AUSTRALIAN NETWORK OF STRUCTURAL HEALTH MONITORING

Newsletter

Issue 5, September 2015

Contents

President Message

Tommy Chan

Professor in Civil Engineering, Queensland University of Technology

Dear All,

On 11 August 2015 I was invited by the Australian Section of ASCE to give a lecture on “Advances in SHM” at Engineering House, Brisbane. It was very well received by over 50 attendants during a lunch hour of a week day. The ASCE Australia section board are very happy with our input on SHM to this society in Australia and particularly that ASCE will be engaged with SHMII 2017 in Brisbane.

I consider this kind of lecture is very useful to help the practising engineers know better about the benefits of SHM and how it could be practically applied to cost effectively manage and maintain civil structures. Most often engineers on one extreme consider that a SHM system is very expensive to install and on the other extreme randomly install sensors on a structure and claim that as a SHM system. This kind of seminars will help our local engineers to better understand what SHM is. I am very pleased that after five years of the effort of us (ANSHM) as a cluster, we clearly demonstrate its importance and help the local engineers to realise its significance. We will continue to witness how we reap the fruit of our effort that more and more of our structures here in Australia will be installed with SHM and how we could lead and advance this kind of technology for the national benefits, locally as well as overseas. One thing is good that some universities, e.g. QUT, started to introduce SHM in their undergraduate courses. In other words, we will have more and more engineers in the future who know its importance and implement this kind of technology in their design and maintenance of the civil structures.

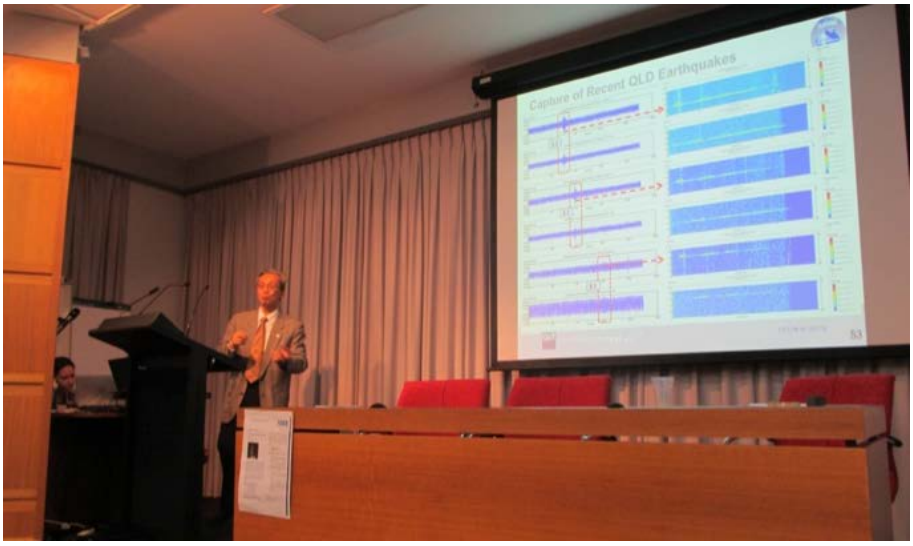


Photo 1 Presenting the Preliminary Analysis Results of the Recent QLD Earthquakes at the Lecture

In the ASCE lecture, I demonstrated how we could spend less than 0.3% of the construction cost of the new Science and Engineering Centre (SEC) at QUT to implement the vibration monitoring system to make it as a living laboratory and monitor its performance and deterioration. In the talk, I also mentioned how excited we were when we noticed that we could be able to capture the vibration caused by the recent earthquake in Queensland, even its scale is 'moderate' and it occurred at a distance more than 300km from us. There is an article in this Newsletter describing our preliminary analysis using the SHM system we installed at QUT. ARRB Group is carrying out numerous projects with QDTMR under the National Asset Centre of Excellence (NACoE) research agreement to improve current bridge assessment projects. We have another article by the ARRB Group in this issue to report their work on the load testing and continuous monitoring of an in-service bridge of deck unit bridges and destructive testing of individual decommissioned deck units. The third article was by Rockfield and QUT reporting the progress of their collaborative research in implementing SHM for post disaster decision. I am so pleased to see that in this issue we have reports mainly from our members from the industry.

