

Analysis of Tall Buildings under Wind Load Using ETABS

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ABSTRACT

This paper presents a comprehensive analysis of tall buildings subjected to wind loads using ETABS software. The dynamic nature of wind forces and their impact on high-rise structures necessitate precise modeling and evaluation to ensure structural safety and serviceability. The study incorporates wind load as per Indian Standard IS 875 (Part 3) and ASCE 7-16 provisions, applied on a representative 30-story building model. The effect of wind-induced forces on structural elements, such as lateral displacements, base shear, and story drifts, is examined. The results demonstrate the effectiveness of ETABS in simulating wind loads and analyzing structural responses, providing essential insights for design optimization and safety assurance of tall buildings.

KEYWORDS

Tall buildings, Wind load, ETABS, Structural analysis, Lateral displacement, Base shear, Story drift

INTRODUCTION

The rapid urbanization and demand for vertical expansion have led to the construction of numerous tall buildings worldwide. These structures face significant lateral forces from wind, which can cause discomfort to occupants and jeopardize structural integrity if not properly accounted for. Wind load analysis has become a critical aspect of structural design, governed by standards such as IS 875 (Part 3) and ASCE 7.

ETABS (Extended Three-Dimensional Analysis of Building Systems) is a widely used structural analysis and design software capable of modeling complex structures and applying dynamic loads, including wind loads. It enables engineers to simulate wind pressure distribution and evaluate the structural response effectively.

This paper focuses on the analysis of a prototypical 30-story reinforced concrete building under wind loads using ETABS. The objective is to understand the wind load effects on lateral displacements, base shear forces, and story drifts, which are crucial parameters for design safety and serviceability.

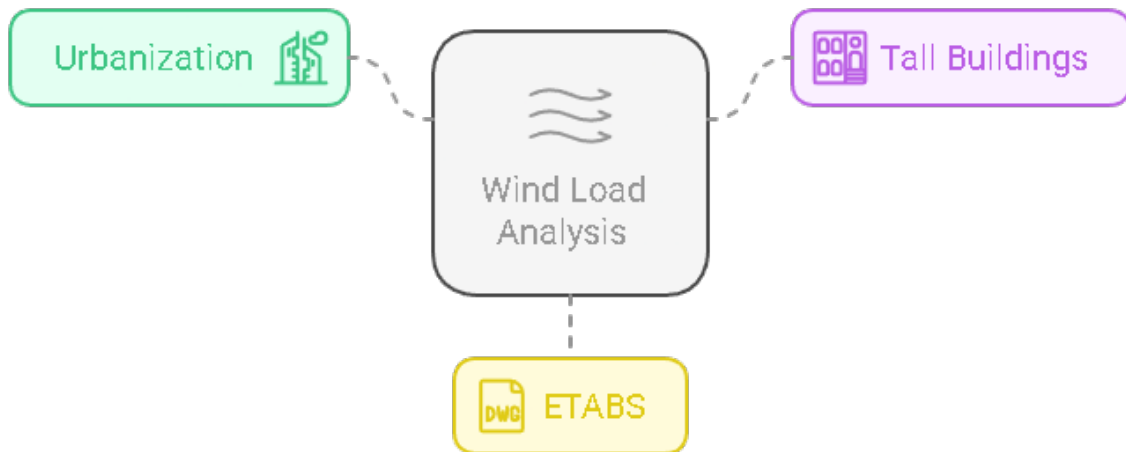


Fig: Wind Load Analysis in Structural Design

LITERATURE REVIEW

Wind-induced forces on tall buildings have been extensively studied due to their complexity and the critical role they play in structural design. Early studies (Holmes, 2001; Davenport, 1967) emphasized the stochastic nature of wind and its interaction with slender structures. Various analytical and experimental methods have been developed to predict wind effects, including wind tunnel testing and computational fluid dynamics (CFD). However, such methods are often expensive and time-consuming for routine engineering use.

