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ANALYSIS OF WIND AND DYNAMIC RESPONSE DATA FROM FULL-SCALE TALL BUILDING IN LONDON

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Introduction

Wind actions are a main concern in the design of tall building, but still there exists uncertainty in these actions. Since there is a trend in recent years for tall buildings to become more slender, and hence more sensitive to wind-induced vibrations, understanding of these issues is becoming more important. Quantifying and identifying trends of modal parameters in a range of different wind conditions can achieve this.

Calculations of the dynamic response of tall buildings use assumptions of the damping, ultimately based on empirical data. Although wind tunnel tests are valuable in assessing the dynamic behaviour of structures, the full-scale damping is still uncertain and some aerodynamic effects may be affected by scaling issues. Therefore, data from measurements of full-scale tall buildings, such as estimates of damping and other modal parameters, are very valuable.

Tower & Monitoring System

- This project is based on a test case of a 47-floor and 150m-high tower in London.
- 3 accelerometers measuring vibrations at a sampling frequency of 61 Hz and 1 ultrasonic anemometer, with sampling frequency of 1 Hz, were installed on the top of the tower.
- 2 sensors monitored motion in the tower's local *x* direction, offset from each other and 1 sensor monitored motion in the local *y* direction.
- The effects of the wind on the structure were monitored from October 2017 to October 2018.

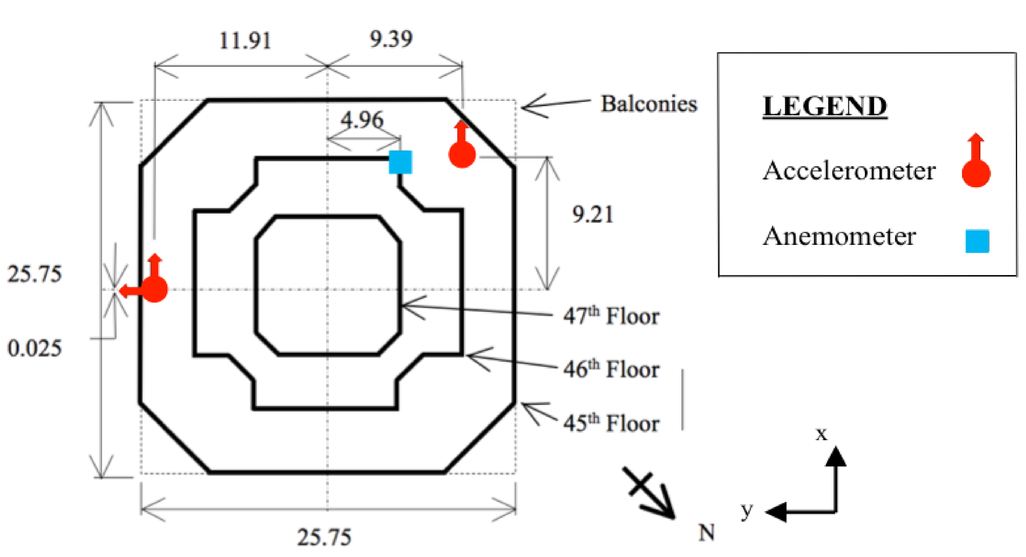

Figure 1. Plan of the top three floors of tower showing locations of instruments and local co-ordinate system (dimensions in m).

System Identification

From the 3 accelerometers on the 45th floor, the *x*, *y* and torsional components of motion were decomposed. The output power spectral density (PSD) of the structural acceleration response was estimated in MATLAB by using the modified Welch's periodogram. Fitting was performed using the Iterative Windowed Curve-fitting Method (IWCM) developed by [1] for estimating modal parameters from ambient vibration measurements. From the curve-fitting of the PSDs for the acceleration, the natural frequency and damping ratio of each mode were identified.

Estimated Modal Parameters

For each record the mean wind velocity was found and the modal parameters were estimated from the curve-fitting. Trends of natural frequency and damping ratio with Root Mean Square (RMS) acceleration amplitude, wind speed and time (only for natural frequency) have been identified.

