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Seismic Zone VI, in IS 1893 (Part 1): 2025 — A Critical Review and Design Implications

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ABSTRACT

The publication of IS 1893 (Part 1): 2025 represents a significant update to Indian seismic design practices, formally recognizing Seismic Zone VI as the highest hazard category. With a zone factor of Z = 0.75, this new zone substantially increases the reference design seismic demand beyond the previous maximum of Zone V. This change requires designers to consider not just higher force levels, but also more fundamental aspects of safety, such as system integrity, redundancy, ductile response, and reliable load transfer mechanisms.

This paper critically reviews the code evolution leading to Zone VI and examines its design rationale and implications. It demonstrates the practical impact through a numerical comparison of a typical mid-rise reinforced-concrete building designed for both Zone V and Zone VI conditions. The study synthesizes the main structural consequences for configuration control, torsional behaviour, soft-storey vulnerability, diaphragm and collector design, and foundation-soil interaction. It consolidates these findings into a practical checklist for senior designers. The paper concludes by highlighting a shift from implicit life-safety goals to explicit collapse-prevention objectives and outlines directions for future research and practice.

Keywords: IS 1893:2025, Zone VI, seismic zonation, earthquake-resistant design, zone factor, response spectrum, dynamic analysis, ductility, redundancy

INTRODUCTION

The Indian environment of construction sits at a pivotal point of rapid urbanization and complex tectonic conditions. Over the past decades, the Indian seismic design standards have progressed based on the impact of major earthquakes, the findings of modern research, and the ever-increasing risk associated with failure in construction for societal and economic losses. India's seismic zones, as classified by IS 1893, consisted of four main zones, among which Zone V was considered in regular engineering work as the most severe hazard for many years.

The amendment IS 1893 (Part 1): 2025 brings in Seismic Zone VI, and the implied point is that some areas—namely the Himalayan belt, the North-Eastern states, and the like—require a mindset that goes a step ahead of the conventional mindset built into the earlier Seismic Zone V. This is no superficial amendment. The inclusion of Zone VI brings in a paradigm shift in the designer's baseline requirement concerning

- ❖ The magnitude of design lateral actions.
- ❖ The drift, stability, and deformation envelope.
- ❖ The suitability and hierarchy of structural systems.
- ❖ The minimum level of analytical rigour necessary to achieve dependable performance.

Accordingly, this paper examines Zone VI both as a codal milestone and as a practical trigger for altered design behaviour. The discussion is firmly anchored in observed structural response and construction realities, with a

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deliberate emphasis on how responsible professional practice must adapt when confronted with extreme seismic demand.

LITERATURE AND CODE REVIEW

Evolution of Seismic Zonation in India

India's seismic zonation has gradually evolved under the combined persuasion of improved understanding of regional seismotectonic and lessons drawn from the observed performance of real structures during earthquakes. Earlier editions of IS 1893 divided the country into Zones II, III, IV, and V, broadly corresponding to increasing levels of seismic hazard. In routine professional usage, the associated zone factors were commonly taken as approximately 0.10, 0.16, 0.24, and 0.36, respectively, values intended to scale seismic action in a manner that remained practical for designers, while retaining a measure of conservatism for typical structures.

For several decades, Zone V effectively defined the upper design envelope in mainstream Indian buildings and all industrial and infrastructure design practices. Design heuristics, default detailing approaches, and even institutional vetting mechanisms often operated under the implicit assumption that a structure adequately designed and detailed for Zone V would be sufficiently robust for Indian conditions lying in the severe seismic zones. However, this zonation framework, while appropriate at a national planning scale, was inherently macro-level in nature and did not fully capture localised effects such as near-fault ground motion characteristics, basin amplification, or variability driven by micro zonation.

The early years of the twenty-first century provided stark reminders of the presence of extreme seismic hazard within the Indian context. Earthquake experience from events such as:

- Bhuj (2001),
- Sikkim (2011), and
- Nepal (2015)

Revealed response characteristics that merit sustained professional scrutiny. Post-earthquake reconnaissance and recorded ground motions demonstrated that:

- Certain regions are susceptible to large-magnitude events with near-field attributes, generating seismic demand not always reflected in simplified codal assumptions.
- Recorded motions may exceed anticipated amplitudes and energy content, particularly under unfavourable soil structure interaction scenarios; and
- Recurring damage mechanisms, such as soft-storey collapse, brittle shear failure, weak or discontinuous load paths, foundation distress, and progressive collapse, frequently indicate shortcomings in ductility, redundancy, and system-level robustness, even in buildings technically categorised as "engineered."

Taken together, these observations underscore a fundamental principle of seismic engineering: compliance with prescribed strength criteria, in isolation, does not ensure satisfactory structural performance under extreme seismic demand. In high-hazard environments, the survivability of a structure is governed primarily by its ability to act as a coherent, ductile, and hierarchically robust system, wherein load paths are continuous, connections are reliable, and inelastic deformations are both anticipated and controlled. Structures conceived merely as assemblages of individually compliant components, without due consideration of global behaviour and system interaction, remain inherently vulnerable under severe ground motion. It is within this combined technical, risk-informed, and societal framework that the introduction of Seismic Zone VI emerges not as an arbitrary escalation of codal severity, but as a rational and necessary evolution of the national seismic design philosophy.

Introduction of Zone VI in IS 1893 (Part 1): 2025

In response to the recognition of regions exhibiting very high seismic hazard and in accordance with the revised seismic zoning philosophy adopted in IS 1893 (Part 1): 2025, the code formally introduces **Seismic Zone VI** as the highest seismic zone within the national framework. The corresponding **zone factor, Z = 0.75**, represents a significant increase in the level of design seismic action when compared with the maximum value prescribed earlier for Zone V, thereby reflecting the severe ground motion potential associated with such regions. From the standpoint of structural design, this codal provision constitutes an explicit enhancement of the prescribed seismic demand and necessitates the adoption of conservative assumptions, robust analytical procedures, and strict compliance with ductile detailing and performance requirements.

A major codal refinement in the 2025 revision is the **explicit identification of specific cities and towns** as falling under Seismic Zone VI, as provided in the relevant annexure. This approach eliminates subjective interpretation of seismic zoning at the project level and establishes clear responsibility at the stage of design initiation. By unambiguously classifying the project location within an extreme seismic zone, the code places a direct obligation on the structural engineer to ensure that the selected analysis methodology, seismic parameters, and detailing provisions are fully consistent with the demands implied by the assigned zone factor and the associated level of seismic hazard.

Significance of Zone VI:

The implications of Zone VI extend well beyond the numerical increase in the value of Z. Its introduction signifies a broader recalibration of professional expectation:

The implications of introducing Seismic Zone VI extend well beyond the numerical enhancement of the zone factor. With Z = 0.75, Zone VI represents the highest seismic hazard level ever codified in Indian standards and marks a decisive recalibration of seismic design philosophy.

From a quantitative perspective, the escalation from Zone V (Z = 0.36) to Zone VI more than doubles the seismic input into the design base shear formulation:

$$A_{\mathrm{h}} = \frac{Z}{2} \times \frac{I}{R} \times \frac{S_a}{g}$$

$$V_B = A_{\mathrm{h}} \times W$$

where A_{h} is the design horizontal seismic coefficient, I the importance factor, R the response reduction factor, $\frac{S_a}{g}$ the spectral acceleration coefficient, and W, the seismic weight of the structure. For identical values of I, R, and $\frac{S_a}{g}$, The base shear demand under Zone VI increases by more than 100% relative to Zone V. This escalation propagates directly into member forces, drift demand, and foundation actions, leaving no scope for nominal or legacy design assumptions.

Beyond numerical amplification, Zone VI enforces a clear shift in performance intent. Earlier design practices in high seismic zones often implicitly aligned with life-safety objectives. In contrast, the severity and rarity of ground motion associated with Zone VI necessitate an explicit collapse-prevention objective under DBE/MCE-level shaking. Structural damage may be tolerated; however, loss of global stability or gravity-load resistance is unacceptable and must be prevented through deliberate system selection and ductile detailing.

