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WIND PRESSURE DISTRIBUTION ON CIRCULAR CANOPY ROOFS

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The present study gives information related to wind pressure distribution on single span and multi span circular canopy roofs. The experiments are carried out in an open circuit boundary layer wind tunnel. Wind pressure is measured on both upper and lower roof surfaces of circular canopy roof model made of Perspex sheet. Models are tested under varying wind incidence angles between 0° and 90° at an interval of 15° on isolated model and 0° to 180° at an interval of 30° on models with multi-span canopy roof. Values of mean wind pressure coefficients are evaluated from the measured values of wind pressures. Results of the study are presented in the form of contours, cross sectional variation and face average values of pressure coefficients. The results of the study are of great use for the structural designers for designing circular canopy roofs.

Keywords: Contours, Pressure coefficient, Wind incidence angle, Cross sectional variation.

1 INTRODUCTION

Canopy roofs are shed like structures which have only roof cladding. Canopy roofs use steel columns as supporting members. These roofs are generally used at railway station platforms, parking places for cars and bicycles, petrol pumps, restaurants and stadiums. Canopy roofs have different shapes like flat, mono-slope, pitched, trough, circular etc. When wind blows, it hits both upper and lower roof surfaces of canopy roofs. These roofs are, therefore, more vulnerable to wind as compared to buildings with wall cladding. While information related to wind pressure coefficients on mono-slope, pitched, and trough canopy roofs are available in 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) (2015)), this information for circular canopy roof is not available. Research publications in this area are also very few. Netalini *et al.* (2013) carried out wind tunnel study on the models of vaulted canopy roofs. An effort has, therefore, been made to carry out experimental study on the models of circular canopy roofs in order to generate more information about wind pressure distribution on it.

2 WIND CHARACTERISTICS

Models of the circular canopy roof are tested in an open circuit boundary layer wind tunnel in the Department of Civil Engineering at Indian Institute of Technology Roorkee, India. The tunnel has 15 m long test section and 2 m × 2 m cross sectional area. Total length of the tunnel is 36 m. Flow roughening devices like vortex generator, barrier wall, and cubical blocks are placed on the upstream side of model to generate the flow for different terrain categories. Wind velocity profile during the study corresponds to terrain category 2 mentioned in Indian Standard on wind loads (IS: 875 (Part-3) 2015).

3 DETAILS OF MODELS

Three models are made for lab experiment. Out of three, one is Perspex sheet model which is used as instrumented model and other two are plywood models. Scale used for the model is 1:50. Dimensions of the model are shown in Figures 1(a) and (b) which show the circumference dimensions of the upper and lower roof surfaces. Figure 1(c) shows 3D view of the model.

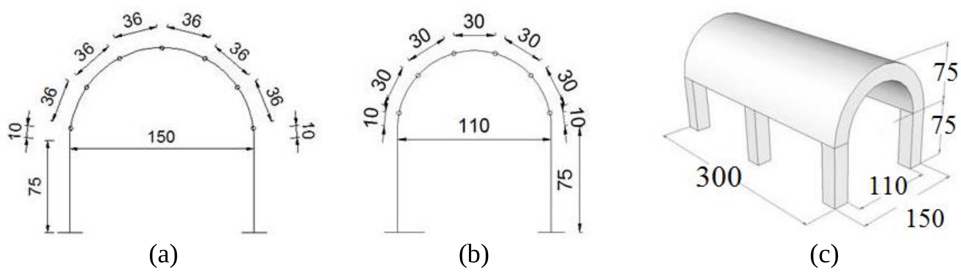

Figure 1. Dimensions of circular canopy roof model (all dimensions are in mm).

Upper and lower roof surfaces have 49 and 42 pressure points respectively. The positions of pressure points on upper roof surface are shown in Figure 2. Pressure points are installed with stainless steel tubes. PVC tubes are connected to free end of stainless steel tubes. Each tube is connected to pressure transducer for 1 minute from where 60 values of pressure for each point are obtained. Figure 3 shows seven cross sections on upper roof surface. Each cross section contains 7 pressure points on upper roof surface and 6 pressure points in lower roof surface respectively.

