Comparison of response of building against wind load as per wind codes [IS 875 – (Part 3) – 1987] and [IS 875 – (Part 3) – 2015]

Naveen Suthara\textsuperscript{a}, Pradeep K. Goyal\textsuperscript{b}

\textsuperscript{a} Post Graduate Student, Department of Civil Engineering, Delhi Technological University (formerly Delhi college of engineering), Delhi, India.
\textsuperscript{b} Associate Professor, Department of Civil Engineering, Delhi Technological University (formerly Delhi college of engineering), Delhi,

Abstract

A comparison of wind loads to make a G+11 building in staad and design the building against wind load is presented in this paper. The importance of this study is to calculate the wind load for a structure by the two different wind loading code and compare them for better analysis. In the present scenario high rise structures have advantages in the populous area and to make more space to live and provide better accommodation in the highly populated area around the world. To make the building cost-effective and proper design should have to do for more area for living purpose and reduce the cost of structure and safety of structure should be considered in this design. In recent times, there had been so many catastrophic damages caused by high wind speed in the coastal regions of India which prove that many buildings that are currently in use are not fully wind resistant. In this paper, we have calculated the wind load using the static method by the old code [IS: 875 – (Part 3) – 1987] and as per the new code [IS: 875 – (Part 3) – 2015] for zone 4 with terrain category 3 and the building is analyzed using STAAD PRO Software. The aim of this paper is comparing the deflection and storey shear on the G+11 building by the previous and new IS 875 code.

Keywords: wind load, wind analysis, high rise structure, deflections, wind pressure.

1. Introduction

The wind is an important factor in the design of high-rise building. The wind is more important than the earthquake and other important loads. The terrain category is defined according to the roughness and the smoothness of the surface. The wind load is affecting many parameters like construction cost, building strength and another parameter of the building. As per the results which help in the selection of different parameter of the building. Standard codes from different countries use their different terrain categories for the calculation of the wind load and they depend on the surface conditions. All the standard wind load codes have their approach to calculate the wind load. they have different formulas and conditions in their map for the calculation of the wind load. For the analysis of wind load, terrain category 3 has taken for the different wind load and the comparative analysis. STAAD-PRO is a very good software for structural analysis and this software is using by many structural engineers nowadays this software can be solved the typical problem like static analysis, finite element model, wind analysis and we can also select various load combination in the design by this software to check RCC codes. For the design of beams, columns, lateral bracing and foundations wind loads on the structural frames are required. Wind load is generally taken in to account when the height of the building is greater than 150m and low-rise buildings are also affected by wind load. When the building is going increasing, they become flexible and more lateral deflection occurs in the building. This paper describes wind analysis of a building which is located in zone IV. For the analysis of wind load, a twelve-storey building is taken. In this project comparison of result from the IS:875- Part3 (2015) code and IS:875Part3 (1987) are discussed so that we can understand the applicability of wind load analysis using both codes.
2. Review of literature

High rise structures are currently in demand because of the continuously increase in population and technological enhancement as compared to the past scenario. In current design practice, the lateral load resisting system of a high-rise building is considered in the design of the structure. Structural components such as column, beam, shear wall are considered in the load resisting system of the high-rise building. In the lateral resisting performance of high-rise building, the nonstructural component is also considered in the loading. In practice, the building is the system of structural and non-structural but the nonstructural components of the building are considered as non-load bearing component and they are not including in the design of the building. Kawale and Joshi (2017) analyzed columns, beams, slabs by using IS code [IS: 875 – (Part 3) – 1987] and as per the new code [IS: 875 – (Part 3) – 2015]. Thejaswini and Sawjanya (2018) stated the behaviour of the junction tower build for the fabric handling purposes in thermal power station subjected to wind load as per IS code [IS: 875 – (Part 3) – 1987] and as per [IS: 875 – (Part 3) – 2015]. Sreedharan (2016) comparative study of the seismic and wind analysis for four different structure and three different tracing system are considered for the concentrated load and analyzed. Rajesh et.al., (2016) Found that shear and lateral deflection in the building at each story is more at wind load when we compare it to seismic load. Higher sections are subjected to the high wind so it is good to provide more reinforcement at higher sections to counter the high lateral loads. Mashalkar et al., (2017) studied the effect of wind on a different shape as I, C, T and L.

