AUSTRALIAN NETWORK OF STRUCTURAL HEALTH MONITORING

Newsletter

Issue 7, March 2016

Contents

President Message

Tommy Chan

Professor in Civil Engineering, Queensland University of Technology

Dear All,

February to some of you may be one of the busiest months in the year - preparing for the new semester, the ARC DP submission, the ARC Linkage rejoinder, etc. Not only that, we also had our first Executive Committee meeting in February to plan for the coming year and also consolidate the tasks we had identified in the Advisory Board Meeting and Annual General Meeting during the 7th ANSHM Workshop in last November. However we believe that all these hard works are worthwhile and rewarding.

Recently, a Campus Review article entitled, "Australia needs to spend smarter in Infrastructure" (18 Feb 2016) drew my attention. In the article, it reports that throughout the last decade, $500 billion has been invested in infrastructure and yet whether such investment is effective deserves careful evaluation. A public paper of the Better Structure Initiative cites an estimate that $63 billion in road projects over the last decade generated no economic returns for Australia. The report also argued state and federal governments need better data to help with their decision-making. I totally agree with that and I consider that we need the governments to invest more money on developing and implementing smarter infrastructure so that they could spend smarter in infrastructure. SHM is the kind of technology that could provide the necessary data to fill some of the data gaps for the governments to make cost-effective decision in planning and maintaining their infrastructure. I believe ANSHM can play a role in that.

Below are the updates of the month.

Departure of Dr. Ying Wang

It is with mixed emotions that I announce the departure of Dr. Ying Wang from Australia to a new academic role at University of Surrey in UK. While I'm saddened to see such a talented academic and capable leader depart our Executive Committee, I am also delighted that Ying has been awarded such a great opportunity in his career path and as what he stated that he will try to extend the influence of ANSHM to Europe. Ying has been an invaluable asset of ANSHM, especially looking after our membership for that many years, since the establishment of the 1st Executive Committee in 2011. He also took the initiative to host the 3rd ANSHM Workshop at Deakin University in December 2011. I will never forget the good time we have together with him in ANSHM. As the President of ANSHM, I would like to thank and acknowledge so much his contributions to the association. In our last EC meeting, we suggested to consider the possibility to allow ANSHM to have members outside Australia and New Zealand who have been serving ANSHM as its members for a number of years. Dr. Alex Ng is now ANSHM Membership Officer.

Welcome to New Members

In the last EC meetings, the following applicants have been approved for their ANSHM memberships:

- Dr. Ricky Chan of RMIT University
- Dr. Yee Yan Lim of Southern Cross University
- Mr. Evan Lo of Transurban

A warm welcome to Ricky, Yee Yan and Evan!
We look forward to your participation to ANSHM activities and your contribution to ANSHM.

ANSHM Research Collaboration

It has been mentioned a number of times that ANSHM has provided an excellent platform for our member to establish research collaboration. However it is also not easy to establish a large collaborative project that could involve all of us because of the funding policies of ARC and various road authorities. However as mentioned in the introduction of this President Message, there is a need in the country to develop a smarter infrastructure. Therefore we have been striving to work on it. A special task force, including Jianchun (coordinator of the task force), Tuan, Alex and myself has been formed. After some discussion, we noticed that the current possible funding schemes for ANSHM collaboration research are:

- Industrial funding
- ARC LP or DP
- New CRC-P scheme (industry CRC project)

- Industrial Transformation Hub
- ARC Centre of Excellence

It seems more feasible for ANSHM to focus on the first three at this stage to build the momentum to attend 4th and 5th later. ANSHM encourages its members to actively seek industrial or competitive funding either individually or collaboratively to practice and promote SHM. However, members are encouraged to utilise ANSHM platform in their proposal or/and research activities. Alex is in the process to collect examples of ANSHM collaborative research. We are still accepting industry collaboration project information if they are interested to promote or advertise their work on ANSHM website.

