9th Asia-Pacific Conference on Wind Engineering
Auckland, New Zealand
3-7 December 2017

Height Effect of Interfering Buildings on Wind Pressure Distribution on Rectangular Plan Tall Buildings

B.S. Chauhan and A.K. Ahuja

Department of Civil Engineering
Indian Institute of Technology Roorkee, Roorkee 247667, Uttarakhand, India

Abstract

This paper presents the effect on wind pressure distribution on rectangular plan tall buildings due to the presence of two other closely spaced tall buildings having similar plan shape. Models of three rectangular plan buildings are arranged in a straight line, keeping the principal building model at the center. The effect of height variation of the interfering buildings is studied, by varying the heights of the interfering building in two different manner: (1) Height of both the interfering building models is varied simultaneously, (2) Height of only one of the interfering building model is varied. Values of wind pressure coefficients are calculated from the values of mean wind pressures measured at different pressure points of the principal building and are reported in the form of pressure contours on different faces of the principal building. It is observed that wind pressure distribution on the faces of the principal building are highly influenced by the arrangement as well as the height of the interfering building. An increase of about 25 percent is observed in drag force compared to isolated condition. Torsion in the principal building model is observed to increase as the height difference of the two interfering building models increase.

Introduction

With the advancement of technology which made it possible to control and operate the business by a distant location, the metropolitan cities have started becoming the operational and business relation centers for most of the industries, leading to population concentration in these cities. To accommodate this growing population within a limited area of land, these cities have started growing vertically for offices as well as for residential buildings. With increase in height of the buildings, concern of the structural designer for wind loads also starts to grow. These wind loads are greatly affected by the presence of other closely spaced buildings as shown by different research studies. Various codes of practice on wind loads (AS/NZS: 1170.2 (2002) [2], ASCE: 7-02-2002 [3], EN: 1991-1-4-2005 [4], IS: 875 (Part-3) 2015 [5]) provide guidance limited to isolated cases only. Many wind tunnel studies (Amin [1], Khanduri et al. [6], Kim et al. [7], Kushal [8], Mara et al. [9], Pandey [10], Xie and Gu [11], Yan and Li [12], Zhao and Lam [13]) have been carried out in the past to study the effect of interference. However, no studies could be found for the effect of interference on wind pressure distribution on tall buildings having rectangular plan shape due to the presence of two other interfering buildings having similar plan shape, but of varying height.

An attempt has, therefore, been made to study the effect of interference on wind pressure distribution on a rectangular plan shape tall building due to the presence of two other closely spaced tall buildings having similar plan shape. Models of three rectangular plan buildings are arranged in a straight line, keeping the principal building model (hatched) at the center. To study the effect of height variation of the interfering buildings, the heights of the interfering building are varied in two different manner: (1) Height of both the interfering building models is varied simultaneously, (2) Height of only one of the interfering building model is varied, as shown in figure 1. The height of interfering buildings is varied with respect to the height of principal building and the wind pressure distribution on the principal building in interference condition is compared to that for isolated condition.

