PRESSURE CORRELATIONS ON A LOW-RISE BUILDING FROM TWO WIND TUNNELS

John Holmes
(CSIRO, Division of Building, Construction and Engineering)
Rajam Sankaran
(James Cook Cyclone Structural Testing Station)

INTRODUCTION

Peak wind load effects in the structural frame of a building are produced by instantaneous pressure distributions over the tributary area of the frame, which can be determined by direct measurements in wind-tunnel tests (Holmes, 1988), or indirectly from the cross-correlations of the fluctuating point or local panel pressures over the tributary area (Best and Holmes, 1980; Holmes and Best, 1981; Kasperski, 1992; Holmes, 1992). Thus accurate and repeatable measurements of correlation coefficients of the pressure fluctuations over the surface (or part) of a building are important. The extensive comparative studies of local pressures on the Aylesbury Building (Sill, 1989) was restricted to single point statistics, i.e. no comparison of the cross-correlations between pressures was carried out.

This contribution describes and compares three sets of measurements of the cross-correlations for the pressures acting on part of a low-rise industrial building model, from two different wind tunnels. Two measurements were made from the (now dismantled) CSIRO tunnel in 1984 and 1987; one set of measurements was made at the James Cook Cyclone Testing Station in 1993.

THE BUILDING MODEL

The model used was a 1/200 scale model of a low-rise industrial building, with 5 degree pitch gable roof, shown in Figure 1. The measurements were carried out on the nine panels of the end bay of the model. Within each panel there are ten pressure taps - these were connected together to an averaging manifold, which was in turn connected to a pressure transducer through a restricted tubing system. For each of the three sets of measurements, a different measurement system was used, but each one was designed and calibrated using the approach described by Holmes and Lewis (1987). The details and upper frequency limit of the flat amplitude response and linear phase response, in each case, are given in Table I.

Table I.
Pressure Measurement Systems

Measurement set	Length of tubing*	Number of restrictors	Scanivalve	Upper frequency response (Hz)
CSIRO 1984	110 + 400	2	no	300
CSIRO 1987	165 + 425	3	no	450
JCCTS 1993	150 + 365	1	yes	400

* pressure tap to manifold + manifold to transducer

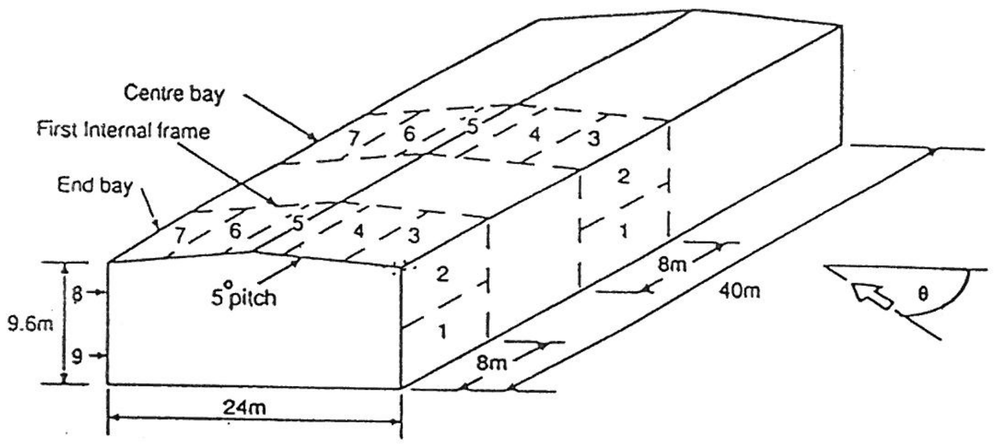


Figure 1. Building and pressure measurement panels

The response limits in each of measurement sets are believed to be quite adequate for the correlation measurements, and any differences to be found in the measurements should not be caused by the measurement systems.

