WIND TUNNEL STUDIES ON CYLINDRICAL ROOFS

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ABSTRACT

Various types of structures including buildings are designed for wind loads apart from other loads for its sustainability under wind storms. Whereas it is important to use appropriate wind velocity in relation to the area where the structure is to be built, it is also necessary to use correct values of force or pressure coefficients acting on various surfaces of the structure to evaluate design wind loads. Generally force or pressure coefficients are referred from the relevant code of practice of concerned country, if available. Such coefficients are generally available for structures with simple shapes only. For structures with special shapes or curved surfaces, very limited information is available.

Values of pressure coefficients for designing a rigid or flexible roof on rectangular building with concave or convex cylindrical roof surface are available only in certain codes of practices. For example, National wind codes of Czechoslovakia, Germany, India and USSR [4, 7] recommend values of external wind pressure coefficients on cylindrical roofs resting on ground and on elevated structures for wind direction normal to eaves. National wind codes on Australia and New Zealand [7, 8] recommend values of external wind pressure coefficients on cylindrical roofs with convex surface for wind direction normal to eaves. National codes of Canada, New Zealand and Switzerland [7, 8] also recommend values of external and internal wind pressure coefficients for hanger curved roof having circular curvature with moderately smooth surface. However, the available information is for certain wind incidence angles only. Further, influence of curvature, height of building etc. are not clearly spelled out.

Therefore, it becomes necessary to carryout wind tunnel measurements on models of buildings with concave or convex cylindrical roofs before the design of roof, to get detailed and comprehensive information about wind pressure distribution on such roofs. Very few researchers have done experimental studies in this direction during last three decades. To quote a few, Ishizaki and Yoshikawa [5] measured values of mean pressure coefficients and gust pressure spectra on a concave cylindrical roof model of different sag to span ratios and height to span ratios, laid across the total width of a wind tunnel. Kumar and Agarwal [6] tested models of cylindrically curved shell roofs with different sets of values of radius, semi central angle and height of supporting wall. Ahuja et al. [2, 3] reported tests on concave cylindrical roof models with similar to the one used by Ishizaki and Yoshikawa [5] to study the effect of sag to span ratio, height to span ratio, wind incidence angle and wind velocity on wind pressure distribution on roof surface. Ahuja [1] studied the effect of turbulence intensity on pressure coefficients over cylindrical roofs.

As mentioned above, available information regarding wind pressure distribution on convex cylindrical roofs is not comprehensive. Specially, information is not available with regard to local extreme values of wind pressure coefficients and also variation in values of coefficients with change in wind direction. The present paper describes efforts taken by the authors in this

direction to bridge between the available information and information required by the designers for designing such roofs for wind loads. Reduced scale models of rectangular building with convex cylindrical roof are tested in boundary layer wind tunnel. Wind pressures at many points on the roof surface are measured and wind pressure coefficients calculated. Wind velocity, wind incidence angle, height to span ratio and rise to span ratio are varied and effects of these parameters on wind pressure coefficients studied. Further, from the values of local pressure coefficients, maximum wind pressure coefficients and average wind pressure coefficients are worked out. These values are compared with available (although limited) information.

The present study is intended to find the external pressure distribution over the roof surface of a single building unit. Building considered has a length of 120 m, breadth of 60 m and eaves height of 18 m. Models are made. Models of size 500 x 250 x 75 mm dimensions are made of timber using a scale of 1:240. One model is made with a flat roof. Second one has height above eaves level as 15 mm and third one has 30 mm, thus resulting in rise to span ratio of 0.00, 0.06 and 0.12 respectively. While studying the effect of height to span ratio on wind pressure coefficients, height of the building with rise to span ratio 0.06 is taken as 12, 18, 24 and 30 m with corresponding model height of 50, 75, 100 and 125 mm (Fig. 1). Thus in all six models are prepared for the present experimental study (Table 1). Each model is provided with 25 external pressure tapings (Fig. 2).