3. Methodology

RCC framed structure is a combination of beam, column, slab in which beam, column, slab and foundation are inter connected to each other. Load transfer of building to soil is through foundation so the foundation must be strong. In frame structure, Load transfers from the slabs to beams, and beams to columns and finally to the foundation. Bearing walled building is 10 to 12 percent of total framed structure. Monolithic construction is done with RCC framed structures. Monolithic buildings can easily resist vibrations, wind loading. Load bearing walled can effectively resist earthquake.

3.1 Assumptions in Design:

- Using partial factor of safety for loads as 1.5 (as per clause 36.4 of IS-456-2000).
- Partial factor of safety is taken as 1.5 and 1.15 for concrete and steel respectively.

These are the load combinations, which are considered in the design of structures (as per IS 456-2000).

(i) \(1.5 \times (\text{Dead load}+\text{Live load})\)

(ii) \(1.2 \times (\text{Dead load}+\text{Live load}+\text{Wind load})\)

When wind load acting in X direction, load combination is considered as \(1.2(\text{D}+\text{L}+\text{W}_{\text{in X}+\text{ve}})\) and wind load acting in Z direction load, the combination of load will be \(1.2(\text{D}+\text{L}+\text{W}_{\text{in Z}+\text{ve}})\).

Therefore, three load combinations are considered in this study.

3.2 Wind load calculation as per IS 875 part3 (1987)

The design wind speed \((V_z)\) is obtained as per formula given below:

\[ V_z = V_b \cdot k_1 \cdot k_2 \cdot k_3 \]  

Where,
- \(V_b\) = design wind speed at any height \(z\) in m/s,
- \(k_1\) = probability factor (risk coefficient)
- \(k_2\) = terrain, height and structure size factor
- \(k_3\) = topography factor

The design wind pressure at height \(z\) can be calculated as

\[ P_z = 0.6 \cdot (V_z)^2 \]
Where,
- $P_z$ = design wind pressure in N/m$^2$ at height $z$,
- $V_z$ = design wind velocity in m/s at height $z$.

The total Wind load ($F$) on particular building or structure is calculated as

$$F = C_f A_e P_z$$

Where,
- $A_e$ = effective frontal area
- $C_f$ = force coefficient depends upon shape of element plan size & wind dir.
- $P_z$ = design wind pressure in N/m$^2$ at height $z$,

3.3 Wind load calculation as per IS 875 part 3 (2015)

The design wind speed ($V_z$) is obtained as per formula given below:

$$V_z = V_b k_1 k_2 k_3 k_4$$

Where,
- $V_z$ = design wind speed at any height $z$ in m/s,
- $k_1$ = probability factor (risk coefficient)
- $k_2$ = terrain, height and structure size factor
- $k_3$ = topography factor
- $k_4$ = importance factor for the cyclonic region

The basic wind pressure at height $z$ can be calculated as

$$P_z = 0.6 (V_z)^2$$

Where,
- $P_z$ = basic wind pressure in N/m$^2$ at height $z$,
- $V_z$ = design wind velocity in m/s at height $z$.

The basic wind pressure at height $z$ can be calculated as

$$P_d = K_d K_a K_c P_z$$

Where,
- $P_d$ = design wind pressure in N/m2 at height $z$,
- $K_d$ = wind directionally factor
- $K_a$ = area averaging factor
- $K_c$ = Combination factor

The total Wind load ($F$) on particular building or structure is calculated as

$$F = C_f A_e P_d$$

Where,
- $A_e$ = effective frontal area
- $P_d$ = design wind pressure in N/m$^2$ at height $z$,
- $C_f$ = force coefficient depends upon shape of element plan size & wind dir.

3.4 Steps for analysis of building using staad. pro:

1: First, we create nodal points according to the dimension, according to the plan we entered the position of the plan of building into the STAAD pro software.
2: By using add beam command we add the beam between nodes for beam and column.
3: To visualize the 3D view of the structure, we simply add a transitional repeat command.
4: After the completion of the structure, we assign support at the bottom as fixed support. also, we assign material and beam and column dimension.
5: Wind loads are calculated as per IS 875 PART 3 and the exposure factor is taken as 1. Then wind load is added in load case details in +X, +Z directions.
7: Dead loads are calculated as per IS 875 PART 1, including self-weight of structure for external walls, internal walls.
8: Live loads are taken as per IS 875 PART 2 and assigned for each floor as 3 KN/m2.
9: After assigning all the loads, the load combinations with suitable safety factor are taken as per IS 875 PART 5.
10: After completing all the steps we have performed the analysis and checked for errors.
11: Design of concrete and steel, concrete and steel design is performed as per IS 456: 2000 after the design process, again we performed an analysis for any errors.