ANSHM Special Issues

In the last EC meeting, we discussed that we have been very successful in preparing ANSHM special issues in various high impact international journal. However in order to avoid confusion and help our members better plan their submissions for various special issues according to the submission deadline of each special issue, we need to better plan and schedule the submission/review deadlines of each special issue. Below gives a summary of the special issues that we are working on:

i. Special Issue in the Journal of Civil Structural Health Monitoring (CSHM2, mainly for reporting research related to the presentations in 6th ANSHM) – paper submission deadline closed but we still could afford to have one to two papers more

ii. Special Issue in Earthquake and Structures (mainly for SHM work in relation to earthquake) - paper submission deadline closed

iii. Special Issue in International Journal of Lifecycle Performance Engineering (mainly for reporting research related to the presentations in 7th ANSHM Workshop and also other SHM research of ANSHM members) - paper submission deadline extended to April

iv. Special Issue in the Journal of Civil Structural Health Monitoring (CSHM3, mainly for reporting research related to the presentations in the ANSHM mini-symposium in SHMII 2015) – paper submission deadline to be determined

Further updates on these special issues are as follows.

Special issue in Journal of Civil Structural Health Monitoring (CSHM2)

For CSHM2, we received 10 submissions: four papers have been accepted, two papers are being under review, two papers were declined, and two papers were withdrawn. We may receive two late submissions soon.

Special issue in Earthquake and Structures (EAS)

Seven papers have been received and six papers have been assigned for review. We are still waiting for another 5 papers. The authors for these 5 papers have been reminded to submit their papers as soon as possible.

Special issue in International Journal of Lifecycle Performance Engineering (IJLPE)
The invitation has been extended from the presenters of 7th ANSHM Workshop to ALL ANSHM members and the full paper submission deadline has also been extended to April 2016.

Special issue in Journal of Civil Structural Health Monitoring (CSHM3)
As we have a number of special issues this year, we need to plan carefully for the schedule of this special issue. Jun will help us to formulate the submission and review schedule for this special, as he is also an editor of the other two special issues (EAS and IJLPE).

Organising SHMII-8 (December 2017)

A meeting was held with QUT event manager/officer on 19 Feb 2016to plan for the working schedule for the twenty one months and identifying the some tasks for the organisation, especially some important and immediate tasks like:

- Conference Website update
- Dinner venue
- Payment plan to ISHMII
- Fund raising plan
- Industry exhibition
- Task allocation

This is the first important event of ANSHM that involves nearly all ANSHM members. Saeed and I will work with the ECM and ABM to identify and allocate tasks to appropriate ANSHM members in the coming months. Please try your best to participate and support this important event and make it to be one of the best in the SHMII series. We plan to have the next LOC in March.

ANSHM Homepage

Hong and her ANSHM Homepage team are so pleased to inform you that we have now included my monthly updates on the Homepage. However as the updates are mainly for the internal information sharing among ANSHM members, only ANSHM members could access this part of the Homepage. The username and password will be released to the members in due course.

Hong and her ANSHM Homepage team have been working hard to update the page regularly. They are doing an excellent job and their effort is very much appreciated.

ANSHM WebForum

The importance of having regular WebForum was raised in the last Advisory Board meeting and in our last EC meeting, Lei has been so kind to take up this important role. He will explore how to implement that using our social network, ANSHM pages on LinkedIn and Facebook as setup by Xinqun. Lei will give more details about the plan in due course.

7th ANSHM Workshop Presentations

It was suggested to upload the presentations to ANSHM website. Jun is working on that and if any presenters would like to update or change their slides, please send their update to him.

ANSHM mini-symposium at ACMSM24

Currently we have received 2 abstracts. You may have received the reminder from Jun that the deadline of the abstract submission is 9 March and please make sure you do not miss the deadline.

Andy has been the main editor of this issue of Newsletter. There are three articles in this issue. As mentioned above that we need to present some industry collaboration project information as examples. In this newsletter, Aflatooni et al. briefly report development of a Rating Method for a network of railway bridges based on their structural condition, which is a CRC project demonstrating the successful collaboration among universities and Industry. We may use the information in this article and transfer it to the information sheet that we are going to use to collect samples of collaborative projects. In the second article, Fan et al. explored an impedance based SHM technique with a time-frequency analysis method as one of the potential approaches which could be applied to the damage detection in gusset plates of steel truss bridges. In the third article, Waldin et al. report interesting results and findings from the first phase of a structural response monitoring programme implemented onto three key bridges in the South Island, New Zealand.