THE WIND TUNNELS AND FLOW CHARACTERISTICS

AT CSIRO, the large wind tunnel at Highett was used; up to 1987 it had a boundary-layer section 1 metre high, 2 metres wide and 10 metres long. This section was downwind of the axial flow fan. The flow simulated was a representation of a developed atmospheric boundary-layer flow over open country at 1/200 scale. For both measurement sets in 1984 and 1987, the flow was produced by a 200 mm high barrier at the start of the test section followed by surface roughness consisting of carpet. The roughness length corresponding to the longitudinal turbulence intensity and the mean velocity profile, corresponded to a value of 40 mm in full scale; thus the Jensen Number (h/z_0) for the tests was 240. The longitudinal and lateral (horizontal) scales of turbulence at a scaled height of 10 metres, were 70 m and 11 m, respectively. The longitudinal turbulence intensity at the top of the building model was 0.20 .

The test section in James Cook tunnel is about 2.0 metres high (adjustable), 2.5 metres wide and 17 metres long. The boundary layer flow was generated in the same way as at CSIRO, i.e. a 200 mm barrier followed by 14 metres of carpet roughness. The roughness length was equivalent to 35 mm in full scale, and the longitudinal scale at a height of 10 metres was about 80 m.

CORRELATION MEASUREMENTS

Correlation measurements were obtained for samples with durations of 11.5 seconds for both the CSIRO 1984 and 1987 tests. The pressure signals were low-pass filtered at 350 Hertz in 1984, and 500 Hertz in 1987. The sampling rate was 1000 Hertz in both cases. In the James Cook tests, the pressure signals were low-pass filtered at 400 Hertz and sampled at 1000 Hertz for a duration of 16 seconds.

Table II shows an example of a correlation matrix obtained for a wind direction of 0 degrees, i.e. the wind is blowing normally on to panel 1. The wall panel 1 is negatively correlated with the roof panels, and the roof and rear wall pressures are positively correlated with each other.

Table II - Example of correlation matrix (CSIRO 1987 tests, $\theta = 0$ degrees)

Panel	1	2	3	4	5	6	7	8	9
1	1.0	0.90	-0.60	-0.13	-0.14	-0.02	0.03	-0.01	-0.01
2		1.0	-0.68	-0.18	-0.24	-0.11	-0.05	-0.07	-0.07
3			1.0	0.54	0.60	0.50	0.42	0.41	0.41
4				1.0	0.60	0.54	0.45	0.39	0.38
5					1.0	0.79	0.64	0.59	0.57
6						1.0	0.80	0.69	0.68
7							1.0	0.86	0.83
8								1.0	0.97
9									1.0

Figure 2 shows a cross-plot of the 1984 and 1987 CSIRO correlation coefficients together with a fitted linear regression line. The agreement is good except for some points for the 45 degree direction. For this wind direction, the roof pressures on the end bay are subject to intermittent conical vortex formation - this may explain some of this variability.

In Figure 3, the CSIRO 1987 data is cross-plotted against the James Cook data. Again the agreement is good, even for the 45 degree wind direction. This result is gratifying considering that the tests were carried out several years apart, in two different wind tunnels. However because the boundary layer simulation methods were similar in the two tunnels, and presumably the scales of turbulence were quite similar, the result is perhaps not too suprising. It would be interesting to repeat this test in other wind tunnels in which other simulation methods are used.

REFERENCES

R.J. Best and J.D. Holmes (1980). Correlation of fluctuating wind pressures on a house. 7th. Australasian Hydraulics and Fluid Mechanics Conference, Brisbane.

J.D. Holmes and R.J. Best (1981). An approach to the determination of wind load effects on low-rise buildings. Journal of Wind Engineering and Industrial Aerodynamics, Vol. 7, pp 273-287.

J.D. Holmes (1988). Distribution of peak wind loads on a low-rise building. Journal of Wind Engineering and Industrial Aerodynamics, Vol. 29, pp 59-67.

