EFFECT OF WIND INCIDENCE ANGLE ON WIND PRESSURE DISTRIBUTION ON TALL BUILDINGS

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ABSTRACT

This paper presents the results of an experimental study carried out on the model of I-shape tall building to examine the wind pressure distribution on its different surfaces. The model of the building is tested in an open circuit boundary layer wind tunnel under varying wind incidence angles. Wind pressure valuesmeasured at numerous pressure points are used to calculate wind pressure coefficients and the experimental observations are presented in the form of pressure contours. It is observed that themagnitudes of pressure coefficients vary considerably with the location and wind direction.

Keywords—Boundary layer wind tunnel, Experimental study, I-shape tall building, Wind incidence angle, Wind pressure distribution

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INTRODUCTION

Many tall buildings with varying cross-sectional shapes are being constructedall over the world. While designing such buildings, structural designers refer to relevant standards on wind loads [AS/NZS: 1170.2(2002), ASCE: 7-02(2002), BS: 63699 (1995), EN 1991-1-4 (2005) and IS: 875 (Part-3)-1987] to arrive at correct values of wind forces that will be acting on the building at different floor levels. Whereas sufficient information regarding wind pressure coefficientson simple plan shapes including square and rectangular ones is available in the standards on wind loads, such information is not available for buildings having non-conventional shapes such as I, L, U, + etc.

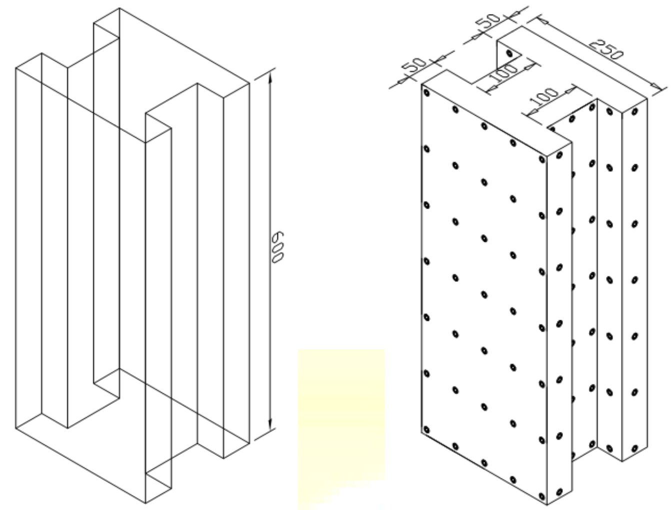
Review of recent research work indicates that very little work has been done in the area of influence of cross sectional shapes on wind effects on tall buildings. Stathopoulos (1985) carried out the study on wind environmental condition around tall buildings with chamfered corners. Jamieson et al.(1992),Amin and Ahuja (2008), and Bhatnagar(2011)carried out wind tunnel studies for the measurement of wind pressures on models of tall buildings with varying cross-sectional shapes. Kwok (1988), Kwoket al.(1988), Hayashida and Iwasa(1990), Miyashita et al.(1993)and Kawai (1998)studied the effects of edge configurations on wind-induced response of tall buildings.

However, information about wind pressure distribution on I-shape tall buildings is not available in the literature. An effort has, therefore, been made to carry out wind tunnel tests on the model of I-shape tall building and generate data, which will be useful for the structural designers while designing similar buildings.

EXPERIMENTAL PROGRAMME

Details of Model

The prototype building is assumed to have I-shape cross-section (Fig. 1a) with floor area of 400 m^2 and 60 m height. Rigid model of the building is made of perspex sheet at a geometrical scale of 1:100. The model is instrumented with 168 number of pressure points at seven different levelsalong height (Fig. 1b) to obtain a good distribution of pressure on all surfaces of the building model.



