AUSTRALIAN NETWORK OF STRUCTURAL HEALTH MONITORING

Newsletter

Issue 19, March 2019

Contents

President Message

Tommy Chan

Professor in Civil Engineering, Queensland University of Technology

Dear All

ANSHM has a very good start of the year. We had our 1st Executive Committee (EC) meeting last Wednesday (20 Feb 2019) and had a very good discussion in various matters including the planning of the year based on the Advisory Board Meeting and the Annual General Meeting held respectively on 10 Dec 2018 and 11 Dec 2018 respectively during our 10th ANSHM Workshop.

In the last monthly updates, I mentioned that I visited the two Hong Kong Branches of Chinese National Engineering Research Centres (CNERCs) while I stayed at the Hong Kong Polytechnic University (HKPolyU). The CNERC scheme was initiated by an open invitation made by the Ministry of Science and Technology of the Mainland China in 2014 to strengthen scientific research cooperation between Hong Kong and the Mainland. The two Research Centres are focusing on high-speed rail engineering and steel structure applications respectively. It is interesting that out of the six approved CNERCs, the two established in the HKPolyU are very much related to our proposed ATCSHM, indicating the similar awareness of the importance of applying SHM to enhance the safety and operational efficiency of the existing and future infrastructure. Just using the CNERC-Rail as an example, 15 of their 23 research projects (more than half) are directly related to the application of SHM for enhancing the operation or monitoring the structural health of rail infrastructure. The model of the funding they received is a bit different from the ARC ITTC or ITRH. Each of the two

CNERCs received HK$5 million a year from the Hong Kong Innovation and Technology Commission for three years, and the HKPolyU provided a one-to-one matching fund to support research and development to each of the centres. It seems that the ARC schemes here require more industry cash support than that for the HK Scheme. I consider the ARC schemes could ensure a better involvement of the industry. Also, it seems that CNERCs in HK are more likely to be funded. When I visited the two CNERCs, their first 3 years have passed. They told me that each of the two CNERCs has just been granted HK$10 million (half from HKITC and half from the university) a year for another 3 years until 2022, which makes me envy as the extension with such a large amount of support could not be sought as easy as that in HK.

For details and updates of these two CNERCs, please go to their official websites.

- https://www.polyu.edu.hk/cnerc-rail/ - The National Rail Transit Electrification and Automation Engineering Technology Research Center (Hong Kong Branch)
- https://www.polyu.edu.hk/cnerc-steel/en/ - The CNERC for Steel Construction (Hong Kong Branch)

Below are the updates of the month.

ANSHM Achievements and Activities 2018

In the last AGM held on 11 Dec 2018, I gave a report on ANSHM achievements and activities. I hereby summarise them as follows:

1. *Membership*

   ANSHM has grown a lot since its establishment in 2009. The number of individual members is close to 100. We have members from 45 organizations that include 20+1 universities (1 from University of Surrey), 16 private companies, 6 government authorities and 3 research institutes.

2. *Special Issues*

   We published two special issues last year, one in *Journal of Civil Structural Health Monitoring* and the other in *Structural Health Monitoring: An International Journal.*

3. *Technical Notes*

   As requested in the Industry Forum in the 9th ANSHM Workshop, we include a section on Technical Notes in our quarterly Newsletter, to help the industry understand some basic techniques in SHM. We published our first technical note in the Issue No. 17.

4. *Technical Workshops*

   In the 9th ANSHM Workshop, it was also suggested that ANSHM organises some technical workshops for the industry to understand better the SHM techniques. The first of this series was held on 16 July 2018, co-organised with VicRoads.

5. *ARC ITTC Workshops*

   In order to understand better the needs of the industry partners and formulate the programs of ATCSHM, the following ARC ITTC Workshops were held last year:

   i. Melbourne (17 Jul 2018)
   ii. Brisbane (21 Aug 2018)
   iii. Sydney (11 Oct 2018)

6. *10th ANSHM Workshop*

   The 10th ANSHM Workshop was held jointly with the 5th Workshop of the Australian Chapter of the International Association of Protective Structures (IAPS-AUS) from 10-11 Dec 2018 in Wollongong. The joint event was hosted by the Centre for Infrastructure and Mining Safety (CIPMS) at the University of Wollongong.

