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Study of High-rise Building with Varying Imposed Loads Condition for Lateral Load Excitation

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Abstract

The demand for land has risen, causing scarcity and leading to a significant increase in the construction of tall residential and commercial buildings. With limited land and a growing population, expanding horizontally is not feasible, making multistory buildings the solution. Urbanization has led to the construction of numerous high-rise structures, emphasizing the need for a thorough understanding and analysis of these structures. The present study aims to determine the critical design loads for a multistory building subjected to basic wind speeds of 55 m/s and earthquake zone classified as V, which are considered extreme conditions for load calculations. The analysis is conducted according to the earthquake loads specified in IS 1893:2016 and wind loads according to IS 875:1987 code. It provides a basis for determining the principal design loads for a specific building situated in a specific wind and earthquake zone. The analysis focuses on three high-rise structures with consistent side dimensions, namely G+20 (60 m), G+25 (75 m), and G+30 (90 m). The study also accounts for three live load cases (2 kN/m^2, 4 kN/m^2, and 6 kN/m^2) for all models to evaluate their impact on lateral loads. The study compares the maximum displacements and story shears of the models. The results indicate that the magnitude of the wind load is greater than the earthquake load with an increase in height. The story shear of the building increases linearly in response to wind load, while the earthquake load results in a more or less constant shear after a certain extent. The findings also suggest that the building's behavior is influenced by seismic loads, but the wind loads remain consistent for live load cases considered.

Keywords: Dynamic analysis, wind analysis, response spectrum method, multistory high-rise structures, load cases, comparative study

INTRODUCTION

There is a scarcity of land, making it difficult to expand horizontally. As a result, vertical expansion has become the new norm Advances in construction materials and techniques have enabled the development of new tall structures that are flexible, slender, and lightweight. These tall structures tend to sway. As buildings grow taller, the forces acting on them, such as wind and earthquake forces, also increase. Tall buildings experience higher column loading and greater structural forces than low-rise buildings, affecting their rigidity and stability. Therefore, these structures must be designed to handle lateral forces, moments, story drift, and horizontal deflection. Earthquake and wind load resisting systems are designed similarly but behave differently. Earthquakes generate sudden and intense forces based on the building's mass and stiffness, while wind loads are constant and influenced by the building's height, wind velocity, and surface area. Also, wind load is considered constant load.

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Buildings are categorized by height: low-rise (up to four stories), mid-rise (5–12 stories), and high-rise (≥9 stories, with a height-to-width ratio greater than 5:1). Earthquake loads depend on the building's mass, dynamic properties, and stiffness differences between floors, while wind loads depend on factors such as geographic location, elevation, and building design.

Seismic design codes in India, such as IS 1893 and others, aim to ensure buildings can withstand moderate earthquakes without damage and severe earthquakes without collapse. Wind load calculations follow the IS-875 standard. Live loads for residential buildings are specified as 2 kN/m^2, with higher loads for other cases.

LITERATURE

The literature studied explore the behavior of tall, midrise, and low-rise structures under lateral loads, primarily earthquake and wind loading. Compared various types of buildings, including reinforced concrete cement (RCC), steel, and composite structures, and some focus on earthquake-resistant designs. Wind analysis measures building deformation and calculates displacements and base shear, comparing them across different heights and lateral loads. The consensus across papers is that lateral load magnification increases with building height, with wind forces predominating in tall structures compared to shorter ones, where their impact is minimal.

Abdelwahab et al. [1]) reviewed the performance-based wind design (PBWD) and provided a historical overview of PBWD development, highlighting its differences and challenges compared to performance-based seismic design (PBSD). It critiques current prescriptive methods, their limitations, and explores various research areas within performance-based design (PBD). The study emphasizes the nonlinear inelastic response of structures to wind loads and overall structural performance, noting that PBWD, like PBSD, shows great potential but contains uncertainties that need further investigation [1].

Hareendran et al. [2] analyzed wind loads on tall buildings, focusing on buffeting and aeroelastic loads. They aimed to include self-excited loads in the response analysis for PBWD, using wind tunnel data to obtain flutter derivatives and rational function coefficients (RFC). Nonlinear dynamic analysis of 44- and 60-story buildings under extreme winds assessed potential flutter instabilities, with PBWD applied to occupant comfort and damage performance objectives [2].

Gonzalez-Fernandez et al. [3] analyzed the dynamic behavior of a 150-m-tall building in London, noting significant changes during construction due to occupation, loading, wind conditions, and aeroelastic phenomena. Over a year, acceleration measurements and wind data revealed that natural frequencies decreased by up to 5% due to increased occupancy and structural softening. The study found that lateral building motion amplitude, rather than wind characteristics, primarily influenced modal damping. An empirical model showed damping ratios increasing from 0.6% at low amplitudes to 2.1% at high amplitudes [3].

Souhaibou and Li [4] compared wind and seismic loads on a 6-story reinforced concrete building, focusing on lateral displacements and story drifts. Using the base shear method and ETABS software, the study found both approaches met Chinese building code criteria for lateral displacements and story drifts. The results showed minimal discrepancy, indicating the base shear method is a viable approximation for buildings under 40 m tall without irregularities. The study underscored the importance of proper design codes and tools for structural safety, suggesting further research on simplified methods for complex structures [4].

Zhang and Far [5] found that high-rise buildings are increasingly common due to population growth and rising land prices. Traditionally, high-rise designs assume a fixed base, considering soil–structure interaction (SSI) beneficial during earthquakes. However, recent studies show that SSI can have detrimental effects. Using Abaqus software, the study analyzed SSI impacts on high-rise frame-core tube structures, revealing that SSI can amplify lateral displacements and inter-story drifts without necessarily reducing base shears. The study concludes that ignoring or solely considering the beneficial effects of SSI in design is neither safe nor economical [5].

Zhao and Li [6] analyzed the impact of multi/high-rise buildings on nearby low-rise buildings' surface wind load characteristics using computational fluid dynamics (CFD) simulations. They found that wind pressure distribution on low-rise buildings is sensitive to height and spacing ratios, with average wind pressure coefficients decreasing with increased height ratio but increasing with spacing ratio. Fluctuating pressure coefficients on low-rise buildings increased with height ratio, reaching a maximum at a ratio of 8. Additionally, they observed larger vortices on the leeward side of multi-/high-rise buildings with higher spacing and height ratios, significantly affecting wind loads on nearby low-rise buildings [6].

