12th Australasian Wind Engineering Society Workshop
Queenstown, New Zealand, 2nd and 3rd February, 2006

FULL SCALE MEASUREMENTS OF FREQUENCY AND DAMPING FOR THE EUREKA TOWER, MELBOURNE

by

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ABSTRACT

Acceleration measurements of the Eureka Residential Tower under crane load drop and wind excitation have been carried out at various stages of completion of the tower. This is the first part of a programme leading to the continuous monitoring of the response of the tower and liquid tuned mass damper under wind action. The first objective of this full scale response study is to compare frequencies with the FE modal analysis and accelerations with those predicted from the wind tunnel linear mode aeroelastic model measurements. The second objective is to gain knowledge with respect to acceptable levels of acceleration for occupancy comfort in residential buildings, that has been the subject of considerable international debate leading up to the draft ISO Standard 10137 'Serviceability of buildings and walkways against vibration'

1. MEASUREMENT AND DATA REDUCTION METHODOLOGY

Acceleration measurements have been made at approximately 80%, 90% and at initial top-out of the Eureka Tower, which is the tallest residential building in the world with apartments and habitable areas up to 300m. Measurements were made by MEL Consultants at the three levels and by The University of Sydney at 80%. Measurements were made in low wind conditions with the building being excited by stopping load drops on the central crane, and under wind excitation.

The best damping data is obtained under the crane excitation as relatively clean acceleration response traces could be obtained and the best frequency measurements could be obtained under wind excitation as the third mode in particular was difficult to excite with the central crane. Photographs of the Eureka Tower at various stages of completion are shown in Figure 1.

The MEL Consultants measurements of accelerations of the Eureka Tower were measured by four accelerometers, positioned in pairs at the tips of the north and south beaks. The accelerometer pairs are configured to measure orthogonal directions as shown in Figure 2. The signals from the accelerometers were transmitted from remote boxes to a local system box connected to a laptop computer. The signals were acquired by the computer for off line processing.

The processing of the data was performed using Mathworks Matlab™ software package to determine the spectra and plot the time series and spectral data. All acquired data was low pass filtered at 0.75 Hz using a high order filter to remove higher frequencies recorded from due to the ongoing construction when the measurements were performed.

The axes of the accelerometers were aligned with the shear wall running between the beak peaks.

The University of Sydney measurements used three accelerometers positioned on level 80 of the tower: two mounted orthogonally and located at the core near the centre of stiffness, and one located away from the core at the southern end of the floor plan. The accelerometer signals were amplified by a gain of 900 and low pass filtered at 2 Hz. The crane excitation tended to excite higher modes of vibration, and the decay traces were also dominated by these higher modes. Power spectra analysis was used on all acceleration records to determine the natural frequencies. To determine the structural damping, data from the free vibration decays following forced vibration were band-pass filtered around the first and second mode natural frequencies. The peaks of the resultant decay traces were used to obtain estimates of structural damping by the logarithmic decrement method.

The results table for The University of Sydney testing indicates the primary direction of translation for mode 1 as east-west, however it is noted that this mode of vibration is coupled, consisting of both north-south and east-west translations. No estimates for torsional modes have been provided in The University of Sydney results, which may not have been excited by the crane at the core.

2. FREQUENCY AND DAMPING MEASUREMENTS

The following values of frequency and damping were determined directly from the acceleration measurements:

80% Completion

Mode	Modal Frequency (Hz)	Peak acceleration amplitude at start of decay trace (typ.)	Average Damping (% of critical)
1 – North – South	0.24	0.35 to 0.2milli-g	0.75 ±0.1
2 – East – West	0.30	0.35 to 0.2milli-g	0.75 ±0.1
3 – Torsion	0.43	0.1 to 0.2 milli-g	0.85 ±0.1

