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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

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ABSTRACT

Comparison of the AS/NZS 1170.2 (2002) quasi-steady total horizontal and total vertical force coefficients with wind tunnel equivalent total force coefficients indicates the Standard quasi-steady coefficients are conservative for the total horizontal force coefficients; and are equal to the wind tunnel equivalent values for the total vertical force coefficient, for a isolated gable ended low rise building.

It is noted that a negative (downward) total vertical force coefficient (-0.06) should be considered in design.

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 horizontal and total vertical force coefficients with wind tunnel equivalent total force 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 load measurements 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 forces are non-dimensionalized by the freestream mean dynamic pressure at the height of the model, $q = \frac{1}{2}\rho U_h^2$, and a reference area to give appropriate peak total force coefficients of C_{Fxpeak} and C_{Fzpeak}. These 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 FORCE COEFFICIENTS WITH WIND TUNNEL EQUIVALENT COEFFICIENTS

The AS/NZS 1170.2 (2002) Standard quasi-steady total horizontal and total vertical force coefficients are determined to compare with the wind tunnel equivalent coefficients. In the calculation of the quasi-steady horizontal force coefficient, $K_a = 1$ and $K_c = 0.8$; and likewise for the quasi-steady vertical force $K_a = 0.86$ and $K_c = 1$.

To determine wind tunnel equivalent quasi-steady total force coefficients, the mean peak wind tunnel total force 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 the gust factor, G_u^2, is the same for dividing into both the wind tunnel total horizontal force coefficient, C_{Fxpeak}, and the wind tunnel total vertical force coefficient, C_{Fzpeak}, (Figures 1, 2, 3 and 4).

The Standard (2002) quasi-steady total horizontal and total vertical force coefficients (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 horizontal force coefficient and the total vertical force 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 horizontal force coefficient range is conservative by a minimum of 28% compared with the wind tunnel range. This is for positive (or windward) direction horizontal force coefficients. It is noted in Table 1 that there is a small negative total horizontal force coefficient (-0.02) which would be considered in design by a wind from the opposite direction – if the wind is not considered to come from any direction in the design, then this small negative coefficient would be neglected. Also in Table 1, the Standard quasi-steady maximum total vertical force coefficient is about the same as the maximum wind tunnel equivalent value. Again, there are small negative (e.g. -0.06), (i.e. downward), total wind tunnel equivalent total vertical force coefficients which should be considered in design.

CONCLUSION

The AS/NZS 1170.2 (2002) quasi-steady total horizontal force coefficient is greater than the wind tunnel equivalent values by a minimum of 28% when I_u = 23%. Furthermore, the AS/NZS 1170.2 (2002) quasi-steady total vertical force coefficient is about the same as the wind tunnel equivalent value.

It is noted that a small negative total horizontal force coefficient (-0.02) exists in the wind tunnel equivalent quasi-steady coefficients, and should be considered in design.

Also, there are negative (downward) wind tunnel equivalent quasi-steady total vertical force coefficients (maximum of –0.06), which are to be considered in design.

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 overturning moment coefficients.

REFERENCES

Roy, R. J. (1982) Total force and moment measurement on wind tunnel models of low rise buildings. MEngSc Thesis, James Cook University.

Roy, R. J. (1998) The effects of scale distortion on boundary layer wind tunnel measurements of total loads on a low rise building model. PhD Thesis, James Cook University.

Roy, R. J., Holmes, J. D., Walker, G. R. (2003) 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. 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 LOAD COEFFICIENTS WITH WIND TUNNEL EQUIVALENT TOTAL LOAD COEFFICIENTS

I_u	G_u^2	C_{Fxpeak}/G_u^2	Quasi-steady C_{Fx} AS/NZS 1170.2	C_{Fzpeak}/G_u^2	Quasi-steady C_{Fz} AS/NZS 1170.2
0.18	2.8	0.06,0.50	0.86,0.97	0.09,0.43	0.17,0.60
0.19	2.9	0.04,0.52	ditto	0.07,0.45	ditto
0.20	3.0	0.03,0.53		0.04,0.47	
0.21	3.2	0.01,0.53		0.01,0.50	
0.22	3.3	0.0,0.58		-0.02,0.55	
0.23	3.4	-0.02,0.62		-0.06,0.59	