(a) Isometric view (b) Pressure points locations

Fig.1 Model of I-shape tallbuilding with cross-sectional dimensions and pressure point locations

Wind Flow Characteristic

The experiments are carried out in Open Circuit Boundary Layer Wind Tunnel at Indian Institute of Technology Roorkee, India. The wind tunnel has a test section of 15 m length with a cross sectional dimensions of 2 m (width) x 2 m (height). Flow roughening devies such as vortex generators, barrier wall and cubical blocks of size 150 mm,100 mm and 50 mm are used on the upstream end of the test section to achieve mean wind velocity profile corresponding to terrain category 2 as per Indian standard on wind loads. The model is placed at a distance of 13.5 m from the upstream edge of the test section at the centre of the turn table and is 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

First of all,Perspex sheet model of the building (Photo. 1) is placed at the centre of the turn tablein such a way that wind hits perpendicular to long wall of the model, i.e. at 0º wind incidence angle (Fig. 2). Pressure measurements are made by connecting pressure tubing from all 168 pressure points one by one to the pressure transducer (Photo.2). Values of pressures varying with time are recorded at an interval of 1 second for a duration of 30 seconds at each point in a computer through data taker (Photo. 3). After completing measurements for 0º wind incidence angle, theexperiment is repeated for other angles namely 15º to 90º at an interval of 15º (Fig. 1c) by rotating the turn table. Values of mean wind pressure coefficients (Cp) are then calculated from the records of pressures (P) at all pressure points for all wind directions using the relationship $Cp = P / (0.6\, V_{ref}^{2})$, where V_{ref} is the reference wind velocity at 1 m height above the floor of the wind tunnel.

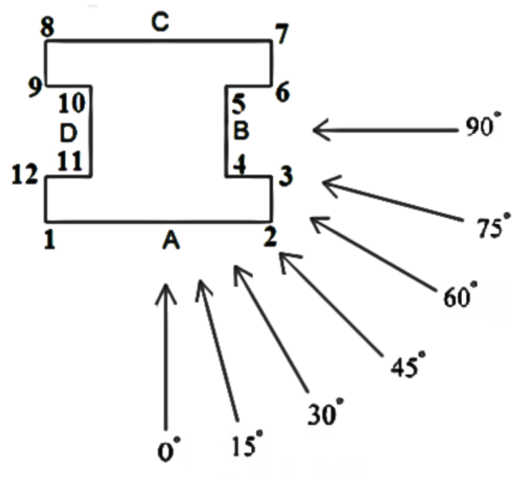


Fig. 2Cross-section of the model

Photo. 1 Perspex sheet model

Photo. 2 Pressure transducer

Photo. 3Data taker

RESULTS AND DISCUSSION

Whereas the model of I-shape building is tested for 7 wind directions, contours of mean wind pressure coefficients (C_p) on the surfaces of the model are presented in this paper for 3 wind incidence angles namely 0º, 45º and 90ºonly (Figs. 3-5) due to paucity of space. It is observed from Fig. 3 that when wind hits perpendicular to face-A (i.e. 1-2) of the building model (i.e. at 0º wind incidence angle), the face is subjected to pressure. The presssure values along the vertical center line of the face are large, which reduce towards the edges. Mean wind pressure coefficient (Cp) value is maximum at almost one fifth height of the model from top, which is around

0.85near the centre line of the face and reduces to 0.4 near vertical edges. Values of pressure coefficients reduces as one moves down due to reduction in wind velocity. These values reduces while moving towards the top edge also due to upwash of streams of wind near the top edge.

At this 0º wind incidence angle, all other large faces namely B (i.e. 4-5), C (i.e. 7-8) and D (i.e. 10-11)are subjected to suction. On faces B and D,suction is high near the upstream or windward edge as compared to downstream or leeward edge. Numerically, Cp varies between -0.5and -0.8 on these faces. Leeward face C is subjected to almost uniform suction with Cp varying between -0.4 to -0.5. Small strips falling on outer and lower sides of the flanges (i.e. 2-3, 3-4, 5-6, 6-7, 8-9, 9-10, 11-12 and 12-1) are also subjected to almost uniform suction at this wind incidence angle.

