FRP INTERNATIONAL

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Editor's Note

Much activity has been going on behind the scenes since the last issue of *FRP International* including the announcement of the APFIS 2007 Best Paper Awards, the election of the new chair of the IIFC Advisory Committee, and the announcement of the winners of the IIFC Medal and Distinguished Young Researcher Award. Articles on all of the above may be found in this issue of *FRP International*.

While it is rewarding to recognize the outstanding achievements of our colleagues, the efforts of the various committee chairs and IIFC members who make all this possible by volunteering their valuable time and expertise must also be acknowledged. And, as we head towards CICE 2008 in Zurich, the official conference of the IIFC, activity continues to mount in preparation for the meetings to be held during the conference. As the IIFC develops and matures, its committees continue to explore new ways to serve and provide benefits to its members. To this end suggestions are always welcome and may be communicated via any of the addresses found on page 4.

The truly international flavor of the IIFC is evident in this issue with articles from China, Japan, Kuwait, Columbia, and the United States covering a range of interesting topics. In addition, a new feature is introduced in this issue proving that IIFC members have a life outside of FRP in construction. As always, members are encouraged to submit articles to *FRP International*. This publication is not possible without your contributions.

Rudolf Seracino, Editor-in-Chief
Email: newsletter.editor@iifc-hq.org

APFIS 2007 – Press Release

The inaugural Asia-Pacific Conference on FRP in Structures (APFIS 2007: http://www.hku.hk/apfis07/) was held in Hong Kong on 12-14 December 2007. It was the first official Asia-Pacific IIFC regional conference on the research and use of fibre reinforced polymer (FRP) composites in civil engineering structures. APFIS 2007 was organised by the Department of Civil Engineering, The University of Hong Kong, as well as the IIFC working groups (WGs) on "Bond Behaviour of FRP in Structures", "FRP-Strengthened Metallic Structures" and "FRP Bridge Decks".

Welcome Address by IIFC President Prof. Neale

APFIS 2007 was attended by over 140 delegates from 26 different countries around the world. The two-volume set of proceedings contains 6 keynote papers and 156 contributed papers authored by a combined total of 351 authors (65 papers from IIFC WGs). Each contributed paper was rigorously peer reviewed by at least two reviewers who were drawn from a large pool of Organising and International Scientific Committee members, as well as other experts in the field.

Papers were published in the following areas: (1) strengthening of concrete beams and slabs, (2) confinement of concrete in compression and seismic retrofit, (3) strengthening of beam-column and slab-column connections, (4) strengthening of masonry members, (5) strengthening of timber and glass members, (6) concrete and masonry members reinforced with internal FRP, (7) concrete members prestressed with internal or external FRP, (8) ductility, (9) hybrid members, (10) all FRP members, (11) field applications and case studies, (12) fibre optic sensors, measurement and nondestructive evaluation, (13) durability, fire and impact, (14) product development and testing, (15) Bond WG topics [(15a) basic bond mechanisms: externally bonded sheets/plates, (15b) basic bond mechanisms: internally embedded bars, tendons and anchors, (15c) flexurally-strengthened concrete beams, (15d) interfacial stresses, (15e) intermediate crack induced debonding, (15f) durability, fatigue and cyclic loading], (16) Metal WG Group topics [(16a) strengthening of metal flexural members, (16b) strengthening of metal compression members and shells, (16c) cyclic loading and fatigue, (16d) analytical and numerical modelling], and (17) Bridge WG topics [(17a) superstructure behaviour and development, (17b) field applications].

The conference was enjoyed both for its technical content and social program. The social highlight was definitely the conference banquet which was held at the world famous Jumbo Floating Restaurant. Guests at the banquet were treated to a Chinese feast as well as cultural entertainment delights.

Banquet Venue

Prof. Teng presented an IIFC Fellow Plaque by IIFC Vice-President Dr Chen

Hand-eye coordination skills of Profs. Rizkalla (left) and Täljsten (right) put to the test at the banquet with varying degrees of success!