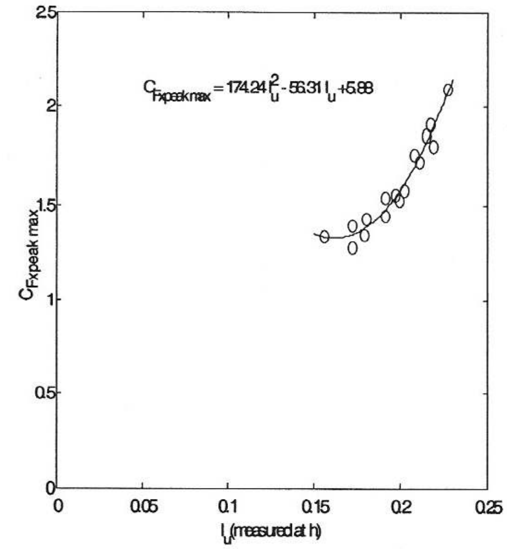

Figure 1 $C_{Fxpeak\ max}$ **against** I_u

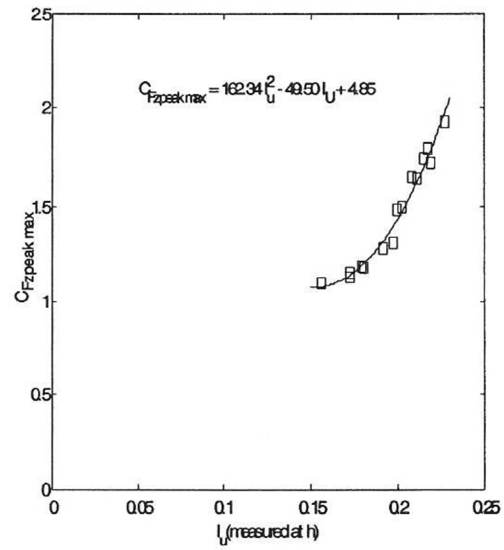

Figure 2 $C_{Fzpeak\ max}$ **against** I_u

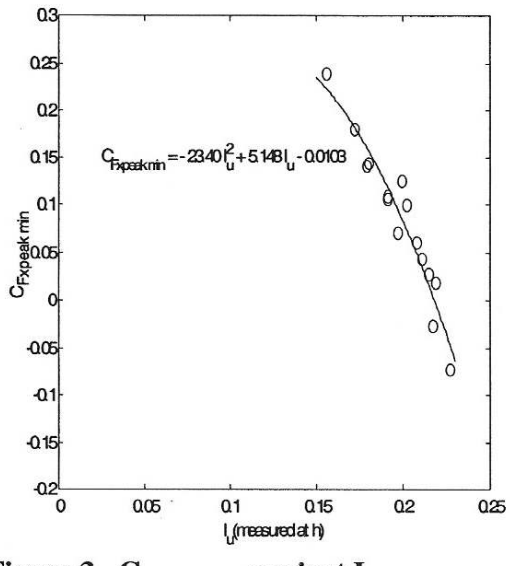

Figure 3 $C_{Fxpeak\ min}$ **against** I_u

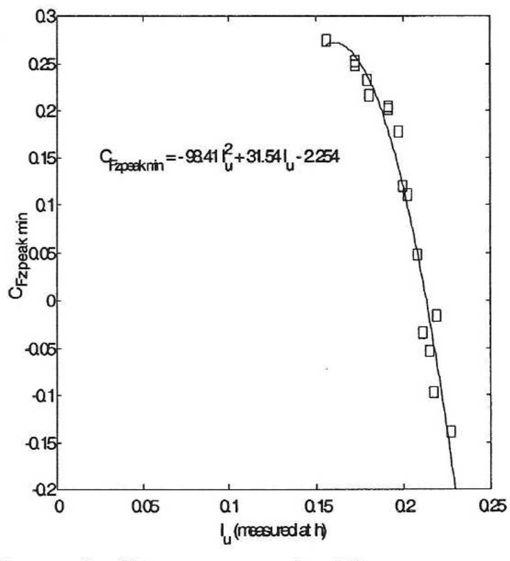

Figure 4 $C_{Fzpeak\ min}$ **against** I_u