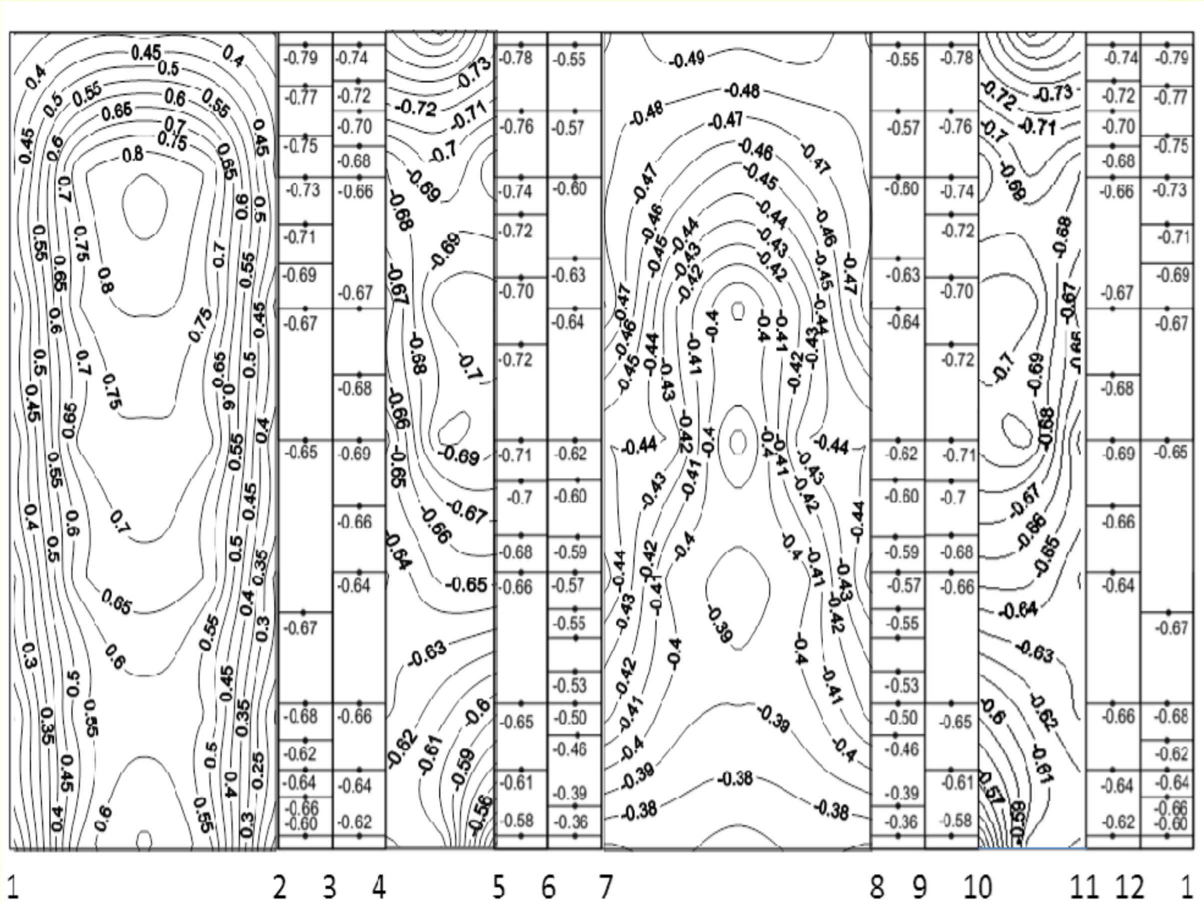


Fig. 3 Pressure contours on the surfaces of I-shape building at0º wind incidence angle

Figure 4 shows distribution of wind pressure on the surfaces of the model at 45º wind incedence angle. In this case, face A (i.e. 1-2), is subjected to pressure which decreases from windward edge to leeward edge. Maximum mean pressure coefficient is around 0.75 and minimum is around 0.05. This large variation of pressure from one edge to another will try to rotate the model resulting in high value of twisting moment when base of the model is held against rotation.

Face B (i.e. 4-5) and nearby strips (i.e. 2-3, 3-4, 5-6 and 6-7) are also subjected to pressure at 45º wind incidence angle. Leeward edge of face B is subjected to higher pressure as compared to windward edge due to the shielding caused by windward flange near windward edge and stagnation caused by leeward flange near leeward edge. Face C (i.e. 7-8), face D (i.e. 10-11) and remaining strips are subjected to suction. Suction on face C increases from windward edge to leeward edge.

