FRP International
Fiber Reinforced Polymers
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# Notable Research Activity

## UCSD Charles Lee Powell Structural Research Laboratories

At the University of California, San Diego, The Charles Lee Powell Structural Research Laboratories were founded in 1986 and dedicated to research in the field of structural engineering systems. The laboratories are used to test buildings up to five stories high and bridges up to 40 m long under service, overloads, as well as seismic loads (Figure 1). In 1994, a structural components and dedicated advanced composites structures laboratory was added with 10 m high reaction walls which double the original test floor capacity. In 1996, a real-time dynamic 6-DOF test system for seismic response modification devices (e.g. isolation bearings and dampers) expanded the large-scale structural test floor space to over 1,200 m² (reaction floor space). Support facilities include a state-of-the-art strain gauge (electrical and fiber optics) shop, machine shop and mechanical testing facilities. The laboratories are augmented by fiber reinforced polymer composites manufacturing laboratories outfitted with autoclaves, hot presses, a filament winder, chopper/spray equipment and RTM equipment. The laboratories also have state-of-the-art materials characterization and durability testing facilities capable of testing composites and constituents from the fiber, resin and interface level to those at the coupon and specimen level.

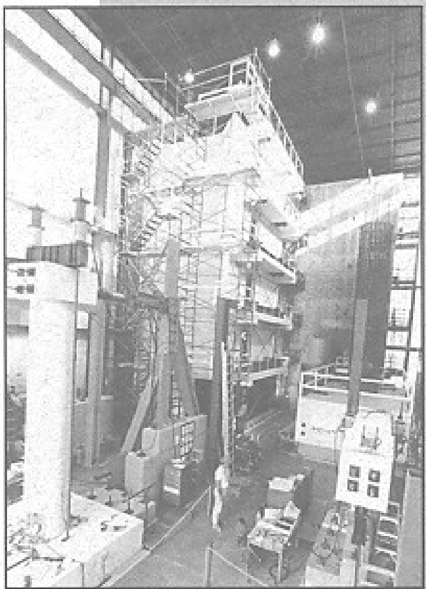

*Figure 1. Structural Testing of Five Storey Building*

One of the three research thrusts at UCSD is the use of FRP systems for civil engineering, in addition to earthquake and renewal engineering. Research on the use of FRPs for civil engineering applications include:

- seismic retrofitting of concrete and masonry walls with carbon overlays (structural wallpaper)
- retrofitting of bridge and building columns with FRP jacket systems
- strengthening of bridge superstructures with FRP soffit overlays
- repair/strengthening of large diameter PCC pipes with FRP

*(continued on page 2)*

In This Issue

(continued from page 1)

- evaluation of the short and long-term behaviour of commercially available FRP cable systems for stay cables and external post-tensioning
- FRP replacement bridge decks (Figure 2)
- new FRP bridge superstructure systems
- new construction systems for short and medium span modular bridges based on concrete filled FRP tubular sections
- industrial structural systems based on concrete filled carbon tubes
- mobile lightweight rapid assault tank bridges
- durability testing of FRP systems for civil infrastructure applications
- development of hybrid structural elements

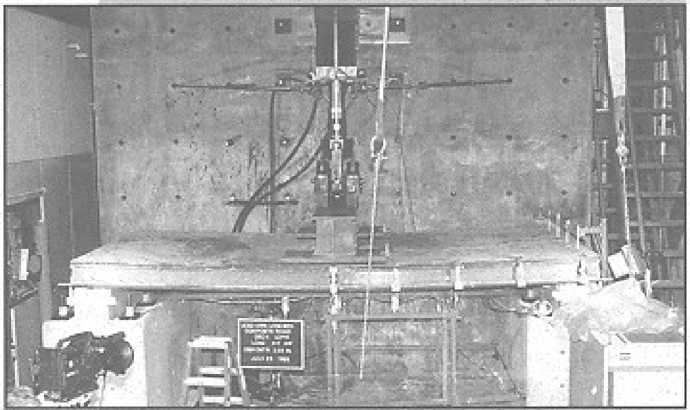

*Figure 2. Testing of Innovative FRP Bridge Deck*

Detailed information on the various research projects at the Powell Structural Research Laboratories can be obtained by contacting Dr. Frieder Seible by e-mail at seible@ucsd.edu or by fax at 619-534-6373.

# Application

## Seismic Retrofitting

The Great Western Bank Building in Sherman Oaks, California, suffered damage in the Northridge earthquake and required both repair work and structural improvements for future seismic events. Reinforced concrete walls requiring in-plane shear enhancement did not have the necessary clearances for conventional (shotcrete) repairs. In order to work in the confined space of both the elevator shaft and stairwell, the Fibrwrap® System was used (Figure 3).

The Fibrwrap® System provided the required shear strength and fire ratings while adding less than one quarter of an inch to the original structure. The equivalent shotcrete scheme would have added approximately four inches of new material.

For further information, please contact Duane J. Gee by fax at 619-642-0947.