All the steps are shown in this figure

![Diagram showing design steps](image)

Figure 1: design steps

4. Numerical study

In this study, a G+11 story building situated in Delhi is considered for comparison of response of building against wind load. The details of building is given in Table 1.

| Table 1: Building details:          |
|------------------------------------|
| No. of storey | G+11  |
| Size of Column | 350 mm × 350 mm |
| Size of Beam | 300mm × 0.500mm |
| Size of Slabs | 150 mm |
| Live load on slab | 3 KN/m2 |
| Floor finish | 3 KN/m2 |
| Concrete grade in column | M 25 |
| Concrete grade in beam | M 25 |
| Steel grade | Fe 415 |
| Total height of building | 36 m |
| ground storey height | 3 m |
| Height of each floor | 3 m |
| Spacing of frame along length and along width | 4m |
| Thickness of external wall | 230 mm |
The building, which is considered situated in Delhi. As per IS per code, parameters are given in Table 2.

| Design Parameter     | Value |
|----------------------|-------|
| Basic wind speed     | 47    |
| zone                 | IV    |
| city                 | Delhi |
| terrain category     | 3     |
| class                | B     |

Values shown in Table 1 and Table 2 are used for input in the STAAD-Pro software for making the elevation and plan of building and design.

Figure 2: elevation

Figure 3: plan

Figure 4: wind load acting in x direction

Figure 5: wind load acting in z direction
Figure 6: Comparison of Lateral Displacements at different height in x direction

Figure 7: Comparison of Lateral Displacements at different height in z direction

Figure 8: Comparison of storey drift at different height in x direction

Figure 9: Comparison of storey drift at different height in z direction
Figure 10: Comparison of wind force at different height in x direction

Figure 11: Comparison of wind force at different height in z direction

Table 3: Comparison of Lateral Displacements at different height in x direction

| Height (m) | Deflection in mm | % deflection decrease |
|-----------|------------------|-----------------------|
|           | As per IS 875 - 1987 | As per IS 875 - 2015 |
| 3         | 2.518             | 1.99                  | 20.96902 |
| 6         | 5.553             | 4.38                  | 21.12372 |
| 9         | 8.418             | 6.622                 | 21.33523 |
| 12        | 11.068            | 8.678                 | 21.59378 |
| 15        | 13.473            | 10.529                | 21.85111 |
| 18        | 15.618            | 12.169                | 22.08349 |
| 21        | 17.487            | 13.596                | 22.25081 |
| 24        | 19.057            | 14.792                | 22.38023 |
| 27        | 20.32             | 15.752                | 22.48031 |
| 30        | 21.271            | 16.474                | 22.55183 |
| 33        | 21.895            | 16.946                | 22.60333 |
| 36        | 22.196            | 17.174                | 22.6257  |

In table no.3 these are Deflection at each story in x direction, as height increases wind load increases and deflection at storey increases. comparison of deflection as per IS 875 – 1987 and as per IS 875 – 2015 mention in above table in x direction.

Table 4: Comparison of Lateral Displacements at different height in z direction

| Height (m) | Deflection in mm | % deflection decrease |
|-----------|------------------|-----------------------|
|           | As per IS 875 - 1987 | As per IS 875 - 2015 |
| 3         | 3.14              | 2.376                 | 24.33121 |
| 6         | 6.952             | 5.251                 | 24.46778 |
| 9         | 10.562            | 7.956                 | 24.67336 |
| 12        | 13.907            | 10.443                | 24.90832 |
| 15        | 16.951            | 12.687                | 25.15486 |
| 18        | 19.672            | 14.681                | 25.37109 |
| 21        | 22.049            | 16.42                 | 25.5295  |
### Conclusion

