Wind loads on parapets

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Introduction

Historically there have been a number of studies examining the effect of parapets on roof wind loads, however, until a recent study by Stathopoulos [1], no study had attempted to directly model and instrument the parapet surface pressures. More than likely, this is due to the difficulty involved in directly instrumenting the parapet section with pressure taps. As such, current wind loading standards provide little information on the appropriate wind loading to apply on the parapet member itself. For example, the new version of the AS/NZS 1170.2:2002 includes a parapet reduction factor, K_r, which allows for a reduction of the roof wind loads in the vicinity of the parapet, but does not provide any information for the loading on the parapet itself. Recently, the ASCE Task Committee on Wind Loads approved a 'Design of Wind Loads for Parapets' section for future standard editions, however, the recommended wind loads are based on a rational approach and not from experimental research. The approach infers the loading on the parapet using the existing MWFRS and local cladding coefficients from the wall and roof surfaces in the vicinity of the parapet, where it is assumed that the pressures on the front surface of the parapet are the same as the wall pressures and the interior parapet wall pressures are identical to the roof suctions. The front and rear parapet pressures are then combined to produce the overall loading on the parapet member.

The lack of experimental research in this area highlighted the need for a comprehensive experimental study to quantify the wind loading on parapet members. This paper summarizes the results of a detailed parametric study completed at the BLWTL where the loading on the parapet members were directly recorded in the wind tunnel. Pressures were also recorded on the walls below the parapet and on the roof behind the parapet in order to determine the accuracy of the ASCE methodology for predicting the loading on the parapet through indirect means.

Experimental Procedure

Testing was carried out using a 1:50 scale model with plan dimensions of 31.1m by 46.3m (102ft x 152ft), and a ¼:12 gable roof slope. Three building heights were examined, with eave heights of 4.6m, 9.1m and 18.3m (15 ft, 30 ft and 60 ft), and for four parapet heights, 0.48,m, 0.91m, 1.83m and 2.74m (1.5ft, 3.0ft, 6.0ft and 9.0ft, with a nominal parapet thickness of 0.3m (1.0ft). An additional configuration with no parapet present was also examined as a reference.

Figure 1 details the pressure tap layout on the parapet members and the definition of wind angle. A total of 108 taps were instrumented on the model, however the number of pressure taps located on the parapet itself varied with parapet height. 26 taps were instrumented on the 1.5ft parapet, 34 on the 3ft parapet, and 60 and 78 taps on the 6ft and 9ft parapets respectively. In addition, 8 pressure taps were placed on the model roof and 22 pressure taps were placed on the model wall, as shown in Figure 1.

Testing was repeated in two terrains, open country (z_o=0.03m) and suburban terrain (z_o=0.3m). Only results from the open country terrain are discussed in this paper. Measurements were made at a wind tunnel reference speed of approximately 13.7 m/s (45ft/sec), which leads to an equivalent 10-metre height speed of 10 m/s (32.5 ft/sec). Pressures were sampled for 120 seconds at a rate of 400 samples per second. The resulting coefficients, normalized to the free stream mean dynamic velocity pressure, were then digitally low-pass filtered at 200 Hz in model scale. The pressure coefficients were then normalized by the mean dynamic velocity pressure at parapet height, $H+h_p$.

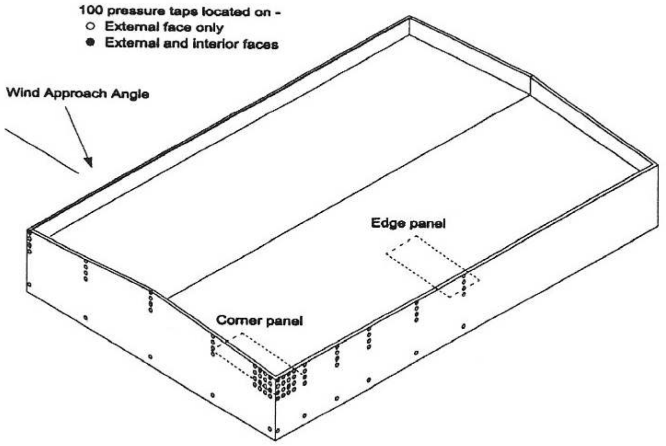

Figure 1 – Pressure tap layout and definition of wind angle

The sampled pressure coefficients were simultaneously combined to produce both structural (horizontal thrust and moments about the parapet base) and local area-averaged loading coefficients for each parapet configuration. A constant sign convention applies to both the structural and local coefficients, where coefficients are deemed to be positive when the net effect of the wind acts to push the parapet towards the roof surface. As such, a suction pressure measured on the interior parapet surface is defined as a positive load as it is acting in the direction of the roof surface. Conversely, negative coefficients constitute loading acting away from the roof surface.

Results and Discussion

Local and Structural Loading Coefficients

Local area-averaged coefficients were developed for three load cases: loading on the individual front and interior surfaces as well as the combined loading case. Figure 2 compares the variation of the peak positive and negative coefficients with loading area for the three load cases, recorded on the 0.46m parapet on the 4.6m building ($h_p/H=0.1$). The figure suggests that, for the positive (inward acting) pressure coefficients, the simultaneously combined loading from the two parapet surfaces is very similar to the loading recorded on the interior parapet surface, rather than from the loading on the external parapet surface. This is caused by the extreme suction pressures experienced at the leading corner of the interior parapet surface during quartering winds. At the same wind angle, the positive loading on the front face of the parapet is almost non-existent and does not contribute to the combined loading. Similarly, the worst negative (outward acting) coefficients were recorded on the external parapet surface, caused from winds approaching perpendicular to the surface of the parapet (270 degrees). At this wind angle, both the external and interior parapet surfaces will experience suction loading, counteracting each other and reducing the combined loading from the two surfaces. Similar results were observed for the remaining parapet heights.

