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DETAILED APPROACH FOR THE EVALUATION OF FULL-SCALE AND MODEL PRESSURE MEASUREMENTS ON A CANTILEVER GRANDSTAND

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ABSTRACT

Practical constraints on sensor location for full-scale testing of wind loads on buildings introduce artificial correlations in the results, which may appear as large negative pressure coefficients. Since the utility of model tests to determine the wind loads on buildings can be established conclusively only by comparative testing, it is essential that such experimental artifacts be corrected. This paper reports a successful method of so doing.

INTRODUCTION

Wind-tunnel model testing is the preferred method for the design prediction of wind loadings on structures, but can be used with confidence only if its prediction accuracy has been established by model/full scale comparison testing on the same structure. Significant apparent discrepancies were found in the negative pressure coefficients on a roof surface (Pitsis & Apperley, (1989), Pitsis & Apperley,(1991)). Such discrepancies can be caused by:

* Actual differences due to scale effects;
* Random fluctuations of the free stream;
* Experimental artifacts.

Of these, the random fluctuations can be dealt with by time averaging (Pitsis & Apperley (1989), Pitsis & Apperley (1991))

The experimental artifacts are of two kinds:

1. The physical separation of reference and measurement points;
2. Interference from other structures.

Physical separation is essentially a time delay between the pressure signals from the roof surface and from the reference point. It can be corrected by time-shifting the recorded signals.

The effects due to interference from other structures depends on wind direction, and the interpretation of this signal is affected by the time-averaging used to adjust for random fluctuations.

This paper reports on systematic correction to full-scale measurements for random fluctuations and to eliminate the artificial errors. Work is now in progress on extensive multi-point testing to determine the true correlation between full-scale and model results.

EXPERIMENTAL DETAILS

Boundary layer wind-tunnels have been in general use for the study of flows around structures for some years now;however, suitable full-scale data which may be used to check their accuracy are still not enough.

In the Aeronautical engineering department full scale pressure measurement investigations have been carried out since 1982 with special attention given at the corners of a cantilever roof in the region were the wind flow develops a pattern similar to "Delta wing effect". Comparisons with wind-tunnel models have been undertaken in order to study and improve the confidence level of wind-tunnel testing techniques.

In previous papers (Apperley & Pitsis,(1986), Pitsis & Apperley,(1989)) and (Pitsis & Apperley,1991) the reference point was in different locations due to limitations imposed to the researchers.

In paper (Apperley & Pitsis,1986) the reference dynamic pressure was measured by a cup anemometer/wind direction assembly 4.0 m. above the roof peak at the centre of the grandstand roof,and the reference static pressure by a pitot static tube assembly at approximately the same location. Roof pressure measurements were taken left and right to the reference location.

In papers (Pitsis & Apperley, (1989) , Pitsis & Apperley,1991)) the reference dynamic and static assembly was attached on a light pole 20.0 m. from the south end of the grandstand roof and 2.0 m. above the grandstand roof peak.

Results obtained from paper (Apperley and Pitsis,1986) showed similar discrepancies as papers (Apperley et al.,1979 and Vickery and Surry,1982) particularly of the standard deviation of the pressure fluctuation.

The results obtained from paper (Pitsis and Apperley,1989) showed close agreement at roof locations taken from distances greater than 100 cm. from the edge of the front of the grandstand roof and discrepancies between model and full scale occurred close to the edge (50 cm.)

Currently wind-tunnel testing is completed and will be compared with the full data obtained from Caltex oval grandstand early last year.

A total of 45 location roof positions were measured with the reference dynamic pressure located at the centre of the grandstand roof and 5.0 m. above the roof peak. Under surface roof pressures were also measured at 25 positions located at equivalent to the upper surface pressure tapping positions.

This multi-point testing was carried out in order to determine the true correlation between full-scale and model results.

For the above multi-point testing, approval was given to install the reference point in a new position and to drill holes on the roof for obtaining under surface pressure measurements, since the grandstand was to be demolished and replaced by another at the same location.

Permission was also given to conduct tests on the new and much larger grandstand next year.

The reference location and method is of great importance for both dynamic and static pressures.

