ductile RC Structural Walls without boundary elements and RC SMRF	5.0	5.5
Dual system - Buildings with ductile RC Structural Walls with boundary elements & RC SMRF	5.0	6.0

2.3 Response spectrum curve & design acceleration coefficient S_a/g:

In the draft code, the horizontal response spectrum curve has been extended to 10 seconds unlike the current code up to 4 seconds so as to incorporate structures with higher time period such as tall buildings. The normalized horizontal pseudo spectral acceleration (PSA) $A_{NH}(T)$ corresponding to damping of 5 percent of critical, for each site as per draft code for use in Linear dynamic method – response spectrum method and for use in linear equivalent static method is shown in Fig. 3 and Fig. 4. The current code curves have been extended to 10 seconds here for better comparison. For values of damping ξ, other than 5 percent (0 %< ξ < 30 %), the normalized horizontal PSA $A_{NH}(T)$ shall be obtained as per the equations given in the draft code.

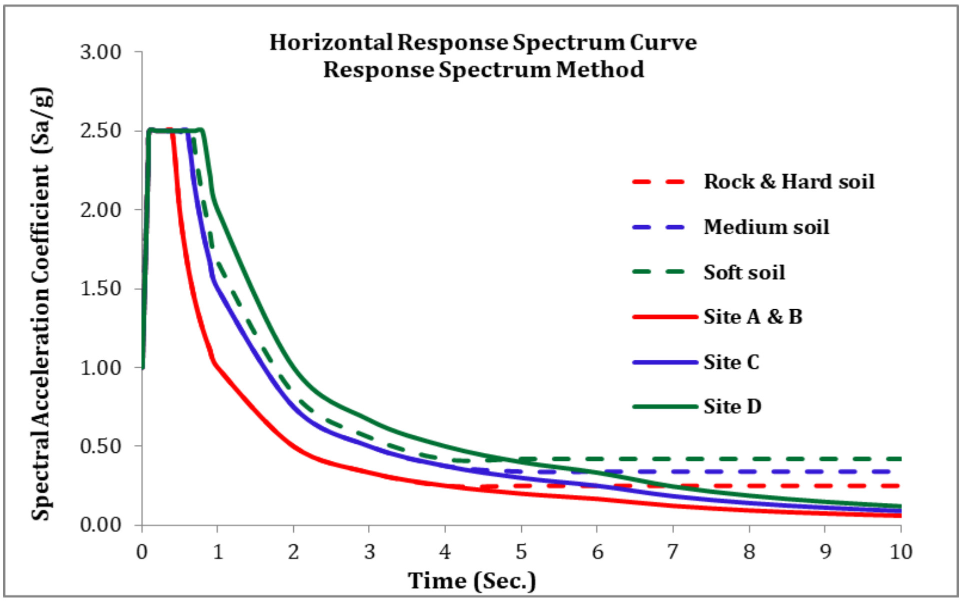

Fig-3: Horizontal spectrum curve comparison for response spectrum method (Solid lines represent draft code, dotted lines represent current code)

