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Indian Journal of Advances in Chemical Science

Indian Journal of Advances in Chemical Science S1 (2016) 169-172

Behavior of Windward and Leeward Columns with Aspect Ratio and Height of the Building

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Received 06th February 2016; Revised 22nd May 2016; Accepted 14th May 2016

ABSTRACT

In the recent past, many tall buildings are being built in India. The effect of wind loads (WL) becomes predominant for the design of tall buildings. Several failures of structures have occurred in India due to wind. The IS 875 Part-3 deals with WLs on different types of structures. This study presents the wind effects on windward and leeward column columns of buildings with different aspect ratio and height of building. The models are categorized based on number of stories and aspect ratio of the building. The effect of WL on gravity load is studied. All the frame models are idealized as three-dimensional models, and analyzed using the software ETABS. The variations of bending moment and axial force in windward and leeward columns are considered to study the behavior of frames. From the study, it is concluded that leeward column are vulnerable compared to windward column.

Key words: *Wind effects, Aspect ratio, Windward and leeward column.*

1. INTRODUCTION

The development of modern materials and construction techniques have resulted in the emergence of a new generation of structures that are often, to a degree unknown in the past, remarkably flexible, low in damping, and light in weight. Such structures generally exhibit an increased susceptibility to the action of wind. Accordingly, it has become necessary to develop tools enabling the designer to estimate wind effects with a higher degree of confidence than was previously required. Wind engineering is the discipline that has developed, primarily during the last few decades from effects aimed at developing such tools [1]. It is the task of the engineer to ensure that the performance of structures subjected to the action of wind will be adequate during their anticipated life from the standpoint of both structural safety and serviceability. Under the action of wind flow, structures experience aerodynamic forces that include the drag (along-wind) force acting in the direction of the mean wind, and the lift (across-wind) force acting perpendicular to the direction. The structural response induced by the wind drag is commonly referred to as the along wind response. The primary cause of wind is traced to earth's rotation and differences in terrestrial radiation.

The radiation effects are primarily responsible for convection either upwards or downwards. The wind generally blows horizontal to the ground at high wind speeds. Since vertical components of atmospheric motion are relatively small, the term "wind" denotes almost exclusively the horizontal wind, vertical winds are always identified as such [4]. The wind speeds are assessed with the aid of anemometers or anemographs which are installed at meteorological observatories at heights generally varying from 10 to 30 m above ground.

2. WIND EFFECTS ON BUILDINGS

Very strong winds (>80 km/h) are generally associated with cyclonic storms, thunderstorms, dust storms or vigorous monsoons. The liability of a building to high wind pressures depends not only upon the geographical location and proximity of other obstructions to air flow but also upon the characteristics of the structure itself [5]. The effect of wind on the structure as a whole is determined by the combined action of external and internal pressures acting upon it. In all cases, the calculated wind loads (WLs) act normal to the surface to which they apply. The stability calculations as a whole shall be done considering the combined effect, as well as separate effects of imposed loads and WLs on vertical surfaces, roofs and other part of the building above general roof level. Buildings shall also be designed with due attention to the effects of wind on the comfort of people inside and outside the buildings [6].

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The variation with height depends primarily on the terrain conditions. However, the wind speed at any height never remains constant and it has been found convenient to resolve its instantaneous magnitude into an average or mean value and a fluctuating component around this average value. The average value depends on the averaging time employed in analyzing the meteorological data and this averaging time varies from a few seconds to several minutes. The magnitude of fluctuating component of the wind speed which is called gust depends on the averaging time [7]. In general, smaller the averaging interval, greater is the magnitude of the gust speed.

3. DESCRIPTION AND MODELLING OF THE FRAMED STRUCTURE

In the present study, five frame models with different aspect ratio 0.25, 0.5, 1, 1.5, and 2 have been considered. Initially, 5 m width of bays in X and Y direction are considered. About 20 m width of the building is considered with 4 bays of 5 m each. Keeping the width of building as 20 m constant, the number of bays in X direction is increased such that the aspect ratio of 0.25, 0.5, 1, 1.5, and 2 is obtained. The typical plan and elevation of the models considered for the study are shown in Figure 1. The details of the building data are shown in Table 1. Wind analysis is carried out considering the three-dimensional frames as per IS-875-Part 3: 1987 [3].

Modeling has been carried out using ETABS-2013 [2]. ETABS is powerful and versatile finite element analysis software for carrying out the analysis and design of R. C. structures.

4. RESULTS AND DISCUSSION

For the design of buildings of low to medium height the wind effects are usually ignored. As the height of the building increases, the wind effects become gradually considerable. In the case of very tall slender frames they even become predominant compared to dead and live load effects. In the present study, the effect of WL on gravity load (GL) is studied with respect to aspect ratio and height of the building. To understand the effect of WL five models with different aspect ratios (0.25, 0.5, 1, 1.5, and 2) are considered

Table 1: Building description and parameters considered for the analysis.

