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Wind Loads on Triangular Shape Tall Buildings

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Present paper describes the details of the experimental study carried out on the models of tall buildings with varying cross-sectional shapes under both stand-alone condition as well as interference condition. Two cross-sectional shapes namely square and triangular are considered. Force measurements are made on the rigid models of tall buildings made of timber. The models are tested in an open circuit boundary layer wind tunnel. Twisting moment developed due to wind is measured in addition to base shear and base moment in along-wind direction as well as across-wind direction. Effect of wind incidence angle on wind loads is studied in case of isolated condition. In case of interference condition, effect of distance between object building and interfering building on wind loads is studied.

Index Terms— **Tall Buildings, Base Shear, Twisting Moment, Interference Effect.**

I. INTRODUCTION

Wind is one of the important loads to be considered while designing tall buildings. The structural designers while designing such buildings refer to relevant code of practices of various countries dealing with wind loads [ASCE:7-02 (2002), AS/NZS:1170.2 (2002), BS-EN 1991-1-4 (2005), IS:875-Part 3 (1987)]. However, available information regarding wind pressure coefficients and wind force coefficients is limited to certain cross-sectional shapes only. Further, these values are for isolated condition of such buildings only. No information is available in connection with interference effect. Designers are, therefore, left with the option of either going for wind tunnel investigation or assuming arbitrary values of wind loads in case of interference.

Review of recent research work also indicates that very few publications are available in the area of wind effects on tall buildings of varying cross-sectional shapes. Balendra and Nathan (1988) reported along-wind, across-wind and torsional fluctuating responses of tall triangular building in wind tunnel at various angle of incidence of wind. Szalay (1989) studied 4 sided, 12 sided and 16 sided polygons, and circular cylinders in wind-tunnel to investigate drag force coefficients on cylinders.

So far as studies on interference effects between tall buildings are concerned, few publications are available. Bailey and Kwok (1985) investigated interference effects between two square tall building models of the same size in wind tunnel. Taniike (1992) studied interference effects between principal square model and interfering square model of various breadths located upstream. Since the information available in literature is not enough for the designers to carry out safe and economical design of tall buildings with varying cross-sectional shapes, the authors have carried experimental study to generate more data in this area. Two cross-sectional shapes namely square and triangular of the same floor-area are considered. Models of the tall buildings are tested in boundary layer wind tunnel under both stand-alone condition as well as interference condition.

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II. EXPERIMENTAL PROGRAMME

A. *Model description*

The cross-sectional shapes of prototype tall building considered in this study are square and equilateral-triangular shapes. Sections of the same floor area about 625m^2 and equal building height about 100m (30 storeys with 3.33m storey height) are selected with dimensions as shown in Figure 1. Force measurements are made on the rigid models. Rigid models of tall buildings are made of timber at a scale of 1:200. The dimensions of the models are shown in Figure 2.

B. *Wind flow characteristics*

In the present study, models are tested in an open circuit boundary layer wind tunnel with a cross-section of 2m x 2m and the length of the test section of 15 m. Flow roughing devices such as vortex generators, barrier wall, cubical blocks of size 70 mm, 50 mm and 38 mm are used on the upstream end of the test section to achieve the mean wind velocity profile of the approaching flow corresponding to terrain category-2 as per Indian Standard on wind loads.

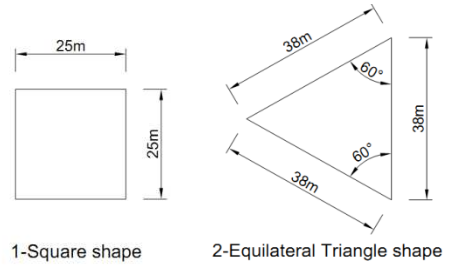

Fig. 1. Cross-sectional dimensions of prototype buildings with equal area.

