FRP INTERNATIONAL

the official newsletter of the International Institute for FRP in Construction

Vol. 16, No. 2, November , 2019

IIFC has a website:

WWW.IIFC.ORG

Table of Contents

Message from the Editor

Professor Peng Feng, Tsinghua University, China. Email: fengpeng@tsinghua.edu.cn

As the editor of FRP International newsletter, I wanted to thank you for your interest as well as submissions for publication. FRP International has now become an important forum for items of interest to the IIFC community, reporting important events, research advances, case studies and field applications among other things. In this issue, you are invited to attend CICE 2020 in Istanbul, Turkey and APFIS 2019 in Gold Coast, Australia. You will also find in this newsletter information about events and the people of IIFC. The abstracts of four new PhD dissertations can also be found. One of my goals is to have the newsletter reflect our membership as well as areas of interest to the members. The newsletter will only be as useful and interesting as you help to make it. I look forward to serving IIFC and working with the entire IIFC community. Please send your submissions to fengpeng@tsinghua.edu.cn .

Welcome to CICE 2020 (https://www.cice2020.org/)

On behalf of the organizing committee and the International Institute for FRP in Construction (IIFC), I would like to invite you to the 10th International Conference on Fibre-Reinforced Polymer (FRP) Composites in Civil Engineering (CICE 2020) to be held in Istanbul, Turkey on 1-3 July, 2020.

Since its launch in 2001 in Hong Kong, the CICE conference series has travelled to Adelaide (2004), Miami (2006), Zurich (2008), Beijing (2010), Rome (2012), Vancouver (2014), Hong Kong (2016) and Paris (2018), and has become one of the most prestigious conferences on FRPs.

CICE 2020 will provide an international forum for scientists, engineers, industrial partners and practitioners to present and discuss the state-of-the-practice, recent advances and future perspectives in the use of FRP composites in civil engineering.

We look forward to welcoming you in Istanbul during CICE 2020.

Conference Chair : Prof. Dr. Alper Ilki

Istanbul Technical University, Turkey

https://www.cice2020.org/

International Institute for FRP in Construction

Welcome to APFIS 2019 (https://www.scu.edu.au/apfis2019/)

APFIS 2019 will be held in Surfers Paradise, Gold Coast, Australia, 10-13 December 2019.

APFIS 2019 is jointly hosted by the University of Adelaide, Southern Cross University, the University of Wollongong, the University of Queensland and Harbin Institute of Technology. Additionally, APFIS 2019 is the official conference of the International Centre for Composites in Infrastructure (ICCI) and is supported by the International Institute for FRP in Construction (IIFC).

APFIS is an international conference series that is open to researchers, academics, students, manufacturers, consultants, contractors and policy makers. Its aim is to showcase research, development and application of fibre-reinforced polymer (FRP) composites in the built environment. The inaugural APFIS conference was held in Hong Kong in 2007. Since then, it has been held in Seoul, Korea (2009), Hokkaido, Japan (2012), Melbourne, Australia (2013), Nanjing, China (2015) and Singapore (2017). The proceedings of all six past conferences can be found on the IIFC website.

APFIS 2019 will contain a variety of technical and social activities. On the technical front, there will be keynote presentations, panel sessions, general session presentations, workshops, and site visits. On the social front, there will be a welcome reception, conference banquet as well as ample opportunities to network with colleagues and friends. The conference will be held in iconic Surfers Paradise and hence delegates (and accompanying partners) are invited to spend time exploring the surrounds. Please consult the website above regularly for up-to-date information about the conference, including the Latest Updates below. Also, all enquiries can be directed to apfis2019@scu.edu.au.

On behalf of the organising committee, we offer you a very warm welcome to Surfers Paradise and we look forward to seeing you at APFIS 2019.

Announcements for the IIFC Awards

Call for Nominations for the IIFC Medal and IIFC Distinguished Young Researcher Award

The IIFC Council decided in May 2006 that it would make the following two awards every two years at the CICE Conference: "The IIFC Medal" and "The IIFC Distinguished Young Researcher Award". The IIFC Honours Committee now calls for nomination for these awards which will be presented at the next official IIFC conference, CICE 2020 in Istanbul, Turkey in July 2020. All IIFC members are invited to nominate appropriate candidates for these awards by **31 December 2019**. Nominations should be forwarded to the IIFC Honours Committee through the Secretary of the IIFC Executive Committee, Professor Tao Yu, at taoy@uow.edu.au. **Please use the special nomination forms.**

(1) The IIFC Medal

To be awarded to an IIFC member who has made distinguished contributions to the field of FRP composites for construction through research, practical applications, or both. One medal is awarded every two years. The winner will be invited to give the IIFC Distinguished Lecture at the next CICE conference.

Each nomination should consist of the following materials, which should be submitted electronically:

a. A statement from the nominee confirming that he/she is willing to be nominated for the IIFC Medal and, if selected, to accept the Medal in person and to deliver the IIFC Distinguished Lecture at the forthcoming CICE conference;
b. A detailed CV of the nominee;
c. A summary of the nominee's achievements and contributions in the field of FRP composites in construction, which must include a) research output (e.g. a list of archival journal publications, conference papers, book chapters and books); b) evidence of impact (e.g. citations, impact on design standards and guidelines, and impact on engineering practice); c) significant contributions to the field of FRP structures and materials; d) contributions in promoting IIFC's aim and objectives and how he/she would continue to do so in the future;
d. A list of 3 nominators. The nominators need to be IIFC Members or Fellows;
e. A nominators' statement outlining the reasons for the nomination.

(2) The IIFC Distinguished Young Researcher Award

To be awarded to an IIFC member not older than 40 years of age at CICE 2020, who has distinguished himself/herself from his/her peers through research contributions in the field of FRP composites for construction. One award is given every two years. The winner will be invited to deliver one of the keynote lectures at the next CICE conference.

Each nomination should consist of the following materials, which should be submitted electronically:

a. A statement from the nominee confirming that he/she is willing to be considered for the Award and, if selected to receive the Award, will accept the Award in person and to deliver a keynote lecture at the forthcoming CICE conference;
b. A detailed CV of the nominee;

c. A summary of the nominee's achievements and contributions in the field of FRP composites in construction, which must include a) research output (e.g. a list of archival journal publications, conference papers, book chapters and books); b) evidence of impact (e.g. citations, impact on design standards and guidelines and impact on engineering practice); c) a list of 10 career-best publications and their significance / contributions to the field of FRP structures and materials; d) contributions in promoting IIFC's aim and objectives and how he/she would continue to do so in the future;
d. A list of 3 nominators. The nominators need to be IIFC Members or Fellows;
e. A nominators' statement outlining the reasons for the nomination.

Call for Nominations for the **IIFC Best PhD Thesis Award**

In order to promote high-quality research on FRP composites for construction, in 2016 the IIFC established the Best PhD Thesis Award which is to be awarded in association with the Composites in Civil Engineering (CICE) conference series. The inaugural Award was awarded at CICE 2016 in Hong Kong and the second Award was awarded at CICE 2018 in Paris.

Using the CICE cycle, all PhD theses completed within two years of the application deadline are eligible for the award. To be eligible, theses must be nominated by a faculty member from the student's department (typically their advisor) who is a member of the IIFC. The nomination package shall include the following:

a. Nominee's name, affiliation and contact information
b. Nominator's name, affiliation, contact information and relationship to nominee
c. Nominator's statement (2 pages) justifying the significance of the dissertation, novelty, research achievements, and scientific or practical contributions
d. 4-5 page 'extended abstract' summary of the thesis ***prepared by the nominee***

Nominated theses making a 'short list' will be invited to give a presentation at a special session of the CICE conference. The Award Panel will select the Best PhD Thesis based on an evaluation of the nomination package ***and*** presentation made at CICE.

The winner will receive a certificate, $1000 (USD) and a two-year complimentary membership to IIFC. The winner will also be expected to prepare an article for *FRP International*.

The third Best Thesis Award will be awarded at CICE 2020 in Istanbul, Turkey. Theses submitted in calendar year 2018 or after, but were not nominated in the 2018 round, are eligible for the award in this round.

Nominations for the 2020 IIFC Best PhD Thesis Award should be submitted to Tao Yu (taoy@uow.edu.au) before 31 December 2019.

More information on the Award may be obtained from Tao Yu (taoy@uow.edu.au).

Nomination Form for the 2020 IIFC Medal

Part A: Information about the Nominee.	
Name	
Affiliation	

Part B: Nominators.		
Corresponding nominator:	1.	
Supporting nominators:	2.	
	3.	

Part C: Statement of Attributes of the Nominee as per the Standards.

Part D: Certification by the Nominee.	
If awarded the IIFC Medal, I agree to accept the Medal in person and to deliver the IIFC Distinguished Lecture at CICE 2020.	
Signature	
Date	

Nominations should be forwarded to taoy@uow.edu.au

Deadline: Tuesday 31 December 2019

Nomination Form for the 2020 IIFC Distinguished Young Researcher Award

Part A: Information about the Nominee.	
Name	
Affiliation	

Part B: Nominators.		
Corresponding nominator:	1.	
Supporting nominators:	2.	
	3.	

Part C: Statement of Attributes of the Nominee as per the Standards.

Part D: Certification by the Nominee.	
If awarded the IIFC Distinguished Young Researcher Award, I agree to accept the Award in person and to deliver a Keynote Lecture at CICE2020.	
Signature	
Date	

Nominations should be forwarded to taoy@uow.edu.au

Deadline: Tuesday 31 December 2019

Nomination Form for the 2020 IIFC Best Thesis Award

Part A: Information about the Nominee	
Name	
Affiliation	
Contact	

Part B: Information about the Nominator	
Name	
Affiliation	
Contact	
Relationship to Nominee	

Part C: Nominator's statement
Please attach a 2-page statement to the form, justifying the significance of the dissertation, novelty, research achievements, and scientific or practical contributions.

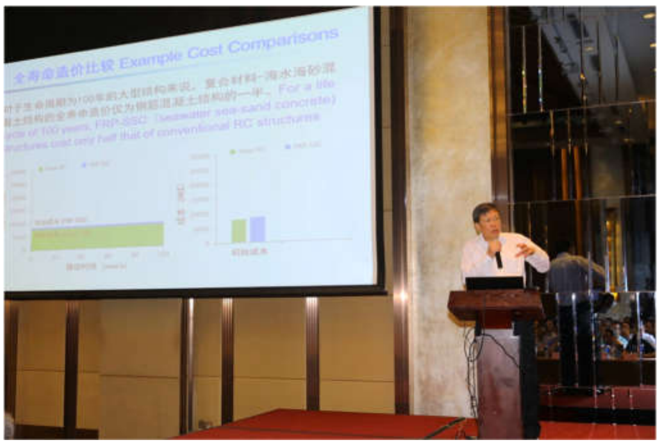
Part D: Extended abstract prepared by the nominee
Please attach a 4- or 5-page "extended abstract" summary of the thesis to the form.

Nominations should be forwarded to taoy@uow.edu.au

Deadline: Tuesday 31 December 2019

Report from ISERCI 2019

The Third International Symposium for Emerging Researchers in Composites for Infrastructure (ISERCI 2019) was successfully held at Hilton Wuhan Optical Valley, Wuhan, China on 05-06 August 2019. This symposium, held by Huazhong University of Science and Technology, is mainly for young researchers who obtained their PhD degree within the last 15 years and current PhD students in the field of use of composite materials in infrastructure.



Prof. Jin-Guang Teng from The Hong Kong Polytechnic University, Prof. Wei-Chen Xue from Tongji University, Prof. Joaquim A.O. Barros from University of Minho, Prof. Jian-Guo Dai from The Hong Kong Polytechnic University, A/Prof. Fabio Matta from University of South Carolina, Prof. Gui-Jun Xian and Prof. ZhenYu Wang from Harbin Institute of Technology, and Prof. Peng Feng from Tsinghua University were invited to give keynote speeches as the senior researchers. Prof. De-Ju Zhu from Hunan University, Prof. Xin Wang from Southeast University, Prof. Jun Deng from Guangdong University of Technology, A/Prof. Dilum Fernando from The University of Queensland, as outstanding representatives of young scholars, were invited to give invited speeches. Professor Scott Smith delivered a presentation on behalf of IIFC.

