The ISHMII MONITOR

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ISHMII INTERNATIONAL SOCIETY FOR STRUCTURAL HEALTH MONITORING OF INTELLIGENT INFRASTRUCTURE

A Message from Editor-in-Chief Sreenivas Alampalli, Ph.D., P.E., MBA, FSHMII

Welcome to *The Monitor*. Recently, ISHMII President Dr. Farhad Ansari asked Nancy Cohen and me to rejuvenate this valuable membership publication. As editors, we are pleased to re-introduce it in a convenient twice-a-year e-magazine format that also saves resources and is environmentally friendly. Its appearance and content will change over time, but its message is certain.

As all of you are aware, the unfortunate collapse of the I-35W Bridge in Minneapolis, Minnesota, U.S.A. in August 2007 brought both bridge safety and the resource constraints faced by infrastructure owners to the forefront of the public conversation. The immediate reaction focused on highway bridge inspection and evaluation practices, especially those related to gusset plates on truss bridges. For the long-term, the U.S. Congress and the bridge industry are focused on reviewing current practices in bridge inspection and management, identifying gaps and issues with practices and policies that can be improved, and providing methodologies to effectively utilize available but limited resources using risk-based methodologies.

We are part of such conversations, wherever we live. ISHMII members are some of the renowned experts in structural health monitoring (SHM), and so we know that when used wisely, SHM and nondestructive evaluation methodologies have an enormous potential to assist the owners in these efforts. We have the potential to play a larger role in assisting infrastructure owners through application of SHM to improve infrastructure safety and durability in a cost-effective manner.

We hope that *The Monitor* can assist in bringing owners and experts together through articles that help you to better understand the owners' needs and help them understand the capabilities of SHM as a tool to make their operations more efficient. As professionals, we also have a responsibility to make sure that we do not oversell the capabilities of SHM. That is why we present a balanced discussion that includes the limitations of these methodologies, technology transfer, and how to train others to effectively use these technologies.

Nancy and I look forward to working with you to make *The Monitor* of interest to ISHMII members whatever their expertise. This issue highlights interesting SHM applications from Shanghai, Australia and the U.S.A. Please circulate *The Monitor* to others, especially infrastructure owners, and invite them to join ISHMII.

As editors, we invite you to provide news items and articles that fulfill these objectives. When you present an issue, whenever possible, please quantitatively address how the applications or research will assist owners in reducing their long- or short-term costs and streamline their operations. Please convey your suggestions, compliments, or constructive criticism on the technical articles to the authors directly. If you have any suggestions, please let Nancy or me know.

In this issue

Left

Right

The SHM for a Skyscraper - 632 meter tall Shanghai Tower, China

Shanghai Tower (632 m), Jin Mao Tower (421 m) and Shanghai World Financial Center (494 m)

Dr. Yong Xia and Prof. You-lin Xu
The Hong Kong Polytechnic University

The Shanghai Tower currently under construction is a super-tall skyscraper with a height of 632 m in total and 580 m at the structure roof. The structure is designed by

Dual truck live load testing performed on a pilot study bridge in Virginia

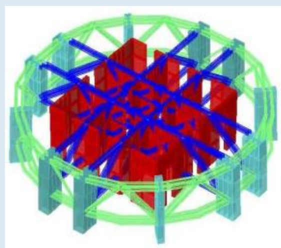
Making Better Decisions through Long-Term Bridge Performance Study

Nancy J. Cohen

A concerted, long-term study of uniform, high quality research data collected on various aspects of bridge performance at sites across the U.S. may lead bridge and highway managers to make more informed decisions that ultimately improve the performance and longevity of bridges and elevated roadways and open the door for new strategies for future construction and maintenance, according to the U.S. Federal Highway Administration (FHWA) and researchers at Rutgers University (New Jersey, USA). That data is now being collected by the Rutgers' Center for Advanced Infrastructure and Transportation (CAIT), which through 2012 is carrying out the initial stages of a potentially twenty-year research study funded by the FHWA, known as the Long-Term Bridge Performance (LTBP) program.

