FRP INTERNATIONAL

The Official Newsletter of the International Institute for FRP in Construction

Volume 3, Issue 4 ***December 2006***

Welcome to the fourth issue of the IIFC Newsletter for 2006. This issue is being published in conjunction with CICE in Miami, which promises to be a very interesting conference. In conjunction with the conference, IIFC will be holding a number of meetings and this will also be the stage for the handing of the baton to the incoming President and Executive Committee. Our sincere thanks go to Professor J.G. Teng, the outgoing President for his tremendous leadership and stewardship of IIFC, and to the current Executive Committee for working as a team to strengthen IIFC.

As we move forward a number of issues arise among which are the further growth of IIFC internationally, the development of closer interactions and synergies between industry and academia in this area, and the facilitation of ties between IIFC and other organizations such as ISHMII and ACMA. These and others will undoubtedly be successfully addressed and the Newsletter will keep the membership abreast of development in these and other areas.

We continue to seek submissions from our readers on new applications of FRP in construction, forthcoming conferences and workshops, or even general items that may be of interest to the worldwide community. Material can be submitted directly to me at vkarbhari@ucsd.edu.

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In this issue

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The Official Newsletter of the International Institute for FRP in Construction

Volume 3, Issue 4 **December 2006**

Reports From Around the World

Fire – Is This a Show Stopper for Composites?

by
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Composites have been used for many years in many different industries, to replace metal, wood and concrete, by providing weight reduction, ease of fabrication, lower cost and corrosion resistance. Several different polymers are used, such as Unsaturated Polyester, Vinyl Ester, Epoxy and Phenolic. These are all thermosets and are used with various reinforcing agents such as fiberglass or carbon fiber to produce a very high strength to weight ratio composite.

The biggest drawback in using composites is the propensity to burn, producing high levels of smoke and toxic fumes, which hinder the ability to escape in a fire. In the transit industry, where trains or buses travel through tunnels, this problem becomes more acute as has been seen in several tragic accidents, resulting in death due to flame and smoke.

Of all the thermoset resins that can be used, one resin type – *Phenolic* – stands out as having the best Fire/Smoke/Smoke Toxicity properties. Phenolic is the oldest man-made polymer, dating back to 1905, when Bakelite was invented. It is used extensively in aerospace – using phenolic prepreg, which is expensive and difficult to use, requiring high temperature and pressure (autoclave). Pelletized Phenolic molding compounds have also been used to mold small parts for electrical and under the hood applications, but because it is compression or injection molded in expensive molds, several hundred thousand pieces would have to be molded to warrant the expense of the tooling. Also, mechanical properties are limited due to the limitations on processing and short fiber length.

In the last twenty years, low viscosity Phenolic resins have been developed, which can be processed via common techniques such as Hand Lay-up, Spray-up, Filament Winding, Resin Transfer Molding, Vacuum Infusion, Pultrusion and Press Molding. Using an acid catalyst, the cure/postcure cycles are reduced to 30 – 40 minutes cure at 140 - 160°F and 2 – 3 hour postcure (off the mold) at 140 - 180°F.

Since Phenolics are inherently fire retardant without the use of additives or fillers such as Alumina Trihydrate, Phenolic composites weigh 20 – 30% less than filled systems

These resins have been used in many transit applications such as BART (Bay Area Rapid Transit) subway cars, Amtrak trains and flooring for trains and buses.

The excellent Fire/Smoke properties of Phenolic composites (see Table 1) easily meet current requirements. They are also used for interiors of cruise ships.

Table 1. Current Passenger Rail Equipment Requirements [Federal Register / Vol. 64, No. 91 (12 May 1999) (also FTA/UMTA 1984 and 1993)] Compared to Cellobond Phenolic Capability

Test	Reqd. Level	Painted Phenolic (35% Glass)
ASTM E 162		
Flame Spread		
Is	≤ 35	0.85
ASTM E 662		
Smoke Density		
Ds (1.5 minutes)	≤ 100	0.6
Ds (4.0 minutes)	≤ 200	15
Ds (Maximum)	–	51
Time to Max Ds (Minutes)	–	14
NBS Smoke Chamber		
Gas Analysis (ppm)		
CO	≤ 3500	100
HF	≤ 200	0
NO_2	≤ 100	0
HCl	≤ 500	0
HCN	≤ 150	0
SO_2	≤ 100	80

Filament wound Factory Mutual approved ducting (see Table 2) for use in clean rooms, has been a big market for Phenolics.

Table 2. Factory Mutual Research Protocol Class Number 4922

ASTM E-84 Flame Spread	5
ASTM E-84 Smoke Density	10
Oxygen Bomb Calorimeter	7,235 Btu/lb (1.682 x 10^4kJ/kg)
Autoignition Temperature	887°F (475°C)
The maximum thermocouple reading taken 1 feet (0.3 m) from the exhaust end of the duct was 639°F (337°C). Maximum allowable: 1,000°F (538°C).	

Other applications are pressure pipe for Offshore Platforms and pultruded grating that meet Coast Guard requirements. Architectural applications such as the Clock Tower on top of City Hall in New York City, ceiling panels in London Underground, building panels for schools and hospitals have initiated the use of composites in interiors of buildings.

In the Corrosion industry, applications such as scrubbers, thermal oxidizers and tank liners that hold corrosive solvents at 160°F have been in service for over 15 years. Vacuum infused Phenolic panels (70% glass, 30% resin) (see Table 3) have met MIL-STD 2031 for submarine interiors.

Table 3. Mechanical Properties of Vacuum Infused Cellobond Phenolic (70 – 75% glass)

Test	Value
Flexural Strength (MPa)	471
Flexural Modulus (GPa)	23.8
Tensile Strength (MPa)	323
Tensile Modulus (GPa)	18.6
Elongation @ Break (%)	2.0
Notched Izod Impact Strength (KJ/m^2)	178
Density (g/ml)	1.5 – 1.6

A first for composites was the construction of a 3,140 $feet^2$ Helicopter Landing Pad that was installed on the roof of Cooper Hospital in Camden, NJ. A light weight Helipad was required. Aluminum was considered but rejected by the military because in case of a crash, the burning fuel would rapidly melt and burn the aluminum.

Since Cellobond Phenolic composites have passed the Jet Fire Test and met ASTM E-136 Non-Combustibility Test (see Table 4), Cellobond Phenolic was specified to build the Helipad. Vacuum infused panels with an iso-Cyanurate foam core were constructed, measuring 16 feet x 26 feet and 8 inches thick.

It has been illustrated that Phenolic composites can provide all the advantages of composites and eliminate concerns over Fire/ Smoke / Smoke Toxicity safety. This should allow their use in many applications where fire concerns were a hindrance.

Distributed Brillouin Sensor Monitoring of an FRP-Concrete Column Subjected to Heavy Load

by
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Structural Health Monitoring (SHM) is used to identify early signs of potential problems, allowing prevention of disasters and then the repair of these damages. SHM is also implemented to improve the construction processes and to produce new building materials, so that it saves millions to billions dollars over structures lifetime. Currently, techniques used for SHM are punctual devices giving only partial information on the stresses and not on the status of the structure. Their localized nature not only fails to give global information on the structure health, they are also incapable of detecting local defects when location is not known in advance. Quasi-distributed sensing can be achieved by using a matrix of these discrete devices spread allover the structure under scrutiny.

These difficulties can be overcome by distributed strain measurements in real time as do DBS systems [Ref. 1]. Recent studies [Ref. 2 and 3] have been conducted to monitor strain of composite and concrete beams. Strain measurements are based on the extraction of the average value of the Brillouin spectrum, which is the most commonly used signal processing technique [Ref. 1, 2 and 3]. If the spectrum has a symmetric shape under the condition of low pump and probe power, this means the asymmetric feature of the Brillouin spectrum is induced only by the stress condition. Then average strain reflects the overall structure condition. Global and local strains almost coincide, so the structure does not suffer deformations, cracks or materials de-bonding. The coincidence of global and local strains is the condition for the concrete column to be in elastic regime as it happens in lab testing. The beam follows the loading condition linearly and reversibly [Ref. 2].

However when civil engineering structures are subjected to substantial loads, induced by earthquakes or severe weather conditions for example, they start to fail, so de-bonding and deformation are developing. Brillouin profile becomes locally asymmetric and the peak is broadened (assuming the pulse width is fixed) with the FWHM much bigger than the Brillouin spectrum linewidth ($\Delta\nu_B$) of the unstressed structure (FWHM>$\Delta\nu_B$≈40MHz for SMF-28). Brillouin peak frequency does not match mass-weight center of the spectrum and average strain value. Peak frequency measurement obtained by curve fitting technique gives only global strain information. Moreover, the average strain does not represent the local strain associated with cracks and deformation of the structure as well as Fiber Reinforced Polymer (FRP)/concrete de-bonding. We find that early sign of structural failures is related to asymmetry and broadening of the Brillouin spectrum.

