

Analytical Study On the Behaviour Of A Tall Structure With Cantilever Projections Using ETABS

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ABSTRACT- The need for high-rise structures is growing significantly as a result of urbanization and population growth worldwide. More thought should be given to this building safety. Lateral forces like wind and earthquakes have the potential to actively cause high-rise buildings to fail. Shear walls and bracings can be added to the building to provide safety against lateral forces. The current study examines a G+31 storey framed building located in seismic zones IV and terrain category 4 by equivalent static method. The ETABS 2017 version is used for modelling and analysis of all models. Storey displacement, storey drift and base shear are determined and compared with all different models. For seismic loading, IS: 1893 (Part1) 2002 and IS: 875 (Part 3) 1987 for wind loads is taken into consideration.

Key Words: Shear Walls, Bracing, Cantilever Projection, Equivalent Static Method ETABS 2017.

I. INTRODUCTION

In this modern era, tall buildings are becoming more popular with slender shapes, which result in greater sway compared to earlier high-rise buildings. Historically, buildings were primarily designed to withstand gravity loads. However, due to the increasing height of modern buildings and their location in seismic zones, designers must now account for lateral forces due to earthquake and wind forces. All tall structures must be capable of resisting not only gravity loads but also lateral loads to ensure structural stability.

Dynamic actions in buildings are caused by both wind and earthquakes. However, designing for these two forces is significantly different. Wind loads apply force type loading where the building is subjected to pressure on its exposed surfaces. Whereas, earthquakes induce displacement type loading, where the ground movement creates inertia forces within the structure.

Under wind forces, the building experiences stress fluctuations with occasional reversals when wind direction changes over time. Whereas, seismic loading causes frequent cyclic stress reversals in a very short period, making earthquake design more complex and demanding. This becomes a significant challenge for structural

engineers to design systems that can resist both gravity loads and lateral loads such as wind and earthquakes loads. Therefore, main lateral load-resisting mechanism installed on high-rise structures for seamless operation is shear walls i.e. structural walls and steel bracings.

Shear walls are vertical lateral-force-resisting elements that act as supports for roof and floor diaphragms, cantilevered from and transferring their forces down into foundations or other support below. They give the structure enough stiffness and rigidity, which lessens the likelihood of failure. Improving the building's seismic response may be accomplished effectively and efficiently by positioning shear walls in strategic locations. Steel bracing improves the building's strength, stiffness, and ductility in a manner comparable to that of shear walls.

1.1 SHEAR WALLS

In order to counteract the effects of lateral load acting on a structure, shear walls are vertical components of a horizontal force-resisting system. A stiff vertical diaphragm used in building construction that may transmit lateral stresses from outside walls, floors, and roofs to the ground foundation. crucial for high-rise structures that are exposed to seismic and lateral wind loads. In reinforced concrete framed systems, the effects of wind forces growth in

significance as the structure will increase in height and the effects of wind forces growth in significance as change in location of building

II. LITERATURE REVIEW

2.1 A. Pavan Kumar Reddy, R. Master Praveen Kumar [1]

The maximum height recognized for the reward gain knowledge is 93.5m. The work has been completed for the unique instances using shear walls and bracings for the exceptional heights. The modeling is finished in order to investigate the effects of particular heights and special conditions on seismic parameters such as base shear, lateral displacements, and lateral drifts. As specified in IS 1893-2002, the knowledge gained has been applied to Zones IV and V in Soil Type II (medium soils). In zones 4 and 5, the story drift increases from the top story to the bottom story. At story 31, the drift is at its highest in comparison to the other stories. When comparing the drift values in zones 4 and 5, we find that zone 5 has a higher drift value. When compared to the forces in all stories for zones 4 and 5, the story shear is at its highest during those moments. When compared to zone 4, the shear value in zone 5 is higher. When compared to X and Y direction support reactions in zones 4 and 5, the Z direction force for support reactions has the highest value. When compared to the Y and Z direction moments in zones 4 and 5, the X direction moment for support reactions has the highest value. For forces and moments in support reactions, zone 5 has a higher value than zone 4.

2.2 Swati D. Ambadkar, Vipul S. Bawner [2]

A variety of variations are analyzed, including terrain with few or no obstacles and heights under 1.5 meters, Terrain with obstacles that range in height from 1.5 to 10 meters, Terrain with many closely spaced obstacles that are as large as buildings and as high as 10 meters, A terrain with many high, large obstacles that are closely spaced. Internal Pressure Coefficients (Cr) account for those different variations. The wind speeds used in this analysis are 44 m/s, 47 m/s, and 50 m/s. The STAAD-PRO analysis results are used to determine important relationships between wind speed and moments, forces, and displacement. Wind speeds are compared with the moments, forces, and displacements derived from each case based on the percentage of opening allowed for different variations. According to the category, Mz values rise in tandem with wind speed My, opening as My values rise more quickly than Mz values. According to the category, Fz values also rise as wind speed Fy increases, with Fy values increasing more quickly than Fz values.

2.3 Aleena Raechal George, Dr. R. Umamaheswari [3]

- loading.

