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RESEARCH ARTICLE

Wind Loads on Cross Shape Tall Buildings

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Abstract

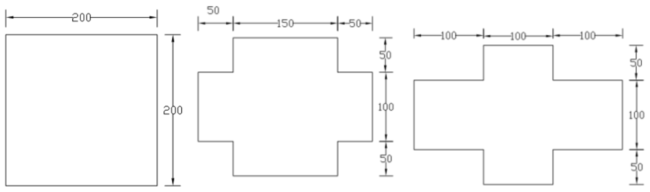
An experimental study has been carried out on rigid models of tall buildings with varying cross-sectional shapes, but with equal floor area, in an open circuit boundary layer wind tunnel to measure wind forces acting on them. This study describes details about the cross-sectional shapes considered, model material and dimensions, testing procedure and important conclusions. It is observed that base shear, base moments and twisting moments developed due to wind loads are not only influenced by wind directions, but also highly affected by cross-sectional shapes.

Keywords: Boundary layer flow, cross-sectional shapes, open circuit wind tunnel, tall buildings, wind loads**.**

Introduction

Numerous tall buildings are being built all over the world including India. Architects generally deign such multistoried apartment/office buildings in square or rectangular plan. However, they sometime make small changes in its cross-section in order to improve its esthetic. Simplest way is to either attach or remove the edges or corners in them. Structural designers while designing such tall buildings for wind loads refer to relevant standards on wind loads to arrive at correct values of wind forces that will be acting on the buildings at different floor levels. Whereas, sufficient information about wind pressure and force coefficients is available in the standards for square and rectangular plan shape buildings with rectangular corners, such information is not available for building with irregular plan shapes. Indian standard on wind loads (IS: 875 (Part-3)-1987) gives the external pressure coefficient values on square and rectangular plan shape clad buildings with rectangular corners for wind incidence angle perpendicular to one of the surfaces only. Whereas, it indicates the effect of height to width ratio on pressure coefficients as well as force coefficients, no information about force coefficients on buildings with varying cross-sectional shape, but having same floor area, is available. This information is not available in the standards of other countries too (AS/NZS: 1170.2(2002), ASCE: 7-02(2002), BS: 63699 (1995), EN 1991-1-4 (2005). Review of recent research work indicates that very little work has been done in the area of influence of cross sectional shapes on wind loads on tall buildings. Stathopoulos (1985) carried out the study on wind environmental condition around tall buildings with chamfered corners. Kwok (1988) and Kwok *et al*. (1988) presented wind tunnel model studies to investigate the effect of edge configuration on the wind induced response of tall buildings with rectangular cross-section. Hayashida and Iwasa (1990) reported the effectiveness of tall buildings with varying corner configurations. Jamieson *et al*. (1992) reported about the wind induced external pressures on a tall building with various corner configurations. Miyashita *et al*. (1993) investigated the wind induced response of tall buildings having corner cut or openings in the buildings. Kawai (1998) presented the work on the effect of corner modification on aero-elastic instabilities of tall buildings. However, most of the above studies focused on the effect of corner configurations on wind loads on tall buildings, where floor or plan area of the building gets modified with the variation in corner configuration. Amin and Ahuja (2008) carried out an experimental study of wind pressures on irregular plan shape buildings wherein the authors considered the models with different shapes but having same floor area. Since available information is yet not enough for the structural designers to make use of it while designing tall buildings with varying cross-sectional shapes for wind loads, an experimental study has been carried out by the authors on the models of tall buildings with different cross-sectional shapes, but having same floor area.

Fig. 1. Varying cross-sectional shapes of tall buildings with equal area.

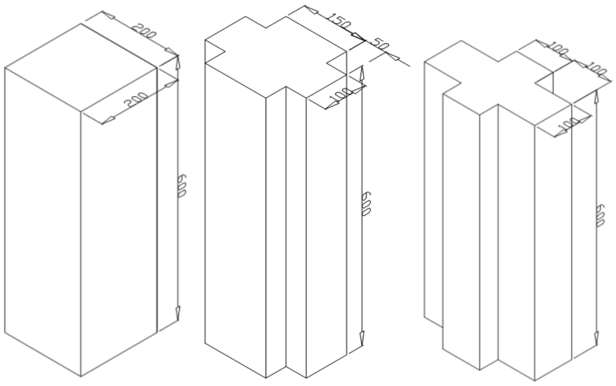


Model-A Model-B Model-C

Materials and methods

Model description: The prototype building is assumed to have floor area of 400 m^2 and a height of 60 m. Three cross-sectional shapes namely A, B and C (Fig. 1) are considered. Whereas, model-A has square shape with rectangular corners, models- B and C have cross shape. Rigid models are made of plywood at a scale of 1:100. Thus all the models have a height of 600 mm and cross-sectional area of 40,000 mm². Detailed dimensions of these models can be seen in Fig. 2.

Fig. 2. Dimensions of rigid models of tall buildings.



Model-A Model-B Model-C

Fig. 3. Wooden models of tall buildings.

Model-A Model-B Model-C

Flow characteristics: In the present study, the models are tested under the boundary layer flow in an open circuit wind tunnel with a cross-section of 2 m (width) x 2 m (height) and the length of the test section as 15 m. Floor roughing devices namely vortex generators, barrier wall, cubical blocks of size 150 mm, 100 mm and 50 mm are used on the upstream end of the test sectionn to achieve the mean wind velocity profile corresponding to terrain category 2 as per Indian standard on wind loads. The models are placed one by one on force balance at a distance of 11.85 m from the upstream edge of the test section and are tested under free stream wind velocity of 9.78 (Approx. 10) m/sec measured at 1 m height above the floor of the tunnel.