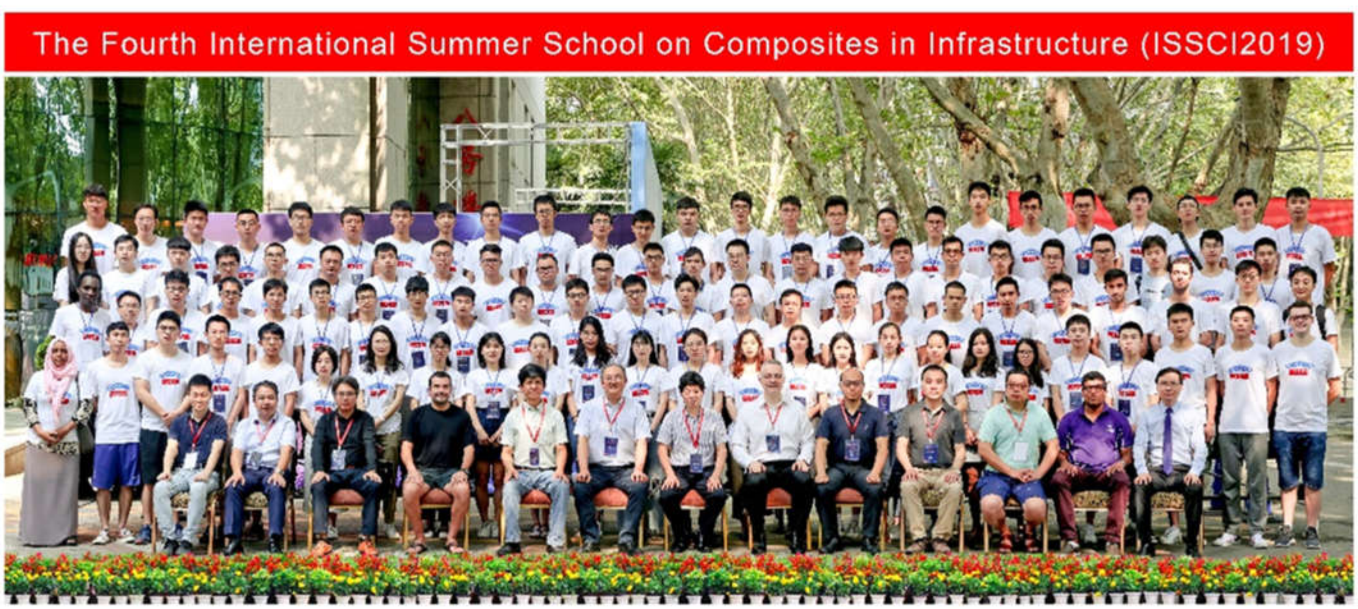
ISERCI 2019 aimed to provide an international platform for upcoming researchers/ practitioners and rising stars in the area to share their recent advances in both research and practice. This symposium attracted more than 130 experts and scholars from nearly 40 universities and research institutions at home and abroad. The presentations cover: FRP-strengthened structures, FRP for new construction, etc.

Report from ISSCI 2019

The Fourth International Summer School on Composites in Infrastructure (ISSCI 2019) was hosted by the International Centre for Composites in Infrastructure (ICCI) at Huazhong University of Science and Technology, Wuhan, China on 07-09 August 2019. ISSCI 2019 aimed to prepare researchers and postgraduate students for high-quality research in the area of structural use of FRP composites in infrastructure, and to prepare engineers for practical applications.

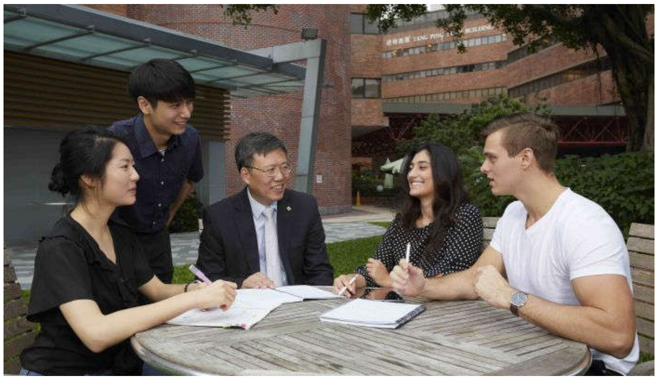
ISSCI 2019 invited the world's leading scholars to give lectures, including: Prof. Jin-Guang Teng from The Hong Kong Polytechnic University, Prof. Zhi-Shen Wu from Southeast University, Prof. Jian-Fei Chen from Queen's University of Belfast, Prof. Scott Smith from University of Adelaide, Prof. Jian-Guo Dai from The Hong Kong Polytechnic University, A/Prof. Fabio Matta from University of South Carolina, Prof. Peng Feng from Tsinghua University, Prof. Tao Yu from the University of Wollongong, Prof. Yu Bai from Monash University, Prof. Guang-Ming Chen from South China University of Technology, A/Prof. Dilum Fernando from The University of Queensland, A/Prof. Tao Jiang from Zhejiang University and Dr. Hon-Ting Wong from Fibrpro International Ltd.

More than 120 scholars and postgraduates from 29 universities, research institutions and enterprises participated in the summer school. The three-day summer school arranged 16 lectures which focused on theory and application of FRP in infrastructure structures. Topics covered the overview and fundamentals of FRP, FRP-Strengthened structures and FRP for new construction.



IIFC Founding President, Professor Jin-Guang Teng assumed duty as the new PolyU President

The new President of The Hong Kong Polytechnic University (PolyU), Prof. Jin-Guang TENG, took office on July 1st, 2019. Over the next couple of months, he aims to build connections with students, faculty, staff, and alumni through different engagement opportunities. He will also meet with different internal and external stakeholders to understand the dynamics and to communicate his thoughts and plans for the future development of the University.



In his message to the staff members, students and alumni of PolyU, Prof. Teng said, "While it is a great honour that I assume the role of President of PolyU, I am also fully aware of the huge responsibilities and demanding expectations associated with the position." He pledged to make every effort to fulfil PolyU's mission and to deliver the University's vision. The PolyU Council announced in March 2019 the appointment of Prof. Teng as its new President with a five-year term of office from 1 July 2019.

Prof. Teng received his BEng Degree from Zhejiang University in 1983. He then pursued further studies in Australia and the United Kingdom. He had served at James Cook University of North Queensland before joining PolyU. A well-accomplished and distinguished scholar in the field of structural engineering, Prof. Teng's publications have been widely cited by researchers around the world, and many of his research findings have been adopted by relevant design codes/guidelines in China, Australia, Europe, the United Kingdom and the United States. He was elected in 2017 as Academician of the Chinese Academy of Sciences, which is the highest academic title in the field of science and technology in China; Corresponding Fellow of the Royal Society of Edinburgh in 2015. And he is a Fellow of the Hong Kong Academy of Engineering Sciences as well as the Hong Kong Institution of Engineers, and served as the founding President of the International Institute for FRP in Construction (IIFC) from 2003 to 2006.

IIFC Former President, Professor Jian-Fei Chen joined SUSTech in Shenzhen

Our former President, Professor Jian-Fei Chen, has recently moved from Queen's University Belfast to Southern University of Science and Technology (SUSTech) in Shenzhen, China.

SUSTech is a new "experimental" university in China, established in 2012. It is a public research university, funded by Shenzhen city. Widely regarded as a pioneer and innovator in collectively moving China's higher education forward to match China's ever-growing role in the international arena, SUSTech aspires to be a globally-renowned university that contributes significantly to the advancement of science and technology by excelling in interdisciplinary research, nurturing creative future leaders and creating knowledge for the world. Located in Shenzhen, one of the fastest growing cities in China and the country's window to the world, SUSTech enjoys strong connections with leading companies in China and renowned universities around the world. SUSTech is raising fast in some global university rankings. For example, it ranked the 7th in the most recent Natureindex ranking of young universities and the 137th among all universities internationally.

One of Professor Chen's roles is to build up Ocean Engineering. He is looking for recruiting up to 20 academic staff, ranging from Assistant Professors to Chair Professors, in Structural Engineering, Fluid Mechanics and Fluid-Structure Interaction, Geotechnics, Engineering Materials, Loading on Ocean Structures, and Ocean Infrastructure such as Pipelines and Floating Structures. He is also recruiting research students and staff for his research projects. SUStech provides internationally (including US, Hong Kong and Singapore) very competitive remuneration packages and generous startup funds (RMB 8-12 million) for academic staff, plus low income tax (capped at 15%). Colleagues are welcome to distribute this information. Candidates interested in any of these positions are welcome to get in touch with Professor Chen at Chenjf3@sustech.edu.cn.

IIFC President, Professor Scott Smith joined the University of Adelaide as Deputy Dean (International) and Professor of Structural Engineering

Professor Scott Smith joined the University of Adelaide as Deputy Dean (International) and Professor of Structural Engineering in the Faculty of Engineering, Computer and Mathematical Sciences at the University of Adelaide, Australia.

In the afternoon of August 29th, Professor Scott Smith, was appointed as Distinguished Visiting Professor of Tsinghua University. Professor Fang Dongping, chairman of the council of School of Civil Engineering, awarded the appointment letter to Professor Smith. Professor Pan Peng, head of the department of Civil Engineering, hosted the appointment ceremony. Professor Feng Peng attended and chaired the presentation.

Professor Scott Smith was awarded BE (Civil, 1994) and PhD (Structural Engineering, 1999) degrees from the University of New South Wales, Australia, as well as an MBA (2018) from Imperial College London, UK. Professor Smith's research interests encompass the repair and strengthening of structures with advanced composite materials, and he is President of the International Institute for FRP in Construction (IIFC). He has published over 180 peer-reviewed journal and conference papers, and he has won several awards including the IIFC Distinguished Young Research Award. Professor Smith is an Editor of the journal Construction and Building Materials and an Associate Editor of the ASCE Journal of Composites for Construction. He is also the founder of the Asia-Pacific Conference on FRP in Structures (APFIS) conference series, and he is the Chair of APFIS 2019 (www.scu.edu.au/apfis2019) which will be held in Gold Coast, Australia, December 2019. Further details about Professor Smith and his research activities can be found here: https://www.adelaide.edu.au/directory/scott.smith.

"SAMPE Fellow Award" to Urs Meier

Award for pioneering CFRP achievements

On September 18, Urs Meier received a prestigious award for his achievements in the field of carbon fiber reinforced plastics in civil engineering - the "SAMPE Fellow Award". This award is presented in recognition of outstanding contributions in the fields of materials and processes.

A CFRP pioneer at EMPA

Urs Meier has worked at EMPA since 1969, 12 years of which as Director of EMPA Dübendorf. He is an internationally recognised pioneer in the field of carbon fibre reinforced plastics (CFRP) in civil engineering and a driving force behind its further development. Meier started as early as 1980 with the idea of using CFRP for ropes in large bridge construction. The idea of using a "super material" in the construction industry, which had previously been reserved exclusively for space travel and military aviation due to its high price, was so crazy that he began to study it in secret. In 1982, the idea of reinforcing concrete structures by bonding extremely thin CFRP lamellas was born.

In 1987, Meier and a small team of enthusiastic young engineers demonstrated for the first time in an award-winning paper that existing bridges can actually be reinforced with CFRP lamellas. In 1991 he shaped the history of civil engineering with the world's first repair of a road bridge with three CFRP lamellas. The structural integrity of the bridge in the canton of Lucerne had been impaired by damage to its prestressing cables. One year later, the first building and the first historical structure followed, which were successfully reinforced with CFRP.

Urs Meier's other CFRP pioneering achievements include their use as cable-stayed bridge cables, the installation of fibre-optic sensors in re-tensioned bridge cables and the reinforcement of wooden bridges and beams with CFRP.

An impressive career

During his career, Meier obtained five US patents and published no less than 264 scientific and technical publications. He presented hundreds of lectures, courses and keynotes around the world to promote the use of composite materials, particularly CFRP in construction. Meier has already received a number of prestigious awards, including an honorary doctorate from the Royal Military College of Canada and the Staudinger-Durrer Medal from the Department of Materials Science at ETH Zurich. He was instrumental in supporting the founders of the EMPA spin-off Carbo-Link during the difficult start-up phase. Today, the company has become a world leader in the production of highly sophisticated lightweight components for marine, aerospace and construction applications.

In Germany, a new, larger railway bridge is currently being completely suspended for the first time from tension elements made of carbon fibre-reinforced plastics (CFRP) produced by Carbo-Link on the basis of the EMPA report by Meier. This milestone is part of a systematic series of EMPA pilot projects, such as the Stork Bridge in Winterthur. In 1998, the risk of suspending the entire bridge from CFRP cables was still considered too great. Only two CFRP cables were used. Thanks to EMPA's many years of research, it has now become possible to suspend entire bridges completely from this non-corroding, fatigue-resistant and lightweight material.

