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Invitation to Attend CICE 2014

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On behalf of the International Institute for FRP in Construction (IIFC), it gives me great pleasure to invite all to the 7th International Conference on FRP Composites in Civil Engineering (CICE 2014) in Vancouver, British Columbia, Canada from August 20-22, 2014. CICE 2014 is the official conference of the International Institute for FRP in Construction (IIFC) and will continue the success of the CICE conferences held in Hong Kong 2001, Adelaide 2004, Miami 2006, Zurich 2008, Beijing 2010, and Rome 2012. The conference is organized into several areas of FRP composites in civil engineering including but not limited to: FRP for Sustainability, FRP Internal Reinforcement, FRP Strengthening, Hybrid FRP Structures, All-FRP and Smart FRP Structures, Durability/Long-Term Performance, Fire, Impact and Blast Loading, Inspection/Quality Assurance, Codes and Design Guidelines, Field Applications and Case Studies, FRP in 2020: Visions and Reality.

By 1 January 2014, the organizing committee received 427 abstracts from 42 countries and by 15 March, over 325 full papers had been received. All papers have undergone peer-review by the International Scientific Committee and acceptance notifications are anticipated shortly. The valuable contribution from the authors is important to the success of CICE 2014 and the organising committee is committed to upholding the high technical/scientific standards of the previous editions of the CICE series of conferences. Two IIFC Best Paper Awards will be given to outstanding paper submissions that present either an original research work or a discovery that advances the state of knowledge in accordance with the Conference theme in the two categories of strengthening of structures and new construction. A number of special issues of leading international journals – *Journal of Construction and Building Materials*, *Polymers*, *Advances in Structural Engineering* and the *Canadian Journal of Civil Engineering* – will be developed based on outstanding CICE submissions.

[Continued on page 4]

FRP International needs your input...

As IIFC grows, we seek to expand the utility and reach of *FRP International*. The newsletter will continue to report the activities of IIFC and focus on IIFC-sponsored conferences and meetings. Nevertheless, we also solicit short articles of all kinds: research or research-in-progress reports and letters, case studies, field applications, book reviews or anything that might interest the IIFC membership. Articles will generally run about 1000 words and be well-illustrated. Submissions may be sent directly to the editor. Additionally, please utilize *FRP International* as a forum to announce items of interest to the membership. Announcements of ***upcoming conferences***, ***innovative research or products*** and ***abstracts from newly-published PhD dissertations*** are particularly encouraged. All announcements are duplicated on the IIFC website (www.iifc-hq.org) and all issues of the *FRP International* are also available in the archive at this site.

FRP International is yours, the IIFC membership's forum. The newsletter will only be as useful and interesting as you help to make it. So, again, please become an *FRP International* author.

It is with sadness that we report the passing of an internationally renowned researcher and leader, Professor Len Hollaway, on 12 December 2013 from mesothelioma, after a short battle with the disease. He will be fondly remembered and sadly missed by his colleagues and friends in the IIFC community and beyond.

Professor Leonard (Len) Charles Hollaway, Eur Ing., CEng., FICE., MIStructE, BSc, MSc, PhD (London). 1930 – 2013

Len was born in Dover on 22 June 1930. He was educated in Glasgow and Canterbury. He was articled 1948-50 and worked as an Assistant Engineer for Thurrock Urban District Council prior to undertaking his first degree and his national service. His studying was done the hard way as he studied by day-release from work for his undergraduate and postgraduate degrees and for his chartered engineering qualifications. As he decided to stay in academia, he needed to undertake research work for a PhD, so embarked on a part time research program leading to a PhD at UCL.

In 1958 he joined John Laing Research and Development Ltd. He then joined Battersea College of Advanced Technology in 1962 as a lecturer in Civil Engineering and also in a pastoral role as the Assistant Warden of Ralph West Hall of Residence in London. At the opening of the University of Surrey campus, he continued in his post before promotion to Senior Lecturer in 1976, to Reader of Composite Structures in 1984 and to Professor of Composite Structures in 1987, finally becoming an Emeritus Professor of the University in 1996.

Len headed the Composite Structures Research Unit of the Department of Civil Engineering, and for over 25 years specialised in polymer composites for civil construction and space satellites. During this time he developed the Unit to become nationally and internationally accepted as a unit of excellence in this area of materials and structures.

He finished in full time employment in 1996 but still continued to go to the University most weekdays and, in many ways, considered the period from then to 2009 as one of the most fruitful times of his life as a research worker, author of scientific papers for engineering journals, contributor to books on various topics associated with advanced composites in civil engineering, keynote speaker and presenter of research papers at many conferences.

Len made major and pioneering contributions of lasting importance to fibre reinforced polymer (FRP) composites and their applications in civil/structural engineering over the past four decades. These contributions can be classified under four broad headings of interest, namely, technological innovation, stress analysis, concept development and design guidelines. He developed structural systems which are for use on earth and deployable skeletal structural systems for space use which would be situated at geostationary orbit. The former involved field testing of full-size FRP structures as well as intricate structural model testing. He developed composite systems which involved the combination of two or more structural units made from different materials but one of which was FRP composite; each material was used to their best advantage. He investigated the addition of additives to polymers to improve particular properties, specifically nanoclays into resin formulations, to reduce to a minimum the ingress of moisture thus lowering the permeability of FRP composites in humid environments and to protect the composite in a fire situation. He had long been aware that structural composite materials are dependent upon their physical properties in the environment into which they are placed and this led him to undertake research into the in-service properties of polymer materials.

