

Effect of Wind on Multi Storey Buildings of Different Shapes

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Abstract

Objective of the Study: To study and analyse the effect of wind load on different shape of the building and assess the most structurally stable shape of a multi storey structure. **Method:** The present study deals with the buildings of seven different shapes: Rectangular; L; U; T; I; Plus and Non-uniform IS: 875 (Part 3)-1987 is the standard code of practice for design loads of buildings and structures which was used to calculate the gust factor. Further, all these shapes were analyzed using Staad. Pro 2007 software. Each building is a 50 storied building with storey height as 3m summing upto a total height of 150m. For, the purpose of analysis the plan area and stiffness of the columns were kept equal. Dead loads and Live loads were calculated by using the code IS: 875-1987 (Part 1, 2) respectively. By using the Indian standard codes the combinations of loads were taken. Parameters like Storey drift, Joint displacement, Intensity, Bending moment are used for the assessment. Based on this study it can be established that the shape of structure plays a very important role in resisting wind loads **Findings:** Plus Shape and Non uniform shape were the most stable shapes whereas L-shape and U-shape was the least stable of all the shapes. More the stiffness of the building more will be its stability. Storey drift and joint displacement increases with increase in height. A reduction in Shear force and bending moment was detected with the increase of height. **Application:** With the increase in population and shortage of land, it has become necessary to construct high rise buildings. Wind load plays an important role in tall structures while designing buildings. Thus, to understand and analyses the wind effect on structures.

Keywords: Gust, High Rise Buildings, Shape, Storey Drift, Wind Load

1. Introduction

The direction of wind is horizontal relative to the surface of earth. The primary generating force behind wind is the constant rotational movement of earth and terrestrial radiations of varying intensity. The radiation results in the convection currents in two directions either upwards or downwards. The nature of wind is very unpredictable, even for the same locality the wind speeds are extremely different and one may experience the effect of gusts lasting for few seconds. The effect of wind on a structure thus depends on many factors like its geographical location and obstructions near the structure which may cause any variation in air flow and also the characteristics of the structure itself.

It is observed that with the rapid growth of population and industrial activity has resulted in the increase of

environmental deterioration and to meet these challenges with such rapid urbanization and the use of new materials and building configurations there is a need to understand the effect of wind not only for the buildings but also for the surroundings. There is increase in the shortage of land for buildings and therefore the vertical construction is given importance. Architects, engineers and urban planners faces this major challenge and are concerned about the wind loads on the buildings from the safety standpoint, both of structural and of cladding systems; about the ventilation of the buildings either naturally or forced; about the pedestrian comfort; and also about the air quality and ventilation in the urban areas. The need is to construct high rise building which are structurally safe. Therefore, to increase the strength, structural designer has to mainly concentrate on two key areas namely, strength of concrete used and the reinforcement provided. This

has led to increase in demand of cement. Quaternary mortars with the combinations of GGBS and MK can reduce our dependency on cement¹. Also, the utilisation of self compacting concrete has increased as it is difficult to compact concrete in such high rise buildings using conventional methods and SCC specimens generated higher bond to reinforcing bars in comparison with normal cement concrete specimens². For a structural designer to design a building which comfortable living conditions for its occupants, he must understand the relationship that exists between air flow and the shape of building³. In structures designed to resist high velocity wind, the emphasis should be placed on the shape of building and its dimension so that the structure is stable throughout its design life. On finding the effect of wind loads, the deflections is much higher in case of irregular structures in comparison to regular structures with or without the effect of gust factor in Zone I and Zone IV⁴.

In order to calculate the dynamic effect on high rise buildings, most of the codes are using the “Gust Loading Factor” (GLF) approach⁵. In 1967 this method was first introduced by Davenport which attempted to trace the involution of a satisfactory to the loading of structure by gusts. The positive or negative departure of wind from its average value not lasting more than 120 seconds over the specified interval of time is known as gust factor. Since, the method to evaluate load across wind or other components is still not well established for all type of structures, one can calculate load along wind or drag load using the gust factor as specified in the codal provisions⁶. The gust factor theory takes into account the randomness involved in the wind characteristics and parameters.

