FRP INTERNATIONAL
the official newsletter of the International Institute for FRP in Construction
Vol. 11, No. 4, October 2014

CICE 2018 to be held in Paris

The 9th International Conference on FRP Composites in Civil Engineering (CICE) will be held in Paris, France. The organisers are Prof. Emmanuel Ferrier (Université Lyon 1), Dr. Karim Benzarti (IFSTTAR) and Prof. Jean-Francois Caron (Ecole des Ponts – Paris Tech). Mark your calendars.

President's Message

Prof. Jian-Fei Chen, Queen's University Belfast, UK

Many readers of this issue of *FRP International*, the official newsletter of the International Institute for FRP in Construction (IIFC), will have attended the Seventh International Conference on FRP Composites in Civil Engineering (CICE) held in Vancouver in August 2014. The vast majority of the delegates would agree with me that this was a most successful conference, due to the excellent effort of an extremely dedicated team led by the conference chair, Dr. Raafat El-Hacha of the University of Calgary. On behalf of the IIFC, I would like to thank Raafat once again for his dedication and leadership in making the conference such a great success. I believe that all delegates have benefited from the numerous impressive presentations, spectacular keynote speeches and lively discussions, as well as new and renewed friendship.

All delegates at CICE 2014 received a copy of a special issue of the ASCE Journal of Composites for Construction, guest-edited by Prof. Scott Smith and myself with the support of the journal's Editor, Prof. Chuck Bakis, commemorating the 10th anniversary of the IIFC. We have come a long way from the conception of the IIFC at the 1st CICE conference in Hong Kong in December 2001 and its formal launch in 2003, led by Prof. Jin-Guang Teng of The Hong Kong Polytechnic University. The IIFC is now well established and recognised around the world as the premier learned society for the international scientific and engineering community of infrastructure use of FRP composites. It is my great honour to have been elected to serve as the President of this vibrant Institute as it enters its second decade.

At CICE 2014, we elected new Council Members, Fellows and a new Executive Committee; details of the election results are reported in this issue of *FRP International*. On behalf of the Executive Committee, I would like to express my deep gratitude to the outgoing President, Prof. Larry Bank of The City College of New York and the US National Science Foundation, for his excellent leadership of the Institute for the last four years. Many of us know that Larry is an extremely energetic leader with numerous creative ideas. Without him the IIFC would not have achieved the very healthy condition it is in now.

I would also like to thank the editor of this newsletter, Dr. Kent Harries, for his dedication. It is now the fifth year since Kent took over the editorship, but through daily contact with him I can tell that he is as enthusiastic as ever; the quality of the Newsletter has been constantly improving under his editorship. I would like to encourage all our readers to get more involved with the IIFC and in particular share your research, projects and new FRP materials stories with the community through publishing short articles in this internationally-distributed newsletter.

The aim of the IIFC is to advance the understanding and the application of FRP composites in the civil engineering infrastructure, in the service of the engineering profession and society. To this end, the new Executive Committee would love to hear from our readers, irrespective of your IIFC membership, what the new Executive Committee could do to elevate the IIFC to a new level of achievement and excellence, in order to better serve the engineering profession and the society. You may contact any member of the Executive Committee with suggestions.

Report from…

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

Vancouver, 20-22 August 2014

Dr. Raafat El-Hacha, Chair, CICE 2014
University of Calgary, Canada

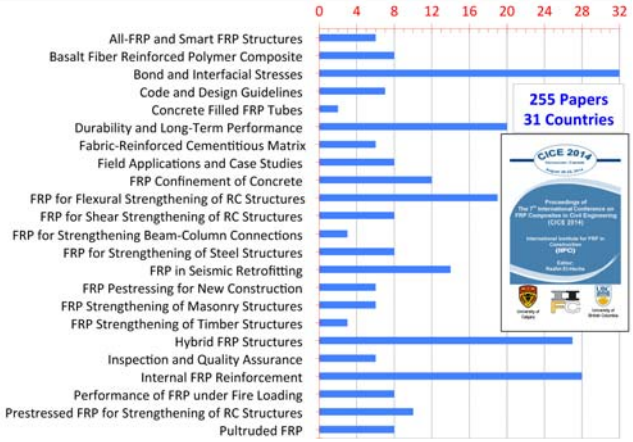
On behalf of the International Institute for FRP in Construction (IIFC), it gives me great pleasure to thank you all for participating and attending the 7th International Conference on FRP Composites in Civil Engineering (CICE 2014) held at the Vancouver campus of the University of British Columbia, Canada from August 20-22, 2014. Your attendance and contribution contributed to the great success of the conference. Preparing for this conference was long and at times hard, however it was enjoyable at each and every level. Seeing it come to life has been an amazing experience.

CICE delegates (at least many of them)

Conference Proceedings and Technical Program

The response to the Call for Papers was overwhelming with over 325 technical papers received and reviewed by the International Scientific Committee. Finally, a total of 255 peer-reviewed papers were accepted and are included in the conference proceedings covering a good distribution over a wide range of topics.

In all, 640 authors representing 31 countries contributed; papers were received from Australia, Belgium, Canada, China, Czech Republic, Egypt, France, Germany, Hong Kong, Iraq, Israel, Italy, Japan, Libya, Lithuania, Malaysia, Netherlands, Pakistan, Poland, Portugal, Saudi Arabia, Slovakia, South Korea, Spain, Sweden, Switzerland, Taiwan, Turkey, United Arab, United Kingdom, USA.



Distribution of topics in CICE 2014 Proceedings

CICE 2014 was intellectually engaging and socially enjoyable. The three-day program included special sessions detailing state-of-the-art research and field applications in different countries, and general technical paper sessions. The technical program included 248 presentations and five keynote lectures presented by distinguished international leading experts from varying backgrounds who provided their perspectives on a wide range of topics of interest beyond those normally covered within the CICE series.