Len was very active in collaborative research into FRP composites and their applications working with both industrial firms and leading international researchers. He was a founding member of national and international networks of research organizations for industry and a founding member of scientific groups within professional engineering institutions. He was also a member of many national and international committees and had organised international conferences on FRP composites in civil/structural engineering.

Len was an enthusiastic supporter, and made significant contributions to the establishment and the operation of the IIFC. He considered his biggest achievement to be his Fellowship of the IIFC; he held this Fellowship dearly and was honoured to have been elected. In recognition of his distinguished life-time contributions to the field of FRP composites for construction, Len was the recipient of a Lifetime Achievement Award in 2006 (which was later succeeded by the IIFC Medal), the most prestigious award given by the IIFC. The IIFC also organised a special issue of the international journal, *Advances in Structural Engineering* (Vol. 13, No. 5, 2010), to celebrate his lifetime achievements in scientific research, particularly in the area of FRP composites for structural engineering applications.

He was very widely published with over 200 publications, including around 10 books and numerous journal and conference publications. He supervised over 30 research students to their PhD & MPhil awards and supported many of his junior academic colleagues in the advancement of their careers. It is a testament to his dedication to his research that he completed the final chapter of his latest book, in collaboration with a former PhD student, just ten days before he died.

Len is survived by his wife, Pat, his daughter, Suzy, her husband, Bob, and his two grandchildren, Ellie and Josh.

[based on an obituary at surrey.ac.uk and by his daughter, Suzy].

IIFC Education Task Group and Webinars

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The objective of the IIFC Education Task Group is to promote education and knowledge transfer of IIFC researcher's to students and industry. The Task Group reported on the various potential activities and the IIFC Executive Committee decided to initiate an IIFC webinar series. The series consists of short online seminars on specialized topics. Students enrol in a virtual classroom and follow the course from their computer; this type of course delivery is well-established at many universities. Each webinar contains commentary from the presenting professor, an annotated dashboard, details on calculation methods described and allows participant interaction. A network of volunteers has been assembled to develop a series of two-hour webinars covering theory, practical information and calculation methods for each topic. The contents of each webinar are approved by the IIFC Education Task Group and an annual program of webinars is envisioned.

Upcoming Webinars

Durability of FRP will be presented by Prof. Brahim Benmokrane on 9 April 2014 at 09:00 EST (13:00 UCT (London)).

Fire behaviour of RC structures, case of FRP strengthening will be presented by Prof. Luke Bisby on 5 June 2014 at 14:00 UTC (London).

To Connect:

http://134.214.128.214/demo/create.jsp?action=invite&meetingID=IIFCwebminar%27s+meeting

Please connect 10 minutes before the beginning of the webinar.

Archived Webinars

FRP material for strengthening of structures in the field of construction, was presented by Prof. Emmanuel Ferrier on 20 November 2013.

RC beam strengthened for flexure was presented by Prof. Enzo Martinelli on 8 January 2014.

RC beam strengthened for shear was presented by Prof. Joaquim Barros on 20 February 2014.

At this time past webinars are available by contacting Prof. Ferrier directly; links will also be posted at the IIFC website: www.iifc-hq.org.

Invitation to attend…

CICE 2014: 7th international Conference on Fibre Reinforced Polymer (FRP) Composites in Civil Engineering

Vancouver, 20-22 August 2014

[Continued from page 1]

CICE 2014 promises to be intellectually engaging and socially enjoyable. The three-day program will contain keynote lectures, special sessions detailing state-of-the-art research and field applications in different countries, and general technical paper and posters sessions. The IIFC General Meeting and Council meetings will be held during the conference. Social programs will also be arranged. Three distinguished keynote speakers will provide perspectives beyond those normally covered within the CICE series. Coming from varying backgrounds, these promise to be thought provoking.

Prof. Urs Meier is the former Managing Director of EMPA, Swiss Federal Laboratories for Materials Science and Technology, in Dubendorf, a position that he held until his recent retirement and has also been lecturer and professor at the Swiss Federal Institute of Technology (ETH) in Zurich. Professor Meier's keynote lecture is "*FRP in Construction: It was a Long Way to Go*".

Prof. Nabil Grace is Dean of the College of Engineering and a University Distinguished Professor at Lawrence Technological University, Southfield, MI, USA. He is also the Director of the Center for Innovative Materials Research, which is one of the largest and most comprehensive testing facilities in the country. Professor Grace's keynote lecture is "*Recent Bridges with CFRP Reinforcement in USA*".