C. *Measurement technique*

The models are tested under free stream mean wind velocity of 10m/sec measured at 1m height above the floor of the tunnel. Experimental observations are recorded for 60seconds at an interval of 1second. Wooden models of square and triangular cross-sections are placed one by one on five component load cell for force measurement first under isolated condition and later under interference condition. Base shear and base moment in along-wind direction as well as across-wind direction are measured. Twisting moment developed due to wind is also measured. Effect of wind incidence angle on wind loads is studied in case of isolated condition by making the wind to hit the models at wind incidence angles of 0º to 180º at an interval of 15º as shown in Figure 3. In case of interference condition, effect of distance between object building and interfering building on wind loads is studied.

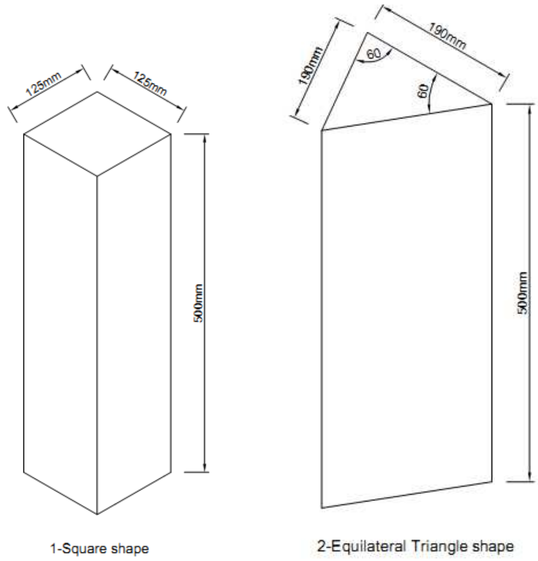

Fig. 2. Dimensions of the models.

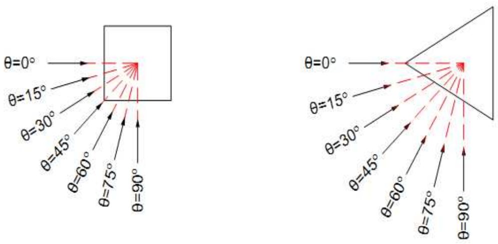

Fig. 3. Wind directions on models.

III. Results and Discussion

Force measurement - Isolated condition.

Variations of along and across-wind forces and moments, and twisting moments measured on square and triangular shape models in isolated condition as a function of wind incidence angle, are shown in Figures 4 to 6. It is noticed from Figure 4 that triangular shape model is subjected to larger along-wind force (Fx) as compared to square shape model. Along-wind force is found to be maximum at 60º and 180º wind incidence angles on triangular shape model when wind blows perpendicular to one of the faces. In case of square shape model, it is maximum at 45º and 135º wind incidence angles. Maximum value of Fx in case of triangular shape model is around 1.5 times that in case of square shape model.

Variation of along-wind base moment (My) with wind incidence angle can be seen in Figure 5. Its variation is identical to that of Fx.

Triangular shape model is also subjected to larger across-wind force (Fy) as compared to square shape model (Figure 6). The maximum across-wind force on triangular shape model is developed at 30º, 90º and 150º wind incidence angles i.e. when wind blows parallel to one of the faces. Comparison of maximum value of Fy on triangular shape model with maximum value of Fx indicates that former is about 70% of later. In case of square shape model, value of across-wind force (Fy) is very small and its variation with wind incidence angle is also not significant. Maximum value of Fy in case of triangular shape model is around 8 times that in case of square shape model.

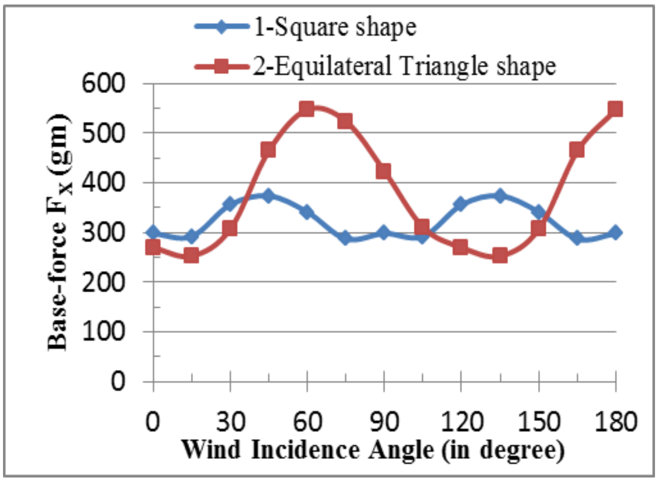

Fig. 4. Variation of along-wind force with wind incidence angle.

