FULL SCALE MEASUREMENTS OF WIND INDUCED RESPONSE OF AN 85m HIGH CONCRETE CONTROL TOWER

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Introduction

An instrumentation system for full scale measurement of building dynamics has been developed at the University of Sydney. This system has been installed in the Port Operations and Communications Centre in Sydney and is currently being used to determine its dynamic characteristics under wind loading. This paper will describe the instrumentation system, the tower under study and will present preliminary results.

The Port Operations and Communications Centre

The POCC is located on Darling Harbour at Miller's Point in Sydney. It is an 85m tall reinforced concrete tower and functions as the control centre for all shipping movements in and around Sydney Harbour. It was designed in 1971 by structural engineers Miller, Milston & Ferris in conjunction with architects Edwards, Madigan, Torzillo & Briggs. The structure consists of a 69m high reinforced concrete shaft of 4.88m diameter topped by a 15m high turret of various diameters between 9.8m & 15.2m. The turret has concrete flooring and the external cladding is stainless steel. The roof is based on a tubular steel space frame, again with stainless steel cladding.
The concrete shaft of the tower contains three main areas: a lift shaft, a fire stair and a service duct (Fig 1). The turret comprises three levels (Fig 2). The lowest is an amenities area containing cooking, washing, toilet and storage facilities. The centre level is an equipment level housing mainly communications equipment. The uppermost level is the control room from where the functions of the tower are implemented.
The roof well of the tower contains two large air conditioning units in addition to a number of radio aerials and lightning conductors around its perimeter.

Instrumentation

The instrumentation system is shown schematically in Figure 3.
The accelerometers used are Lucas Novasensor models selected for their high output (1.25V/g), low cross axis sensitivity and low cost. They also include signal conditioning which regulates the excitation voltage and temperature compensates the output. Further signal conditionin is applied by the addition to the system of a purpose built amplifier, with a fixed gain of 50, and 10Hz low pass filter.
Wind data is obtained using a Gill UVW anemometer (with the W propeller removed) mounted on a mast on the tower roof. The Gill anemometer was selected for its accuracy, long term reliability and good gust response. The output from the anemometer is again low pass filtered at 10Hz. Carbon fibre thermoplatic propellers were selected for durability and nose extensions were added to reduce the stall angle. It is well known that the output from the Gill anemometer does not follow exactly the theoretical cosine curve

as wind direction varies from 0 to 360°. There are a number of readily available correction curves and algorithms, two of which are applicable to the set-up used here[1,2]. However, both of these sets of figures make two major assumptions: firstly that the corrections are symmetrical about 180° and secondly that they are identical for the U & V propellers. On comparison with the results obtained for this study (Fig 4) it can be seen that both of these assumptions, while largely true in many areas, are quite erroneous in certain critical areas. For this project separate correction factors have been applied for each 180° sector of each propeller.
From wind tunnel tests it became clear that to find free stream flow the anemometer would require to be mounted at least 12m above the top of the tower. The anemometer was finally mounted 13.2m above the top of the building on a telescopic guyed mast. The telescopic mast allows periodic maintenance of the anemometer and removal of the mast to allow maintenance of surrounding communications aerials. The mast has, in addition, been fitted with lightning protection and aviation hazard lighting. It is worth noting that the wind speeds measured at this height are approximately twice those at the meteorological standard of 10m.
Data is logged by a 486 personal computer fitted with an analogue to digital converter and located with the accelerometers and other equipment below the lift motor room on the equipment level. Data is sampled at 20Hz for 14 minutes and then reduced and stored in the following minute before the sequence is repeated in a method similar to that of Kwok & Macdonald[3]. The dedicated software contains velocity and acceleration thresholds. Below these thresholds, mean, peak and standard deviation records for acceleration and wind velocity are recorded. Above one or both of the thresholds, raw data for the whole of the 14 minute cycle is stored, thus allowing more rigorous analysis at a later date.

