Parapet Effects on Full-Scale Wind-Induced Pressures

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ABSTRACT

Parapet walls around the perimeter of a building affect the wind-induced pressures on the walls and roof surfaces of the building. Full-scale testing on the Texas Tech University’s (TTU) Wind Engineering Field Laboratory (WERFL) test building with and without a parapet around the entire building perimeter was performed to provide a holistic view of the effects to the pressures of the building surfaces by the parapet. The 204 pressure taps of the WERFL building provide the capability to observe the pressures on the building surface and parapet with a high degree of detail so that the windward wall, roof, and leeward wall pressures are correlated. The use of aerodynamic symmetry provides a full data set so that comparisons can be made and uncertainties can be accounted. The building centerline reflected summary pressure coefficients for the building with and without a parapet are presented.

INTRODUCTION

Parapets perform a variety of functions. Architecturally they cap the building and hide roof top equipment. From an engineering perspective they change the wind flow and thus the wind pressure on the roof. A number of general observations can be made about parapets. Baskaran and Stathopoulos [1] note parapet thickness does not affect the roof pressures; however, the height of the parapet does. High parapets decrease the wind pressures on the roof where as low parapets decrease the frequencies of fluctuating pressure, stabilizing the loading process but creating high pressure fluctuations. This is specifically for parapets less than 1 m (3.3 ft) tall and most notable in corner sections where delta-wind vortices form for specific angles of attack. The increased pressures based on parapet height is also noted by Beinkiewicz and Sun [2] who concluded small relative parapet heights, defined as the ratio of parapet height to building height, increases the overall maximum uplift which always occurs very close to the windward edge.

While there has been a great deal of research to understand how parapets affect the roof pressures there is very limited data on the wind loads on the parapet wall themselves. Stathopoulos et al. [3] was the first to report on the pressures acting of the parapet itself. This research determined that the corners experienced greater pressures than the middle span section of the parapet wall. Stathopoulos et al. [3] noted the importance of correlated pressures from both sides of the parapet wall. Using peak pressures from both surfaces, without considering correlation, overestimates the resulting loads. Stathopoulos et al. [4] compared this research to the standards being adopted by ASCE 7-02 [5]. They determined that the assumptions used by ASCE 7-02 were conservative. ASCE 7-05 [6] reduced the main wind force combined net pressure coefficients based on Stathopoulos et al. [4] observations.
Experimental Setup

The goal of this research was to determine how a parapet affects the wind induced pressures on the building walls and roof. To achieve this goal a wooden parapet was constructed around the entire perimeter of the test structure. The test structure was the 9.1 m x 13.7 m x 3.9 m (30 ft x 45 ft x 13 ft) flat roof research building at the Wind Engineering Research Field Laboratory (WERFL). The roof is considered flat, but does have a 1.2 deg slope to shed rainfall. The structure rests on a metal rail embedded in a concrete slab. This allows the building to be rotated 360 degrees to receive differing wind angle of attack. The WERFL building instrumentation included a 3-axis ultrasonic anemometer mounted above the test structure at 10 m (33 ft). The WERFL field site also has a 49 m (160 ft) meteorological tower with six levels of anemometers.

An initial parapet of 1.2 m (48 in) was added around the top of the entire building. The parapet was constructed using wood studs spaced at 40.6 cm (16 in) on center and was 15.2 cm (6 in) deep and was clad with plywood siding. The construction and pressure tap installation is shown in Figure 1. The base board of the parapet was bolted to main structural members of WERFL. The parapet is supported by 2.5 cm (1 in) square metal tube “kickers” that angle away from the wall and attach directly to the roof on WERFL providing for a rigid parapet structure.

The parapet was instrumented with pressure transducers on the exterior, top, and interior wall surfaces of the parapet as well as the cavity between the studs. The transducers receive pressures from a tap in the surface of the cladding. The taps were located at the center line of each of the building walls. These transducers along with 204 transducers distributed on all the building walls and roof provide a holistic view of the full-scale pressures on the building. The locations of the building pressure taps are in Figure 2. As the experiment continued the parapet height was reduced to 85.1 cm (33.5 in) and 48.3 cm (19 in) and wind pressure data was collected for the entire building based on the new parapet height.

When the parapet height was lowered to 85.1 cm (33.5 in), additional instruments were added to the corners of the parapets. The instruments were placed in walls 1 and 4 located 45.7 cm (18 in) from the outside edge of the building with the outside, top, and inside panels being instrumented. Due to lack of space, the cavity instrument was not included in the corners. In the diagonally opposite corner, only the interior parapet walls were instrumented.

