FRP International

Fiber Reinforced Polymers

Autumn 1997 Volume V, Issue 4

Notable Research Activity

Constructed Facilities Center

With its establishment in August 1988, the Constructed Facilities Center, West Virginia University, Morgantown, West Virginia, U.S.A., became the home of a unique fiber reinforced polymer (FRP) research and development center. Under the direction of Dr. Hota V. S. GangaRao, the Center fosters and conducts research and development vital to the rehabilitation of constructed facilities. The hallmark of the centre is its innovative ideas, interdisciplinary program, and integration of advanced composite material technology into current construction practice.

According to many experts, infrastructure in the United States is deteriorating at a rate that exceeds the ability to renovate it. A dramatic example is the country's bridges, approximately half of which will very soon reach their 50-year life expectancy. Recent studies indicate that it could cost trillions of dollars to bring all of the constructed facilities to safe and efficient operating levels within the next 10 to 15 years.

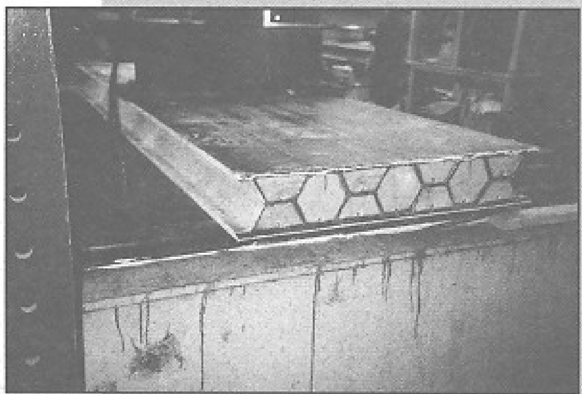

Figure 1. Testing of GFRP Modular Panel

The center is engaging faculty, research engineers, students, and others in an interdisciplinary research and development approach which combine innovative ideas and innovative materials with more conventional concepts and materials. In recent years, examples include:

- optimized FRP modular sections for bridge deck replacement (see Figure 1);
- development of FRP shapes for buildings;
- development of composite and hybrid material components and systems for bridges;
- preparation of design manuals for modern timber bridges and the repair of wooden railway ties;

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• Composite Institute • Japan Concrete Institute • ACMBS Network of Canada • ISIS Canada •

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- development of design specifications for FRP reinforced concrete;
- development of non-destructive testing techniques for structures and bridges;
- evaluation of new rehabilitation technologies for bridge piers with FRP; and
- field implementation of FRP.

One of the distinguishing features of the Constructed Facilities Center is its ability to adapt rapidly to changing research needs. This important feature allows the Center to study emerging technologies and adapt them to create new products such as diagnostic tools, design procedures and new structural components. A second distinguishing feature of the Center is its close relationship with the owners of constructed facilities in the United States. Much of the Center's work is conducted in cooperation with industry, highway agencies and other government agencies. Through joint projects, the Constructed Facilities Center is involved in several field implementation projects using FRP bars and new innovative pultruded modulars. Some of these projects are:

- use of glass FRP for the deck of the McKinleyville Bridge (see Figure 2); and
- FRP modular for the Wickwire Run Bridge in Taylor Country, West Virginia.

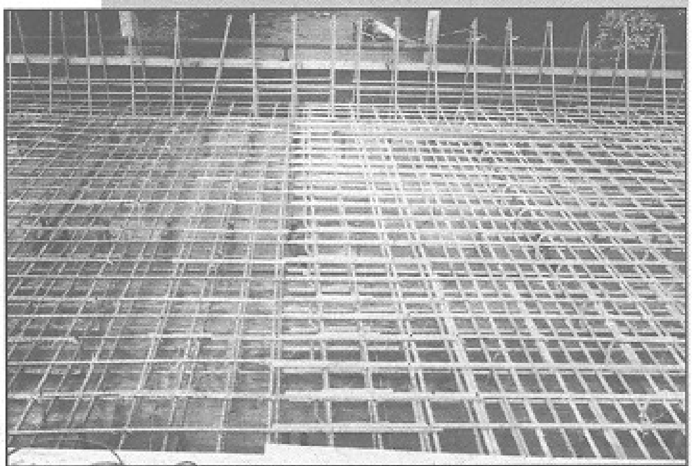

Figure 2. GFRP Bars for Deck Slab of McKinleyville Bridge

For more information, please contact Prof. Hota V. S. GangaRao by e-mail at gangarao@cemr.wvu.edu.

Application

Magazine Ditch Bridge

Figure 3. Magazine Ditch Bridge, Delaware, U.S.A.

