May 2009

THE MONITOR

Publication of the

INTERNATIONAL SOCIETY FOR STRUCTURAL HEALTH MONITORING OF INTELLIGENT INFRASTRUCTURE

ISHMII

SHMII-4 INVITATION

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Zurich
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www.zuerich.com and www.myswitzerland.com

Venue
The conference will be held at the ETH Zurich (Swiss Federal Institute of Technology), Rämistrasse 101, 8092 Zurich, which is located in the center of the city. Transport by train is available from the Zurich Airport to the Zurich Main Station (duration 10–15 minutes). Tramways will take you within few minutes to the Hotels and to the ETH.

Hotel
Many hotels are located close to the conference venue. More information can be found at www.zuerich.com
For special hotel offers, please refer to the conference website shmii.empa.ch

Conference Secretary:
Ms Bernadette Havranek
Empa
Structural Engineering Research Laboratory
Ueberlandstrasse 129
CH 8600 Duebendorf

Phone: + 41 44 823 44 33
Fax: + 41 44 823 44 55
Email: shmii@empa.ch
shmii.empa.ch

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INTRODUCTION:

The 4th International Conference on Structural Health Monitoring of Intelligent Infrastructure, SHMII-4 2009, will provide a forum for international scientists, engineers, enterpriser and young researchers to discuss recent advances in smart sensors, wireless sensor networks, signal acquisition and processing, real-time data transferring and management, and explore the potential for international cooperation. Participants will be able to share innovative ideas on the state-of-the-art, state-of-the-practice and future trends of smart sensors, advanced sensor networks and integrated systems for structural health monitoring of intelligent infrastructure.

SHMII-4 is the official conference of the International Society for Structural Health Monitoring of Intelligent Infrastructure (ISHMII) and is being organized by Empa, the Swiss Federal Laboratories for Materials Testing and Research. SHMII-4 will build on the success of SHMII-1, held in Tokyo 2003, SHMII-2 in Shenzhen 2005, and SHMII-3 in Vancouver 2007.

TOPICS:
- Smart and other advanced sensors
- Wireless and other advanced sensor networks
- Data acquisition, processing and management
- Damage identification and localization
- Model updating, safety evaluation and reliability forecast
- Damage control, repair and strengthening
- Life-cycle performance-based design
- Smart materials and structures
- Global positioning system (GPS) and related systems for wind and earthquake hazard mitigation of civil infrastructure
- Remote monitoring systems
- Integrated systems and implementations of SHM
- Design guidelines and codes of SHM
- Standardization of SHM systems
- Critical issues for SHM
- Monitoring of the heritage structures rehabilitated by FRPs

KEYNOTE LECTURERS

Hojjat Adeli, The Ohio State University, Columbus
Farhad Ansari, University of Illinois at Chicago
Baidar Bakht, J.M.B.T Structures Research Inc., Scarborough
Hyun-Moo Koh, Seoul National University
Douglas Thomson, University of Manitoba, Winnipeg
Helmut Wenzel, VCE Holding GmbH, Vienna

IMPORTANT DEADLINES:

15 March	2009	Acceptance notification to authors
15 April	2009	Submission of FINAL revised manuscript
15 April	2009	Early registration

CONFERENCE

20 July 2009	Technical & cultural Tour Southern Switzerland
21 July 2009	Evening: Welcome reception at ETH Zurich
22 – 24 July 2009	SHMII 4 CONFERENCE
24 July 2009	Conference Dinner on the Top of Zurich

An interesting social program is planned for the SHMII 4 2009 Conference that will include siteseeing and visits to local attractions

COMMITTEES

Conference Chair: Aftab A. Mufti, University of Manitoba, CA
Conference Co-Chairs: Emin Aktan, Drexel University, USA
Masoud Motavalli, Empa, Duebendorf, CH
Paolo Ermanni, ETH Zurich, CH

Organizing Committee Chair: Urs Meier, Empa, Duebendorf/CH
Empa: Swiss Federal Laboratories for Materials Testing and Research, Duebendorf

International Scientific Committee: for a detailled list see: shmii.empa.ch

REGISTRATION FEES:

Early registration before 15 April 2009
EUR 580.00 for non-members of ISHMII including ISHMII Membership 2010
EUR 530.00 for members of ISHMII including ISHMII Membership 2010
EUR 240.00 for Students

Registration after 15 April 2009:
EUR 700.00 for non-members of ISHMII including ISHMII Membership 2010
EUR 640.00 for members of ISHMII including ISHMII Membership 2010
EUR 290.00 for Students

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International Society for Structural Health Monitoring of Intelligent Infrastructure is a non-profit organization of leading structural health monitoring institutions.The goal of the association is to enhance the connectivity and information exchange between participating institutions and to increase the awareness for structural health monitoring disciplines and tools among end users.

www.ishmii.org

THE MONITOR

EDITOR

Dr. John Newhook
Dalhousie University
Department of Civil Engineering
D Building, 1360 Barrington St.
Halifax, NS B3J 1Z1 Canada
Ph: 902-494-5160
Fax: 902-494-3108
Email: john.newhook@dal.ca

Submissions to the Monitor

ISHMII invites individuals to submit information for publication in the upcoming editions of the Monitor {to **john.newhook@dal.ca** (editor)}.

Information Articles for Reader Interest
- news items
- brief information articles on research or field applications of SHM
- notice of member awards and honours
- notices of key publications or thesis
- notices of conferences and events

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INTERNATIONAL SOCIETY FOR STRUCTURAL HEALTH MONITORING OF INTELLIGENT INFRASTRUCTURE

REAL-TIME PERFORMANCE TRACKING ON A 183M CONCRETE CHIMNEY AND TUNED MASS DAMPER SYSTEM

J.M.W. Brownjohn, Vibration Engineering Section, University of Sheffield, UK
E. P. Carden, Lloyds Register, UK
R. C. Goddard, Bierrum International, UK
G. Oudin, Multitech, France

Introduction: large-amplitude oscillations and experimental studies of concrete chimneys

Performance of tall reinforced concrete chimneys due to both along-wind and cross-wind loading has long been a concern for operators of industrial facilities such as conventional power stations. As well as public failures e.g. at Ferrybridge Power Station in 1965 when three cooling towers collapsed due to wind effects, there have been concerns with other structures, including those affected by upstream structures that cause interference effects.

Prediction of response levels requires accurate estimates of modal parameters, in particular damping ratio, and their evaluation at full-scale has led to some novel experimental efforts, including use of rocket thrusters, and an inertial force generator (using a hydraulic ram and suspended mass). New developments in system identification procedures are such that chimney response to random wind-buffeting is sufficient for recovering reasonable parameter estimates from multi-mode response.

The chimney studied here stood happily since it was built in 1968 at a conventional power station in the English midlands. However, during construction of a replacement chimney in the upstream direction of the prevailing wind, the original chimney was observed to vibrate excessively, leading to safety concerns and an investigation (1) into the problem and its possible remedies. One of the recommendations of the investigation was installation of a vibration monitoring system with a number of alarm threshold levels, and another was installation of additional damping.

No experimental values of modal properties were available for the response calculations undertaken in the investigation, which were based on analytical models and previous studies (for damping). In fact obtaining reliable estimates of modal properties of the chimney to validate the calculations presented a challenge: access to upper levels of the chimney was impossible without expensive specialist services (steeplejacks) and suitable 'point and shoot' response measurement technology such as laser vibrometer was not available at the time.

