Message from the Chairman of SIMTReC

Donald W. Whitmore, MBA, PEng.

SIMTReC is very active with highly qualified personnel prominently engaged in leading-edge training. As you read this edition of "The Innovator," you will find exciting reports on activities held recently and those we plan to hold in early 2017. Research activities and projects underway that involve our graduate students and Post-doctoral researchers are also discussed.

Our Alumni Reception provided a great opportunity for SIMTReC’s graduates to re-engage with the Centre and their classmates and professors, and to learn about our current projects. This reception will become an annual event, one that will further strengthen our relationships with alumni and, indirectly, their employers across industry, government or academia.

Innovation Day 2016 was successful. Industry attendance, an indication of the growing importance of the Centre’s linkage to experts and our research agenda, was much higher than in prior years. Networking between industry leaders and government infrastructure owners with our keynote speakers and project leaders was a clear indication of the value being passed from our research community to end-users. A full report enclosed highlights our Innovation Day keynote speakers and their presentations.

This edition includes articles on several of SIMTReC’s on-going leading-edge research projects. These projects focus on the provision of specific knowledge to owners of infrastructure and the private sector firms that work with them. As Canada’s infrastructure ages, the demand for cutting-edge knowledge and solutions that ensure safe, reliable structures continues to grow. To help meet the growing demand for better solutions, SIMTReC continues to receive substantial research project funding from Research Manitoba. An article in “The Wave,” Research Manitoba’s publication, describes recent
SIMTReC projects funded by Research Manitoba. Follow this link for a very insightful and interesting article titled “Innovative Solutions”.

To extend today’s best knowledge on condition assessments of bridges and structures to those who have not recently studied current developments on-campus, SIMTReC will present “Bridge Analysis, Design and Structural Health Course,” a training course in Winnipeg on March 27 – 29, 2017. More information to come in January 2017.

Recent discussions at the federal and provincial level on the urgency to improve Canada’s infrastructure and increase our country’s productivity and competitiveness have strongly the need for more innovation in the construction and rehabilitation of our structures. SIMTReC, with our industry partners, will focus our attention on providing potential, practical solutions along with the highly-qualified personnel necessary to design, install and monitor structures to ensure safe long-term performance. Future opportunities for SIMTReC in this regard will be monitored closely in the months ahead.

SIMTReC’s priority is innovative research and development opportunities to improve the design, construction and operation of our infrastructure as well as the training of the highly-skilled personnel necessary who deliver those technologies.

Your continued interest and support is appreciated. Please watch for SIMTReC’s next issue of “The Innovator” in Spring 2017.
Innovation Day 2016 - Highlights

Innovation Day is SIMTReC’s networking event of the year. This year it was held on October 26, 2016. It brought together representatives from academia, industry, and government.

The day began by browsing through a display of posters prepared by SIMTReC graduate students and research staff. We had our first Best Poster Competition, with the Best Poster Award going to Ms. Sarah Boila (Department of Civil Engineering, University of Manitoba) for her poster titled: Thermally Broken Reinforced Concrete Slabs. This project, led by Professor Svecova is being completed in collaboration with Red River College and Crosier Kilgour and Partners Ltd. A short description of the project may be found in this issue of The Innovator.

The first morning session featured two keynote speakers: Dr. Sami Rizkalla, Distinguished Professor of Civil Engineering from North Carolina State University, and Mr. Glenn Hewus from the Federal Bridge Corporation Limited. The presentations inspired our attendees to work with innovative materials, and made it clear that collaborations between University researchers and industry are essential for bringing innovation to industry.

The remainder of the day was spent on presentations from SIMTReC project leaders, which included monitoring of a bridge in Morris, Manitoba, the development of Bridge-Weigh-in-Motion monitoring system, and development of new ways to detect cracking in steel bridge girders and in heavy ground vehicles. There was something for everyone to choose from. The day concluded with our lunch presenter, Dr. Brian Westcott from Intelligent Structures, Inc. Dr. Westcott presented on the mission of the company, which is to combine the technologies of the Industrial Internet of Things (I-IoT) with Structural Health Monitoring to create intelligent bridges and solve the world issue of infrastructure decay.