7. *Submission of the ARC ITTC on SHM Proposal*

   The proposal was submitted on 12 Dec 2018. It involves 18 Partner Organisations and 24 Chief Investigators from 11 leading universities. As I always say, *if we could complete all the details and submit the proposal for this ATCSHM, it is already a great achievement.*

ATCSHM Proposal

According to ARC website, the Rejoinder period is 1 March 2019 to 8 March 2019. Therefore when this Newsletter is published, we should have received the comments from the assessors. In the EC meeting on 20 Feb 2019, we discussed about our lobbying plan for the proposal. The ITTC scheme is different from other ARC schemes like Discovery or Linkage projects, the assessors will not be mainly academics, we could also have assessors from the industry, e.g. from an Industry Growth Centre like NERA, AMGC. Therefore it is not easy to guess who will be the assessors of the proposal and lobby our proposal to them. However it will always be great to maintain our communication with the industry and consider anyone of them to be our assessors and try to promote the ATCSHM as much as we can if we have an opportunity to talk to such persons. We expect that not only the EC members will do that, other Chief Investigators (CIs), as well as any members of ANSHM will try our best to do that for the promotion of the establishment of the ATCSHM for the benefits of ANSHM.

The EC also alerted all the CIs to be made themselves available from 1 March for preparing the rejoinder until the corresponding Rejoinder for the proposal has been submitted, as sometimes the dates stated in the ARC website may be delayed. We really look forward to receiving positive comments of the proposal as we consider that establishing such a training centre is timely and crucial for the practical implementation of this technology for reduced frequency of operational disruption, maintenance and rehabilitation costs; improved design and construction efficiency; and enhanced safety and performance of infrastructure.

ANSHM Tasks Allocated

In our last EC meeting, we have allocated the tasks we identified in the Industry Forum, ABM and AGM in the 10th ANSHM Workshop. I list below first their duties individually for your better understanding of our operation. Then I will summarize the persons in charge of various tasks for your easy reference, especially when you looking for help in a particular area.

ANSHM Executive Committee Members

- Tommy Chan
  - President
- Jianchun Li
  - Deputy President
  - the Coordinator of the ANSHM Research Collaboration Task Force (RCTF)
- Mehri Makki Alamdari
  - Editor of ANSHM Newsletter
  - ANSHM Technical Note Coordinator
- Ulrike Dackermann
  - ANSHM Workshop Coordinator
- Hong Guan
  - ANSHM Webmaster
  - Organiser of the 11th ANSHM workshop hosted by Griffith University
- Lei Hou
  - ANSHM Webforum Coordinator
  - Review of ANSHM Rule
  - ANSHM Membership Survey
- Jun Li
  - Editor of ANSHM Newsletter
  - Acting ANSHM Workshop Coordinator.
- Alex Ng
  - ANSHM Membership Officer
- Andy Nguyen

  - External Affair Officer
- Tuan Ngo
  - ANSHM Research Collaboration Task Force Member
- Richard Yang
  - Editor of ANSHM Newsletter
  - ANSHM Education Team (Webforum, Seminar and Technical Workshop) Member
- Xinqun Zhu
  - ANSHM Technical Workshop Coordinator
  - ANSHM Education Team (Webforum and Technical Note) Member

Persons in charge corresponding to the identified Tasks

i. Prepare a standard ANSHM PPT for presentation for people to better understand what we have been doing and what we have achieved
   - Under Research Collaboration Task Force (RCTF)
     - Jianchun Li (Coordinator), Tuan, Alex and me

ii. Continue to take a more proactive role to help the industry understand SHM, appreciate the technologies and apply the technologies practically
   - Under ANSHM Education Team
     - Technical Note
       - Mehri Makki Alamdari (Coordinator), Xinqun
     - Technical Workshops
       - Xinqun Zhu (Coordinator), Richard
     - ANSHM WebForum
       - Lei Hou (Coordinator), Richard, Xinqun

iii. Continue to work on transferring the SHM knowledge to Industry and collecting their needs and problems and how SHM could help fill the gap between academic research and industry requirements so that more SHM developments could be implemented
   - Under ANSHM Education Team

