INTERNATIONAL SOCIETY FOR STRUCTURAL HEALTH MONITORING OF INTELLIGENT INFRASTRUCTURE

ISHMII Membership Notes
April-May 2013

Vol. 3 Issue 4

President's Letter

Dear Society Members and Colleagues,

ISHMII’s corporate membership represents the leading firms, research institutions and government agencies involved in a full spectrum of infrastructure health monitoring. With each corporate membership, organizations have the ability to involve up to four members in ISHMII’s work. It broadens that organization's ability to reach colleagues around the world – all part of the exchange of knowledge that is a foundation of ISHMII’s mission.

This month, ISHMII invited two of our corporate members to contribute research reports for *Membership Notes*. For that reason, we are publishing a longer issue of *Membership Notes* for April-May 2013. I am pleased to share these interesting reflections on the application of both commercially available and proprietary devices and processes to their domestic and international SHM projects. COWI, an international market leader in bridge engineering, located in Denmark, explains how it is connecting development of an SHM system for a long span bridge with graduate student research at a university in the UK. SMARTSENSYS, an Illinois-based firm with exceptional expertise in wireless sensing systems for geriatric infrastructure, focuses here on non-wired sensing technologies for SHM and NDE that includes the interesting use of drones.

I thank Jacob Egede Andersen, Ph.D., Head of Dynamics, Bridge, Tunnel & Marine Structures at COWI and Paul Sumitro, Ph.D, P.E., M.B.A, Founder and President of SMARTSENSYS and a long-time, well-respected member of the ISHMII Council, for their contributions. We are proud of the vision of all of our corporate members as they are at the heart of advancements in SHM and are committed to diverse aspects of SHM, and invite all corporations and organizations to explore a corporate membership in ISHMII.

Linking a New Bridge in Turkey with Graduate Research in the UK

COWI has a long tradition as the designer of some of the world's most challenging bridges. The hundreds of bridge projects around the world that it has designed and also been in charge of structural health monitoring systems or testing by monitoring range from the world’s longest road and rail spans to modest pedestrian crossings. Some examples include the

Stonecutters Bridge in Hong Kong, Great Belt Bridge in Denmark, Puente Nigale, which is under construction in Venezuela, and Fisketorv pedestrian bridge across Copenhagen Harbor. As part of its bridge design services, COWI has two groups working on structural dynamics within the Bridges International department at COWI Denmark and Flint & Neill in the United Kingdom. One of their areas of expertise is the design of Structural Health Monitoring Systems (SHMS) for the large cable supported bridges that the company designs.

Over the past 30 years, COWI has completed projects from the total design of SHMS for new and existing structures to planning, installation, testing, and trouble-shooting. Throughout, COWI has developed state-of-the-art methods for integrating SHM data with maintenance management systems based on probabilistic approaches.

The New Izmit Bay Bridge

Currently, COWI is a consultant for the Japanese contractor IHI, which is building a bridge spanning the Izmit Bay in Turkey, and has been awarded the contract for the detailed design of the bridge in cooperation with IHI. Upon completion, the bridge will be the world's fourth longest suspension bridge and part of a new, extended highway system linking the metropolitan areas of Izmir and Istanbul.

The bridge is an extremely complex project with a free span of 1,550 m between its pylons and a total length of about three kilometers. The pylons will be made of steel and be 250 m high.