Figure 3 presents the worst positive (inward acting) and negative (outward acting) horizontal thrust coefficients for the three building heights tested, as a function of parapet height. The figure shows the structural coefficients are independent of parapet height and building height when normalized by the mean dynamic velocity pressure at the top of the parapet, $H+h_p$, in particular for the taller parapet heights. Some variation with parapet height can be observed for the smaller parapets, possibly due to the reduced number of pressure taps on the shorter parapets and not from any change in loading pattern between building heights.

Estimation of Parapet Loads from Wall and Roof Pressures

Estimations of parapet wind loads were observed by comparing the instantaneously recorded parapet loading with estimates derived using only the wall and roof pressures recorded in the vicinity of the parapet. Three estimation techniques were examined. Firstly, by simultaneously combining the pressures recorded on the wall and roof taps with a parapet present, and secondly, with no parapet present. The third, simplified method, summed the worst pressures recorded on the individual wall and roof pressure taps with no parapet present. This reflects the approach adopted by the ASCE committee for extending the non-parapet data to the design of parapets.

Figure 4 compares the alternative peak horizontal thrust coefficients with parapet height. The figure suggests the accuracy of the results depends primarily on the accuracy of the estimation method. Coefficients developed using the wall and roof taps with the parapet present were found to overestimate the measured parapet loading by approximately 15%, compared to an overestimation of 35% with the parapet removed. Finally, the simplified non-simultaneous method, which considers only the peak coefficients on the wall and roof, produced coefficients approximately twice as large as the measured parapet loading coefficients.

Figure 5 examines the accuracy of the three methods in estimating the local pressure coefficients. The figure suggests, for low parapet heights, approximating the local area-averaged loading on the parapet by using the wall/roof taps, without a parapet present, may underestimate the true loading on the parapet. Although not shown, for tall parapets, estimating the local parapet pressures from the wall/roof taps, with a parapet present, may underestimate the true parapet loading. The later can be attributed to the significant reduction in negative pressures experienced on the roof of the building immediately behind the parapet when in the vicinity of tall parapets. Therefore, the roof pressure taps can not be regarded as an approximation of the loading on the interior parapet surface when considering relatively tall parapets, say greater than 1.8m (6ft) in height. Instead, it is better to combine the wall/roof taps with no parapet present.

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ASCE 7 Task Committee on Wind Loads – Private Communication.

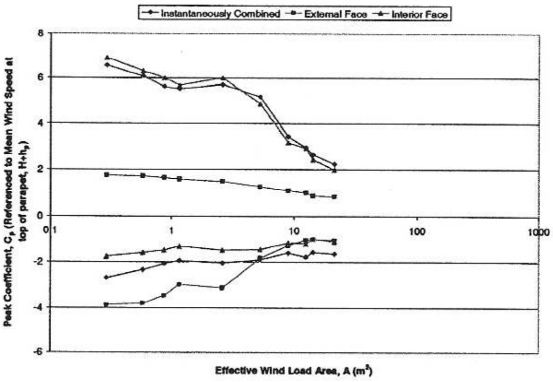

Figure 2 – Peak pressure coefficient variation with loading area recorded on 0.46m parapet on the 4.6m tall building.

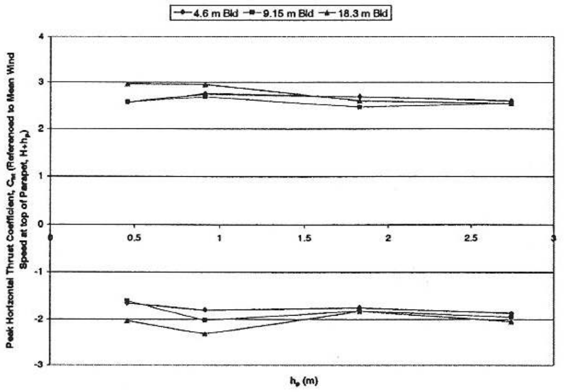

Figure 3 – Variation of worst positive and negative horizontal thrust coefficients with parapet height and building height.

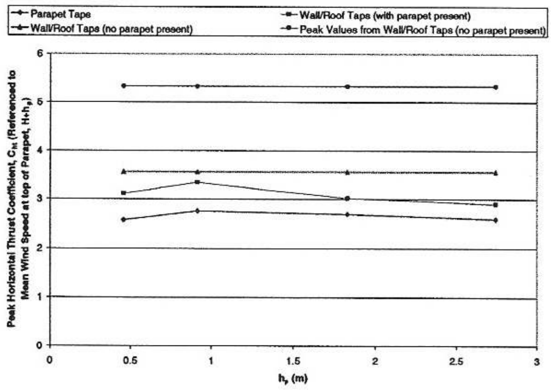

Figure 4 - Comparison of estimation methods for determining horizontal thrust coefficients on a 4.6m tall building.

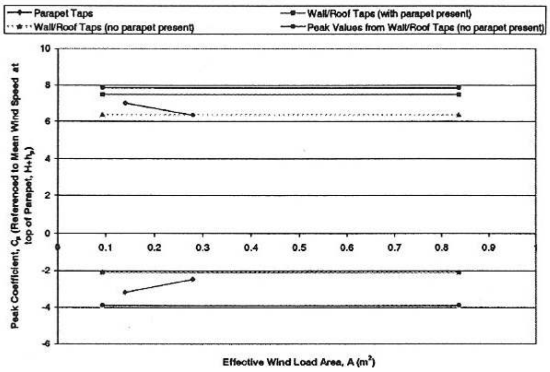

Figure 5 - Comparison of estimation methods for determining local cladding coefficients on a 0.91m tall parapet on a 4.6m tall building.