1.1 Scope of Study

The scope of this study is limited to the change in the shapes of the structure. Seven different shapes which are taken are as follows:

- Rectangular Shape
- L-Shape
- U-shape
- T-shape
- I-shape
- Plus Shape
- Non Uniform Shape

2. Parameters of Building

Various parameters of the building which are kept

constant are as follows:

- Height : 150m
- Total number of stories: 50
- Story height: 3m
- Bay length : 5m x 5m
- Length: 25m
- Width: 20m
- Column size : 600 mm x 600 mm
- Beam size: 450mm x 450mm
- Grade of concrete in columns: M60
- Grade of concrete in beams: M25
- Grade of steel : Fe 415
- Slab thickness : 150mm
- Wall thickness : 200mm

2.1 Loadings Considered

2.1.1 Dead Load

The loads of the beams and columns had been taken in account by STAAD using the command of Self weight. Dead load of slab at each floor was taken as 3.83 kN/m². The Brick wall load of inner 4.5” thick wall was taken 5.7 kN/m and of outer 9” thick wall with glazing was taken as 11.4 kN/m².

2.1.2 Live Load

Live Load The live loads had been taken as 3.00 kN/m² at all floors and 1.5 kN/m² at roof.^[8]

2.1.3 Wind Load

As discussed earlier due to unavailability of other well established methods for calculating the load along wind, the researcher shall be using the gust factor method. Knowledge of the maximum wind speeds averaged over one hour at a particular location is required for the use of existing theories of gust factor method⁹. The parameters and calculation of factors are as follows:

$$V_b = 47 \text{ m/s } k_1 = 1, k_2 = 1.03, k_3 = 1.2$$

$$V_z = 47 \times 1 \times 1.03 \times 1 = 48.41 \text{ m/s}$$

$$P_z = 0.6 V_z^2 = 0.6 \times (48.41)^2 = 1406.11 \text{ N/m}^2$$

$$T = 0.09H / (\sqrt{d}) = 0.09 \times 150 / (\sqrt{25}) = 2.7 \text{ sec}$$

$$\text{Frequency} = 1/T = 1/2.7 = 0.370 \text{ Hz}$$

Calculation of Gust Factor

From Figure 8 -11 (IS 875(part 3)-1987)

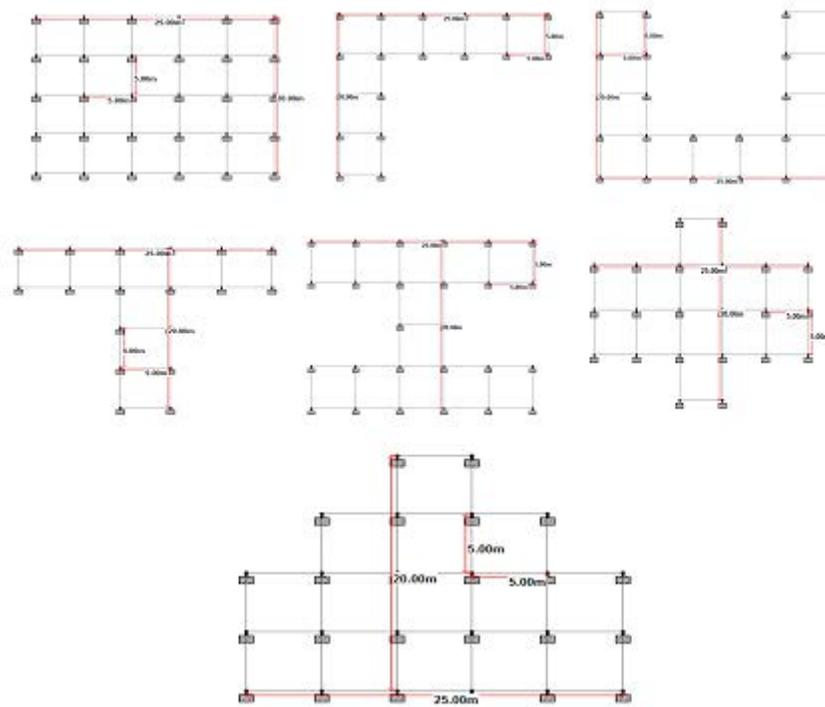


Figure 1. Different shapes of building plan.