4.1 FLOWCHART

This paper examines a ten-story framed building located in seismic zones II and V, both with and without a shear wall. The shear wall is positioned at two distinct locations: the corners of the sides and the centres of the sides. The ETABS 17 version is used for modelling and comparative analysis of various models' base shear, storey stiffness, storey displacement, and storey drift. The best place to install a shear wall is determined. By adding more strength and stiffness, shear walls lower the likelihood of buildings failing seismically. Compared to shear walls positioned at centers, models with shear walls at the corners have the highest base shear and storey stiffness. This lessens the effect of lateral forces that are applied. For models with corner shear walls, the maximum displacement and maximum storey drift are at their lowest. This demonstrates the decrease in the building's deflection and movement during seismic activity. Because it exhibits superior seismic performance, the corners of exterior sides are the best locations for shear walls on a multi-story building.

III. OBJECTIVES AND SCOPE OF STUDY

3.1 OBJECTIVES OF PRESENT STUDY

1. To determine how a tall building with cantilever projections affect the building under strong wind and earthquake forces.
2. To determine Displacement, Storey Drift and Base Shear of all different models.
3. To observe the impact on the Displacement, Storey Drift and Base Shear by adding shear walls and bracings to the structure.
4. To compare all models Displacement, Storey Drift and Base Shear.
5. To find the best design to make the building safe against wind in terrain category 4 and earthquake Loads in zone IV.

IV. METHODOLOGY

- G+31 storey building of each storey height 3.5 m with a total height 112m of structure.
- The structure is designed as per Indian Standard code of practice for design of building.
- The structure is modelled and analysed using ETABS 2017.
- The structure is fixed at the base, columns and beams are of rectangular shape.
- 10 different models were prepared having cantilever projections at different levels under the action of Wind and seismic

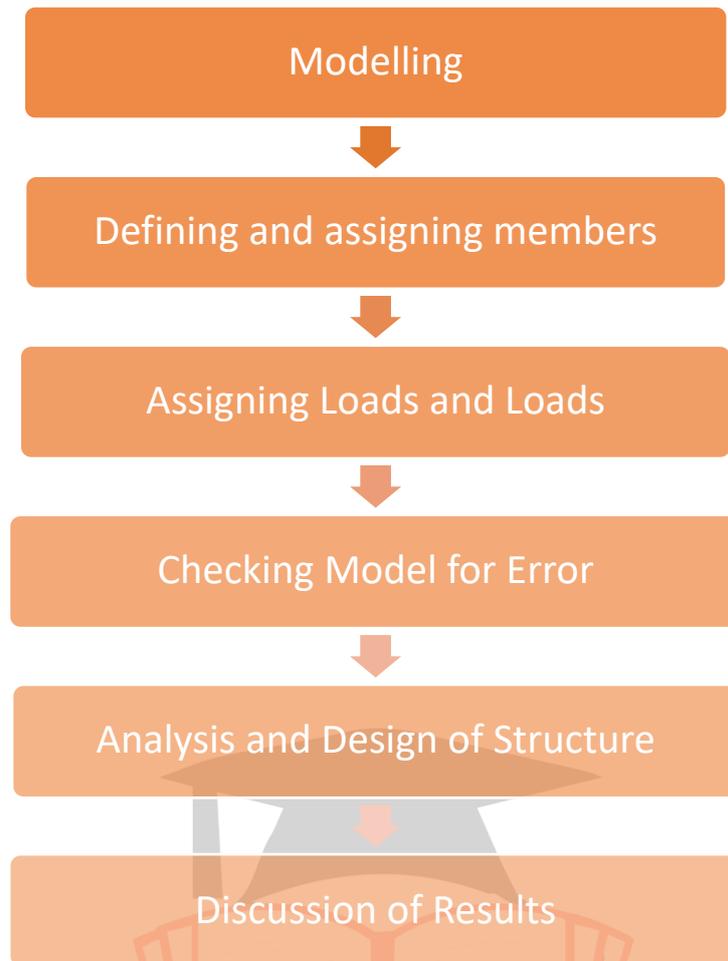


Figure 4.1: Flow Chart for Analysis of Structure.

4.2 DETAILS OF TALL STRUCTURE FOR ANALYSIS

Table 4.1: Details of material and geometrical properties

Description	Parameter	
No of Storey	G+31 (32 Storey)	
Cantilever projection length	1 m	
Concrete Grade	M ₃₀	
Rebar Grade	Fe 550	
Grade of Steel	Fe 345	
Storey height	3.5 m	
Beam size	400 mm x 400 mm	
Column size	Storey No	Size
	0 to 10	600 mm x 600 mm
	11 to 21	550 mm x 550 mm
	21 to 32	500 mm x 500 mm
Slab thickness	150 mm	
Wall thickness	230 mm	
Shear wall thickness	100 mm	
Bracing	ISA 100 x 100 x 10 mm	
Steel Density	78.5 KN/m ³	
Concrete Density	25 KN/m ³	
Brick masonry Density	18 KN/m ³	
Live load	4 KN/m ²	
Floor Finish	1 KN/m ²	
Terrain Category	4	
Terrain and size factor	0.98	
Seismic zone	4	

Importance factor	1.5
Soil type	Medium
Building Type	SMRF
Analysis Method	Equivalent Static Method

4.3 PLAN, 3D VIEW, ELEVATION OF VARIOUS MODELS IN ETABS

4.3.1 PLAN OF DIFFERENT MODELS

➤ **Model 1: Conventional RCC framed of G+31 storey with cantilever projection.**