Preliminary Results

A typical 14 minute record was selected for further analysis and passed the run test for self stationarity at the 95% confidence level using 42 samples of rms acceleration as described by Bendat & Piersol[4]. The acceleration response was plotted and the major and minor axes of the resulting elliptical path defined (Fig 5). These coincided very closely with along and cross wind axes. From analysis of many more records it was seen that the major and minor axes of response are alomost entirely dependent on wind direction, although at present the vast majority of strong wind records involve southerly winds. From spectral analysis (Fig 6), the first two modes of vibration are clearly identified as being at 0.41Hz and 2.69Hz compared with the original design predictions of 0.37Hz and 2.59Hz. These values were identical for both along and cross wind response. Damping was estimated at between 1.54% and 1.70% for along and cross wind axes respectively using autocorrelation analysis (Fig 7).
Plotting mean wind speed v r.m.s.acceleration for wind speed records above 8m/s it can be seen that, as expected, response increases with increasing wind velocity and cross wind response is markedly larger than along wind response particularly at the higher wind speeds (Figs 8,9).

Further Work

Records will continue to be gathered for the remainder of the year by which time more reliable data relating acceleration to wind data should be available. It is then hoped to fit a retrofit damping system to the tower.

Conclusions

A long term full scale measurement program has begun to determine the dynamic characteristics under wind load of a slender circular section tower. A relatively low cost instrumentation system has been developed along with flexible dedicated data acquisition and analysis software. Initial results are promising but further strong wind records are required to allow fuller analysis of data.

References

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2. Littler, J.D., Personal Communication, Building Research Establishment, U.K., 1992.
3. Bendat J.S. and Piersol A.G., "Measurement and Analysis of Random Data", John Wiley & Sons, New York, 1966. pp156-158,170.
4. Kwok K.C.S. and Macdonald P.A., "Full-scale Measurements of Wind-Induced Acceleration Response of Sydney Tower", Engineering Structures, Vol 12, 1990, pp153-162.