Prof. Jin-Guang Teng is a Chair Professor of Structural Engineering and the Director of the Research Institute for Sustainable Urban Development at The Hong Kong Polytechnic University. Professor Teng's keynote lecture is "*Structural Use of FRP Composites in China: Research, Code Development and Field Applications*"

Two prestigious awards will be given at the CICE 2014 conference. The IIFC Medal, the Institute's highest honour, is awarded every two years to an IIFC member who has made distinguished contributions to the field of FRP composites for construction through research or practical applications, or both. Professor Antonio Nanni is the winner of the 2014 IIFC Medal. Professor Nanni is the Lester and Gwen Fisher Endowed Scholar, and Chair of the Department of Civil, Architectural & Environmental Engineering at the University of Miami, USA. Professor Nanni will give the IIFC Distinguished Lecture at CICE 2014 on "*Personal Reflections Following 20 years of R&D in FRP Construction*".

The Distinguished Young Researcher Award is given every two years to an IIFC member not older than 40 years of age at the CICE conference, who has distinguished themselves from their peers through research contributions in the field of FRP composites for construction. Professor Luke Bisby is the winner of the 2014 IIFC Distinguished Young Researcher Award. Prof. Bisby is the Arup Chair of Fire and Structures and RAEng Research Chair within the School of Engineering at the University of Edinburgh, UK. Professor Bisby will deliver a keynote lecture at CICE 2014 on "*Fire-Safe Use of FRP Composites in Construction: Myths and Realities*".

Two Mini-Symposia that form an integral part of the CICE 2014 are being organized in honour of Professor Aftab Mufti and Professor Kenneth Neale. At the symposia, colleagues, collaborators, friends and former students will gather to pay tribute to Professors Mufti and Neale for their lifetime achievements in scientific research especially in the area of FRP in construction, and their excellence services to the IIFC. Participation at the symposia as a speaker is by invitation, although the events will be open to all CICE 2014 attendees.

The CICE 2014 conference will be held at The University of British Columbia (UBC) campus, only 20 minutes to downtown or the Vancouver International Airport. The UBC campus offers amazing attractions from world class museums (Museum of Anthropology, Beaty Biodiversity Museum, Pacific Museum of the Aarth), music and arts (Chan Centre for the Performing Arts, UBC School of Music & Old Auditorium, Frederic Wood Theatre Dorothy Somerset Studios, Morris and Helen Belkin Art Gallery, Irving K. Barber Learning Centre), to gardens (UBC Botanical Garden, Nitobe Memorial Garden) and more. The conference hotels (from stylish one-bedroom suites and studios suites both with fully-equipped kitchens to hostel-style rooms) are located on campus and are a few minutes walking distance to the conference venue. A full continental breakfast at the Pacific Spirit Place Cafeteria is included with the on-site hotel accommodations.

The Conference Meet & Greet Reception will be at the Museum of Anthropology, on Wednesday, 20 August from 6 to 8 p.m. Conference delegates will be welcomed with a Gitxsan "People of the River of Mists" song complimented by a rich performance of dramatic spirit-masked dances by The Aboriginal Dancers of Damelahamid from the Northwest Coast of British Columbia. The Conference Banquet will be a Sunset Dinner Cruise on Thursday evening from 7 to 11 p.m.

This conference could not be put together without the help, dedication, and cooperation of numerous people and the assistance of many volunteers. First I would like to thank all authors for meeting the various deadlines for submission allowing the conference proceedings to represent the most current knowledge in the field, which will undoubtedly serve as a useful reference to practitioners, researchers, students and academics, and allied disciplines. Special thanks are to members of the International Scientific Committee, who carefully evaluated and thoroughly reviewed the papers, and whose input and advice have been a contributing factor to the success of this conference. I am also grateful to many distinguished members of the Organising Committee. I am indebted to the service provided by the team from Conferences and Accommodation at the University of British Columbia for their tireless efforts and quick responses to the many demands of the conference. The support of Gold (FIBRWRAP, MAPEI), Silver (Sika Canada) and Bronze (Strongwell and Schöck) Sponsoring Organizations and Companies is gratefully acknowledged. A Products and Services exhibition will be open during the conference. The CICE 2014 conference is under the auspices of the International Institute for FRP in Construction, University of Calgary, University of British Columbia, BC Ministry of Transportation and Infrastructure, City of Vancouver, Canadian Society of Civil Engineers, American Concrete Institute, American Society of Civil Engineers Construction Institute, Korean Society of Civil Engineers, Korea Concrete Institute, Japan Society of Civil Engineers, and Japan Concrete Institute.

Finally, I invite you to enjoy the spectacular beauty of Vancouver; third largest city in Canada, voted one of the world's premier meeting and convention destinations, ranked fourth on the list of the world's 10 best places to live, and located halfway between Europe and Asia. The Vancouver International Airport is easily accessible from UBC, offering direct flights to major cities around the world. Vancouver, located on Canada's spectacular West Coast, and surrounded by mountains and ocean side beaches has one of the mildest Canadian climates. The city of Vancouver is composed of 23 communities in which 67 different languages are spoken; it is a cosmopolitan city with a vibrant and multicultural population of two million. It is a safe, clean, and pedestrian-friendly city. Vancouver was the host city of the 2010 Winter Olympics and Paralympics Games and is a dynamic, international city offering an unprecedented range of activities, experiences and unique attractions including the Vancouver Aquarium, Capilano Suspension Bridge, Vancouver Art Gallery, Vancouver Maritime Museum, Museum Of Anthropology, Botanical Gardens, and more. The city centre is easily accessible by public transit, with many bus routes offering frequent service.

