

## Fire Performance of FRP Strengthened Structures



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ISIS researchers at Queen's University and the Institute for Research in Construction at the National Research Council of Canada (NRC), in collaboration with industry partners (Fyfe Co. and Watson-Bowman Acme, a division of Degussa Construction Chemicals), are actively investigating the fire performance of concrete members strengthened with FRP sheets.

The research involves extensive fire endurance experiments on full-scale FRP-strengthened concrete columns and beams, and associated numerical modelling.

At this point in the research, fire endurance experiments on two circular concrete columns, wrapped with carbon FRP and insulated with an active/passive system that is patent pending by Fyfe Co. LLC, have been conducted.

Figure 1 shows the strengthened and insulated column (400 mm diameter 3800 mm length) in the NRC column furnace before fire testing and immediately after the test.

**"From the results thus far, the performance of insulated FRP wrapped columns under fire conditions can be considerably greater than commonly believed."**

- Dr. Mark Green, Queen's University

These tests demonstrated that the specific system under investigation was able to achieve a 4-hour fire endurance rating, under load, according to guidelines set out in ASTM E119.



Figure 1 - before testing

The FRP remained intact during the first 4 hours of the test. Figure 2 shows the measured temperatures in one of the tested columns.



Figure 1 - immediately after testing

The insulating system kept the average temperature of the FRP below 150 C for the first 4 hours of the experiment.

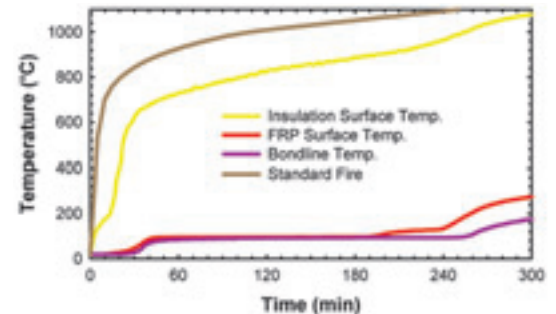


Figure 2

Over the next year, plans are in place to conduct a number of additional experiments on columns and beam-slab assemblies using either Tyfo Fibrwrap or WaboMBrace with appropriate insulating systems.

For more information on this research program, please contact Dr. Mark Green at [greenm@civil.queensu.ca](mailto:greenm@civil.queensu.ca) or Dr. Venkatesh Kodur at [Venkatesh.Kodur@nrc-cnrc.gc.ca](mailto:Venkatesh.Kodur@nrc-cnrc.gc.ca). The contacts for the industrial partners are Ed Fyfe (Fyfe Co. LLC) at [ed@fyfeco.com](mailto:ed@fyfeco.com) and Jim Derrigan (Watson-Bowman Acme) at [jim.derrigan@degussa.com](mailto:jim.derrigan@degussa.com).

## COMPETITIONS

Visit the ISIS website for details on all student competitions and the four scholarships offered.

Scholarships  
Posters  
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[www.isiscanada.com/competitions/studentc.htm](http://www.isiscanada.com/competitions/studentc.htm)

Civil infrastructure systems are generally the most expensive assets in any country (an estimated \$2 trillion in Canada). The estimated infrastructure deficit is \$60 billion and increasing at a rate of \$2 billion per year. Additionally, these systems have a long service life in comparison to most other commercial products. As well, the introduction of intelligent materials and innovative design approaches in these systems is painfully slow due to heavy reliance on traditional construction and maintenance practices and the conservative nature of design codes. Feedback on "state of the health" of constructed systems is practically non-existent.

## ISIS Canada 9<sup>th</sup> Annual Conference

**April 28<sup>th</sup> - 30<sup>th</sup>, 2004 Public Forum Day April 28<sup>th</sup>, 2004**

Plan to participate in this exciting presentation of smart, alternative **solutions for replacement and maintenance of civil infrastructure**. You will learn about the latest advances in research and application of **fibre reinforced polymers** and **structural health monitoring**. These innovative, cutting-edge solutions will be discussed by ISIS Canada researchers as well as guest speakers who are putting these technologies to work right now.