Rugeley stack and new chimney

The chimney at the Rugeley Power Station, north of Birmingham, was constructed around 1968 and at the time of writing still exists (so is described in the present tense). It consists of a 183m high reinforced concrete windshield, internally protected by a sectional, acid resisting brickwork lining. The windshield tapers from an external diameter of 9.4m at the top to 15.7m at the base. Its outer surface has suffered from environmental actions and external reinforced concrete cladding was added in 1998 over top 24m.

Due to the installation of a new flue gas desulphurisation plant, construction of a replacement 183m chimney of the exact same height began in 2006, at a distance of 110m and a bearing of 218 , approximately in the southwest direction of the prevailing winds in the UK. The two chimneys, shown in Figure 1 were intended to coexist for approximately two years until demolition of the original chimney.

The wind effect investigation concluded that 'interference effects associated with the construction of the new chimney would significantly increase loads on the existing chimney' and that maximum response of the existing chimney, at a level depending on the damping capacity, would occur with free-stream wind speed of 31m/sec. In fact concern due to swaying of the old chimney led to delays in construction of the new chimney.

Mild steel reinforcement was used in the construction and given historical wind conditions, it was found that there was a significant probability of design capacity being exceeded over the remaining lifetime for a damping ratio of 1%. Hence a decision was made to install a tuned mass damper (TMD) and a monitoring system to check performance of the chimney in the meantime and of the chimney and TMD later. Installation of the monitoring system by University of Sheffield and of the TMD by Multitech ran in parallel during the first four months of 2007, with early data from the monitoring system being used to fine-tune the TMD, hence the TMD itself is first described, briefly.

Installation and operation of tuned mass damper (TMD)

Multitech - France was awarded the order for the TMD in January 2007 and within seven weeks the 4.2×104kg of moving mass plus five viscous damper units were delivered to site. Compared to the analytically estimated 1.07×106kg modal mass of the chimney in the first vibration mode (expected to be around 0.3Hz), this is a mass ratio of 3.9%. In order to limit the cost of erection the damper was designed to have the smallest moving mass possible to generate sufficient damping. Keeping the mass to a minimum also helped with connection of the brackets onto the old concrete shaft using post-drill anchors. As well reducing installation issues due to the weight, the design of the steel structure and moving mass had to be such as to allow all site adjustments without site welding as the perimeter of the stack is not a perfect circle.

The design of the damper was such as to allow up to 450 mm relative displacement between stack and moving mass and the damper units were tested in the laboratory before shipping. Final verification of the performance of the TMD via site measurement, described in the next section, showed that it provided total damping up to 4% and that it has continued to be effective throughout its operational life.

Monitoring system design and operation

Performance limits for the chimney were specified in terms of peak displacements, but tracking the chimney motion using an optical system was ruled out for logistical and operational reasons. Since first mode response was expected to dominate in strong winds, the dynamic displacement levels could be derived from acceleration signal amplitudes.

Hence a simple acceleration monitoring system was designed comprising four Honeywell QA750 quartz-flex servo-accelerometers oriented in 'tangential' and 'radial' directions on the chimney in watertight enclosures at two levels (180m and 40m), and a simple 4-channel National Instruments data acquisition (DAQ) system, described later. The system was installed on 2nd February. Installation of the boxes required a team of steeplejacks installing an access ladder the full height of the chimney and anchoring the cables to existing cables for aircraft warning lights. Hence the accelerometer axes differ by 11 from crosswind and along-wind axes with respect to wind coming from the direction of the new chimney. Figure 2 shows the TMD under construction, with the lower accelerometer box visible at the level of the access rungs.

The system was initially left to run unsupervised from 2nd February until the ADSL internet connection was installed. During this relatively short period signals from the top pair of accelerometers were lost and it was found that water under pressure from the signal cable was spraying into the instrument cabinet at the base of the chimney, due to fraying of the cable as it whipped against the chimney surface in strong winds. The cables were replaced with more robust alternatives fixed to the chimney at short intervals, and from 15th March data were available remotely via ADSL connection.

Acquisition, signal processing and parameter estimation

Initially the system was set up to show (acceleration) response levels and to sound an alarm when preset acceleration limits (corresponding to critical displacement levels) were exceeded.

At the start of the monitoring modal parameters were required to validating the response prediction investigation and for designing the TMD. Only a few minutes of data were recorded and retrieved during installation on 2nd Feb 2007 but no further data were available until March due to the 'technical' problem. These very limited data provided an interesting challenge to estimate modal properties. The first two bending mode frequencies were estimated at 0.33 Hz and 0.34 Hz with damping values of 2% and 1% respectively. The six minutes of data were simply too short to provide accurate estimates and there was no logical cause for a difference in values for the first two modes.

During the March visit to fix the cables a little over two hours of data were recorded from the bottom set of accelerometers (this cable was still intact). These data were enough to provide better parameter estimates for the first two bending modes of 0.33 Hz with 0.6 % to 0.7 % damping and 0.34 Hz with 0.5 % to 0.6 % damping.

The ADSL was operational from 20th March and cables had been replaced (while a hoist was still in place for the TMD installation) so this marked the start of continuous remote monitoring.

To minimize costs, a relatively simple acquisition system was installed. NI-USB-6251 16-bit National Instruments DAQ chassis fitted with two SCC-AI13 low pass filter modules with 4Hz cut off frequency were installed but unfortunately, being only 2-pole filters, a substantial amount of energy was being aliased making the first 4 Hz band very noisy. This, and the lack of simultaneous sample and hold facility, were managed by over-sampling at 64 Hz and digitally decimating the signal by a factor of eight (incorporating an eight pole Chebyshev filter). A LabVIEW virtual instrument (VI) was written to collect 180-second length frames and recorded on the local DAQ laptop computer (Panasonic Toughbook T4). In addition the data are also transmitted over the broadband line using Labview's datasocket protocol for viewing at any computer equipped with a LabVIEW and a second VI (or a stand alone executable client application) to read the data.

The alarm trigger levels for the top set of accelerometer responses were set to correspond with three levels of displacement associated with the strength capacity of the concrete windshield. The highest response level represents 25cm displacement amplitude with exceedence requiring site evacuation for personal safety. The bottom set of accelerometers were installed as a backup in case of failure of the top set. Trigger levels for the lower set were obtained via mode shape ordinate measurements from analysis of data from 21st March to the 10th April, resulting in an estimated value of 0.07 for mode shape normalised to 1.0 at the top accelerometer.

Each 180-second 8Hz data frame is transmitted by ADSL for viewing with a client application installed on several remote computers; Figure 3 shows a screen shot from the client application at the time of a low level alarm. The system also emails a daily log file of minimum and maximum response values for every 3-minute frame in the preceding 24 hours.

Verification of the TMD

Bierrum needed to check the correct functioning of the TMD immediately after installation and during the remainder of operational life of the chimney/TMD. Hence it was decided to extract the damping parameters of the first two bending modes automatically online using a procedure based on a previous implementation at the Tamar suspension bridge (2). The system batch processes large amounts of data to extract modal parameters using Reference based covariance-driven Stochastic Subspace Identification (SSI-COV) (3) implemented using the Mathscript language of Labview, rather than MATLAB which would have required a costly commercial license.

Speed of computation is an important issue for real-time operation hence the choice of SSI-COV over data-driven SSI. At the time of the original implementation the linear algebra functions of the Mathscript language were not as fast as those of MATLAB-based procedure used in the Tamar system. To provide more reliable parameter estimates without overloading the processor and compromising the DAQ operation a second VI was written which operated in tandem with the acquisition VI on a timed loop analyzing two-hour sequences of data.