- Prof. Urs Meier, *FRP in Construction: It was a Long Way to Go*
- Prof. Nabil Grace, *Recent Bridges with CFRP Reinforcement in USA*
- Prof. Jin-Guang Teng, *Structural use of FRP composites in China: Research, Code Development and Field Applications*

Two prestigious awards were given at the conference to two distinguished IIFC members who made significant contributions in the field of FRP composites

for construction through research or practical applications, or both. Congratulations to:

IIFC Medal – Prof. Antonio Nanni

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 delivered the IIFC Distinguished Lecture at CICE 2014 on "*Personal Reflections Following 20 years of R&D in FRP Construction*". [The abstract appears in *FRP International* Vol. 11, No. 3]

Distinguished Young Researcher Award – Prof. Luke Bisby

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 delivered a keynote lecture at CICE 2014 on "*Fire-Safe Use of FRP Composites in Construction: Myths and Realities*". [The abstract appears in *FRP International* Vol. 11, No. 3]

IIFC President's Award – Prof. Charles Bakis

Congratulations also to Prof. Chuck Bakis recipient to the 2014 IIFC President's Award in recognition of his distinguished services for advancing the understanding and the application of fibre-reinforced polymers in the civil infrastructure, in the service of the engineering profession and society [See announcement in this issue.].

Mini-Symposiums

Two commemorative Mini-Symposiums that formed an integral part of the CICE 2014 were organized in honour of Prof. Aftab Mufti and Prof. Kenneth Neale to recognize their lifetime scientific achievements in the area of FRP in research and development, and their excellent services and significant contributions to the IIFC. I would like to extend a very special thank you to all attendees and presenters at these symposiums. It is our great privilege that at this conference these two long-time friends and colleagues came together to be recognized by the FRP community for their many contributions to the profession.

CICE Honorary Chair Prof. Nemkumar Banthia, symposia honourees Profs. Aftab Mufti and Ken Neale and CICE Chair, Dr. Raafat El-Hacha.

CICE 2014 Best Paper Awards

Three best paper awards were given at CICE 2014. Selected from the 255 submitted papers, the following papers and authors were honoured at CICE 2014 and will be reprinted in *FRP International* in the coming months; the paper by Galati and Alkhrdaji appears in this issue:

Best Paper – Repair Application

Cyclic Interface Behavior of External Composite Reinforcements: A Coupled Damage-Plasticity Model
Pietra Carrara and Laura DeLorenzis

Best Paper – New Construction Application

Long Term Bending Creep Behaviour of Thin-Walled CFRP Pretensioned High Strength Spun Concrete Poles Under Sustained Load
Giovanni P. Terrasi and Urs Meier

Best Paper – Industry/Field Applications and Case Studies

Load Test Evaluation of FRP-Strengthened Structures
Nestor Galati and Tarek Alkhrdaji

The award review committee was chaired by Dr. Kent Harries, University of Pittsburgh and Editor of *FRP International*. The committee consisted of:

Prof. Charles Bakis, The Pennsylvania State University and Editor of *ASCE Journal of Composites in Construction*

Prof. Brahim Benmokrane, University of Sherbrooke

Prof. Amir Fam, Queen's University

Dr. Yail 'Jimmy' Kim, University of Colorado at Denver

Dr. Ahmad Rteil, University of British Columbia

Dr. Thomas Tannert, University of British Columbia

Dr. Baolin Wan, Marquette University

Thanks to entire committee for their efforts.

A number of special issues of leading international journals – *Construction and Building Materials*, *Polymers*, *Advanced Structural Engineering* and the *Canadian Journal of Civil Engineering* – will be developed based on outstanding CICE submissions. Authors of those papers recommended by the international scientific committee will be invited to submit extended versions of their papers that will undergo the rigorous review process of the above-mentioned journals.

Social Events

The Conference Meet & Greet Reception was held at the Museum of Anthropology where delegates were welcomed with a Gitxsan "People of the River of Mists" song complimented with a rich performance of dramatic spirit masked dances by The Aboriginal Dancers of Damelahamid from the Northwest Coast of British Columbia, celebrating the diversity and timelessness of many beautiful Indigenous cultures across Canada.

Aboriginal Dancers of Damelahamid

The Conference Banquet was an enjoyable Sunset Dinner Cruise. Delegates enjoyed an evening cruise viewing the breath-taking panoramic view of Vancouver's skyline. As we boarded the *Magic Spirit* and departed from the docks near the Plaza of Nations, we enjoyed the scenery of False Creek including the iconic Science World and the Olympic Village. The boat continued cruising past Granville Island and English Bay out to the West Vancouver shoreline where we saw some fabulous homes of Vancouver's elite. We observed UBC from the water and sailed past Kitsilano. With food, great conversation, entertainment and views, it was a night to remember.

Memories of the event (photos and videos) will be uploaded to the following dropbox-shared folder by the end of September:

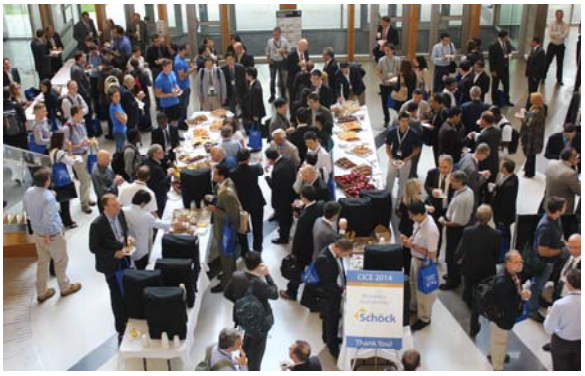
https://www.dropbox.com/sh/b6d5rgbv41tywrs/AABj_2syUYtBOVUi5d13ePSxa?dl=0

Please feel free to upload your own photos, so we can all share them! A video clip summarizing the three days is under production. Stay tuned for the announcement to download it along with the photos.

Finally, I would like to thank all participants – without them this conference would not be successful. I hope that the CICE 2014 was a simulating and rewarding experience for everyone and that you had a pleasant, productive, memorable and enjoyable stay in Vancouver.

In Tribute to Professor Khaled Soudki

We could not but remember Prof. Kahled Soudki who passed away on September 17, 2013 after a long battle with cancer. We all missed him at this conference. On a personal note, I will always remember Khaled as an outstanding researcher, talented professor, knowledgeable scholar, successful colleague, kind and humble person, and a true gentleman. His passing is a great loss to the field and to all of us as his friends. Words are not enough to express our sorrow for losing him. [see *FRP International* Vol. 11, No. 1.]



Networking during a coffee break.

Images from the Dinner Cruise

Your Newsletter editor was unable to attend CICE 2014 (for excellent reason, as many know). Dr. El-Hacha has provided me with a number of photos. From these, I have selected those that most lead me ask the question "What on earth did I miss?"