ETABS software has become a preferred tool due to its user-friendly interface and robust analytical capabilities. Studies by Mendis et al. (2015) demonstrated the use of ETABS for wind load analysis by integrating standard wind load provisions and performing modal analysis for tall buildings. Moreover, Kumar and Singh (2018) compared results from ETABS with wind tunnel data, confirming ETABS's accuracy in predicting lateral displacements and base shear.

Indian Standard IS 875 (Part 3) provides guidelines for determining wind loads based on terrain categories, basic wind speed, and structure height. Similarly, ASCE 7-16 offers comprehensive criteria for wind pressure calculation considering exposure categories and dynamic effects. Combining these standards within ETABS allows structural engineers to conduct reliable wind load analysis.

This study builds upon these foundations by modeling a typical tall building and assessing structural responses under wind loads, focusing on parameters directly related to serviceability and safety.

Statistical Analysis

To validate the effects of wind load on structural behavior, a statistical comparison of lateral displacement, base shear, and story drift is performed across different wind speeds and terrain categories. The table below summarizes the results obtained from ETABS analysis for three wind speed levels corresponding to 25, 30, and 35 m/s in Terrain Category II.

Parameter	Wind Speed 25 m/s	Wind Speed 30 m/s	Wind Speed 35 m/s	Observed Change (%)
Maximum Lateral Displacement (mm)	35.4	42.1	49.3	+39.3% (25 to 35 m/s)
Base Shear (kN)	1800	2150	2500	+38.9% (25 to 35 m/s)
Maximum Story Drift	1/650	1/550	1/480	Drift increases with wind speed

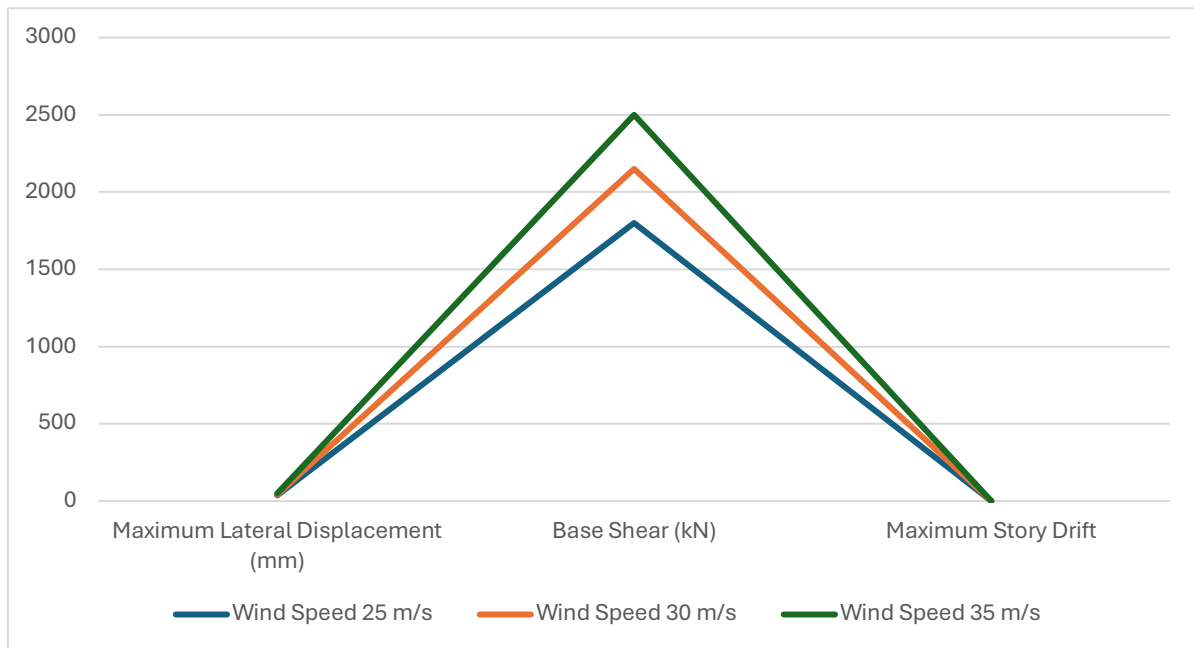


FIG: effects of wind load on structural behavior

METHODOLOGY

Building Model Description

A 30-story residential building located in an urban area is modeled. The building has the following characteristics:

- Height: 90 meters (3 m floor-to-floor height)
- Plan dimensions: 20 m × 30 m
- Structural system: Reinforced concrete moment-resisting frame

- Number of bays: 5 in longitudinal and 6 in transverse direction
- Materials: Concrete grade M30, Steel reinforcement Fe500
- Dead and live loads applied as per IS 875 (Parts 1 and 2)

Wind Load Calculation

Wind loads are calculated based on IS 875 (Part 3) guidelines:

- Basic wind speed (V_b) taken as 39 m/s (urban terrain)
- Terrain Category II with roughness factor $k_r = 1.0$
- Importance factor $I = 1.0$ (normal occupancy)
- Topography factor = 1.0
- Gust factor calculated as per code provisions

ETABS Modeling

- The structure is modeled in ETABS using frame elements for beams and columns and shell elements for slabs.
- Loads include self-weight, live loads, and calculated wind loads.
- Wind loads are applied as lateral forces per floor according to the height.
- Modal analysis is performed to obtain the natural frequencies and mode shapes.
- Response spectrum analysis is also conducted for dynamic load effects.
- The structure is analyzed for displacement, base shear, and story drift.

Analysis Procedure

1. **Static Wind Load Analysis:** Wind loads applied as static equivalent lateral loads on the structure.
2. **Modal Analysis:** Natural frequencies and modes are extracted to understand dynamic behavior.
3. **Response Spectrum Analysis:** To account for dynamic effects of wind-induced vibrations.
4. **Results Extraction:** Maximum lateral displacement, base shear at foundation, and story drift ratios are extracted.

RESULTS

Displacement and Drift

The analysis showed that lateral displacement at the top floor increases with wind speed, consistent with expectations from lateral load theory. The maximum displacement observed at 35 m/s wind speed was 49.3 mm, which is within permissible limits as per IS 456 and wind load standards. Story

drifts increased with height and wind speed but remained within serviceability limits (less than 1/400 for most floors).

Base Shear

Base shear increased proportionally with the increase in wind speed. The maximum base shear at 35 m/s was 2500 kN, indicating higher demand on foundation design and lateral load resisting systems.

Modal Characteristics

The fundamental period of the building was found to be approximately 2.1 seconds, which aligns with empirical formulas for reinforced concrete buildings of this height. The modal mass participation factor exceeded 85% for the first three modes, ensuring a reliable dynamic analysis.

Structural Element Forces

The bending moments and shear forces in columns and beams at wind load cases increased significantly compared to gravity load cases, emphasizing the importance of wind load consideration in tall building design.

CONCLUSION

The study confirms that ETABS is an effective tool for the analysis of tall buildings under wind loads, providing reliable predictions for lateral displacements, base shear, and story drifts based on IS 875 and ASCE guidelines prevalent up to 2019. The results demonstrate the necessity of incorporating dynamic wind effects in design to ensure occupant comfort and structural safety.

Key conclusions are:

- Wind load effects significantly influence lateral displacement and internal forces, increasing with wind speed.
- The building modeled meets serviceability and safety criteria under specified wind loads.
- Modal analysis is essential to capture dynamic characteristics and accurately predict wind response.
- ETABS enables efficient modeling and analysis, supporting optimized design decisions for tall buildings.

Future work can involve wind tunnel testing or advanced CFD simulation for complex geometries; however, ETABS remains a practical choice for preliminary and detailed wind load analyses in engineering practice up to 2019.

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