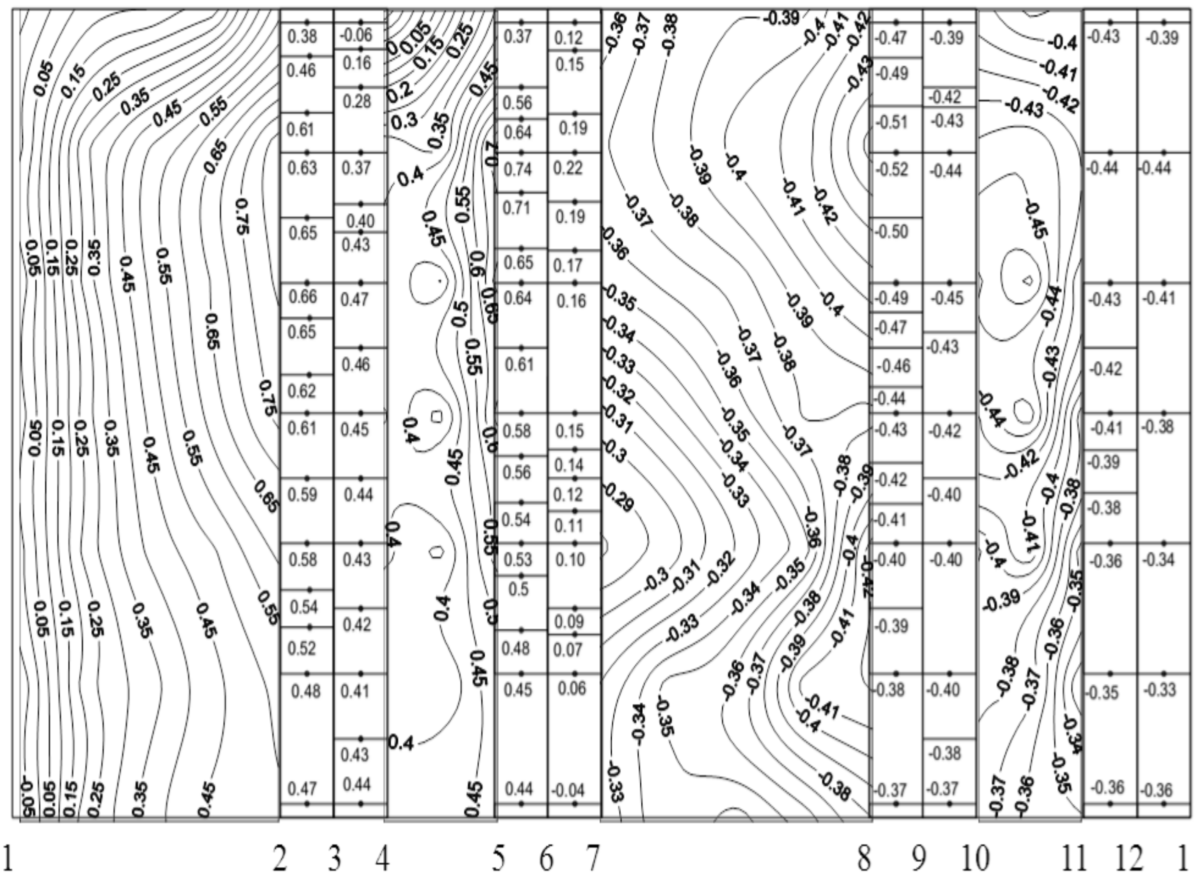


Fig. 4 Pressure contours on the surfaces of I-shape building at 45º wind incidence angle

Distribution of mean wind pressure coefficients on different surfaces of I-shape tall building model at 90º wind incedence angle is shown in Fig. 5. At this wind angle, wind hits the model perpendicular to face B (i.e. 4-5) and nearby strips (i.e. 2-3 and 6-7) (Fig. 2). As a result, all these three surfaces are subjected to pressure at this angle with values of mean wind pressure coefficients on side strips (i.e. 2-3 and 6-7) a bit smaller than those on central strip (i.e. face B). All other faces are subjected to suction at this wind incidence angle. Suction on side faces namely A (i.e. 1-2)and C (i.e. 7-8) is of large value near windward edges which decreases towards leeward edges. Face D (i.e. 10-11) and nearby strips (i.e. 8-9, 9-10, 11-12 and 12-1), which are on rear side of the model, are subjected to suction of very small magnitude.