Gensler and the Architectural Design and Research Institute of Tong Ji University. Upon completion in 2014, it will be the tallest skyscraper in China and second in the world.

The Shanghai Tower is a frame-core-outrigger system, as shown in the figure below. The outer frame consists of eight mega RC columns and eight two-story spatial steel trusses. The inner core is a 30 × 30 m square consisting of nine RC tubes, which reduce to five at the top. The outriggers connect the inner core and the outer frame at six strengthening levels.



Frame-core-outrigger system showing mega columns, truss, outrigger and inner core.

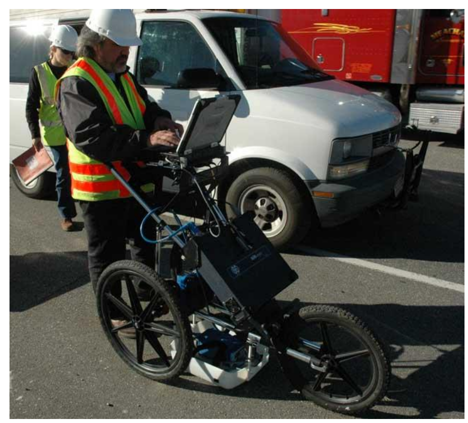
Construction of mega columns

To ensure the safety and performance of the structure during both construction and operation, a comprehensive SHM system was designed and is constructed by a joint venture from the Tong Ji University, the Hong Kong Polytechnic University, and the Architectural Design and Research Institute of Tong Ji University, under the endorsement of the developer, the Shanghai Tower Construction & Development Co., Ltd. The SHM system consists of four modules: sensory system, data acquisition and transmission system, data process and control system, and structural performance evaluation system. The sensory system has about 500 transducers of 12 different types, including anemometers, wind pressure sensors, accelerometers, seismographs, strain gauges, thermometers, GPS, total stations, theodolites, tiltmeters,

CAIT is the prime contractor of this competitive contract.

Bridge owners are acutely aware of the dual constraints they face. An aging infrastructure combined with limitations on available funds to address infrastructure needs is driving them to manage the nation's highway bridges more efficiently. This is a challenging situation according to CAIT director and principal investigator Ali Maher. "We can no longer afford to look at bridges as isolated components in our highway infrastructure."

That is why CAIT takes an integrated approach to the data collection and considers "how engineering, environmental, operational and functional factors intersect and interact to affect how a bridge performs," says Maher. "The high-quality data that we gather and the subsequent data analysis and mining aim to significantly enhance our knowledge of bridge performance." Participants in the program include PB Americas as the primary partner with CAIT, Utah State University, University of Virginia, Virginia Polytechnic Institute and State University, University of California-Berkeley, Siemens Corporate Research, Bridge Diagnostics Inc., and Advitam.



Members of CAIT's Infrastructure Condition Monitoring Program demonstrate ground penetrating radar on a pilot study bridge in Utah.

Using a mix of advanced condition monitoring technologies and detailed visual inspections, the teams will inspect, periodically monitor, document results, and evaluate each of the bridges in the first-of-its-kind nation-wide sample. With this unique body of data, CAIT and the FHWA expect that the LTBP researchers and engineers will develop "condition assessment methods, more accurate predictive models, and better asset management and decision-making tools to help bridge and highway managers make more informed decisions when planning maintenance, rehabilitation, and replacement projects."

digital video cameras, and crack sensors.

Main objectives of the SHM system include:

- To monitor structural behavior in the real time such that the construction error is minimized
- To measure the real wind loading on the curtain wall and ground motion of the site
- To understand the wind- and earthquake-induced vibration of the super-tall structure,
- To provide the client with maintenance guidance.

Please direct your questions to Dr. Yong Xia at ceyxia@polyu.edu.hk or Professor You-lin Xu at ceylxu@polyu.edu.hk.

