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A Comparative Study of the Wind Load Effect on High-Rise Buildings

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Abstract

Tall buildings are going up all over the world, so it increases the importance of design for wind-induced building motion. Tall structures that comply with lateral drift requirements specified in building codes can still experience significant swaying under strong wind conditions. Severe wind-related disasters in India and the United States have highlighted the fact that many existing buildings are not entirely wind-resistant. This underscores the need to reevaluate and enhance the computational techniques currently used to determine along-wind loads. This paper examines methods for calculating wind load using the gust factor method. The analysis focuses on a G+17 RCC high-rise building, considering the effects of wind load on its structural integrity. By employing the gust factor method, this study aims to provide a comprehensive understanding of wind load impacts and improve the design and resilience of high-rise buildings against strong winds. change in zones 3 and 5 and terrain categories 3 and 4 and analyzed for story drift ratio, bending moment, shear force, gust factor, and gust pressure as per the unrevised and revised code by using ETABS-2016. Results are plotted graphically to study the pattern of variation in story drift ratio, bending moment, shear force, gust factor, and gust pressure. Comparisons are made with results obtained from the software, and it was observed that the IS: 875 Part 3-2015 gives more sensitive and accurate values as compared to the IS: 875 Part 3-1987 and the value is approximately 30% to 40% higher for the revised code.

Keywords: High-rise building, IS: 875 (part 3):1987, IS: 875 (part 3): 2015, Gust factor method, Story drift, Wind effect, Etabs-2016

INTRODUCTION

The height of a building is relative and cannot be defined in absolute terms based solely on its height or the number of stories. However, from a structural engineering perspective, tall buildings or multi-story buildings are characterized by their susceptibility to lateral forces, such as wind or earthquakes. These lateral forces significantly influence the structural design of the building. A building is subjected to gravity loads, such as dead loads, live loads, and lateral loads, such as wind or earthquake loads. These loads are safely transferred to the earth below ground level through a system of interconnected structural members referred to as the structural system. In addition to gravity forces, lateral forces due to wind or seismic activity must be taken into account for tall buildings. The design of tall buildings is often dictated by the need to resist these lateral loads in conjunction with gravity loads [1–5]. Wind impacts the design of tall buildings in two primary ways:

- It exerts forces and moments on the structure and its cladding.
- It also distributed the air in and around the building, which is termed wind pressure.

These oscillations are in the direction of ground motions in the case of earthquake loading and along

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the wind, across the wind under the influence of strong winds. As the height of the structure increases, the wind intensity also increases. At a particular height, the wind force is the governing factor in the design of the structure against lateral loading. Many of these high-rise structures are needed in regions where wind intensity is higher. Also, in coastal regions where tornados and hurricanes are active, there is a need for wind design structures. So in this project, a wind study is done and finds the effect of wind forces on the structures for different terrain categories and zones. [6–9].

The literature related to pressure and response measurements on building and structure is discussed. Some of the historical or recent works that have greatly contributed to understanding the wind loading on structures are also described.

The body of literature on the subject of wind loading on tall buildings has grown significantly in recent years. Much of this information can be found in conference proceedings, which are invaluable for understanding recent advancements in wind engineering [11, 12].

MODEL DESCRIPTION AND ANALYSIS

To obtain the response of highrise buildings, ETABS software is used in the present study. And the gust factor method is used for calculating the design wind load. To do that, you first need to create the model in ETABS software with the help of available structural and building dimension data, as shown in Table 1.

Structural modeling has been done in ETABS. The beam and column are modeled as line element using frame element. The beam and column provided in the building have different dimensions. The support condition at the base has been assigned as no translation and no rotation in any direction, i.e., fixed support. The complete prepared structural model is shown in Figure 1.