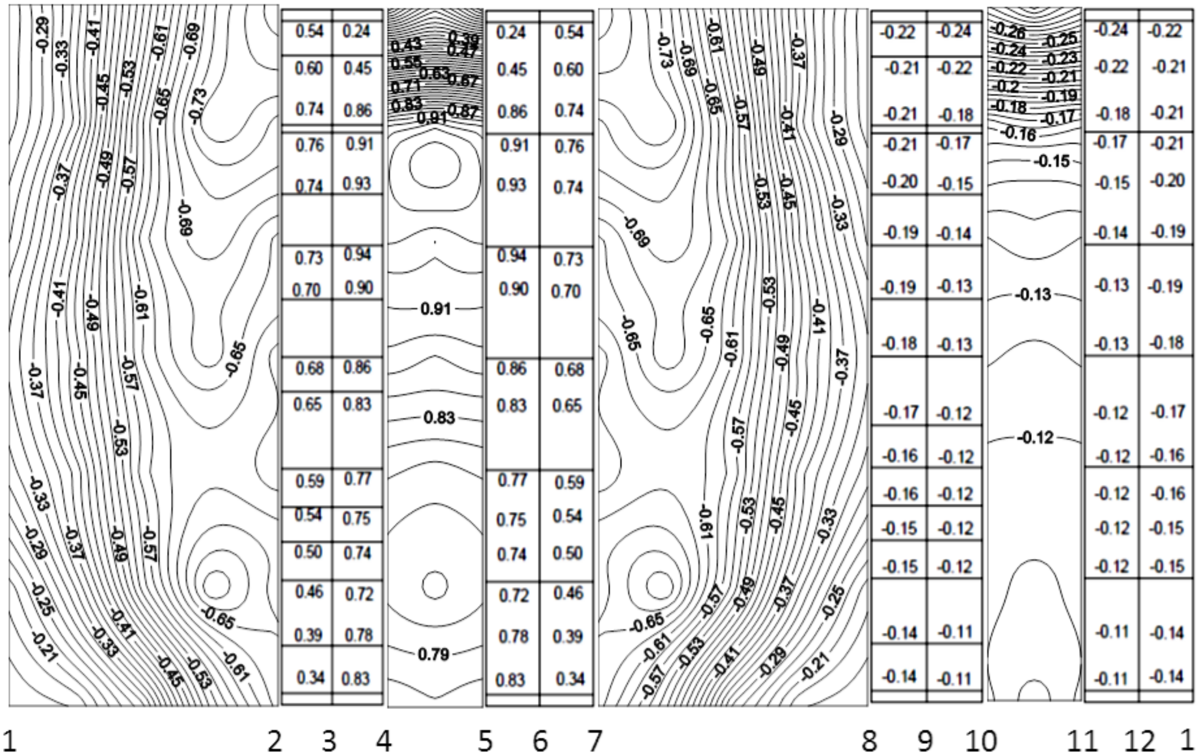


Fig. 5 Pressure contours on the surfaces of I-shape building at 90° wind incidence angle

CONCLUSIONS

Following conclusions are drawn from the study presented here in.

1. Wind pressures on the surfaces of the I-shape building are highly influenced by wind incidence angle.
2. Distribution pattern and magnitute of pressure coefficients along web surfaces and inner sides of flanges in I-shape building differ appreciably as compared to square shape building with same floor area.
3. The building with I-shape will be subjected to larger twisting moment at oblique wind incidence angle as compared to square shape building, due to large variation of pressure on large surfaces from one edge to another.
4. Values of mean wind pressure coefficients given in the form of pressure contours in the present paper are useful to the structural designers for designing I-shape tall buildings against wind loads.

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