They did promise a sunset cruise…

…but no one said anything about a poker game…

I cannot even start to imagine a caption for this… perhaps this will be IIFC's inaugural caption contest?

Finally, I could not resist including Prof. Bank's (and his lovely wife Rebecca's) channelling of Kate Winslet. Or perhaps stepping down as CICE President is really just that liberating?

CICE Acknowledgements

This conference could not be put together without the assistance of many people who contributed enormously to its success. First, I would like to thank all authors for making this conference a total success with their valuable contribution to research and development in the field of FRP in civil engineering applications 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.

Special thanks are to Members of the International Scientific Committee who thoroughly reviewed the papers, and whose input and advice have been contributing factors to the success of this conference. I am also grateful to many distinguished members of the Organization Committee especially the assistance of my PhD students (Ms. Donna Chen, Mr. Fadi Oudah, Mr. Khaled Abdelrahman and Mr. Hothifa Rojob) who generously donated their time to this worthwhile cause. The help provided by all volunteers is also appreciated.

Special thank you to Professor Kent Harries for chairing the committee of the Best Paper Awards. I am very thankful to all session chairs for their kind assistance in keeping concurrent sessions running on time. The continued support provided by IIFC and its Executive Committee, in particular Professors Larry Bank (IIFC President) and Jian-Fei Chen (IIFC Senior Vice President), and the support from the Sponsors and exhibitors (Fyfe, Fibwrap, MAPEI, Sika, Schöck, Strongwell, StrongTie) are gratefully acknowledged.

The CICE 2014 was held with the support of national and international organizations, institutes and societies (British Columbia Ministry of Transportation and Infrastructure, City of Vancouver, Canadian Society of Civil Engineers, American Society of Civil Engineers, American Concrete Institute, Construction Institute, Korean Society of Civil Engineers, Korean Concrete Institute, Japan Society of Civil Engineers, Japan Concrete Institute).

This conference would not have succeeded without the great support of the team from Conferences and Accommodation at UBC who worked hard to make sure all the details, big and small, were executed with the utmost accuracy and professionalism. I am indebted to the service they provided, their tireless efforts and quick responses to the many demands of the conference. Their dedication and hard work has been nothing less than exemplary and I would like to specifically thank Sarah Johnson, Jennifer Campbell, and Alysha Hassanali for their hard work and contributions.

IIFC Business Conducted at CICE 2014

Dr. Raafat El-Hacha, IIFC Incoming Secretary
University of Calgary, Canada
relhacha@ucalgary.ca

Dr. Rudolf Seracino, IIFC Outgoing Secretary
North Carolina State University, USA

IIFC General Meeting

The IIFC General Meeting was held on August 20, 2014 at CICE 2014. Thirteen members were elected and/or re-elected to the IIFC Council: seven new members and six current Council members whose terms had expired; their profiles are presented in the following pages. Seven IIFC Council members retired from the Council at CICE 2014:

Prof. A. Katz, Technion-Israel Institute of Technology, Israel
Prof. J.S. Sim, Hanyang University, Korea
Prof. J. Barros, University of Minho, Portugal
Prof. A. Ilki, Istanbul Technical University, Turkey
Prof. H. Seliem, Helwan University, Egypt
Prof. G. Monti, Sapienza University of Rome, Italy
Prof. M.D.G. Pulido, San Pablo University, Spain

All were thanked for their service by outgoing IIFC President Prof. Larry Bank. The IIFC Council, listed in its entirety on the back page of *FRP International*, now has 40 elected members representing 14 countries. Members of the Advisory Committee, also listed on the back page, are also Members of the Council. Council terms are six years.

IIFC Council Meeting

Following the General Meeting in Vancouver, the Council met to elect the IIFC Executive Committee that will steer IIFC through CICE 2016. The new roster is presented on the following pages. IIFC President Prof. Larry Bank (City College of New York, USA) and Dr. Laura DeLorenzis (Tech. Univ. of Braunschweig, Germany) completed their terms on the Executive Committee at CICE 2014 and were recognised for their service and contributions. Profs Nabil Grace (Lawrence Technical University, USA) and Tao Yu (University of Wollongong, Australia) join as Members-at-Large and Prof. Peng Feng (Tsinghua University, China) replaces Dr. Jian Guo Dai (Hong Kong Polytechnic University) as Webmaster. Dr. Dai remains on the Executive Committee as the CICE 2016 Conference Coordinator.

IIFC Council also elected four new IIFC Fellows:

Prof. Riadh Al-Mahaidi
Swinburne University, Australia

Dr. Raafat El-Hacha
University of Calgary, Canada

Prof. Amir Fam
Queen's University, Canada

Dr. Kent A. Harries
University of Pittsburgh, USA

IIFC Fellows

IIFC presently honours 23 Fellows elected over the last decade representing 11 countries.

Z.T. Lu, China (2003)
U. Meier, Switzerland (2003)
A. Nanni, USA (2003)
S. Rizkalla, USA (2003)
L. Taerwe, Belgium (2003)
L.C. Bank, USA (2004)
J.G. Teng, China (2004)
T. Ueda, Japan (2004)
V.M. Karbhari, USA (2006)
K.W. Neale, Canada (2006)
Z.S. Wu, Japan (2006)
C.E. Bakis, USA, (2008)
J.F. Chen, UK (2008)
B. Taljsten, Sweden (2008)
L.P Ye, China (2008)
B. Benmokrane, Canada (2010)
J. Sim, Korea (2010)
T. Triantafillou, Greece (2010)
X.L. Zhao, Australia (2010)
T. Keller, Switzerland (2012)
R. Seracino, USA (2012)
S.T. Smith, Australia (2012)
R. Al-Mahaidi, Australia (2014)
R. El-Hacha, Canada (2014)
A. Fam, Canada (2014)
K.A. Harries, USA (2014)

