Effect of Wind Incidence Angle on Wind Pressure Distribution on Square Shape Tall Building

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Abstract
An experimental study has been carried out in the wind tunnel on the model of a tall building with square cross-section. Measurement of wind pressure values is made at many points on all four surfaces of the rigid model of the tall building made of Perspex sheet. Wind is made to hit the model perpendicular to one of the surfaces as well as at skew angles. Results of the study are shown in the form of contours and cross-sectional variation of mean wind pressure coefficients. It is observed that there is a large influence of wind incidence angle on wind pressure distribution on the surfaces of the building.

Keywords: Pressure Coefficient, Force Coefficient, Scale Ratio, Incidence Angle.

Introduction
Relevant standards on wind loads of different countries [ASCE: 7-02 (2002), AS/NZS: 1170.2 (2002), BS-EN 1991-1-4 (2005), IS:875-Part-3 (1987)] are referred by the designers while designing tall buildings for wind loads. The structural designers obtain information regarding wind pressure coefficients and wind force coefficients from such literature. However, available literature is limited to certain wind incidence angles only. Review of published research work also indicates that very limited work has been done in this area.

An effort has, therefore, been taken to study experimentally the effect of wind incidence angle on wind pressure distribution on the model of tall building with square cross-section by testing the same in the wind tunnel.

Experimental Programme

Details of Models
The prototype building having square shape is considered to be of 30 storeys with a height of 100m and floor area of 625m² at each floor. Rigid model of the building is made of Perspex sheet (Photo.1) at a scale of 1:200. Thus model has a height of 500mm and cross-sectional dimension of 125mm x 125mm (Fig.1). To obtain a good distribution of pressure, the building model is provided with 35 pressure points on each of its four wall surfaces (Fig. 2).

Measurement Technique
Perspex sheet model of the tall building is placed at the centre of the turn table inside the Boundary Layer Wind Tunnel of the Department of Civil Engineering, Indian Institute of Technology Roorkee in such a way that wind hits the model perpendicular to one of the surfaces, i.e. at 0° wind incidence angle. Wind is made to flow inside the tunnel at free stream
velocity of 10.32m/sec measured at 1m height above the floor of the tunnel. Pressure tapings from each of 140 pressure points are connected to the pressure transducer one by one for the measurement of pressures. Experimental observation of pressure at each pressure point is recorded in the computer for 60 seconds at an interval of 1 second which is later averaged to obtain the value of mean wind pressure. These values of pressures are then used to calculate mean wind pressure coefficients (Cp) at all pressure points.

After measuring the pressures at 0° wind incidence angle, turn table is rotated by 15° and measurement of pressure at all 140 pressure points is repeated. Similarly wind pressure measurement is done for 30° and 45° wind incidence angles also.

Photo: 1 Rigid model of the building

Fig. 1 Dimensions of the model

Fig. 2 Details of pressure points on four faces of square shape building model
Results and Discussion

Contour plots of mean wind pressure coefficients (Cp) on all surfaces of square shape model at 4 wind incidence angles namely 0°, 15°, 30° and 45° are presented in Figs. 3 to 6 including wind flow pattern around the model in horizontal plane.

At 0° wind incidence angle (Fig. 3), windward surface (face-A) is subjected to pressure increasing from bottom to near to the top edge of the face with values of pressure coefficients (Cp) varying from 0.45 to 0.60 and then decreasing toward the top edge. It is observed that maximum Cp occurs along the vertical centre line of face-A and then decreases toward the edges. Leeward surface (face-C) is subjected to suction with maximum Cp of -0.30 at mid height and decreasing toward the edges to value of Cp about -0.40 at top edge. Side faces (face-B and face-D) are subjected to varying suction decreasing from windward edge to leeward edge with minimum Cp of -0.75 at nearest top edge.

![Fig. 3 Mean pressure coefficients (Cp) on faces of square shape model at 0° wind incidence angle](image-url)
At 15° wind incidence angle (Fig. 4), front surface (face-A) is subjected to varying pressure with maximum $C_p$ of 0.70 near to top edge. Leeward surface (face-C) is subjected to suction with minimum $C_p$ of -0.40 at furthest edge. Face-B is subjected to varying suction with minimum $C_p$ of -0.90 at nearest top corner; and face-D is subjected to suction with minimum $C_p$ of -0.53 at furthest edge.

![Mean pressure coefficients ($C_p$) on faces of square shape model at 15° wind incidence angle.](image)

**Fig. 4** Mean pressure coefficients ($C_p$) on faces of square shape model at 15° wind incidence angle

At 30° wind incidence angle (Fig. 5), front surface (face-A) is subjected to varying pressure with maximum $C_p$ of 0.70 at nearest edge. Leeward surface (face-C) is subjected to suction with minimum $C_p$ of -0.48 at furthest edge. Face-B is subjected to suction near to edges of the face and partly subjected to pressure at centre of the face; and face-D is subjected to varying suction with minimum $C_p$ of -0.52 at furthest corner.
Fig. 5 Mean pressure coefficients (C_p) on faces of square shape model at 30° wind incidence angle

At 45° wind incidence angle (Fig. 6), windward surfaces (face-A and face-B) are subjected to varying pressure with maximum C_p of 0.65 at nearest edges and partly subjected to suction at furthest edges. Leeward surfaces (face-C and face-D) are subjected to varying suction with minimum C_p of -0.45 at vertical edges.
Higher suction is generally found near the top windward edge of side face of square model and higher pressure is generally found on windward surface of square model (Figs. 3 to 6). In this study, the minimum suction found near the top windward edge of the side face is about -0.90 and the maximum pressure found on the top of the front face is about 0.70.

Cross-sectional variation of mean wind pressure coefficients ($C_p$) of square shape model at horizontal sections 50mm and 250mm from top of the model for 4 different wind incidence angles are shown in Figs. 7 and 8. Minimum and maximum pressure coefficients ($C_p$) are found at 15° and 30° wind incidence angles, respectively.

**Fig. 6 Mean pressure coefficients ($C_p$) on faces of square shape model at 45° wind incidence angle**
Fig. 7 Variation of mean pressure coefficients ($C_p$) at section 50mm from top of square shape building model

Fig. 8 Variation of mean pressure coefficients ($C_p$) at section 250mm from top of square shape building model
Conclusions
1. Wind pressure distribution on surfaces of building is found to depend on direction of wind.
2. Positive pressure occurs on windward faces, and suction occurs on side faces and leeward faces at all wind incidence angles.
3. The minimum suction with value of pressure coefficient (Cp) about -0.90 is found at 15° wind incidence angle near the top windward edge of the side face, and the maximum pressure with value of Cp about 0.70 found at 15° and 30° wind incidence angles near to top edge of the windward face.
4. Maximum positive pressure is observed along the vertical centre line of front face at the top which decreases toward the edges.
5. Wind pressure is observed on windward face which increases with height up to the top edge of the face due to increase in wind velocity with height. Pressure value reduces near the top edge of windward face due to up wash.
6. Suction is observed on side faces which decreases from windward edge to leeward edge.

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References