The first advanced composite bridge in Delaware was installed on a private service road on the property of the Delaware River and Bay Authority on June 23, 1997 (see Figure 3). The 22-meter long, single-span, simply-supported bridge, spans Magazine Ditch and replaces an existing two-span concrete box-beam structure.

The bridge opened to traffic in June 1997 and was designed by J. Muller International and is modeled after their channel-bridge design. The foam-core glass fiber reinforced plastic (GFRP) deck was manufactured by Hardcore Composites and has evolved over several years of research and testing. The decks are sandwich structures made up of foam-filled, square, honey-comb type core that is sandwiched between upper and lower face sheets. The decks are made from glass fiber fabric and a vinyl ester resin. The deck sections are fabricated using the SCRIMP process (a vacuum assisted resin infusion process). Sub-component testing, as well as testing of a full-scale portion of the deck (1.2 m X 6 m), was performed at the University of Delaware. The test included applying the relevant AASHTO service and strength loads, and subjecting the deck to 2,000,000 fatigue cycles at the applicable AASHTO fatigue load.

The bridge utilizes traditional post-tensioned concrete edge girders to carry the loads longitudinally to the abutments. A large (22 m X 5 m) continuous GFRP deck distributes the loads transversely to the edge girders. A 45 mm latex-modified concrete wearing surface was placed on the GFRP deck. The installation of the bridge superstructure (edge girders and GFRP composite deck) was completed in a single day. The bridge also has an ongoing "health" monitoring system that is being installed and monitored by researchers at the University of Delaware.

For further information, please contact Michael Chajes by e-mail at chajes@ce.udel.edu or by fax at 302-831-3640.

FRP for Telecom Tower

Glass fiber reinforced polymer (GFRP) cylinder segments were used in the construction of a 123 m Telecom Tower in Santis Mountain, Switzerland (Figure 6). Self-supporting heatable fiber glass cylinders were used on the outer sheathing of the tower. The owner has decided to heat the tower to eliminate any danger of falling ice during the winter season. The tower is located at the summit of a mountain, 2,500 meters above sea level. Large GFRP square panels with middle dome configuration were also used to resist the wind pressure on the main structure that was built as a tourist attraction with lookout terraces. Use of the GFRP panel was convenient for erection and transportation to the mountain's summit by cable car. The non-magnetic characteristics of GFRP were also useful to the functioning of the dish antennae installed and sheathed within these panels.

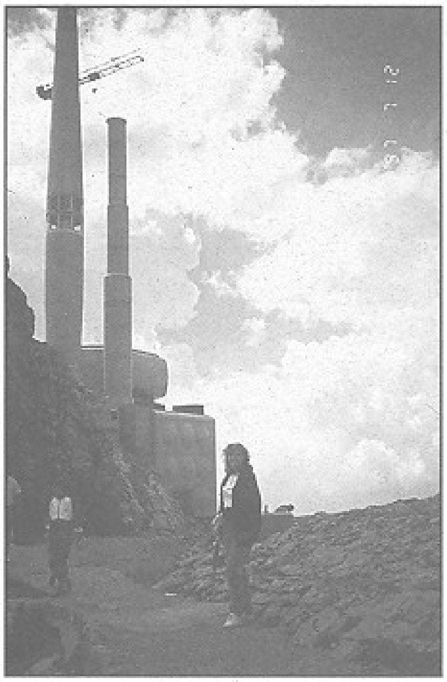

Figure 6. GFRP Telecom Tower, Switzerland

For further information, please contact Prof. Urs Meier of the Swiss Federal Laboratories for Materials Testing and Research (EMPA) by fax at +41-1-821-6244 or by e-mail at urs.meier@empa.ch.

Rehabilitation Bridge in Montréal, Canada

In September 1996, the Jacques Cartier and Champlain Bridges Inc. proceeded with the rehabilitation of a concrete pier in Montréal. The base of each pier is under water and subject to a high current (see Figure 7). The pier that was repaired is located at the confluence of two parts of the St. Lawrence River, which makes it vulnerable to ice collision during winter and spring. The pier in question measures 1.37 meters in diameter and was repaired over a 4 meter height measured from the base. The repair of the Champlain Bridge was executed by Les Spécialistes en corrosion Zedco Inc. The rehabilitation of the pier began with the restoration of the column surface using shotcrete. Once the cure of the shotcrete was completed, a sand blast was carried out, followed by the resin application. This resin was required in order to limit the migration of cement alcali inside the composite. The fibers used for this rehabilitation were glass fiber, type E (SEH51/TYFO S), from Composite Retrofit