With kind regards,

Tommy Chan

President, ANSHM

www.ANSHM.org.au

Synthetic Rating Method for Railway Bridges

Mehran Aflatooni, Tommy H.T. Chan

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Safety, serviceability and durability of a network of bridges are dependent on timely identifying those bridges which need repair, assessing their condition, predicting their future condition, developing strategies and plans for repair and/or maintenance and taking appropriate actions accordingly. Due to the scarcity of resources, a bridge management system (BMS) is required to fulfill the above tasks. The current BMSs needed to continually improve and become more reliable as development in knowledge and technology provides us with better tools every day. Each country or agency including Australia develops or improves its own BMS to better suit their own conditions. An innovative model of BMS uses the state of the art mathematical models, new structural evaluation analysis and systems, and new technologies. A reliable BMS enhances the reliability, availability, maintainability and safety of a network of bridges.

The above brief explanations were the motivation to initiate the Life Cycle Management of Railway Bridges (LCMRB) project. Four Universities including QUT, CQU, UoW and MU and many industries such as Vline, ARTC, Tasrail, RioTinto, and Kiwirail were involved in the project. The LCMRB project was led by Professor Tommy Chan from QUT and aimed at developing a reliable BMS which provides higher level of safety and serviceability for a network of railway bridges in Australia by investing minimum cost for their maintenance over their lifetime. The three main parts of the project were 1) prediction of the remaining service life of bridges and their components, 2) development of a synthetic rating method for rating bridges and their components at a network level, and 3) development of a life time strategy for repair and maintenance of a railway bridge network. Some of the journal papers arising from the LCMRB are mentioned in the reference (Aflatooni et al., 2014, 2015a, 2015b; Aflatooni et al., 2013; Nielsen et al., 2013a; Nielsen et al., 2013b; Wellalage et al., 2014). The different sections of the LCMRB project were also presented in international conferences which some of them may be found in the reference list of the above publications. This paper briefly explains the second part of the LCMRB project.

In the LCMRB project, the prioritization of maintenance and repair works is carried out considering structural details and structural components, and non-structural factors. The synthetic rating focuses on structural components and details (Aflatooni, 2015; Aflatooni et al., 2014). It is carried out based on the probability and consequences of failure and considering the current and future conditions of bridges and their components. In the developed method as the vulnerability of different components towards different loadings including train, earthquake, flood, wind, collision loads, and environmental factors are different, different ratings are calculated and assigned to each component of each bridge. The evaluation of the current structural condition of bridges is conducted based on the data collected through inspection, and structural analysis. As the safety and its strict rules and regulations are the issue for structural condition evaluation, the structural analysis is incorporated in the synthetic rating method. To identify the contribution of different loads and environment factors towards bridge deterioration risk and hazard assessment available in design standards and analytic hierarchy process (AHP) are used in the method. The future condition of components are predicted using probabilistic method (e.g. Markov Chain) by the researchers at the University of Wollongong (Wellalage et al., 2014) and incorporated to the synthetic rating method (Aflatooni, 2015; Aflatooni et al., 2014). The synthetic rating procedures (SRP) (Aflatooni, 2015; Aflatooni et al., 2014) introduce the criteria for determining the deadlines for taking actions including inspection, repair and maintenance and structural analysis. The engineers and managers use the criteria to make decisions on the condition of the components and the bridge at different stages.

To maintain the practicality of the synthetic rating method to be applied to a network of thousands of bridges, the structural analysis is restricted to be performed only a few times over the lifetime of bridges. The results of the structural analysis are recorded as weighting factors and will be used any time that the structural condition of the components will be reassessed by inspectors to identify the criticality of the condition of bridges and their components. The weighing factors are defined to be the demand by capacity ratios of components subjected to different loads at both safety and serviceability levels. The second method introduced in the synthetic rating method for calculating the weighting factors and the associated criticality of the components are based on the measured responses (e.g. strain, deflection, and vibration) of the bridges components using sensors (Aflatooni, 2015; Aflatooni et al., 2015a). The usage of sensors provides continual online information about the structural condition of the components at both safety and serviceability levels.