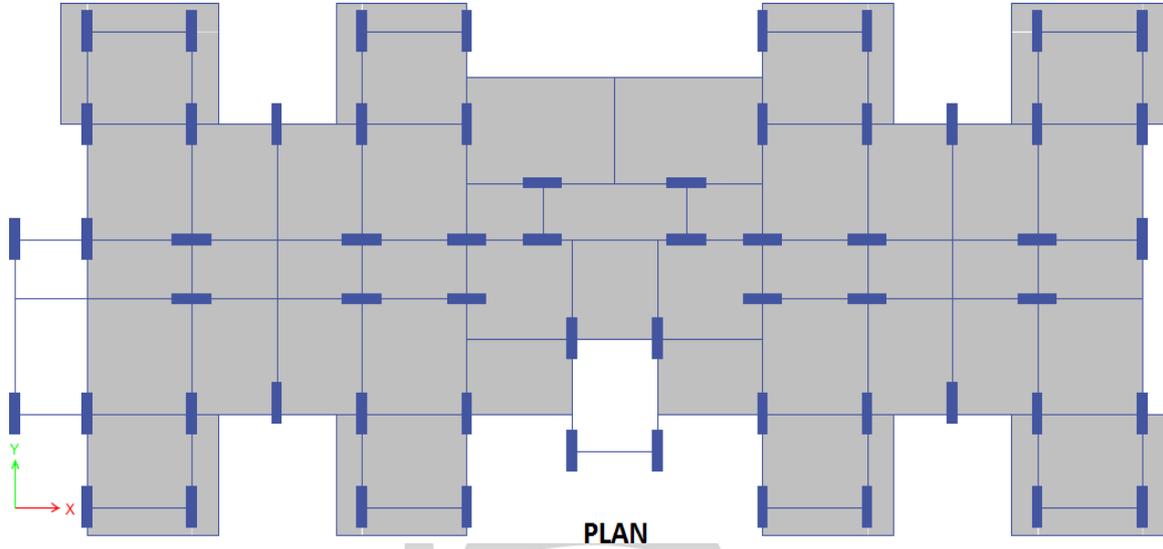


Figure 4.2: Plan of Model 1

➤ **Model 2: Soft Storey RCC framed of G+31 storey with cantilever projection.**

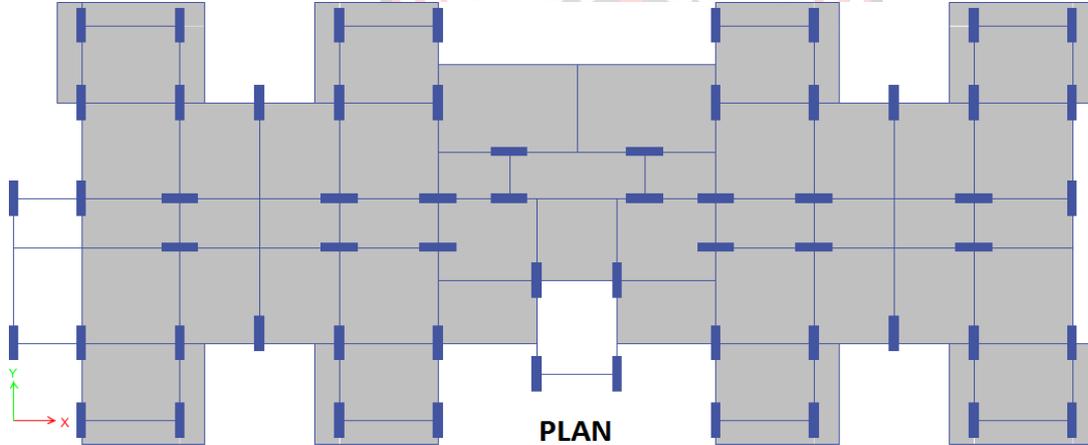


Figure 4.3: Plan of Model 2

4.3.2 3D AND ELEVATION VIEW OF DIFFERENT MODELS

Model 1: Conventional RCC framed of G+31 storey with cantilever projection