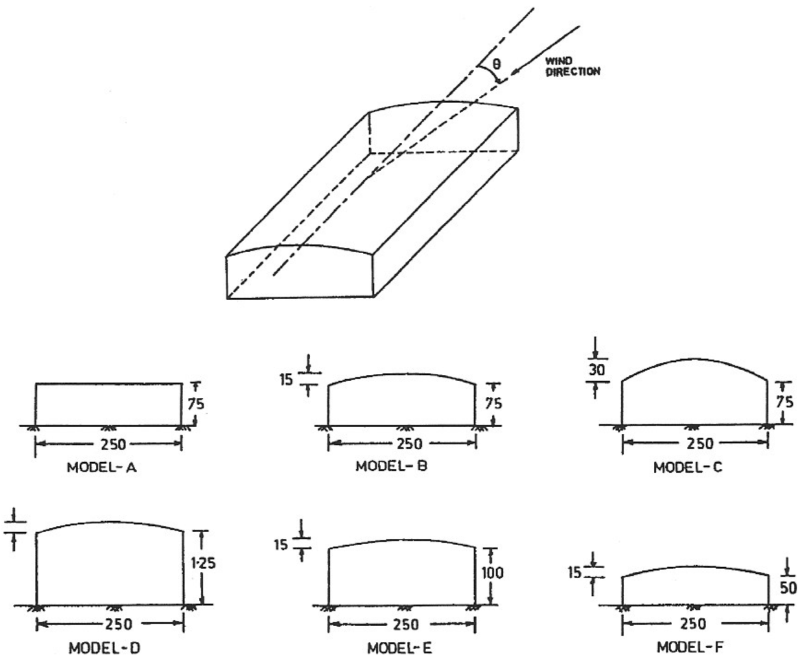

Fig. 1 Rigid models of cylindrical roofs

Rigid models of flat and cylindrical convex roof are tested in order to study the effects of various structural and flow parameters (Table 2) on mean pressure distribution on roof surface. In all 39 tests are conducted. Local values of mean wind pressure coefficients (Cp) at twenty five pressure points on each model are calculated from the measured values of wind pressures.

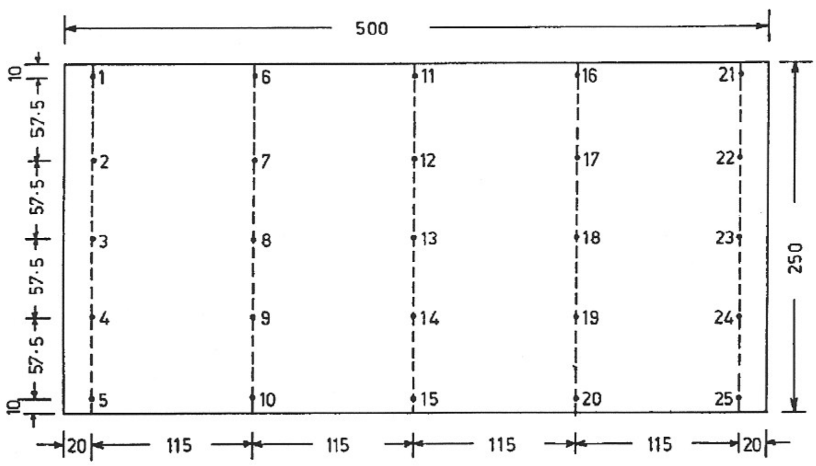

Fig. 2 Pressure points on roof surface

Table 1 Dimensions of rigid models

Model identification	Size of model (mm) Length	Breadth	Height	Height to span ratio	Rise to span ratio	Reference wind velocity (m/sec)
A	500	250	75	0.3	0.00	7.05, 10.80
B	500	250	75	0.3	0.06	7.05, 10.80
C	500	250	75	0.3	0.12	7.05, 10.80
D	500	250	125	0.5	0.06	10.80
E	500	250	100	0.4	0.06	10.80
F	500	250	50	0.2	0.06	10.80

Table 2 Structural and flow parameters

Sl. No.	Parameter		Values
1	Wind incidence angle (θ)		0°, 15°, 30°, 45°, 60°, 75° and 90°
2	Wind velocity :	Free stream	10 and 15 m/sec
		Reference	7.05 and 10.80 m/sec
3	Rise to span ratio		0.00, 0.06 and 0.12
4	Height to span ratio		0.2, 0.3, 0.4 and 0.5

During analysis and design of roofs for wind loads, it is not convenient to use the local values of mean pressure coefficients (Cp) at closely spaced points on roof surface, but average values of mean wind pressure coefficients (Cpavg) on larger area may be used with convenience.

Therefore, roof surfaces of all models are divided into 3 parallel strips and average values of mean wind pressure coefficients are calculated for wind direction normal to eaves.

Followings are some of the important conclusions drawn from the present study.

(i) All the points on the flat and convex cylindrical roofs are subjected to suction for all wind incidence angles except very few spots subjected to pressure of very small magnitude.

(ii) Range of maximum to minimum pressure coefficient is found to be -2.24 to 0.00 in case of flat roof, -1.92 to +0.03 in case of convex cylindrical roof with rise to span ratio 0.06 and -1.80 to 0.00 in case of convex cylindrical roof with rise to span ratio 0.12. These large values of local suction need to be considered by the designers for design of fasteners etc. on such roofs.

(iii) Effect of rise to span ratio on C_p values is not significant for 0° wind incidence angle. For 45° wind incidence angle, variation in C_p values is significant for central part of roof as compared to edges. At 90° wind incidence angle, variation is significant on the windward side.

(iv) Mean wind pressure coefficients are not affected significantly with the variation in height to span ratio.

(v) Average values of mean wind pressure coefficients on the roof surface can be used for approximate and conservative design of similar roofs for wind loads.

(vi) Local values and maximum values of mean wind pressure coefficients can be used with ease as and when needed by the designers.

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