NATURAL FREQUENCY

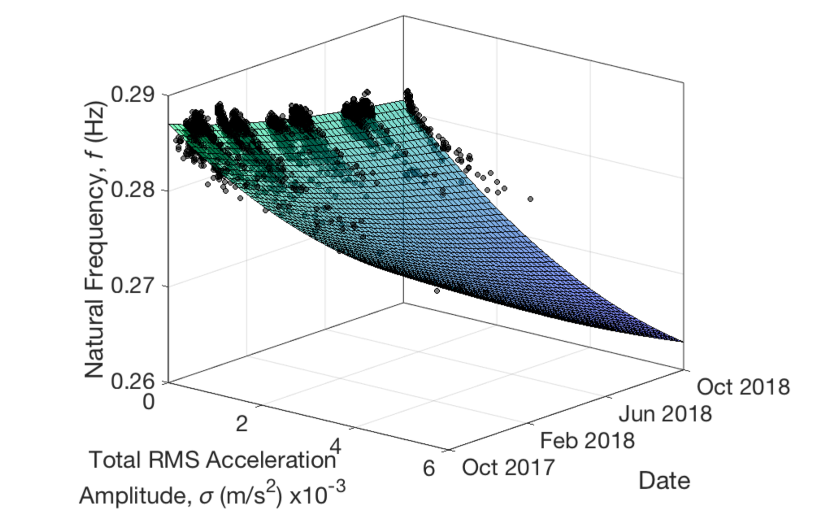

Figure 4. Relationship between first natural frequency and the corresponding RMS acceleration amplitude with respect to time in the *x* direction.

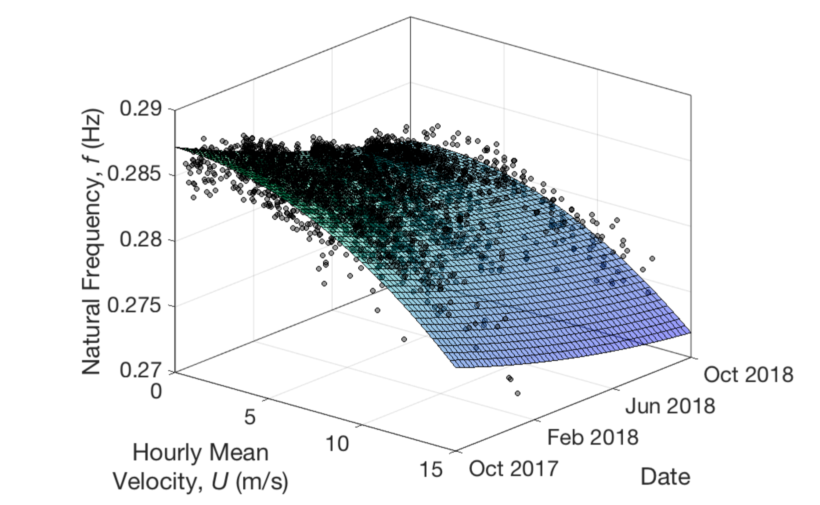

Figure 5. Relationship between first natural frequency and the corresponding 1-hour mean wind speed with respect to time in the *x* direction.

DAMPING RATIO

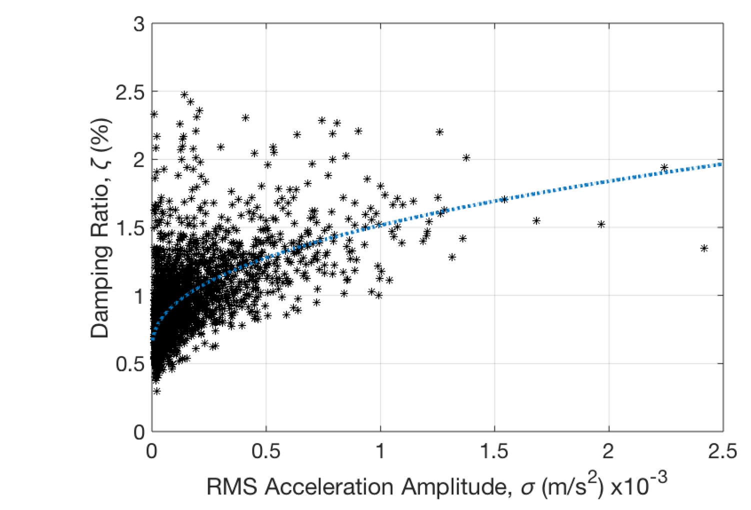

Figure 2. Relationship between damping ratio of the first mode and the corresponding RMS acceleration amplitude in the *x* direction