Research Collaboration

ANSHM Executive Committee (EC) has been discussing strategy for enhancing and supporting ANSHM research collaborations and ANSHM publicity. Prof Jinachun Li, our Deputy President of ANSHM is the person in charge of coordinating the research collaboration in EC. We understand the challenges in securing an ARC Linkage project due to the existing ARC rules and the constraints of the road authorities in allocating their funds. We also understand that our members may individually collaboratively work with the industry for various projects in the area of SHM. We are so pleased to know that many of our members from the Industry have indicated their willingness to contribute cash

and in-kind for ANSHM based projects or individual projects with ANSHM involvement. We on one hand will continue to promote collaborative research amongst ANSHM members (and the best is of course to establish ANSHM based projects with ARC funded grants) and on the other hand continue to encourage research projects individually with industrial participants. Based on this understanding, we will continue to work on formulating a strategy aiming at establishing sustainable growing models for ANSHM research collaborations/projects toward the critical goal on establishing an ARC Centre of Excellence.

Therefore ANSHM wishes to encourage its members to take versatile approaches toward establishment of the ANSHM or ANSHM related projects, for examples:

- To be established and awarded based on capacity of different institutes from ANSHM
- To be established and awarded based on collaboration of key researchers from ANSHM
- To be established and awarded based on individual institute but shares data within ANSHM or invited expertise from ANSHM members.

In general, when establishing projects, ANSHM members are encouraged to put ANSHM in their research proposals and if possible to allocate budget for ANSHM activities.

This is one of the main tasks of ANSHM and we will have further discussion on that in the forthcoming Advisory Board (AB) meeting at the 7th ANSHM Workshop at Perth.

In the last ANSHM EC meeting, Alex and Tuan were appointed as aliasing officers to help connecting ANSHM members with industries. They will also collect information from ANSHM members about their projects collaborating with industrial participants which will be put on ANSHM website. This helps us and others to get a better picture about how we get involved with the industry. Alex will send us an email requesting information of our successful/potential industry collaboration. As we may not like to disclose this information at an early stage of collaboration, we understand if any of us who only like to provide such information until the projects have been well established.

SHMII 2017

In my last updates, I mentioned about our presentations about our SHMII 2017 preparation to ISHMII Council members at their council meeting and to the delegates at the closing ceremony of SHMII 2015, were warmly received. Below show two photos (Photos 2 and 3) of our presentation at the closing ceremony of SHMII 2015. The third photo (Photo 4) was taken to signify the transmission of SHMII from Turin to Brisbane.

Photo 2 - Saeed Introducing our SHMII-8, Brisbane, Ausralia at the Closing Ceremony of SHMII-7

Photo 3 - Continuing the Presentation by Introducing the Conference Venue

In Turin, Prof Mufti Aftab suggested us to have a session to invite industrial participants to discuss implementation of SHM from industrial aspects, which have not been included in any of the SHMII before. I considered that it is very similar to the Industrial Forum that we introduced to our ANSHM Workshops two years ago. Therefore, I proudly responded to him that although the implementation of SHM in Australia is still slow when comparing with other parts of the world, yet ANSHM has already realised the importance of the involvement of the Industry for its practical implementation and we

had already introduced this kind of industrial forum in our annual workshop two years ago. With the experience we have, we will definitely make this kind of industrial session a success in the forthcoming SHMII 2017 in Brisbane.

Photo 4 With Prof Alessandro De Stefano (Left, SHMII-7 Conference President) and Prof Mufti Aftab (between Saeed and myself)

ANSHM-7 Workshop, 26-27 November 2015, Perth

Jun and Hong Hao have been working hard to organise the workshop. They have been working on the program of the 7th ANSHM workshop. The information on the venue, accommodation and program will be sent to all members in due course. Up to now, we have received 11 abstracts.

As mentioned above, we will continue to have our industrial forum in the Workshop. We are working on it and more information will be given soon.

ANSHM Advisory Board Meeting and Annual General Meeting

As previous ANSHM workshops, we will have our Advisory Board Meeting together with the AB and EC Dinner after the meeting (many thanks for Hong Hao and Jun of Curtin U to host it) and the Annual General Meeting to be held at the 7th ANSHM Workshop. These two important meetings are important as we could meet face to face to plan for ANSHM future development. I am so excited that we could meet in this important annual event. There are so many issues that we need to discuss in the meetings. For your information, Alex is scrutinizing our ANSHM Rules to identify any necessary amendment to be discussed and endorsed in the two meetings. Agenda for the meetings will be distributed in due course.

