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EFFECT OF HEIGHT AND ORIENTATION OF INTERFERING BUILDINGS ON WIND LOADS ON TALL BUILDINGS

BHARAT CHAUHAN and ASHOK AHUJA

Dept of Civil Engineering, IIT Roorkee, Roorkee, India

The research work presented in this paper investigates the effect of interference on wind loads on a tall building (instrumented building) having rectangular cross-sectional shape due to the presence of two interfering buildings close to the instrumented building. The effect of interference on the instrumented building is studied with the variation of height and relative orientation of the interfering buildings with respect to the instrumented building. Wind tunnel experiments are undertaken using five component force balance load cell and the results are reported in the form of X-Y plots. The effect of interference in both shielding as well as enhancing the wind load on the instrumented building, is seen to increase with the increase in the height of the interfering building. Negative drag force is also observed in few cases where shielded part of the instrumented building is large. Value of torsion on the instrumented building is observed to be as high as ten times of that in the isolated case.

Keywords: Wind tunnel, Interference, Rectangular cross-section, Orientation, Height variation, Force study.

1 INTRODUCTION

A rapid decrease in the availability of land in the cities along with the increasing population has led to the promising solution of tall buildings. It has been seen that with the increasing height of the buildings, the effect of wind load dominates. These wind loads are greatly affected by the presence of nearby structures and become critical to study these effects before designing such tall buildings. Various codes of practice on wind loads (AS/NZS: 1170.2 (2002), ASCE: 7-02-2002, EN: 1991-1-4-2005, IS: 875 (Part-3) 2015) provide guidance limited to isolated cases only.

Many wind tunnel studies have been carried out in the past to study the effect of interference by varying the position of the interfering building (Khanduri *et al.* 1998, Xie and Gu 2004, Amin 2008, Zhao and Lam 2008, Kim *et al.* 2011, Kushal 2013, Pandey 2013, Mara *et al.* 2014, Yan and Li 2016). However, no studies could be found for the effect of interference on wind loads on tall buildings having rectangular plan shape due to the presence of two interfering buildings having similar plan shape. Also, there were no studies in which the effect of relative orientation of the interfering building with respect to the instrumented building was studied.

An attempt has, therefore, been made to study the effect of interference on wind loads on a rectangular plan shape tall building due to the presence two closely spaced tall buildings having similar plan shape. The position of one of the interfering building is varied with respect to the instrumented building in terms of the relative orientation. The height of the interfering building is also varied to study its effect on wind loads on the instrumented building.

2 MATERIALS AND METHODS

2.1 Model Description

Prototype considered for the instrumented tall building in the given study is of rectangular shape in plan having plan dimensions of 60 m x 20 m (i.e., 1200 m^2 area in plan) and having height of 100m which correspond to width to length ratio of 1:3 and width to height ratio of 1:5. Similarly, the prototype considered for the interfering tall buildings in the study are also of rectangular shape in plan having plan dimensions of 60 m x 20 m (i.e., 1200 m^2 area in plan) but having variation in heights as 100 m, 80 m, 60 m, 40 m and 20 m. Force measurements are conducted by using rigid models of rectangular shape tall building (for both instrumented and interfering buildings) made of Plywood to a scale of 1:200. Figure 1 shows the dimensions and arrangement of the models used for instrumented (hatched) and interfering buildings for wind tunnel tests.