90% Completion - MEL Consultants measurements

Mode	Modal Frequency (Hz)	Peak acceleration amplitude at start of decay trace (typ.)	Average Damping (% of critical)
1 – North – South	0.21	0.8 to 0.6 milli-g	wind corruption
2 – East – West	0.26	0.8 to 0.6 milli-g	range 0.6 to 1.0
3 – Torsion	0.38	0.5 to 0.3 milli-g	

90% Completion – The University of Sydney measurements

Mode	Modal Frequency (Hz)	Peak acceleration amplitude at start of decay trace (typ.)	Average Damping (% of critical)
1 – North – South	0.21	0.09 milli-g	0.78 ±0.2
2 – East – West	0.25	0.02 milli-g	0.90 ±0.2
3 – Torsion	-	-	-

Initial top-out at 300m

Mode	Modal	Peak acceleration	Average Damping

	Frequency (Hz)	amplitude at start of decay trace (typ.)	(% of critical)
1 – North – South	0.18		
2 – East – West	0.23		
3 – Torsion	0.36		

3. EXTRAPOLATION OF DAMPING TO HIGHER AMPLITUDES

3.1. Damping

The measured damping values for the 80% Completion are shown plotted in Figures 4 and 5 with the Tamura variation with period and the Davenport and Hill-Carol variation with amplitude.

The standard deviation amplitude of the Mode 2 (east-west) motion for a five year return period for 1.5% damping is about 0.05m giving a standard deviation over height ratio of 1.7×10^{-4}, which when using the Davenport and Hill-Carol slope gives an estimated damping value for the Completed Tower of 1.0% % ± 0.1%.

4. ACKNOWLEDGEMENTS

The assistance of Grocon Constructors, and Messrs S Coker, D Emery and R Galle in particular, in facilitating these full scale measurements and permission to present these preliminary data for discussion at the 12th AWES Workshop is gratefully acknowledged.