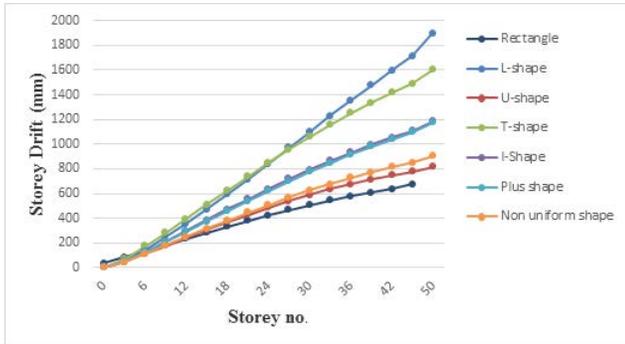


Figure 2. Storey drift for various shapes of buildings.

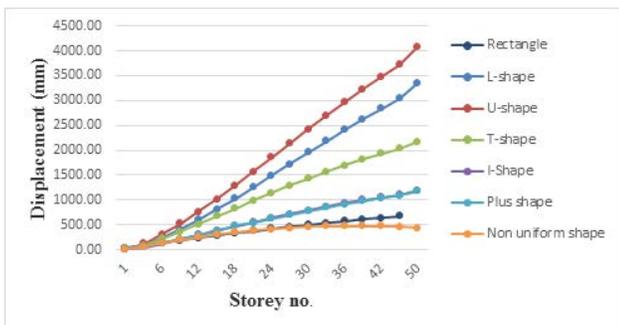


Figure 3. Variation of joint displacement for different shapes of building.

Building lies in the **Category 1** and class is **Class C** [Clause 5.3.2.2, Page 11].

$$A_c = 150 \times 25 = 3750 \text{ m}^2$$

$$L(h) = 2250, g_f r = 0.685, C_y = 10, C_z = 12, h = 150\text{m}, b = 20\text{m}$$

$$\lambda = (C_y/C_z) \times (b/h) = (10/12) \times (20/150) = 0.111$$

$$C_z \times (h/L(h)) = 12 \times (150 / 2250) = 0.8$$

$$B = 0.7, \Phi = 0$$

$$F_0 = (C_z f_0 h)/V_z = (12 \times 0.370 \times 150)/48.41 = 13.75$$

$$S = 0.135, E = 0.08, \beta = 0.016$$

$$G = 1 + g_f r \sqrt{[B(1 + \Phi)^2 + SE/\beta]} = 1 + 0.685 \sqrt{[0.7(1 + 0)^2 + 0.35 \times 0.08/0.016]} = 1.803$$

2.1.4 Load Combinations

Load combinations were considered as per IS 875 (part 5).

3. Analysis of Result

3.1 Intensity

As the height varies the value of k_2 will vary. Thus intensity is calculated for different heights of building.

Calculation is shown for the rectangular building. For all the other shapes same type of procedure will be followed.

$$H = 0 \text{ m, } k_2 = 0.99$$

$$V_z = 46.53 \text{ m/s}$$

$$P_z = 1299.02 \text{ N/m}^2$$

$$A_e = 15 \times 25 = 375 \text{ m}^2$$

$$F_z = C_f A_e P_z G = 1.4 \times 375 \times 1299.02 \times 1.803 = 1229.61 \text{ kN}$$

$$\text{Intensity} = F_z / A_e = 1229.61 / 37 = 3.28 \text{ kN/m}^2$$

C_f values for each shape taken was as follows:

- Rectangular : 1.4
- L-shape : 1.9
- U- Shape : 2.05
- T-Shape : 1.5
- I-Shape : 1.6
- Plus Shape: 1.75
- Non Uniform Shape: 2

Table 1 it is observed that the wind intensity will increase with the increase in the height of the building. Also with the variations in the shapes the intensity will vary. It is maximum for the U-shape and minimum for the T-shape when it is compared with the rectangular shape. Thus pressure will be more on the U-shape whereas it will be least on the T-shape when compared with the rectangular shape.

