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RESEARCH ARTICLE

Wind Loads on 'T' Plan Shape Tall Buildings

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Abstract

Wind tunnel tests were carried out on models of 'T' plan shape tall building to evaluate the wind loads generated namely base shear (Fx), overturning moment (My) and torsional moment (Mz), in isolated as well as interference conditions. For the isolated condition, measurements were made for many wind incidence angles and considering the effects of interference; the interfering model had the same shape and dimensions as that of the instrumented model. The models were placed in side-by-side as well as tandem configuration and the spacing between these models varied. It was observed that the presence of a neighbouring building greatly affects the wind flow pattern around a building which causes change in the wind loading on the building. Depending on the position of the interfering building, the interference effects may either be beneficial or may have an adverse effect.

Keywords: Wind tunnel, wind loads, base shear, overturning moment, torsional moment.

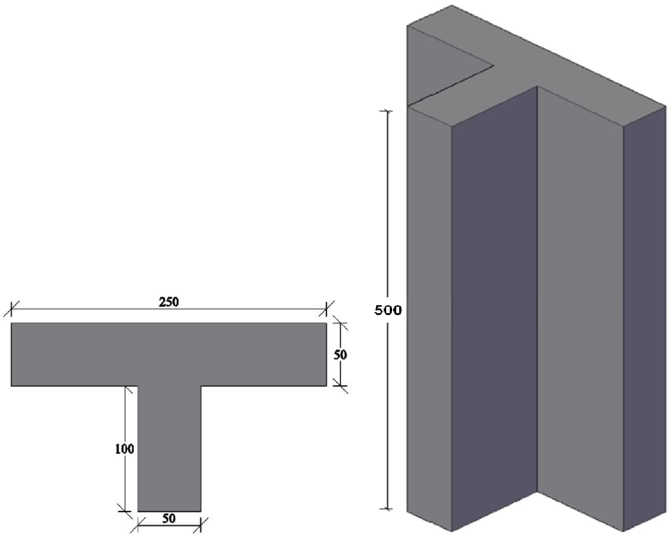
Introduction

Tall buildings are required for office and residential complexes to cater the population growth and also for the shortage of space in large cities. These buildings have generally been designed with regular cross-sectional shapes like square or rectangle. However, recently there has been an increasing trend by the architects to design tall buildings with unconventional shapes. Some of the causes that have led to this trend are improvement in aesthetic features of a building, restrictions of construction sites and building regulations. For design of buildings for wind loads, the designers use values of design pressure coefficients and force coefficients given in the relevant standards on wind loads (AS/NZS: 1170.2-2002, ASCE: 7-02-2002, BS: 63699-1995, EN: 1991-1-4-2005, IS: 875 (Part-3) 1987). However, these standards provide information for regular cross-sectional shapes with limited wind incidence angles. Information on wind induced loads on buildings with unconventional shapes is not available in these codes. Hence, wind tunnel testing is generally conducted on the models of such buildings. Similarly, very little guidance is available for considering the interference effects. Kwok (1988) found that modification to the shape of a tall building with a rectangular cross-section has a significant effect on both the along-wind and cross-wind excitation processes and the response characteristics. Kawai (1998) studied the effect of various corner modifications on aeroelastic instabilities such as vortex induced excitation and galloping oscillation by wind tunnel tests for square and rectangular prisms. Models of irregular-plan shapes ('L' and 'U' plan shapes) were tested by Gomes *et al.* (2005) to assess the surface pressure distributions. Amin (2008) carried out tests on rectangular plan buildings having same plan area and height but different side ratios. Author also analyzed 'L' and 'T' plan shape buildings comprising of two blocks with variety of geometric configurations. Gu (2009) tested models of 27 typical tall buildings having different cross-sectional shapes and found the wind induced pressures and loads. Lam *et al*. (2009) measured the dynamic wind loads induced on a number of 'H' plan shape tall buildings with different sizes of recessed cavities. Effects of various corner modifications on wind loads on tall buildings were investigated by Bhatnagar (2011) who also measured the base shear and moments induced on rectangular-plan buildings having different length-to-width ratios and L-shaped building with different block sizes. Notwithstanding that 'T' shape is a very basic shape; the experimental data for such a shape is quite rare and limited. Also no information is available for interference between two similar 'T' plan shape buildings. Therefore, an experimental study has been carried out on 'T' plan shape building model to measure the wind induced loads for isolated as well as interference condition.