We are looking forward to seeing you at our next year’s event.
Effective and Economical Use of FRP for Civil Structures
Sami Rizkalla, Distinguished Professor - Department of Civil, Construction, and Environmental Engineering - North Carolina State University, Raleigh, NC, USA

Researchers have been studying new and innovative uses of composite materials for civil engineering infrastructure for the past 25 years. The research has led to the extensive use of composites for repair and rehabilitation of existing buildings and bridges. The relatively high initial costs of FRP materials have historically proven to be a barrier to the adoption of this technology for new construction, despite the potential life-cycle cost savings that have been reported.

Recently, the weight savings, environmental durability, and reduced labor costs, associated with the use of fiber reinforced polymer (FRP) composite materials, have encouraged the use of these materials by the precast concrete industry. The research undertaken has helped to overcome many of the practical, technical, and economic challenges associated with implementing FRP materials in several types of precast concrete members.

The presentation at the SIMTReC Innoation Day focused on the use of FRP materials in several precast products including double-tee beams, insulated precast load-bearing wall panels, architectural cladding and piles. The presentation also included the use of FRP for strengthening steel bridges and structures.

1. DOUBLE-TEE BEAMS (DT)

Under harsh exposure conditions, flanges of the DTs are subjected to deterioration due to corrosion of the steel WWF mesh used as reinforcement in the transverse direction. Corrosion of the steel typically leads to spalling of concrete cover and deterioration of the entire structure. The non-corrosive properties and high strength-to-weight ratio of CFRP grids, shown in Fig. 1(a), provide a promising alternative to replacing the steel WWF as reinforcement for the flanges, as shown in Fig. 1(b).

Fig. 1(a): CFRP grid

Fig. 1(b): CFRP grid used as reinforcement for the flange of DT

To examine the effectiveness of the CFRP grid, several full scale DTs were tested using sealed vacuum chambers to apply uniform load distribution on the top surface of the flanges, as illustrated in Fig. 2.
2. PRECAST CONCRETE SANDWICH PANELS

The same CFRP grid was cut at a 450 angle to produce a “Truss Configuration”, shown in Fig. 3, used as shear transfer mechanism for Concrete Sandwich Panels. Full scale testing indicated that CFRP grid achieved full composite action of the two concrete wyths under the effect of the gravity and wind loads. Therefore, the concept produced a new generation of Precast Concrete Sandwich Panels that are structurally and thermally efficient.

3. ARCHITECTURAL CONCRETE CLADDING

The same CFRP grid was used as flexural reinforcement and as shear transfer mechanism for prestressed Concrete Sandwich Panels. The CFRP grid shear mechanism achieved an excellent composite action and the use of rigid foam between the two concrete wyths provided excellent thermal efficiency. The test setup to simulate the presence of windows above and below is shown in Fig. 4. The pressure and suction loads were produced by large turbine for the sealed chamber.
4. PRECAST CONCRETE PILES

The use of the CFRP grid is extended to replace the typical spiral steel reinforcements used for precast concrete piles. Since the spiral steel reinforcements is the outer layer of reinforcement, they are the most exposed reinforcement to the environment and consequently corrode over time when they are subjected to severe environmental conditions. Casting of the piles follow the same traditional construction technique used by the precast industry, as shown in Fig. 5.

5. STRENGTHENING OF STEEL BRIDGES

The efficient use of small cross section of CFRP material was also used to produce small diameter CFRP strands to strengthen the flexural and shear capacity of steel bridge girders. The advantage of using these small diameter strands, shown in Fig. 6, is the elimination of any possible de-bonding which is commonly observed for the use of CFRP plates and laminates used for strengthening steel surfaces since the CFRP laminates are typically bonded to the steel surface from one side. These small diameter strand with the gap in between eliminate any possible de-bonding since each strand is totally covered by the epoxy similar to the bond characteristics of near surface mounted (NSM) used for concrete surface. Testing of the efficiency of the CFRP small strand for shear strengthening used steel panel is shown in Fig. 7.
The presentation was ended by extending invitation to the audience to visit the Constructed Facilities Laboratory at North Carolina State University (Fig. 8).
**SIMTReC Alumni Reception**

On October 25, 2016 SIMTReC hosted its first Alumni Reception at the University of Manitoba. The event was sponsored by the University of Manitoba and brought together alumni and former leaders of Intelligent Sensing for Innovative Structures Canada. It was inspiring for our current graduate students to see our alumni in prominent positions in industry, government and academia.