Lingeshwaran et al. [7] studied community buildings with floating columns and shear walls, common in modern leveled-story constructions in urban India. They highlighted the importance of seismic analysis for earthquake-resistant design due to recent seismic events. The study compared buildings with and without floating columns, focusing on floor displacement, base shear, and inter-story drift using time history and response spectrum methods. Alternate measures were explored to reduce structural irregularities, emphasizing the significance of floating columns and shear walls in seismic-prone areas for safety and structural integrity [7].

Jeong et al. [8] investigated PBWD for high-rise structures, focusing on response modification factors in windward and leeward directions. They addressed challenges like limited guidelines and impractical wind tunnel tests by studying initial designs with a response modification factor (R_W), generating time-history wind loads from power spectral density (PSD) functions, and evaluating wind resistance performance in a case study with R_W factors of 1, 2, and 3. Results showed that the R_W factor effectively reduced wind loads, especially on horizontal members like coupling beams. The study emphasized the importance of considering gradual loading/unloading and vertical load distribution for accurate wind load analysis [8].

Mahmoud [9] investigated the effects of lateral loads from wind and earthquakes on interconnected tall buildings, considering the rising trend of horizontal linkages between such structures. The study analyzed how sky-bridge placement impacted structural responses to earthquake loads, finding minimal influence on story moments along the building height but significant effects on moments at the bases. Overall, energy absorption by interconnected buildings during earthquakes was slightly affected by sky-bridge height [9].

Dumaru et al. [10] conducted a thorough investigation into the influence of wind on various structural parameters such as story drift, shear forces, and support reactions across different categories of buildings – low-rise, medium-rise, and high-rise – situated in varying terrain conditions. Using ETABS, they analyzed 12 models ranging from G+5 to G+15. The study revealed consistent story drift values in low-rise buildings, decreasing drift trends in medium- and high-rise structures from top to bottom stories, with the highest drift and force values observed in terrain category 1 and the lowest in terrain category 4. These findings underscore the significant impact of terrain conditions on wind-induced structural responses, with terrain category 1 showing the most pronounced effects compared to other categories [10].

Ambraseys [11] explored seismic analysis evolution, from early static approaches to advance nonlinear methods. Initial seismic codes used basic lateral loads, evolving to dynamic and nonlinear analyses. Today, linear dynamics are common, with explicit nonlinear methods growing. Nonlinear response history analysis (NRHA) is a key modern tool, often required for specific structures. Future methods may integrate probabilistic elements for improved seismic assessment [11].

Dadashi and Nasserasadi [12] investigated the impact of near-field earthquakes on structures, noting that while these events can cause severe damage due to high-period pulses in some records, the overall probabilistic analysis did not show a significant difference in failure probabilities compared to far-field earthquakes. They used nonlinear dynamic analyses and fragility functions to assess damage states, focusing on low-rise concrete frames [12].

Patil and Sangle [13] conducted an analysis on multistorey buildings with different shapes using ETABS software. The study focused on evaluating the structural behavior and response to seismic and wind loads based on IS-875-Part3 and IS1893-2002-Part1 guidelines. They analyzed 15-, 30-, and 45-story buildings, considering parameters like story displacement, story drift, base shear, overturning moments, acceleration, and time period. The results indicated that wind effects were critical for the 45-story building, while seismic effects were more pronounced for the 15- and 30-story buildings. Circular-shaped buildings exhibited greater stability under both seismic and wind loads. Overall, the study highlighted the importance of shape in determining structural response to different types of loads, with wind effects being particularly critical for taller buildings [13].

Shashidhar [14] compared the impact of earthquake and wind forces on multistory buildings. It aimed to determine the critical design loads for structures subjected to different basic wind speeds and earthquake zones, using standards like IS 1893:2002 for earthquakes and IS 875:1987 for winds. The analysis revealed that low-rise buildings were significantly more affected by earthquakes than winds, while high-rise buildings showed equal vulnerability to both forces. As building height increased, wind forces became more dominant. The severity of lateral forces increased with higher wind speeds and earthquake zones. Ultimately, earthquake forces were found to be more severe, especially for low-rise buildings, with zone V earthquakes exhibiting the highest severity [14].

AIMS AND OBJECTIVES

The specific objectives of the research are:

1. To obtain the maximum design driving force for the high-rise multistory structure with different aspect ratio.
2. To study the variation of response of the forces between high-rise multistory structures for different live load cases.
3. To determine the variation of response of the forces between high-rise multistory structures for different aspect ratio.

System Development

The ETABS software is used to develop 3D model and to carry out the lateral load analysis. The lateral loads as wind and earthquake loads to be applied on the buildings are based on the Indian standards. The study is performed for seismic zone V and wind speed of 55 m/s for different live load cases (2 kN/m^2, 4 kN/m^2, and 6 kN/m^2) as per IS 875:1987 part I and part II (dead load, live load), IS 1893:2016 (earth quake load), and IS 875:2015 part III (wind load). The building consists of reinforced concrete and brick masonry elements.

The forces acting on the structure, such as lateral wind and earthquake forces, cause the building to move sideways, resulting in lateral displacement of the structure. The maximum forces that can act on the building when subjected to lateral forces are known as story shears. The impact of lateral forces on the building is assessed by comparing story displacements and story shears. A graphical representation is created to illustrate the influence of these forces on the structure.

The aforementioned structures are subsequently analyzed under various live load cases (2 kN/m^2, 4 kN/m^2, and 6 kN/m^2) across all three heights to determine the impact of live loads on wind and seismic load calculations, and to observe whether their intensity increases or remains constant.

The analysis and design process involves the following steps:

1. Modeling
2. Assignment of live load cases

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3. Analysis phase for earthquake and wind loads
4. Comparing the displacement and story shear

Structure Descriptions

In the current study, residential building is considered of size 20 m × 20 m, building height is changed from G+20 (60 m), G+25 (75 m), and G+30 (90 m). When calculating for lateral loads with varying heights, the value of the live load is adjusted from 2 kN/m^2 to 4 kN/m^2 and 6 kN/m^2 while accounting for wind and earthquake loading, as well as changes in displacement and story shear, which vary according to height. Consequently, each high-rise building has three separate live load cases to consider (Table 1).

Table 1. Structure descriptions.

