WIND PRESSURES ON A CATENARY ROOF

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Introduction

Wind loads on low-rise structures with predominantly flat or low-pitch roofs have been the subject of extensive research in recent years. Catenary roofs (single curvature) have been proposed as alternative roofing system for structures such as indoor sport stadiums and reservoirs. This paper presents the results of a program of wind tunnel measurements of the wind-induced pressures on a catenary roof.

Venting of the region underneath the separates shear layer by vented eave has been proposed by Melbourne (1979) and Sharp (1980) to reduce the high negative (suction) pressures near the leading edge of low-rise structures caused by re-attachment of the shear layer. More recently, Cook (1982) has reported that venting the leading edge was effective in reducing the wind loads on a cantilevered groundstand roof. Kwok (1983) and Kwok and Bailey (1984) have found that venting near the corners of tall prismatic structures caused significant reduction of both the side wall pressures and dynamic responses. The effect of the fitting of eave or vented eave on the pressure distribution on a catenary roof is also presented in this paper.

Experimental Arrangement

A model of a low-rise structure with a catenary roof, as shown in Fig.1, was tested in the Boundary Layer Wind Tunnel at the School of Civil and Mining Engineering. Pressure distributions on the roof were measured by 42 pressure-taps made of 1.6 mm OD hypodermic tubings. These pressure-taps were connected to a pressure transducer via 450 mm long 1.5 mm ID PVC tubings and a 48 ports "Scanivalve". Two 5 mm long 0.38 mm ID restrictors were placed about half way in each tubing to ensure a flat response (to about ±10%) to about 100 Hz (Holmes, 1983).

A 1/200 scale model of wind flow over open terrain (Terrain Category 2 as defined in AS1170 (1983)) was generated in the wind tunnel. A 200 mm high trip-board spanning the start of the working section and carpet covering the upstream fetch were used in the simulation.

Three model configurations were tested: (i) plain roof, (ii) roof with vented eave, and (iii) roof with eave (same as (ii) but with the vent sealed). Pressure measurements were taken for a number of incident wind angles. The fluctuating pressure signals were low-pass filtered at 100 Hz and were digitised at a sampling rate of 800 Hz. 30 seconds records (24,000 samples) were processed for each pressure-tap from which the mean, standard deviation and peak pressures were determined. These pressures were normalised in coefficient form using the dynamic pressure measured by a pitot-static tube at 0.5 m height as reference.

Experimental Results and Comments

The vast majority of mean pressure measurements taken on the catenary roof are negative. For incident wind angles of 60° and 75°, some positive pressures were recorded on area of the roof surface which was significantly shielded by

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Table I. Maximum mean pressure coefficients on a catenary roof

Wind direction	Plain roof			Roof with vented eave			Roof with eave		
	Short edge	Long edge	Corner	Short edge	Long edge	Corner	Short edge	Long edge	Corner
0°	-0.74	-0.34	-0.74	-0.56	-0.28	-0.55	-0.62	-0.18	-0.48
30°	-0.93	-0.59	-0.40	-0.68	-0.48	-0.33			
45°	-0.90	-1.16	-0.37	-0.53	-0.83	-0.37	-0.52	-0.96	-0.26
60°	-0.63	-1.33	-0.62	-0.29	-0.98	-0.60			
75°	-0.36	-0.96	-1.13	-0.33	-0.71	-0.80			
90°	-0.54	-0.56	-0.62	-0.45	-0.47	-0.51	-0.41	-0.62	-0.66

Table II. Maximum peak pressure coefficients on a catenary roof

Wind direction	Plain roof			Roof with vented eave			Roof with eave		
	Short edge	Long edge	Corner	Short edge	Long edge	Corner	Short edge	Long edge	Corner
0°	-1.69	-1.02	-1.97	-1.30	-0.63	-1.13	-1.42	-0.59	-1.08
30°	-2.41	-1.74	-1.58	-1.27	-1.45	-0.86			
45°	-2.11	-3.13	-0.86	-1.27	-1.79	-0.79	-1.31	-1.75	-0.68
60°	-1.60	-2.49	-2.18	-0.82	-1.90	-1.56			
75°	-1.48	-2.54	-2.74	-0.85	-1.27	-1.56			
90°	-1.33	-1.42	-1.92	-1.08	-0.95	-1.13	-0.94	-1.31	-1.49