J.D. Holmes (1992). Optimised peak load distributions. Journal of Wind Engineering and Industrial Aerodynamics, Vol. 41, pp 267-276.

J.D. Holmes and R.E. Lewis (1987). Optimization of dynamic-pressure-measurement systems. II. Parallel tube-manifold systems. Journal of Wind Engineering and Industrial Aerodynamics, Vol. 25, pp 275-290.

M. Kasperski (1992). Extreme wind load distributions for linear and nonlinear design. Engineering Structures. Vol. 14. pp 27-34.

B.L. Sill, N.J. Cook, P.A. Blackmore (1989). IAWE Aylesbury Comparative Experiment, Journal of Wind Engineering and Industrial Aerodynamics, Vol. 32, pp 285-302.

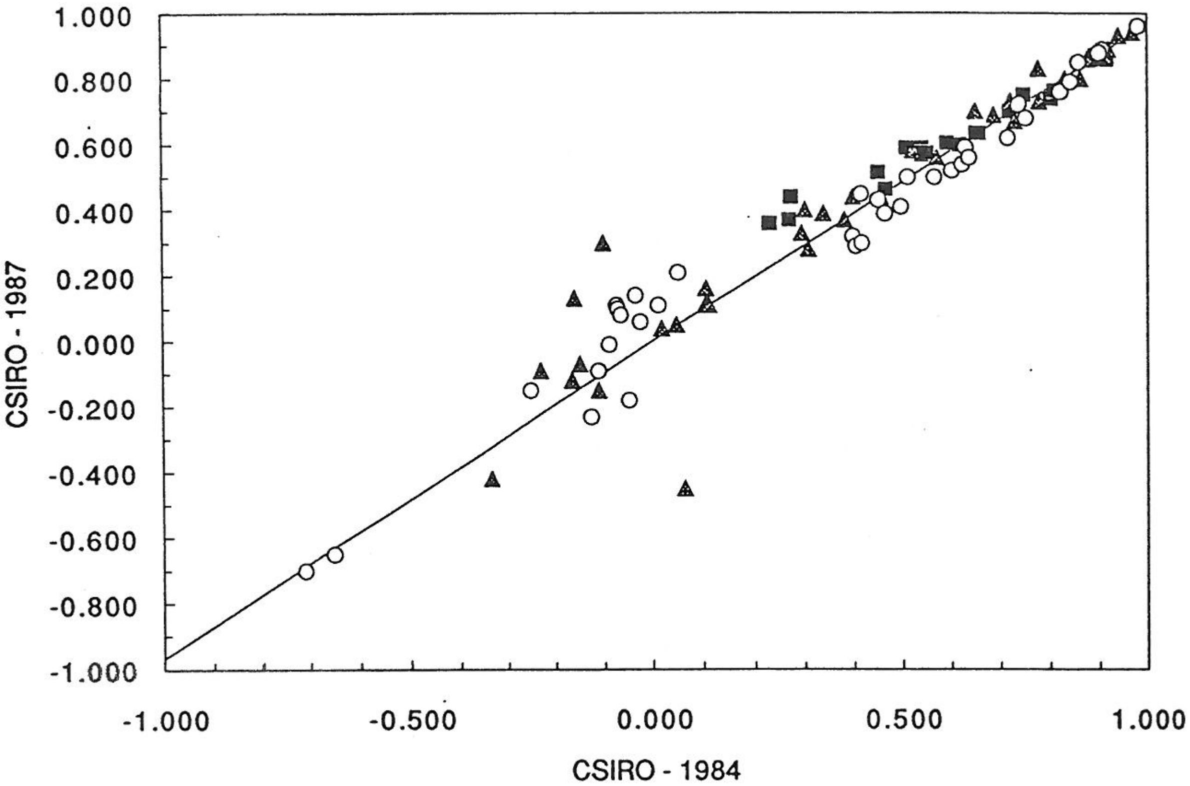
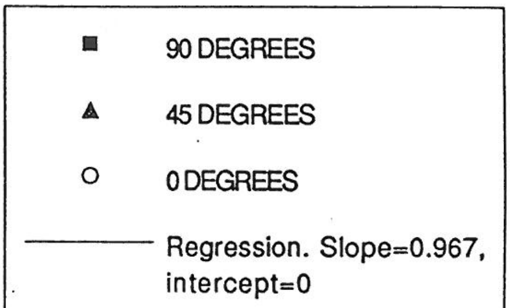