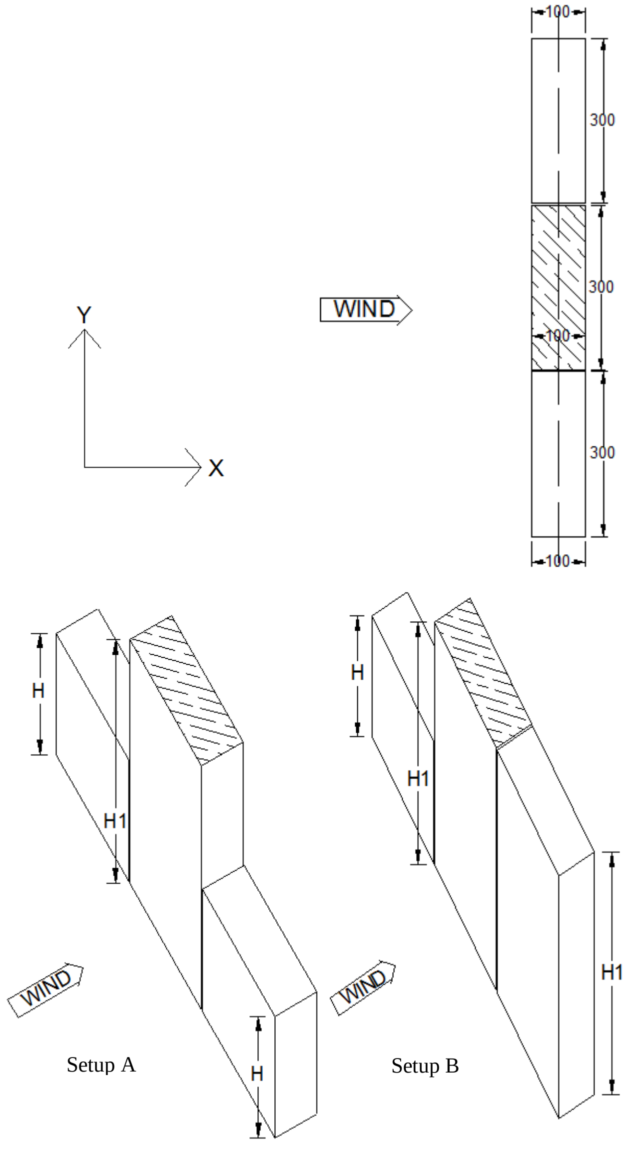

Figure 1. Plan and isometric view of the arrangement for experimentation (All dimensions are in mm). [H/H1=0.0, 0.2, 0.6, 1.0]

Model Description

Rigid models are made using perspex sheet for principal building model and plywood for interfering building models, at a geometric scale of 1:200 to the corresponding prototype, having width to length ratio of 1:3 and width to height ratio of 1:5. The assumed prototype for the instrumented tall building considered in this study is of rectangular shape in plan having plan dimensions of 60m × 20m (i.e. 1200 m^2 area in plan) and having height of 100m. Similarly, the prototype considered for the interfering tall buildings in the study are also of rectangular shape in plan having plan dimensions of 60m × 20m (i.e. 1200 m^2 area in plan) but having variation in heights as 100m, 60m and 20m. Principal building model has 35 pressure points on both Face A and Face C, while Face B and Face D has 21 pressure points each, as shown in figure 2.

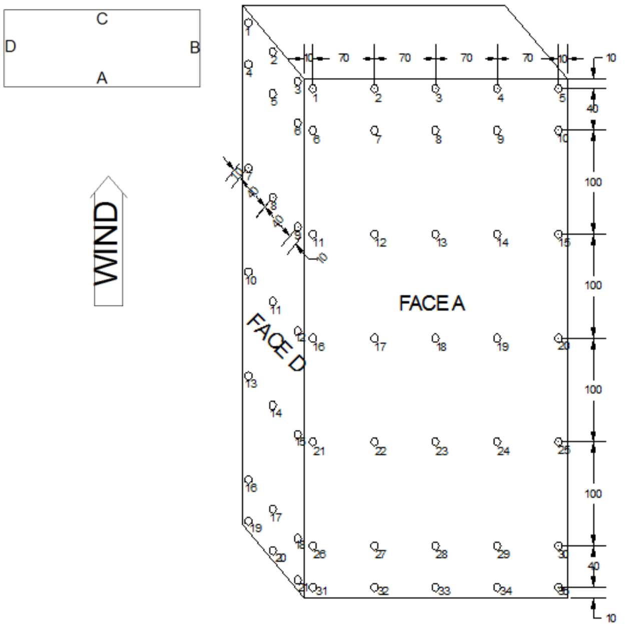

Figure 2. Plan and isometric view of the principal building model showing the location of different pressure points (All dimensions are in mm).

Wind Flow Characteristics

An open circuit boundary layer wind tunnel having a cross-section of 2m × 2m and length of the test section as 15m is used for the testing of the models.

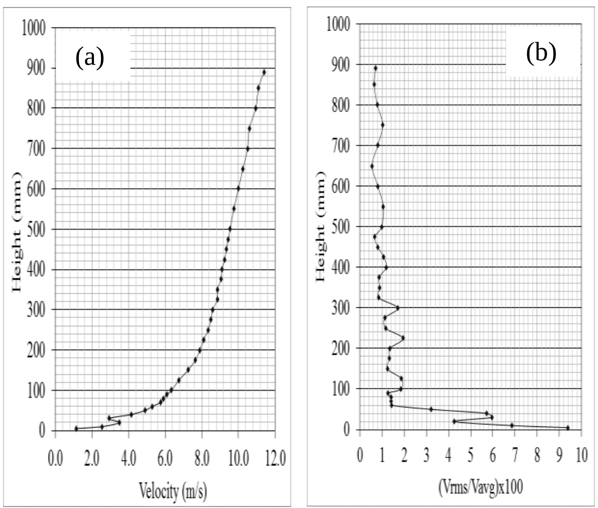

Figure 3. Wind characteristics used for experiments: (a) Mean wind speed profile; (b) Turbulence intensity profile.