Our signal processing approach requires both high spatial and frequency resolutions. In commercial DBS systems, this requirement is impossible to achieve due to the pulse induced spectral broadening. In our sensor, that effect is mitigated by taking advantage of the existence of a dc part to the pulse which contributes to coherent probe (pulse) - pump (continuous wave) interaction [Ref. 5].

We propose a novel signal processing approach to extract both global and local strain information. We keep the Brillouin peak measurement as the global strain tag but we introduce, for the first time in distributed sensing field, two form factors, Asymmetric (F_A) and Broadening (F_B) Factors that are the signatures of local degradations such as cracks, deformation and de-bonding. The Form Factors are defined as $F_A=\Delta\nu_R/\Delta\nu_L$ and $F_B=\Delta\nu_{Bs}/\Delta\nu_B$ where $\Delta\nu_R$ ($\Delta\nu_L$) and $\Delta\nu_{Bs}$ are respectively the right (left) half width at half maximum and the FWHM of the broadened Brillouin loss spectrum. Brillouin loss spectra measured at every location are analyzed to extract these three parameters as illustrated in Figure 1.

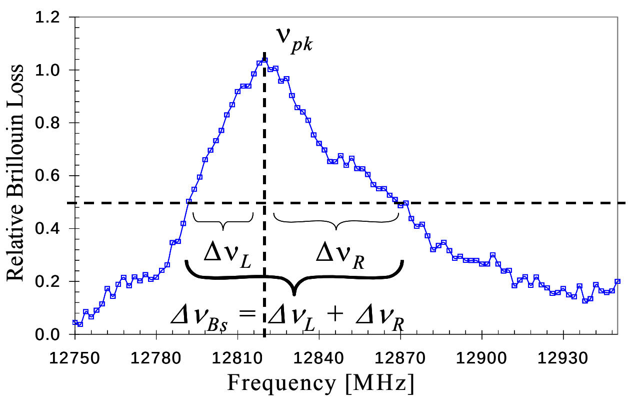

Figure 1. Definition of the width parameters on an experimental Brillouin loss spectrum of a strained section of a single-mode optical fiber.

The first parameter (ν_{pk}) is the frequency shift that gives us global information on the longest strained section observed within the pulse width (w) at a given position in the fiber (z). Brillouin frequency varies with strain when temperature remains unchanged as $\varepsilon = (\nu_{pk}- \nu_{0b}) / C_E$ where ε is the tensile strain, ν_{pk} is the Brillouin frequency shift when the fibre is strained, ν_{0b} is the Brillouin frequency shift of the unstrained fibre and C_E is the strain proportionality coefficient with $C_E = 0.05941MH / \mu\varepsilon$ [Ref. 1]. The second parameter, F_A, indicates the presence of higher but short strain components. Finally, F_B describes the broadening of the Brillouin loss spectrum induced by non-uniform strain distribution. We discuss various strain regimes associated with the form factors value. Figures 2(a) and 2(b) show various cases with the same ν_{pk} but different strain distributions. These spectra are the results of simulations [Ref. 4], for given pump and probe conditions (P_{pump}=10mW, P_{probe}=5mW), at the same location in the fiber (fiber length is 40m and z=20m) and identical pulse-width (w=2m). When F_A=1 and F_B=1, the strain distribution is uniform.

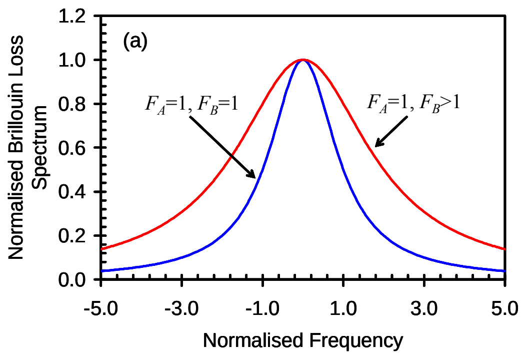

Figure 2(a). Results of numerical simulations [4] for various strain profiles included within w: uniform strain (F_A=1, F_B=1), linear strain (F_A=1, F_B>1).

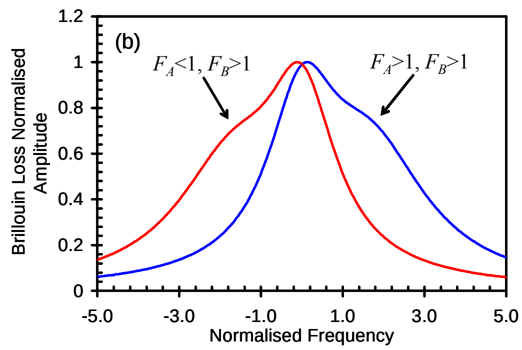

Figure 2(b). Results of numerical simulations [4] for various strain profiles included within w: non-linear strain with short components larger than main strain contribution (F_A>1, F_B>1), non-linear strain with short components smaller than main strain contribution (F_A<1, F_B>1).

The spectrum is simply shifted and a peak finding approach is enough to characterize the status of the structure (Figure 2(a)). If the spectrum is still symmetric (F_A=1) but F_B>1, then the distribution is non-uniform [Ref. 6]. Peak finding technique describes the global behavior of the structure but it fails to detect the presence of strain over section shorter than pulse-width. The strain distribution becomes asymmetric when F_A≠1 as in Figure 2(b). For F_A>1, the strain distribution is non-uniform corresponding to large local strain components while the global strain (ν_{pk}) is low. It indicates that small defects start to build up in the structure. When F_A<1, global strain becomes the highest component. It means that the structure is in jeopardy because the local strain becomes the dominating contribution. Apparently, the use of F_A and F_B introduces two advantages: 1) even if the global strain is the same (same ν_{pk}), they show distinct structural status; 2) it provides a complete picture compared to average strain detection or multiple peak analysis.

Common distributed Brillouin sensors are limited in frequency resolution when pulse width is smaller than the acoustic phonon lifetime due to pulse induced spectral broadening. At the contrary, we developed and designed our sensor to take advantage of the influence of the electro-optic modulator finite extinction ratio (ER) that enhances spatial resolution [Ref. 5]. The dc component of the pulse interacts with the pump giving two contributions to the loss spectrum: 1) the interaction of the component present in the dc part of the probe with the pump gives a spectrum characteristic of the whole fiber; 2) the interaction of the pulse part of the probe with the pump gives a spectrum characteristic of local stress. Eventually, the Brillouin loss signal is enhanced and narrower than the signal that would be produced by the pulse-pump interaction only (infinite ER case). In our experiment we used an ER of 15 dB which keeps the spectrum *FWHM* within a few percent of the Brillouin gain natural linewidth under unstrained or uniform strain conditions. A non uniform strain spectrum measured with a 1.7 ns pulse, which is equivalent to a spatial resolution of 17 cm, is presented in Figure 1. Spectra are taken every 5 cm (which is the sampling interval of sensor digitizer) allowing us to achieve cm-size crack detection [Ref. 4 and 5]. Our sensor operates at 1319nm. The sensing medium is a single-mode optical fiber.

A large reinforced concrete building column, encased in FRP casing, was constructed and tested under simulated seismic loading (Figure 3). SMF-28 fibres are glued horizontally at 10 distinct cross-sections of the column (from bottom, layer 1, to the top, layer 10) shown in Figure 3(b), which is separated by 1 m of loose fibre. An optical pulse is launched at the end of the fibre located at the top of the column (layer 10). The specimen represented a first storey column of a multi-storey building and it was tested under an axial load of 1880 kN, corresponding to 31% of the column concentric capacity.

Figure 3(a). Test Setup of Instrumented FRP/Concrete Column

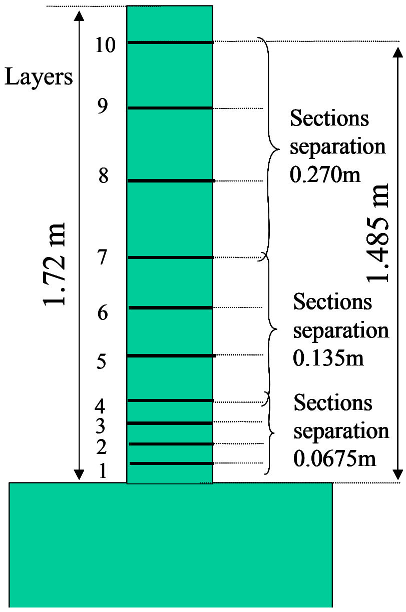

Figure 3(b). Column Dimensions and Fiber-Optic Layout

Push and pull refers to the relative location of the observatory. The push and pull amplitudes are measured by the drift over 3 to 8%. The drift parameter is defined as the ratio of the lateral displacement (δl) to the height of the column (h). The specimen was subjected to lateral displacement excursions, consisting of incrementally increasing deformation reversals. Three full cycles were applied at each deformation level, starting with 0.5%, then 1%, 2%, 3% etc, in the deformation control mode of the horizontal actuator. Lateral loading continued until the specimen was unable to maintain a significant fraction of its maximum lateral load resistance. Measured strain data with distributed sensor was used to monitor columns response to seismic loading at each drift step.