ANSHM Special Issues

We have been successful in producing special issues, so we will continue to work on it. I am so pleased to inform you that because of the hard work of Ying, Saeed and Jun, we are able to submit the full package of our special issue to the editor-in-chief of Structural Monitoring and Maintenance (SMM) for its publication in September, 2015. We should also thank all the reviewers and authors for their timely reviews and revisions respectively. Once again, it reflects our team spirit in ANSHM.

After the completion of the editorial work of our special issue in SMM, we will continue to work on the preparation of our another special issue in Journal of Civil Structural Health Monitoring (JCSHM). With the support of the Chief Editor, Prof Farhad Ansari, an online submission system was set up. Please prepare your paper following "Introductions for Authors" (http://www.springer.com/engineering/civil+engineering/journal/13349) and submit online to this issue 'SI: Australian Experiences in Monitoring of Civil Structures'. As mentioned earlier, Xinqun, Bijan and myself will look after the review process. Although the deadline of submission is **1st October 2015**, we have already received two papers. These two papers are in peer-review process. We expect we will have 8-12 papers and all members are welcome to submit your papers of which the contents were presented at the 6th ANSHM Workshop.

ANSHM LinkedIn

As mentioned earlier that, we have launched LinkedIn for ANSHM (http://www.linkedin.com/grp/home?gid=4965305) as another platform for everyone to exchange ideas on various topics related to Structural Health Monitoring and share the successful experience in applying this technology. In our last EC meeting, we proposed to schedule regular webforum discussions. Xinqun will plan, arrange and promote such discussions. He will then summarise and report such discussions in the Newsletter. We need volunteers to lead the discussions. All members are welcome to email Xinqun (xinqun.zhu@uws.edu.au) to provide a topic and lead the discussion about the topic.

Achievements of Members

I am so glad to inform you that Saeed has been awarded the 2014 RW Chapman Medal by Engineers Australia for his paper "Structural Health Monitoring of Older Timber Bridge Girders using Laser-based Techniques".

Congratulations to Saeed!

This is a national award perpetually honouring the commitment of a former professor of engineering at Adelaide University and a member of the inaugural Council of Engineers Australia, Sir Robert Chapman. He was Chairman of the former Adelaide Division in 1920 and was President of the

Institution in 1922. It has been awarded since 1935 and is awarded for the most important contribution to practice of structural engineering in Australia in a particular year.

Photo 5 Saeed Mahini with other Award Recipients

Mini-Symposium in PLSE 2015

As mentioned earlier, we are organising a mini-symposium in PLSE 2015, 9 – 11 December 2015, Brisbane (http://plse2015.org/), jointly with Prof Y.Q. Ni of the HKPolyU. It is expected to have around 12 papers in total to be presented at the mini-symposium. On ANSHM side, we have received 6 papers and one paper has been alternately submitted to Prof. Y.Q. Ni.

ANSHM mini-symposium in ACMSM24

We have decided to organise an ANSHM mini-symposium in 24th Australasian Conference on the Mechanics of Structures and Materials (ACMSM24) (http://civil.eng.curtin.edu.au/ACMSM24/), which will be held in Perth from 6-9 Dec 2016. Please keep note on our updates regarding this mini-symposium and the call for abstracts.

With kind regards,
Tommy Chan
President, ANSHM
www.ANSHM.org.au

AUSTRALIAN NETWORK OF STRUCTURAL HEALTH MONITORING

Newsletter

QUT Structural Health Monitoring system and the capture of recent Queensland earthquakes

