Resilient Structures and Sustainable Construction
Edited by Pellicer, E., Adam, J. M., Yepes, V., Singh, A., and Yazdani, S.

ISBN: 978-0-9960437-4-8

WIND PRESSURE DISTRIBUTION ON NORTH-LIGHT INDUSTRIAL BUILDING ROOF

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Present paper describes details of the experimental study carried out on the models of industrial building with north-light roof in order to generate the information about wind pressure distribution on it. The models are tested in a closed circuit boundary layer wind tunnel to measure values of wind pressures on roof surface. Four cases namely one, two, three and four spans are considered. The side of Perspex sheet model in case of multi-span study places plywood models. Wind is made to hit the models at 13 wind incidence angles from 0° to 180° at an interval of 15°. Values of mean wind pressure coefficients are evaluated from the measured values of wind pressures and contours are plotted.

Keywords: Low-rise building, Wind incidence angle, Wind pressure coefficient, Wind tunnel testing, Multi-span roof.

1 INTRODUCTION

Industrial buildings are generally provided with sloping roofs in order to achieve large column free areas. Whereas gable or pitched roof is one of the most commonly used sloping roofs for such low-rise buildings, saw-tooth roof, north-light roof and sky-light roof are used at many places as they permit entry of natural light into the building through roof. It is noticed that roofs of many of such buildings are blown off during cyclonic storms. Whereas one of the possible reasons may be improper construction, another reason may be under estimation of wind loads acting on them. Structural designers generally refer to standards on wind loads of different countries to choose suitable values of wind pressure coefficients acting on sloping roofs. However, values of wind pressure coefficients available in literature are limited to certain roof slopes and certain wind incidence angles only.

Although Australian/New Zealand wind loading code [AS/NZS: 1170.2 (2002)], American code [ASCE: 7-02 (2002)], British code [BS: 63699 (1995)] and European code [EN: 1991-1-4 (2005)] recommend the values of wind pressure coefficients on north-light roof (Figure 1), Indian standard on wind loads [IS:875-Part-3 (2015)] does not provide any information regarding wind pressure coefficients on north-light roof. Further, no research publication is available in this area.

An effort has, therefore, been made to carry out wind tunnel tests on the models of low-rise buildings with single, two, three and four span north-light roofs (Figure 2) so as to generate the data regarding wind pressure distribution on it, which would be useful for the structural designers while designing similar buildings.

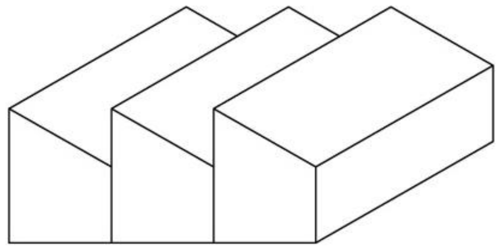
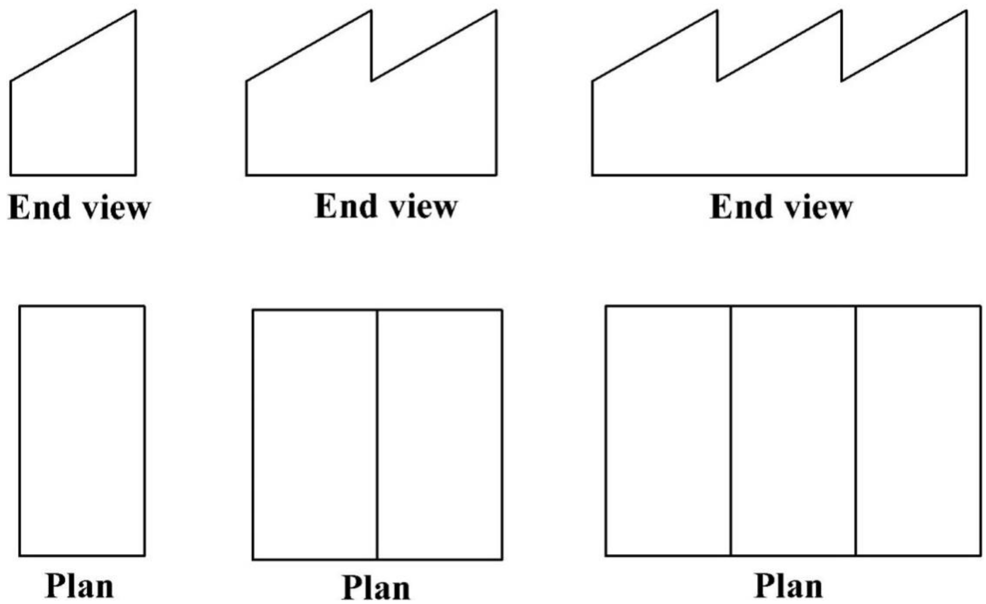


Figure 1. Low-rise building with north-light roof.



