STUDY OF WIND TUNNEL RESULTS ON BUILDING FEATURES CAUSING VERY LOW LOCAL WIND PRESSURES

by

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1. INTRODUCTION

Wind tunnel model studies on the very low (high negative) intermittent peak pressures under the reattaching shear layer on the surface near the leading edge have been conducted for many years at Monash University. Particular attention has been drawn to the importance of freestream turbulence and scale in the whole process of generating such low pressures. During these years, Melbourne (1975) associated the occurrence of such low pressures with an unstable process causing the shear layer reattachment to move upstream closer to the leading edge, i.e. decreasing the radius of curvature of the separation bubble. Sharp (1980) observed this phenomenon by flow visualisation in conjunction with pressure measurements and Saathoff (1988) further concluded that it is the generation, stretching and convection of vortices under the reattaching shear layer which causes the apparent early reattachment (movement of the reattachment closer to the leading edge) and the occurrence of the very low peak pressures.

2. EDGE DISCONTINUITY, CANOPY AND PODIUM ROOF (previous studies)

In parallel with these researches aimed at understanding the fundamentals and mechanism generating these very low pressures, model studies on limited configurations directly related to specific practical situations have also been the subject of research on the applied industrial front at Monash University. Melbourne (1979) speculated the possibility of reducing these low pressures by venting the leading edge, i.e. venting the volume under the reattaching shear layer. Melbourne and Cheung (1987) later developed an optimised configuration for this venting slot and this has been used on several grandstand cantilevered roofs. Also a number of wind tunnel model studies have shown that these very low pressures occurring under the reattaching shear layer can be greatly enhanced by an edge discontinuity. Cheung (1984) confirmed for a square building alone, Figure 1a, with a minimum peak pressure coefficient of -3.7 (referenced to the mean wind speed at building height) would increase to -4.9 with edge discontinuities. It has also been shown that the reduction in pressure coefficient varies with the freestream turbulence intensity at the height of the discontinuity and the angle θ of the horizontal edge discontinuity outwards from the building face. Other building features which experience low wind pressures are those, as reported by Cheung (1989), on a canopy or podium roof around the base of a tall building as shown in Figures 1b and 1c. Exceptionally low peak intermittent pressures have been measured on these canopies and podium roofs near the building tower edge discontinuity with relatively high wind speed and high turbulence, ranging from -5.4 to -7.0.

The present paper further describes more building features which cause even lower (high negative) wind pressures. This draws particular attention to practising engineers who are specifying cladding pressures and to the researchers for more investigations into the causes of these low wind pressures.

3. PRESENT STUDIES AND RESULTS

Model arrangements and test procedures are typical and consistent with common wind tunnel testing practices for pressure measurement at Monash University. The description is the same as reported by Cheung (1989) on the low wind pressure on a canopy or podium roof around the base of a tall building. The pressure coefficients were normalised with respect to the freestream atmospheric pressure well clear of the influence of buildings and the dynamic pressure at the scaled height of the building in front of the model over the approach suburban terrain. Again the present results are extracted from consulting work by MEL Consultants Pty. Ltd. using boundary layer wind tunnel facilities at Monash University. Building shapes shown in Figure 2 are simplified and indicative only in order not to identify the source and the exact building studies which are of proprietary nature.

Minimum peak pressure coefficient, $C_{\check{p}} = \dfrac{\check{p} - p_o}{\frac{1}{2}\rho \bar{V}_h^2}$

Peak factor $g = \dfrac{\check{p} - \bar{p}}{\sigma_p}$

where

$\bar{p}$	=	mean pressure at tapping
p_o	=	reference freestream static pressure
$\check{p}$	=	minimum peak pressure (-ve)
σ_p	=	standard deviation pressure
ρ	=	air density (1.2 kg m^{-3})
$\bar{V}_h$	=	mean wind speed at building height over Terrain Category 3.

3.1 Inclined roof and building faces at an obtuse angle (Figure 2a)

The presence of intermittent reattachment of separation off the horizontal roof edge and the vertical building edge generally causes low peak local pressures. This is particularly so when the roof is inclined $\alpha > 0°$ and when the building faces are at an obtuse angle $\theta > 90°$.

3.2 Inclined roof with building tower edge discontinuity (Figure 2b)

The low pressures measured on a podium roof near the building tower edge discontinuity are seen to be enhanced when the podium roof starts at a short distance d close to the edge discontinuity to incline at an angle α. It is possible that the accelerated flow over the inclined portion of the podium roof speeds up the process of vortice convection under the reattachment shear layer which in turn causes earlier reattachment and lower peak pressures.

3.3 Podium roof with double edge discontinuity (Figure 2c)

Pressures on a podium roof are seen to be lower in the presence of another building at a distance d away from the tower doubling the edge discontinuity effect and creating a funnelling situation above the podium surface. These low pressures are seen to be further reduced when the podium is open underneath for a height h as in cases for a canopy or bridge link between buildings.

