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COMPARATIVE DYNAMIC ANALYSIS AND SEISMIC PERFORMANCE EVALUATION OF A MULTI-STOREY REINFORCED CONCRETE RESIDENTIAL BUILDING IN SEISMIC ZONE II AND ZONE V

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Abstract:

Earthquake-resistant design of reinforced concrete buildings requires explicit consideration of dynamic characteristics and regional seismic demand. This study presents a comparative Response Spectrum Analysis of an identical G+10 reinforced concrete residential building representing Seismic Zone II and Seismic Zone V in India. A three-dimensional model was developed in ETABS using an RC moment-resisting frame, M30 concrete, Fe500 reinforcement, a 25 m × 20 m regular plan, 3.0 m storey height, and fixed-base supports. Dead, live, and seismic actions were assigned in accordance with the Indian Standard provisions adopted in the source study. The response spectrum was defined for medium soil and 5% damping, and modal responses were combined using CQC where applicable. The fundamental period was 1.45 s in both cases, while the reported base shear increased from 1,280 kN in Zone II to 4,610 kN in Zone V, representing a 260.16% increase. Roof displacement increased from 36 to 126 mm, and maximum storey drift increased from 0.0014 to 0.0038. Base overturning moment increased from 18,450 to 66,420 kN•m. Storey stiffness remained unchanged because the structural geometry and material properties were identical. The results demonstrate that seismic zoning strongly affects force and deformation demand while leaving the inherent dynamic properties of the unchanged model essentially constant. The study emphasizes the need for enhanced member sizing, reinforcement, confinement, ductile detailing, and foundation resistance in higher seismic zones.

Keywords: Response Spectrum Analysis; ETABS; reinforced concrete; seismic zone; base shear; storey drift; storey displacement; G+10 building

1. Introduction

Earthquakes impose dynamic inertia forces on buildings and can cause severe structural and economic losses when adequate seismic resistance is not provided. The seismic response of an RC building is governed by its mass, stiffness, damping, configuration, height, soil condition, and earthquake intensity. In India, seismic zoning is used to represent regional seismic hazard, with Zone II associated with lower design demand and Zone V with very severe seismic conditions.

For medium- and high-rise buildings, dynamic analysis is more representative than simplified static procedures because it accounts for natural vibration modes and modal participation. Response Spectrum Analysis (RSA), as adopted in the present study, estimates peak modal responses without requiring a specific time-history record. ETABS provides an integrated environment for three-dimensional modelling, modal analysis, response-spectrum loading, and extraction of structural response quantities.

The literature summarized in the source documentation indicates that seismic demand generally increases with zone factor, building height and lateral flexibility, while ductile detailing and adequate stiffness improve seismic performance. A practical gap identified by the study is the limited presentation of a direct, parameter-by-parameter comparison of an identical residential building subjected to Zone II and Zone V response spectra using current Indian Standard provisions. The present work addresses this gap by keeping the structural model unchanged and varying the seismic zone parameters only.

2. Materials and Methods

2.1. Building configuration

A regular G+10 reinforced concrete residential building with a total height of 33 m was selected. The plan measures 25 m × 20 m and contains five bays in the X direction and four bays in the Y direction, each with 5 m spacing. Storey height is 3.0 m. The structural system is an RC moment-resisting frame with reinforced concrete slabs and rigid floor diaphragms. The base is represented using fixed supports.

Table 1: Building configuration

Parameter	Value
Building type	Residential
Structural system	RC moment-resisting frame
Storeys / total height	G+10 / 33 m
Plan dimensions	25 m × 20 m
Bay spacing	5 m
Storey height	3.0 m
Beam section	300 mm × 450 mm
Column section	450 mm × 600 mm
Slab thickness	150 mm

