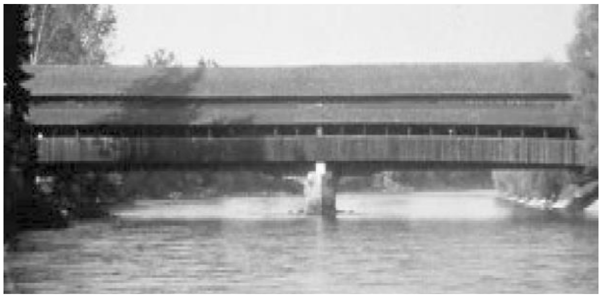
FRP INTERNATIONAL
the official newsletter of the International Institute for FRP in Construction
Vol. 10, No. 2, April 2013

20th Anniversary of *FRP International* and 10th Anniversary of IIFC

Twenty Years Ago…

The Spring 1993 (Vol. 1 No. 2) *FRP International* was introduced by Prof. Urs Meier of the Swiss Federal Laboratories for Materials Testing and Research (EMPA) in Zurich. Dr. Meier was already "an outstanding world recognized researcher in the field of advanced fibre reinforced plastic material for the last 20 years." Let me emphasize, this was the 'last 20 years' *in 1993*!

The article focuses on Meier's 1992 restoration of a 19th century two span wooden bridge in Sins, Switzerland. The bridge, originally only having to carry horse-drawn vehicles, permitted 20 tonne loads in 1992. Solid oak cross beams were reinforced with CFRP plates and, where visible, covered with a thin veneer of wood so as to preserve the historic fabric of the bridge.



Historic covered wooden bridge, Sins, Switzerland. Two 31 m spans constructed in 1807.

CFRP plates reinforcing oak floor beams (studs for strain measurement are seen in photo).

both images from: *Strengthening of Reinforced Concrete Structures - Using Externally-Bonded FRP Composites in Structural and Civil Engineering* (L.C. Holloway, editor), Woodhead Publishing, 1999.

The Spring 1993 issue also reported the longest GFRP bridge in the United States: the 50 foot (15.25 m) long pedestrian bridge at Devil's Pool in Fairmount Park, Philadelphia. Constructed by Creative Pultrusions and designed by E.T. Techtonics, the light weight of the bridge - only 2500 lb (1130 kg) - helped to minimise the cost ($25,000) and environmental impact of the structure.

Ten years ago *FRP* International was biannual, we'll return to the summer of 2004 in the next issue. All past issues of *FRP International* are posted in an archive at www.iifc-hq.org.

Devil's Pool bridge (photo: E.T. Techtonics).

FRP International
Fiber Reinforced Plastics
Spring, 1992 Volume 1, Issue 2

Guest Author Dr. Urs Meier

Restoration of a Historic Wooden Bridge with CFRP

Dr. Meier has been an outstanding world recognized researcher in the field of advanced fibre reinforced plastic material for the last 20 years. One of his recent achievements was the use of carbon fibre reinforced plastics in restoration of a historic two span wood bridge, in Sins, Switzerland. Built in 1807 to cross the Reuss River, each span is 30.8 meters, as shown in Figure (1). The bridge span on the Cham side was blown up on November 10, 1847, during the civil war and rebuilt in 1852 with a modified structural system different from the Sins side, as shown in Figure (2). The bridge was originally dimensioned for horse-drawn vehicles; today, vehicles with a load of 20 tons are permitted.

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In 1992, rehabilitation of the bridge consisted of replacing the old wooden pavement with 200 mm thick bonded wooden planks pretensioned transversely.

The cross girders were strengthened using carbon fibre reinforced epoxy resin sheets. Each of these cross girders was constructed of two solid oak beams placed on top of each other as shown in Figure (3). To increase the depth, wooden blocks were originally inserted between the two beams as shown in the same figure. The two different types of CFRP sheets used are given in Table 1.

Figure 1. Historic wooden bridge of Sins/Switzerland

(continued on page 2)

In This Issue

• American Concrete Institute • American Society of Civil Engineers • Canadian Society for Civil Engineering • Composite Institute • Japan Concrete Institute •

Spring 1993, Vol. 1, No.2

Invitation to APFIS 2013

Profs Riadh Al-Mahaidi, Xiao-Ling Zhao and Scott Smith
Co-Chairs of APFIS 2013

On behalf of the Asia-Pacific Conference on FRP in Structures (APFIS2013) Committee, it gives us great pleasure to invite all to APFIS 2013 in Melbourne, Australia from 13 to 15 December 2013.

Melbourne is a vibrant community, typical of many cities in Australia. It has a well-developed infrastructure and a network of roads and bridges which serve a growing demand from users, particularly freight and road-users. Its bridge engineers, who are faced with many maintenance and rehabilitation challenges, will benefit greatly from exposure to the experience and knowledge of international FRP researchers and practitioners.