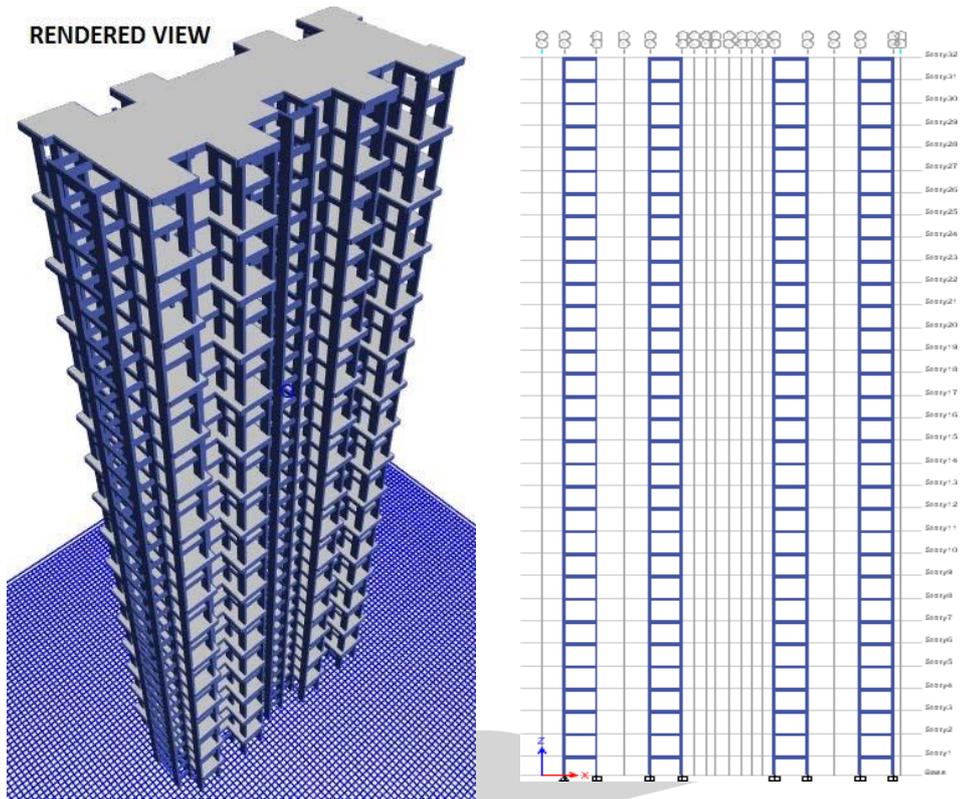


Figure 4.12: 3D view and elevation of Model 1

Model 2: Soft Storey RCC framed of G+31 storey with cantilever projection.

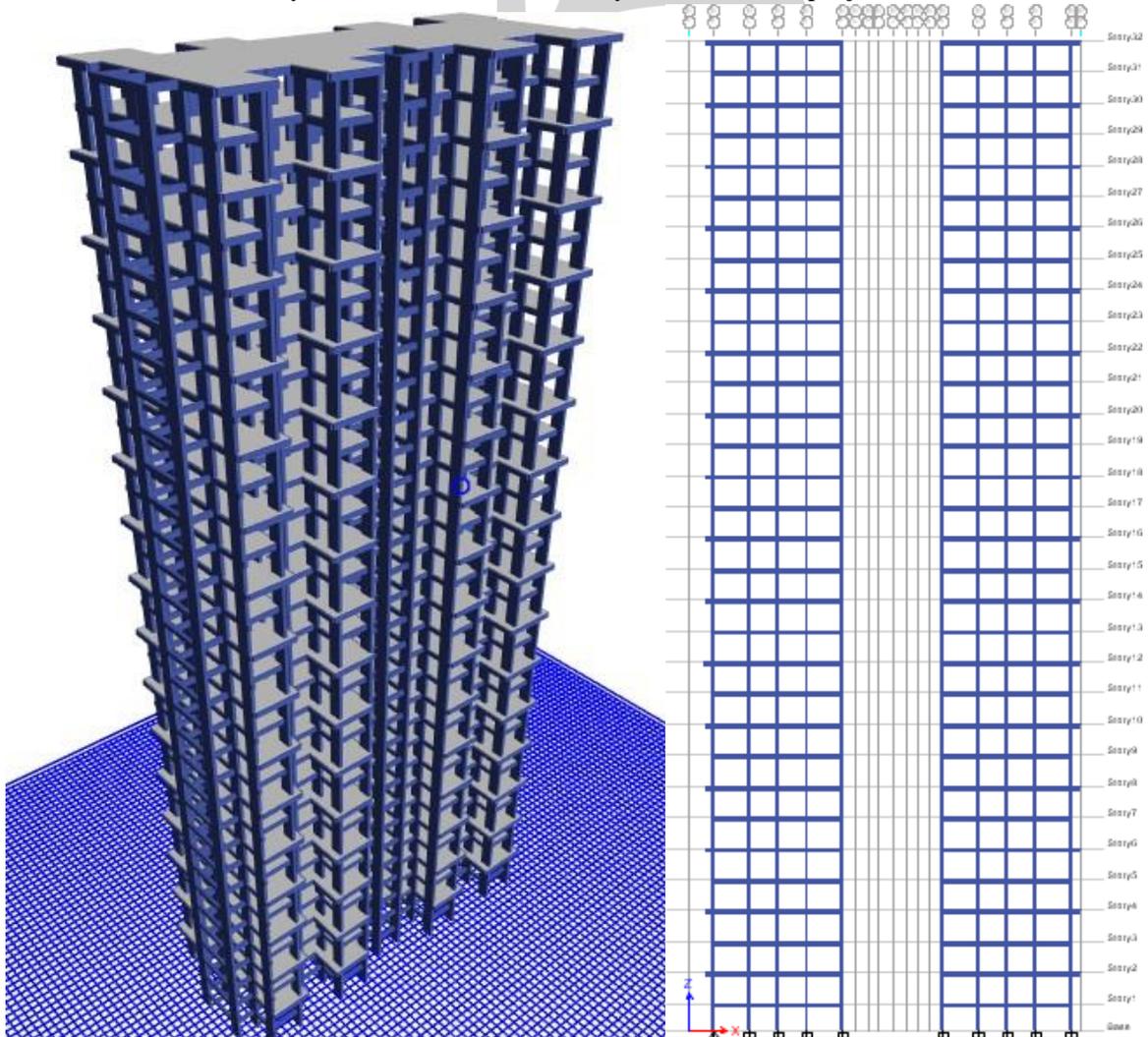


Figure 4.13: 3D view and elevation of Model 2

4.4 INDIAN STANDARD CODES FOR LOAD ANALYSIS

Following loads are considered for analysis of tall structure with cantilever projection.