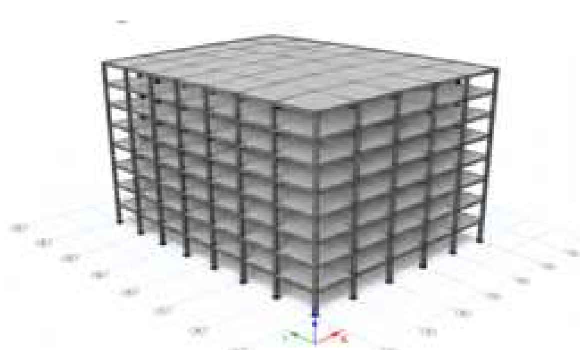

Fig. 1: *3D structural model from the project.*

2.2 Material properties and loading

M30 concrete and Fe500 reinforcing steel were used. Concrete density was taken as 25 kN/m³ with Poisson's ratio 0.20 and Young's modulus 27.39 GPa. Reinforcing steel was assigned a yield strength of 500 MPa, density of 78.5 kN/m³ and Young's modulus of 200 GPa. Dead load included self-weight, 230 mm brick wall load, and floor finish. The reported wall load was 13.8 kN/m and floor finish was 1.0 kN/m². Residential live load was 2.0 kN/m² and roof live load was 1.5 kN/m².

2.3 Seismic parameters and analysis procedure

The same building, materials and modelling assumptions were analysed for Zone II and Zone V. The zone factors were 0.10 and 0.36, respectively; importance factor and response reduction factor were 1.0 and 5.0 in both cases. Medium soil and 5% damping were adopted. The response spectrum followed IS 1893 (Part 1):2016, with separate spectra for the principal horizontal directions.

Table 1: Seismic parameters and analysis procedure

Parameter	Zone II	Zone V
Zone factor, Z	0.10	0.36
Importance factor, I	1.0	1.0
Response reduction factor, R	5.0	5.0
Soil type	Medium	Medium
Damping ratio	5%	5%

The ETABS workflow comprised grid and storey definition, material and section assignment, member modelling, fixed supports, rigid diaphragms, load definition, response-spectrum functions, modal analysis, load combinations and response extraction. Representative combinations included 1.5(DL+LL), 1.2(DL+LL±EQ), 1.5(DL±EQ), and 0.9DL±1.5EQ. Slabs were automatically meshed. Linear elastic RSA and modal analysis were used, and sufficient modes were retained to achieve cumulative modal mass participation above 90% in the principal directions.

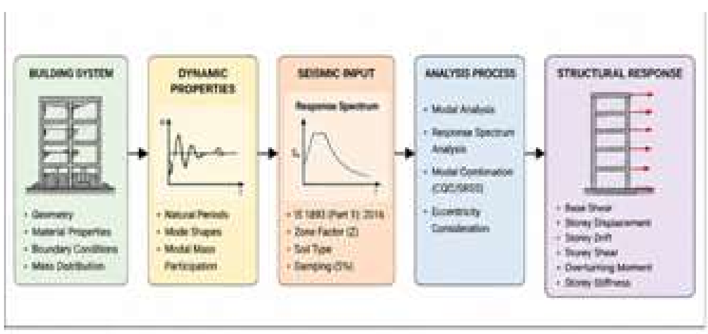

Fig. 2: Building analysis framework

3. Results and Discussion

3.1 Dynamic characteristics

The fundamental natural period was 1.45 s for both seismic zones. Because the building geometry, mass and stiffness were unchanged, the zone factor altered the magnitude of seismic response but not the inherent vibration period. The reported modal participation values for the first six modes were 58.3%, 25.6%, 8.4%, 4.2%, 2.0% and 1.5%, giving

100% cumulative participation in the reported modal set. The first two modes therefore accounted for most of the participating mass.

Table 2: Dynamic characteristics

Mode	Period (s)	Frequency (Hz)	Participation (%)
1	1.45	0.69	58.3
2	1.32	0.76	25.6
3	1.12	0.89	8.4
4	0.95	1.05	4.2
5	0.81	1.23	2.0
6	0.72	1.39	1.5

