Implementing Innovative Ideas in Structural Engineering and Project Management
Edited by Saha, S., Zhang, Y., Yazdani, S., and Singh, A.

ISBN: 978-0-9960437-1-7

WIND PRESSURE DISTRIBUTION ON LOW-RISE BUILDINGS WITH CYLINDRICAL ROOFS

ASTHA VERMA and ASHOK KUMAR AHUJA

Dept of Civil Engineering, Indian Institute of Technology Roorkee, Roorkee, India

Wind is one of the important loads to be considered while designing the roofs of low-rise buildings. The structural designers refer to relevant code of practices of various countries dealing with wind loads while designing building roofs. However, available information regarding wind pressure coefficients on cylindrical roofs is limited to single span only. Information about wind pressure coefficients on multi-span cylindrical roofs is not available in standards on wind loads. Present paper describes the details of the experimental study carried out on the models of low-rise buildings with multi-span cylindrical roofs in an open circuit boundary layer wind tunnel. Wind pressure values are measured at many pressure points made on roof surface of the rigid models under varying wind incidence angles. Two cases namely, single-span and two-span are considered. The experimental results are presented in the form of contours of mean wind pressure coefficients. Results presented in the paper are of great use for the structural designers while designing buildings with cylindrical roofs. These values can also be used by the experts responsible for revising wind loading codes from time to time.

Keywords: Wind Pressure Coefficients, Multi-span Roofs, Wind Incidence Angles, Boundary Layer Flow, Pressure Points, Perspex Sheet, Open Circuit Wind Tunnel.

1 INTRODUCTION

Evaluation of design wind loads on the roof of a building requires information about pressure coefficients and design wind speeds, which are generally obtained from the relevant code of practice. Wind codes of India (IS:875-Part-3, 1987), Britain (BS: 63699, 1995), America (ASCE: 7-02, 2002), Australia/New Zealand (AS/NZS: 1170.2, 2002) and Europe (EN 1991-1-4, 2005) recommend the values of wind pressure coefficients on convex type cylindrical roof on elevated structure whereas only Indian code provides information regarding wind pressure coefficients on cylindrical roofs resting on the ground. Whereas enough research work has been carried out to obtain wind pressure distribution on sloping roofs, such work on curved roofs is limited. Ahuja, Krishna and Pande (1990) carried out experimental investigation of wind pressure distribution on concave shape cylindrical roof. Kumar (1991) and Amareshwar (2005) studied effects of rise-to-span ratio and height-to-span ratio on wind loads on convex shape cylindrical roofs but with single span only. Kasperski (2008) studied two building models for two different rise of parabolic shaped arch namely, 2.5 m and 5 m respectively so as to obtain wind pressure distributions on walls and parabolic roof surface.

However, information about wind pressure distribution on convex type multi-span cylindrical roof surface is not available in the literature. An effort has, therefore, been made to carry out wind tunnel tests on the models of low-rise buildings with convex type single-span and two-span circular cylindrical roofs and generate data regarding wind pressure distribution on it, which will be useful for the structural designers while designing similar buildings.

2 EXPERIMENTAL PROGRAMME

2.1 Details of Models

Each of prototype rectangular plan low-rise building with circular cylindrical roof is assumed to have length = 20 m, width = 10 m, eaves height = 7.5 m and rise = 5 m. Rigid models of the building are made of Perspex sheet at a geometrical scale of 1:50. Thus, the model has length = 400 mm, span = 200 mm, eave height = 150 mm and rise = 100 mm (Figure 1 and Photo.1). The shape of the convex type cylindrical roof follows the segment of a circle. Seventy seven pressure points are provided on the roof surface in 7 sections with 11 pressure points on each section (Figures 2 and 3) at 15^0 intervals so as to obtain good pressure distribution on the roof surface.