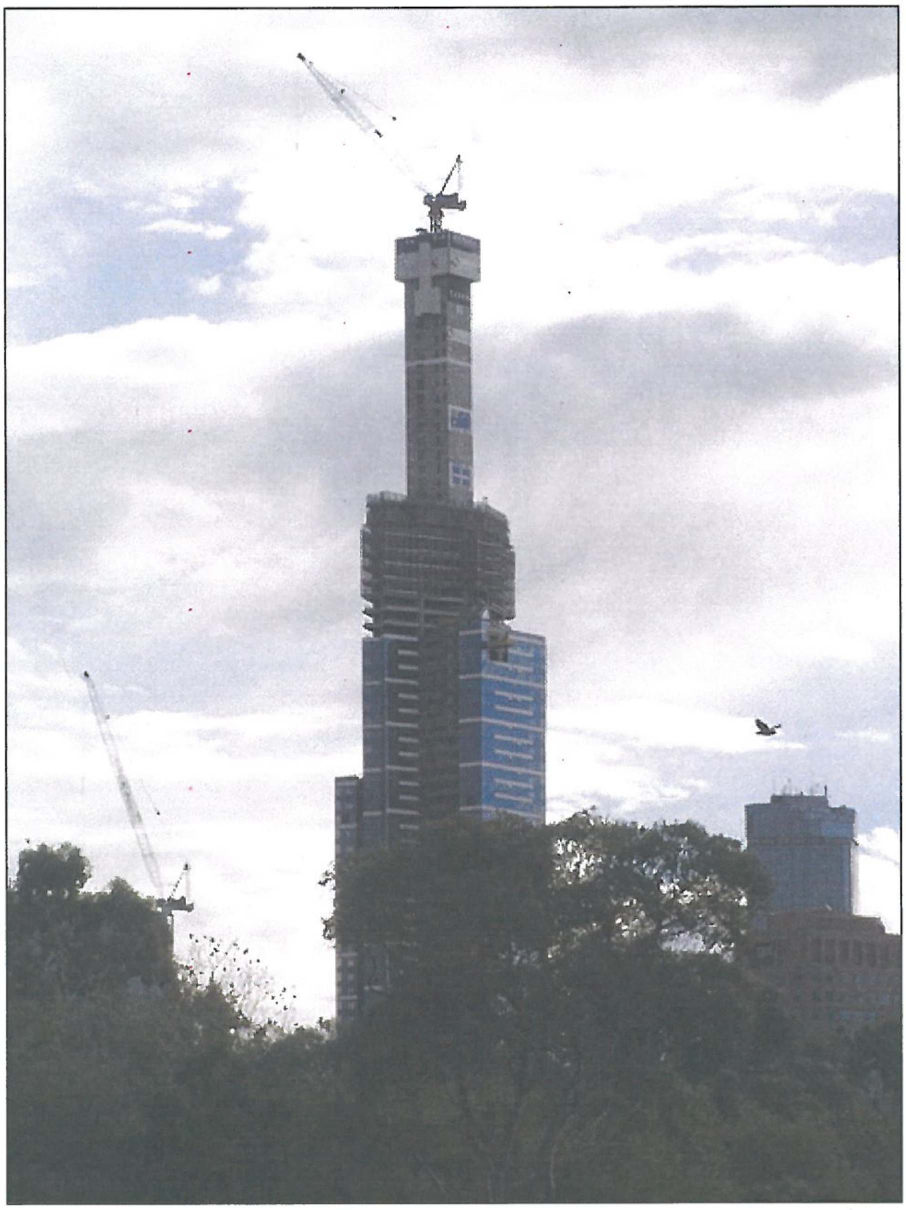

Figure 1A – Photo of approximate completion stage as at 3rd and 4th May 2005

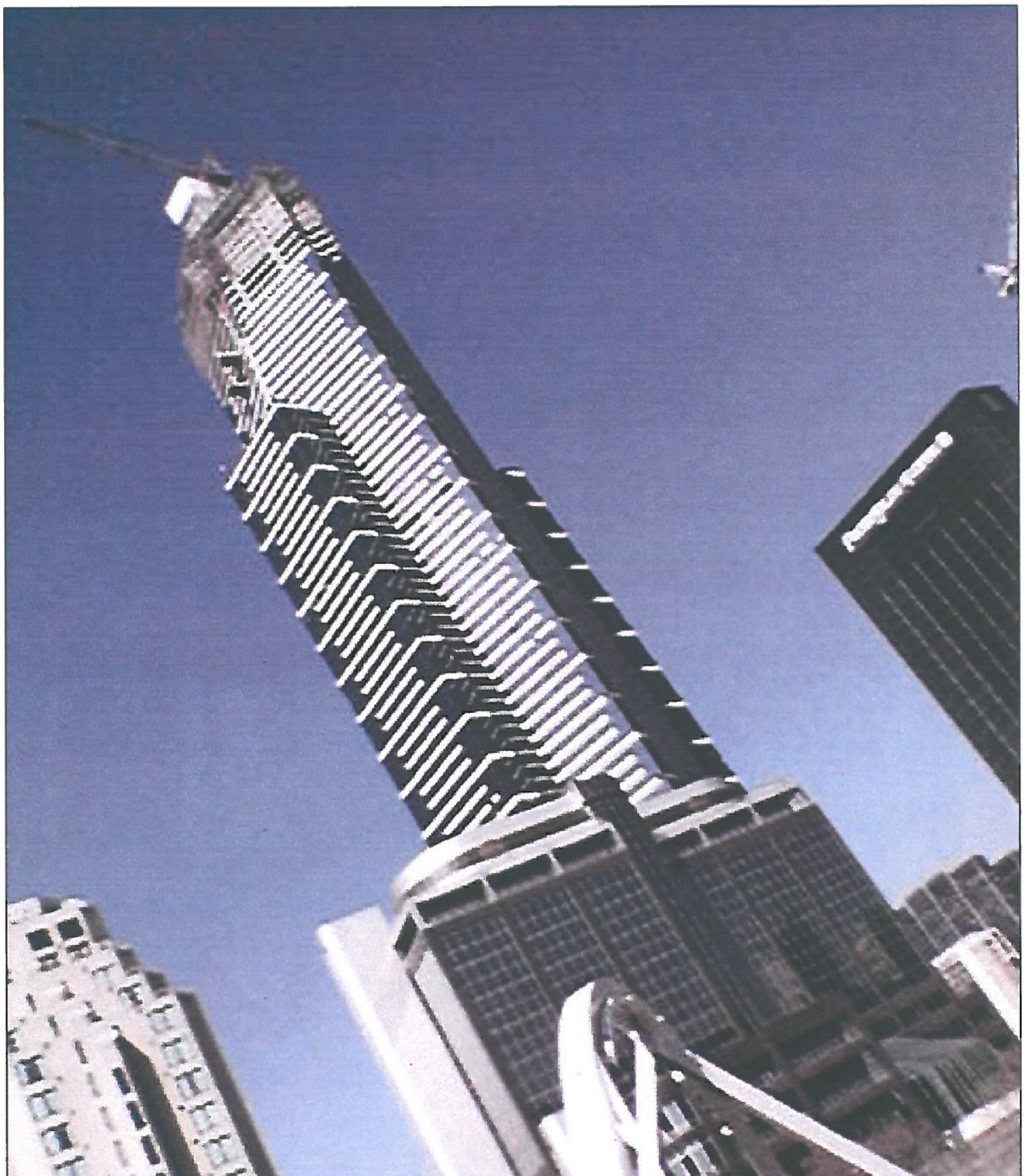

Figure 1B – Photo of approximate