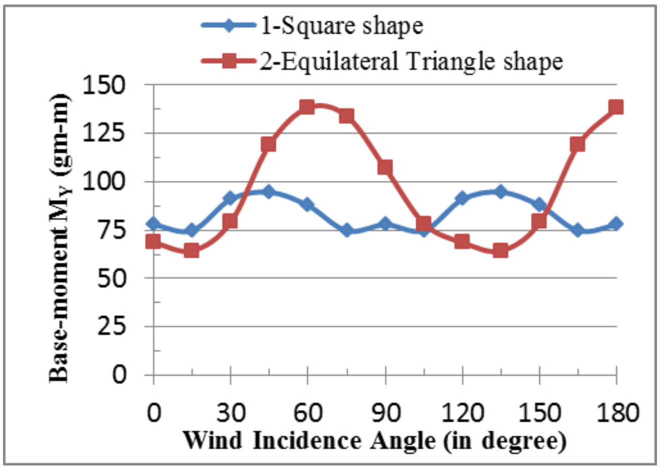

Fig. 5. Variation of along-wind moment with wind incidence angle.

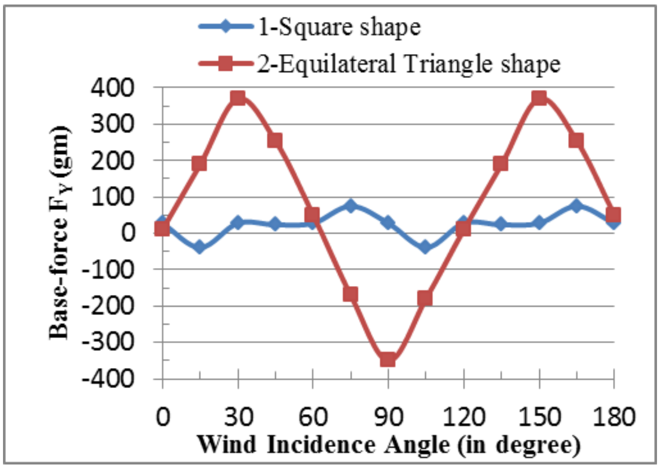

Fig. 6. Variation of across-wind force with wind incidence angle.

Variation of across-wind base moment (Mx) with wind incidence angle is identical to that of across-wind force (Fy) (Figure 7).

It is seen from Figure 8 that whereas twisting moment (Mz) is developed in case of both square and triangular shape models at certain wind incidence angles, its value is

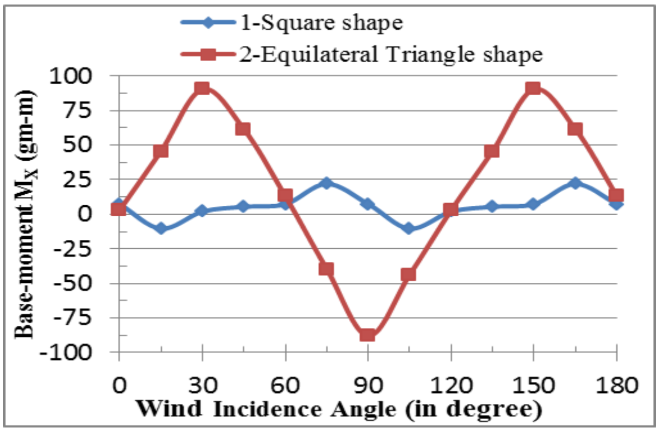

Fig. 7. Variation of across-wind moment with wind incidence angle.