We extracted peak frequencies from the spectra in order to obtain axial and hoop strain distribution. The peak strains for push and pull condition at drifts 4 and 8% are presented in Figure 4.

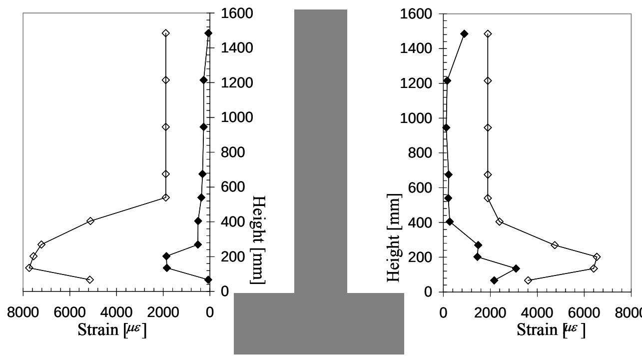

Figure 4. Axial profile of peak strain for (a) pull face and (b) push faces under respectively pull and push conditions. Open symbol curves correspond to a drift of 8% and full symbols are associated with a drift of 4%. Constant strain for 8% cases (layers 6 to 10) means that actual strain is smaller than reported values. In this case, Brillouin frequency span started at 12900MHz.

Large strains are concentrated at the bottom of the column (layers 1 to 5) with a peak value at layer 2 confirmed by structural engineering theory predictions. The most extensive damage occurred at approximately 100 mm to 160 mm above the column-footing interface, which coincided with the location of first fibre rupture in all columns. The shifting of the critical section from the interface was attributed to the confining effect of the footing as previously reported [Ref. 7 and 8].

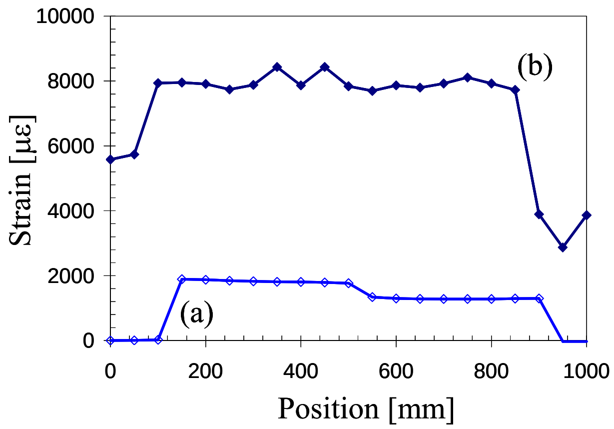

Figure 5. Hoop strain profiles for layer 2 under pull condition with drifts of 3% (a) and 8% (b)

Figure 5 represents the hoop strain along layer 2, the layer of largest strain, for pull case with drifts of 3% (Figure 4(a)) and 8% (Figure 4(b)). ε_{pk} is maximum at 3% drift on pull face. Highest strains are concentrated on pull side of the column with maximum non-uniform strains. The structure is capable to absorb stresses locally. At the contrary, it appears very different in 8% case: ε_{pk} is high everywhere around the column when large strains dominate. This suggests that concrete at critical section of column is significantly damaged and generating large amount of pressure on FRP casing.

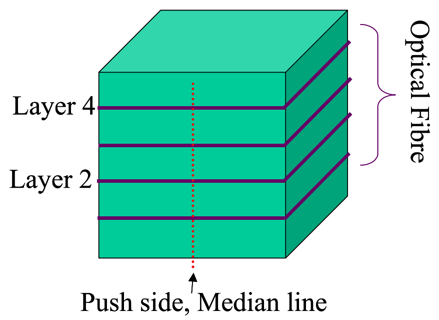

Figure 6. View of the bottom of the column with the four first optical fiber layers

From each Brillouin measurement, we also calculated F_A and F_B. We then drawn ν_{pk} and the two form factors as a function of the drift amplitude for both push and pull condition. We concentrated our analysis on two fiber sections located on the median of layers 2 and 4 of push side (Figure 6). We also analyzed the median point of layer 4 of pull (i.e. symmetric of layer 4 push side).

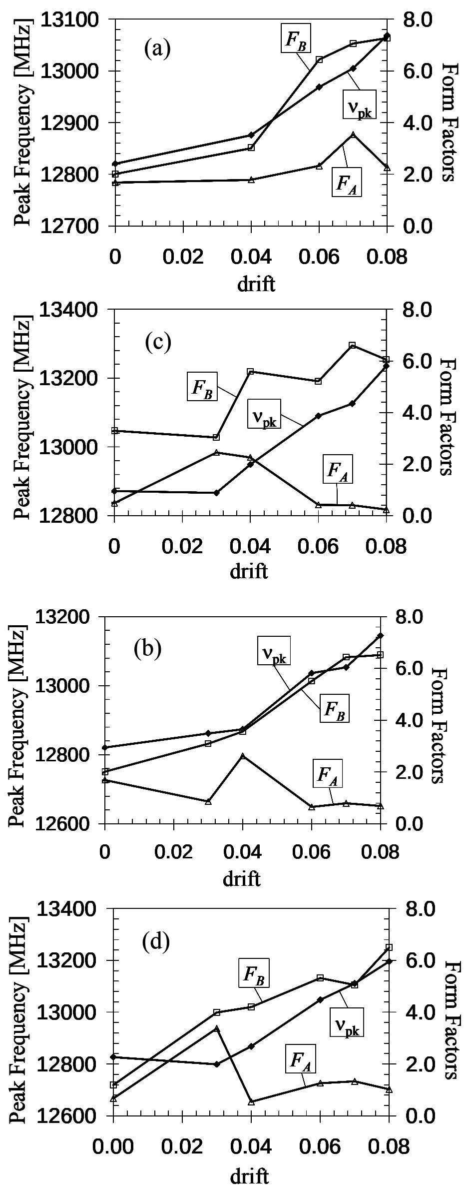

Figure 7. Peak frequency (left y axis) and form factors (right y axis) as a function of column drift:
(a) push side, Layer 4, median point, push condition;
(b) push side, Layer 4, median point, pull condition;
(c) push side, Layer 2, median point, push condition;
(d) pull side, Layer 4, median point, pull condition.

The graphs of Figure 7 show that ν_{pk} and F_B experience monotonic increase with a bend in the curve when $F_A \approx 2$ and $F_B \approx 3$. At larger drifts, F_B tends to saturate (Figures 7(a) and 7(b)) or to fluctuate (Figures 7(c) and 7(d)). F_A increases above 2 (it can reach a maximum of 4) and then drops below 1 and becomes steady. The region of smaller ν_{pk} slope corresponds to elastic regime of the column without deformation. The increase of F_A and F_B values are associated with the appearance of local stresses, contributing to the crushing and deformations of the concrete. The bend in ν_{pk} is followed by a sudden slope rise, when $F_A \approx 2$ and $F_B \approx 3$, which is due to the complete concrete collapse as observed in the experiment. FRP and concrete are fully de-bonded, the structure is maintained by the FRP only, leaving it free to follow the load changes. Ultimately, F_B saturates and/or fluctuates when the drift becomes large and $F_A \lesssim 1$. Large strain is the dominant contribution. The column safety is then threatened. The FRP, being the only element supporting the structure, starts to rupture locally. These ruptures release locally the tension inducing a local strain reduction and then mitigating the spectrum broadening.

Strain Observation	F_A	F_B	ν_{pk} Slope	Structure Status
Uniform	<2	<3 Small slope	Constant, small	Elastic regime, good shape
Non-uniform, low strain dominates	>2 Peak value	>3 Large slope	Increase	Deformation, local cracks, local de-bonding
Non-uniform, large strain dominates	<1 Stationary	>>3 Constant and large slope	Constant, Large	Full FRP/concrete de-bonding
Reduced non-uniformity, large strain dominates	<1 Stationary	>>3 Stationary	Constant, Large	FRP cracks

Figure 7. Signature of Structure Failure With Form Factors

Figure 7 summarizes the relationship of the structure behavior with the three parameters variation. Monitoring the changes of these values can predict the early sign of collapse. The conclusions drawn in Table I are valid for 1.7 ns pulses but should not be affected by pulse width of the same order of magnitude, which is the best spatial resolution that can be currently achieved.

