FRP INTERNATIONAL

the official newsletter of the International Institute for FRP in Construction

Vol. 8, No. 3, July 2011

Editor's Note – Chock Full O' Case Studies

West Gate Bridge [photo: Gary Sissons]

This issue is exactly that – full of case studies. We begin with an article describing the strengthening of Melbourne's West Gate Bridge – believed to be the single largest use of FRP material in one project to date. Professor Moy then provides an extensive review of the use of FRP to repair steel and cast iron structures in the UK. The application of FRP materials for the repair and retrofit of steel structures remains a relatively rarefied field although applications and research are growing rapidly.

We continue our History of FRP feature with a description of the 1957 Monsanto 'House of the Future'. Although demolished in 1967, I would draw readers' attention to the similarities between this iconic, but ultimately mid-20th century folly, and this year's JEC Innovation Award Winner: the Sheraton Hotel and Conference Centre at Milan Malpensa Airport (page 12). Perhaps the House of the Future was on to something after all.

Finally, it is with great sadness that we report the passing of FRP pioneer Arie Gerritse. A remembrance from his colleagues appears on page 2.

I would also like to draw everyone's attention to the ***NEW IIFC WEBSITE***. The address remains the same: www.iifc-hq.org, but the look and utility are greatly improved. Among many improvements, the website now contains an archive of all 18(!) years of *FRP International*.

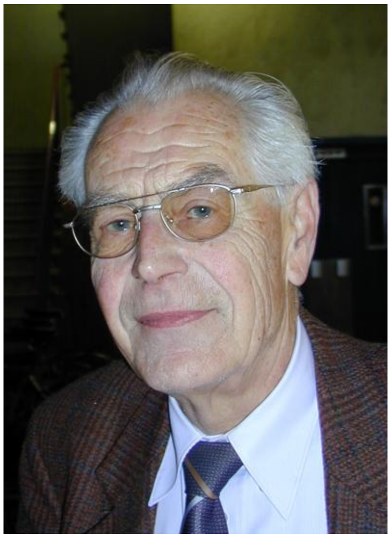
Kent A. Harries
University of Pittsburgh
newsletter.editor@iifc-hq.org

Become an *FRP International Author…*

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. 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 and abstracts from newly-published PhD dissertations are particularly encouraged. *FRP International* is yours, the IIFC membership's forum. The newsletter will only be as useful and interesting as you help to make it. So, again, *please become an* FRP International *author*.

Remembrance of Arie Gerritse

Mr. Arie Gerritse, who was born 15 September 1929, was one of the pioneers in the development of FRP reinforcement. He passed away on May 27th 2011, aged 81 years.



Arie Gerritse, 1929-2011

Arie Gerritse was principal of Gerritse Consultancy in The Netherlands, specializing in the use of FRP for Civil Engineering applications and assisting research organisations in developing codes and regulations in several structural engineering fields. He was one of the founders of fib Task Group 9.3 'FRP reinforcement for concrete structures' in 1996, and remained a valuable contributor.

He received his engineering degree in 1950 from Rotterdam Technical College and accumulated rich experience working for the research and development department of HBG (Hollandsche Beton Group - an international contractor based in the Netherlands - since 2002 part of the Royal BAM Group), as well as in other consulting companies. For many years he contributed to developments in concrete technology, and was actively involved in a number of international committees. This led to his involvement in the field of advanced composite materials, which began in 1979, when HBG and AKZO worked together on the development of a pultruded aramid rod (Arapree) for use in civil engineering applications. He quickly realised that it was ideally suited for use as a pretensioning tendon in concrete and a number of precast products were developed, including noise barriers for motorways and planks for fish weirs, where aramid's enhanced resistance to corrosion meant that much thinner elements could be produced. He was involved in many research projects to determine relevant material properties, and was heavily involved in a Brite/Euram project in the development of non-metallic tensile elements from 1991-1996, which has been an important milestone in FRP's emergence from an interesting research topic to a practical technology and led to the formation of fib TG9.3. Arie was also a founding member of ACI Committee 440.

Arie could be forthright in the expression of his views. He was keen to see the more widespread adoption of FRP, but he wanted it to be used in ways that exploited its beneficial properties, rather than simply being seen as a direct replacement for steel. He could be disparaging about researchers who failed to read earlier papers, and especially those who repeated tests he had performed 20 years before. But he could be relied on to ask the direct questions that got to the heart of the topic under discussion, and his combination of a distinguished researcher's knowledge about advanced materials, and the practical engineer's knowledge of the problems to which they could be applied, led him to make very positive contributions. His ready smile and his acerbic wit will be missed.

Arie leaves a wife, Cocky, three children and several grandchildren.

Chris Burgoyne
Luc Taerwe
Stijn Matthys

Milestones

Gerritse, A. and Schürhoff, H.J., (1986) Prestressing with Aramid Tendons, Technical Contribution to the *10th fip Congress*, New Delhi.

Gerritse, A. and Werner, J., (1991) ARAPREE - a non-metallic tendon, *Advanced Composite Materials in Civil Engineering Structures*, ASCE Materials Engineering Division, New York, NY, pp. 143-154.

BRITE/ EURAM Program 4142, *Fibre Composite Elements and Techniques as Non-Metallic Reinforcement of Concrete*, 1991-1996. Objectives of this project were to: 1) characterize materials and manufacturing processes suitable for applications in civil engineering structures; 2) determine load-carrying characteristics of concrete members rein-forced or prestressed with FRP; 3) develop reinforcing elements, anchorages and application techniques; and 4) develop criteria for design, detailing, and execution.

This article is excerpted from the paper "Carbon fibre retrofitting of the West Gate Bridge". The paper first published earlier this year in Vol. 37 No. 1 of <u>*Concrete in Australia*</u>*, an edition in which the retrofitting program for the West Gate Bridge was extensively covered in a series of papers.*

Strengthening of the West Gate Bridge, Melbourne, Australia

Grahme Williams, Sinclair Knight Merz
Prof. Riadh Al-Mahaidi and Robin Kalfat, Swinburne University of Technology, Melbourne
ralmahaidi@groupwise.swin.edu.au

The final phase of construction on the West Gate Bridge Strengthening project in Melbourne has recently been completed and commissioned for public use (Fig. 1). As a major part of the $1.39 billion M1 Freeway Upgrade project, the bridge has been strengthened to add two additional lanes, resulting in five traffic lanes in each direction (Fig. 2).

Fig. 1 West Gate Bridge

The strengthening work has been carried out by an alliance of VicRoads, John Holland, Sinclair Knight Merz and Flint and Neill. The alliance said that every aspect of the $240 million strengthening project, from the original design to actual fit up of the strengthening elements, has seen the team set new world benchmarks and innovations in safety, engineering design and construction.