Vortex generators for generating turbulence in horizontal plane, barrier wall for generating turbulence in vertical plane, and floor roughening cubical blocks of size 70mm, 50mm and 38mm 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 used during the experimentation are shown in figure 3.

Measurement Technique

Pressure measurements are conducted by placing the principal building model of rectangular cross-section on top of the turn table. Experiments are carried out under free stream mean wind velocity of 11.4 m/sec Wind pressure at each pressure point is measured with the help of pressure transducer for 60 seconds.

The testing is undertaken in isolated as well as interfering conditions. Going through the literature, it is found that the effect due to interference for wind loads are maximum when the interfering building is present in close proximity of the principal building. Therefore, the distance between the principal building and the interfering buildings, is kept zero and effect of height variation of interfering buildings is studied by varying it with respect to the height of principal building for the arrangements as shown in figure 1. A total of 7 different arrangement conditions are tested including the isolated case and the contour diagrams are plotted for mean wind pressure coefficients for all 7 cases on all four faces of the principal building. Figure 4 shows the photographs for some of the arrangements.

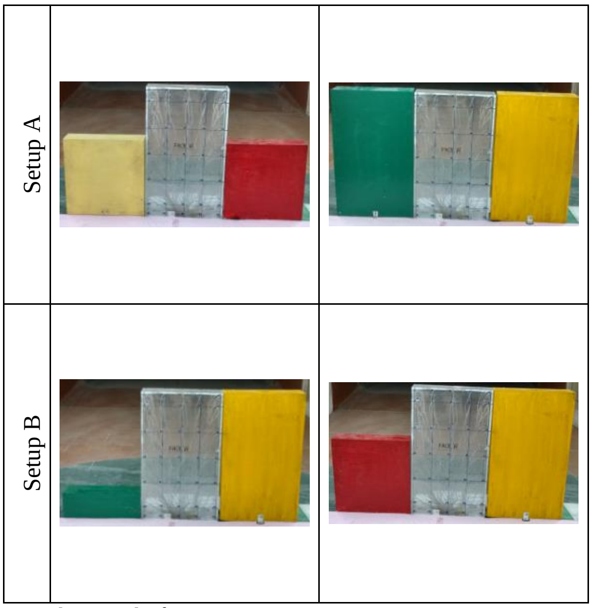

Figure 4. Photographs for some arrangements.

Experimental Results and Discussion

The mean wind pressure coefficient $\overline{C}_P$, is evaluated from the pressure values obtained at all pressure points and contours are plotted as shown in figure 5, for different arrangements.