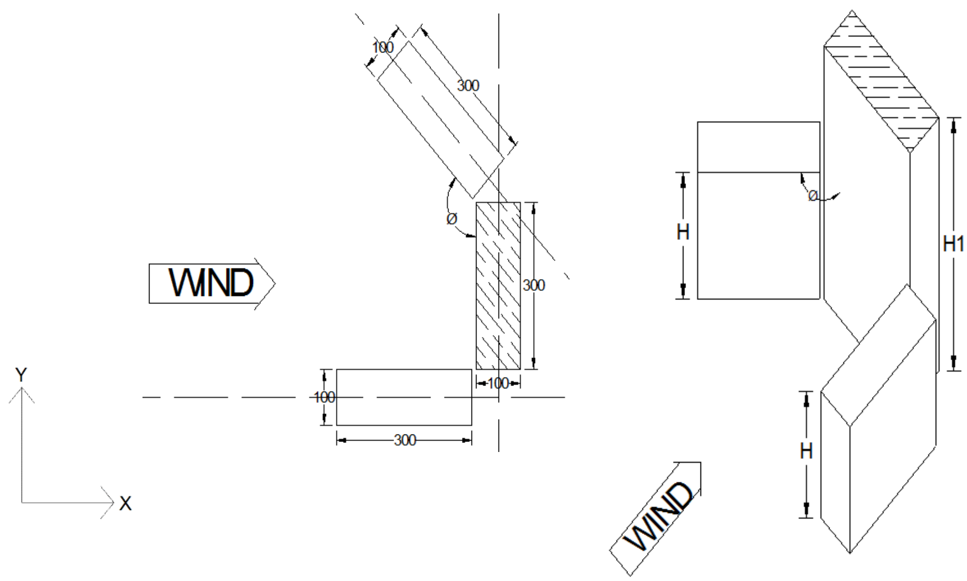


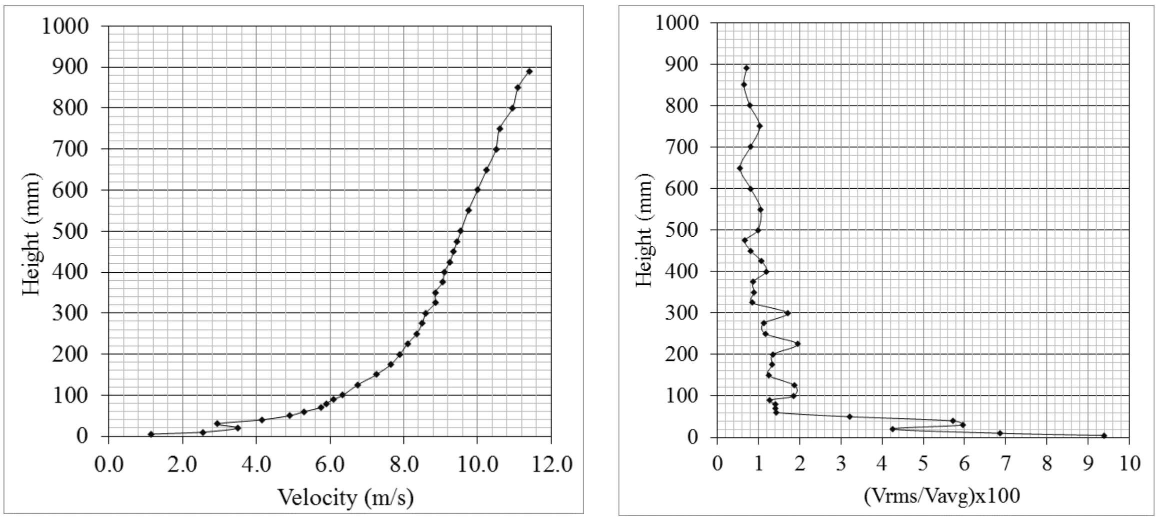
Figure 1. Plan view and isometric view of the models (All dimensions are in mm).
[Ø = 0^0 to 180^0 @ 15^0; H1 = 500 mm; H = 100 mm, 200 mm, 300 mm, 400 mm, 500 mm.]

2.2 Wind Flow Characteristics

An open circuit boundary layer wind tunnel having a cross-section of 2 m x 2 m and length of the test section as 15 m is used for the testing of the models. Vortex generators for generating turbulence in horizontal plane, barrier wall for generating turbulence in vertical plane, and floor roughening 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 power law exponent of 0.3. The wind velocity profile and the turbulence intensity profile during the experimentation are shown in Figure 2.

2.3 Measurement Technique

Plywood model for the instrumented building is placed at top of the 5 component load cell and is tested under free stream mean wind velocity of 11.4 m/sec measured at 0.89 m height above the floor of the tunnel. Recording of observations are undertaken at an interval of 1 second for 60 seconds. The instrumented model is tested for isolated condition and for 13 different arrangements of interfering buildings keeping one of the interfering building normal to the instrumented building, while rotating the other interfering building from 0° to 180° at an interval of 15° (Figure 1) for each height of the interfering building, making a total of 66 different arrangements. Photographs for a few arrangements are added in Figure 3.



(a) (b)

Figure 2. Wind characteristics used for experiments: (a) Mean wind speed profile; (b) Turbulence intensity profile.