The West Gate Bridge is a 2.6 km long structure comprised of a central 850 m long cable stayed steel box girder portion having 870 m and 670 m long segmental prestressed concrete box girder approach viaducts (Fig. 2). The strengthening works implemented by the alliance have been carried out on both the eastern and western viaducts. On each viaduct, supplemental post tensioning has been added to increase the flexural and shear resistance of the concrete box girder section. Additionally, carbon fibre reinforced polymers (CFRP) have been applied to the cantilevers to increase their flexural capacity while carbon fibre (CF) fabric was applied to the base of the cantilever struts to provide additional necessary confinement, thereby increasing their compressive strength. A combination of CF laminates and fabric have been applied to the spine girder to increase the shear and torsion capacity (Fig. 3).

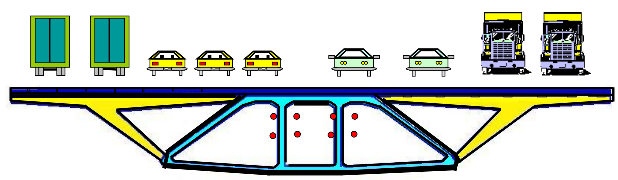


Fig. 2 West Gate Bridge Viaduct Section
(deck is 37 m across; spine girder is 3.9 m deep)

Strengthening of the concrete viaducts required careful consideration of material type, grade and geometry to develop the most appropriate methodology. On the eastern viaduct the laminates chosen for application on the exterior of the spine girder to supplement the combined shear and torsion forces were 120 mm wide by 2mm thick and had a modulus of 210 GPa. On the western viaduct, which was previously strengthened in 2002, 120 mm by 1.4 mm laminates having a modulus of 165 MPa were adopted to match what had been applied. The same CF fabric, having a modulus of 240 GPa, was used on both viaducts (Fig. 3).

Ultimately similar quantities were applied to each viaduct as the demands on the east were slightly greater due to the tighter radius of the viaduct in plan view (Fig. 1), which contributed to greater anticipated torsion demands than on the west.

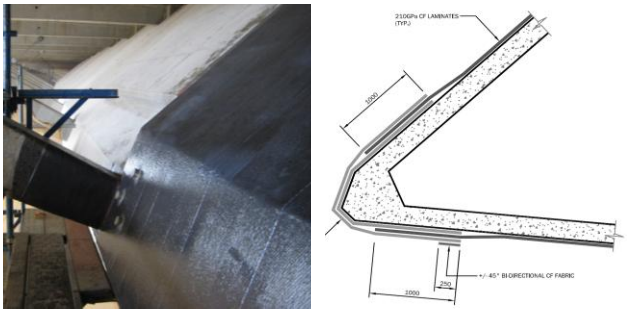


Fig. 3 Spine Girder Strengthening

Typically the design of reinforcement to carry torsional forces suggests the use of a continuous closed system to transfer forces around the section. The use of only laminates would have therefore been inappropriate as the tight radius near the interface of the outer web and soffit at the bottom corner of the box girder would violate standard detailing practice (Fig. 3). Fabrics were therefore introduced in a splice arrangement to transfer the laminate forces from one face of the spine girder to the other, due to their ability to be formed around a radius as small as 25 mm.

Traditionally CF fabrics available for civil infrastructure works have been limited to unidirectional sheets. Unique to this detail was the introduction of a +/-45^{o} bidirectional CF fabric applied along the terminating edge of unidirectional fabric on the soffit of the spine girder. It was verified through testing (Fig. 4) that the bidirectional fabric enabled the system to achieve much greater strains prior to failure of the bond to the concrete substrate than allowed by codified approaches alone. In particular configurations, samples consistently achieved almost twice the allowable strain limits permitted by standard guidelines. By distributing the laminate forces over a wider bond area it was possible to use a far greater contact with the concrete substrate to anchor the system than was possible to achieve with unidirectional fabric alone.

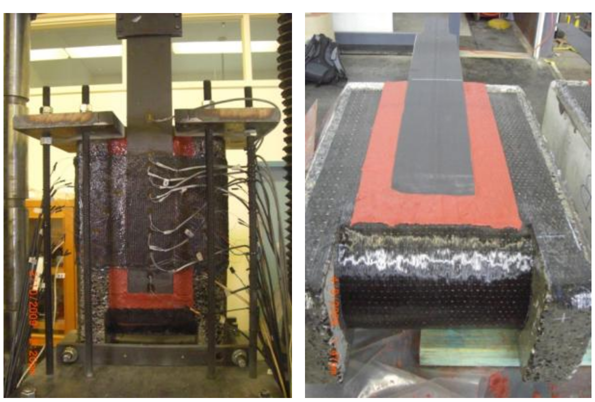


Fig. 4 Bond Testing at Monash University

Achieving these details on site posed a number of challenges. Primarily, handling large sections with limited stiffness made positioning the materials difficult and required several hands on each laminate to navigate the sheets into position. Additionally, managing the application of the epoxies used to bond the CF fabric to the concrete substrate required careful consideration as cure times were highly dependent on environmental conditions which varied greatly over the 16 months of application. If sufficient time was allowed between subsequent layers for the epoxy to cure to a hardened, shiny surface, intentional roughening with sand paper was required to provide a mechanical bond as well as a cleaned surface for a chemical bond to form between layers of epoxy prior to application of the next layer.

The second primary anchorage detail was along the top edge of the outer web of the spine girder at the interface with the deck soffit. The geometry of the viaduct in this location made closing of the torsion reinforcement CF laminates virtually impossible. The detail which was ultimately implemented in the most critical locations included an embedded steel reinforcement bar which was inserted into a cored hole in the corner of the spine girder and into a chase on the outer surface of the exterior web along the face of the CF laminates. The arrangement of this detail was two-fold, providing both higher strain transfer from the CF laminates into the concrete substrate (verified through laboratory testing) and also providing additional longitudinal shear resistance along the interface of the top flange and outer web of the spine girder.

In total, bridge strengthening works have used 12,000 m^2 of carbon fibre applied to the concrete sections. The alliance design team worked closely with BASF, the eventual supplier of the MBRACE CF system adopted.

Workers fitting the CF were generally operating from platforms beneath the structure, nearly 50 m above ground level (Fig. 5).