4.4.1 Plain and Reinforced Concrete as per IS 456: 2000

The general structural application of both reinforced and unreinforced concrete is covered by this standard. For the purposes of this standard, plain concrete structures are those in which the strength of the structure is determined without taking into account any reinforcing that may be present. This standard will be used in conjunction with other standards that address specific requirements for structures, such as shells, folded plates, arches, bridges, chimneys, blast-resistant structures, hydraulic structures, liquid-retaining structures, and earthquake-resistant structures.

4.4.2 Dead loads as per IS 875 (Part 1): 1987

This standard deals with Construction and storage material unit weights. To ensure the structural safety and efficiency of buildings and other structures, engineers and architects need a through list of the unit weights and masses of various construction materials and items stored in buildings. This standard is crucial for precisely calculating the dead load components in structural design.

4.4.3 Live loads as per IS 875 (Part 2): 1987

This standard deals with Live loads, sometimes referred to as imposed loads, are temporary forces that can change in position and intensity. They make sure a structure can sustain the highest loads anticipated over its lifetime by taking into consideration the dynamic effects of use and occupancy. Live loads examples the weight of building occupants and their activities. Computers, desks, chairs, and temporary partitions are examples of furniture and movable equipment. Any materials that are momentarily kept inside a building are referred to as stored materials. The weight of automobiles, trucks, and other vehicles traversing bridges

4.4.4 Wind loads as per IS 875 (Part 3): 1987

These codes give engineers precise instructions and formulas to determine design wind speeds, pressures, and the forces that result on structures and buildings while taking topography, building height, location, and terrain into account.

Design Wind Speed (V_z): For any structure in a location, acquired primary wind speed (V_z) will be custom designed to incorporate the following outcomes to obtained design wind speed for any elevation (V_z). The design wind velocity at any elevation V_z , may be found by using equation,

$$V_z = V_b * k_1 * k_2 * k_3$$

wherein,

V_z = design wind speed at any height in m/s

V_b = Basic wind speed in m/s

k_1 = Risk coefficient

k_2 = Terrain roughness and peak component

k_3 = Topography factor

4.4.5 Seismic loads as per IS 893 (Part 1): 2002

This standard establishes guidelines for evaluating seismic loads and designing structures to withstand earthquake impacts, as well as general provisions and criteria for earthquake-resistant building and structure design in India. The country is divided into seismic zones. Although special structures require site-specific, in-depth investigations, it outlines the goal to ensure that structures can withstand moderate earthquakes without damage and heavy ones without completely collapsing. For the purpose of hazard assessment, the standard also specifies India's seismic zones II, III, IV, and V, with Zone V being the most seismically active.

V. RESULTS AND DISCUSSION

5.1 GENERAL

The Equivalent Static Method, a seismic analysis technique for RCC of G+31 stories, is used to create and assess eight different models using ETABS 2017 software. The following four parameters are examined and contrasted:

- Storey displacement
- Storey Drift
- Base Shear

5.2 STOREY DISPLACEMENT

Table 5.1: Storey Displacement in mm for Model 1 under both Wind and Seismic loads.

STOREY DISPLACEMENT IN MM FOR MODEL 1				
STOREY NUMBER	WIND		SEISMIC	
	X-DIRECTION	Y-DIRECTION	X-DIRECTION	Y-DIRECTION
Storey 31	47.043	94.963	151.141	215.676
Storey 30	46.552	92.818	148.655	209.01
Storey 29	46.048	91.165	147.064	205.915
Storey 28	45.415	88.852	143.934	198.756
Storey 27	44.747	86.969	141.601	194.904
Storey 26	43.948	84.433	137.787	187.157
Storey 25	43.106	82.293	134.748	182.537
Storey 24	42.138	79.528	130.328	174.271
Storey 23	41.125	77.13	126.663	168.953
Storey 22	39.991	74.144	121.731	160.28
Storey 21	38.809	71.497	117.526	154.36
Storey 20	37.514	68.305	112.174	145.401
Storey 19	36.17	65.425	107.516	138.984
Storey 18	34.72	62.047	101.837	129.862
Storey 17	33.221	58.951	96.809	123.056
Storey 16	31.624	55.412	90.892	113.892
Storey 15	29.978	52.124	85.576	106.808
Storey 14	28.244	48.453	79.504	97.721
Storey 13	26.464	45.005	73.98	90.472
Storey 12	24.607	41.241	67.834	81.581
Storey 11	22.711	37.676	62.185	74.286
Storey 10	20.752	33.866	56.033	65.703
Storey 09	18.76	30.227	50.318	58.462
Storey 08	16.721	26.421	44.244	50.285
Storey 07	14.662	22.773	38.543	43.222
Storey 06	12.574	19.047	32.615	35.579
Storey 05	10.483	15.476	27.005	28.844
Storey 04	8.384	11.934	21.304	21.897
Storey 03	6.303	8.58	15.893	15.732
Storey 02	4.253	5.432	10.576	9.828
Storey 01	2.319	2.931	5.677	4.88
PLINTH	0.855	1.21	2.057	1.581
BASE	0	0	0	0