completion stage as at 25th August 2005

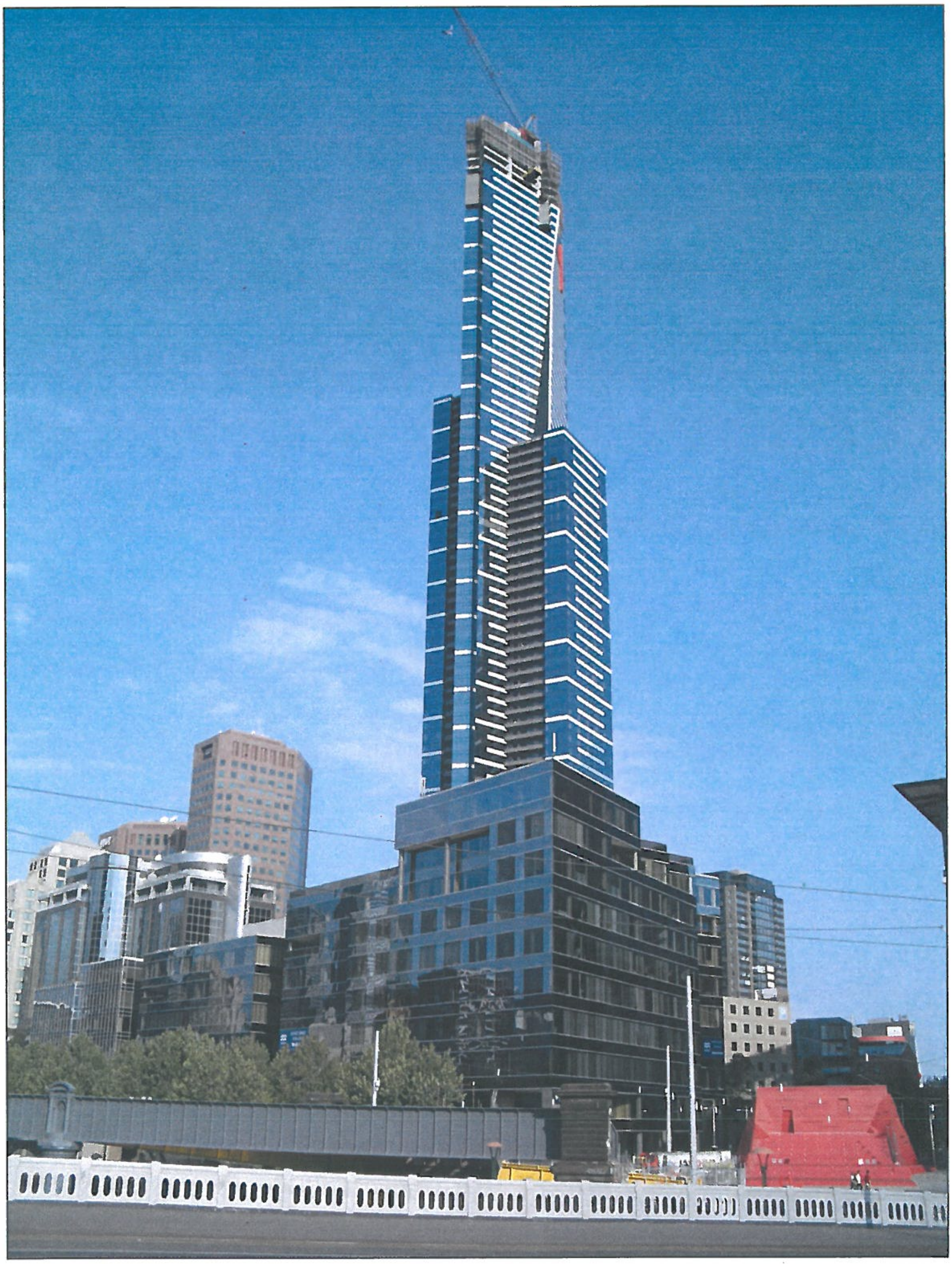

Figure 1C – Photo of approximate completion stage as at 30th January 2006

Figure 1D – Photo of approximate