Figure 2. Comparison of correlation coefficients CSIRO 1987 versus CSIRO 1984



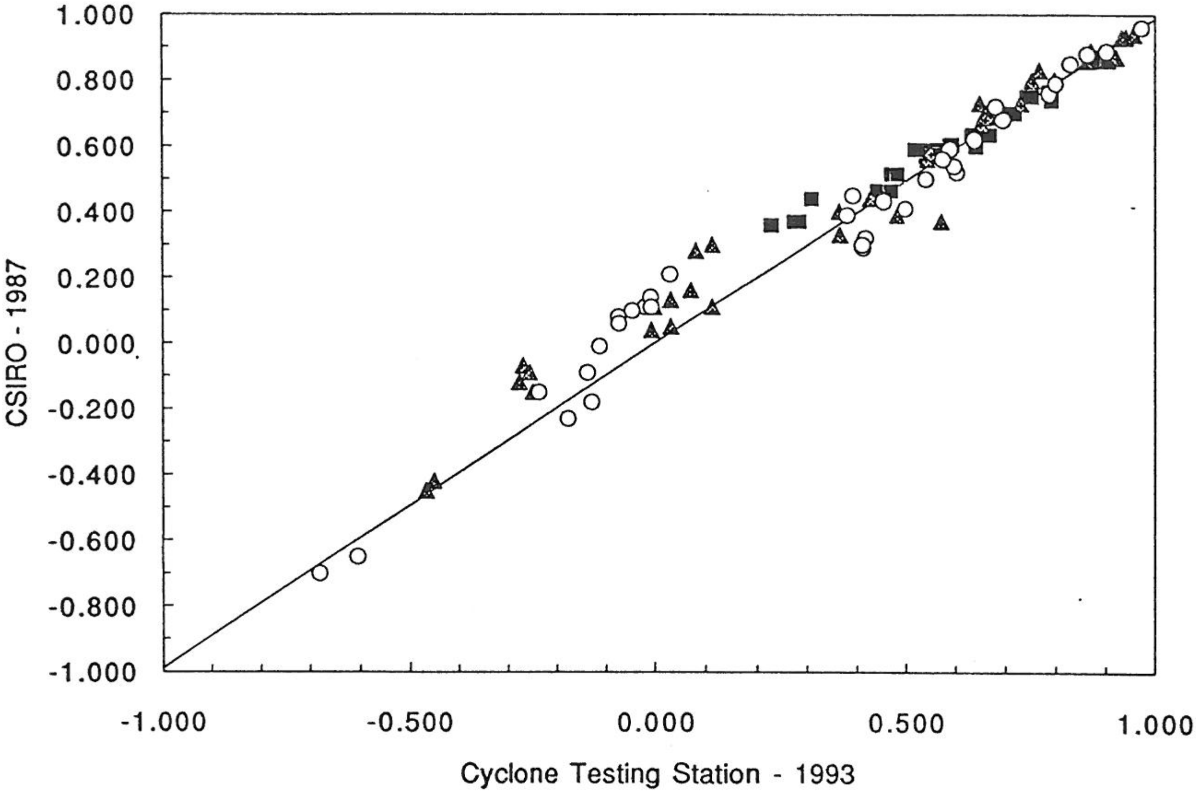


Figure 3. Comparison of correlation coefficients
CSIRO 1987 versus James Cook C.T.S. 1993