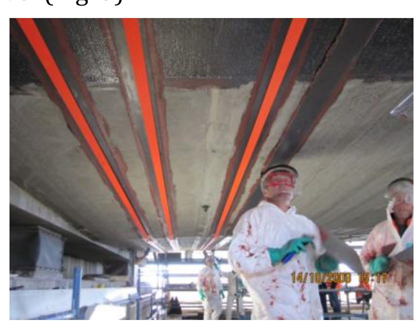


Fig. 5 Strengthening Soffit of Spine Girder

Case Studies: FRP Repair of Steel and Cast Iron Structures in Great Britain

Prof. Stuart Moy, University of Southampton
s.s.moy@soton.ac.uk

The 19th Century (particularly the reign of Queen Victoria (1837-1901)) and the early 20th Century saw massive development in the UK transport system. Firstly there were the canals, then the railways and finally roads. Great engineers, such as Brunel, Telford and Stephenson, were responsible for the aqueducts, bridges, tunnels and other infrastructure. Some of these are now iconic heritage structures but the majority remain just the structures which keep the systems running.

A driving force for these developments was the ability to produce ferrous metal on an industrial scale. Initially there was cast iron, then wrought iron and by the end of the 19th Century, steel. Cast iron had been used since about 1770 and although a sound material in compression it was found to be brittle and weak in tension due to its coarse granular structure and the presence of inclusions. To some extent this was managed by the use of particular structural forms, for example: beams with large tension flanges and small bulbous compression zones to avoid buckling. Henry Cort's puddling process (1783) allowed large scale production of wrought iron with its unusual laminar structure which resulted from the production process. Wrought iron production was one of the major Victorian industries with hundreds of companies distributed over the entire country. Wrought iron was a ductile material with similar compressive and tensile properties which were highly directional depending on the orientation of the slag fibres. It was superior to cast iron but also more expensive. Consequently there were hybrid structures with cast iron compression zones and wrought iron tensile zones. By the beginning of the 20th Century steel, produced by the Bessemer process, was the only ferrous structural metal.

Much of the early ferrous metal infrastructure is still in use and in many cases the structures are too strategically important to replace. Network Rail, the company responsible for the UK overground rail infrastructure is responsible for about 40,000 bridges of which some 9000 are metallic. The London Underground (the capital's subway system) has several hundred more. The maintenance and upkeep of these structures has been generally sound but problems have arisen due to poor initial design or construction. Another significant factor is that loadings on both road and rail have and still are increasing.

Old cast iron is surprisingly corrosion resistant but presents real problems if it has to be strengthened with conventional materials. Drilling holes for bolts is risky because of the possibility of the drill bit hitting an inclusion or hard spot and welding is impossible. Poor drainage at supports or wet ballast resting on shear webs has caused serious corrosion in wrought iron, water penetrating between laminae and corrosion products splitting the metal. Even worse is the use of new steel with wrought iron because steel and wrought iron have slightly different electro-potentials leading to galvanic corrosion. On many simple bridges fatigue can be a problem since the cyclic loading from a train passing can make up over 90% of the total load carried. Fatigue life can often be extended by stiffening the structure to reduce stresses but dealing with increased load or repairing corrosion damage requires strengthening.

Fibre reinforced polymer composites (FRP) are used in the UK for stiffening and strengthening metallic structures. Most commonly the composites are manufactured from ultra-high modulus (UHM) carbon fibres and epoxy resins. These high quality carbon fibre composites (CFRP) have an elastic modulus of over 300 GPa compared to about 200 GPa for steel. This favourable modular ratio provides the most efficient use of the CFRP. Usually 'pre-preg' CFRP sheets, fabricated under factory conditions, are bonded to the metal surface using an epoxy adhesive. Good surface preparation of the metal, usually by grit blasting, is considered essential. In cases where the metal surface is too poor, for example due to imperfections or distortions, a vacuum infusion process is used. The dry fibres are placed inside a membrane sealed to the metal surface. A vacuum is drawn, removing the air and compressing the fibres. The liquid resin is then sucked through the bag, wetting out the fibres and the vacuum is maintained until the composite has cured. Bonding to the metal is ensured by the adhesive properties of the epoxy resin. The very high shear and tearing stresses at the ends of the composite plates are reduced by tapering the ends of the plates, the use of splay fillets and even by mechanical fasteners.

The following case studies demonstrate some of the UK applications of FRP composites to metallic structures. They include cast iron, steel and even aluminum structures, stiffening and strengthening, preformed plates and vacuum infusion. Wrought iron is noticeably absent because of concerns about the possibility of delamination in its unique laminar structure. Recent research (Moy and Clarke, 2009) however has shown that the inter-laminar strength is at least twice that of the adhesives currently used and that FRP strengthening of wrought iron is safe and feasible.

Steel Structures

Slattocks Canal Bridge (1936), Rochdale

Longitudinal riveted steel beams with reinforced concrete deck.

Strengthened in 2000: HM CFRP plates applied to inner beams, allowing bridge to carry 40 tonne vehicles. Plastic capacity mobilized in design.

Luke (2001) The use of carbon fibre plates for the strengthening of two metallic bridges of an historic nature in the UK. *Proc. CICE 2001* pp.975-983.

Underbridge D65A, Acton, London

Early riveted plate girder bridge (I-section girders with timber deck).

Strengthened in 2002: UHM CFRP applied to cross girders. Designed to reduce live load stresses and increase fatigue life. Demonstration project indicated 24% reduction in live load stresses.

Moy and Bloodworth (2007) Strengthening a steel bridge with CFRP composites, *Proc. ICE, Structures and Buildings* 160 (SB2) pp 81-93

Repair of corroded pipes

Sub-sea steel pipes (offshore infrastructure).

Strengthened in 2001: wet lay-up HM CFRP patch around pipe.

DML Composites

Steel blast wall, Mobil Beryl Platform

Offshore infrastructure, steel blast wall supported by steel H beams.

Strengthened in 2001: UHM CFRP applied to columns to increase overpressure capacity of blast wall threefold.

DML Composites

Type 42 destroyers (1974-83), HMNB Portsmouth

Fatigue cracks found in food lifts of five Type 42 destroyers

Strengthened in 1998-2001: over 30 CFRP patches applied to reinforce crack sites. Hand lay-up, resin infusion and prepreg techniques

Type 42 destroyer

Type 21 frigate

Type 21 frigates (1972-75), HMNB Portsmouth

Fatigue cracks found in aluminium superstructure of Type 21 frigates

Strengthened in 1983-84: CFRP/epoxy patches were selected due to their ability to conform to the uneven deck surface

QinetiQ

Boots Building, Nottingham

Badly corroded curved steel I-beam.

Strengthened in 2001: cold cure impregnation under vacuum of preimpregnated CFRP

Hollaway and Cadei (2002) Progress in the technique of upgrading metallic structures with advanced polymer composites, *Progress in Structural Engineering and Materials*, 4, pp 131-148.

Cast Iron Structures

Shadwell station, London Underground

18 cruciform section cast iron struts in brick ventilation shaft.

Strengthened in 2000: up to 26 plies of UHM and HS CFRP, vacuum infusion.