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

Figure 2. Buildings with single and multi-span north-light roofs.

2 EXPERIMENTAL PROGRAMME

2.1 Details of Models

Prototype rectangular plan low-rise industrial building with north-light roof is assumed to have length = 20 m, width = 10 m, lower eave height = 7.5 m, upper eave height = 13.25 m and roof slope angle = 30^0. Four rigid models of the building are made at a geometrical scale of 1:50. One model is made of Perspex sheet and another three are made of plywood. Thus, each model has length = 400 mm, width = 200 mm, lower eave height = 150 mm, upper eave height = 265 mm and roof slope angle = 30^0 (Figure 3). The north-light roof building has slope in one direction only. Perspex sheet model is provided with thirty-five pressure points on the roof surface (Figure 4) so as to obtain good pressure distribution on it.

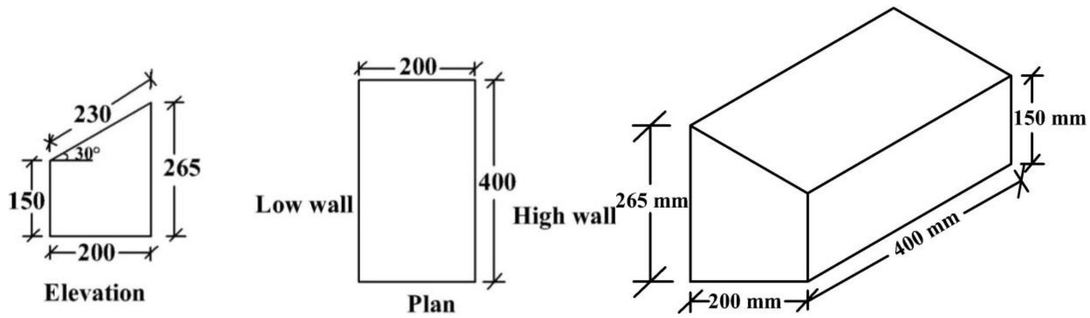


Figure 3. Model of rectangular plan building with north-light roof.

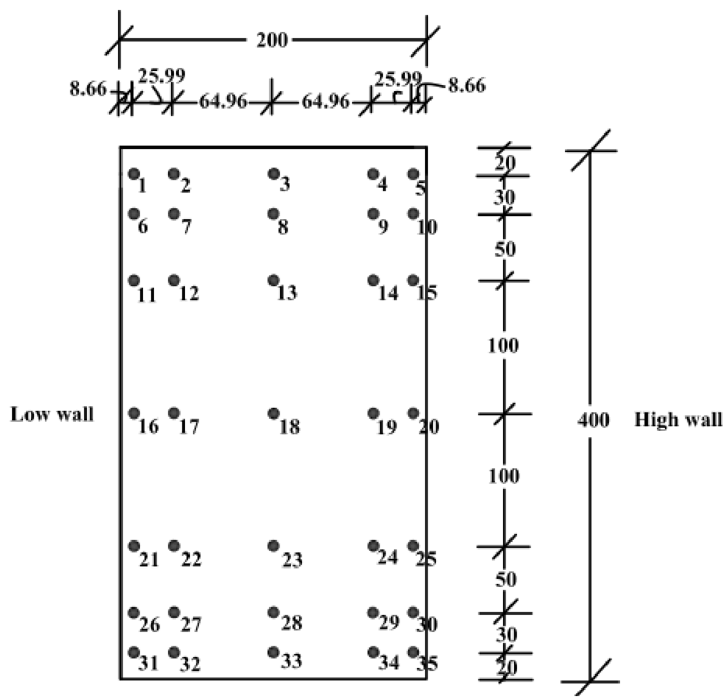


Figure 4. Pressure points on north-light roof.

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 15 m long test section with a cross sectional dimensions of 2 m x 2 m. 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 center of the turntable and is tested under free stream wind velocity of 10 m/sec measured at 1 m height above the floor of the tunnel.

2.3 Measurement Technique

First of all, Perspex sheet model of the building is placed at the center of the turn table inside the wind tunnel representing single-span north-light roof in such a way that wind hits the instrumented model perpendicular to the low-wall, i.e., at 0^0 wind incidence angle (Figure 5). Connecting pressure tubing from all 35 pressure points one by one to the pressure transducer makes pressure measurements. 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 35 pressure points on the single-span north-light roof surface for 0° wind incidence angle, the process is repeated for 12 more wind directions up to 180° at an interval of 15° (Figure 5) by rotating the turn table.

