

Response Spectrum Analysis of A G+3 Building With Wind Loads

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ABSTRACT: This article conducts a Response Spectrum Analysis (RSA) of a G+3 reinforced concrete framed structure utilizing STAAD Pro. The natural frequencies for the initial three vibration modes, total base shear, inter-story drift ratios, and roof-level displacement are extracted and analyzed. The RSA is performed in accordance with IS 1893:2016 (Part 1) for Seismic Zone V, utilizing medium soil, an importance factor of 1.0, a response reduction factor of 5.0, 5% damping, and CQC combination methodology. The findings indicate that the initial three natural frequencies are 2.933 Hz, 5.056 Hz, and 9.372 Hz, the cumulative base shear is 243.86 kN, and the maximum roof displacement is 4.050 mm. These values offer insight into the building's dynamic performance.

Keywords: Wind, response spectrum analysis, base shear

1. INTRODUCTION

Seismic design is a crucial component of structural engineering, ensuring that buildings can endure seismic forces without failure [1]. Seismic loads generate dynamic forces, prompting engineers to employ seismic analysis techniques such as Response Spectrum Analysis (RSA) to assess the dynamic response of structures, including multi-storey reinforced concrete frames

[2]. This study examines the application of seismic and wind loads while comparing response metrics, including base shear, displacement, and story drift. The seismic study is conducted utilizing Response Spectrum study (RSA) in accordance with IS 1893 (Part 1): 2016, whereas wind load is evaluated per IS 875 (Part 3): 2015 [3]. STAAD.Pro was utilized to conduct these analyses.

The examined construction is a low-rise reinforced concrete frame building with three stories, reaching a height of 12 meters. The structure is evaluated for seismic zone V, with a zone factor of 0.36, an importance factor of 1, medium soil type, and a response reduction factor of 5, presuming a special moment-resisting frame (SMRF). The duration is calculated as 0.54 seconds according to paragraph 7.6.2 of IS 1893 (Part 1): 2016, where $T=0.09h/\sqrt{d}$ [4]. Modal analysis was conducted to ascertain the natural frequencies. The seismic loads were subsequently applied utilizing the CQC (Complete Quadratic Combination) approach for the amalgamation of modal responses. Wind loads were produced in accordance with IS 875 (Part 3):2015 and applied in four orientations: +X, -X, +Z, -Z. Data were obtained for natural frequencies, upper storey displacements, base shear, and storey drift. Manual computations were employed to validate storey drifts for seismic scenarios in lieu of STAAD.Pro does not explicitly calculate drift in RSA load scenarios. Additionally, the impact of wind displacements at the roof level was assessed to compare its magnitude with seismic demands [5]. The results were within acceptable limits, demonstrating structural stability and adequate performance under wind and earthquake conditions.

2. METHODOLOGY

A G+3 reinforced concrete frame, measuring 12 meters in total height, was modeled with fixed

base supports to replicate realistic boundary circumstances. The load calculations encompassed dead, live, seismic, and wind loads in compliance with applicable Indian requirements. The dead load accounted for the self-weight of structural parts with a factor of -1, a uniform line load of -14 kN/m applied to beams to reflect wall loads, and a dispersed floor load of -0.2 kN/m² to approximate floor finishes. Live loads were represented as a uniform floor load of -2 kN/m². Two response spectrum analysis (RSA) cases, RSX and RSZ, were established for seismic analysis in accordance with IS 1893:2016 parameters. These cases incorporate a zone factor (Z) of 0.36, indicative of Seismic Zone V, an importance factor (I) of 1.0, a response reduction factor (R) of 5.0, medium soil classification (Type II), and a damping ratio of 5%. The modal replies were integrated via the Complete Quadratic Combination (CQC) approach. Wind load was calculated in accordance with IS 875 (Part 3):2015 for the Delhi region, utilizing a risk coefficient (K1) for general buildings (Class 1), a topographical factor (K3) of 1.0 for flat terrain, and an importance factor (K4) of 1.0 for standard occupancy structures.

3. RESULTS

3.1 Natural Frequencies: These frequencies represent the fundamental lateral vibration mode of the structure. A frequency over 2 Hz for mode 1 signifies considerable stiffness, perhaps because to the compact design and reduced height.

The substantial increase from Mode 1 in Mode 2 indicates a diminished energy input from higher modes.

Table 1 Base shear, frequency and time period of the building

Base shear in X	Base shear in Z	
243.86 KN	243.86 KN	
Mode	Frequency(cycles/sec)	Period(sec)
1	2.933	0.34100
2	5.056	0.19778
3	9.372	0.10670

Base shear: In the RSX/RSZ scenarios, the cumulative horizontal base shear was determined to be 243.86 kN in both primary directions. Equal base shear in both the X and

Z directions signifies symmetric geometry and uniform modal participation, leading to balanced seismic demands.