APFIS 2007 was supported by numerous institutions, namely, the Hong Kong Institution of Engineers (Structural Division) (HKIE), China Civil Engineering Society (CCES), Engineers Australia (EA), Australian Composite Structures Society (ACSS), Korea Concrete Institute (KCI), Japan Concrete Institute (JCI), Japan Society for Composite Materials (JSCM), American Concrete Institute (ACI), American Society of Civil Engineers (ASCE) Hong Kong Section, American Composites Manufacturers Association (ACMA), and the Canadian Research Network on Intelligent Sensing for Innovative Structures (ISIS). Industrial sponsorship was provided by several locally based organisations, of which four exhibited at the event. The Hong Kong based newspaper Ta Kung Pao provided media support and published several press-releases (in Chinese) around the time of the conference.

APFIS 2007 Delegates

Post-conference Technical Tour: Stonecutter's Bridge Construction Site, Hong Kong

Thank you to all the authors, invited guests, keynote speakers, session chairs, speakers, sponsors, committee members and reviewers for making APFIS 2007 a success. Such a positive start to this biennial conference series paves the way for the second APFIS which will be held in Seoul, Korea in December 2009.

Dr Scott T. Smith
The University of Hong Kong, China
APFIS 2007 Chair
stsmith@hku.hk

New Chair of the IIFC Advisory Committee

It is my distinct pleasure to announce that in May 2008 Professor Jin-Guang Teng was elected Chair of the IIFC Advisory Committee by his fellow Advisory Committee members. Professor Teng replaces Professor Len Hollaway who chaired the committee since the formation of the IIFC in 2003. The Advisory Committee is IIFC's highest body and its main role is to provide advice to the Executive Committee. In his capacity as Chair, Professor Hollaway made numerous important and influential contributions to IIFC and his efforts are deeply appreciated. In recognition of his distinguished career and service to IIFC, a special issue of the international journal "Advances in Structural Engineering" will be published in honour of Professor Hollaway.

Jin-Guang Teng is currently Associate Vice President, Dean of the Faculty of Construction and Land Use and Chair Professor of Structural Engineering at The Hong Kong Polytechnic University. Well known and recognized by the international community for his outstanding contributions to research in various fields of structural engineering, Professor Teng was also the founding President of IIFC and served in this capacity from 2003-06. Professor Teng is the recipient of several awards for his achievements in research. He is the Editor-in-Chief of the international journal "Advances in Structural Engineering" and a member of the editorial boards of several other international journals. He has given keynote lectures at and served on the scientific committees of numerous international conferences.

Kenneth W. Neale
President of IIFC
president@iifc-hq.org

APFIS 2007 Best Paper Awards

Three APFIS 2007 papers were selected among the 156 contributions for Best Paper Awards. Two papers were selected in the category "FRP for repair and strengthening" and one in the category "FRP in new construction". The selection committee consisted of Jian-Fei Chen (Edinburgh University), Ken Neale (Sherbrooke University), Rudi Seracino (North Carolina State University), Scott Smith (Chair, Hong Kong University) and Tim Stratford (Edinburgh University) who were assisted by several readers in the pre-selection stage. Congratulations to the authors of the following winning contributions:

Quantifying Strain Variation in FRP Confined Concrete using Digital Image Correlation: Proof-of-Concept and Initial Results

L. Bisby [1], W.A. Take [2] and A. Caspary [2]

[1] *Institute for Infrastructure and Environment, The University of Edinburgh, UK (Formerly, Department of Civil Engineering, Queen's University, Canada)*
[2] *Department of Civil Engineering, Queen's University, Canada*

Crack Development in CFRP Reinforced Mortar - An Experimental Study

B. Täljsten [1], K. Orosz [1,2] and G. Fischer [1]

[1] *Technical University of Denmark, Lyngby, Denmark*
[2] *Norut Technology Ltd., Narvik, Norway*

Replacing a Composite RC Bridge Deck with an FRP Deck - The Effect on Superstructure Stresses

K.A. Harries [1] and J. Moses [2]

[1] *Department of Civil and Environmental Engineering, University of Pittsburgh, PA, USA*
[2] *Pennsylvania Department of Transportation, Bridgeville, PA, USA*

The award winning papers may be viewed online at:
http://www.iifc-hq.org/awards/paper.html

In This Issue

IIFC Awardees Announced

In May 2003 the IIFC took the decision to award one IIFC Medal and one Distinguished Researcher Award every second year.

The IIFC Medal is the highest honour bestowed upon a member of the IIFC and is awarded to a candidate who has made outstanding contributions to research and practice, or both in the science of Advanced Polymer Composites in Civil Engineering. Likewise the Distinguished Young Researcher Award is bestowed upon an IIFC member who has shown endeavour and has undertaken eminent research into areas of Advanced Polymer Composites in Civil Engineering; it is awarded to an IIFC member who is not older than 40 years of age.