Retired Fellows

M. Erki, Canada
L. Holloway, UK (deceased)
A. Machida, Japan
A.A. Mufti, Canada

2014-2016 IIFC Executive Committee

President
Prof. Jian-Fei Chen
Queen's University
Belfast, UK

Senior Vice President
Prof. Scott Smith
Southern Cross
University, Australia

Vice President and Treasurer
Prof. Amir Fam, Queen's University, Canada

Vice President
Prof. Rudolf Seracino
North Carolina State
University, USA

Vice President
Dr. Renata Kotynia
Technical University of
Lodz, Poland

Member-at-Large
Prof. Charles E. Bakis
Pennsylvania State
University, USA

Member-at-Large
Prof. Emmanuel Ferrier
Université Lyon 1, France

Member-at-Large
Prof. Nabil Grace
Lawrence technical
University, USA

Member-at-Large
Dr. Tao Yu, University of
Wollongong, Australia

Webmaster
Prof. Peng Feng
Tsinghua University,
China

Secretary
Dr. Raafat El-Hacha
University of Calgary,
Canada

Newsletter Editor
Dr. Kent A. Harries
University of Pittsburgh,
USA

Conference Coordinators
Dr. Xin Wang (APFIS 2015) Southeast University, China

Dr. Jian-Guo Dai (CICE 2016) Hong Kong Polytechnic University, China

IIFC Council Members elected at CICE 2014

Prof. Laura Delorenzis
Technische Universität
Braunschweig, Germany
(re-elected)

Dr. Rami Eid
Shamoon College of
Engineering, Israel

Prof. Amir Fam
Queen's University,
Canada (re-elected)

Dr. T. Russell Gentry
Georgia Institute of
Technology, USA

Prof. Mark F. Green
Queen's University,
Canada

Dr. Kent A. Harries
University of Pittsburgh,
USA (re-elected)

Dr. Yail Jimmy Kim
University of Colorado
Denver, USA

Dr. Renata Kotynia
Lodz University of
Technology, Poland
(re-elected)

Prof. Scott Smith
Southern Cross
University, Australia
(re-elected)

Prof. Rudolf Seracino
North Carolina State
University, USA
(re-elected)

Dr. Jialai Wang
The University of
Alabama, USA

Dr. Xin Wang
Southeast University,
China

Dr. Tao Yu
University of
Wollongong, Australia

2014 IIFC President's Award – Professor Charles Bakis

The IIFC President's Award is bestowed at the discretion of the Institute's President in recognition of distinguished services by members for advancing the understanding and the application of fibre-reinforced polymers in the civil infrastructure, in the service of the engineering profession and society. Past recipients of this award were Jian-Fei Chen (2006), Vistasp Karbhari (2006), Scott Smith (2008), Rudolf Seracino (2010) and Kent Harries (2012).

In Vancouver, IIFC President Larry Bank had the privilege of announcing Prof. Charles (Chuck) Bakis as the recipient of the 2014 President's Award.

Prof. Larry Bank, President's Award recipient, Prof. Chuck bakis and CICE Chair Dr. Raafat El-Hacha.

"I am very pleased to make the 2014 IIFC President Award to Prof. Charles (Chuck) Bakis. Chuck has served as the IIFC Vice President for Membership since 2012. In this capacity he has worked tirelessly, together with his assistant Renee Lindberg, to reorganize the membership database of the Institute. The membership data was transferred to Penn State University when the headquarters of IIFC moved to Queen's University in Canada from the University of Manitoba. The IIFC now has a fully functioning database of our membership which has been a significant aid to identifying members and billing for membership dues. Chuck also worked with the organizers of the APFIS 2013 and CICE 2014 conferences to ensure that the data collected from attendees during registrations was appropriate for the IIFC member database. Chuck has now retired as a VP of IIFC (but continues to serve on the Executive Committee as an at-large member) and the membership duties are being transferred to IIFC recently-elected Vice-President, Prof. Amir Fam at Queen's University." – Prof. Lawrence Bank, IIFC President, 2010-2014.

Prof. Bakis has been a member of the graduate faculty at Penn State since 1988 and currently holds the rank of University Distinguished Professor. He has also worked for short times in the aerospace industry, at NASA Glenn Research Center, and at the US Army Research Laboratory. He received a BS in Mechanical Engineering from Lehigh University in 1977, and MS and PhD degrees in Engineering Mechanics from Virginia Tech in 1984 and 1988 respectively. He is a fellow of ASME, IIFC, and the American Society for Composites (ASC). He has received outstanding research and teaching awards from the Penn State College of Engineering and the ASC Award in Composites from the American Society for Composites. His research focuses on the development of novel lightweight composite materials, such as self-sensing composites for structural health monitoring, flexible composites for adaptive structures (shape and stiffness change), energy absorbing composites for crashworthy vehicles, nanoreinforced composites with superior interlaminar fracture toughness and tailored electrical and thermal conductivity. He also works on the thermomechanical behavior and durability of composites used in civil construction. His work spans manufacturing, testing, and analysis. Prof. Bakis has advised or co-advised the theses of 34 MS students and 16 PhD students. He has published over 130 refereed journal and conference papers and over 140 non-refereed conference papers. Prof. Bakis directs the Composites Manufacturing Technology Center at Penn State, which houses facilities for manufacturing and testing of fiber reinforced polymer composites, such as autoclaving, hot pressing, filament winding, resin transfer molding, and pultrusion processing, and quasi-static, creep, and fatigue testing. Dr. Bakis has been editor of the ASCE *J. Composites for Construction* since 2003. He is President of the American Society for Composites. He chairs ACI subcommittee 440K on Fiber Reinforced Polymer Material Characteristics and is co-chair of ASTM subcommittee D30.10 on Composites for Civil Structures.

Upcoming Conferences and Meetings

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

Composites World Carbon Fiber, December 9-11, 2014, Lo Jolla CA, USA. http://www.compositesworld.com/conferences/compositesworld-2014-carbon-fiber-conference

International Conference on Advances in Composite Materials and Structures, April 13-15, 2015, Istanbul, Turkey. https://sites.google.com/site/cacmsistanbul2015/

Abstracts due September 15 2014

Early Registration Deadline November 30 2014

NOCMAT 2015 – Nonconventional Materials: construction for Sustainability – Green Materials and Technologies, August 10-13, 2015, Winnipeg, Canada. http://umanitoba.ca/conferences/nocmat2015/

Abstracts due January 15 2015

CAMX: Composites and Advanced Materials Expo, October 26-29, 2015, Dallas TX, USA. www.thecamx.org

JOINT CONFERENCE

FRPRCS-12 ***12th International Symposium on Fiber Reinforced Polymer for Reinforced Concrete Structures***, and

APFIS 2015 – 5th ***Asia-Pacific Conference on FRP in Structures***, December 14-16, 2015, Nanjing, China.