The first testing was conducted at the Caltex oval, the home ground of the Cronulla Sutherland Leagues club. The reference location was mounted on a light pole 20.0 m south of the grandstand. This location proved not to be the best possible location but it was the only choice we had other than 20.0m to the north end of the grandstand on another light pole.

The desired wind directions were the north and south easterly for the investigation of the Delta wing effect at the corners of the structure.

Although the north eastern location would have been the preferred reference point for the tests, since the winds were from the north easterly direction, it would have omitted two important findings.

1 The positional effect,hence time delay
2 The sheltering effect on the reference point,thus interference from other structures affecting the dynamic pressure measurement.

The recording time period for every point taken was 40 to 45 min. It is important that a long record is taken for a credible assessment of the full-scale data.

A computing programme (Newman,D.M,1991) applicable to data acquisition and reduction was used to analyse low frequency data. It can also be used to identify the "real" data from a possible electrical interference that may occur during switching on/off of heavy current equipment, by essentially "stretching" the signal.

As normal practice, the coefficient of pressures were calculated and plotted, since the analysis of wind direction, wind velocity, dynamic pressure and roof pressures recorded simultaneously with respect to time.

Figure (1)shows an isolated peak pressure which requires to be recognised if it is a "real" signal and figure (2) identifies the peak signal as "real". When data was reduced no allowances were made for the time delay between the roof pressure measurement and the dynamic reference pressure 50.0m downstream.

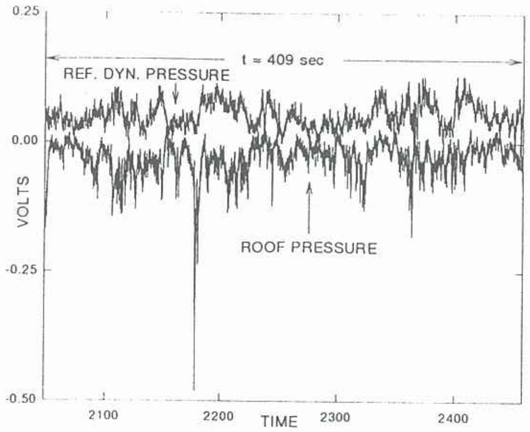

FIGURE 1.

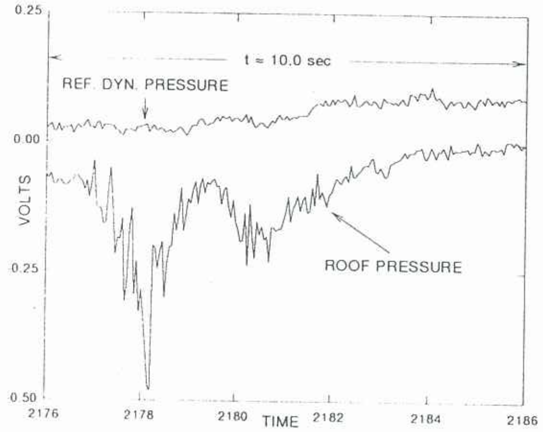

FIGURE 2.

Figure (3), presented in papers (Pitsis & Apperley,1989) and (Pitsis & Apperley,1991) clearly showed an increase in peak pressure coefficient by reducing the sampling period, whilst the same did not occur in the wind-tunnel data reduction correlation. This was due to time delay between the roof and the reference dynamic pressure as both data are recorded simultaneously and at 50.0m apart. No allowances were made for the time delay.

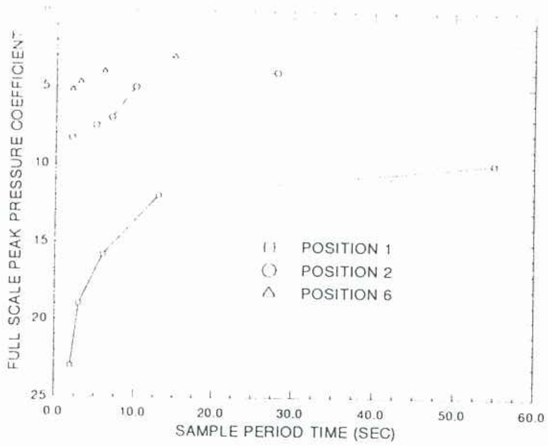

FIGURE 3.