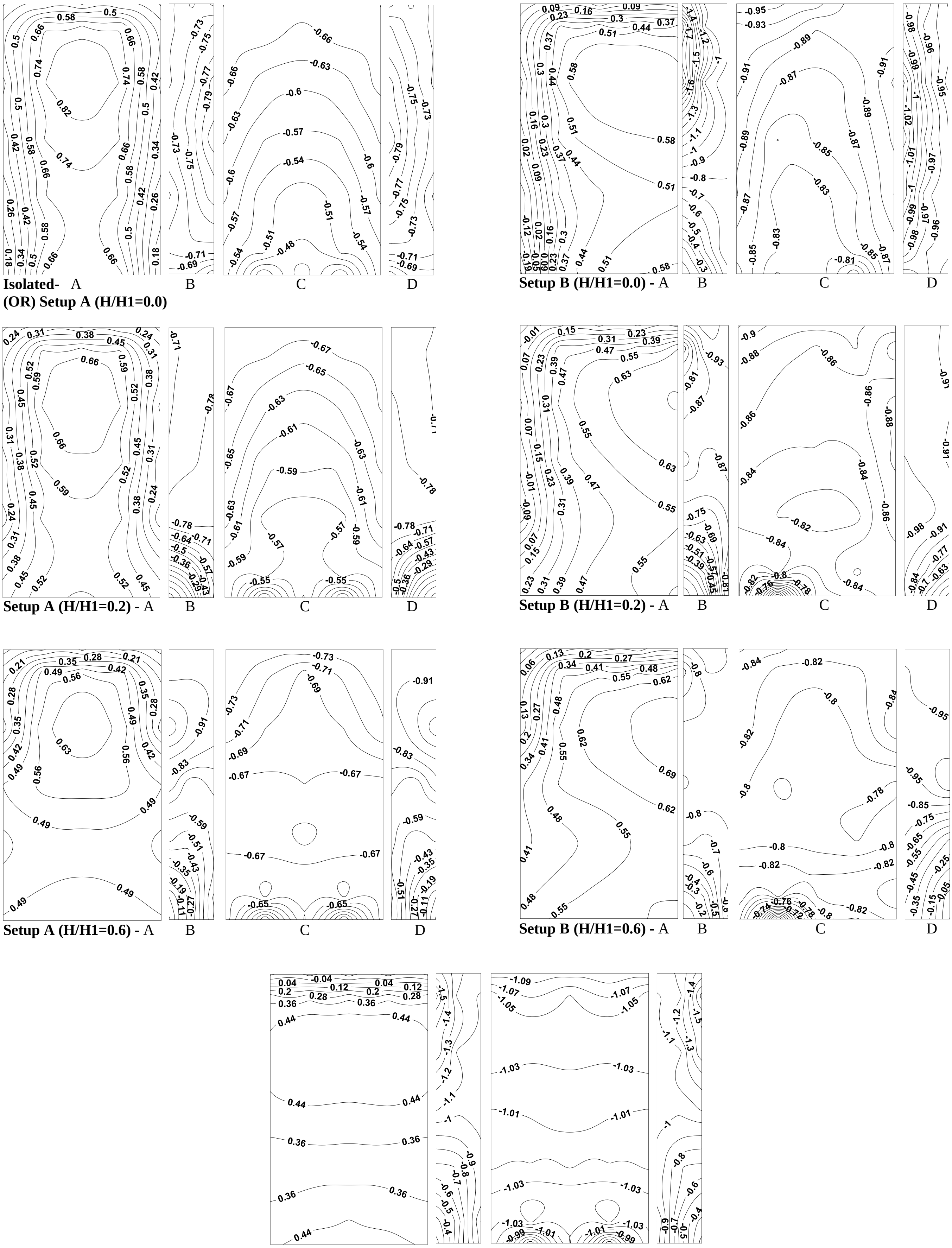

Figure 5. Contour diagrams for distribution of mean wind pressure coefficients for isolated, setup A and setup B.

It is observed from figure 5 that in isolated condition, windward face A of the building is subjected to pressure whereas all other faces are subjected to suction. Pressure in the central part is more as compared to side edges on windward face.

With increase in the height of the interfering buildings, wind pressure on face A becomes almost uniform since the wind streams are unable to pass through the sides of the principal building model. However, a high variation is seen close to the top edge of the face A for H/H1=1.0, since the wind streams close to the top edge are free to skim through the top of the building model. Observing face A for setup B it can be seen that large variation in pressure is observed near the edge where the height of the interfering building is less. For setup B, it can be seen that suction is observed near the edge close to the interfering building of lesser height. Since this suction is highest for H/H1 = 0.0, the eccentric windward pressure together with this suction causes largest amount of torsion in the building model for this case.

Observing leeward face C in setup A, it can be noted that with the increase in height of the interfering building the suction on this face enhances and becomes more and more uniform. Similarly, for setup B the contour curves on face C become more and more flat, thus giving a uniform distribution with the increase in height of the interfering building model.

For face B and face D, it can be seen that a large variation in pressure is observed on these faces up to the height of closely located interfering building model. Observing contour diagrams for these faces in figure 5, we can note that the presence of interfering building cause the reverse in trend of the suction on these faces as compared to the isolated case, like if we observe the lower part of these faces for isolated case there is a reduction in the pressure from windward edge to leeward edge, while under interference case this trend reverses, similar reversal of trend can be observed for the upper part. Also, the location and magnitude of maximum suction also gets altered with change in height of the interfering building.

Overall observing from all the faces of the principal building, it can be inferred that, as the heights of nearby buildings reduce, the wind pressure distribution on principal building model tend to become same as in case of isolated condition.

Conclusions

- As the height of the interfering buildings is decreased the effect of interference decreases.
- An increase of about 25 percent is noted in drag force compared to isolated condition.
- The torsional moment in the principal building model is observed to increase as the height difference of the two interfering building models increase.

Acknowledgments

The work presented in this paper is part of the research work being done by the first author for his Ph.D. degree under the supervision of second author.

References

[1] 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.

[2] AS/NZS: 1170.2-2002, *Australian/New Zealand Standard: Structural Design Actions Part-2: Wind Actions*.

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

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

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

[6] 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**, 1998, 617–630.

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

[8] 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.

[9] 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, *Journal of Wind Engineering and Industrial Aerodynamics*, **133**, 2014, 200–210.

[10] 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.

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

[12] Yan, B. and Li Q.S., Wind Tunnel Study of Interference Effects Between Twin Super-Tall Buildings with Aerodynamic Modifications, *Journal of Wind Engineering and Industrial Aerodynamics*, **156**, 2016, 129–145.

[13] 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, 2008, 1-18.