Australian Network of Structural Health Monitoring Formed

Saeed Mahini, Ph.D.
The University of New England, Australia

The importance of structural safety and reliability was firmly established in Australia following the collapse of Melbourne's Westgate Bridge in October 1970, in which 35 people were killed. These lessons are still as relevant 40 years later. However, the issue of safety for older bridges becomes more vital to address than that of new bridges. This is because it is difficult to determine the load-carrying capacity of degraded bridges in order to assess suitable designs for more economic and efficient repairs and maintenance versus replacement. Therefore, it is necessary to use Structural Health Monitoring (SHM) to identify the load-carrying capacity of older bridges in order to identify alternative maintenance and repair strategies. The SHM of road traffic bridges and heritage buildings and reliability assessment of the design of structural members and systems have both received a great deal of attention by researchers in Australia, with many methods of monitoring and analysis developed. Both forms of assessment are vital for any transport managing authority and the government's heritage sectors.

A researcher performs top of the deck visual inspection on a pilot study bridge.

The LTBP program should also generate a comprehensive body of high quality data on bridge characteristics and performance and form the basis for analysis that opens the door to a better understanding of life-cycle cost. As scientists develop better predictive models, there should be an improved understanding of how bridges behave under various stresses and environmental conditions. Together, this should lead to both more effective maintenance and repair strategies and new design and construction strategies. The latter could include ways to increase durability for new bridge construction, including material selection, and lead to the development of innovative and high-performance materials. Better inspection and management protocols and standards may also result.

From a fiscal standpoint, researchers expect that the information they collect on how, why, and how fast bridges deteriorate will actually provide policy-makers and owners with insight into costs and instruct them on how they can "optimize the manner through which funds for bridge improvements are allocated," reports Dr. Maher.

For information on the Long-Term Bridge Performance program, visit http://cait.rutgers.edu/ltbp

CASE STUDIES
SHM IN PRACTICE

More than 60 Case Studies are available at the ISHMII Knowlege & Education Center. Find Case Studies listed by country at:

www.ishmii.org/knowledge-education-center/case-studies

Bridge failure - a safety issue in Australia

In 2010, the Australian Network of Structural Health Monitoring (ANSHM) was organized to sustain Australian national and regional infrastructures and raise the recognition of SHM. The founding president is from Queensland University of Technology (QUT). With a unique cross-section of the industry members who are responsible for bridges in the transport network and heritage buildings, and governments and universities, the membership of the ANSHM is growing. These government agencies include the Commonwealth Scientific and Industrial Research Organisation; the Australia's national science agency; the Queensland (QLD) Department of Transport and Main Roads (DTMR) and New South Wales (NSW) Roads and Traffic Authority (RTA). The latter two are industry advisory bodies.

Australian universities play a large role in the success of ASHM as centres of research and SHM activity. The University of New England's (UNE) main research is in the rehabilitation of infrastructures and heritage buildings using fibre composites and reliability assessment of bridges in regional areas based on SHM. A new laser-based technique provides a continuous indication and low cost measurement system for timber/concrete bridge girders. UNE has applied for an Australian Research Council Collaborative Grant in cooperation with the University of Queensland, QLD DTMR, Inverell Shire Council and Armidale Dumaresq Council to monitor the structural health of older bridges in New South Wales and Queensland for reliability and safety. That team will use Fibre Bragg Grating sensors together with a laser-based technique to determine alternative maintenance and repair strategies. UNE already conducts similar research supported by Forest Wood Products Australia.

QUT conducts damage assessment of cable-supported bridges using developed Wind and SHM System, and investigations into vibration-based damage detection and acoustic emission techniques for SHM.

Deakin University focuses on damage identification and safety assessment of infrastructures, while University of Western Australia works on sensor development, vibration-based methods, signal-processing techniques, and guided-wave propagation and model-updating methods.