- The maximum deflection in the top most storey is 22.196 mm for structure which is designed as per Old IS code and 17.174 mm in case of structure which is designed as per new IS Code in x dir.
- The maximum deflection in the top most storey is 28.143 mm for structure which is designed as per Old IS code and 20.864 mm in case of structure which is designed as per new IS Code in z dir.
- Wind force has been decreased as per the new code [IS: 875 (Part 3) 2015]. Percentage decreased is 15.56% along “X” direction and 18.87% along “Y” direction.
- Displacement for the top most storey of G+11 storey building as per new code 22.62% as been decreased along “X” direction and along “Z” direction as per new code 25.86% as been decrease in new code when compared with old code.
- Storey drift for the top most storey of G+11 storey building as per new code 6.37% along “X” direction as been decreased and along “Y” direction as per new code 27.09% as been decreased in new code when compared with old code.
- From the above results it can be concluded that new IS Code [IS: 875 – (Part 3) – 2015] will provide high safety to the structure for static analysis as compared to Old IS Code also structure is economical that designed as per [IS: 875 – (Part 3) – 2015].
- Lateral deflection at each storey shall not exceed 0.002 times the storey height and all the lateral displacement at each story is under permissible limit.

### References

[1]. Is 875: (1987) part3 Indian Standards Code of Practice for Design Loads for Buildings and Structures Part.3 - Wind Loads. Bureau of Indian Standards, India.
[2]. Is 875: (2015) part3 Indian Standards Code of Practice for Design Loads for Buildings and Structures Part.3 - Wind Loads. Bureau of Indian Standards, India.
[3] Saurabh Kawale, Dr. S.V. Joshi, Department of Civil Engineering “Analysis of High-Rise Building for Wind Load” International Journal for Scientific Research & Development| Vol. 5, Issue 03, 2017 | ISSN (online): 2321-0613.
[4] Thejaswini, Dr sawjanya, Department of Civil Engineering “comparitive study of old or new code for high Rise Building for Wind Load” International Journal for Scientific Research & Development| Vol. 7, Issue 11, Nov 2018 | ISSN (online): 2278-0181.
[5] Prof. Sarita Singla, Taranjeet Kaur, Megha Kalra and Sanket Sharma, Civil Engineering Department, Chandigarh, India. “Behaviour of R.C.C. Tall Buildings Having Different Shapes Subjected to Wind Load”. Conf. on Advances in Civil Engineering 2012 DOI: 02. AETACE.2012.3.17.
[6]B. S. Mashalkar “Effect of Plan Shapes on the Response of Buildings Subjected to Wind Vibrations” IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684, p-ISSN:2320-334X PP80-89.
[7]. Megha Kalra, Purnima Bajpai and Dilpreet Singh. Effect of Wind on MultiStorey Buildings of Different Shapes Indian Journal of Science and Technology, Vol 9(48), DOI:10.17485/ijst/2016/v9i48/10570, December 2016.
[8]. Higgins, Theodore R. 1979 “Structural Design of Tall Steel Buildings: Council on Tall Buildings and Urban Habitat” Vol. 8. American Society of Civil Engineers.
[9]. Vikrant Trivedi“Wind Analysis and Design of G+11Storied Building Using STAAD-Pro” International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056 Volume: 05 Issue: 03-Mar.2018.
[10]. Md Ahesan, M d Hameed “Comparative Study on Wind Load Analysis Using Different Standards” Vol.7, Special Issue 3, March 2018.
[11].Alkesh Bhalerao (2016)”Effect of structural shape on wind analysis of multi storied RCC structures”.

|  |  |  |  |
|---|---|---|---|
| 24 | 24.054 | 17.885 | 25.64646 |
| 27 | 25.674 | 19.067 | 25.73421 |
| 30 | 26.905 | 19.963 | 25.8019 |
| 33 | 27.725 | 20.56 | 25.8431 |
| 36 | 28.143 | 20.864 | 25.86434 |

In table no.4 these are Deflection at each story in z direction, as height increases wind load increases and defection at storey increases comparison of deflection as per IS 875 – 1987 and as per IS 875 – 2015 mention in above table in z direction.
[12]. Shaikh Muffassir (2016) “Comparative Study on Wind Analysis of Multi-story RCC and Composite Structure for Different Plan Configuration