In his nomination for the "SAMPE Fellow Award" Scott Beckwith, technical director of SAMPE, explains that Meier has contributed more to CFRP research than any other current or former SAMPE member - he is considered a real "guru" in the field of composite materials in civil engineering. Meier's merits as a CFRP pioneer have now been honoured: SAMPE Director Gregg Balko presented him with the award at the SAMPE conference on 18 September 2019 in Nantes / France.

What is SAMPE

SAMPE is the "Society for the Advancement of Materials and Process Engineering", an international professional association with currently more than 15,000 members. The association was founded in 1944 by California aerospace engineers with the aim of establishing a professional network and improving the exchange of technical information. Today SAMPE is represented in 40 countries. As the only global technical society covering all areas of materials and process research, SAMPE provides a unique forum for scientists and engineers around the world.

The Fellow Award represents prestigious recognition of a SAMPE Member for distinguished contributions in the fields of materials and processes.

Applications are due February 15, 2020. Login the network: https://www.sampe.org/fellows-award for application form and more information. Contact Sylvia Smith at sylvia@sampe.org with questions.

China Summit Forum on FRP in Civil Engineering held in Shanghai

China Summit Forum on FRP in Civil Engineering, and also the 11th Conference on Application Technology of FRP in infrastructure in China, was held on September 19 to 21 in Shanghai. The conference was jointly hosted by Division of Civil, Hydraulic and Architecture Engineering, Chinese Academy of Engineering (CAE), Central Research Institute of Building and Construction Co., LTD.MCC, Tongji University, Carbon Fiber and CFRP Industry Technology Innovation Alliance (National Pathfinder Union) and Periodical Office of “Industrial Construction”. Meanwhile, the Chinese Academicians forum of "High performance and sustainable development of civil engineering in China - Application Research and Prospect of Emerging Materials and Structure" was held.

17 academicians from all over the world, 6 officers from Chinese Academy of Engineering, the Shanghai Government and China Civil Engineering Society, and nearly 600 scholars took part in the Forum, focusing on the recent research progress and engineering practice of FRP in the world and exploring the frontier of sustainable development of civil engineering in China. Ten keynote speeches were given by the distinguish professors. 30 experts gave speeches on the sub-forums, focusing on FRP and FRP products in Civil Engineering, FRP application in new structures and FRP application in structural strengthening. Chinese Academicians forum of "High performance and sustainable development of civil engineering in China - Application Research and Prospect of Emerging Materials and Structure" was held at the same time. The topic of the Forum included “future application of FRP in civil engineering”, “challenges for application of FRP in civil engineering”, “the implementation path of high performance, long service life and intelligent application of FRP”, “application research and prospect of emerging material and structural system in civil engineering during the 14th Five-Year”, “How to improve the development of key strategic materials and technologies in the field of frontier materials in civil engineering” and “the new generation of engineering structural materials in marine engineering, bridge engineering, military engineering, geomechanical engineering, industrial engineering and disaster prevention and mitigation engineering”.

This Forum awarded scholars and experts who have made outstanding contributions to the development and application of composite materials in construction engineering. Prof. Wang Xin from Southeast University won the "Outstanding Young Scholar Award for FRP Materials and Structures in Construction Engineering", and Prof. Feng Peng from Tsinghua University won the "Promotion Award for the Application of FRP in Construction Engineering".

Structural Performance of Precast Reinforced Geopolymer Concrete Sandwich Panels Enabled by FRP Connectors

Jun-Qi HUANG

(Supervisor: Professor Jian-Guo Dai)

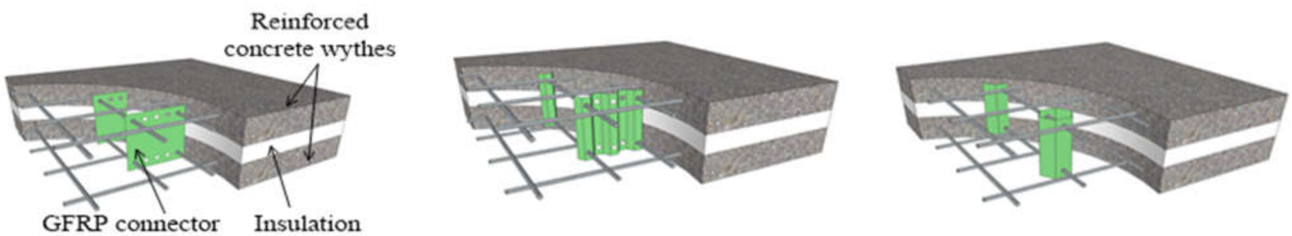
(*Department of Civil and Environmental Engineering, The Hong Kong Polytechnic University, Hong Kong, China*)

Precast concrete sandwich panels (PCSPs), as a typical structural element used in the precast industry, have been widely used as the facade walls or load-bearing walls in engineering practice. They consist of inner and outer reinforced concrete wythes, core insulation and connectors penetrating through the insulation. Depending on the stiffness and strength performance, the PCSPs are classified into three categories: fully composite, partially composite and non-composite. Traditionally, concrete block and steel bent-up bar were used as the connectors, which could achieve a high degree of composite action (in terms of stiffness and strength). However, the thermal bridge effect may occur due to the higher thermal conductivity of steel and concrete. Consequently, the energy efficiency of the entire sandwich panel is reduced. Therefore, fiber-reinforced polymer (FRP) materials have been recently used to manufacture the connectors due to their high strength but low thermal conductivity. However, limited work has been conducted to investigate how the FRP connectors influence the structural performance of the formed PCSPs. In addition, most existing FRP connectors were designed to transfer one-directional shear force and the formed PCSPs were usually non-composite type due to the lower stiffness and capacity of the connectors.

Against the above background, this study aims to develop an innovative PCSP system. In this system, environmentally friendly geopolymer cement concrete is adopted to replace ordinary Portland cement (OPC) for use in the two wythes. The geopolymer concrete is produced by the alkaline activation of industrial by-products (i.e., blend of fly ash and slag) to realize ambient temperature curing and achieve comparable performance to the OPC. Meanwhile, FRP rebar is used to replace steel rebar to improve the durability and minimize the thickness of the entire panel. In addition, a tubular glass FRP (GFRP) connector is developed to enhance the composite action of the PCSP. As a result, the proposed PCSP system can retain the energy efficiency of all existing PCSPs but is entitled with low carbon-footprint, high durability and superior structural efficiency. The study is composed of extensive experimental and finite element (FE) analysis work covering three main parts: (1) the development of a new type of GFRP tubular connector and its performance characterization; (2)

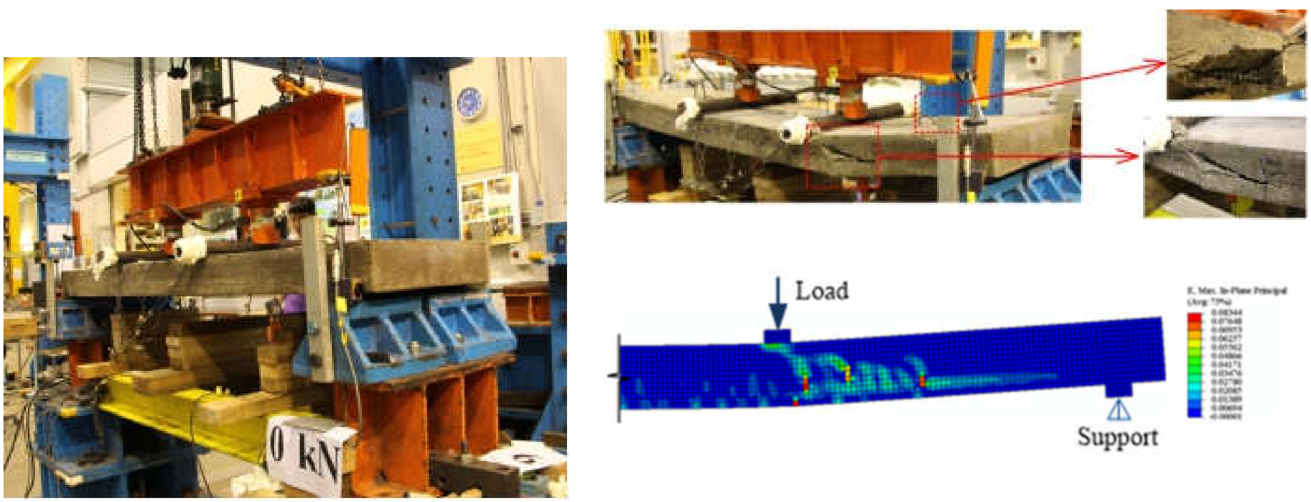
structural performance of steel and FRP-reinforced geopolymer concrete one-way slabs; and (3) the structural behaviour of the GFRP connector-enabled PCSP system.

In the first part of this study, twenty-five in-plane direct shear tests were conducted to evaluate the effect of GFRP laminate thickness, projected length, and shear force direction on the performance of three types of GFRP connectors (i.e., flat plate, corrugated plate and hexagonal tube in Fig. 1). The shear force vs. relative slip relationships and failure modes of all types of connector were studied and discussed. Besides, three-dimensional FE analysis was conducted to reproduce the test results, aiming to facilitate an in-depth understanding of the failure mechanisms and the full-range performance of the connectors.



(a) Flat plate (b) Corrugate plate (c) Hexagonal tube

Fig. 1 PCSP with the proposed connector

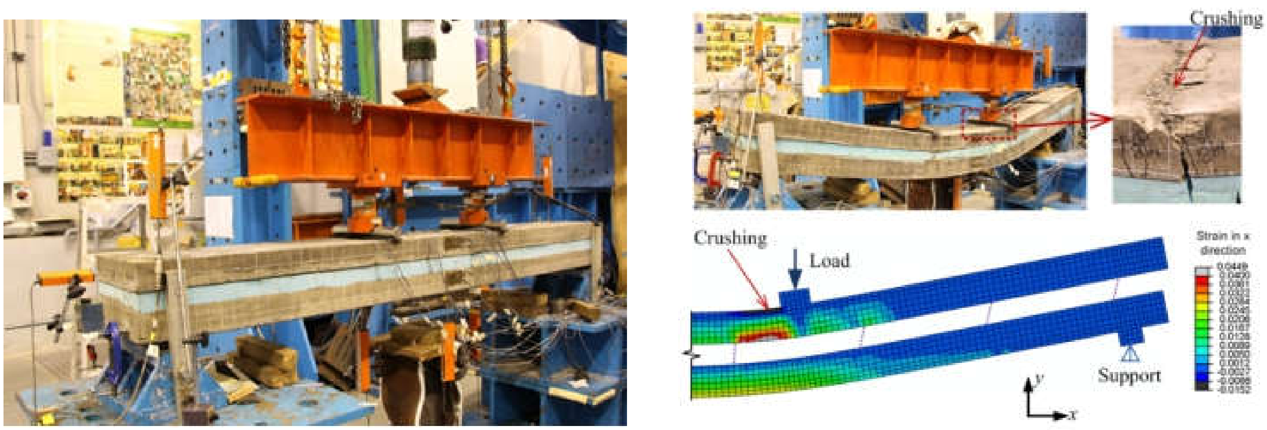


(a) Test setup (b) Test and FE analysis results

Fig. 2 BFRP reinforced one-way slab test setup and test results

In the second part of this study, the flexural performance of six steel reinforced geopolymer concrete one-way slabs and six OPC concrete counterparts were tested through four-point bending. The shear performance of six basalt FRP (BFRP) reinforced geopolymer concrete one-way slabs were also evaluated (See Fig. 2a). The investigating parameters mainly included concrete strength and reinforcement ratio. Their load-deflection relationships, crack patterns, failure modes and load-strain relationships were studied and compared. Meanwhile, two dimensional (2D) FE analysis was conducted to reproduce the test results to fully understand the behaviour of the reinforced geopolymer concrete slabs (See Fig. 2b) as the two wythes in the PCSP system.

In the third part of this study, an experimental study was carried out on the flexural performance of eight precast geopolymer concrete sandwich panels (See Fig 3a). Four parameters were investigated, including the connector type (i.e., plate-type and hexagonal tube connector), connector spacing, rebar type (i.e., steel and BFRP rebar) and reinforcement ratio. The load-deflection relationships, crack patterns, failure modes, load-strain relationships and degrees of composite action (in terms of both stiffness and strength) of the specimens were carefully investigated. In addition, 2D FE analysis incorporating the shear-slip constitutive laws of FRP connectors was conducted to reproduce the test results (See Fig. 3b). A simplified but innovative approach (with closed-form solutions) based on the continuum method was developed for predicting the stiffness and serviceability of the PCSP under out-of-plane load and validated by the test results.