The Honours Committee is/will be constituted from those members who received lifetime achievement awards at the CICE 2006 IIFC Conference and from future IIFC Medal Holders. The task of the Honours Committee is to put forward suggestions for possible candidates, to receive nominations from IIFC members and to recommend to the President the two nominated engineers.

As these Honours are to be given for the first time at the IIFC conference CICE 2008, it was decided that only current IIFC fellows were considered for the IIFC medal and that only qualified Council Members and Executive Committee Members be considered for the Distinguished Young Researcher Award.

The members of the Awards Committee for the year 2008 were:
Professor L C Hollaway
Professor A Mufti
Professor S H Rizkalla
Professor U Meier

The awardees for the two Honours Awards for the year 2008 are:

IIFC Medal

Professor Jin-Guang Teng
Associate Vice President, Dean of the Faculty of Construction and Land Use, and Chair Professor of Structural Engineering, at The Hong Kong Polytechnic University, China.

Professor Teng is Past President of the IIFC and is a world expert in research and practice of advanced polymer composites in civil engineering. He was the principal founder member of the IIFC. Professor Teng's research interests include the application of FRP in construction, steel structures, and shell structures. His publications include the book 'FRP-Strengthened RC Structures' (John Wiley and Sons, 2002), over 120 refereed journal papers and over 130 conference papers. He has received a number of prizes and awards for his research contributions. In the FRP area, his research has been focused on an understanding of the failure mechanisms of RC structures strengthened with externally bonded FRP reinforcement for the development of theoretical models for use in design. More recently, he has embarked on research topics exploring the use of FRP in new construction, particularly when in combination with traditional materials.

Distinguished Young Researcher Award

Dr Renata Kotynia
Assistant Professor, Department of Concrete Structures at Technical University of Lodz, Poland

Dr Kotynia is a Member of Council of the IIFC. Dr Kotynia, has pioneered the research and the use of FRP composite technology for civil engineers in Poland and is instrumental in introducing successful FRP construction applications in that country. Under restrictive research facilities she has published several refereed journal papers and has written and presented scientific papers at national and international conferences. She is/has been a member of a number of scientific committees of international conferences, and has both academic research and practical experience. Her research interests are in the application of advanced polymer composites to the strengthening/rehabilitation of reinforced concrete structures and masonry structures with both unstressed and prestressed externally bonded composites and in near surface mounted composites. She has also experience in the bond behaviour between FRP composites and concrete, ductility and serviceability of RC structures.

The Awardees have been invited to deliver a keynote lecture at the CICE 2008 conference in Zurich.

Information on CICE 2008 may be found at:
http://www.cice2008.org/

IIFC Headquarters

IIFC Administrative Center
c/o The University of Manitoba
Agriculture and Civil Engineering Building
A250 - 96 Dafoe Road
Winnipeg, Manitoba, R3T 2N2
Canada
Phone: + 1 204 474 8506
Fax: + 1 204 474 7519

IIFC President president@iifc-hq.org
IIFC Secretary secretary@iifc-hq.org
Newsletter Editor newsletter.editor@iifc-hq.org

Web www.IIFC-hq.org

A CFRP Strengthening System for Steel Structures

Dr. Sami Rizkalla & Mr. Mina Dawood
North Carolina State University
Raleigh, NC, USA
srizkal@ncsu.edu mmdawood@ncsu.edu

Recently a high modulus CFRP system was developed, in collaboration with Mitsubishi Chemical FP America Inc., for strengthening steel bridges and structures. Previous research focused on development of the system which included selection of the adhesives and large-scale verification of the strengthening system. The current research focuses on evaluating the bond characteristics and environmental durability of the system.

Bond Characteristics

Due to the use of high modulus CFRP material plate end debonding was determined to be a concern particularly for long span structures which may require splice joints. A comprehensive experimental program was conducted to study the bond characteristics of the strengthening system. The experimental program consisted of eight CFRP double-lap shear coupons and ten large-scale steel beams. Figure 1 shows a typical test beam which included a CFRP splice joint at midspan within the constant moment region. Several parameters were considered including the details and geometry of the plate ends, the length of the splice and the possible use of mechanical anchorage near the plate end.

