Wind Pressure Distribution on Rectangular Plan Buildings with Multiple Domes

Astha Verma, Ashok K. Ahuja

Abstract—**Present paper describes detailed information of the experimental study carried out on the models of low-rise buildings with domical roofs. Wind pressure measurements are made on rigid models by placing them in an open circuit boundary layer wind tunnel. This study includes the rectangular plan buildings with two, three and four domes. The experimental results of pressure measurements are reported in the form of contours and cross-sectional variations of mean wind pressure coefficients on the surfaces of domes.**

Index Terms— **Domical Roofs, Interference Effect, Low-rise Buildings, Multi-span, Wind Pressure Coefficients**

I. INTRODUCTION

Most of the low-rise buildings are built for residential purpose and have simple roof forms such as flat or sloping roofs. Another category of low-rise buildings that are built for industrial or assembly purposes such as air, railway and bus terminal buildings, exhibition halls, hangers and sport complexes need large column free areas. Such buildings are thus provided with curved roofs namely cylindrical roofs and domical roofs.

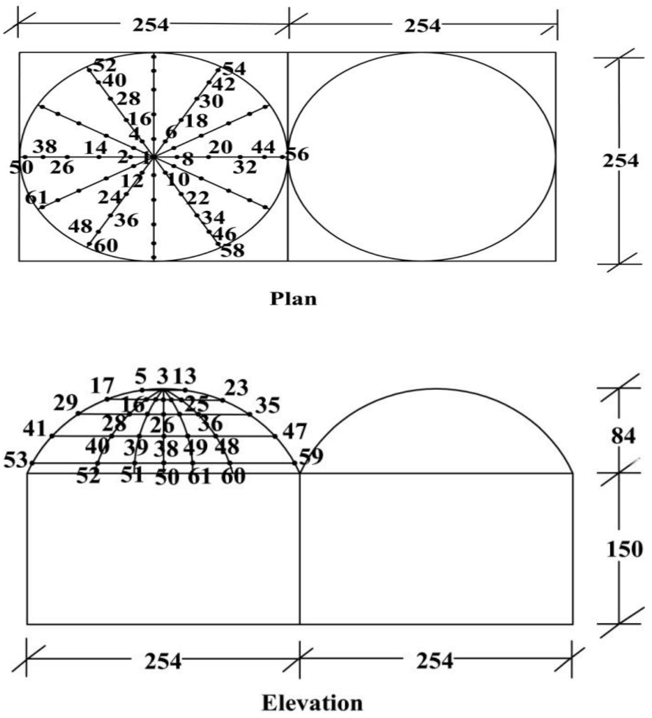
Wind is one of the important loads to be considered while designing the roofs of low-rise buildings. The structural designers while designing building roofs refer to relevant code of practices of various countries dealing with wind loads [1]-[5]. However, available information in such codes regarding wind pressure coefficients on roofs in general and especially on curved roofs is very limited, which are only for single-span or isolated curved roof building. Whereas wind pressure values on a building roof get modified due to the presence of nearby building, such information is not available in code of practices. Review of the research work published during last 3 decades [6]-[12], also indicates that very limited information regarding wind pressure coefficients on curved roofs is available.

An experimental study has, therefore, been carried out by the authors on the models of rectangular plan low-rise buildings with roofs made of multiple domes.

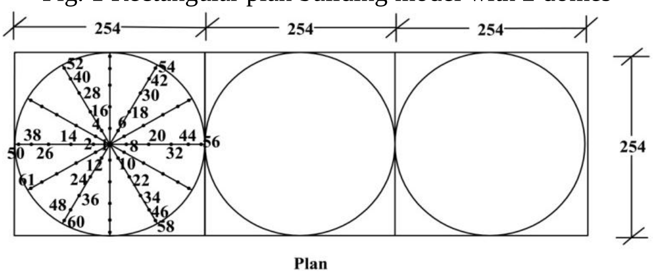
II. EXPERIMENTAL PROGRAMME

A. Details of Models

Prototypes chosen for study are low-rise rectangular plan buildings with (i) 2 domes, (ii) 3 domes and (iii) 4 domes, all in aligned position. Wall elements of the building models are made of Perspex sheet whereas domes are made up of aluminum. Plan dimensions of the models are 254 x 508 mm, 254 x 762 mm and 254 x 1016 mm respectively. Eaves height of each model is 150 mm. Each dome has base diameter of 254 mm and height of 84 mm (Figs. 1-3). One of the domes of each building model is provided with pressure points for the measurement of pressures on roof surface. A total of 61 pressure points are provided at the locations where latitudes and longitudes on the dome intersect each other. The instrumented model is placed at two, three and four different locations for measurement of pressures in case of rectangular plan buildings with 2, 3 and 4 domes respectively. It is placed first as windward dome and then as leeward dome in case of rectangular plan building with 2 domes. Position of instrumented dome is similarly changed again and again in case of buildings with 3 and 4 domes.