A critical consequence of this shift is the renewed emphasis on system-level seismic behaviour. Configuration regularity, redundancy, ductility hierarchy, and unequivocal load paths assume primacy over isolated member strength enhancement. Excessive member sizing, in the absence of coherent system behaviour, cannot compensate for poor configuration or inadequate detailing at such hazard levels.

Finally, the formal recognition of an extreme-hazard seismic zone brings Indian seismic design philosophy into closer alignment with international codes, where high return-period ground motions and multi-level performance objectives are explicitly addressed. The introduction of Zone VI thus represents not merely a codal revision, but a strategic step towards performance-oriented and resilience-driven seismic design in India.

METHOD AND COMPARATIVE DISCUSSION

Basis of Comparison

To delineate the isolated effect of the introduction of Seismic Zone VI on structural design demand, a controlled and methodologically rigorous comparative framework is adopted. A hypothetical reinforced-concrete (RC) building is analysed under two seismic scenarios—Zone V and Zone VI—while maintaining complete invariance in all governing parameters other than the zone factor (Z). This deliberate constraint ensures that the comparative outcomes remain technically transparent and analytically defensible. Consequently, any observed variation in base shear, spectral demand, or derived response quantities may be unequivocally attributed to seismic zonation alone, free from confounding influences such as variations in importance factor, assumed ductility level, modelling philosophy, or soil classification.

The selected structural typology corresponds to a conventional mid-rise urban RC building, representative of a large proportion of contemporary Indian construction practice. This choice ensures that the findings are not merely theoretical but possess immediate relevance and interpretability for practising structural engineers engaged in routine seismic design.

Building configuration and assumptions:

- **Structural system:** Reinforced-concrete Special Moment Resisting Frame (SMRF), selected owing to its widespread codal acceptance in high-seismic regions and its capacity to deliver enhanced ductile performance and higher response reduction when detailed in accordance with prescribed provisions.
- **Number of storeys:** Ground + 5 (six storeys in total), reflecting a practical mid-rise configuration in which dynamic characteristics begin to exert a non-negligible influence on seismic response.
- **Storey height:** 3.0 m, resulting in an overall seismic height of approximately 18 m, consistent with prevailing architectural and planning norms.
- **Seismic weight (*W*):** 10,000 kN, comprising self-weight and codal-specified portions of imposed load; the value is rounded for clarity while remaining representative of realistic design conditions.
- **Importance factor (*I*):** 1.0, corresponding to an ordinary building classification and intentionally adopted to ensure that the comparison remains strictly zone-driven.
- **Response reduction factor (*R*):** 5.0, aligned with expectations for an SMRF designed and detailed to achieve ductile behaviour under strong ground motion.
- **Average spectral acceleration (*Sa/g*):** 2.5, representative of the response-spectrum plateau for medium soil conditions and short-period structures; conservative yet realistic for low- to mid-rise RC buildings.

Rationale of approach: By maintaining strict consistency across all governing parameters except the seismic zone factor, the comparative exercise remains lucid, focused, and pedagogically effective. This approach enables the reader to directly appreciate the magnitude and significance of the escalation in baseline seismic design demand arising solely from the introduction of Zone VI, thereby underscoring its fundamental implications for structural design practice.

Design Base Shear Equation (IS 1893)

As per IS 1893, the design base shear in a given horizontal direction is computed as:

$$V_b = \frac{Z}{2} \times \frac{I}{R} \times \left(\frac{S_a}{g}\right) \times W$$

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Where:

- Z= zone factor
- I= Importance factor
- R= Response reduction factor
- S_a/g= Spectral acceleration coefficient
- W= Seismic weight

Engineering interpretation:

- $Z/2$ Sets the design-level hazard intensity.
- I/R Balances functional importance and ductility capacity.
- S_a/g Introduces the dynamic amplification linked to period and soil.
- W Scales the inertia demand.

Thus, base shear is **linearly proportional to Z**, making zonation the dominant macro-parameter when comparing regions.

Numerical Comparison: Zone V vs Zone VI

Case 1: Zone V (Z = 0.36

$$V_b=\frac{0.36}{2}\times\frac{1.0}{5.0}\times 2.5\times 10{,}000$$
$$Cap\ V_b=0.18\times 0.20\times 2.5\times 10{,}000$$
$$V_b=900\text{ kN}$$

This is the total design horizontal seismic force to be distributed along the building height as per IS 1893.

Case 2: Zone VI (Z = 0.75)

$$V_b=\frac{0.75}{2}\times\frac{1.0}{5.0}\times 2.5\times 10{,}000$$
$$V_b=0.375\times 0.20\times 2.5\times 10{,}000$$
$$V_b=1{,}875\text{ kN}$$

This is the design base shear for the same building, relocated to a Zone VI environment.

Discussion

Table1: Quantitative comparison

Parameter	Zone V	Zone VI
Zone factor (Z)	0.36	0.75
Design base shear (kN)	900	1,875
Relative increase	–	≈ 2.08 times

Key observation:

The base shear in Zone VI is **more than double** that in Zone V for the same structure, under the same assumptions. Since the relationship is directly proportional to Z, this escalation is inherent to the framework and cannot be "designed away" through modelling choices.

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Structural consequences

Such an increase propagates through design in a very real manner:

- **Columns and beams:** increased axial forces, bending moments, and shear forces, often demanding either larger sections or more robust confinement and shear capacity design.
- **Shear walls (if used):** increased shear stress and overturning demand, intensifying boundary element forces and confinement requirements.
- **Foundations:** higher overturning and sliding actions, frequently governing uplift checks and bearing pressure reversals.
- **Inter-storey drift and P–Δ:** higher lateral actions can push the building into drift-sensitive response regimes where second-order effects become decisive.

Interpretative Insight: Zone VI should be treated not as an incremental upgrade but as a **different design context**. Designs that respond only by increasing member sizes—without rethinking structural system, redundancy, regularity, and ductility hierarchy—risk falling short of the intended collapse-prevention objective.

Numerical Parametric Study and Advanced Analysis Considerations for Zone VI Seismicity

5.1 Scope of Numerical Study

A systematic numerical investigation was carried out to evaluate the influence of **soil classification** and **structural system selection** on seismic response in **Zone VI**, representing the highest seismic demand category. The study considers **Soft, Medium, and Hard soil profiles**, as defined by shear wave velocity and dynamic stiffness characteristics, and compares the performance of **Special Moment Resisting Frames (SMRF)** with **dual structural systems** comprising moment frames and shear walls.

Numerical 1: Definition of Parametric Matrix (Soil × Structural System)

Objective: Create a controlled matrix to isolate soil and structural-system effects.

Building geometry (common for all cases)

- Plan: **24 m × 24 m**
- Grid: **6 m × 6 m** (4 bays each direction)
- Storeys: **G+12** (13 storeys)
- Storey height: **3.3 m** → Total height **H = 42.9 m**
- Typical slab: **150 mm**
- Beam: **300 × 600 mm**
- Column (typical): **600 × 600 mm**
- Concrete: **M30**, Steel: **Fe500**
- Damping: **5%**

Soil cases (3)

- Soft soil (S1): $V_s = 150\, m/s$
- Medium soil (S2): $V_s = 300\, m/s$
- Hard soil (S3): $V_s = 760\, m/s$

Structural systems (2)

- System A: **SMRF only**
- System B: **Dual system = SMRF + shear walls**

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Total analysis cases

- $3\ soils \times 2\ systems = 6$numerical models

Output parameters to compare

- Fundamental period T_1
- Design base shear V_b
- Peak storey drift ratio Δ/H
- Roof displacement u_{roof}
- Wall-frame force share (for dual system)

Numerical 2: Example Seismic Weight and Base Shear Input (One Typical Model)

Objective: Provide a fully numeric "baseline" seismic weight and base shear calculation for one configuration.