(a) Test setup (b) Test and FE analysis results

Fig. 3 Precast geopolymer concrete sandwich panel test setup and test results

Upon the completion of the study, an in-depth understanding of the shear transfer mechanism of the proposed tubular GFRP connectors, the failure mechanisms of steel and BFRP reinforced geopolymer concrete one-way slabs, and the mechanisms of full-range interaction between the tubular GFRP connectors and BFRP-reinforced geopolymer concrete wythes has been achieved. These scientific findings arisen from this PhD project have laid a solid foundation for the development of design guidelines for the proposed PCSP system, which is believed to have great potential for use in the prefabricated construction industry in Hong Kong, mainland China as well as the rest of the world.

Thermal and Structural Response of Pultruded GFRP Profiles Under Fire Exposure

Tiago Morgado

(Supervisors: João Ramôa Correia, Nuno Silvestre, Fernando Branco)

(Instituto Superior Técnico, University of Lisbon, Lisbon, Portugal)

Fibre reinforced polymer (FRP) materials in general and pultruded glass fibre reinforced polymer (GFRP) profiles in particular have great potential for civil engineering applications. When compared with traditional materials, the main advantages of pultruded GFRP profiles are the lightness, strength, good insulation properties, durability in aggressive environments and low maintenance requirements. However, GFRP profiles present some drawbacks, namely the relatively high initial costs, low elastic moduli, lack of design codes and poor fire behaviour. This last aspect is particularly relevant for building applications, where materials and components need to fulfil specific requirements in terms of fire reaction and fire resistance.

With the purpose of investigating the viability of the structural use of pultruded GFRP profiles in the construction industry, namely in buildings, this PhD thesis aimed at obtaining a better understanding of the thermal and structural responses of pultruded GFRP profiles exposed to fire. To achieve this goal, experimental, numerical and analytical studies were carried out, in which the following specific aspects were investigated: (i) mechanical behaviour of pultruded GFRP material at elevated temperature, in particular under compression and shear (Figure 1); (ii) thermal and mechanical response of pultruded GFRP profiles subjected to different types of fire exposure (1 and 3 sides – 1S and 3S) and comprising different fire protection systems (Figure 2); and (iii) numerical and analytical models to simulate the fire behaviour of GFRP structural elements (Figure 3).

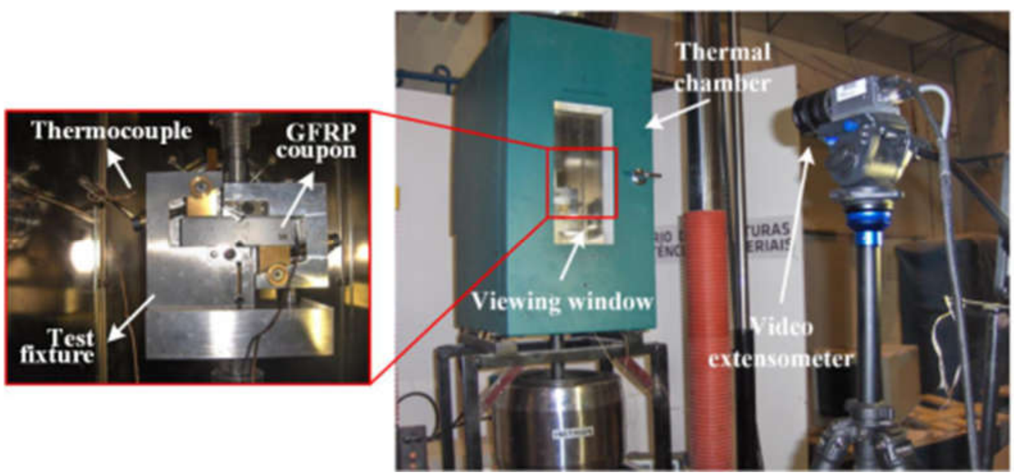


Figure 1: Test setup used in shear tests at elevated temperatures.

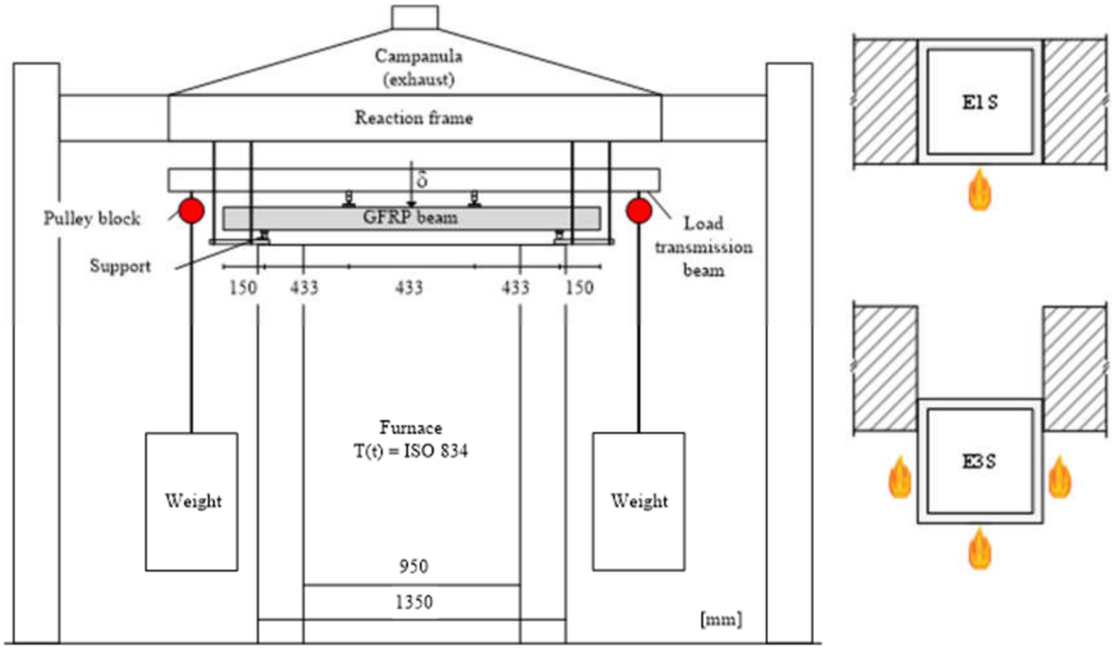
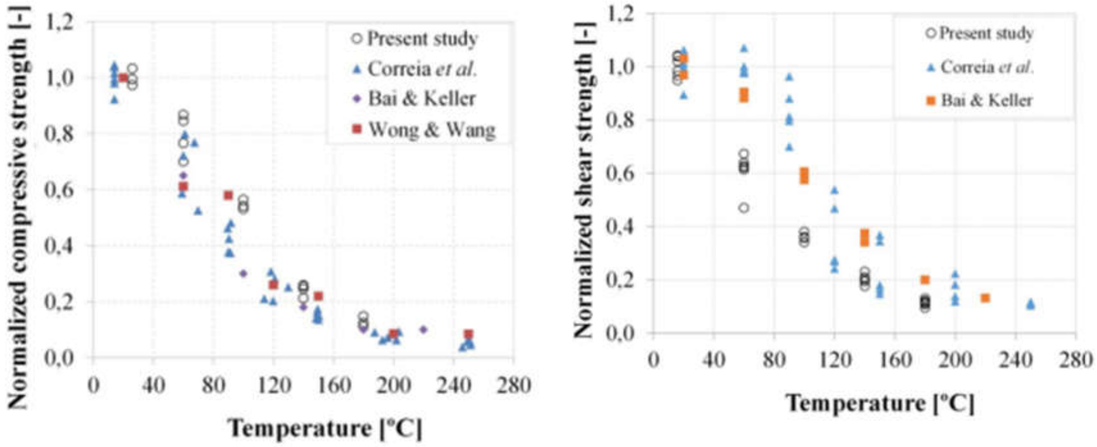


Figure 2: Test setup: frontal view (left) and types of fire exposure (right).

Figure 3: Finite element model used to simulate fire behaviour of GFRP columns.

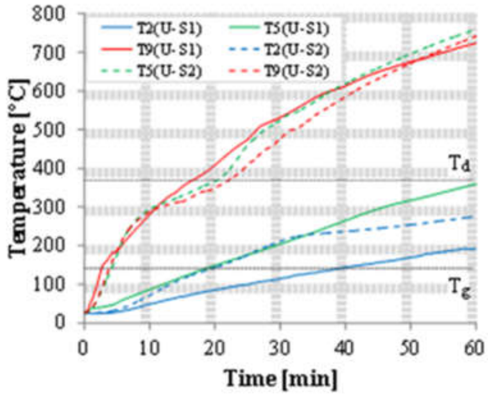
In a first stage, experimental and analytical studies were carried out in order to characterize the compressive and shear behaviour of pultruded GFRP material at elevated temperatures (~20-180 ºC). The results obtained from these material characterization tests showed that (i) compressive strength is severely affected by temperature increase, with a reduction of 87% at 180 ºC (see Figure 4(a)); (ii) shear strength (from Iosipescu tests) is noticeably reduced at elevated temperature, with significant reductions (~36%) already at moderately elevated temperature (60 ºC) and a reduction of 88% at 180 ºC; and (iii) shear modulus is also significantly affected by elevated temperature, with reductions of 30% at 60 ºC and 80% at 140 ºC (*cf.* Figure 4(b)).



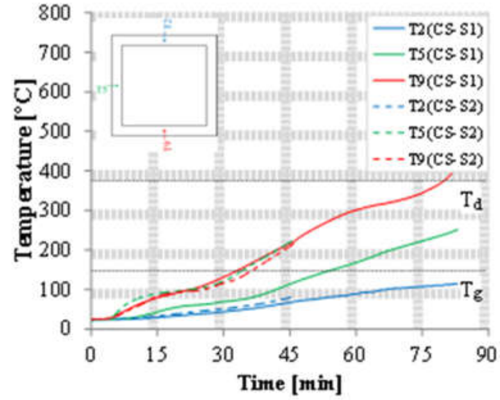
(a) (b)

Figure 4: Normalized (a) compressive and (b) shear strength reduction with temperature (present study *vs.* other studies reported in literature).

In a second stage, fire resistance tests were performed on pultruded GFRP square tubular beams and columns. The experimental results obtained confirmed the effectiveness of some fire protection systems in delaying the temperature increase of GFRP profiles and, consequently, in improving their fire resistance (see Figures 5 and 6): intumescent coating (IC), intumescent mat (IM), agglomerated cork (AC), rockwool (RW), calcium silicate (CS), stagnant (WC_s) and flowing (WC_f) water cooling. As an example, for one-side fire exposure, the fire resistance of beams was increased from 36 min (unprotected - "U") to 83 min and 120 min (with passive - "IC, IM, AC, RW, CS" - and active - "WC" - fire protections, respectively); the fire endurance of columns was increased from 16 min (unprotected - "U") to 51 and 120 min (with passive - "CS" - and active - "WC" - fire protections, respectively). The experimental results also showed that the number of sides exposed to fire affects severely the fire resistance behaviour of GFRP profiles (series S1 *vs.* S2). For three-side fire exposure, the fire resistance of the unprotected beams and columns was remarkably reduced (about 80% and 50%, respectively). In this case, passive fire protection was clearly more effective than active protection. Regarding the effect of load level on the fire performance of GFRP structural members (series S1 *vs.* S3), while the fire endurance of beams was moderately reduced (~15%), the fire resistance of columns was significantly affected (~45%) by the load level increase. Failure of GFRP members was associated to approaching and/or exceeding the glass transition temperature of the material in parts under compression (axial or transverse) and/or shear. Accordingly, the GFRP columns proved to be much more susceptible to fire than GFRP beams subjected to the same type of fire exposure; this was attributed to the fact the residual strength in tension at elevated temperature is much higher than that in compression.