(All dimensions are in mm)
Fig. 1 Rectangular plan building model with 2 domes



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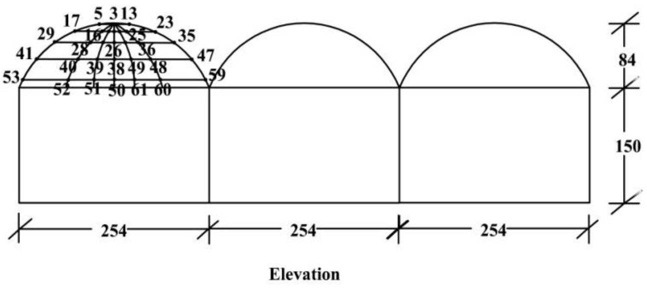
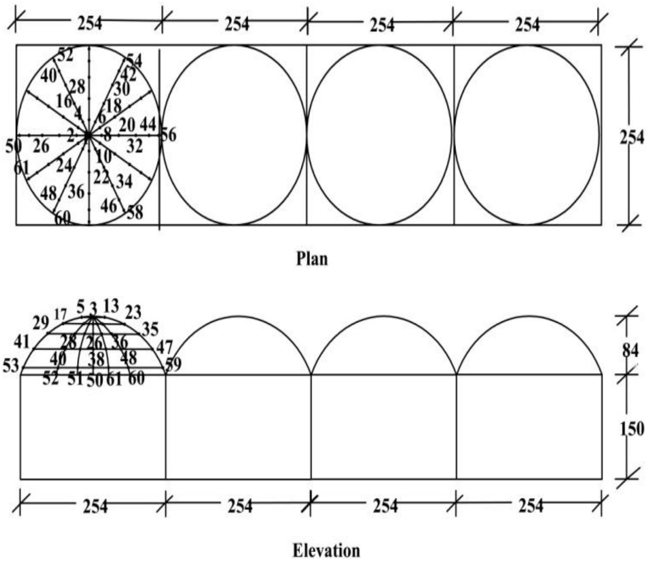


(All dimensions are in mm)
Fig. 2 Rectangular plan building model with 3 domes



(All dimensions are in mm)
Fig. 3 Rectangular plan building model with 4 domes

B. *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 dimension of 2 m (width) x 2 m (height). Flow roughening devices such as vortex generators, barrier wall and cubical blocks of various sizes are used on the upstream end of the test section to achieve boundary layer mean wind velocity profile corresponding to Terrain Category II as per Indian Standard on Wind Loads. The models are placed at the center of the turntable and are tested under free stream wind velocity of 10 m/sec measured at 1 m height above the floor of the tunnel.

C. *Measurement Technique*

The models of the rectangular plan buildings are placed inside the wind tunnel in such a way that the dome with pressure points on it, falls exactly at the center of the turn table and wind hits perpendicular to one of the short walls. Further, it is ensured that pressure point number 2, 14, 26, 38 and 50 fall in the direction of wind (Fig. 4). Measurements of pressure are made by connecting pressure tubing from all 61 pressure points one by one to the pressure transducer. Values of pressures varying with time are recorded at an interval of 1 second for duration of 30 seconds at each pressure point and stored in a computer through data taker.