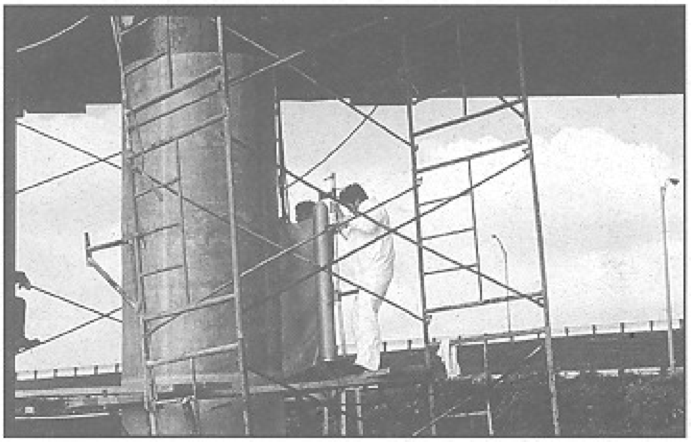

Figure 7. Rehabilitation of Champlain Bridge, Montreal, Canada

International, Inc. Nine layers of composites have been installed, for an overall thickness of 10 millimeters over the 4 meter height. These composites were required to provide the protection and the needed confinement.

For further information, please contact Sandra Martel by fax at 819-821-7974 or by e-mail at smartel@vinci.gci.usherb.ca.

Fiber Optics for All-Composite Bridge

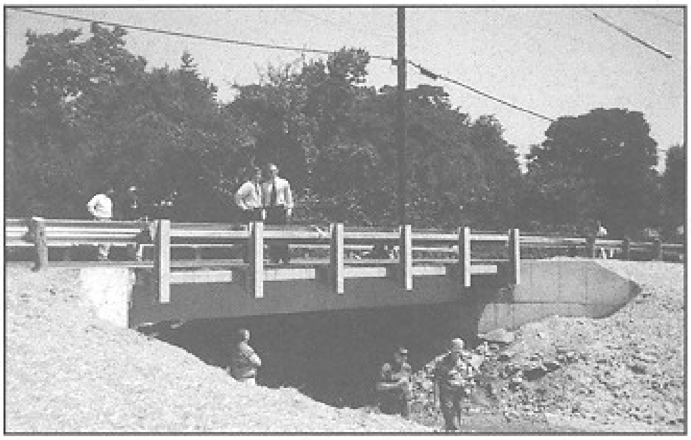

Figure 8. GFRP Bridge Monitored by Optic Sensors, Ohio, U.S.A.

A new all-composite bridge features a unique safety and performance monitoring system developed by Foster-Miller under contract to the United States Air Force and Martin Marietta Materials, the bridge manufacturer. The prototype bridge was installed in Butler County, Ohio, in July 1997 (see Figure 8). The sensor system, developed under the Small Business Innovative Research (SBIR) program, is based on two separate fiber optic measurement technologies. Fiber optic chemical sensors have been embedded in the field bond lines between the bridge sections to detect moisture incursion or other changes to the chemical structure of the epoxy over time. Fiber optic Bragg grating strain sensors were embedded within the composite structure at 18 locations during fabrication. Ongoing work by Foster-Miller includes periodic live load tests, continuous strain monitoring via an Internet link, and further sensor instrumentation development.

For further information, please contact Doug Thomson of Foster-Miller, Inc. by e-mail at dthomson@foster-miller.com.

FRP Grid for Concrete Wall

Carbon-type NEFMAC C16 with a grid spacing of 125 millimeters was used as reinforcement for the continuous underground concrete wall of the vertical shaft of the shield tunnel in the Kuwana area in Mie prefecture, Japan (see Figure 9). The tunnel was built to stabilize transmission of electricity from the Kawagoe thermal power plant of the Chubu Electric Power Company.

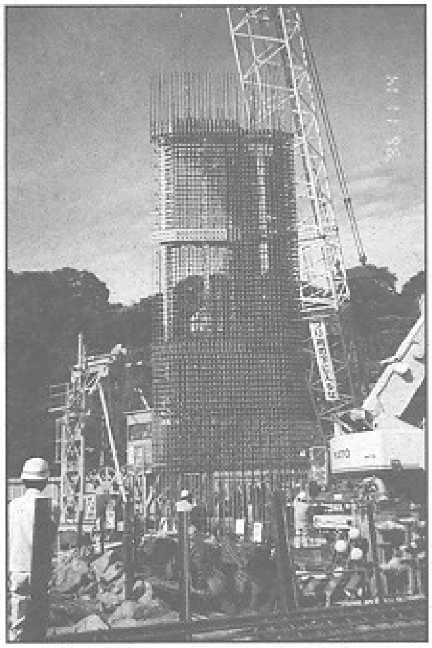

Figure 9. NEFMAC for Concrete Wall, Kawogoe, Japan

The NEFMAC was fabricated in the form of a flat sheet (1.3 m X 6.4 m) and also in three-dimensional shapes to construct both sides of the concrete wall. The low strength of the NEFMAC in the direction perpendicular to the fibers allowed easy cutting of the wall by cutter bits of the drilling machine to provide a circular opening of 5.15 meters in diameter.