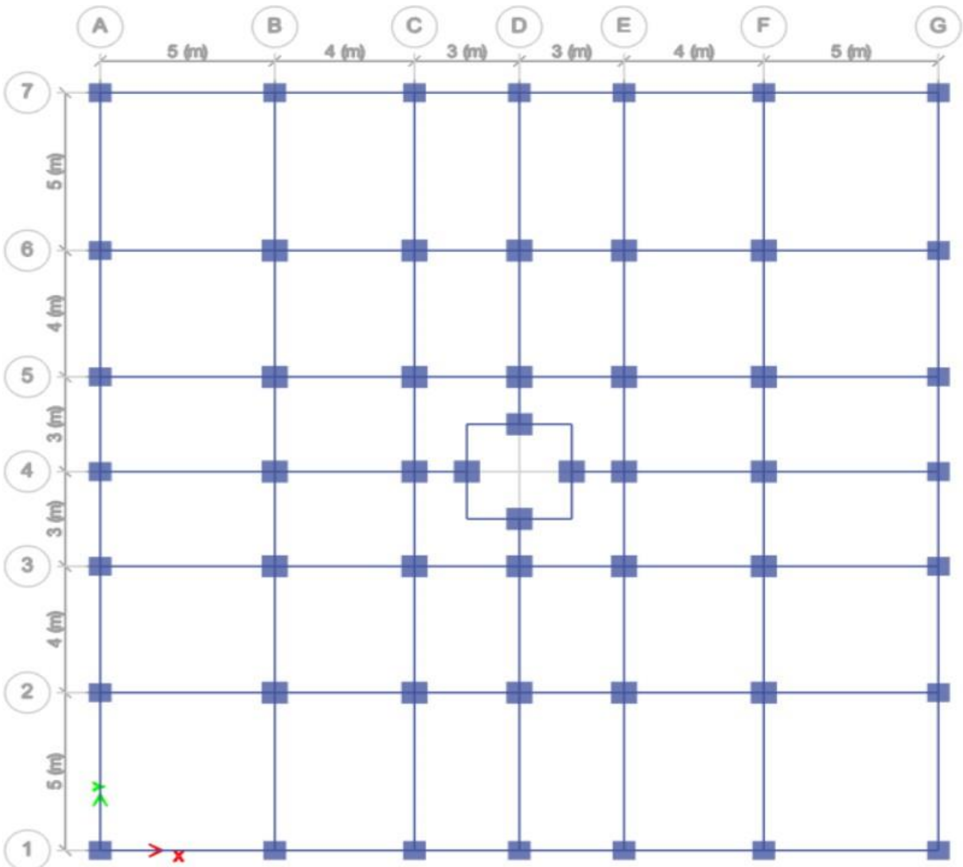

Figure 1. Plan of structure.

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Table 1. Dimensions and structural properties of structures.

S.N.	**Dimensions of Model**	
1	Length of building	28 m
2	Width of building	24 m
3	Height of building	56 m
4	Height of each story	3.3 m
5	Total stories	17
6	Outer columns	550 x 650 mm
7	Inner columns	650 x 750 mm
8	Main beams (length 5 m)	300 x 500 mm
9	Secondary beam (length less than 5 m)	300 x 400 mm
10	Slab	125 mm
S.N.	**Structural Properties**	
1	Grade of concrete	M30
2	Grade of steel	Fe 415

Load Calculations

Various dead loads are calculated based on the dimensions and material properties of the structure. However, the self-weight of beams and columns is taken into consideration by the ETABS software itself. Live load and wind load are calculated as per the code of provisions.

Dead Load

1. Self-weight of beam and column as per ETABS software.
2. Load intensity on slab = 0.125 x 25 = 3.125 kN/m (assume 125 mm thick slab)
3. Floor finish = 0.5 kN/m^2 (IS875 part I) Total load on slab = 3.625 kN/m^2
4. Outer wall load intensity = 0.23 x 3.3 x 20 = 15.18 kN/m
5. Inner wall load intensity = 0.115 x 3.3 x 20 = 7.59 kN/m
6. Parapet wall load intensity = 0.23 x 1 x 20 = 4.6 kN/m

Live Load

1. Live load on floors = 3 kN/m^2

Wind Load

As per the gust factor method [As IS: 875 part 3-1987 and IS: 875 part 3-2015]

Load Combinations

The modeled structure is to be checked for the following load combinations as per IS: 1893 (Part 1): 2002.

1. 1.5 (Dead load ± Live load)
2. 1.2 (Dead load ± Live load ± Wind load)
3. 1.5 (Dead load ± Wind load)
4. 0.9 (Dead load ± 1.5 Wind load)

RESULTS AND DISCUSSION

After analyzing all the building models for zones 3 and 5 and terrain categories 3 and 4 as per the methods suggested by the unrevised IS Code and studying graphs plotted for various parameters and comparisons are made between zones and terrain categories (Figure 2 and Tables 2 and 3).

The variation of the gust factor as per zones and terrain category is represented in Figures 2 and 3, and the gust factor at each story height for zones 3 and 5 and terrain categories 3 and 4 is tabulated from Tables 2 to 5. As per the revised and unrevised IS code, it is observed that in terrain categories 3 and 4 for zones 3 and 5, there is a slight difference at the base of story, whereas at the top of story the difference is approximately double as per the revised IS code, i.e., IS: 875-3-2015 and when the comparison is made between two-zone and two terrain categories, it can be concluded that the gust factor is approximately higher for terrain 4 as compared to terrain 3 for both revised and unrevised codes.