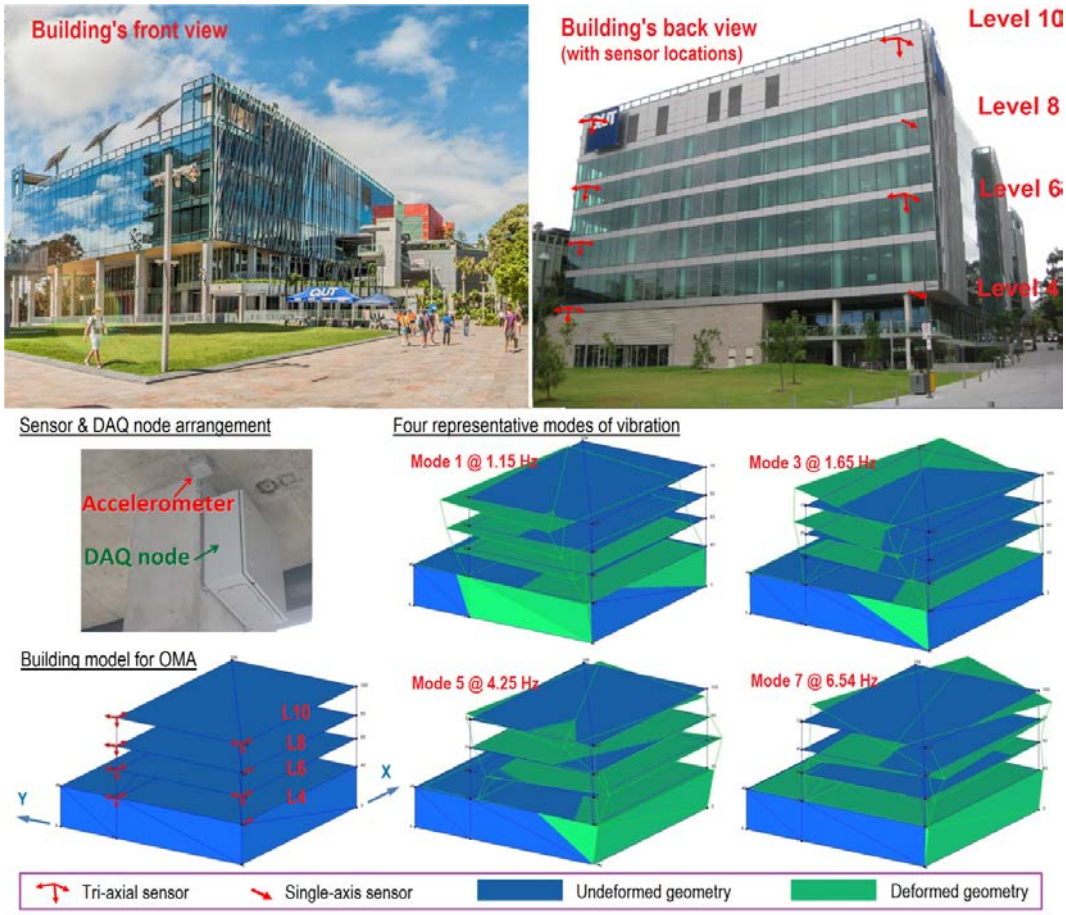
Theanh Nguyen, Tommy H.T. Chan, David P. Thambiratnam & K.A.Tharindu Kodikara

School of Civil Engineering and Built Environment,

Queensland University of Technology (QUT)

This article reports the main features of an innovative full-scale Structural Health Monitoring (SHM) system which has been implemented onto a landmark building on QUT Gardens Point Campus and its efficacy in capturing the recent Queensland earthquakes although they occurred almost 300 km away from where the system is located.