For further information, please contact Mr. Kenichi Sekine, Manager of NEFCOM Corporation, by fax at 81-3-3254-9210.

Seismic Upgrade

The masonry vaulted arch roof of the Christ Church Cathedral in Victoria, British Columbia, Canada, showed recent signs of cracking and dusting (see Figure 10). The church is one of Victoria's oldest historic landmarks and was designed by John Malcolm Keith in 1891. The problem in this type of construction is the scenario of the "rain" of thousands of bricks as a result of one brick becoming loose. Excel Fyfe Tyfo "Web" fabric was used to tie the bricks together and upgrade the structure for seismic resistance, while maintaining its architectural integrity. The installation started at the top of the masonry vaults by vacuuming and smoothing the surface using epoxy bonding coat which bonded to a layer of epoxy-impregnated web fabric. The fabric was capped on the ridges with a reinforced concrete ballast to further compress

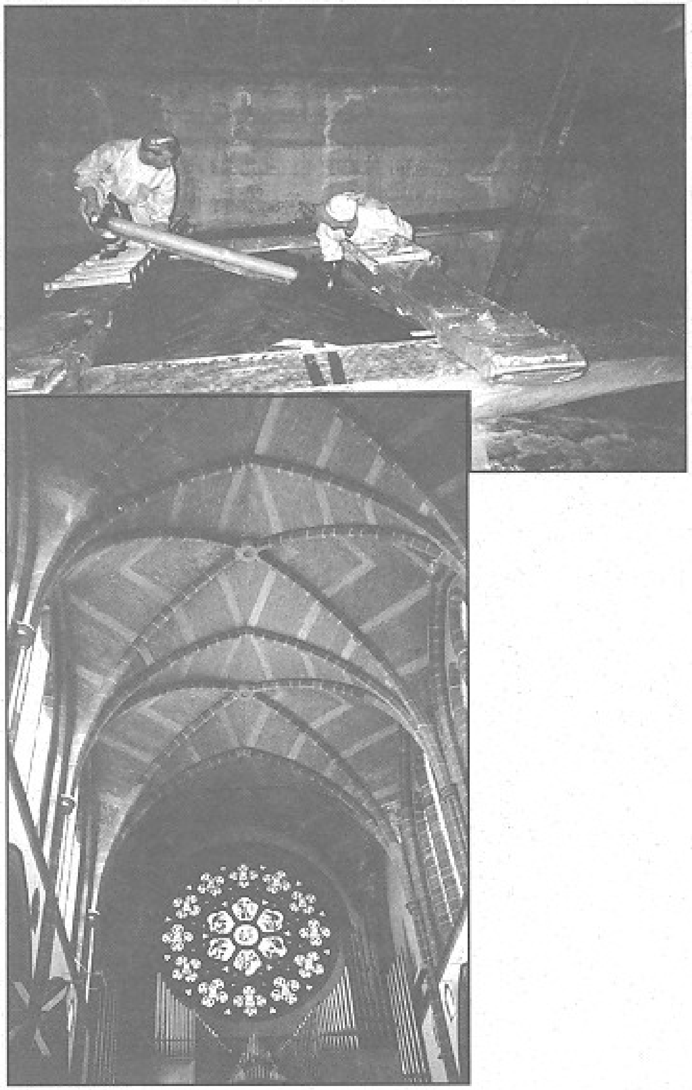

Figure 10. Seismic Upgrade for Church Built in 1891, Victoria, Canada

the vault. In all, 17,000 square feet of Kevlar/glass fibre were used to complete the seismic upgrade.

For further information, please contact Tom Ingeberg by telephone at 604-669-2466.

Application of "COMPOSE" to PC Bridge

The new carbon fiber reinforced polymer tendons "COMPOSE" were used for prestressing of a concrete bridge "Mugen" in the yard of Gifu Research Laboratory of Ube-Nitto Kasei Co., Ltd. in Gifu prefecture, Japan, in 1996 (see Figure 11). The bridge consists of a pre-tensioned slab with a span length of 10.0 meters and a width of 4.2 meters. This is the first time that the COMPOSE (FTA 18) has been used as a tendon for a prestressed bridge. The total COMPOSE length used for this bridge is about 1,200 meters. COMPOSE was anchored using special wedge-type anchorage devices.