Abstracts due December 15 2014

ADVANCED COMPOSITES IN CONSTRUCTION

ACIC 2015 – 5th ***Advanced Composites in Construction***, September 2015, UK.

info@acic-conference.com

CICE 2016 ***8th International Conference on FRP Composites in Civil Engineering***

December 2016, Hong Kong

CICE 2018 ***9th International Conference on FRP Composites in Civil Engineering***

July 2018, Paris

CICE 2014 Proceedings available on IIFC website SOON!

Proceedings of the following official IIFC conferences are archived on the IIFC website, www.iifc-hq.org:

CICE 2014, Vancouver, 20-22 August 2014

CICE 2012, Rome, Italy, 13-15 June 2012

CICE 2010, Beijing, China, 27-29 September 2010

APFIS 2009, Seoul, Korea, 9-11 December 2009

CICE 2008, Zurich, Switzerland, 22-24 July 2008

APFIS 2007, Hong Kong, 12-14 December 2007

CICE 2006, Miami, USA, 13-15 December 2006

BBFS 2005, Hong Kong, 7-9 December 2005

CICE 2014 Best Paper – Industry/Field Applications and Case Studies

Load Test Evaluation of FRP-Strengthened Structures

Nestore Galati and Tarek Alkhrdaji, Structural Technologies, USA
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Introduction

The use of FRP for the strengthening of structures has become a mainstream practice. Many countries and professional organizations currently have a published design guide that provides the design or performance criterion, design limits, and detailing requirements. Amongst these are the documents listed in the references section of this paper (JSCE 2001, fib Bulletin 14 2001, ACI 440.2R-08 2008, S806 Canadian Standard Association 2002, Concrete Society Technical Report 55 2004, CNR-DT 200/2004).

FRP are typically used on existing structures, many of which have been in service for many years and their original structural design and constructions drawings may not be available. Determining the load carrying capacity of these structures may not be possible without detailed investigation to verify members' geometry, reinforcement details, and material strengths. Even when an investigation is carried out, many uncertainties may remain due to unknown detailing conditions or strength deterioration due to years in service. In many of these instances, load testing can be used to verify the load carrying capacity of the existing structure. Load testing can also be used to confirm is a repair or strengthening system can restore or increase the design capacity of the structures, or any of its components.

One practical load test protocol that has been successfully used to perform full scale load testing is the Cyclic Load Test Method or CLT (Galati et al., 2008, Alkhrdaji et al. 2010, ACI 437.1R-07). In this load test protocol, several cycles of loading and unloading (typically six) are used during the load test the structural elements to obtain insight into their performance and load carrying capacity. Structural adequacy is typically verified by examining the linearity of the measured deflection and the magnitude of any observed permanent deformation resulting from loading the member to near its ultimate strength.

Two case studies are presented in the following sections to demonstrate how the cyclic load testing protocol was used to validate the performance of FRP strengthened structural members and to optimize the strengthening solution to improve construction schedule and reduce the repair cost. In the first case study, load tests were used to determine the capacity of the existing floor system and to validate the performance of the structural floor after strengthening with externally bonded FRP as well bonded concrete overlay. In the second case study, the strengthening and cyclic load testing was performed on the structural floor of a large multi-story commercial building slated for increase in the design live loads due to a change in use. FRP composites were used to increase the load carrying capacity of all components of the floor system. For both case studies, externally bonded carbon FRP (CFRP) reinforcement provided a cost-effective strengthening solution.

Case Study 1: Structural Upgrade of Commercial Floor System

This case study discusses the strengthening and cyclic load test performed on the second-level structural floor of a building located in downtown Cleveland, Ohio. The building was occupied by a department store for many years. Once became vacant, the owner of the building decided to change its use to house telecommunications equipment and become a downtown telecommunications hub, essentially a warehouse space for internet related telecommunications and other equipment. The new use of the building requires structural floors capable of supporting loads in the range of 125 psf (6.0 kPa) to 175 psf (8.4 kPa).

The building was constructed in 1917 and its structural system consists of reinforced concrete floors supported by concrete encased steel columns having height of approximately 14 ft (4270 mm), and spacing varying from 19 to 23 ft (5800 to 7000 mm). The floor system consists of reinforced concrete joists supporting a concrete slab monolithically cast with the joists.

Preliminary analysis of the existing floor system indicated that the existing beams and slab are capable of carrying the proposed loads. The existing concrete joists, on the other hand, were found deficient and their live load capacity was limited to approximately 96 psf (4.6 kPa), and was governed by the shear strength of the joists. Due to limited information on the existing structure, the exact negative and positive moment capacity of the joists could not be determined. To house

telecommunication equipment, the floor needed to be upgraded to carry its own weight, a super imposed dead load of approximately 25 psf (1.2 kPa), and a service live load of 150 psf (7.2 kPa). The additional superimposed dead load was included to account for a new concrete overlay required to address the rough surface of the existing concrete slab.

The shear strength of the joists was addressed by applying FRP in the form of U-Wrap. A second option using FRP installed only on the sides of the joists (see Fig. 2) was also considered. This second option would improve the construction schedule due to reduced amount of surface preparation.

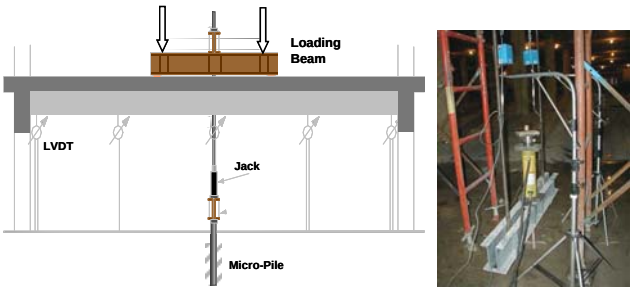


Fig. 1 test set-up.

The cyclic load tests were designed to locally verify the performance of some typical joists that appeared to be the "weakest link." To this end, the joists were loaded near their ultimate strength and their response was measured in terms of deformation and crack width. The cyclic load testing procedure involved applying concentrated loads to the test joists at predetermined locations to simulate the effect of maximum flexural forces at mid span and maximum flexural as well as maximum shear forces at the supports of the joists.