Leonard (2002) The design of carbon fibre composite strengthening for cast iron struts at Shadwell Station vent shaft. *Proc. ACIC 2002.*

Tower Bridge (1894), London

Lamp Standards.

Strengthened in 2000: Invisible repair of cracks due to thermal movement and traffic vibration.

Ironbridge (1779), Shropshire

Original railings on the world's first cast iron bridge.

Strengthened in 2000: minimal intervention repair to upgrade to modern crowd loading standards. 3.8mm thick CFRP plates bonded to inside faces of parapet posts.

New Civil Engineer, 14 February 2002.

Bid Road Bridge (1876), Hildenborough, Kent

Nine cast iron beams supporting brick jack arches.

Strengthened in 1999: tapered UHM CFRP plates bonded to the beams to allow the bridge to carry 40t vehicles.

Bow Road Bridge (1850), East London

Carries A11 over Docklands Light Railway. Cast iron beams supporting a combination of brick jack arches and steel plates.

Strengthened in 1999: 170 x 20mm UHM CFRP plates were used to strengthen cast iron beams beneath the footways to support 40t vehicles.

Covered ways 12 & 58 (1860), Kelso Place, London Underground

Brick jack arches over cut-and cover tunnels, supported by cast iron girders.

Strengthened in 1999: CFRP plates bonded to underside of the girders to prevent overstressing while work was carried out on the foundations of the tunnel wall. Plates did not encroach on headroom.

Church and Silva (2002) Application of carbon fibre composites at covered ways 12 and 58 and bridge EL , *Proc. ACIC 2002*.

King Street Bridge, Mold, Wales

Railway bridge.

Strengthened in 2000 to meet new 40t load requirement: Preloaded to relieve stresses and transfer some dead load to the CFRP. Tapered UHM CFRP and GFRP plates bonded to cast iron.

Farmer and Smith (2001) King Street Railway Bridge – Strengthening of cast iron girders with FRP composites, Proc. 9th Int'l Conference on Structural Faults and Repairs (2001), 4th – 6th July 2001, London.

New Moss Road, Bristol

Bridge over railway

Strengthening: Unstressed UHM CFRP plates

Luke (2001) The use of carbon fibre plates for the strengthening of two metallic bridges of an historic nature in the UK. *Proc. CICE 2001* pp.975-983.

Redmile Canal Bridge

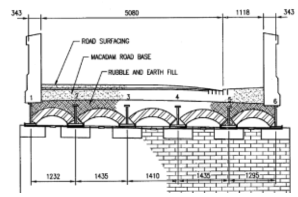
Bridges over railway and canal, respectively

Strengthening: Unstressed UHM CFRP plates

Luke (2001) The use of carbon fibre plates for the strengthening of two metallic bridges of an historic nature in the UK. *Proc. CICE 2001* pp.975-983.

Maunders Road Bridge (1870), Stoke on Trent

Beams supporting brick jack arches, carrying road over railway line.

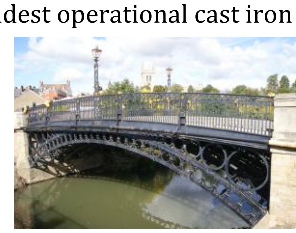
Strengthened in 2001: tapered UHM CFRP plates. Load-relief jacking used to transfer a proportion of dead load into CFRP and increase load capacity of bridge for heavy goods vehicles.

Canning, Farmer, Luke and Smith (2006) Recent Developments in Strengthening Technology and the Strengthening/Reconstruction Decision, *Railway Bridges Today and Tomorrow*.

Tickford Bridge (1810), Newport Pagnell

Oldest operational cast iron road bridge in the world.

Strengthened in 1999: wet lay-up CFRP final thickness up to 10mm.

Lane and Ward (2000) *Restoring Britain's Bridge Heritage* ICE (South Wales Ass'n) Transport Engineering Group Award 2000.

Hammersmith Bridge (1860-80), London

3 span road bridge over London Underground rail lines. Cast iron girders, brick jack arches.

Strengthened in 2005-8: UHM CFRP bonded to girders. Upgraded to 40t vehicles.

MBrace

Waterloo Bridge (1848), Liverpool

Cast iron girders, brick jack arches.

Strengthened in 2008: UHM CFRP bonded to girders. Upgraded to 40t vehicles.

MBrace

Bridge EL31, Surrey Quays, London Underground

Cast iron beams and columns supporting brick jack arches and early riveted trough decking.

Strengthened in 2001: HM CFRP applied to increase load capacity of bridge. Very limited access through ticket barriers.

Church and Silva (2002) Application of carbon fibre composites at covered ways 12 and 58 and bridge EL , *Proc. ACIC 2002*.

Milltown Bridge, Ireland

Strengthened in 2008: UHM CFRP bonded to girders.

Mouchel/MBrace

Hythe Bridge (1861)

Cast iron girders, brick jack arches.

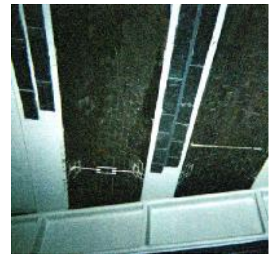
Strengthened in 1999: 4 prestressed CFRP plates bonded to each of 16 girders to increase load capacity to 40t vehicles.

Luke (2001) Strengthening structures with carbon fibre plates case histories for Hythe bridge, Oxford and Qafco Prill tower, Qatar, *NGCC first annual conference and AGM – Composites in construction, through life performance*. 30-31 October 2001, BRE, Watford, UK

Linney Lane Rail Bridge, Oldham

Cast iron girders, brick jack arches.

Strengthened in 2003: 42 HM CFRP plates of various sizes, bonded to girders.



Mouchel Parkman/Balvac

Newcastle High Level Bridge (1849), Newcastle upon Tyne

Robert Stephenson Railway Bridge, cast iron girders, wrought iron hangers.

Strengthened in 2008

http://www.bridges.mottmac.com/bridgeprojects/railwaybridges/newcastlehighlevelbridge/

The bonding of FRP composites to metallic structures is now accepted practice in the UK. The Department of Transport has produced a Design Manual (2008) and Design Guides (ICE 2001 and CIRIA 2004) are also available. It is worth concluding with a word of warning: CFRP is an expensive material when compared weight-for-weight with conventional materials. It is important not to carry out comparative cost analysis between FRP and conventional materials on such a basis. The high strength and light weight of FRP means that much less material is required and thus the amount of falsework, lifting gear and labour required is reduced. Additionally, the excellent durability of FRP means that maintenance costs are lower. Consequently, comparisons need to be made on the basis of expected life cycle. This represents something of an attitude change for both private and public bodies which all too often are obsessed with the initial bottom line. Such change is happening in the UK and is to be welcomed.