For further information, please contact Nishimatsu Construction Co., Ltd. by fax at 81-3-462-75-6796.

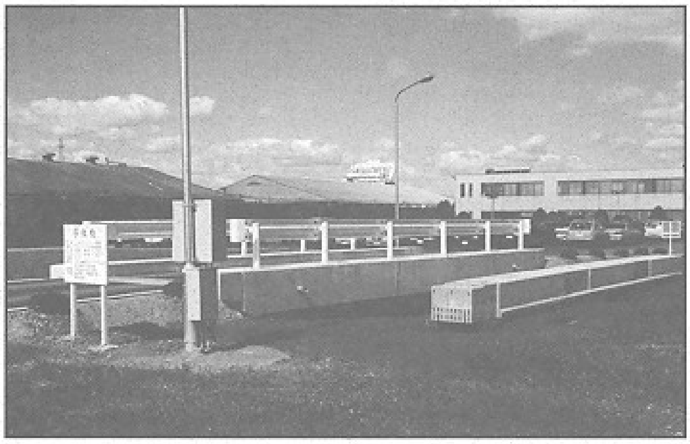

Figure 11. New CFRP Tendons ("COMPOSE") Used for Mugen Bridge, Japan

NEFMAC for a Highway Bridge in Canada

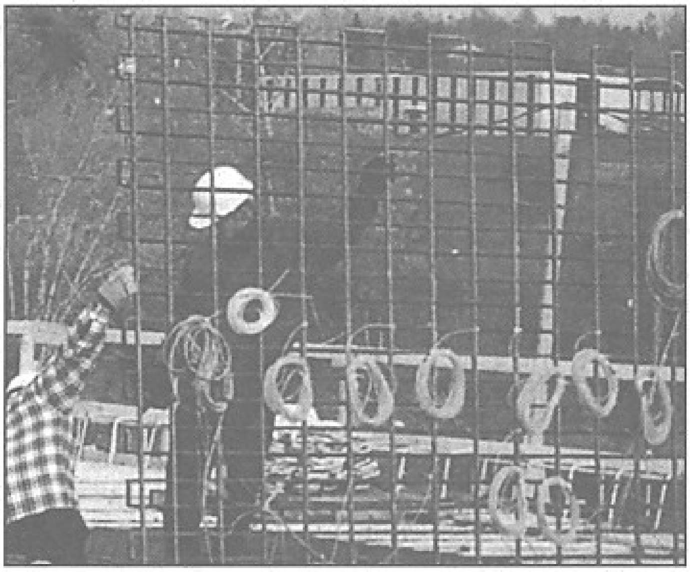

Figure 12. Carbon NEFMAC for Joffre Bridge, Sherbrooke, Canada

A portion of the concrete deck slab of the Joffre Bridge in Sherbrooke, Québec, Canada, was reinforced by carbon fibre polymer mesh, NEFMAC, produced by Autocon of Toronto, Ontario, Canada (see Figure 12). The bridge is located over the Saint-Francois River and consists of five spans, 26 meters to 37 meters in length. The span of the deck slab is 3.7 meters and is supported by steel girders.

For further information, please contact Dr. Brahim Benmokrane by fax at 819-821-7974.

FRP Bars for Renovation

C-Bar™, produced by Marshall Composites Industries, Inc., was used for the renovation of the Kennedy Mansion Seawall in West Palm Beach, Florida (see Figure 13). The seawall was extensively cracked with crack widths in the range of one-quarter of an inch resulting in serious corrosion of the steel

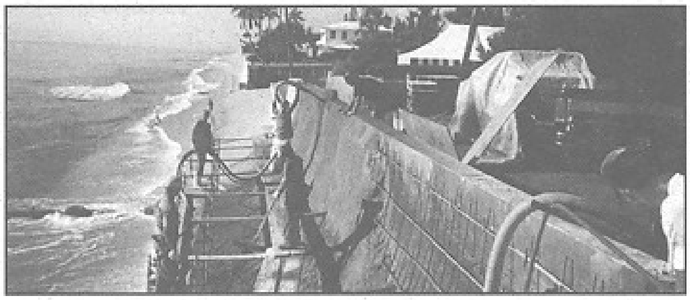

Figure 13. Pultruded ACM for Geodetic Beam

reinforcement for more than 35 percent of the total surface of the wall. The renovation started by removing the spalled area. The existing steel was cleaned and chemically treated. The voids were filled with gunite before placing the C-Bars, which were covered with 15 cm - 4,000 psi gunite. L-shaped C-Bar dowels were installed at 32 inches on center as shown in Figure 14. Construction was done between tides.

For further information, please contact Dr. Salem Faza by fax at 904-443-6028.