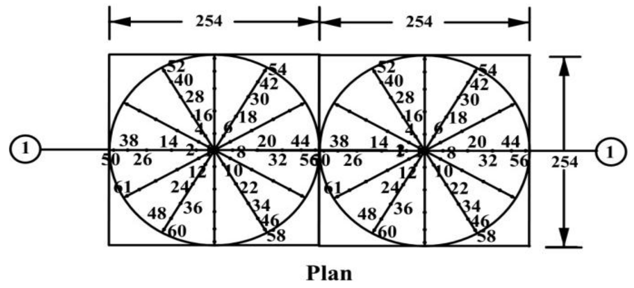


Fig.4 Plan of the building with 2 domes showing section 1-1

In order to measure wind pressure distribution on the domes of rectangular plan building model with 2 domes, 2 blocks of square plan building models are placed one behind another in alignment in the direction of wind (Fig. 5). Building block with instrumented dome is first placed on upstream side and pressure values are measured at all 61 pressure points. Then the instrumented model is placed on downstream side and measurements of pressure values are taken at all pressure points again. Thus, pressure distributions on both windward and leeward domes are obtained. Similar steps are followed in case of models with 3 and 4 domes also (Fig. 6).

Fig. 5 Model of rectangular plan building with 2 domes

(a) (b)

Fig. 6 Models of rectangular plan building with (a) 3 domes and (b) 4 domes

Mean wind pressure coefficients (C_p) values are then calculated from the records of pressures (P) 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.

III. RESULTS AND DISCUSSION

A. *Rectangular Plan Building with 2 Domes*

Wind pressure distribution on the domes of the rectangular plan building with 2 domes, when wind hits it perpendicular to one of the short walls, is shown in Fig. 7 in the form of the countors of mean wind pressure coefficients (C_p). Cross sectional variation of C_p on section 1-1 can be seen in Fig. 8.

It is seen from Figs. 7 and 8 that major portions of both the domes are subjected to suction and small portions are subjected to pressure. Maximum value of C_p is 0.25 near the windward edge of windward dome and its value is 0.27 on leeward dome. Point of maximum pressure on leeward dome is closer to the top of the dome. Suction is maximum near the top of the dome. Suction is slightly greater on windward dome (C_p = - 0.43) as compared to that on leeward dome (C_p = - 0.37). Suction decreases towars the leeward edges. Whereas leeward edge of leeward dome is still subjected to suction although of very small value, leeward edge of windward dome is subjected to pressure.

B. Rectangular Plan Building with 3 Domes

Fig. 9 shows the countors of mean wind pressure coefficients (C_p) on the domes of the rectangular plan building with 3 domes, when wind hits the same perpendicular to one of the short walls. Cross sectional variation of C_p on section 1-1 can be seen in Fig. 10.

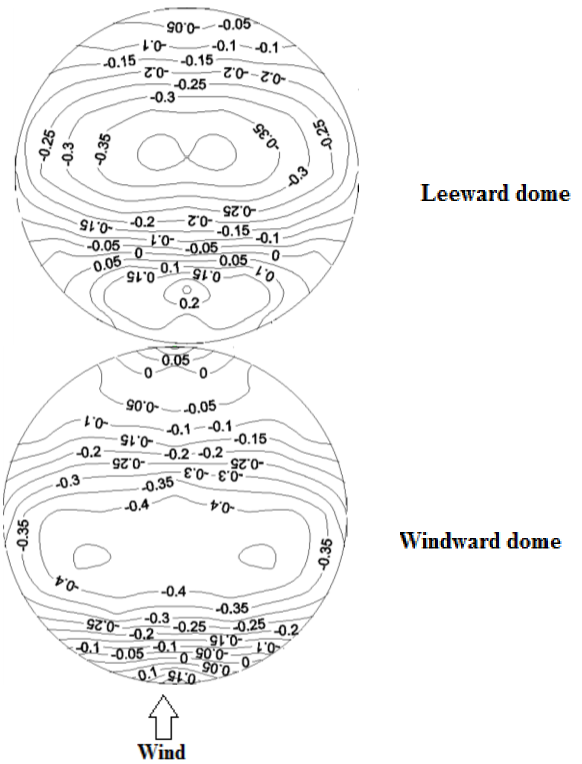


Fig. 7 Wind pressure distribution on domes of rectangular plan building with 2 domes

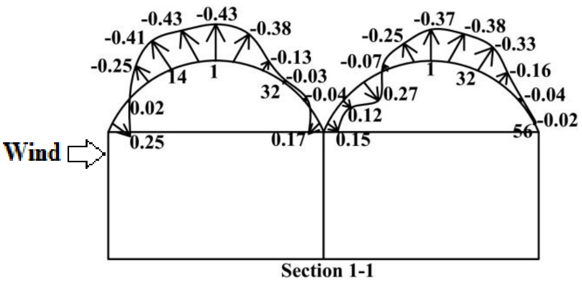


Fig. 8 Cross-sectional variation of C_p on section 1-1 of rectangular plan building with 2 domes

It is noticed from Figs. 9 and 10 that as in the case of building with 2 domes, major portions of all the domes are subjected to suction and small portions are subjected to pressure in case of building with 3 domes also. Wind pressure distributions on windward and leeward domes are quite similar to the previous case with larger suction on windward dome as compared to leeward dome and larger pressure on leeward dome as compared to windward dome. The central dome is subjected to pressure near both windward and leeward edges and suction near the top. Maximum suction on this dome is the least of all three domes.