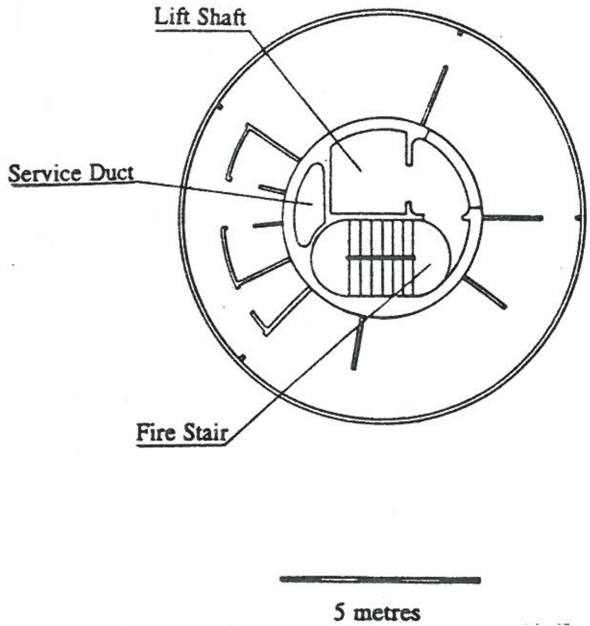

Figure 1 Plan Section of POCC

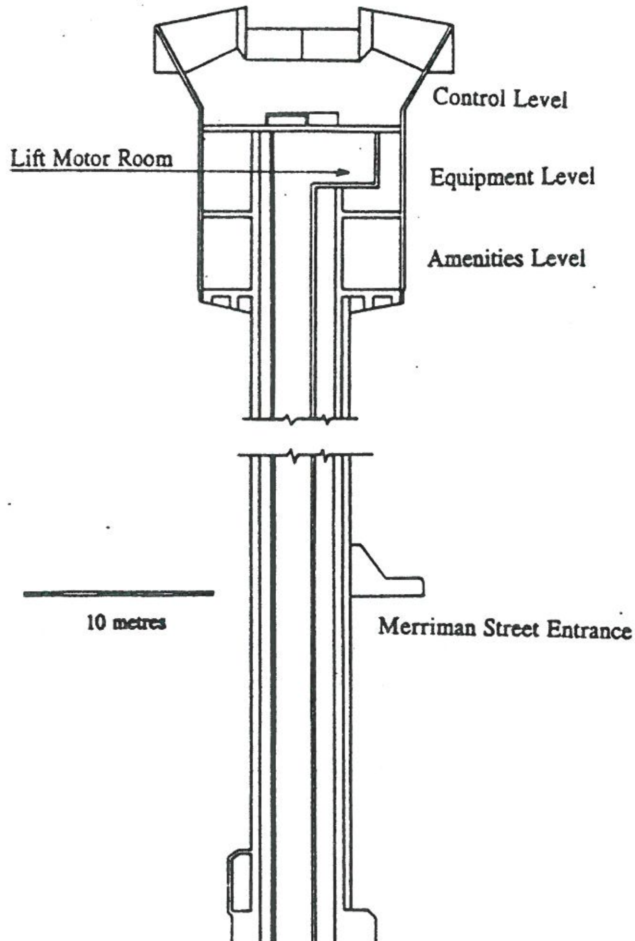

Figure 2 Sectional Elevation of POCC

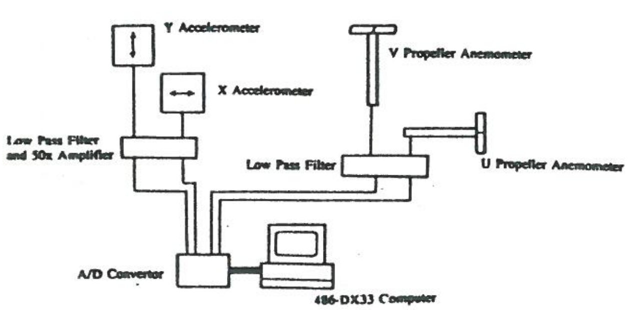

Figure 3 Instrumentation

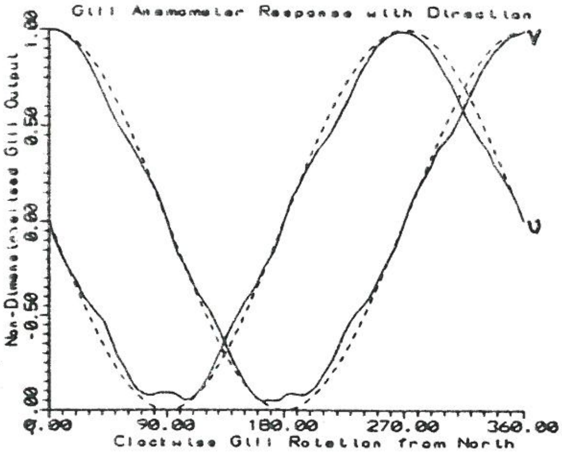

Figure 4

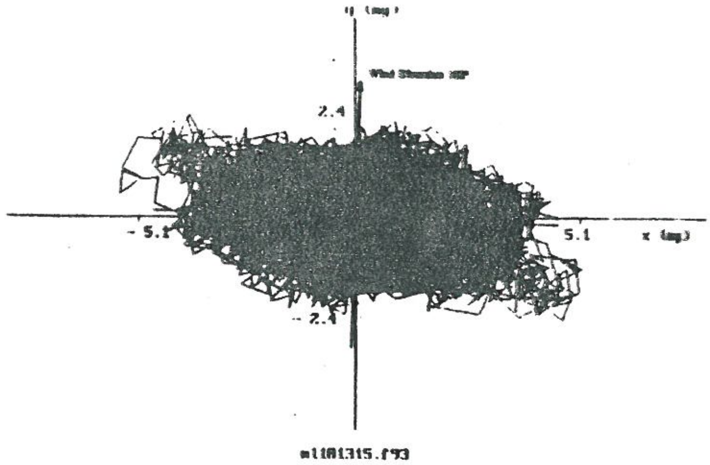

