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Analysis of Wind Load on Tall Building of Various Aspect Ratios

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ABSTRACT - *The rapid increase in the population in developing countries such as India has an acute shortage of land and space. To get rid of all these problems, people have resorted to multi-story or tall buildings both for commercial as well as for residential purposes. As the weight of the building increases wind flow is an important consideration for the designers. Tall building considering categories like relative height, proportion, and structural design. Under the Relative height categories, we call a building is tall depending upon the height relative to the surrounding structures. Most importantly from the structural design point of view, those buildings which are subjected to gravity loads are not considered as tall buildings only those which are additionally subjected to lateral loads like wind loads, etc. are referred to as tall buildings. But when we go higher wind excitation becomes one of the most precarious forces acting on the surface of the structure and if the plan geometry is irregular Also direction of wind plays a very vital role in the behavior of the structure. In this Research paper, we study the various types of the spect ratios of the building and the effect of wind forces on the building and also we study about, four-building models having different Horizontal Aspect ratios viz. 1, 2.25, 4 & 9 and height of the building is 96m.*

Key Words: **Aspect Ratio, Horizontal Aspect Ratio, Wind Load, Tall Building, Wind Pressure**

1. INTRODUCTION

The major effects of wind on buildings can be generalized to some degree because of the bracketed range of characteristics that coverall conditions in shape, resulting in various aerodynamic responses. Some buildings have stiff structures, resulting in a limited range of variations of the structure. The wind being fluid is composed of circular eddies of varying sizes and rotational characteristics. These eddies give gusty or turbulent character to the wind which causes a significant effect on the object that comes in its way. The building surface resists the flow of the fluid over them. The fluid exits reaction force on the building which is called drag. The wind also creates vortex shedding in the building in the opposite direction of the wind flow which creates and tremendous load on the building and it differs with the shape of the body that the fluid encounters. The Reynolds number for when having turbulent flow characteristics will be approximately around this value and we know for the same fluid velocity of the drag, or the resistance is much higher in the non-streamlined body shapes like cubes and cylinders. Thus, while designing tall structures engineers take into consideration the shape of the building and for a few shapes having lesser Drag coefficient.

The Tall building RCC structures' construction, high-speed wind forces are known to be causing vibrations and oscillations in the structures. All structures undergo several shape changes under loading.

1.1 ASPECT RATIO

Aspect ratios are of two types of horizontal aspect ratio and vertical aspect ratio. In our research paper, we work on the horizontal aspect ratio. Horizontal aspect ratio is the ratio of L/B which is length L to the base B. The horizontal Aspect Ratio is also called the plan aspect ratio.

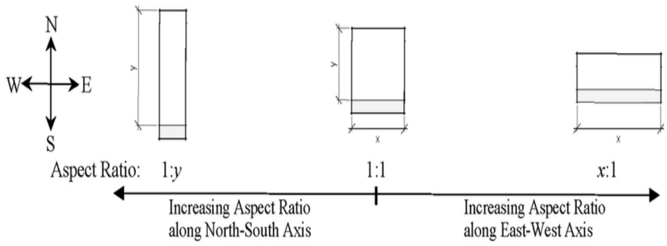


Fig 1.1.1 horizontal aspect ratio

1.2 OBJECTIVES

- To study the behavior of tall high-rise buildings which is subjected to wind loads.
- To study the effect of the shape of the building in the plan on the behavior of the structure.
- To study the various aspect ratio of the building of the same area.
- To determine the effect of wind force on various parameters like maximum displacements, maximum story drift, shear force, a bending moment in the building.
- To define the best suitable Aspect ratio in tall buildings that can provide sound wind loading by observing the comparative studies.
- To make high rise structure in Software which is used for the structural design called ETABS.

2 Literature Review

Guleria, 1481–1485 (2014) The structural behavior of multi-story buildings for various plan configurations such as rectangular, C, L, and I-shape was concluded in his research article. The ETABS software is used to model a 15-story R.C.C. framed building for study. Maximum shear forces, bending moments, and maximum narrative displacement are computed and compared for all of the studied scenarios once the structure has been analyzed. The storey overturning moment varies inversely with storey height, according to the multi-story building's investigation. Furthermore, L-shape and I-shape buildings have nearly identical responses to the overturning moment. The displacement of stories grew with storey height up to the sixth storey, reaching a maximum value, and then began to decrease. Mode forms are created via dynamic analysis, and it may be stated that asymmetrical plans go through this process.

