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Effect of Wind on Tall Building Frames - Influence of Aspect Ratio

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ABSTRACT

Now a day's many tall structures and high rise towers are being built all around the world .Wind plays an important role in design of tall structures because of its dynamic nature. Effect of wind is predominant on tall structures depending on location of the structure, height of the structure. In this paper equivalent static method is used for analysis of wind loads on buildings with different aspect ratios. The aspect ratio can be varied by changing number of bays. Aspect ratio 1, 2, 3 were considered for present study. The analysis is carried out using STAAD PRO.

Keywords: *Aspect Ratio, Staad Pro , Tall Buildings, Wind Load.*

I. INTRODUCTION

The emergence of modern materials and construction techniques resulted in structures that are often, to a degree unknown in the past, remarkably low in damping, and light in weight. Generally such structures are more affected by the action of wind. The structural engineer should ensure that the structure should be safe and serviceable during its anticipated life even if it is subjected to wind loads. Wind forms the predominant source of loads, in tall free standing structures. The effect of wind on tall structures can be divided into two components they are

1. Along-wind Effect
2. Across-wind Effect

Along wind loads are caused by the drag components of the wind force whereas the across –wind loads are caused by the corresponding lift components.

II. WIND LOADS ON TALL BUILDINGS

The action of a natural wind, gusts and other aerodynamic forces will continuously affect a tall building. The structure will deflect about a mean position and will oscillate continuously. Swami studied that if the wind energy that is absorbed by the structure is larger than the energy dissipated by structural damping then the aptitude of oscillation will continue to increase and will finally lead to destruction. The structure becomes aerodynamically unstable. The structure forms used these days have greater flexibility with less mass and damping than those used in olden days. Knowledge on the maximum steady or time averaged wind loads can ascertain the overall stability of a structure IS 875-part –III deals with wind load. The effect of wind is high in case of buildings over 10 storey. Wind loads must be considered for the design of buildings over 10 storeys.

II. NATURE OF WIND

Winds are large scale movements of air currents in the atmosphere. It is of great complexity because of the many flow situations arising from the interaction of wind with structures. The wind speed is zero at ground level and maximum at the critical height.

IV. DETAILS OF PRESENT STUDY

The present study includes the study of nature and variation of static wind pressures. For this study multistoried frames of 10, 15, 20 storeys are considered. From this the variation of static pressures with height will be clearly known. In the present study emphasis is on change of aspect ratio with length and breadth and different heights. The wind load is applied both along and across the building frame.

The typical size of column is 0.3m x 0.49 m. the size of beam is 0.3m x 0.4m.The height of each storeys is 3m.Bay length is 5m.

Wind data:
Wind zone: basic wind speed 50 m/s
Terrain category: II open terrain with well scattered obstructions having height generally between 1.5m and 10m.
Class of building: general
Topography: flat

V. EQUIVALENT STATIC METHOD

The basic wind speed of a region corresponding to certain reference condition shall be modified to include the effect of risk level, terrain roughness, height and local topography. Design wind speed, V_z in m/s at height z for the chosen structure as given below.

$$V_z = V_b X K_1 X K_2 X K_3 X K_4$$
$$P_z=0.6V_z^2$$

Where

V_z =Design wind speed (in m/s) at height z
P_z= wind pressure in N/m^2 at height z
V_b= basic wind speed for the site(50 m/s)
K_1= probability factor
K_2= terrain roughness and height factor
K_3= Topography factor
K_4= importance factor
K_1,K_2,K_3,K_4 values are taken from IS 875 part 3

At 30 m wind speed is calculated as follows

$V_z = V_b X K_1 X K_2 X K_3 X K_4$
V= 50 x1x1.12x1x1
= 56 M/S
$P_z=0.6V_z^2$
= 0.6 x 56x56
=1.88 KN/M^2

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VI. STATIC PRESSURE VARIATION WITH HEIGHT

This table indicates values of static pressure values.

Table 1: Static Pressure

HEIGHT	K2	V	P
0	1	50	1.5
3	1	50	1.5
6	1	50	1.5
9	1	50	1.5
12	1.02	51	1.56
15	1.05	52.5	1.65
18	1.062	53.1	1.69
21	1.075	53.75	1.73
24	1.09	54.5	1.78
27	1.105	55.25	1.83
30	1.12	56	1.88
33	1.1275	56.37	1.90
36	1.135	56.75	1.93
39	1.1425	57.25	1.96
42	1.15	57.5	1.98
45	1.1575	57.87	2.009
48	1.165	58.25	2.03
51	1.1714	58.57	2.058
54	1.1756	58.78	2.073
57	1.1798	58.99	2.087
60	1.184	59.2	2.102

VII. MODELING

STAAD PRO is user friendly interface which allows modeling the frames, applying loads of varying dimensions. This software helps in modeling the building frames, analyzing different parameters and changing the properties of all materials which are used for building structures.