Isolated canopy roof or canopy roof with single span is tested under seven wind direction from 0° to 90° at an increment of 15° (Figure 4) and multi span models are tested under seven wind directions from 0° to 180° at an interval of 30° (Figure 5). Figure 6 shows arrangement of three span models inside the wind tunnel where one model is instrumented and other two are non instrumented models.

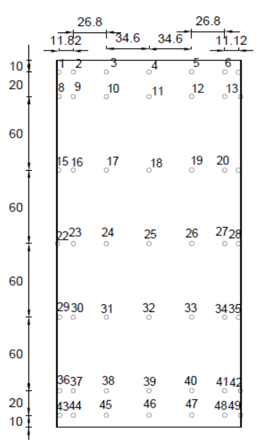

Figure 2. Pressure points on upper roof surface.

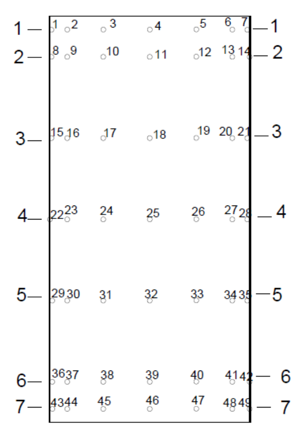

Figure 3. Cross sections on upper roof surface.

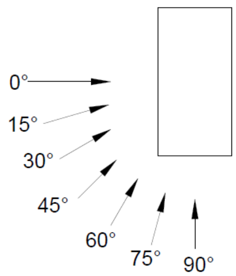

Figure 4. Wind incidence angles on isolated model.

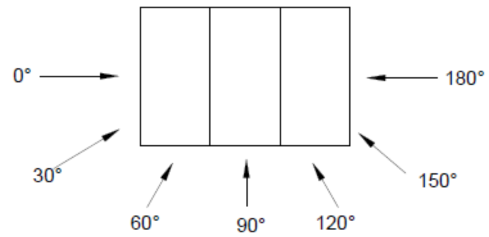

Figure 5. Wind incidence angles on multi-span models.

Figure 6. Models inside the wind tunnel.

4 RESULTS AND DISCUSSION

Results of the present study are shown in the form of contours and cross sectional variation of mean wind pressure coefficients (Cp). Results for upper and lower roof surfaces for 0° wind incidence angle only are included in this paper due to space limitation.

4.1 0° Wind Incidence Angle

4.1.1 *Upper roof surface*

At 0° wind incidence angle, i.e. when wind hits the model perpendicular to its length, windward side of first span is subjected to pressure near the eave (Figure 7). Later pressure changes to suction from windward to leeward direction. Suction is maximum at central part (ridge) because maximum flow separation takes place at ridge. In three span models, value of suction is less in middle span as compared to the rest two models. Value of suction on last span in three span model is very similar to that on second span in two span model. Maximum value of Cp is -1.6 in single span at section 4-4 and it is -1.4 and -1.5 in two and three span cases respectively.

Similar vaiation of wind pressure can be seen in Figure 8 also. Contours are showing the overall variation of wind pressure coefficients on upper roof surface.