APFIS 2013 promises to be intellectually engaging and socially enjoyable. The following six keynote speakers will provide perspectives beyond those normally covered within the APFIS series. They come from varying backgrounds and therefore promise to be thought provoking.

Prof .Zdeněk Bažant, Northwestern University, USA
Dr. Geoff Taplin, AECOM, Australia
Prof. Hui LI, Harbin Institute of Technology, China
Prof. Yiu-Wing Mai, University of Sydney, Australia
Prof. Alper Ilki, Istanbul Technical University, Turkey
Dr. Jian-Guo Dai, The Hong Kong Polytechnic University, Hong Kong

The conference will be held prior to the end of year summer festive season. You may therefore use this opportunity to spend time in and around Melbourne and the state of Victoria in Australia. You may also use the opportunity to travel to other parts of Australia such as Sydney, Canberra and the Gold Coast.

We look forward to welcoming APFIS2013 delegates to Melbourne in December 2013.

Melbourne is home to the Westgate Bridge. The city's iconic structure is also of primary importance to the national transportation network. The 38 approach spans of the bridge were recently retrofitted with FRP, making it the world's largest FRP retrofitting project [see *FRP International*, Vol. 8, No. 3; available online at www.iifc-hq.org]. The bridge currently services approximately 160,000 vehicles per day compared with only 40,000 vehicles when it opened 30 years ago, with future predictions indicating escalating demands expected. The increased traffic volume is accommodated by the introduction of two additional lanes through the main carriageway to carry peak hour traffic. The retrofitting comprised of nearly 40 km of carbon fibre laminates along with 11,000 sq. m of carbon fibre fabric applied to the structure.

CICE 2012 Proceedings available on IIFC website

The complete Proceedings of CICE 2012 are now available on the IIFC website: www.iifc-hq.org.

All proceedings of IIFC-sponsored conferences presently archived on the IIFC website are:

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

This article is a submission to FRP International *describing the development of an all FRP building system.*

STARTLINK **Lightweight Building Systems – Wholly Polymeric Structures**

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The *Startlink Lightweight Building System* is being developed by a consortium of companies, with additional funding from the Technology Strategy Board (UK), and aims to revolutionise house building. Startlink is a pultruded glass reinforced composite component kit which can be rapidly assembled into a wide variety of low-rise building forms without metal fastenings. Sections are mostly hollow and can be filled with insulation where necessary; therefore thermal bridging is virtually eliminated. The Startlink system is stable, inert and impervious to moisture, requiring only the addition of insulation. The inherent dimensional stability of pultruded profiles means that air-tightness is easily achieved. It is intended that both *Passivhaus* and *Sustainability Code 6* specifications for overall thermal resistance and air-tightness will be met by the external envelope of the prototype Startlink house. With appropriate insulation, the Startlink house has lower embodied energy than a timber frame building, avoids site waste and reduces shipping and assembly costs due of its light weight.

Lightweight houses are easier to build and heat but lack thermal mass to even out summertime temperatures. The Startlink solution is to use a 'green' roof which retains water for evaporative cooling and to engage the thermal mass of the ground below. The low-maintenance system offers the possibility of extremely energy efficient housing.

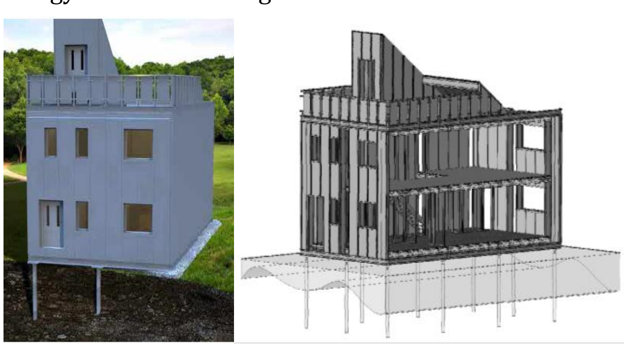

Figure 1. Schematic views of Startlink homes.

Pultruded GFRP Materials for Housing Construction

Although composites have been used in building construction for over forty years, relatively little is known within the industry about the superior properties and structural performance of pultruded glass reinforced (GFRP) profiles. Pultruded GFRP has almost twice the strength-to-weight ratio of mild steel and about five times the strength-to-weight ratio of reinforced concrete. Pultrusion optimises the fibre-matrix ratio, which has the effect of stiffening the composite. The value for Young's Modulus can be as high as 45 GPa for unidirectional profiles and typically 23 GPa or 17 GPa for specifically designed structural profiles. The comparable figure for conventional GFRP is between 7 and 10 GPa. Softwood suitable for structural applications has a modulus of between 7 and 11 GPa.

Pultruded GFRP is electrically insulating, an intrinsically good thermal insulator, and is acoustically absorbent and attenuates the passage of structure-borne sound. It is mostly impermeable to both liquid water and to vapour (although there is some absorption by the polymer matrix) and is resistant to 'freeze thaw' effects. It can be confidently asserted that pultruded GFRP is a highly competent engineering material, capable of being specified for a large number of building construction applications; not least components for house building in rural areas.

