International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 10 Issue: 11 | Nov - 2026 SJIF Rating: 8.659 ISSN: 2582-3930

Seismic Response of A G+10 Reinforced Concrete Framed Building in Different Earthquake Zones Using Response Spectrum Analysis

*** B. RAJESH[1], Dr. M. MADHURI [2]**

[1]M.Tech Scholar (Structural Engineering), Department of Civil Engineering,

Sanketika Vidya Parishad Engineering College, P.M. Palem, Visakhapatnam – 530041, Andhra Pradesh, India

[2]Associate Professor & HOD, Department of Civil Engineering, Sanketika Vidya Parishad Engineering College, P.M. Palem, Visakhapatnam – 530041, Andhra Pradesh, India

Abstract

This study evaluates the influence of seismic-zone classification on the response of a regular G+10 reinforced concrete (RC) framed building using the response spectrum method in STAAD.Pro. The building has a 24 m × 24 m plan comprising four 6 m bays in each principal direction and a total height of 33.6 m. The adopted member dimensions are 300 × 500 mm for beams and 500 × 500 mm for columns, with 125 mm slabs. M30 concrete and Fe500 reinforcement are specified. The comparison considers Seismic Zones II, III and V while maintaining the same geometry, material properties, gravity-loading assumptions, soil category, damping and support conditions. The manually estimated seismic weight is 75,865 kN. Based on the stated design horizontal seismic coefficients, the estimated base shears are 986, 1,577 and 3,549 kN for Zones II, III and V, respectively. Provisional estimates of roof displacement (45, 72 and 162 mm), maximum inter-storey drift (9.0, 14.4 and 32.4 mm) and critical beam moment (131, 168 and 246 kN·m) are also examined. These displacement, drift and member-force values are preliminary estimates and are not validated direct extractions from STAAD.Pro response-spectrum analysis. In addition, the reported horizontal support reaction of approximately 17.922 kN is inconsistent with the manual Zone II base-shear estimate. The findings are therefore interpreted as preliminary comparative estimates, and the model checks required for validation are identified.

Keywords—G+10 RC frame, seismic analysis, response spectrum method, STAAD.Pro, seismic zones, base shear, storey displacement, inter-storey drift.

1. INTRODUCTION

Earthquake ground motion induces inertia forces in buildings through the acceleration of their structural masses. In multistorey reinforced concrete (RC) frames, these forces produce storey shear, overturning effects, lateral displacement, inter-storey drift and internal forces in beams and columns. The distribution of seismic demand is governed by structural mass and stiffness, natural periods, mode shapes, damping, soil conditions and the level of seismic hazard [1], [6], [19], [20].

The response spectrum method is a linear dynamic procedure in which peak modal responses are obtained from a design response spectrum and combined using a statistical modal-combination procedure, such as the square-root-of-the-sum-of-squares (SRSS) or complete quadratic combination (CQC) method [6], [10]–[12]. The method is useful for multistorey structures in which higher-mode contributions may influence the overall response. The reliability of the results, however, depends on the appropriate definition of structural mass, stiffness, boundary conditions, response spectrum and modal participation.

This investigation compares the response of a regular G+10 RC frame under three seismic-zone factors. The structural configuration and the other stated modelling assumptions are kept unchanged so that the comparison focuses on the effect of the adopted zone-dependent seismic demand. The work presents an applied comparison of global response indicators and member-level demands using the response spectrum approach.

2. OBJECTIVES AND SCOPE

The objectives are to develop a three-dimensional model of a G+10 RC frame in STAAD.Pro; define seismic response spectra for Zones II, III and V; evaluate modal characteristics; compare base shear, floor displacement and inter-storey drift; examine beam and column force demands; and discuss the implications for preliminary reinforcement requirements. The scope is limited to a regular moment-resisting RC frame

with fixed-base supports and linear-elastic modal response-spectrum analysis, using the modelling assumptions and parameters specified in this study.

3. BUILDING CONFIGURATION AND MODELLING PARAMETERS

The building is a regular, symmetrical RC framed structure with a 24 m × 24 m plan and four 6 m bays in each principal direction. The ground-floor height is 3.60 m, while each typical upper storey is 3.00 m high, giving a total roof elevation of 33.60 m. The floor plan and front elevation are presented in Fig. 1.