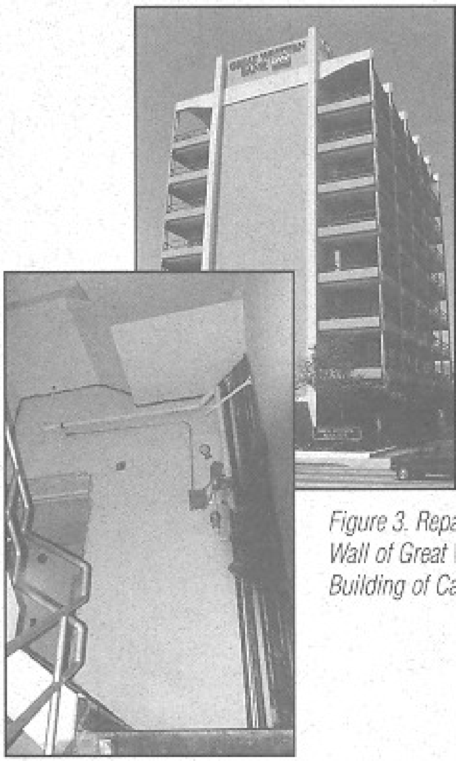

*Figure 3. Repair of Concrete Wall of Great Western Bank of Building of California*

## Carbon Sheets Strengthen Old Masonry Church

Carbon fiber sheets (Replark System) were used to strengthen the dome of an old masonry church in the town of Aegeon, Greece (Figure 4). The 150 mm wide sheets, in the form of circumferential straps, were applied in a reversible manner. This was achieved by bonding the sheets on a thin plastic film which was then placed on the surface of the masonry. The work was carried out by ETANE S.A., a Greek firm specializing in advanced rehabilitation techniques.

For further information, please contact Prof. Triantafillou by e-mail at ttriant@upatras.gr or by fax at +30-61-997694.

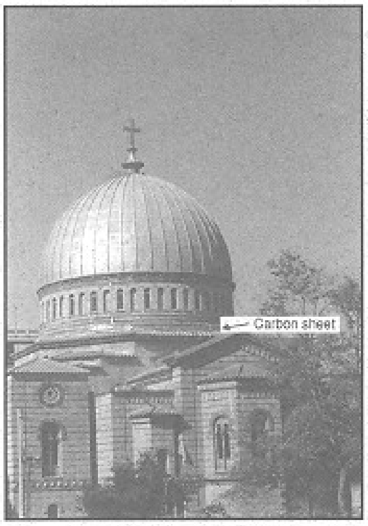


*Figure 4. Strengthening of Dome*

## Repair of Apartment Building

An apartment building located at Diver's Cove in Laguna Beach was in danger of catastrophic failure due to the severe corrosion of the supporting beams (Figure 5). The beams required strengthening and protection from further environmental attack without substantially altering their existing cross-sections.

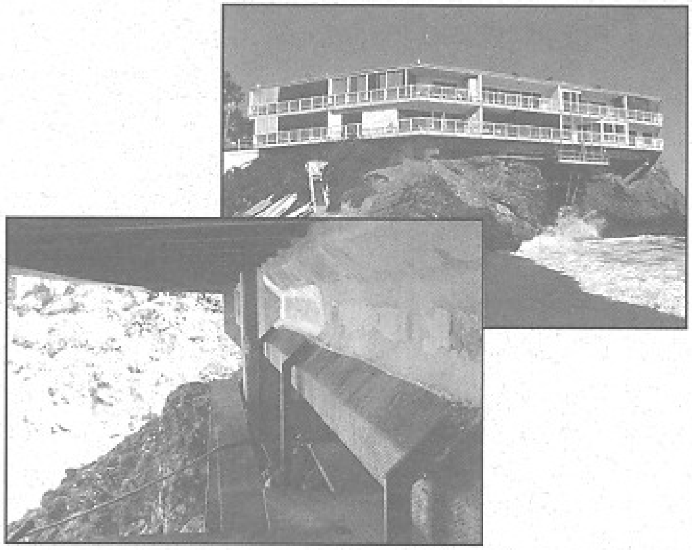

*Figure 5. Repair of Supporting Beam of Apartment Building, Laguna Beach*

After providing conventional crack injection and patching, the Fibrwrap® System was applied. A hybrid composite jacket was designed to meet the project requirements. Both the SGH 41 (primary carbon) and the SEH 51 (primary glass) reinforcing fabrics were used. The composite system provided the necessary strengthening with a minimal amount of visual change to the structure.

For further information, please contact Duane J. Gee by fax at 619-642-0947.

## FRP for Short Span Bridges

As part of the EUROCRETE research program, a concrete bridge containing only non-metallic reinforcement was built this year at the Oppegaard Golf Course outside Oslo, Norway.