Building construction is a complicated but often wasteful process. Waste and off-cuts from materials used on site are seldom recycled (at least in the UK). On site construction tends to be chaotic unless the standard of site management and supervision is of the highest order. Site confusion and disorderliness gives rise to wasteful practice. In the UK, construction waste contributes 20-25% of the total solid waste stream. If building processes were to be off site to the more controlled conditions of a factory, the standards of supervision and quality control will improve, which would have the effect of significantly reducing waste.

Another means of reducing waste is to construct modular buildings in which all the parts are pre-designed and fabricated to fit neatly together without cutting. Modular construction is far more suited to factory mass-production. If an entire building can be made as a kit of parts to fit onto a low-loading truck, unlike conventional building construction, there need only be a minimal number of deliveries to site by means of large vehicles consuming hydrocarbon fossil fuel.

The embodied energy in pultruded GFRP is similar to or slightly higher than that of mild steel (approximately 35 and 59 MJ/kg) or reinforced concrete (as high as 30 MJ/kg) when measured by weight. Pultruded GFRP has approximately 54 MJ/kg, although being much lighter and less dense has the effect of greatly reducing the embodied energy in a structure made from it.

The lightness of pultruded GFRP structures reduces the structure's self-weight which, in turn, reduces the quantity of material needed to make the building. Lightweight buildings consume far fewer resources and non-renewable energy in their construction than heavy ones. Lightweight buildings are much easier and less energy demanding to heat in winter since less energy is wasted in heating a massive structure. Similarly, there is no heavy structure to become heated as a result of summertime solar gain. No mechanical cooling is required to remove heat from massive building elements.

Pultruded GFRP buildings can be made to be air tight and vapour tight without the need to install vapour control layers, air sealing mastics in joints or 'breather' membranes behind rain-screen elements. There is no need for rain-screening, because the material is, in most respects, resistant to the passage of water (although a polymer matrix will absorb some moisture). The only additional item required is a layer of insulation between the two construction leaves, which is a necessity for any well insulated, energy saving building, regardless of construction. The resulting simplicity of the building envelope saves time and energy in the construction process.

The dimensional stability of pultruded GFRP has the effect of eliminating the possibility of air infiltration at joints between panels and window/door frames. Hygrothermal-induced differential movement in conventional building systems imposes stress on joints and an attendant risk of rupture or fatigue failure of sealing tapes or mastic sealants resulting in infiltration. For the best possible results, it is recommended to specify pultruded GFRP window and door frames, thus ensuring materials compatibility between the panels and the frames.

The greatest potential for energy saving is below ground. Because pultruded GFRP is so light, mass concrete foundations are not required. Instead, a Startlink building would be best supported on pultruded GFRP piles driven or, if threaded during pultrusion, screwed into the ground beneath the building to a depth determined by bearing requirements. The quantities of raw materials and energy required to construct the foundation of a Startlink are therefore a tiny fraction of those required in a conventional building.

STARTLINK - Energy Efficient Housing Project

The objective of the Startlink consortium was to develop energy-efficient, low cost housing that is rapid to build, by developing a family of lightweight pultruded fire-resistant GFRP profiles and innovative labour-saving assembly techniques. The consortium represents the complete supply chain brought together to deliver high quality, market oriented results and enhance the sustainability and global competitiveness of the UK composites industry. This research work is co-funded by Technology Strategy Board's - Low Impact Building Innovation programme and includes six partners; Costain PLC., Larkfleet Homes Ltd., Odour Control Systems Ltd., John Hutchinson (Architect), Warwick University, and Exel Composites (UK).

Technical Approach

The technical approach was based upon developing a 'global analysis' of the Startlink house. This included the preparation of the initial designs and joining details for analysis along with assessment of the requirements of manufacturing, materials, processing and assembly. Research and development, along with design considerations, allowed engineering solutions for a system of connections and profile material specifications to be developed.

Once the design had been ratified, the design and manufacture of the pultrusion tooling and reinforcement guidance for trial profile production began. Pultruded profiles for the house construction started in early May 2011. Load test and characterisation of the profiles for sub-assemblies will be completed as the materials are manufactured. Fabrication drawings and method statements will also be prepared in anticipation of the main off-site manufacturing processes.

Following basic ground preparation, composite piles will be positioned and set to carry the Startlink house which will be assembled in accordance with the method statements developed. A turf roof and energy saving technology will be incorporated into the construction. Video monitoring of all stages of prototype construction will produce feedback to further refine the processes for future developments beyond the programme. Environmental assessment, SWOT analysis and through life costs of the system and construction process will also be carried out.

Design

The Startlink house is designed to sit on a composite pile system, which has been specifically developed for the project (seen in Fig. 1). The floor beams arrive on site in singular modular panel systems, which can be readily attached to the main ground and interlocked with adjacent floor panels. This allows for a rapid installation program of the entire ground floor system. The interlocking is completed by a bridging channel as shown in Fig. 2.