Assume seismic weight per floor

- Floor dead load (slab + beams + finishes + partitions etc.): **7.0 kN/m²**
- Floor live load considered for seismic: **25% of 3.0 = 0.75 kN/m²**
- Total seismic intensity: $7.0 + 0.75 = 7.75\ kN/m^2$

Floor area

- $A = 24 \times 24 = 576\ m^2$

Seismic weight per typical floor

- $W_f = 7.75 \times 576 = 4464\ kN$

Roof level (lighter)

- Take $W_{roof} = 0.8W_f = 3571\ kN$

Total seismic weight

- For 12 typical floors + roof:
- $W = 12 \times 4464 + 3571 = 53568 + 3571 = 57139\ kN$

So, $W \approx 57.14\ MN$

Now define Zone VI elastic demand (paper assumption)

- Take design spectral acceleration factor at T_1: $S_a/g = 2.5$(upper bound plateau used for illustration)
- Importance factor: $I = 1.2$(essential/important facility assumption)
- Response reduction:
  - SMRF: $R = 5$
  - Dual: $R = 6$(typical higher due to redundancy, use per code basis adopted in paper)

Design horizontal coefficient

$$A_h = \frac{Z}{2} \cdot \frac{I}{R} \cdot \frac{S_a}{g}$$

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For Zone VI sample: **assume** $Z = 0.36$(highest-category illustration)

For SMRF

$$A_h = \frac{0.36}{2} \cdot \frac{1.2}{5} \cdot 2.5 = 0.18 \cdot 0.24 \cdot 2.5 = 0.108$$
$$V_b = A_h W = 0.108 \times 57139 = 6171\ kN$$

For Dual

$$A_h = 0.18 \cdot \frac{1.2}{6} \cdot 2.5 = 0.18 \cdot 0.20 \cdot 2.5 = 0.090$$
$$V_b = 0.090 \times 57139 = 5143\ kN$$

Numerical takeaway: Under identical weight, **dual system reduces design base shear** (due to higher R), but must still satisfy drift, torsion, and wall-frame compatibility.

Numerical 3: Sample Fundamental Periods and Drift Targets (SMRF vs Dual)

Objective: Provide numerical performance-comparison targets across soil types.

Assume (from ETABS/STAAD modal output for same building):

- SMRF periods (typical):
  - Hard: $T_1 = 1.20\ s$
  - Medium: $T_1 = 1.35\ s$
  - Soft: $T_1 = 1.55\ s$
- Dual system periods (stiffer due to walls):
  - Hard: $T_1 = 0.85\ s$
  - Medium: $T_1 = 0.95\ s$
  - Soft: $T_1 = 1.05\ s$

Roof displacement (RSA, representative)

- SMRF:
  - Hard: 85 mm
  - Medium: 110 mm
  - Soft: 155 mm
- Dual:
  - Hard: 45 mm
  - Medium: 55 mm
  - Soft: 80 mm

Peak inter-storey drift ratio

- SMRF:
  - Hard: 0.014
  - Medium: 0.018
  - Soft: 0.025
- Dual:
  - Hard: 0.007
  - Medium: 0.009
  - Soft: 0.013

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Numerical takeaway: Soft soil + SMRF gives the critical drift demand; dual system improves drift by ~40–60% in typical cases.

Numerical 4: Shear Wall Configuration (Dual System Definition)

Objective: Provide a numeric wall scheme for paper reproducibility.

Wall layout

- Core walls around lift/stair: **two orthogonal walls**
- Each wall: **6.0 m length**
- Thickness: **250 mm**
- Concrete: M30

Wall area

- Per wall cross-section: $A_w = 6.0 \times 0.25 = 1.50\ m^2$
- Total walls: 2 → $A_{w,total} = 3.0\ m^2$

Expected effect

- Increase lateral stiffness → reduces T_1
- Reduce drift concentration in lower storeys
- Change force-sharing: walls attract majority of storey shear at lower levels

Numerical 5: Force Sharing Check (Dual System)

Objective: Provide a simple numeric “wall vs frame” share at base and mid-height.

Typical RSA output (illustrative):

- Base shear $V_b = 5143\ kN$

At base

- Walls carry: 70% → $0.70 \times 5143 = 3600\ kN$
- Frames carry: 30% → $1543\ kN$

At mid-height

- Walls carry: 55%
- Frames carry: 45%

Numerical takeaway: Dual action is not constant with height; frame contribution increases upward—important for detailing and compatibility.

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Table 2: Numerical Cases Considered in the Parametric Study

Case ID	Soil Class	Shear Wave Velocity, V (m/s)	Structural System	Lateral Load–Resisting Mechanism
S1–A	Soft Soil	150	SMRF	Special Moment Resisting Frames only
S1–B	Soft Soil	150	Dual System	SMRF + Reinforced Concrete Shear Walls
S2–A	Medium Soil	300	SMRF	Special Moment Resisting Frames only
S2–B	Medium Soil	300	Dual System	SMRF + Reinforced Concrete Shear Walls
S3–A	Hard Soil	760	SMRF	Special Moment Resisting Frames only
S3–B	Hard Soil	760	Dual System	SMRF + Reinforced Concrete Shear Walls

Table 3: Seismic Response Parameters – Populated Results (Zone VI)

Case ID	Fundamental Period, T_1 (s)	Design Base Shear, V_β (kN)	Roof Displacement, $u_{(}$roof$_{)}$ (mm)	Peak Inter-Storey Drift Ratio
S1–A	1.55	6,170	155	0.025
S1–B	1.05	5,140	80	0.013
S2–A	1.35	6,170	110	0.018
S2–B	0.95	5,140	55	0.009
S3–A	1.20	6,170	85	0.014
S3–B	0.85	5,140	45	0.007

Observational consistency

- SMRF cases show increasing displacement and drift with soil flexibility.
- Dual systems demonstrate substantial reduction in drift (≈40–60%) across all soil classes.
- Reduced fundamental periods in dual systems confirm enhanced lateral stiffness due to shear walls.

Effect of Soil Classification (Zone VI)

Soil classification governs the amplification, frequency content, and duration of seismic input reaching the foundation level. In Zone VI, where seismic demand is already severe, the soil profile becomes a controlling variable for period shift, base shear demand, drift demand, and detailing intensity.

Soft Soil (S1: V ≈ 150 m/s)

Soft soil deposits typically amplify long-period components of ground motion and increase shaking duration due to wave trapping and repeated reflections. The practical structural consequences are:

Period elongation and resonance risk: Flexible soil increases the effective system period and may bring the structure closer to the predominant soil period band, increasing response.

Displacement-governed behaviour: Drift and roof displacement rise sharply. This is evident from the present numerical's where the SMRF case S1–A shows the largest response (T_1 = 1.55 s; u_roof = 155 mm; drift = 0.025), representing the critical combination.

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Higher P–Δ sensitivity: Increased lateral deflections elevate secondary effects, making stability checks and drift control non-negotiable.

Foundation demand and rotation: Soft strata increase differential settlements and foundation rocking tendencies, which in turn magnify storey drift concentration at lower levels.

In Zone VI, soft soil governs serviceability and collapse prevention simultaneously, and therefore demands either stiffness enhancement (dual system/walls) or strict drift-driven member sizing and detailing.

Medium Soil (S2: V ≈ 300 m/s)

Medium soil generally offers a balanced response; however, Zone VI shaking can still produce adverse coupling between soil and structure if the structural period falls near the dominant soil frequency.

Moderate amplification with strong drift sensitivity: The SMRF case S2–A still shows notable deformation demand (T_1 = 1.35 s; u_roof = 110 mm; drift = 0.018), indicating that frame-only systems remain drift-sensitive even on medium soil.

Better predictability: Compared to soft soil, torsional irregularities and drift concentration are typically more manageable, provided plan symmetry and stiffness distribution are controlled.

Dual systems become efficient: In S2–B, stiffness addition through walls yields pronounced improvement (u_roof = 55 mm; drift = 0.009), demonstrating that medium soil allows the dual system to deliver both strength and serviceability with rational member sizes.