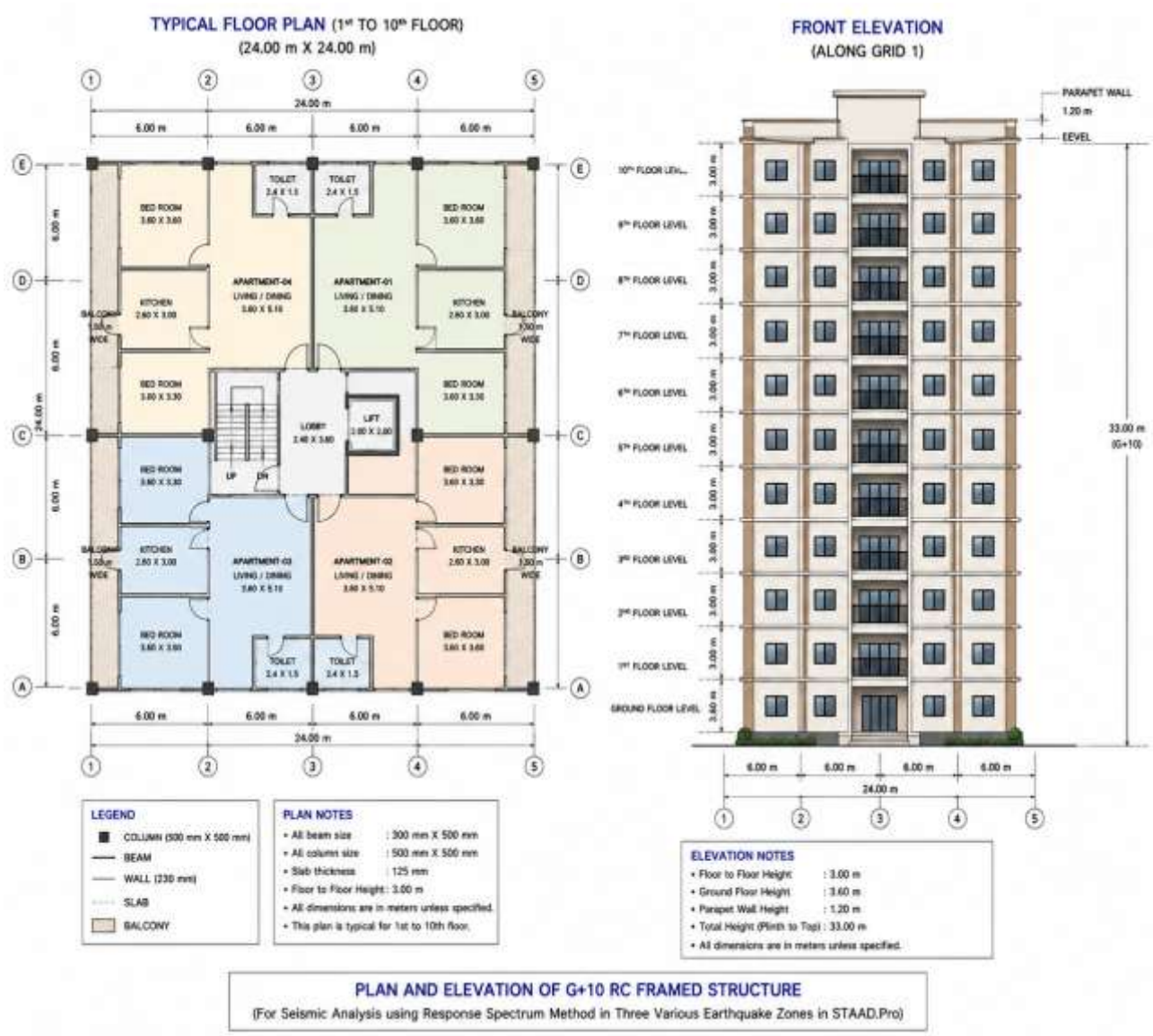


Fig. 1. Typical floor plan and front elevation of the G+10 building

Table 1. Principal building and material properties

Parameter	Adopted value
Building configuration	G+10 RC residential frame
Plan dimensions	24 m × 24 m
Bays in X and Z directions	4 bays each; 6 m bay width
Ground / typical storey height	3.60 m / 3.00 m
Total height to roof	33.60 m
Beam section	300 × 500 mm
Column section	500 × 500 mm
Slab thickness	125 mm
Wall thickness	230 mm