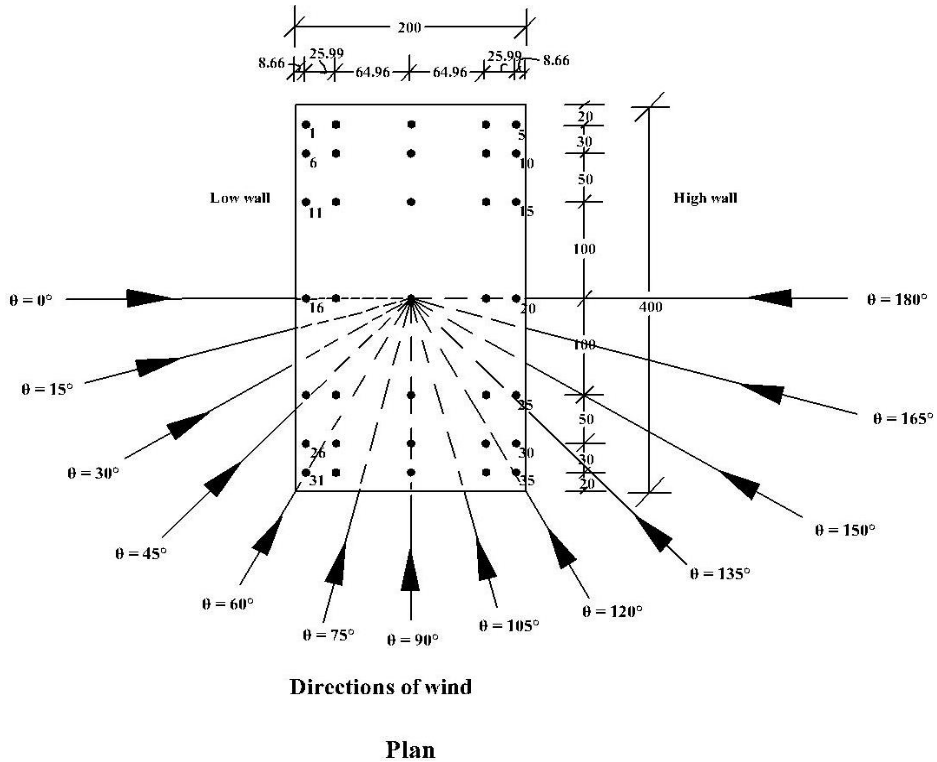


Figure 5. Wind directions on single-span north-light roof building.

For the measurement of wind pressure distribution in case of two-span north-light roof building, Perspex sheet model is placed at center of the turntable and one plywood model is placed on its leeward side. Pressure measurements are made similar to single-span north-light roof. Wind pressures are measured at seven wind incidence angles namely 0° to 180° at an interval of 30°.

After measuring the wind pressures on models of two-span north-light roof building, process is repeated for three-span and four-span cases. Values of mean wind pressure coefficients (C_p) are then calculated from the records of pressure (P) at all pressure points using the relationship, $C_p = P / (0.6\ V_{ref}^{\ 2})$, where V_{ref} is the reference wind velocity at 1 m height above the floor of the wind tunnel.

3 RESULTS AND DISCUSSION

Due to paucity of space, results of single-span and double-span north-light roofs are only presented herein. Results presented are in the form of contour plots of C_p obtained for all wind incidence angles considered (Figure 6) and cross-sectional variations for only 0° and 180° wind incidence angles (Figure 7).