Muley, P. V, Senghani, J. M. & Radke, A. S. 2460–2464 (2019) In this study, the performance of high-rise buildings under seismic and wind excitation for various plan configurations in the same area was reinforced. During seismic and wind excitation, high-rise building constructions of various Plan configurations will behave. The general geometry, scale, and shape of tall RCC buildings will affect how they behave. For the G+60 story structure, twenty-one models were created, ranging from a Ly: Lx ratio of 1:1 to 1:3. These are thought to be in the seismic zone -IV. Finite Element Analysis is used to create and analyze all of the models, and the software ETABS 2017 is used to evaluate them. As the Plan aspect ratio grows in the Y direction, the displacement of the top storey increases. The building's stability, on the other hand, appears to be rising as the Ly: Lx ratio rises. For high-rise buildings, the plan aspect ratio Ly: Lx is critical. With increasing aspect ratios, the Y-direction storey drift parameter for top storey displacement is maximized.

Tirkey, N. & Ramesh Kumar, G. B. 514–518 (2020) The diagrid structure (diagonal perimeter, also known as the diagrid structure) has emerged as an innovative method in the recent construction field, Tall buildings and high-rise structures are being developed not only in the engineering industry, but also in the architectural field., according to his paper. In comparison to traditional buildings, it has also made the construction stiffer and lighter. ETABS software is used to design, evaluate, and compare the diagrid structure to the conventional construction, with a focus on seismic and wind analysis parameters. All structural parts of the diagrid model are constructed according to IS 456:2000 and the Linear Static Method, and seismic load combinations are calculated using IS 1893 (PART 1): 2002. When the structure's height is increased, the lateral load resisting system outperforms the structural system in resisting gravity loads. The layout and efficiency of the diagrid system have reduced the number of structural elements.

3. Methodology

The method of analysis of the tall building of various aspect ratios are:-

- We have to do extensive literature surveys by referring to books, technical papers or research papers carried out to understand basic concepts of the topic.
- Then identification of the need for research is done.
- Formulation of process in analytical work which is to be carried out.
- Then all the data collection is done.
- Then we prepare models in ETABS.
- 30 story building is considered for the analysis.
- After that various Aspect ratio plans are prepared for the buildings.
- After the preparation of models all the loads, dead load, live load, and load combinations are assigned.
- Wind loads for the building according to IS 875 part 3 have been done by using the various parameters.
- Assigning of calculated wind loads on the modeled buildings is to be done.
- After that our model is ready for analysis and design.
- Run the analysis and check the design.
- Check results.
- Studies of results are done and then story drift, shear, story displacement, wind intensity all the aspect ratio of model and determination of structurally efficient building is to be done.
- After all works interpretation of results and conclusion.

4. Structure Details

- Cross-section of beam 0.5x0.5 m for all models.
- Cross-sectional dimension of column 0.9mx0.9 m for 60mx60m , 90mx40m,120mx30m,180mx20m.
- Slab thickness 0.15m
- Number of storeys G+30
- Each story height is 3.2m.
- Supports: Fixed.

- Concrete grade M45 for beam and for column M50
- Steel grade Fe500 for longitudinal bars and distribution bars.
- Steel grade for stirrups Fe250.

MODEL NO.	DIMENSION		SLAB THICKNESS	STOREY HEIGHT	CONCRETE GRADE		STEEL GRADE	
	BEAM	COLUMN	M50 GRADE		BEAM	COLUMN	MAIN BAR	STIRRUPS
M1(60X60)	0.5X0.5	0.9000X0.900	0.15	3.2	M45	M50	Fe500	Fe250
M2(90X40)	0.5X0.5	900X900	0.15	3.2	M45	M50	Fe500	Fe250
M3(120X30)	0.5X0.5	900X900	0.15	3.2	M45	M50	Fe500	Fe250
M4(180X20)	0.5X0.5	900X900	0.15	3.2	M45	M50	Fe500	Fe250

