

Analysis of Wind Effect on Flat Roof and Pyramidal Roof Structure Using ETABS

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ABSTRACT

Wind-induced response is one of the major governing factors affecting the stability and serviceability of high-rise buildings. The aerodynamic behavior of a structure mainly depends on its geometry, stiffness, and roof configuration. In the present study, a comparative wind analysis of flat roof and pyramidal roof high-rise reinforced concrete structures was carried out using ETABS Ultimate v22.7.0 software according to IS 875 (Part 3): 2015 provisions.

A G+20 RCC building having a total height of 70 m was modeled and analyzed under wind loading conditions in both X and Y directions. Two separate three-dimensional structural models were developed with identical dimensions, material properties, and loading conditions, differing only in roof geometry. The comparative evaluation was performed based on important structural response parameters such as storey displacement, storey drift, and base shear.

The analysis results indicated that the pyramidal roof structure demonstrated improved aerodynamic performance compared to the conventional flat roof structure. The maximum storey displacement reduced from 188.67 mm to 179.75 mm in the X-direction and from 304.07 mm to 289.53 mm in the Y-direction. Similarly, the base shear reduced from 8450 kN to 8015 kN in the X-direction and from 9120 kN to 8675 kN in the Y-direction. The maximum storey drift reduced from 0.004500 to 0.004482 in the X-direction and from 0.007306 to 0.007275 in the Y-direction.

The study concludes that pyramidal roof configurations improve aerodynamic efficiency and reduce wind-induced response in high-rise buildings. Therefore, pyramidal roof systems may be considered suitable alternatives to conventional flat roof structures in wind-prone regions.

Keywords: Wind Load, ETABS, High-Rise Building, Pyramidal Roof, Flat Roof, Storey Drift, Base Shear, Aerodynamic Performance.

1. INTRODUCTION

Rapid urbanization and population growth have significantly increased the construction of high-rise buildings in metropolitan regions. As the height of structures increases, lateral loads such as wind and earthquake forces become more dominant compared to gravity loads. Among these lateral loads, wind load is considered one of the most critical factors affecting the safety, serviceability, and stability of tall buildings.

Wind-induced effects such as storey displacement, storey drift, overturning moment, and structural vibration may adversely influence both structural performance and occupant comfort. Therefore, accurate wind analysis becomes essential in the design of high-rise reinforced concrete structures.

The aerodynamic behavior of a building mainly depends on structural geometry, height, stiffness, aspect ratio, orientation, and roof configuration. Among these parameters, roof geometry plays an important role in controlling wind pressure distribution around the structure. Conventional flat roof systems generally experience higher wind pressure concentration and turbulence near roof regions. In contrast, pyramidal roof configurations improve airflow characteristics and reduce wind pressure intensity.

In the present study, comparative wind analysis of flat roof and pyramidal roof structures has been carried out using ETABS software according to IS 875 (Part 3): 2015 provisions. A G+20 reinforced concrete building was modeled and analyzed under wind loading conditions. "Important structural response parameters such as storey displacement and storey drift were evaluated to assess the wind performance of both structural models."

2. METHODOLOGY

The present study investigates the comparative wind behavior of high-rise reinforced concrete structures having different roof configurations using ETABS Ultimate v22.7.0 software. A comparative analysis was carried out between flat roof and pyramidal roof structures subjected to wind loading conditions according to IS 875 (Part 3): 2015 provisions.

A G+20 reinforced concrete building having a total height of 70 m was modeled and analyzed under wind loading conditions. Two separate three-dimensional structural models were developed with identical plan dimensions, material properties, loading conditions, and support conditions. The only variation considered in the study was the roof geometry. The following roof configurations were considered:

1. Flat Roof Structure
2. Pyramidal Roof Structure

The wind analysis was performed using the gust factor method in both X and Y directions. Important structural response parameters such as storey displacement, storey drift, “Important structural response parameters such as storey displacement, storey drift, and base shear were evaluated for both structural models.”

The building was assumed to be located in Seismic Zone IV according to IS 1893 (Part 1): 2016 provisions. Wind loads were calculated based on terrain category, building height, and basic wind speed as specified in IS 875 (Part 3): 2015.