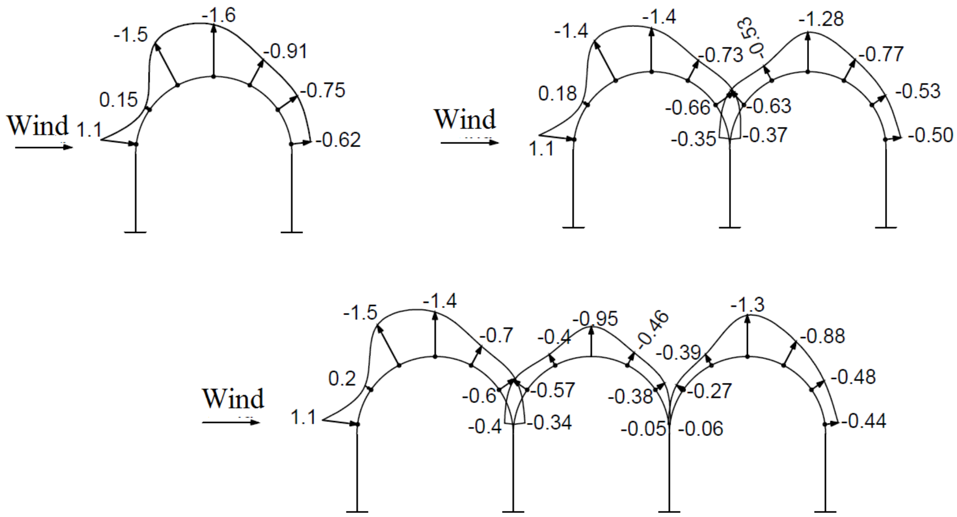

Figure 7. Cross sectional variation at section 4-4 for 0° wind incidence angle on upper roof surface.

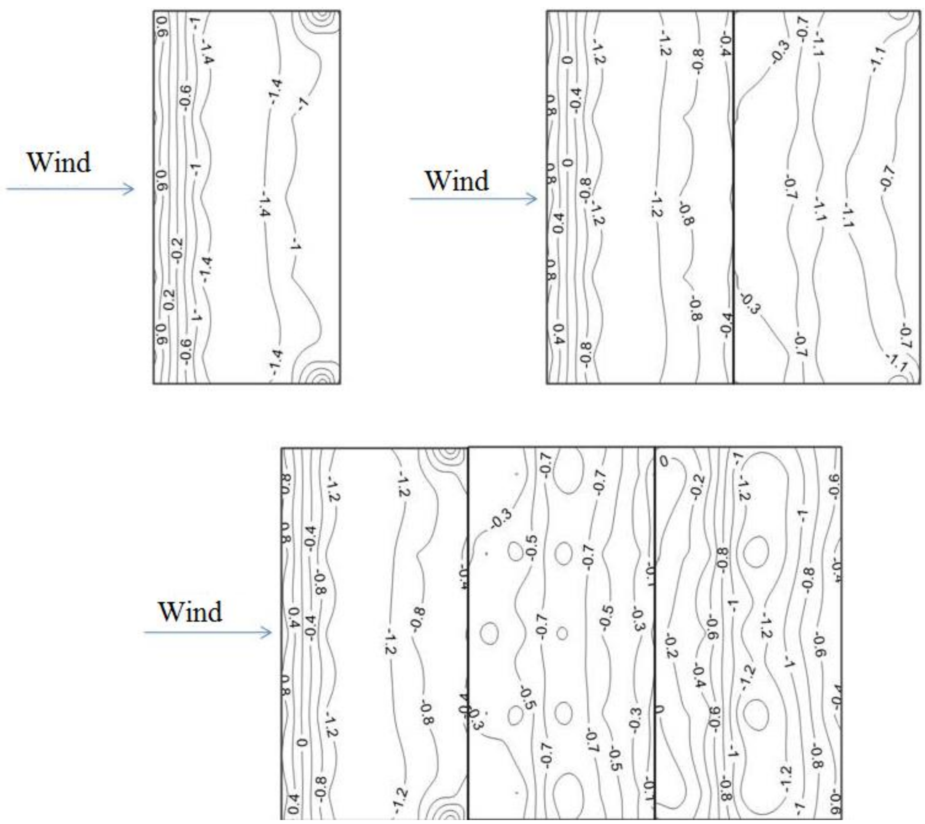

Figure 8. Countours of Cp on upper roof surface for 0° wind incidence angle.

4.1.2 *Lower roof surface*

Entire surface is subjected to suction on lower roof surface at 0° wind incidence angle (Figure 9). Value of suction is less on second and third spans as compared to first span. Maximum value of suction at section 4-4 is -0.85 in case of single span. But in two and three span cases, it is -0.69 and -0.66 respectively.

Similar variation can be seen in Figure 10 also. Contours are showing the overall variation of wind pressure coefficients on lower roof surface.

