The 5th Annual Workshop for Australian Network of Structural Health Monitoring

(Web site: www.anshm.org.au)

Time Schedule

Day 1: Monday, 18 Nov, 2013

Time	Activity	Venue
15:30 – 16:00	Reception and Afternoon tea	**Meeting Room B309, Level 3, Block B, Department of Infrastructure Engineering, Building 175** The University of Melbourne Campus *(see next page for the map)*
16:00 – 18:00	Advisory Board Meeting*	
18:30 – 21:00	Dinner*	TBA

NOTE: Items with " * " are for Advisory Board and Executive Members only

Day 2: Tuesday, 19 Nov, 2013

Time	Activity	Venue
09:30 – 11:00	Annual General Meeting	**Meeting Room B309, Department of Infrastructure Engineering, Building 175**
11:00 – 17:30	Workshop Presentations *(see page 6 for the schedule)*	**Lecture Theatre C1, Level 4, Department of Infrastructure Engineering, Building 175**

Contact

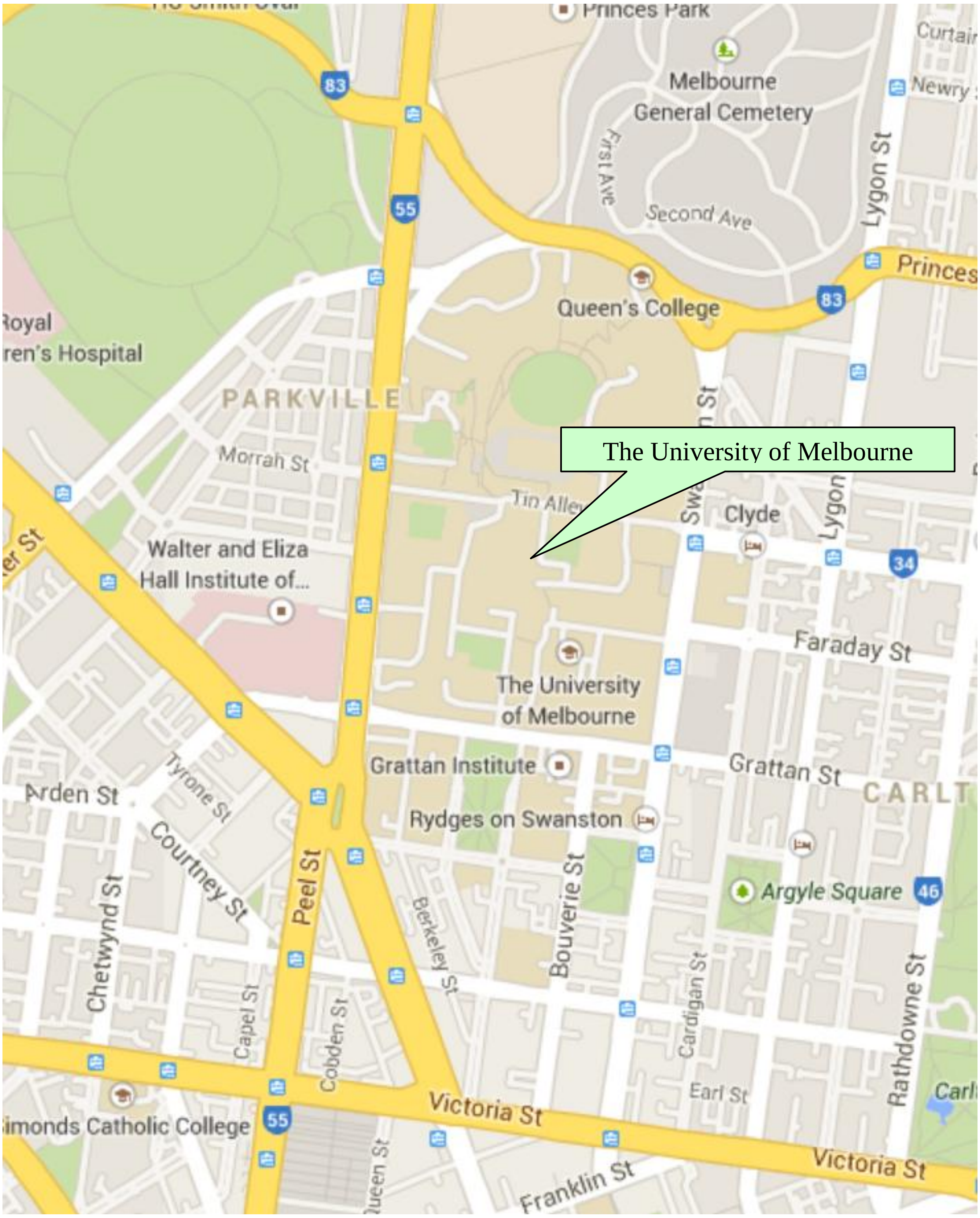
For any enquiry, please contact:

