WIND PRESSURE DISTRIBUTIONS FOR A COMMON CLASS OF FABRIC STRUCTURES

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SUMMARY

Wind pressure distributions over pre-tensioned conical fabric roof structures have been investigated using wind tunnel testing. The results were obtained in terms of local and pneumatically averaged pressures so as to deduce total differential pressures under various typical configurations. This information provides a foundation data-base to assist structural and fabric designers in assessing the wind response of these structures.

INTRODUCTION

With the development of material science and modern engineering construction techniques, fabric structures are becoming more and more common in our architectural environment. While wind loading is one of the most significant loads experienced by fabric roofs, relatively little documentation exists as to its characteristics. Most Wind Codes (eg. AS 1170.2-1989) do not specify any guidelines to assist in their design, and engineers have had no alternative but to apply overly conservative wind loading estimates using data pertaining to structures considered to be "similar" in geometry. When considering the shapes used in pretensioned fabric roofs, the double curvature conical shape and hypar shape are the most commonly used. Between these two shapes the conical shape represents the most popular application.

A parametric study using wind tunnel model testing for a common class of fabric structures has been conducted, in order to define peak quasi-static wind loading on stiff roofs under different geometric conditions. Studies have shown [1-3] that a rigid model of the undistorted fabric structure can be used to estimate the peak pressures experienced by its roof with reasonable accuracy. Both local and pneumatically or "patch-averaged" (ie. spatially and time averaged) pressures were measured in order to provide loading information suitable for fabric and structural designers.

TEST METHODOLOGY

Wind Tunnel Models

Rigid pressure models of two typical double curvature conical fabric roofs (referred hereafter as "tents") were constructed using fibreglass. A geometric scale of 1:50 was used to accommodate sufficient model detail considering the typical size of these structures. Both tent models were square in plan approximately 30m x 30m full-scale. The "low tent" roof has a smaller radius of curvature, whereas the "high tent" represents a relatively high radius of curvature. The ring diameter (d) at the apex opening of each tent was kept constant, at d/w = 0.17 (w = tent plan width). The models represent typical structures used as pavillions, open-air market enclosures, swimming pool covers, etc.

Both models were made of rigid fibreglass and instrumented with pressure taps to measure the wind pressures on both outer and inner surfaces. Considering the axes of symmetry associated with the selected shape one instrumented quadrant was able to fully define the pressure distribution over the whole roof. Two quadrants were instrumented in order to measure both discrete and patch averaged pressures. For the discrete pressure measurements, 47 pressure taps were mounted on the upper surface with another 47 on the lower surface at corresponding locations. For patch-averaged measurements four patches on each surface with seven manifolded taps for each patch were used. Both individual patch pressures as well as total differential pressures across the roof surface were measured. The tubing system used was tuned using constrictors to give an undistorted frequency response up to 50Hz.

Model Test Configurations

Each of the tent models was tested in 4 configurations to investigate the relative effects of changes in the nature of building underneath the roof, apex covering, and support height. The under-blockage consisted of a solid styrofoam block, (full-scale) 23m x 23m x 4m, mounted directly below the tent representing a non-porous building. The apex covering was a hemispherical cap, 3.9m in diameter, made of thickened fibreglass resin. Support heights of 14m and 21mm were used with the "low tent". The corresponding support heights for the "high tent" were 22m and 29m. The eight configurations tested are shown in Table 1.

Test	Tent	Under Building	Apex Cap	Support
1	Low	No	No	Short
2	Low	Yes	No	Short
3	Low	No	Yes	Short
4	Low	No	No	Long
5	High	No	No	Short
6	High	Yes	No	Short
7	High	No	Yes	Short
8	High	No	No	Long

Table 1. Wind Tunnel Tests

The models were tested at Vipac's Boundary Layer Wind Tunnel in Port Melbourne, Australia. The 1:50 scale, Terrain Category 2 mean wind profiles were simulated using techniques prescribed by Holmes [2]. The measured longitudinal turbulence intensities, mean wind profiles as well as longitudinal spectra at apex height showed good correlation with Category 2 representative values. Discrete and patch-averaged pressures as well as instantaneous patch-averaged differential pressures for each zone were measured using a scanivalve system connected to Honeywell transducers. The signal from the transducers was statistically analysed to give mean, peak +ve and peak -ve pressures for each pressure tap, patch and patch-differential. The mean dynamic wind pressure at the apex height was used to normalize the measured pressures. Suction pressures, ie. upward or outward pressures, are considered negative.

RESULTS AND DISCUSSION

Due to the symmetry of the tents in plan view, a wind test azimuth range of 0° to 45° can adequately define pressure distributions over the entire roof. To account for naturally occurring random variations in approaching wind direction between these azimuths, the peak +ve and peak −ve values of C_p were selected from a range of ± 22.5° for each of those azimuths. The following findings were noted.