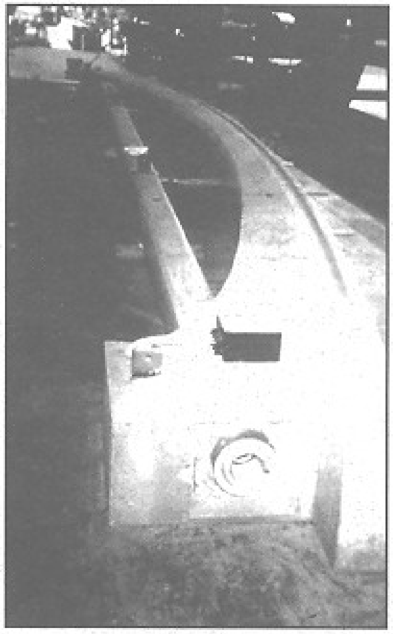

*Figure 6. Pretensioned Arch Concrete Girder*

EUROCRETE is a four-year (1994 to 1997) research program on the use of FRP in concrete structures within the European research cooperation EUREKA. The Norwegian companies and institutions involved in the program are headed by Norsk Hydro in cooperation with Dr. techn. Olav Olsen a.s.

The 9.5 meter span bridge for pedestrians and light vehicles consists of two prefabricated concrete edge girders with a wood deck. Each girder is post-tensioned with VSL-LCL Parafil tendons (nominal ultimate load 900 kN) equipped with aluminum anchorages (Figure 6).

The project is a close collaboration between Dr. tech Olav Olsen a.s., the VSL licensee Internordisk Spännarmering AB and the tendon supplier Linear Composites Ltd. (LCL).

For further information, please contact Karl-Erik Nilsson by fax at +46-8-753-4973.

## Rehabilitation of Historical Building

A two-storey frame building of historical value and interest in the County of San Mateo, Redwood City, California, required strengthening for seismic conditions.

The building had been constructed of sandstone veneer with brick walls. Seismic analysis resulted in the need for additional in-plane shear capacity between existing walls and slabs throughout the perimeter of the building.

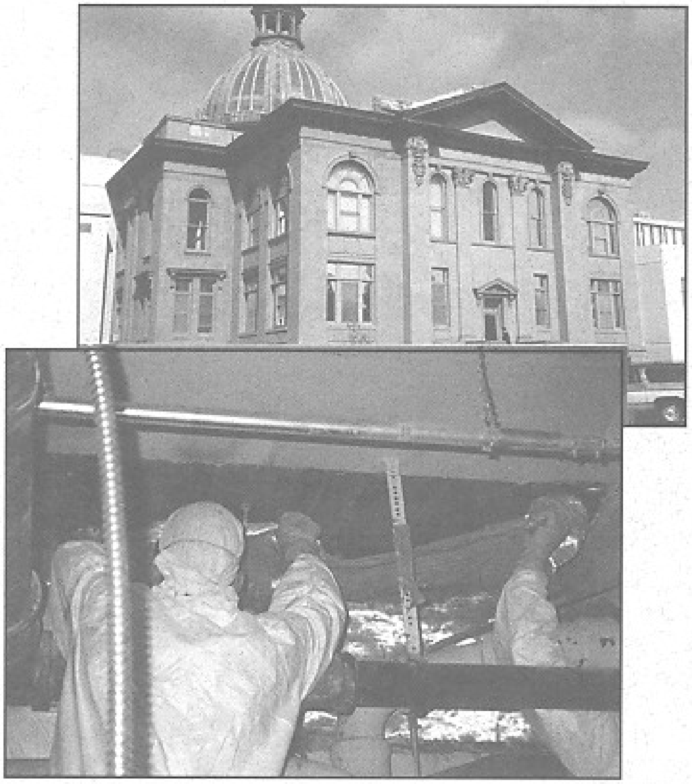

*Figure 7. Rehabilitation of Historic Building in the County of San Mateo, Redwood City, California*

The Fibrwrap® System was used to increase the seismic rating and maintain the historic appearance of the building. The Tyfo® JT System was installed at an angle configuration to allow transfer of the shear forces between the slab and the wall (Figure 7). The Tyfo® FC/F Fire Coating System provided the necessary Class 1 three-hour flame and smoke spread rating for the internal portions of the building.

The Tyfo® JT System can be used as an alternative to conventional steel angle retrofits. The JT system results in a less obtrusive retrofit and maintains the existing architecture and appearance of the structure. The system eliminates the need for welding and fabrication of steel angles. The composite resin possesses virtually no V.O.C.'s or odor and, therefore, poses no health hazard to the building's occupants.

For further information, please contact Duane J. Gee by fax at 619-642-0947.

## FRP, A Solution for Design Deficiency

Checking the design of the Ferry Bridge Horgen, Switzerland, built in 1972, revealed that the top reinforcement for the negative moment of the double cantiliever deck slab was inadequate to carry the full design load. The repair required removing the old polymer bitumen membrane and cleaning the top concrete surface of the bridge. The surface was grooved to accommodate the Sika CarboDur S1212 at intervals of 600 mm (Figure 8). The grooves were filled with epoxy mortar prior to the application of the Sika laminates. To protect the top surface of the laminates, the entire surface of the deck slab was covered with a layer of epoxy cement mortar, Sigagard 720 EpoCem, with an average thickness of 5 to 10 mm. The surface was then covered with a polymer bitumen membrane.

*Figure 8. Ferry Bridge Horgen, Switzerland*

For further information, please contact Werner Steiner by fax at +41-01-436-4855.