CIRIA (2004) *Strengthening Metallic Structures Using Externally Bonded FRP*, CIRIA Report C595, Cadei, Hollaway, Stratford, and Duckett (eds). Construction Industry Research and Information Association, London.

Department for Transport (2008) *Design Manual for Roads and Bridges*, Vol. 1, Sec. 3, Part 18: BD85/08 Strengthening Highway Structures Using Externally Bonded Fibre Reinforced Polymer.

ICE (2001) *Design and Practice Guide for FRP composites – Life extension and Strengthening Metallic Structures*, Moy (ed.), Thomas Telford, London.

Moy and Clarke (2009) Strengthening wrought-iron structures using CFRP. *Proc. of ICE, Structures and Buildings* **162** (SB4) 251-261.

History of FRP in Construction

Monsanto House of the Future – revisiting the past's view of the future

Kent A. Harries, University of Pittsburgh

The Monsanto House of the Future was a prefabricated fibreglass house developed at the Massachusetts Institute of Technology (MIT) under Monsanto Chemical Company sponsorship from 1953 to 1956. Based on research in structural plastics by Professor Albert Dietz, the house was designed by Architecture Professors Marvin Goody and Richard Hamilton. Goody and Hamilton wanted to create an affordable and flexible substitute for poorly designed, developer-driven tract houses. Under the direction of plastics engineer and Monsanto project manager, Robert Whittier, and construction engineer Frank Heger (one of the founders of Simpson Gumpertz & Heger), a 119 m^2 prototype (Figure 1) was built in 1957 and exhibited at Disneyland in Anaheim California until it was demolished in 1967. The entire development and installation of the House reportedly cost $1 million.

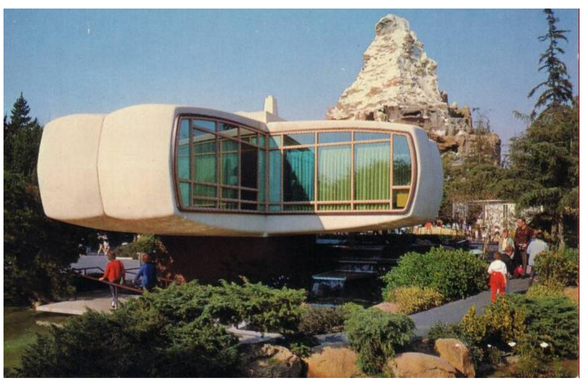


Fig. 1 Monsanto House of the Future [Disney]

The House of the Future was cruciform in plan having a 4.8 m square concrete foundation topped with a central core housing the kitchen and bathroom. The core was built of laminated timber beams and fibreglass columns. Four 4.8 m square wings are cantilevered from the core (Figure 2). Each wing was comprised of four monocoque shell units: two floor units and two roof units (Figure 3). The shells were manufactured by Winner Manufacturing Company in Trenton New Jersey, shipped across the country to Anaheim, and assembled on-site (Figure 5). A constraint and feature of the design was the need to keep the shipped components within legal highway size and weight limits. The 16 nested shell components (Figure 4) were shipped on a single truck.

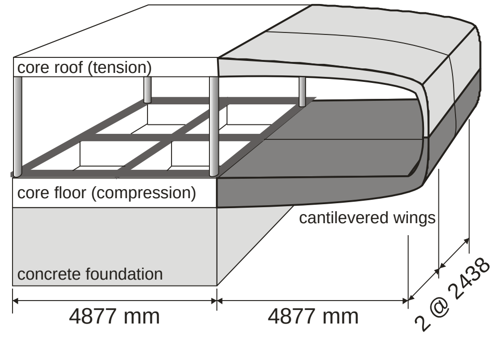


Fig. 2 Monocoque modular U-shaped shells cantilevered off foundation.

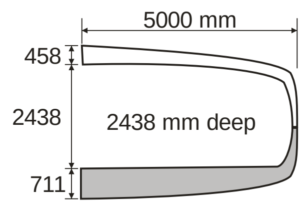


Fig. 3 Shell modules.

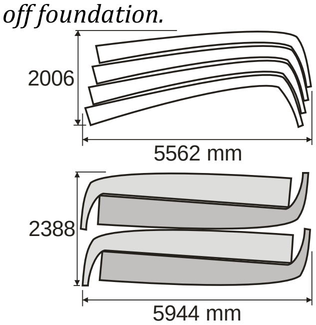


Fig. 4 Nested for shipping.

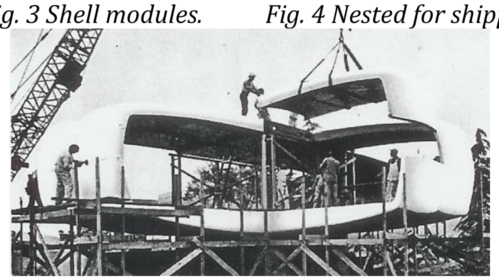


Fig. 5 Erection of shells.[Disney]

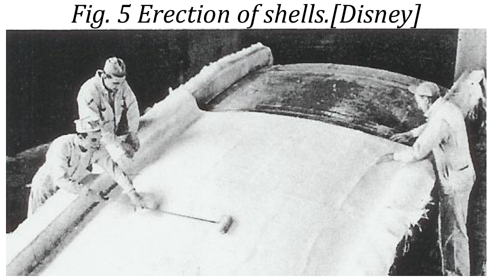


Fig. 6 Hand lay-up of shell. [Disney]

The monocoque shells were fabricated of 10 plies of woven glass roving over a urethane foam core (Figure 6). The house was designed considering significant loading conditions (see box on following page). Its performance was validated through full-scale load and temperature tests of a mockup structure (Figure 7). Perhaps more demanding than the design loads were the service loads this house was subject to: When the house opened in 1957, it welcomed 435,000 visitors in the first six weeks; 6 million visitors by 1960; and as many as 20 million by 1967. In 1960, *Monsanto Magazine* put it this way: "*The Monsanto "Plastics Home of the Future," tested by more than 12 million tramping feet, has demonstrated the rugged practicality and* *attractiveness of plastics as structural materials.”* Although the permitted cantilever deflection was 19 mm (span/256), the measured deflection in the first three years was only 1.3 mm (span/3750) per year. The reported ‘per year’ value would appear to indicate some degree of creep taking place.