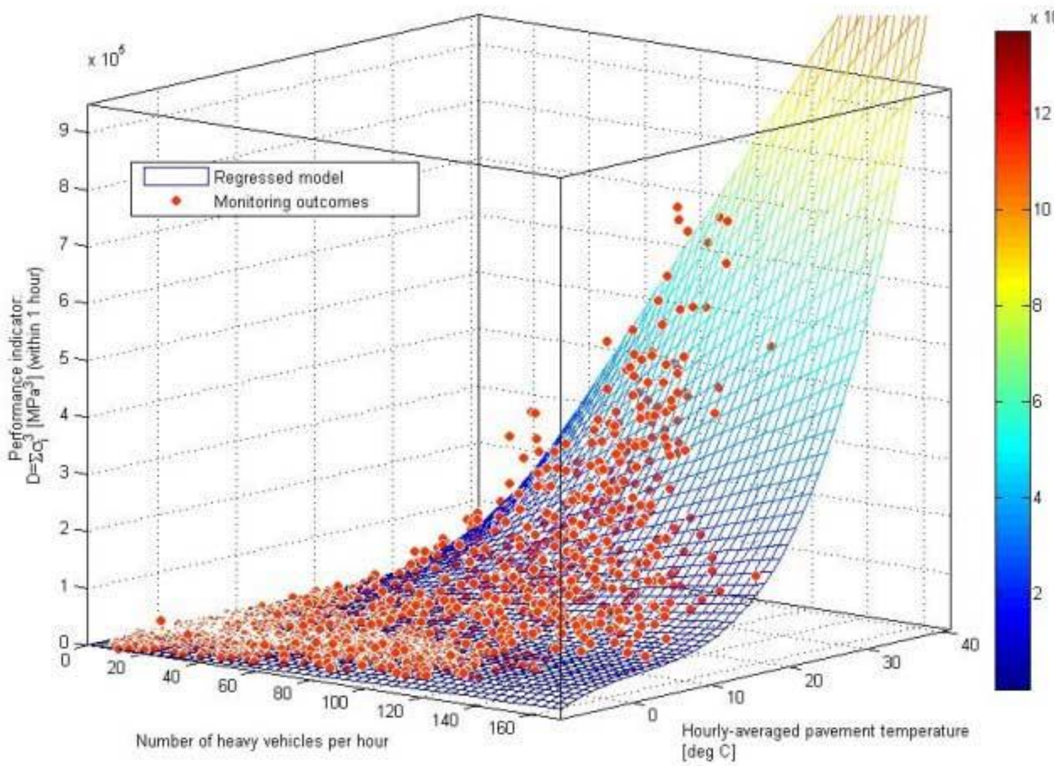
The SHMS of the New Izmit Bay Bridge illustrates both the challenges and benefits of modern SHMS on long-span bridges. First, since the bridge will be built in a zone with high seismic activity, the tower foundations are designed with seismic fuses in order to make the tower slide in case of large earthquakes. With considerable vessel traffic in the navigation canal, ship impact is a major consideration as well - the SHMS must provide safety assessments in case of earthquakes or collisions. Second, the SHMS will be designed to assist in both improved control and maintenance planning. Third, there is a risk of overloaded heavy vehicles. Due to this, the SHMS will provide data for the development of models for performance assessment and the simulation of the welded joints of the orthotropic steel deck in order to update the remaining fatigue life estimates. This approach is based on an ongoing research project.

Apart from design activities, COWI is participating in the European research project SmartEN or Smart Management for Sustainable Human Environment (www.smarten-itn.eu). Funded by the European Commission, the aim of SmartEN is to move forward the state-of-the-art in the development, integration and application of sensor technology in these specific sectors: wireless sensor networks, sensor signal processing, non-destructive evaluation, and smart proactive management. COWI is mainly involved in the non-destructive evaluation (NDE) work program, which tackles relevant research areas of SHM including optimum sensor locations and requirements, combined monitoring and inspection systems, assessment and long-term performance modeling, performance model updating based on sensor information, and damage identification.

COWI's research work within the SmartEN project led to a collaborative Ph.D. research project with the University of Surrey (UK) that focuses on the development of data-based predictive models for performance assessment of welded joints in orthotropic steel decks considering strains monitored at critical details, pavement temperatures and traffic levels.

Strain gauges at welded joints of an orthotropic deck

Model parameters are estimated using 'real-world' data acquired from the SHMS of Denmark's Great Belt Bridge, a long-span suspension bridge with a main span of 1624 m. The world's third longest main span, the longest outside of Asia, it provides an excellent platform for model development and detailed investigations. Once developed, these models can be used to interpret new sets of monitoring data to detect abnormal responses and to predict future performance profiles. Those, in turn, can be used to compute updated fatigue life estimates.