## Tom's Creek Bridge Re-opens with Composite Beams

The Tom's Creek Bridge in Blacksburg, Virginia, was re-opened to traffic on June 23, 1997, and is one of the first composite short-span vehicular bridges in the United States (Figure 9). The corroded steel beams supporting the bridge were replaced with composite beams manufactured by STRONGWELL of Bristol, Virginia. The new 8" x 6" composite beam was part of a joint development project with Georgia Tech for the government sponsored Advanced Technology Program (ATP). Using a new optimized shape (twin webbed cellular I-sections with transverse stiffeners), the beam is pultruded from a composite matrix of carbon/e-glass reinforced vinyl ester resin. The design significantly improves the flexural modulus and torsional bending over the present fiberglass I-beam design. The flexural modulus of the composite beam (6300 to 6500 ksi) is more than twice the flexural modulus of a standard fiberglass I-beam, and the rotational bending is less than one half of a degree versus the normal three to four degrees.

*Figure 9. Composite Beams for Tom's Creek Bridge, Blacksburg, Virginia*

Using the composite beams, the 17.5' x 22' wide bridge was upgraded from a 10 ton to a 20 ton capacity. More than 1,000 cars per day cross the bridge. Designing the replacement bridge was a joint venture of VPI, the Virginia Department of Transportation and the Virginia Transportation Research Council. The Tom's Creek Bridge will be monitored for ten years for signs of wear and tear.

For further information, please contact Vicki Clark by fax at 540-645-8132.

## Strengthening for Additional Floor

Carbon fiber strips produced by Sika Corporation were used to strengthen an existing structure in order to add a storey to the flat concrete roof of the King's College Hospital Joint Education Center in South London, England. Carbon fiber strips replaced the typically used steel plates which needed to be bolted or propped into place until the adhesive cured. The steel plates would have been 7 mm thick to match the composite strips which were only 1 mm thick. The concrete surface was prepared in two weeks using needle-gunning and vacuuming. The alternative solution was to use 11 m long steel plates requiring at least one splice with a significant number of bolts. The carbon fiber strip comes in 400 m long rolls which eliminates the need to splice. A standard wallpaper roller is used to remove air bubbles between the strip and the concrete surface a (Figure 10). A simple "anti-peel" bolt was used at each end.

For further information, please contact Richard Barton by fax at +44-1707-329129.

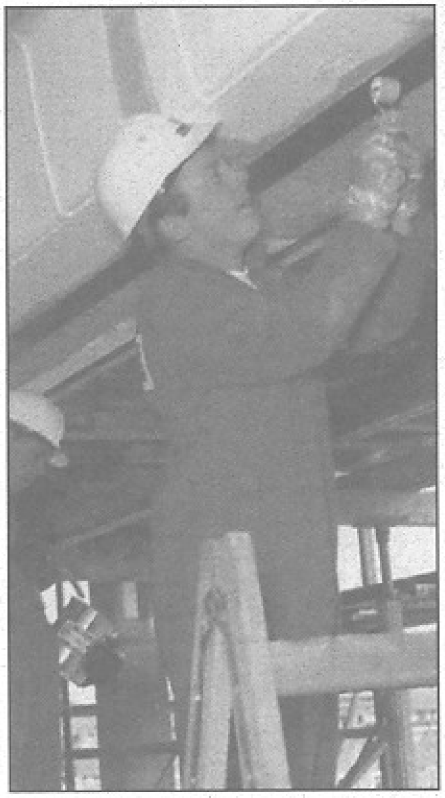

*Figure 10. Strengthening of Concrete Beams of King's Hospital in England*

## Repair of a Swimming Pool in Belgium

After many years of exposure to a very hostile environment (chlorids, humidity) combined with an insufficient concrete cover, all the internal steel bars of the roof plate of a swimming pool in Kalmthout, Belgium, were seriously corroded. After research by the Reyntjens Laboratory from the Department of Civil Engineering, Catholic University of Leuven, Belgium and TRI-consult N.V., it was recommended to remove all the internal steel bars and replace them with two or three layers of externally bonded CFRP sheets after repairing the concrete with an epoxy mortar (Figure 11).

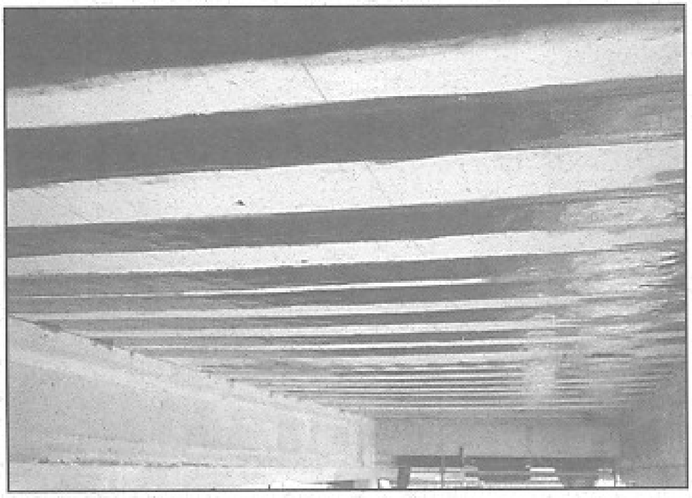

*Figure 11. Repair of a Swimming Pool in Belgium*

The repair took only six weeks and was done by De Neef Engineering in August/September 1997.