Monsanto House Design Loads

Live Load	2.4 kPa
Wind	40 m/s 0.6 kPa uplift and effect of torsion
Snow	1.9 kPa
Earthquake	single storey in Zone 3
Temperature	56°C differential: 77°C at roof; 21°C at underside
Floor deflection	span/360
Cantilever deflection	19 mm (span/256)

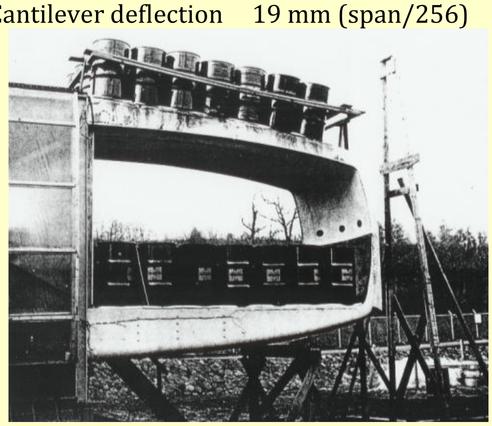


Fig. 7 Load test of mockup structure. [Disney]

After 10 years as an attraction at Disneyland, the Monsanto House of the Future was slated for the wrecking ball. But it wasn’t that easy; reportedly the wrecking ball (Figure 8) just glanced off the GFRP shell. Demolition crews tried claw shovels (Figure 8), torches, chainsaws and jackhammers. In the end, choker cables were used to crush the House into smaller pieces. Demolition took two weeks.

In 1957, some 60,000 people visited the house each week. "Everybody marvelled at it, everybody loved it, and everybody wanted one," remembers Robert Whittier (Scanlon 2005). But as enthusiastic as the response was, it wasn't enough to create a viable market. Gary Van Zandt, architecture curator of the MIT museum summed it up: “In the end, Monsanto found that the idea of living in a plastic house was an idea that the public would not accept. The public did not like to be enclosed in plastic.” (MIT 2010)

The Monsanto House of the Future was among the most important of many 20th-century prototypes for low-cost, factory-built housing, and was one of many exhibition houses. The House was an ideal laboratory for experimentation in design, materials, and construction. It has been considered one of the most important vehicles for the investigation of architectural ideas in the 20th century.

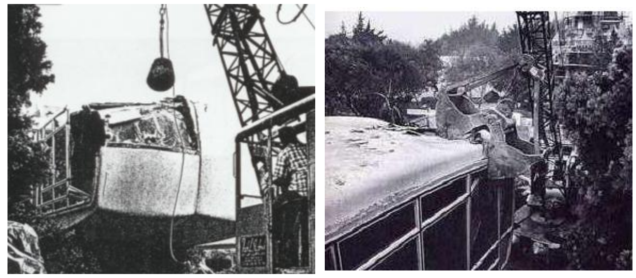


Fig. 8 Demolition was much tougher than anticipated. [Disney]

References

MIT, (2010) Monsanto House of the Future, Marvin Goody, Richard Hamilton, Robert Whittier, and Frank Heger, 1950s, *The MIT 150 Exhibition*, http://museum.mit.edu/150/131.

Monsanto Chemical Company (1960) The Future Won’t Wait, *Monsanto Magazine*.

Scanlon (2005) The House of the Future That Wasn't, *MIT Technology Review*, January 2005.

1987 in 1957...

The Monsanto House of the Future, opened in 1957 and showcased what life would be like 30 years later, in 1987. In addition to the innovative monocoque GFRP modular structure, features of the House included:

- Disappearing appliances
- Microwave cooking range
- Ultrasonic dishwasher
- Push-button phones
- Remote front-door viewing
- Flat screen television
- Bathroom with adjustable appliances

The House was remodelled twice: in 1960 and 1965.

Green Construction?

The reinforced concrete foundation of the House of the Future was never removed. It remains in its original location, now within the Pixie Hollow attraction. The foundation has been painted green and is currently in use as a planter.

IIFC at JEC Paris

Emmanuel Ferrier, Université Lyon 1
emmanuel.ferrier@univ-lyon1.fr

At the end of March, 2011, IIFC participated in the JEC show in Paris. JEC had proposed to IIFC to moderate the JEC Construction Forum and to present its activities in the Forum. IIFC was also afforded the opportunity to present the Construction Innovation Award in the name of JEC and IIFC.

IIFC Booth at JEC Paris

Every year, players from the composites sector gather at the leading trade fair: the JEC Composites Show in Paris, regarded as the flagship tradeshow in the international composites scene with around 27,700 visitors and more than 1,000 exhibitors. From 29 to 31 March, 2011, North Rhine-Westphalian (NRW) companies and research and education institutes had the exclusive opportunity to present themselves at the NRW Joint Company Forum. For IIFC, the objective was to promote our IIFC activities in Europe. IIFC EXCOM member Emmanuel Ferrier and two colleagues from LGCIE laboratory (L. Michel and A. Si-Larbi) participated with an IIFC booth for the three day show. IIFC received financial support from French company SPPM for the entire cost of this booth. Numerous contacts were made with companies involved in the field of construction. Many were interested by *FRP International* and our planned education modules.

IIFC at JEC 2011 Innovation Awards

Over 14 years and involving 1600 companies worldwide, the JEC Composites Innovation Awards program has honouring innovative products and processes from all aspects of the global composites industry. Created in 1998, the objective of the Innovation Awards Program is to identify, promote, and reward the most effective composite solutions that create more value for end users. 157 companies and 359 partners have been rewarded for the excellence of their composite innovations, including 216 Asian companies.

This year, 14 companies and their partners received awards at the JEC Composites Show. The 2011 JEC Awards ceremony took place on Tuesday March 29th at 5:00 pm at the JEC Show and was open to all visitors. The Construction Award was given by Emmanuel Ferrier, representing IIFC to 3B the Fibreglass Company for their ventilated facade for the new Sheraton Hotel at the Milan Malpensa Airport (see following page).

Ferrier (right) presenting the JEC Innovation Award to representatives of 3B Fibreglass

IIFC Moderator of JEC Construction Forum

Now, at the beginning of the twenty-first century, the structural engineering community is about to enter a stage in which structural design with fibre reinforced polymers composites is poised to become as routine as design with conventional materials such as masonry, wood, steel, and concrete. In this Forum, six projects highlighted cost-effective integrated processes enabling the maximum capability of industrialization of components both for the Construction and Civil Engineering markets. Two projects are highlighted in this *FRP International*: The JEC Innovation Award-winning New Sheraton Hotel & Conference Centre at Milan Malpensa Airport by 3B Fibreglass and the New Passenger Terminal at the Carrasco Airport, Uruguay by MVC-Poloplast.