Table 4.0.1: structure details

5. Structural Load Calculation

5.1 Calculation of Dead Load as per IS 875 Part 1 and Live Load as per IS 875 Part 2

Calculation of wall load Table 1.11

Thickness of wall =0.3m

brickwork density = 20 kn/m^3 (we take 1st class brick)

= Density of brick X thickness of wall X (Height of Wall – Depth of Beam) + (plaster thickness X (Height of Wall – Depth of Beam) X density of plaster) = 20 X 0.3X (3.2-0.70) +(0.027 X 2.6X 22) =16.54 KN/M^2

For inner wall whose thickness is 0.2m = 10 KN/M^2

- **Slab load calculation**

Thickness of slab =150mm or 0.150m

Density of concrete =25 KN/M^3

= Density of concrete X thickness of slab

= 25 X 0.150

=3.75 KN/M^2

- **Floor Finish Load in Slab**

As per IS:875 part 1 (dead load) for floor finish load is taken as =1kN/m^2

For thickness of 50mm =0.05M , density of cement mortar =20 KN/M^3

=Thickness of floor finish X density of cement plaster

= 0.05 X 20

=1 KN/M^2

So, the total load in slab = 3.75 + 1

=4.75 KN/M^2

Live Load as per IS:875 part 2 1987

Live Load for commercial building as per IS code is = 5 KN/M^2 Table 1.12

Parapet wall load = 1m

= 1X20X0.254 = 5.08kN /M^2

Table 5.0.1 load details

Load name	Load
Wall load (outer wall and inner wall)	16.54 KN/M^2 and 10 KN/M^2
Slab load	3.75 KN/M^2
Floor finish load	1 KN/M^2
Live load	5 KN/M^2
Parapet wall load	5.08kN /M^2

6. Structure Figures

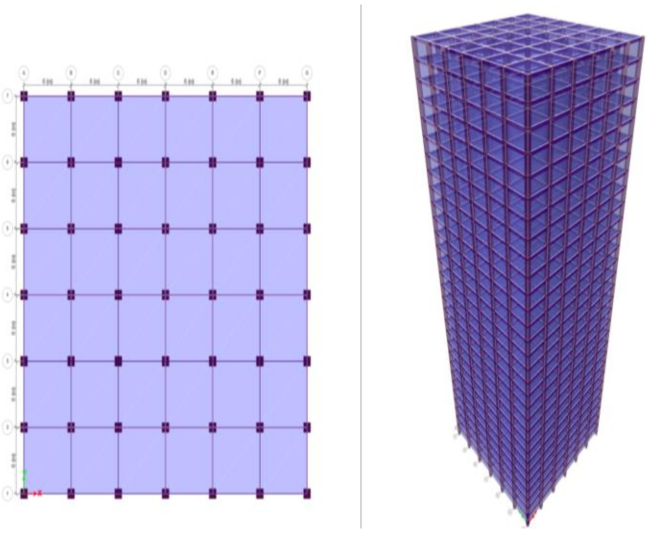


Fig 6.0.1 Model m1 (60m x 60m)