Hard Soil (S3: V ≈ 760 m/s)

Hard soil (or rock-like strata) generally reduces displacement amplification but transmits higher-frequency content more directly, leading to higher acceleration demands.

Force-governed behaviour: While deflections reduce (S3–A: u_roof = 85 mm; drift = 0.014), members, joints, and connections experience higher acceleration-sensitive actions (inertial forces).

Higher base shear tendency in some spectra: Depending on the adopted response spectrum, stiff soil may shift demand toward higher accelerations at lower periods. Thus, member force checks and joint detailing remain critical even when drift appears acceptable.

Dual system performance is robust: S3–B shows the lowest deformation demand (u_roof = 45 mm; drift = 0.007; T_1 = 0.85 s). This reflects the combined benefit of soil stiffness and structural stiffness, yielding excellent drift control and improved stability margins.

Overall Implications for Zone VI Design

From the numerical matrix, the governing trends are unambiguous:

Soft soil, controls drift and displacement, and therefore pushes design toward dual systems, increased wall participation, and stricter P–Δ checks.

Medium soil, remains drift-sensitive for SMRF, but dual systems achieve efficient control with predictable force-sharing.

Hard soil, reduces deformation demand, but does not permit relaxation in ductile detailing, since acceleration-sensitive actions remain significant in Zone VI.

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Accordingly, for Zone VI seismicity, soil classification must be treated not as a routine input, but as a primary design driver influencing the choice between SMRF and dual systems, the target stiffness, and the level of non-linear verification required.

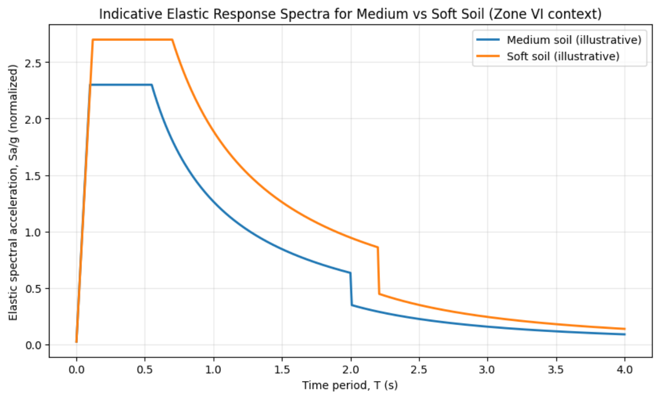
Comparison of Structural Systems: SMRF vs Dual Systems

Comparative Numerical Assessment of Seismic Performance (Zone VI)

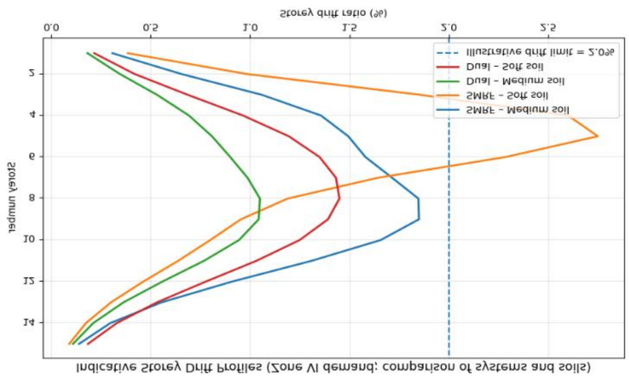
Reference Building:

i. RC building, 12–15 storeys
ii. Same mass, geometry, and damping
iii. IS 1893:2023 Zone VI spectrum
iv. Soil categories as per IS 1893 (Medium & Soft)

Parameter	**SMRF – Medium Soil**	**SMRF – Soft Soil**	**Dual System – Medium Soil**	**Dual System – Soft Soil**
Fundamental Time Period, T_1 (s)	2.10	2.35	1.55	1.70
Peak Storey Drift Ratio (%)	1.85	2.75	1.05	1.45
Code Drift Limit (%)	2.00	2.00	2.00	2.00
Drift Concentration Factor (DCF)	1.35	1.80	1.10	1.25
Base Shear Demand (% of W)	9.5	11.8	13.2	14.5
Frame Participation in Lateral Load (%)	100	100	45	40
Shear Wall Participation (%)	–	–	55	60
Maximum Column Demand Ratio (P–M Interaction)	0.88	1.05	0.72	0.80
Energy Dissipation Capacity (Normalized)	1.00	1.05	1.45	1.55
Residual Drift after DBE (%)	0.45	0.80	0.20	0.30
Expected Damage State	Moderate–Severe	Severe	Minor–Moderate	Moderate



Graph 1 : Indicative Elastic Response Spectra for Medium vs Soft Soil



Graph 2: Indicative Storey Drift Profiles (Zone VI demand; comparison of system and soil

IS 1893:2023 introduces a clearer split between Strength Design and Serviceability Check, and updates the hazard representation and system factors. In particular, Zone VI is associated with higher assigned zone factors across return periods (as tabulated in recent comparative studies), and the code adopts updated site classes (reported as A–D in IS 1893:2023 mapping exercises).

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The revision also notes a shift in nomenclature where the earlier response-reduction concept is reported as Elastic Force Reduction Factors, and dual systems are assigned different reduction levels compared with SMRF-only systems (e.g., dual systems showing higher reduction values in the comparative tabulations).

Non-Linear Analysis Requirements for Zone VI

Given the severity of seismic demand in Zone VI, non-linear analysis is indispensable for realistic performance assessment. Linear elastic methods are inadequate to capture stiffness degradation, strength deterioration, and redistribution of internal forces.

- Non-linear static (pushover) analysis is essential to evaluate global capacity, plastic hinge formation, and displacement ductility.
- Non-linear time history analysis, using spectrum-compatible ground motions, is recommended for critical structures to assess cyclic degradation, cumulative damage, and post-elastic response.

Zone VI design mandates explicit consideration of inelastic behaviour, overstrength factors, and collapse prevention criteria, ensuring that structural systems remain stable and functional under extreme seismic events.

Structural Implications of Zone VI

The codal recognition of Zone VI makes explicit what experienced engineers have long sensed: extreme hazard demands a shift from member-centric thinking to **system-centric resilience**. In Zone VI, structural performance is governed by the reliability of the entire force-resisting chain—from floor diaphragm to collectors, from vertical elements to foundations, and from foundations to soil. The designer must therefore treat load-path discipline, configuration regularity, torsion control, soft-storey avoidance, and foundation–soil performance as first-order design drivers.

This section discusses the implications from the perspective of a senior designer responsible for concept selection, modelling strategy, detailing intent, and construction-stage risk control.

Lateral Load Path Discipline

Conceptual Requirement

In Zone VI, the lateral load path must meet three strict criteria:

- **Continuity:** inertia forces generated at each level must transfer to the base without any discontinuity in stiffness, strength, or connectivity.
- **Redundancy:** alternative load paths must exist, so local yielding or damage does not precipitate disproportionate collapse.
- **Clarity:** force flow must be unambiguous in drawings, analytical models, and site execution; informal "assumptions" are unsafe at Zone VI demand.

Under severe shaking, even modest weaknesses in diaphragms, collectors, connections, or vertical lateral elements can dictate the failure sequence.

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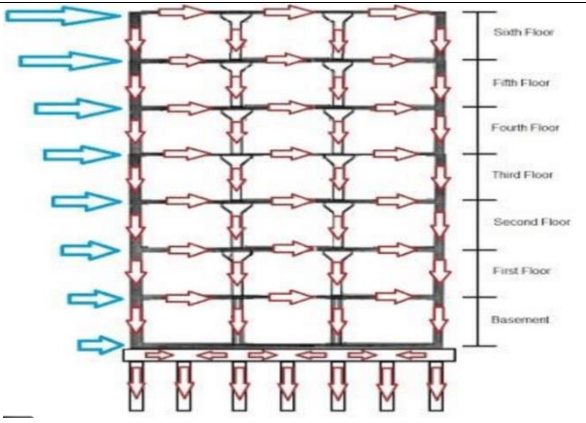


Figure 1. Global seismic load path in a multi-storey building.