JEC Construction Forum Featured Projects

Winner, 2011 JEC Innovation Award

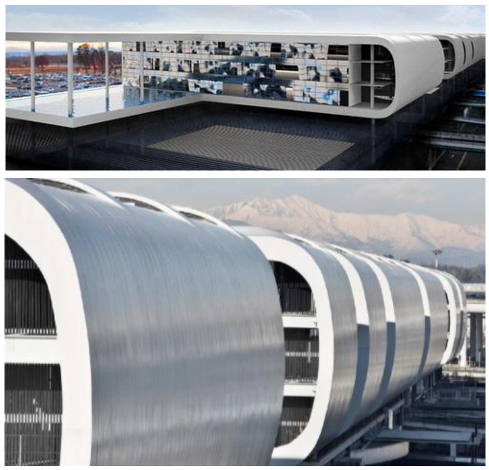
Sheraton Hotel and Conference Centre at Milan Malpensa Airport, Milan, Italy

3B the Fibreglass Company, www.3b-fibreglass.com

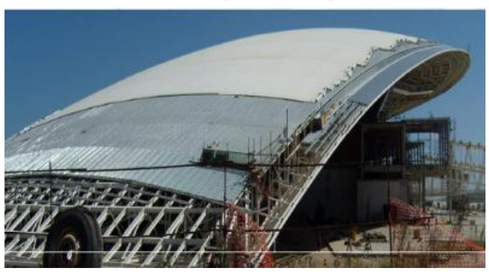
The new Sheraton Hotel & Conference Centre at Milan Malpensa Airport in Italy, which opened in July 2010, is a highly contemporary building. This is reflected in its design as well as in the technologies that were applied and the materials that were selected for its construction. Designed by the architects King Roselli (Rome), the building was commissioned in 2006, and constructed by Gruppo Degennaro, at a cost of approximately 64 million euro. The overall structure is 420 m wide and 21 m high. It has 3 floors which contain offices, 436 sleeping rooms, cafés and restaurants, and a 2000 m^2 conference centre. This hotel concept is based on the idea of a large folding skin wrapping the modules containing the rooms.

The desired effect was to achieve a perfectly smooth surface with hardly perceptible joints. The roof and joints had to keep the weather out and be stable in temperature differences of 70°C (Malpensa Airport is close to the Alps). The final solution was a combination of a reinforced damp-proof membrane finished in white for the flat roof, and approximately 11,400 m^2 of pultruded glass fibre reinforced plastic sheeting on a sub-structure for the curves and the down-stands of the skin. The shell is curved around a sub-frame fabricated of approximately 43,000 linear meters of pultruded structural profiles and steel arches. Where a double curvature was required, for example for the vent covers on the roof, a mould was manufactured around which the GRP was cast.

[The hotel design would appear to owe something to that of Monsanto House, also featured in this *FRP International* – editor]



Sheraton Hotel and Conference Centre at Milan Malpensa Airport



Terminal at the Carrasco Airport

Winner, 2010 FEIPLAR Award for Excellence in Composites Market Innovation

Passenger Terminal at the Carrasco Airport, Montevideo, Uruguay

MVC-Poloplast Painéis, www.mvcplasticos.com.br

The roofing for this building was designed by architect Rafael Viñoly in the shape of a paraglider. This architectural feature gives the project a unique and striking feature, as well as introduces a number of challenges for realisation and implementation. The first challenge was the realization of the roofing's special structure: the geometric premise included three axes of curvature [see *FRP International* April 2011 article on Heinz Isler – editor]. Additionally, the location of the structure and shape of the roof resulted in design suction forces of up to 1.8 kPa!

Another challenge was lining the structure's surface. In the words of MVC director general, Gilmar Lima: "Our challenge was to develop a lining system that could meet the requirements of strength and safety, be applied without the need for special equipment and have the greatest resistance at the lowest possible weight." In the original concept, this lining would be made with a succession of layers of steel, wood and plaster covered with a thermoplastic polyolefin (TPO) membrane. The top surface allowed this solution, but the TPO couldn't be properly stretched on the concave bottom surface. MVC's eventual solution was to cover the bottom surface with sandwich panels made of composite plates having a gelcoat finish and expanded polystyrene and polyurethane core. These were attached to the building's main structure by a secondary aluminum structure so as to allow for the correction of imperfections present in the main structure. 24,000 m^2 of panels were supplied and assembled, without interfering with the other activities at the construction site, over a period of 9 months.

FRPRCS-10 in Tampa

Rajan Sen and Rudolf Seracino, Co-Chairs

The 10th International Symposium on Fiber Reinforced Polymer for Reinforced Concrete Structures (FRPRCS-10) was held at the Marriott Tampa Waterside in Tampa, Florida, on 2 – 4 April 2011. The symposium was held in conjunction with the American Concrete Institute (ACI) spring convention and hosted by ACI Committee 440 on Fiber Reinforced Polymer Reinforcement. The conference proceedings, published as *ACI Special Publication SP-275* contain 72 peer reviewed papers from 16 countries. Over the three-day symposium, a total of 136 delegates attended half hour presentations organized into 12 sessions. The extended presentation time allowed for interesting discussions to develop. Topics covered included: Internal FRP reinforced concrete structures; Strengthening of reinforced concrete columns; Characterization of FRP materials and systems; Bond of FRP-to-concrete systems; Emerging FRP-concrete systems; FRP shear strengthening of RC beams; Fatigue performance and anchorage of FRP systems; FRP strengthening of masonry structures; Performance of FRP systems subject to extreme events; Applications of FRP systems in reinforced concrete; Durability of FRP systems; and FRP strengthening of concrete structures.

At the symposium opening reception, it was officially announced that FRPRCS-11 will be organized by Prof. Joaquim Barros at the University of Minho in Guimarães, Portugal.

Many delegates also participated in other activities associated with the ACI convention, including the technical meetings of ACI Committee 440 and fib TG9.3 on FRP Reinforcement for Concrete Structures. The IIFC also held a joint meeting of its Executive and Advisory Committees where Melbourne, Australia, was selected as the host of APFIS 2013 to be organized by Prof R. Al-Mahaidi at Swinburne University of Technology, Prof X.L. Zhao at Monash University, and Dr S.T. Smith at The University of Hong Kong.

The conference co-chairs would like to thank all of the authors, presenters, reviewers and delegates for helping make this a successful event. In particular, the efforts of Carol Shield and Will Gold (chair and secretary, respectively, of ACI Committee 440) are gratefully acknowledged.