Storey height	3.5 m
Thickness of slab	0.15 m
Beam size	0.3 m×0.45 m
Column size	0.3 m×0.45 m
Thickness of slab	0.15 m
Number of stories considered	3, 5 and 7
Aspect ratio	0.25, 0.5, 1, 1.5, 2
Wind speed	50 m/s
Terrain category	II
Structural class	B
Topography	Flat
Grade of steel	Fe 415
Grade of concrete	M 25
Live load	4 kN/m^2

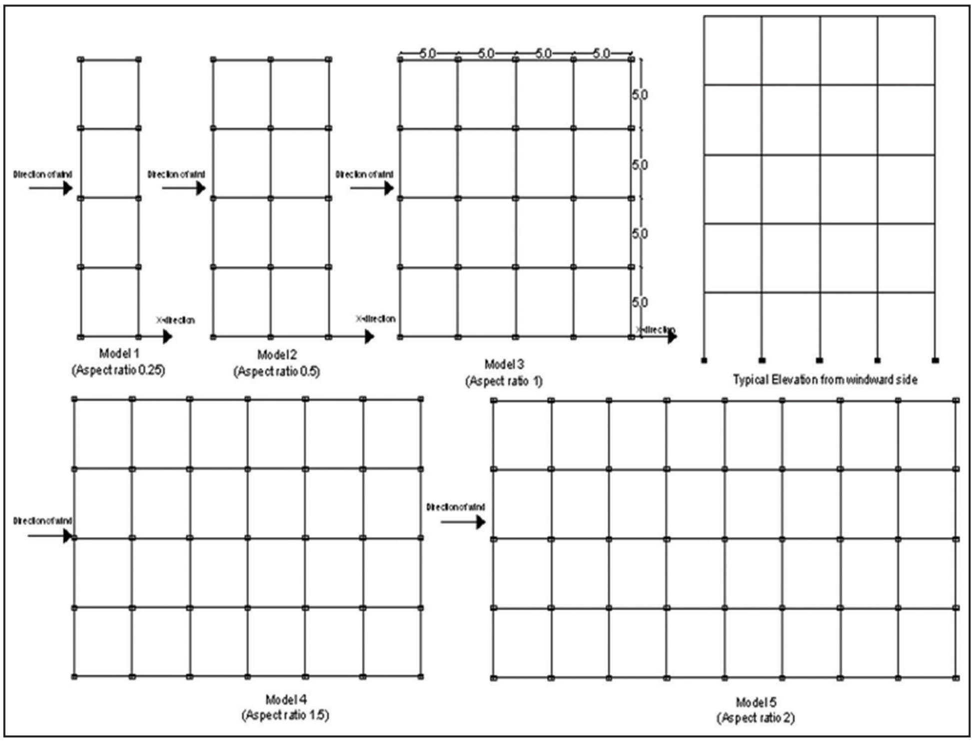

Figure 1: Models with different aspect ratio considered for the study.

and numbers of stories are varied from 3, 5, and 7. Moreover, four different load cases (LC) as per IS 875 Part 5:1987 are considered to study the effect of wind.

The LC considered are as follows:

- 1.5 (DL+LL) - LC-1
- 1.2 (DL+LL+WL) - LC-2
- 1.5 (DL+WL) - LC-3
- 0.9DL+1.5WL - LC-4

LC-1 is considered to study the effect of DL+LL and LC-2 to LC-4 are considered to study the effect of WL. LC-1 is treated as GL and the worst case among LC-2 to LC-4 is treated as WL.

Figure 2 shows the variation of axial force in windward and leeward column with respect to number of stories. The axial force due to the wind effect is normalized with respect to gravity effect of the bottom storey column. The aspect ratio of 1.0 is considered for this study. As the storey height increases from 3 to 7 the axial force in the leeward column gradually increases. The wind effect is not predominant for all stories and the axial force is less compared to the GL. However, as the storey height increases there is a gradual increase in the axial force in leeward column and decrease in windward column.

To understand the variation of bending moment in column due to effect of wind on structures, the height of building is increased from 3 to 7 keeping the aspect ratio of building equal to 1. Figure 3 shows the variation of normalized bending moment in windward and leeward column with respect to number of stories. The bending moments due to WL in the bottom storey is normalized with respect to bending moment due to GL in top storey. The moment due to the wind increases in windward and leeward columnas the number of stories of the building increases from 3 to7. The moment due to wind in leeward column is around 1.75 times the GL where as in windward column it is only 1.5 times the GL for 7 storey building. Moreover, in both windward and leeward column, the bending moments are almost less than GL up to 5 stories and beyond 5 stories the wind moments are gradually increases with respect to gravity moments.

Figure 4 shows the variation of axial forces in the windward and leeward column in the bottom storey with respect to aspect ratio. The axial forces in the windward and leeward column are less compared to GL for all aspect ratio. However, the axial force in leeward column reduces as the aspect ratio increases, and the axial force in windward column increases as the aspect ratio increases.