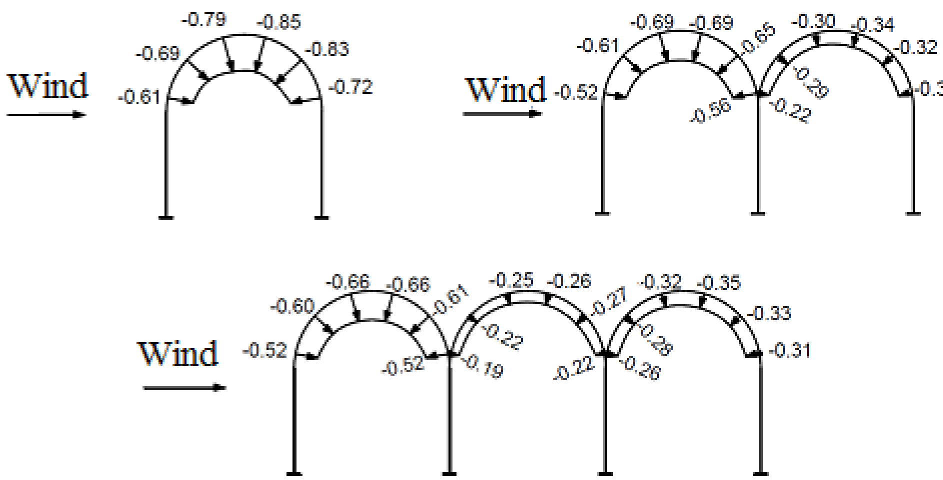

Figure 9. Cross sectional variation at section 4-4 for 0° wind incidence angle on lower roof surface.

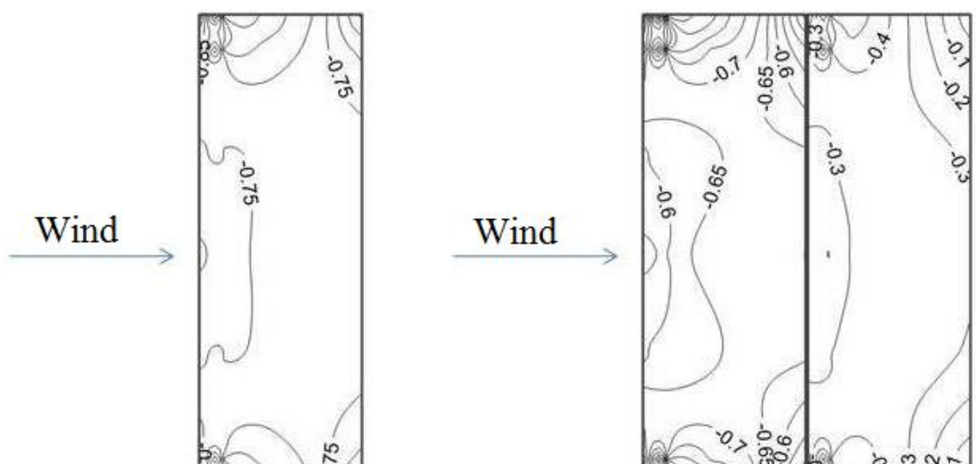

Figure 10. Countours of Cp on lower roof surface for 0° wind incidence angle.

5 CONCLUSION

- Windward side of upper roof surface of first span of a circular canopy roof is subjected to pressure near eave.

- Central portion (ridge) of every span on upper roof surface is subjected to higher suction due to maximum flow sepration.
- Upper roof surface has higher suction in comparison with lower roof surface.
- In three span case, middle span has lower suction than other two spans.

References

AS/NZS: 1170.2-2002, *Australian/New Zealand 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.

BS 6399: Part 2: 1995, *British Standard 1995, Loading for Buildings Part 2. Code of Practice for Wind Loads*, 1995.

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

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

Netalini, M. B., Morel, C., and Natalini, B., Mean Loads on Vaulted Canopy Roofs, *Journal of Wind Engineering and Industrial Aerodynamics*, Elsevier, 119, 102-113, 2013.