Materials and methods

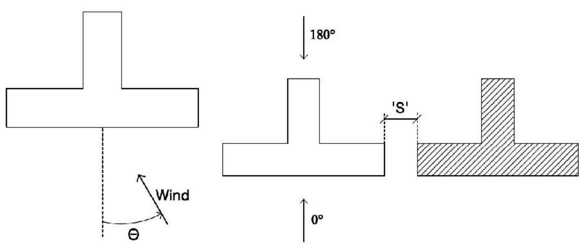
Wind flow characteristics: All the tests were performed in open circuit boundary layer wind tunnel having a cross section of 2 m (width) x 2 m (height) and 15 m long test section. Test models were placed on five component load cell at a distance of 10.5 m from the upstream end of test section. Using various flow roughening devices like vortex generators, barrier wall and cubical blocks, mean wind velocity profile corresponding to terrain category-II as per Indian standard on wind load is generated. The experiment is carried out at free stream wind velocity of 10 m/sec.

Fig. 1. Dimensions of the 'T' plan shape building model (in mm).

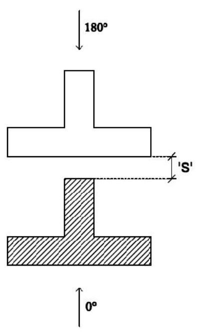


Model description: The models (both instrumented and interfering model) used in the experimental study were constructed of plywood at a geometric scale of 1:200. The dimensions of the 'T' plan shape building model are shown in Fig. 1. The instrumented and the interfering model are of the same dimensions. The height of each model is kept as 500 mm which represents a 100 m high prototype building. The width of the smaller face and the larger face is 50 and 100 mm respectively which represent 10 and 20 m on the prototype. The model was tested for the following isolated and interference conditions (Fig. 2).

Fig. 2. Isolated and interference configurations.



a. Isolated case b. Setup A



c. Setup A

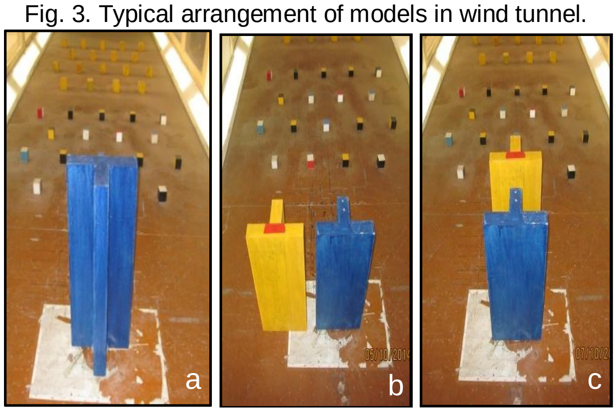
Isolated case: Variation of Fx, My and Mz on single instrumented model with wind incidence angle varying from 0^o to 360^o (Fig. 2a).

Interference case: Setup A (side-by-side configuration): Variation of Fx, My and Mz on instrumented model with spacing between the instrumented and interfering model for wind incidence angles of 0^o and 180^o (Fig. 2b).

Setup B (tandem configuration): Variation of Fx, My and Mz on instrumented model with spacing between the instrumented and interfering model for wind incidence angles of 0^o and 180^o (Fig. 2c).

Measurement technique: The 'T' plan shape building model is placed on five component load cell. The model is first placed in isolated condition (Fig. 3a). Later, the interfering model is placed in side-by-side configuration (Fig. 3b) and tandem configuration (Fig. 3c). The values of base shear (Fx), overturning moment (My) and torsional moment (Mz) acting on the instrumented model are recorded. For isolated condition, wind incidence angle is varied from 0^o to 360^o, the angle of increment being 15^o. For interference condition, the measurements are made for wind incidence angles of 0^o and 180^o. The spacing between the instrumented and the interfering building model is also varied. For setup A, the spacing was varied from 0 to 200 mm and for setup B, the spacing was varied from 0 to 600 mm.

Fig. 3. Typical arrangement of models in wind tunnel.



Results and discussion

Variation of base shear (Fx), overturning moment (My) and torsional moment (Mz) measured on single instrumented model as a function of wind incidence angle is shown in Figs. 4 to 6. It is noticed from Fig. 4 that the maximum value of Fx is obtained at an angle of 0^o because the effective area of the building model is maximum at 0^o wind angle. Minimum value of Fx is obtained at angles of 75^o and 285^o because the orientation of the model at these angles facilitates easy flow of wind from the sides thereby causing reduction in the base shear. Variation of My is identical to that of Fx (Fig. 5). Maximum value of torsional moment (Mz) is obtained at 90^o and 270^o.

Fig. 4. Variation of base shear (Fx) with wind incidence angle (Isolated case).