For further information, please contact Kris Brosens by fax at +32-016-32–19-76 or by e-mail at kris.brosens@bwk.kuleuven.ac.be.

## Rehabilitation of Historical Museum

Sika CarboDur S812 was used to rehabilitate the main oak beams of a 200 year old historical museum in Lucern, Switzerland. The beams carrying the floor deck were seriously cracked and had vertical cracks in the tension zone. The beam was strengthened by cutting a 8 mm thick slot into the side of the beam 90 mm deep and 1.8 m long, and filling it with Sikadur 30 and Sika CarboDur S812 laminate which was pressed into the fresh epoxy (Figure 12). Prior to curing, the beam was temporarily supported to release the carrying load. The Sikadur 30 was colored to match the wooden beam.

For further information, please contact Werner Steiner by fax at +41-01-436-4855.

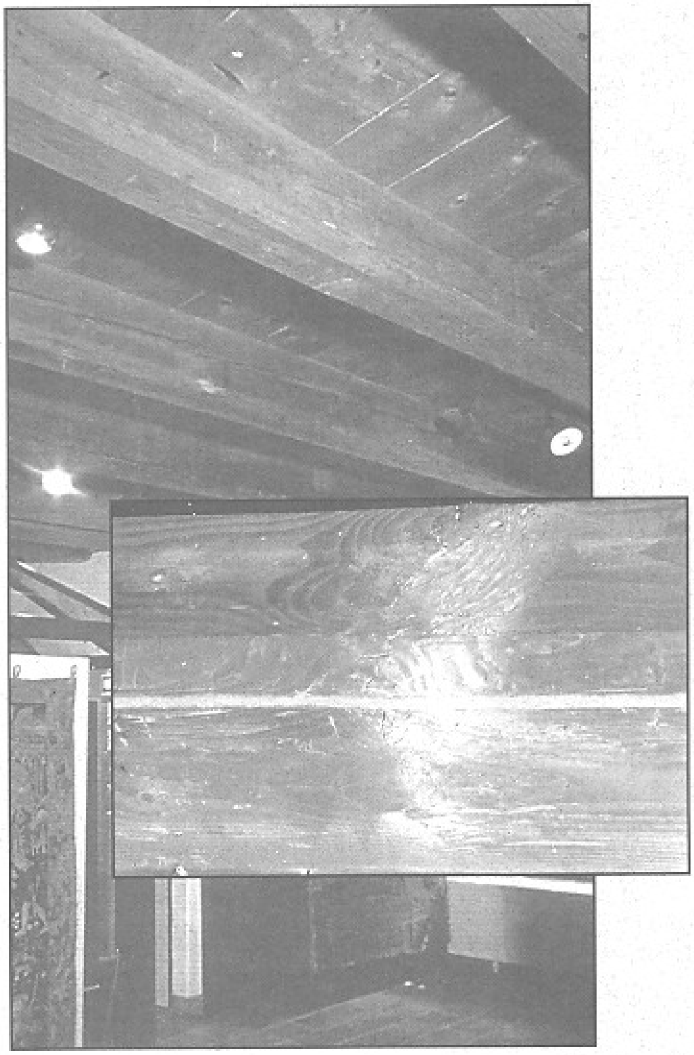

*Figure 12. Rehabilitation of Wood Floor, Switzerland*

# Research

## Advanced Composites for Geodetic Beam

A 25 foot long geodetic cone and cylinder pultruded from rod stock utilizing select properties of graphite, glass and poly-sulfone prepreg tape has been successfully tested by NASA's Johnson Space Centre (Figure 13). The composite structure is designed to carry 3,000 lbs. of axial compression while weighing only 23 lbs. including the end fittings. The beam is thermally inert and can be easily lifted by one person. The stock was pultruded by Glasforms, Inc., under supervision of the Design and Technology Engineering Division of McDonnell Douglas Corporation.

For additional information, please contact Glasforms, Inc. by fax at 408-297-0601.