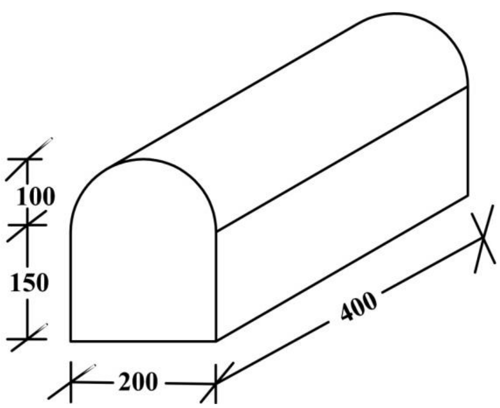


Figure 1. Model dimensions.

Photo. 1 The Model.

2.2 Wind Flow Characteristics

The experiments are carried out in an 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 devices 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 the centre of the turn table and is tested under free stream wind velocity of 10 m/sec measured at 1 m height above the floor of the tunnel.

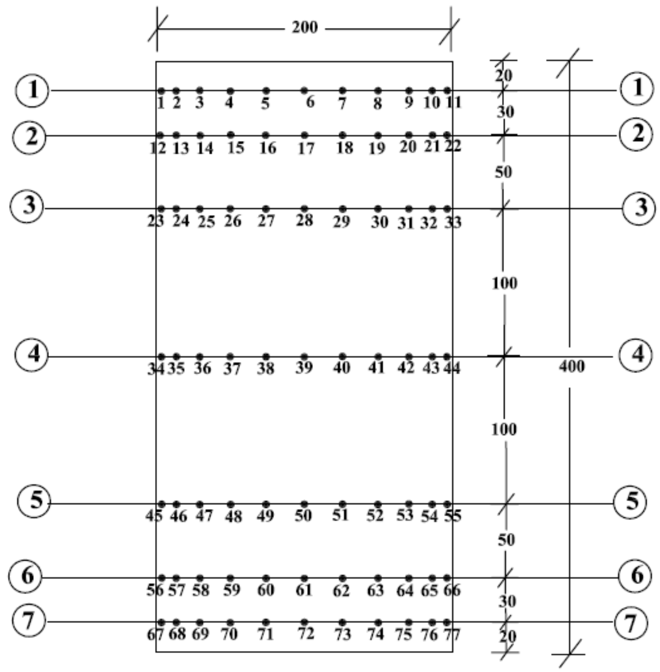
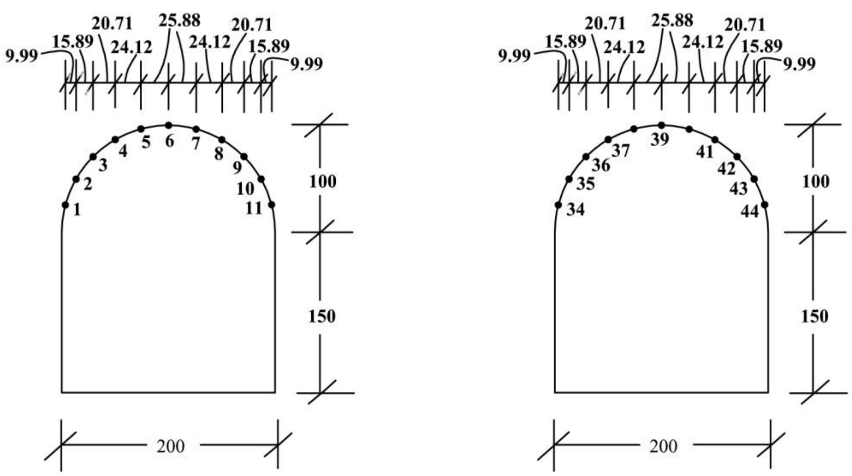


Figure 2. Plan of the model showing various sections.