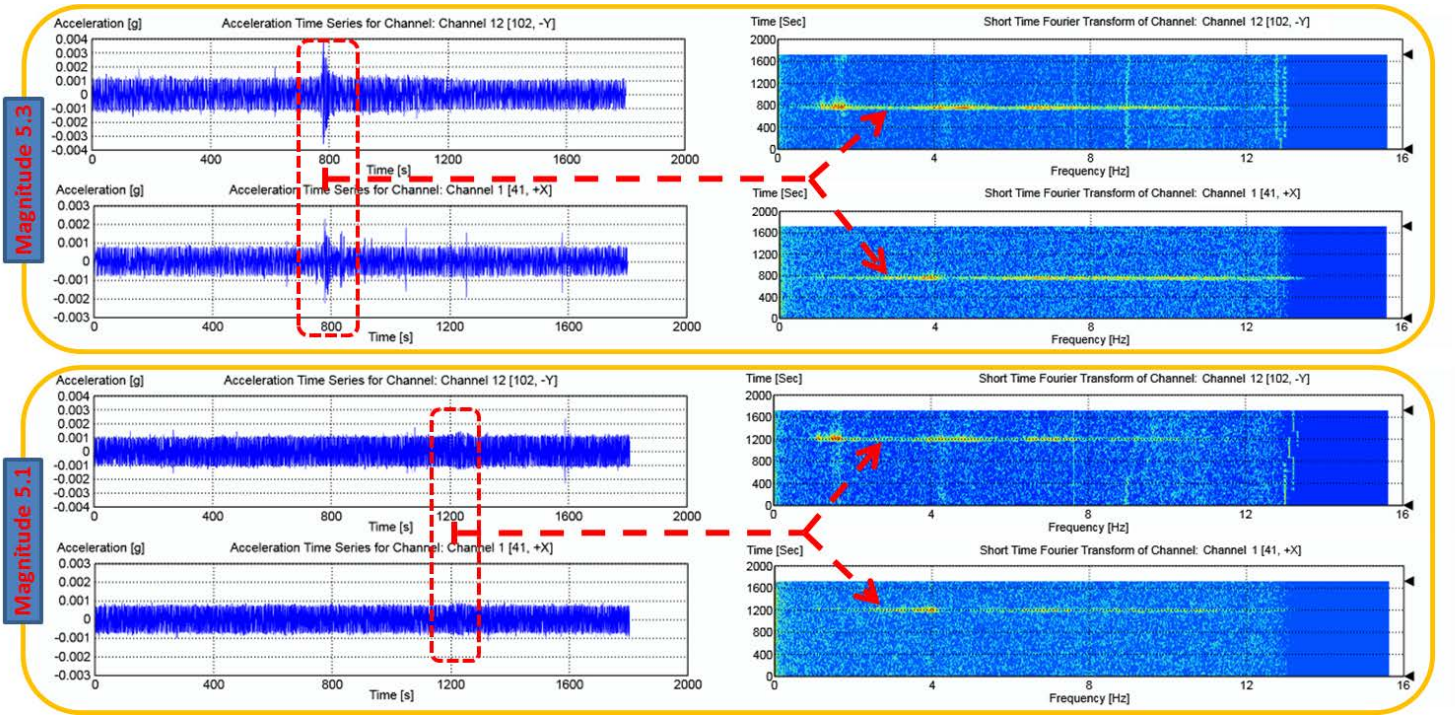
Instrumented structure and QUT SHM system



The site of the SHM system is the 10-story main building (called P block, as illustrated above) of QUT Science and Engineering Centre complex which is notable for its 5-star Green Star rating as well as the giant digital lab named "the Cube" (www.thecube.qut.edu.au). The SHM system herein is the main part of the three monitoring systems that have been deployed onto the complex. At the lowest system level, the SHM system consists of 8 capacitive-type vibration sensors (accelerometers) with fairly high sensitivity (2V/g) to overcome common adversities in ambient vibration monitoring such as low-frequency and low-level vibration measurements. In order to economically tackle the sparse measurement problem, the distributed DAQ architecture is first adopted and realized by a cost-optimized peripheral DAQ model (NI cRIO-9074). An innovative data synchronization method based on TCP/IP command communication technologies is then derived as a cost-effective and flexible substitute for traditional hardware-based synchronization modules. Using output-only modal analysis (OMA) approach, a total of seven vibration modes can be estimated well facilitating system validations as well as calibration of the analytical model of the structure [1, 2]. Modal-based health checks have also be made through combining long-term modal data with statistical unsupervised learning methods [1]. More details can be found in the related publications of the authors [1, 2].

Capturing recent Queensland earthquakes

On Saturday 1 August 2015, two significant earthquakes with magnitudes of 5.3 and 5.1 struck Eastern Queensland at 1:38pm and 2:46pm, respectively (note that the first one was initially cited at the magnitude of 5.7 but later revised by Geoscience Australia, see www.ga.gov.au/earthquakes/). Two days earlier on Thursday 30 July 2015, a similar quake also occurred in the same region. Even though they are rather significant earthquakes in the Queensland history, the epicentres of the two earthquakes on Saturday were relatively far from Brisbane (almost 300 km away) and it can be questioned whether the SHM system at QUT could capture these events for the exercises of rare event monitoring and post disaster assessment. A quick assessment programme was therefore set up and the datasets recorded at the times these two successive earthquakes occurred were rapidly screened in both time and time-frequency domains to detect singularities. The figure below shows the screenshots of time histories (left) and short-time Fourier transforms (right) of two representative measurement channels – one at level 10 (channel 12) and the other at level 4 (channel 1). As can be seen from this figure, both earthquakes are well captured by the system, reflected by excellent agreement between the timings of the singularities in two domains. An additional check has also indicated that these timings perfectly match the records provided by Geoscience Australia. Moreover, the changes in the amplitudes of time histories and in the colour maps tend to well reflect the difference in energy between the two earthquakes. Magnitude 5.3 is known to be around twice larger than magnitude 5.1 (in terms of initial energy release) while the actual position of the 5.3 magnitude earthquake herein was 2.3 times closer to the Earth's surface than that of its successor. Finally, by comparing data before and after each of the earthquakes, it can be concluded that the seismic waves did not make any significant long-term impact on the structural performance of the building.