S.N.	Specifications	Value
Geometry Definition		
1.	Building dimension	20 m × 20 m
2.	Floor to floor height (each story height)	3 m
3.	Bottom story height	3 m
4.	Height of parapet wall	1.5 m
5.	Number of stories	20, 25, 30
6.	Total height of building	60 m, 75 m, 90 m
7.	Thickness of exterior walls	230 mm
8.	Thickness of partition walls	150 mm
9.	Thickness of parapet wall	150 mm
10.	Beam size	0.3 m × 0.45 m
11.	Column sizes	0.75 m × 0.75 m
Material Properties		
1.	Grade of concrete	M30
2.	Grade of steel (HYSD rebar) for longitudinal reinforcements	Fe500
3.	Grade of Steel (HYSD rebar) for transverse reinforcements	Fe415
4.	Density of concrete	25 kN/m^3
5.	Density of masonry infills	20 kN/m^3

Loading Conditions

The primary focus of structural analysis is the thorough examination of loading conditions. The analysis and design process is contingent upon these loading conditions, which are determined according to the IS Code. Tables 2 and 3 provide a comprehensive breakdown of the loading conditions calculated for the purpose of structural analysis.

Table 2. Loading conditions.

S.N.	Loads	Specification	Value	IS Code
1	Dead load	Self-weight factor	1.0 kN/m^2	IS 875(Part 1)
		Floor finish load	1.0 kN/m^2	
		Exterior wall load	13.8 kN/m^2	
		Partition wall load	6.9 kN/m^2	
		Parapet wall load	6.9 kN/m^2	
2	Live Load	Live load	2 kN/m^2, 4 kN/m^2, 6 kN/m^2	IS 875 (Part 2)
3	Wind Load	Terrain category	2	IS 875(Part 3)
		Windward coefficient (Cp)	0.8	
		Leeward coefficient (Cp)	0.25	
		Internal pressure coefficient (Cpi)	+/-0.5	

S.N.	Loads	Specification	Value	IS Code
		Wind speed	55 m/s	
		Risk coefficient (K1)	1	
		Terrain, height, and structure size factor (K2)	As per building height	
		Topography factor (K3)	1	
		Directionality factor (Kd)	0.9	
		Area averaging factor (Ka)	0.8	
		Combination factor (Kc)	0.9	
		Structural class (greatest dimension greater than 50 m)	C	
4	Earthquake Load	Seismic zone	V	IS 1893 (Part1)
		Zone factor	0.36	
		Response reduction factor	5	
		Importance factor	1	
		Soil type	Medium (Type 2)	
		Damping ratio	5 %	

Response Spectrum Method

Response spectrum analysis is conducted to ascertain the peak response of a structure in terms of displacements, story shears, and story drifts. Seismic motion comprises both horizontal and vertical ground movements, with vertical motion generally counteracting gravity loads. Nonetheless, all buildings exhibit some degree of flexibility in practice. For a structure that undergoes slight deformation, thereby absorbing some energy, the resultant force is defined as the design lateral force or design seismic base shear (VB) along the principal direction.

Model

Plan layout and three-dimensional (3D) views of residential buildings were designed with different building heights for 20, 25, and 30 stories, with each story having a story height of 3 m with masonry infills are detailed in Figure 1, which shows the case plan, and Figures 2, 3, and 4 show the respective 3D models. These structural models were designed by using ETABS software.

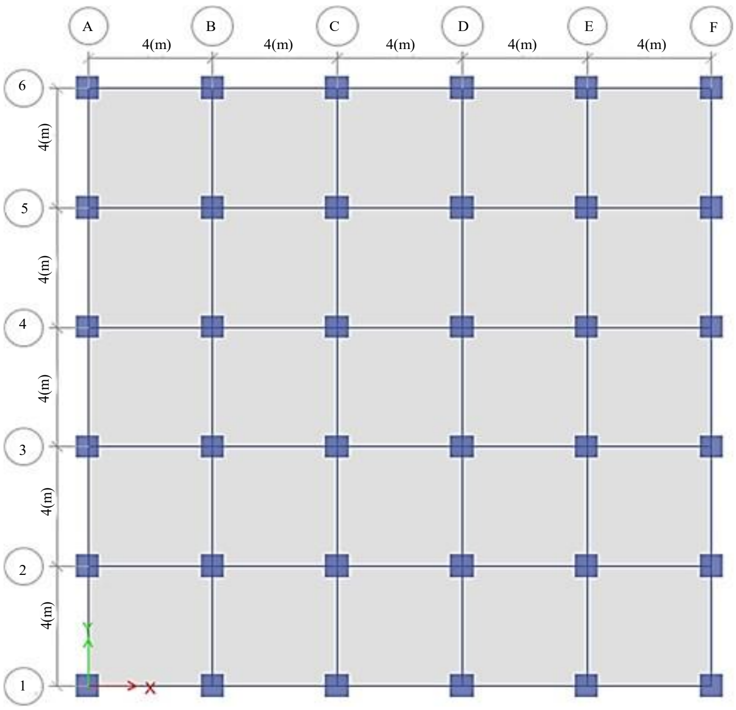

Figure 1. Plan of high-rise structures.

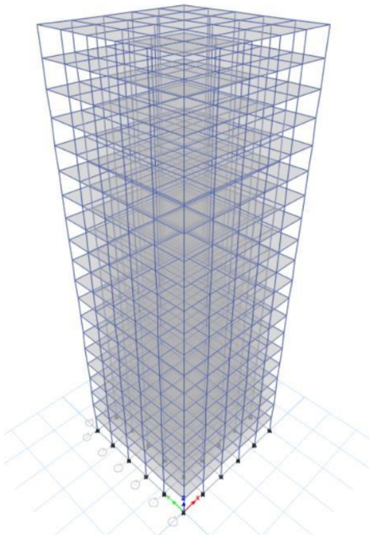

Figure 2. G+20 structure.

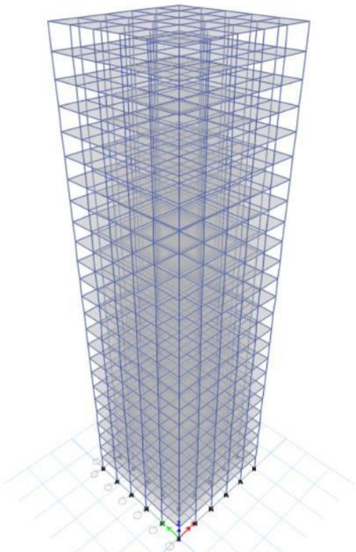

Figure 3. G+25 structure.