There is a full companion's program at CICE 2014 and plenty of activities for families. The conference is held in the summer (average temperature around 23°C). You may therefore use this opportunity to spend time in and around Vancouver. You may plan your pre- or post-conference vacations to Victoria and Vancouver Island, Whistler, Okanagan, the Canadian Rocky Mountains, or Alaska cruises.

I look forward to welcoming all CICE 2014 delegates to Vancouver in August 2014!

More information is available at www.cice2014.ca or by contacting cice2014@ucalgary.ca.

Research Innovation

Multi-Axis Substructure Testing (MAST) System for Hybrid Simulation of Large-Scale Structures

Prof. R. Al-Mahaidi, Dr. M.J. Hashemi and Dr. Graeme Burnett, Swinburne University of Technology, Melbourne, Australia
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By 2025 more than 5.5 billion people will live in cities; more than the entire 1990 combined rural and urban population [1]. Natural hazards, such as earthquakes and strong winds are the largest potential source of casualties for inhabited areas. Damages to structures cause not only loss of human lives and disruption of lifelines, but also long-term impact on the local, regional, and sometimes national and international economies. The costs to rebuild and recover from the damage caused by 2011 earthquake off the Pacific coast of Tohoku is estimated to be $309bn, about 6% of Japan's total economic output in 2010, according to the World Bank.

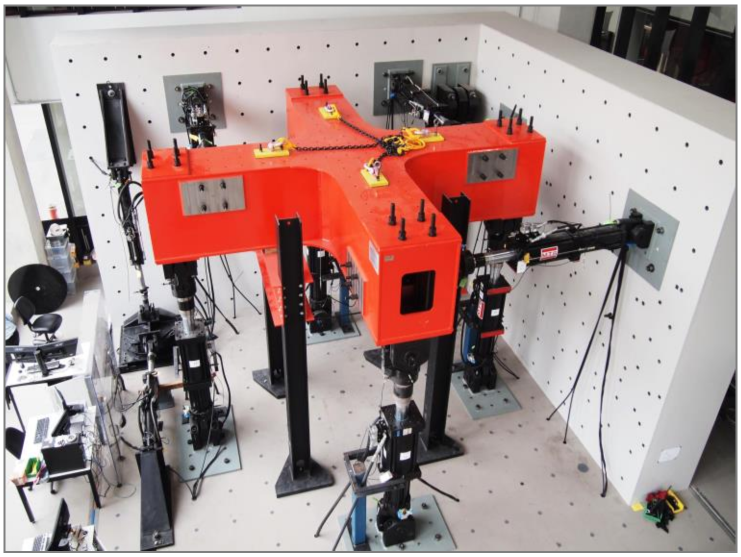

Figure 1 MAST system at Swinburne.

One of the main goals of structural and earthquake engineering is to improve the understanding of earthquake and their effects on the structural systems and non-structural components. The application of innovative smart structure technology has been introduced in structural engineering since 1970 to reduce the impact of natural hazards. Accordingly, in order to develop new smart materials, new devices and technologies and new smart structural systems for extreme dynamic load-resistant structures the priorities refer to the understanding of the behaviour of various classes of structures under different dynamic load types from elastic range through failure and developing collapse mechanisms. However, the reliable assessment and prediction of nonlinear structural behaviour and their failure mechanism has proven to be and extremely difficult task.

Nowadays, dynamic analysis of complex structures can be efficiently computed utilizing different available software. The cost of computation has been continuously reduced and now very complicated and detailed numerical simulations are possible on personal computers. Nevertheless, for many components or materials, failure modes are still not well-understood. In such cases, numerical analyses and simulations may not be reliable since more detailed and complex properties are needed for the critical components to obtain meaningful results. Therefore, laboratory testing still has significant importance for the research community for verification and further development of numerical models and it is broadly accepted that this role will remain for a long time.

Currently, there are three experimental methods to evaluate structural behaviour subject to dynamic loadings: shake table testing, quasi-static testing, and hybrid simulation [2]. With shake table testing, an engineer is able to produce realistic test conditions to evaluate the dynamic behaviour of civil structures. In this method, the researcher needs to know only the capabilities/capacities of the table, and there is usually no stability concern. Using shake table testing, some critical issues such as collapse mechanisms, component failures, acceleration amplifications, residual displacements and post-earthquake capacities can be investigated independently. Nevertheless, very few shake tables in the world are capable of testing full-scale large civil structures. Therefore, shake table testing is excessively expensive and limited to prototypes structures and payload projects [3]. Quasi-static testing is another technique to evaluate the dynamic performance of civil structures. Commonly, this technique is applied to study the hysteretic and cyclic behaviour of structural components subjected to seismic loading. Even though quasi-static testing can be implemented on large civil structures, it has two major drawbacks. Firstly, it requires a pre-defined displacement history, which is generally inadequate for resembling the structural behaviour as the load distribution continuously changes during an actual seismic event. Secondly, the effect of the specimen's nonlinear behaviour on the overall response cannot be studied since there is no interaction between the specimen response and the pre-determined loading sequence. Evolved from pseudo-dynamic testing (PSD), Hybrid simulation (HS) is a versatile and economically viable experimental technique to evaluate the dynamic performance of large civil structures. According to a report developed by the US earthquake engineering community in 2010, hybrid simulation capabilities are a major emphasis of the next generation of earthquake engineering research [4].