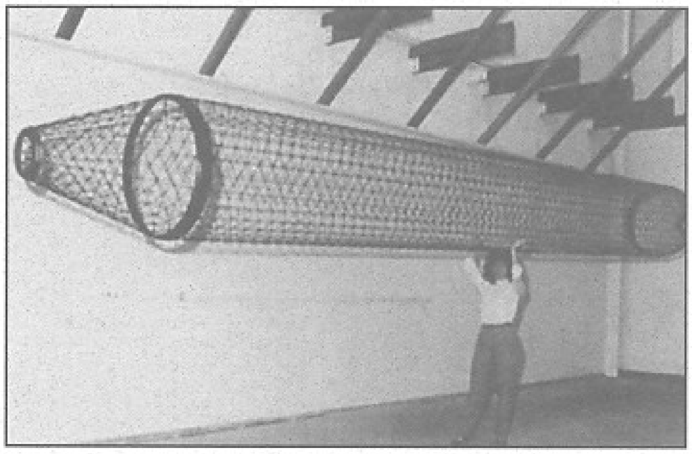

*Figure 13. Pultruded ACM for Geodetic Beam*

## Field Testing of Post-tensioned CFRP Plates

The testing program is part of the Project ROBUST (st**R**engthening **O**f **B**ridges **U**sing polymeric compo**S**ite ma**T**erials) launched in May 1994 for three years under the government's LINK Structural Composites Programme. This program investigates the use of both pultruded and pre-preg carbon and glass fiber reinforced polymer materials as an alternative to the use of steel plate bonding used for strengthening reinforced or prestressed concrete bridges. Research within ROBUST has shown that prestressing the composite plates before bonding onto the beam is viable under field conditions (Figure 14). The various parameters considered in the testing program included plate conditions, number of layers of plates, fixity at the end of the plates and the length of the plate.

For further information, please contact Dr. P. Samuel Fashole-Luke by fax at +44-1932-356122.

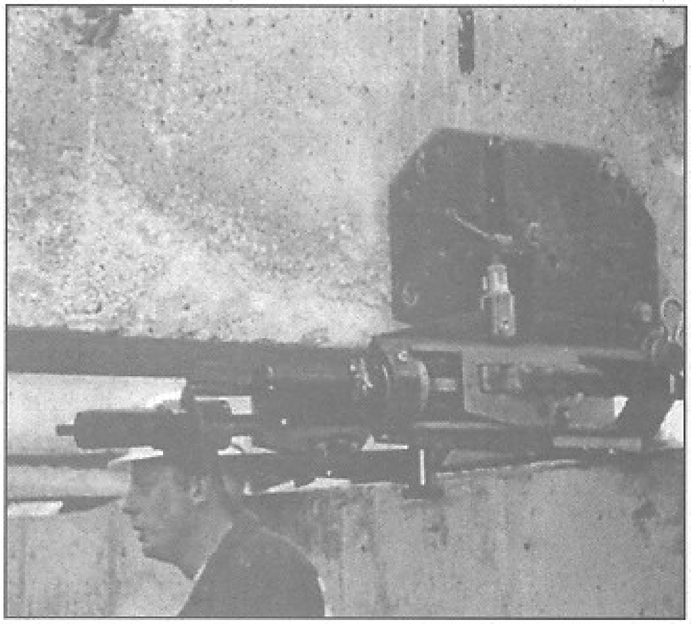

*Figure 14. Prestressing of CFRP Plates Bonded to Concrete Beams*

## Vertical Axis Wind Turbine Blade

FRP composite pultruded blade has successfully accomplished a 50% energy output upgrade for an existing wind turbine formerly outfitted with segmented extruded aluminum blades. The turbine's rated power has been increased to over 300 KW and survival wind speed has been increased to 130 mph. This new advanced turbine is a major breakthrough in the drive to achieve low cost renewable energy production (Figure 15). The blades are supplied in single section length of 160 ft. Installation costs are reduced due to the avoidance

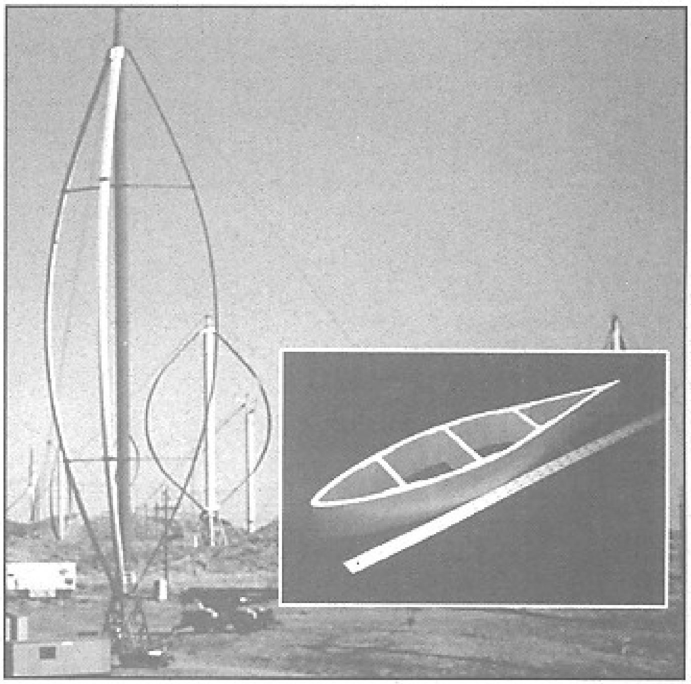

*Figure 15. FRP Wind Turbine Blade*

of assembly required for the pre-bent aluminum section. Each blade weights 3,247 lbs., making it the largest single pultruded composite part ever manufactured. The cross section is a hollow air foil shape with three internal shear webs and a chord of 27 inches. Each wind turbine uses three blades for a total pultrusion weight of near 5 tons per turbine.

For additional information, please contact Glasforms, Inc. by fax at 408-297-0601.