Concrete / reinforcement	M30 / Fe500
RCC unit weight	25 kN/m³
Base condition	Fixed
Soil and damping	Medium soil; 5% damping

A three-dimensional STAAD.Pro model is defined using 300 nodes, 715 members and 176 plates. A representative view of the analytical model is presented in Fig. 2. The intended analysis sequence comprises gravity-load assignment, seismic-mass definition, modal analysis, response-spectrum loading in the global X and Z directions, modal combination, base-shear verification and extraction of member forces. The validity of the resulting response quantities depends on confirming the model inputs and analysis outputs described in Section 6.

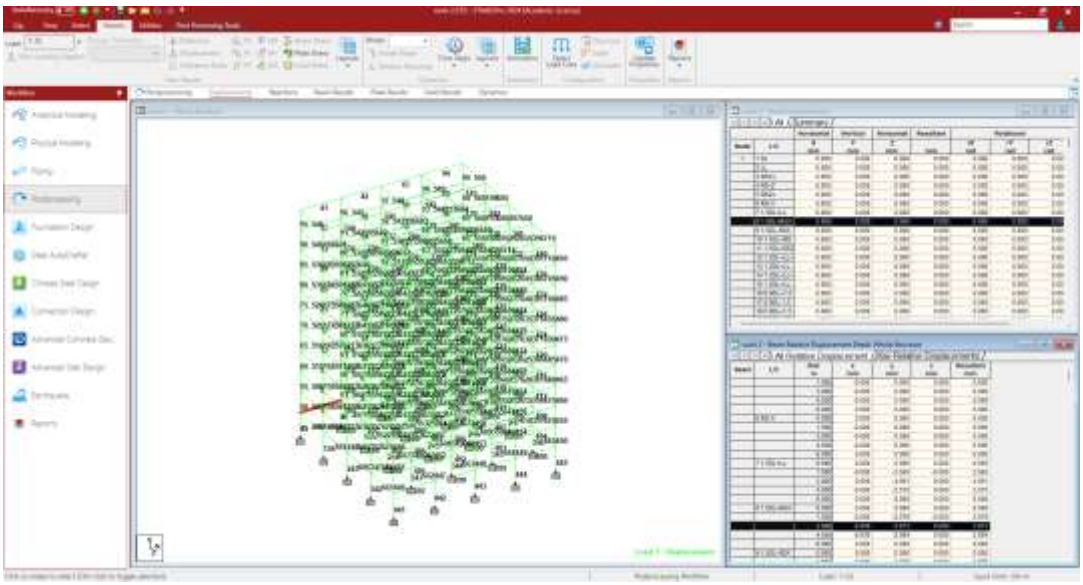


Fig. 2. Representative STAAD.Pro analytical model screenshot

4. LOADING, SEISMIC PARAMETERS AND ANALYSIS METHOD

The seismic weight is estimated by combining the self-weight of the structural concrete, masonry walls, floor finishes, the specified portion of live load, parapet loads and stair/lift allowances. The resulting preliminary seismic weight is 75,865 kN. The adopted zone factors are 0.10, 0.16 and 0.36 for Zones II, III and V, respectively. The importance factor is 1.0, the response reduction factor is 5.0, the damping ratio is 5%, and medium soil (Type II) is specified.

Table 2. Seismic-zone parameters and manual base-shear estimates

Parameter	Zone II	Zone III	Zone V
Zone factor, Z	0.10	0.16	0.36
Design horizontal coefficient, Ah	0.01299	0.02079	0.04678
Estimated seismic weight (kN)	75,865	75,865	75,865
Manual base shear (kN)	986	1,577	3,549

The manual base shear is calculated using Vb = AhW. For W = 75,865 kN, the estimated base shear is approximately 986 kN in Zone II, 1,577 kN in Zone III and 3,549 kN in Zone V. Relative to Zone II, the estimated values are approximately 1.60 and 3.60 times higher in Zones III and V, respectively, consistent with the ratios of the adopted zone factors.

A preliminary estimate of the fundamental period is obtained from Ta = 0.075h^0.75, with h = 33.6 m, giving approximately 1.05 s. This value is an empirical estimate and is not an extracted modal period from STAAD.Pro. The period obtained from the validated analytical model should be used in the final response-spectrum assessment.