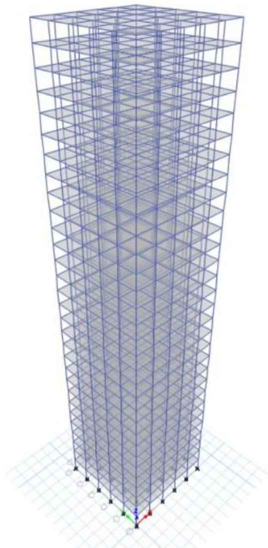

Figure 4. G+30 structure.

RESULTS AND DISCUSSION

This study utilizes ETABS software to develop 3D models and conduct lateral load analysis on buildings made of reinforced concrete and brick masonry elements. The analysis, based on Indian Standards (IS 456:2000, IS 1893:2002, IS 875:1987), covers all seismic zones and considers wind and earthquake loads. The study examines how these lateral forces cause sway movements and lateral displacements, resulting in story shears. By comparing lateral displacements and story shears, it provides insights into the structural behavior of buildings under different live load scenarios, with graphical representations illustrating the impact of these forces.

Lateral Displacement Results

The lateral forces acting on the structure such as wind and earthquake forces produce a sway movement of the building as a result the structure produces lateral displacement of the building (Tables 3–8).

Table 3. Lateral displacement for G+20 for wind and earthquake load for live load cases.

Story Height (m)	Wind Displacement: 2 kN/m^2, 4 kN/m^2, and 6 kN/m^2	Earthquake Displacement 2 kN/m^2	Earthquake Displacement 4 kN/m^2	Earthquake Displacement 6 kN/m^2
Base	***0***	***0***	***0***	***0***
3	1.104	1.6	1.639	1.663
6	3.304	4.829	4.945	5.018
9	5.854	8.608	8.813	8.943
12	8.47	12.51	12.806	12.993
15	11.042	16.359	16.744	16.988
18	13.523	20.084	20.555	20.853
21	15.891	23.653	24.209	24.56
24	18.133	27.055	27.693	28.096
27	20.241	30.282	30.999	31.453
30	22.208	33.33	34.124	34.627
33	24.028	36.197	37.062	37.611
36	25.697	38.876	39.808	40.399
39	27.21	41.36	42.352	42.981

Story Height (m)	Wind Displacement: 2 kN/m², 4 kN/m², and 6 kN/m²	Earthquake Displacement 2 kN/m²	Earthquake Displacement 4 kN/m²	Earthquake Displacement 6 kN/m²
42	28.564	43.637	44.682	45.345
45	29.755	45.689	46.781	47.472
48	30.781	47.498	48.629	49.345
51	31.641	49.041	50.204	50.94
54	32.337	50.299	51.486	52.237
57	32.88	51.267	52.47	53.232
60	33.301	51.987	53.202	53.972

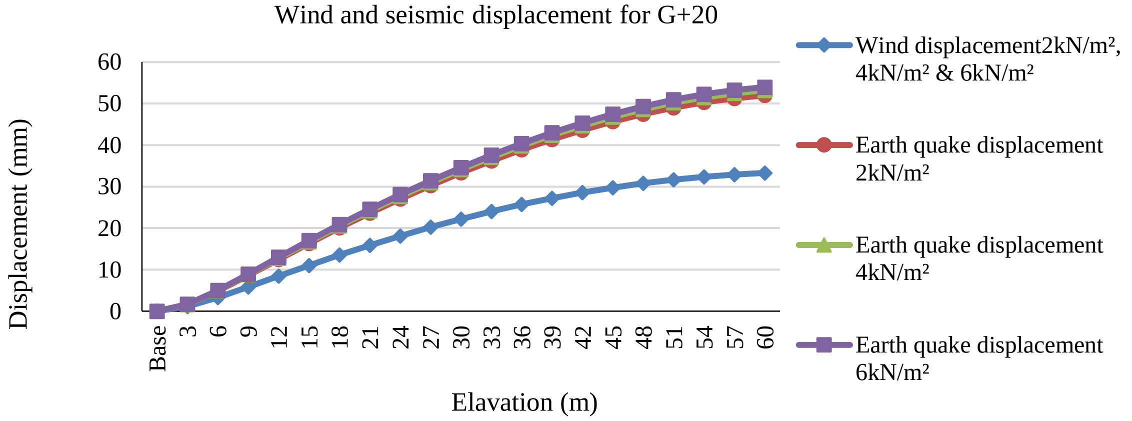

Figure 5. Displacement for G+20 for live loads 2 kN/m², 4 kN/m², and 6 kN/m².

In Figure 5, it is seen that the displacement for wind is less for 55 m/s speed than displacement for earthquake for zone V. Also, as the live load cases increases, the displacement shows increases for seismic load but for wind load it remains constant.

Table 4. Lateral displacement for G+25 for wind and earthquake load for live load cases.

Story Height (m)	Wind Displacement: 2 kN/m², 4 kN/m², and 6 kN/m²	Earthquake displacement 2 kN/m²	Earthquake Displacement 4 kN/m²	Earthquake Displacement 6 kN/m²
Base	0	0	0	0
3	1.451	1.541	1.577	1.579
6	4.369	4.663	4.771	4.776
9	7.788	8.341	8.534	8.539
12	11.341	12.173	12.451	12.455
15	14.887	15.996	16.355	16.361
18	18.365	19.742	20.179	20.199
21	21.749	23.386	23.897	23.956
24	25.023	26.919	27.503	27.61
27	28.178	30.338	30.994	31.15
30	31.204	33.642	34.369	34.573
33	34.095	36.826	37.624	37.873
36	36.845	39.888	40.754	41.047
39	39.449	42.822	43.755	44.088
42	41.901	45.622	46.619	46.991
45	44.199	48.283	49.341	49.748
48	46.336	50.798	51.913	52.351

Story Height (m)	Wind Displacement: 2 kN/m², 4 kN/m², and 6 kN/m²	Earthquake displacement 2 kN/m²	Earthquake Displacement 4 kN/m²	Earthquake Displacement 6 kN/m²
51	48.31	53.158	54.327	54.792
54	50.117	55.356	56.572	57.062
57	51.754	57.379	58.641	59.15
60	53.219	59.218	60.52	61.047
63	54.511	60.859	62.198	62.739
66	55.63	62.286	63.657	64.211
69	56.577	63.485	64.884	65.448
72	57.366	64.455	65.876	66.449
75	58.029	65.232	66.67	67.251

