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PART II: COMPARISON OF AS/NZS 1170.2 (2002) QUASI-STEADY TOTAL OVERTURNING MOMENT COEFFICIENTS WITH WIND TUNNEL EQUIVALENT COEFFICIENTS OF AN ISOLATED LOW RISE BUILDING

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ABSTRACT

Comparison of the AS/NZS 1170.2 (2002) quasi-steady total overturning moment coefficients with wind tunnel equivalent total moment coefficients indicates the Standard quasi-steady coefficients are inadequate when $I_u > 20\%$, for an isolated gable ended low rise building.

The Standard (2002) quasi-steady coefficient for negative overturning does not exist (wind tunnel equivalent coefficient = -1.2; when $I_u = 23\%$). These negative wind tunnel equivalent overturning coefficients can be designed for by wind from the opposite direction, if wind is assumed to come from any direction.

INTRODUCTION

The AS/NZS 1170.2 (2002) Standard uses the quasi-static approach to determine design wind loads i.e. 3 second peak gust wind speeds are used with quasi-steady pressure coefficients to determine the peak wind loads on a structure. The quasi-steady pressure coefficients are assumed not to vary significantly for change in gust wind speed and turbulence intensity. This design approach is generally successful; although the Standard quasi-steady coefficients could be compared with either full-scale or wind tunnel equivalent quasi-steady coefficients.

This paper compares the AS/NZS 1170.2 (2002) quasi-steady total overturning moment coefficients with wind tunnel equivalent total moment coefficients.

EXPERIMENTAL

Measurements were made in the James Cook University open circuit boundary layer wind tunnel which is driven by a 45 kW A.C. motor.

Four boundary layers were simulated atmospheric surface layers applicable to open country terrain. These agree with full-scale roughness length of 10 to 30 mm. The turbulence intensity, I_u, and the length scales of turbulence, L_{ux} and L_{uy}, were measured at the long wall height of each model for each boundary layer.

A set of 4 low rise building models of a simple rectangular shape with 9° gable roofs having a ridge parallel to the longwall was constructed with 4:2:1 width to depth to height ratio, respectively. A force balance system developed by Roy (1982) was used to measure the fluctuating total loads. For a constant flow speed in the wind tunnel of about 14 ms^{-1} at mid-height and assuming a full-scale velocity of 30 ms^{-1}, an appropriate low-pass filter cut-off frequency was chosen in each case giving a constant full-scale wave number – i.e. equivalent full-scale low-pass cut-off frequency of 1.35 Hz.

The moment measurements about the y axis were made in the xz plane on the models placed in the boundary layers at 0 degree azimuth coincident with the x direction normal to the long wall through the center of the base of the model – the z direction is vertical through the center of base.

The moment is non-dimensionalized by the freestream mean dynamic pressure at the height of the model, $q = \frac{1}{2}\rho U_h^2$, a reference area, A_y, and the height, h, to give peak overturning moment coefficient, C_{Mypeak}. The peak coefficients are mean peaks or average peaks of up to 120 equivalent full-scale 10 minute records.

COMPARISON OF AS/NZS 1170.2 QUASI-STEADY TOTAL OVERTURNING MOMENT COEFFICIENTS WITH WIND TUNNEL EQUIVALENT COEFFICIENTS

The AS/NZS 1170.2 (2002) Standard quasi-steady total overturning moment coefficient is determined to compare with the wind tunnel equivalent coefficient. In the calculation of the quasi-steady overturning moment coefficient, $K_a = 0.86$ and $K_c = 0.8$.

To determine wind tunnel equivalent quasi-steady total moment coefficients, the mean peak wind tunnel total overturning moment coefficient [Roy (1998)] is to be divided by the square of the wind tunnel gust factor where the velocity is filtered according to a 3 second gust, (G_u^2). However, this wind tunnel gust factor is unavailable so a representative value for G_u^2 is used.

The gust factor for the wind tunnel is written $G_u = 1 + n\, I_u$. The value of the peak factor, n, is chosen as 3.7 according to Eqn (E3.2.5(3)) of AS 1170.2 (1989). Using dynamic similarity scaling of the models in the wind tunnel appropriate for the full-scale low rise building (h=3.75 m), a set of different turbulence intensities, I_u, are obtained with corresponding total loads on the different models, for open country terrain – since the full-scale turbulence intensity at 3.75 m height varies for a range of the roughness length, z_o, in open country terrain. With the values of the turbulence intensities, I_u, measured in the wind tunnel, values of the gust factor, G_u, are determined. The square of this gust factor, G_u^2, is divided into the wind tunnel total overturning moment, C_{Mypeak}, (Figures 1 and 2).

The Standard (2002) quasi-steady total overturning moment coefficient (using appropriate values of K_a and K_c aforementioned) along with the wind tunnel equivalent values are shown in Table 1.

DISCUSSION

In this paper, the Standard (2002) quasi-steady values of the total overturning moment coefficient are compared with the wind tunnel equivalent values for an isolated gable ended low rise building. No inference about other loads, e.g. frame, for the low rise building is made – other loads have to be investigated separately.