China National Aquatics Center

Case Study: Application of SHM Technology in Civil Structures in Mainland China

Prof. Hui Li, Harbin Institute of Technology, Harbin
Prof. Na Li, CCCC Highway Consultants CO., Ltd, Beijing
Prof. Zhiming Guo, Nanjing 3rd Bridge Administration Agency, Nanjing
Prof. Zonglian Guo, Jiangsu Maritime Institute, Nanjing
Prof. Jinping Ou, Harbin Institute of Technology and Dalian University of Technology, Dalian, China

Mainland China initiated structural health monitoring (SHM) in the early 1990s, beginning with an extensive and comprehensive study of smart sensing materials, smart sensing technology and novel sensors. By 2000, China had moved into the application of SHM technology and by 2005 was designing and fully implementing SHM in its bridge structures, building structures, offshore platforms, tunnels, high-speed railways, wind energy generation facilities, and industrial facilities. This includes more than 100 bridges and about 50 buildings.

The teams operating the SHM systems across China have collected a significant amount of monitoring data and are studying both the data and the basic research issues that have emerged. A growing number of companies are now engaged in design and implementation of SHM systems. A design code for the SHM system and for the inspection of bridges is being prepared.

We are pleased to present three of these projects.

China's longest suspension bridge

The Civionics Research Centre, a multidisciplinary research group at University of Western Sydney, focuses on structural health monitoring projects including structural condition assessment, development of wireless sensor network, and signal processing.

The University of Newcastle studies the reliability and safety assessment of RC beams subject to corrosion in order to identify the remaining service life of structures and the maintenance strategies. It carries out vibration tests to study the natural frequency of deteriorated beams. Vibration method (i.e. vibration-based damage detection) has also been used at the University of Technology Sydney for evaluation of damage in utility poles and timber bridges.

A backward prediction model technique developed at Griffith University helps to generate unavailable historical data for bridge deterioration models in order to provide more accurate prediction outputs.

Finally, the QLD DTMR is planning to monitor health of wide range of new and older bridges in Queensland using SHM techniques such as optical sensors to control long-term response of newly developed fibre composite girders for replacement of older timber bridges.

Verification of in-service behaviour of deck unit bridges in Queensland and also a new long span reinforced concrete box girder bridge in Brisbane is under process.

Photo "Bridge failure - a safety issue in Australia" by Rex Glencross-Grant

Dr. Mahini can be reached at ***smahini@une.edu.au***

PUBLICATIONS

The inaugural issue of the *Journal of Civil Structural Health Monitoring* is available to members at the ISHMII.org Web site.

To access the articles to read or download, please log in

Xihoumen Bridge and its location

One of the bridges being monitored is the Xihoumen Bridge, a cross-sea suspension bridge with a main span of 1650m located in Eastern China. This is China's longest suspension bridge. A comprehensive SHM system was designed for and implemented into this bridge. Its overall framework of sensors includes10 anemoscopes, 123 wind pressure sensors, weigh-in-motion in each lane, 7 temperature and humidity integrated sensors, 46 temperature sensors, 14 GPS, 24 accelerometers, 16 inclinators, and 7 displacement transducers. Since operation of the SHM system began, an extensive catalogue of data has been collected using these sensors.

The response of Nanjing 3rd Bridge during 2011 earthquake in Japan

Nanjing 3rd Bridge

The Nanjing 3rd Bridge is a cable stayed bridge with a main span of 648m over the Yangzi River. Its SHM system,operational since 2006, routinely monitors vehicle loads, temperature, wind, strain, tension in stay cables, deformation of the deck and vibration of the deck. The response of this bridge was measured on March 11, 2011 during the northeast Japan earthquakes. The analysis showed that there was no distinct variation in the stress of the deck or tension in the cable compared with the corresponding response as a member. Then, click on ***Journal of CSHM***, located on the menu.