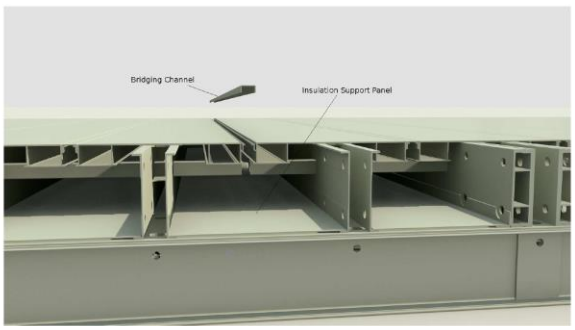

Figure 2. Ground floor beams in position, completed by bridging channel.

The wall panels arrive on site in modular form ready for positioning onto the base frame ring beam, these are locked into position with a locking pin system (Fig 3). The sequence of the build allows the lower floors to be installed with the necessary insulation in place, this is followed by the installation of the side walls as shown in Fig. 4.

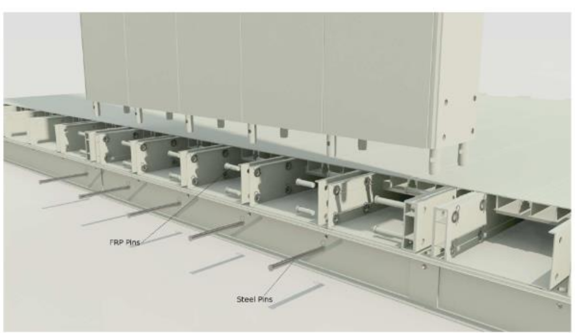

Figure 3. Outer wall panels installed using locking pins.

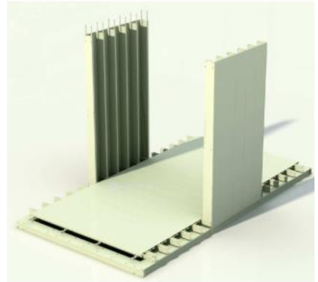

Figure 4. Outer wall panels in position.

Figure 5. Outer wall panels and first floor.

The build continues with the middle floor and side wall, temporary stabilization being used where necessary. Figure 5 shows the side walls and first floor level installed. Figure 6 illustrates the inner walls before the insulation is fitted. In the prototype house, the insulation will be added during the 'fitting out' stage; in future projects it is anticipated that the insulation will be added during the 'offsite build' stage. The build continues until all the side walls, end walls, first floor and rooftop floors are in place (Fig. 7).

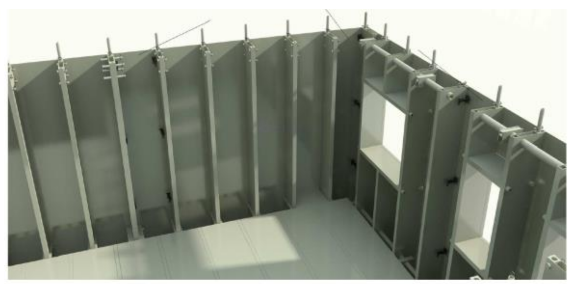

Figure 6. Inner wall section before fitting insulation.

Figure 7. Main side walls, end walls and roof panels.

Infill panels are then put into position which completes the main house outer structure. Once completed, the internal fit out will begin, which includes the insulation, internal panel system, electrics, fixtures and fittings, stairways etc. Figure 8 shows a schematic view of the lower stair system. Once the insulation and electrical work is completed the inner walls will have their linings fitted.

Figure 8. Schematic of the lower staircase.

Space heating will be mechanically linked to an electric powered heat exchanger/ventilation fan located at roof level. Extraction is from the upper floor bathroom, input is to the living room through a *Passivhaus* compliant inlet. Internal door frames are modified to permit air flow through the house. Incoming air heating, when needed, is achieved by means of an air heat pump.

The final section of the house to be completed will be the 'green roof'. Green roofing has become increasingly popular as they include rich vegetation that not only provides an additional green space but also attracts wildlife including butterflies, honeybees and other insects as well as birds that are otherwise rarely seen. The 'green roof' will consist of plants and vegetation that is resistant to weather effects and requires little or no irrigation. Native, hardy, pest- and disease-resistant plants will be utilized. In addition to collecting rainwater, plants on rooftops also absorb the heat which keeps the building warmer during cold winter months, while the growing medium helps keep the building cooler during hot summer months. Green roofs have been shown to reduce the costs for cooling and heating for as much as 50 percent offering major financial benefits to building owners. Another major advantage is green roofs over conventional roofing is absorption of air pollutants including carbon dioxide by the plants.

Conclusion

Pultuded GFRP is potentially the most energy efficient, low cost, structurally competent building material available for construction use. The Startlink Lightweight Building System is a modular building system of great elegance and simplicity. The combination of these two elements offers the possibility of constructing energy efficient buildings quickly and cost effectively. The fully operational prototype house is located at the head offices of the Larkfleets Group – Bourne, Lincolnshire.