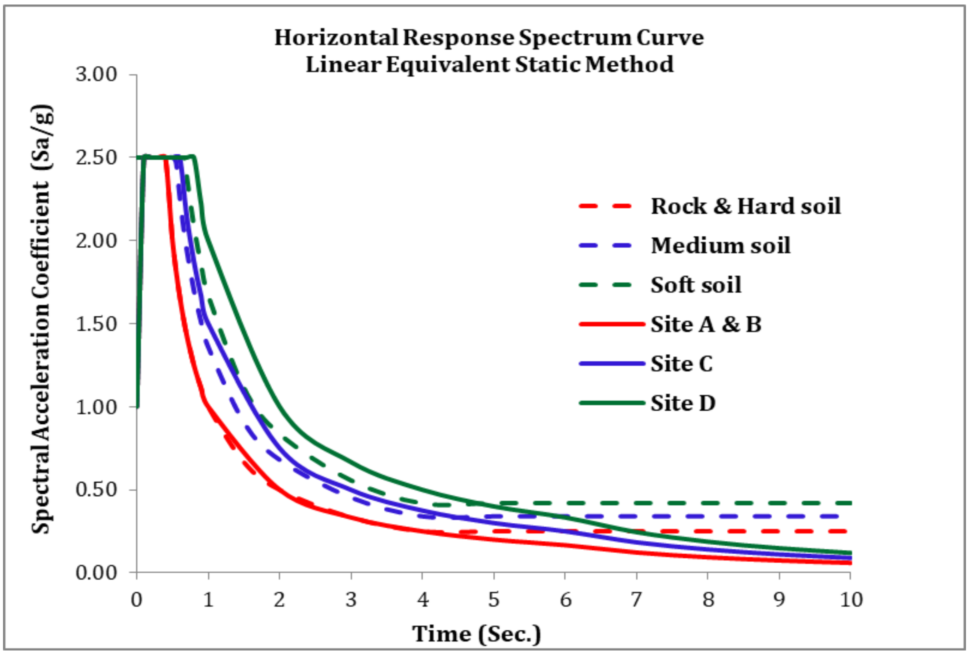

Fig-4: Horizontal spectrum curve comparison for equivalent static method
(Solid lines represent draft code, dotted lines represent current code)

The soil site classification to select appropriate response spectrum curve has been modified in the draft code. The current code appears to use the SPT (Standard Penetration Test) "N" value for soil classification [4] as shown in Table 7 whereas the draft code proposes to use shear wave velocity V_S of the soil for classification as shown in Table 8. It is based on the weighted average V_S of the underlying soil strata in the top 30m. There is no direct reference in draft code which relates shear wave velocity and N value of a soil. International Building Code [6] clearly relates soil site class with average shear wave velocity V_S, N value and Average undrained shear strength of a given soil as shown in Table 9. Comparing these, we can conclude that the soil type A, B and C as per draft code corresponds to type I soil of the current code. Type D soil as partly type I and partly type II and type E soil as partly type II and partly type III. No response curve is provided for type E soil in draft code which is partly under type III soil as per current code.

Table -7: Soil type Classification (current code)

Soil Class	SPT value N
Type A – Rock or Hard soils (Type I)	> 30
Type B – Medium or stiff soils (Type II)	10 - 30
Type C – Soft soils (Type III)	< 10
Type D – Unstable, collapsible, liquefiable soils	Requires site specific study

Table -8: Site Classes for estimating Normalized PSA (draft code) [2]

Site Class	Weighted Average Shear Wave Velocity V_S - (m/s)		
	Lower Limit		Upper Limit
A		V_S >	1500
B	760	< V_S <	1500
C	360	< V_S <	760
D	180	< V_S <	360
E		V_S <	180

Table -9: Site Class Definitions, International Building Code IBC-2009 [6]

Site Class	**Average shear wave velocity (V_s)**	**Average standard penetration resistance (N_1 or N_{ch})**	**Average undrained shear strength in the case of cohesive soils (s_u)**
A : Hard Rock	>1500 m/s	Not applicable	Not applicable
B : Rock	760 to 1500 m/s	Not applicable	Not applicable
C : Very dense soil or soft rock	370 to 760 m/s	>50	>100kPa
D : Stiff soil	180 to 370 m/s	15 to 50	50 to 100 kPa
E : Soft soil	<180 m/s	<15	<50 kPa
	Any profile with more than 3 m of soil having Plasticity Index PI>20, Moisture content ω ≥ 40% ,Average undrained shear strength su < 24 kPa		
F : Soils requiring site-specific evaluation	Soils vulnerable to potential failure or collapse (liquefiable, quick- or highly sensitive clays, collapsible weakly cemented soils) More than 3 m of peat and/or highly organic clays More than 7.5 m of very high plasticity clays (PI>75) More than 37 m of soft to medium clays		

The vertical response spectrum has been modified in the draft code. The new formula varies with the period (T) of the structure's response, as opposed to the current code, which employs a flat line with S_a/g as 2.5 as shown in Fig. 5. In the current code, the flat line effectually represents S_a/g value of 0.83, achieved through a calculation involving the multiplication of 2.5 x (2/3) x (1/2), where (1/2) accounts for the conversion from MCE to DBE.