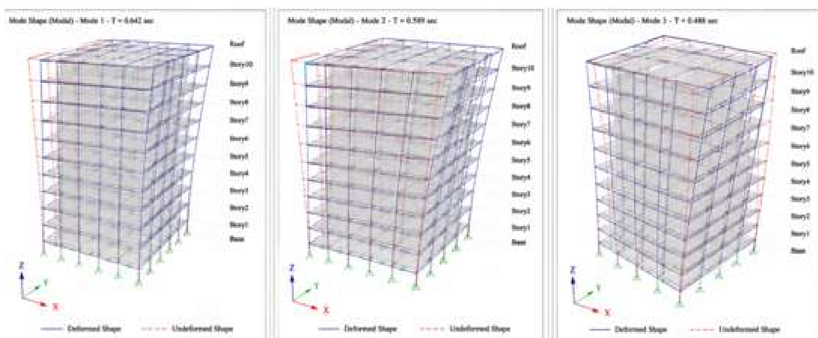

Fig. 3:*. First three mode shapes reported in the ETABS analysis.*

3.2 Base shear and overturning moment

The most pronounced effect of seismic zoning was observed in base shear. Zone V produced 4,610 kN compared with 1,280 kN in Zone II. The reported increase is 260.16%, consistent with the substantially larger Zone V zone factor. The corresponding overturning moment increased from 18,450 kN·m to 66,420 kN·m, approximately 3.6 times the Zone II value. These results imply substantially greater demands on beams, columns, foundations and reinforcement in Zone V.

Table 3: Base shear and overturning moment

Response parameter	Zone II	Zone V	Change
Fundamental period (s)	1.45	1.45	No change
Base shear (kN)	1,280	4,610	+260.16%
Roof displacement (mm)	36	126	+250%
Maximum drift	0.0014	0.0038	Higher
Overturning moment (kN·m)	18,450	66,420	≈3.6×

Storey stiffness	Same	Same	No change

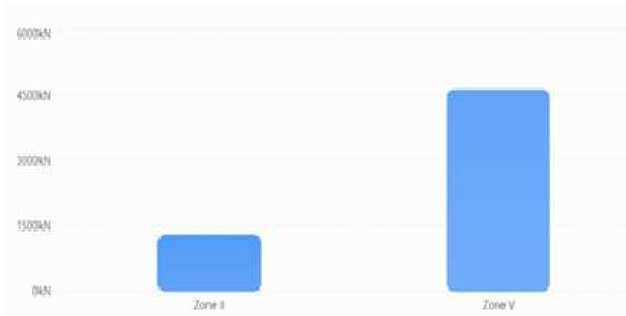

***Fig. 4:**. Base shear comparison.*

3.3 Storey displacement and drift

Lateral displacement increased progressively from the lower storeys toward the roof in both cases. The roof displacement was 36 mm in Zone II and 126 mm in Zone V. Thus, the Zone V roof displacement was 3.5 times the Zone II value. The larger deformation is a direct indicator of increased seismic demand acting on the same structural system.

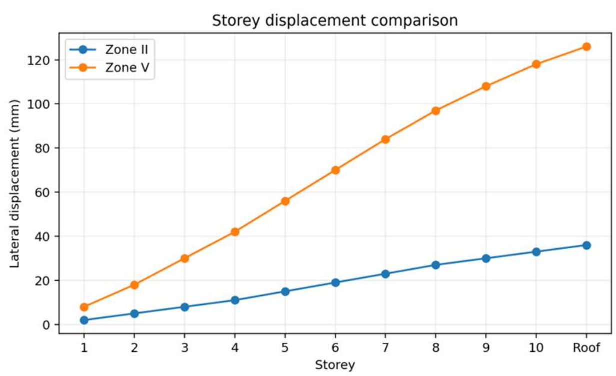

***Fig. 5:** Storey displacement comparison using the ETABS values.*

Inter-storey drift followed a characteristic profile with the maximum value occurring around the middle storeys. The maximum reported drift was 0.0014 in Zone II and 0.0038 in Zone V. The documentation states that these values should be checked against the permissible limit of IS 1893 (Part 1):2016; the journal paper retains this qualification rather than introducing an external limit not explicitly reported in the source.