Figure 9 Prototype Startlink home.

References

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Useful Links

Passivhaus Standard
http://www.passivhaus.org.uk

Code for Sustainable Homes
www.breeam.org

Technology Strategy Board Low Impact Buildings
www.innovateuk.org

Network Group for Composites in Construction
www.ngcc.org.uk

Building Research Establishment
www.bre.co.uk

National House Building Council
www.nhbc.co.uk

[copy edited by Kent A. Harries]

Upcoming Conferences and Meetings

Innovative Composites Summit Asia 2013, June 25-27, 2013, Singapore. www.jeccomposites.com.

11th International Symposium on Fiber Reinforced Polymer for Reinforced Concrete Structures (FRPRCS-11), June 26-28, 2013, Guimarães City, Portugal. www.frprcs11.uminho.pt

Revised Papers due: March 31, 2013

2nd Conference on Smart Monitoring, Assessment and Rehabilitation of Civil Structures, September 9-11, 2013, Istanbul, Turkey. www.smar-2013.org

Early Registration ends April 30, 2013

ACIC 2013 *6th Advanced Composites in Construction,* September 10-13, 2013, Belfast, UK. www.acic-conference.com

Papers due: April 1, 2013

Innovative Composites Summit Americas 2013, October 2-4, 2013, Boston, USA. www.jeccomposites.com.

APFIS 2013 *4th Asia-Pacific Conference on FRP in Structures,* December 11-13, 2013, Melbourne Australia. www.apfis2013.org

Papers due: May 1, 2013

CICE 2014 *7th International Conference on FRP Composites in Civil Engineering*, August 19-22, 2014, Vancouver, Canada. relhacha@ucalgary.ca

Abstracts due: May 1, 2013

CICE 2016 *8th International Conference on FRP Composites in Civil Engineering*, June 2016, Hong Kong.

IIFC requests your input...

In an effort to better serve IIFC membership, the IIFC Executive Committee is asking all IIFC members and readers of *FRP International* to complete a brief survey addressing the utility of FRP International and the IIFC website: www.iifc-hq.org. We ask that you take three minutes of your time to complete the online survey located at:

http://www.surveymonkey.com/s/FB8WBV7

Innovative Research and Products

Mechanical Behaviour of Ultra High-Performance Fibrous-Concrete wood panels Reinforced by FRP Bars

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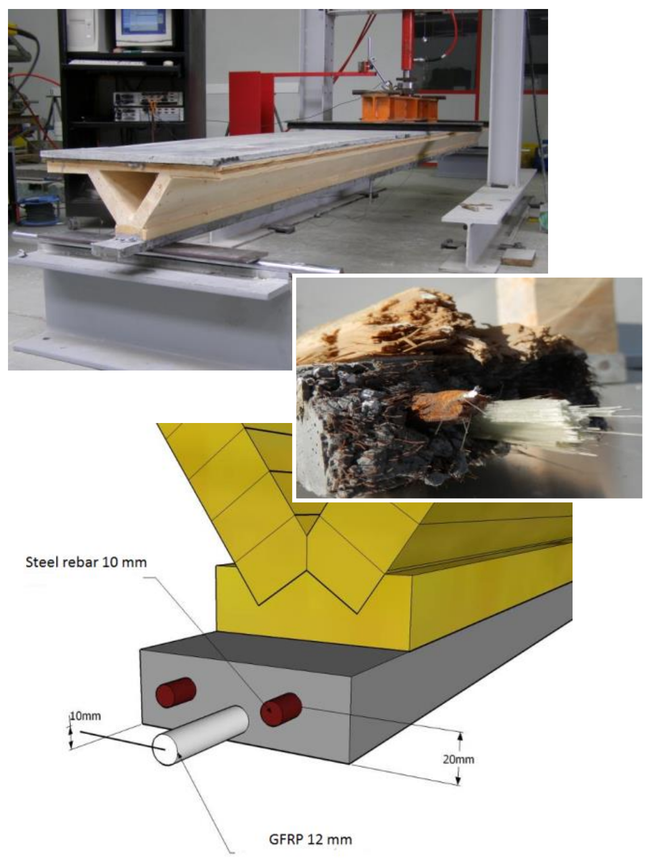
Dr. Michel Laurent, Université Lyon 1, France laurent.michel@univ-lyon1.fr

The objective of this research project is to develop a new hybrid glulam panel that will increase the performance of timber structures and optimize the use of wood in such structures. The hybrid panel is made by combining glulam with ultra-high performance short fiber reinforced concrete (UHPC-SFR) planks with or without internal reinforcement consisting of steel or fiber-reinforced polymer (FRP) reinforcing bars. This research presents an experimental program of tests on seven large-scale hybrid panels under four-point bending. The results show that by combining wood and UHPC-SFR, it is possible to obtain a hybrid panel with greater bending stiffness and increased ultimate load capacity. A WIPO patent application was submitted in 2010.



