Special issue on benchmark study on modal identifiability of large-scale structures

Preface

Over the past decades, modal identification of civil engineering structures based on ambient vibration measurement has been widely investigated for structural dynamic response analysis, model updating, and vibration-based structural health monitoring (SHM). A variety of output-only operational modal identification methods have been developed. However, in some circumstances deficient modes exist that cannot be correctly identified by ambient vibration tests, even in the case of fundamental low-order modes. The identifiability of modes when applying output-only modal identification techniques to ambient vibration responses was scarcely studied. It is helpful for attracting research interest of investigating the mechanism of output-only modal identifiability by establishing a benchmark problem to provide an open platform on this study. By referring to the same monitoring data, interested researchers worldwide have opportunities to verify their output-only modal identification techniques and explore the mechanism behind unidentifiability of deficient modes with the use of ambient vibration data.

A benchmark study on modal identifiability has therefore been developed by taking the instrumented Ting Kau Bridge (TKB) as a test bed. The TKB located in Hong Kong is a three-tower cable-stayed bridge with two main spans. A long-term SHM system has been implemented on the bridge in 1999 after the completion of its construction. Ambient vibration responses under different wind excitation conditions have been acquired from the online SHM system. Nineteen sets of vibration monitoring data including both non-blind and blind data have been uploaded to the benchmark study website and announced to the profession for investigation of modal identifiability and its mechanism.

A total of 8 peer-reviewed papers have been presented in this special issue. The first paper "Mode identifiability of a cable-stayed bridge under different excitation conditions assessed with an improved algorithm based on stochastic subspace identification" by Wu *et al.* elucidates that the identifiability of the second mode (a suspected deficient mode) is related to both wind and traffic excitations, and this mode can be stably identified under all the circumstances with the addition of tower measurements. The second paper "Mode identifiability of a multi-span cable-stayed bridge utilizing stabilization diagram and singular values" by Goi and Kim presents an investigation of the mode identifiability of TKB using stabilization diagrams obtained by the stochastic subspace identification technique, showing the feasibility of the cumulative contribution ratio (CCR) of singular values to assess the performance of output-only modal identification. In the third paper "Modal identifiability of a cable-stayed bridge using proper orthogonal decomposition" by Li and Ni, an adapted proper orthogonal decomposition with a band-pass filtering scheme is applied to obtain proper orthogonal modes (POMs), from which an energy participation factor is derived to determine a threshold to evaluate the identifiability of the deficient mode. In the fourth paper "Automated identification of the modal parameters of a cable-stayed bridge: Influence of the wind conditions" by Magalhães and Cunha, a ViBest/FEUP algorithm for automated data processing is presented, which succeeds to identify modes from the non-blind data and evaluate the modal identifiability and excitation level in regard to the blind data.

The fifth and sixth papers address the benchmark problem from the Bayesian prospective. In the fifth paper "Investigation of modal identification and modal identifiability of a cable-stayed bridge with Bayesian framework" by Kuok and Yuen, the Bayesian spectral density approach and Bayesian model class selection approach are investigated for modal identification and modal identifiability of the TKB. It is revealed that the credibility of the identified modes can be served as a reference to decide the monitoring wind condition. In the sixth paper "Mode identifiability of a cable-stayed bridge based on a Bayesian method" by Zhang *et al.*, a fast Bayesian FFT method is applied to derive the modal signal to noise (s/n) ratio which is used to evaluate the modal identifiability. The seventh paper "Wind and traffic-induced variation of dynamic characteristics of a cable-stayed bridge – Benchmark study" by Park *et al.* presents an estimation of the typhoon-induced variation of the dynamic characteristics of the TKB. The sensitivity of different types of modes to excitation level is particularly addressed. The eighth paper "Optimal reduction from an initial sensor deployment along the deck of a cable-stayed bridge" by Casciati *et al.* introduces a bio-inspired Firefly Algorithm to find the optimal deployment of a reduced number of sensors across the TKB deck and validates the modal identification capability of the optimal configuration without any significant loss of accuracy.

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