SSI is a well documented procedure which usually requires a significant amount of user intervention, including the interpretation of 'stability diagrams'. These show vibration modes identified as the order (or number of mathematical poles, related to the number of modes) of the estimated system is increased. Interpretation of these diagrams can be automated up to a point using various quality measures, while the choice of 'reference' channel(s) and the way in which the covariance function functions are constructed and how many data points from them are used also affect the results. A typical stability diagram formed from the chimney data is shown in Figure 4, with the power spectrum of the four accelerometers. The first two modes of the chimney which have very close frequencies and represent modes in geometrical orientations that are approximately orthogonal and are clearly identified in Figure 4. The third stable set of poles at about 0.8 Hz are artificial effects due to the decimation process.

The client monitoring software graphically displays the previous few days of estimated damping parameters giving a medium-term trend used for monitoring the performance of the TMD. As expected the TMD performance proved to be amplitude dependent; apparently it was not engaged substantially during periods of weak wind. Moreover the damping parameters were identified with a higher (poorer) variance when the modes were weakly excited. Observing the TMD performance (through damping ratios) is aimed not at identifying sudden failure of the TMD (which is not expected) but rather to show slower deterioration due to say water ingress to the damping fluid baths, giving due warning for maintenance. The emailed daily log files can be viewed collectively to identify trends using standard viewing tools in MATLAB or Excel for examples.

Figure 5 is a screenshot of the damping plot for June, two months into TMD operation, showing a number of features. The damping values appear to have been stable below 1% up to 25th June 2007 when the values rose progressively to around 3% due to strong winds (associated with the heavy downpours that led to flooding throughout the UK in 2007). Around 22nd June and at the end of the data sequence, zero values are indicated, showing that no mode met the criteria for a stable identified mode. Likewise some outlying values are present. Minor adjustments to the system (during operation) including rejection of modes higher than 0.5Hz, provided for clearer identification in subsequent monitoring.

Characteristics of response during and after installation of TMD

Because of the loss of signals from the upper accelerometer box until the TMD was installed, there are no useable data describing the wind-induced response of the bare unmodified chimney. The TMD installation was completed on 5th April 2007 and modal analysis of data recorded from March 21st to April 20th is presented in Figure 6. This shows that for the majority of the time, damping levels were below 1%, until about a quiet week after the TMD installation was completed when damping levels began to increase noticeably. Modal frequency variation appears to show a changed pattern, but the reliability of the estimates is reduced due to the calm conditions.

Data available in the year following the TMD installation include time series of response continuously recorded (with short breaks due to period maintenance resets), daily summary files of maxima and minima for each channel during each three-minute frame and daily summaries of frequency and damping values for two-hour frames. The only useful wind data were one-hour average values obtained via http://weather.noaa.gov/ for the weather station at Birmingham Airport at a distance of 37km, and East Midlands Airport at a similar distance of 40km, to the east. These wind data have been used only as general indicators of prevailing conditions.

Figure 7 shows examples of acceleration signals. The diagonal straight line shows the cross-wind direction for winds coming from the direction of the new chimney. One of the key concerns for the operator was whether interference effects led to enhanced response level. The investigation of this effect (1) predicted that interference effects for winds with bearings in line with the new chimney, plus or minus a generous margin, and that with 5% damping, would result in peak tip displacement approximately 120mm at the critical wind speed of 30m/sec. The largest recorded response, which occurred on 31st January 2008 is illustrated in Figures 7a and matches this value, with average winds up to 40mph (17.8m/sec, logged at EGBB) from SSW direction and certainly including gusts around the critical speed. By comparison Figure 7b shows highly aligned (i.e. transverse) response due to similarly strong north-westerly winds which could not cause interference effects. Study of such traces suggests the conclusion that the mechanism is vortex shedding but that for the critical direction response is enhanced.

For the longer term, Figure 8 shows the variation of peak responses for 3-minute frames and damping and frequency estimates for the first of the two fundamental modes for 2-hour frames during the monitoring up to mid-March 2008. Clearly radial response dominated, not least because that was the cross-wind alignment for prevailing strong winds. The damping values show the lower bounds for zero response at around 0.5%, rising to over 4% during periods of strong response.

The frequency estimates are particularly interesting although they show no apparent relationship with the other response parameters, other than a diurnal variation. There are occasional significant drops in frequency that do not correspond with unusual weather conditions and the only possible explanation is likely to be thermal effects due to operation of the power station. Seasonal temperature variations (i.e. from sub-zero to midsummer highs) are not responsible for these large excursions.

During the operational life of the chimney is has shown some reduction in natural frequency and the maximum damping ratio achieved is, at the end of 2008, about 3%. So far only one weather event has resulted in any alarm condition, although normal strong south westerly wind conditions regularly generated transfer vortex-induced responses of the order 0.1m amplitude.

Radar measurements

In March 2008 in collaboration with researchers from IDS in Italy, measurements were made of the dynamic performance of both chimneys using a new interferometric radar sensing system (4). The system has a line of sight resolution as good as 0.01mm and can sample at frequencies e.g. 100Hz limited by data storage. Radar is reflected from a structure strongly at surface existing or artificial features that can be separately identified when more than about 1m apart. The system is shown in Figure 9; the mode indicated in Figure 9c is for the old chimney mode dominating in the line-of-sight direction of the sensor and confirms the estimated from the monitoring system, while providing additional information about mode shape. The mode shape ordinates were not resolved for the lower two-thirds of the chimney due to reflections from the various industrial hardware around the sensor and chimney.

References

1. Galsworthy, J. K. and Vickery, B. J., "Wind loads and interference effects for new and existing chimneys at the Rugeley power station, UK," Alan Davenport Wind Engineering Group, Boundary Layer Wind Tunnel Laboratory, London, Ontario, Canada, N6A 5BP, 2006.

2. Brownjohn, J. M. W. and Carden, E. P., "Tracking the effects of changing environmental conditions on the modal parameters of Tamar Bridge," Proceedings of the 3rd International Conference on Structural Health Monitoring and Intelligent Infrastructure, 2007.

3. Peeters, P. and De Roeck, G., "Reference-Based Stochastic Subspace Identification For Output-Only Modal Analysis," Mechanical System & Signal Processing, Vol. 13, No. 6, 1999, pp. 855-878.

4. Gentile, C. and Bernardini, G., "Output-only modal identification of a reinforced concrete bridge from radar-based measurement," NDT & E International, Vol. 41, No. 7, 2008, pp. 544-553.

James Brownjohn, University of Sheffield
email: james.brownjohn@sheffield.ac.uk

Figures

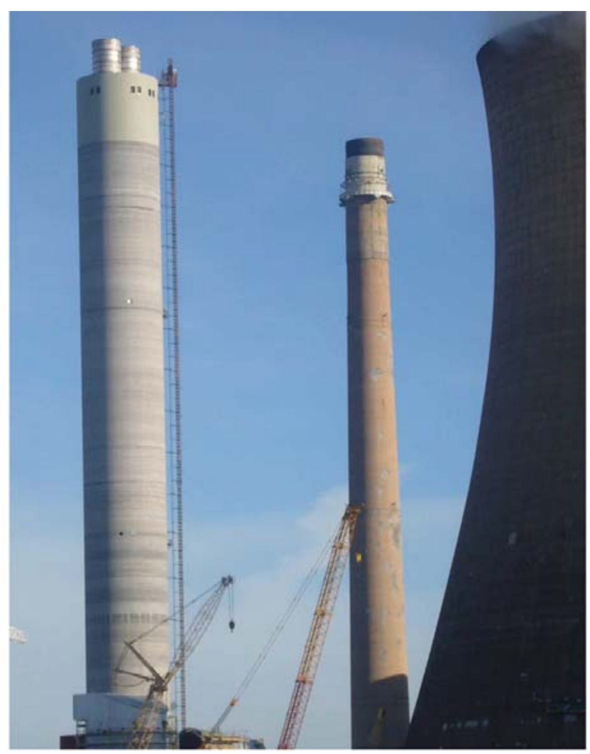


Figure 1 Chimneys at Rugeley Power station: old chimney crowned by tuned mass damper is in the centre