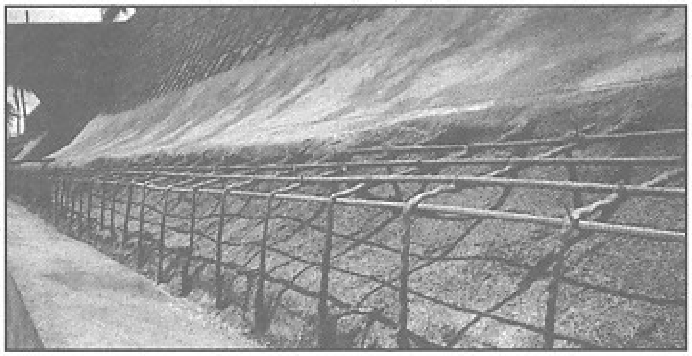

Figure 14. L-Shaped C-Bar Dowels for the Seawall

FRP for Public Parking Structures

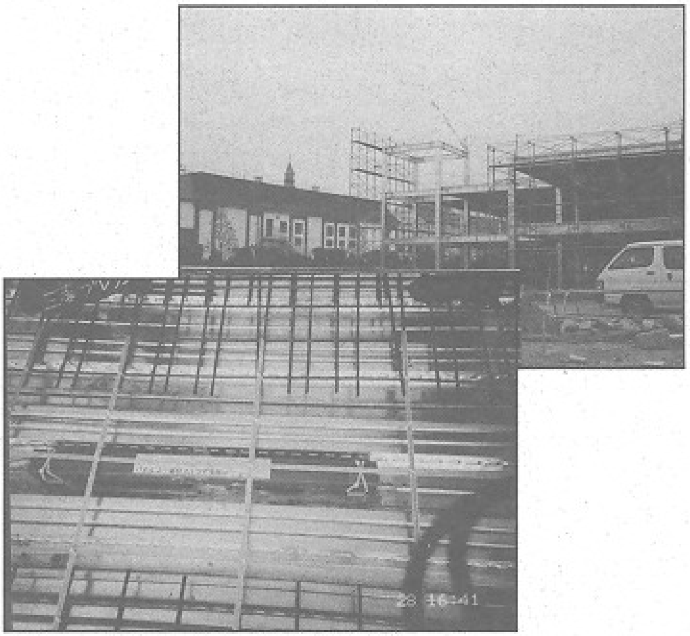

Figure 15. Arapree for Parking Structures, Japan

Arapree type f200,000 was used to strengthen a reinforced concrete floor in a public parking structure of Okayama Public Corporation built next to Kurashiki Tivoli Park, Japan (see Figure 15). The structure is 400 square meters in total area and 2,000 meters in total length. Magnetic sensors were installed in the concrete slab to count the number of cars parked at any given time. Arapree was selected instead of steel reinforcing bar due to its non-magnetic characteristics that will not interfere with the magnetic sensors.

For further information, please contact the Nippon Aramid Co., Ltd. by fax at 81-3-5543-5946.

FRP Pedestrian Bridge in Japan

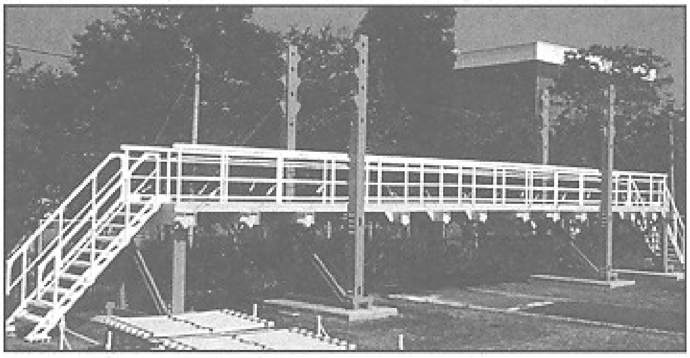

Figure 16. FRP Continuous Cable-Stayed Bridge, Japan

The Public Works Research Institute of Japan recently constructed a three-span continuous cable-stayed bridge, 20 meters long with a center span of 11 meters and a 2 meter wide deck. Glass fiber reinforced polymer (GFRP) pultruded members were used as shown in Figure 16. The bridge is designed for 350 kg/m2 live load. The connections were designed to allow disassembly of the bridge to be reconstructed in another location. The joints were bolted using fiber reinforced polymer (FRP) bolts. The total weight of the bridge, including the handrail and the staircase, is 4.4 tons. The weight of each individual member of the bridge is less than 150 kg. The bridge was erected in four days using four workers and one crane. The bridge was tested to verify the analytical methods and the assumptions used in the design.