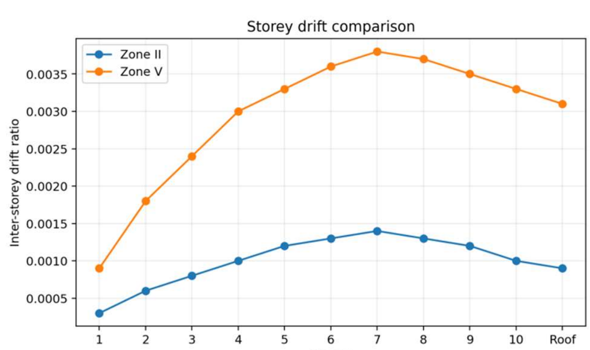

***Fig. 6:** Inter-storey drift comparison using the ETABS values.*

3.4 Storey shear and stiffness

Storey shear increased toward the base because each lower level accumulates the lateral forces from the storeys above. At the base, storey shear was 1,280 kN for Zone II and 4,610 kN for Zone V. At every reported level, Zone V produced the larger shear demand.

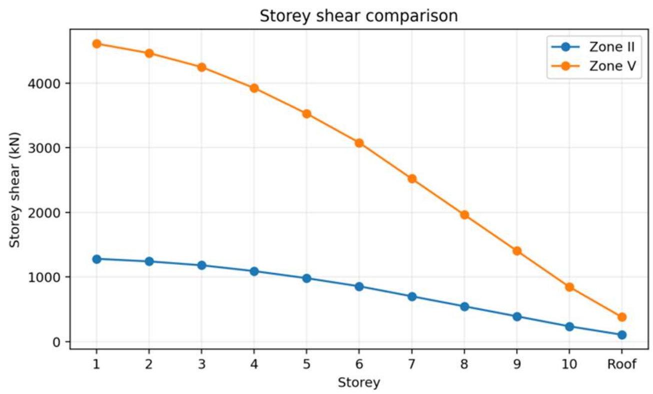

Fig. 7: *Storey shear comparison using the ETABS values.*

Storey stiffness was identical for both seismic cases because the structural model was unchanged. The reported stiffness decreased from 12,400 kN/mm at Storey 1 to 7,100 kN/mm at the roof. This distinction is important: the higher deformation in Zone V is attributed to higher seismic demand rather than a change in structural stiffness.

Storey	**Stiffness (kN/mm)**
1	12,400
2	11,750
3	11,120
4	10,540
5	9,980
6	9,420
7	8,950
8	8,320
9	7,860
10	7,450
Roof	7,100

3.5 Engineering interpretation

The comparison isolates the effect of seismic zoning by holding geometry, materials, soil type, damping, support conditions and response-reduction assumptions constant. The increase in Zone V response is therefore dominated by the larger seismic input. Higher base shear and overturning moment imply greater force demand on the lateral-force-resisting system and foundation. Larger displacement and drift make serviceability and non-structural damage control more critical. The source documentation therefore recommends larger or stronger structural members where required, increased reinforcement, improved confinement, and enhanced beam–column joint and ductile detailing for Zone V.

The results also demonstrate why dynamic characteristics should not be interpreted solely from the magnitude of seismic response. The natural period and storey stiffness remain unchanged between the two cases, whereas the demand-dependent quantities—base shear, displacement, drift and overturning moment—change substantially.

4. Conclusions

• The G+10 RC building exhibits substantially greater seismic demand in Zone V than in Zone II when analysed using the same structural configuration and Response Spectrum Method.

• The reported base shear increases from 1,280 kN to 4,610 kN, a 260.16% increase, while the base overturning moment increases from 18,450 kN·m to 66,420 kN·m.

• Roof displacement increases from 36 mm in Zone II to 126 mm in Zone V, and the maximum reported storey drift increases from 0.0014 to 0.0038.

• The fundamental natural period remains 1.45 s in both cases because the structural mass and stiffness are unchanged. Storey stiffness likewise remains identical.

• The first few vibration modes dominate the response, and the reported modal set provides 100% cumulative mass participation.

• For higher seismic zones, the increased force and deformation demands require careful member sizing, reinforcement, confinement, beam–column joint detailing, and foundation design.

• Response Spectrum Analysis implemented in ETABS is an effective linear dynamic procedure for comparing the seismic response of regular multi-storey RC buildings.

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