The proposed method is illustrated with applications to some bridges (Aflatooni, 2015; Aflatooni et al., 2014). One of the bridges is shown in Figure 1. Figures 2 and 3 show the rating of components of a network of two bridges respectively associated with train and flood loads. The larger values in Figures 2 and 3 represent the higher criticality of conditions. The synthetic rating method adopts several tools such as AHP for decision making, structural analysis for the criticality of the components for the structure, and utilizes the risk assessment available in design standards to become more reliable than the current existing methods. The practicality of the method is also taken into account by simplifying the method and reducing the number of times for conducting structural analysis and limiting the required data related to the contribution of critical factors. The equations of synthetic rating method are not sensitive to the number of components; hence the method can be applied to a network of bridges with different components and structural configurations. In the method, the condition of the structure are evaluated by using available data, therefore, lack of data will not be a problem for the application of the method, although more data increase the reliability of the outputs.

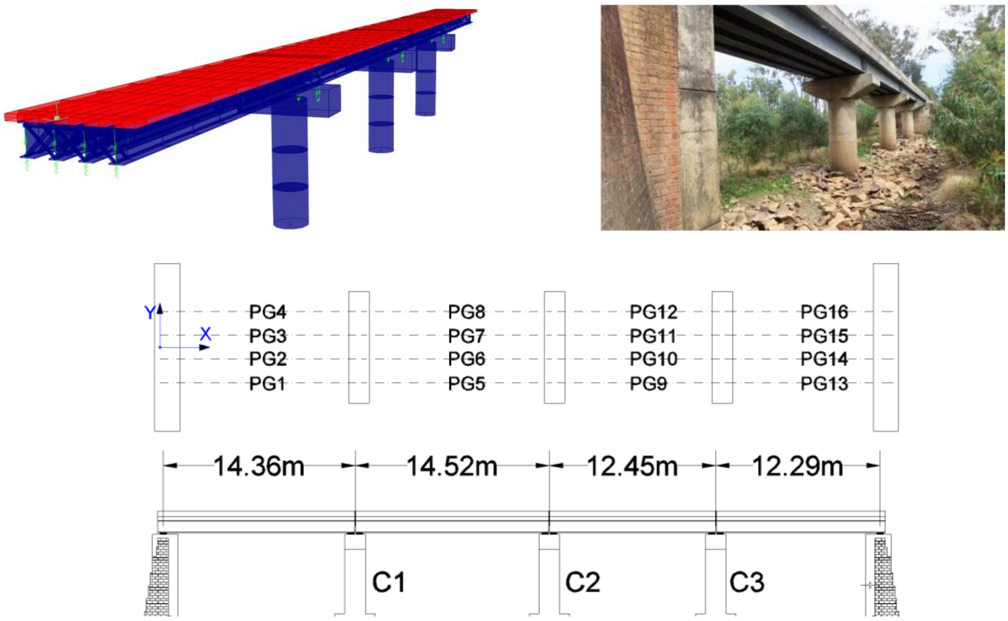

Figure 1 Geometry of the railway bridge structure

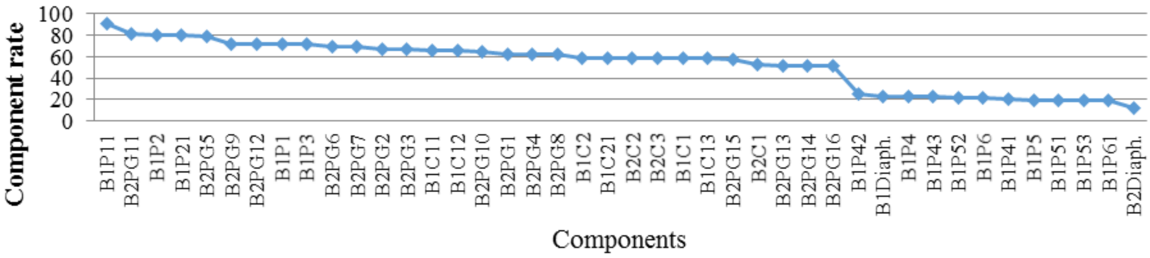

Figure 2 Rating of components of the network of two bridges associated with train load