Example of a data-based model using monitoring data from a welded joint

The research findings so far have demonstrated good agreement between model-based predictions and performance profiles derived using monitoring data. COWI believes that the development of data-based models for the performance prediction of deteriorating infrastructures will contribute to and further develop the theoretical framework in which to integrate monitoring outcomes and assess the benefit of SHM approaches in support of management strategies for civil infrastructures.

Currently COWI is also developing SHMS for cable supported bridges in South America.

Information on the many projects at COWI can be found on its homepage www.cowi.com. And, test drive the Izmit Bay Bridge via video.

Remote Sensing Technologies, Drones Included, Aid Rational Decision-making

SMARTSENSYS assists engineers and owners to obtain structural assessment information through smart or intelligent sensing systems that support rational decision-making in a strategic infrastructure maintenance scheme. As infrastructure continues to age and becomes a more complicated system, its behavior changes. In these cases, traditional sensing methodologies have limits that pose a significant challenge to engineers during structural inspections, load rating and the overall safety assessment of these geriatric structures. Even though current conventional approaches may have met the needs of the owners, a number of situations have shown these as insufficient. In recent years, engineers and infrastructure owners have started to embrace smart technologies and sensing techniques in planning, evaluation and monitoring of their most at-risk assets. Typically, these are the most geriatric signature structures that cannot be replaced or where the replacement would require several years during which structure functionality would have to be retained. The appropriate technology for decision-making, and real-world examples, helps to mitigate the risks associated with infrastructure serviceability and safety.

Remote sensing technologies exhibit higher accuracy, compact features, high durability, and minimize power consumption, features that are beneficial to the structure owner. Two remote sensing technologies used by SMARTSENSYS are highlighted here: Smart wireless sensors and GPS-based UAV drone sensing technology.

Smart wireless sensors and their system network

A smart wireless sensing system consists of sensors, data collector and controller. Commercially available wireless sensors are small, easy and fast to install on steel, concrete, masonry and timber surfaces such as those on bridges, high-rise building, seawalls, and tunnels, during or post-construction. Data collectors can be either a low power SW Collector that can communicate up to one thousand sensors making data accessible anytime and anywhere through CDMA and/or GPRS cellular providers or a USBS link that facilitates direct connection with a computer. The software controller is designed for real-time structural monitoring, automated structural diagnostic and alert generation, without continuous human intervention.

Types of Sensors and Their Range and Resolutions

Type	**Range and Resolution**
Strain gage	Resolution: 1 μstrain
Accelerometer	Resolution: 1mg, adjustable range: $\pm 2g$, $\pm 4g$, $\pm 8g$
Tilt-meter	2 types: HP (high precision) with 0.00014°resolution; and P (precision) with 0.003°resolution
Crack-meter	Range: 25mm, resolution: 0.1mm
Humidity/Temperature	Resolution: 1%RH ／0.5°F
Displacement sensor	Range: 25mm or 50mm, Resolution: 0.1mm
MMP	2 types: MMP25, range: 0-25mm, resolution 1% (full scale); and MMP50, range 0-50mm, resolution 1% （full-scale）
	Smart Wireless Sensing System Specification
Adjustable sampling rate	0.0001Hz – 100Hz
Working temperature	-40 to 105 °F
Communication distance	1.3km (free space); 300m (bridge trusses, beams, etc.)
Embedded battery	Li-Ion battery (in case of steady state monitoring, life time can be 20 years minimum)
Sensor weight/size	45gram/1.3” x 3.5” x 0.55” or W35mm, L75mm, T15mm
SW Collector’s power	Solar panel