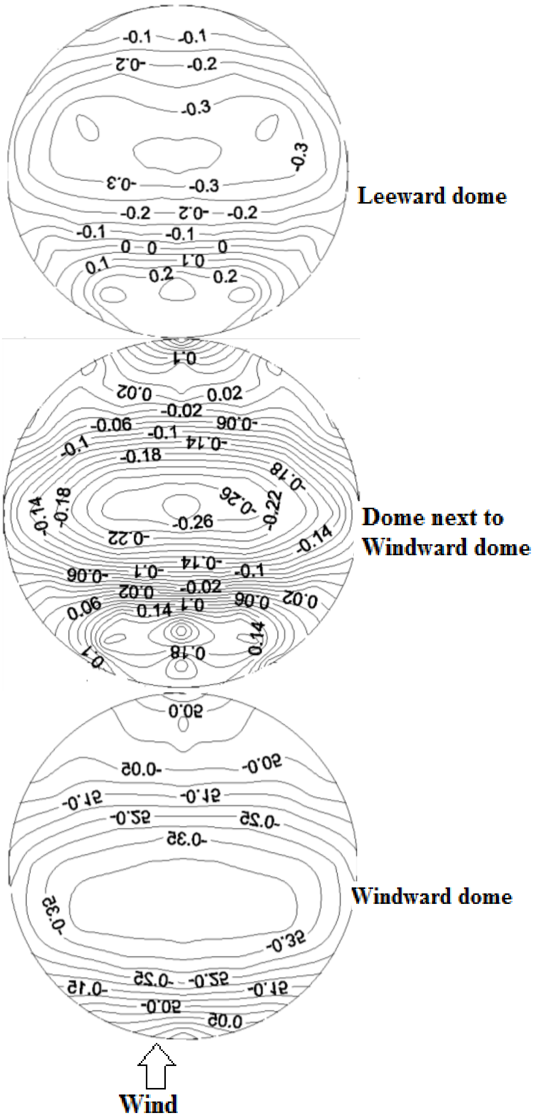


Fig. 9 Wind pressure distribution on domes of rectangular plan building with 3 domes

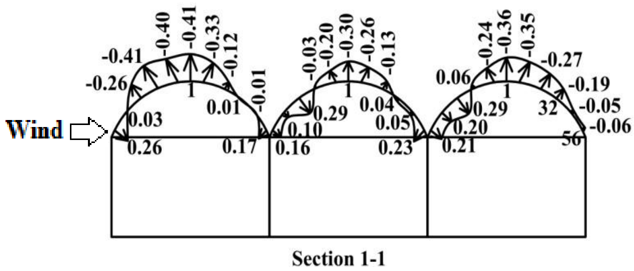


Fig. 10 Cross-sectional variation of C_p on section 1-1 of rectangular plan building with 3 domes

C. Rectangular Plan Building with 4 Domes

Cross sectional variation of mean wind pressure coefficients (C_p) on section 1-1 of the rectangular plan building with 4 domes, when wind hits it perpendicular to one of the short walls is shown in Fig. 11. Countours of C_p on the domes can be seen in Fig. 12.

It is noticed from Figs. 11 and 12 that wind pressure distributions on windward and leeward domes in this case are quite identical to those of previous cases. Middle 2 domes are subjected to identical distribution of wind pressures with values of C_p being quite close to those on central dome of 3 domes building. It implies that 3 sets of wind pressure coefficients need to be considered for design of domical roofs under wind loads, namely first one for windward dome, second one for in-between domes and third one for leeward dome.