Dr. Tuan Ngo
Department of Infrastructure Engineering
The University of Melbourne,
Victoria, VIC 3010, Australia
Email: dtngo@unimelb.edu.au
Mobile: +61 (0) 411 987 732, Tel: +61 (0)3 8344-7950, Fax: +61 (0)3 8344-4616



ANSHM Annual Workshop Venues

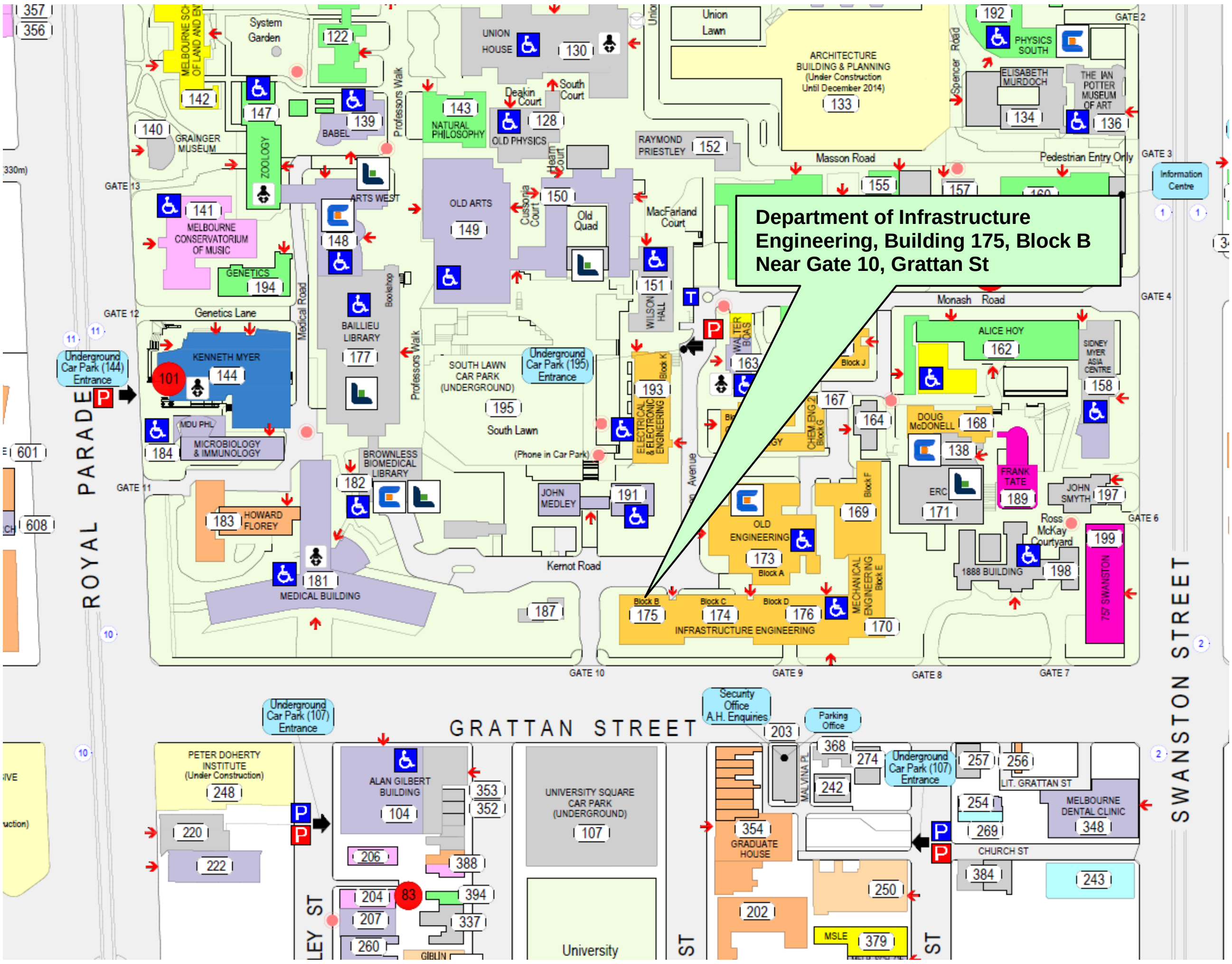
Address: The University of Melbourne, VIC, 3010



ANSHM Annual Workshop Venues

<u>Advisory Board & Annual General Meeting:</u> Meeting Room B309, Level 3, Block B, Department of Infrastructure Engineering, Building 175