Figure 2 TMD under construction, with lower accelerometer box in position and flue openings flanking chimney

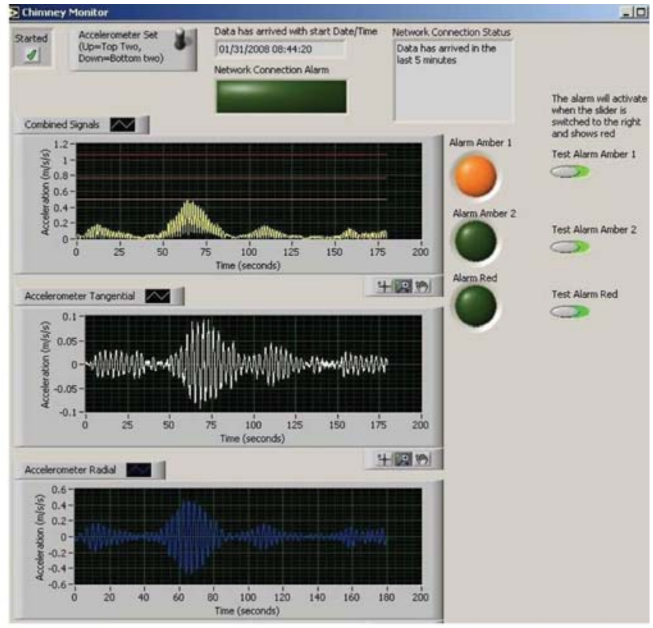


Figure 3 Monitoring system indicating alert level Amber 1, 31/01/2008

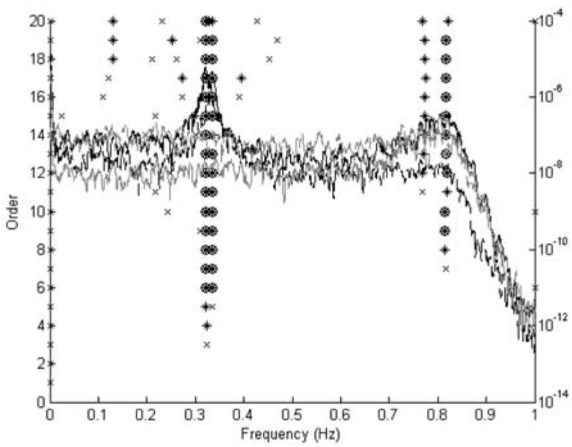


Figure 4 Typical stability diagram obtained from decimated response data. 'x' are non-stable poles, stars are stable in frequency only, circles are stable poles. Black solid and dashed lines are power spectrum of top two accelerometers, grey solid and dashed lines are power spectrum of bottom two accelerometers

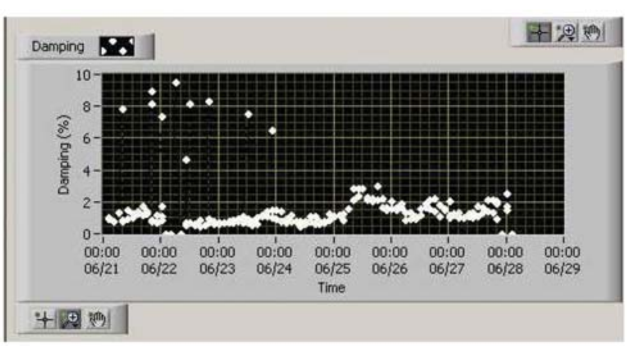


Figure 5 Damping values from seven days of monitoring, varying from 0.5% to 3%

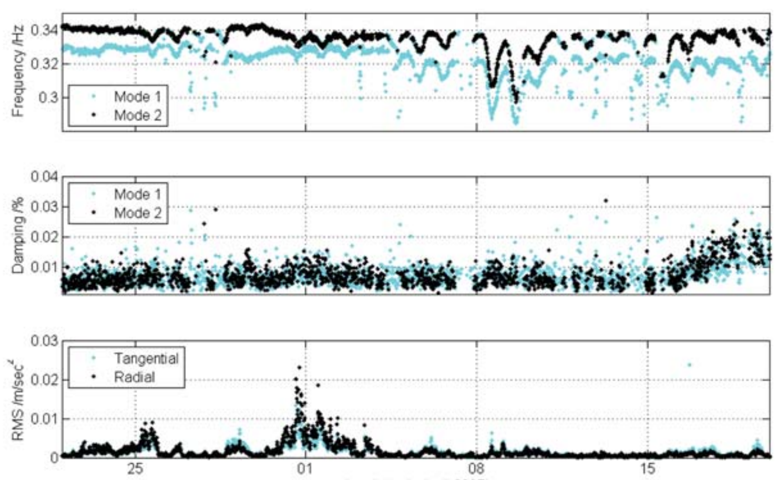


Figure 6 Variation of fundamental mode frequency and damping and of chimney response levels over 18-minute frames during 31 days of operation spanning commissioning of the TMD

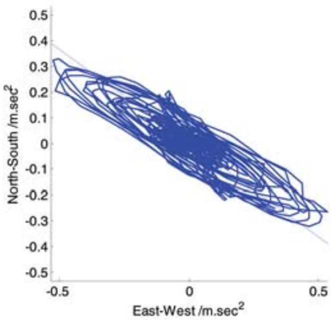


Figure 7a Acceleration values during winds registered as SSW, 39 mph (17.4m/sec) at Met station EGBB, 080131074420

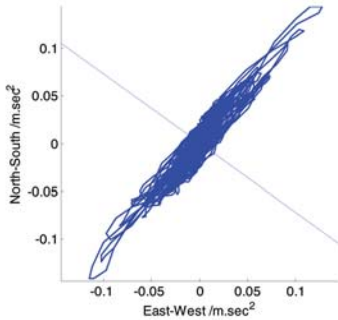


Figure 7b Acceleration values during winds registered as WNW, 22mph (9.8m/sec) at Met station EGBB, 071209224427

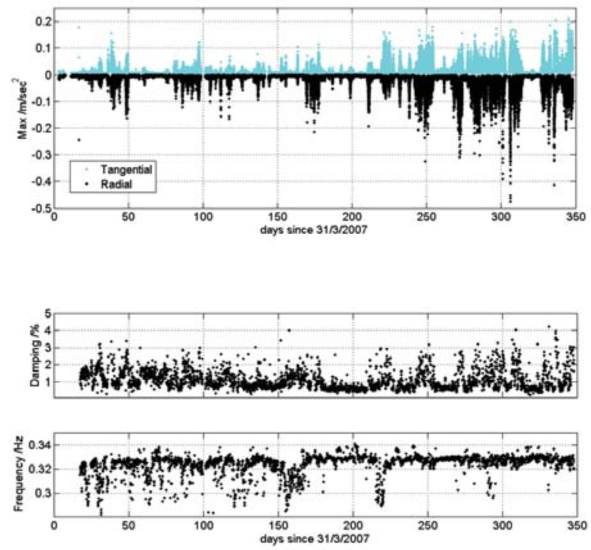


Figure 8 (upper) maximum acceleration values over 3-minute frames, (lower) damping and frequency estimates over 2-hour frames