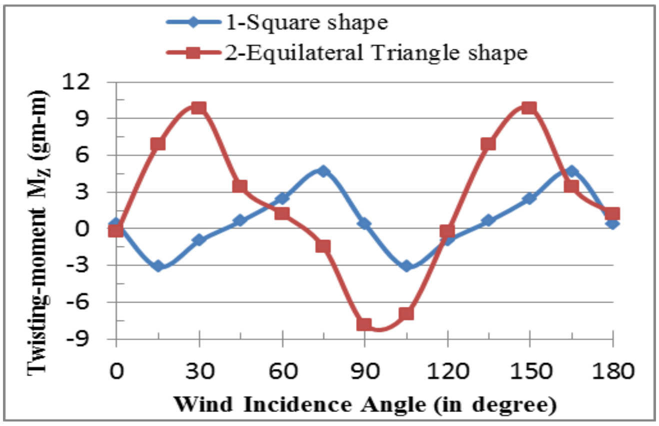

Fig. 8. Variation of twisting moment with wind incidence angle.

larger in case of triangular shape model than square shape model. The maximum twisting-moment is developed at 30º, 90º and 150º wind incidence angles for triangular shape model i.e. when wind blows parallel to one of the faces. In case of square shape model, it is maximum at 15º, 75º, 105º and 165º wind incidence angles. Maximum value of Mz in case of triangular shape model is around 2 times that in case of square shape model.

Force measurement - Interference condition.

Wind loads on the leeward model of tall building with triangular cross-sectional shape under interference condition between 2 buildings of similar cross-sectional shape and height has also been measured by varying the longitudinal spacing (x/b) and transverse spacing (y/b) between them. Variation of along-wind force (Fx) as a function of longitudinal and transverse spacing is shown in Figure 9. It is noticed that along-wind force (Fx) increases with increase in longitudinal and transverse spacing of buildings and its value is close to that in case of isolated condition at large spacing. Fx is almost zero when interfering building is situated exactly on the upstream side of the object building (i.e. at y/b = 0) at a distance of 1.5b in the direction of wind (i.e. x/b = 1.5). When transverse spacing (y) is equal to side of the triangle (b) and longitudinal spacing (x) becomes equal to 4 times side of the triangle, effect of interference vanishes.

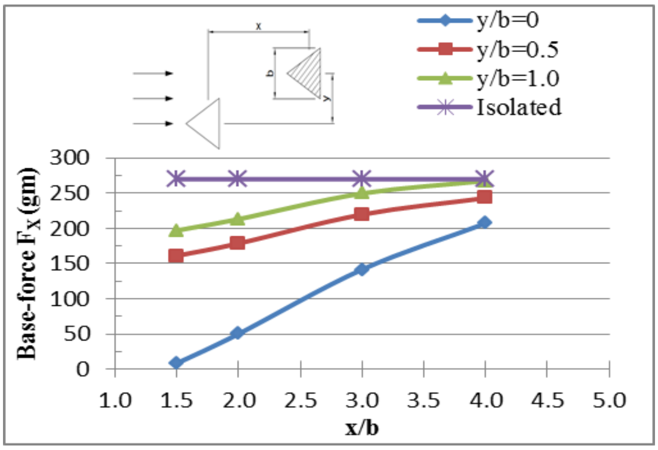

Fig. 9. Variation of along-wind force on triangular shape model with spacing between buildings under interference condition.

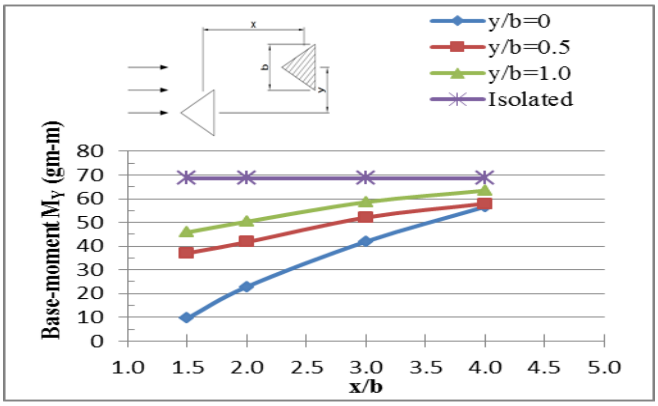

Fig. 10. Variation of along-wind moment on triangular shape model with spacing between buildings under interference condition.