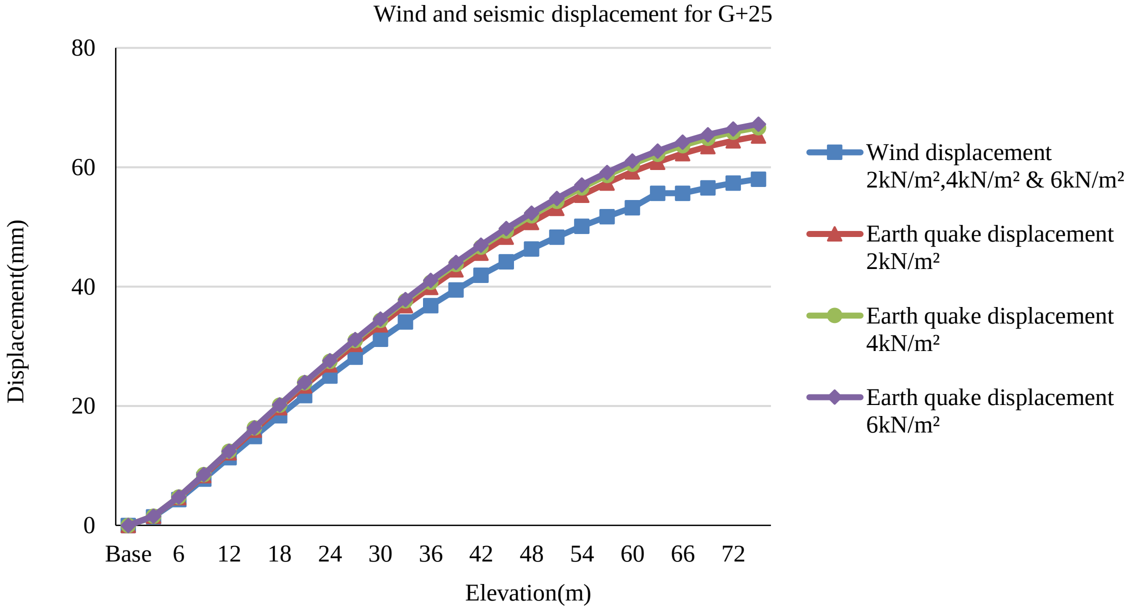

Figure 6. Displacement for G+25 for live cases 2 kN/m², 4 kN/m², and 6 kN/m².

As the building's height rises from G+20 to G+25, the wind-induced displacement increases at a rate of 75%, while the earthquake-induced displacement increases at a lower rate of 25%. Consequently, at the same loading conditions of speed and zone, wind tends to dominate the load. This is illustrated in Figure 6.

Table 5. Lateral displacement for G+30 for wind and earthquake load for live load cases

Story Height (m)	Wind Displacement: 2 kN/m², 4 kN/m², and 6 kN/m²	Earthquake Displacement 2 kN/m²	Earthquake Displacement 4 kN/m²	Earthquake Displacement 6 kN/m²
Base	0	0	0	0
3	1.814	1.478	1.515	1.548
6	5.482	4.481	4.592	4.693
9	9.812	8.037	8.237	8.417
12	14.351	11.764	12.056	12.32
15	18.926	15.508	15.893	16.241
18	23.462	19.205	19.681	20.113
21	27.928	22.829	23.396	23.909
24	32.305	26.372	27.028	27.623

Story Height (m)	Wind Displacement: 2 kN/m^2, 4 kN/m^2, and 6 kN/m^2	Earthquake Displacement 2 kN/m^2	Earthquake Displacement 4 kN/m^2	Earthquake Displacement 6 kN/m^2
27	36.582	29.833	30.579	31.254
30	40.749	33.214	34.05	34.805
33	44.797	36.516	37.44	38.275
36	48.72	39.736	40.748	41.661
39	52.512	42.871	43.97	44.96
42	56.165	45.919	47.102	48.167
45	59.676	48.874	50.14	51.278
48	63.038	51.734	53.08	54.288
51	66.247	54.494	55.918	57.195
54	69.298	57.15	58.65	59.992
57	72.187	59.697	61.268	62.675
60	74.911	62.128	63.768	65.235
63	77.466	64.437	66.143	67.667
66	79.85	66.617	68.385	69.963
69	82.059	68.663	70.488	72.117
72	84.092	70.566	72.444	74.119
75	85.945	72.317	74.244	75.962
78	87.619	73.904	75.875	77.632
81	89.112	75.315	77.325	79.117
84	90.428	76.538	78.583	80.405
87	91.579	77.575	79.649	81.497
90	92.6	78.455	80.556	82.426

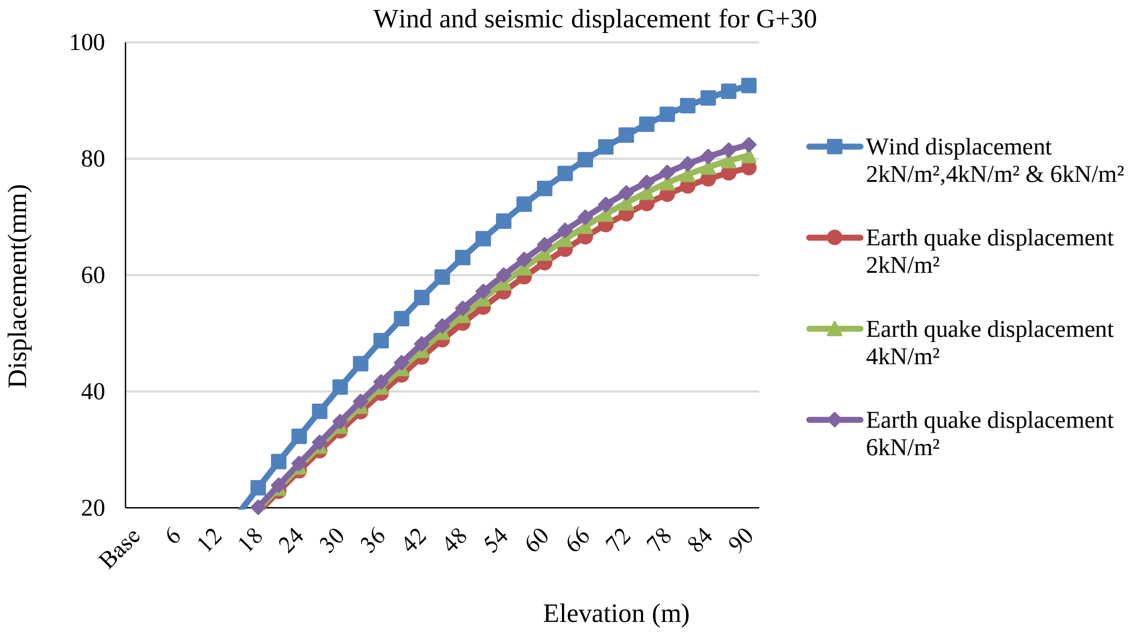

Figure 7. Displacement for G+30 for live cases 2 kN/m^2, 4 kN/m^2, and 6 kN/m^2.