To submit a Journal paper, please visit https://www.editorialmanager.com/cshm

The **Editor-in-Chief** of the Journal of Civil Structural Health Monitoring is Aftab Mufti (Canada). He is joined by **associate editors** James Brownjohn (United Kingdom), Fritz Brunner (Austria), Francisco Carrion-Viramontes (Mexico), Vistasp Karbhari (USA), Hyun-Moo Koh (Korea), Masoud Motavalli (Switzerland), Toshiyuki Oshima (Japan), and You-lin Xu (China).

To renew your membership or join ISHMII and gain access to the JCSHM, go to http://www.ishmii.org/members

Review: Multi-Disciplinary Books Offer Insight into Monitoring and Communications among Experts

Nancy J. Cohen

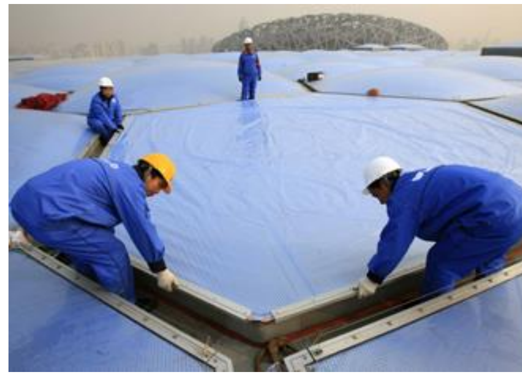
The publishers of "Monitoring Technologies for Bridge Management," edited by Baidar Bakht, Aftab Mufti and Leon Wegner and published in April 2011, point out that communication can become difficult "when experts in different fields come together for an SHM project." The problem is this – one expert may not understand the expertise demonstrated by others. This text and "New Trends in Vibration Based Structural Health Monitoring," lectures edited by Arnaud Deraemaeker and Keith Worden and published in 2010, provide field- and research-based expertise from the specialists in many fields of engineering and physics who are defining SHM today. Their contributions enhance our insight into advanced monitoring.

On the global scale, "Monitoring Technologies for Bridge Management" is well-set to fill an interdisciplinary gap. Its chapters are based on both original, basic research and novel applications of sensors to highway and railway bridges, among other civil infrastructure constructed from concrete, steel and wood. It addresses the "integration of traditional visual assessment and field and laboratory destructive testing programs with state-of-the-art internal condition assessment through non-destructive evaluation" according to Multi-Science Publishing Co. Ltd. (http://www.multi-science.co.uk/mtbm_bakht-book.htm)

The topics covered include the lifecycle savings of SHM as a value of information approach, conventional, fibre optic and wireless sensors, data acquisition systems, optical methods in SHM, the use of GPS for bridge deformation monitoring, vibration-based monitoring, non-destructive testing of concrete structures, Civionics, the

at other times. This implies that no damage occurred to the Nanjing 3rd Bridge during the earthquake.

SHM of the China National Aquatics Center



Construction of the roof sections

The China National Aquatics Center, also known as the 'Water Cube', was built for the 2008 Summer Olympics. The SHM system incorporated into the 'Water Cube' includes 230 FBG strain sensors, 30 FBG temperature sensors, 16 accelerometers, 1 anemometer, 32 wind pressure sensors, and 1 laser displacement transducer. Among the strains that the system has monitored are temperature-induced and snow-induced strains. The data indicated that the temperature-induced strain is very large, while the stain of the structure subjected to very heavy snow (occurrence period is 50 year) is relatively small.

Prof. Hui Li may be reached at lihui@hit.edu.cn

Photo "Construction of roof sections" courtesy of www.chinadaily.com.cn

This full case study may be read at http://www.ishmii.org/shm-in-mainland-china-2011

Keeping the Huey P. Long Bridge Open During Construction

communication of data, bridge analysis tools, monitoring of a suspension bridge and girder bridges, truss bridges, soil-steel bridges, the testing of a railway bridge, and the effect of monitoring on the reliability of structures.

