DYNAMIC CHARACTERISTICS OF THE SYDNEY AIRPORT CONTROL TOWER

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Abstract

Full-scale measurements of structural characteristics of the new Sydney Airport Control Tower were made. Natural frequencies, structural damping and mode shape were measured under forced excitation. A long-term program of measurement of wind-induced response is also underway.

1. Introduction

A new air traffic control tower has recently been completed at Sydney Airport as part of the parallel runway project. The new tower consists of a concrete and steel turret on top of a 9 m steel shaft and 23.4 m reinforced concrete stem, as shown in Figures 1 and 2. A steel and glass lift shaft is attached to the exterior of the stem. The more unusual features of the tower include the three guys to the turret, the spiral fire stair leading down from the turret and the unusual plan section of the lower half of the turret.

A series of tests were carried out to determine the natural frequency, damping and mode shape of the tower. A further long-term measurement program of wind-induced vibration is also being undertaken.

2. The Measurement Program

The initial full scale measurements were to determine the natural frequency, mode shape and damping of the structure.

The natural frequency of the structure was found by taking a record of acceleration of the tower under wind excitation and subjecting this record to spectral analysis.

Damping values were obtained by free vibration decay, having excited the tower at its dominant natural frequency. Excitation was carried out by the rhythmic motion of three bodies in the turret of the tower.

The mode shape was measured by comparing the acceleration response at several levels down the shaft of the tower with a reference in the turret. Forced excitation was again used.

The equipment used in the testing consisted of two pairs of accelerometers with dedicated signal conditioners, an analogue tape recorder, an oscillographic recorder and a metronome. Data analysis was carried out both manually and by digital computer.

3. Natural Frequency of the Tower

As can be seen from Figure 3, the dominant natural frequency of the tower is around 0.95 Hz. This was computed only for the North-South (Y-Y) direction. Manual examination of records from the oscillographic recorder indicated that the dominant natural frequency in the East-West (X-X) direction is very similar.

4. Structural Damping of the Tower

The structural damping was measured from free vibration decay following forced excitation. The tower was excited by three people in the turret moving rhythmically in time with a metronome at 0.95 Hz. Accelerometers and an oscillographic recorder were used to record the decay, with the output from the accelerometers being band-pass filtered from 0.85-1.05 Hz.. The results, presented as a percentage of critical damping; are shown in Figures 4 and 5. The usual scatter of results can be observed but there was no evidence of any amplitude dependence, probably as a result of the small amplitude range tested. The mean values of damping for the Y-Y and X-X directions were very similar at 0.77 % and 0.73 % respectively.

5. Mode Shape of the Tower

The mode shape in the Y-Y direction was measured at all eight intermediate levels within the tower from the control level down. When measuring the mode shape in the X-X direction, it was not possible to gain access to the control level and an incomplete set of results was thus obtained. It is shown in Figure 6, however, that the mode shape in the X-X direction compares very well with the mode shape in the Y-Y direction. Figure 7 demonstrates that this mode shape is closely approximated by a power law equation with an exponent of 1.9.

6. Discussion of Results

The dominant natural frequency of 0.95 Hz is around the figure which would be expected. The approximate '46/h' method of prediction results in a prediction of 1.05 Hz. Computer modelling of the structural response suggests a torsional mode of response at a very low frequency.

The damping values of 0.73 % and 0.78 % of critical damping are centrally located within the AS1170.2-1989 band of damping values of 0.5 % to 1.0 %. These values of damping agree closely with those found for other tower type structures such as Denoon (1994) who reports a value of 0.8 % for the Sydney Harbour Control Tower.

The mode shape power law exponent of 1.9 is also a reasonable value. AS1170.2-1989 gives typical power law exponents for uniform cantilevers and towers with large masses at the top of 1.5 and 2.3 respectively. The value of 1.9 probably results from the extra restraint provided by the three cable stays.

7. Further Work

A long term measurement program of the response of the tower to wind loading has begun. This involves constant monitoring of the dynamic response of the tower by two pairs of accelerometers. One pair of accelerometers is centrally located on the control level with the other pair to the exterior of the control level. It is hoped that these can be used to detect torsional response of the tower.

8. Conclusions

A program of measurement of structural dynamic properties was carried out at the new Sydney Airport Control Tower. The dominant natural frequency was found to be 0.95 Hz. Structural damping values of 0.73 % and 0.78 % were measured in orthogonal directions. The mode shape in both of these orthogonal directions was found to be closely approximated by a power law with an exponent of 1.9. Further long term measurements of wind-induced response are being made.

9. Acknowledgements

The author wishes to thank Airservices Australia for access to the tower, Ove Arup and Partners for providing structural information on the tower and Messrs Craig Fitzharris and Chris McDougall for assistance in the fieldwork.

10. References

AS1170.2-1989, Minimum design loads on structures, Part 2: Wind Loads. Standards Australia, North Sydney, Australia.

