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THE EFFECTS OF TURBULENCE ON TOTAL LOADS ON A LOW RISE BUILDING MODEL

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ABSTRACT

The turbulence intensity scaling parameter does affect the total loads on a low rise building model dramatically. This is found by examining distortion of scale effects on the low rise building model in a boundary layer by keeping the length scale of turbulence constant.

INTRODUCTION

Saathoff (1988) performs measurements on a square cylinder (50 mm) in 2-D flow. He finds that for turbulence intensity greater than 20% with large-scale turbulence ($L_X/D=2.1$) that the point pressures beneath the separating shear layers are the smallest. This is a similar turbulence intensity experienced by low rise buildings, however, Saathoff is not investigating loads on low rise buildings in the atmospheric boundary layer surface layer.

Stathopoulos and Surry (1983) study the effects of change in geometrical scale of models in a simulated boundary layer. The boundary layer scale coincides with the smallest model scale of 1/500. They only consider a change in h/z_O without consideration of the effects of length scale of turbulence. Thus, it is concluded from this work that the effects of both turbulence intensity and scale of turbulence are not independent. When h/z_O changes I_U changes particularly at the eaves height and with a small change in intensity of turbulence there will most likely be a pressure distribution change as a result.

Surry's (1982) review of experiments indicates difficulty in obtaining correct velocity, turbulence intensity and scale of turbulence profiles, when artificial generation of the boundary layer is required. The discrepancies due to these distortions of the flow in a target boundary layer are usually as a result of distortion of a number of flow parameters rather than a single parameter. Surry suggests that these discrepancies could be "isolated" and the magnitude may be determined - however, this has not been achieved.

This paper presents the effect of turbulence intensity on total loads of a low rise building model in the atmospheric boundary layer independent of length scale of turbulence with reasonable success [(Roy (1997)].

EXPERIMENTAL

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

Four boundary layers were simulated atmospheric surface layers applicable to open country terrain. These agreed with a full-scale roughness length of 10 to 30 mm. The turbulence intensity was measured at a long wall height of each model for each boundary layer.

A set of 4 low rise models of a simple rectangular shape with 9° gable roofs having a ridge parallel to the long wall 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.

The load measurements were made in the xz plane on the models placed in the boundary layers at 0 degree azimeth coincident with the x direction normal to the long wall through the centre of the base of the model - the z direction is vertical through the centre of base.

The forces are non-dimensionalized by the freestream dynamic pressure at the height of the model, $q=\frac{1}{2}\rho\bar{u}_h^2$, and a reference area to give appropriate coefficients for the total horizontal force, C_{Fx}, and total vertical force, C_{Fz}.

EFFECTS OF TURBULENCE ON TOTAL LOADS

Mean horizontal and vertical coefficients (Figures 1, 2) do show small change due to turbulence intensity. The mean horizontal coefficient increases generally a little amount from I_u equal to 20% to 23% for Luy/W equal to 1.0 to 2.12. This emphasises the effect of turbulence intensity greater than 20% at the eaves height of a building model. The freestream turbulence perturbates the separating shear layers deflecting them toward the surface of the model causing them to roll up close to the leading edge where a strong vortex forms within the bubble. Below the strong vortex are high negative pressures occurring near the leading edge spanning about 0.6 times the reattachment length. It almost appears that another mechanism takes over to drive the pressure field over the model when the turbulence intensity is greater than 20%. This is more clear for the mean vertical coefficient.

For the r.m.s. vertical coefficient (Figure 4) the data show good collapse onto an upward rising curve with an increase in turbulence intensity and scale ratio, Luy/W. Less is the influence by the wake recirculation region on the data although, there are some data which have not collapsed well. This proves the need to model turbulence intensity and scale ratio, Luy/W, correctly because of the slight discrepancies in the data when Luy/W is about 1.0. If Lux/D would have been significantly smaller then this would have been of the order of the spanwise vortex wavelength and the data would have reacted adversely, similar to when Luy/W is equal to about 1.0 [Kiya et al. (1986)].

With regard to the maximum peak horizontal coefficient (Figure 5), it is clear that the turbulence intensity at the eaves height of the building has dominating effects on the separating shear layers because it is the most important scaling parameter, although, together with the turbulence intensity increase is the increase in the scale ratio, Luy/W. The greatest effect is when the turbulence intensity is greater than 20% and Luy/W is greater than 1.0. Again the separating reattaching shear layers dominate the flow over the roof of the models (Figure 5) with buffeting on the front wall, and wake recirculation effects on the leeward wall and the shear layers (i.e. turbulence intensity effects).

The separating reattaching shear layers are the most affected for the maximum peak vertical coefficient (Figure 6). These are affected by the turbulence in the freestream perturbating the separating shear layers. However, these effects seem to be relevant when Luy/W is greater than about 1.0. An increase of 75% in the maximum peak vertical coefficient is seen in Figure 6 for turbulence intensity increase of about 15% to 23% and length scale ratio of 0.6 to 2.12.