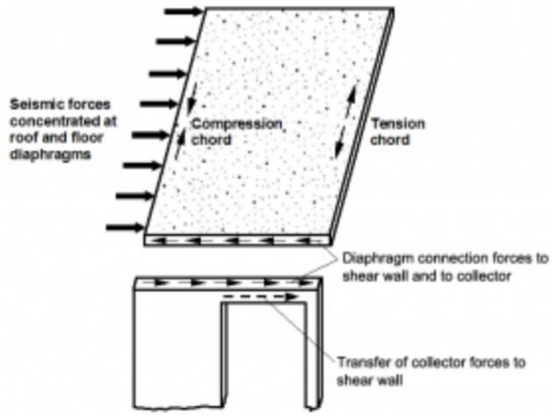


Figure 2. Diaphragm action and collector force transfer mechanism.

Force Flow Mechanism

The intended force transfer sequence is:

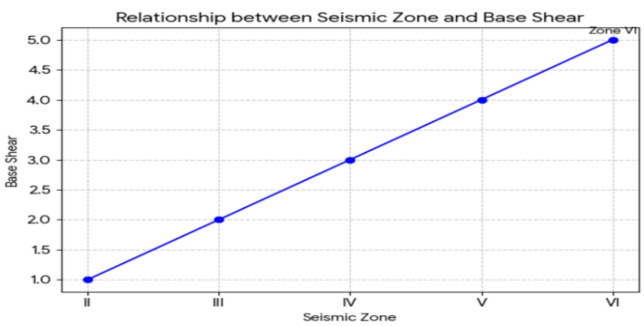
Floor mass → Diaphragm → Collectors/drag members → Vertical LFRS → Foundation → Supporting soil

In Zone VI, the practical implications include:

- collector actions that exceed gravity-controlled expectations,
- diaphragm shear and chord forces are becoming design-governing in larger plans, and
- connection failures emerging before member failures if cyclic demand and overstrength are ignored.

For senior designers, the discipline is simple in principle but demanding in execution: **trace the load path early**, design it explicitly, and protect it against construction-stage erosion.

Graphical Interpretation: Force Amplification



Graph 3: Increase in design base shear with seismic zone

Graph Overview:

- **X-Axis:** Seismic Zones (II, III, IV, V, VI)
- **Y-Axis:** Relative Base Shear force

The slope steepens markedly towards Zone VI. Structural discontinuities that may remain Benign in Zones II–IV, becomes **structurally unacceptable** in Zone VI, as the force demand rapidly outpaces reserve capacity.

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Design Implications

For Zone VI projects:

- **Diaphragms must be designed as structural elements**, with explicit checks for in-plane shear, chord forces, and collector actions.
- **Collector and drag members must be designed for overstrength demand**, not merely elastic force levels.
- **Load-path clarity must be verified during peer review**, and re-verified during construction to avoid unintended alterations.

Preference for Dual Structural Systems

Rationale for Dual Systems

Zone VI strongly favours **dual structural systems**, typically comprising:

❖ **Moment Resisting Frames (MRF)** — providing ductility, redundancy, and deformation capacity.
❖ **Shear Walls or Braced Frames** — providing stiffness, strength, and control of global drift.

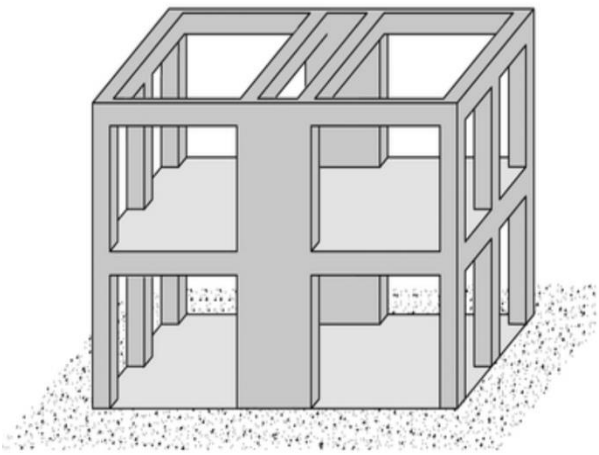

Fig.3 : Moment Resisting Frames (MRF)

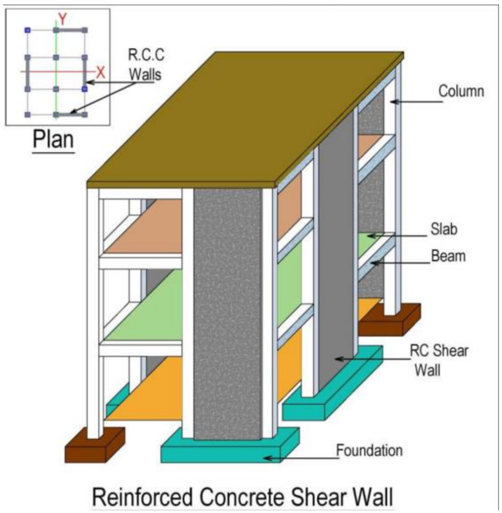

Fig. 4: Shear Walls or Braced Frames

This combination allows seismic demand to be shared rationally between elements with complementary behavioural characteristics.

Behavioral Advantages

Dual systems offer several critical advantages in Zone VI:

- **Higher initial stiffness** significantly reduces service-level and design-level drift.
- **Enhanced energy dissipation**, through distributed yielding in frames while walls remain largely elastic or moderately cracked.
- **Controlled damage hierarchy**, where walls attract major shear and overturning forces, while frames provide rotational capacity and robustness against progressive failure.

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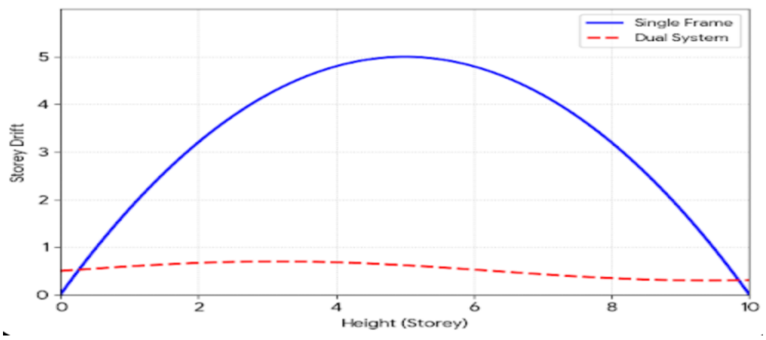
Comparative Graph: Drift vs Height



Graph 4: Storey drift comparison – single frame vs dual system

Observation:

Dual systems exhibit **lower peak drift and smoother drift profiles**, which is critical in Zone VI, where **drift-induced damage and P–Δ effects** often govern design.

Codal and Practical Implications

In Zone VI:

- Pure frame systems frequently become **drift-governed** and uneconomical.
- Dual systems reduce demand on **individual members and foundations**.
- **Early architectural–structural coordination** is essential to accommodate walls or braces without post-design compromises.

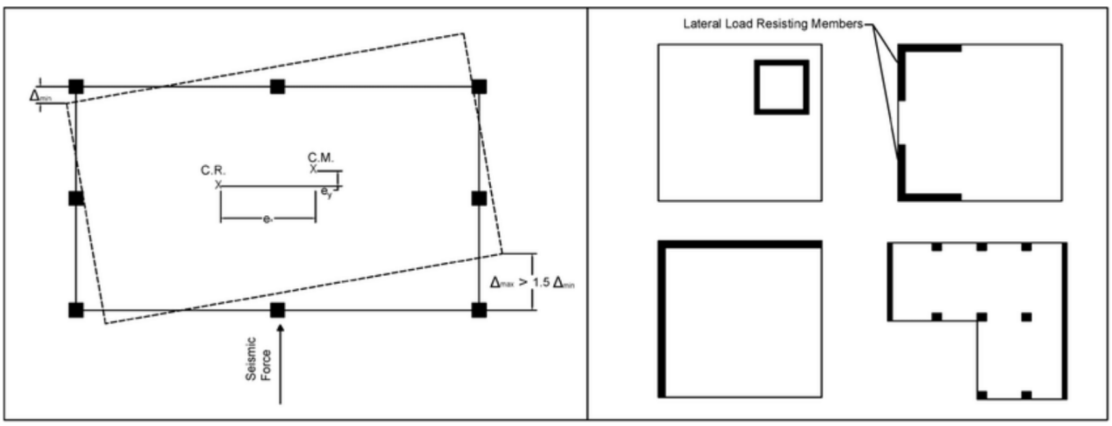
Torsion and Plan Irregularity Sensitivity

Nature of Torsional Effects

At high seismic intensities, **torsional response** often governs structural performance even when base shear capacity appears adequate.