<u>Workshop Presentation:</u> Lecture Theatre C1, Level 4, Department of Infrastructure Engineering, Building 175



5^{th} ANSHM Annual Workshop

Structural Health Monitoring (SHM) is defined as the use of an on–structure sensing system to monitor the performance of the structure and evaluate its health state. For the last two decades SHM has been attracting enormous research efforts around the world because it targets at monitoring structural conditions to prevent catastrophic failure, and to provide quantitative data for engineers and infrastructure owners to design reliable structures and economical asset management plans. SHM has been accepted as a justified effort for civil structures. It is a worldwide trend to install a SHM system on a significant structure, e.g. Burj Khalifa tower in Dubai, Huey P. Long Bridge in USA, Haram Grand Mosque Expansion in Saudi Arabia, Millau Viaduct bridge in France. The objective of the 5^{th} Annual Workshop for Australian Network of Structural Health Monitoring (ANSHM) is to bring together civil engineers, designers, researchers, construction companies as well as responsible persons from government and road/highway authorities who have an interest in improving the service life, safety and reliability of civil structures.

We have members from the following institutions:

Institute or government
CSIRO
Deakin University
Griffith University
QDTMR
Queensland University of Technology
RMSNSW
University of Adelaide
University of Melbourne
Monash University
University of Newcastle
University of New England
University of Technology Sydney
University of Western Australia
University of Western Sydney
University of New South Wales
VicRoads
NICTA
James Cook University
ARRB
University of Wollongong
University of Southern Queensland

Company
Opus
Rockfield

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Dr Ying Wang (Deakin University)
Dr Xinqun Zhu (University of Western Sydney)

Detailed Program for Workshop Presentation (19 Nov 2013)

Time	Activity
11:00 – 11:10	Opening Speech *Dr Tuan Ngo & Prof. Priyan Mendis, UOM*
11:10 – 11:30	Guided Wave based Quantitative Identification of Damage in Beams using a Bayesian Approach *University of Adelaide*
11:30 – 11:50	Assessment and Management of Bridge Loading using Traffic Microsimulation *Monash University*
11:50 – 12:10	Condition Assessment of Composite Bridges Subjected to Moving Traffic *University of Western Australia*
12:10 – 12:30	Structural Health Monitoring of Buildings and Bridges: From Theory to Application and Implementation *Queensland University of Technology*
12:30 – 12:50	Infrastructure Health Monitoring Program of Research at UNSW *University of NSW*
12:50 – 14:00	Lunch
14:00 – 14:20	EMA and other dynamic testing of a 2-span prestressed concrete floor *Swinburne University of Technology*
14:20 – 14:40	Recent Research Progress on Structural Damage Identification in Deakin University *Deakin University*
14:40 – 15:00	Advances in Architecture Design of a Distributed Structural Health Monitoring System at NICTA *National ICT Australia*
15:00 – 15:20	An Integrated Deterioration Approach for Predicting Long-Term Bridge Performance: Case Studies *Griffith University*
15:20 – 15:30	Coffee Break

15:30 – 15:50	Energy-Efficient Time Synchronization in Wireless Sensor Networks for Monitoring Buildings, Bridges and other Infrastructure *University of Melbourne*
15:50 – 16:10	Development of integrated multidisciplinary management system for Infrastructure *University of New England*
16:10 – 16:30	Fibre Composite Bridge Girder In-service Structural Health Monitoring *University of Southern Queensland*
16:30 – 17:30	Industrial Forum *Chair: Dr. Yew-Chin Koay (Vic Roads); Facilitator: Mr. Peter Runcie (NICTA)*
17:30 – 17:40	Closing Speech *Prof. Tommy Chan, President of ANSHM, QUT*

Presentation Information:
In each presentation, speakers will have 20 minutes to present their work (including Q&A).

Information on Presentations

Contribution from University of Adelaide

Guided Wave based Quantitative Identification of Damage in Beams using a Bayesian Approach

Ching-Tai Ng

School of Civil, Environmental & Mining Engineering, The University of Melbourne, Melbourne, SA 5005, Australia

Abstract

The aging and deterioration of engineered infrastructure across the developed world have become a universal challenge for governments and industries. Monitoring structural integrity to enhance the sustainability and reliability of both new and old structures, and the reduction of their life cycle costs have become increasingly important. Beams are commonly used as structural components in different engineering structures, such as civil and mechanical engineering. Existence of damages in structural components can potentially lead to failure of structures. It is important to detect and identify the damages at their early stage for ensuring the safety and integrity of structures, and reducing the risk of catastrophic failure.