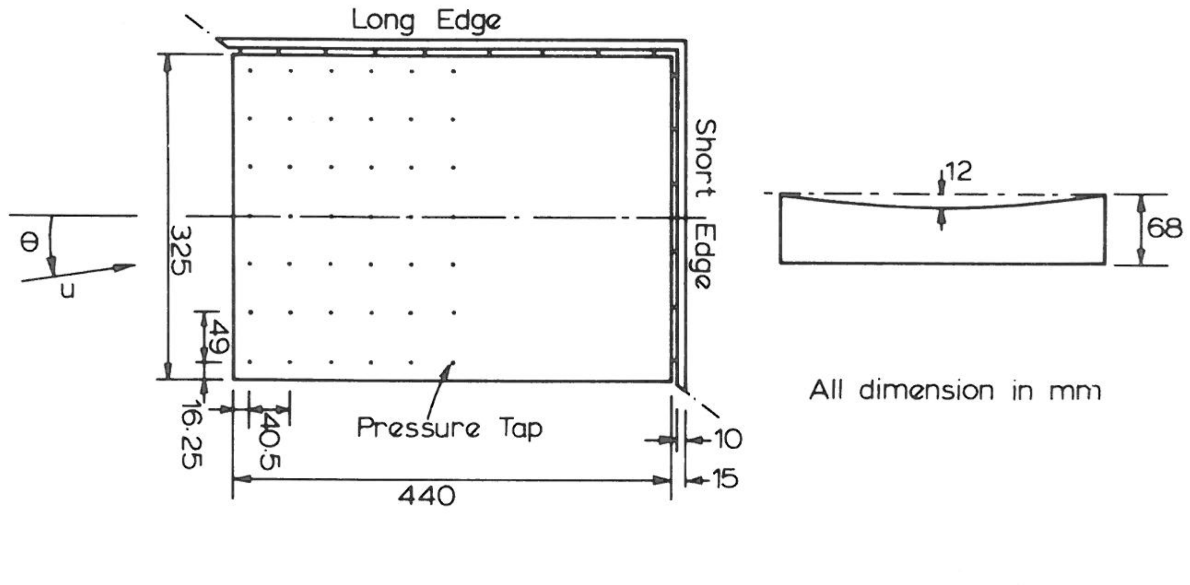

FIG.1 PRESSURE-TAPPED MODEL OF CATENARY ROOF SHOWING VENTED EAVE

the windward corner. High negative mean and peak pressures occurred near the windward edges and corner. The maximum mean and maximum negative peak pressure coefficients measured are -1.33 and -3.13 respectively for the plain roof, -0.98 and -1.90 when vented eave was fitted, and -0.96 and -1.75 when eave was fitted. The reduction of mean and peak pressures caused by the fitting of eave or vented eave can be clearly seen in Fig. 2 for a incident wind angle of 45°. For other incident wind angles, the reduction of pressures are summarised in Tables I and II.

The effect of fitting vented eave is a general reduction of both the mean and peak pressures for all incident wind angles. The most significant reductions are near the windward edges and corner. These reductions of pressures are consistent with Melbourne's hypothesis (1979) which suggested that venting of the region underneath the separated shear layer could result in a significant reduction of wind loads in region near the leading edge of low-rise structures.

The fitting of eave also caused a general reduction in pressures, but the magnitude of the reductions are not as marked as those achieved by vented eave. It should be noted that the fitting of eave effectively moves the flow separation and hence the region of high negative pressure forward. While there might be significant reduction of pressures near the edge of the roof, the significant wind loads on the eave should not be overlooked.

Conclusions

Mean and peak pressure distributions on catenary roof were determined from a program of wind tunnel model tests. It was found that the fitting of vented eave and, to a lesser extent, eave caused a general reduction of both the mean and peak pressures, particularly at near the windward edges and corner.