By changing number of bays, 40 building frames were modeled. Later analysis is carried out by using STAAD PRO software. Fig. 1, Fig. 2, Fig. 3, Fig. 4 and Fig. 5 shows the typical layout of columns, model of frame, Live Load and Wind load application, Deformation respectively.

Fig 1: Plan View of The Building

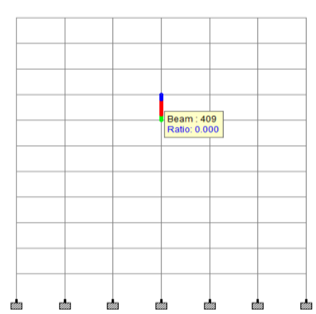

Figure 2: Elevation of The Building

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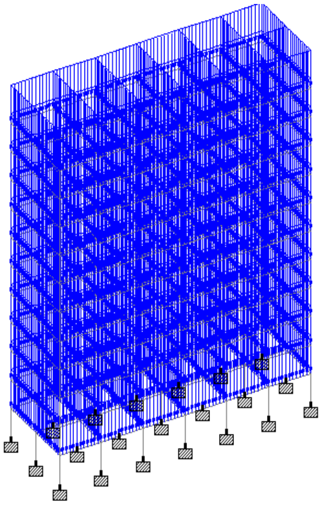


Figure 3: Live Load Applied on the Frame

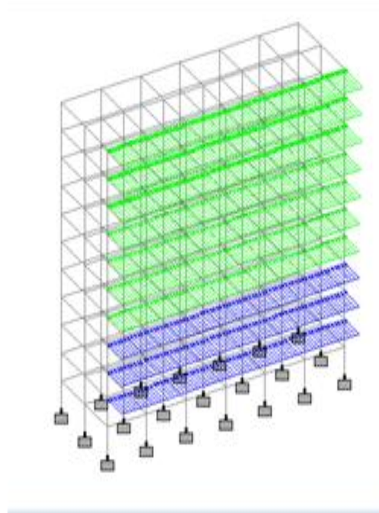
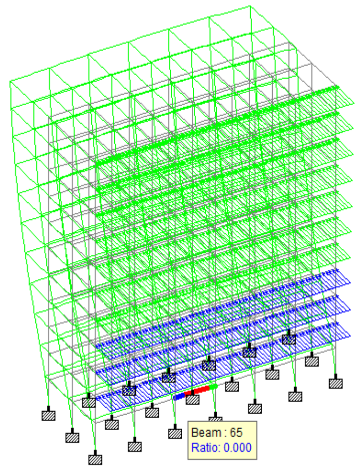


Figure 4: Wind Load Applied on the Frame

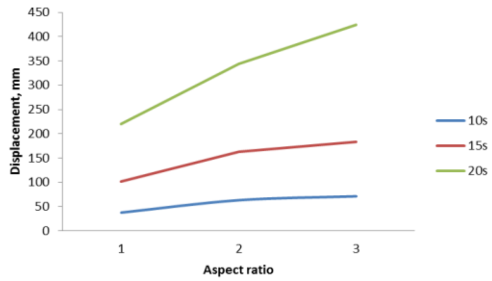


. **Figure 5: Displacement Due to Wind Load**

VIII. RESULTS AND DISUSSIONS

The effect of wind becomes considerable as the building frames height increases. Wind load will be predominant compared to dead and live loads in case of tall slender frames. The safety and stability of structure may become critical as the tall slender buildings interact with the wind. Hence for the design of tall buildings a thorough study of wind effects is much necessary. This is particular in regions where wind is more critical than the earthquake.

Figure 6: Aspect ratio Vs Displacement



In fig 6 aspect ratios 1(5x5), 2(5x10), 3(5x15) are taken on x axis and displacement values are taken on y axis .The graphs is drawn for 10 storeys, 15 storeys and 20 storeys. The wind load is applied along the length of the frame. The variation of displacement at different aspect ratios is increasing at low rate. The same trend is observed at different storey heights.