Figure 9a Aligning radar sensor

Figure 9b Radar sensor tracking new chimney

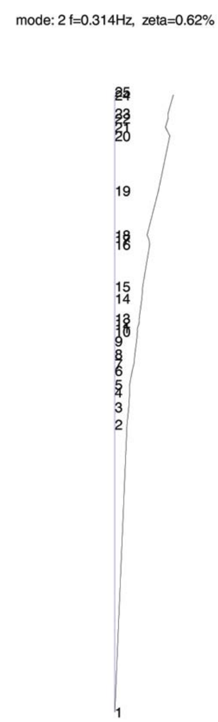


Figure 9c Modal parameter estimates for old chimney

STATUE'S "HEARTBEAT" SENDS MESSAGES ON STRUCTURAL CORROSION

SENSORS ENSURE THE GOLDEN BOY STANDS TALL

Kathy Riggs Larsen

Just as doctors routinely use their patients' heartbeats as one indicator of good health, researchers at the ISIS Canada Research Network (Intelligent Sensing for Innovative Structures) (Winnipeg, Manitoba, Canada) monitor the heartbeat of the Golden Boy statue that stands on the dome of the Manitoba Legislative Building in Winnipeg to ensure the statue stays healthy.

The Golden Boy's "heartbeat" is actually a vibrational reading taken from sensors located inside the hollow, cast-bronze statue and is part of an overall structural health monitoring (SHM) system that continuously sends data to the ISIS Canada SHM Lab on the structural integrity of the statue. The Golden Boy has a natural vibration frequency of 3 Hz, or three beats per second, according to Aftab Mufti, professor of Civil Engineering at the University of Manitoba (Winnipeg, Manitoba, Canada); program leader and president of ISIS Canada; and first president of ISHMII (International Society for SHM of Intelligent Infrastructures).

With SHM, he says, researchers can immediately detect a significant change, i.e., a drop in frequency to 1.5 Hz, and know that the Golden Boy has a health issue, such as corrosion of the stainless steel (SS) structural support rod that keeps the statue safely standing tall. Since the SHM system was installed five years ago, Mufti notes, the daily data reports indicate that all is well with the statue. But in 2002, the Golden Boy was not in the peak of health and prior to the implementation of SHM, its structural safety issues had to be addressed.

Corrosion of the Structural Support Rod

Officially named Eternal Youth by the French sculptor Georges Gardet, who created the 1,650 kg, 5.25-m tall statue, the Golden Boy is Manitoba's most well-known landmark. The Golden Boy survived World War I during its journey to Winnipeg from France on a troop transport ship and was originally mounted on the dome of the Legislative Building on November 21, 1919. There, the Golden Boy stood for 82 years until 2001, when engineers discovered severe corrosion of the statue's steel support rod during a major restoration of the Legislative Building.

At the time, initial plans only called for regilding the Golden Boy with 24-karat gold leaf, and the work was to be done while the statue remained in place on the dome. When inspectors examined the statue from the scaffolding and noted the extreme weathering of the existing gilded surface, the decision was made to remove the dome's copper cladding and further investigate the condition of the statue's base.

The Golden Boy is fabricated around a central 125-mm diameter steel rod, known as an armature, which extends from the chest of the statue down into the dome of the building. According to Sital Rihal, a NACE International member and part of the consulting team from Dillion Consulting Limited (Winnipeg, Manitoba, Canada) hired by the Manitoba government to examine the Golden Boy, the team discovered that corrosion was visible on the statue's central steel support rod.

Endoscopy and gamma-ray x-rays obtained from various angles of the statue's stationary foot confirmed the support rod and support plate below the statue's foot had suffered corrosion and in places the rod had lost up to 10 to 15 mm of the original 125-mm diameter. One contributor to the corrosion, Rihal says, was the accumulation of moisture from condensation that formed on the support rod when warm air flowing from the building encountered cold air in the interior of the statue. Also to blame was the installation of an electric light to the Golden Boy's torch in 1966-to mark Canada's centennial-that allowed rainwater to penetrate the statue's bronze skin.

The Manitoba government made the decision to utilize wind testing to determine if the corrosion had reduced the statue's ability to safely withstand future Manitoba weather. To determine the impact of the rod's corrosion on the statue's strength and load-carrying capacity, the consulting team tested yield strength of the existing support rod from a sample taken from the rod at the area exposed behind the left knee. Using a photogrammetric survey to produce a three-dimensional digital image, the Dillon team devised a 1/20 scale model of the statue and tested it for wind load at the University of Western Ontario Boundary Layer Wind Tunnel Laboratory (London, Ontario, Canada).

Results of the wind tunnel tests and yield strength tests conducted indicated that at its current rate of corrosion, the statue's support rod had an estimated lifespan of only 20-30 more years. In order to effectively repair the statue, the decision was made to remove the Golden Boy from the dome and replace the corroded steel support rod with a new 124-mm diameter 17-4 Precipitation Hardened Condition 1150 SS rod. To mitigate future corrosion, the electric torch was removed and the holes in the statue were sealed. Rihal adds that the building's ventilation system was also modified to prevent warm air from escaping into the dome.

The Golden Boy's Structural Health Monitoring

With the Golden Boy on the ground for repairs and regilding, the Manitoba government approved the installation of an SHM system inside the statue to monitor the structural integrity of the statue and facilitate protection of the provincial symbol for many future generations.

"Structural health monitoring uses a variety of sensors to gather information about the behavior of a structure," says Mufti. "The information creates a valuable knowledge base that can be analyzed to help identify potential structural risks, develop safer and more efficient new structures, and determine more effective ways to rehabilitate existing structures."

The SHM system for the Golden Boy is comprised of four types of gauges: accelerometers, electric resistance strain gauges, fiber optic strain gauges, and thermocouples. By using these sensors, Mufti explains, researchers can determine the internal stress, vibration, and inclination of the structure and examine its response to loading. Responses can be used to assess the condition of the structure or structural components, to identify damage, or to verify its current level of safety.

Two accelerometers measuring movements or vibrations in response to wind and various weather systems are located at the heart of the Golden Boy, on the top of the replacement SS supporting rod. The Fast Fourier Transform (FFT) method is used to convert accelerometer readings to the frequency domain to provide a meaningful viewing of frequency response. A healthy Golden Boy will have a natural vibration frequency of 3 Hz. If the rod diameter reduces by 25 mm due to corrosion, the vibration frequency will be reduced to 1.5 Hz, which indicates a problem.

Since maximum strain occurs at the heel, Mufti explains, the team determined that eight fiber optic sensors, eight electric strain gauges, and four thermocouples would be located at the base of the statue's support rod. The strain gauges and fiber optic sensors monitor the strains in the rod due to wind pushing the Golden Boy. The thermocouples measure temperature and report how the structure expands, contracts, and changes its behavior. This is important, Mufti says, because temperature affects the strains on the supporting rod, which, in turn, affects the integrity of the rod where it is connected to the dome. Electrical resistance strain gauges and fiber optic sensors installed on the support rod near the heel of the Golden Boy monitor the strains in the rod due to wind on the statue.

A wind meter is installed on the roof of the Legislative building close to the statue. The measurement of wind speed and direction coupled with strain gauge readings from the rod help engineers to determine the wind force applied to the Golden Boy statue.