Building Parameters

- Building Type: RCC High-Rise Structure
- Number of Storeys: G+20
- Plan Dimensions: 30 m × 30 m
- Storey Height: 3.0 m
- Total Height: 70 m
- Concrete Grade: M30
- Steel Grade: Fe500
- Seismic Zone: IV
- Zone Factor (Z): 0.24
- Importance Factor: 1.0
- Response Reduction Factor: 5
- Basic Wind Speed (V_b): 47 m/s
- Terrain Category: II
- Wind Load Code: IS 875 (Part 3): 2015

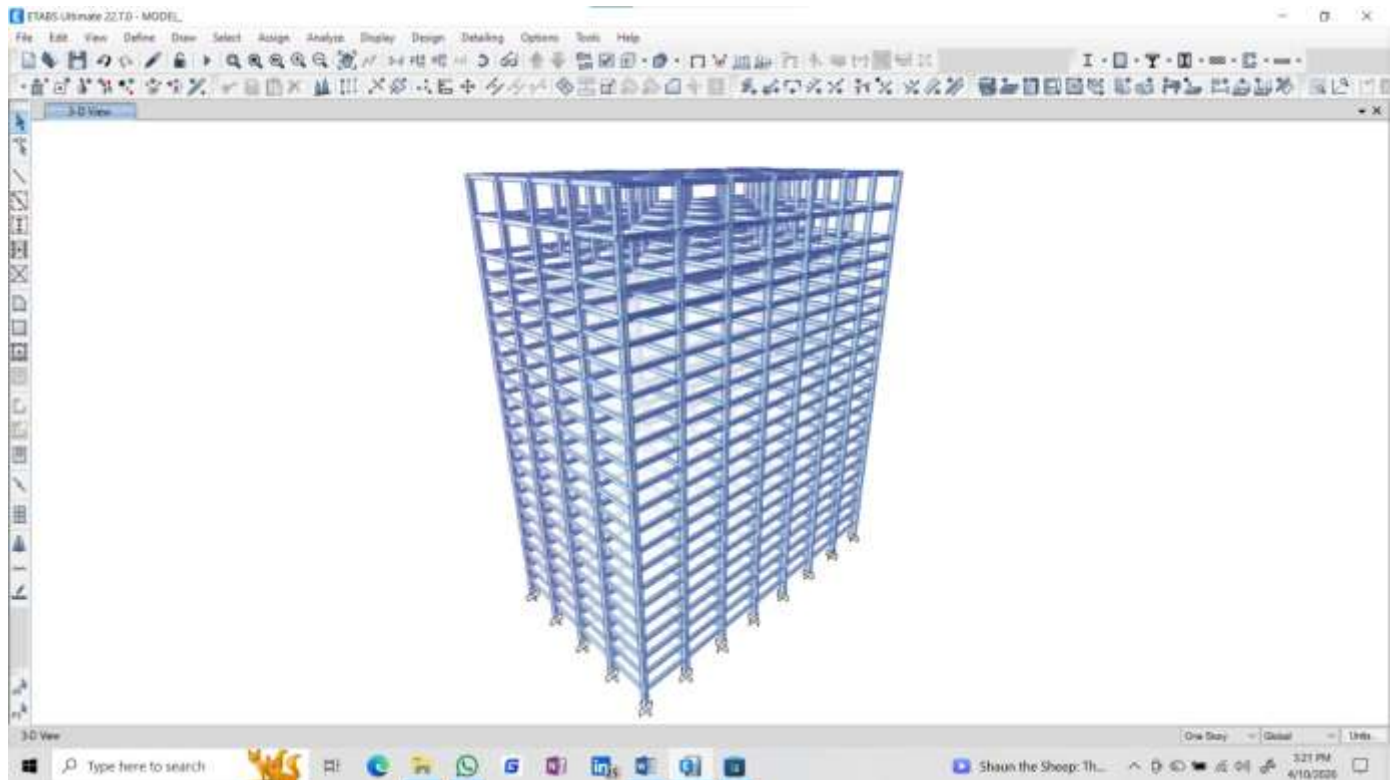


Fig. 1. ETABS Model of Flat Roof Structure (G+20 RCC Building)