DENOON, R.O. (1994). The wind-induced dynamic response of an 84 m high control tower. ME(Res.) thesis, University of Sydney, Australia.

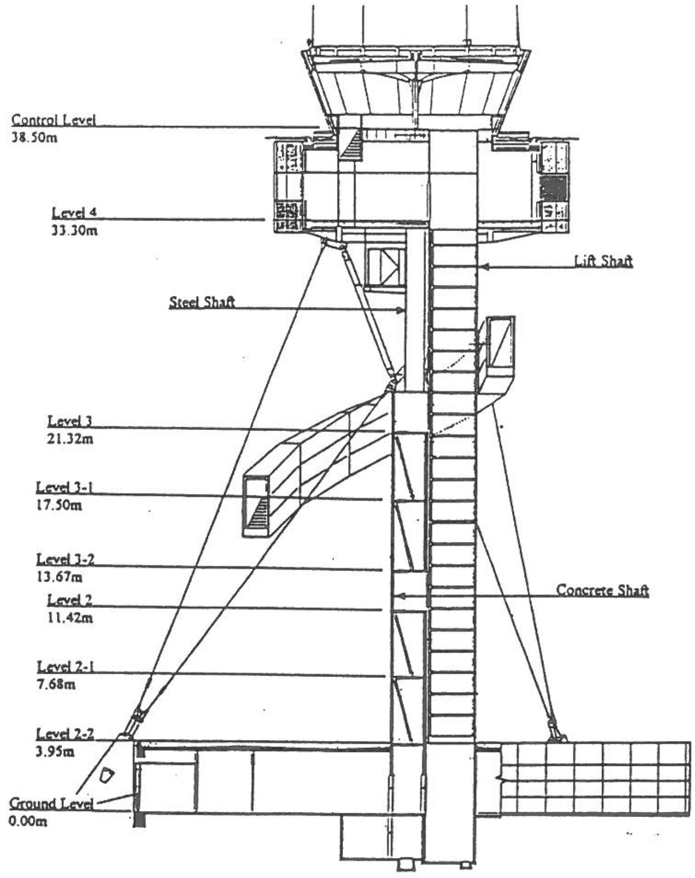

Figure 1 Vertical Section Through Airport Control Tower

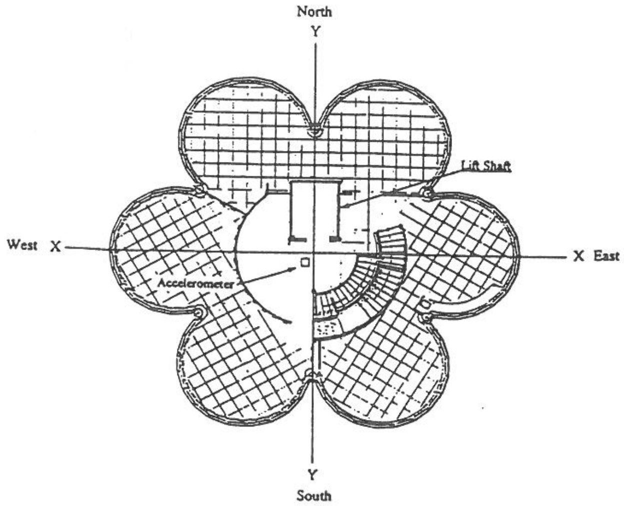

Figure 2 Cross-Section Through Level 4

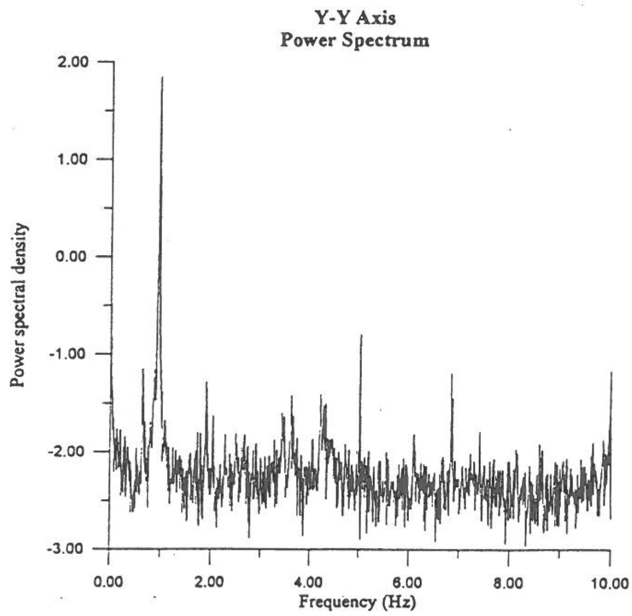