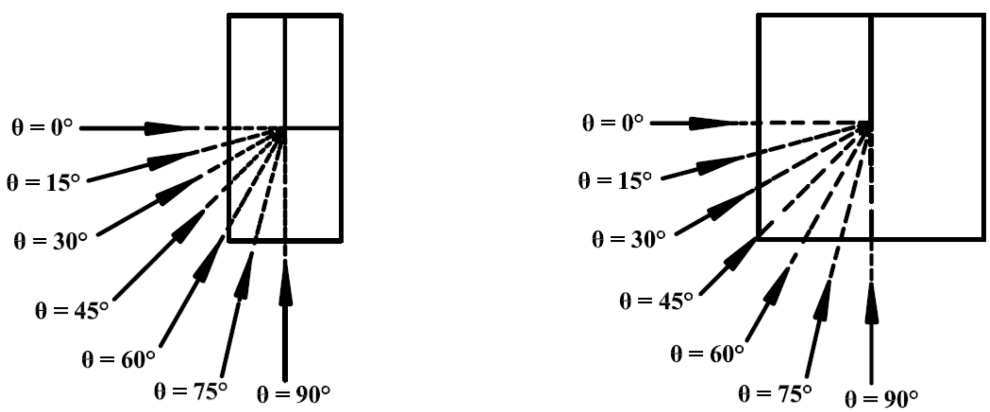
(a) Section 1-1.

(b) Section 4-4.

Figure 3. End view of the model showing pressure point locations.

2.3 Measurement Technique

First of all, one number Perspex sheet model of the building is placed at centre of the turn table representing single-span roof in such a way that wind hits the model perpendicular to the length i.e., 0^o wind incidence angle (Figure 4a). Pressure measurements are made by connecting pressure tubing from all 77 pressure points one by one to the pressure transducer. Values of pressure varying with time are recorded at an interval of 1 second for the duration of 60 seconds at each point in a computer through data taker. After measuring wind pressure values at all 77 pressure points on roof surface, turntable is rotated so that wind hits the model at 15^o wind incidence angle and wind pressure values are recorded again. This process is repeated till wind hits the gable end i.e., at 90^o angle. After completing measurements for single-span cylindrical roof model, same procedure is repeated for two-span building (Figure 4b). Values of mean wind pressure coefficients (Cp) are then calculated from the records of pressure (P) at all pressure points 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.



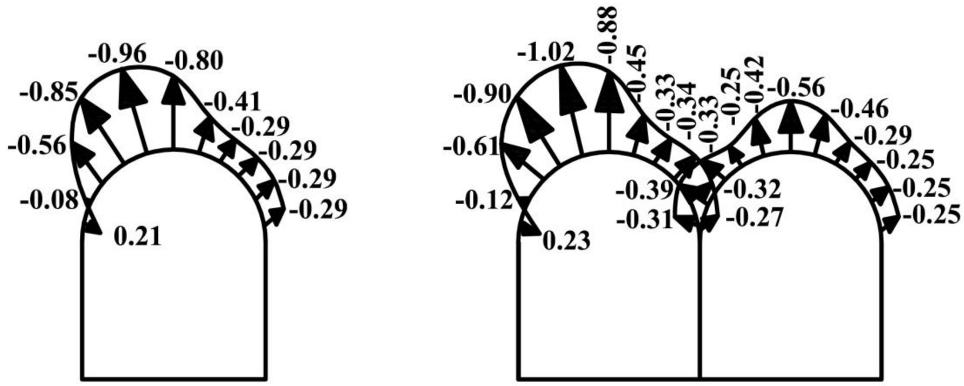
(a) Single-span. (b) Two-span.

Figure 4. Wind directions on the models.