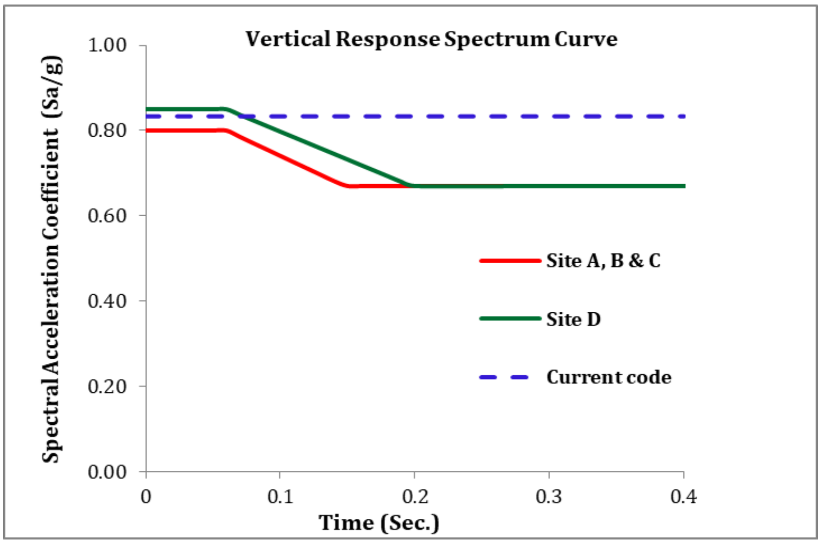

Fig-5: Vertical spectrum curve comparison
(Solid lines represent draft code, dotted lines represent current code)

3. DESIGN HORIZONTAL BASE SHEAR

The seismic horizontal coefficient A_h for design as per the current code is taken as

$$A_h = Z/2 * I/R * S_a/g \quad (1)$$

where,
Z = zone factor for MCE as per Table 3
I = Importance factor
R = Response reduction factor
S_a/g = Design acceleration coefficient for different soil types

The elastic maximum horizontal PSA $A_{HD}(T)$ for design as per the draft code is taken as

$$A_{HD}(T) = Z * I/R * A_{NH}(T) \quad (2)$$

where,

Z = zone factor as per Table 1 and Table 2
I = Importance factor
R = Elastic force reduction factor
$A_{NH}(T)$ = Normalized horizontal pseudo spectral acceleration (PSA) for different soil type

3.1 Load combinations and partial load factors

In the draft code [2], for limit state of strength, the following combinations are considered when earthquake effects are combined with dead and imposed loads.

- 1.5 DL + 1.5 LL
- 1.2 DL + 1.2 LL ± EE_D
- 1.5 DL ± EE_D
- 0.9 DL ± EE_D

When performing the serviceability check of structures, the following combinations are considered when earthquake effects are combined with Dead and Imposed Loads.

- DL + LL
- DL + 0.8 LL ± EE_S
- DL ± EE_S
- 0.9 DL ± EE_S

Here EE_D is earthquake load for design and EE_S is earthquake load for serviceability.

The draft code proposes a partial load factor of 1.0 for earthquake loads in both design and serviceability combinations, contrasting with the current code's use of a load factor of 1.5. This modification is credited to the vigilant selection of T_{RP} aimed at accounting for qualms epitomized by partial safety factors. This can be proved by taking example of normal structure category and comparing Z values and partial load factors as shown in Table 10. Simultaneously, it's a concern for cities currently designated as Zone IV, facing a proposed shift to Zone VI in the draft, accompanied by substantial increases in values for 1.2(DL+LL+EQ) by 247% and for 1.5(DL+EQ) by 177%.

Table -10: Zone factor and partial load factor comparison (current code and draft code IS1893)

Seismic Zone	Normal structures Draft code Z	Zone factor Current code Z/2	Zone factor with partial load factor 1.2(DL+LL+EQ) Current code	% increase in zone factor of draft code w.r.t Current code	Zone factor with partial load factor 1.5(DL+EQ) Current code	% increase in zone factor of draft code w.r.t current code
II	0.075	0.05	0.06	25 %	0.075	0 %
III	0.150	0.08	0.096	56.25 %	0.12	25 %
IV	0.300	0.12	0.144	108.33 %	0.18	66.66 %
V	0.400	0.18	0.216	85.18 %	0.27	48.14 %
VI	0.500	-	-	-	-	-
Shimla, Chandigarh, Roorkee, Dehradun	0.500	0.12	0.144	247.22 %	0.18	177.77%
Madurai, Trichy	0.150	0.05	0.06	150%	0.075	100%
Bhuj	0.500	0.18	0.216	131.48%	0.27	85.18%

3.2 Minimum Design Horizontal Base Shear Force

As per the draft code, the minimum design horizontal earthquake base shear force $V_{BD,H}$ for strength design should be
$V_{BD,H,\,min}$ = 0.625 * Z * I/R * W > 0.015W i.e. 1.5%
where,

Z = zone factor as per Table 1 and Table 2
I = Importance factor
R = Elastic force reduction factor
W = Seismic weight of the building

The equation clearly states that the minimum value of $A_{NH}(T)$ should be 0.625. It also highlights that in any case the zone factor Z should not be less than 0.12 considering normal ductile structure. The minimum design horizontal earthquake base shear force for strength as per current code is shown in Table 11.