Essentially, hybrid simulation attempts to combine the realism of shake table testing with the economy and convenience of quasi-static testing. Hybrid simulation reduces fabrication costs and the overall time for testing in the laboratory. In shake table testing, the fabrication of the whole structure is necessary, which is an expensive and time-consuming process for a physical test. Since the damage essentially starts as a local phenomenon, hybrid simulation allows the physical testing of only the critical portion of the structure where the damage is expected. For example to evaluate the seismic response of a bridge through the hybrid simulation technique, one of the bridge piers can be constructed and physically tested in the laboratory and the remaining parts of the bridge such as: bridge girders, viscous and friction damping, gravity and dynamic loads and second order effects can be reliably calculated in sophisticated computer simulations.

Nevertheless, due to the limited resource in the laboratories, boundary effects where the specimen couples to the reaction structure are often reduced to simple uniaxial loading configurations, which do not necessarily representing the physical boundary conditions experienced in practice. Furthermore, imposing multiple-degree-of-freedom states of displacement and force using conventional structural testing means can be expensive, time-consuming, and difficult to achieve. The MAST system in the Smart Structures Laboratory at Swinburne advances the current state of technology by allowing the experimental simulation of complex boundary effects through its multi-axial capabilities. The unique and versatile capabilities of the MAST system will greatly expand the experimental testing of large-scale structural components such as beam-column frame systems, walls, bridge piers, etc. Specifically, there are great benefits in using the system for the researchers interested in FRP retrofitting of structural components. The effectiveness of FRP retrofit for seismically damaged structural elements can be reliably evaluated through hybrid simulation and the analytical models can be accordingly developed and validated for future applications.

State-Of-Art System for Hybrid Simulation at Swinburne

An overview of the MAST system and the hybrid simulation framework is discussed. This framework allows the researchers to experimentally simulate the complex boundary interactions of the test specimen through the multi-axis capabilities of the system.

MAST System

Multi-Axis Substructure Testing in the Smart Structures Laboratory at Swinburne provides a powerful tool for investigating the effects of earthquakes, hurricanes, and other extreme loading events on large structural components using hybrid simulation testing. A Sophisticated six degrees-of-freedom (DOF) control system is used utilizing eight high-capacity hydraulic actuators that enables application of complex multi-directional deformation or loading schemes to structural components.

The MAST system shown in Figure 1, utilizes a highly stiff steel crosshead attached to eight hydraulic actuators (i.e., four vertical and two in each of the horizontal orthogonal directions) connected to an L-shaped strong-wall strong-floor system that enables testing of large-scale structural components. The rigid steel crosshead is used to apply tri-axial control, Yaw, Pitch and Roll, to the test structure and also to apply planar translations to planar substructures.

Nonlinear Finite element simulations were performed to optimize the design of the MAST steel cruciform. The model included all relevant details such as: holes for base plate connections and stiffener plates. Zones of weakness at weld connections were considered by modelling local elements of lower strength/stiffness in the vicinity of welds. Four load cases were considered to induce the highest possible flexure, shear and torsion within the structure.

The 1.0 m thick strong-floor measures 20 × 8 m in-plan with two 5 m tall reaction-walls meeting at one corner.

The 3D strong-cell contains a grid of tie down points 0.5 m apart to secure the test specimens in place. The 6-DOF hybrid testing facility introduces an array of possible loading conditions to both the strong floor and reaction wall. 3D solid models were constructed to assess the maximum load that may be applied to the reaction wall in any given configuration without exceeding the tensile strength of the concrete. Over 100 load configurations were constructed to determine maximum allowable wall loading in any given scenario.

The MAST system has the capability to test large-scale structural components up to nearly 3 m cubed. Two sets of actuator pairs with strokes of ±250 mm provide lateral loads up to ±500 kN in the orthogonal directions. These actuator pairs are secured to the L-shaped strong-wall. Four ±1 MN vertical actuators, capable of applying a total force of ±4 MN with strokes of ±250 mm, connect the crosshead and the strong floor. The system uses additional high precision string potentiometers (25 μm precision) for displacement feedback in hybrid simulation.

The system features mixed-mode control, allowing users to specify the position or force required for the desired direction of loading to test large-scale structural components including portions of beam-column frame systems, walls, tanks, and bridge piers. Experiments conducted in the MAST system are done under a slow rate of speed to enable the careful documentation of the progression of damage in the structure under test.

Hybrid Simulation Architecture

Hybrid simulation facilitates the study of structural response by experimentally testing only the critical portion of the structure while the rest of the structure is modelled numerically in the computer.