All of the Golden Boy's sensor data are sent by cable to a data logger that is connected to an on-site PC-based data acquisition (DAQ) unit located inside the legislative building. The DAQ utilizes a Data Space Transfer Protocol (DSTP) data exchange. Considered by the team to be a simple way to transmit data over a network, this data exchange consists of a data socket server, a data publisher, and subscribers. An application program running continuously on the PC collects data from the Golden Boy's sensors and publishes it to the data socket server every 5 s. The data socket server is located in the on-site PC with a unique Internet IP address for the data publisher at that site. Because of the amount of data transferred, the SHM system uses a cable modem for the internet connection.

At the central control site, located at the ISIS Canada SHM Lab in Winnipeg, an application program on the data server is continuously running to subscribe the data from the remote site. Every 5 s, the new data are transferred and analyzed. The data server generates a data file every day for the Golden Boy.

Currently, Mufti says, about 1 GB of data per day on the Golden Boy is reported, and a software program uses statistical analysis to sort through and interpret the data. If data patterns remain basically the same, the software doesn't store the data. However, data are stored when the patterns change significantly, and researchers are notified if something completely new happens.

Real-time data received and interpreted by the central control site are published to the ISIS Canada Web site (www.isiscanada.com). However, Mufti stresses, various levels of data security are in place and sensitive information is highly secure. Available for viewing are accelerometer readings (including FFT); strain gauges readings (including FFT); wind meter readings, including wind pressure, wind force, and wind velocity (north-south, east-west, and resultant force); and thermocouple temperature readings. Web cameras are also installed on-site and images of the statue are integrated into the Web site. Researchers can use controls to pan, tilt, or zoom the camera image to see real-time views of the condition of the structure.

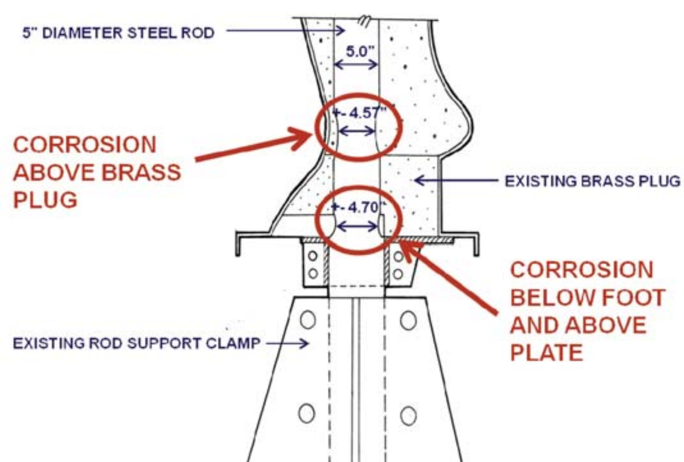
Researchers at ISIS Canada are continually working to develop techniques to collect scientific data as well as improve data collecting and interpretation software-all with the goal of more accurately assessing the reliability and safety of the Golden Boy and other structures monitored by ISIS Canada. Benefits realized by incorporating SHM into structures include the development of cost-efficient maintenance procedures based on SHM data analysis; early access to information regarding the physical and structural state of a structure that will help identify potential risks; and the ability to create better and safer designs of similar structures based on results on SHM data analysis.

Because of the work done with the Golden Boy, Mufti adds, other organizations are starting to inquire about incorporating an SHM system when rehabilitating structures. "In the past, we relied on limited visual inspection of structures, which is expensive," he notes. "Now we are able to collect data and scientifically assess structures as they are aging."

Consequently, Mufti explains, a new discipline-civionics-is emerging. Civionics is a new term derived from civil-electronics, and describes the application of electronics to civil structures. With an objective of capturing all the advantages of SHM, civionics assists civil engineering professionals with integrating electronic monitoring systems into the design and construction of structures.

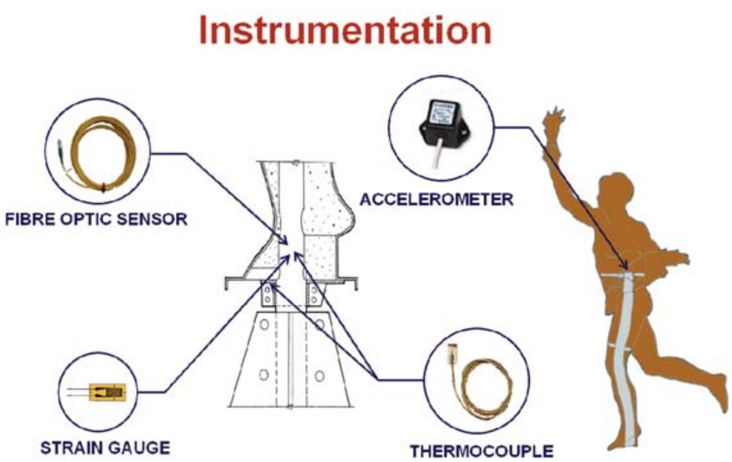
Dr. Aftab Mufti, ISIS Canada, University of Manitoba
email: muftia@cc.umanitoba.ca

Georges Gardet's statue Eternal Youth, also known as the Golden Boy, is Manitoba's most well-known landmark. (Photo by Tony Nardella, Nardella Photography, Winnipeg, Manitoba, courtesy of ISIS Canada.)



The image illustrates where corrosion was found on the Golden Boy's support rod and plate.
(Image by Chad Klowak, courtesy of ISIS Canada.)

In places, the statue's steel support rod had lost up to 10 to 15 mm of its original 125-mm diameter. (Photos courtesy of ISIS Canada.)



Four types of SHM gauges are installed on the Golden Boy's support rod.
(Image by Chad Klowak, courtesy of ISIS Canada.)

Masters student Chad Klowak installs accelerometers on top of the new SS rod that supports the Golden Boy.
(Photo courtesy of ISIS Canada.)

US Sweeping Bridge Safety Bill Includes Fiber Optic

U.S. Rep. Steven C. LaTourette (R-Bainbridge Township) today announced that a sweeping bridge safety bill approved by the House includes a study of fiber optic sensors like those developed by companies with offices in Twinsburg and Mentor that can detect stresses on bridges before they collapse or fail.

The House of Representatives today approved H.R. 3999, the Highway Bridge Reconstruction and Inspection Act, by a vote of 367-55. LaTourette said the measure authorizes $2 billion over two years for bridge reconstruction nationwide and requires the Federal Highway Administration (FHWA) to update national bridge inspection standards. It also calls on the FHWA to improve training for highway bridge inspectors. The bill was introduced after the August 2007 bridge collapse in Minneapolis that killed 13 people.

LaTourette said the bill includes language he supported that will authorize the FHWA to study the effectiveness of fiber optic sensors and other sensors in detecting deficiencies in bridges, particularly those under construction or renovation. LaTourette said he believes fiber optic sensors marketed by companies in Twinsburg and Mentor might have detected extreme stresses on the 35W Bridge in Minneapolis before it collapsed. It was loaded with heavy equipment and traffic had been shifted to accommodate construction, he said.

LaTourette said two 14th District companies are marketing cutting edge products that might have been able to avert the tragedy in Minneapolis. Cleveland Electric Laboratories Co. in Twinsburg is marketing fiber-optic sensors that are attached to bridges to detect and monitor stress loads, and its product is being used on a project in Albany, NY. Roctest Ltd. of Quebec, which has its U.S. office in Mentor, is also marketing a fiber optic sensor system to detect stresses on bridges, and it will be used as the 35W Bridge in Minneapolis is rebuilt.

“We’re lucky that inspectors almost always catch problems and avert tragedies, but there are situations where unusual stresses on a bridge can lead to catastrophe. I think this technology certainly merits more study so we never experience another disaster like the one in Minneapolis. It’s exciting to have two Northeast Ohio companies right in the mix,” LaTourette said.