Table -11: Minimum Design Earthquake Horizontal Lateral Force, current code [4]

Seismic Zone	%
II	0.7
III	1.1
IV	1.6
V	2.4

4. Lateral Storey Drifts & structural systems in Buildings

The draft code has undergone changes in the permissible drift limits as well. The limits are to be taken from Z for serviceability and reduced for higher zones as shown in Table 12, resulting in stricter criteria for higher zones. The current code imposes a uniform restriction on storey drifts, limiting them to 0.004 for buildings regardless of the seismic zones.

Table -12: Lateral Storey Drifts in Buildings as per draft code

Seismic Zone	Lateral Storey Drifts
II	0.004
III	0.004
IV	0.003
V	0.0025
VI	0.002

4.1 Admissible structural systems in RC Buildings

The structural systems permitted as per draft code for RC buildings are outlined in Table 13, emphasizing that relying solely on moment frames may not yield optimal performance in higher seismic zones. Table 13 should be interpreted in conjunction with the minimum Structural Plan Density (SPD) of Structural Walls in RC Buildings as outlined in Table 14, with zone-specific limits. Notably, there are specific provisions, such as the requirement for shear walls in buildings on slopes (Fig. 6 and Table 15 to be referred together), aimed at mitigating torsional effects in such structures. The notations given are:

OMRS = Ordinary Moment Resisting Frames

SMRF = Special Moment Resisting Frames

SMRF+SSW = Special Moment Resisting Frames with Special Structural Walls

Table -13: Admissible structural systems in RC Buildings as per draft code

Seismic Zone	Building Category		
	Normal	**Important**	**Critical and 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

Table -14: Minimum Structural Plan Density of Structural Walls alone in RC Buildings

Seismic Zone	Minimum Structural Plan Density of Structural Walls - SPD
II	1%
III	1.5%
IV	2%
V	2.5%
VI	2.5%

Table -15: RC Wall Configurations in Step-Back Buildings on Hill Slopes

Difference between Highest and Lowest Column Base Levels	Wall configuration
<= 10m	A
10 – 15m	B
> 15m	C

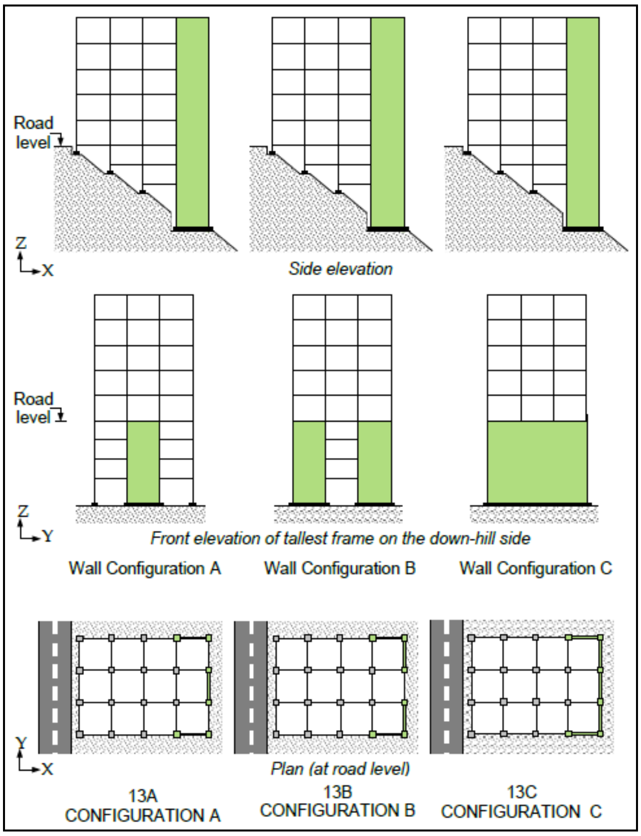

Fig- 6: Shear Wall Configurations for Buildings on Slope as per draft code

4.2 Small residential Buildings

The draft code adopts a lenient approach towards the design of small residential framed structures up to two storeys (including basement), where the Equivalent Static Method of analysis suffices. However, in zones II and III, it mandates at least Special Moment Resisting Frames (SMRF) with infill walls covering a minimum of 90% of the bays. In zones IV and V, the requirement is for at least SMRF (with infills) along with Special Shear Walls (SSW), ensuring a minimum of 1.5% Structural Plan Density (SPD) in each principal plan direction.