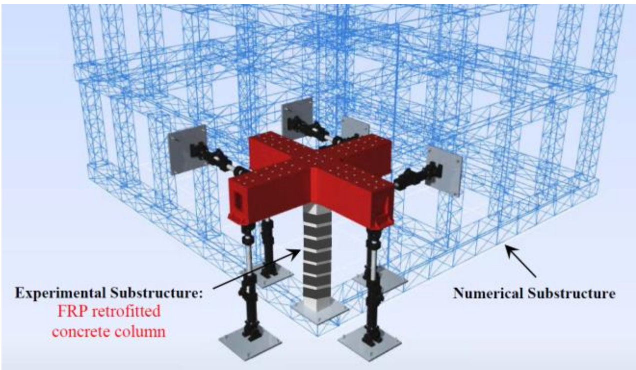

Figure 2 Hybrid simulation example.

For instance, to evaluate the effectiveness of FRP retrofit for seismically damaged structural components of a multi-story building, the structure is partitioned into two substructures. The experimental substructure consists of the FRP retrofitted concrete column that is attached between the crosshead and the strong floor as shown schematically in Figure 2, and the numerical substructure consists of the remainder of structural elements, inertia and damping forces, gravity and dynamics loadings and second order effects.

At each step of the analysis the governing equations of motion is solved similar to pure numerical simulations using a time-stepping integration. The calculated

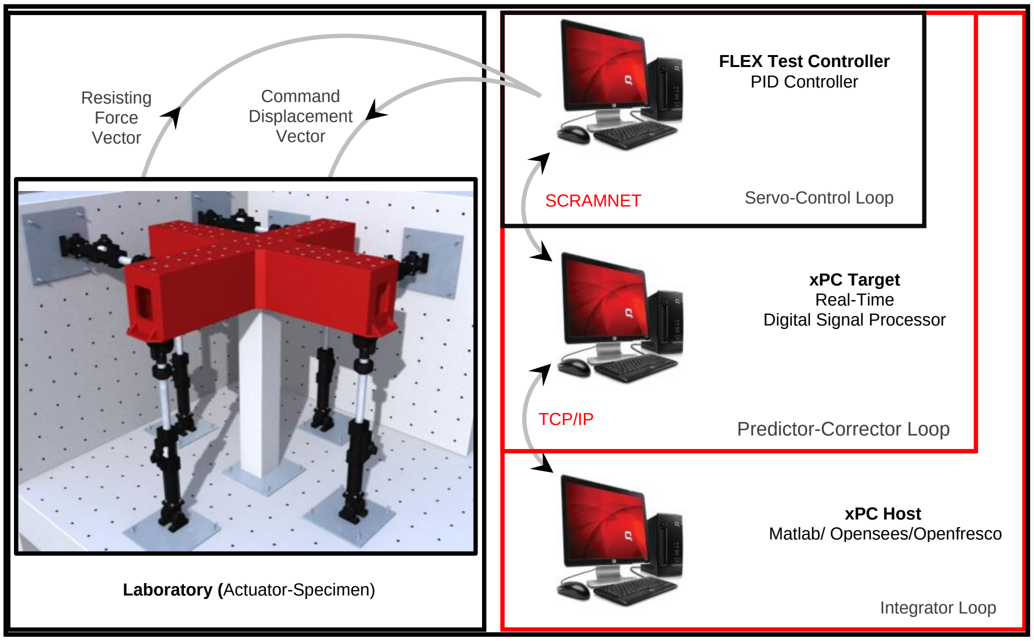

Figure 3 Hybrid Simulation Architecture at Swinburne.

displacement demands are then sent to the lab and applied to the physical specimen using computer-controlled actuators, while the numerical portion is analysed on the computer. The resisting forces including shear, axial and moment reactions are measured and fed back to the computation solver to calculate the displacements corresponding to the next time step. This process is repeated until the ground motion is concluded.

The hybrid simulation control system at Swinburne, uses xPC-Target and consists of a three-loop architecture, which is depicted in Figure 3. The innermost Servo-Control Loop contains the MTS-Flex Test controller that sends displacement commands to the actuators while reading back measured displacements and forces. The middle loop runs the Predictor-Corrector actuator command generator on the xPC-Target real-time digital signal processor (DSP) and delivers the command displacements to the Flex Test controller in real-time through the shared memory SCRAMNet. Finally, the outer Integrator Loop runs on the xPC-Host and includes OpenSees, MATLAB and OpenFresco that can communicate with the xPC-Target through TCP/IP network.

Local vs. Distributed Hybrid Simulation

The popularity of hybrid simulation amongst structural engineering researchers has grown to a great extent. Geographically-distributed testing is one recent concept that has been developed from the use of substructuring techniques and benefited from technological advances in data transfer and computing.

The concept of geographically-distributed testing is that individual substructures do not need to be within the same facility, but can be linked by either the internet or other methods of data transfer. Therefore, laboratories with much larger capacities can be used for experimental subassemblies. In terms of the numerical portion of hybrid simulation, there are also benefits in allowing for the use of more powerful computers or even super-computing facilities to run the hybrid simulation test since the computers running the analysis do not need to be in the same laboratory.