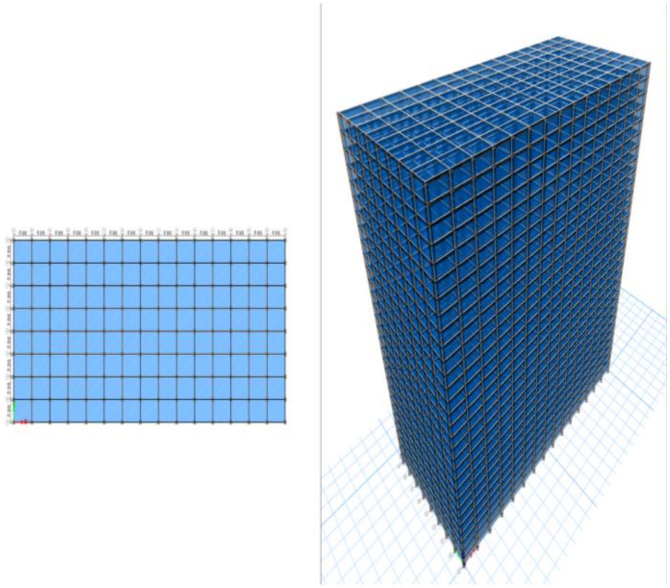
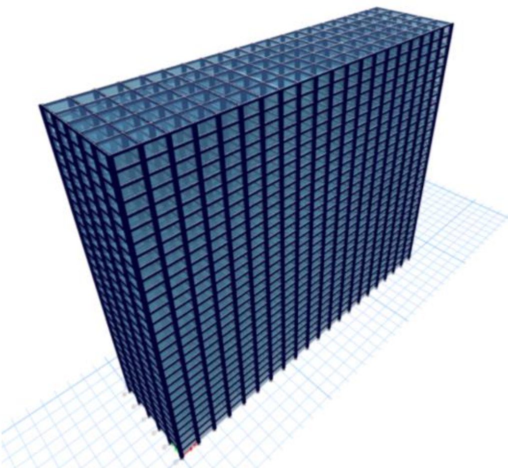


Fig 6.0.2 Model M2 (90m x 40m)



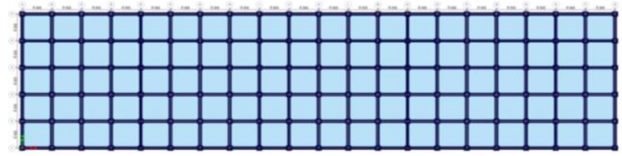


Fig 6.0.3 model M3 (120m x 20m)

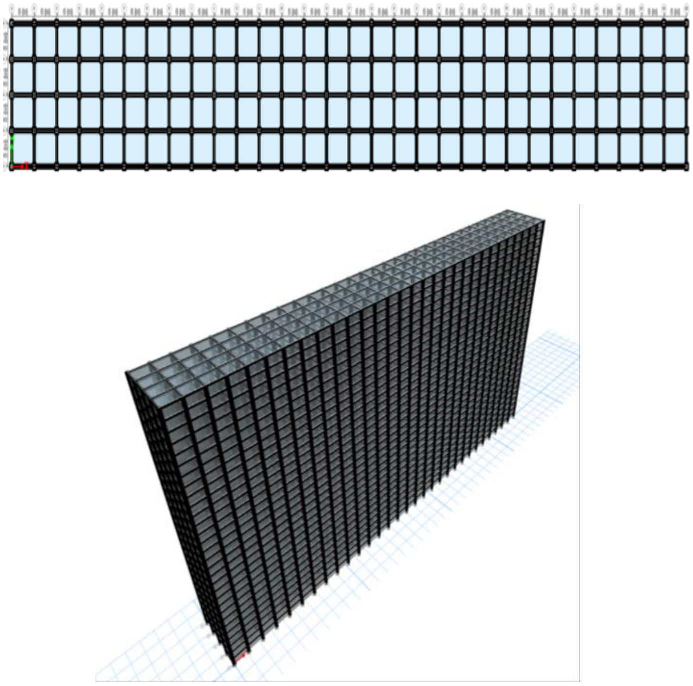


Fig 6.0.4 model M4 (180m x 60m)

7. Load Combination

Table 7.0.1 Load Combinations Details

Numbers	Combinations
DCon1	1.5D. L
DCon2	1.5D. L+1.5LL
DCon3	1.2D. L+1.2LL+1.2WL
DCon4	1.2D. L+1.2LL-1.2WL
DCon5	1.5D. L+1.5WL
DCon6	1.5D.L-1.5LL
DCon7	0.9D. L+1.5WL
DCon8	0.9D.L-1.5LL

8. Wind Load Analysis As Per Is-875 Part-3 (2015)

8.1 Wind load calculation

Wind speed (As per IS-875 2000 Cl.6.3)

Vz = Vb K1 K2 K3 K4

Vz - design wind speed in m/s (Clause 5.3)

Vb - basic wind speed in m/s (Appendix A Clause 5.2)