Analytical modeling of the joists indicated that the maximum moments and shear forces can be reproduced using two-point loads applied in the mid-span region, and spaced 6 ft (1830 mm) apart. The load was applied using hydraulic jacks that pulled against a reinforced concrete micro-pile that was installed on the ground floor below the second floor slab. A high strength steel bar was used to transfer the load from the jacks to the micro-pile. Linear variable differential transformers (LVDTs) were used to measure joists deflections at five locations along the span (see Fig. 1). A load cell was used to measure the applied load. All measurements were collected using a data acquisition system that allowed for real-time monitoring of the applied load and the behavior of the test joists. During the test, deflections and crack width were monitored for stability.

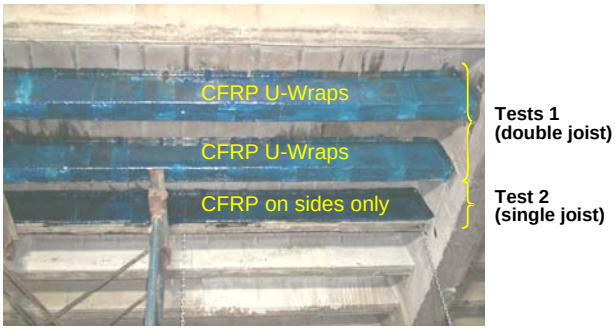


Fig. 2 Shear strengthening of joists.

Two load tests were performed on the joists. Test 1 was performed on two joists that were isolated by saw-cutting the concrete slab along a line between the joists. Prior to testing, the joists were strengthened for shear using carbon FRP strengthening systems applied in the form of U-strips 12 in. (305 mm) wide and spaced at 18 in. (457 mm) on centers (see Fig. 2). The load test was terminated when the mid-span deflection became unstable and inelastic behavior was observed. Large residual deflections were measured at mid-span when the load was removed.

Results of the first test indicated that failure of the joist was governed by yielding of top reinforcement at the support. No failure signs were observed at the mid-span region. Based on the test results, the joist was rated for a super-imposed dead load of 25 psf (1.2 kPa) plus a live load capacity of 135 psf (6.5 kPa). The shear performance was adequate with no shear cracks or failure signs observed.

In the second test, bonded reinforced concrete overlay was used to address the observed joist deficiency. The overlay consisted of 3 in. (76 mm) thick concrete reinforced with steel wire mesh. To ensure adequate bond between existing and new concrete, the slab surface was prepared by aggressive abrasion blasting to remove all weak concrete and provide an open-pore structure. Pull-off tests were then performed on the overlay to verify that failure will not occur at the concrete-to-concrete interface. Additionally, FRP was placed only on the sides of the joists.

Results of the second load test demonstrated the improved strength and stiffness of the joists after strengthening (see Fig. 3). Based on the test results, the strengthened joists were rated for the self-weight plus 36 psf (1.7 kPa) super-imposed dead load (RC overlay) and 150 psf (7.2 kPa) live load.

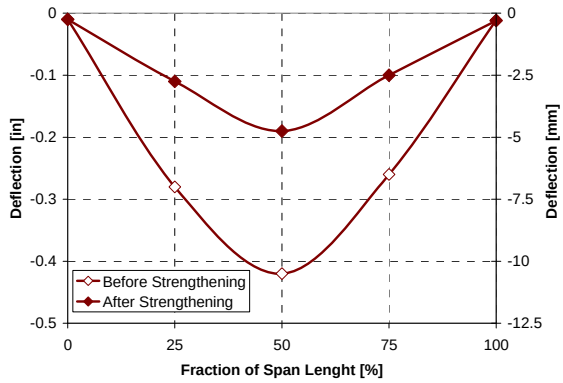


Fig. 3 Performance of the structure before and after strengthening.

Case Study 2: Omni Technology Center

This case study presents how FRP strengthening was used as an economical solution to convert a major mall in South Florida to house a communications center. The structure included one million plus square foot (93,000 m2) of slab area that consists of a one-way precast joist system simply supported on continuous composite pre-cast/cast-in-place concrete beams running normal to the direction of the joists.

The objective of the upgrade was to increase the live load capacity of the floor system from approximately 100 psf, to a new capacity including a super-imposed dead load of 25 psf (1.2 kPa) plus a uniformly distributed live load of 150 psf (7.2 kPa). Design of FRP system was achieved using ACI 440.2R-02.The installed strengthening system consisted of multiple plies of CFRP sheets attached to joist's soffit to increase their positive bending moment capacity. CFRP strips were also wrapped around the joists' stem at each end to provide anchorage against peeling. The beams were strengthened using FRP to improve their positive and negative moment capacity. For positive moments, CFRP strips were installed on the soffit of the beam along the entire beam span. The required amount of CFRP for negative moments was equally divided and installed on each side of the column, in the direction of the beam. For shear, CFRP strips were U-wrapped around the beam for approximately 1/3 span at each end (See Fig. 4).

Fig. 4 Strengthening beams and joists (left) and negative moment strengthening (right).

Due to novel use of FRP for this type of construction, the local building officials required that cyclic load tests be conducted to confirm the load rating of the existing structure and to assess the performance of the technology. The objective was to test the performance of the structural components of the floor system (slab, joist, and beam) using point loads applied at the mid-span region. To this end, 5 cyclic in-situ load tests were performed on the floor system, 3 before strengthening and 2 after FRP strengthening. The aim of the first test, TEST 1, was to verify the positive moment capacity of the existing one-way slab between the joists. TEST 2 was used to verify the positive moment capacity of the typical joist. TEST 3 was used to verify the positive moment strength of the typical beam. Two tests were conducted after strengthening: TEST 4 was conducted on FRP strengthened joists and TEST 5 was conducted on a FRP strengthened beam. Each test consisted of 6 loading-unloading cycles followed by a 24-hour test conducted in accordance to Chapter 20 of ACI 318. For all load tests, the critical test section was at the mid-span of the test member. The structural elements were loaded until the desired moment at the critical section was produced or inelastic behavior was observed.

The load test configuration was a pull-type test in which the hydraulic jack pulled against a reinforced concrete micro-pile cast into the ground on the level below (See Fig. 5). Based on the test results it was concluded that the slab had sufficient capacity to resist the new design loads. As such, no strengthening was required for the slab.