3 EXPERIMENTAL RESULTS

Experimental results are reported in the form of X-Y plots with internal angle (Ø, Figure 1) on X axis and the corresponding value of interference factor on Y axis, where the interference factor being defined as:

Interference Factor (K_{FX} or K_{FY} or K_{MX} or K_{MY} or K_{MZ}) =

$$\frac{\text{Measurment Parameter (Fx or Fy or Mx or My or Mz) under interference condition}}{\text{Corresponding Parameter (Fx or Fy or Mx or My or Mz) under isolated condition}}$$

where, Fx = Base shear force on the instrumented building along the wind flow;
Fy = Base shear force on the instrumented building across the wind flow;
Mx = Base overturning moment on the instrumented building about the X-axis;
My = Base overturning moment on the instrumented building about the Y-axis;
Mz = Twisting moment on the instrumented building about the Z-axis;

Interference factors for various measurement parameters are calculated using average values (for 60 readings) for the corresponding parameter and are reported in the form of line graphs in Figure 4. Numerical values for isolated case are also reported in Figure 4 in form of bar graphs.

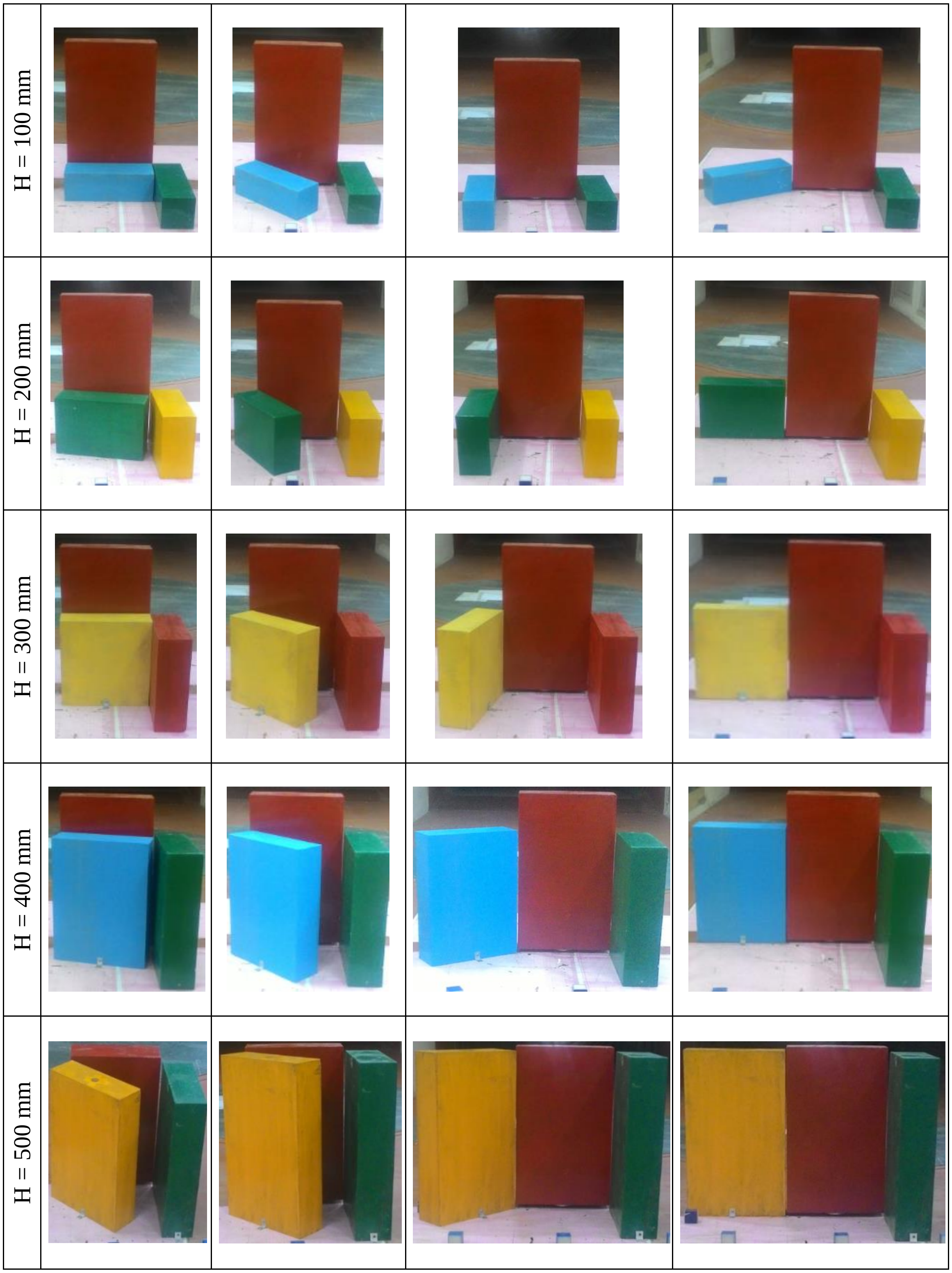


Figure 3. Photographs for few arrangements.

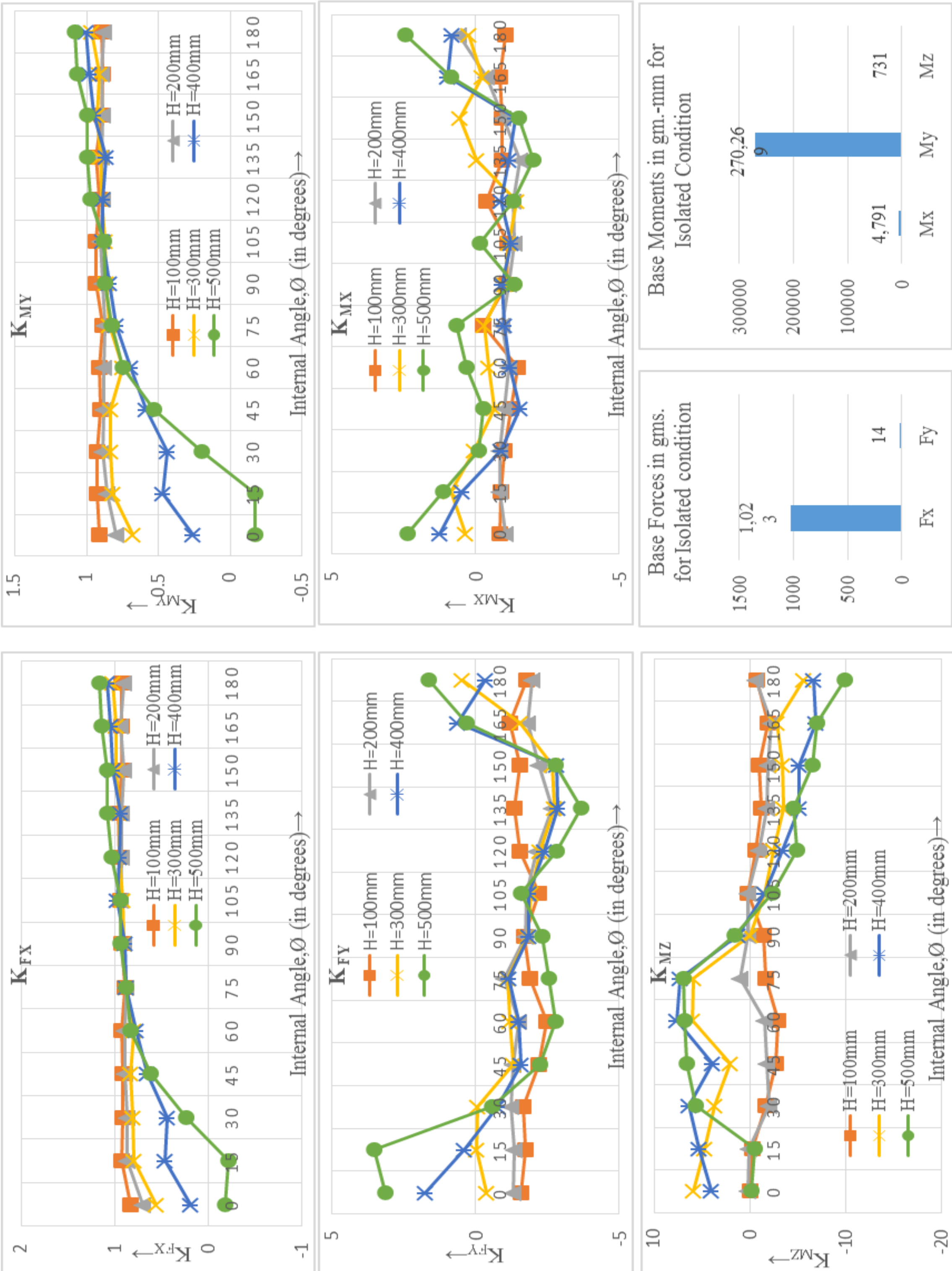


Figure 4. Line graphs - interference factors for various experimental setups; bar graphs – numerical values for isolated condition.