### **Keynote Speaker Dr. Jin-Guang Teng, B.Eng.**

Professor of Civil & Structural Engineering The Hong Kong Polytechnic University



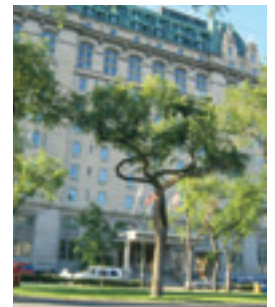
Dr. Teng's research interests include the application of FRP composites in civil engineering, shell and spatial structures, steel and steel-concrete composite structures, and nonlinear and buckling behaviour of structures. He is the inventor of the steel-concrete composite shell roof system (the Comshell roof) and was the Chairman of an ad-hoc committee which recently founded the International Institute for FRP in Construction (IIFC). He was also elected the founding President of this new organization. The aim of the Institute is to advance the understanding and the application of FRP composites in civil infrastructure, in the service of the engineering profession and society.

**Register on-line at [www.isiscanada.com/conference/conference04.htm](http://www.isiscanada.com/conference/conference04.htm)**

The Westin Nova Scotian, Halifax  
Reservations 1.877.9WESTIN or <http://www.westin.ns.ca>

## **2<sup>nd</sup> International Workshop on Structural Health Monitoring of Innovative Civil Engineering Structures**

**September 22-23rd, 2004 Winnipeg, Manitoba  
Fort Garry Hotel**



Structural Health Monitoring (SHM) is an evolving technology that will monitor and define the health of emerging innovative civil engineering infrastructure. New construction and rehabilitation of old infrastructure is the largest industry in the world, amounting to 10 percent of the world's gross domestic product.

### **KEYNOTE SPEAKERS**

**Dr. Baidar Bakht, JMBT Structures Research Inc., Canada**

**Prof. Konrad Bergmeister, Institute of Structural Engineering, Austria**

**Dr. J.J. Roger Cheng, University of Alberta, Canada**

**Dr. Dan Frangopol, University of Colorado at Boulder, USA**

**Prof. Toshiyuki Oshima, Kitami Institute of Technology, Japan**

**Dr. Zhishen Wu, Ibaraki University, Japan**

**Online registration at:**

**[http://www.isiscanada.com/shm\\_workshop/shm.htm](http://www.isiscanada.com/shm_workshop/shm.htm)**

## President's Site Visit of ISIS Research Projects

In October 2003, **Dr. Aftab Mufti**, President of ISIS Canada, conducted a site review of the ISIS research projects and met with Project Leaders to assess the progress and results of their research. Joining him were distinguished experts Prof. Urs Meier and Dr. Rolf Broennimann of EMPA, Switzerland, who prepared a report on their assessment. This initiative ensures accountability of the Network and is of great value in formulating the Strategic Plan for the NCE mid-term review that will take place in 2005.

The international experts stated that ISIS Canada

- is now the world leader in the field of intelligent sensing for innovative civil engineering structures;
- continues to have excellent program partners, both academic and technical, with a very broad interdisciplinary background, competence, high degree of motivation, expertise and innovative ideas;
- has very professional management; and
- works excellently as a network.

Prof. Meier stated that, since his previous assessment in January 1997, ISIS has made tremendous progress within the research program.

## Project 2.3.5: FRPs for Glulam Structural Members

**Dr. Farid Taheri, Dalhousie University**

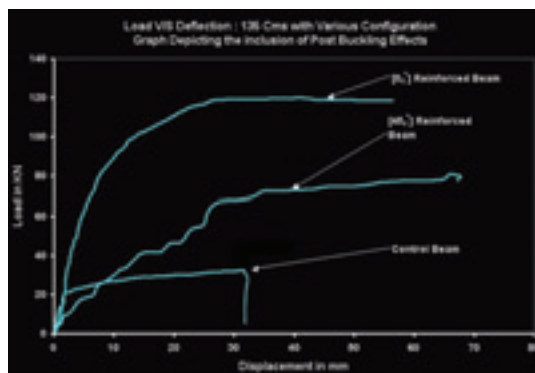
In the early 1980s, a patent was launched for glue laminated beams reinforced with FRP sheets (FRP/Glam), thereafter called FiRP<sup>®</sup>. In 2001, another novel FRP-reinforced Glulam product, under the name of TENLAM<sup>®</sup>, was developed by Hi Tech Wood Products of Nova Scotia, using proprietary methodology. TENLAM was promised to offer superior mechanical properties to that of the FiRP Glulam. However, no design guidelines are available for this new product, nor have there been any studies conducted to explore the impact and vibration characteristics of these structural products. Moreover, other structural applications of FRP/Glam have not been explored. It is therefore the aim of this project to: (a) gain a better understanding of the static and dynamic mechanical behaviour of FRP/Glam beams, produce robust and accurate solutions for their characterization, and (b) with the gained knowledge, to explore new applications of FRP/Glam with the aim of producing cost-effective FRP/Glam columns and arches.