We heard from Dr. Sami Rizkalla, the first president of Intelligent Sensing for Innovative Structures Canada and Dr. Aftab Mufti, former President and current Scientific Director of SIMTReC.

If you missed this year’s event, please look out for invitation for our next year’s event. We would love to see you all and catch up on your accomplishments.
Developing a Thermally Broken Reinforced Concrete Balcony Slab  
Researchers: Sarah Boila, MSc. Student, University of Manitoba; Dr. Dagmar Svecova, Professor, University of Manitoba  
Industry Collaborator: Red River College, Crosier Kilgour & Partners Ltd.  

In an effort to reduce our collective consumption of natural resources and greenhouse gas emissions, the building industry has recently focused on improving the insulation of the building envelope and thus lowering heating and cooling loads. However, thermal bridging occurring at locations such as the interface of concrete balconies and wall systems continue to compromise the integrity of the building envelope for the entire structure.

The main objective of this project is to design a practical and cost-effective thermal break system for concrete balconies to improve the sustainability and cost efficiency of modern buildings as well as enhancing the health, safety and comfort of the building occupants. This project aims to determine the optimum combination of materials to provide excellent structural and thermal properties for this purpose while ensuring cost-effectiveness. Reinforcing materials to be investigated include regular carbon steel, stainless steel, and glass fiber reinforced polymer. Stainless steel and glass fiber reinforced polymer both provide reduced thermal conductivities (25 and 5 W/mK, respectively) in comparison to carbon steel (50 W/mK), while providing the required structural strength. Potential thermal break materials to be investigated include Armatherm, ultra-high molecular weight polyethylene, and ceramic. These materials are designed to provide significant insulation with thermal conductivities approximately a thousand times smaller than that of carbon steel.

The project is divided into the following three phases: structural system design and computer modeling, thermal performance testing, and structural capacity testing. Three samples of each material combination measuring 1.6 meters long by 0.5 meters wide and 0.19 m in depth will be cast, with a total of 45 samples for five insulation variations. Thermal testing will be performed at Red River College, subjecting the interior portion of the slab to +21°C and the exterior portion to -31°C, separated by an insulated wall. The slabs will be instrumented with thermistors to record the temperature profile and calculate total heat flux through each slab. Destructive structural testing will then be performed at the University of Manitoba by applying a monotonically increasing point load at the tip of the cantilever until failure. Measurements of interest will include the ultimate bending moment and shear force at the location of the thermal break upon failure, as well as total rotation and deflection of the slab.

Based on the results of the three phases, the optimum combination of structural and insulating materials will be determined for use as a thermal break. The summary of the study will consider various criteria including structural and thermal performance as well as cost-effectiveness. The project will be closely coordinated with industry partners, Crosier Kilgour & Partners Ltd., to ensure a direct transfer of knowledge for rapid implementation.
Scour Monitoring Method Using Ultrasonic-based Flow Meters and Advanced Machine Learning

Researchers: Young-Jin Cha, Ph.D., Assistant Professor, University of Manitoba; Sadegh Mahmoudkhani, Ph.D. Candidate, University of Manitoba