Figure 1: Typical splice beam test

All of the tested specimens failed due to debonding of the splice plate. The research findings indicate that implementation of a reverse tapered joint detail can approximately double the splice joint capacity as compared to the standard square plate end configuration. Alternatively, increasing the length of the splice plate did not increase the joint capacity. Similarly, the use of mechanical anchorage, either by a transverse CFRP wrap or a steel clamp, did not increase the capacity of the splice for the tested beams.

A non-linear finite element analysis of some of the double-lap shear coupons was conducted. Pull-off tests were conducted to asses the tension strength of the bond interface and the results were incorporated into the analysis to simulate cracking and debonding of the joint. The analytical results correlate well with the measured experimental values.

Environmental Durability

A comprehensive experimental program is on going to evaluate the environmental durability of the proposed strengthening system. The experimental plan was distributed to members of the IIFC Working Group on Strengthening Metallic Structures for critical review prior to implementation of the program. The experimental program consists of 52 steel-CFRP double-lap shear coupons. The parameters being considered include the use of a silane adhesion promoter, presence of an insulating layer of glass fiber between the steel and the CFRP, the magnitude of the sustained applied load and the duration of exposure. Three different environmental conditions were considered including unconditioned laboratory control specimens, accelerated exposure and outdoor environmental conditions. The typical test setup is shown in Figure 2.

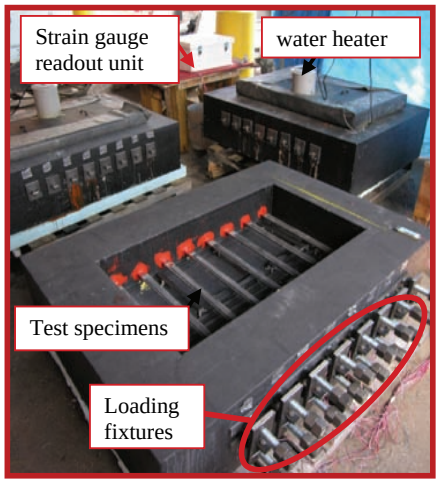


Figure 2: Environmental durability test setup

To date the control coupons and a series of coupons subjected to one month of accelerated environmental deterioration have been tested. The results indicate that the use of a silane adhesion promoter did not affect the initial bond. The presence of the glass fiber insulating layer increased the average bond strength by about 40 percent. This suggests that the glass fibers acted as a reinforcement of the adhesive which may have possibly delayed cracking and debonding of the CFRP. The findings also indicate that minimal degradation of the bond strength was observed after one month of exposure to the accelerated environment. Six month and 12 month duration tests are currently ongoing.

Conclusions

The findings of the research program demonstrate that the proposed CFRP system can be effectively used for strengthening steel bridges and structures. The current research work highlights the importance of proper detailing of the system to enhance the bond characteristics and environmental durability of the system.

References

Rizkalla, S., Dawood, M. & Schnerch, D. (in press). Development of a carbon fiber reinforced polymer system for strengthening steel structures. *Composites: Part A* doi: 10.1016/j.compositesa. 2007.10.009.

Feasibility of Using FRP as Reinforcement in Concrete Constructions in Kuwait

Dr. Amr Sadek & Dr. Moetaz El-Hawary
Kuwait Institute for Scientific Research (KISR)
Safat, Kuwait
asadeq@safat.kisr.edu.kw mhawary@safat.kisr.edu.kw

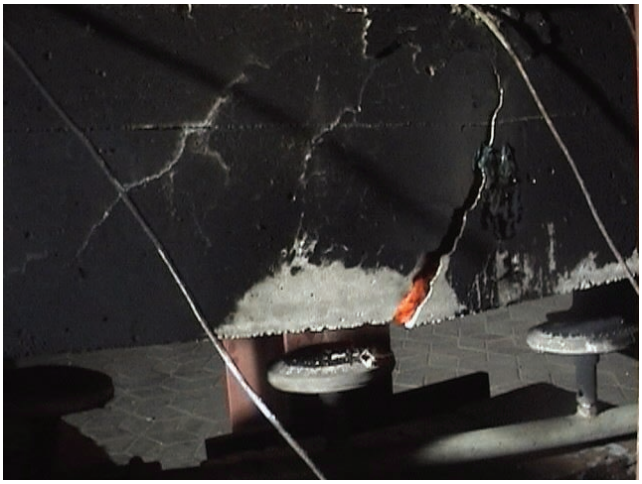
The conducted study was motivated by the genuine need to combat corrosion of conventional steel reinforcement in concrete constructions in Kuwait, which are subjected to one of the worst weather conditions of high temperature, salinity and humidity during long summer seasons. The study included examining economical and technical feasibility of employing FRP bars as main reinforcement. The project was funded by the Kuwait Foundation for the Advancement of Science (KFAS) and the Kuwait Institute for Scientific Research (KISR).