In Table 1, the Standard quasi-steady total overturning moment coefficient is adequate up to $I_u = 20\%$, but for $I_u > 20\%$ the Standard quasi-steady total overturning moment coefficient is inadequate to a minimum of 54% when $I_u = 23\%$.

As shown in Roy et al. (2003), the Standard quasi-steady total vertical force coefficient is the same as the maximum wind tunnel equivalent value. It would be better if the Standard quasi-steady vertical force coefficient is greater than the wind tunnel equivalent values by some reasonable margin – it follows that if the Standard quasi-steady vertical force coefficient is increased (i.e. on the windward roof), then the Standard quasi-steady overturning moment coefficient will be increased. Thus, if this is so, the Standard quasi-steady overturning moment coefficient will be increased to be adequate in design up to $I_u = 23\%$ in this case.

It is noted in Table 1 that the Standard quasi-steady negative total overturning moment coefficient is not adequate compared with the wind tunnel values – the quasi-steady value is +0.85 and the wind tunnel value is –1.2, (e.g. when $I_u = 23\%$). This inadequacy could be overcome by designing for wind in the opposite direction, however, if the wind is not considered to come from any direction, then design for negative overturning moment is neglected.

CONCLUSION

There is concern for the inadequacy of AS/NZS 1170.2 (2002) quasi-steady total overturning moment coefficient. This quasi-steady coefficient for positive overturning is inadequate to a maximum of 54% when I_u =23%.

On the other hand, the Standard (2002) quasi-steady coefficient for negative overturning does not exist (wind tunnel equivalent coefficient = -1.2, when I_u = 23%) – this can be attended to in design by considering wind from the opposite direction; i.e. if wind is assumed to come from any direction.

These comparisons are only for an isolated gable ended low rise building with the one roof pitch of 9 degrees and there should be further comparisons carried out using other roof pitches. Also, a range of geometrical ratios of height: width: depth of low rise buildings should be investigated to compare the results with AS/NZS 1170.2 (2002).

Refer Roy et al. (2003) for comparison of total horizontal and total vertical force coefficients.

REFERENCES

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Roy, R. J., Holmes, J. D., Walker, G. R. (2003) Part I: Comparison of AS/NZS 1170.2 (2002) quasi-steady total horizontal and vertical force coefficients with wind tunnel equivalent coefficients of an isolated low rise building. 10th Australasian Wind Engineering Society Workshop, Sydney, 6-7th February.

SAA (1989) AS 1170 Pt.2 Wind loads.

SA/SNZ (2002) AS/NZS 1170 Pt.2 Wind actions.

TABLE 1 COMPARISON OF AS/NZS 1170.2 QUASI-STEADY TOTAL OVERTURNING MOMENT COEFFICIENTS WITH WIND TUNNEL EQUIVALENT TOTAL OVERTURNING MOMENT COEFFICIENTS

I_u	G_u^2	C_{Mypeak}/G_u^2	Quasi-steady C_{My} AS/NZS 1170.2
0.18	2.8	0.15,0.89	0.85,1.3
0.19	2.9	0.0,1.0	ditto
0.20	3.0	-0.23,1.2	
0.21	3.2	-0.50,1.4	
0.22	3.3	-0.85,1.7	
0.23	3.4	-1.2,2.0	

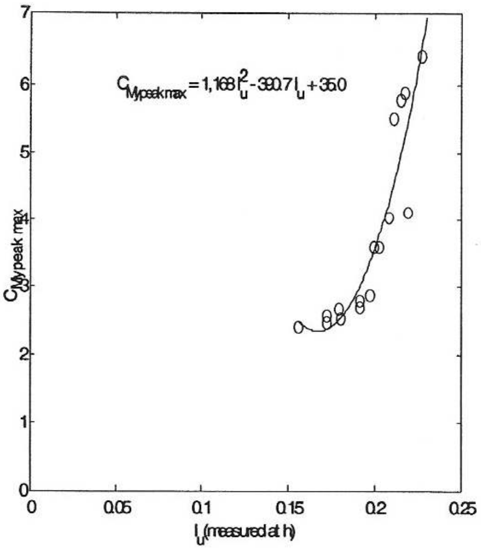

Figure 1 $C_{Mypeak\ max}$ **against** I_u

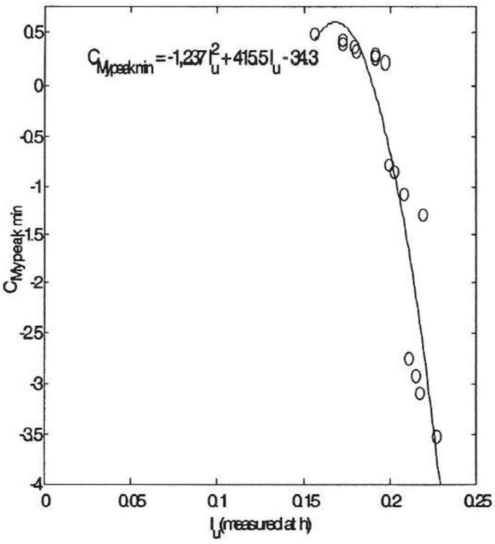

Figure 2 $C_{Mypeak\ min}$ **against** I_u