iv. Continue to help the industry better understand the SHM section in the latest version of AS5100 by conducting technical seminars, preparing technical notes in the Newsletter, etc.
   - Under ANSHM Education Team

v. Continue to publish our quarterly newsletter and special issues in high impact journals
   - Under ANSHM Newsletter Editorial Team
     - Jun Li (Editor)
     - Richard Yang (Editor)
     - Mehri Makki Alamdari (Editor)

vi. Continue to improve ANSHM webpage
   - Under ANSHM Webmaster (Hong Guan)

vii. Continue to help members establish and strengthen their connections with one another and industry, and promote the research collaborations
  - Under External Affairs Officer (Andy Nguyen)
  - Under Research Collaboration Task Force (RCTF)

viii. Continue to establish a platform for regular forums (physical and/or online)
  - Under ANSHM Education Team

ix. Prepare the 11th ANSHM Workshop to celebrate our 10th Anniversary
  - Under Hong Guan as the Organiser working with other EC members

x. Administration of Membership
  - Under Membership Officer (Alex Ng)

ANSHM Newsletter

We launched our quarterly Newsletter in September 2014. We have received very good responses regarding the ANSHM Newsletter, especially those in the industry. They consider the Newsletter could not only help them know better about ANSHM, but also help them build up the knowledge of SHM bit by bit. In order to enhance this, we even introduce articles as technical note, aiming to help those who are not familiar with SHM but would like to see how it can be applied practically to solve their problems. As academics, we have no problem to find articles based on the research studies conducted in universities. However we also would like to know how industry applied SHM technologies in their work or how they consider SHM could help them improve their operations, especially we have a large proportion of members from the industry. In this regard, in our last EC meeting, it was decided to approach and invite members from the industry to write short articles for the Newsletter to give us some ideas on these. We also understand that those from the industry may be busy to find a time to write such an article. Therefore, the editorial team will work with Alex, the Membership Officer and liaise with the members from the industry to formulate a plan for article contribution. Such plan will incorporate with the research articles contributed by the academic researchers. It is expected to have such article collection plan covering the forthcoming publication of the Newsletter for two to three years and will be reviewed and appended after every year. As noted above, Andy is now our External Affair Officer, so his role in the ANSHM Newsletter Editorial Team has been taken by Richard. Now the Editorial Team includes, Jun, Richard and Mehri. Thank Andy for his excellent service in serving the Editorial Team since ANSHM launched the Newsletter in 2014.

11th ANSHM Workshop

As announced earlier, the 11th ANSHM Annual Workshop (in 2019) will be hosted by the Griffith University as coordinated by Prof Hong Guan. Same as other ANSHM Workshops, the first step is to find a best date for the Workshop. Hong will approach the EC and Advisory Board members to identify the best dates for the Workshop. We will also consider the dates of other relevant conferences being held in Australia or overseas to avoid clash, e.g. g. EASEC16 (3-6 Dec, Brisbane), Australasian Association for Engineering Education (AAEE) 2019 (9-11 Dec, Sydney) and the 13th Shock & Impact Loads Conference (13-15 Dec, Guangzhou Uni).

In this issue, we have two interesting articles, one as a research article and the other as a technical note. Yang et al. presented structural health monitoring of steel girder bridges using vibration based methods. Rashidi presented using drones for bridge health monitoring, and the point cloud of an example bridge is generated for inspection and asset management.

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

AUSTRALIAN NETWORK OF STRUCTURAL HEALTH MONITORING

Newsletter

Structural Health Monitoring of Steel Girder Bridges using Vibration Based Methods

Kevin Yang[1], Govinda Pandey[1], Rabin Tuladhar[2], Dick Yau[1]

[1]Rockfield Technologies Australia Pty Ltd

[2]James Cook University

As part of crucial infrastructure to transportation networks, bridges are important for the function of communities. As bridges age and suffer from deterioration and changing design loads, it becomes increasingly important that their structural integrity is maintained. Structural Health Monitoring (SHM) aims to achieve this by implementing damage detection strategies to provide an assessment of a structure with respect to structural strength. In Australia, Queensland's current bridge inspection manual employs routine visual inspections, and if deemed required, will be followed by a detailed structural engineering inspection. Evidently, this procedure can be subjective and hence this paper aims to investigate Vibration-Based Damage Detection (VBDD) methods to provide quantitative data to infrastructure owners and to reduce the subjectiveness of current procedures.