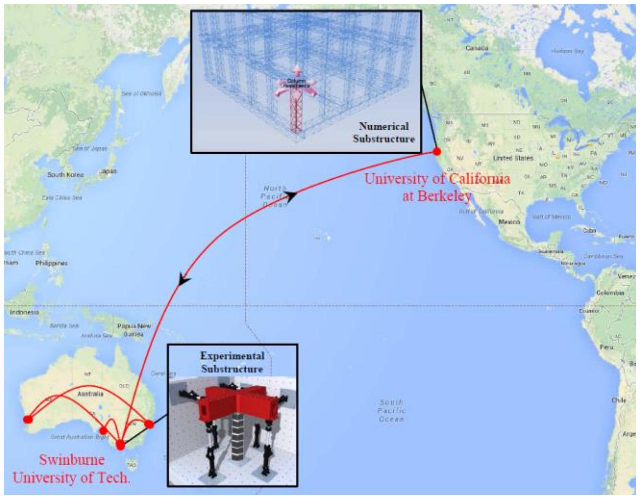

Figure 4 Geographically-distributed hybrid simulation.

For example to evaluate the seismic response of the same multi-story building presented in Figure 2, a multi-site hybrid simulation can be carried out. The FRP retrofitted column of the structure can be tested in the Smart Structures Laboratory at Swinburne that is able to perform multi-axis substructure testing, while the rest of the structure can be modelled numerically in a facility with super computers, for example, in University of California at Berkeley.

References

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Recent Dissertation

Multiscale modeling of the cohesive zone law at the FRP-concrete interface (*Modellazione multiscala del legame coesivo all’interfaccia FRP-calcestruzzo*)

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Dissertation Advisor: Prof. Laura De Lorenzis

Externally bonded Fibre-Reinforced Polymer (FRP) sheets are a well-established strengthening technique in civil engineering, in particular for reinforced concrete structures. Failure of the strengthened member generally occurs by various mechanisms which all originate from the loss of bond at the interface between the sheet and the concrete substrate.

Almost all interface models proposed to simulate this behaviour are based on the assumption of macroscopic local laws between tractions and relative displacements (most often indicated as cohesive zone laws or, in the tangential direction, as bond-slip laws). These models present a number of limitations, as macroscopic laws spatially homogenize complex damage and failure processes taking place at the lower scales.

This thesis deals with the numerical modelling of the debonding process between FRP sheets and concrete based on the meso-mechanical analysis of the interface. This includes explicit modelling of the heterogeneous material geometry close to the bonded zone, as well as a continuum damage description for both the cement matrix and the matrix-aggregate interfacial transition zone. From this analysis, a cohesive zone model for the interface is obtained through a computational homogenization procedure.

The two-dimensional model adopted for the concrete is characterized by polygonal-shaped aggregates with grading dictated by Fuller’s curve. Aggregates are numerically generated through a Monte Carlo-type random sampling procedure combined with the Take-and-Place method. Benchmark numerical analyses were performed on the concrete sample and compared with experimental and numerical results from the available literature. Reasonable damage patterns can be observed during the simulations (Figure 1). As the aggregates are assumed to have a higher stiffness and strength than the matrix, damage arises in the cement matrix and in the interfacial zones and propagates into the matrix around the aggregates.

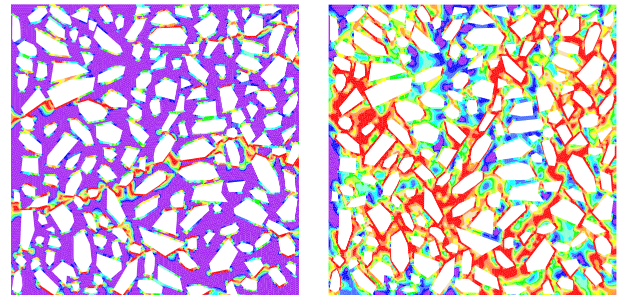

Figure 1 Damage variable distribution within a concrete sample under uniaxial tension (left) and compression (right) at failure.

A mesomechanical numerical test setup is developed to study the behaviour of the FRP/concrete interface. The macroscopic cohesive zone laws are derived through a suitable meso-macro scale transition, in compliance with Hill’s energetic criterion (Figure 2). The choice of the representative volume element is discussed and the cohesive behaviour under mode-I, mode-II (Figures 3 and 4) and mixed-mode loading conditions with different degrees of mode mixity is analysed.

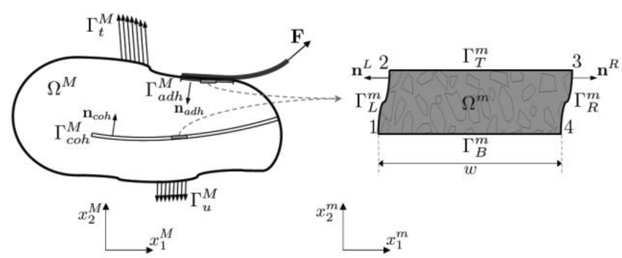

Figure 2 Generic representation of the macroscale (left) and mesoscale (right) models with the relevant symbols. The boundaries Γ_{coh}^M and Γ_{adh}^M represent a cohesive crack and an interfacial (or adhesive) crack, respectively.