3.4 Negative edge discontinuity (colonnade) (Figure 2d)

In addition to the intermittent reattachment of the separation along the vertical building edge, strong wind flow from the higher level is seen to be induced down the upstream face of the building to the lower level near the base of the tower. This induced wind flow, augmented by the low pressure in the wake region of the tower and the vertical edge separation region on the streamwise face is seen to cause high wind speed flow around the corner, angle θ, at the base of the tower inside the colonnade. Depending on the width d and the height h of the colonnade, the induced wind flow further turns upward, separating from the horizontal edge at the bottom of the tower above the colonnade towards the streamwise face. The combination of separation and reattachment from both the vertical and horizontal edges above the colonnade seems to be the cause of these exceptionally low (negative) pressures. Filling in the colonnade substantially increased the negative C_p as shown in Figure 2d.

4. CONCLUSION

Further to previously reported effects of edge discontinuities on facade pressures on building towers, this paper has discussed other building features which cause even lower (higher negative) pressures. Each of these features causing high negative pressures tends to be additive and is capable of producing very adverse effects in combination with high upstream turbulence and interference from nearby buildings.

5. REFERENCES

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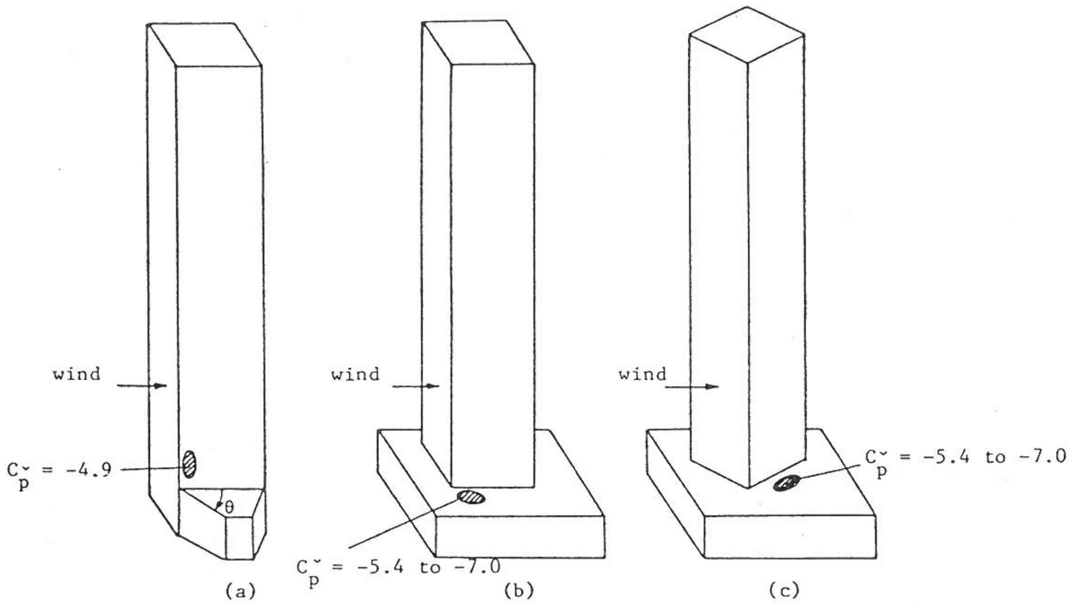
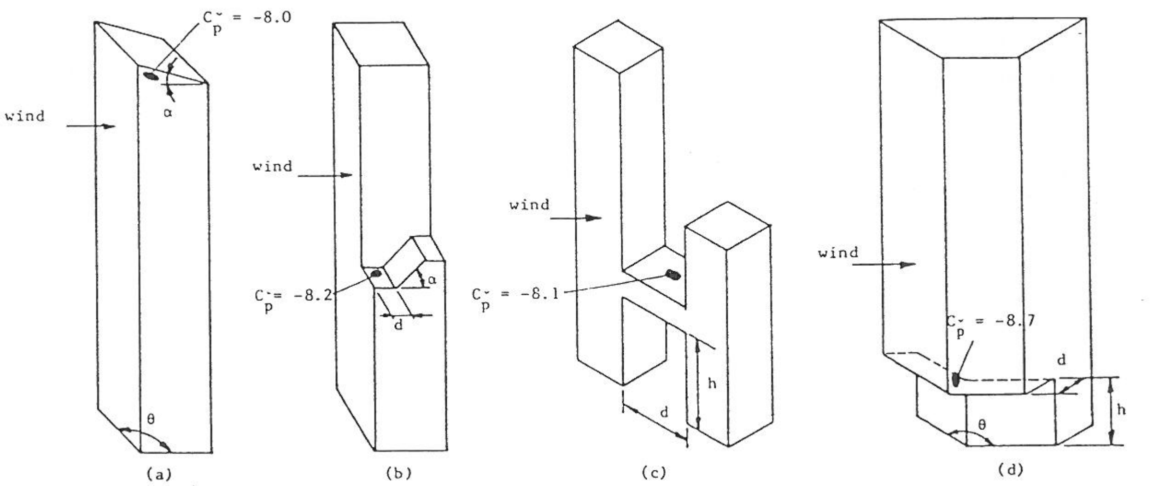


FIG. 1 Low (high negative) wind pressures caused by tower edge discontinuities



$C_p^{\vee}$ = -8.0 g = 6.9

$C_p^{\vee}$ = -8.2 g = 7.2

$C_p^{\vee}$ = -8.1 g = 15.6

$C_p^{\vee}$ = -8.7 g = 8.5
with colonnade filled in
C_p = -4.6 g = 7.2

FIG. 2 Building features causing exceptionally low (high negative) wind pressures