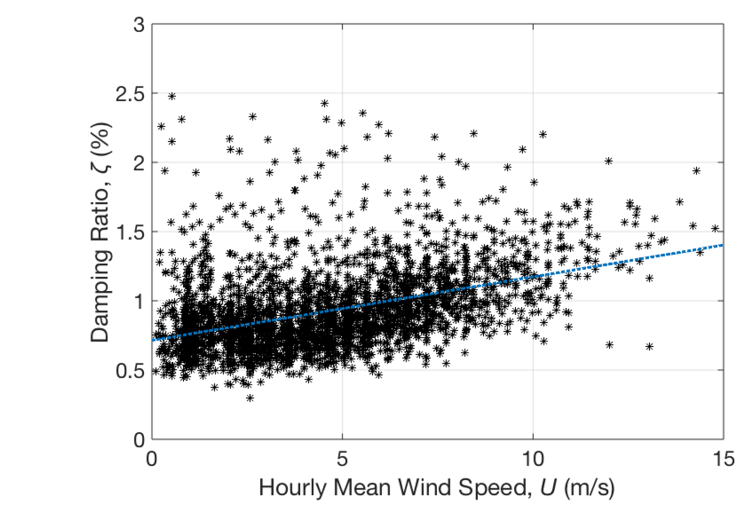

Figure 3. Relationship between damping ratio of the first mode and the corresponding 1-hour mean wind speed in the *x* direction.

Similar trends have been found for results corresponding to accelerations measured in the *y* and in the torsional direction.

Wind-induced Response Analysis

The RMS acceleration amplitude has been used to characterize the wind-induced response of the building. Significant decreases in the estimated natural frequencies of the structure were found with increasing wind speed and amplitude responses. The amplitude responses tend to increase monotonically directly proportional in logarithmic scale to the mean wind speed approximately at a cubic power rate approximately. This behaviour has been observed previously by [2], where some preliminary measurement results on this building were presented.

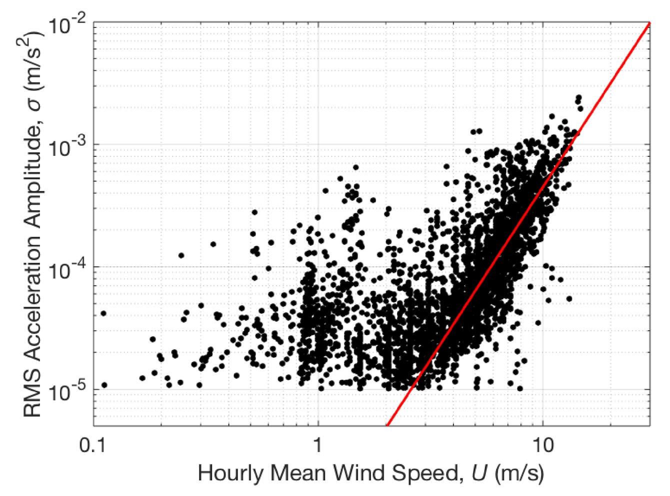

Figure 6. Relationship between modal RMS acceleration amplitude and the corresponding 1-hour mean wind speed in the *x* direction.

Conclusions

- Significant decreases in the estimated natural frequencies of the structure were found with increasing wind speed and amplitude responses in two orthogonal planes.
- Gradual decrease of natural frequencies during the full monitoring period has been assumed to be due to the increase in the mass of the structure.
- Although there is scatter between the individual estimates, damping has been found to be positive and gradually increases with an increase in wind velocity and amplitude for vibration in the first mode in two orthogonal planes.
- Damping ratio estimates from full-scale measurements in this building match relatively well with design values from codes and standards.
- The value of the design natural frequencies were underestimated by a 24 % compared to the results obtained from full-scale measurements.
- The acceleration amplitude responses tend to increase monotonically directly proportional in logarithmic scale to the mean wind speed approximately at a cubic power rate approximately.

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References

1. .H.G. Macdonald, Identification of the dynamic behaviour of a cable-stayed bridge from full-scale testing during and after construction, PhD thesis, University of Bristol (2000).
2. A. Margnelli, L. Greco, K. Gkoktsi, M. Leeks, J. Janssen, J. Macdonald and M. Zanchetta, Wind-induced response of tall buildings: Case study of a slender tall building in London, In Proc. 13th UK Conf. on Wind Engineering, Leeds, 2018.