The trend appears to be ongoing, as the height increases from 75 to 90 m, the wind becomes more dominant at a rate of 60%, while the earthquake load remains at 25%. Additionally, the wind displacement exceeds that of earthquakes, a contrast to the G+20 and G+25 structures, as illustrated in Figure 7.

Story Shear Data

The earthquake story shear is higher than that of wind, and as the live load increases, the seismic loading's story shear also increases. In contrast, wind loading remains unchanged for the same circumstances. The wind story shear increases linearly, while the earthquake story shear increases exponentially and reaches a constant level at the base, as referred in Figure 8.

Table 6. Story shear for G+20 for wind and earthquake load for live load cases.

Story Height (m)	Wind Shear: 2 kN/m^2, 4 kN/m^2, and 6 kN/m^2	Earthquake Shear 2 kN/m^2	Earthquake Shear 4 kN/m^2	Earthquake Shear 6 kN/m^2
0	2723.0408	2910.7408	3041.882	3126.26
3	2723.0408	2910.7408	3041.882	3126.26
6	2608.6958	2909.6669	3040.752	3125.093
9	2494.3508	2905.3714	3036.229	3120.424
12	2379.665	2895.7064	3026.053	3109.92
15	2260.6409	2878.5241	3007.962	3091.247
18	2135.2868	2851.6769	2979.695	3062.069
21	2006.3162	2813.0168	2938.99	3020.053
24	1874.1358	2760.3962	2883.587	2962.865
27	1738.2783	2691.6672	2811.223	2888.17
30	1598.6559	2604.6821	2719.638	2793.635
33	1455.5394	2497.2931	2606.569	2676.924
36	1310.1765	2367.3524	2469.757	2535.704
39	1162.8733	2212.7122	2306.938	2367.641
42	1013.617	2031.2247	2115.853	2170.4
45	862.3947	1820.7422	1894.239	1941.648
48	709.1935	1579.1169	1639.835	1679.049
51	554.006	1304.201	1350.38	1380.27
54	397.1475	993.8468	1023.613	1042.976
57	239.1184	645.9063	657.2714	664.8341
60	79.958	258.232	249.0948	243.509

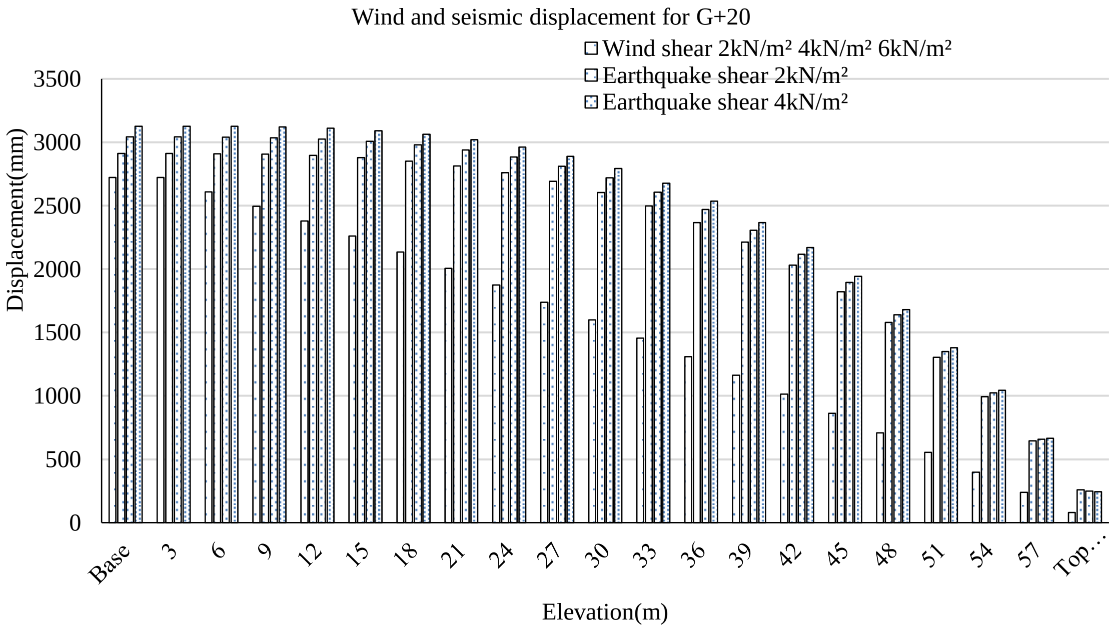

Figure 8. Story shear G+20 for live load cases 2 kN/m^2, 4 kN/m^2, and 6 kN/m^2.

Table 7. Story shear for G+25 for wind and earthquake load for live load cases.