LaTourette said construction can place unusual stresses on a bridge, and the small fiber optic sensors can monitor and record the level of stress. “Who hasn’t been on a bridge where all the traffic is shifted to one side while the other is filled with workers and heavy equipment?” LaTourette said. “If a tiny sensor can detect when stress becomes so great that it makes a bridge susceptible to collapse, that’s a tremendous safety benefit not only for motorists but the workers renovating the bridge.”

Daniele Inaudi, Roctest Ltd. - Smartec SA
email: inaudi@smartec.ch
www.roctest.com

CORPORATE MEMBER PROFILE

VCE HOLDING GmbH

VCE is an independent, high tech and development oriented consulting firm with its head office in Austria (203 employees, 18% RTD). The company operates in three principal lines of business:

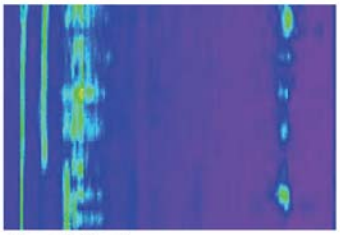
- the building and industrial sector (general design and management as well as process development and technological expertise),
- the development sector (from research and development to feasibility and environmental studies, financial engineering, to development aid),
- the transportation sector, infrastructures in general, particular bridges, tunnels and railways.

VCE has major operations in Austria, Taiwan, Korea, Eastern Europe, the Middle East and Africa. To date, over 2200 contracts have been successfully completed in 62 countries world-wide with larger, more exciting projects currently underway. The key personnel at VCE consist of experts in many highly specialized fields with long experience records. Close cooperation of the firm with major European and overseas universities provides additional expertise to the company when required. VCE has a proud heritage. The firm was founded by Professor K. Wenzel, and has made a major contribution to the technical advancement and aesthetic evolution and refinement of modern bridge design in Austria and around the world. And since the formation of VCE in 1980 that contribution has expanded to an international level.

VCE has developed a monitoring system BRIMOS. It is recognized throughout the world that major structures require comprehensive "health" monitoring systems for the purpose of structural damage detection and safe operations. Major structures are expensive to maintain, rehabilitate or replace and they frequently pose complex technical problems so that it is important to secure the operation of these vital lifeline infrastructures and to protect the vast investments made in these road and rail transportation systems.


BRIMOS


Application


Trend Card

The highly qualified personnel, with long and varied experience around the world provide expertise and versatility which has brought VCE international recognition.

Technology Management bridges the gap between industry and academic research by integrating technological considerations into business decision making. In the field of construction it is a precondition for the successful market introduction of new and innovative developments. Therefore Technology Management has been strength throughout the lifetime of VCE.

Helmut Wenzel, VCE Holding GmbH
www.vce.at

ROCTEST WINS THE PRESTIGIOUS CONTRACT FOR THE ST. ANTHONY FALLS BRIDGE (I-35W)

Roctest Ltd. "Group Roctest" (TSX:RTT) has been awarded a major contract from Flatiron Constructors/Manson Construction Company of Minneapolis (Flatiron-Manson JV), principal contractors for the I-35W Minnesota Bridge construction. The contract includes instrumenting the I-35W Bridge with conventional vibratingwire products and fiber optic instruments. This bridge project is a world-first for Group Roctest for this type of combined applications as it also combines Roctest newly introduced SensCore concrete corrosion monitoring system.

The new I-35W Bridge project, designed by FIGG Engineering Group, was started in October 2007 following the tragic collapse of the original bridge on August 1, 2007.

Group Roctest worked in close relationship with Minnesota DOT and the University of Minnesota in finalizing the optimal instrumentation solution for the bridge.

The monitoring instruments on the I-35W Bridge will measure dynamic and static parameter points to enable close behavioural monitoring for the bridge's life span. This bridge will be considered one of the first Smart Bridges to be constructed in the United States.

"Roctest has instrumented hundreds of structures with fiber optic sensors and many customers have also combined our traditional vibrating wire technology with our fiber optic sensors in geotechnical applications. In this contract, fiber optic has been selected as a complementary solution for monitoring I-35W Bridge, clearly proving the maturity of our solution and it will certainly lead to more opportunities in bridge and other structural applications" said François Cordeau, President and Chief Executive Officer of Roctest. "Roctest is really the only instrumentation company offering a complete toolbox of solutions, providing world-class traditional vibrating-wire instruments, leading edge fiber optic sensors, the unique SensCore concrete corrosion monitoring system and the application software to monitor complex structures." added François Cordeau.

ROCTEST WINS PRESTIGIOUS CONTRACT FOR JINPING 2 DAM IN CHINA

Roctest Ltd. and its Chinese agent, Earth Products China Ltd, have been awarded a major contract for the deliveries of numerous instruments for the second highest dam in the world, Jinping 2 HPP, located on the Yalong River in China. The project started in February 2007 and is scheduled to be completed by 2014. Roctest is the main supplier of geotechnical instrumentation for the project, which is part of a network of five dams along the Yalong River, including the Ertan Dam , which was also instrumented by the Roctest Group between 1995 and 2000.

"We are very proud to have won another prestigious contract in such a highly competitive market. This not only demonstrates our ability to meet stringent requirements but also to offer a complete solution to a very complex engineering structure," said Francois
Cordeau, President & Chief Executive Officer of Roctest. "Roctest is the only instrumentation company offering a complete toolbox of solutions, providing world-class traditional vibrating-wire instruments, leading edge fiber optic sensors, the unique SensCore concrete corrosion monitoring system and the application software to monitor complex structures," added Mr. Cordeau.

With a height of 305 meters, this concrete dam will be the second highest in the world, after the Rogun Dam, in Tajikistan at 335 meters high. The total capacity of Jinping 2 will be 4800 MW, with its eight generators at 600 MW each.

This project will require thousands of sensors, a magnitude rarely seen in the industry, and will measure different parameters such as pore pressure in the foundation of the dam, settlement, strain and other types of movement during construction and all along the
lifespan of the structure.

Daniele Inaudi, Roctest Ltd. - Smartec SA
email: inaudi@smartec.ch
www.roctest.com

ROCTEST INTRODUCES THE NEW SENSCORE SYSTEM

Roctest Ltd. "has announced the immediate introduction of the new SensCore product line, dedicated to the monitoring of corrosion in reinforced concrete structures. The SensCore system is a wireless sensor network, designed to detect and predict the onset of steel corrosion in concrete. The system consists of sensors, dataloggers and a measurement hub that concentrates the data from several dataloggers and transmits it to a central database, where it can be accessed by the authorized users. The sensors are able to measure several parameters, which are critical to evaluate the present and future risk of rebar corrosion in concrete. In particular the corrosion current and the concrete humidity are measured at several depths between the concrete surface and the rebar depth, to analyze the progression of the corrosion front as well as evaluate the performance of hydrophobic coatings.

The sensors are extremely simple to deploy and can transmit their data wirelessly to the measurement hub, thus eliminating the need to install any wiring in the structure to be monitored. Because of its modular design, this system is adapted to structures of all sizes, from a small overpass to a long tunnel and can be installed in both new and existing structures. The SensCore system integrates seamlessly with all present Roctest, Télémac and SMARTEC product lines, based on electrical, vibrating wire or fiber optics technologies. It is therefore possible to combine several technologies in order to implement an optimal monitoring network for any type of structure, being it a bridge, a building, a tunnel, a dam or any other concrete structure. The SensCore System ties into Roctest's SDB database system, providing a unified display and interface to all monitoring data, regardless of the underlying sensing technologies.

