DYNAMIC CHARACTERISTICS OF CONTROL TOWERS IN AUSTRALIA

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INTRODUCTION

A series of full-scale measurements of structural dynamic characteristics of control towers in Australia has been undertaken. Measurements have been taken at airport control towers in Sydney, Brisbane and Perth and the maritime control tower in Sydney. These measurements have determined natural frequencies, structural damping ratios and modeshapes. Modeshapes and structural damping ratios of the airport towers were determined by forced vibration of the structures using a simple and novel technique.

EXPERIMENTAL PROCEDURE

The four towers tested are shown in section in Figures 1 to 4. Sydney Airport Tower is a 43 m high steel and concrete tower with a large external spiral stairway and three sets of two stainless steel guys. Sydney Harbour Tower is an 84 m high reinforced concrete tower of circular cross-section. Perth Airport Tower is a 69 m high reinforced concrete tower of decagonal cross-section. Brisbane Airport Tower is a 71 m high reinforced concrete tower of octagonal cross-section.

Instrumentation consisted of accelerometers, signal conditioners, an FM tape recorder and an oscillographic recorder.

The Sydney Harbour Tower was not tested using forced vibration methods. The modeshape was determined under storm wind conditions and natural frequencies and damping ratios determined by spectral methods.

The wind-induced dynamic response of cantilever control tower type structures is normally dominated by first mode vibration. This frequency is usually easy to identify, even under light wind conditions. Each of the airport towers were forced under light wind conditions so that the response to the forcing dominated the wind-induced response. The forcing was created by movement of human bodies near the top of the tower. This movement of bodies is synchronised at the structural natural frequency of interest. The airport towers were forced using only three or four people.

RESULTS AND DISCUSSION

Results are shown below in Table 1. Frequencies are given in hertz and damping as ratio of critical damping. Mode shape exponents are given as the best fit exponent to a power law to the mode shape as given in AS1170.2-1989.

It can be seen from Table 1 that some very low values of damping were obtained. Sydney Harbour Tower, although being a concrete tower, has the highest value of structural damping. This is probably due to the connecting bridge to Merriman Street acting as a damping device. Sydney Airport Tower has the next highest damping values. This is due to the numerous connections in the structure providing energy dissipation mechanisms. Perth and Brisbane Airport Towers are free-standing cantilevered concrete towers and can be seen to have very low values of structural damping. This is consistent with occupant reports of significant motion of the towers in strong winds.

The natural frequencies of the structures are in reasonable ranges for the types and heights of structures tested. The difference in natural frequencies between Perth and Brisbane is most likely due to the greater mass at the top of the Brisbane Tower.

Mode shape exponents are around the range expected for cantilever structures (c.f. AS1170.2-1989 exponent of 1.5). Brisbane data did not fit a power law well due to the changing cross-section of the tower with height over the top half of the tower. The Brisbane Tower mode shape can be approximated by a linear mode shape although it would be better fitted by two linear gradients for the top and bottom halves of the tower.

FURTHER WORK

Brisbane and Sydney Airport Towers are currently being used in a full-scale program to determine human perception of motion. Perth is expected to be introduced to the program soon. The work notes levels of perception while the occupants are working and psychological testing to determine effects on mental efficiency is also being carried out. This work will be used to calibrate a laboratory experiment using a controlled room on a shake table.

CONCLUSIONS

Natural frequencies, damping ratios and modeshapes of four control towers in Australia were measured. A novel method of forced vibration was used. Results show low values of structural damping for free-standing concrete towers. These low values are consistent with reports of high accelerations in the towers.

Tower	X direction 1st mode frequency	Y direction 1st mode frequency	X direction damping	Y direction damping	X modeshape exponent	Y modeshape exponent
Sydney Airport	0.95	0.95	0.0073	0.0077	1.9	1.9
Sydney Harbour	0.38	0.39	0.0082	0.0089	1.6	1.6
Perth Airport	0.74	0.73	0.0062	0.0063	1.4	1.4
Brisbane Airport	0.54	0.55	0.0048	0.0049	1.0	1.0