Story Height (m)	Wind Shear: 2 kN/m^{2}, 4 kN/m^2, and 6 kN/m^2	Earthquake Shear 2 kN/m^2	Earthquake Shear 4 kN/m^2	Earthquake Shear 6 kN/m^2
0	3538.8163	2833.5074	2961.153	3000.48
3	3538.8163	2833.5074	2961.153	3000.48
6	3424.4713	2832.9703	2958.33	2997.602
9	3310.1263	2830.8219	2953.248	2992.421
12	3195.4405	2825.9882	2944.214	2983.21
15	3076.4164	2817.3948	2930.097	2968.819
18	2951.0624	2803.9677	2909.77	2955.928
21	2822.0917	2784.6327	2909.77	2955.928
24	2689.9114	2758.3156	2882.102	2927.722
27	2554.0538	2723.9422	2845.964	2890.881
30	2414.4314	2680.4384	2800.228	2844.254
33	2271.3149	2626.73	2743.763	2786.689
36	2125.952	2561.7429	2675.44	2717.037
39	1978.6489	2484.4028	2594.131	2634.144
42	1829.3926	2393.6356	2498.705	2536.86
45	1678.1702	2288.3671	2388.033	2424.034
48	1524.969	2167.5232	2260.987	2294.515
51	1369.7815	2030.0297	2116.436	2147.15
54	1212.9231	1874.8125	1953.253	1980.79
57	1054.8939	1700.7973	1770.306	1794.281
60	895.7335	1506.9099	1566.467	1586.474
63	735.438	1292.0764	1340.607	1356.217
66	574.0032	1055.2223	1091.596	1102.359
69	411.4251	795.2737	818.3057	823.7478
72	247.6997	511.1563	519.6058	519.2328
75	82.8229	201.7959	194.3673	187.6627

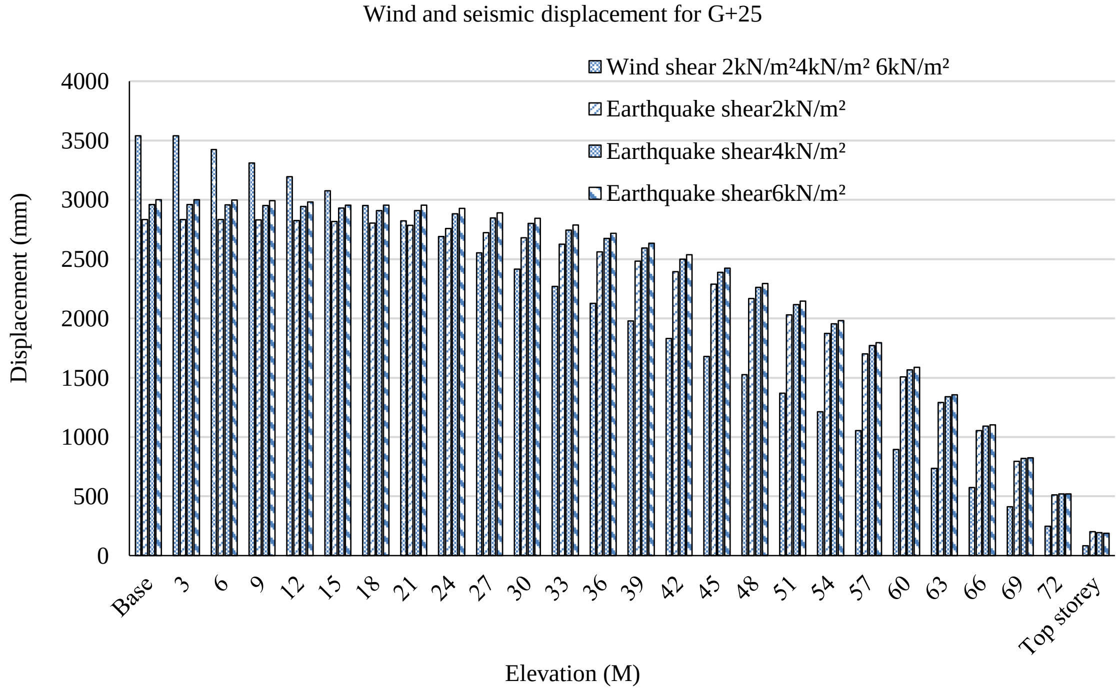

Figure 9. Story shear G+25 for live load cases 2 kN/m^2, 4 kN/m^2, and 6 kN/m^2.

The increase in story shear for both wind and earthquake loads is influenced by the height of the building. While the wind shear increases at a rate of 30%, the earthquake load story shear decreases at a rate of 4%.

This is because taller buildings are more likely to sway during an earthquake than to shake. As illustrated in Figure 9, the relationship between building height and story shear is complex and depends on various factors.

Table 8. Story shear for G+30 for wind and earthquake load for live load cases

Story Height (m)	Wind Shear: 2 kN/m^2, 4 kN/m^2, and 6 kN/m^2	Earthquake Shear 2 kN/m^2	Earthquake Shear 4 kN/m^2	Earthquake Shear 6 kN/m^2
0	4383.5269	2756.8265	2881.0391	2960.9569
3	4383.5269	2756.5234	2880.7207	2960.6288
6	4269.1819	2755.3111	2879.4475	2959.3163
9	4154.8369	2752.5833	2876.5825	2956.3634
12	4040.1511	2747.7341	2871.4894	2951.1137
15	3924.127	2740.1571	2863.5313	2942.9111
18	3795.7729	2729.2462	2852.0717	2931.0994
21	3666.8023	2714.3953	2836.4739	2915.0223
24	3534.6219	2694.9982	2816.1012	2894.0237
27	3398.7643	2694.9982	2816.1012	2894.0237
30	3259.1419	2670.4487	2790.3171	2867.4472
33	3116.0254	2640.1408	2758.4848	2834.6369
36	2970.6626	2603.4681	2719.9678	2794.9363
39	2823.3594	2559.8246	2674.1293	2747.6893
42	2674.1031	2508.6042	2620.3327	2692.2397
45	2522.8808	2449.2006	2557.9415	2627.9314
48	2369.6795	2381.0076	2486.3189	2554.108
51	2214.492	2303.4192	2404.8282	2470.1134
54	2057.6336	2215.8292	2312.833	2375.2913
57	1899.6044	2117.6313	2209.6964	2268.9857
60	1740.4441	2008.2196	2094.7819	2150.5401
63	1580.1485	1886.9877	1967.4528	2019.2986
66	1418.7137	1753.3295	1827.0724	1874.6047
69	1256.1356	1606.6389	1673.0042	1715.8024
72	1092.4102	1446.3098	1504.6115	1542.2355
75	927.5335	1271.7358	1321.2576	1353.2476
78	761.5013	1082.311	1122.3059	1148.1826
81	594.3098	877.4291	907.1197	926.3844
84	425.9548	656.484	675.0624	687.1966
87	256.4323	418.8695	425.4974	429.9631
90	85.7383	163.9795	157.788	154.0277

As demonstrated in Figure 10, the story shear due to wind loading increases linearly with building height. In contrast, the story shear resulting from earthquake loading decreases as the building height increases. This phenomenon occurs because taller buildings tend to exhibit greater flexibility, leading to an increased dominance of wind load compared to earthquake load.