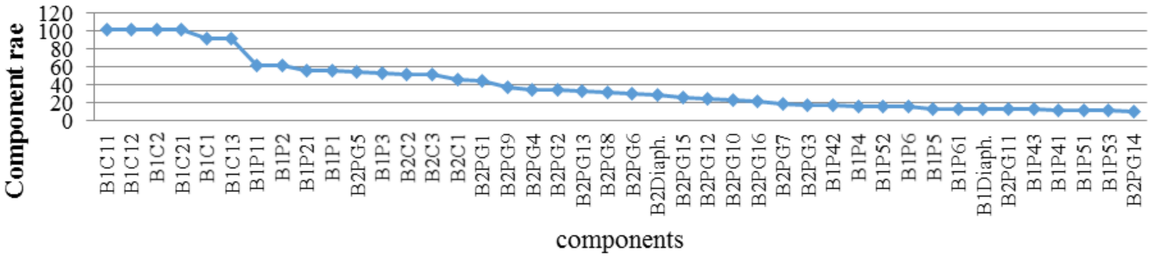

Figure 3 Rating of components of the network of two bridges associated with flood

The method can communicate with different stakeholders and experts using different types of descriptive and/or technical information. The advantage of the synthetic rating method is that its outputs will be more reliable over time by quantifying the contribution of more factors towards bridge deterioration and incorporating them in the synthetic rating equations. By recording more data about the condition of components overtime or continually measuring the responses of bridges, the future condition of components and bridges will be more reliably predicted and the output of the synthetic rating method that will be used for the estimation of the life-cycle cost will be more reliable. The above mentioned improvements in structural condition evaluation and rating reduce the subjectivity of the current rating methods used in practice and enhance the efficiency of the usage of resources and improve the safety and serviceability of bridges within their lifespan.

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Piezoelectric Impedance Based Damage Detection in Truss Bridges

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Damage may occur in civil infrastructure during their service life due to excessive loading and harsh environmental conditions. Steel truss bridge is a very typical form and vital part of civil infrastructure worldwide. It is considered as an economical and reliable long span bridge solution. The collapse of the I-35W Bridge in Minnesota is a recent disaster that exposes the weaknesses in current visual inspection practices and structural health monitoring of steel structures. The Electro-Mechanical Impedance (EMI) based structural health monitoring techniques such as those using Lead Zirconate Titanate (PZT) transducers are rapidly developing in the recent years. These techniques have been successfully applied to monitoring structural systems, i.e. beam and plate like structures. One advantage of PZT material is that it can act as both the actuator and sensor simultaneously. The basic principle of EMI method is to excite the PZT transducer which is bonded on structure surface with an alternating voltage and record the impedance variation of this transducer. The change in impedance signals from bonded PZT transducers reveals the condition change on the host structure.

The impedance signals from bonded PZT transducers may be analyzed and used to calculate a statistical index to detect the damage, such as Root Mean Square Deviation (RMSD). One significant limitation of the conventional statistical damage index is its low sensitivity to detect the local minor damage especially in the large-size complex structures. Impedance based structural health monitoring technique with a time-frequency analysis method is investigated in this study as one of the potential approaches which could be applied to the damage detection in gusset plates of steel truss bridges. With the use of the Time-Frequency Autoregressive Moving Average (TFARMA) model, a Singular Value Decomposition (SVD) based damage index is defined to detect the damage. The performance of proposed approach is investigated by experimental studies on a steel truss bridge model (Figure 1). Damage of the host structure is introduced by loosening bolts on the central gusset plate.