Table 1

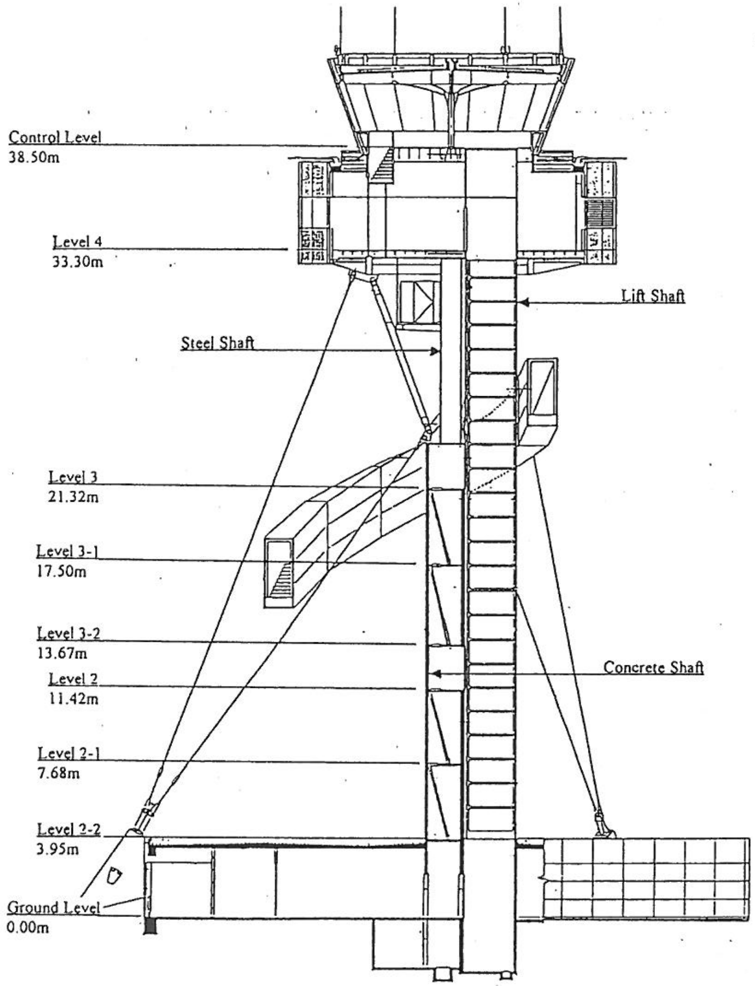

Figure 1 Section Through Sydney Airport Tower

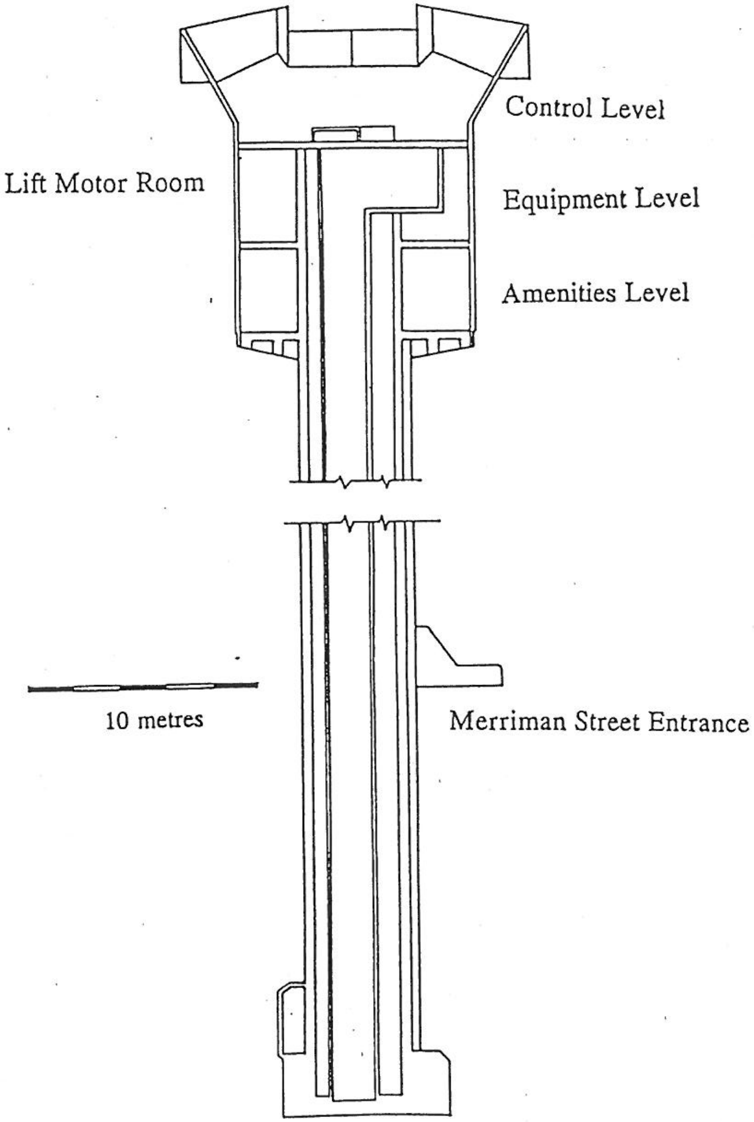

Figure 2 Section Through Sydney Harbour Tower