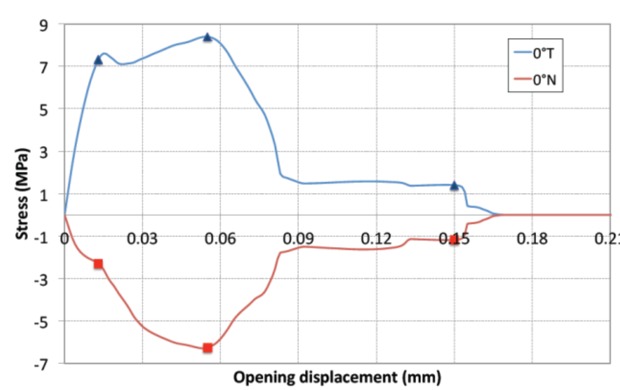

Figure 3 Tangential and normal stresses vs. total opening displacement in macroscopic mode II.

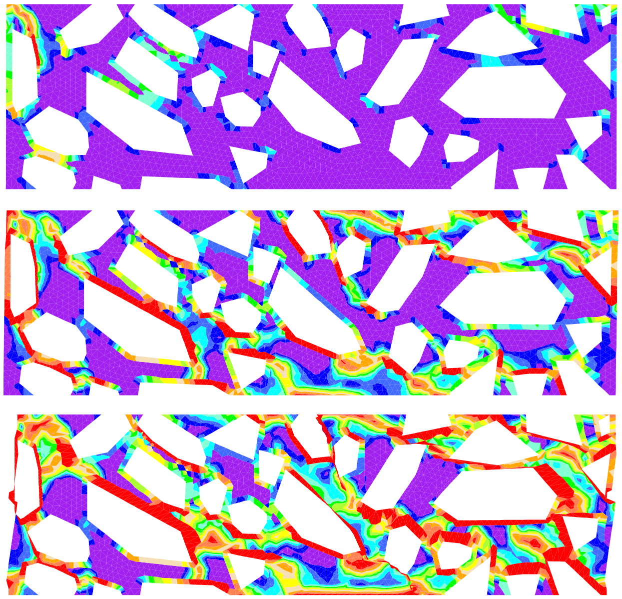

Figure 4 Damage variable distribution within the concrete sample under loading at macroscopic mode II at the stages of loading indicated with the markers in Figure 3.

Being able to shed light on the role played by the mesoscale parameters on key quantitative aspects of the macroscopic response such as the fracture energy under a given mode mixity, the proposed approach may allow for tailoring and optimization of the lower-scale features to achieve a desired macroscale response.

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Early Registration deadline: April 30, 2014

FRP Bridges 2014, September 11-12, 2014, London, UK. www.frpbridges.com

Abstracts due: March 28, 2014

CAMX: Composites and Advanced Materials Expo, October 13-16, 2014, Orlando, USA. www.thecamx.org

Abstracts due: April 4, 2014

FRPRCS-12 *12th International Symposium on Fiber Reinforced Polymer for Reinforced Concrete Structures*, 2015, Nanjing, China.

APFIS 2015 – 5th *Asia-Pacific Conference on FRP in Structures*, 2015, Nanjing, China.

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Erratum for "Slender Steel Columns Strengthened Using High-Modulus CFRP Plates for Buckling Control" by Amr Shaat and Amir Z. Fam

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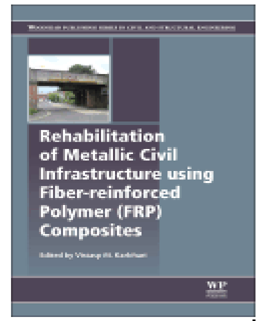

Rehabilitation of Metallic Civil Infrastructure Using Fiber Reinforced Polymer (FRP) Composites

Editor: Prof. Vistasp M. Karbhari

Fibre-reinforced polymer (FRP) composites are becoming increasingly popular as a material for rehabilitating aging and damaged structures. *Rehabilitation of Metallic Civil Infrastructure Using Fiber-Reinforced Polymer (FRP) Composites* explores the use of fibre-reinforced composites for enhancing the stability and extending the life of metallic infrastructure such as bridges.

Part I provides an overview of materials and repair, encompassing topics of joining steel to FRP composites, finite element modelling, and durability issues. Part II discusses the use of FRP composites to repair steel components, focusing on thin-walled (hollow) steel sections, steel tension members, and cracked aluminium components. Building on Part II, the third part of the book reviews the fatigue life of strengthened components. Finally, Part IV covers the use of FRP composites to rehabilitate different types of metallic infrastructure, with chapters on bridges, historical metallic structures and other types of metallic infrastructure.

Rehabilitation of Metallic Civil Infrastructure Using Fiber-Reinforced Polymer (FRP) Composites represents a standard reference for engineers and designers in infrastructure and fibre-reinforced polymer areas and manufacturers in the infrastructure industry, as well as academics and researchers in the field. Available at:

https://www.elsevier.com/books/rehabilitation-of-metallic-civil-infrastructure-using-fiber-reinforced-polymer-frp-composites/karbhari/978-0-85709-653-1

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