completion stage as at 30th January 2006

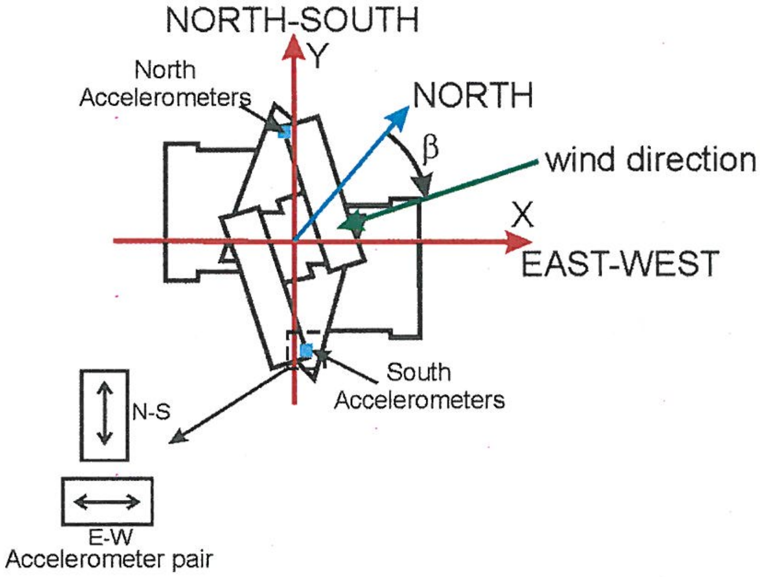

Figure 2 – Diagram of the accelerometer locations for Levels 54 and 69 and principle axes for Eureka Tower