On a more specific topic, "New Trends in Vibration Based Structural Health Monitoring" covers the six lectures presented at the CISM School in 2009 as an outcome of the Smart Sensing for Structural Health Monitoring (S3HM) project sponsored by the European Science Foundation. A multi-disciplinary reference book, it features a comprehensive state-of-the art overview suitable for postgraduate students as well as researchers working in aerospace, mechanical and civil engineering.

Also using illustrations from experimental and field measurement data, the book presents the three stages required for the successful implementation of an SHM system. These are sensor networks and data acquisition, signal processing, data reduction and feature extraction, and the statistical analysis of the data. The lectures emphasize "data reduction in large sensor networks, sensor failure detection, extraction of modal parameters from operational data, removal of the variability due to changing environmental or operational conditions, statistical analysis of the data through supervised (neural networks) or unsupervised (outlier analysis, control charts) learning techniques." And, the publishers stress, the last chapter on wave-based methods provides "a very promising complementary technique to the vibration-based methods."

Part of the series CISM International Centre for Mechanical Sciences, it is available at www.springer.com/engineering/mechanical+eng/book/978-3-7091-0398-2

UPCOMING CONFERENCES AND WORKSHOPS

SHMII-5 2011 CANCUN, MEXICO
CSHM-4 2012 BERLIN, GERMANY
SHMII-6 2013 HONG KONG, CHINA

SHM of the Huey P. Long Bridge

Asad Bassam, Ph.D., P.E. and Bernard J. Schulze
CTLGroup

The 77-year old Huey P. Long Bridge, the second longest railroad bridge in the U.S., is a cantilever truss bridge that crosses the Mississippi River near the famed city of New Orleans and it is the only railroad bridge within 100 miles. Thirty trains ride over this 2,400 ft. (732 m) long bridge, which is comprised of three navigation spans, daily. While lacking shoulders, it also carries 50,000 vehicles on two narrow roadway decks 18 ft. (5.5 m) wide that are uniquely placed on the outside of the bridge, while the rail tracks are in the center. With rail and auto usage growing, the Louisiana Department of Transportation (LADOT) could not take this important bridge out of use to widen it and improve traffic flow. Instead, LADOT is keeping the bridge open to avoid delays and extensive and costly re-routing of traffic while it widens the bridge to hold three 11 ft. (3.35 m) wide lanes of traffic in each direction, with 2 ft. (.61 m) inside and 8 ft. (2.3 m) outside shoulders.

Designer's rendering of the widened bridge

Widening in action

The construction plan calls for strengthening the existing piers by adding W Frames to the piers prior to the installation of the new trusses both upstream

Enhancing the Dialogue: SHMII-5 Comes to Cancún, Mexico
December 11-15, 2011

Members and colleagues are invited to participate in the 5th International Conference on Structural Health Monitoring of Intelligent Infrastructure. SHMII-5 provides a unique opportunity for engineers, scientists and practitioners from around the world, who represent a broad range of disciplines and enterprises, to discuss the latest knowledge and techniques for structural health monitoring of intelligent infrastructure.

Thanks go to the SHMII-5 Secretariat chair Sergio M. Alcocer, Institute of Engineering, National Autonomous University of Mexico (UNAM), co-chairs Francisco Carrión, Mexican Institute of Transportation and Roberto Gómez-Martínez, UNAM, and Alexis Méndez, MCH Engineering LLC, USA, the head of the international steering committee, along with the dedication and work of an extensive local organizing committee.

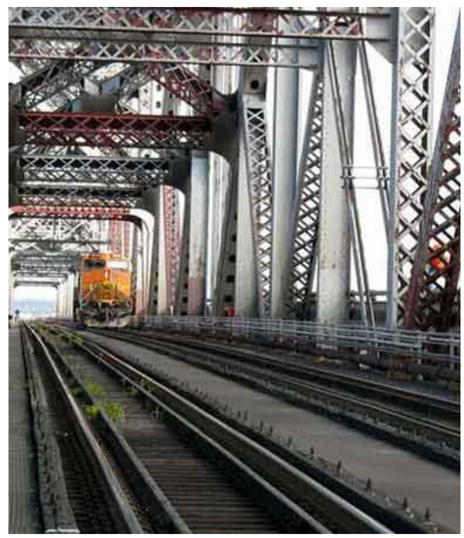
The SHMII-5 conference Web site may be accessed from the Events menu at ISHMII.org or directly at www.shmii.unam.mx/Sitio_SHMII/principal.htmlConference