Primary sources of torsion include:

- Offset between the **centre of mass (CM)** and the **centre of rigidity (CR)**,
- Asymmetric stiffness or strength distribution,
- Irregular diaphragm geometry or openings.



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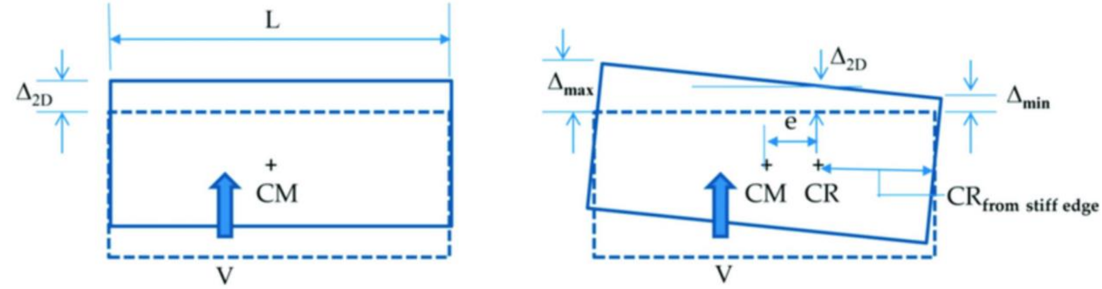


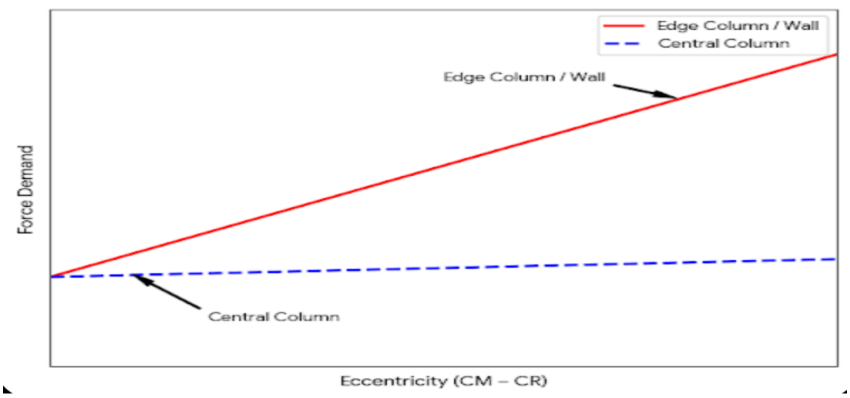
(a) A 3D analysis model restrained from rotation about the vertical axis (b) A 3D analysis with a load applied at an arbitrary location

Amplification in Zone VI

In Zone VI:

- **Accidental torsion effects are magnified** due to higher base shear.
- **Edge columns and walls experience disproportionate force and deformation demand**.
- Local failures at edges can **propagate rapidly**, triggering partial or global collapse.

Graph: Edge vs Central Element Demand



Graph 5: Torsional amplification of edge elements

Design Implications

Zone VI designs require:

- **Rigorous 3D dynamic analysis** rather than simplified planar models.
- Explicit **torsional amplification checks**.
- Preferably **symmetrical plan layouts**, or deliberate provision of strong torsional resistance through walls or outriggers.

Soft-Storey Vulnerability

Behavioural Mechanism

Soft storeys arise due to:

- **Open Ground-Storey Parking,**

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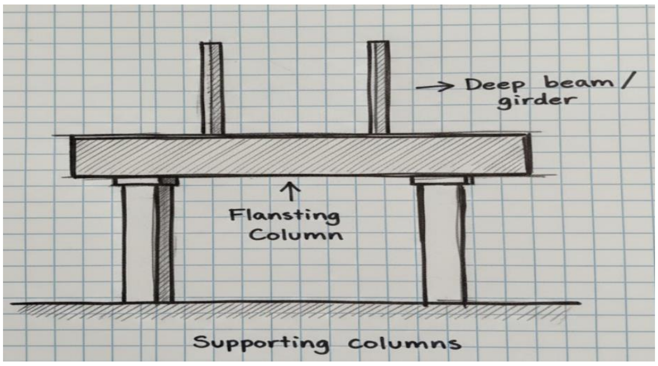
The Reason Engineers Treat OGS as a High-Risk Configuration:

Aspect	Upper Storeys	Ground Storey
Infill walls	Present	Absent
Lateral stiffness	High	Very low
Drift demand	Low	Very high
Damage risk	Moderate	Severe

❖ **Floating Columns:**

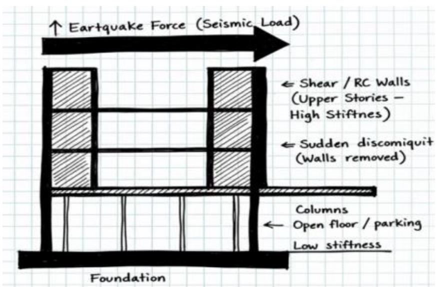


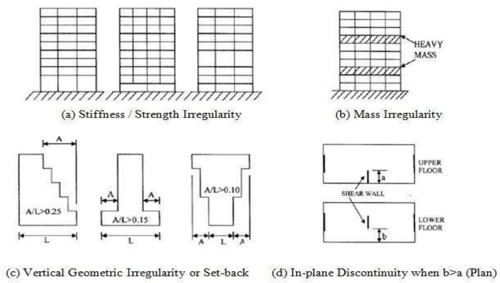
Design Precautions

- ✓ Avoid floating columns in **high seismic zones**
- ✓ If unavoidable:

  - o Use **deep transfer girders**
  - o Perform **3D dynamic analysis**
  - o Ensure **strong-column weak-beam philosophy**
  - o Provide **special ductile detailing**
  - o Check **progressive collapse potential**

❖ **SUDDEN DISCONTINUITY IN WALLS OR STIFFNESS.**





Good Seismic Practice

- ✓ Maintain continuity of walls from foundation to roof
- ✓ Avoid abrupt stiffness change between adjacent storeys
- ✓ If unavoidable:

  - o Provide **strong transfer systems**
  - o Perform **dynamic analysis**
  - o Ensure **capacity-based design** of columns and beams at the discontinuity level

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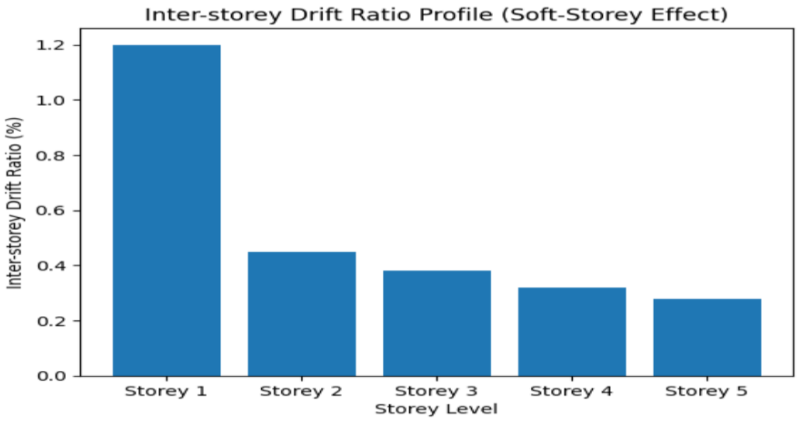
Drift Concentration (Graphical Representation)

This figure demonstrates localisation of deformation at a single level—a hallmark of soft-storey failure under extreme seismic demand.