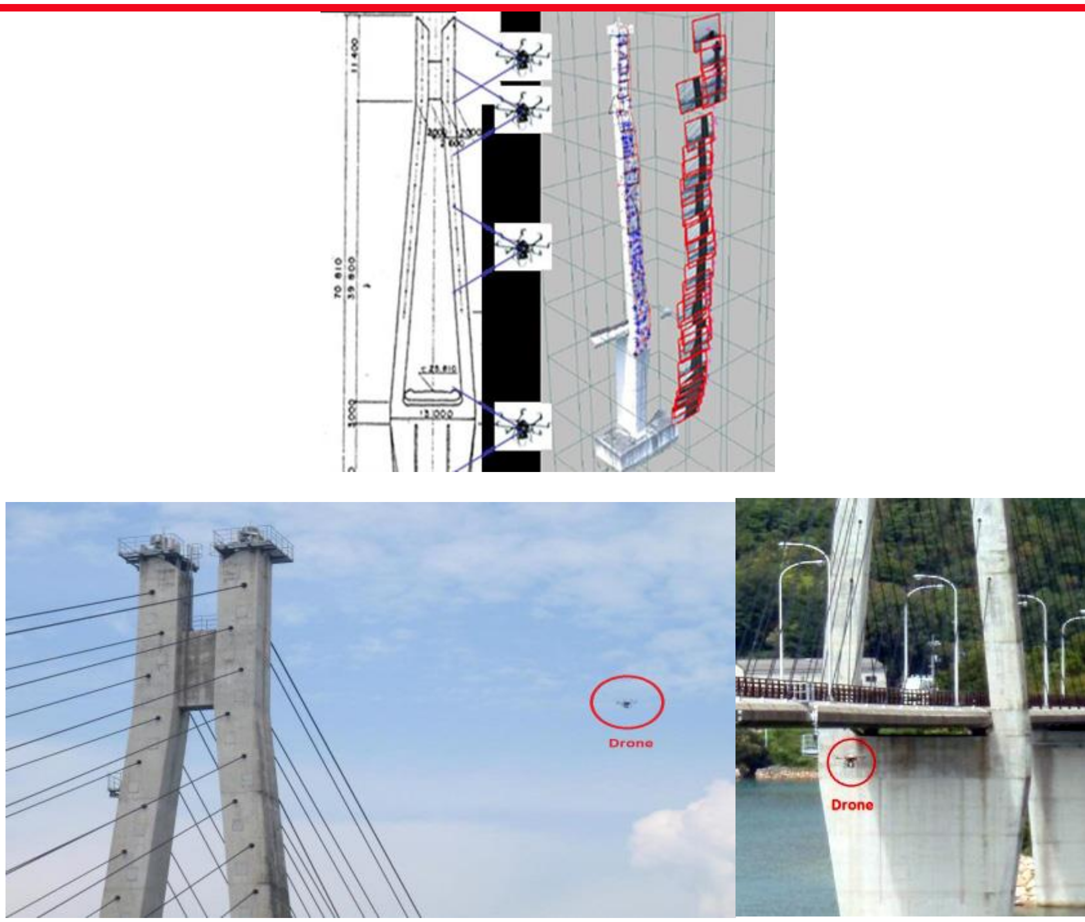
Full stress monitoring system during erection at Morgan Street Bridge

During the erection of the tie girder of the Morgan Street Bridge over the Rock River in Rockford, Illinois, 12 wireless strain gauges installed at the critical locations for a full stress monitoring system showed that they accurately monitored the strain change. The data were recorded every 30 seconds, monitored remotely and quickly interpreted on-line without any interference during the construction process. Since the data was readily understood by the field engineers and contractor, this system provided added safety. The wireless sensors are immune to the signal data quality degradation normally associated with long wiring runs. Furthermore, alerts can be provided through email or text messaging based on the client's desired setting. And, as the data is stored on a cloud server, it is readily accessible anytime, anywhere with the internet connections.

Smart wireless tilt-meters were applied to the Pasopati Bridge, Indonesia, to evaluate the functionality of the Lock Up Devices (LUD). The LUD provides a temporary rigid link between the deck of a bridge and its supporting abutments and piers, so that under fast acting and short duration seismic, traction, braking, or collision forces, the load is shared between the supports. If for some reason, the LUD does not work properly, the impact load may not be redistributed and this could change the curvature of the bridge pier. To mitigate this eventuality, wireless sensors are combined with fiber optic displacement sensors to measure lateral bridge deformation at the adjacent piers. For this specific application the wireless sensors are designed to be detachable - reusable, unfastened or disconnected without damage.