Introduction

As many structures approach their design life, replacement or rehabilitation may not be a viable option due to the huge costs. As a result of increased awareness to this, periodic visual inspection has been utilised to ensure safety of structures throughout their lifespan. As a means to provide quantitative data however, the civil engineering community in the early 1980s made considerable efforts into development of SHM methods based on structural vibration response (C. R. Farrar & Worden, 2007). Since then, numerous research has been shown to successfully detect damage through the use of vibrational response; however there are still challenges in practical application due to environmental variability and noise (Brownjohn, 2007).

Experimental test set-up

To demonstrate a procedure, a single girder setup, pin-roller supported RHS (4 m span) were chosen to represent a scaled girder of a bridge. To then investigate a scaled steel girder bridge system, 7 mm structural plywood were fastened to three RHS (4 m span) spaced at 0.9 m (Figure 1).

Figure 1: Dimensions of Experimental Bridge System

The data acquisition was completed by dividing the girder into ten even sections with eleven node points at 0.4 m spacing. As the two end nodes were supports, measurements were not required for these nodes and accelerometers were placed at nodes 2 to 10 only. The damage that was induced involved cutting directly into the soffit of the steel RHS. Specifically, a damage that consisted of a 20 mm deep rectangular cut.All of damage scenarios that were investigated are summarised in Tables 1 and 2Table for the single girder and scaled bridge system respectively.

Table 1: Summary of Single Girder Damage Scenarios

Scenario	Damage Location (x Span Length)	I_x Reduction (%)
Single Damage		
Case 2	1/4	82.2
Multi Damage		
Case 4	1/4, 3/4	82.2, 82.2

Table 2: Summary of Scaled Bridge System Damage Scenarios

Scenario	Damage Depth (mm)	Damage Width (mm)	Damage Location (x Span Length)			I_x Reduction (%)
			Girder 1	Girder 2	Girder 3	
Single Damage						
Case 5	20	5	-	-	1/4	82.2
Case 6	20	5	-	1/4	-	82.2
Multi Damage						
Case 8	20, 20	5, 5	1/4, 3/4	-	-	82.2, 82.2
Case 9	20, 20	5, 5	-	2/4	3/4	82.2, 82.2

Results and Discussions

Single Girder Results

For the single girder experiment, it was evident that the experimental natural frequency was in agreement with the trend that was observed in literature. The damaged cases had decreased natural frequencies from the undamaged case, where larger changes were noted when the damage severity was increased. These trends are evidently shown in Table 3.

Table 3: Experimental Natural Frequency Results

	1st Flexural Mode			2nd Flexural Mode		
Damage Case	Trial 1	Trial 2	Average	Trial 1	Trial 2	Average
Undamaged	8.972	8.936	8.954	34.253	34.290	34.271
Case 2	8.618	8.655	8.637	32.715	32.813	32.764
Case 4	8.460	8.521	8.490	31.787	-	31.787

The strain energy, fractional energy and the damage index were determined using MATLAB code and the damage indices were plotted. The calculated damage indices are as seen in Figures 2. It was noticed however, that despite these peaks at locations close to the actual damage, other non-damage peaks were still present which points to false damage detection. In summary, the various peaks in the damage indices can be used as a way to detect the presence of damage and also be used to localise damage to some extent.