Storey Drift: The drift values diminish with elevation, as anticipated, due to the decreased mass and accumulated stiffness. All values significantly fall below the 0.004 threshold, affirming exceptional seismic performance. The minimal drift values can be ascribed to the building's height of 12 meters, which exhibits

more lateral stiffness due to its shorter columns and reduced number of floors. Drifts, albeit being minimal, underscore the necessity for lateral stiffness in low-rise structures to regulate deflections caused by wind loads.

Table 2: Storey drift of the building

Levels	Node no.	Nodal displacement	Drift Ratio
Ground Level	7	0.365 mm	(1.540-0.365)/3000 =0.000392
	25	1.540 mm	
1 st Storey	25	1.540 mm	

	34	2.663 mm	$(2.663 - 1.540)/3000 = 0.000374$
2 nd Storey	34	2.663 mm	$(3.530 - 2.663)/3000 = 0.000289$
	43	3.530 mm	
3 rd Storey	43	3.530 mm	$(4.050 - 3.530)/3000 = 0.000173$
	52	4.050 mm	

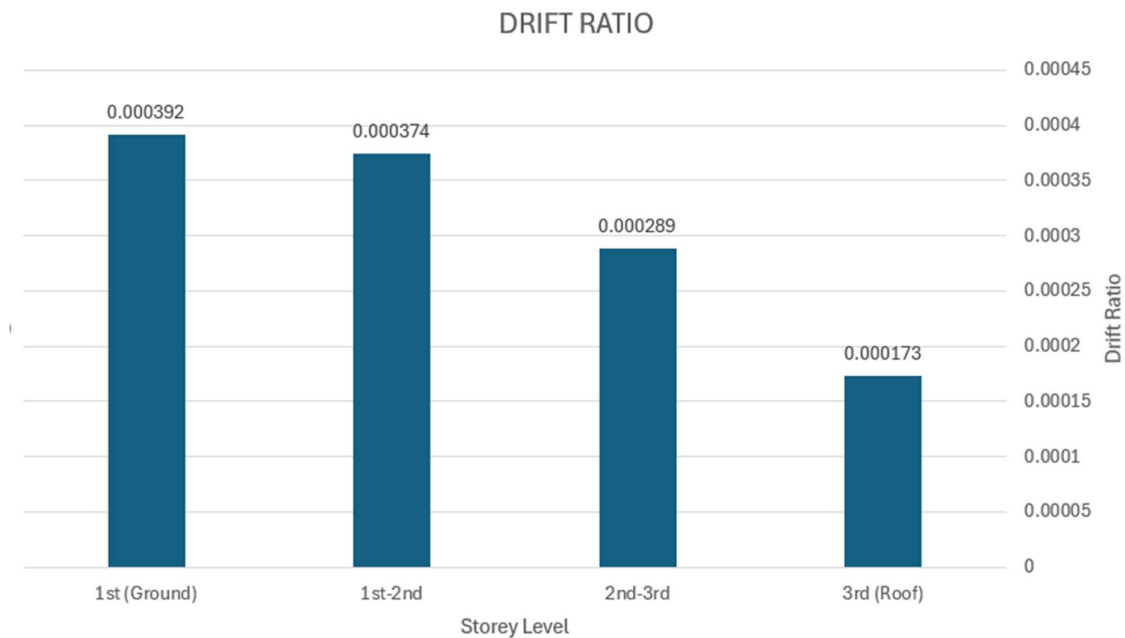


Figure 1. Storey Drift Ratio per Storey Level

- All storey drift ratios are much below the permissible threshold of 0.004 (IS 1893).
- Drift diminishes with elevation, indicating an appropriate stiffness distribution.
- Natural frequencies exceeding 2 Hz signify a comparatively rigid structure. Shorter time intervals diminish response amplification, hence enhancing performance.
- The base shear values correspond with the anticipated range for Zone V and medium soil.
- The effects of wind load were diminished relative to seismic forces, owing to the building's low elevation and square configuration.

- RSA yielded more precise displacement forecasts compared to static seismic load methodologies.

4. Conclusion

This research confirms the dynamic performance of a low-rise reinforced concrete frame by Response Spectrum Analysis in STAAD.Pro. The construction complies with IS 1893 seismic drift standards and has adequate lateral stiffness. RSA, in conjunction with wind load analysis, provides a comprehensive approach to assess earthquake and wind resilience. Recommendations suggest employing bracing or shear walls in elevated constructions to mitigate drift.

References

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