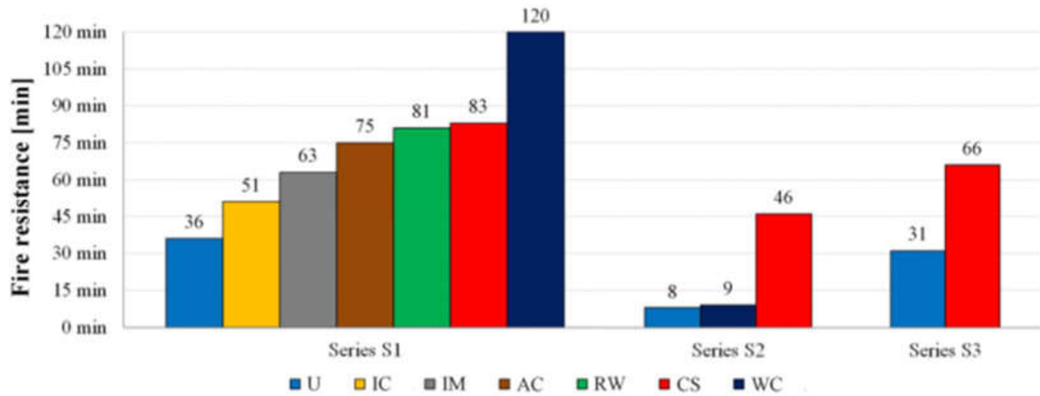


(a)

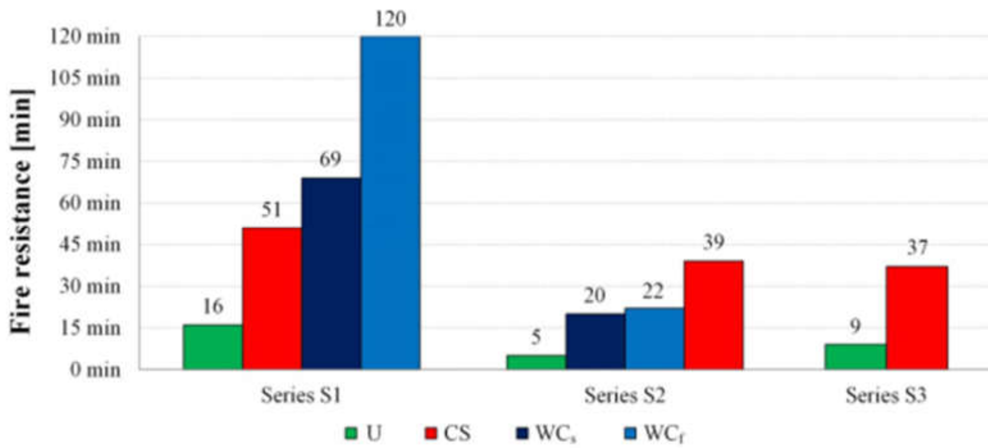


(b)

Figure 5: Temperature profiles for series S1 (one-side exposure) and S2 (three-side exposure) in (a) unprotected beams and (b) beams with CS protection.



(a)



(b)

Figure 6: Fire resistance of square tubular (a) beams and (b) columns tested.

Aiming at simulating the thermal response of GFRP tubular profiles exposed to elevated temperatures, 2D and 3D finite volume models were developed, in which the entire cross-section was considered, including the thermal radiation and convection inside the section cavity (through CFD). The results obtained from this thermal analysis (Figure 7) were in agreement with the experimental ones and highlighted the importance of considering conduction, internal radiation and convection inside the tubular section in this heat transfer problem.

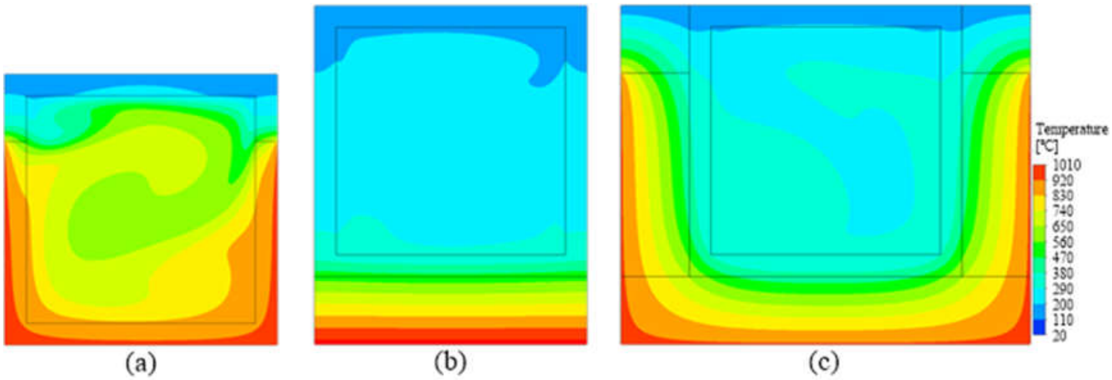


Figure 7 : Temperature distribution for profiles (a) U-E3S, (b) CS-E1S and (c) CS-E3S (time=60 min).

3D finite element (FE) models were also developed to simulate the mechanical behaviour of the GFRP beams and columns, in which different curves were considered for the degradation of the compressive, tensile and shear properties with temperature. This numerical investigation provided interesting insights about the most relevant *kinematic* (longitudinal and transversal deformations) and *static* (stresses and failure initiation) issues of the structural response of GFRP members. Although the numerical models did not take into account the material progressive failure, the mechanical behaviour of GFRP beams was simulated with reasonable accuracy by the numerical models. On the other hand, the numerical models were less accurate in simulating the mechanical response of GFRP columns exposed to fire – although providing a fair agreement with the overall qualitative response of the columns, the calculated axial deformation rates were lower than measured and this should be related, among other effects, to the non-consideration of creep (due to the lack of material data). Despite not considering the effects of delamination, the models were able to capture the main features of the failure modes, as illustrated in Figure 8. In addition to the FE models, analytical models based on beam theory were also developed to simulate the mechanical response of GFRP beams exposed to fire; in spite of the simplifying assumptions made, the results provided by these models were in close agreement with those obtained from the numerical and experimental studies.

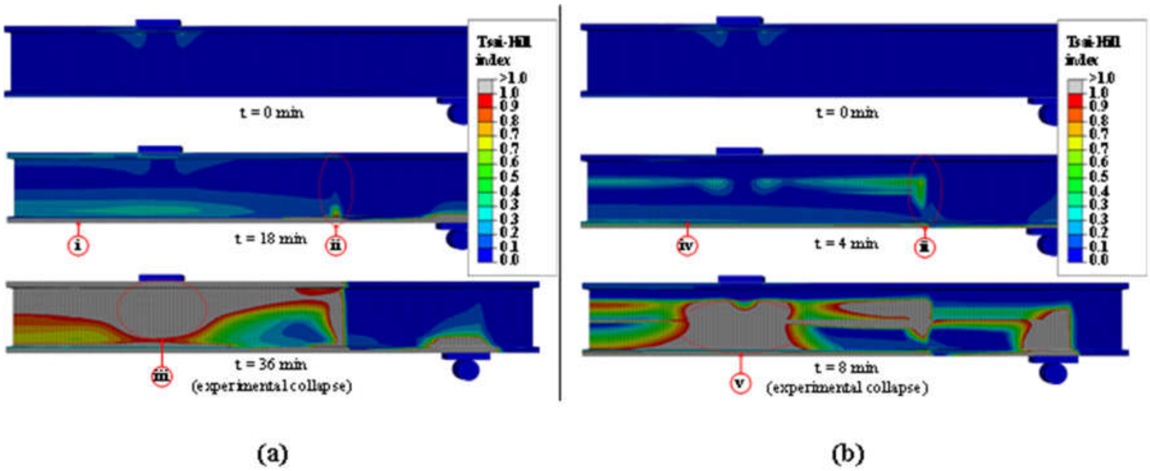


Figure 8: Tsai-Hill index evolution in beams (a) U-S1 and (b) U-S2 for different time steps.

Keywords: Glass fibre reinforced polymer (GFRP); fire behaviour; GFRP beams and columns; thermal and mechanical responses; experimental, numerical and analytical studies.

Durability of Pultruded GFRP Profiles and Adhesively Bonded Connections Between GFRP Adherends

João Meireles de Sousa

(Supervisors: João Ramôa Correia, Susana Cabral-Fonseca, Fernando Branco)

(Instituto Superior Técnico, University of Lisbon, Lisbon, Portugal)

The durability problems experienced by traditional materials, such as steel or reinforced concrete, and the need for increased construction speed in civil engineering applications have been fostering the development of new structural solutions, using alternative construction materials, more durable and with lower maintenance requirements.

Fibre reinforced polymer (FRP) materials are playing an increasingly important role in this respect; their demand for both new construction and rehabilitation of existing structures has been steadily increasing in the construction sector. In particular, pultruded glass fibre reinforced polymer (GFRP) profiles are now being used in a growing number of applications, including structural parts or components of bridges and buildings. Compared to conventional solutions, these profiles offer low self-weight, high specific strength, ease of handling, electromagnetic transparency, non-corrodibility and low maintenance operations. The main disadvantages are their brittle behaviour, the low elasticity and shear moduli, the relatively high initial costs, the low development of connection technology and the lack of specific design codes.

In spite of practical evidence of improved performance under harsh conditions, namely when compared with more traditional materials, comprehensive and validated data on the durability of pultruded GFRP profiles is still scarce. The quantification of the durability and of the damage tolerance of GFRP constructions is becoming critical to their structural design. In addition, the connection technology for pultruded GFRP profiles also presents challenges, and despite the potential benefits of adhesively bonding these materials, there are also concerns about their durability, namely with respect to the influence of the exposure conditions on both the adhesives and the GFRP adherends.

The main objective of the present thesis was to study the durability of pultruded GFRP profiles and their adhesively bonded connections. The thesis thus focused on the following four research topics: (i) the durability of pultruded GFRP profiles for civil engineering applications; (ii) the long-term behaviour of structural adhesives typically used to bond GFRP elements; (iii) the durability of GFRP bonded connections in civil engineering applications; and (iv) the performance of a GFRP structure after more than 10 years in service conditions.

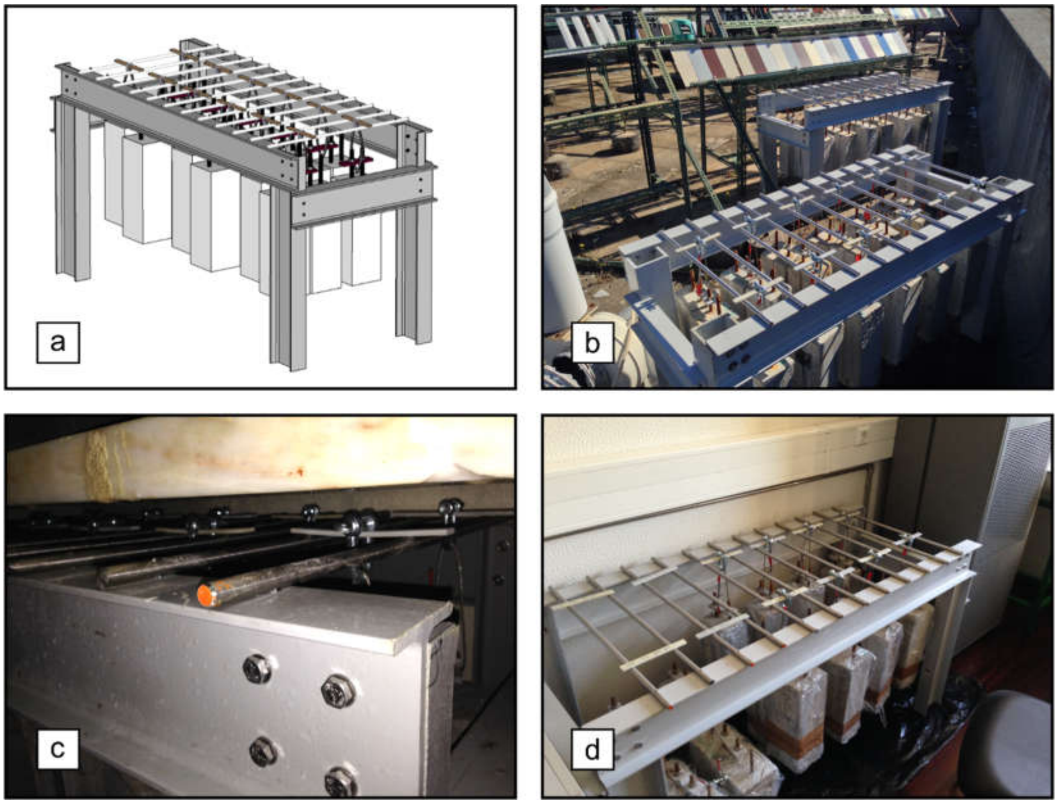


Figure 1. Synergistic effects – ageing environments in loading conditions

(10% and 20% flexural strength).

The research about the durability of pultruded GFRP profiles comprised an extensive experimental campaign, in which the physical, viscoelastic, mechanical and aesthetical properties of profiles made of vinylester or unsaturated polyester resins were monitored. The profiles were subjected to hygrothermal ageing, natural weathering, thermal cycles, and synergistic effects (*cf.* Figure 1) of different ageing conditions and sustained loading for periods up to two years. Figure 2 depicts the sorption behaviour and analytical models, for both materials when exposed to several ageing environments. Increasing temperature led to an overall higher mass uptake. Results obtained showed that hygrothermal degradation, *cf.* Figure 3, was the most severe conditioning, when compared to thermal cycling or natural weathering, with the latter leading to relatively small changes over the exposure period. Post-curing phenomena were observed for all ageing environments. For immersion in water and salt water, the long-term material properties were predicted using Arrhenius models and none of the estimated properties fell below 50% after 100 years, depicted in Figure 4. Sustained loading produced small effects when acting synergistically with the different ageing environments.