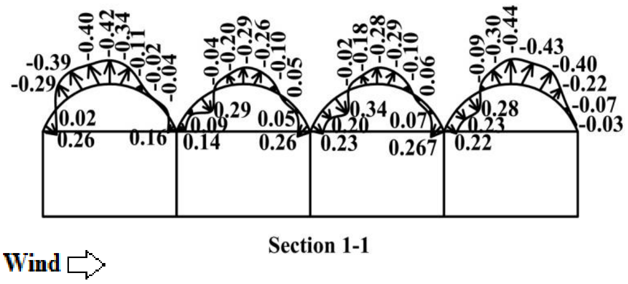


Fig. 11 Cross-sectional variation of C_p on section 1-1 of rectangular plan building with 4 domes

IV. CONCLUSIONS

Following conclusions are drawn from the study presented herein.

1. Major portions of the domes are subjected to suction and small portions are subjected to pressure under wind, in case of rectangular plan buildings with domical roofs in aligned position.
2. Pattern of wind pressure distribution on all in-between domes is identical and values of pressure and suction almost equal, irrespective of the number of domes.
3. Maximum suction occurs near the peak in case of all the domes.
4. Values of maximum suction on windward and leeward domes are almost equal, and are greater than those on in-between domes.
5. Windward edges of all the domes are subjected to pressure, with small portion and value on windward dome as compared to all other domes.
6. Leeward edges of all the domes except the leeward dome are subjected to pressure.

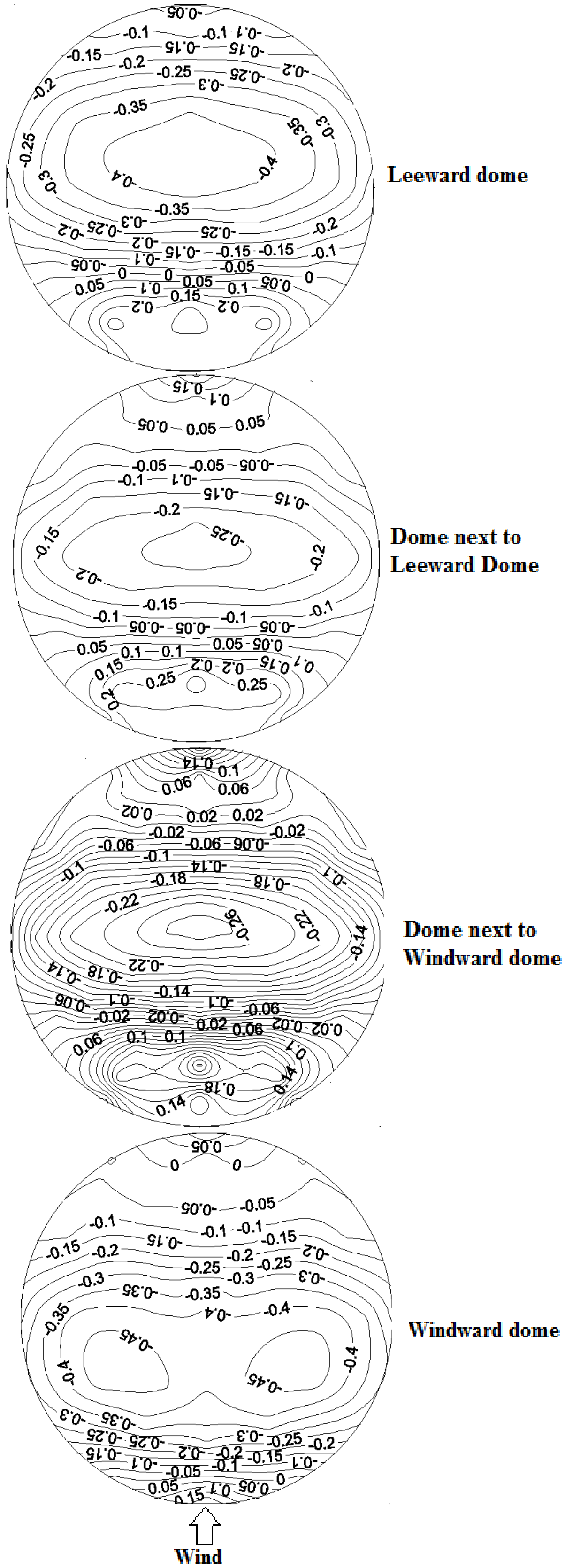


Fig. 12 Wind pressure distribution on domes of rectangular plan building with 4 domes

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