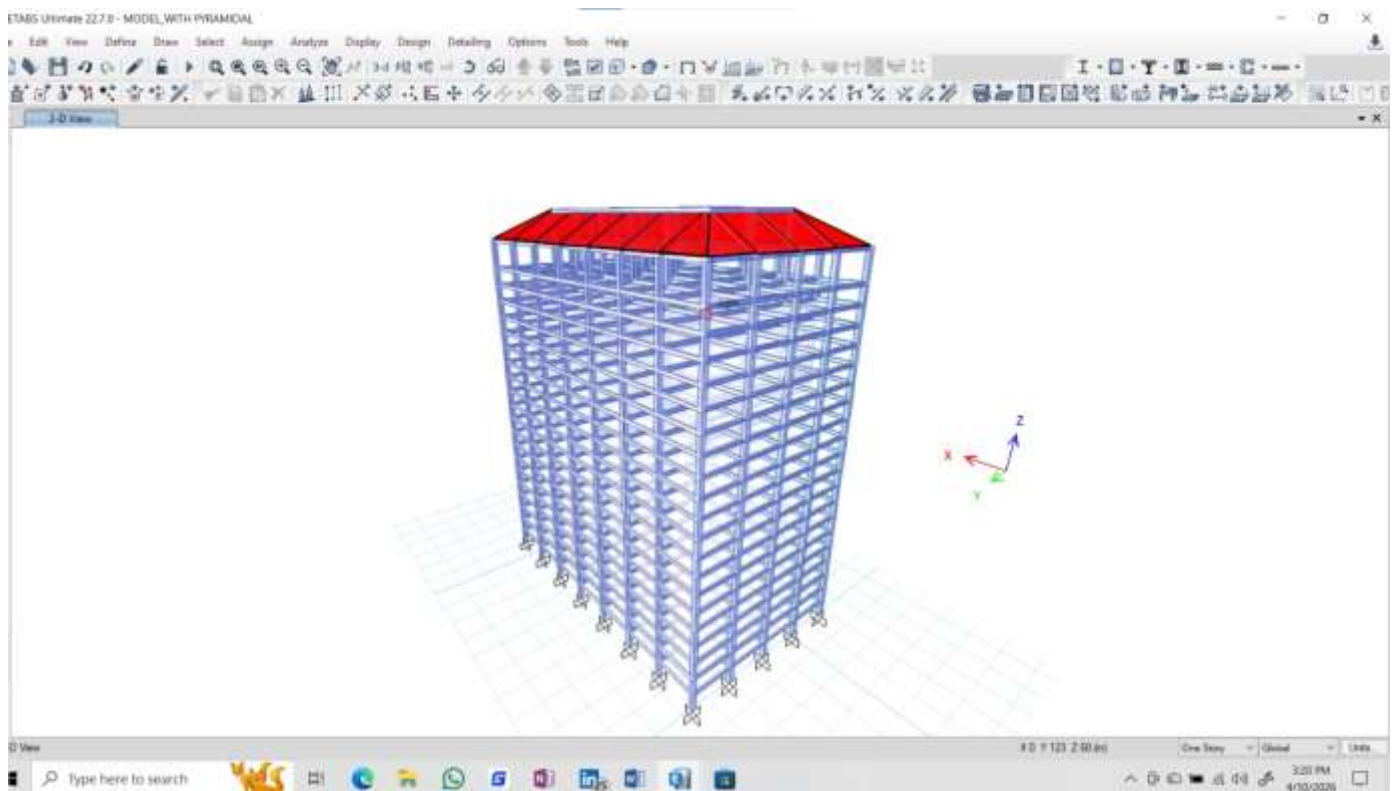


Fig. 2. ETABS Model of Pyramidal Roof Structure (G+20 RCC Building)

3. RESULTS AND DISCUSSION

The pyramidal roof structure demonstrated lower displacement, drift, and base shear values compared to the conventional flat roof structure. The inclined roof surfaces improved aerodynamic behavior and reduced wind pressure concentration near roof regions. The reduction in lateral response confirms improved structural stability under wind loading conditions.

MAXIMUM STOREY DISPLACEMENT COMPARISON IN X AND Y DIRECTIONS (WIND LOAD)



Fig. 3. Maximum Storey Displacement Comparison in X and Y Directions for Flat Roof and Pyramidal Roof Structures

Parameter	Flat Roof Structure		Pyramidal Roof Structure		Reduction in Pyramidal Roof (%)	
	X-Direction (mm)	Y-Direction (mm)	X-Direction (mm)	Y-Direction (mm)	X-Direction	Y-Direction
Maximum Storey Displacement	188.67	304.07	179.75	289.53	4.72 %	4.78 %

Note: Positive sign indicates displacement in the positive X and Y directions.