This presentation reports an experimental study of quantitative identification of damage in beams using guided wave. A Bayesian probabilistic approach is proposed to identify the damage location, length and depth. The damage identification is achieved by solving an optimization problem, in which the probability density function (PDF) of the damage parameters is maximized. A hybrid particle swarm optimization (HPSO) algorithm is employed to guarantee the global optimum solution. One advantage of the proposed methodology is that the Bayesian approach not only pinpoints the location, length and depth of the damage, but also quantifies the uncertainties associated with the damage identification results through calculating the posterior PDF of the identified damage parameters. This provides essential information for making decisions on necessary remedial work. In the experimental study a piezoceramic transducer is used for excitation. The guided wave signals are then measured using a laser Doppler vibrometer system. Metallic beams with different damage configurations are considered in the experimental verification.

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Contribution from Monash University

Assessment and Management of Bridge Loading using Traffic Microsimulation

Colin Caprani

Dept. of Civil Engineering, Monash University. colin.caprani@monash.edu

Abstract

Traffic load is a highly variable parameter in the safety assessment of bridge structures. For existing structures, its accurate assessment is important as rehabilitation measures are expensive, and may not be needed. Successful mitigation of critical loading events could significantly increase the useful service life of existing structures. The use of traffic management methods to influence the traffic stream experienced by a bridge offers a means of reducing the uncertainty in the loading.

Traffic microsimulation offers a comprehensive approach to the modelling of traffic. It is based on individual vehicle behaviour, with parameters that can account for differences in vehicle type and driver behaviour. Thus it can inherently capture both free-flowing and congested traffic states naturally, offering a more realistic picture of traffic states and their consequent load effects on bridges. Further, traffic microsimulation enables the simulation of potential traffic management methods to estimate their effectiveness.

This work presents some recent results from the use of traffic microsimulation. Comparison with bridge loading codes of practice is made for a range of bridges and load effects. Various traffic management strategies are investigated for their effect on loading. The possibility of bridge-to-vehicle communication is explored, as is the use of lane change restrictions zones in the lead up to the bridge. A bridge load control system is also examined.

Given the ageing bridge stock and increasing financial limitations of the developed world, this research offers a means of extending the useful life of existing infrastructure. Modern wireless communication tools and traffic management and modelling techniques are used to reduce the bridge live load. As such, this work offers bridge owners a means of ensuring safety, whilst reducing costs.

Contribution from University of Western Australia

SHM of Buildings and Bridges: Research at QUT From Theory to Application and Implementation

Jun Li [a,*], Hong Hao [b]

[a,*] *Research Associate, School of Civil and Resource Engineering, The University of Western Australia,35 Stirling Highway, Crawley, WA 6009, Australia. jun.li@uwa.edu.au*

[b] *Winthrop Professor, School of Civil and Resource Engineering, The University of Western Australia,35 Stirling Highway, Crawley, WA 6009, Australia. hong.hao@uwa.edu.au*

Abstract

Composite bridges are widely constructed on Australia highways with concrete slab supported on concrete or steel girders. The slab and girders are connected with shear connection, which will suffer the shear force due to the loading on the bridge and therefore is significant for the estimation of load-carrying capacity of bridges. Visual-based inspection approaches may not be able to access the conditions of shear connection buried in composite bridges. Vibration-based approaches may require a number of measurements, i.e. accelerations on the slab and girder, for the condition assessment. An innovative relative displacement sensor has been developed to directly measure the relative slip between slab and girder in composite bridges, which indicates the health condition of shear connection. The condition monitoring of shear connection in composite bridges is conducted with experimental studies on a slab on steel girders composite bridge. The damage of shear connection is introduced by removing a specific shear bolt to simulate the failure of a shear connector. Continuous Wavelet Transform and Hilbert-Huang Transform are applied to identify the damage of shear connectors in composite bridges with measured responses from the bridge subjected to a moving vehicle. The performance of using the relative displacement, acceleration and displacement responses respectively for damage detection are demonstrated and compared. The location and moment of the introduced damage can be identified accurately with the relative displacement measurements. Experimental studies demonstrated that the shear displacement response has a better and stable performance than acceleration and displacement for condition assessment of composite bridges.