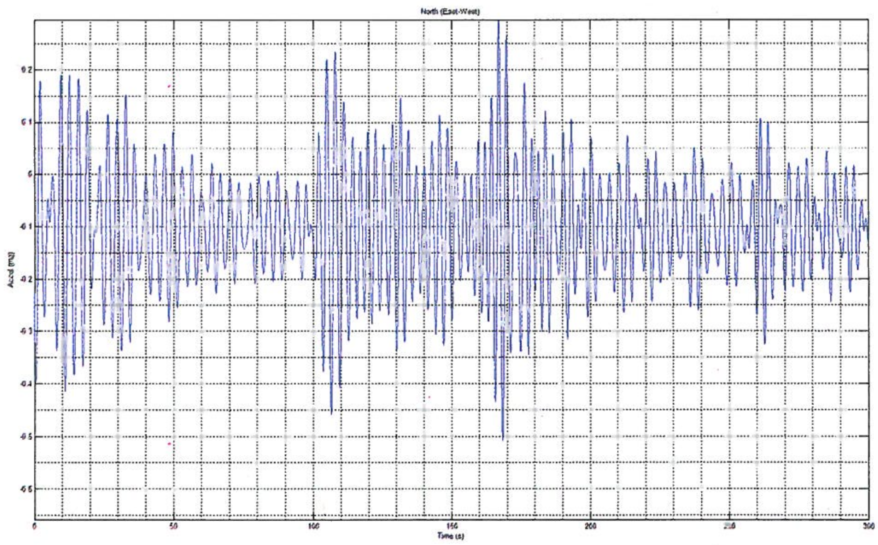

Figure 3 – Typical accelerometer traces from the 19th April crane drop excitation for the East-West direction