Dr. Farid Taheri



*In-phase and out-of-phase delaminations of GFRP reinforced Glulam columns*



*Graph from experiments*

## Project 1.1.2: Brillouin Sensing and Demodulation

Dr. Xiaoyi Bao, University of Ottawa



Dr. Xiaoyi Bao

The objective of this research is to develop a portable and economical distributed FOS system based on Brillouin scattering for remote monitoring of temperature and strain. The benefits of this system are that it does not require localized sensors and it makes its measurement on the standard telecom optical fibre. Furthermore, this system can be employed as a monitoring instrument over very large distances and provide data at arbitrary locations over these distances. It has been demonstrated that the Brillouin frequency that is actually measured by Brillouin scattering is proportional to temperature and strain. Hence, it is essential to separate them for purposes of determining the structural response.



During the last several years, ISIS Canada has characterized the Brillouin gain spectrum and discovered that it is linearly proportional to both temperature and strain. Hence, by monitoring both Brillouin frequency shift and Brillouin gain coefficients, simultaneous temperature and strain measurements can be achieved. However, due to the polarization dependence of the Brillouin gain coefficient and laser power/frequency drifts, the measurement accuracy for both temperature and strain is low (4°C temperature and 180 micro-strain). This is obviously not acceptable for field monitoring of civil engineering structures. In addition, the size, complexity and cost of the current systems render them unsuitable for field use. Recently, crystal fibers have been used to measure both temperature and strain simultaneously with double frequency peaks, resulting in temperature accuracy of <1°C, strain accuracy of <2 micro-strains, combined with 10 cm spatial resolution for the first time.

*Front view of sensing system and associated equipment*

## Project 4.1.5: Educational Modules

Dr. Luke Bisby, Queen's University



Dr. Luke Bisby

The Educational Modules is a technology transfer focused project which seeks to develop 'teaching toolkits' that can be used to encourage incorporation of ISIS technologies into undergraduate civil engineering curricula in Canada. Eventually, it is hoped the toolkits will also be used in universities, technical colleges and industrial workshops. As a first step, five targeted modules - which include lecture notes, slides, solved examples, and suggested laboratories - are currently under development. These modules are being developed to allow for inclusion in various existing undergraduate engineering courses, with three to four lecture units on fibre reinforced polymers and/or structural health monitoring technologies. Modules currently under development include:

1. Mechanics Examples Incorporating FRP Materials;
2. FRP Composites for Construction;
3. An Introduction to FRP Reinforced Concrete;
4. An Introduction to FRP Strengthening of Concrete Structures; and
5. An Introduction to Structural Health Monitoring.

Educational Modules 1 through 4 will be unveiled at the ISIS Annual Conference in Halifax in the Spring of 2004, and will subsequently be made available publicly. Module 5 will be available by the fall of 2004. The first in a series of ISIS educational workshops for invited engineering professors, in which the educational modules will be presented and discussed, will be held in Toronto in May of 2004.

## Project 2.3.10: Durability of FRP Pins and Reinforcement in Heritage Concrete Structures Dr. Aftab Mufti, University of Manitoba

Since 1990, concerns have been expressed regarding the rapid deterioration of heritage reinforced concrete structures in many regions of Canada. ISIS Canada was asked by Veteran Affairs Canada and Heritage Conservation Services PWGSC to provide a durable and economic solution to this problem. A large-scale experimental program is being conducted at the W.R. McQuade Structural Engineering Laboratory of the University of Manitoba under the auspices of ISIS Canada to investigate the suitability of innovative design procedures for using FRPs as reinforcement in the support beams and as pinning rods to anchor the markers to the support beams. The objective of the study is to secure the necessary data to make recommendations on an improved system for the reinforced concrete ground beams and the marker attachment method to be used at the graves of Canadian veterans across Canada.