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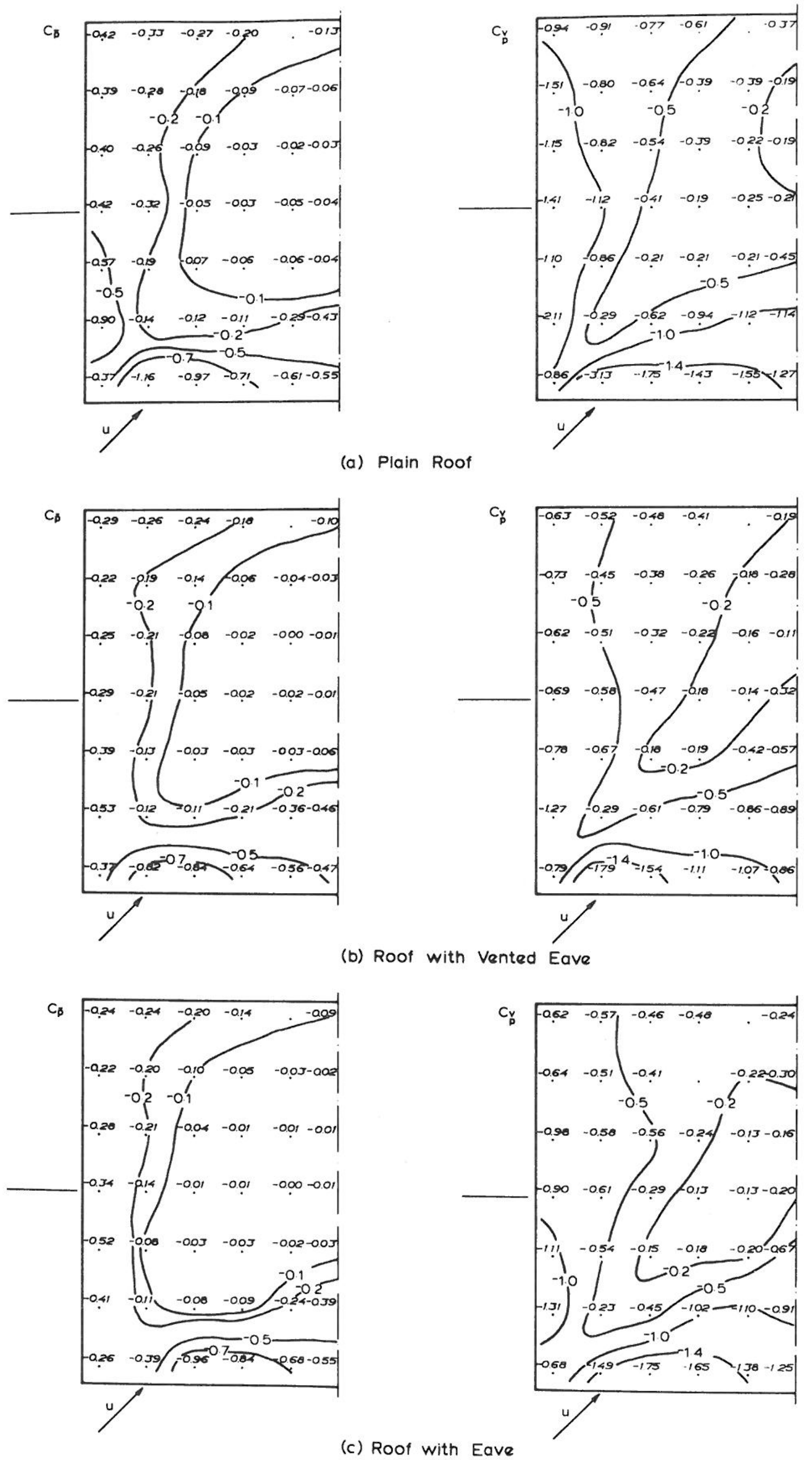

FIG. 2 MEAN AND PEAK PRESSURE DISTRIBUTIONS FOR CATENARY ROOF AT 45° INCIDENT WIND ANGLE