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Contribution from Queensland University of Technology (QUT)

Structural Health Monitoring of Buildings and Bridges: From Theory to Application and Implementation

Tommy H. T. Chan, David P. Thambiratnam, Andy C. C. Tan, Sabrina Fawzia, Regina Sampaio (Augusta) , Liang Wang, Manindra R. Kaphle, Buddhi L. Wahalathantri, Rupika P. Bandara, Man H. Yau, Craig J. L. Cowled, Theanh Nguyen, Mehran Aflatooni, Kuo Li, Parviz Moradi Pour, Wasanthi R. Wickramasinghe, Thisara S. Pathirage, Manal Hussin & Ziru Xiang

School of Civil Engineering & Built Environment, Queensland University of Technology, Brisbane, QLD 4001, Australia

Abstract

Structural Health Monitoring (SHM) research at Queensland University of Technology (QUT) can be divided into three main categories: (i) system development, (ii) sensors / measurement and (iii) applications. There are *three* projects in the first category. For the *first* project, an 3D steel-truss-bridge physical model was simulated in STRAND7. The FE model of the structure was updated to match the experimental modal analysis results using a multi-layer-hybrid global optimisation method. The *second* project establishes a real-world SHM test-bed on a newly built 5-star-green rated building. The *third* project, having previously identified Data Synchronisation Errors (DSE) as the most inherent uncertainty of Wireless Sensor Networks (WSNs) was investigated its impact on level 1 of Output-only Modal-based Damage Identification (OMDI). The sensors / measurement category consists of *two* completed and *two* ongoing projects. The *first* completed project developed advanced Acoustic Emissions (AE) signal processing techniques for improved damage detection (DD) in metal structures. The *second* completed project proposed two methods for measuring the vertical displacements of bridges using Fibre Bragg Grating (FBG) sensors. The *first* ongoing project investigates the use of unsupervised learning novelty detection methods for Vibration Based Damage Detection (VBDD) to cope with Environmental and Operational Variations (EOVs) impacts. The *second* ongoing project aims to develop a practical FBG system for measuring the temperature, acceleration, strain/displacement and etc. using the modulation of the FBG strain. The last category includes *four* completed and *seven* ongoing projects. The *first* completed project developed a correlation-based DD method employing Modal Strain Energy (MSE) with a Multi-Layer Genetic Algorithm (ML-GA) optimisation approach for steel truss bridges. The *second* completed project developed an MSE based damage index for reinforced concrete (RC) structures. The *third* completed project developed an VBDD method using a three-stage Artificial Neural Network (ANN) pattern recognition approach to analyse Frequency Response Function (FRF) data. The *last* completed project extracts modal parameters of a heavy-haul-railway RC bridges network. Acceleration data was experimentally obtained and modal parameters identification was also performed using ARTeMIS. The *first* ongoing project aims to determine the use of previous completed project to assist bridge management of a RC bridge network. The *second* ongoing project introduces a Synthetic Rating method for a railway bridges network based on its current and future conditions at network level which identifies critical factors of train loads, extreme environmental impacts

and etc. In the *third* ongoing project an existing sensitivity-matrix-based MSE DD method was mathematically improved and then numerically applied to some 2D bridges using STRAND7 & MATLAB. The *fourth* ongoing project develops a multi-criteria approach for damage detection in cables and hangers of suspension bridges. The numerical FE model of some suspension bridges will be developed in ANSYS and then verified using available data and data from testing. The *last* ongoing projects aim to develop a method to identify the effective prestress force (PF) in prestressed concrete (PSC) box girder bridges.

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Contribution from University of NSW

Infrastructure Health Monitoring Program of Research at UNSW

Brian Uy

Centre for Infrastructure Engineering & Safety, School of Civil and Environmental Engineering, The University of New South Wales

Abstract

The research program of Centre for Infrastructure Engineering & Safety includes a number of research threads, including assessment of structures at a global and local level. This paper will highlight the major research in this theme and will also outline the coupling of this theme with reliability approaches in structural engineering.

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Contribution from Swinburne University of Technology

EMA and other dynamic testing of a 2-span prestressed concrete floor

*Nguyen, T. H., [1] Haritos, N., [2] Gad, E. F. and [3] Wilson, J. L.
*Research Assistant, [1]Adjunct Professor, [2]Professor, [3]Executive Dean

Swinburne University of Technology
John St, Hawthorn, Vic 3122

Abstract

It has become common practice nowadays that owner-clients specify in their tender documentation that provision be made for a load test investigation to be conducted, to give confidence to the analysis model, when bidding on important infrastructure rehabilitation and construction projects. This paper discusses experimental modal analysis (EMA) using swept sine wave forcing from a shaker and other dynamic field tests including heel drop and walking performed on a 2-span prestressed concrete floor. The test floor is part of a building whose construction is in progress and where vibrations induced by human activities, delivery vehicles and fork-lifts are of concern.

The modal frequencies and damping ratios of the floor obtained from the simple un-instrumented heel drop test were found to compare well with those acquired from the more sophisticated shake test, which verifies the usability of the former technique. A slight non-linearity was found in the damping ratio whereby damping values can change with different levels of vibration. The measured fundamental frequency is within the typical range for building floors whilst the observed damping level appears to be rather low, possibly because the floor was prestressed and in a bare as-built condition without furnishing when tested. The measured mode shapes also showed the presence of partial continuity between the two test bays separated by movement joints. An investigation of the floor response due to single persons and people in pairs walking at a range of pacing rates revealed that perfect synchronization between different walkers was unlikely to be achieved.