We conducted an experiment on a reinforced concrete column confined by FRP stay-in-place formwork. The column was monitored with the DBS during a trial reproducing earthquake like conditions. Our technique allows the detection of deformations and cracks using Distributed Brillouin Sensors and the appropriate signal processing approach. It strengthens the distributed Brillouin sensor position as a serious candidate for SHM Applications.

ACKNOWLEDGEMENTS

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Global Focus: Portugal

In this issue we highlight activities being conducted in the area of FRP in Portugal. We hope that this will be a continuing feature and invite future summary articles from our members worldwide.

Birds Eye View of Polymeric Matrix Composites in Civil Engineering in Portugal

by
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The application of polymeric matrix composites in the Portuguese industry of construction has been gradual and slow whereas in terms of research efforts, given the size of the academic community of Civil Engineers, the developments have been more satisfactory. A brief description of some applications and research in the past 5 years is made hereafter, touching the following aspects: (i) confinement of columns, (ii) strengthening of slabs, beams and masonry, (iii) durability and (iv) other applications.

CONFINEMENT

Basic studies have been conducted at several institutions, namely at the Technical University of Lisbon (IST), at the University of Porto (FEUP) and at Universidade Nova de Lisboa (UNL), on confinement of columns based on experiments conducted on scale models and specimens of different geometry. Tests made at UNL to evaluate the importance of size effects on mechanical characteristics of GFRP wrapped cylindrical specimens, Figure 1, [Ref. 1], showed that (a) increasing the number of layers, the capacity load increases more than predicted by available models, and (b) the ratio of stiffness (outer shell/confined core) is the determining factor on the effectiveness of the confinement and, as a result, on the increase of strength.

Figure 1. Instrumented specimens of different H (300, 450, 600, 750 mm), wrapped with GFRP.

A recent PhD thesis on strength of columns wrapped with FRP composites and submitted to axial monotonic or cyclic compression was concluded at UNL and was based on forty-five experimental tests of RC cylindrical specimens of 150 mm diameter, 750 mm height, and twelve columns of 250 mm diameter, 1500 mm height. The tests, Figure 2, and computational models produced a lot of information [Ref. 2] among which were (a) Ultimate tensile strain on FRP jackets was more than 50% smaller than the values found in tensile tests of flat coupons, (b) Compressive strain of FRP at maximum force is near the ultimate compressive axial strain obtained in tests; such strain, at failure of the column, reaches much higher values, and (c) Early failure of steel stirrups due to poor workmanship may lead to longitudinal buckling of bars and cause considerable lowering of the column strength.

Figure 2. Cyclic displacement imposed on CFRP strengthened column (UNL) and axial tests on confined cylinders (IST)

The influence of the sharpness (as opposed to the roundness) of corners on CFRP wrapping of square columns, was also subject of study [Ref. 3] with results showing that (a) Columns with cross sections resulting in sharp edges show reduced benefit from FRP confinement; the decrease of strength is mitigated by rounding the corners, with better results for larger radii R, until a threshold is found; and (b) Strain at failure for sections with rounded corners did not allow a general conclusion, with sections of larger radii showing smaller increase.

At FEUP a recent study was concluded on strengthening of hollow rectangular columns with CFRP strips, Figure .3, preventing the shear failure mechanism, with new collapse in bending, at the pier base. Tests showed that internal strengthening is also required.

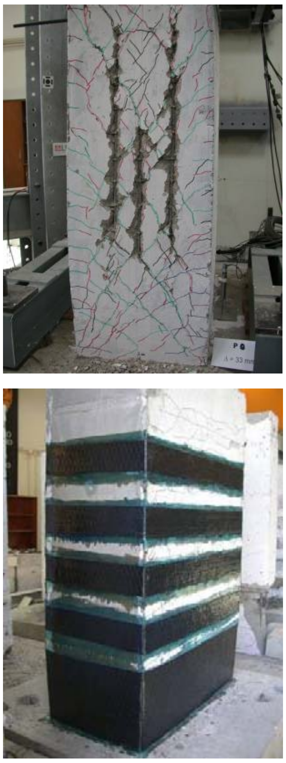


Figure 3. Hollow piers before and after the shear retrofitting with 2 layers of CFRP strips (UP).

The consequences of environmental ageing on the capacity of columns, relating the degradation of the GFRP material to that of the overall system, are reported in [Ref. 4] and include the following conclusions: (a) The reduction of the tensile ultimate strains of flat laminates of GFRP due to temperature cycles, salt fog cycles, or moisture cycles are congruent with reductions on the ultimate strains measured on the GFRP jackets, but remain above the latter, (b) The loss of the compressive strength of the wrapped cylinders found, e.g. at 10000h, is, then, much smaller than the reduction obtained for the tensile strength of the laminates, also at 10000h.

Columns partially wrapped with strips were monotonically and cyclically loaded, in compression, up to failure [Ref. 5], at Universidade do Minho, to examine the influence of the width of the strips, the distance between strips and the number of CFRP layers on the increase of the load carrying capacity and ductility of concrete column elements, was determined in the studies [Ref. 6].

BEAMS AND SLABS

Strengthening of beams and slabs has shared with confinement of columns most attention of researchers in Portugal, but there are not many publications reporting results in technically known journals. An exception lies on a strong program on Near Surface Mounted (NSM) laminates conducted at Universidade do Minho (UM) [Ref. 7].

The bond performance of near-surface-mounted CFRP laminate strips was assessed at UM by means of pullout-bending tests, Figure 4, under monotonic and cyclic loading and is reported in [Ref. 8]. A local bond stress-slip relationship was derived from the tests, but the parameters that define the relationship were found to be dependent on the bond length.

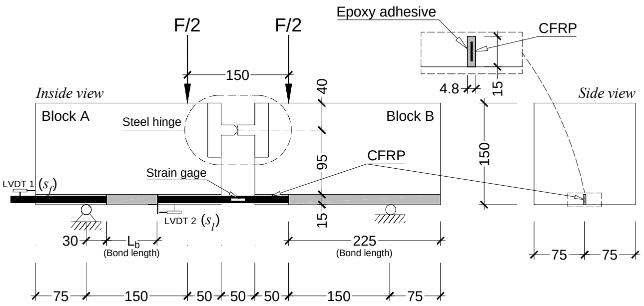


Figure 4. Pullout tests for determination of bond for NSM composites [Ref. 8].

Effects of salt fog and moisture cycles, at constant temperature, on the bond between CFRP laminates and concrete, were studied with specimens, as shown in Figure 5, and artificially aged at UNL. Different mechanisms of failure resulted from different aging processes. Moisture cycles did not significantly change the mechanisms from those observed on naturally aged specimens with rupture on the concrete near the surface, while for salt fog the separation took place at the interface adhesive-concrete. One possible cause is the gain of tensile strength of concrete also recorded in pull out tests. This behaviour did not translate on higher rupture loads for salt fog because of the more irregular distribution of bond stresses detected for that condition [Ref. 9].

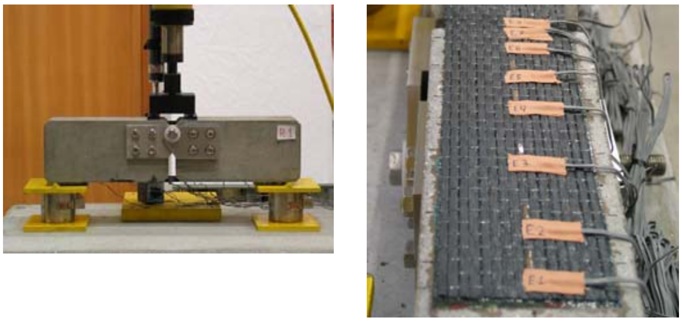


Figure 5. Bond tests of CFRP and concrete.

A much more complete program was also undertaken at UNL to examine environmental effects on bond between GFRP strips and RC. Pull off tests and tests on models similar to those used for CFRP were made [Ref. 10]. Immersion in salt water, temperature cycles, salt fog and moisture cycles and tidal-like effects were studied after enduring up to 10000h of accelerated aging. Computational results were also generated and appear to be of satisfactory quality.

Major conclusions included that the temperature cycles were most detrimental and that aging associated with salt water caused important degradation of bond between the GFRP strips and concrete.

For the temperature cycles and for reference specimens, ultimate failure took place in the concrete layer, while otherwise separation occurred, essentially, at the adhesive interface.

MASONRY

Masonry of different types is found everywhere in Portugal and some shows need of urgent rehabilitation. Experimental programs that address problems associated with interventions on masonry are mentioned below.