Conclusions

In summary, the long-term SHM system on QUT Science and Engineering Centre complex has not only helped to assess long-term structural health such as deterioration but it has also enabled quick safety screenings for the building after rare events such as the recent earthquakes. Besides, the long-term SHM system could also help acquire valuable information for future designs and better understanding of structural behaviours under different environmental/loading conditions. With such benefits, the authors of this article hope to see more civil infrastructures around Australia in general and in Queensland in particular to be equipped with SHM systems to enable accuracy and timeliness in both emergency response and life-cycle assessment.

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AUSTRALIAN NETWORK OF STRUCTURAL HEALTH MONITORING

Newsletter

Load Capacity Assessment of Deck Unit Bridges

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[2]*Queensland Department of Transport and Main Roads*

The Queensland Department of Transport and Main Roads (TMR) is continuously investigating ways to refine current bridge assessment procedures in order to realise economic and strategic benefits across its network of approximately 3000 bridges and 4000 major culverts. To this end, TMR is carrying out a number of research projects in conjunction with ARRB Group under the National Asset Centre of Excellence (NACoE) research agreement. The current multi-year research program covers various areas of strategic interest, including the dynamic interactions between bridges and heavy vehicles. Given that a large number (over 1900) of the bridges on the network comprise transversely stressed deck unit bridges, one of the projects focuses on the structural behaviour of a specific type of bridge.

Deck unit bridges are unique in its design and performance, with a low level of transverse post-tensioning, upright external units and no shear-keys between units. While standard assessments indicate overloading, the observed actual in-service performance does not necessarily indicate distress. Accurate modelling of this family of bridges has been difficult to achieve. The motivation for testing these structures was to validate current theoretical assessment procedures and assumptions against the observed performance of each bridge. The results will be used to further improve structural capacity assessments for existing bridges and ensure consistent and reliable heavy vehicle access decisions.

Several milestones have been achieved in the first two years of this research project, including load testing and continuous monitoring of an in-service bridge of this type and destructive testing of individual decommissioned deck units. Destructive testing was undertaken collaboratively with UQ in their new structural laboratory. Results confirmed that these bridges behave similar to solid reinforced concrete slabs and perform better than current assessments indicating better alignment with condition and performance. Test results suggest that individual deck and kerb units have significantly higher ultimate shear capacities than expected and the reasons are being investigated further.

Figure 1: Load testing of deck unit bridge (left), and Laboratory testing of deck unit (right)

The next stage of the project involves planning for destructive testing of a decommissioned deck unit bridge to investigate bridge performance under ultimate loading. The outcomes of this project will be incorporated into existing TMR's assessment/design guidelines as well as the permit process for all transversely stressed deck unit bridges on the whole network. Given the large number of bridges of this type on the network, substantial savings may potentially be gained through this research, such as elimination of conservative restrictions on existing bridges on key routes, increased freight movements and better risk management. This project supports TMR's proactive strategies to improve knowledge, build capability and ensure international best-practice is incorporated in guidelines, specifications and procedures.

AUSTRALIAN NETWORK OF STRUCTURAL HEALTH MONITORING
Newsletter

Researcher in Business program between QUT and Rockfield

Structural Health Monitoring of Bridges for Post Disaster Decision

Dick M.H. Yau[1], *Govinda Pandey*[2] & *Tommy H.T. Chan*[1]

[1]*Queensland University of Technology (QUT)*

[2]*Rockfield Technologies Australia (Rockfield)*

Background

Recent natural disasters in Queensland (Brisbane Flood, Cyclone Yasi, Bundaberg Flood) have exposed the vulnerability of our infrastructure in the face of extreme weather events. The challenge is that while there is an urgent need for relief and rescue operation, which requires the use of vital infrastructure such as bridges, these assets must be inspected by experienced bridge engineers to confirm their structural integrity prior to use. This adds to the cost of post disaster operations and causes grief to disaster victims, government authorities and volunteers.