## FRP for Shear Reinforcement

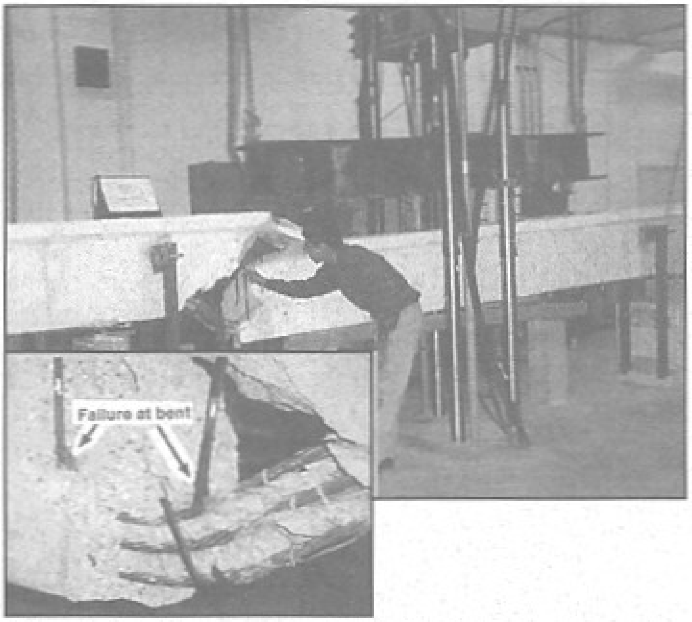


*Figure 16. Beam Specimen Reinforced by FRP Stirrups*

A comprehensive research program sponsored by ISIS Canada in 1996 which is currently in progress at the University of Manitoba examines the structural performance of FRP stirrups for shear reinforcements of concrete structures. The research program included large-size T-section beams reinforced by three different types of FRP stirrup material, Leadline produced by Mitsubishi Chemical Corporation in Japan, Tokyo Rope produced by Tokyo Rope in Japan, and C-bar glass fibre produced by Marshall Industries Composites Inc. in the United States as shown in Figure 16. The program also included specially designed specimens used to examine the bent effect of the stirrup capacity and the embedment length as shown in Figure 17. The research provided design guidelines for the use of FRP as stirrups for concrete structures.

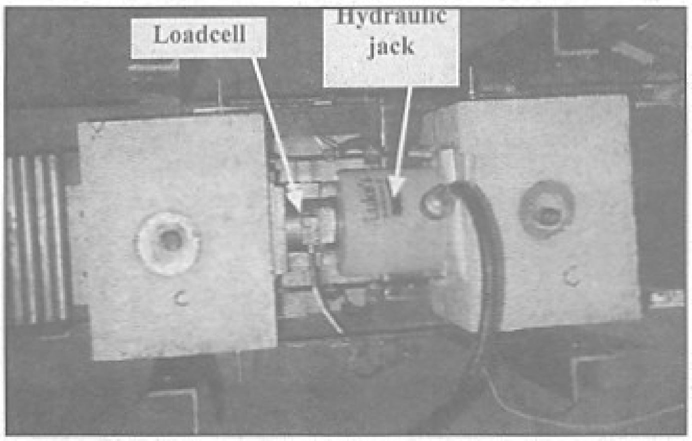


*Figure 17. Panel Specimens*

For further information, please contact Dr. S. Rizkalla by fax at 204-474-7519 or by e-mail at rizkall@cc.umanitoba.ca.

# Call for Papers

A Technical Session on Seismic Repair and Retrofit of Structures with Fiber Composites will be held during the 1998 Annual American Concrete Institute (ACI) Fall Convention in Los Angeles, California, U.S.A. Presentations on the repair and retrofit of existing concrete or masonry structures using fiber composite materials are solicited. Appropriate topics include case studies, field application, research investigations and analytical studies. Abstracts must be submitted by March 1, 1998. For further information, please contact Dr. M. Ehsani by e-mail at ehsani@u.arizona.edu or by fax at 520-621-2550.

# FRPRCS-3

The Third International Symposium on Non-Metallic (FRP) Reinforcement for Concrete Structures (FRPRCS-3) was held October 14 to 16, 1997, in Sapporo, Japan. A total of 334 people from over 20 countries attended the conference. Of the 169 papers published in the proceedings, 163 presentations were made. Conference proceedings and "Recommendation for Design and Construction of Concrete Structures Using Continuous Fiber Reinforcing Materials", published by the Japan Society of Civil Engineers (JSCE), October 1997, may be purchased by contacting the Japan Concrete Institute by fax at +81-3-3263-2115.

# Theses

Depla, J., "Fibre Composites for the Repair and Strengthening of Concrete Structures" (in Dutch), M.Sc. Thesis, 1996, University of Ghent, Belgium. Advisor, Dr. Luc Taerwe.

Heffernan, P.J., "Fatigue Behaviour of Reinforced Concrete Beams Strengthened with CFRP Laminates", Ph.D. Thesis, 1997, Royal Military College of Canada. Advisor, Dr. Marie-Anne Erki.