The performance of brick masonry arches, both plain and strengthened with GFRP, is reported in [Ref. 11]. The plain specimens developed a typical four-hinge mechanism, for small displacements, just after reaching the maximum load, Figure 6. Strengthening with GFRP increased the load capacity and caused the appearance of new dominant failure modes, with detachment of the composite from the arch surface and sliding along a mortar joint. The separation of GFRP from the arches took place when the strips were bonded to the intrados, whereas for strengthening at the extrados failure occurred due to slipping along a mortar joint. Large deformation capacity was gained prior to failure with the reinforcement, i.e. considerable ductility was added to the arches.

Figure 6. Reinforcement and failure mechanisms of brick masonry arches [Ref. 11].

The effectiveness of externally bonded reinforcement with CFRP strips and near surface mounted (NSM) CFRP laminates to increase the flexural resistance of masonry panels is assessed in [Ref. 12]. As mentioned earlier, in the former technique the CFRP laminates are externally bonded to the concrete joints of the panel, while in the NSM technique the CFRP laminates are fixed into precut slits on the panel concrete joints. Three series of masonry panels were tested each one consisting of three specimens. One series had no strengthening elements, while the other two series were strengthened with CFRP laminates: three panels with the laminates externally bonded and the other three were NSM strengthened. In the study, the NSM technique provided a higher increase on the panel load carrying capacity as well as a larger deflection at the failure of the panel, proving to be a good alternative when applicable.

Seismic retrofitting of large scale models has been experimentally studied in the National Laboratory of Civil Engineering (LNEC), Figure 7, and a summary of the results for masonry reinforced with GFRP is presented in [Ref. 13]. With adequate anchorage of the composite, it was found a significant gain of ductility and energy dissipation, with no sudden brittle collapse. The authors include some design recommendations.

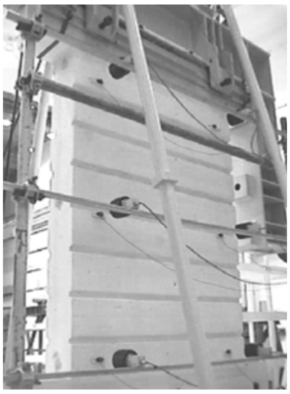


Figure 7. View of one instrumented model to be tested on the shaking table [Ref. 13]

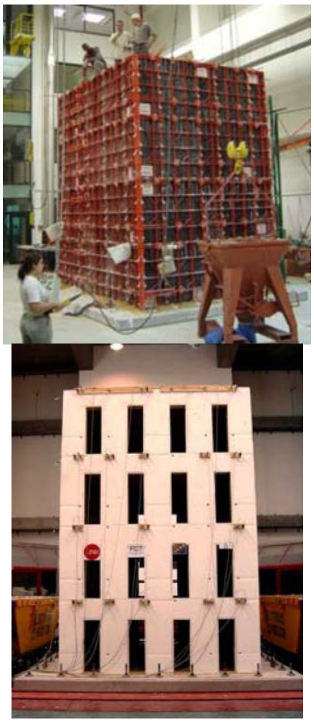


Figure 8. Scale models of typical old buildings of Lisbon to be strengthened [Ref. 14]

Lisbon is located in a seismic area and part of its residential housing is not capable of withstanding the type of design earthquake now considered in the Codes. In particular, houses built with unreinforced masonry in the later part of the 19th century and the earlier decades of the 20th need special attention and retrofitting or demolition posing an economic and social problem of large magnitude. To analyse the typical performance to be expected from those buildings and quarters for a severe quake, models were built at a geometric scale 1:3, Figure 8. Solutions that comprised metallic connectors and reinforcement with epoxy and GFRP for wall-pavement connections, as well as tensile bars linking parallel external walls and strengthening of members with GFRP strips were introduced [Ref. 14]. The tests were made at the main shaking table at LNEC and preliminary results are being used to define possible large scale repairs.

APPLICATIONS

A brief note on applications is presented herein, essentially described by some images. Typical strengthening of slabs is shown in Figure 9, on a viaduct and a building, and a less common repair performed in an old building in Porto is also shown, Figure 10. In the latter case, two faculty members from FEUP, A. Costa and L. Juvandes, besides structural strengthening, had to ensure adequate repair of statues that threatened to fall and imperil pedestrian lives. They used GFRP strips and wrapping to achieve that goal.

Figure 9. Great Porto: widening road IC24 (Mota-Engil/TRIEDE engineers); building in Cascais (LEB engineers).

Figure 10. Repair of building and decorative elements in Central Porto (Photo courtesy of A. Costa/ now at Univ. Aveiro)

Pioneering work, in Portugal, has been made on the strengthening, maintenance and monitoring of a bridge in Ponte de Lima, in Northern Portugal, with participation of the UP, through both its Mechanical and Civil Engineering Departments. A pilot project with participation of four engineering companies was started in 1999 and has proceeded until present, generating an array of important results on CFRP strengthening and post-performance, including thermal and humidity variations, which can be looked at or traced from reference [Ref. 15].

Another application of composite materials under study in the Civil Engineering Department of UNL is the use of Kevlar and dyneema plates as protective barriers against impact. A research program that derived from earlier studies of Kevlar helmets with the UP (Mechanical Engineering) evolved and has led to the study of the effectiveness of different plate designs against different types of impact with or without perforation of the plates.

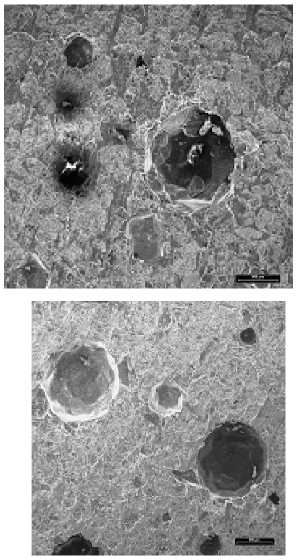
Failure for impact of fragments at moderately high speed is brittle and material stiffness coefficients are difficult to ascertain experimentally and, when known, they are usually considered confidential. Studies made at the Navy School and at the UNL found a minimum threshold for the velocity that initiates damage of the plates be it by delamination or matrix crazing. At higher velocities, composite cracking takes place and, for still higher impact velocity, partial or complete material break-out appears [Ref. 16]. Recent and still unreported tests include the interposition of layers of polymeric mortars or thin, light ceramic material with interesting results.

POLYMERIC MORTARS

Some research emphasis has been placed on studies of polymeric mortars, more than polymeric concrete, and on their eventual role on structural repairs [Ref. 2] that makes reference to the topic mandatory on this summary of composite related development. Most work has been done at INEGI, an Institute associated with the Department of Mechanical Engineering of UP, leader on composite studies in the country, and at the Civil Engineering Department of UNL.

Figure 11. Repair of column with epoxy mortar [Ref. 2]

Durability studies of epoxy and polyester mortars have been made [Ref. 17] and Figures 11 and 12. Scanning Electron Microscopy (SEM) and petrographic observations were used in a team effort with researchers from Earth Sciences as tools to allow further insight into the mechanisms of degradation of the mechanical properties [Ref. 18 and 19]. From published results it is excerpted that: (a) Cycles of salt fog were more severe on bending strength than temperature cycles, (b) Epoxy mortar was more affected than polyester mortar for both salt fog and temperature cycles, (c) Compressive strength was much more affected for epoxy concrete than for polyester concrete, and (d) Effects of solar radiation on strength were minor, while an increase of bending deformability was identified. The fact that the PhD thesis [Ref. 20] has not yet been discussed advises no further comment, but part of its experimental data have been published by the candidate and co-workers, namely in [Ref. 21].



Polyester - 0, 10000h

Figure 12. SEM images of polyester mortar before and after 1000h salt fog cycles [Ref. 18]

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A Perspective From A Leader of Industry

While the use of FRP in civil construction is still growing, there is a tremendous level of activity in the area of architectural products. The perception that applications in this area are merely facades and sculptures could not be further from reality. A large number of applications undergo tremendous levels of design and engineering and have to be built to not only withstand large forces, but also have to survive in harsh environments over long periods of time. In a sense, applications in this area have for years used composites to integrate form and function, blending the performance characteristics of composites with their aesthetic potential. In this article William Kreysler, a leader and innovator in this field discusses the use of FRP from a vantage point of looking at successes of the past and the promise of the future.