Test set-up (top), tension flange detail (bottom) and tension flange failure (inset).

Innovative Research and Products

Innovative Hybrid Beam

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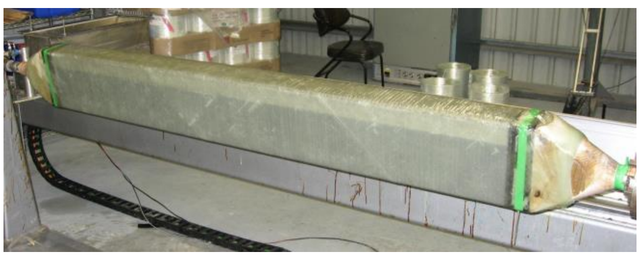
The hybrid beam consists of a pultruded GFRP profile, a concrete block in the compression zone, and a CFRP laminate in the tension zone. The whole system is confined with a wrapping consisting of external filament winding to ensure composite action between the GFRP box and the concrete block.

To address the inherent lack of stiffness of hybrid beams, the CFRP laminate is not designed to fail first in order to give a warning of imminent failure. Instead, its primary role is to provide the required stiffness for the beam. As such, there is no upper limit on its thickness. The stiffness of the beam can be therefore tailored. The warning of imminent failure is achieved through the crushing of the concrete.

With fibres oriented at $\pm 45^{o}$, the filament-wound outer laminate serves an additional purpose. It enhances the shear strength of the pultruded profile, which has fibres predominantly in the longitudinal direction.



Filament-wound hybrid beam.

FRP International needs your input...

As IIFC grows, we also hope 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 are also soliciting short articles of all kinds: research or research-in-progress reports and letters, case studies, field applications, or anything that might interest the IIFC membership. Articles will generally run about 1000 words and be well-illustrated. Additionally, please utilize *FRP International* as a forum to announce ***innovative research activities or products*** of interest to the membership. Submissions may be sent directly to the editor at kharries@pitt.edu.

UHPC-Filled FRP Tubes

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Advanced materials such as fiber-reinforced polymer (FRP) composites and ultra-high performance concrete (UHPC) have received much attention in the construction industry. FRP composites provide high strength-to-weight and stiffness-to-weight ratios, and excellent electrochemical corrosion resistance. Application of FRP tubes as stay-in-place formwork, protective jackets, confinement devices, and shear and flexural reinforcement in concrete-filled FRP tubes (CFFT) has been shown to simplify and accelerate the construction process and improve the durability and performance of the system. On the other hand, a moderate amount of longitudinal steel reinforcement was found necessary to provide adequate strength and ductility for CFFT systems in earthquake prone regions. Given the excellent properties of UHPC, such as ultra-high compressive strength and modulus of elasticity and usable tensile strength, replacing conventional concrete with UHPC in a CFFT system may allow eliminating the longitudinal steel reinforcement, while producing the same earthquake resistance as that of a conventional RC column. Therefore, a steel-free novel hybrid column system in which the FRP tube is filled with UHPC within the plastic hinge zone and conventional concrete for the remainder of the column was developed. A series of quarter-scale bridge columns, including five novel UHPC-filled FRP tube (UHPCFFT) columns with different cross sections, types of FRP tubes, and reinforcement ratios, as well as a reference steel-reinforced concrete (RC) column, were constructed and tested under cyclic loading. The results showed that the proposed UHPCFFT column has more earthquake resistance as compared to conventional reinforced concrete columns, while no steel reinforcement is used in this system.

Cyclic Testing of a UHPC-Filled FRP Tube

Innovative Research and Products

In-plane seismic capacity of a perforated masonry wall before and after external strengthening with an inorganic matrix-grid system

Drs Fulvio Parisi , Nicola Augenti, Andrea Prota and Gaetano Manfredi, University of Naples Federico II, Italy