A GPS-based remote optical monitoring system has been developed by SMARTSENSYS, integrating three technologies: advanced HD camera capturing technology, digital image processing technology and an advanced GPS navigation system. This sensing system can be attached to a drone or an UAV (Unmanned Aerial Vehicle).

The waypoints are set using the GPS to compel the UAV to automatically fly over the desired sensor locations. Combined with a reference real time kinematic GPS (RTK-GPS), the UAV can be directed to return to the original location with an accuracy of several centimeters. The applicability of this system was confirmed through its deployment with numerous types of bridges including the tower and bridge deck of the Asa and Oshiba Bridges at Hiroshima, Japan.



UAV sensing application at Oshiba Bridge, Hiroshima, Japan. Top: Shooting formation along the tower; Bottom: (Left) UAV at a distance of 20m from the tower and (Rifht) UAV capturing images at bridge deck.

A video of a drone at work can be viewed at http://smartsensys.com/Drone_Sensing.php.

Integrating the advanced HD camera capturing technology with 3D orthogonal digitized image processing, crack width can be captured with accuracy better than 0.1mm and be analyzed and displayed by a crack recognition system (CRS). This intelligent system can perform infrastructure inspection at both micro and macro scales - an asset management scheme that captures critical structural parameter changes, e.g., crack distribution.

Additional information and videos are available at the SMARTSENSYS home page www.smartsensys.com and http://www.smartsensys.com/Wireless_Sensor.php.

I invite you to contact Jacob Egede Andersen, Ph.D. at JCA@cowi.dk and Paul Sumitro, Ph.D. at sumitoro@gmail.com to discuss their projects and research, and to visit their home pages.

ISHMII has two important meetings this year. I invite those of you whose work touches the life-span of bridges to attend CSHM-5, a workshop on the structural health monitoring and maintenance of short-& medium-span bridges, in Japan in October. Then, we gather for SHMII-6, our international Society Conference in December in Hong Kong, on December 9 to 11, 2013. I encourage you to make your plans to attend now.

The *Journal of Civil Structural Health Monitoring* welcomes your research submissions. *JCSHM* Volume 3, Issue 1 is available on-line. Members may log in through the ISHMII.org Web site to read the *Journal*. Non-members are invited to peruse the

JCSHM Index and read abstracts.

I hope this motivates you to become an active member of ISHMII.

In closing, I urge all our colleagues to renew their individual, student or corporate membership. Your financial contributions make it possible for ISHMII to thrive and fulfill its mission.

With warm wishes,

Farhad Ansari, President

FAnsari@uic.edu

Articles published in *Membership Notes* may be cited as follows: Name(s) of the authors, (Year), "*title of the article*," ISHMII Membership Notes, Vol. No., Issue No., pp.

Thank you to Dr. Jacob Andersen and Dr. Paul Sumitro for the providing graphics and photographs used here. Dr. Sumitro extends his thanks to Keisoku Research Consultant Co. for use of the photo of the UAV sensing application at Oshiba Bridge.

ISHMII INTERNATIONAL WORKSHOP & CONFERENCE

CSHM-5 (2013)

October 24-26, 2013

CSHM-5 focuses on the structural health monitoring and maintenance of short & medium-span bridges including rational health monitoring system using a moving vehicle (truck, bus, train, etc.) to collect data and maintenance strategies.

CSHM-5 (2013) will discuss developing an IT-based bridge health monitoring system that incorporates the latest information technologies for lifetime management of existing bridges, and how to manage a data collecting system designed for successful bridge health monitoring.