William Kreysler founded K&A in 1982 after 10 years as Executive V.P., Production Manager, and Sales Manager for Performance Sailcraft Corp. Mr. Kreysler is active in the composites industry, having served on the board of directors of the Composite Institute, and beginning his second term on the board of the Composite Fabricators Association (ACMA). He is Chairman of the ACMA Architectural Division, and founder of the ACMA Architectural Division's committee on the Building Code Initiative for Composite Materials. Mr. Kreysler is also a visiting lecturer at Stanford University, and the U.S. Military Academy at West Point. In addition, Mr. Kreysler is a member of the Construction Specification Institute, the Association for Preservation Technology, and the American Institute of Conservation.

Composites – Synthesis of Form and Function

by
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Over 50,000 years ago, Neolithic man built composite structures of mud and straw, portions of which survive to this day.

The "Composite" Building Material From Ancient Times

The Hyskos tribe used composite bows developed by engineers/craftsmen of the steppes probably centuries earlier, to conquer Egypt during the IVX dynasty. American Indian pueblos, Asian houseboats, even dinosaur nests, in fact most structures of pre-industrial revolution civilizations are examples of composite or quasi composite designs. Man would observe natural structures; natural structures are based primarily on some derivation of composite principles, and thus, man made structures would mimic natural composites.

Separating the structure from the shell of an enclosed building is fairly new. Not until the industrial revolution and the advent of steel along with the desire to build "up" for economy has the idea of sticks covered by non load bearing skins been common. Even early bridges were either composites (lignin and cellulose) or stone. The abandonment of monocoque structures was dictated by economic factors. Sticks and skins were the only way in pre industrial revolution economies to realize cost effective buildings. More efficient material systems simply did not exist.

Almost immediately after FRP was discovered in the 40's it was used by the military in a classified program at Wright Patterson AFB to fabricate aircraft parts. Concurrently plastic Quonset huts were being experimented with to conserve on metals needed for the war effort. Buckminster Fuller's 50 foot diameter all FRP composite "Fly-eye" geodesic dome is an early example of this shift. Through the use of synthetic composites, Fuller had demonstrated that material evolution would now allow a return to the more efficient and versatile monocoque structures. Two obstacles remained, cost and convention.

In 1954, Monsanto opened its "House of the Future" at Disneyland. Engineered by SGH (Simpson Gumpertz and Hager) and built to show how homes would be made in the future, this monocoque composite structure remained a symbol of where building design could go until it was demolished in the late 60's. The planned one day demolition turned into two weeks after the wrecking ball proved ineffective and the FRP building was sawn apart with electric hack-saws. During the Reagan administration and under the direction of automotive executive George Romney the department of housing and urban development (HUD) sponsored Operation Breakthrough resulting in manufactured housing some of which was made of composite and some of which is still occupied today. Waterproofing and assembly detail failures prevented widespread acceptance.

As time went by material costs went up. Low cost plastics had to compete with gasoline. As gasoline demand grew, synthetic resin prices increased relative to traditional materials. Meanwhile the wood, steel and concrete industry, which had dominated construction since the 19th century, had mastered the art of exclusion. Building codes made gestures toward accommodating new materials but barriers were significant. To this day, qualifying an "alternate" material means rigorous testing and finally satisfying the local code official of all people. The new IBC section 104.11 reads in part:

"An alternative material, design or method of construction shall be approved where the building official finds that the proposed design is satisfactory and complies with the intent of the provision of this code, and that the material, method or work offered is, for the purpose intended, at least the equivalent of that prescribed in this code in quality, strength, effectiveness, fire resistance, durability and safety."

To qualify an alternate, the engineer must be willing to invest in extensive testing and documentation, take the risk and responsibility of providing these assurances, and then after that, subject all to the often capricious code official for final approval. Little wonder new materials are scarce in construction. Furthermore, without significant advantages, developers and building owners see no reason to pay the price of qualifying new materials. Material suppliers or manufacturers, knowing this is just the first step to generally accepted use of a new material, and with other markets already developed, are reluctant to invest. Without someone willing to pay the bills, engineers have little incentive to innovate, even if they are willing to take the risk. Composites get stuck in academia where researchers compete over scarce resources and receive little support from industry. There is only one way out. Someone has to want composites in their building badly enough to pay the price.

To pay the price there has to be something to gain. Engineers won't benefit. In fact new materials mean new learning curves, more risk, and probably more hours for the same fees. Academics will actually lose if composites move from the research phase to the mainstream. Research focused on durability and mechanical properties will become less relevant as standards are adapted. Material manufacturers try but they have shown they are not ready to make the commitment.

The owners of these new structures will foot the bill since they are the ones with most to gain. They with their architects and design engineers are the ones who will decide when this happens. Building owners or developers are constantly searching for something that increases return on investment. Composite materials offer this more than any traditional material can. Strong lightweight materials reduce moment of inertia. Even with current codes, composite skins can reduce the steel needed to build a traditional building. Environmental considerations give light translucent building components advantages. Look at the architecture of the recent past. 3-D computer programs, finite element analysis and computer aided manufacturing are all tools that allow architects and their engineers to explore entirely new designs based on monocoque structures and inherently strong compound curved shapes. Design is evolving towards more organic shapes simply because it can and because the structural and aesthetic advantages warrant the change. These materials accommodate this shift and the analytical tools are there to document it, integrate the complex systems required of a modern building, and show the contractor how to put the whole thing together.

FRP acoustic panels in Louise M. Davies Symphony Hall in San Francisco (some weigh as much as 8500 lbs).

A typical restoration

A 40 feet high, 10,000 lb "Bear" in Denver

Venetian glass dome in Beverly Hills, CA. The Entire Dome was fabricated off-Site, shipped to site and then lifted into position and bolted down in less than 3 hours.

In the long run, I doubt much will come from copying 19th and 20th century design methods using composites instead of the materials these systems were designed to exploit. The steel industry did not copy masonry to become what it is today; steel bricks never evolved for the same reason I believe composite I beams are limited in use. I beams and 2x4 studs were designed to take advantage of the material properties and manufacturing methods more suited to them. The mechanical properties of composites suggest structural designs that behave more like the leaves of trees, seed pods or the most important structure on earth, the egg. Copying an egg shell in steel would be an economic disaster. In composites it is simple.

75 Foot Tall FRP Structure (Todd Williams and Billie Tsin Architects)

Leonardo da Vinci, so far ahead of his time he had nowhere to go but to nature to learn, made observations so profound we are still, to this day discovering how to put them to use. Engineers today need new models to inspire them to use composites properly. Composites should be viewed by engineers like the material equivalent of DNA, a tool to create new ideas, new materials and new designs, demanding we reinvent how we think and how we design our built environment. We now have at our disposal the building blocks that allow us to efficiently and even economically copy nature and natural design. The sooner we abandon traditional means and methods and throw away their restrictive tools, the sooner we will see composite materials enter the stage where they belong, as the re-emerged material of ancient times adapted to a contemporary world facing challenges that demand new thinking, new ideas, and new tools to exercise and execute those ideas. Antonio Gaudi, the brilliant Spanish engineer of the last century who invented the idea that led to finite element analysis literally turned design on its head to discover analytical tools unheard of in his time. Visiting his cathedral today in Barcelona which is still under construction, and seeing how composites are allowing contractors to realize his design more economically and quickly, one can only imagine what amazing things he or Leonardo might have dreamt of had they been with us today. We have that chance but it will take imagination, creativity, courage, and skill to see the future. We must imagine whole new structures based on entirely new ideas about building born out of a re-examination of our surroundings and the greatest of engineers, our natural environment.

A Perspective From A Leader in Academia

From its outset academics have been deeply involved with the development of FRP for use in civil infrastructure. Professor Aftab A. Mufti, presently the President of ISIS Canada and ISHMII, in addition to being a Professor of Civil Engineering at the University of Manitoba, has been one of the pioneers in this field. In this article he reflects on the past and provides inspiration for the future. His ideas on the integration of developments in the areas of FRP and SHM resonate with needs in both areas, and he provides a fascinating glimpse of the past merging into the future.

Reflections on the Development and Use of FRPs and SHM in Canada

by
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About 20 years ago, Professor Urs Meier of EMPA (Swiss Federal Laboratories for Materials Testing and Research) wrote a paper on a futuristic bridge across the Strait of Gibraltar with a main span of 8.4 km. Since a bridge with such a long span was not possible with conventional building materials, i.e. steel and concrete, Professor Meier proposed that this structure be made of carbon fibre reinforced polymer, a material that was being used in Canada in the aerospace and automotive industry but not in civil infrastructure. When I read this paper, my colleagues and I decided to pay a visit to Professor Meier at his laboratories in Zurich. This visit to EMPA convinced me that there was an urgent need in Canada to conduct extensive research into the use of fibre reinforced polymers (FRPs) - or Advanced Composite Materials (ACMs) as they are otherwise called - in bridges and other civil structures.