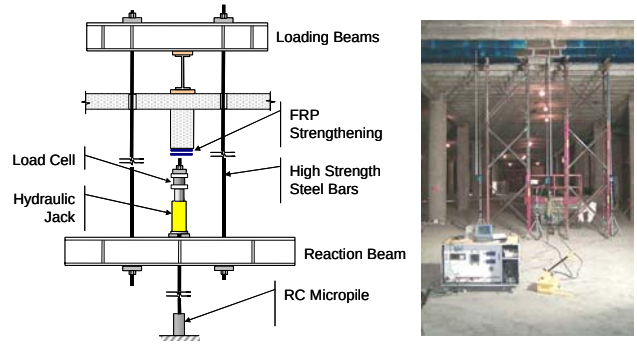
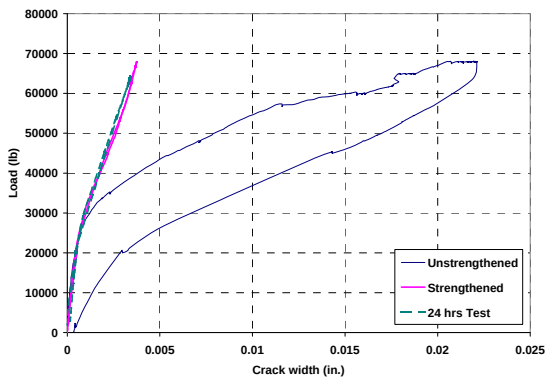


Fig. 5 Pull-down test procedure.

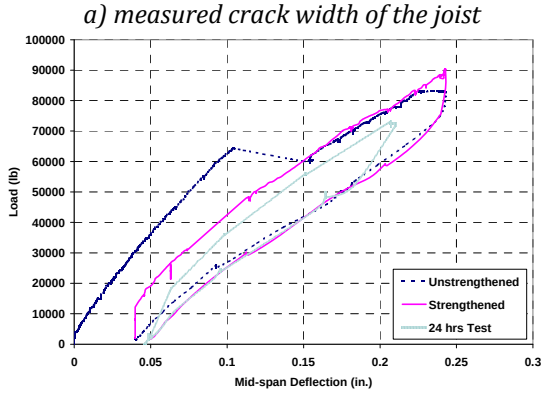
For the joists, significant residual deflections and crack widths were observed after the unstrengthened joists was unloaded. Based on the load test results of the joist, it was rated for 77 psf (3.7 kPa) dead load plus 125 psf (6 kPa) live load. FRP strengthening was then designed to provide the difference between the measured capacity and new demand.

After FRP strengthening, the joists were load tested again. Significantly smaller crack widths were measured compared to those measured prior to strengthening. No residual crack widths were measured after the load was removed. The load test confirmed that the strengthened joists are able to support its self-weight plus 25 psf (1.2 kPa) super-imposed dead load and a live load of 150 psf (7.2 kPa). The load was maintained for 24 hours at the end of test cycles and was then removed. The behavior of the joist was elastic with no residual crack width (see Fig. 6).

The beam was loaded to a maximum load of 83 kip (369.3 kN). Cracking occurred at approximately 62 kip (275.9 kN). Significant residual deflections and crack width were observed after the beam was unloaded. Based on the test results and accounting for the load magnification factors and strength reduction factors of the ACI 318 building code, the tested beam did not have sufficient capacity to support the new design loads.



a) measured crack width of the joist



b) load-deflection curve of beam

Fig. 6 Typical Test Results for Joist and Beam.

After strengthening with FRP, the beam was again loaded to a maximum load of 91 kip (404.8 kN). Significantly smaller deflections and crack width were measured compared to those achieved prior to strengthening. Very small residual deflection was measured after the load was removed. The beam was then loaded to 73 kip (324.7 kN). This load level produced nominal positive moment at mid-span equal to 85 percent of the ultimate moment. The load was maintained for 24 hours and was then removed. The behavior of the member was almost perfectly elastic with insignificant residual deflection and crack width (see Fig. 6). Based on these results, the strengthened beam was considered adequate to support the design loads required for new use as a telecommunications center.

Conclusions

Two case studies were presented to demonstrate how the cyclic load testing protocol can be used to validate the performance of FRP strengthened structural members and to optimize the strengthening solution to improve construction schedule and reduce the repair cost.

In both of the described cases, externally bonded carbon FRP reinforcement provided a cost effective strengthening solutions. For both structures, the load test was conducted to validate the FRP technology and to reduce costs through optimization.

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Composites Around the World

3D Printed Houses

Google (now a verb according to Merriam Webster and Oxford) "3D printed house" and you will see a number of quite unique innovations; most involving composite materials.

3D printing, or more correctly, additive manufacturing (AM), refers to a number of processes for fabricating a three-dimensional object using an additive process of laying down successive layers of material(s) under computer control. The 3D printer is an industrial robot.

House-sized 3D printer erected at site. Photo: Contour Crafting

Such manufacturing techniques open remarkable opportunities for creating low-cost (although somewhat customisable) housing and other forms of shelter on a large production scale. Recent stories include:

Chinese Company Showcases Ten 3D-Printed Houses
Rory Stott, ArchDaily.com; 2 September 2014

Chinese company WinSun Decoration Design Engineering has constructed a set of ten single story, 3D-printed homes which it produced in under 24 hours. The homes, printed in prefabricated panels which fit together on site, were created using WinSun's custom-built 3D printer which measures 10 meters by 6.6 meters, and took the company twelve years to develop.

3D-printed house made out of glass-fibre reinforced cement. Photo: WinSun

Formed with a cement-based mixture containing construction waste and glass fibre, each of the houses cost just $5,000 to build. Each of the houses is designed to accommodate plumbing, electrical wiring and insulation which are all added after construction. CEO of WinSun Ma Yihe said: "Industrial waste from demolished buildings is damaging our environment, but with 3D-printing, we are able to recycle construction waste and turn it into new building materials. This would create a much safer environment for construction workers and greatly reduce construction costs."

First 3D Printed House to Be Built In Amsterdam
Vanessa Quirk, ArchDaily.com; 2 April 2014

Working with another Dutch firm, Ultimaker, Dus Architects have developed the KamerMaker (Room Maker), a 3D Printer big enough to print chunks of buildings, up to 2x2x3.5 meters high, out of hotmelt, a bio-plastic mix that's about 75% plant oil. The chunks can then be stacked and connected together like LEGO bricks, forming multi-story homes whose designs can be adapted according to users' needs/desires. For Dus' first project, they've taken as inspiration the Dutch canal house, replacing hand-laid bricks with "a faceted plastic facade, scripted by computer software."

