A PARAMETRIC STUDY OF WIND LOADS ON GRANDSTAND ROOFS

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Introduction

Most large grandstand roofs receive specialist wind tunnel testing of one form or another, however this is not always the case, often because of the fast track nature of some of these projects. It is therefore appropriate that some general information is available to designers, even if it is just to assist in the initial scheming stage. The Austalian Standard on wind loads [1] offers some advice on uplift wind loads on cantilever roofs of simple configuration. This project was concerned with extending this general information to include the effects of several variables, including, roof pitch, height/span ratios, subroof venting, shielding by upstream grandstands and the effect of large advertising fascias to name a few. In addition, quantification of any downwards load was to be undertaken. Full details are presented in [2].

Experimental procedure

The generic grandstand roof chosen for study here was in fact modelled on the new Castlemaine Street grandstand at Suncorp Stadium in Brisbane. The grandstand is a cantilever type structure supported by over roof ties. The roof is rectangular in plan form with a width of 140m, span of 30m, 35m above the playing pitch and with a 3° upwards pitch. The seating is in two tiers.

A 1:200 scale model was constructed with the roof manufactured from a sandwich of perspex sheets machined so that pneumatically averaged panels on both the top and bottom could be analogued differenced to obtain the net pressure acting on the roof. The model was rigid and only net pressures were measured, no aeroelastic effects were studied here. Each panel contained 6 pressure taps and four panels made up one bay of the structure which consisted of 14 bays on a 10m grid. Figure 1 shows the tapping and panel configuration. The sandwich construction led to a roof that was 9mm thick, somewhat distorted from the full scale.

Surface oil flow visualization studies were undertaken to determine the effect of the scale distortion of roof thickness. Two roof thicknesses, 9mm and 4.5mm and a tapered 9mm roof were studied for several wind directions. As expected, the upper surface separation bubble was larger on the thicker model and for each blunt edged model approximately 5 to 6 times the roof thickness. For the tapered model this reduced to approximately 4 times the roof thickness. However, the enlargement of the separated flow region was much less for quartering winds producing conical vortices and it was deemed that this scale distortion influence on area-averaged pressures would not be that significant for this parametric study. It was decided that the leading edge would not be tapered but remain blunt to facilitate the fascia study.

The tests were conducted in the Department of Civil Engineering's Boundary Layer Wind Tunnel which is 3m wide by 2m high and has some 12m of upstream fetch for boundary layer simulation. A 300mm fence and uniform carpet roughness were employed in the simulation which was approximately a 1:200 scale of a suburban terrain category 2.5 [1]. The turbulence intensity at roof height, 175mm was approximately 16%. The 0° wind direction was defined as normal to the leading edge of the grandstand roof.

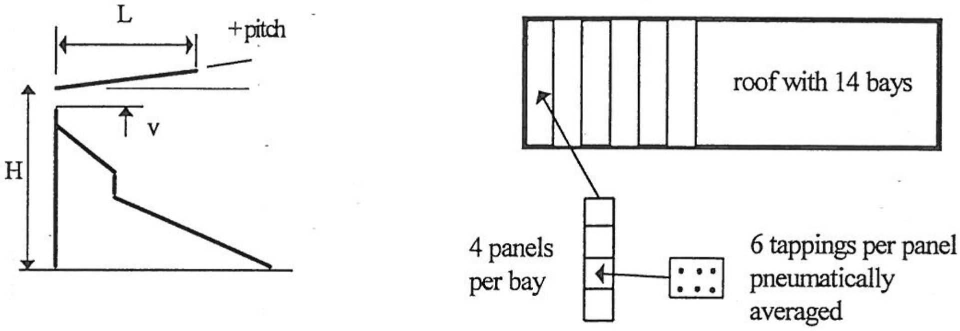

Figure 1. Sketch of grandstand roof and pressure tapping arrangement.

Net pressures were sampled at 400Hz for 15sec and repeated 16 times. The 15seconds corresponds to approximately 10minutes full scale and a Fisher-Tippett type 1 extreme value distribution was fitted to the extremes. Mean, rms and hourly maxima and minima were obtained and non-dimensionalized by the mean dynamic pressure at roof height. Cross correlation coefficients were also obtained between various panels and together with weighted peak factors from each panel (typically 6 for upwards and 3.5 for downwards loads) and influence coefficents for a cantilever, the covariance integration technique was used to estimate peak roof bending moment coefficients. All results presented here are peak bending moment coefficients with positive defined as anticlockwise or corresponding to an upwards wind load.

Results

Figure 2 shows the variation of peak bending moments on a central bay of the roof with angle of attack and as a function of roof pitch varying from +7° to -7°. Also shown in the figure is the value obtained from [1] assuming a reduced velocity, V_h/Ln_c<0.4. It is apparent that there is little relationship between peak moment coefficient on the central bay and roof pitch. This is because the flow is deflected over the roof for all pitches due to the presence of the grandstand below. For this low reduced velocity the code is unconservative but in many real situations this result would be modified by the reduced velocity term employed in the code formulation.