Immediately upon our return from Zurich in 1989, myself and two of my research colleagues published a position paper entitled, “Has the time come for advanced composite materials in bridges?” Others would have been content to just publish the paper, but not us. Anxious to translate our vision into action, I asked the Canadian Society for Civil Engineering (CSCE) to form a technical committee on ACM in bridges and structures, with the goal of fast-tracking research in the use of ACM in civil structures. The committee was quickly formed and I was appointed its chair. The CSCE committee was very proactive in achieving its goal. It persuaded the Federal Government of Canada to partially finance fact-finding missions to Western Europe in 1990 and to Japan in 1991; it being noted that extensive research was being conducted in these countries on the subject under consideration. The work of the two missions led to two state-of-the art books (*Advanced Composite Materials in Bridges and Structures*, ISBN: 0-921303-40-8; and *Advanced Composite Materials with Application to Bridges*, ISBN: 0-921303-28-9), which are still being cited in technical literature.

Thanks to the enthusiasm of my colleagues and business associates, the CSCE Technical Committee grew in 1992 into the ACMBS (Advanced Composite Materials in Bridges and Structures) Network of Canada. The goal of this Federal Government-sponsored network was to promote alliances between Canadian industries and universities in the field of advanced composites and materials. I was elected as the chair of this new network; and through the efforts of my colleagues and myself, we quickly achieved a dramatic increase in both the research and the use of advanced composite materials in civil structures in Canada. A number of bridges were built in Canada to demonstrate the use of these futuristic building materials and monitoring technologies. These structures have now stood the test of time proving their durability and value to the Canadian economy and public.

The formation of the ISIS (Intelligent Sensing for Innovative Structures) Canada Research Network in 1995 was a natural sequel to the ACMBS Network of Canada. The goal of the new network is to promote research activity in Canada in the use of innovative building materials and methods in civil infrastructure and its mandate is to revolutionize the design and construction of civil engineering structures so that they will last 100 instead of 50 years. I was, once again, very honored when my colleagues paid me the tribute of appointing me as the president of ISIS Canada when the first president left to take up a position elsewhere.

It is important to note that 20 years ago not a single research project was on the books in Canadian universities on the use of ACM or FRP in civil structures. Today, there are more than 200 Canadian researchers devoting themselves to this topic. The use of ACM in civil structures in Canada is now on par with that of Western Europe and Japan.

The journey from a visit to the EMPA laboratories to the formation of ISIS Canada was not an isolated event as it initiated the concept of using Structural Health Monitoring (SHM) for innovative structures using fibre reinforced polymers. The field of monitoring structures with the help of electronic and photonic sensors in research is not new, but it needed an entity such as ISIS Canada to promote its general use in the field. The monitoring of field projects by ISIS led by natural progression to the development of a new discipline ‘civionics’, which was designed to instruct new and practicing engineers in the proper use and installation techniques of sensor systems for monitoring the health of civil structures with electronic and photonic sensors. This was essential for the development of intelligent infrastructure. The next major step required in this process, for SHM and FRPs to be internationally accepted by the civil engineering community, was the development of internationally-accepted guidelines for the application, use and interpretation of data from SHM installations. Once again, ISIS spearheaded the formation of an international association whose purpose was the development of an international set of guidelines to ensure uniform quality control in these areas. The association was called the International Society for SHM of Structures (ISHMII); and it is with pride that I accepted the invitation by my colleagues to become the founding president of this organization.

Also, for the use of innovative materials to become an acceptable, widely utilized tool by civil engineers in the field, it was necessary for their comfort level and the safety of the travelling public, to develop a uniform set of guidelines in the form of a building code that would be acceptable to government regulatory bodies. To ensure this acceptance, my colleagues and I were invited to form the technical subcommittee that re-wrote a section of the Canadian Highway Bridge Design Code (CHBDC) to allow for the use of FRP materials in the construction and rehabilitation of bridges and bridge components in Canada. This committee, which I chaired, recently completed its work. The revised section was unanimously accepted by the Technical Committee of the Canadian Standards Association and is expected to be published Canada-wide in November 2006.

Structural health monitoring and innovative structures incorporating advanced composite materials are now an established fact in Canada and in many other parts of the world thanks to the efforts of many including the ACMBS Committee, ISIS Canada, ISHMII and many other notable individuals. These committees are comprised of the leading scientific minds in civil, electrical and computer engineering, as well as experienced business leaders. Through their efforts, new, safer, more durable structures are being created; and as well, older infrastructure is being rehabilitated. This has resulted in significant cost savings in the area of maintenance, but more importantly, has contributed to the safety of the travelling public. Much has been accomplished, but there is so much more to do. It is an exciting time in the field of engineering and I would like to encourage all young people who love mathematics, the beauty of design, the art of lasting infrastructure, and the satisfaction of creating something for posterity, to give this field some thought. Engineering has been and continues to be a passion in my life and I can think of no greater reward than to spend one's life fulfilling a dream.

Conference Announcement

The First Asia-Pacific Conference on FRP in Structures (APFIS 2007)

12-14 December 2007
Hong Kong, China

APFIS 2007 is the first official Asia-Pacific regional conference of the International Institute for FRP in Construction (IIFC) on the research and use of fibre reinforced polymer (FRP) composites in civil engineering structures. It is one of the few FRP related conferences in the Asia-Pacific region, and is a unique opportunity for researchers and practitioners in the region and indeed the world to show case their work and learn about the latest developments in the field.

The key dates for the conference are:

Submission of Abstracts for Review:	31 December 2006
Abstract Acceptance Notification:	15 February 2007
Submission of Papers for Review:	1 June 2007
Paper Acceptance Notification:	1 August 2007
Submission of Final Camera Ready Papers:	1 September 2007
Conference:	12-14 December 2007

The three-day program will consist of keynote lectures, invited sessions, general sessions, and doctoral student sessions. Selected sessions will be organized by IIFC working groups "FRP Strengthened Metallic Structures", "Ductility of FRP Plated Beams and Structures" and "Bond Behaviour of FRP in Structures". The third day of the conference will contain presentations on practical applications of FRP and will be of particular interest to practicing engineers. Various IIFC meetings will also be held during the conference.

Please visit the conference website (http://www.hku.hk/apfis07/) regularly for up-to-date information pertaining to the conference as information is made available. Enquiries about this conference should be addressed to:

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IIFC Perspectives and News

As the year draws to an end and brings with it a transition from the wise elder of 2006 to the baby of 2007, it brings with it the transition in leadership of IIFC. Professor Jin-Guang Teng who has over the past few years ably nurtured and guided the organization will be stepping down at the end of his second term, leaving to his successor a vibrant and active organization. From IIFC's birth as a result of discussions among a few of its founding members to its growth as an institute with conferences, symposia, working groups and as a forum for international collaboration, Professor Teng has been at the helm working tirelessly on behalf of IIFC. In the following "message from the President", he provides his perspective on IIFC and his hopes for its future. All of us salute him and thank him for his tireless service and leadership over these past few years.

Message from the President

by

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A few weeks ago, I wrote to inform the IIFC Advisory Committee that I would not stand as a candidate for the IIFC Presidency for a third term, although a third term is permitted by the IIFC by-laws. The Advisory Committee has since gone through much deliberation and has been in the process of nominating candidates for the next term of the IIFC Presidency. Upon the invitation of Professor Vistasp M. Karbhari, Editor-in-Chief of this newsletter, I am writing this farewell message to readers of “FRP International”. My term as the founding IIFC President will formally end at CICE 2006 to be held on 13-15 December 2006 in Miami, U.S.A.

This decision has been a very difficult one for me as IIFC is dear to my heart, but due to increases in my commitment in other areas, I have found it increasingly difficult to find sufficient time for IIFC. In addition, a new leadership can bring in fresh ideas to grow IIFC further. I also believe that IIFC has attained a degree of maturity that will allow a leadership change to be smoothly implemented. I will of course remain an active member of IIFC, and do my best to support the next President and to contribute to activities of IIFC in a different capacity. It is one of my top professional priorities to see IIFC moving from success to greater success.

It did not seem to be a long time ago when a meeting of leading researchers in the infrastructure composites area attending CICE 2001 in Hong Kong was convened to discuss the possibility of forming an international association. The time was December 2001, now almost 5 years ago. IIFC formally began its life when its Council was established in 2003, which was followed by the elections of the Executive Committee, the first Fellows and the Advisory Committee of IIFC. The Institute became fully functional and started to accept applications for membership on 1 January 2004.