For the purpose of demonstrating the economical feasibility of FRP as reinforcement, a comparative cost analysis was performed on concrete members reinforced either with conventional steel or GFRP rebars.

A detailed mechanical testing program of GFRP rebars was conducted to establish the main mechanical properties of the material. The program included investigating compressive strength, tensile strength, bond characteristics, Young's modulus, impact resistance and others. Long-term durability of FRP products was examined through accelerated exposure to moisture, salinity and alkalinity. Effect of high temperature exposure was also evaluated.

A comprehensive experimental testing program was conducted to examine the performance of concrete beams, slabs and columns reinforced with GFRP rebars, as compared to ordinary reinforced concrete members. An experimental study was also conducted to examine the effect of wrapping columns with FRP laminates. To examine the effect of wrapping beams with FRP laminates, six beam specimens were tested.

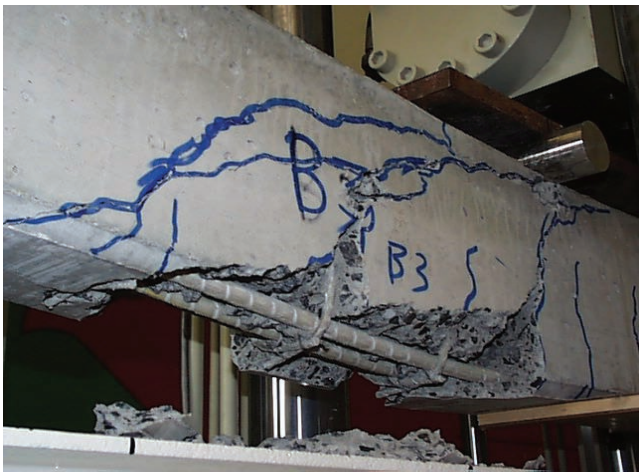
Fire resistance testing of concrete beams and slabs reinforced with GFRP rebars was conducted through exposure to a standard fire test. Three beam specimens and three slab specimens were used in the fire exposure testing with emphasis on their ability to sustain loads under fire exposure.



Beam after fire exposure

Burnt FRP bars

A design guideline for flexural members with GFRP reinforcement was prepared. The guide is based on the unified limit-state philosophy currently used by existing design codes. It also includes the required serviceability checks for cracking and deflection.



GFRP reinforced beam at failure

In view of the findings of the conducted comprehensive study, it was concluded that employing FRP rebars as reinforcement in concrete constructions is feasible both technically and economically and it is highly recommended for immediate applications in the construction industry in Kuwait.

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newsletter.editor@iifc-hq.org

CFRP Strengthening of Bridge in Bogota City, Columbia

Jorge Rendon
Structural Engineer, Sika Colombia S.A.
rendon.jorge@co.sika.com

In Colombia many bridges were designed and constructed many decades ago when the number and size of trucks were smaller than today. Through the years, these bridges have been deteriorating due to increased truck weights, much higher than the original design loads.

Figure 1 shows a 9-span reinforced concrete bridge, located at a main street intersection in Bogota City. The prestressed concrete beams do not have sufficient reinforcement to withstand the higher vehicle loads, including the buses of the massive transportation system of Bogotá Transmilenio.

Other strengthening alternatives considered included reinforced concrete jacketing and additional external prestressing cables. However, the structural engineer preferred the FRP option because it allowed the installation without stopping traffic over and below the bridge, the beams maintained their overall section, and the bridge clearance was not reduced.

Some of the beams had several layers applied to the bottom face of the beam as well as the sides of the bottom flange. This strengthening project was carried out in the second half of 2005 and required 4,314 m of CFRP strips (with widths of 120 and 150 mm, and thicknesses of 1.2 and 1.4 mm). It is believed that this represents the biggest strengthening project using CFRP strips in the South American continent.