Figure (4) presented in paper (Pitsis,1992) clearly demonstrates the time delay. The peak pressure develops first whilst the dynamic pressure occurs about 5 min. later.

Figure (5) shows the time delay between the wind direction and the roof pressure signals.

When the reduction of the wind-tunnel data in paper (Pitsis and Apperley,1991) for 50 degrees east of north was performed, a decrease of about 40% on the average reference dynamic pressure was noticed. This was due to the interference effect produced by the location of the main building of the Cronulla Sutherland Leagues club (the main building being nearly double in linear size to the smaller grandstand) which is centrally located across the smaller grandstand on the eastern side of the oval.

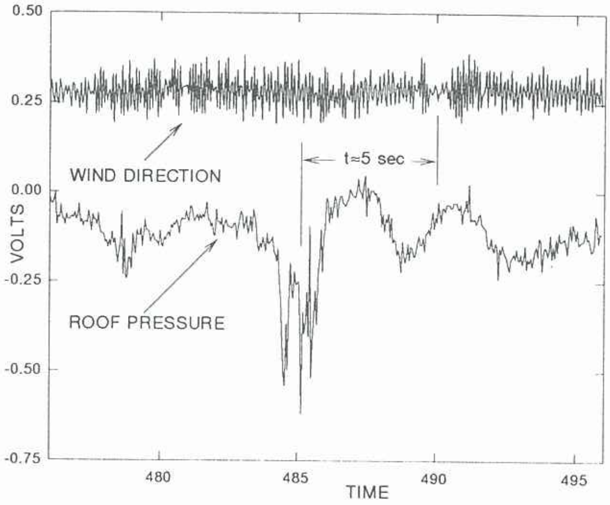

FIGURE 4.

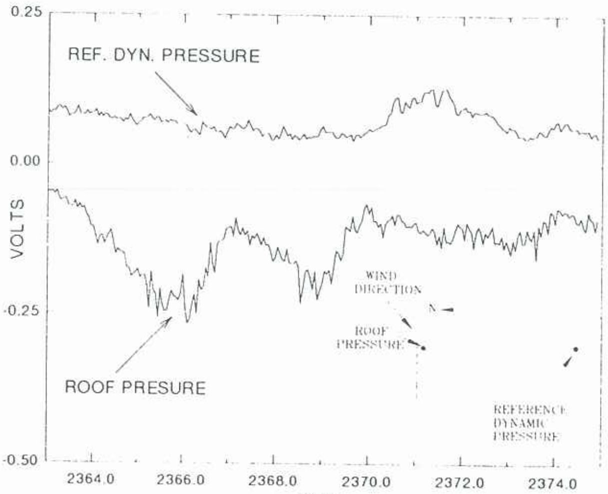

FIGURE 5.

DISCUSSION

As shown in Figure (1) a segregated peak roof pressure needs to be identified if it is a "real" signal out of a scale data of 410 sec (8188 points).

The programme has the tool to select any designated time period as shown in Figure (2) and the analysis of 6.2sec (125 points) displays a "real"peak value.

The average dynamic pressure was reduced because no allowance was taken for the time delay, since the location of the pressure tapping point on the roof top of the grandstand is approximately 50 m downstream from the reference dynamic pressure location.

Figure (3) demonstrates (Pitsis and Apperley, 1989 & Pitsis and Apperley,1991) how the coefficients of pressure increased as the sample period time in seconds decreased. Therefore, a much larger sample period should be used for the evaluation of the full scale data. It is very important if a small sample period has to be analysed and coefficients obtained, the time delay should be considered and the necessary adjustments made.

Figure (4) displays the time delay between the peak roof and the reference dynamic peak pressures. The wind direction is from the north-east, the reference station is 20.0 m south of the grandstand.

When a comparison is to be made between full-scale and model, attention should also be taken between peak pressures and wind directions in order to select the wind direction for the wind-tunnel data, corresponding with the full-scale measurements.

Figure (5) displays an instant wind gust and the corresponding wind direction signal follows five seconds later.

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