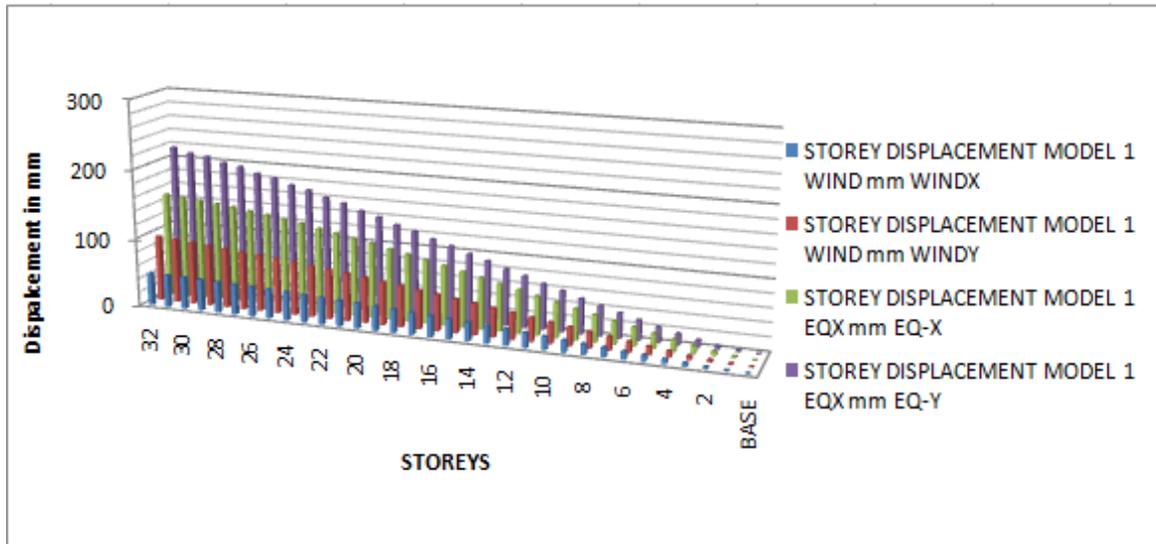


Figure 5.1: Storey Displacement in mm for Model 1 along X and Y direction under both Wind and Seismic loads.

Storey displacement for Model 1 is 227.11% more for seismic compared to wind forces. For storey 31 wind forces are more along Y-direction i.e. 94.963 mm compared to 47.043 mm in X-direction. Seismic forces are more along Y-direction i.e. 215.676 mm compared to 151.141mm in X-direction therefore storey displacement for Model 1 is lesser under wind loads compared to seismic loads.

Table 5.2: Storey Displacement in mm for Model 2 under both Wind and Seismic loads.

STOREY DISPLACEMENT IN MM FOR MODEL 2				
STOREY NUMBER	WIND		SEISMIC	
	X-DIRECTION	Y-DIRECTION	X-DIRECTION	Y-DIRECTION
Storey 31	47.037	94.278	145.693	201.025
Storey 30	46.572	92.196	143.872	195.064
Storey 29	46.043	90.503	141.756	191.887
Storey 28	45.434	88.253	139.294	185.457
Storey 27	44.743	86.333	136.485	181.588
Storey 26	43.965	83.859	133.338	174.598
Storey 25	43.102	81.686	129.875	170.028
Storey 24	42.154	78.982	126.114	162.542
Storey 23	41.121	76.557	122.078	157.341
Storey 22	40.005	73.631	117.788	149.462
Storey 21	38.806	70.962	113.267	143.72
Storey 20	37.526	67.829	108.535	135.558
Storey 19	36.168	64.93	103.615	129.374
Storey 18	34.731	61.611	98.13	121.044
Storey 17	33.219	58.502	93.293	114.519
Storey 16	31.633	55.019	87.932	106.133
Storey 15	29.977	51.723	82.464	99.372
Storey 14	28.252	48.107	76.909	91.04
Storey 13	26.463	44.656	71.286	84.149
Storey 12	24.614	40.943	65.613	75.98
Storey 11	22.711	37.38	59.916	69.07
Storey 10	20.757	33.618	54.192	61.17
Storey 09	18.76	29.986	48.478	54.334

Storey 08	16.725	26.224	42.784	46.793
Storey 07	14.662	22.587	37.129	40.147
Storey 06	12.578	18.901	31.531	33.087
Storey 05	10.483	15.344	26.01	26.768
Storey 04	8.387	11.837	20.589	20.34
Storey 03	6.303	8.5	15.303	14.574
Storey 02	4.255	5.508	10.216	9.107
Storey 01	2.319	3.099	5.466	4.5
PLINTH	0.856	1.311	2.023	1.571
BASE	0	0	0	0