Figure 1: Example of Parapet Wall Cavity Construction and Instrumentation
Figure 2: Diagram of pressure tap locations on WERFL and the definition of angle of attack. The shaded area is the region of the walls and roof where the data correlates to when it is reflected about the longitudinal and transverse axes.
DATA PROCESSING AND VALIDATION

The full scale data was collected for the first experiment configuration (Mode 1200) over a three month period. During that time 1497 15-minute duration runs were collected with a mean wind speed over 6.7 m/s (15 mph). From the 1497 runs collected 302 runs were stationary both in wind speed and in wind direction. The time histories of the 302 qualifying runs were validated using a three step validation procedure to first identify anomalies based on summary statistics, second to look at pressure coefficients for each individual tap as a function of angle of attack, and finally to flag the anomaly to remove it from the data set for this comparison.

The tap layout of the test structure has two planes of aerodynamic symmetry, thus the pressure coefficient data can be reflected about the two axes. Reflecting the data about the axes of symmetry quadrupled the data set for development of confidence intervals.

RESULTS

This research was to determine how a parapet affects the wind induced pressures on the building walls and roof. The effects are determined by comparing the pressures of the taps on the axes of the building when the building did not have a parapet and when it did have a parapet. The experimental configuration of the building without a parapet was Mode 1001. Data from both Mode 1001 and Mode 1200 were processed and validated using the same methods. This paper presents the comparisons for specific pressure tap locations based on the angle of attack versus the mean, standard deviation, minimum and maximum pressure coefficients (Cp).

Figures 3 thru 9 provide the summary pressure coefficient (mean, standard deviation, minimum, and maximum) versus angle of attack for the centerline two tap reflection about the transverse axis of the building. Figure 3 is the comparisons for lowest wall tap at 1.2 m (4 ft) off of the ground on the short walls of the building. The comparison shows that there is very little difference between the mean pressure coefficients for the building with and without a parapet. This is also true for the summary pressure coefficient comparison of the 2.4 m (8 ft) wall pressure taps shown in Figure 4.

Figure 5 is the 4 m (13 ft) wall taps that had been near the top of the building when it did not have a parapet. As expected the mean and maximum pressure coefficients are greater in magnitude for an angle of attack near 0 deg for Mode 1200.

Figure 6 is for the first of the roof data comparisons. The taps are located 1.5 m (5 ft) from the roof and short wall edge of the building. The mean pressure coefficients are decreased in magnitude when the tap location is beyond the windward wall parapet but the data also indicates that the roof surface experiences positive pressure when the parapet is on the leeward wall. The data shows that while the minimum pressure coefficients for the roof are effectively similar with or without a parapet, the maximum pressure coefficients are distinctly different. The maximum pressure coefficients can be positive for all angles of attack except near 0 deg or perpendicular to the near wall.

Figure 7 is for the roof tap located 3 m (10 ft) from the edge of the building. The observations of taps 51540-51505 in Figure 6 are evident again although maximum pressure coefficients do not deviate as much between Mode 1001 and Mode 1200. However, the mean pressure coefficients do indicate a larger deviation when the wind angle of attack is 90 deg or parallel to the short walls of the building. The difference between the mean pressure coefficients is due to the parapet along the long wall. The long wall parapet increases the magnitude of the negative pressure on the roof when the angle of attack is 90 deg.
Figures 8 and 9 have the same trends previously described for the roof taps. The taps nearer the transverse axis of Figures 8 and 9 also indicate a trend that the maximum pressure coefficients occur when the wind angle of attack is approximately 30 deg from normal to the wall (30, 150, 210, and 330 angles of attack).

**CONCLUSIONS**

This research shows that the parapet wall can significantly change the wind-induced pressures on the walls and roof of a building. The change is most prevalent on the roof. The positive pressure created by the leeward wall parapet on the roof is of particular interest as the mean positive pressure coefficient is approximately 1/3 of the mean negative pressure coefficient.

The peak mean positive pressure coefficient occurring at wind angles of attack 30, 150, 210, and 330 for the roof taps is an observation that needs to be further investigated. Data analysis resulting in a four tap data reflection will provide more information in the corner areas of the roof and possibly indicate the aerodynamic cause of these peak pressure coefficients.

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Figure 3: Summary pressure coefficients versus angle of attack for two tap reflection 11504-31504.
Figure 4: Summary pressure coefficients versus angle of attack for two tap reflection 11508-31508.
Figure 5: Summary pressure coefficients versus angle of attack for two tap reflection 11513-31513.
Figure 6: Summary pressure coefficients versus angle of attack for two tap reflection 51540-51505.
Figure 7: Summary pressure coefficients versus angle of attack for two tap reflection 51535-51510.
Figure 8: Summary pressure coefficients versus angle of attack for two tap reflection 51530-51515.
Figure 9: Summary pressure coefficients versus angle of attack for two tap reflection 51525-51520.
REFERENCES