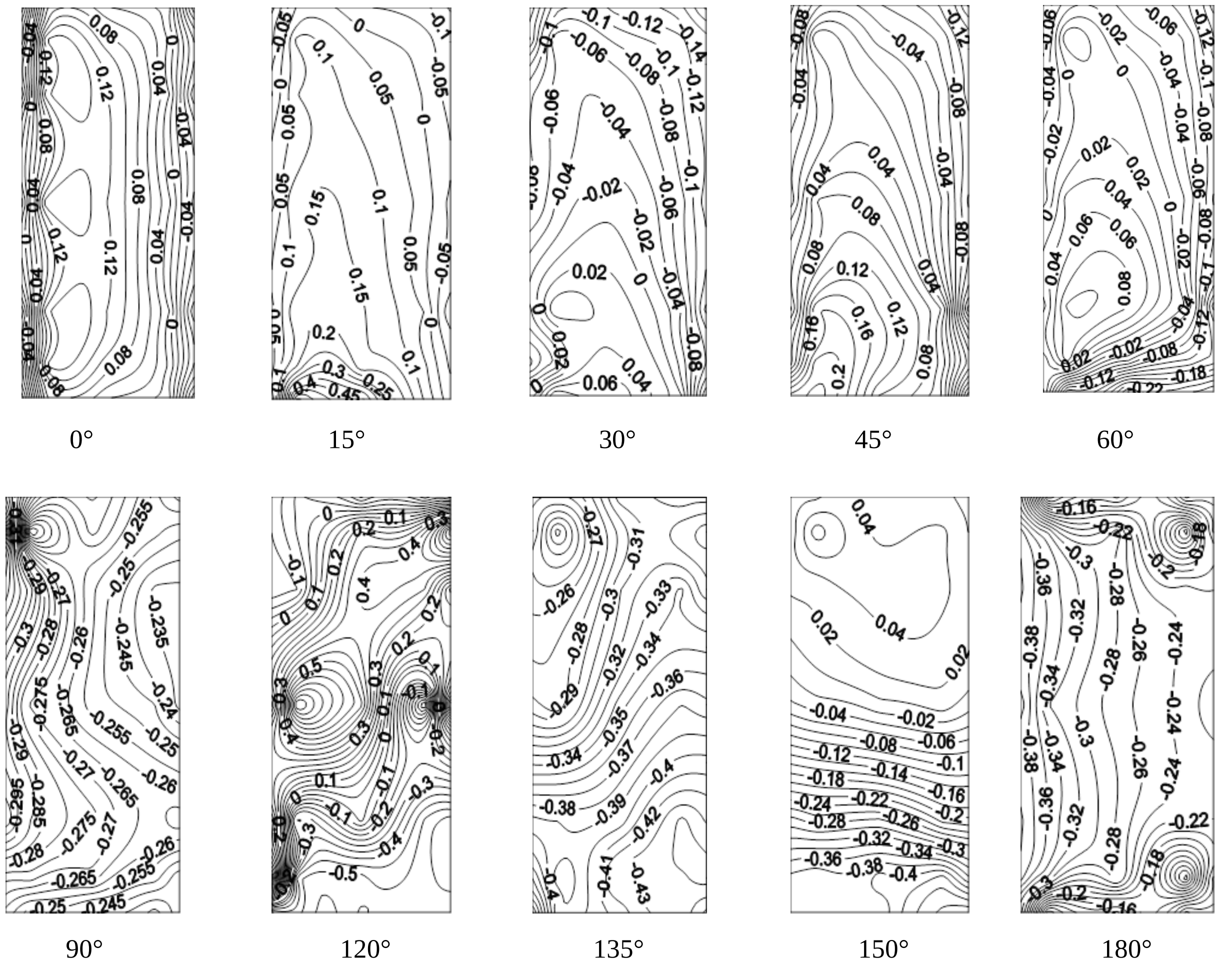


Figure 6. Variation of C_p on single-span north-light roof building under different wind incidence angles.

It is seen from Figure 6 that in case of single-span north-light roof, almost entire roof is subjected to pressure when wind hits perpendicular to low-wall i.e. at 0° wind incidence angle. As wind direction changes from 0° to 60°, windward zone is subjected to pressure with suction on leeward zone. From 90° to 180° wind incidence angles, entire roof surface is subjected to suction. Figure 7 shows variation of C_p at central section in case of two-span roof under 0° and 180° wind directions. At 0° wind incidence angle, windward slope is subjected to pressure with suction on leeward slope. At 180° angle, both windward and leeward slopes are subjected to suction with almost two time suction on one as compared to another one.

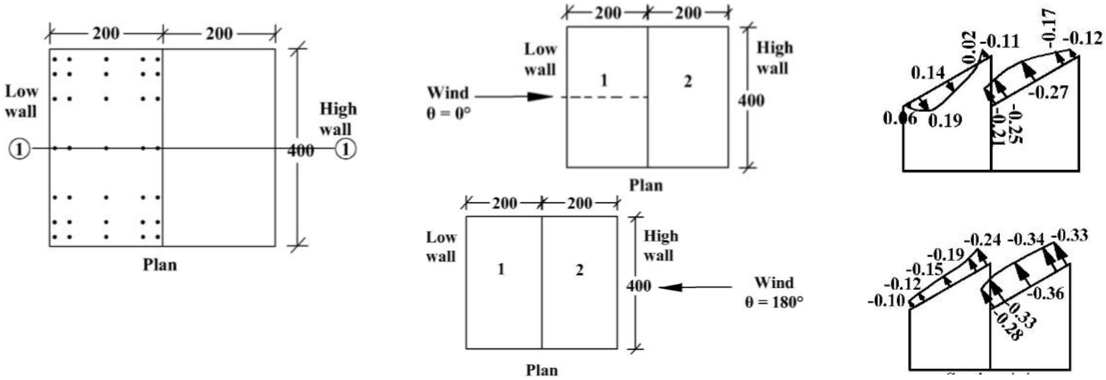


Figure 7. Variation of C_p at section 1-1 of two-span north-light roof building.

4 CONCLUSIONS

Following conclusions are drawn from the study presented herein.

- Pressure occurs on windward slope of both single-span and two-span north-light roof when wind hits perpendicular to low-wall.
- Suction occurs on all slopes of both single-span and double-span north-light roofs when wind hits perpendicular to high-wall.
- Both pressure and suction values in case of two-span north-light roof are more as compared to those on single-span roof.

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.

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