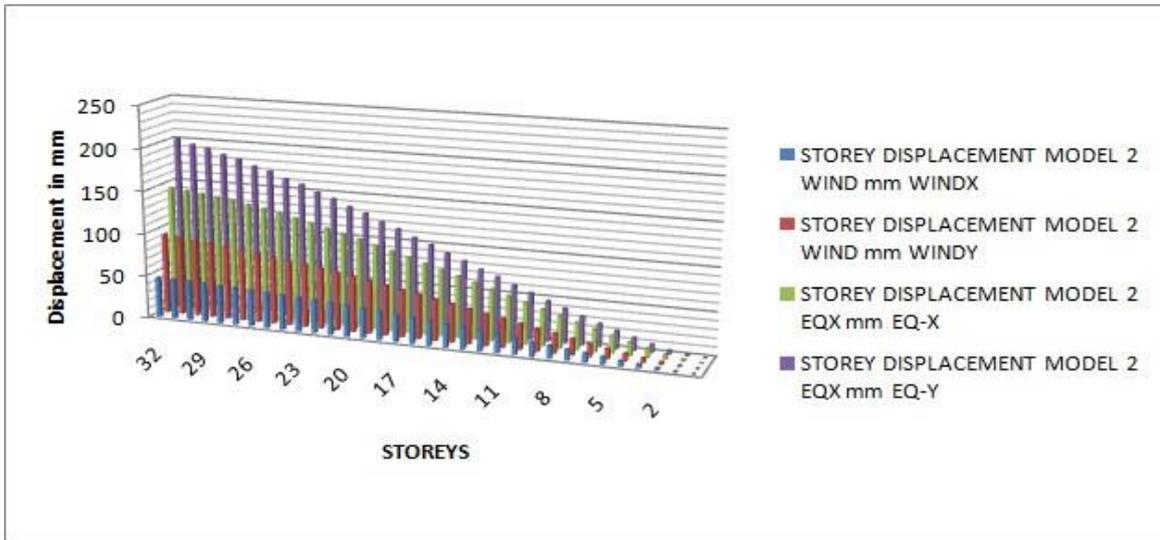


Figure 5.2: Storey Displacement in mm for Model 2 along X and Y direction under both Wind and Seismic loads.

Storey displacement for Model 2 is 213.22 % more for seismic compared to wind forces. For storey 31 wind forces are more along Y-direction i.e. 94.278 mm compared to 47.037 mm in X-direction. Seismic forces are more along Y-direction i.e. 201.025 mm compared to 145.693 mm in X-direction therefore storey displacement for Model 2 is lesser under wind loads compared to seismic loads.

5.3 BASE SHEAR

5.3.1 BASE SHEAR DUE TO WIND LOADS

Table 5.21: Base Shear for all different Model due to Wind loads

BASE SHEAR IN KN DUE TO WIND LOADS		
MODEL NO	X-DIRECTION	Y-DIRECTION
1	3569.08	5809.79
2	3569.0786	5809.79
3	3526.04	5846.81
4	3569.08	5877.81
5	3569.79	5804.71
6	3569.08	5804.73
7	3569.08	5804.73
8	3569.08	5804.73
9	3569.08	5877.55
10	3569.08	5809.79

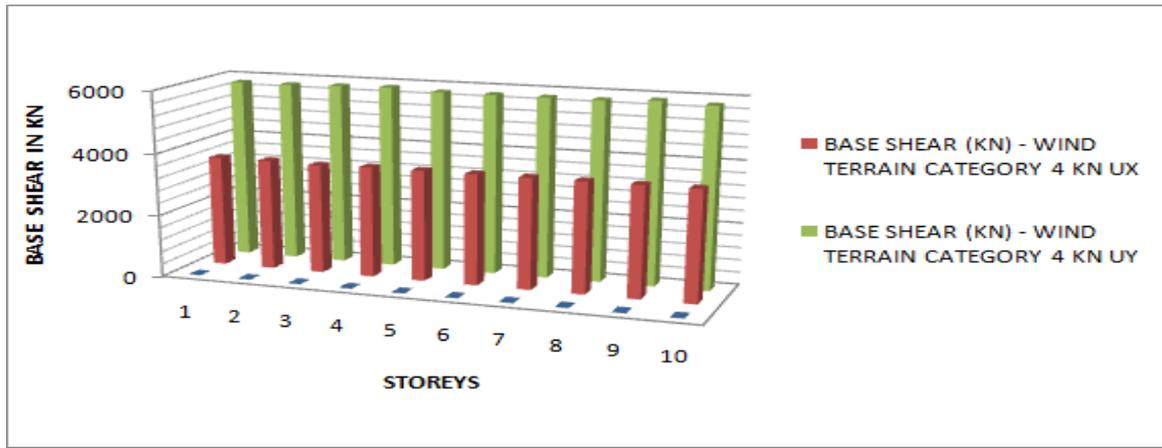


Figure 5.31: Base Shear for all different Model along X and Y direction due to Wind loads

Base shear due to wind loads along X-direction in maximum for Model 5 i.e. 2569.79 KN and minimum for Model 3 i.e. 3526.04 KN. Along Y-direction maximum for Model 4 i.e. 5877.81 KN and minimum for Model 5 i.e. 5804.71 KN therefore base shear is approximately lower for the model 5, model 6, model 7 than other models

5.3.2 BASE SHEAR DUE TO SEISMIC LOADS

Table 5.22: Base Shear for all different Model due to Seismic loads

BASE SHEAR IN KN DUE TO SEISMIC LOADS		
MODEL NO	X-DIRECTION	Y-DIRECTION
1	8126.89	8126.86
2	8123.89	8126.886
3	8445.58	8028.672
4	8116.60	8113.601
5	7955.85	7724.79
6	7769.10	7412.07
7	11185.00	7080.32
8	7386.13	7012.12
9	13867.00	8537.95
10	9001.67	8531.57