For further information, please contact Mr. Iwao Sasaki of the Public Works Research Institute by e-mail at isasaki@pwri.go.jp.

CFRP Sheets for J. H. Do-oh Express Highway

Carbon fiber reinforced polymer (CFRP) sheets are currently being used to strengthen the columns of concrete highway bridges in the Hokkaido province of Japan (see Figure 17). Repair of J. H. Do-oh Express Highway Bridge is part of a three-year strengthening program including 109 bridges planned by the Japan Highway Public Corporation. Strengthening in this particular project included three layers

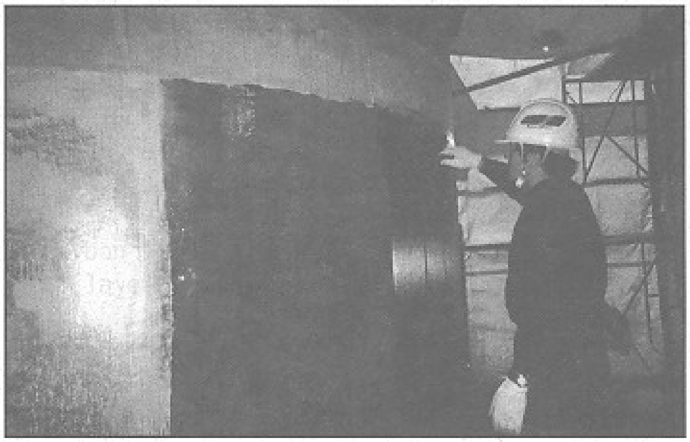

Figure 17. Rehabilitation of J. H. Do-oh Express Highway, Okkaido, Japan

with the fibers in the longitudinal direction to increase the flexural capacity followed by one layer wrapped for confinement and improved shear capacity.

For further information, please contact Dr. T. Ueda by e-mail at ueda@eng.hokudai.ac.jp.

Research

Rehabilitation of Unreinforced Masonry Walls Using FRP

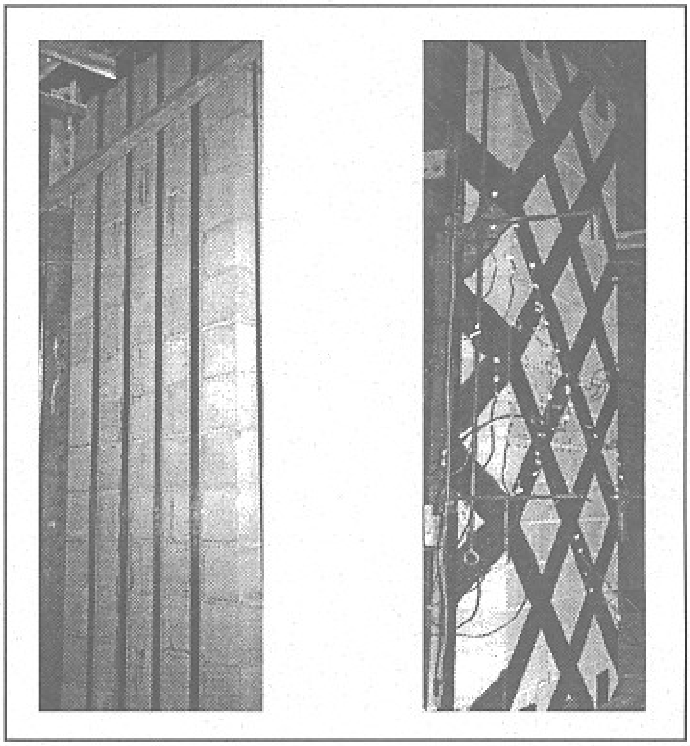

Figure 18. Different Configuration for CFRP Used for Strengthening a Masonry Wall

A testing program conducted at the University of Alberta showed that externally applied fiber reinforced polymer (FRP) is effective in increasing the load-carrying capacity of unreinforced masonry walls. The project is sponsored by ISIS Canada and Canadian Masonry Research Institute. A total of ten walls with a vertical span of 4 m were used to conduct 13 tests in two series. The parameters of the testing program included: (a) type of fibre reinforcement (carbon strap, carbon sheet, and glass sheet, shown in Figure 18), (b) amount of reinforcement, (c) layout of reinforcement, (d) axial load effects, and (e) cyclic behavior. Series one involved seven tests on four walls and focused on varying the type of reinforcement. Series two involved six tests on six newly constructed walls and focused on varying the layout and the amount of carbon fiber sheet. Preliminary results show the out-of-plane strength can be increased by 20 to 25 times that of an unreinforced wall tested under the same conditions. The ductility is also greatly increased. Overall, the tests showed that externally bonded FRP is an effective alternative to rehabilitating unreinforced masonry walls.