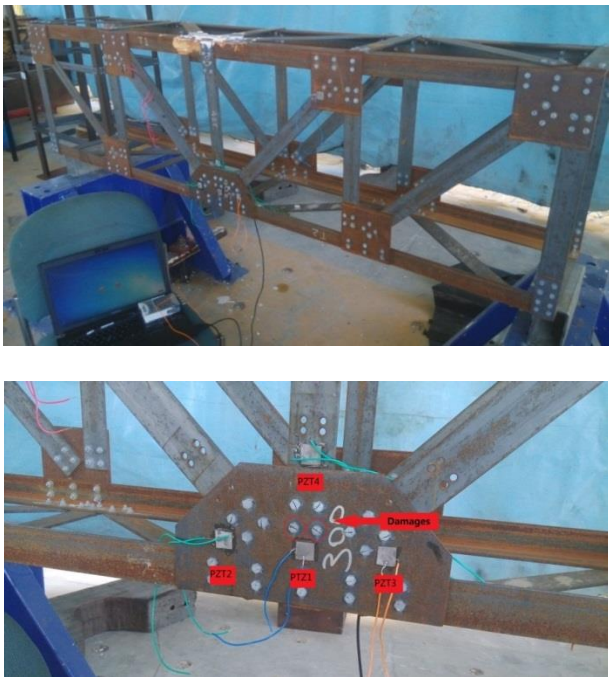
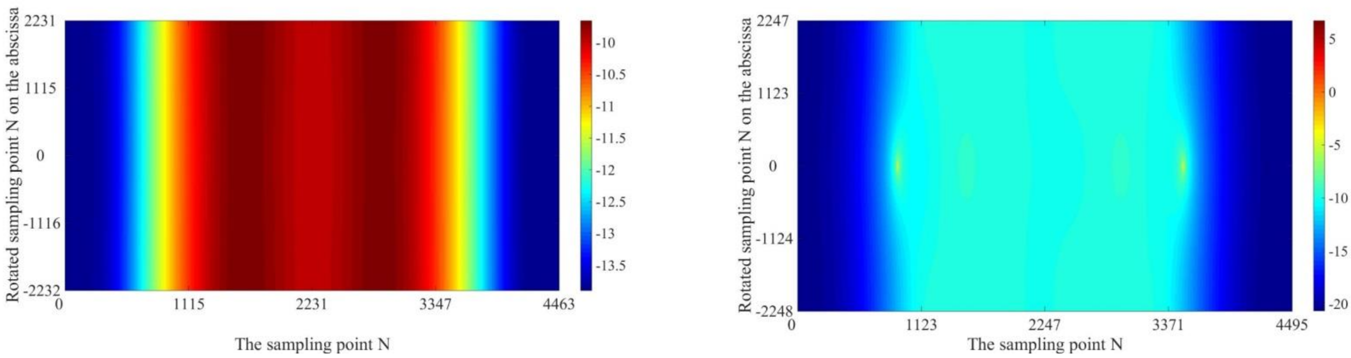


Figure 1 The tested truss bridge model

To visualize the TFARMA model parameters and provide a better demonstration for the damage detection, the evolutionary spectrum of TFARMA models are calculated (Figure 2). The TFARMA model could indicate the feature and pattern of the varying process of impedance signals in the time–frequency space. SVD is applied to define the pattern of spectrum which is used to compare the evolutionary spectra of the healthy and damage responses. the damage index from TFARMA model analysis is defined based on the characteristics vectors of the evolutionary spectrums.



(a) (b)

Figure 2 The evolutionary spectra of time domain impedance signal from PZT 4: (a) healthy structure, (b) damaged structure

From the comparison between two conventional indices and TFARMA damage index (Figure 3) we can see that all the TFARMA damage indices at four PZT transducer locations are significantly higher than the baseline value, and the RMSD/CC damage index values (CC stands for Correlation Coefficient). It is interesting to note that there is a quite large increase in the TFARMA damage index of the PZT transducer bonded on the chord member. It is not recognized by the conventional damage indices.

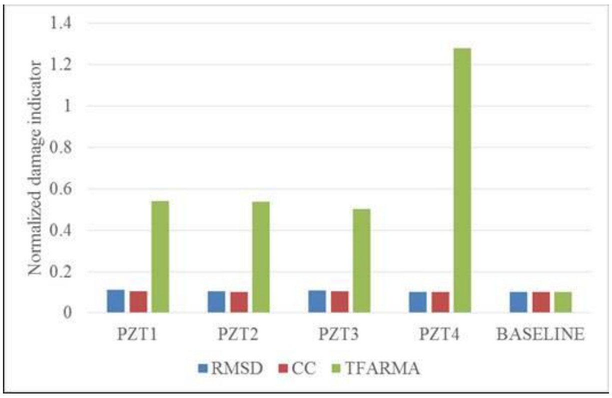


Figure 3 Comparison of RMSD, CC and the proposed TFARMA damage index

In summary, this paper proposes a structural damage detection approach based on analyzing the time domain impedance responses from PZT transducers for structural health monitoring of joint connections in steel truss bridges. The TFARMA damage index shows a higher sensitivity and an improved performance to detect the bolt damage in the gusset plates of steel truss bridges. The TFARMA damage index also shows a significant improvement on the sensitivity range of using PZT transducers to identify the local damage in the targeted monitoring area by placing the PZT sensor on a different location such as the chord member connected to the gusset plate.