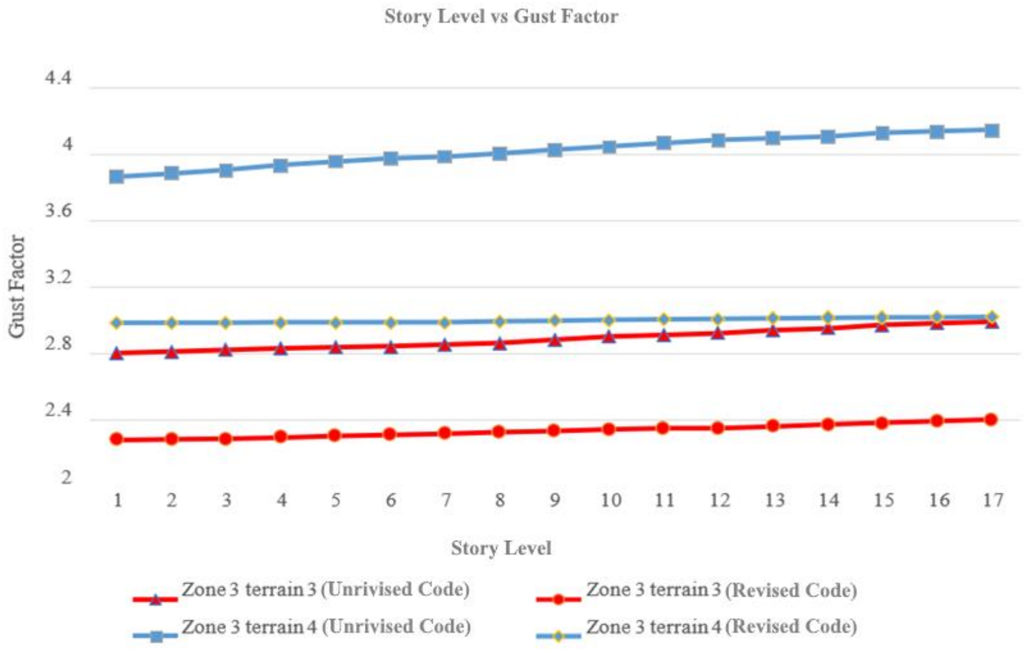

Figure 2. Story level vs gust factor zone 3 terrain 3 and 4.

Table 2. Story level vs gust pressure for zone 3, terrain 3.

S.N.	Story Level	Terrain 3 Revised	Terrain 3 Unrevised	% Increased
1	Base	2.8	2.28	22.807
2	Middle	2.88	2.33	23.605
3	Top	2.99	2.4	24.583

Table 3. Story level vs gust pressure for zone 3, terrain 4.

S.N.	Story Level	Terrain 3 Revised	Terrain 3 Unrevised	% Increased
1	Base	3.86	2.98	29.530
2	Middle	4.02	2.99	34.448
3	Top	4.14	3.02	37.086

Table 4. Story level vs gust pressure for zone 5, terrain 3.

S.N.	Story Level	Terrain 3 Revised	Terrain 3 Unrevised	% Increased
1	Base	2.85	2.318	22.951
2	Middle	2.92	2.49	17.269
3	Top	2.95	2.62	12.595

Table 5. Story level vs gust pressure for zone 5, terrain 4.

S.N.	Story Level	Terrain 3 Revised	Terrain 3 Unrevised	% Increased
1	Base	4.01	2.99	34.114
2	Middle	4.16	3	38.667
3	Top	4.23	3.03	39.604