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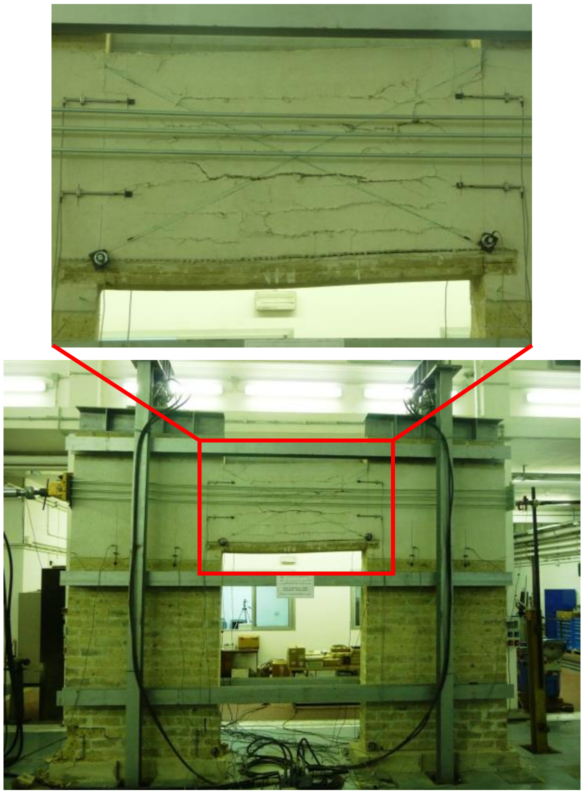
A full-scale tuff masonry wall with an opening was tested under in-plane lateral loading in as-built, pre-damaged and repaired conditions to assess: (1) the influence of spandrels (i.e., the horizontal components which connect piers) on the in-plane seismic capacity; (2) the effectiveness of an inorganic matrix-grid (IMG) strengthening system in increasing the energy dissipation capacity of the spandrels (Augenti *et al*. 2011). The as-built masonry specimen was first subjected to monotonically increasing lateral displacements until diagonal shear cracking was observed in the spandrel. The pre-damaged masonry specimen was then tested cyclically until the lateral drift reached approximately the same value attained during the monotonic test. At that drift level, diagonal cracks were again observed in the spandrel. Finally, the masonry wall was repaired by filling cracks with mortar and upgraded by applying the IMG system to both sides of the spandrel. The third in-plane lateral loading test was carried out on the IMG-strengthened masonry wall up to a lateral drift equal to 2.5% (near-collapse state). The failure mode of the IMG-upgraded spandrel panel changed from brittle diagonal shear cracking to ductile horizontal uniform cracking, producing a 17% increase in the lateral load-carrying capacity of the wall.

Nonlinear finite element analyses and a simplified analytical model (Parisi *et al*. 2011) demonstrated that the change in the failure mode of the spandrel panel and the increase in the load-bearing capacity of the wall were provided by the IMG strengthening system. The transition from diagonal cracking to horizontal cracking was allowed by the significant increase in shear capacity of the spandrel, according to diagonal compression tests (Parisi *et al*. 2013). Furthermore, the IMG-strengthened wall suffered only 15% strength degradation at 2.5% lateral drift – a drift level that was more than twice that achieved in the as-built and pre-damaged specimens. A bilinear idealisation of the experimental force–displacement curve related to the IMG-strengthened wall evidenced a displacement ductility, overstrength and strength reduction factor significantly higher than those provided by seismic codes. Finally, the IMG strengthening system was found to be fully reversible, so it also meets worldwide restoration principles which are mandatory for cultural heritage structures.



Masonry wall at 2.5% lateral drift showing deflection and damage of IMG-strengthened masonry spandrel.

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Augenti, N., Parisi, F., Prota, A., and Manfredi, G. (2011) In-plane lateral response of a full-scale masonry subassemblage with and without an inorganic matrix-grid strengthening system. *ASCE Journal of Composites for Construction* **15**(4), 578–590.

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Parisi, F., Iovinella, I., Balsamo, A., Augenti, N., Prota, A. (2013) In-plane behaviour of tuff masonry strengthened with inorganic matrix-grid composites. *Composites Part B* **45**, 1657–1666.

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/

***ASCE Journal of Composites for Construction*, Volume 17, No. 1, pp 1-165. February 2013.**

Punching Shear Resistance of Interior GFRP Reinforced Slab-Column Connections

Long Nguyen-Minh and Marián Rovňák

Anchorage Devices Used to Improve the Performance of Reinforced Concrete Beams Retrofitted with FRP Composites: State-of-the-Art Review

R. Kalfat, R. Al-Mahaidi, and Scott T. Smith

Characterization of Mechanically Enhanced FRP Bonding System

Yu-Fei Wu and Kang Liu

Shear Strength Model for FRP-Strengthened RC Beams with Adverse FRP-Steel Interaction

G. M. Chen, J. G. Teng, and J. F. Chen

Factors Affecting the Ultimate Condition of FRP-Wrapped Concrete Columns

J. F. Chen, S. Q. Li, and L. A. Bisby

Shake Table Tests on FRP-Rehabilitated RC Shear Walls

H. El-Sokkary, K. Galal, I. Ghorbanirenani, P. Léger, and R. Tremblay

Reliability Assessment of FRP-Strengthened Concrete Bridge Girders in Shear

Ayman M. Okeil, Abdeldjelil Belarbi, and Daniel A. Kuchma

Use of Anchors in Shear Strengthening of Reinforced Concrete T-Beams with FRP

L. Koutas and T. C. Triantafillou

Flexural and Shear Behavior of Reinforced Concrete Members Strengthened with a Discrete Fiber-Reinforced Polyurea System

Courtney E. Greene and John J. Myers

Bond Characteristics of Various NSM FRP Reinforcements in Concrete

Dongkeun Lee, Lijuan Cheng, and Jason Yan-Gee Hui

Novel Joint for Assembly of All-Composite Space Truss Structures: Conceptual Design and Preliminary Study