3.2 Storey Drift

The total horizontal deflection and the maximum storey

drifts are considered along both X and Z axes¹⁰. From Figure it is observed that with the change in the shape from rectangular to non-uniform shape the storey drift will decrease for the building of same height. It is observed that the percentage reduction is maximum in case of L-shape building and then it is followed by T-shape, I-shape, Plus shape, Non uniform and U-shape. For the bottom half of the building, the storey drift is reduced by 60-120 % for L-shape, 28-30% for U-shape, 90-124% for T-shape, 40-70% for I-shape, 48-64% for Plus shape and 30-35% for Non-uniform shape. Peak storey drift in the rectangular is 674.58mm and in L-shape is 1899.33mm, T-shape is 1602.4mm, I-shape is 1184mm, U-shape is 815.56, Plus shape is 1177mm and Non uniform shape is 902.87mm and there percentage reduction in peak storey's are 181.56%, 137.54%, 75.55%, 20.90%, 74.51% and 33.84% respectively. Thus it is clear that with the increase in the number of sides for the same column stiffness and grid size the storey drift will reduce. According to IS 1893 (Part 1), 2002 the storey drift due to minimum designed lateral force shall not exceed 0.004 times the storey height. But the calculated drift is more than the allowable drift due to combination of loads.

3.2 Joint Displacement

The lateral joint displacement in rectangular, L-shape, U-shape, T- shape, I-shape, Plus shape and non-uniform shape at different heights is compared in table 3. It is evident from the above graph that with the change in the shape the displacement will decrease. Peak lateral

Table 1. Calculation of intensity for a different shapes of building

Sl. No.	Height (m)	Rectangle	L-Shape	U-Shape	T-Shape	I-Shape	Plus-Shape	Non uni-form-Shape
		Intensity (kN/mm ²)						
1.	0	3.28	4.45	4.80	3.51	3.74	4.09	4.68
2.	15	3.54	4.81	5.19	3.80	4.06	4.44	5.07
3.	30	3.97	5.39	5.82	4.25	4.52	4.97	5.67
4.	45	4.27	5.79	6.25	4.57	4.88	5.34	6.10
5.	60	4.42	6.00	6.48	4.74	5.05	5.53	6.32
6.	75	4.58	6.21	6.70	4.90	5.23	5.72	6.54
7.	90	4.74	6.42	6.93	5.07	5.41	5.92	6.76
8.	105	4.82	6.53	7.05	5.16	5.0	6.02	6.88
9.	120	4.98	6.73	7.29	5.33	5.69	6.22	7.11
10.	135	5.06	6.86	7.41	5.42	5.78	6.32	7.23
11.	150	5.14	6.98	7.53	5.51	5.87	6.43	7.34

displacement in the rectangular is 674.54mm and in L-shape is 3350mm, T-shape is 2171mm, I-shape is 1191mm, U-shape is 4078, Plus shape is 1175mm and Non uniform shape is 476mm and there percentage reduction in peak storey's are 396.3%, 221%, 76.70%, 504%, 74.25% and 17.44% respectively. It is observed that L-shape has the highest displacement but for non-uniform shape and I shape the values are closest to the rectangular shape. The range of decrease in displacements of non-uniform shape and I shape are 35-65% and 20-76% respectively.

4. Conclusions

It can be concluded that for 50 storied building with a height of 150m, by varying its shape there will also be variation in the storey drift which will increase with the increase in the height. Similar is the case for joint displacement also. It can be concluded that L-shape and U-shape are the least stable of all the shapes. Plus shape and Non uniform are the most stable. In case of Plus shape and Non uniform shape the stiffness was high as compared to the other cases, that is why there values were near to that of the rectangular shaped building. By increasing the number of beams and columns without changing the dimensions of the building, the stiffness can be increased and thereby increasing the stability of other shapes.

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