Scanning electron microscope (SEM) observations were also addressed in the fracture zones, which evidenced degradation of the fibre-matrix interface (*cf.* Figure 5).

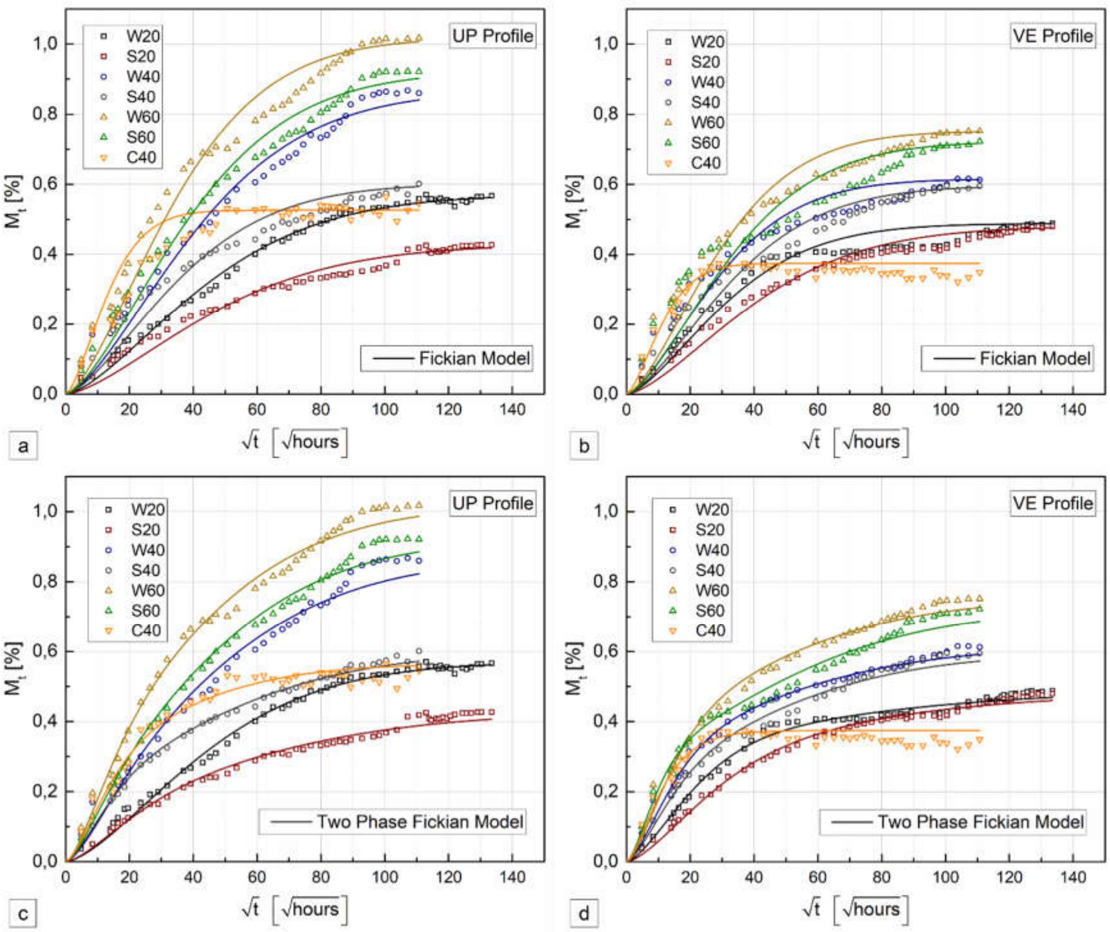


Figure 2. Sorption behaviour for several ageing environments

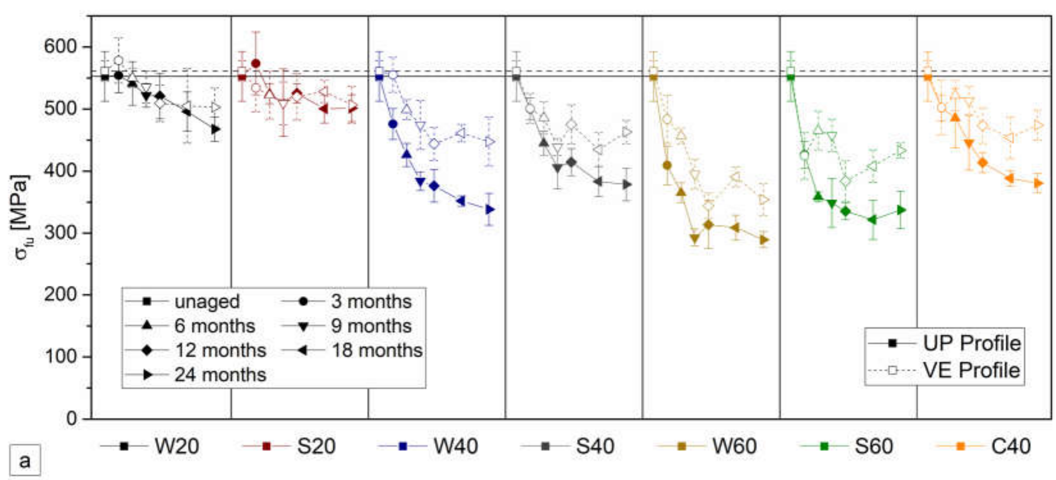


Figure 3. Flexural Strength retention for several ageing environments.

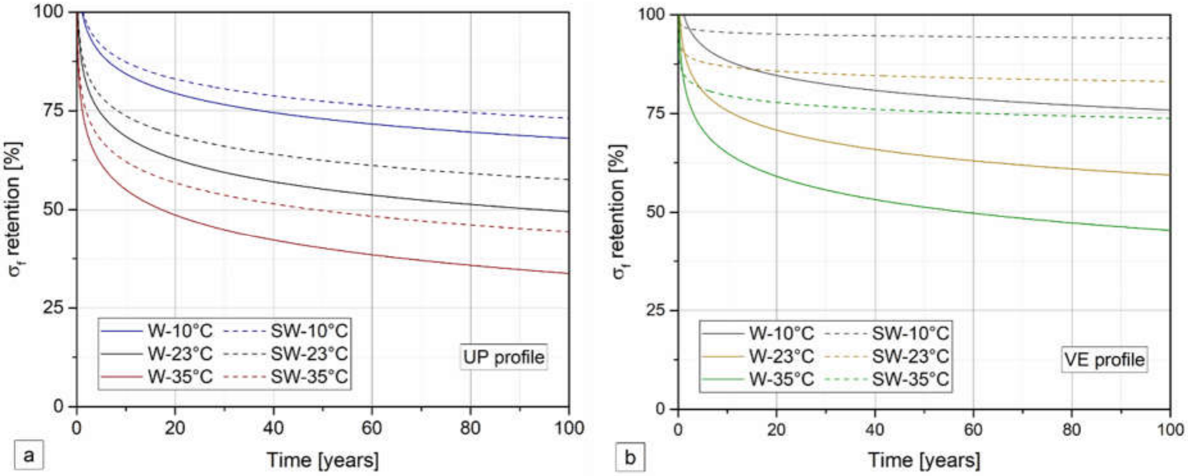


Figure 4. Flexural properties long-term prediction based on Arrehenius behaviour.

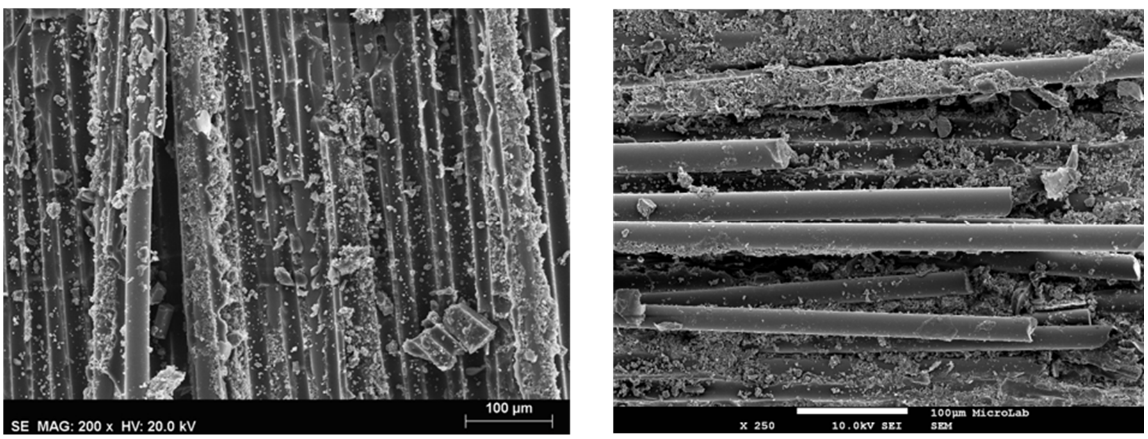


Figure 5. SEM micrograph of unaged (left) and aged (right) UP profile, after bending tests.

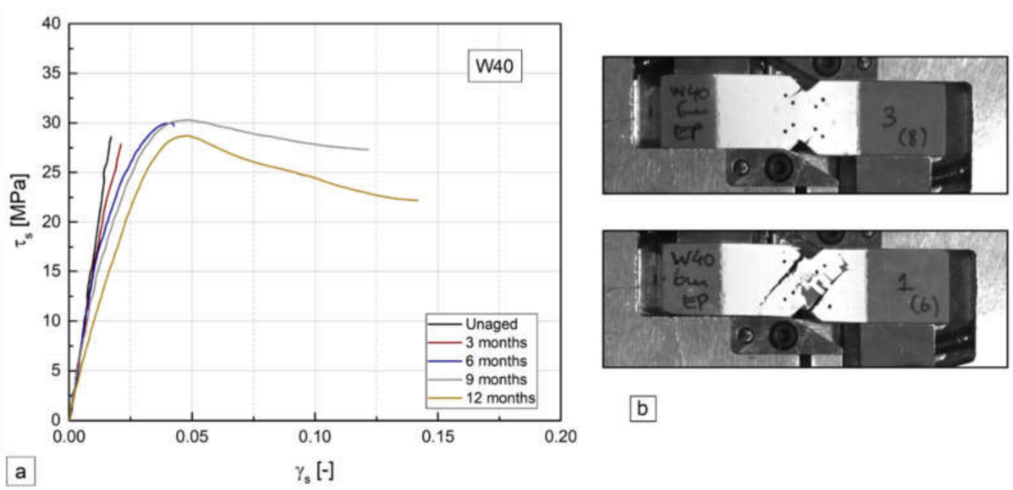


Figure 6. Epoxy structural adhesive shear response when subjected to ageing conditions.

Two different structural adhesives (epoxy and polyurethane) were experimentally studied regarding their durability. Although post-curing effects were observed, hygrothermal ageing had negative effects on both adhesives, causing irreversible degradation mechanisms, as seen in Figure 6. In a similar way as for the GFRP profiles, the effects of natural weathering were much less severe.