Yu Bai and Xiao Yang

Global Restraint in Ultra-Lightweight Buckling-Restrained Braces

Peter Dusicka and John Tinker

Axial Compressive Behavior of Square and Rectangular High-Strength Concrete-Filled FRP Tubes

Togay Ozbakkaloglu

Discussion of *"Design Approach for Calculating Deflection of FRP-Reinforced Concrete" by Peter H. Bischoff and Shawn P. Gross*

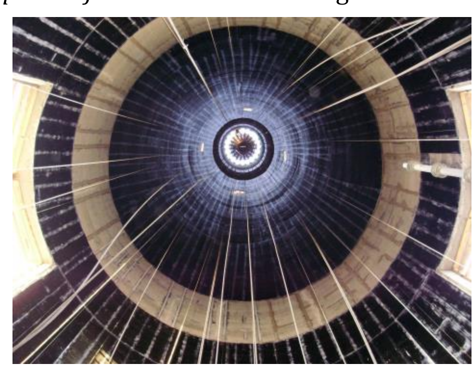
Hayder A. Rasheed and Quinn M. Jacobs

Closure to *"Design Approach for Calculating Deflection of FRP-Reinforced Concrete" by Peter H. Bischoff and Shawn P. Gross*

Peter H. Bischoff and Shawn P. Gross

Congratulations to Structural Technologies, LLC.

Their 2012 IIFC Photo Competition winning entry will be featured on the cover the *ASCE Journal of Composites for Construction* throughout 2013.



Installation of 11,000 m^2 of CFRP sheets in a 140 m high chimney for seismic flexural strengthening.

Recent Dissertations

Analysis of Time-dependent Flexural Behaviour of Concrete Members Reinforced with Fibre Reinforced Polymer Bars

Cristina Miàs, PhD (2012)
AMADE, Universitat de Girona, Spain

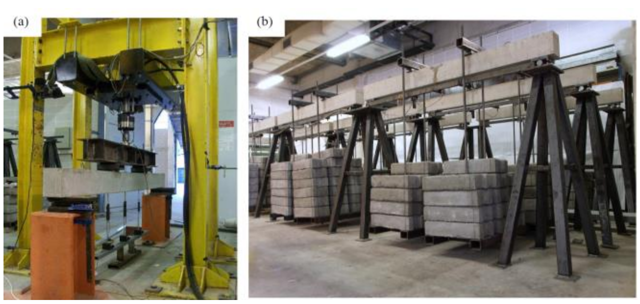
advisors: Drs Lluís Torres and Albert Turon

http://www.tdx.cat/handle/10803/96914

In the past two decades, a large number of research programmes focussed on short-term flexural behaviour of fibre reinforced polymer (FRP) reinforced concrete members have been carried out. However, the number of studies on the long-term behaviour is still scarce.

In this thesis, long-term behaviour of FRP reinforced concrete beams has been investigated both analytically and experimentally to further extend the knowledge in this research domain. In this respect, a methodology to predict long-term deflections due to creep and shrinkage based on rational multiplicative coefficients deduced from general principles of structural mechanics has been developed. Being simple and straightforward, the proposed methodology accounts for the main mechanical properties of materials, variations in environmental conditions and other parameters that can affect creep and shrinkage of concrete.

In addition, an experimental campaign on two series of GFRP reinforced concrete beams subject to long-term loading was performed. Different reinforcement ratios, concrete strengths and sustained load levels were considered. For comparison purposes, steel reinforcement has also been used. The experimental long-term results are reported and discussed. Furthermore these are compared to predictions using the most representative procedures, as well as the proposed methodology presented in this work.



Experimental set-up for (a) short-term loading tests and (b) sustained loading tests.

IIFC encourages the announcement of recently completed theses and dissertations in FRP International*. Announcements should conform to the format shown and be sent directly to the editor at* *kharries@pitt.edu*.

FRP International needs your input...

As IIFC grows, we also hope 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 are also soliciting short articles of all kinds: research or research-in-progress reports and letters, case studies, field applications, or anything that might interest the IIFC membership. Articles will generally run about 1000 words and be well-illustrated. Additionally, please utilize *FRP International* as a forum to publish ***abstracts from newly-published PhD dissertations*** of interest to the membership. Submissions may be sent directly to the editor at kharries@pitt.edu.

IIFC ExCOM members on the move...

Three IIFC ExCOM members have recently taken new academic positions:

IIFC Senior Vice President, Prof. Jian-Fei Chen, has taken a Professorship of Civil and Structural Engineering at Queen's University Belfast, UK.

IIFC Vice President, Prof. Scott T. Smith, is now Foundation Professor and Dean of Engineering at Southern Cross University in Lismore, NSW, Australia.

ExCOM Member-at-large, Prof. Laura De Lorenzis has taken a Professorship in the Institut für Angewandte Mechanik of the Technische Universität Braunschweig, Germany.

On behalf of the entire IIFC community, we congratulate Jian-Fei, Scott and Laura and wish them all success in their new positions.

International Institute for FRP in Construction

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