The response-spectrum analysis procedure requires definition of the structural mass, modal analysis and verification of cumulative modal mass participation. The IS 1893 (Part 1):2016 spectrum is then applied in both horizontal directions, and modal responses are combined using SRSS or CQC, as appropriate. The dynamic base shear is compared with the equivalent-static base shear and the spectrum is scaled where required. Storey displacements, inter-storey drifts, support reactions and member forces are then extracted from the verified analysis.

5. RESULTS AND DISCUSSION

The results are separated into (i) manual calculations and (ii) provisional response estimates. The displacement values are preliminary because the available STAAD.Pro output does not provide validated response-spectrum displacement results. The beam- and column-moment comparisons and the reinforcement provisions are likewise provisional. Accordingly, these values are reported as estimates and are not treated as verified software outputs.

Table 3. Provisional comparative response estimates for the three seismic zones

Response parameter	Zone II	Zone III	Zone V
Maximum X displacement (mm)	45	72	162
Maximum inter-storey drift (mm)	9.0	14.4	32.4
Critical beam moment (kN·m)	131	168	246
Critical column moment (kN·m)	220	290	430
Preliminary beam reinforcement	3–20 mm	4–20 mm	4–22 mm
Preliminary column reinforcement	8–25 mm	10–25 mm	12–25 mm

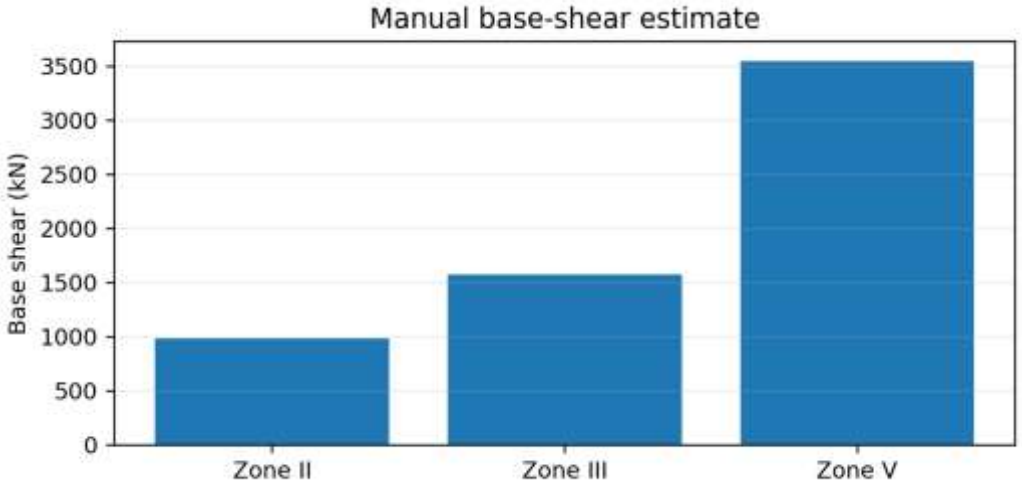


Fig. 3. Manual base-shear estimates for the three seismic zones

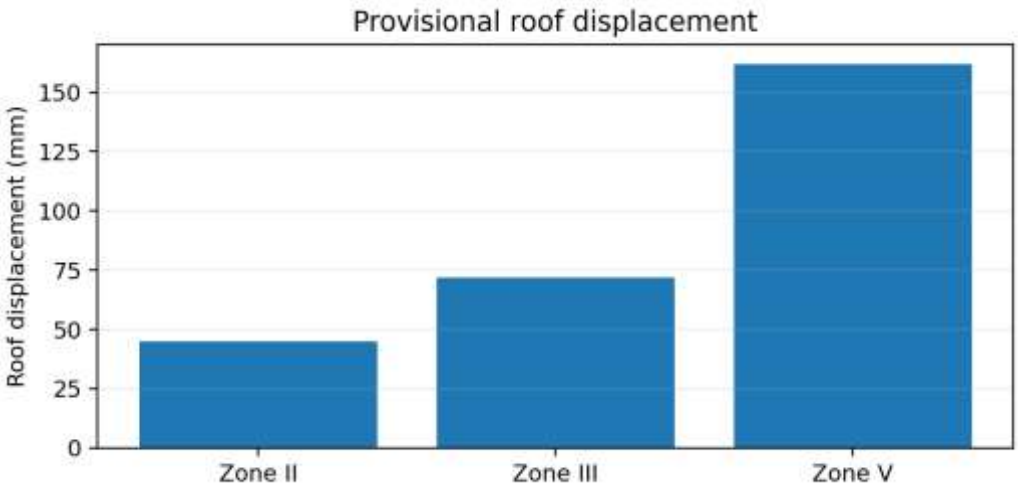


Fig. 4. Provisional maximum roof-displacement estimates; not validated STAAD.Pro response-spectrum outputs