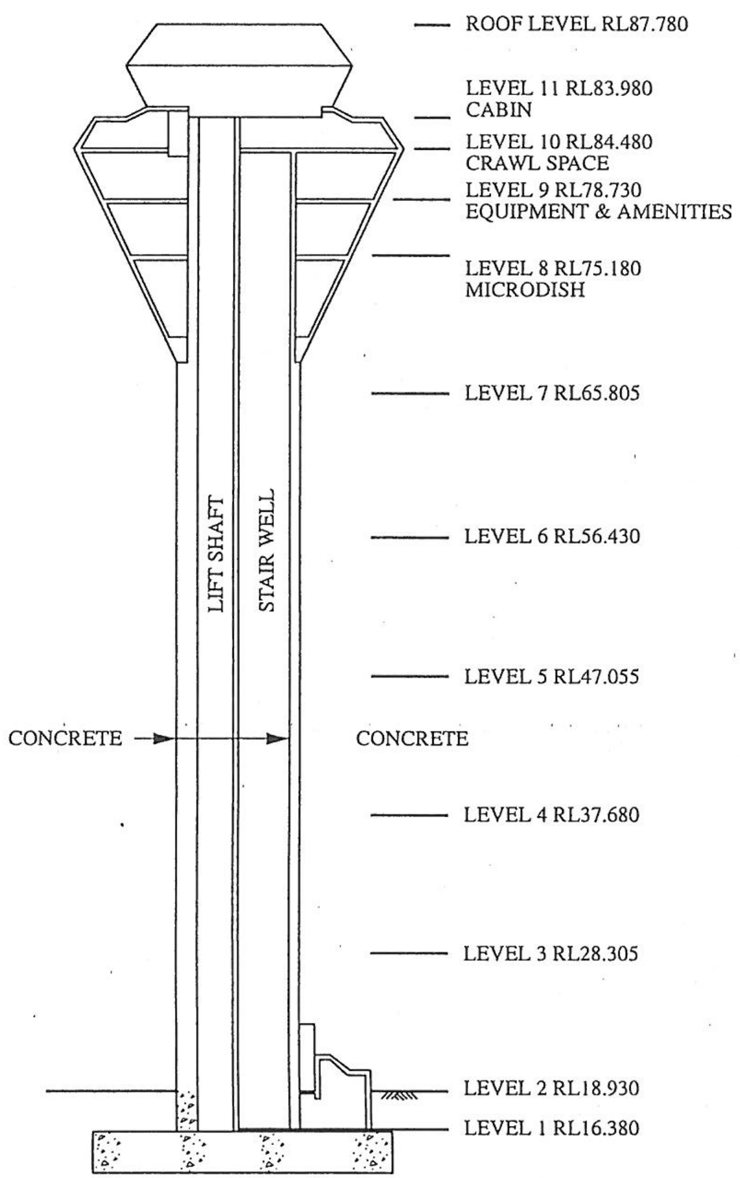

Figure 3 Section Through Perth Airport Tower

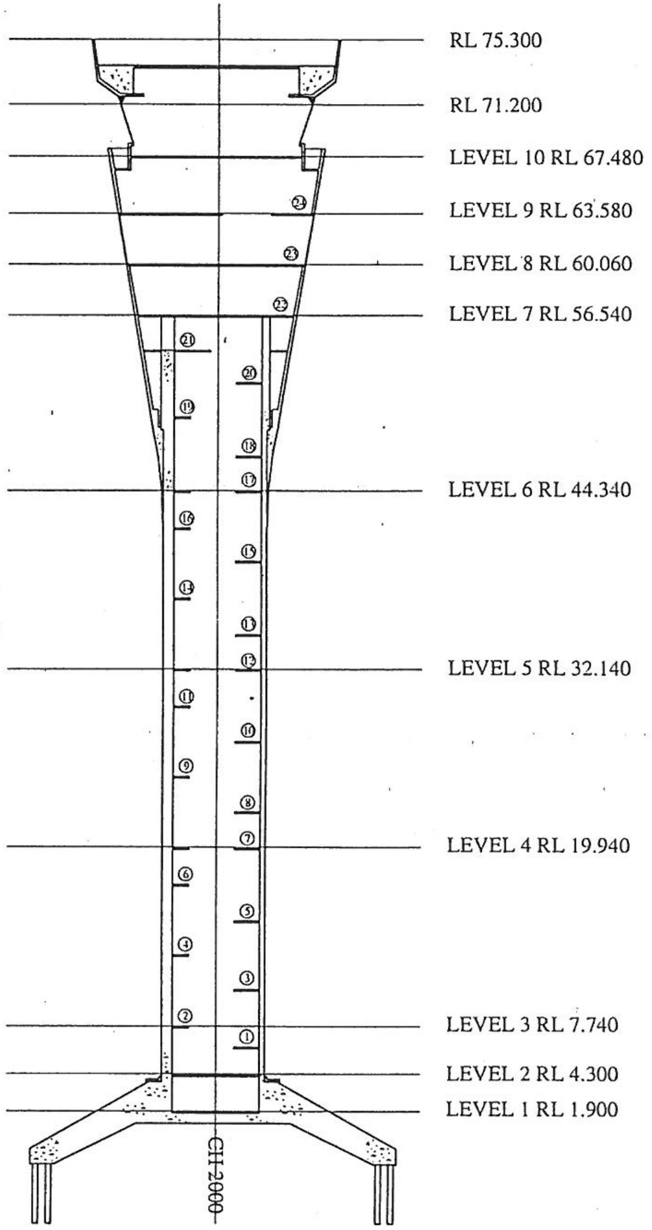

Figure 4 Section Through Brisbane Airport Tower