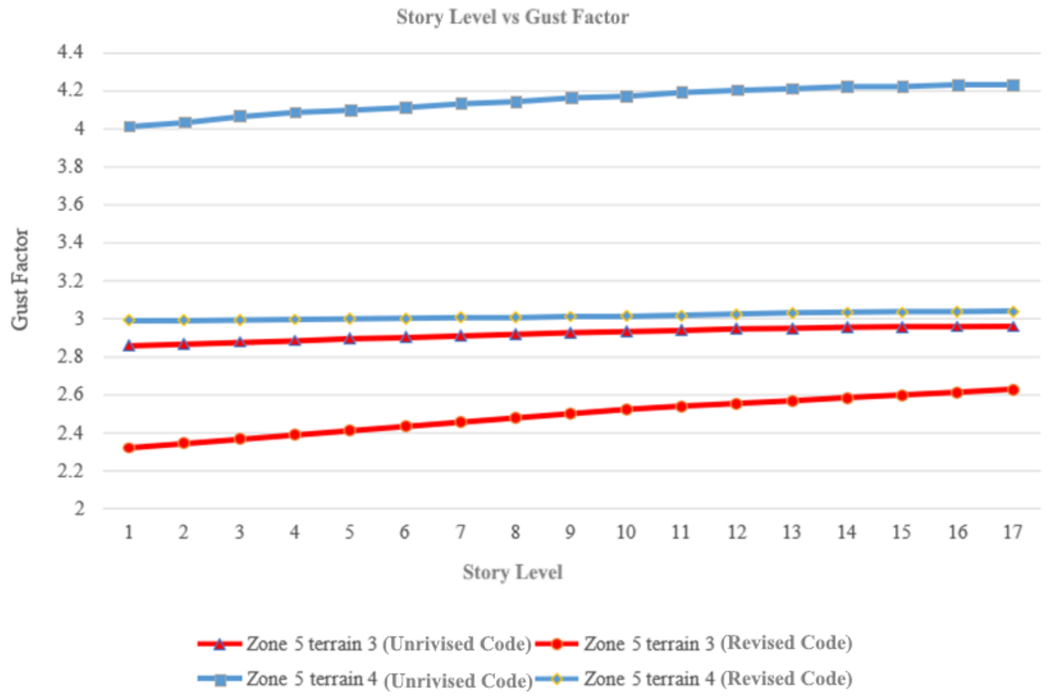

Figure 3. Story level vs gust factor zone 5, terrain 3 and 4.

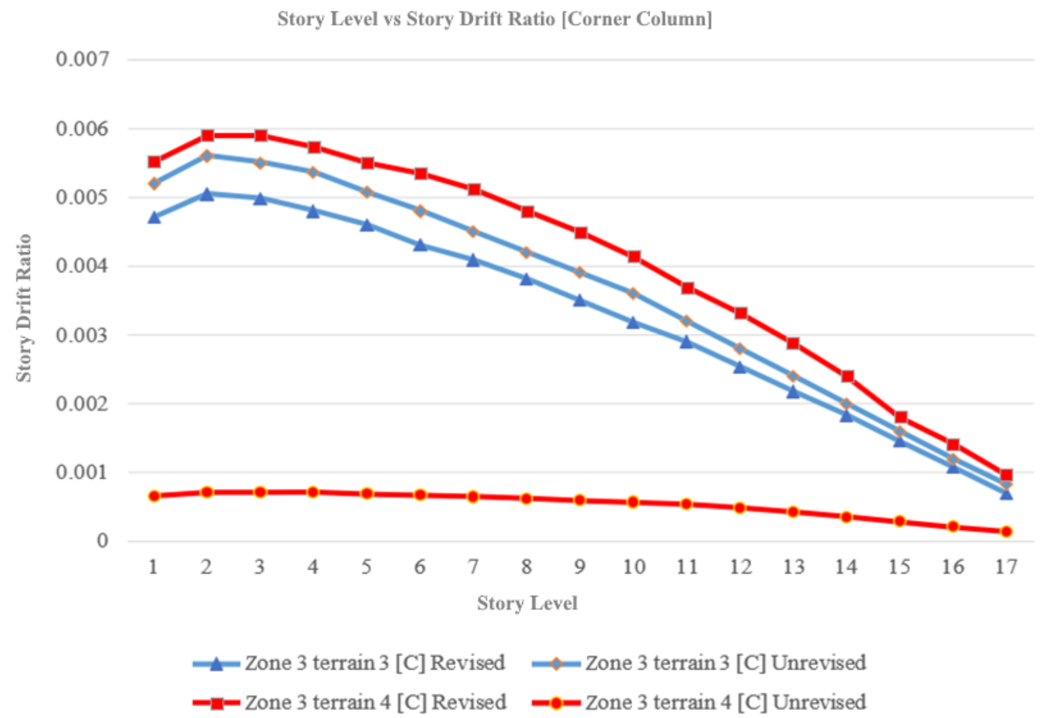

Figure 4. Story level vs story drift ratio zone 3, terrain 3 and 4.

Table 6. Story level vs story drift ratio for zone 3, terrain 3.

S.N.	Story Level	Terrain 3 Revised	Terrain 3 Unrevised	% Increased
1	Base	0.0047	0.0052	-9.615
2	Middle	0.0035	0.0039	-10.256
3	Top	0.0007	0.0008	-12.500

Table 7. Story level vs story drift ratio for zone 3, terrain 4.