K1 - probability factor (risk co-efficient) Cl.6.3.1

K2 - Terrain roughness and height factor Cl.6.3.1

K3 - Topography factor Cl.6.3.1

K4 - Importance factor for the cyclonic region Cl.6.3.1

8.2 Design Parameter for wind load

Vb = 50 (for Vishakhapatnam region)

K1 = for 50 year life span of building = 1

K2 = 1.15

(Terrain category)= 3 ,

Structure class = C (for building height above 50 m)

K3 = 1 (when the upwind slope is more than 3 than the effect of topography K3 will be taken as 1)

k4 =1

MODEL NO.	LENGTH	WIDTH	BUILDING ASPEC RATIO (H/W)	BUILDING LENGTH ASPECT RATIO (L/W)	WIND ANGLE (DEGREE)	HEIGHT	EXTERNAL PRESSURE COEFFICIENT (Cpe) FOR SURFACE			
							A	B	C	D
M1	60	60	1.6	1	0	96	+0.8	-0.25	-0.8	-0.8
M2	90	40	2.4	2.25	0	96	+0.7	-0.4	-0.7	-0.7
M3	120	30	3.2	4	0	96	+0.7	-0.4	-0.7	-0.7
M4	180	20	4.8	9	0	96	+0.7	-0.4	-0.7	-0.7

Table 8.01 Wind load Calculation

9. Results and Discussion

When the aspect ratio of a building increases, the storey displacement also increases. This will show how much wind load a building of a specification can stand and therefore, this gives an important point of consideration in designing a building that will be subjected to the heavy wind loads, especially in the areas where the effect of wind load is more prominent than the effect of an earthquake. This chapter deals with the concluding remarks drawn from the results of all the analysis and design made for the G+30 storey building with the different type of aspect ratio having same floor area (3600 sq. m)is considered for analysis. The results have been presented in tabular form along with the graphical mode in this chapter.

Table 9.0.1 Results

Results	MAXIMUM DISPLACEMENT	MAXIMUM STORY DRIFT
model 60x60	0.3563	0.000043
model 90x40	0.3545	0.000104
model 120x30	0.3796	0.0001
model 180x20	0.4783	0.000104

From the results, we can say that the displacement in model 180X20 is much more than in another model with respect to wind loads. The axial forces in columns increase as the aspect ratio increases as well as the bending moment in columns also increase. The base reaction in the x-direction is comparatively less than in the y-direction. The same effect has been observed for beam, no major changes have been seen

9.1 Maximum displacement graph

This graph shows a Maximum displacement on each building due to wind load. Results are shown as a comparison of all the models Starting from plan aspect ratios of all the structures, analysis with different aspect ratios located in a high wind zone.

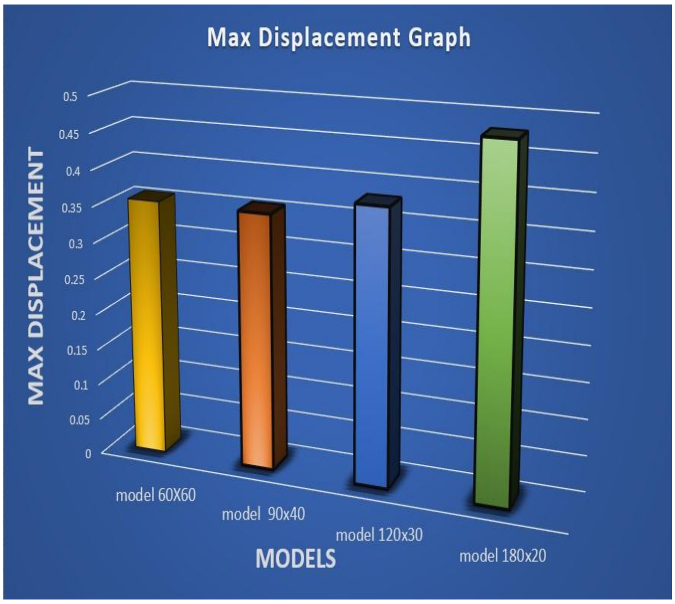


Fig 9.0.1 Max Displacement

9.2 Maximum Story Drift

This graph shows a maximum story drift on each building due to wind load. Results are shown as a comparison of all the models Starting from plan aspect ratios of all the structures, analysis with different aspect ratios located in a high wind zone

