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COMPARISON OF DYNAMIC CHARACTERISTICS OF A HIGH-RISE BUILDING UNDER AMBIENT VIBRATION, FORCED VIBRATION, AND EARTHQUAKE EXCITATION

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In this paper, the dynamic characteristics of a full-scale building is presented under various excitation sources, including forced vibration, ambient vibration and earthquake excitation. The testbed structure is a 13-story pile-supported concrete building that is the part of the School of Engineering in the University of Auckland, New Zealand. The building designed in 1964 is supported by 12 reinforced concrete columns around its perimeter and pre-stressed shear walls at its core.

In 2002, a forced vibration test was carried out on the building using an eccentric mass shaker in the machine room at roof level. The mass shaker was installed 1.77 m from geometric center of the building perpendicular to the north-south direction to excite both translational and torsional modes of the structure. Three different sets of vibration testing were performed on the building, including frequency sweep test and free vibration decay test to measure the natural frequencies and damping ratios and tests to obtain mode shapes in translational and torsional directions. LCF-100-14.5 uniaxial servo accelerometers with a range of ±0.25 g were used during the test to measure the structural vibration with a sampling rate of 1000 Hz.

In 2012, a series of ambient vibration tests was also conducted on the building using 49 Micro-Elecro-Mechanical System (MEMS) triaxial accelerometers. The sensors were installed throughout the building to measure the ambient vibrations induced by wind, traffic on the street and operational activities during two weeks of monitoring period. A sampling rate of 40 Hz was used, which was deemed appropriate for measurement of the first four modes of the building. It should be noted that during the monitoring period, the building was excited by a M 6.5 earthquake roughly 350 km away from the building and high-quality sets of earthquake-induced vibration were recorded. Therefore, during ambient vibration testing, three sets of vibration data, including wind dominated ambient vibration, traffic and operational activities dominated ambient vibration and excitation from a distal earthquake were recorded using the accelerometers.

The modal characteristics of the building, such as natural frequency, mode shape and damping ratio, were obtained from various vibration data sets using several system identification techniques in both time and frequency domains and subsequently several comparisons have been made between the results of each. The following conclusions could be extracted from the analysis results which could provide valuable information in the area of system identification and dynamic testing of large-scale civil structures.

1. The results showed that the natural frequencies and the corresponding modal damping ratios respectively decreased and increased as the level of excitation increased during forced vibration testing. Therefore, it can be concluded that

the amplitude of excitation force in forced vibration test could affect the accuracy of the dynamic characteristics of the structure.

2. The low-amplitude ambient vibration data sets induced by wind, operational uses and the subjected earthquake could present satisfactory estimation of modal characteristics for the first four dominant modes of the structure including the first two translational modes and first two torsional modes.
3. The modal parameters obtained using ambient vibration is comparable with those measured during forced vibration testing. This indicates that ambient vibration testing can be as accurate as forced vibration testing for dynamic characteristics estimation of large-scale structures.
4. The comparison between various system identification methods showed a strong correlation between the results of modal parameters. Both time and frequency domain techniques could develop very consistent estimation of modal parameters when used with output-only measurements from large-scale structures.
5. The analysis on the earthquake-induced signal indicated that although the near stationary part of the signal could accurately estimate the dynamic characteristics of the building, the non-stationary part of the signal provided a poor representation for all mode shapes. The results showed that further study is needed to evaluate the level of non-stationarity in the signal to ease the application of output-only system identification methods with non-stationary data.