Calibration of an FE model of the floor based on the experimental findings and physical observations of the floor system when under construction is also discussed.

Contribution from Deakin University

Recent Research Progress on Structural Damage Identification in Deakin University

Ying Wang and Mr. Ali M. Ay
School of Engineering, Faculty of Science, Engineering and Built Environment, Deakin University, 75 Pigdons Rd, Waurn Ponds, VIC 3216

Abstract

Currently the most popular approach in regards to structural damage identification is primarily based on model-dependent methods created from mathematical models which directly estimate the evolution of structure's modal parameters due to subjected damage conditions. However, this approach reaches a bottleneck, particularly with the case of matching FEM based model modals with experimentally acquired modal parameters. Two key limitations include 1) match of the analytical modal parameters to experimental results, and 2) substantial level of environment induced vibration (noise pollution) on experimentally acquired modal parameters.

The current research in Deakin University focuses on damage identification based on a combination of multiple statistical models in different domains. From time domain (raw data), only the response acceleration from the test structure is used to develop an ARMAX model interpretation for each damage scenario, under a supervised format. A number of damage scenarios are established with one being an intact structure. Per damage scenario, three impulse vibrations are recorded and averaged. The calibration procedure for each damage scenario is completed with an iteration program where the four non-linear model defining parameters are tuned until a value higher than the set minimum coefficient of determination value. The calibrated ARMAX program is then fed with an unlabeled response signal and directly compared to the three models in turn. Using the maximum obtained value of normalized root mean square (NRMSE) from the three comparisons, the identified damage scenario is presented. This data is also coupled with a confidence margin, a value denoting the difference between the top two NRMSE values obtained in the comparison procedure, providing a quantitative value that can be observed directly when evaluating the accuracy of damage identification.

Then, data are transformed into the frequency domain (FRF). On this domain a nonlinear regression algorithm (Advanced Statistical Algorithm) is used. It is based on natural frequency evolution in conjunction to the severity of quantifiable damage and environmental conditions (temperature, wind, and others). Various influencing parameters are defined in accordance to the fundamentals of the structure under investigation. Such influences can be seen as either boundary conditions or directing parameters on the statistical fitting procedure. The key features extracted from the FRF for this algorithm are the resonance peaks of the structure within a limited bandwidth. Prior to extraction of resonant peak points, the sum of all FRF curves are made accordingly in order to make the real vibration modes more apparent and minimize incorrect picking of resonant points by the algorithm.

Once the two algorithms are correctly calibrated and evaluated in regards to performance of damage identification, two sets of damage identifiers are obtained. At this point an

innovative decision making process is implemented that effectively serves as a data fusion process, combining data from multiple algorithms that are intrinsically different in their damage identifiers, however deal with an identical test structure and damage scenarios. It is worthy to note that the two types of algorithms are not given the same weighting for the decision making process. The criterion of weighting is based upon the level at which the algorithm is provided with the 'influencing' parameters.

Contribution from National ICT Australia

Advances in Architecture Design of a Distributed Structural Health Monitoring System at NICTA

Samir Mustapha∗, Peter Runcie, Thierry Rakotoarivelo, Khoa Nguyen, Rodney Berriman, Clinton Freeman, Serge Lichman and Hilary Cinis

National ICT Australia, Eveleigh, NSW 2015, Australia

Abstract

Structural Health Monitoring (SHM) systems are increasingly been used for early detection of damage. Benefits to owners of civil structures include extending asset life and reduction in life cycle costs. The application of SHM systems on large structures, in particular infrastructure such as bridges, high-rise buildings and dams can be challenging. The physical size of these structures, difficulty of access and sometimes-remote geographical location must all be catered for. In addition to these challenges, SHM system may use hundreds or thousands of sensors that further increases the problem's complexity. System control and maintenance, data collection, retrieval, storage, and analysis all must be considered. In addition, asset managers, engineers and researchers have somewhat different though complimentary needs.

An SHM system based on a distributed architecture can address many of these requirements and provide a reliable, robust, and scalable solution that can accommodate new data sources analytical techniques as they become available. In this work, the key challenges faced when designing a large-scale SHM system are discussed. Address those challenges with cost effective and innovative software, hardware and communications networks are also described. The case study used is that of a damage detection system installed on the Sydney Harbour Bridge – one of Australia's iconic structures. Furthermore, multiple novel approaches to localized damage detection and identification were developed. These approaches include supervised/unsupervised machine learning algorithms to identify and characterize the state of structures.