Yin, Jiansheng, "Modeling and Numerical Simulation of the Progressive Failure of Pultruded Fiber Reinforced Plastic Structures", Ph.D. Thesis, July 1997, The Catholic University of America, Washington, D.C. Advisor, Dr. Lawrence Bank.

# Conferences

**Al-Azhar Engineering Fifth International Conference (AEIC'97),** December 19 to 22, 1997, Nasr City, Cairo, Egypt. For further information, please contact Dr. M. K. El-Samny by fax at 202-260-1706.

**Second International Conference on Composites in Infrastructure (ICCI'98),** January 5 to 7, 1998, Tucson, Arizona, U.S.A. For further information, please visit the conference website at http://engr.arizona.edu/~ICCI.

**Transportation Research Board 77th Annual Meeting,** January 11 to 15, 1998, Washington, D.C., U.S.A. For further information, please visit the TRB website at http://www.nas.edu/trb/meeting.

**International Composites Expo (ICE'98),** January 19 to 21, 1998, Nashville, Tennessee, U.S.A. For further information, please contact the Composites Institute by fax at 212-370-1731.

**SPIE's Fifth Annual International Symposium on Smart Structures and Materials,** March 1 to 5, 1988, San Diego, California, U.S.A. For further information, please SPIE's international headquarters by fax at 360-647-1445.

**ACI Spring Convention,** March 22 to 27, 1998, Houston Texas, U.S.A. For further information, please contact ACI International by fax at 1-248-848-3701.

**Fourth World Pultrusion Conference entitled "Connecting with Pultrusion",** April 9 to 11, 1998, Vienna, Austria. For further information, please contact the EPTA Association Office by fax at 31-341-42-56-14.

**Tenth International Conference on Mechanics of Composite Materials,** April 20 to 23, 1998, Riga, Latvia. For further information, please fax 371-782-0467.

**Sixth International Symposium on Acoustic Emission from Composite Materials (AECM-6),** June 1 to 5, 1998, San Antonio, Texas, U.S.A.. For further information, please contact Becky Fose by e-mail at rfose@asnt.org or by fax at 614-274-6899.

**Eighth European Conference on Composite Materials - Science, Technologies and Applications (ECCM-8),** June 3 to 6, 1998, Naples, Italy. For further information, please contact Professor A. Langella by fax at +39-81-761-4212 or visit the conference website at http://www.eccm98.etruria.net.

**The XIIIth FIP Congress,** May 23 to 29, 1998, RAI Congress Centre, The Netherlands. For further information, please contact the Congress Secretariat by fax at +31-182-537-510.

**The Annual Conference of the Canadian Society for Civil Engineering and Second Structural Speciality Conference,** June 10 to 13, 1998, Halifax, Nova Scotia, Canada. For up-to-the-minute information, please visit the conference website at http://www.apens.ns.ca/csce98/.

**Second International Conference on Concrete Under Severe Conditions,** June 21 to 24, 1998, Tromsø, Norway. For further information, please contact professor O. E. Gjørv of the Norwegian University of Science and Technology by telephone at +47-73-59-45-48, by fax at +47-73-59-45-51 or by e-mail at bml@bygg.ntnu.no.

**Fifth International Conference on Composites Engineering,** July 5 to 11, 1998, Las Vegas, Nevada, U.S.A. For further information, please visit the conference website at http://www.uno.edu/~engr/composites.html.

**Fifth International Conference on Short and Medium Span Bridges,** July 13 to 16, 1998, Calgary, Alberta, Canada. For further information, please contact Margaret-Anne Stroh by fax at 403-284-4184.

**The Structural Engineers World Congress (SEWC),** July 18 to 23, 1998, San Francisco, California, U.S.A. For further information, please contact Dr. N. K. Srivastava by fax at 506-858-4082.

**Durability of Composites for Construction,** August 5 to 7, 1988, Sherbrooke, Quebec, Canada. For further information, please contact Dr. B. Benmokrane by fax at 819-821-7974.

**Ninth International Congress on Polymers in Concrete (ICPIC'98),** September 15 to 18, 1997, Bologna, Italy. For further information, please contact the conference website at http://www.unibo.it/goon/icpic/main.htm.

**American Society of Civil Engineers 1998 Annual Convention and Exposition,** October 18 to 21, 1998, Boston, Massachusetts, U.S.A. For further information, please contact ASCE by fax at 703-295-6144.

**ACI Fall Convention,** October 25 to 30, 1998, Los Angeles, California, U.S.A. For Further information, please contact ACI International by fax at 1-248-848-3701.

**International Conference on Corrosion and Rehabilitation of Reinforced Concrete Structures,** December 8 to 11, 1998, Orlando, Florida, U.S.A. For further information, please visit the conference website at http://www.cta.fhwa.dot.gov/nrc.

**Creating with Concrete International Congress,** September 6 to 10, 1999, Dundee, Scotland. For further information, please contact Professor R. K. Dhir by telephone at +44-1382-344-347, by fax at +44-1382-345-524 or by e-mail at r.k.dhir@dundee.ac.uk.

**ACI Spring Convention,** March 14 to 18, 1999, Chicago, Illinois, U.S.A. For further information, please contact ACI International by fax at 1-248-848-3701.



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