Bridges play a critical role in emergency responses when natural disasters strike. Their functionality and safety are directly associated with public safety and socio-economics. Scouring is the primary cause of bridge failures, and it is particularly a major concern during floods. Bridge scour monitoring is thus an important structural health monitoring task. However, traditional scour monitoring, which is based on visual inspection by divers, is costly and impractical for the timely detection of an accurate scouring depth. To overcome the drawbacks of the traditional method, some monitoring methods have been developed. That said, they too have certain limitations that render them impractical. By way of example, the sonar technique is significantly affected by attenuation and noise. Radar-based methods are not usable for real-time monitoring, nor are they usable during floods since they require manual operation. Driven-based methods can measure the scour depth but are susceptible to damage during heavy flooding. Further, they need to be reinstalled after a flood, and are not usable for real-time monitoring. Vibration-based methods are limited by their sensitivity to environmental vibrations. The Time Domain Reflectometry (TDR) method uses an electromagnetic pulse to monitor scouring but is limited by electromagnetic interference, saline water, changes to water temperature and TDR signal loss. Like TDR, thermometry-based methods are sensitive to ambient temperature variation. Methods which use Fiber Bragg Grating Methods, can measure scour depth with time, but they are highly vulnerable to soil and water pressure. To address the drawbacks of these approaches, we propose a quasi-real-time scour monitoring method using ultrasonic flow meters and one-class support vector machines (OCSVM) to detect scour and measure the levels of both scour and scour refill. Unlike the parameters that were used in previous studies, water velocity is not considerably affected by environmental noises in the proposed method. To monitor bridge scour, the proposed approach uses only the measured water velocity from the ultrasonic flow meters installed on different levels of the bridge pier buried in a stream bed. When scour occurs, the buried flow meter, which is exposed to water, measures flow velocity. With this monitoring methodology, the data obtained from flow meters are analyzed by a well-trained OCSVM to derive a quasi-real-time scour monitoring method. This research program would develop a reliable and low-cost bridge scour monitoring methodology that could be directly applied to existing and new bridges to monitor and access the status of scouring.
The Inuvik-Tuktoyaktuk Highway (ITH) in the Northwest Territories is a newly-constructed all-weather road that will complete Canada's road network from the Pacific to the Atlantic, and further to the Arctic coasts. Road access to the North is essential as it addresses the goals of northern economic development and the strengthening of Canadian sovereignty in the Arctic. The northern environment and the increasing effects of climate warming pose serious challenges in the construction and serviceability of highway embankments in the region.

A research program is on-going in collaboration with the Government of the Northwest Territories (GNWT) and Structural Innovation and Monitoring Technologies Resource Centre (SIMTReC). Two instrumented embankment test sections along the ITH were constructed. These test sections are being monitored for their performance. Wicking geosynthetics were used to reinforce the side slopes of one of the test sections. The other section, which is unreinforced, serves as a control section. The research has an extensive field monitoring program, advanced laboratory testing, and computer simulation.

The overall long-term objective of the research is to improve the design and performance of northern transportation infrastructure. Although the focus is on highways, the research program is also applicable to other transportation infrastructure including airports, railways, and river crossings. The short-term objective is to investigate the use of wicking geosynthetics to improve the structural stability of embankment fills. This research, the first of its kind, will advance the knowledge and technology of designing transportation infrastructure in Canada's North. The Province of Manitoba will gain highly relevant and significant knowledge and experience in developing Manitoba's northern infrastructure.
Placement of geosynthetic reinforcements instrumented with strain gauges.

Placement of instrumentation to measure highway movements

Installation of data acquisition and satellite system for wireless data collection.
Identification of Breathing Cracks in a Beam Structure with Entropy

Student Name: S.R. Buddhi Wimarshana
Degree Obtained: MSc
Supervisor Name: Dr. Nan Wu & Prof. Christine Wu

Abstract of Project: During vibration of engineering structures, fatigue cracks may exhibit a repetitive crack open-close breathing like phenomenon which ultimately result in a distinct crack type, breathing cracks. This breathing phenomenon generates bi-linearity and irregularities in vibration signals of the cracked structure which carry useful information about the crack occurrence. In this thesis, the concept of entropy is employed to quantify this bi-linearity/irregularity of the vibration response so as to evaluate crack severity. To increase the sensitivity of the entropy calculation to detect the damage severity, sample entropy and quantized approximation of sample entropy are merged with wavelet transformation (WT) which is capable of amplifying the weak irregularities in vibration signal caused by small and initial breathing cracks. A cantilever beam with a breathing crack is studied to asses proposed crack identification method under two vibration conditions with sinusoidal and random excitations. An iterative numerical model is established to generate accurate time domain vibration responses of the cantilever with a breathing crack. Through both numerical simulations and experimental testing, the breathing crack identification with entropy under sinusoidal excitation is studied first and proven to be effective. Then, the crack identification sensitivity under lower excitation frequencies is further improved by parametric optimization of sample entropy and WT. Finally, effective breathing crack identification under general random excitations are experimentally studied and realized using frequency response functions (FRFs) which adapts the proposed crack identification technique to the incurred extra complexity due to random nature of the excitation and structural response.