Figure 5 Acceleration Response Record

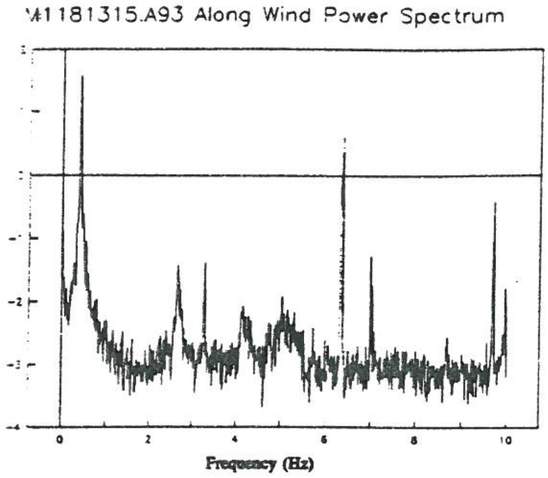

Figure 6 Power Spectrum

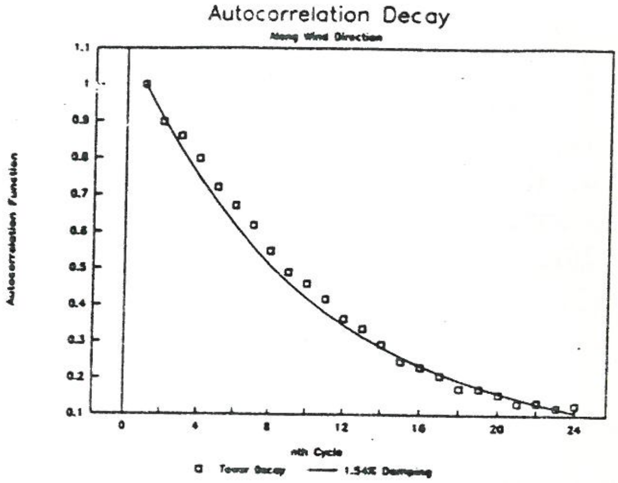

Figure 7 Autocorrelation Decay

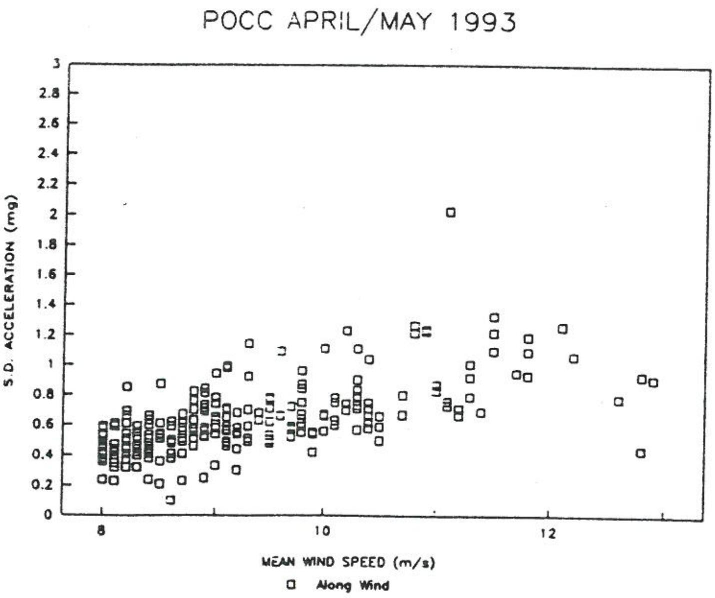

Figure 8 Along Wind Response

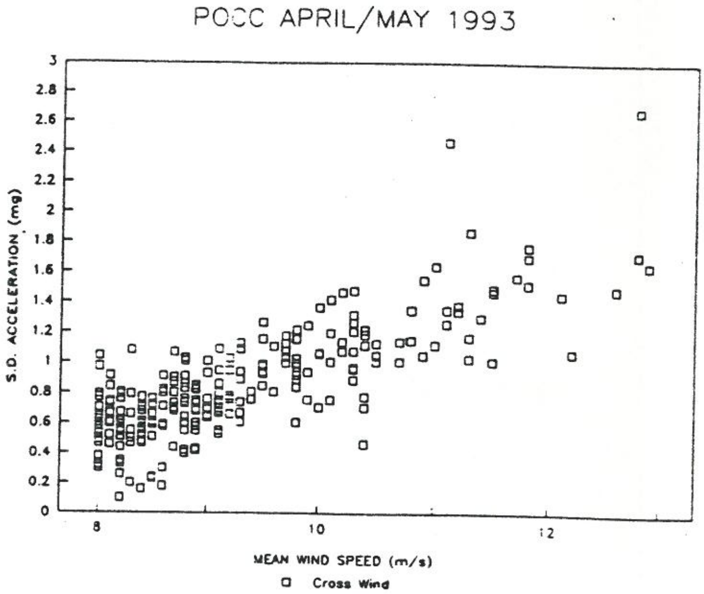

Figure 9 Cross Wind Response