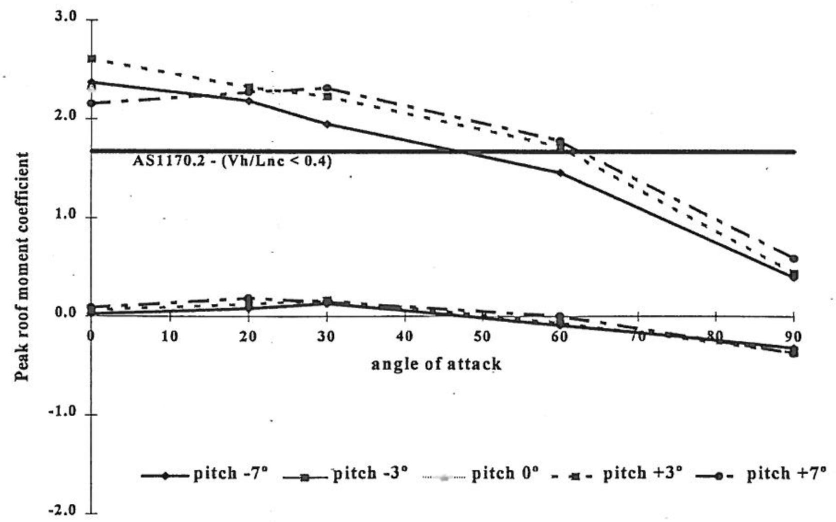

Figure 2. Peak moment coefficients as a function of wind direction and roof pitch on the central bay of an isolated, H/L=1.1 grandstand roof.

Figure 3 shows the variation of peak bending moment coefficient for the standard grandstand (isolated, H/L = 1.1, +3° pitch) as a function of subroof venting at the rear of the grandstand for v/H up to 6%. v is defined in Figure 1. Both end and central bays for clockwise (minima) and anti-clockwise (maxima) moments are presented. It is seen that subroof venting to this percentage has little influence on the peak moment coefficients.

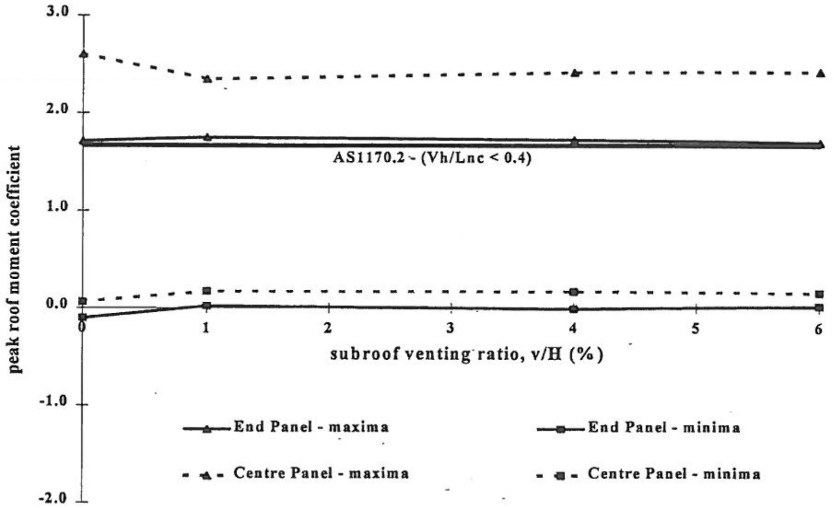

Figure 3. Peak moment coefficients as a function of subroof venting (v/H) on the central and end bays of an isolated, H/L=1.1, +3° pitch grandstand roof for an attack angle 0°.

Figure 4 shows the variation of peak bending moment coefficient as a function of wind direction and various fascia scenarios. Two fascia depths F/H = 0.1 and 0.2 were studied. It is seen that irrespective of where the fascia is located relative to the roof level, ie. above, centrally or below, the presence of the fascia significantly reduces the peak bending moment for angles of attack of +/- 30°. In some instances a gap, m, has been left between the fascia and the cantilevered roof. This gap had little influence on the peak moments.