The minimum peak coefficients are similar in trend to the maximum peak coefficients, although, they are opposite in magnitude.

CONCLUSION

Turbulence intensity at the height of the model is the most important scaling parameter when measuring total loads on low rise buildings. As found in this paper, the peak and r.m.s. total loads are the most affected by turbulence intensity. However, the length scales of turbulence are also important scaling parameters in the modelling of the atmospheric boundary layer [Roy (1997)].

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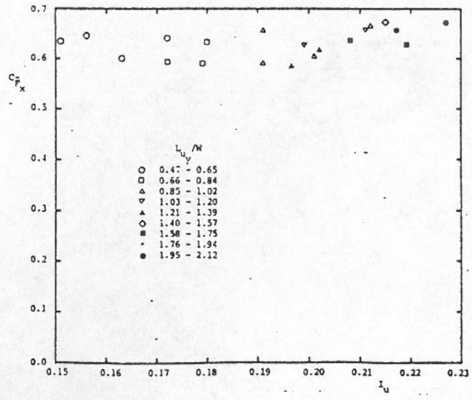

Fig. 1 Mean horizontal force coeff.

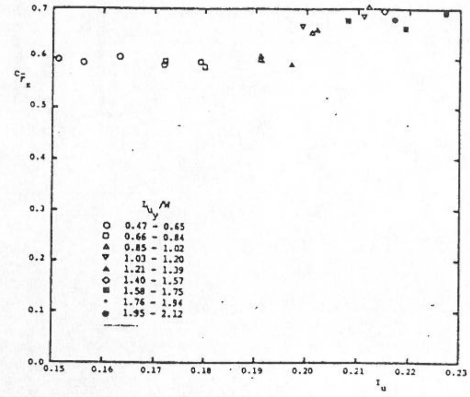

Fig. 2 Mean vertical force coeff.

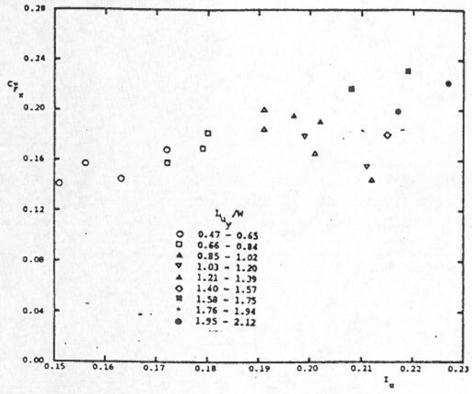

Fig. 3 R.M.S. horizontal force coeff.

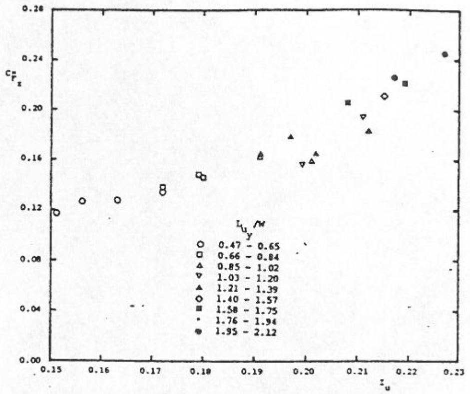

Fig. 4 R.M.S. vertical force coeff.

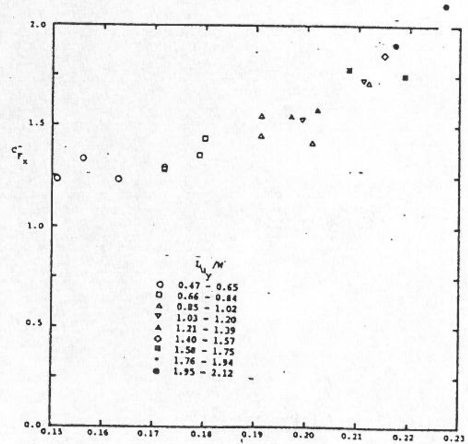

Fig. 5 Peak horizontal force coeff.

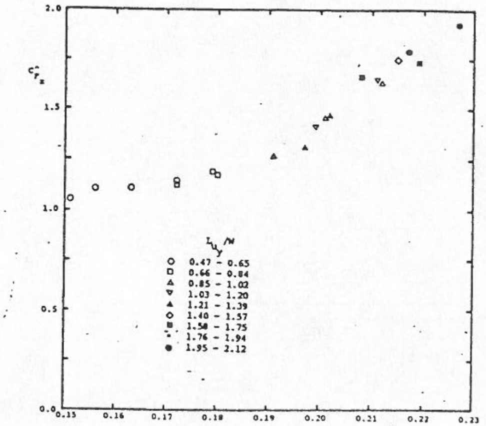

Fig. 6 Peak vertical force coeff.