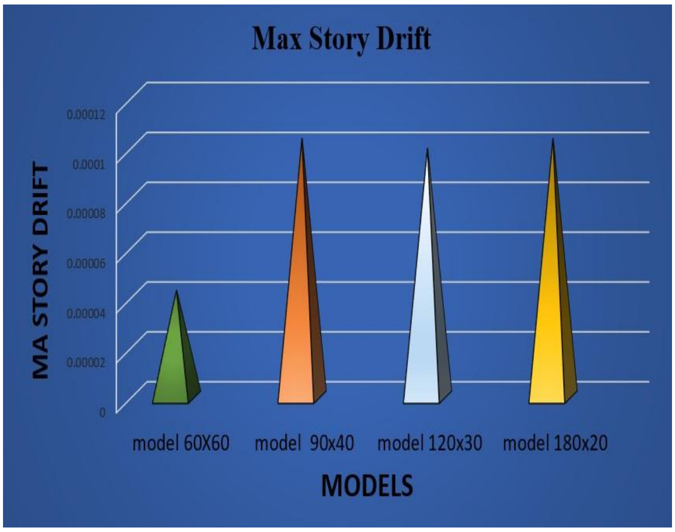


Fig 9.0.2 Max Story Drift

10. Shear Force and Bending Moment Diagram of Model 60m X 60m

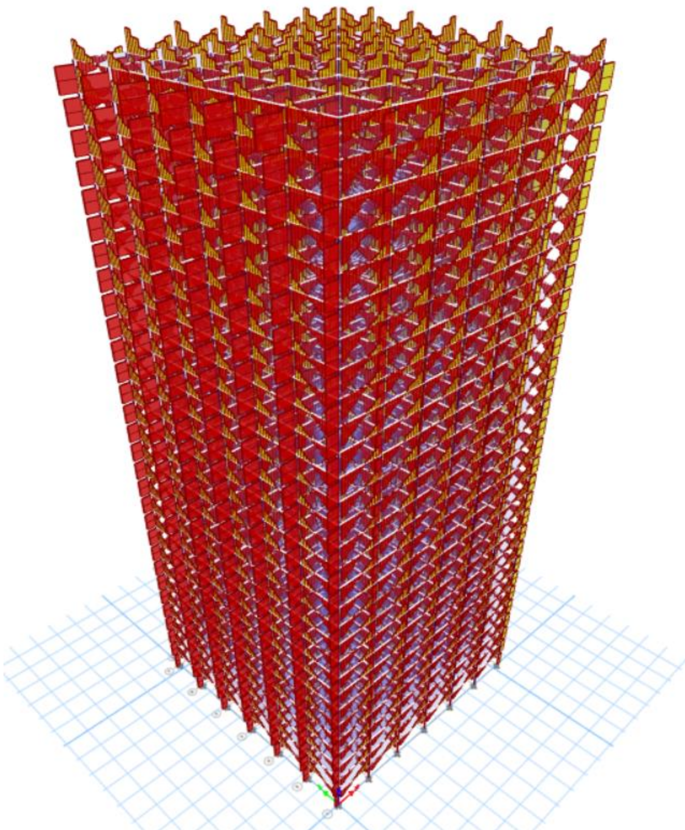


Fig 10.1 Shear Force (Elevation View)