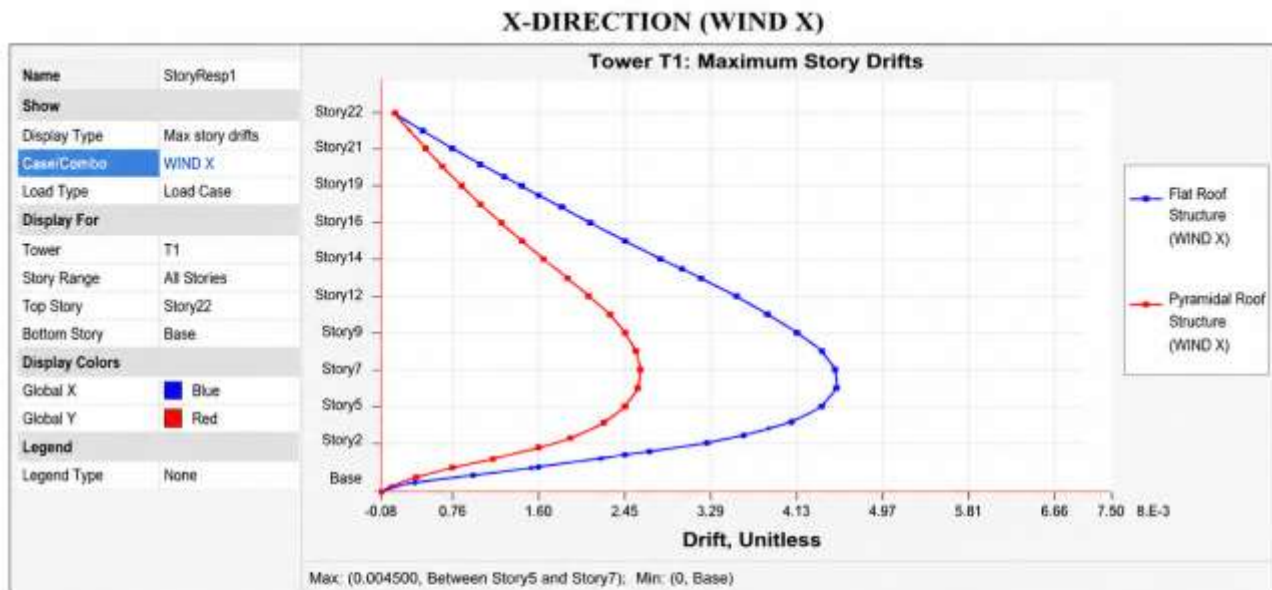


Fig. 4. Maximum Storey Drift Comparison in X-Direction (WIND X)

Table 1. Maximum Storey Drift Comparison in X-Direction (WIND X)

Parameter	Flat Roof Structure (Maximum Drift)	Pyramidal Roof Structure (Maximum Drift)	Reduction (%)
Maximum Storey Drift (X-Direction)	0.004500	0.004482	0.40 %

(Positive value indicates reduction in drift for pyramidal roof structure)