The system provides asset managers, and bridge inspectors with convenient access to actionable structural health and system information via a web-based interface with sms and email notifications.

Contribution from Griffith University

An Integrated Deterioration Approach for Predicting Long-Term Bridge Performance: Case Studies

G.P. Bu[1], J.H. Lee[2], H. Guan[1], and Y.C. Loo[1, 2]

[1]*Griffith School of Engineering, Griffith University, Gold Coast Campus, QLD, Australia*
[2]*Smart Infrastructure Asset Management Australia (SIAMA) Research and Development Pty Ltd, Australia*

Abstract

An integrated deterioration prediction method has been developed to predict long-term performance of bridge elements for various situations in terms of the quantity and distribution of available condition rating data. The method employs a categorisation and selection process in conjunction with the Backward Prediction Model (BPM) as well as the time-based and state-based models. The main advantage of the categorisation process is to group similar elements together, thereby identifying the common deterioration patterns. The selection process embedded in the proposed method offers the ability to automatically select the most appropriate model (i.e. state- and time-based model with/without BPM) for predicting future bridge condition ratings. To check the accuracy of the proposed integrated method, a series of case studies are carried out based on the U.S. National Bridge Inventory (NBI) datasets. A total of 38 bridges with 429 bridge inspection records are selected from the New York State network. Amongst these records, 303 are used as input to predict the bridge condition ratings using both the proposed method and the standard Markovian-based procedure. The predicted bridge condition ratings are cross-validated with the actual condition ratings - i.e. the remaining 126 inspection records. For long-term performance prediction, both methods are also compared which further confirms the superiority and merits of the proposed integrated method.

Contribution from the University of Melbourne

Energy-Efficient Time Synchronization in Wireless Sensor Networks for Monitoring Buildings, Bridges and other Infrastructure

Tuan Ngo, Aravinda S. Rao, Jayavardhana Gubbi, and Marimuthu Palaniswami

School of Engineering, University of Melbourne

Abstract

Wireless sensor networks based applications are widespread and serve as a low-cost solutions for monitoring buildings, bridges and other infrastructure. The time-stamp of the data is affected by both spatial and temporal sampling process. The data collected by asynchronous clocks mismatch in time of the data collected by different nodes for a given event, resulting in time synchronization error. Energy efficient time synchronization is proposed in this paper. Parent nodes accumulate the time differences measured during each data transfer interval. A parent node maintains a virtual clock of the child node. The method uses short-term relative skew measurement to keep track of long-term drift. It has options for predicting child node time and estimation of dynamic synchronization intervals. Simulation results show that it minimizes the error by maintaining a virtual child clock while preserving energy. The average timing error obtained between two nodes was 10 ms (for one-hop) and 9:1 ms (for two hops) for 300 s re-synchronization interval; 32:6 ms and 38:6 ms for 1000 s re-synchronization interval.

Contribution from University of New England

Development of integrated multidisciplinary management system for Infrastructure

Saeed Mahini John C. Moore and Rex Glencross-Grant

University of New England, Armidale, NSW 2351, Australia

Abstract

The main objective of this study is to monitor the structural health of older regional bridge girders in regional NSW to collect data in order to upgrade regional bridges and local infrastructures and help to carry agricultural products with larger vehicles to the markets safer, quicker and more reliably to ensure that produce reaches the markets in a timely manner. The project aims to develop an effective integrated and intelligent infrastructure management system to automatically transfer bridge data from remote areas to asset managers' offices for possible on-time action for design of the most economical and efficient repair and maintenance solution for degraded bridges such as using advanced natural and glass fibre composites.

The research program will involve:

- the strength testing for loading capacity of extant timber girders;
- the determination of the reliability of structural safety and reliability of bridge infrastructure (to wit, regional bridges in NSW);
- the investigation of related electronic sensors to determine strength; safety and reliability; and
- the investigation of network systems to allow the remote determination of structural safety using intelligent systems.

Contribution from University of Southern Queensland

Fibre Composite Bridge Girder In-service Structural Health Monitoring

Hao Wang*, Joshua Peauril, Malcolm McKay

Centre of Excellence in Engineered Fibre Composites, University of Southern Queensland

Abstract

Fibre Reinforced Polymer (FRP) composites are being introduced into bridge structures as new materials for bridge girder and deck. The lack of historical data in Australia brings into question the durability of these materials in civil structures. A structural health monitoring program is being carried out that would monitor the performance of the FRP bridge beams after installation for a period of one to two years with Queensland Department of Transport and Main Roads.