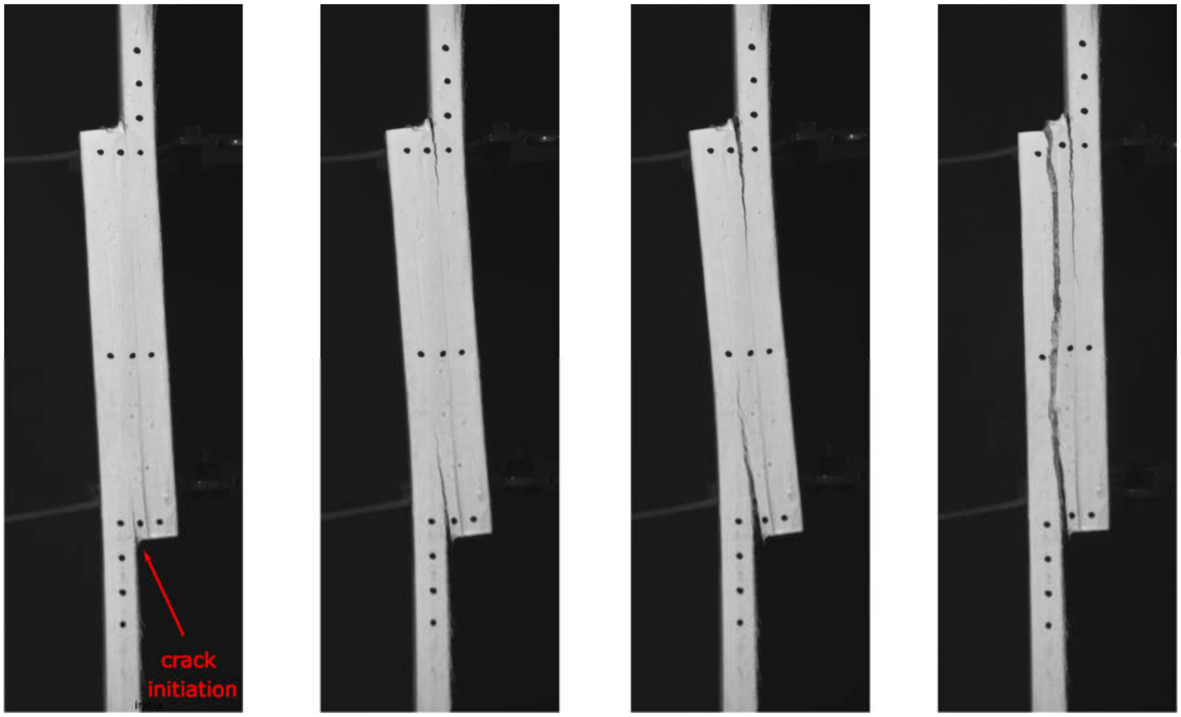


Figure 7. Single lap bonded joint specimen failure mechanism for both adhesives.

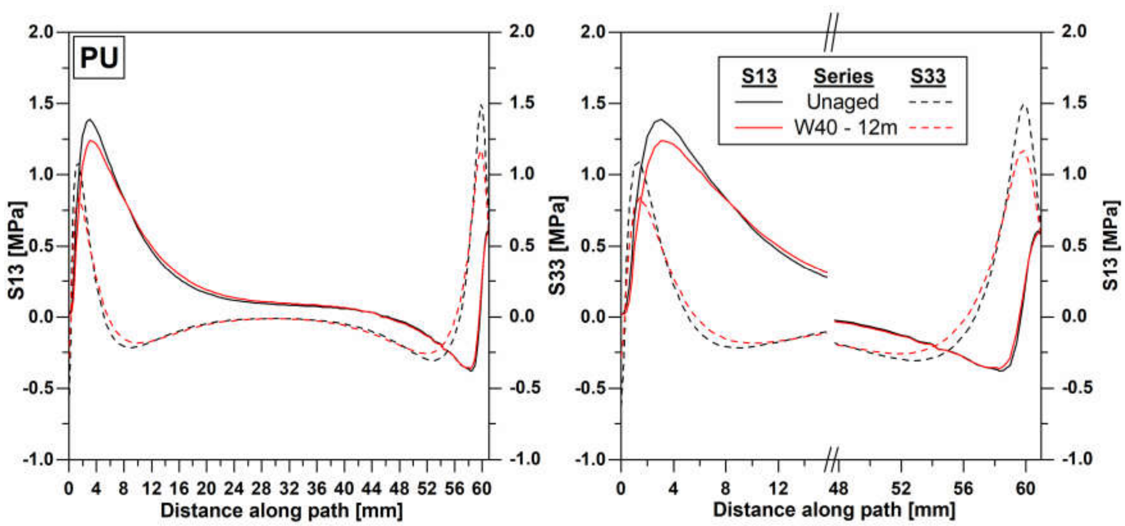


Figure 8. Stresses along the path for the PU adhesive: full path (left-hand side) and detail of peak zones (right-hand side) – FEM analysis.

Single lap bonded joints were produced with the above-mentioned adhesives and GFRP adherends, and exposed to similar ageing conditions, *i.e.* hygrothermal ageing, natural weathering and thermal cycles. The degradation of the mechanical performance of such joints, in terms of ultimate load and stiffness and failure mechanisms (Figure 7) and modes, was monitored during the exposure period. Alongside the experiments, numerical models were developed in order to simulate the tests and to obtain a better understanding of the mechanical behaviour of the bonded joints, including the effects of ageing, depicted in Figure 8. Both hygrothermal and thermal cycles caused detrimental effects on the joints' response and influenced their failure modes, while natural weathering produced smaller changes. Effects from post curing were also visible on the performance of such joints.

Regarding the case study of a 10-year-old GFRP construction, the visual inspection and the laboratory tests performed on the GFRP material and profiles extracted from the construction showed that its structural safety is presently largely fulfilled.

The results obtained in this thesis show that the degradation levels exhibited by pultruded GFRP profiles and their bonded connections, although relevant and needed to be duly accounted for at design, are compatible with their structural use in civil engineering applications.

Keywords: Glass fibre reinforced polymers (GFRP), pultrusion, structural adhesives, adhesively bonded joints, durability.

RC Columns Reinforced with FCCC-R: Axial Compressive Behavior and Seismic Performance

Zeyuan Wang

(Supervisor: Peng Feng)

(*Department of Civil Engineering, Tsinghua University, Beijing, China*)

In the present paper, a novel FRP confined concrete core-encased rebar (FCCC-R) is proposed as shown in Fig.1. The FCCC-R is composed of the high strength internal steel bar, the filled high strength concrete and outside FRP tube. For a single FCCC-R, The GFRP tube is light-weighted and can protect internal steel bar from corrosion in critical areas (e.g. plastic hinge area). The confinement effect of FRP tube is quite strong considering its high tensile strength in the hoop direction, which leads to a much better compressive performance of internal concrete. By equipping this component into RC columns, the axial compression ratio can be reduced and the ductility and load capacity of the hybrid column can be enhanced. Moreover, buckling of the internal steel bar can also be prevented by FCCC-R, which will prevent or postpone the low-cycle fatigue fracture of the longitudinal rebar and the column's final collapse. Based on the proposed component FCCC-R and corresponding composite column, a series of studies were carried out.

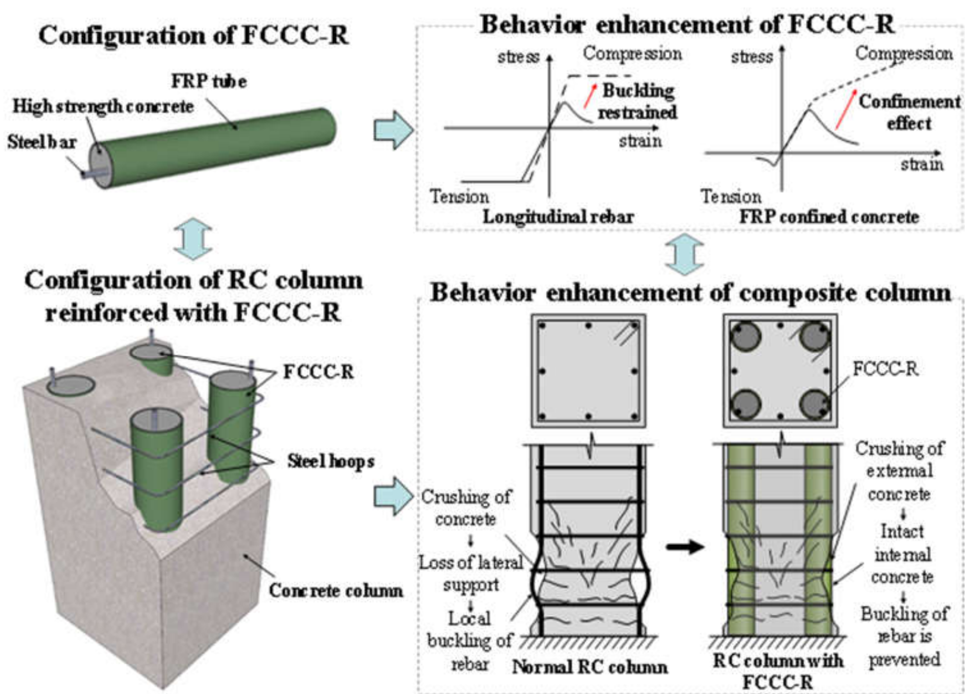


Fig.1. Configuration and mechanism of FCCC-R and corresponding composite column

For component FCCC-R, the mechanical behavior of the internal steel bar under axial compressive load was firstly studied. Test results indicated that the internal steel bar can reach its yield strength under compression even with a relatively large slenderness ratio for FCCC-R with proper section configuration. The final failure mode of the specimens generally illustrated cracks in FRP tube and filled concrete at mid-height region. The axial load-displacement relationship was also figured out, which illustrated a three-stage curve as shown in Fig.2. Among different parameters which affect the compressive behavior of internal rebar in FCCC-R, the slenderness and area ratio is two most critical issues. In this way, a detailed FE model of FCCC-R was established and the influence of the two parameters was further studied. Based on the principle that the yield of internal steel bar should be guaranteed, a simple design equation was finally proposed to calculate the minimum effective area ratio of FCCC-R.

Secondly, the axial compressive behavior of FCCC-R was studied by experimental study, numerical simulation, theoretical calculation, and simplified design methods. The axial strain-load behavior of FCCC-R under compression is obtained, which illustrated a similar shape as normal CFFT (concrete-filled FRP tube). However, due to quite large confinement stiffness of FCCC-R specimens, the traditional model for CFFT shows a large deviation in predicting the ultimate strength of the FCCC-R specimens. In this way, 56 test results of CFFT with large confinement stiffness (E_h>2000 MPa) was reviewed and summarized in this paper. Based on this database, the confinement model of Jiang and Teng (2007) was refined. The refined model shows a better agreement with the test results as shown in Fig. 3. And the compressive behavior of FCCC-R can be predicted used the refined model proposed in this paper.

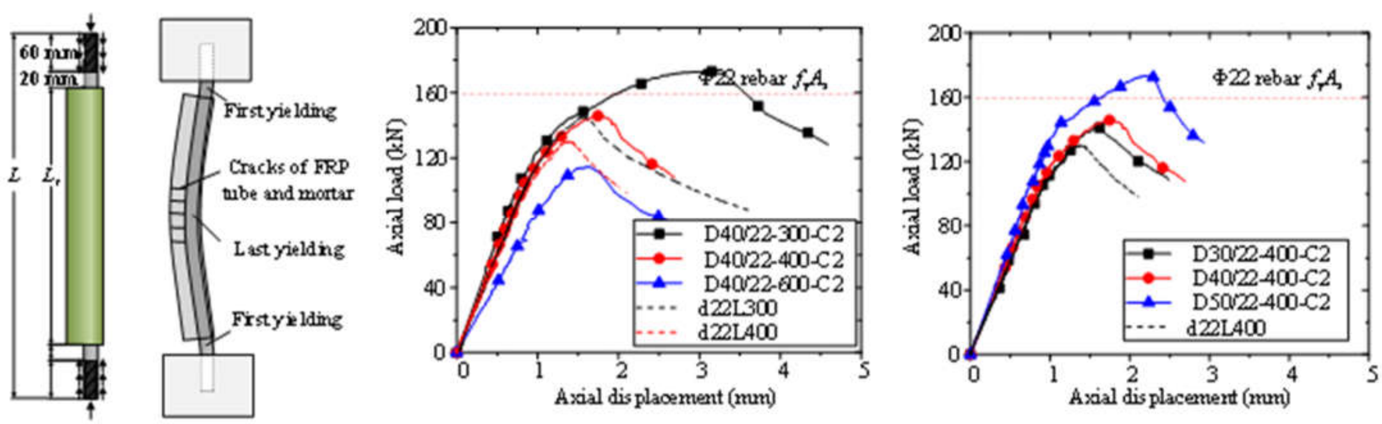


Fig.2. Configuration and mechanism of FCCC-R and corresponding composite column

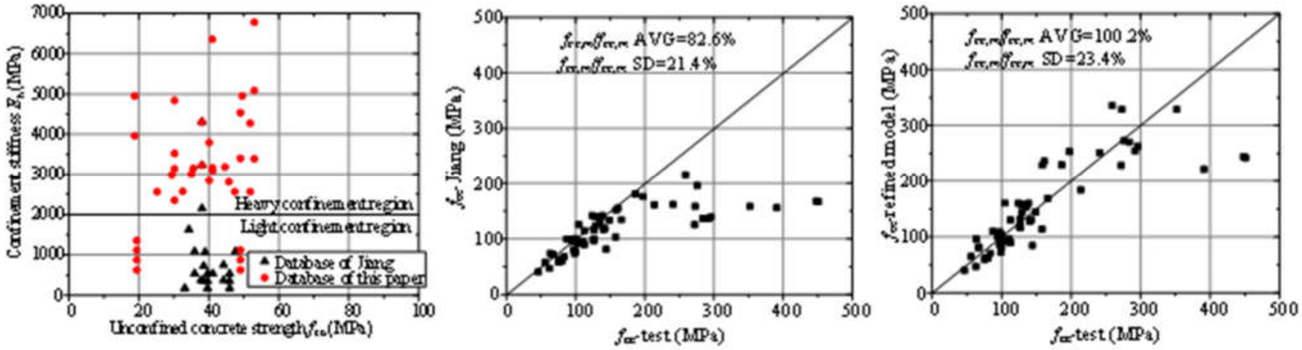


Fig.3. Configuration and mechanism of FCCC-R and corresponding composite column

For RC columns reinforced with FCCC-R, the mechanical behavior of the hybrid column under a cyclic axial compressive load and the seismic load was studied experimentally. The failure mode, failure procedure and different mechanical performance (i.e. load-displacement relationship, hysteretic behavior, load capacity, and ductility) were discussed.