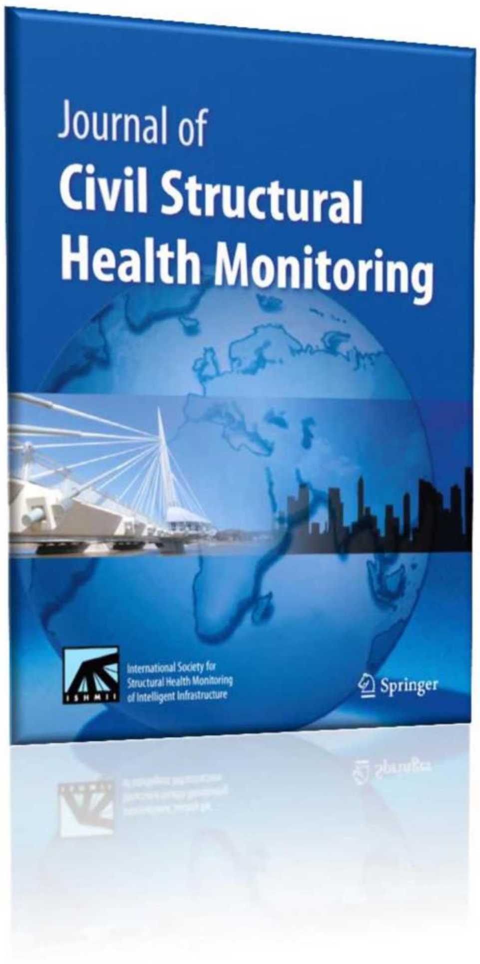
Information is available at

http://civil.design.csse.yamaguchi-u.ac.jp/CSHM-5/index.html

6th International Conference on Structural Health Monitoring of Intelligent Infrastructure (SHMII-6)

Make Your Plans to Attend!

[Visit the SHMII-6 Website]



Curious about the *Journal of Civil Structural Health Monitoring?*

Investigate the **Abstracts** here.

You may submit research articles through the *JCSHM* Editorial Manager

Volume 3, Issue 1, February 2013 is available to ISHMII members who have logged in to their account at ISHMII.org.

WORKSHOPS AND CONFERENCES

2013

THE MONITOR

7NSC 2013
Oakland, California
May 20-22, 2013

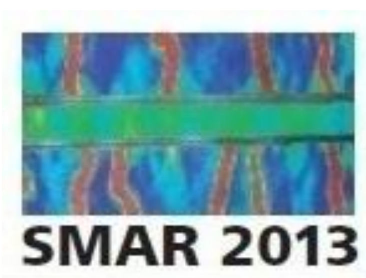
7th National Seismic Conference on Bridges & Highways

Additional information is also available from Jerome O'Connor, P.E., Conference Coordinator at conf7NSC@buffalo.edu.

ISHMII is Proud to be an Outreach Partner of 7NSC.

ICSBOC - 2013
8th International Cable Supported Bridge Operators Conference
June 3-5, 2013
Edinburgh, Scotland, UK

The only event hosted by and for owners and operators of the world's major bridges.



SMAR 2013
Istanbul, Turkey
September 9-11, 2013

2nd Conference on Smart Monitoring, Assessment and Rehabilitation of Civil Structures.

2014

Build ISHMII by Contributing to *The Monitor*

Brief research articles suitable for publication in *The Monitor*, ISHMII's e-magazine, are now being solicitated.

Please submit articles through Sreenivas Alampalli, Ph.D., Editor-in-Chief, or the members of the Editorial Board.

CONTACT ISHMII

www.ISHMII.org

ISHMII President
Farhad Ansari, Ph.D.
University of Illinois at Chicago
Civil & Materials Engineering
(MC 246)
842 W. Taylor Street
Chicago, Illinois 60607-7023
USA
FAnsari@uic.edu

ISHMII Administrative Centre
University of Manitoba
Agricultural & Civil Engineering Bldg.
A250 - 96 Dafoe Road
Winnipeg, Manitoba R3T 2N2
Canada

Membership Notes and *The Monitor* are

European Transportation Research Arena (TRA) - Symposium on Composite Materials in Transport Infrastructures, Vehicles & Vessels

Paris La Défense (France) 14-17 April 2014

Detailed information is available at the Conference Web site

http://tra2014.sciencesconf.org/

delivered to members and colleagues. Your colleagues can receive both for free.

Refer them to or forward contact information to NancyC@ishmii.org. Your comments on *Membership Notes* are welcome.

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Join ISHMII Today or Renew Your Membership for 2013