Conference Registration
We welcome all members and friends to register for the conference at www.shmii.unam.mx/Registration.html. Conference fees will increase on August 15, 2011.

and downstream. The addition of these new structural members will result in some construction loads being transferred to the existing bridge truss members during the construction. Overloading is a concern as it is difficult to predict the precise load transfer. So, a fulltime monitoring system was created to watch the change of stresses and deformations every step of the way.

The truss monitoring program includes:

- Determination of initial forces in the eye bars through vibration testing
- Installation of strain gages for bridge model validation as well as continuous measurement of stresses in 433 members
- Design of remote monitoring system software to read all gages, make comparisons with predicted values and provide continuous reporting through a secure web site.



Dynamic load test with a single locomotive

The use of programmable data loggers and wireless data transmission capabilities allow them to process large quantities of data that provides the owners, engineers and contractors the insight for construction monitoring, performance and surveillance of the bridge structures. Meanwhile, new web-based interfaces allow secure password protected access to the data in real time. That is helping all of the parties to make timely decisions regarding potential loading hazards.

This monitoring system will measure and transmit data about the bridge's structural behavior until late 2011 at which time all major structural additions will be completed. The estimated budget for the widening project was nearly $450 M and the cost of

Venue Registration and Visiting Cancún
The Ritz-Carlton Cancún provides an enticing setting for this conference. Please visit www.shmii.unam.mx/Venue.html.

Cancún is a popular resort destination with easy access to traditional markets and historic archeological sites and beaches along the Mayan Riviera.

Brandenburg Gate

CSHM-4 Workshop
Integrity of SHM Systems for Deficient Structures
November 6-8, 2012 Berlin, Germany

The 2012 Civil Structural Health Monitoring Workshop will be held at the Bundesanstalt für Materialforschung und-prüfung (BAM), the Federal Institute for Materials Research and Testing.

Wolfgang R. Habel, Ph.D., the organizer, will announce details of the workshop in December 2011. For additional information contact Wolfgang.habel@bam.de.

Make Plans for SHMII-6
Hong Kong – December 2013

The 6th International Conference on Structural Health Monitoring of Intelligent Infrastructure, SHMII-6, will be held in December 2013. SHMII-6 2013 is organized by Professor Y.L. Xu and members of the Department of Civil and Structural Engineering, The Hong Kong

the monitoring system including the installation, hardware and maintenance has been about $1.25 M which is less than 0.3% of the total estimated project cost.

Dr. Asad Bassam and Bernard J. Schulze may be contacted at ABassam@ctlgroup.com and BSchulze@ctlgroup.com

Photo "Widening in action" by Ted Davisson.

Case Studies are accessible in full at www.ishmii.org/knowledge-education-center/case-studies

This case study may be read at http://www.ishmii.org/shm-of-the-huey-p-long-railroad-bridge

Membership Reminder

Has your ISHMII membership lapsed? Membership fees are due on January 1, based on a calender year.

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Contact the Monitor Team

INTERNATIONAL SOCIETY FOR STRUCTURAL HEALTH MONITORING OF INTELLIGENT INFRASTRUCTURE

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To submit Case Studies, News, information on meetings and events, or feature articles for *The Monitor* or the ISHMII Web site, please direct them to NancyC@ishmii.org.

To read the **Journal of CSHM**, visit www.ishmii.org/jcshm

To submit an article for publication in the

Polytechnic University. The organizing committee will announce details in December 2011. Dr. Yu can be reached at shmii6.2013@polyu.edu.hk.

Journal, visit https://www.editorialmanager.com/cshm/

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