Variation of along-wind base moment (My) with spacing between buildings under interference condition is identical to that of Fx (Figure 10). Figure 11 shows variation of twisting moment on triangular shape model with spacing between buildings under interference condition. It is noticed that maximum twisting moment is developed at longitudinal spacing of 2b and transverse spacing of 0.5b. Twisting moment is zero when object building is fully shielded by another building for all values of longitudinal spacing.

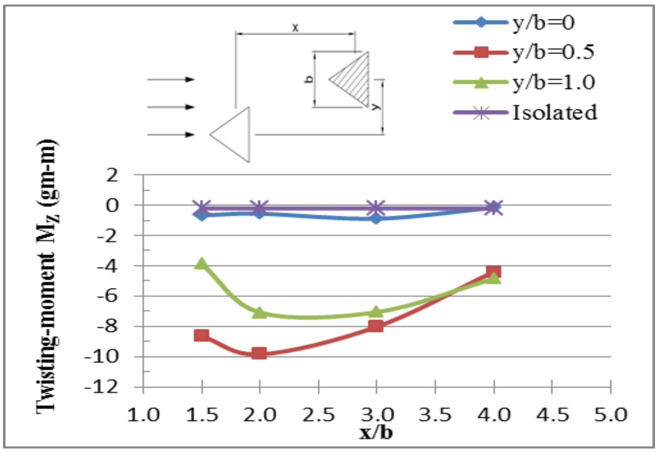

Fig. 11. Variation of twisting moment on triangular shape model with spacing between buildings under interference condition.

IV. CONCLUSIONS

The following conclusions are drawn from the study presented in this paper.

1. All components of wind loads namely along-wind force, along-wind moment, across-wind force, across-wind moment and twisting moment on triangular shape model are found to be larger in magnitude as compared to square shape model.
2. Along-wind force and moment developed on triangular shape model are maximum when wind blows perpendicular to one of the faces, whereas these values on square shape model are maximum when wind blows along one of the diagonals.
3. Across-wind force and moment developed on triangular shape model are maximum when wind blows parallel to one of the faces, whereas variation of these values with wind incidence angle on square shape model is not significant.
4. Twisting moment developed on triangular shape model is maximum when wind blows parallel to one of the faces, whereas this value on square shape model is maximum at 4 skew angles.
5. In case of triangular shape model, maximum value of along-wind force is around 1.5 times, maximum value of across-wind force is around 8 times and maximum value of twisting moment is around 2 times that in case of square shape model.
6. In interference condition, along-wind force and moment on leeward triangular shape model are found to be increasing with increase in longitudinal and transverse spacing between buildings. At large spacing, these values become close to those in isolated condition.
7. Twisting moment developed on triangular shape model in interference condition is maximum when longitudinal spacing is equal to 2 times side of the triangle and transverse spacing is equal to half of the side of the triangle.

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REFERENCES

[1] ASCE: 7-02 (2002). "Minimum design loads for buildings and other structures".

[2] AS/NZS: 1170.2, (2002). "Structural design actions, Part 2 - Wind actions".

[3] Bailey, P. A. and Kwok, K. C. S. (1985). "Interference excitation of twin tall buildings", *J. Wind Engg. and Ind. Aero.*, 21, 323-338.

[4] Balendra, T. and Nathan, G. K. (1988). "Dynamic response of a triangular building model in an atmospheric boundary layer", *J. Wind Engg. and Ind. Aero.*, 31, 29-39.

[5] BS-EN 1991-1-4 (2005). "Euro code 1: Actions on structures – Wind actions".

[6] IS: 875-Part 3, (1987). "Code of practice for the design loads (other than earthquake) for buildings and structures (Part 3 - wind loads)".

[7] Szalay, Z. (1989). "Drags on several polygon cylinders", *J. Wind Engg. and Ind. Aero.*, 32, 135-143.

[8] Taniike, Y. (1992). "Interference mechanism for enhanced wind forces on neighbouring tall buildings", *J. Wind Engg. and Ind. Aero.*, 41-44, 1073-1083.

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