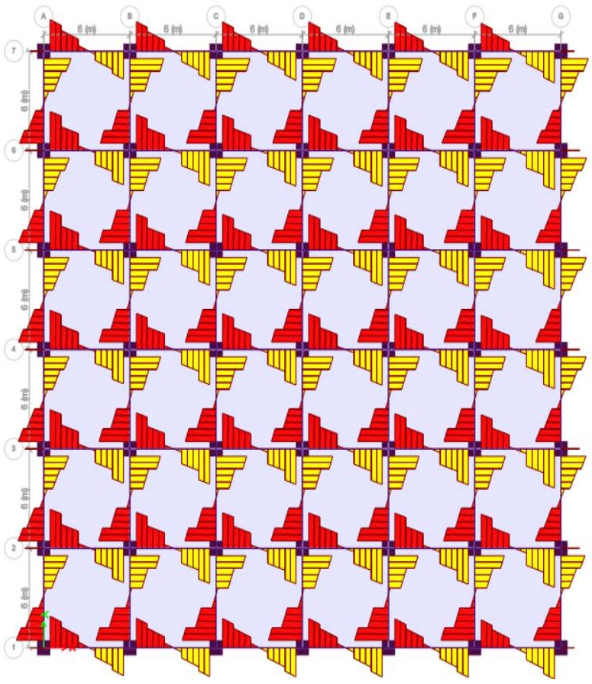


Fig 10.2 Shear Force (Plan View)

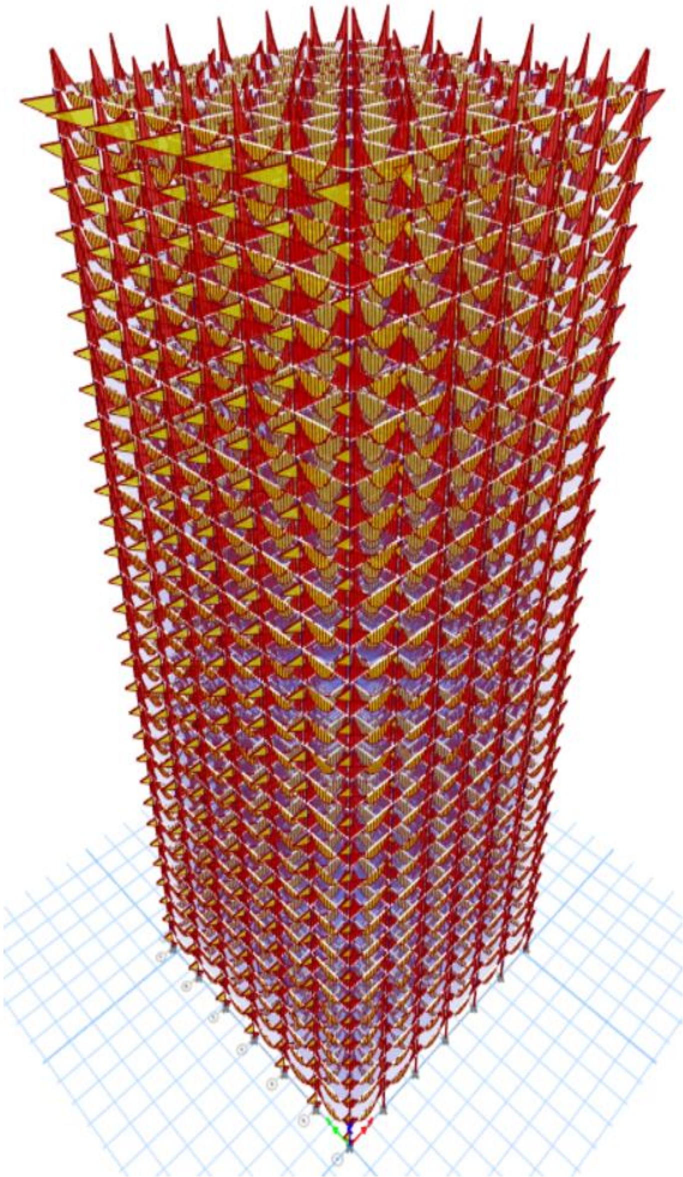


Fig 10.3 Bending Moment (Elevation View)