4.3 3D Modeling and soil stiffness

The draft code now mandates the consideration of soil flexibility for all cases, demanding that building analysis models have their supports assigned with calculated springs rather than being fixed or pinned. For Linear Equivalent Static Analysis without explicitly considering inertial effects, it's essential to account for flexible soil translational and/or rotational springs into the analysis. It's essential to incorporate all aspects of soil-structure interaction when performing Dynamic Analysis for the structure under design or evaluation. However, this requirement excludes buildings in site classes A and B, as well as those up to five storeys in height resting on individual footings. In the draft code, the flexibility of soil is captured through its modulus of subgrade reaction for different foundations.

4.4 Soil damping

One of the numerous enhancements to the code is the introduction of soil damping for the purpose of design. The damping ratio of soil is to be taken as 2.5 percent. But, for assessment of structures under earthquake loading, it is required to use strain-dependent hysteretic damping instead of viscous damping, when modeling soil.

5. TORSION IN BUILDINGS

The draft code has introduced a significant criterion regarding building irregularities, particularly crucial for tall structures, focusing on torsion. The existing criterion in the current code identifies a building as torsionally irregular when the ratio of maximum floor edge displacement Δ_{max} to its minimum Δ_{min} exceeds 1.5 times as shown in Fig. 7. In addition to it, the draft code specifies Torsional Flexibility Factor, ψ of the building, derived by evaluating the influences of three aspects contributing to the building's torsional tendencies. If $\psi < 0.4$, the building is said to be torsionally stiff else is termed as torsionally flexible. Torsional Flexibility Factor is calculated as

$$\psi = (e_K/B)*(B/r)^2*(\tau)^2 = (e_K/r_{K\theta})*(B/r_{K\theta}) \quad (3)$$

where,

B = Outer Dimension of the building along the direction to the considered direction of shaking

e_K = Stiffness eccentricity of the building with respect to CR

(e_K/B) = Normalized stiffness eccentricity of the building

r = Translational radius of gyration of the mass of the building at the floor level

$r_{K\theta}$ = Torsional Radius of gyration of the mass of the building at the floor level

τ = Ratio of Natural Periods of Fundamental Torsional and Fundamental Translational Modes of oscillation of the building, i.e. T_θ / T_X or T_θ / T_Y for considered direction of shaking of X and Y.

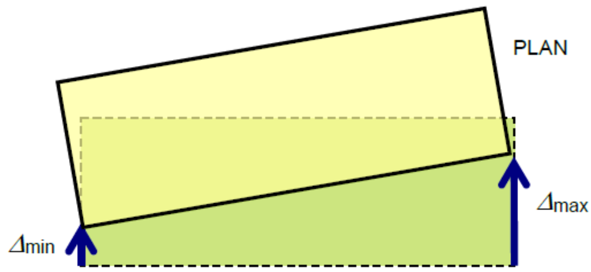

Fig- 7: Torsional Irregularity in Buildings

In the case of rectangular regular plan buildings, the decision to conduct either a torsional analysis or revise the structural configuration is determined by considering the torsional eccentricity and the ratio of the τ's as specified in Table 16. However, for buildings with non-rectangular irregular plan geometry, it must be ensured that the Torsional Flexibility Factor-ψ is less than 0.4. Otherwise, the structural configuration needs to be revised.