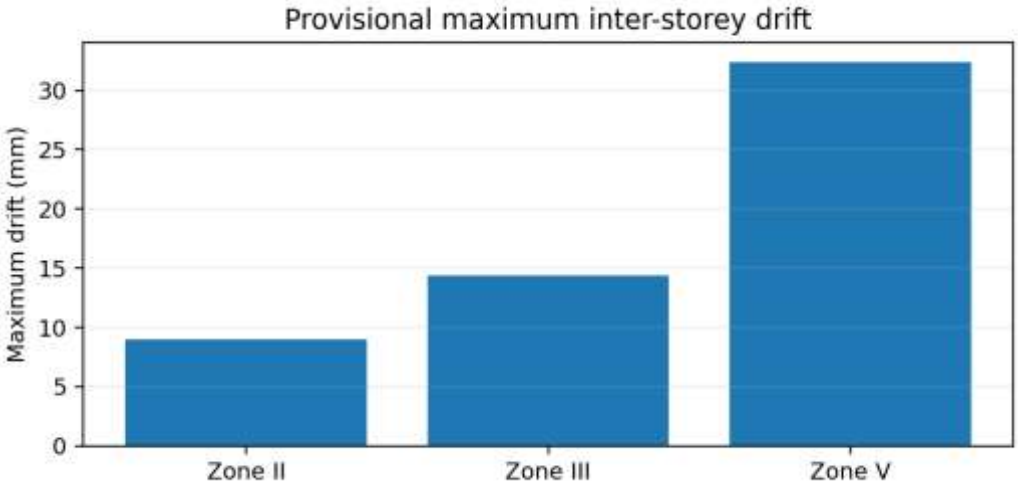


Fig. 5. Provisional maximum inter-storey drift estimates

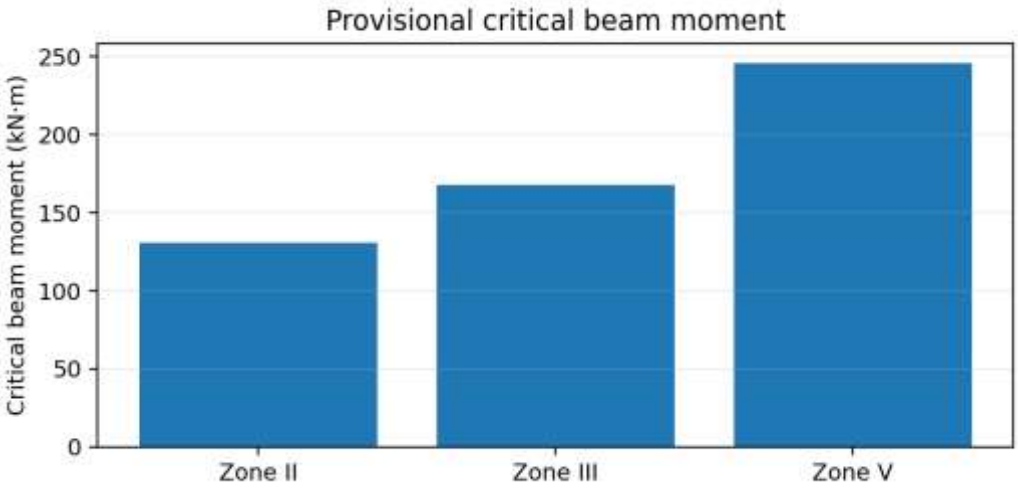


Fig. 6. Provisional comparison of critical beam-moment estimates

The manual base-shear estimate increases by approximately 60% from Zone II to Zone III and by approximately 260% from Zone II to Zone V. The provisional roof-displacement estimates increase from 45 mm to 72 mm and 162 mm across the three zones. The corresponding provisional maximum inter-storey drift values are 9.0 mm, 14.4 mm and 32.4 mm. These trends follow the increase in the adopted zone factor. However, drift ratios and compliance with permissible limits cannot be established without validated storey-wise response output and the relevant code checks.