S.N.	Story Level	Terrain 3 Revised	Terrain 3 Unrevised	% Increased
1	Base	0.0055	0.0007	685.714
2	Middle	0.0045	0.0006	650.000
3	Top	0.001	0.0001	900.000

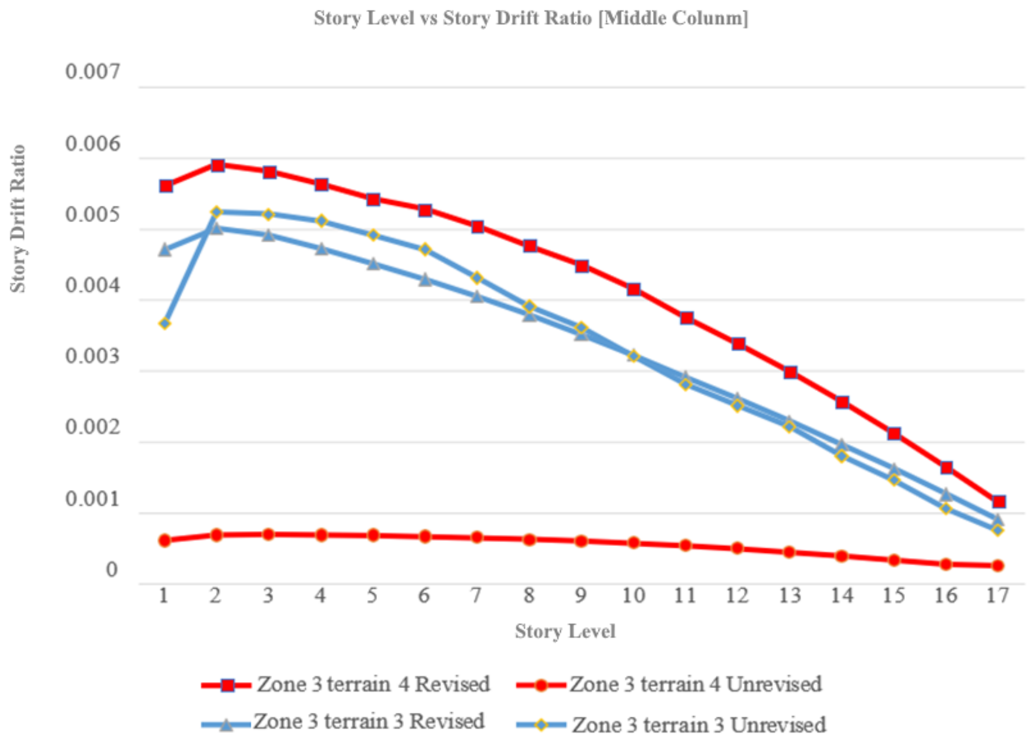

Figure 5. Story level vs story drift ratio zone 3, terrain 3 and 4.

Table 8. Story level vs story drift ratio for zone 3, terrain 3.

S.N.	Story Level	Terrain 3 Revised	Terrain 3 Unrevised	% Increased
1	Base	0.0047	0.0037	27.027
2	Middle	0.0035	0.0036	-2.778
3	Top	0.0009	0.0007	28.571

Table 9. Story level vs story drift ratio for zone 3, terrain 4.

S.N.	Story Level	Terrain 3 Revised	Terrain 4 Unrevised	% Increased
1	Base	0.0056	0.0006	833.333
2	Middle	0.0045	0.0006	650.000
3	Top	0.0012	0.0002	500.000

As the wind effect acts laterally on structure, the corner column gets more disturbed as compared to the middle column. In this study, to calculate story drift as at the corner and at the middle column for terrain categories 3 and 4 for zones 3 and 5, Figures 4 and 5 show the variation of the story drift ratio as per zones and terrain category with the help of a graph and from Tables 6 to 9, it is observed that base-story drift is low as compared to the top story for both terrains 3 and 4.

As increasing the height building story drift also increase so at the top of story the drift is always maximum. As comparisons are made between revised and unrevised codes for the same terrain categories 3 and 4 for zones 3 and 5, it can be concluded that the story drift ratio is increased as the story level increases, and terrain category 4 is more safe as compared to terrain category 3 due to the higher terrain category, higher wind speed, and higher pressure at the top floor of the building.

CONCLUSION

Based on the analytical study, it is concluded that IS: 875 Part 3-2015 gives more significant and accurate results, and it is approximately 30% to 40% higher when compared with IS: 875 Part 3-1987 and the most critical load combination is found to be 1.5 (DL + WL), as it gives maximum values for gust pressure, story drift, bending moment, and shear force. The bending moment, shear force, and story drift ratio increase significantly in the case of the revised IS code, which will make the structure in much safer.

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