*Brookside Cemetery - Winnipeg, MB*



*Crack and deterioration of concrete ground beam*



**Dr. Aftab Mufti**

## Project 3.2.2: Sprayed FRPs for Rehabilitation Dr. Nemkumar Banthia, University of British Columbia

Within the auspices of ISIS, Dr. Banthia is developing fibre reinforced polymers that can be sprayed on the surface of a structure for strengthening. The process, pioneered at the University of British Columbia, involves spraying a very high performance fibre reinforced polymer on the surface of concrete, steel or wood at speeds exceeding 100 km/h, such that a well compacted and well-bonded composite with high strength and stiffness is formed. With a 2-D random distribution of the fibre phase on the surface of the structure, the composite depicts a non-linear stress-strain response and has an isotropic strength performance in the plane of its placement. The process uses high performance fibres (glass, carbon, or aramid), and durable hybrid polymeric resins. Over the last seven years, the team has made significant improvements to the strength and stiffness of the composite produced, and has developed numerous bi-functional bonding agents that ensure a strong and long-lasting bond.

The Safe Bridge on Vancouver Island was the first bridge in the world to undergo shear strengthening using this innovative technique. After the face-lift, the channel beam bridge built in 1955 is at least twice as strong and will absorb three times as much energy during an earthquake. The other applications currently being investigated include seismic strengthening of columns, environmental protection, repair and strengthening of pipelines and the use of sprayed composites as protective coatings on structures in highly aggressive environments.

The technique was awarded the Earth Science Systems Research Award at the American Society of Civil Engineers' International Conference on Structural Faults and Repairs.



*The spray operation*



*Safe Bridge - Duncan, B.C.*



**Dr. Nemkumar Banthia**

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## Innovator Newsletter

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## Officer of the Order of Canada for Dr. Lloyd McGinnis, ISIS Canada CEO

The ISIS Canada Research Network is pleased to announce the appointment of its Chief Executive Officer, **Dr. Lloyd McGinnis**, as an Officer of the Order of Canada.

In addition to being the founding Chair of ISIS Canada, Dr. McGinnis founded the following organizations: Winnipeg Business Development Corporation; Canada/Asian Business Council (for Pacific Rim countries trade initiatives); and the International Institute for Sustainable Development (a Winnipeg-based research centre, with a global mandate for environmental issues). He was also a founding Member of Winnipeg's "CentreVenture" development initiative and given the Global Citizen Award by the United Nations.



The **Technology Transfer and Commercialization Committee** welcomes its newest member, **Darrell Evans**. Mr. Evans is Manager, Design & Bridge Maintenance with the Prince Edward Island Department of Transportation and Public Works. He is currently a member of the Transportation Association of Canada (TAC), the Canadian Society for Civil Engineering (CSCE), the Canadian Standards Association (CSA) and the Atlantic Chapter of the American Concrete Institute (ACI).

Mr. Evans is also a member of TAC's Structures Standing Committee, as well as CSA's Regulatory Authority Committee for the Canadian Highway Bridge Design Code (CHBDC) and an Associate Member of the CHBDC Technical Committee. Mr. Evans is looking forward to providing input and, more importantly, gaining experience and utilizing the technologies in this increasingly important field of engineering.



**Dr. Nemkumar Banthia** was given the **Innovation and Science Council of British Columbia's "Solutions Through Research Award"** for his research into spraying FRPs onto structure surfaces for strengthening purposes.

## Our Talented Administrative Centre Support Team

As **Managing Director, Kim Archer** oversees the operations of the Administrative Centre and assists the CEO in orchestrating the many events and activities of the ISIS Network.

**Nancy Fehr** is the **Executive Assistant to Dr. Mufti** and is responsible for the overall coordination of Dr. Mufti's schedule and responsibilities. She also liaises with students, staff and outside agencies on his behalf.

**Tobi Fletcher** fills the **Communications Officer** role and takes care of all communications materials, special events and media relations.

**Heather Lamoureux** holds the position of **Financial Officer** and administers the financial activities of both the Administrative Centre and Dr. Mufti's research accounts.

**Janet Leclerc** is a bilingual **Administrative Assistant**, responsible for travel arrangements and planning the numerous ISIS conferences, retreats and meetings.

**Charleen Choboter** rounds out the team as front-line **Receptionist/Secretary** and is a proud member of the International Association of Administrative Professionals. She also provides administrative support to Nancy Fehr.

**Jennifer Radford** continues in her role as **Office Assistant** and provides support on a part time basis while she works towards her nursing degree.