Figure 5 shows the variation of normalized bending moments in windward and leeward column with

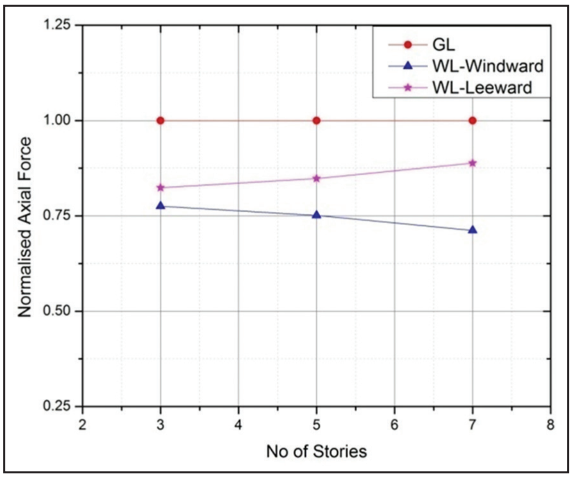

Figure 2: Variation of normalized axial force in windward and leeward column with respect to number of stories.

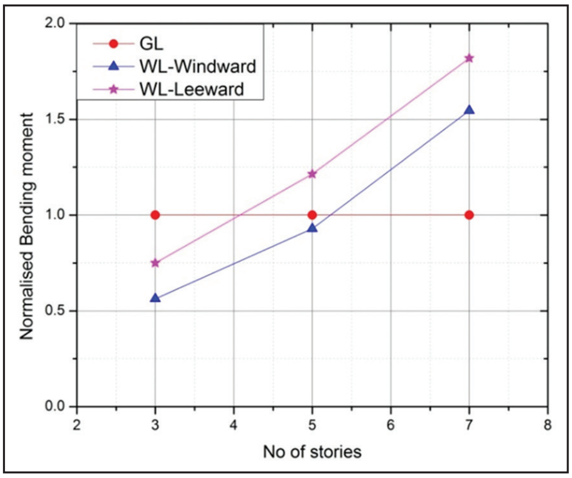

Figure 3: Variation of normalizes bending moments in windward and leeward column with respect to number of stories.

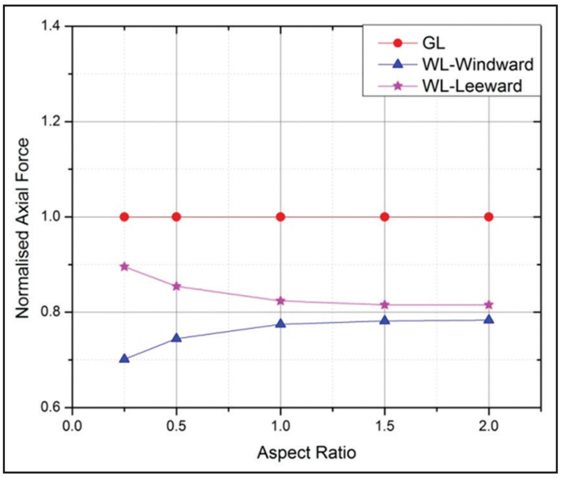

Figure 4: Variation of normalized axial force in windward and leeward column with respect to aspect ratio.

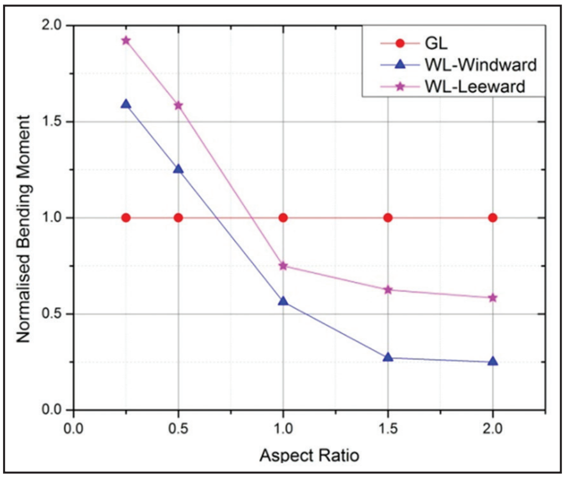

Figure 5: Variation of normalized bending moments in windward and leeward column with respect to aspect ratio.

respect to aspect ratio. The bending moments due to WL in the bottom storey is normalized with respect to bending moment due to GL in top storey. Number of stories considered for the study is three. As the aspect ratio increases from 0.25 to 2, the bending moment in the windward and leeward column reduces. However, when the aspect ratio is less than 1.0 the wind effects are predominant and the bending moment is almost twice the gravity effect, whereas it is 1.5 times the gravity effect in windward and leeward column when the aspect ratio is 0.25.

5. CONCLUSIONS

Based on the present study and the discussions made, the following conclusions are drawn:

- When the aspect ratio of the building is one, the wind effect on the axil load in both the columns is less than the gravity case for all storey buildings.
- In both windward and leeward column the bending moment due to winds is less than gravity effect up to five storeys and beyond five storeys the wind moments are more with respect to gravity moments.
- The axial force in leeward column reduces as aspect ratio increases, and the axial force in windward column increases as the aspect ratio increases. However, in both columns the wind effects are less compared to gravity effects.
- When the aspect ratio is <1.0, the wind effects are predominant. The bending moment due to wind effects are almost 2.0 times the gravity effect in leeward column and about 1.5 times the gravity effect in windward column when the aspect ratio of building is 0.25.

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***Bibliographical Sketch**

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