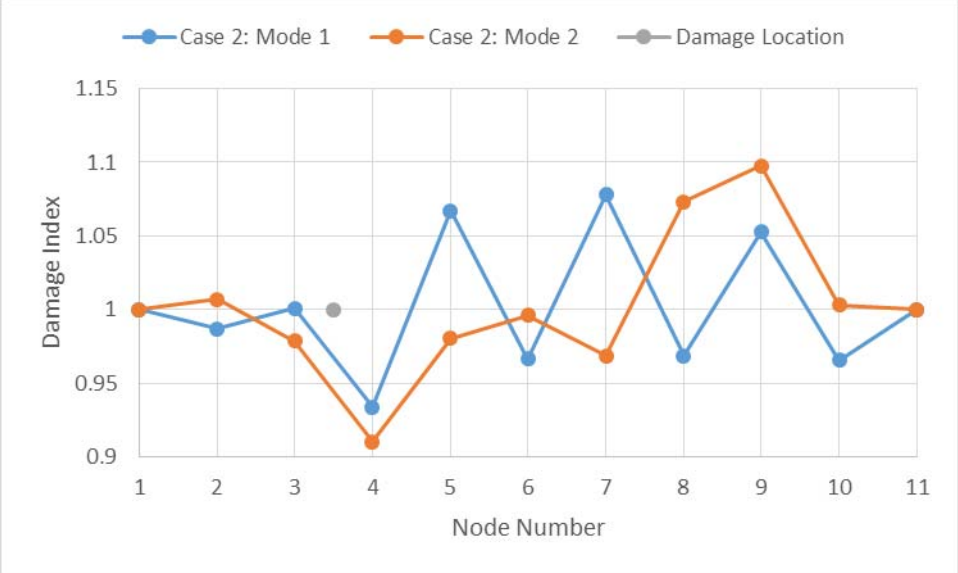

Figure 2: Damage Indices for Case 2 (Experimental)

Multi-Girder Results

In the multi-girder experiment, the natural frequency change was observed to increase with damage, with the exception of Case 5. Since damage associates with decreased stiffness, the natural frequencies with respect to damage should decrease. The results therefore did not demonstrate the expected trend to indicate the presence of damage (Table 4). This anomaly was deemed to be the result of the apparatus, as the fastening system did not represent a full bonded deck unit to the girders. The practicality of the experiment was therefore limited as there were clear discrepancies with expected results.

Table 4: Experimental Natural Frequencies

Damage Case	1st Flexural Mode (Hz)
Undamaged	10.669
Case 5	10.641
Case 6	10.904
Case 7	10.709
Case 8	10.684
Case 9	10.815

Conclusion

This study investigated the application of vibration based damage detection (VBDD) to detect and locate various damage scenarios in steel girders, using the first two flexural mode shape and its corresponding natural frequency. Developed one-dimensional VBDD methods from literature were verified by numerical and experimental single girder investigations, and then extended to a scaled bridge system investigation. The results of the investigation showed that damage can be detected with frequency-based methods and further localised with mode shape-based methods in single girder scenarios. For multi-girder scenarios, further investigation is required for practical application.

References

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Brownjohn, J. M. W. (2007). Structural health monitoring of civil infrastructure. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 365*(1851), 589-622. doi:10.1098/rsta.2006.1925

AUSTRALIAN NETWORK OF STRUCTURAL HEALTH MONITORING

Newsletter

A Technical Note on: Drones for Bridge Health Monitoring

Maria Rashidi[1]

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There are now over 900,000 kilometres of roads and over 50,000 bridges in Australia. Millions of commuters rely on the transportation network. The reliability and safety of these infrastructure elements are crucial to the Australian economy. Bridge inspection is an essential element of any Bridge Management System (BMS) particularly for aged and deteriorated bridges and a path way to condition rating. The accuracy of condition assessment is relied heavily on the quality of inspection.

The ever-changing dynamics of infrastructure asset management and the success of accommodating to these changes is mainly in credit of adopting different technologies and methods of construction, inspection and maintenance. Remotely Piloted Aircrafts (RPAs), commonly known as drones, have been heralded as one of the next big developments in technology. However, until recently, very limited research has been done to investigate the benefits of the technology for use in bridge inspections.

The use of drones is one such technology, favored for their features of safety, functionality and sustainability in the processes of infrastructure inspection. Building this bank of proof is necessary for government organisations and transportation agencies looking to move bridge inspection into the 21st century.

Figure 1 Drone Inspection of Peats Ferry Bridge

RPAs have become an increasingly familiar technology and have become smaller, more capable, and less expensive because of both military investment in the RPA industry and improved technology. Current generation of RPAs can be transported in small vehicles and launched from a road or a small truck but are still large enough to be equipped with cameras and sensors that can provide low-cost aerial information. These aircrafts are capable of flying autonomously and completing pre-set flight paths.