The SensCore system has been developed in cooperation with a leading Swiss University and has already being deployed on tens of structures, including the I35 St. Antony Falls Bridge in Minneapolis recently instrumented by Roctest. "Corrosion is one of the leading concerns in reinforced concrete structures and often limits their durability" said Daniele Inaudi, Roctest's CTO, "it is therefore advantageous to complement the current monitoring strategies with a direct measurement of the corrosion progression".

"The SensCore system ideally expands our growing toolbox of sensing systems" added François Cordeau, Roctest's CEO, "further positioning our Company as the leading provider of Structural Health Monitoring solutions".

The SensCore system will be distributed by Roctest, Télémac and SMARTEC.

François Cordeau, President and Chief Executive Officer
Roctest Ltd. Tel.: (450) 465-1113 info@roctest.com
www.roctest.com

P.L. PRATELY AWARD

Dr. Aftab Mufti, President and Scientific Director of ISIS Canada, and Professor of Civil Engineering at the University of Manitoba, is the recipient of the P.L. Prately Award from the Canadian Society for Civil Engineering for the paper, "Development of a glass-fiber-reinforced-polymer bridge deck system".

International Workshop "Civil Structural Health Monitoring 2" Taormina - Sicily (Sept 28-Oct 1, 2008)

Delegates met to promote international cooperation in the fields of load capacity, bridge performance maintenance and safety. Further information on the conference can be found at www.cshm2.enea.it/index.html

IRIS SUMMER ACADEMY 2009

The Summer Academy is an initiative of IRIS, an EC funded European project within the 7th Framework Program on risk assessment and management for industrial systems, coordinated by VCE Holding GmbH. The IRIS joins construction companies, bridge-owners and managers, railway consultants, road authorities, equipment suppliers, research institutions, regional and city governments and universities.
The project is led and driven by industry to consolidate and generate knowledge and technologies to enable the integration of new safety concepts related to technical, human, organizational and cultural aspects.
The IRIS Summer Academy 2009 will take place from September 1st to 4th 2009 in Zell am See / Austria, in the beautiful province of Salzburg. It will be a 4-day-event taking place at the "Cultural Centre Lohninghof" in Zell am See.

Objectives & Target Groups

The Summer Academy is addressed to interested engineers in administration and management, industry, private enterprise and research. It is aimed at bringing benefit to owners of infrastructure, end users of technologies, consultants, service providers and engineers in general as well as to scientists working in the fields of structural engineering, earthquake engineering, seismic assessment, monitoring and control, insurance, equipment and transportation.
The objectives of this academy are to:

- give information about the global infrastructure performance
- provide a tutorial on bridge monitoring and management
- enable access to the international collaboration
- IRIS Award of Excellence
- IRIS Forum

Information & Registration:

Mrs. Nicole Krims-Steiner: krims-steiner@vce.at
Mrs. Klaudia Ratzinger: ratzinger@vce.at

First Announcement and Call for Papers

CSHM-3 2010

Ottawa- Gatineau, Canada
11-13 August 2010

International Workshop on Preservation of Heritage Structures Using ACM and SHM

The focus of the workshop will be to provide a forum to highlight current applications of ACM and SHM in heritage structures, discuss research and application needs and establish the future role of ACM and SHM in the preservation of heritage buildings. Through the efforts of the ISIS Canada Research Network, several projects have already been implemented in Canada including veterans cemetery monuments, the Golden Boy statue in Winnipeg and most recently, the historic Canada Parliament Buildings. The restoration and preservation of Canada's Parliament Buildings in Ottawa is an important heritage building project in Canada. The choice of Ottawa as a venue will allow this project, as well as many other heritage structures in the region, to be showcased during the workshop.

The workshop will also provide an opportunity for a working meeting of the joint task group of ISHMII and IIFC on the use of FRPs and SHM in preserving World Heritage Structures.

SPONSORS

University of British Columbia (UBC)
ISIS Canada Network Association
ISIS Canada Research Network
International Society for Structural Health Monitoring of Intelligent Infrastructure (ISHMII)
International Institute for FRP in Construction (IIFC)
Public Works and Government Services Canada (PWGSC)

All abstracts and full papers should be submitted by mail to: muftia@cc.umanitoba.ca

CALL FOR PAPERS

Papers are invited in all areas of SHM and ACM in the preservation of Heritage Structures including

- Global climate change and its impact on heritage structures
- Seismic, wind and erosion resistance of heritage structures
- Use of advanced composite materials (ACM) to strengthen heritage masonry and wood structures
- Structural health monitoring (SHM) systems for heritage masonry and wood structures
- Long term performance of ACM, resins, cementitious mortar with heritage materials and structures
- Education and Research Programs
- Design and construction techniques of heritage structures
- Guidelines and codes to preserve heritage structures
- Economic and social impact of protection of heritage structures
- Case studies and future directions
- Preservation of aesthetics of heritage structures

IMPORTANT DATES

Abstract submission	**September 15, 2009**
Abstract acceptance	**October 15, 2009**
Submission of full paper	**January 15, 2010**
Paper acceptance	**March 15, 2010**
Final submission of revised paper	**April 15, 2010**

PROCEEDINGS

Proceedings of the CSHM-3 will be published and available at the workshop.

WORKSHOP DIRECTORATE

Nemkumar (Nemy) Banthia, PhD, PEng
Professor, Distinguished University Scholar & Canada Research Chair in Infrastructure Rehabilitation
Department of Civil Engineering, The University of British Columbia, 2024-6250 Applied Science Lane, Vancouver, BC, Canada V6T 1Z4. Tel: 604-822-9541 Fax: 604-822-6901 E-mail: banthia@civil.ubc.ca

First Announcement and Call for Papers

CSHM-3 2010

Ottawa- Gatineau, Canada
11-13 August 2010

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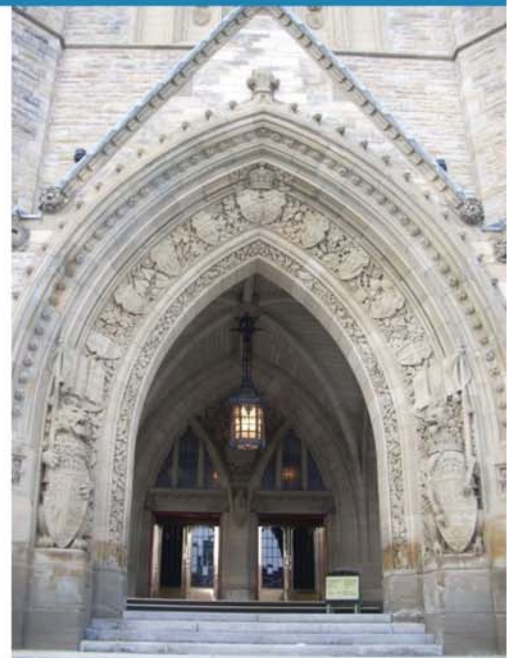

International Workshop on Preservation of Heritage Structures Using ACM and SHM

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Jozsa Zszusanna, Hungary

WORKSHOP DIRECTORATE
Nemkumar (Nemy) Banthia, PhD, PEng
Professor, Distinguished University Scholar & Canada Research Chair in Infrastructure Rehabilitation
Department of Civil Engineering, The University of British Columbia, 2024-6250 Applied Science Lane,
Vancouver, BC, Canada V6T 1Z4. Tel: 604-822-9541 Fax: 604-822-6901 E-mail: banthia@civil.ubc.ca