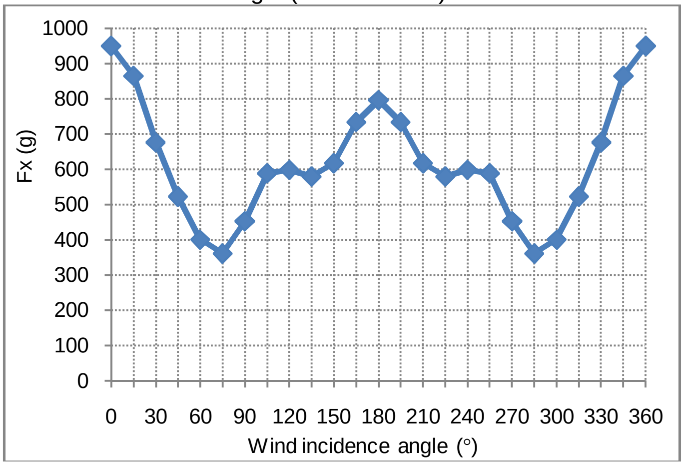


Fig. 7. Variation of base shear (Fx) with spacing.

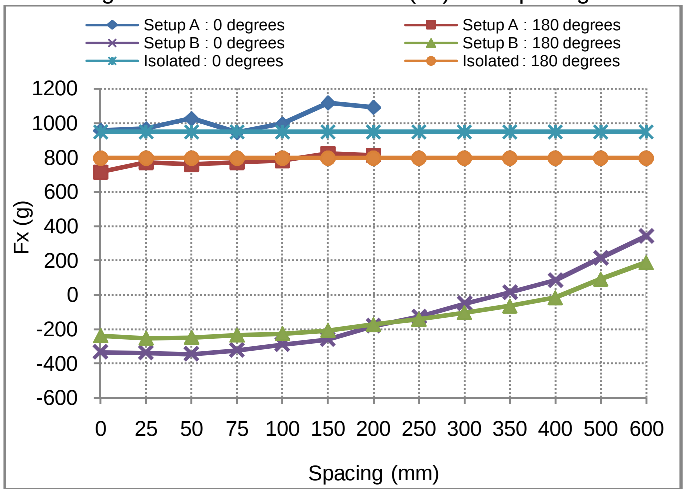


Fig. 5. Variation of overturning moment (My) with wind incidence angle (Isolated case).

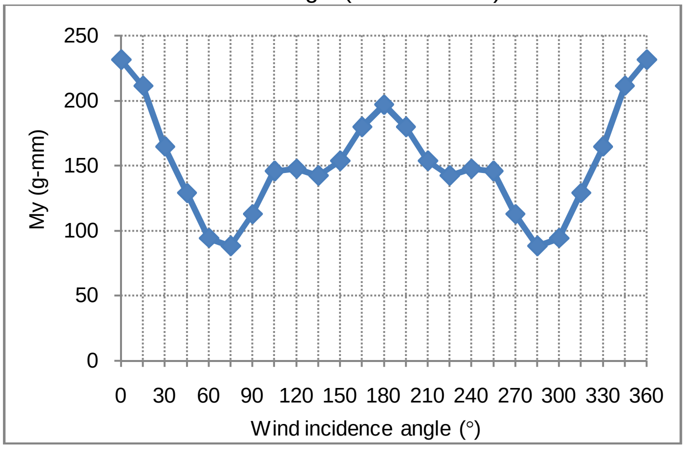


Fig. 8. Variation of overturning moment (My) with spacing.

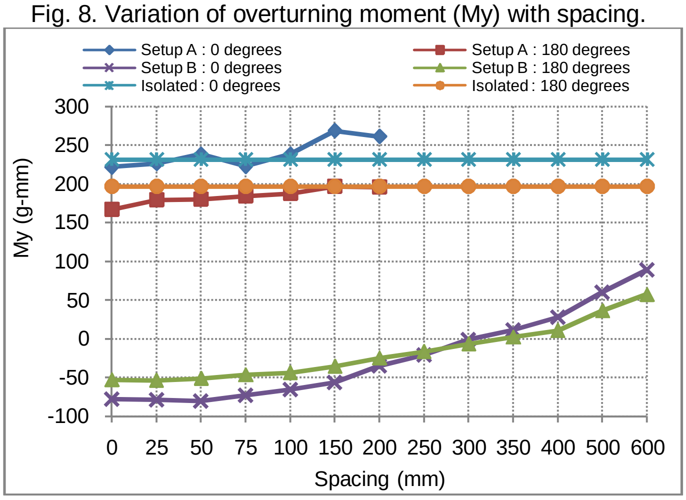


Fig. 6. Variation of torsional moment (Mz) with wind incidence angle (Isolated case).