3D-printed pieces of the Canal House. Silver tower in background is the printer. Photo: Dus Architects

So far, only a 3m-high, 180-kg sample corner of the future canal house has been printed; moreover, the blocks will need to be back-filled with lightweight concrete, meaning it's not yet as biodegradable as its creators would like. However, its game-changing potential is already provoking much interest in the

public; over 2,000 people have come to visit the site, including Barack Obama.

"The building industry is one of the most polluting and inefficient industries out there," Hedwig Heinsman of Dus Architects says, "With 3D-printing, there is zero waste, reduced transportation costs, and everything can be melted down and recycled. This could revolutionise how we make our cities."

Building Bytes 3D-printed bricks. Photo: Brian Peters

Contour Crafting: Automated Construction

Prof. Behrokh Khoshnevis, University of Southern California

This April 2012 TEDx talk is available at http://tedxtalks.ted.com/video/TEDxOjai-Behrokh-Khoshnevis-Con. The talk describes 'contour crafting' which is essentially scaling-up 3D printing techniques for automated construction of civil structures or even entire neighbourhoods. Khoshnevis suggests the ability to construct customised single family homes in 20 hours.

Countour crafting … Researchers at the University of Southern California have been developing a technology that 'prints' quick-setting concrete from a computer controlled gantry. Photo: Contour Crafting

IIFC Education Task Group and Webinars

Emmanuel Ferrier, Université Lyon 1
Chair, IIFC Education Task Group
emmanuel.ferrier@univ-lyon1.fr

The objective of the IIFC Education Task Group is to promote education and knowledge transfer of IIFC researcher's to students and industry. The IIFC webinar series consists of short online seminars on specialized topics. Students enrol in a virtual classroom and follow the course from their computer. Each webinar contains commentary from the presenting professor, an annotated dashboard, details on calculation methods described and allows participant interaction. The contents of each webinar are approved by the IIFC Education Task Group. A new series of webinars is expected to initiate in Fall 2014; more details will be available at the IIFC website: www.iifc-hq.org. New topics on FRP in construction will be presented.

Archived 2013-14 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 the first three webinars are available in the following dropbox:

https://www.dropbox.com/sh/qa8bb5g2u8ljhbt/O1ogdbR_9w

Durability of FRP was presented by Prof. Brahim Benmokrane on 9 April 2014. This webinar is available at the following link (Chrome or Mozilla required):

http://bigbb.univ-lyon1.fr/playback/presentation/playback.html?meetingId=4e2eee83835988e1bac5c2628dad687ae3fdd17d-1398347413102&t=58s

Fire resistance of FRP systems was presented by Prof. Luke Bisby on 11 July 2014. This webinar is available at the following link (Chrome or Mozilla required):

http://bigbb.univ-lyon1.fr/playback/presentation/playback.html?meetingId=29dc42288871ba4f4320e67da1c548c6801939d6-1405083020454

ASCE *Journal of Composites for Construction*

ASCE Journal of Composites for Construction
Volume 18, No. 4. August 2014.

Buckling of Built-Up Columns of Pultruded Fiber-Reinforced Polymer C-Sections

Giosuè Boscato, Carlo Casalegno, Salvatore Russo, and J. Toby Mottram

Performance and Parametric Analysis of Flexural Strengthening for RC Beams with NSM-CFRP Bars

Gang Wu, Zhi-Qiang Dong, Zhi-Shen Wu, and Li-Wei Zhang

Use of CFRP Overlays to Repair Fatigue Damage in Steel Plates under Tension Loading

Fatih Alemdar, Regan Gangel, Adolfo Matamoros, Caroline Bennett, Ron Barrett-Gonzalez, Stan Rolfe, and Hao Liu

Flexural Behavior of Concrete Beams Strengthened with New Prestressed Carbon-Basalt Hybrid Fiber Sheets

Gang Wu, Jia-Wei Shi, Wen-Jun Jing, and Zhi-Shen Wu

Modulus Effect of Bonded CFRP Laminates Used for Repairing Preyield and Postyield Cracked Concrete Beams

Timothy Richardson and Amir Fam

Load-Bearing Capacity of Deviated CFRP Strips

Mohamed Hwash and Jan Knippers

Experimental Investigation of an Appropriate Anchorage System for Flange-Bonded Carbon Fiber–Reinforced Polymers in Retrofitted RC Beam–Column Joints

A. Eslami and H. R. Ronagh

Out-of-Plane Behavior of URM Walls Strengthened with Fabric-Reinforced Cementitious Matrix Composite

Saman Babaeidarabad, Francisco De Caso, and Antonio Nanni

Confinement Model for FRP-Confined High-Strength Concrete

Jian C. Lim and Togay Ozbakkaloglu

Splices of FRP Stay-in-Place Structural Forms in Concrete Bridge Decks

Mark Nelson, Emir Beriker, and Amir Fam

Experimental Investigation of Exterior RC Beam-Column Joints Retrofitted with FRP Systems

Ciro Del Vecchio, Marco Di Ludovico, Alberto Balsamo, Andrea Prota, Gaetano Manfredi, and Mauro Dolce

Plastic Hinge Length of FRP-Confined Square RC Columns

Cheng Jiang, Yu-Fei Wu, and Gang Wu

Flexural Behavior of Stone Slabs Reinforced with Prestressed NSM CFRP Bars

Y. Ye, Z. X. Guo, and Z. L. Chai

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http://ascelibrary.org/cco/

ASCE JCC subscribers and those with institutional access are able to obtain full text versions of all papers. Preview articles are also available at this site. Papers may be submitted to ASCE JCC through the following link:

http://www.editorialmanager.com/jrncceng/

IIFC Working Group on FRP-Strengthened Metallic Structures Announcement

An updated July 2014 list of technical publications on FRP-Strengthened Metallic Structures is now available from Working Group Chair Prof. Xiao-Ling Zhao (zhao.xiao.ling@monash.edu). The list presently contains 325 journal papers, 252 conference papers, 20 theses and 22 Books/Reports!

Five broad areas of study are represented in the listing. The first four are relatively uniformly represented with well over 100 citations each; Durability has only about 30 citations.

- Bond
- Flexural Strengthening
- Compression Strengthening and Stability
- Dynamic and Cyclic Loading (Blast, Impact, Fatigue and Fracture)
- Durability

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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.

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