Natural Frequency Based Damage Identification of Beams Using Piezoelectric Materials

Student Name: Shengjie Zhao
Degree Obtained: MSc
Supervisor Name: Dr. Nan Wu

Following the studies of natural frequency based damage detection methods, an advanced technique for damage detection and localization in beam-type structures using a vibration characteristic tuning procedure is developed by an optimal design of piezoelectric materials. Piezoelectric sensors and actuators are mounted on the surface of the host beam to generate excitations for the tuning via a feedback process. The excitations induced by the piezoelectric effect are used to magnify the effect of the damage on the change of the natural frequencies of the damaged structure to realize the high detection sensitivity. Based on the vibration characteristic tuning procedure, a scan-tuning methodology for damage identification detection and localization is proposed. From numerical analytical simulations, both crack and delamination damage in the beams are detected and located with over 20% change in the natural frequencies. Finite element method (FEM) simulations are conducted to verify the effectiveness of the proposed methodology.

Study on Efficient Piezoelectric Energy Harvesting with Frequency Self-tuning

Student Name: Yukun Cheng
Degree Obtained: MSc
Supervisor Name: Dr. Nan Wu

A frequency self-tuning energy harvesting methodology is proposed to achieve efficient energy harvesting. To simulate the self-tuning process, a theoretical model of the harvester made of an aluminum beam bonded with piezoelectric patches is developed for numerical simulation. The energy harvesting is realized by converting ambient vibration to electric charge through piezoelectric patches on the host beam. To accomplish the frequency self-tuning process, a control voltage is applied on a piezoelectric stack actuator to tune the natural frequency of the beam harvester matching the major excitation frequency of the ambient vibration with large power generation. Two tuning methods with different electric circuits are developed to find the most efficient and feasible self-tuning process, which is then further verified by the finite element method (FEM). Research findings show that the optimal frequency self-tuning method significantly
increases the power output from the harvester by more than 26 times compared with the one without tuning.

ON THE MOVE

Dr. Amir Ghaṭefar, E.I.T.

One of our post-doctoral fellows, Dr. Amir Ghaṭefar, EIT, is moving on and joining the bridge/structures department at WSP/MMM Group in the Winnipeg office. While with SIMTReC, after graduation from the University of Manitoba, Amir has worked across a wide range of different projects related to the use of fibre-reinforced polymers in civil infrastructure and structural health monitoring. His main research is focused on three areas: Fiber Reinforced Polymer (FRP) application in Reinforced Concrete (RC) structures, particularly their durability, construction, design, field testing and remote monitoring using fiber optic sensors; the application of finite element and computational methods in material and structural engineering; and the development of innovative systems intended to improve the performance of conventional masonry structures.

Even though we are sad to see Amir leave our group, we are proud of his achievements and wish him all the best in his new workplace, and we look forward to future collaboration.

Meet the Centre

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Dr. Douglas Thomson, P.Eng. - Associate Director
Dr. Aftab Mufti, P.Eng. - Scientific Director
Mr. Andrew Horosko, P.Eng., Business Development Coordinator
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Upcoming Events

Innovation Day
Smart Park Event Centre
October 25, 2017

Bridge Analysis, Design and Structural Health Course
March 27 to 29, 2017
Smart Park Event Centre

The course will be provided by two of Canada’s leading experts in the field, and will be based on a book that they have just published entitled: “Bridges: Analysis, Design, Structural Health Monitoring, and Rehabilitation”. The book has just been published by Springer Verlag (engl: publishing company) Germany and each participant will receive a hard copy of the reference book included with their registration (retail is over $200 CDN), along with a CD containing five
computer programs described in the book. Each participant will also receive hard copies of all the presentations.

Course instructors will be the authors of the book:
1. Dr. Baidar Bakht, C.M., D.Sc, P.Eng.
2. Dr. Aftab Mufti, C.M., FRSC, Ph.D., P.Eng.
3. Dr. Huma Khalid

The instructors are currently affiliated with SIMTReC – Centre for Structural Innovation and Monitoring Technologies Inc. (formerly known as ISIS Canada Resource Centre), at the University of Manitoba. The course instructors will be assisted in running of the computer programs by Post-doctoral Fellow, Dr. Huma Khalid.

It will be a full three-day course held from March 27 to 29, 2017 at the SmartPark Event Centre at the University of Manitoba. The registration fee, including three breakfasts, three lunches, and six refreshment breaks, will be $825 for Full Registration, and $425 for Students. SIMTReC will provide ‘Certificates of Attendance’ for those needing them for professional development credits. The investment is highly cost-effective for a three-day course of this nature.

Full course information to be found on our website in January 2017.

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