For columns under axial compressive load, the buckling behavior of FCCC-R illustrates the great influence on the mechanical behavior of the hybrid column, as shown in Fig.4. The axial load-displacement curve of the composite column can illustrate a second ascending branch with proper section configuration. Besides, based on the strain development of different components in the column, the contribution of different materials were figured out. Since the buckling behavior of FCCC-R is the most critical failure mode of the composite column, which highly limits the axial load of FCCC-R. In this way, the influence of slenderness on compressive behavior of FCCC-R and the combination of section band method and Newmark method. And a simple calculation method based on the modified Euler equation was proposed in order to calculate the compressive behavior of FCCC-R. Finally, a simple superposition method was proposed in order to calculate the axial load-strain behavior of the column reinforced with FCCC-R.

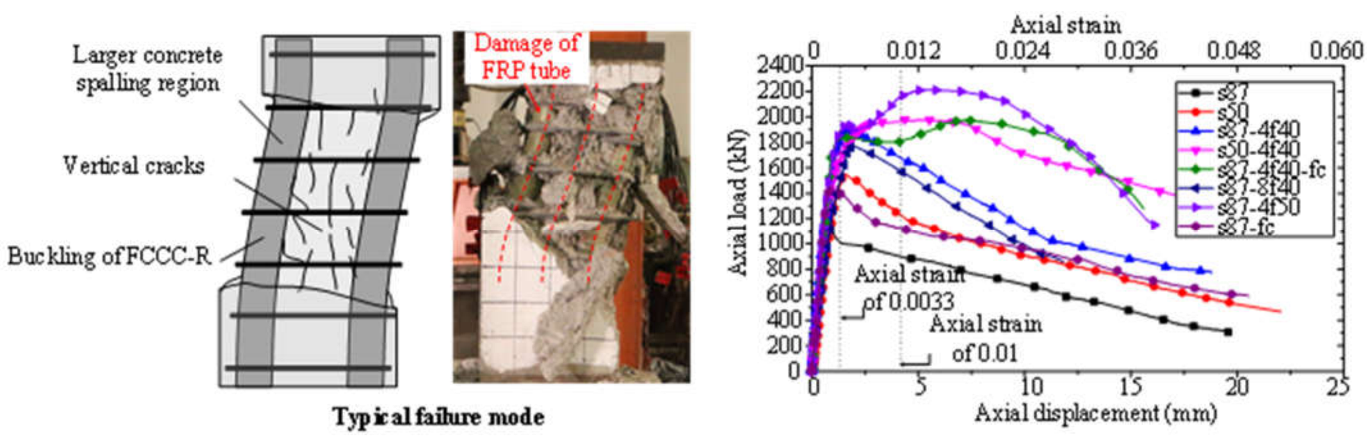


Fig.4. Configuration and mechanism of FCCC-R and corresponding composite column

For columns under combined constant axial and cyclic lateral load, the final failure mode and typical hysteretic curves are illustrated in Fig.5. Based on test results, lateral load capacity and ductility behavior of the column is enhanced by equipping FCCC-R component. Besides, columns reinforced with FCCC-R generally shows vertical cracks along with the columns' height due to the bond failure between FRP and external concrete. And the columns seismic behavior can be enhanced greatly if the bond behavior is enhanced by external FRP wraps. The compressive strength of concrete inside the FRP tube can be strengthened due to the confinement effect of FRP tube based on the strain development measured during the test. On the other hand, the lateral confinement effect of stirrups can be shared by the FRP tube, which prevents the stirrups from fracture and concrete core from severe crushing. The energy dissipation capacity and equivalent viscous damping ratio can also be enhanced by FCCC-R component. Besides, based on test results, FE analysis of columns with FCCC-R was carried out using software Opensees. Influence of different parameters including bond behavior, axial compression ratio, the strength of concrete and longitudinal rebar were analyzed and discussed.

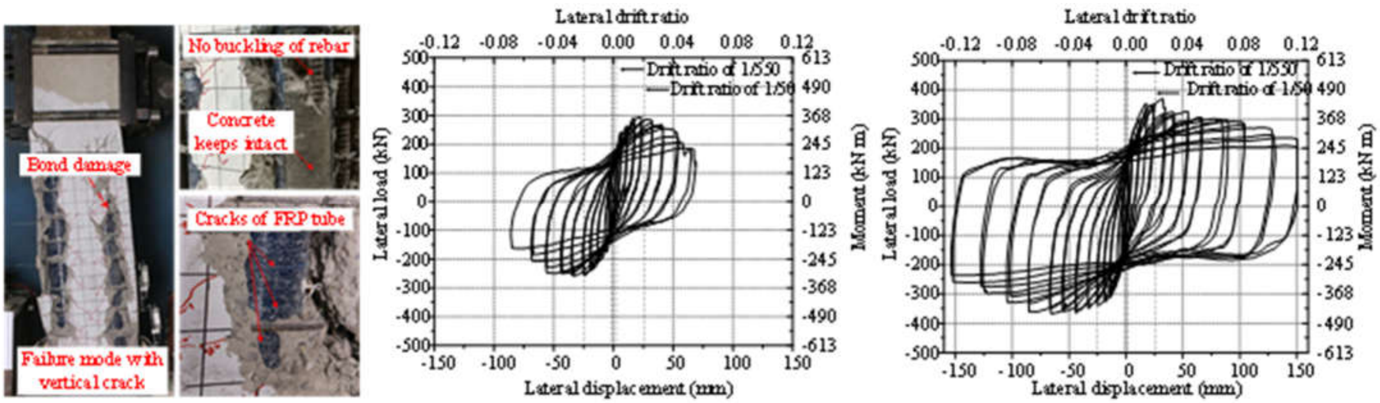
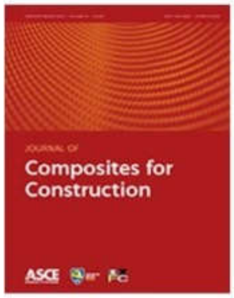


Fig.5. Configuration and mechanism of FCCC-R and corresponding composite column

Finally, based on the mechanical behavior of FCCC-R and the hybrid column, the design equations were proposed. *M-N* relationship of the hybrid column could be obtained by the proposed design equations. Besides, two ultimate conditions were used in the design procedure which are corresponding to the ultimate condition of unconfined and confined concrete, respectively. Influence of FRP confined concrete and bond behavior of FRP-concrete interface was also considered. According to the design method, the reinforcement effect of FCCC-R on *M-N* relationship of RC columns was illustrated and discussed. Finally, a simple design example was carried out in order to illustrate the influence of FCCC-R on the section dimension of RC columns.



ASCE Journal of Composites for Construction

The American Society of Civil Engineers (ASCE) Journal of Composites for Construction (JCC) is published with the support of IIFC. As a service to IIFC members and through an agreement with ASCE, *FRP International* provides an index of ASCE JCC. The ASCE JCC may be found at the following website:

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/

Volume 23, Issue 4. August 2019

Seismic Retrofit Schemes with FRP for Deficient RC Beam-Column Joints: State-of-the-Art Review

Daniel A. Pohoryles, Jose Melo, Tiziana Rossetto, Humberto Varum and Luke Bisby

A Recalibration of the Crack Width Bond-Dependent Coefficient for GFRP-Reinforced Concrete

Carol Shield, Vicki Brown, Charles E. Bakis and Shawn Gross

Combined Impressed Current Cathodic Protection and FRCM Strengthening for Corrosion-Prone Concrete Structures

Mei-ni Su, Liangliang Wei, Ji-Hua Zhu, Tamon Ueda, Guan-ping Guo and Feng Xing

Axial Behavior of Noncircular High-Performance Fiber-Reinforced Cementitious Composite Members Externally Jacketed by CFRP Sheets

Ugur Demir, Medine Ispir, Yusuf Sahinkaya, Giray Arslan and Alper Ilki

Experimental Study on CFRP-to-Steel Bonded Interfaces under Quasi-Static Cyclic Loading

Anchor Bolt Patterns for Mechanically Fastened FRP Plates

Brad C. McCoy, Zakariya Bourara, Rudolf Seracino and Gregory W. Lucier

Experimental Investigation of the Effectiveness of Hybrid FRP–Strengthened RC Columns on Axial Compression–Bending Interaction Behavior

Maheswaran Chellapandian, Shanmugam Suriya Prakash and Akanshu Sharma

Experimental and Analytical Approach for Prediction of Out-of-Plane Capacity of Reinforced Masonry Walls Strengthened with Externally Bonded FRP Laminate

Zuhair Al-Jaberi, John J. Myers and Mohamed A. ElGawady

Experimental Investigation of the Lateral Load–Carrying Capacity of a Developed GFRP-Reinforced TL-5 Bridge Barrier Using Special Profile Hooked Bars

Michael Rostami, Khaled Sennah and Ahmed Mostafa

A Simple Method for the Determination of the Bond-Slip Model of Artificially Aged Joints

Hugo C. Biscaia, Carlos Chastre and Manuel A. G. Silva

Influence of Resin Biocontent and Type on Bond Strength between FRP Wet Layup and Concrete

Anne McIsaac, Kenneth Mak and Amir Fam

Single Crack–Based Model for FRP Shear-Strengthened RC Beams

Cheng Chen and Lijuan Cheng

Novel Ductile FRP System for Concrete Reinforcement: Concept and Experimental Characterization

Wei Sun, Haifeng Liu, Mithila Achintha, Chunlin Pan and Tao He

Y. Doroudi, D. Fernando, V. T. Nguyen and J. P. Torres

Volume 23, Issue 5. October 2019

Performance of Eccentrically Loaded Reinforced-Concrete Masonry Columns Strengthened Using FRP Wraps

Hossam El-Sokkary and Khaled Galal

Influence of Anchor Size on Anchored CFRP Systems

Douglas Pudleiner, Wassim M. Ghannoum and James O. Jirsa

In-Plane Shear Characterization of Composite GFRP-Foam Sandwich Panels

Oludare E. Oluwabusi and Elias A. Toubia

Flexural Strengthening of RC Beams with Steel-Reinforced Grout: Experimental and Numerical Investigation

Luciano Ombres and Salvatore Verre

Effect of Temperature on Bond Behavior of Externally Bonded FRP Laminates with Mechanical End Anchorage

L. Correia, C. Barris, P. França and J. Sena-Cruz

Compressive Behavior of Brick Masonry Columns Confined with Steel-Reinforced Grout Jackets

Lesley H. Sneed, Giulia Baietti, Giacomo Fraioli and Christian Carloni

Experimental In-Plane Shear Capacity of Clay Brick Masonry Panels Strengthened with FRCM and FRM Composites

Marta Del Zoppo, Marco Di Ludovico, Alberto Balsamo and Andrea Prota

Shear Behavior Model for FRP-Confined and Unconfined Rubberized Concrete

Zhao Wang, Lin Chen, Maurizio Guadagnini and Kypros Pilakoutas

Bending Performance of Splice Connections for Assembly of Tubular Section FRP Members: Experimental and Numerical Study

Chengyu Qiu, Yu Bai, Lei Zhang and Li Jin

Transverse Static and Low-Velocity Impact Behavior of CFRP Wires under Pretension

Yawei Fang, Zhi Fang, Ruinian Jiang, Yu Xiang and Daobin Huang

Stochastic-Based Nonlinear Numerical Modeling of Shear Critical RC Beam Repaired with Bonded CFRP Sheets

Özgür Yurdakul, Onur Tunaboyu, Ladislav Routil and Özgür Avşar

FRP INTERNATIONAL
the official newsletter of the International Institute for FRP in Construction

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.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