Special Issue on SHM Benchmark for High-Rise Structures

Preface

Structural health monitoring (SHM) is one of the most popular research areas in civil engineering community. Various structural health evaluation and damage detection methods have been developed by different investigators in the past two decades. However, the feasibility of these methods for real-world applications, especially for applications to large-scale structures, has been rarely examined. A gap still exists between the research and the practice in this field, which impedes broader applications of SHM techniques in civil engineering community. It is significant to establish an SHM benchmark problem in regard to a full-scale structure with the use of field measurement data, aiming to provide an international platform for direct comparison of various algorithms and methods. Thus the participants have opportunities to verify their SHM techniques using real-world monitoring data from a full-scale structure and recognize the obstructions in real life implementations.

Under the auspices of Asian-Pacific Network of Centers for Research in Smart Structures Technology (ANCRiSST), an SHM benchmark problem for high-rise structures has been established by taking the instrumented Canton Tower as a host structure. The Canton Tower assures a place among the supertall structures of the world by virtue of its total height of 610 m. It has been instrumented with a sophisticated long-term SHM system consisting of over 700 sensors of sixteen types. In the past five years the SHM system has successfully monitored seismic responses of the Canton Tower during more than ten earthquakes as well as wind properties around and structural responses of the tower during nine typhoons. The monitoring data are exceedingly useful for detecting anomalies in loading and response and assessing the structural integrity, serviceability, and safety. At this stage, 24-hour field monitoring data from 20 accelerometers, one anemometer and one temperature sensor, and a calibrated reduced-order finite element model of the Canton Tower have been uploaded to the SHM benchmark website and announced to over 250 researchers worldwide for the investigation of modal identification, model updating, force identification, SHM-oriented optimal sensor placement, and damage detection. The measurement data obtained during typhoons and earthquakes will further be shared with collaborators for advanced SHM investigations.

This special issue features a total of 11 peer-reviewed papers. The first paper "SHM benchmark for high-rise structures: a reduced-order finite element model and field measurement data" by Ni *et al.* is a pilot paper which outlines the SHM system deployed on the Canton Tower, the selected monitoring data, and the development of a reduced-order finite element model. The second to fourth papers address output-only modal identification of the Canton Tower. The paper "Operational modal analysis for Canton Tower" by Niu *et al.* presents the vector autoregressive models (ARV) method for operational modal analysis of the Canton Tower, and compares the identified modal parameters with those obtained by the data-driven stochastic subspace identification (SSI-DATA) algorithm, the enhanced frequency domain decomposition (EFDD) algorithm and the natural excitation technique based eigensystem realization algorithm (NExT-ERA). The paper "Modal identification of Canton Tower under uncertain environment conditions" by Ye *et al.* proposes an improved NExT-ERA for modal identification of the Canton Tower, and compares the identified modal parameters with those obtained by the EFDD and SSI-DATA algorithms. In the paper "SSA-based stochastic subspace identification of structures from output-only vibration measurements" by Loh *et al.*, the authors introduce a newly developed signal processing technique, called singular spectrum analysis (SSA), into the stochastic subspace identification (SSI) algorithm for modal identification of the Canton Tower. The fifth paper "Mode shape expansion with consideration of analytical modelling errors and modal measurement uncertainty" by Chen *et al.* presents a procedure for expanding mode shapes with the consideration of both the error in analytical model and the noise in measured modal data, and demonstrates the applicability of the proposed approach by using the field monitoring data from the Canton Tower.

The sixth to eighth papers explore finite element model updating of the Canton Tower by use of the identified modal parameters. In the paper "Finite element model updating of Canton Tower using regularization technique" by Chung *et al.*, the authors first identify the modal properties of the Canton Tower by using the frequency-domain decomposition (FDD) technique and the SSI algorithm, and then update the reduced-order finite element model by incorporating the L-curve regularization technique in the solution of an optimization problem. The paper "Update the finite element model of Canton Tower based on direct matrix updating with incomplete modal data" by Lei *et al.* proposes a direct matrix updating algorithm to update the reduced-order finite element model of the Canton Tower using incomplete identified modal information, in which neither model reduction nor modal expansion is required. In the paper "Updating finite element model using dynamic perturbation method and regularization algorithm" by Chen and Huang, the authors propose a novel dynamic perturbation method based on an exact relationship between the perturbation of structural parameters and the modal properties, and apply the proposed method for finite element model updating of the Canton Tower. The ninth paper "Structural health monitoring of Canton Tower using Bayesian framework" by Kuok and Yuen addresses the modal identification, model updating and detection of stiffness variation of the Canton Tower in Bayesian framework. The Bayesian spectral density approach is used for output-only modal identification and uncertainty quantification; the finite element model updating is then conducted in the context of Bayesian inference; and finally the Bayesian framework is applied to the field monitoring data to investigate the variation in stiffness parameters. The tenth and eleventh papers address SHM-oriented optimal sensor placement for the Canton Tower. The paper "Sensor placement for structural health monitoring of Canton Tower" by Yi *et al.* presents a dual-structure coding based generalized genetic algorithm for sensor placement optimization of the Canton Tower, in which only translational degrees-of-freedom (DOFs) of the structure are taken as the slave DOFs in consideration of difficulty in measuring rotational DOFs. In the paper "Information entropy based algorithm of sensor placement optimization for structural damage detection" by Ye and Ni, the authors formulate a multi-objective optimal problem in terms of information entropy for sensor placement optimization of the Canton Tower, and compare the damage localization results obtained from the optimally determined sensor placement configuration and from the existing in-service sensor network deployed on the Canton Tower.

As the Guest Editor of the special issue, I would like to express my sincere appreciation to all the authors who contributed their work to this special issue and the reviewers for their contributions in shaping this issue. The Guest Editor would also like to express his whole-hearted thanks to the Editors-in-Chief of SSS, Prof. C.K. Choi, Prof. J.M. Ko, Prof. B.F. Spencer, Prof. F. Casciati, Prof. C.B. Yun, and Dr. S.C. Liu for their kind guidance and support leading to success of this special issue.

Guest Editor: Yi-Qing Ni
Department of Civil and Structural Engineering
The Hong Kong Polytechnic University, Hong Kong
Email: ceyqni@polyu.edu.hk