In recent years, structural health monitoring (SHM) has attracted much attention from research and industry. The SHM system uses non-destructive techniques to provide continuous information about the state of a structure. In general, an SHM system consists of measurements, a signal processing system and data interpretation. Measurements can be made under static or dynamic conditions.

For dynamic measurements, it is difficult to excite the whole structure and measure the input force, therefore, an output-only method becomes a new trend in the applications of civil structures. Operational modal analysis (OMA), also known as output-only modal analysis, is a technique for extracting the global dynamic characteristics (natural frequencies, mode shapes and damping) of structures from the measurements of the vibration responses only. OMA uses the natural and freely available excitation due to ambient and operational loads (traffic, wind, etc.) instead of using artificial excitation in traditional experimental modal analysis, also known as input-output methods. Since OMA requires output-only measurements, they do not interfere with the operation of the structures. Many successful OMA case studies have been implemented [1-4].

Approach

This project aims to develop a real time structural response monitoring system for rapid deployment and prioritized inspections of bridges, and investigate the applications of the measured modal parameters. OMA techniques will be employed to determine the modal parameters of bridges. These parameters will be applied to implement Vibration-Based Damage Detection (VBDD) methods. The measurement and modal analysis modules will be implemented automatically for long term monitoring. If any anomaly is captured, the bridges' authorities will be alerted to inspect the bridge before the scheduled routine inspection. The systematic diagram of the system is shown in Figure 1.

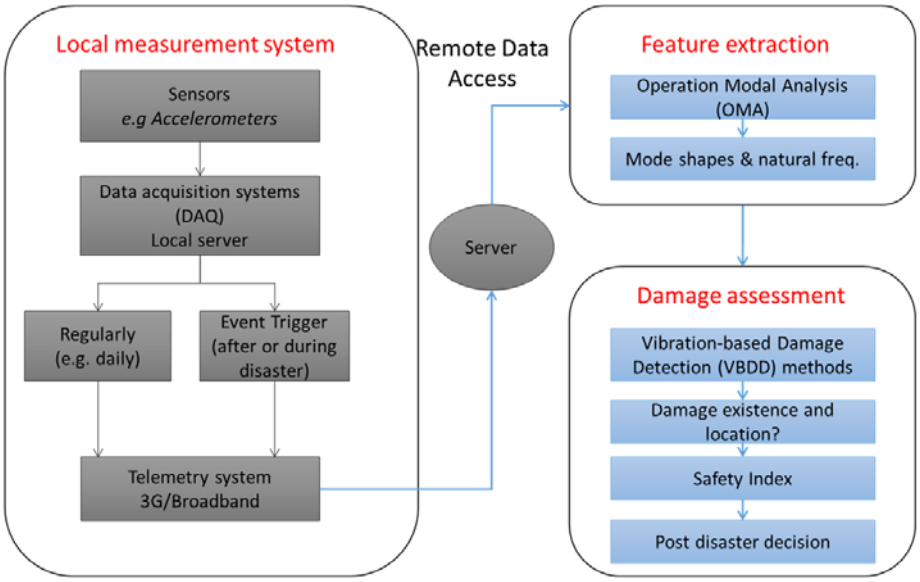

Figure 1: Proposed structural response monitoring system

Numerical modal analysis

A typical highway bridge located in Northern Queensland was utilized in this study. It is a steel girder bridge with concrete decking. A 3D finite element model (FEM) of the bridge has been established using ANSYS® software in order to understand the modal parameters of the bridge, as shown in Figure 2. Static and modal analyses have been conducted to evaluate the modal parameters. The natural frequencies and mode shapes are shown in Figure 3.