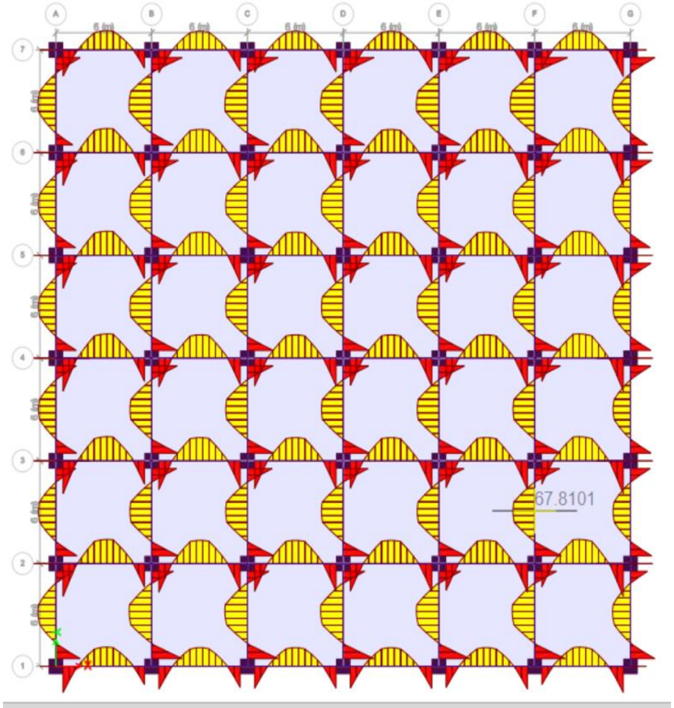


Fig 10.4 Bending Moment (Plan View)

11. Conclusions

Comparison of regular and irregular structures in terrain category was done on the basis of storey displacement, storey drift, storey shear. Following conclusion points wind analysis of the G+30 story buildings.

1. It was discovered in this investigation that when the number of spans rises, the base shear increases gradually.
2. The base shear is obtained lower for 2 spans buildings and higher for 20 spans buildings. The lowest value is obtained in the case of 2 bay (square) building whereas the highest is in the case of a 20 bay (rectangular) building.
3. With an increase in the number of spans, the storey drifts gradually decrease in the x-direction. The storey drift is smaller for buildings with 20 spans and higher for buildings with two spans.
4. In x-direction, the story displacement decreases with an increase in the number of spans.
5. The storey displacement is greatest in a building with two spans (square) and lowest in a building with twenty spans (rectangular).
6. The storey drifts in y-direction increase gradually with an increase in the number of spans since it is much narrow side comparative to the x-direction.

7. It has been observed that the storey displacement in y-direction increases with the increase of spans.

12. REFERENCES

[1] Paul, R. & Dalui, S. K. Wind effects on 'Z' plan-shaped tall building: a case study. Int. J. Adv. Struct. Eng. 8, 319–335 (2016).

[2] Sanyal, P. & Dalui, S. K. Effects of courtyard and opening on a rectangular plan shaped tall building under wind load. Int. J. Adv. Struct. Eng. 10, 169–188 (2018).

[3] Chen, F. Bin et al. Study of Wind Loads and Wind Speed Amplifications on High-Rise Building with Opening by Numerical Simulation and Wind Tunnel Test. Adv. Civ. Eng. 2020, (2020).

[4] Ahmed, M., Ahmed, N. S., Roy, S. & Haque, M. A Comparative Study on Various Horizontal Aspect Ratios on Seismic Performance of Regular Shape G + 10 Storey RCC Building. (2019) doi:10.13140/RG.2.2.24052.81284.

[5] Guleria, A. Structural Analysis of a Multi-Storeyed Building using ETABS for different Plan Configurations. Int. J. Eng. Res. Technol. 3, 1481–1485 (2014).

[6] Muley, P. V, Senghani, J. M. & Radke, A. S. Performance of High Rise Building Under Seismic and Wind Excitation for the Different Plan Configurations of Same Area. 2460–2464 (2019).

[7] Tirkey, N. & Ramesh Kumar, G. B. Analysis on the diagrid structure with the conventional building frame using ETABS. Mater. Today Proc. 22, 514–518 (2020).

[8] Rajas, A. S. & Shelke, N. L. Wind Analysis of High Rise Building with Different Bracing Systems. 3, 1923–1930 (2016).

[9] Sadh, A. & Pal, A. A Literature Study of Wind Analysis on High Rise Building. Int. J. Adv. Eng. Res. Sci. 5, 263–265 (2018).

[10] Sadh, S. K. & Pendharkar, U. Influence of Aspect Ratio & Plan Configurations on Seismic Performance of Multistoreyed Regular R.C.C. Buildings: An Evaluation by Response Spectrum Analysis. Int. Res. J. Eng. Technol. (2016).