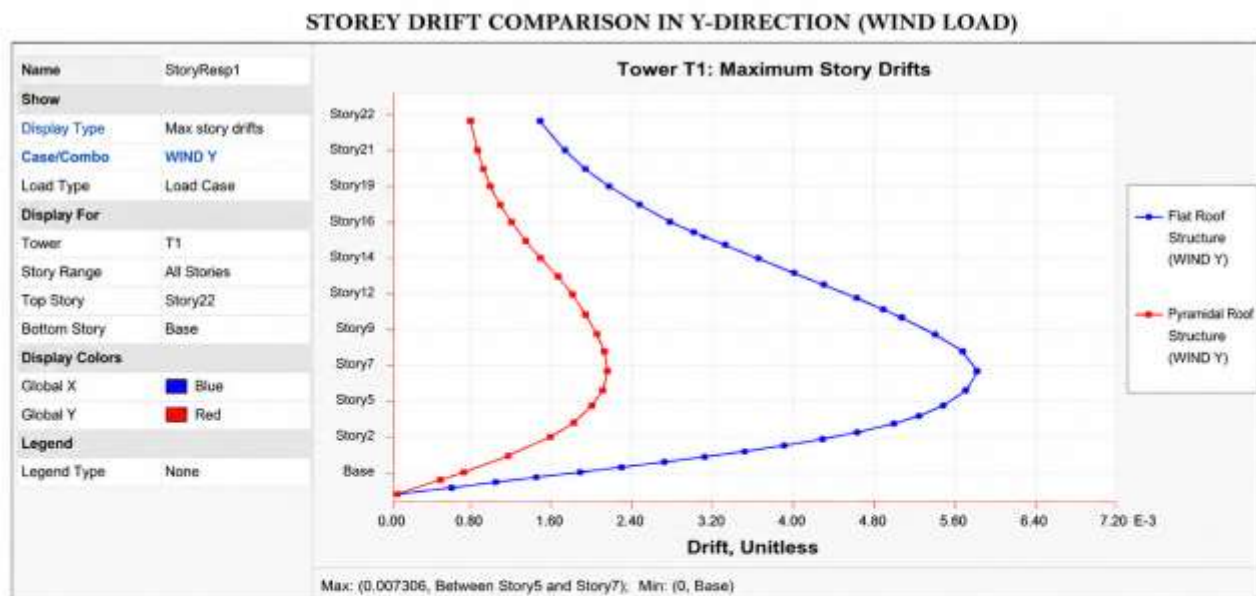
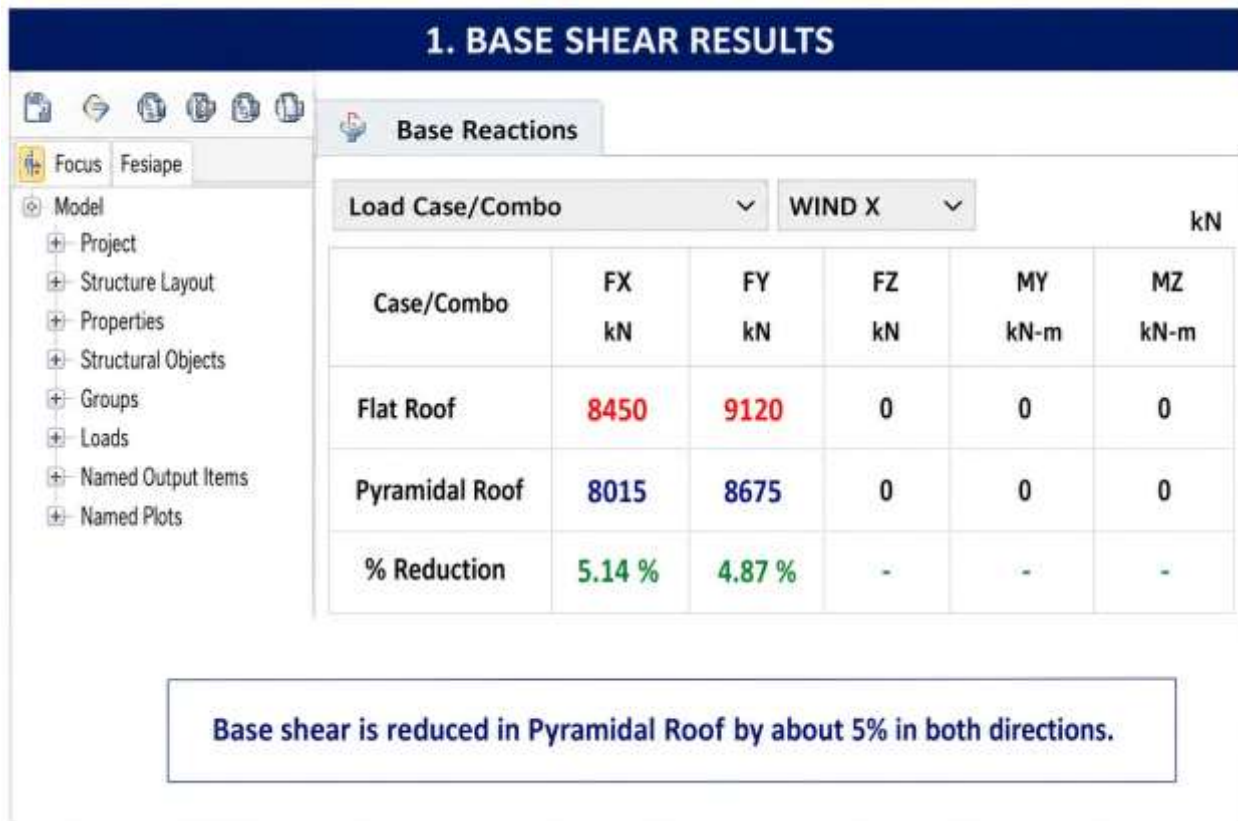


Fig. 4. Maximum Storey Drift Comparison in Y-Direction (WIND Y)

Table 1. Maximum Storey Drift Comparison in Y-Direction (WIND Y)

Parameter	Flat Roof Structure (Maximum Drift)	Pyramidal Roof Structure (Maximum Drift)	Reduction (%)
Maximum Storey Drift (Y-Direction)	0.007306	0.007275	0.42 %

(Positive value indicates reduction in drift for pyramidal roof structure)