Figure 3 Y-Y Axis Power Spectrum

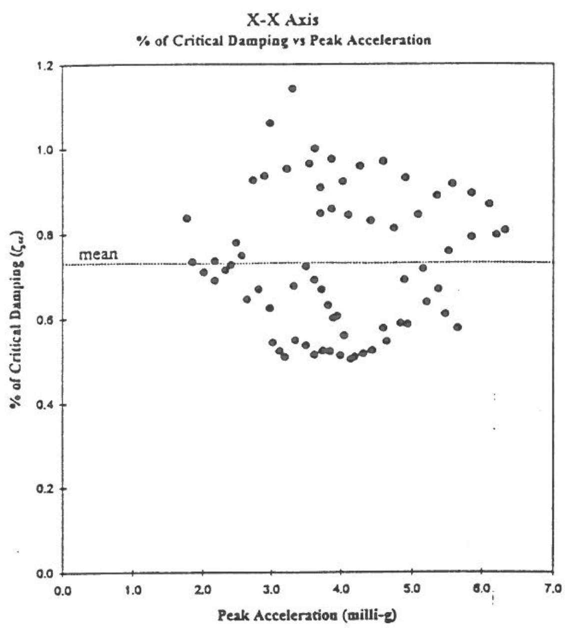

Figure 4 X-X Axis Damping

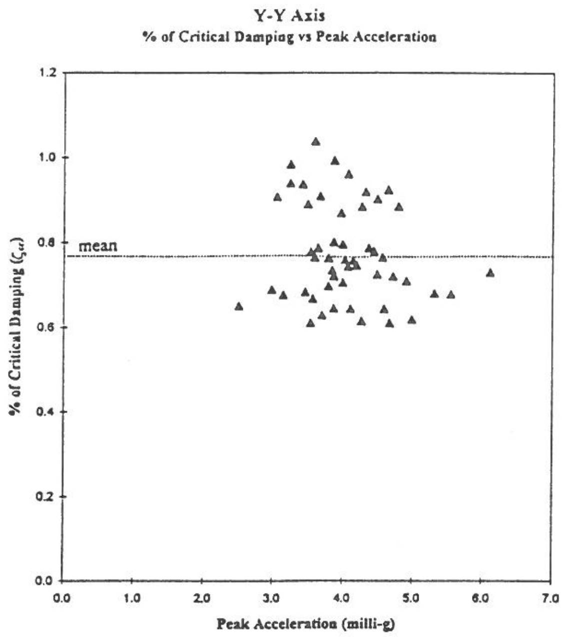

Figure 5 Y-Y Axis Damping

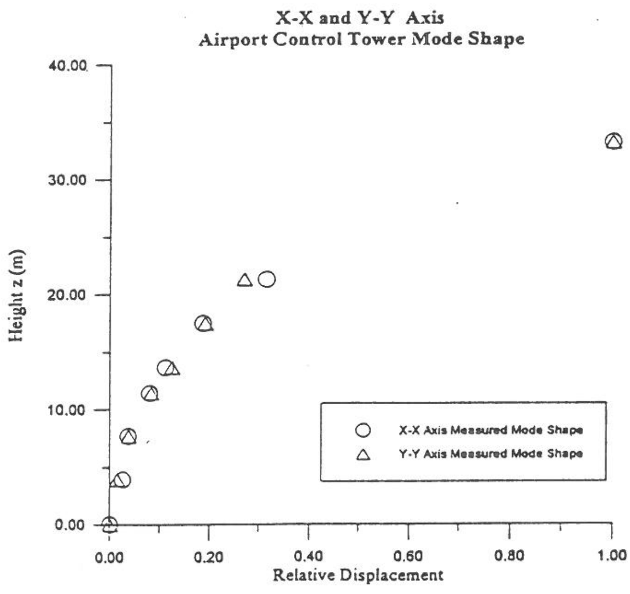

Figure 6 X-X and Y-Y Axis Mode Shapes

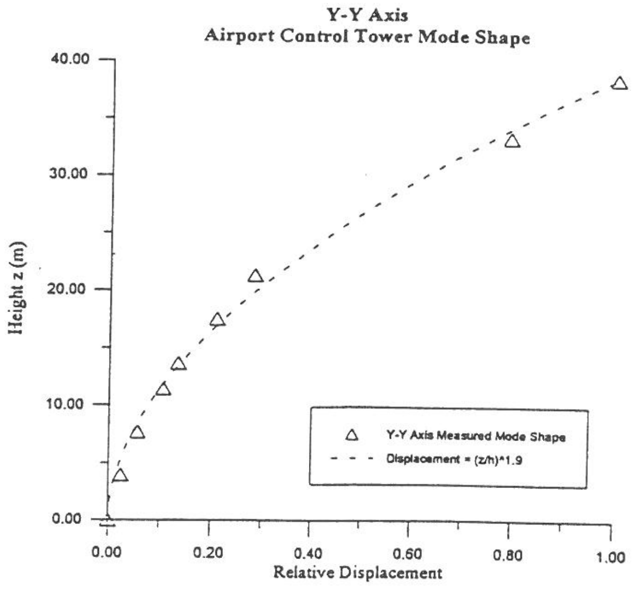

Figure 7 Y-Y Axis Mode Shape