Measurement technique: Rigid models of the tall buildings (Fig. 3) are placed on five component load cell one-by-one to measure base shear, base moments and twisting moments acting on them for wind incidence angles 0° to 180° at an interval of 15°. Experimental observations are recorded for 30 sec at an interval of 1 sec and average values are calculated.

Fig. 4. Variation of base shear with wind incidence angle.

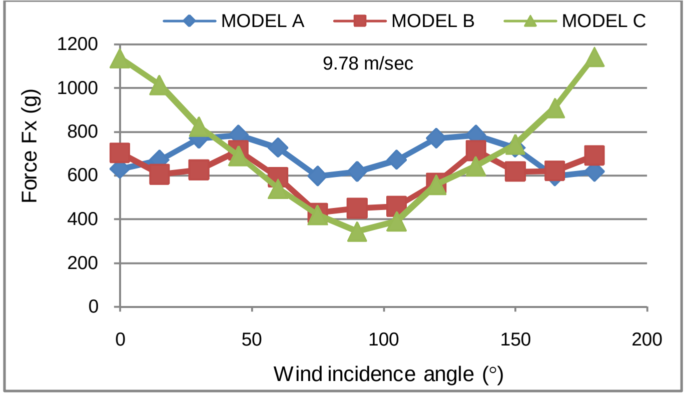


Fig. 5. Variation of base moment with wind incidence angle.

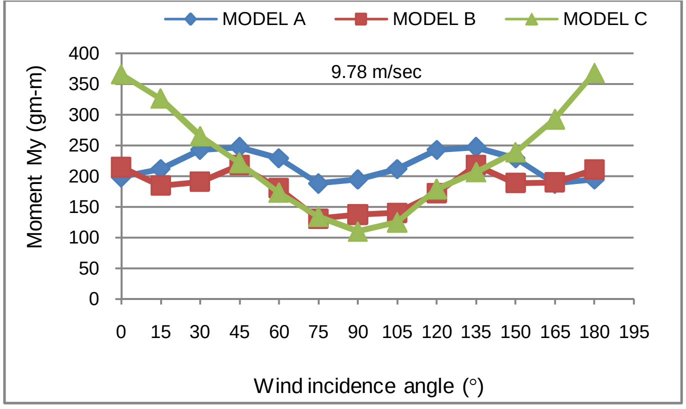
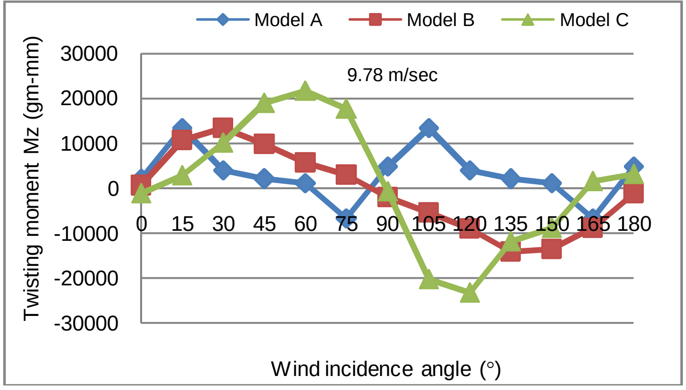


Fig. 6. Variation of twisting moment with wind incidence angle.



Results and discussion

Variations of base shear, base moments and twisting moments measured on three models namely A, B and C as a function of wind incidence angle are shown in Figs. 4, 5 and 6 respectively. It is noticed from Fig. 4 that force Fx, i.e. base shear in the direction of the wind varies within a small range in case of model-A and model-B. Further, its values are maximum at 45° and 135° wind incidence angles and minimum at 90° angle. In case of model-C, maximum value of Fx occurs at 0° and 180° due to maximum exposed area, with minimum at 90° wind incidence angle. Maximum value is almost 3 times the minimum value. Further, maximum value of Fx on model-C is almost 1.7 times the maximum value of Fx for model-A and model-B. Model-B is subjected to lesser force as compared to model-A almost at all wind incidence angles, except at 0° and 180°. Figure 4 thus indicates that the variation in cross sectional shape can increase the base shear to a large extent for certain wind incidence angles even keeping the floor area of the building the same.

Variation of My, i.e. base moment, is identical to that of Fx. Its maximum value in case of model-C is about 2 times as compared to the values in case of model-A and model-B (Fig. 5). It is noticed from Fig. 6 that all three models are subjected to zero twisting moment (Mz) at 0°, 90° and 180° as wind hits the models parallel to major or minor axis at these angles. In case of model-A, the twisting moment is maximum at 15° and 105°. Model-B is subjected to maximum twisting moment at 30° and 150°. In case of model-C, twisting moment is maximum at 60° and 120°, and its value is around 1.3 times that of model-A and model-B.

Conclusion

The following conclusions are drawn from the study presented herein.

1. Wind load on a building is maximum when it has maximum exposed area.
2. Wind loads get modified with wind incidence angle.
3. Cross-sectional shape of the building influence the wind loads acting on the building to a great extent, even if the floor area of the buildings are kept the same for all buildings.
4. The percentage increase in the values of these forces as compared to square section depends upon cross-sectional shapes of the buildings.

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