At the FRPRCS-10 reception

Upcoming Conferences and Meetings

CDCC 2011 ***4th International Conference on Durability and Sustainability of FRP Composites for Construction and Rehabilitation***, July 20-22, 2011, Quebec City, Canada. www.civil.usherbrooke.ca/cdcc2011

APFIS 2012 ***Third Asia-Pacific Conference on FRP in Structures,*** February 2-5, 2012, Sapporo, Japan. http://www.eng.hokudai.ac.jp/labo/maintenance/APFIS2012

Papers due: July 31, 2011

ACMBS-VI ***Advanced Composite Materials in Bridges and Structures***, May 22-25, 2012, Kingston, Canada. http://www.acmbs2012.ca/

Papers due: September 15, 2011

CICE 2012 ***6th International Conference on FRP Composites in Civil Engineering***, June 13-15, 2012, Rome, Italy. www.cice2012.it

Papers due: December 2011

4th International Symposium on Bond in Concrete 2012, June 17-20, 2012, Brescia, Italy. http://www.rilem.net/eventDetails.php?event=461

Abstracts due: August 31, 2011

APFIS 2013 ***Fourth Asia-Pacific Conference on FRP in Structures,*** December 2013, Melbourne Australia.

CICE 2014 ***7th International Conference on FRP Composites in Civil Engineering***, August 2014, Vancouver, Canada.

IIFC Working Group Report

Xiao-Ling Zhao, Monash University
zhao.xiao.ling@monash.edu

The IIFC Working Group on ***FRP Strengthened Metallic Structures***, chaired by Prof. X.L. Zhao of Monash University in Australia has been active since 2009. Presently having 35 members from 11 countries, this Working Group (WG) has been active in technology transfer in the area of FRP Strengthening of Steel Structures. The WG has helped to develop IIFC conference papers into Special Journal Issues. In October 2009, a special issue on "FRP Strengthened Metallic Structures" was published in *Thin-Walled Structures* (Vol. 47, No. 10) containing twelve papers. Later in 2011, A Special Issue on "Strength, Stability and Fatigue Strengthening using Fibre Reinforced Polymer" will be published in the *International Journal of Structural Stability and Dynamics*. This special issue contains 10 papers contributed by authors from Australia, Canada, China, Japan, Sweden, UK and USA and is based on papers presented at three WG-sponsored sessions at CICE 2010 in Beijing. The WG also maintains a bibliography of publications in this field. Updated each December, this listing presently contains more than 350 entries! The bibliography will be available on the new IIFC website in the near future.

Two FRP Sessions at 2012 TRB

Transportation Research Board (TRB) Committee AFF80 - *Structural Fiber Reinforced Polymers* is sponsoring two sessions at the January 2012 TRB meeting in Washington DC:

New Applications for FRP in Infrastructure Repair and Rehabilitation
http://pressamp.trb.org/CallForPapers/CFPDetail.asp?cid=1321

Retrofit of Metallic Bridges with FRP Materials
http://pressamp.trb.org/CallForPapers/CFPDetail.asp?cid=1320

Papers may be submitted June 1 to August 1, 2011. See the TRB website for more information: www.trb.org.

APFIS2012, Sapporo Japan

Tamon Ueda, Hokkaido University
ueda@eng.hokudai.ac.jp
http://www.eng.hokudai.ac.jp/labo/maintenance/APFIS2012

The Third Asia-Pacific Conference on FRP in Structures (the Official Asia-Pacific Regional Conference of the IIFC) will be held at Hokkaido University, Sapporo on 2-4 February 2012.

We have received 87 abstracts from 16 countries. In addition, six internationally-known keynote lectures will be given:

Prof. Watanabe Goichi, Nihon University, Japan
Prof. Maruama Kyuichi, Nagaoka University of Technology, Japan
Prof. Teng Jin-Guang, HKPU, China
Prof. Feng Peng, Tsinghua University, China
Prof. Sim Jongsung, Hanyang University, Korea
Prof. T. Aravinthan, University of Southern Queensland, Australia

Join us in Sapporo for a fantastic opportunity to obtain the latest development in FRP materials in construction especially in Asia, where the most dynamic construction activities, including FRP application, have been seen.

63rd Sapporo Snow Festival, February 6 - 12, 2012.

Sapporo has not been affected by the recent earthquake or nuclear power plant incident. While this problem will take some time to be fixed at the site, it seems that radiation will not spread beyond the local area of the plant. APFIS2012 will be unaffected. Travel to and from Japan and to Hokkaido remains safe. What concerns all Japanese is an economic slowdown due to people's perception, both domestically and internationally. A successful APFIS2012 will both directly and indirectly positively affect the restoration of the affected areas and all of Japan.

International Institute for FRP in Construction

Membership Application

Dr./Mr./Ms./Prof. ___________ Surname: ___________________________

First/Middle Names: ___________________________ Title: ___________________________

Employer/Company: ___________________________

Address: ___________________________

City: _______________ State/Prov: _______________ Postal/Zip Code: ___________ Country: ___________

Telephone: _______________ Fax: _______________ Email: ___________________________

Education/Experience: ***Please attach a current resume or CV***

I/we wish to join the International Institute for FRP in Construction (IIFC) as a (please tick one box)

☐ Fellow (US$100) ☐ Member (US$100) ☐ Associate Member (US$50) ☐ Student Member (US$25)

☐ Collective Member (US$750) ☐ Patron Member (US$1500)

If applying for a Collective Membership, please nominate two representatives to receive the privileges:

Dr./Mr./Ms./Prof. ___________ Surname: ___________________________

First/Middle Names: ___________________________ Title: ___________________________

Telephone: _______________ Fax: _______________ Email: ___________________________

Dr./Mr./Ms./Prof. ___________ Surname: ___________________________

First/Middle Names: ___________________________ Title: ___________________________

Telephone: _______________ Fax: _______________ Email: ___________________________

METHOD OF PAYMENT (Payable in US Funds) Cheques and money orders to be made payable to "IIFC"

☐ Check / Money Order

☐ Visa ☐ Mastercard

Credit Card No. *Expiration Date*

Name on Credit Card

Signature of Cardholder

For Office Use Only

Date of Receipt: ___________

Application Outcome: ___________

Membership Number: ___________

Date of Approval: ___________

Transaction Date: ___________

Amount: ___________

Authorization No: ___________

Invoice No: ___________

Journal Entry No: ___________

Submit to: IIFC Administrative Center c/o University of Manitoba
Agricultural and Civil Engineering Building • A250-96 Dafoe Road
Winnipeg, Manitoba, R3T 2N2, Canada
Email: iifc@iifc-hq.org • Website: www.IIFC-hq.org

By submitting this application you agree to share your contact information with fellow IIFC members and any conference/organization associated with IIFC.

IIFC

FRP INTERNATIONAL

the official newsletter of the International Institute for FRP in Construction

Did You Know?

IIFC Members receive the ASCE member's subscription rate for the *ASCE Journal of Composites for Construction*. *JCC* is published by ASCE bimonthly and is sponsored by IIFC through an agreement with ASCE. Internationally, *JCC* is available in print ($178/yr), online ($135), or both ($198). Print rates are $30 less in the United States. Regrettably, members of both IIFC and ASCE do not receive an additional discount [I know, I tried - ed.]. To subscribe: www.asce.org.