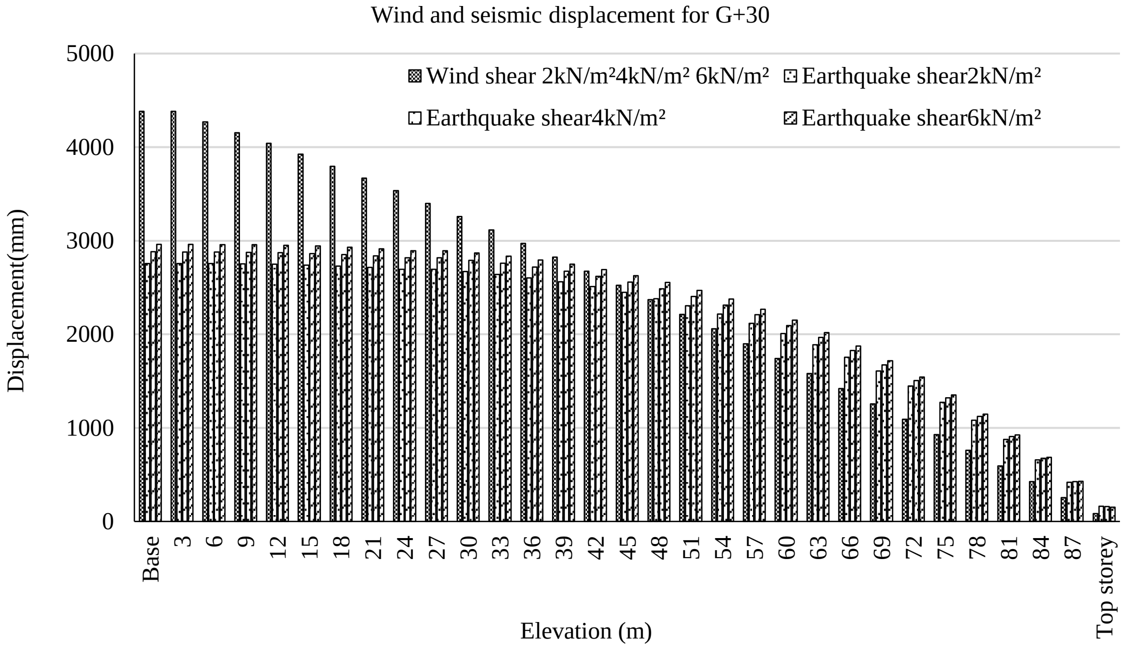

Figure 10. Story shear G+30 for live load cases 2 kN/m^2, 4 kN/m^2, and 6 kN/m^2.

CONCLUSIONS

1. Displacement in high-rise structures increases more rapidly for wind load, exceeding 60% at 55 m/s, compared to over 25% for earthquake load. Wind load dominates at higher elevations, even in earthquake zone V.
2. As live load increases from 2 kN/m^2 to 6 kN/m^2, earthquake-induced displacement rises but remains under 4 mm. Wind load displacement is unaffected by live load changes, showing minimal impact for small live load increases.
3. With live load increasing from 2 kN/m^2 to 6 kN/m^2, story shear for earthquake load increases but stays under 4 mm. Wind load story shear is unaffected by live load changes, showing minimal impact for small live load increases.
4. Increasing building height from 60 to 90 m significantly raises wind load story shear by over 25%, while earthquake story shear decreases by less than 3%. Wind load becomes more dominant at higher elevations.
5. Story shear due to wind load increases linearly. For seismic load, story shear initially rises, then stabilizes and remains constant at the base.

REFERENCES

1. Abdelwahab M, Ghazal T, Nadeem K, Aboshosha H, Elshaer A. Performance-based wind design for tall buildings: review and comparative study. J Build Eng. 2023; 68: 106103.
2. Hareendran SP, Alipour A, Shafei B, Sarkar P. Characterizing wind-structure interaction for performance-based wind design of tall buildings. Rng Struct. 2023; 289: 115812.
3. Gonzalez-Fernandez D, De Risi R, Rezgui D, Macdonald JH, Margnelli A, Titurus B. Identification of varying modal parameters of a tall building from the full-scale wind-induced responses. Structure. 2023; 56: 104770.
4. Souhaibou A, Li L-Z. A comparative study on the lateral displacement of a multistory RC building under wind and earthquake load actions using base shear method and ETABS software. Mater Today Proc. 2023; 89: 510–514.
5. Zhang X, Far H. Seismic behavior of high-rise frame core tube structures considering dynamic soil-structure interaction. Bull Earthquake Eng. 2022; 20: 5073–5105.
6. Zhao L, Li Y. The influence of multi high-rise buildings on the surface wind load of low-rise buildings. Alexandria Eng J. 2022; 61 (12): 11979–11991.

7. Lingeshwaran N, Nadimpalli SK, Sailaja K, Sameeruddin S, Kumar YH, Madavarapu SB. A study on seismic analysis of high-rise building with and without floating columns and shear wall. Mater Today Proc. 2021; 47 (Part 15): 5451–5456.
8. Jeong SY, Alinejad H, Kang TH. Performance-based wind design of high-rise buildings using generated time-history wind loads. J Struct Eng. 2021; 147 (9): 04021134.
9. Mahmoud S. Horizontally connected high-rise buildings under earthquake loadings. Ain Shams Eng J. 2019; 10 (1): 227–241.
10. Dumaru R, Rodrigues H, Varum H. Comparative study on the seismic performance assessment of existing buildings with and without retrofitting strategies. Int J Adv Struct Eng. 2018; 10: 439–464.
11. Ambraseys N. Analysis in seismic provisions for buildings: past, present and future. Bull Earthquake Eng. 2018; 16: 2567–2608.
12. Patil DM, Sangle KK. Seismic behavior of different bracing systems in high-rise 2-D steel buildings. Structures. 2015; 3: 282–305.
13. Dadashi R, Nasserasadi K. Seismic damages comparison of low-rise moderate reinforced concrete moment frames in the near and far field earthquakes by a probabilistic approach. Int J Adv Struct Eng. 2015; 7: 171–180.
14. Shashidhar K. Comparison of Influence of Wind and Earthquake Forces on Low-Rise and High-Rise Multistory Structures. MTech Thesis. Visakhapatnam, India: GITAM Institute of Technology; 2015.