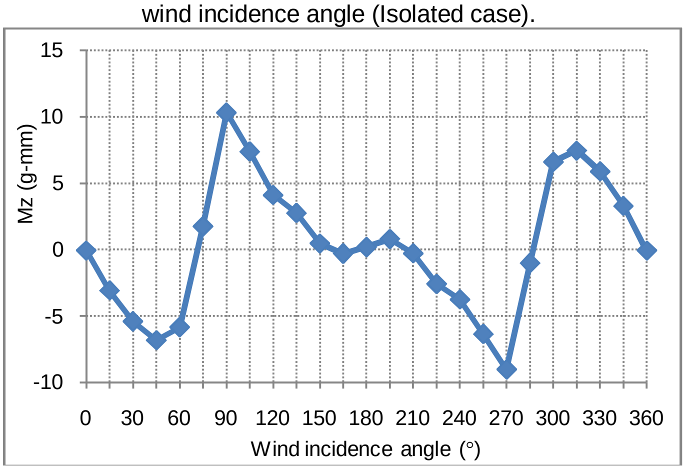
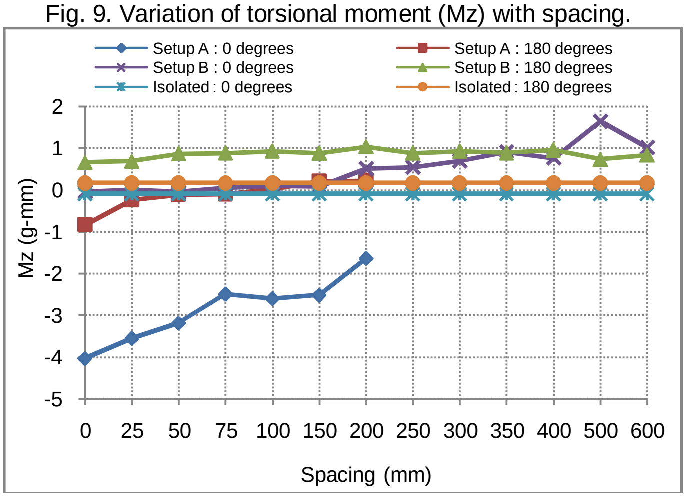


Fig. 9. Variation of torsional moment (Mz) with spacing.



At these angles, the wind is parallel to the flange and strikes only on the web of 'T', thereby causing increased torsional moment. Mz is found to be zero at 0^o and 180^o. This happens due to the wind flow being parallel to the axis of symmetry of the 'T' shape and hence there is symmetric loading on the building model at these wind incidence angles.

Figures 7, 8 and 9 depict the variation of Fx, My and Mz with spacing between the instrumented model and the interfering model for interference cases (setup A and B) for 0^o and 180^o wind incidence angles. Corresponding values for isolated case with wind angle of 0^o and 180^o are also plotted for comparison purpose.

For setup A, there is a slight variation of base shear due to interference from the adjoining building model at 0 mm spacing. This variation gradually diminishes as the spacing is increased. In case of setup B, the presence of interfering model on the upstream side causes shielding effect on the instrumented model resulting in reduced values of Fx as compared to the isolated case. Infact, for spacings upto 350 mm for setup B (0^o) and upto 400 mm for setup B (180^o), the values of Fx are found to be negative i.e. wind induced force acts in the upstream direction. As the spacing is increased, the effect of interference decreases significantly. However, even at spacing of 600 mm, there is a considerable effect of interference for setup B. Overturning moment (My) shows the same trend as that of Fx (Fig. 8). For setup A, the presence of the interfering building model causes asymmetric wind loading on the instrumented model due to which the torsional moment is generated. Torsional moment decreases rapidly with increase in spacing between the instrumented and the interfering model for setup A (Fig. 9). However, the effect of interference is more pronounced for wind angle of 0^o than 180^o. In setup A (0^o), the flange of 'T' is in upstream direction and it contributes to the torsional moment in the instrumented model by diverting wind towards it. But, in setup A (180^o), the flange of 'T' is in downstream direction and its effect on the interference is not so severe. For setup B, due to the symmetry of 'T' shape, there is symmetric distribution of wind around the instrumented building. Hence, there is negligible change in torsional moment in setup B as compared to that of isolated case.

Conclusion

The following conclusions are drawn from the study:

1. Presence of a neighbouring building greatly affects the wind flow pattern around a building.
2. Due to changes in the wind flow pattern caused by neighbouring structures, there is change in the wind loading on the building.
3. Wind loads on 'T' plan shape building is highly influenced by the wind incidence angle.
4. Interference effects are beneficial for setup B (tandem configuration) but have an adverse effect in setup A (side-by-side configuration).
5. Torsional moment on the building under interference condition may be greater than that of isolated condition due to the asymmetric distribution of wind around the building.

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