Special Issue on Real-world Application of Structural Identification and Health Monitoring Methodologies

Guest Editors: Babak Moaveni1, Stefan Hurlebaus2, and Franklin Moon3

1 Dept. of Civil and Environmental Engineering, Tufts University, Medford, MA
2 Zachry Dept. of Civil Engineering, Texas A&M University, College Station, TX
3 Dept. of Civil, Architectural and Environmental Engineering, Drexel University, Philadelphia, PA

Although the importance of civil infrastructure is universally recognized, the funding to maintain the U.S. system has proven insufficient over the last several decades. As has been reported recently by ASCE, an estimated $2.2 trillion is needed to bring the country’s overall infrastructure up to good working order. While the increase in infrastructure funding that will accompany this attention is welcome, it will likely be insufficient. Owners will continue to face budget shortfalls and continue to turn to the civil engineering profession to provide them with the tools needed to inform allocation decisions for their limited resources.

Currently such decisions are based on engineering heuristics and visual inspection procedures, which are qualitative in nature and have shown to be highly variable and potentially unreliable in addition to being insufficient for prognosis. Structural Identification (St-Id) refers to the process of system identification – to realize a numerical model of a dynamic system based on its measured response – with emphasis on assessment of a structure’s health and performance as well as decision making regarding its maintenance and/or rehabilitation. Similarly, Structural Health Monitoring (SHM) refers to the process of damage identification – to detect, localize, quantify and in some cases to predict the remaining life – and health assessment of a structural system. Over the last decade or so there have been significant advances in sensing and simulation technologies as well as in the paradigms of St-Id and SHM which aim to leverage such tools to inform decisions. To benchmark these advances, in 2011 the ASCE SEI Committee on Structural Identification of Constructed Systems prepared a state-of-art report titled “Structural Identification of Constructed Facilities: Approaches, Methods and Technologies for Effective Practice of St-Id”. In addition to structuring the paradigm and documenting the current state-of-the-art, the report also highlights the need to close the gap between applications of St-Id and SHM methods to small-scale models in the laboratory and successful applications to actual real-world structures in the field.

To help bridge this gap, the objective of this special issue is to promote applications of St-Id and SHM on actual operating infrastructures by highlighting recent advances and documenting successful “real-world” applications. While many researchers have successfully developed and applied various St-Id and SHM approaches to numerical and/or small scale lab models of civil structures, to date such demonstrations have not compelled widespread applications in the field. Although by comparison there have been few actual applications to full/large-scale real-world structures, such applications do exist and should be widely disseminated. Field applications allow the various approaches to be examined under realistic instrumentation constraints, levels of measurement noise, mechanisms of uncertainty, and especially modeling errors, and as such are likely to be more compelling and to spur on wider-spread applications.

The special issue includes two forum papers and twelve technical papers. In the first forum paper, Aktan and Brownjohn articulate the state-of-the-practice of civil engineering and the pressing needs for greater applications of SHM to properly selected constructed systems. The second forum paper by Catbas and Kijewski-Korrea overviews the latest ASCE-SEI report on structural identification of constructed facilities.
The first technical paper by Im et al. provides a review of GPS technology application in structural health monitoring (SHM). The second technical paper by Moaveni et al. presents a study on the identification of progressive damage, using an equivalent linear finite element model updating strategy, in a large-scale masonry infilled reinforced concrete frame that was tested on the UCSD-NEES shake table. Kijewski-Correa et al. introduce a SHM system which utilizes the building’s existing Internet backbone as a system of “virtual” instrumentation cables to permit modular and largely “plug-and-play” deployments. This study overviews the installation/operation of the developed system in the world’s tallest building, Burj Khalifa, and proof-of-concept in triggering under dual excitations (wind and earthquake). Paper by Kurata et al. reports on the development of a novel wireless SHM system specifically tailored for large-scale civil infrastructure systems by architecturally combining dense wireless sensor networks with a suite of information technologies remotely accessible by the Internet. The monitoring system architecture is validated on the New Carquinez (Alfred Zampa Memorial) Bridge, a long-span suspension bridge, in Vallejo, California.

Gokce et al. illustrate the use of a family of models to incorporate the uncertainties and make predictions in terms of load rating and system-level reliability based on SHM data. The methodology is applied on a bascule bridge in Florida. Goulet and Smith propose a method to determine to what degree measurement data are useful for structural identification. The method is applied to the measured data of the Langensand Bridge in Switzerland. Soliman et al. propose to integrate the SHM data into a probabilistic bi-linear S-N approach for fatigue assessment and service life prediction of existing fatigue-prone steel bridges. The proposed method is applied on an existing steel bridge. Soyoz et al. investigate the effects of seismic retrofitting on the modal characteristics of a six-story reinforced concrete building located in Istanbul, Turkey. The building was retrofitted via jacketing of columns, addition of structural walls, and construction of a mat foundation. Paper by Chang and Pakzad presents a method to improve the computational efficiency of the Natural Excitation Technique combined with Eigensystem Realization Algorithm. The method is then applied for modal identification of the Golden Gate Bridge using a dense wireless sensor network. Stull et al. present the development and testing of a SHM system capable of identifying damage to critical components of the RAPTOR telescopes in real-time and providing that information to telescope operators, in order to improve the scheduling of maintenance procedures and lower the lifecycle costs of the telescopes. Bell et al. propose an objective load rating protocol that includes structural modeling and SHM data. The proposed load rating was computed for a steel girder bridge in Massachusetts. Finally, the last paper by Yang and Nagarajaiah formulate the blind source separation method into a time-frequency framework with improved accuracy for modal identification. The method is applied for identification of a three-story frame in the laboratory.

The guest editors wish to thank Dr. Emin Aktan, the former chair of the ASCE Structural Identification technical committee, for initiation and support of this special issue and Dr. Sherif El-Tawil, Editor of the ASCE Journal of Structural Engineering, for his supervision and assistance in producing this special issue.