Over the past three years, IIFC has come a long way. It is now the leading international organization in the infrastructure composites area and a well recognized organization in the structural engineering field. Most of the leading researchers in the area are members of IIFC. IIFC now has 2 Patron Members, 1 Collective Member, 157 Full Members (including 12 Fellows), and 11 Student Members from 32 countries. It has a well established biennial official conference series, the CICE series: CICE 2004 was held in Adelaide, Australia; CICE 2006 will soon be held in Miami, U.S.A.; CICE 2008 will be held in Zurich, Switzerland; and the location of CICE 2010 will be announced at CICE 2006. It has also established a global-local conference structure whereby in each even-numbered year a CICE conference will be held, while in each odd-numbered year, regional conferences will be organized; this conference structure, together with a framework for Working Groups to focus attention on some of the key issues, provides an efficient and effective international exchange platform. IIFC publishes a quarterly newsletter “FRP International”, which provides timely and concise reports on recent advances in both research and practice, and co-sponsors the Journal of Composites for Construction of the American Society of Civil Engineers. It has developed a series of awards to give due recognitions to distinguished members of IIFC, including the one-off Lifetime Achievement Award, the President’s Award for Excellent Services to IIFC, the IIFC Medal and the Distinguished Young Researcher Award; in addition, best paper awards are given at CICE conferences and other IIFC conferences.

These achievements would not have been possible without the willing contributions of many individuals. On behalf of IIFC and on a personal level, I would like to express my sincere gratitude to all IIFC members and many others for their support to IIFC. Special thanks are due to members of the Executive Committee, the Advisory Committee and the Council. I have enjoyed very much working with them and the friendship we have developed through working together. Last but not least, I would like to thank Ms. Yvonne Lo and Ms. Connie Lam for looking after the IIFC Secretariat in a capable and efficient manner, and the Department of Civil and Structural Engineering of The Hong Kong Polytechnic University for hosting the IIFC Secretariat. IIFC is still a young organization and needs the support and contributions of all who share the aims and objectives of IIFC. In this connection, you are strongly encouraged to provide your best support to the future development of IIFC.

Finally, I would like to congratulate the recipients of the Lifetime Achievement Awards and the President’s Awards for Excellent Services to IIFC. I would also like to thank them for their distinguished contributions to the infrastructure composites area and the society at large. The names of the award recipients and their achievements are provided inside this issue. If we all follow the excellent examples they have set, a very bright future for IIFC is ensured.

I look forward to seeing many of you at CICE 2006 in Miami.

2006 IIFC Award Winners

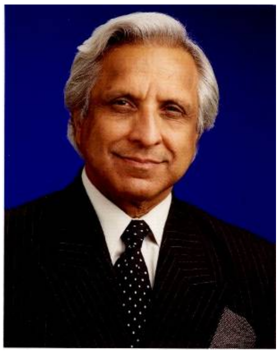
This year IIFC is honoring a select number of its members in recognition of their lifetime dedication to the use of fiber reinforced polymers in construction and for their distinguished contributions to research, education and professional outreach in this area. Professor Len C. Hollaway, Professor Urs Meier, Professor Aftab A. Mufti, and Professor Sami H. Rizkalla will be presented with the **“Lifetime Achievement Award”** at CICE in Miami in December.

In addition, two President’s Awards are being bestowed in recognition of distinguished services by members to the International Institute for FRP in Construction for advancing the understanding and the application of fibre-reinforced polymers in the civil infrastructure, in the service of the engineering profession and society. Dr. Jian-Fei Chen and Professor Vistasp M. Karbhari will be presented with the **“President’s Award”** at CICE in Miami in December.

Lifetime Achievement Award Winners

Professor Len C. Hollaway is Emeritus Professor of Composite Structures in the School of Engineering - Civil Engineering, University of Surrey and is also visiting Research Professor at the University of Southampton. He has considerable research interests in advanced polymer composite systems and has been engaged on research into fibre/matrix composites for more than 35 years; his areas of interest can be classified under four broad headings, namely, innovation, stress analysis, concept development and design guidelines. He has had published over 180 refereed technical papers and is the author, co-author or editor of eight books on various aspects of composites in the civil engineering industry. He is serving on, or has served on, a number of national and international committees and has organized International Conferences in FRP Composites in Construction. In 1970, he founded the Composite Structures Research Unit, University of Surrey. He was a founder member (1988) of a working group at the Institution of Structural Engineers, U.K. concerned with Composites in Structural Engineering. In 1999, he was a founder member of a national network of research organizations and industry in the U.K. which was set up by the Universities of Surrey and Southampton (Advanced Polymeric Composites for Structural Applications in Construction Network, [CoSACNet],); this organization has recently been incorporated into the Research Group of the Network Group for Composites in Construction (NGCC) at NetComposites, Chesterfield, U.K. In 2001, he was a founder member of the IIFC.

Professor Urs Meier was for seventeen years the managing director of the Swiss Federal Laboratories for Materials Testing and Research (EMPA) with 420 co-workers in Dubendorf, Zurich, Switzerland. Since 2001, he has been on the board of directors of the United EMPA-Laboratories. He is an associated member of the Department of Materials Science of the Swiss Federal Institute of Technology (ETH) in Zurich. Professor Meier has accomplished much in the application of advanced composites in civil engineering during the past 30 years and has received worldwide recognition for his pioneering work. Especially noteworthy is the post-strengthening of civil structures with carbon fiber reinforced polymer strips, which has been successfully implemented at a growing rate worldwide and the CFRP stay- and post-tensioning cables. He has received a number of prizes and awards for his R&D-contributions. He is the holder of several patents on CFRP tendons and the application of pre-tensioned FRP strips.



Dr. Aftab A. Mufti is a Professor of Civil Engineering at the University of Manitoba, Winnipeg, Manitoba, Canada. He is also the Program Leader and President of the ISIS Canada Research Network, a Network of Centres of Excellence, and the President of ISHMII (International Society for Health Monitoring of Intelligent Infrastructures). His research interests include FRPs, FOSs, FEM, bridge engineering, structural health monitoring and civionics. He has authored or co-authored 5 books, plus provided chapters for 2 others, edited 7 books, and written more than 350 technical publications. Dr. Mufti is the recipient of 22 awards. He is the holder of several patents on the steel-free bridge deck concept, of which he is the principal developer. In addition, he is the Chair of the Technical Subcommittee of the Canadian Highway Bridge Design Code that recently completed developing code clauses to design, rehabilitate and repair structures using fibre reinforced polymers. The revised code is expected to be published in late 2006.

Professor Sami H. Rizkalla, Ph.D. is an elected Fellow of the American Concrete Institute (ACI); Fellow, American Society of Civil Engineering (ASCE); Fellow, Canadian Society for Civil Engineering (CSCE); Fellow, The Engineering Institute of Canada (EIC); Fellow, International Institute for FRP in Construction (IIFC). He is currently a Distinguished Professor of Civil Engineering and Construction, and Director of Constructed Facilities Laboratory, Department of Civil Engineering, North Carolina State University. Director, NSF I/UCRC – Repair of Buildings and Bridges with Composites, North Carolina State University; Immediate past Chair of ACI Committee 440 "FRP Reinforcements"; Immediate past President and Scientific Director of the Canadian Networks of Center of Excellence "Intelligent Sensing for Innovative Structures"; Regional Editor, Elsevier Science "Construction and Building Materials" Journal; Member, Editorial Board, ASCE "Composite for Construction" Journal; Member, Advisory Board, Journal of Advanced Concrete Technology, Japan.

President's Award Winners

Dr. Jian-Fei Chen is a lecturer at Edinburgh University, U.K. He has research experience in many areas in structural engineering including the nonlinear and dynamic behaviour of 3D structures, strength and stability of shell structures, behaviour of RC structures under static and explosion loadings, materials handling and particulate solids flow, stresses in silo structures, and behaviour of FRP strengthened concrete structures and thin shells. He has authored or co-authored over 120 refereed publications, including the book "FRP-Strengthened RC Structures" published by Wiley in 2002. Dr. Chen is a member of the IIFC Council and the Secretary to its Executive Committee. He co-chairs the IIFC Working Group on Bond Behaviour of FRP in Structures. He is the recipient of several awards including the Howard Medal 2004 awarded by the Institution of Civil Engineers.

Professor Vistasp M. Karbhari is a Professor of Structural Engineering and of Materials Science and Engineering at the University of California, San Diego, where he leads research groups in the areas of processing and mechanics of composites, durability of polymers and composites, bio-materials, application of composites to infrastructure renewal and multi-threat mitigation, impact/damage mechanics, nondestructive assessment of materials and structures, and structural health monitoring. He is the author/co-author of over 160 papers in archival journals and over 200 papers in refereed conference proceedings. In addition to serving on the IIFC Executive Committee and as the Editor of the IIFC Newsletter, he also serves on the ISHMII Council, and is co-chair of ACI-440L. He is the Editor for the Americas for the International Journal of Materials and Product Technology and is an editorial board member of Composite Structures.

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