Figure 2 shows the CFRP strips at the retrofit site already cut and ready to be installed. Figure 3 shows the installation of the CFRP strips in the tension zone of beams. The bridge was in service during the strengthening works.

Figure 2: Rolls of CFRP strips ready for installation

Figure 3: Installation of the CFRP strips under the beams

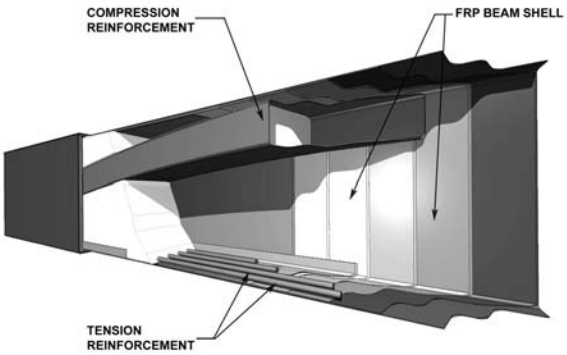
Figure 1: General view of the bridge in Bogotá city during the strengthening work

First Hybrid-Composite Railroad Bridge

Pueblo, Colorado, USA

On November 7, 2007, on the FAST (Facility for Accelerated Service Testing) Loop at the TTC (Transportation Technology Center) near Pueblo, Colorado, the first composite railroad bridge was load tested with a full-size locomotive pulling 26 heavy axle load coal cars. The 30 foot (9.1 m) span bridge is comprised of 8 hybrid-composite beams, known as Hillman-Composite Beams (HCB). The response of the bridge matched exactly the predicted strains and displacements calculated in accordance with the limits specified in the AREMA (American Railway Engineering and Maintenance-of-Way Association) design codes. The live train tests were the final objective of a project called the IDEA (Innovations Deserving Exploratory Analysis) HSR (High Speed Rail) program, which is funded by the Federal Railroad Administration and managed by the Transportation Research Board (TRB) in the USA. With the performance of the HCB validated and recognized by the rail community, the next step is production of a prototype for extended testing in Pueblo.

The HCB is comprised of three main sub-components that are a shell, compression reinforcement and tension reinforcement. The compression reinforcement consists of self-consolidated concrete that is pumped into a profiled conduit within the beam shell. The tension reinforcement consists of Hardwire® steel reinforcing fabrics that run along the bottom flange of the beams.



Essentially, the beam functions like a tied arch in a glass box and this principle was used to improve load performance and decrease weight. The concrete arch is tied at each end with multiple layers of Hardwire® steel reinforcements, which run along the bottom flange. The beams are manufactured using a closed-mold, Vacuum Assisted Resin Transfer Method (VARTM). In this process, the preforms that include glass fabrics, Hardwire® steel reinforcement and a low density foam core are all placed inside a reusable steel mold. Once the preforms are in place, the mold is sealed and vacuum pressure applied to evacuate all of the air. While maintaining vacuum pressure at 1 atmosphere, a vinyl ester resin is pulled into the mold to wet-out the preforms and consolidate the glass, foam, and resin into a monolithic unit. The beam can be removed from the mold within hours of infusion. After removal from the mold, the shell is then filled with self-consolidating concrete. Much less concrete is used in this method than in standard prestressed concrete girders.

The beams can be erected in the same manner as prestressed concrete or steel beams, but with smaller equipment because of the lighter weight. The spacing of beams in a highway bridge is similar to the beam spacing of conventional materials. For railroad applications, the beams are placed side by side. A simple reinforced concrete deck is easily cast on top of the erected beams, in the same manner as conventional beams.

Plans are in place for the technology to be tested on two highway bridges - a 58 foot (17.7 m) span in Illinois and a 36 foot (11.0 m) span in New Jersey. The beams for the Lockport Township bridge in Illinois have been fabricated, tested, and are scheduled to be installed in mid-June 2008. The bridges will be constructed with project funding provided by the Federal Highway Administration through the IBRD (Innovative Bridge Research and Design) Program.

The HCB technology will continue to evolve with each new installation as well as becoming more cost-competitive with each refinement. The HCB represents a logical progression of bridge technology using conventional materials in harmony with advanced composite materials to create bridging solutions that address the future needs of our aging infrastructure.