A large variation in pressure was found over the surfaces of all test configurations. For the wind direction normal to a side (0°), highest positive pressures (C_p approximately 4.0) occurred along the windward edge of the tent whereas the worst suctions (C_p approximately −3.2)were found in the region immediately to the lee of the apex. A similar pattern was observed for the 45° wind azimuth. Increasing the radius of curvature of the roof produced larger positive pressures immediately in front of the apex. The general overall effect of this variation in curvature was to only slightly increase the peak positive pressures and suctions.

Addition of a roof apex cap, and an increase in the support column height had no significant effect on the pressure distributions for both models.

However, blockage under the tent significantly altered the surface pressures. As a result of such blockage, higher momentum airflow was directed onto the roof causing larger overall negative pressures with different reattachment points. The peak positive pressures were significantly reduced with the addition of under-blockage.

The test results also indicated the degree to which local peak pressures, especially along the windward edges of the tent and lee of the apex, exceed the corresponding patch-averaged values. Reduction of over 50% in both positive and suction pressures were measured for roof areas greater than $50m^2$.

Figures 1 and 2 depict some of the wind tunnel test results. Figure 1 shows the peak local positive C_p's for Test 1-0° azimuth indicating the strong gradient of pressure contour near the windward edge. Figure 2 shows the peak patch-averaged positive and negative pressures for the same tent configuration.

REFERENCES

1. Johnson, G.L., and Surry, D. "Unsteady Wind Loads On Tents", The University of Western Ontario, Engineering Science Research Report, BLWT-SS5-1985.

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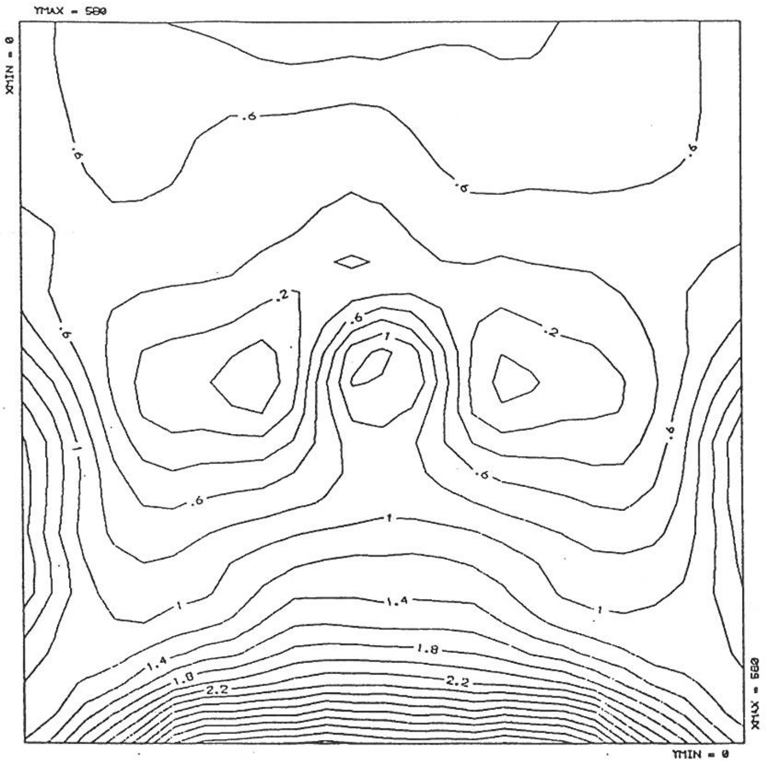

Figure 1. Peak Local Positive Pressures - Test 1, 0°

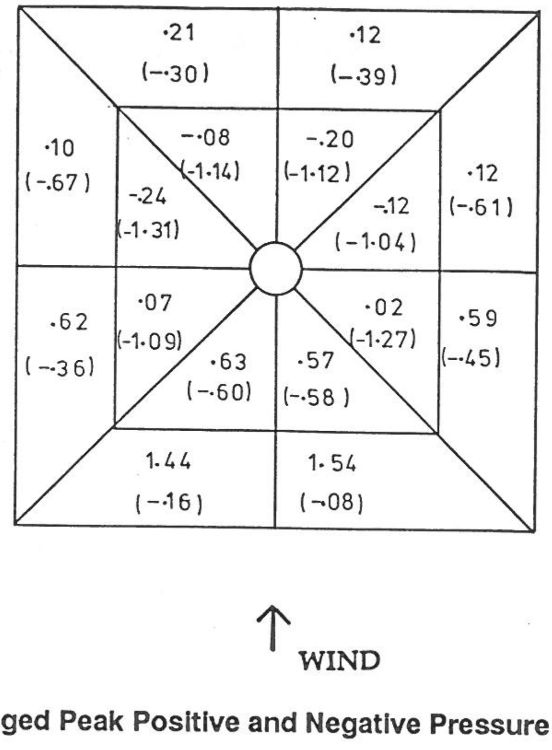

Figure 2. Patch-Averaged Peak Positive and Negative Pressure - Test 1, 0°