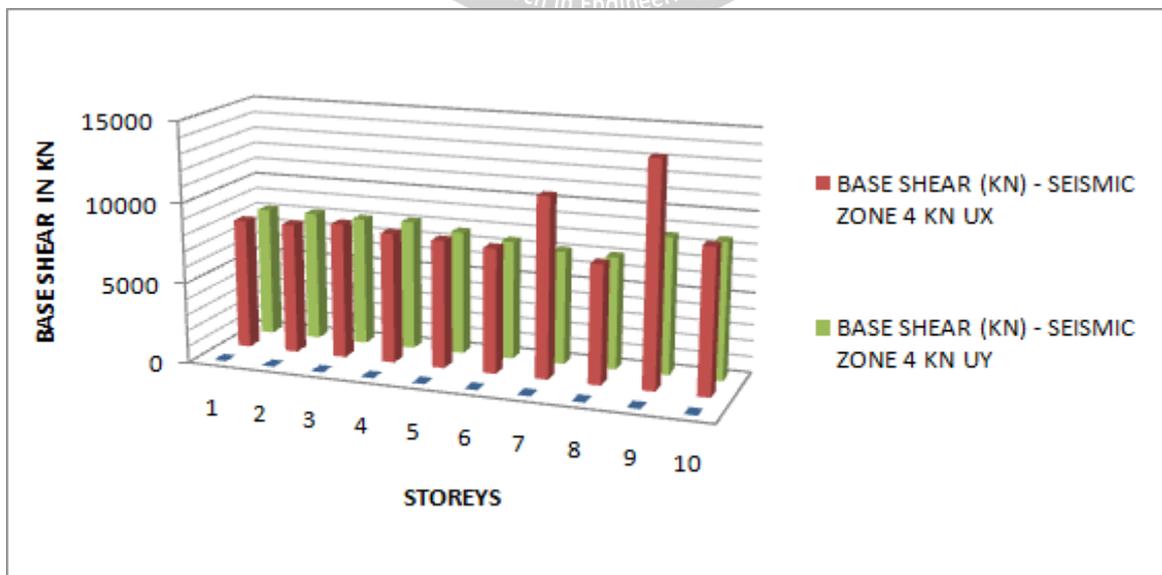


Figure 5.32: Base Shear for all different Model along X and Y direction due to Seismic Loads

Base shear due to seismic loads along X-direction in maximum for Model 9 i.e. 13867 KN and minimum for Model 8 i.e. 7386.13 KN. Along Y-direction maximum for Model 9 i.e. 8537.95 KN and minimum for Model 8 i.e. 7012.12 KN therefore base shear is lower for the model 8 compared to other models

VI. CONCLUSIONS

1. Storey displacement due to seismic loads along Y-direction for model 6 is maximum i.e. 441.421 mm and minimum for model 3 i.e. 194.476 mm and along X-direction for model 8 is maximum i.e. 168.289 mm and minimum for model 9 i.e. 93.126 mm
2. Storey displacement due to wind loads along Y-direction for model 6 is maximum i.e. 235.569 mm and minimum for model 10 i.e. 86.794 mm and along X-direction for model 8 is maximum i.e. 56.905 mm and minimum for model 9 i.e. 17.153 mm
3. Storey drift due to seismic loads along Y-direction for model 8 is maximum i.e. 0.003691 and minimum for model 3 i.e. 0.001219 and along X-direction for model 7 is maximum i.e. 0.000955 and minimum for model 2 i.e. 0.000518 and storey drift is within permissible limit, i.e., 0.004 times the height of storey for all models
4. Storey drift due to wind loads along Y-direction for model 6 is maximum i.e. 0.001577 and minimum for model 3 i.e. 0.000517 and along X-direction for model 8 is maximum i.e. 0.000186 and minimum for model 9 i.e. 0.000085 and storey drift is within permissible limit, i.e., 0.004 times the height of storey for all models
5. Base shear due to seismic loads shear is lower for the model 8 i.e.7012.12 KN compared to other models and due to wind loads is approximately lower for the model 5, model 6, model 7 than other models
6. best design to make the building safe against wind in terrain category 4 and earthquake Loads in zone IV is model 9

REFERENCES

- [1] **A. Pavan Kumar Reddy, R. Master Praveen Kumar** “Analysis of G+30 Highrise Buildings by Using ETABS for Various Frame Sections in Zone IV and Zone V” International Journal of Innovative Research in Science, Engineering and Technology (IJIRSET) Volume 6, Issue 7, July 2017
- [2] **Swati D. Ambadkar, Vipul S. Bawner** “Behaviour of multi-storeyed building under the effect of wind load” International Journal of Applied Sciences and Engineering Research Volume 1, Issue 4, 2012
- [3] **Aleena Raechal George, Dr. R. Umamaheswari** “Comparative study on RCC framed structures with and without shear wall at seismic zones ii and v” International Research Journal of Engineering and Technology (IRJET) Volume: 08, Issue: 07, July 2021
- [4] **Abhishek Yadav, Prince Yadav** “Analysis of High-Rise Multi-storeyed Building With and without Shear Wall by Response Spectrum Method” International Research Journal of Engineering and Technology (IRJET) Volume: 09, Issue: 08, Aug 2022
- [5] **Md. Mohayminul Islam, Syed Abdul Mofiz** “Effect of positioning of shear walls in a multi-storied building on response to earthquake” Engineering Research Express Volume 6, 2024
- [6] **IS 456: 2000** “Code of practice for plain and reinforced concrete” Bureau of Indian Standards, New Delhi.
- [7] **IS 875: (Part 1) 1987** “Code of practice for design loads (Dead Loads) for buildings and structures” Bureau of Indian Standards, New Delhi.
- [8] **IS 875: (Part 2) 1987** “Code of practice for design loads (Imposed Loads) for buildings and structures” Bureau of Indian Standards, New Delhi.
- [9] **IS 875: (Part 3) 1987** “Code of practice for design loads (Wind Loads) for buildings and structures” Bureau of Indian Standards, New Delhi.
- [10] **IS 1893: (Part 1) 2002** “Criteria for earthquake resistant design of structures” Bureau of Indian Standards, New Delhi.