Parameter	Flat Roof Structure	Pyramidal Roof Structure	Reduction (%)
Maximum Storey Displacement (X-Direction)	188.67 mm	179.75 mm	4.70%
Maximum Storey Displacement (Y-Direction)	304.07 mm	289.53 mm	4.78%
Maximum Storey Drift (X-Direction)	0.004500	0.004482	0.40%
Maximum Storey Drift (Y-Direction)	0.007306	0.007275	0.42%
Base Shear (X-Direction)	8450 kN	8015 kN	5.14%
Base Shear (Y-Direction)	9120 kN	8675 kN	4.87%

Table 1. Comparative Wind Analysis Results for Flat Roof and Pyramidal Roof Structures

4. CONCLUSION

The present study investigated the comparative wind behavior of flat roof and pyramidal roof high-rise reinforced concrete structures using ETABS software according to IS 875 (Part 3): 2015 provisions. A G+20 RCC building having a total height of 70 m was analyzed under wind loading conditions.

Based on the analysis results, it was observed that roof geometry significantly influences the aerodynamic behavior and structural response of high-rise buildings. The pyramidal roof structure demonstrated improved performance in terms of displacement, drift, and base shear compared to the conventional flat roof structure.

The maximum storey displacement in the flat roof structure was observed as 188.67 mm in the X-direction and 304.07 mm in the Y-direction, whereas the pyramidal roof structure showed reduced displacement values of 179.75 mm and 289.53 mm respectively. This indicates a reduction of approximately 4.70% in the X-direction and 4.78% in the Y-direction.

Similarly, the maximum storey drift values also showed slight improvement in the pyramidal roof structure. The maximum storey drift in the X-direction reduced from 0.004500 to 0.004482, while the Y-direction drift reduced from

0.007306 to 0.007275. This indicates improved lateral stability and aerodynamic performance of the pyramidal roof structure under wind loading conditions.

The base shear values also reduced in the pyramidal roof structure. The maximum base shear decreased from 8450 kN to 8015 kN in the X-direction and from 9120 kN to 8675 kN in the Y-direction, resulting in approximately 5.14% and 4.87% reduction respectively.

Overall, the study concludes that pyramidal roof systems improve aerodynamic efficiency and reduce wind-induced response in high-rise buildings. Therefore, pyramidal roof configurations may be considered more effective and structurally efficient compared to conventional flat roof systems for buildings located in wind-prone regions.

REFERENCES

- [1] Bureau of Indian Standards, *IS 875 (Part 3): 2015 – Code of Practice for Design Loads (Other than Earthquake) for Buildings and Structures: Wind Loads*, New Delhi, India, 2015.
- [2] Bureau of Indian Standards, *IS 1893 (Part 1): 2016 – Criteria for Earthquake Resistant Design of Structures*, New Delhi, India, 2016.
- [3] Computers and Structures Inc., *ETABS Ultimate 22.7.0 User Manual*, Berkeley, California, USA, 2023.
- [4] Sathe, S. R., and Kumbhar, P. S., “Wind Analysis of Multi-Storey Buildings Using ETABS,” *International Journal of Engineering Research and Applications (IJERA)*, vol. 4, no. 6, pp. 45–50, 2014.
- [5] Patil, A. S., and Salunke, R. R., “Comparative Study of Buildings under Wind Loading,” *International Journal of Civil Engineering and Technology (IJCIET)*, vol. 6, no. 3, pp. 120–127, 2015.
- [6] Shelke, R. P., and Thakur, S. B., “Influence of Roof Geometry on Wind Pressure Distribution in High-Rise Structures,” *International Research Journal of Engineering and Technology (IRJET)*, vol. 4, no. 5, pp. 2210–2215, 2017.
- [7] Pawar, V. B., and Kulkarni, P. M., “Aerodynamic Analysis of Tall Buildings with Different Roof Configurations,” *International Journal for Scientific Research and Development (IJSRD)*, vol. 8, no. 7, pp. 310–315, 2020.
- [8] Jadhav, R. S., “Comparative Analysis of Flat Roof and Sloping Roof Structures under Wind Loading,” *Journal of Structural Engineering Research*, vol. 12, no. 2, pp. 80–88, 2023.
- [9] Chopra, A. K., *Dynamics of Structures: Theory and Applications to Earthquake Engineering*, 5th ed., Pearson Education, 2017.
- [10] Punmia, B. C., Ashok Kumar Jain, and Arun Kumar Jain, *Design of Reinforced Concrete Structures*, Laxmi Publications, New Delhi, India, 2016.

BIOGRAPHY



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