4 CONCLUSIONS

- It can be seen that the effect of interference on wind loads increases with the increase in height of the interfering building.
- The presence of an interfering building is not always beneficial as it can be seen that at Ø = 180°, for H = 500 mm the value of K_{FX} is 1.164 (i.e., 16% higher load than the isolated case), and K_{MZ} is -9.9, emphasizing on the importance of interference studies.
- K_{MY} follows the trend similar to K_{FX}. The effect of height of the interfering building is negligible in the range Ø = 75° to Ø = 105° for these two parameters.
- Negative drag force is observed for Ø = 0° and Ø = 15° for H = 500 mm, this might be explained as in these two cases the most part of the instrumented building is shielded, the wind streams separate at the edges of the interfering building and the instrumented building lies in the wake zone of the interfering building.
- K_{MX} follows the trend similar to K_{FY}. The sign of K_{FY} changes after Ø = 15°. It may be due to the presence of stronger suction on the end where the normal interfering building is not present compared to the other end. It again changes sign at Ø = 165°, which may be because as the width of the interfering building and instrumented building become parallel to each other, it causes the formation of vortices in the small gap, causing change in direction of the F_Y on the instrumented building. Highest value of K_{FY} observed is -3.68 at Ø = 135°, because at this position the instrumented building is forced to move towards the interfering building by both the interfering buildings.
- K_{MZ} for all the building heights is close to zero at Ø = 90° as expected.

References

Amin, J., *Effects of Plan Shape on Wind Induced Response of Tall Buildings*, Ph.D. Thesis, Department of Civil Engineering, Indian Institute of Technology Roorkee, India, 2008.

AS/NZS: 1170.2-2002, *Australian/NZ Standard: Structural Design Actions Part-2: Wind Actions*, 2002.

ASCE: 7-02-2002, *American Society of Civil Engineers: Minimum Design Loads for Buildings and Other Structures*, 2002.

EN: 1991-1-4-2005, *Euro Code 1: Actions on Structures – Wind Actions*, 2005.

IS: 875 (Part-3), *Code of Practice for Design Loads (other than Earthquake Loads), for Building and Structures – Wind Loads*, 2015.

Khanduri, A. C., Stathopoulos, T., and Bédard, C., Wind Induced Interference Effects on Buildings - a Review of the State-of-the-art, *Engineering Structures*, 20, 617–630, 1998.

Kim, W., Tamura, Y. and Yoshida, A., Interference Effects on Local Peak Pressures Between Two Buildings, *Journal of Wind Engineering and Industrial Aerodynamics*, 99, 584–600, 2011.

Kushal, T., *Effect of Plan Shapes on the Response of Tall Buildings under Wind Loads*, M.Tech. Thesis, Department of Civil Engineering, Indian Institute of Technology Roorkee, India, 2013.

Mara, T. G., Terry, B. K., Ho, T. C. E., and Isyumov, N., Aerodynamic and Peak Response Interference Factors for an Upstream Square Building of Identical Height, *J. of Wind Engrg. and Indust. Aerodynamics*, 133, 200–210, 2014.

Pandey, S. C., *Influence of Proximity on the Response of Tall Buildings under Wind Loads*, M.Tech. Thesis, Department of Civil Engineering, Indian Institute of Technology Roorkee, India, 2013.

Xie, Z. N. and Gu, M., Mean Interference Effects Among Tall Buildings, *Engineering Structures*, 26, 1173-1183, 2004.

Yan, B. and Li Q.S., Wind Tunnel Study of Interference Effects Between Twin Super-Tall Buildings with Aerodynamic Modifications, *J. of Wind Engrg. and Indust. Aerodynamics*, 156, 129–145, 2016.

Zhao, J.G. and Lam, K.M., Interference Effects in a Group of Tall Buildings Closely Arranged in an L- or T-Shaped Pattern, *Wind and Structures*, Vol. 11, No. 1, 1-18, 2008.