The preliminary member-force estimates indicate increasing beam and column moment demand with increasing seismic-zone severity. The corresponding proposed reinforcement changes from 3–20 mm to 4–22 mm in beams and from 8–25 mm to 12–25 mm in columns. These provisions are illustrative and preliminary; they do not replace complete flexural, shear, axial–flexural interaction, beam–column joint, anchorage and ductile-detailing checks in accordance with IS 456 and IS 13920.

The reported STAAD.Pro support reactions include FY ≈ 6,412.55 kN and FX ≈ 17.922 kN for the stated load case. The horizontal reaction is substantially lower than the manual Zone II base-shear estimate of approximately 986 kN. This discrepancy indicates that the current support-reaction output cannot be used to validate the seismic response without first checking the response-spectrum load definition, applied directions, mass reference load, units, modal participation and base-shear scaling.

6. MODEL-VALIDATION REQUIREMENTS AND LIMITATIONS

The following issues require resolution before the numerical results can support final design conclusions or publication claims:

- Seismic-zone definition: The principal comparison in the abstract and tables uses Zones II, III and V, whereas parts of the results-chapter introduction refer to Zones III, IV and V. The present comparison consistently uses Zones II, III and V. This selection should be checked against the final STAAD.Pro input files and the intended study design.
- Model-output consistency: The reported horizontal support reaction of approximately 17.922 kN is substantially below the manual Zone II base-shear estimate of approximately 986 kN. The response-spectrum load definition, seismic-mass reference load, loading directions, unit system, modal participation and base-shear scaling should be audited.
- Status of response quantities: Roof displacement, inter-storey drift, beam and column moments, and reinforcement comparisons are preliminary estimates. They must not be described as validated direct STAAD.Pro response-spectrum results until the corresponding analysis output has been checked.
- Seismic-weight verification: The estimated total seismic weight of 75,865 kN includes approximate contributions from wall lengths, floor finishes and live-load participation. Each component should be reconciled with the final structural model, architectural layout and load take-off.
- Design verification: The listed reinforcement is preliminary. The available numerical summary does not demonstrate complete IS 13920 ductile detailing, shear-capacity checks, beam–column joint checks, anchorage and development-length checks, strong-column/weak-beam verification or foundation-action assessment.
- Reference verification: The bibliographic details of all cited literature should be checked against the original publications. In particular, article titles, author details, volume and issue numbers, page ranges and DOIs require confirmation before submission.

7. CONCLUSIONS

1. A regular G+10 RC frame with a 24 m × 24 m plan and a total height of 33.6 m was considered for a comparative seismic investigation using the response spectrum method.
2. Using the adopted zone factors and the estimated seismic weight of 75,865 kN, the manual base-shear estimates are approximately 986 kN, 1,577 kN and 3,549 kN for Zones II, III and V, respectively.
3. The estimated manual base shear increases by approximately 60% between Zones II and III and by approximately 260% between Zones II and V.
4. The provisional response estimates indicate increasing roof displacement, inter-storey drift and member-force demand as the adopted seismic zone becomes more severe. These trends require confirmation through validated response-spectrum analysis.
5. The preliminary reinforcement provisions increase with seismic-zone severity. Their adequacy cannot be established without complete member-design checks and ductile-detailing verification in accordance with the applicable Indian Standards.
6. The reported horizontal support reaction of approximately 17.922 kN is inconsistent with the manual Zone II base-shear estimate. The available STAAD.Pro output therefore does not establish a validated response-spectrum result.

7. With unchanged structural mass and stiffness, the fundamental period is expected to remain broadly similar across the zone cases. The value of approximately 1.05 s is an empirical estimate and must be replaced by the verified modal period from the analytical model.
8. Among the three zones considered, Zone V produces the highest manual base-shear estimate and the highest provisional response estimates.