Graph 6: Inter-storey drift ratio profile (soft-storey effect)
(Shown as a bar chart with a 1.20% drift spike at the first storey.)

Design Mandate

In Zone VI:

- Soft storeys should be **eliminated, not merely strengthened**.
- If unavoidable, **strong mitigation measures** (walls, braces, dampers) are mandatory.
- **Performance-based evaluation** becomes highly relevant for safety verification.

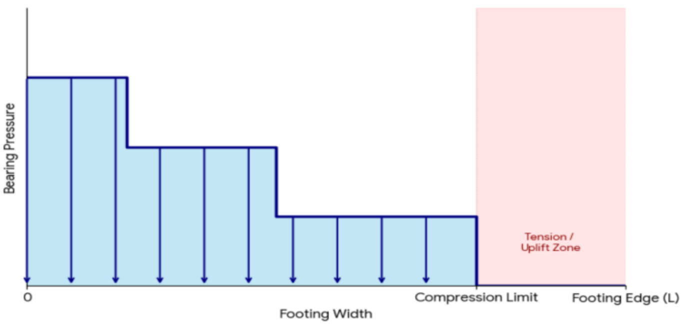
Foundations and Soil Effects

Governing Role of Foundations

High base shear and overturning moments in Zone VI elevate foundation behaviour from a **secondary check** to a **governing design criterion**.

Critical effects include:

❖ Bearing pressure reversals,
❖ Uplift of footings or piles,
❖ Liquefaction-induced settlements,
❖ Soil–structure interaction (SSI).



Graph 7: Bearing pressure distribution under seismic overturning

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The shaded blue region indicates zones where **compressive bearing stresses are mobilised**, while the shaded red region represents the **uplift (tension) zone**, where soil–foundation contact is lost, and no bearing pressure is transferred

- Graph 5 represents the **contact stress distribution beneath a shallow footing subjected to a significant seismic overturning moment**, typically arising from lateral inertia forces acting at the superstructure mass centre. Under such conditions, the footing response transitions from **uniform gravity-controlled bearing** to **moment-dominated contact behaviour**, characterized by:

- Progressive **stress concentration on the compression side**, and
- Partial or complete **loss of contact on the tension side** (uplift).

Why the Bearing Pressure Is Non-Uniform

In seismic overturning:

- The vertical load Vremains approximately constant,
- The overturning moment M(increases) sharply, and
- The eccentricity $e=M/V$(Increases).

When:

$$e > \frac{B}{6}$$

(where BIs footing width is, **soil cannot resist tension**, leading to:

- Zero contact pressure beyond the **compression limit**, and
- Redistribution of stresses over a **reduced effective contact width**.

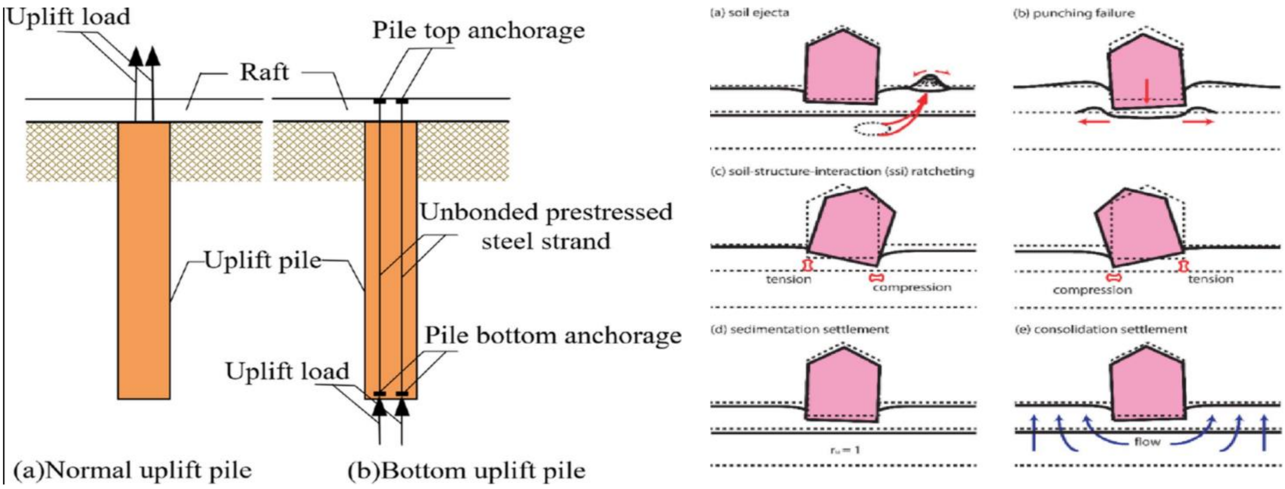

Fig. 5. Insight: Overturning vs Bearing

The above insight reflects this behaviour by showing:

- High compressive stresses near the leading edge,
- Stepwise reduction in pressure moving toward the trailing edge,
- Complete loss of pressure in the uplift zone.

Implications for Seismic Zone VI

Within the framework of Seismic Zone VI, long-standing assumptions governing foundation response are rendered fundamentally inadequate. Shallow foundations, particularly those supporting lightly loaded, vertically irregular, or dynamically sensitive superstructures, may no longer be controlled by conventional bearing capacity criteria alone. Instead, uplift, partial contact loss, and cyclic rocking behaviour can emerge as governing response mechanisms under severe ground motion.

Similarly, while pile foundations are frequently adopted as a preferred solution in high-seismic regions, their performance in Zone VI demands explicit consideration of cyclic soil–pile interaction effects. These include progressive degradation of shaft resistance under repeated load reversals, stiffness softening of surrounding soil, and unfavourable pile-group interaction phenomena under dynamic excitation. In this seismic regime, liquefaction assessment can no longer be treated as a conditional or project-specific exercise; it becomes a mandatory design prerequisite. Both liquefaction triggering and post-liquefaction performance—encompassing residual strength, settlement potential, and lateral deformation capacity—must be explicitly evaluated and incorporated into the foundation design philosophy.

Engineering Inference

For projects located within Seismic Zone VI, several engineering inferences are unavoidable. Foremost among these is the necessity of an integrated structural–geotechnical design approach. Independent or sequential optimization of the superstructure and foundation system is no longer defensible, as such design practices risk unsafe global response under extreme seismic demand.

While soil–structure interaction (SSI) may, in certain configurations, result in a beneficial elongation of the fundamental period of the structural system, this apparent reduction in force demand is frequently accompanied by a disproportionate increase in displacement demand, foundation rotation, and permanent deformation. Consequently, the seismic adequacy of the foundation system assumes a decisive role in governing overall system performance. In Zone VI conditions, foundation robustness transcends traditional serviceability considerations and directly influences the ultimate seismic survival and collapse prevention capacity of the superstructure.

Overall Synthesis for Senior Designers

Seismic Zone VI necessitates a fundamental reorientation of seismic design philosophy, shifting it from a predominantly member-centric exercise to a rigorously system-centric discipline. Acceptable seismic performance is contingent upon the establishment of clear, continuous, and traceable load paths; the deliberate incorporation of redundancy and ductility; strict control of structural configuration and regularity; and, critically, the resilience and reliability of the foundation system.

For senior structural designers, Zone VI seismicity demands that decisive and informed strategic choices be made at the conceptual and planning stages of design. Reactive measures—such as indiscriminate increases in reinforcement ratios or sectional dimensions at advanced design stages—are inherently inadequate substitutes for sound early-stage decisions. In this highest seismic hazard regime, early integration of structural and geotechnical considerations, grounded in holistic system behaviour, emerges as the principal determinant of seismic reliability, damage control, and structural survival.