Structural Response Monitoring of New Zealand Bridges

Jeremy Waldin[1], Chloe McKenzie[1], Jeremy Jennings[1], and Russell Kean[2]

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[2]*Opus International Consultants Ltd, Opus Research, Lower Hutt, NZ*

Introduction

In 2010, New Zealand introduced High Productivity Motor Vehicles (HPMVs) onto the road network. To date, the movement of these heavier vehicles has been limited by the capacity of infrastructure, particularly bridges on the State Highway and local road networks. To limit the extent of costly bridge strengthening and replacement, the New Zealand Transport Agency is currently undertaking Structural Response Monitoring of the Rakaia River and two Rangitata River Bridges in the South Island. All three bridges were constructed between 1939 and 1940, and comprise of conventional two lane reinforced concrete bridges, with essentially identical superstructures. The superstructures consist of four reinforced concrete T-beams, supported on reinforced concrete columns and pile caps, founded on driven reinforced concrete piles. The Rakaia River Bridge is particularly significant, being the longest bridge in New Zealand (1.76km long).

Structural Response Monitoring (SRM) Methodology

Historically, Structural Health Monitoring (SHM) of bridges has typically been limited to larger more complex structures. Detailed monitoring of more simple, low value structures is often cost-prohibitive, due to the cost of electronic equipment, access for installation, maintenance and ongoing storage, processing and interpretation of data.

To mitigate risk and minimise costs, a five-step SRM methodology has been developed for the monitoring of the Rakaia and Rangitata River Bridges, as shown in Figure 2. This methodology has the potential to provide significant whole life cost improvements to older bridge structures by avoiding, reducing or delaying costly strengthening or bridge replacement. This is particularly the case where observed deterioration is less than would be expected from analysis, or where significant unknowns exist in the assessment and modelling of the structure. The monitoring also provides valuable data on the strength and performance of the most common type of weaker bridge in New Zealand, thereby assisting the management of other typical bridges.

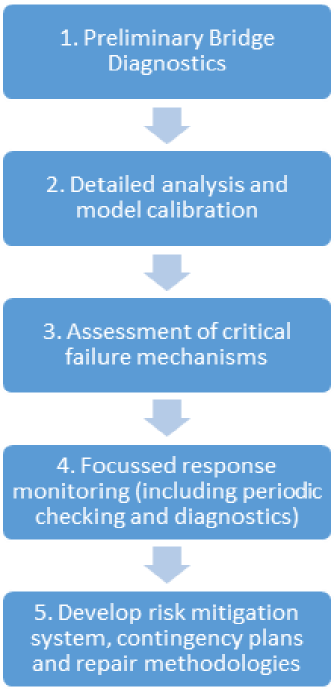

Figure 1 Proposed Structural Response Monitoring (SRM) Methodology

Structural Response Monitoring (SRM) Case Study

The five-step SRM methodology outlined in Figure 1 has been employed on the Rakaia and Rangitata River Bridges between June 2014 and February 2016. The Structural Response Monitoring systems employed to date include a range of conventional bridge monitoring and testing techniques, such as visual inspections, material testing, and survey levelling; as well as more advanced monitoring systems using accelerometers, displacement transducers, vehicle weigh-in-motion testing, advanced bridge model calibration, and concrete condition assessment. Figures 2, 3 and 4 outline the critical joint failure mechanisms on the bridges; vertical displacement response of the beams; and continuous displacement transducer monitoring employed to date.

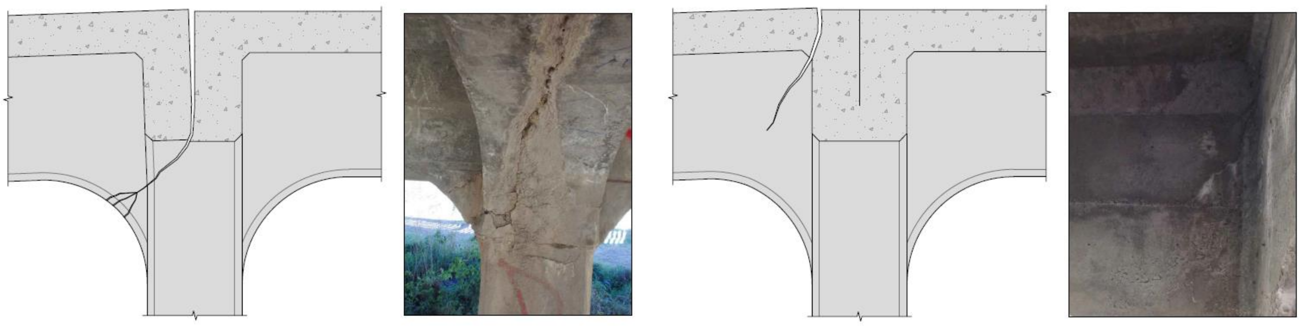

Figure 2: Critical joint failure mechanisms and examples of similar cracking on site