Bridge inspection drones need to have advanced safety features considering that they fly over traffic, are subject to gusts of wind and weak GPS signals. Furthermore, the drone needs to be quite robust in resisting magnetic fields, as a bridge inspection drone will get close to big masses of metal elements e.g truss bridges. Another issue is that almost all the drones in the market have a camera that is attached underneath of the drone, which limits its ability to look overhead, a major problem when carrying out bridge inspections.

The Structural Assessment and Health Monitoring (SAHM) team at the Centre for Infrastructure Engineering (CIE), led by Dr. Maria Rashidi, has collaborated with Road and Maritime Services RMS to trial remotely-piloted aircraft (RPA or drones) for bridge inspections. As part of this feasibility study, qualified pilots from our team and RMS used a high-end drone to examine the effectiveness of RPAs for bridge inspection. Four bridges with various features and configurations have been tested to determine the efficiency of RPAs as bridge inspection tool. This research has already sparked interest across Australia, including other states' transportation departments.

Drone images from multiple locations and point clouds can be used to construct 3D models using the photogrammetry tools and techniques. These drone models can be employed for virtual inspection and also as-built model development of bridges. Figure 2 shows the constructed point cloud of cedar point bridge in NSW.

Figure 2 Point Cloud of Cedar Point Bridge

When comparing RPA inspections to conventional methods, one of the major benefits is the higher degree of safety. RPA inspections provide a mechanism that insure the bridge inspectors and the relevant crew aren't exposed to higher risk situations. RPAs today are capable of capturing images from under bridge regions without the need of man lifts and potentially closing down roads. This has dramatically increased the safety aspect of bridge inspections as there are many risks that come into place when ropes and cherry pickers are used for under bridge inspections in conventional methods.

With the use of RPA's technical abilities today, complex and large bridge inspections can be completed at a significantly faster time than conventional methods. For example, it only took 40 minutes to complete a full bridge inspection on the 116 m long St Alban Bridge through the use of RPAs. The 40 minutes consisted of a 18-minute setup time, 22-minutes flight.

Besides the safety and speed of operation, cost effectiveness is another advantage; many of the cost savings are associated with time reductions and safety. Our pilot study for large-scale bridges, showed that RPA-inspection was 46% faster and 61% cheaper than the conventional inspection.
As a conclusion, Remotely Piloted Aircrafts (RPAs) offer substantial potential in undertaking visual inspection with high accuracy and reduced risk to bridge crew, allowing a bridge to be visually inspected without the need for inspectors to walk across the deck or utilise costly and often heavy under-bridge inspection units. This can significantly reduce the overall inspection costs and disruption caused to the general public. In addition to this, the use of air borne Aerial Photogrammetry enables asset managers and engineers to better understand a situation through the 3D spatial context offered by RPA systems.

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DORAFSHAN, S. & MAGUIRE, M. 2018. Bridge inspection: human performance, unmanned aerial systems and automation. Journal of Civil Structural Health Monitoring, 8, 443-476.

RASHIDI, M. & GIBSON, P. 2012. A Methodology for Bridge Condition Evaluation. Journal of Civil Engineering and Architecture, 6, 1149–1157.

RASHIDI, M., SAMALI, B. & SHARAFI, P. 2016. A new model for bridge management: Part B: Decision Support System for Remediation Planning. Australian Journal of Civil Engineering, 14, 46-53.

Conference News

- **Special session "Recent Research Advances on Innovative Techniques for Structural Health Monitoring" in the 16th East Asia-Pacific Conference on Structural Engineering & Construction (EASEC-16), 3-6 Dec 2019, Brisbane, Australia. Organized by Dr Jun Li and Dr Qingzhao Kong. https://easec16.com.au/**

  Abstract submission due: 31 March 2019

  Full paper due: 1 July 2019

  Submit to: junli@curtin.edu.au or qzkong123@gmail.com

- **9th International Conference on Structural Health Monitoring of Intelligent Infrastructure, 4-7 August 2019, St Louis, Missouri, USA. https://shmii-9.mst.edu/**

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www.linkedin.com/groups/ANSHM-Australian-Network-Structural-Health-4965305

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