For additional information, please contact Dr. Roger Cheng by fax at 403-492-0249.

FRP for Continuous Prestressing

Carbon fiber reinforced polymer (CFRP) strands were used to prestress a 17 meter long continuous beam over two spans, 8 meters each (see Figure 19). Two beams were prestressed with bonded CFRP, two beams with unbonded CFRP and one with bonded steel strand to serve as the basis test for comparison. Test results indicated that CFRP can be used for statically indetermine systems. The research used additional strands at the center support to provide equal fracture mount resistance equal to the fracture moment at mid-span. The research recommended that CFRP tendons are basically feasible for statically indeterminate systems.

Figure 19. Testing of Continuous Concrete Beam Prestressed with FRP, EMPA, Switzerland

For further information, please contact Prof. Urs Meier of the Swiss Federal Laboratories for Materials Testing and Research (EMPA) by fax at +41-1-821-6244 or by e-mail at urs.meier@empa.ch.

Networking

The Composites Institute's (CI) Market Development Alliance (MDA) formed the Composites Bridge Team which includes leading bridge manufacturers and material suppliers to match the nation's bridge restoration movement with the durability of composites products. The Composites Bridge Team will focus on the following accomplishments:

- Origination of a database of manufacturers and researchers.
- Origination of bridge installation database.
- Establishment of performance and cost targets.
- Creation of regular networking activities with bridge industry representatives to coordinate design, demonstration and further research requirements.
- Development of test methods and drafting of design standards.
- Implementation of practitioner education and training.

Working in partnership with trade and industry organizations, such as the Highway Innovative Technology Evaluation Center at the Civil Engineering Research Foundation, the Federal Highway Administration, The American Association of State and Highway Transportation Officials, the Transportation Research Board, and the Great Lakes Governors Council, the Composites Bridge Team will establish itself as a key leader in providing solutions to America's deteriorating bridge problems.

Manufacturing members include Caine, Composite Rebar Technologies, Creative Pultrusions, Glasforms, Resolite FRP Composites, Seaward International, TPI, and Trimas of Long Island. Material supplier members include Alpha-Owens Corning, Ashland Chemical, Baltek, Brunswick Technologies, Cook Composites and Polymers, Interplastic, Master Builders, Ownes Corning, PPG Industries, Reichhold Chemicals and Vetrotex CertainTeed. The team's Chair is John Burke, Director of Commercial Development for PPG Industries.

For further information, please contact John Busel of the Composites Institute by fax at 212-370-1731.

Theses

Dowden, D. M. B., "Shear Capacity of Prestressed Concrete Beams Reinforced with FRP Reinforcement", M.Sc. Thesis, 1997, University of Wyoming. Supervised by Dr. C. Dolan.

Gilstrap, J., " Characterization of Fiber Reinforced Polymer Prestressing Tendons", M.Sc. Thesis, 1997, University of Wyoming. Supervised by Dr. C. Dolan.

Mahmoud, Z., "Bond Characteristics of Fibre Reinforced Polymers Prestressing Reinforcement", Ph.D. Thesis, 1997, University of Alexandria. Supervised by Dr. E. Zaghloul and Dr. S. Rizkalla.

Scott, D., "Short and Long-term Behavior of Axially Compressed Slender Doubly Symmetric Fiber-Reinforced Polymeric Composite Members, Ph.D. Thesis, 1997, Georgia Institute of Technology. Supervised by Dr. A. Zureick.

Conferences

American Concrete Institute 1998 Spring Convention, March 22 to 27, 1998, Houston, Texas, U.S.A. For further information, please contact ACI International by fax at 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.

Advances in Cement and Concrete, July 5 to 10, 1998, Banff, Alberta, Canada. For further information, please contact the Engineering Foundation by fax at 212-705-7441.

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, 1998, 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.

American Concrete Institute 1998 Fall Convention, October 25 to 30, 1998, Los Angeles, California, U.S.A. For further information, please contact ACI International by fax at 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.ota.fhwa.dot.gov/nrc.

American Concrete Institute 1999 Spring Convention, March 14 to 18, 1999, Chicago, Illinois, U.S.A. For further information, please contact ACI International by calling 810-848-3700.

Structural Faults and Repair'99, July 6 to 8, 1999, Edinburgh, Scotland. For further information, please contact Professor M. C. Forde by telephone by e-mail at m.forde@ed.ac.uk.

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.

American Concrete Institute 1999 Fall Convention, October 31 to November 5, 1999, Baltimore, Maryland, U.S.A. For further information, please contact ACI International by fax at 248-848-3701.

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