REFERENCES

[1] Bureau of Indian Standards, IS 1893 (Part 1):2016, Criteria for Earthquake Resistant Design of Structures—General Provisions and Buildings. New Delhi, India: BIS, 2016.
[2] Bureau of Indian Standards, IS 13920:2016, Ductile Design and Detailing of Reinforced Concrete Structures Subjected to Seismic Forces. New Delhi, India: BIS, 2016.
[3] Bureau of Indian Standards, IS 456:2000, Plain and Reinforced Concrete—Code of Practice. New Delhi, India: BIS, 2000.
[4] Bureau of Indian Standards, IS 875 (Part 2):1987, Code of Practice for Design Loads (Other than Earthquake) for Buildings and Structures—Imposed Loads. New Delhi, India: BIS, 1987.
[5] Bentley Systems, STAAD.Pro CONNECT Edition—Technical Reference Manual. Exton, PA, USA: Bentley Systems.
[6] A. K. Chopra, Dynamics of Structures: Theory and Applications to Earthquake Engineering, 5th ed. Hoboken, NJ, USA: Pearson, 2017.
[7] S. K. Duggal, Earthquake Resistant Design of Structures, 2nd ed. New Delhi, India: Oxford University Press, 2013.
[8] P. Agarwal and M. Shrikhande, Earthquake Resistant Design of Structures. New Delhi, India: PHI Learning, 2006.
[9] T. Paulay and M. J. N. Priestley, Seismic Design of Reinforced Concrete and Masonry Buildings. New York, NY, USA: Wiley, 1992.
[10] E. L. Wilson, A. Der Kiureghian and E. P. Bayo, "A replacement for the SRSS method in seismic analysis," Earthquake Engineering and Structural Dynamics, vol. 9, no. 2, pp. 187–194, 1981, doi: 10.1002/eqe.4290090207.
[11] A. Der Kiureghian, "A response spectrum method for random vibration analysis of MDF systems," Earthquake Engineering and Structural Dynamics, vol. 9, no. 5, pp. 419–435, 1981, doi: 10.1002/eqe.4290090503.
[12] C. Menun and A. Der Kiureghian, "A replacement for the 30%, 40% and SRSS rules for multicomponent seismic analysis," Earthquake Spectra, vol. 14, no. 1, pp. 153–163, 1998, doi: 10.1193/1.1585993.
[13] A. K. Chopra and R. K. Goel, "A modal pushover analysis procedure for estimating seismic demands for buildings," Earthquake Engineering and Structural Dynamics, vol. 31, no. 3, pp. 561–582, 2002, doi: 10.1002/eqe.144.
[14] F. A. Najam and P. Warnitchai, "A modified response spectrum analysis procedure to determine nonlinear seismic demands of high-rise buildings with shear walls," The Structural Design of Tall and Special Buildings, vol. 27, no. 1, Art. no. e1409, 2018, doi: 10.1002/tal.1409.
[15] K. Khy and C. Chintanapakdee, "Modified response spectrum analysis to compute shear forces in tall reinforced concrete shear wall buildings," Engineering Structures, vol. 180, pp. 295–309, 2019.
[16] S. Tesfamariam, K. Goda and G. Mondal, "Seismic vulnerability of reinforced concrete frame with unreinforced masonry infill due to mainshock–aftershock earthquake sequences," Earthquake Spectra, vol. 31, no. 3, pp. 1427–1449, 2015, doi: 10.1193/042313EQS111M.
[17] A. Furtado, H. Rodrigues and A. Arêde, "Effect of the infill panels in the floor response spectra of an eight-storey RC building," Structures, vol. 34, pp. 2476–2498, 2021, doi: 10.1016/j.istruc.2021.08.102.
[18] S. Sivakumar et al., "Seismic analysis of RC building (G+9) by response spectrum method," Materials Today: Proceedings, 2023, doi: 10.1016/j.matpr.2023.03.659.
[19] J. Wang, Y. Xie, T. Guo and Z. Du, "Predicting the influence of soil–structure interaction on seismic responses of reinforced concrete frame buildings using convolutional neural network," Buildings, vol. 13, no. 2, Art. no. 564, 2023, doi: 10.3390/buildings13020564.
[20] P. Ricci, M. Di Domenico and G. M. Verderame, "Behaviour factor and seismic safety of reinforced concrete structures designed according to Eurocodes," Structures, vol. 55, pp. 677–689, 2023, doi: 10.1016/j.istruc.2023.06.060.