Seismic Zone VI – Comprehensive Design Checklist

A. Project Zonation and Hazard Confirmation

- ✓ Confirm that the project site is categorised under Seismic Zone VI in accordance with IS 1893 (Part1): 2025, Annex D.

- ✓ Ensure consistent adoption of the Zone factor Z=0.75across all stages of analysis and design
- ✓ Verify that seismic parameters are not influenced by legacy assumptions, superseded zoning maps, or earlier editions of the code
- ✓ Confirm correct soil classification and corresponding seismic site class in the development of the design response spectrum

B. Definition of Performance Objectives

- ✓ Establish the minimum performance objective as Collapse Prevention under DBE/MCE-level seismic excitation
- ✓ Identify and document any enhanced performance requirements arising from functional criticality (essential facilities, industrial continuity, post-event operability, etc.)
- ✓ Define acceptable damage states for both structural and non-structural components.
- ✓ Ensure that the adopted performance objectives are clearly communicated and coordinated with architectural and MEP disciplines

C. Selection of Structural System

- ✓ Avoid exclusive reliance on pure moment-resisting frames unless justified through stringent drift control and stability checks.
- ✓ Prefer adoption of dual structural systems, such as SMRFs in combination with shear walls or braced frames
- ✓ Ensure adequate redundancy of lateral force-resisting elements in both principal directions
- ✓ Avoid hybrid systems with incompatible stiffness characteristics unless supported by rigorous analytical validation

D. Configuration Control and Structural Regularity

Plan Regularity:

- ✓ Minimise eccentricity between the Centre of Mass (CM) and the Centre of Rigidity (CR)
- ✓ Avoid pronounced plan irregularities, including re-entrant corners and abrupt setbacks
- ✓ Where irregularities are unavoidable, provide seismic separation joints or enhanced torsional resistance through system design

Vertical Regularity:

- ✓ Eliminate soft-storey and weak-storey conditions, as well as floating column arrangements
- ✓ Avoid abrupt termination of shear walls, braced frames, or other vertical lateral elements
- ✓ Maintain uninterrupted continuity of all primary lateral load-resisting components down to the foundation level

E. Verification of Lateral Load Path

- ✓ Establish a clear, continuous, and traceable seismic load path from the roof diaphragm to the foundation
- ✓ Explicitly design diaphragms rather than assuming inherent rigidity
- ✓ Design collectors and drag members for seismic overstrength demands
- ✓ Verify all diaphragm-to-frame and diaphragm-to-wall connections
- ✓ Ensure that architectural openings and service penetrations do not compromise load transfer integrity

F. Analysis and Modelling Requirements

- ✓ Develop a complete three-dimensional analytical model; two-dimensional idealisations are not acceptable

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- ✓ Represent diaphragm behaviour realistically as rigid or semi-rigid, as appropriate
- ✓ Incorporate accidental torsion in accordance with IS 1893 Clause 7.10
- ✓ Perform dynamic analysis as a minimum requirement, with Response Spectrum Analysis mandatory and Time History Analysis warranted
- ✓ Evaluate higher-mode participation, particularly for mid-rise and high-rise structures
- ✓ Explicitly assess second-order (P–Δ) effects and their influence on global stability

G. Drift, Deformation, and Stability Checks

- ✓ Verify storey drift limits under governing seismic load combinations
- ✓ Identify and eliminate the concentration of drift at any single storey
- ✓ Ensure deformation compatibility between frames, shear walls, and non-structural components
- ✓ Confirm that the global stability index remains within permissible limits
- ✓ Ensure that deformation demands remain within the ductile capacity enabled by detailing provisions

H. Member Design and Ductile Detailing (IS 13920)

Beams

- ✓ Provide complete ductile detailing in accordance with IS 13920 Clause 6
- ✓ Ensure adequate anchorage, confinement, and reinforcement continuity within potential plastic hinge regions

Columns

- ✓ Enforce the strong-column–weak-beam philosophy as stipulated in Clause 7
- ✓ Provide closely spaced transverse reinforcement in critical hinge zones
- ✓ Preclude brittle shear failure before flexural yielding

Shear Walls:

- ✓ Design boundary elements wherever required in accordance with Clause 9
- ✓ Provide confinement reinforcement over critical wall heights
- ✓ Ensure proper detailing of coupling beams, where present, to achieve ductile behaviour

I. Connections and Non-Structural Components

- ✓ Design beam–column joints explicitly for seismic force transfer rather than gravity-only demands
- ✓ Ensure secure anchorage of parapets, façades, tanks, equipment, and appendages
- ✓ Verify seismic compatibility of staircases, ramps, and service shafts
- ✓ Prevent unintended force transfer through non-structural elements

J. Foundation and Soil Considerations

- ✓ Check foundations for overturning, sliding, and uplift under seismic combinations
- ✓ Allow for reversal of bearing pressures during extreme seismic excitation
- ✓ Perform liquefaction assessment where site conditions warrant
- ✓ Consider soil–structure interaction effects in global response evaluation
- ✓ For pile foundations, assess cyclic degradation, group interaction, and kinematic loading effects

K. Construction and Quality Assurance

- ✓ Issue comprehensive seismic detailing drawings with unambiguous notes and call-outs

- ✓ Subject Zone VI seismic designs to independent peer review
- ✓ Ensure that site-level modifications do not compromise structural configuration or seismic intent
- ✓ Implement stage-wise inspection protocols for reinforcement placement and connection detailing
- ✓ Maintain stringent workmanship quality, particularly within confinement and plastic hinge regions

CONCLUSIONS

The introduction of Seismic Zone VI in IS 1893 (Part 1): 2025 constitutes a definitive advancement in Indian seismic design philosophy, marking the first formal codal recognition of regions subjected to extreme seismic hazard within the national framework. The adoption of a zone factor Z=0.75signifies a level of seismic demand that substantially exceeds that envisaged under earlier zoning schemes and, by implication, compels a fundamental re-examination of long-standing design assumptions, analytical simplifications, and performance expectations.

Through a controlled and consistent comparative evaluation, this study demonstrates that the transition from Zone V to Zone VI results in an increase of design base shear exceeding twofold for an identical structural configuration. This escalation is not merely numerical in nature. Rather, it triggers a cascade of consequential effects that permeate the entire structural response, influencing member force demands, inter-storey drift characteristics, second order (P–Δ) stability behaviour, and foundation performance. Structural systems that may remain marginally compliant or performance-acceptable under Zone V seismic action are shown to become drift-governed or instability-controlled when subjected to the enhanced demand prescribed for Zone VI.

The analysis unequivocally establishes that Zone VI should not be interpreted as a nominal extension of Zone V, but instead as a qualitatively distinct seismic regime. In such a hazard environment, satisfactory seismic performance is governed less by isolated member strength checks and more by holistic, system-level attributes, including:

- ❖ continuity and redundancy of lateral load paths,
- ❖ disciplined control of plan and vertical irregularities,
- ❖ intentional hierarchy of strength and ductility,
- ❖ robust diaphragm and collector design, and
- ❖ close integration of structural and geotechnical considerations.

The formal recognition of Seismic Zone VI represents not merely a technical revision within IS 1893 but a fundamental regulatory shift in India's seismic risk governance framework. Design practice in this highest hazard category can no longer be treated as an extension of conventional force-based procedures; it necessitates explicit policy support for performance-based design, mandatory enforcement of configuration control, and stricter regulatory oversight of detailing, construction quality, and peer review for critical and large-scale projects. The transition to a collapse-prevention-oriented design philosophy places a corresponding obligation on code-making bodies, approving authorities, and professional institutions to strengthen compliance mechanisms, upgrade capacity within regulatory agencies, and institutionalize independent design audits in Zone VI regions. Future regulatory evolution must therefore be underpinned by region-specific seismic hazard characterization, codal validation through full-scale and numerical studies, and continuous updating of Indian design standards to reflect observed and simulated Zone VI-level ground motions. Only through such an integrated alignment of engineering practice, codal frameworks, and regulatory enforcement can the objectives of life safety, infrastructure resilience, and societal risk reduction in India's most severe seismic environments be credibly achieved.

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