Table -16: Design Limit for (e_K/B) and τ for Rectangular Regular Buildings

$\tau = (T_\theta / T_X)$ or (T_θ / T_Y)	Total Torsional Eccentricity e_K/B				
	$e_K/B \le 0.05$	$0.05 < e_K/B \le 0.07$	$0.07 < e_K/B \le 0.10$	$0.1 < e_K/B \le 0.125$	$e_K/B > 0.125$
$\tau \le 0.6$					
$0.6 < \tau < 0.7$					
$0.7 < \tau < 0.8$	Perform Torsional Analysis			Revise Structural Configuration	
$0.8 < \tau < 0.9$					
$0.9 \le \tau$	Not Permitted				

6. ARCHITECTURAL ELEMENTS &UTILITIES (AEU)

A significant enhancement to the code is the inclusion of analysis for Architectural Elements and Utilities (AEU), previously mainly found in NDMA guidelines but now integrated into the draft code. AEU encompasses various appendages, ranging from partition walls and storage cabinets to electrical and mechanical equipment. They are categorized as acceleration-sensitive AEUs and displacement-sensitive AEUs, with the latter further subdivided based on whether they are fixed at different building levels or at the same level. The code elaborates on methods of analysis for each category, providing dedicated tables for Importance, Acceleration Amplification, and Response Reduction factors for reference. The design lateral force F_p for the design of anchorages connecting Acceleration-Sensitive AEUs to the Structural Elements (SEs) of the building shall be taken as:

$$F_p = (1+x/H)*I_{AEU}*(a_{AEU}/R_{AEU})*W_{AEU} \ge 0.04W_{AEU} \quad (4)$$

Where,
Z = Earthquake zone factor as per Table 2 of draft code for the earthquake zone of the site of the structure on which the AEU is mounted, given by the Earthquake Zone Map of India (Fig. 1)
x = Height of the point of attachment of AEU above top of the foundation of the structure
H = Overall height of the structure above top of the foundation
I_{AEU} = Importance factor of the AEU (Table 17)
a_{AEU} = Acceleration Amplification Factor of the AEU (Tables 11 and 12 of draft code)
R_{AEU} = Elastic Force Reduction Factor of the AEU (Tables 11 and 12 of draft code)
W_{AEU} = Weight of the *AEU*

The provision of this clause is equally applicable for the design of infill walls and partition walls that are placed with a gap between the structural elements, so that these walls do not foul with the lateral displacement of the structural elements, the provisions of these clauses shall be applicable.

Table-17: Importance Factor IAEU of AEUs

AEU	I_{AEU}
Component containing hazardous contents	2.5
Life safety component required to function after an earthquake (e.g., fire protection sprinklers system)	2.5
Storage racks in structures open to the public	2.5
All other components	2.0

7. SUMMARY & CONCLUSIONS

- The momentous changes in the Draft codes of IS 1893, in comparison to the current 2016 edition, are highlighted. Notably, in the draft code, zone factors are determined based on Probabilistic Seismic Hazard Assessment (PSHA), diverging from the Deterministic Seismic Hazard Assessment (DSHA) approach utilized the current code. Wang [7] sees PSHA as a purely numerical concept without physical or mathematical basis which could lead to engineering designs that are either unsafe or overly cautious, with serious consequences for society. Also Krinitzsky [8] argues that PSHA is a flawed procedure.
- The code complicates the well-understood concepts of Maximum Considered Earthquake (MCE) and Design Basis Earthquake (DBE) by excluding the factor '2' from the expression for Ah, which is recognized by structural engineers. Consequently, structural engineers may lack clarity on whether they are designing for the actual earthquake forces or for reduced values.
- The code undervalues the importance factor 'I' by typically setting its value to 1.0, rendering it insignificant.
- The earthquake load factor, previously speciously set at 1.5 in earlier versions, is now correctly acknowledged as 1.0.
- While the existing code uses the SPT value of soil for classification, the draft code employs the shear velocity of soil, Vs, for this purpose.
- The allowable drift limits are sterner for the higher zones.
- The draft code recommends specific structural systems for RC buildings across different zones, alongside minimum requirements for Structural Plan Density (SPD) of structural walls. Implementing these guidelines, particularly in severe zones, may pose challenges and could potentially constrain the creativity of architects and engineers.
- An important aspect involves incorporating shear walls in buildings located on slopes to mitigate torsional tendencies. To address this, a new provision has been introduced for calculating the Torsional Flexibility Factor, aiming to reduce torsional irregularities in the building design.
- FEMA P-2012 [9] conducted collapse analyses on different types of buildings, both with and without irregularities. Their findings exhibited that the Equivalent Lateral Force (ELF) method tends to yield more conservative results compared to Response Spectrum Analysis (RSA), aligning more closely with the force outcomes derived from Nonlinear Time-History Analysis. Consequently, the ELF method is recommended in the latest ASCE 7-22 [10] with fewer limitations. However, it's noted that the proposed codal provisions overall lean towards being overly cautious.

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BIOGRAPHY

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