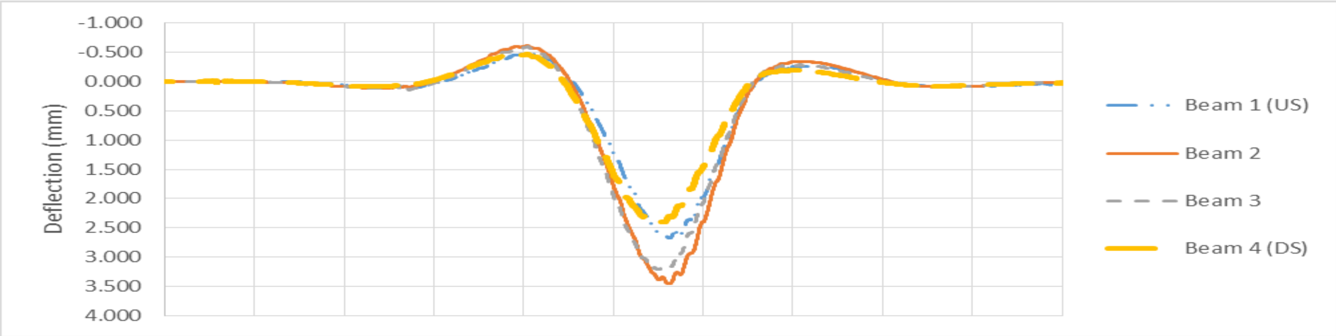

Figure 3: Typical vertical displacement vs time response at mid-span under side-by-side test load runs. This is for span 6 from the northern end, which has a split pier at one end.

Figure 4: Permanent displacement transducer installed to monitor beam/column joint opening

Conclusions

Whilst the SRM on the Rakaia and Rangitata River Bridges is still at its initial stages, significant conclusions around the structural performance of the bridge have already been made. These include the following:

- The vehicle speeds required to cause resonance in the beams are around 130km/hr, and therefore increased impact loading through resonance is highly unlikely.
- The maximum span specific impact factor for these bridges is likely to be less than specified in the NZ Transport Agency Bridge Manual.
- Impact on these common T-Beam bridges increases with increased speed, as assumed by the NZ Transport Agency Bridge Manual.
- The bridge spans are not acting as simply supported, and have considerable continuity across the partially split joints.
- Some continuity exists between superstructures even across the split piers, due to the interaction between the split pier columns.

- The inner beams displace significantly more than the outer beams. This is due to the additional stiffness from the kerbs and handrails, and the position that vehicles travel within their lane.
- Given the continuity through the spans and the reduced impact factor; the HPMV Evaluation capacity of the beams is > 100%.
- The beam/column joints are under significant stress under Class 1 and HPMV loading.
- This common form of beam/column joint is vulnerable to cracking. This vulnerability is exacerbated for longer span bridges.
- The WiM data indicates that the level of overloading over the Rakaia River Bridge is relatively low, with no discernable increase following the introduction of HPMV's.

In addition to the conclusions above; the five-step SRM methodology has provide a cost effective framework for monitoring, which can be employed to other bridge structures in the future. This process is particularly beneficial where programmed strengthening or replacement is expensive, observed deterioration is less than would be expected from analysis, or where significant unknowns exist in the assessment and modelling of the structure.

Conference Information

- ANSHM mini-symposium in the ***24th Australasian Conference on the Mechanics of Structures and Materials (ACMSM24),*** 6-9 Dec 2016, Perth, WA. Organized by Prof. Tommy Chan, Prof. Jianchun Li, and Dr. Jun Li.
- ***The 8th Annual ANSHM workshop***, Melbourne, VIC (late November or early December, to be confirmed later). Organized by Dr. Colin Caprani of Monash University.

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- ANSHM Facebook group: www.facebook.com/groups/ANSHM
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