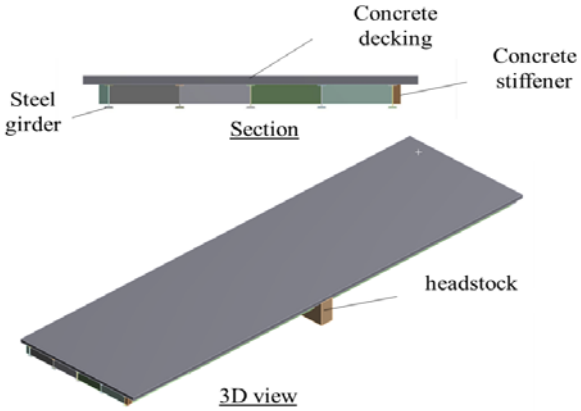

Figure 2: ANSYS model

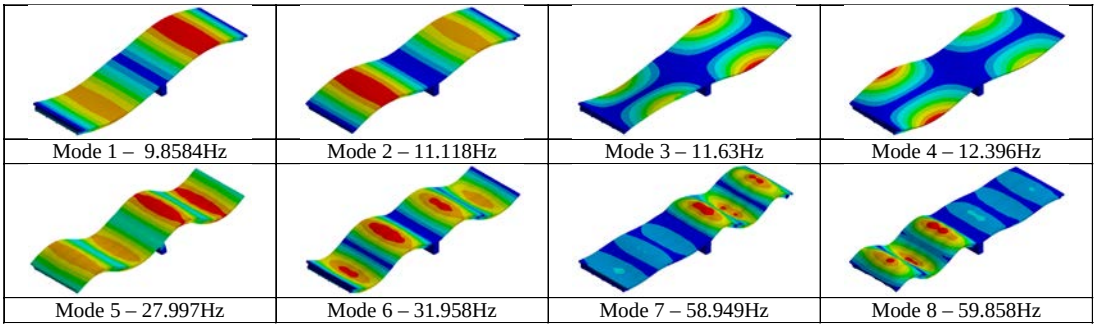

Figure 3: Vibration modes from FEM

Damage identification methods

A MATLAB® code is written for implementation of the VBDD methods which include:

- Mode shape curvature (MSC) change [5]
- Modal strain energy change (MSEC), also known as damage index method [6]

A series of damage cases is applied to the girder of the FEM for studying the performances of the VBDD methods. These methods use the mode shapes for the intact and the damaged structures to indicate the damage existence and location. MSEC method has a better performance for locating damage. For the case of damage location at a girder, the result is presented in Figure 4, indicating clearly how the method being able to locate the damage.

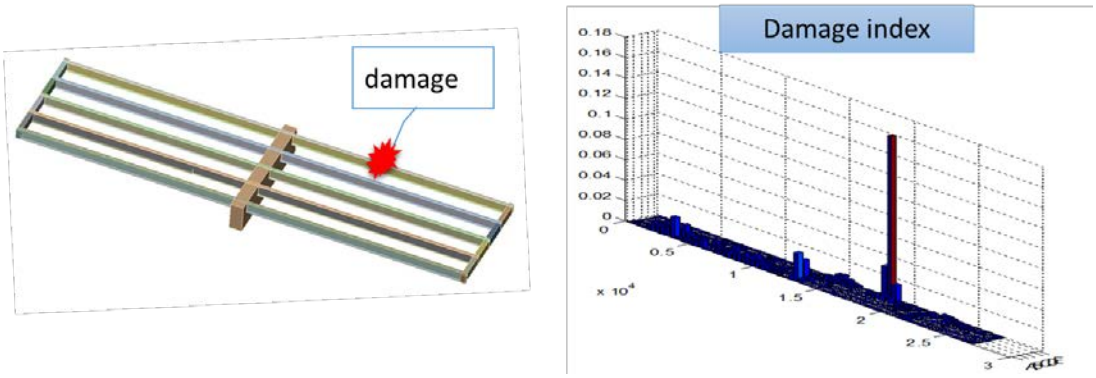

Figure 4: Damage location (left) and damage location result (right)

In summary, the proposed system uses ambient vibrations to obtain the dynamic characteristics of a bridge structure. The VBDD methods are implemented to evaluate the damage existence and location. The bridge authority will be immediately alerted to take necessary action such as prioritized inspection.

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Conference Information

- ANSHM mini-symposium in the ***24th Australasian Conference on the Mechanics of Structures and Materials (ACMSM24)*** (http://civil.eng.curtin.edu.au/ACMSM24/), 6-9 Dec 2016, Perth, Australia. Organized by Prof. Tommy Chan, Prof. Jianchun Li, and Dr. Jun Li
- Mini-symposium "***Structural Health Monitoring for Performance Assessment & Recent Research by Australian Network of Structural Health Monitoring***" in the ***Second International Conference on Performance-based and Life-cycle Structural Engineering (PLSE 2015)***, 9-11 Dec 2015, Brisbane, Australia. Organized by Prof. Yi-qing Ni, Prof. Tommy Chan, and Dr. Saeed Mahini.
- ***The 7th Annual ANSHM workshop***, 26-27 Nov 2015, Perth. Organized by Prof. Hong Hao and Dr. Jun Li

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Welcome your any comments and suggestions, please contact

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