The constructions of the bridge beams are often thin wall sections surrounding a light weight core. They can be constructed from sandwich panels or pultruded sections that are assembled or by a single hollow section. The more ductile designs contain steel reinforcement of some kind. The beams are deigned to match the theoretical axial stiffness (EI) for the loading and deflection requirements according to the bridge design code AS5100.

Fatigue tests for fibre composite panels indicate no endurance limit for the materials and a reduction in capacity of up to 35% after 10^6 cycles [**Error! Reference source not found.**]. It has also been shown that hybrid materials with a large difference in E moduli of the constituents where worse than homogeneous ones.

The primary indicators of fatigue or damage over time that may occur in the beams are:
1. Increased deflection/reduction in stiffness
2. Buckling or wrinkling - especially due to shear load at ends of beams or in thin walled sections.
3. Local failures –especially at areas of stress concentration -bolt locations
4. Any mechanical damage due to impact
5. Any damage due to fire

Primary measurements being taken:
1. Axial strain/deflections along the length of beam
2. Strain in and around bolt/attachment locations
3. Temperature
4. Visual observation

The sensors used are a combination of strain gauges, temperature sensors, accelerometers and fibre optic sensors (emerging technology). All sensors are surface mounted to the beams during installation by super glue, rapid cure epoxy adhesive, prepreg patches and sealed from the environment with an epoxy coating.

The sensors are also being compared for durability and ease of use in this harsh and difficult to access environment. Surface mounted fibre optic sensors have undergone

durability tests to show signal distortions and debonding after 50,000 cycles at 4,000 microstrain [**Error! Reference source not found.**]. They found that the variation in readings to traditional foil gauges to be no more than 9%. Due to the load factors applied in bridge design, approximately 900 microstrain is expected under the highest loads.

Two types of monitoring systems are being set up: scheduled monitoring and continuous monitoring.

1. Scheduled Monitoring is being done by monthly site visits where data is taken for a period of several hours. This uses a mobile data logging system and has the advantage of being used at several different sites during the program. The fibre optic sensor doesn't require balancing or zeroing each time and can therefore indicate damage that has occurred outside of the monitoring hours.
2. Continuous monitoring can give the 'big' picture by logging data 24 hours day. This requires a dedicated system being designed and installed on site running continuously. The system has been designed to use off-the-shelf devices and components to reduce the complexity of the implementation program.

The program is running continuous monitoring at one site and scheduled monitoring at two sites involving 2 FRP beams at each site.

The first batch of results will be collated for presentation and will reflect on: beam performance after installation, sensor methods of applying to FRP and protection from environment, sensor performance and comparison.

Useful Information for the 5th ANSHM Annual Workshop

Transportation

- ***Taxi from Airport to University of Melbourne – Gate 10 Grattan St***

A typical taxi fare is AUD$50. It will take about 35-40 minutes. The taxi rank is located directly out the front of Terminal on the ground level. There is a AUD$2 levy added to fares for taxis leaving the airport.

- ***SkyBus:***

Public transport buses – known as the SkyBus service – pick up and drop off from the bus stop ground level directly outside Terminal adjacent the domestic baggage carousels. Sky Bus services travel to and from the city. Single trip ticket can be purchased from bus.
Go to the website http://www.skybus.com.au/ for more information.

Accommodation Information

There are a number of hotels and serviced apartments located close to the University.

Name	Distance to the workshop venue
A: Rydges on Swanston Hotel 701 Swanston St http://www.rydges.com/accommodation/melbourne-vic/swanston-melbourne/welcome/	150 m
B: Best Western Plus Travel-Inn Hotel 225 Drummond St http://www.thetravelinn.com.au/the-travel-inn-accommodation-melbourne.php	500 m
C: Arrow On Swanston 488 Swanston St http://www.arrowonswanston.com.au/short-term/apartments/	700 m
D: Quality Hotel Downtowner on Lygon 66 Lygon Street http://www.choicehotels.com.au/en/quality-hotel-downtowner-on-lygon-melbourne-hotel-au404?promo=gglocalau	800 m

University of Melbourne

Established in 1853, the University of Melbourne is the Australia's second oldest university and a public-spirited institution that makes distinctive contributions to society in research, learning and teaching and engagement. It's consistently ranked among the leading universities in the world, with international rankings of world universities placing it as number 28 in the world (Times Higher Education World University Rankings 2012-2013). Four Australian prime ministers and five governors-general have graduated from Melbourne. Seven Nobel laureates have been students or faculty, the most of any Australian university.

The School of Engineering at the University of Melbourne is the oldest engineering faculty in Australia. It has come a long way from the modest beginnings in 1861 with 15 students enrolled. Today the School has 305 academic & research staff, more than 2000 undergraduate students, 880 graduate students and more than 600 research higher degree students.