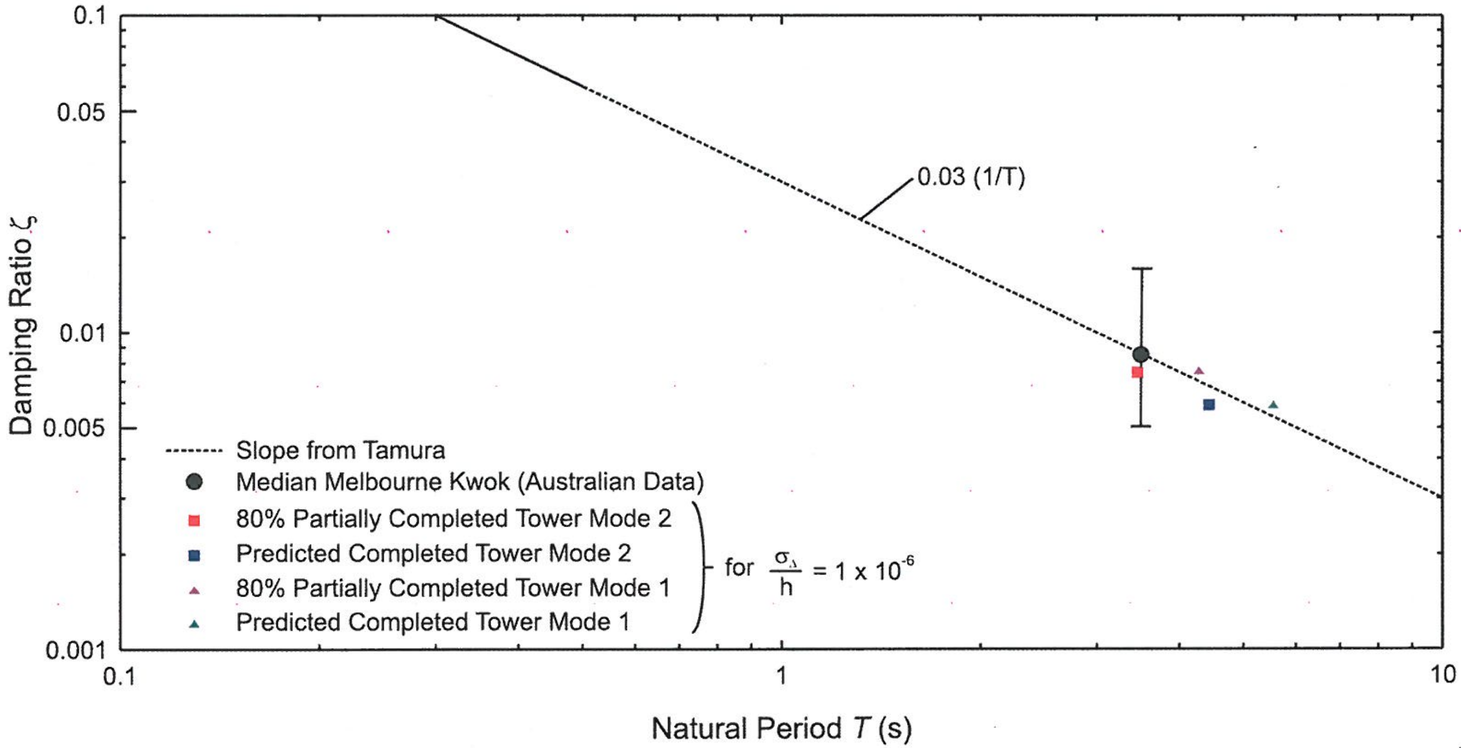

Figure 4 – Relationship between damping ratio and natural periods for reinforced concrete buildings

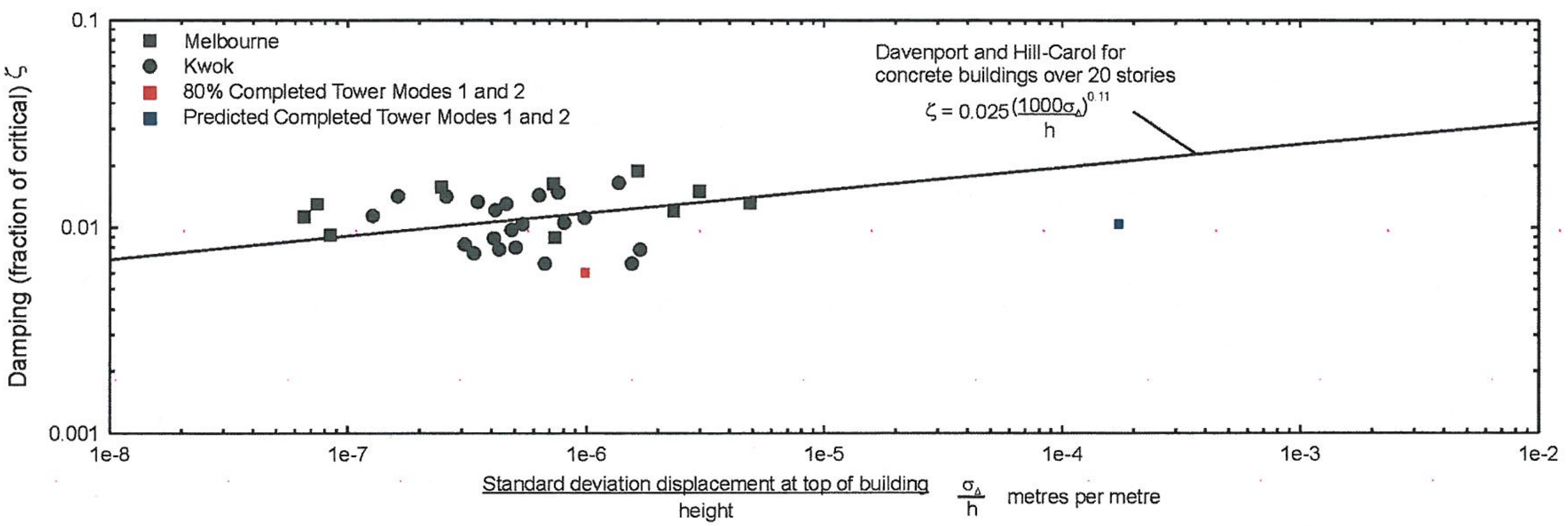

Figure 5 – Structural damping as a function of displacement/height for tall concrete buildings