Contributed by:
Mr John Hillman
HillmanJR@teng.com
HC BRIDGE COMPANY, LLC

Recent Publications

Draft Chinese Code for the Application of FRP Composites in Construction

T. Yu and J.G. Teng
The Hong Kong Polytechnic University
ceyutao@polyu.edu.hk cejgteng@polyu.edu.hk

A national standard for the application of fibre-reinforced polymer (FRP) composites in construction is being finalised for approval by the Ministry of Construction of the People's Republic of China. A national committee comprising leading experts in China in the area was formed in 2001 to draft the code which has by now gone through several rounds of revisions. In formulating provisions for the code, the latest international research was reviewed and new research was undertaken at several institutions in China. The code drafting effort was led by the Central Research Institute of Building and Construction of the China Metallurgical Group Corporation and the National Engineering Research Center of Industrial Building Diagnosis and Rehabilitation, Beijing, China. Among the main contributing institutions are Tsinghua University, Southeast University, The Hong Kong Polytechnic University, Tongji University and Harbin Institute of Technology.

The code covers the use of FRP composites in both the retrofit of structures and in new construction. It includes the following eight chapters: Chapter 1-General; Chapter 2-Terminology and Notation; Chapter 3-Materials; Chapter 4-Strengthening and Repair of Concrete Structures; Chapter 5-Strengthening and Repair of Masonry Structures; Chapter 6- Concrete Members Reinforced or Prestressed with FRP; Chapter 7-Hybrid FRP-Concrete Tubular Members; and Chapter 8-Hybrid FRP-Concrete Beams. It is expected that this code, once approved, will greatly facilitate the wide application of FRP composites in construction in China.

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IIFC Member Profile

Professor Zhishen Wu

Professor Wu received his Ph.D. from Nagoya University, Japan, in 1990. Since 2002 he is Professor of Urban and Civil Engineering at Ibaraki University, Japan. From 1997 – 2005 he concurrently held a senior research position at the National Institute of Advanced Industrial Science and Technology of Japan. Professor Wu is a Vice-President and Council Member of the International Institute for FRP in Construction. In addition, he is Chairman of the Japanese Society of Civil Engineering research committee on structural health monitoring for concrete structures, and Council/Executive Committee member of the International Society for Structural Health Monitoring of Intelligent Infrastructure. He is Associate Editor, or Editorial Board Member, of more than 10 national and international journals including Structural Health Monitoring, ASCE Journal of Composites in Construction, and Computer-Aided Civil and Infrastructure Engineering. Prof Wu has received numerous honors and awards, including the Japan Society for Composite Materials 2006 Technology Prize. His research interests include: computational fracture and failure mechanics of composite materials and structures; FRP technologies for maintenance and life-cycle engineering; and structural health monitoring and smart materials.

Calendar of Events

2008

4th International Conference on FRP Composites in Civil Engineering (CICE 2008), Zurich, Switzerland, July 22-24, 2008. (CICE 2008 is the official conference of the IIFC.)
www.cice2008.org

5th International Conference on Advanced Composite Materials in Bridges and Structures (ACMBS-V), Winnipeg, Canada, September 22-24, 2008.
www.isiscanada.com/acmbs

2009

Composites & Polycon 2009: Shaping our Future, Tampa, Florida, USA, January 15-17, 1009.
www.acmashow.org/home.cfm

9th International Symposium on Fiber Reinforced Polymer Reinforcement for Concrete Structures: Current Challenges and Future Trends (FRPRCS-9), Sydney, Australia, July 13-15, 2009. (Abstracts are now due.)
www.iceaustralia.com/frprcs9

2nd Asia-Pacific Conference on FRP in Structures (APFIS 2009), Seoul, Korea, December 9-11, 2009.
www.apfis2009.hanyang.ac.kr

Email upcoming events to:
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Youngest delegate at APFIS 2007, Kaiden, attending his first conference is accompanied by his parents Scott Smith (APFIS 2007 Chair) and Xia-Ping (Lisa).

International delegates of the Workshop on the use of FRPs for Sustainable Structures near the Pyramids at Giza, Egypt.

Twin daughters Jess (*l*) and Kate (*r*) graduating from High School (June 2008) with proud parents Joanne and Rudi Seracino.

IIFC President Ken Neale.
(Editors Note: I wonder if that's an FRP club.)

Tim Stratford (*l*) and Luke Bisby (*r*) at the Forth Rail Bridge in Scotland prior to the Structural Faults and Repair conference.

IIFC Advisory and Executive Committee members enjoying dinner after a *long* meeting at APFIS 2007 in HK.

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