3 RESULTS AND DISCUSSION

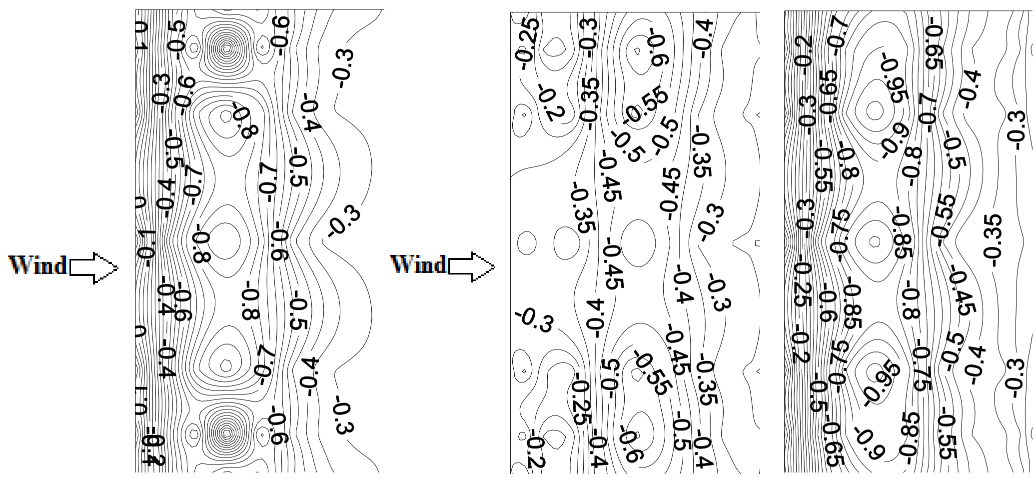
Due to paucity of space, results for 0^o wind incidence angle only are presented in this paper. Cross-sectional variations of Cp on the central section (i.e., section 4-4) are shown in Figure 5. Corresponding contours of Cp are shown in Figure 6.

It is seen from Figures 5 and 6 that in case of single-span roof, very small portion of windward edge of the roof is subjected to pressure, whereas entire remaining part of the roof is subjected to suction. Further, suction is maximum at a point near the apex of the roof on windward side. Suction becomes very small near the leeward edge. In case of two-span building, wind pressure distribution on windward span is similar to that in case of single-span. No part of leeward span is subjected to pressure. Entire roof surface is subjected to almost uniform suction. But suction on leeward span is found to be smaller as compared to suction on windward span with maximum value being almost half of that on windward span. Thus, there is advantage of shielding by windward span on wind pressure distribution on leeward span.



(a) Single-span. (b) Two-span.

Figure 5. Cross-sectional variations of C_p at section 4-4 under 0^0 wind incidence angle.



(a) Single-span. (b) Two-span.

Figure 6. Contours of C_p under 0^0 wind incidence angle.

4 CONCLUSIONS

Following conclusions are drawn from the study presented herein.

(1) Only very small portion of the single-span cylindrical roof near windward edge is subjected to pressure. Otherwise entire roof surface is subjected to suction.

(2) Maximum suction on roof occurs near apex on windward side.

(3) Wind pressure distribution on windward span in case of two-span building remain almost same as in the case of single-span building.

(4) Leeward span in case of two-span building is subjected to almost uniform suction with maximum value being almost half of that on windward span.

(5) There is advantage of shielding by windward span on wind pressure distribution on leeward span.

Acknowledgment

Work presented in this paper is part of the research work being done by the first author for her Ph.D. Degree under the supervision of second author.

References

Ahuja, A.K., Krishna, P. and Pande, P.K., "Wind Loads on Cylindrical Roofs", *Proc. Int. Symp. on Wind Loads on Structures, Roorkee, India,* 5-7 December, 1990.
Amareshwar, K., "Wind Pressure Distribution on Elevated Structures with Curved Roofs", *M.Tech. Thesis,* Indian Institute of Technology Roorkee, Roorkee, India, 2005.
AS/NZS: 1170.2, *"Structural Design Actions, Part-2: Wind Action"*, Australian/New Zealand Standard, 2002.
ASCE: 7-02, *"Minimum Design Loads for Buildings and Other Structures"*, American Society of Civil Engineers, 2002.
BS: 63699, *"Loading for Buildings: Part 2 – Code of Practice for Wind Loads"*, British Standard, 1995.
EN 1991-1-4, *"Euro code 1: Actions on Structures - Wind Actions"*, European Standard, 2005.
IS:875-Part-3, *"Code of Practice for Design Loads (other than Earthquake Loads) for Buildings and Structures-Wind Loads",* Indian Standard, 1987.
Kasperski, M., "Design Wind Loads for Arched Roofs", *Journal of Wind and Engineering*, Vol. 5, No. 2, 2008, pp. 17-30.
Kumar, R., "Mean Wind Pressure Distribution on Convex Cylindrical Roofs", M.E. Thesis, University of Roorkee, Roorkee, India, 1991.