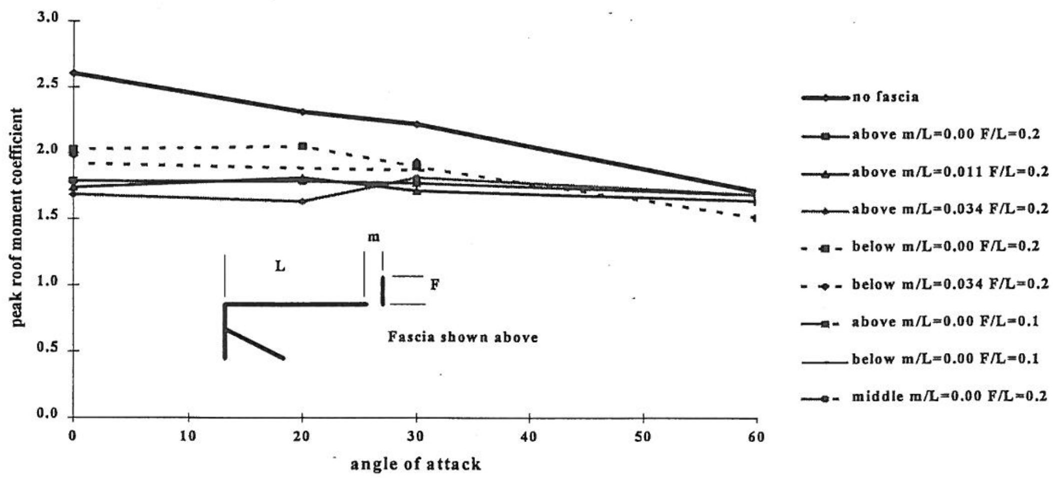

Figure 4. Peak moment coefficients as a function of fascia scenarios on the central bay of an isolated, H/L=1.1 and pitch = +3° grandstand roof.

Figure 5 shows the effect of shielding caused by an upstream grandstand. The peak bending moment coefficients are plotted as function of spacing ratio (s/H) for three different shielding grandstands (H/h), one approximately half as high, one of equal height and one twice as high. It is noticeable that over the range of most normal sportsgrounds ($2 < s/H < 6$) significant downwards loads are generated on the roof even if shielded by a grandstand of twice the height. An enclosed stadium configuration was also tested and the peak upwards and downwards moment coefficients were approximately equal at |0.5|, which is in good agreement with those reported by Hansen et al [3] for a similarly enclosed stadium.

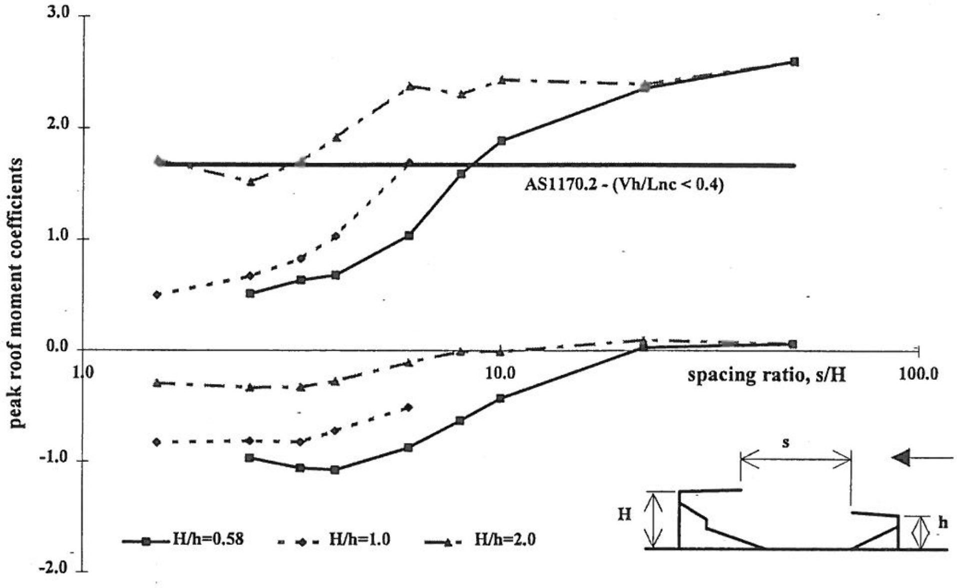

Figure 5. Peak moment coefficients as a function of upstream grandstand spacing ratio (s/H) on the central bay of the standard, H/L=1.1 and pitch = $+3^{o}$ grandstand roof.

Conclusions

A parametric study of wind loads on cantilever grandstand roofs has revealed that roof pitch and subroof ventilation do not significantly affect peak bending moments, however, the presence of fascias can reduce bending moments while upstream shielding by similar grandstand structures will induce significant downwards loading.

References

[1] Standards Australia, AS-1170.2, SAA loading code Part 2: Wind Loads, 1989.

[2] G.P. Killen, A parametric study of wind loads on grandstand roofs, MEngSt Thesis, Department of Civil Engineering, The University of Queensland, 1997.

[3] S.O. Hansen, P. Hojholt & K. Nielsen, Wind load on grandstands around a full perimeter of a stadium, JWEIA, 42, 1423-1434, 1992.