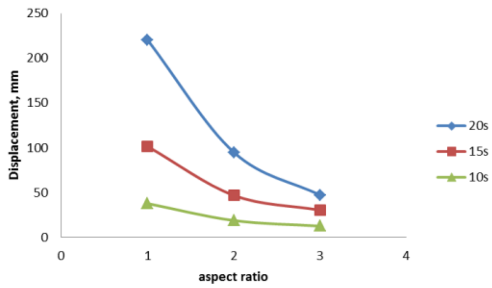


Figure 7: Aspect ratio vs Displacement

In fig 7 aspect ratios 1(5x5), 2(5x10), 3(5x15) are taken on x axis and displacement values are taken on y axis. The graph is drawn for 10 storeys, 15 storeys, 20 storeys. The wind load is applied across the length of the frame. The variation of displacement at different aspect ratios is decreasing i.e. when the wind is applied across (along the smaller side) with increase in aspect ratio displacement decreases.

In fig 8 number of storeys is taken on x-axis and displacement values are taken on y-axis. In the above graph aspect ratio is constant 1, with variation in length and breadth: 5m X5m, 10mX10m, 15mX15m at different storey heights. The variation of displacements at same aspect ratio is an increasing function. Similar trend is observed in all the 3 cases.

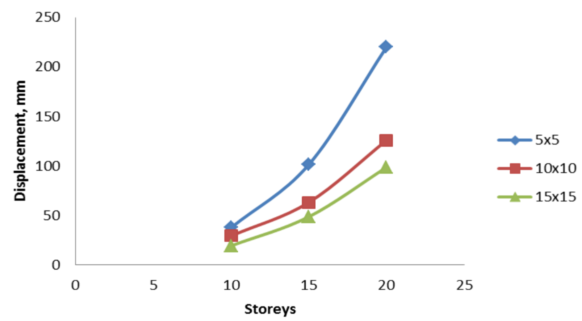


Figure 8: Number of storeys vs Displacement

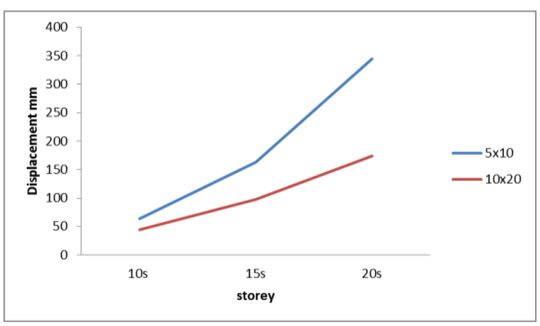


Figure 9: Storey vs displacement

In fig 9 number of storeys is taken on x axis and displacement is taken on y axis .The above graph is drawn for aspect ratio 2 but two cases are considered in one case length and breadth are 5m x 10m, in other case length and breadth are 10m x 20 m .The wind load is applied along the length of the frame. The variation of displacement at different storey heights is increasing trend similar to aspect ratio 1.

In fig 10 number of storeys is taken on x axis and displacement on y axis. Same as figure 9 but here the wind load is applied across the length of the building. The variation of displacements at different storeys heights is similar as in fig.8 and fig 9.

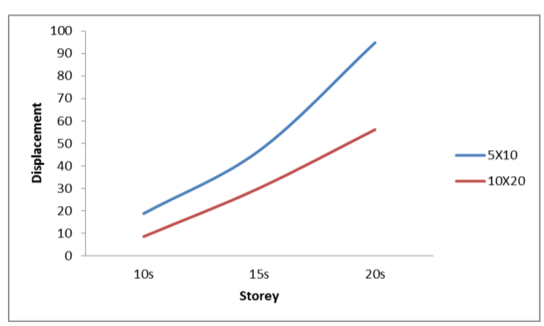


Fig 10: Storey vs displacement

VII. CONCLUSIONS

After performing the analysis of the building frames using STAAD PRO software, the conclusions obtained are:

1. When wind load is applied along the length of the building frame displacement for 20 storied frames is very high when compared to 10 and 15 storied frames.

2. When wind load is applied across the length of the building frame; as aspect ratio increases, displacement gradually decreases. This displacement reduction is high in case of 20 storied frame compared to 10 & 15 storied frames.

3. For aspect ratio 1, displacement is high for 5X5 frame compared to 10X10 and 15X15 frames.

4. For aspect ratio 2, displacement is more when wind load is applied along the length of the building frame. The displacement decreases when wind load is applied across the building frame.

As the stiffness of the member increases the displacement of the frame decreases. The aspect ratio plays a major role in affecting the displacements up to certain height. Further research can be carried out for more accurate results.2

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