FRP International

Fiber Reinforced Polymers

Fall 2001

*Dear Friends:*

*FRP International is expanding its international scope. Dr. Sami Rizkalla continues as chief editor but is joined by new editors representing Canada (Dr. Aftab Mufti), Europe (Editor by Invitation), Japan (Dr. Tamon Ueda), and the United States (Dr. Issam Harik). On behalf of the FRP International readers, I would like to express our gratitude to Dr. Antonio Nanni, Dr. Srinivasa Iyer, and Dr. Leon Wegner for their exemplary service and dedication as former associate editors.*

*Issam Harik*

*During the past decade, we have witnessed exponential growth in research and field demonstrations of FRP Composites in civil engineering. In the United States, the growth was fueled by financial support from the National Science Foundation, the National Institute of Standards and Technology, the Federal Highway Administration, the National Cooperative Highway Research Program, the Department of Defense Advanced Research Projects Administration-Technology Reinvestment Project, and other funding agencies. Since the late 1990s, deployment of FRP composites in highway bridges has increased considerably due to funding through the Transportation Equity Act-21/Innovative Bridge Construction Program.*

# Notable Research Activity

## The University of Cincinnati

Infrastructure applications of FRPs is one of the research thrusts at the University of Cincinnati Department of Civil and Environmental Engineering. Eight structures faculty members are involved in research projects addressing these issues. Some of the projects take advantage of the newly constructed large-scale structural laboratory that allows full-scale testing of structural elements and

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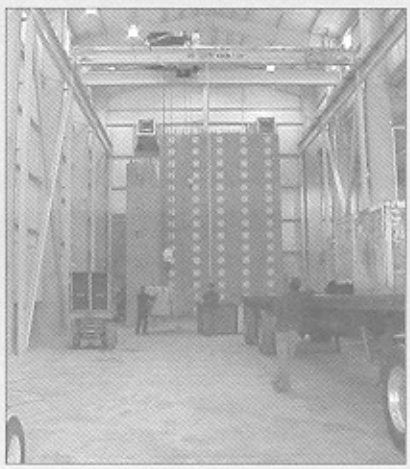

*Figure 1: Structural laboratory with 4.5 ft thick floor and L-shaped reaction wall*

In This Issue



• University of Kentucky • Market Development Alliance • American Concrete Institute • American Society of Civil Engineers • Canadian Society for Civil Engineering • Japan Concrete Institute •

*University of Cincinnati*
*Continued from front page*

assemblies up to two stories. The following projects are related to FRP applications:

- Time-Dependent Behavior of Hybrid FRP-Concrete Columns.
- Non-Destructive Testing of RC with External FRP.
- Creep and Durability of Environmentally Conditioned FRP-RC Beams Using Fiber Optic Sensors.
- Slenderness Effects in RC Columns with Internal or External FRP Reinforcement.
- Hysteretic Behavior of Concrete-Filled FRP Tubes.
- Five-Mile Road Project: Three 45-ft-long existing prestressed concrete bridges along Five-Mile Road in Hamilton County, Ohio, have received new FRP decks.

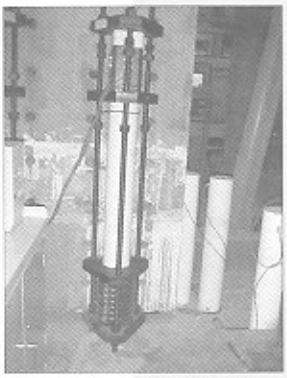

*Figure 2: Time- dependent testing of hybrid FRP-concrete column*

*Figure 3: Five-Mile Road Bridge with FRP deck*

- The University of Cincinnati, in collaboration with other researchers, is involved in developing national specifications for bonded repair and retrofit of concrete structures using FRP.
- Low-Cycle Fatigue of Plastic Piles at Connections.
- Field Performance Evaluation of Multiple Fiber Reinforced Polymer Reinforced Bridge Decks.

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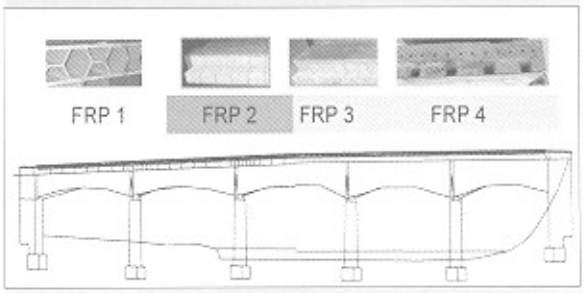



*Figure 4: First Salem Bridge in Dayton, Ohio, with four types of FRP decks*

- Retrofit of Existing Reinforced and Prestressed Concrete Bridges With FRP.
- Environmental Durability Evaluation of Externally Bonded Composites.

For more information, contact Dr. Amir Mirmiran at: amir.mirmiran@uc.edu, or Dr. Bahram Shahrooz at: Bahram.Shahrooz@uc.edu, or Dr. James Swanson at: james.swanson@uc.edu.

# Application

## CFRP Reinforced Bridge Deck

Carbon FRP rebars, produced by Marshall Industries, were used as the main reinforcement in the deck of a bridge spanning Two-Mile Creek in Clark County, Kentucky. The deck is supported by prestressed concrete spread box beams. Construction workers commented in favor of the lightweight rebars while placing them in the deck. Funding for this project was provided by the Federal Highway Administration through the Transportation Equity Act-21/Innovative Bridge Construction Program.

*Figure 5: Deployment of CFRP rebars in Two-Mile Creek Bridge*

For more information, contact Dr. Issam Harik at: iharik@engr.uky.edu.

## Strengthening Using Prestressed CFRP Sheets

A technique for strengthening concrete beams using prestressed Carbon Fiber Reinforced Polymer (CFRP) sheets was pioneered at the Royal Military College of Canada and Queen's University. A practical and innovative mechanical anchorage system was developed to directly prestress the CFRP sheets by jacking and reacting against anchors mounted on the strengthened beam itself.

*Figure 6: Prestressed concrete T-beam strengthened with prestressed CFRP sheets.*

For more information, contact Dr. Raafat El-Hacha at: raafat@civil.queensu.ca.

## Composite Pile: A Successful Drive

Restrictive requirements on concrete piles in salt or brackish water have made concrete-filled FRP tube a potential alternative to concrete piles by eliminating the formwork, reinforcing cage, and additional corrosion-deterrent cover. A pilot study for the Florida Department of Transportation showed composite piles to be a feasible alternative for bridge substructure.

For more information, contact Dr. Amir Mirmiran at: Amir.Mirmiran@UC.Edu.

*Figure 7: Concrete-filled FRP tubes being driven as load-bearing piles in Florida.*

## CFRP Grid Reinforced Concrete Bridge Deck

A vehicular bridge designed and load tested for HS 25 loading was recently constructed in Rollinsford, New Hampshire, containing the first concrete bridge deck in the states to be reinforced entirely with carbon fiber NEFMACÒ grid. The bridge was designed by collaboration between the University of New Hampshire and the NHDOT.

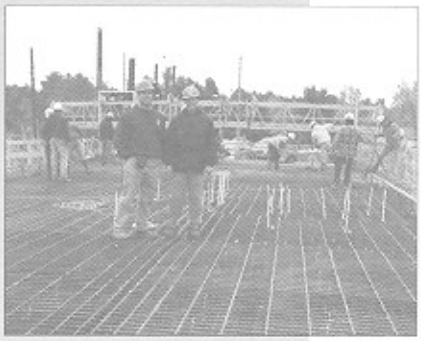


*Figure 8: Deployment of NEFMACO in New Hampshire Bridge.*

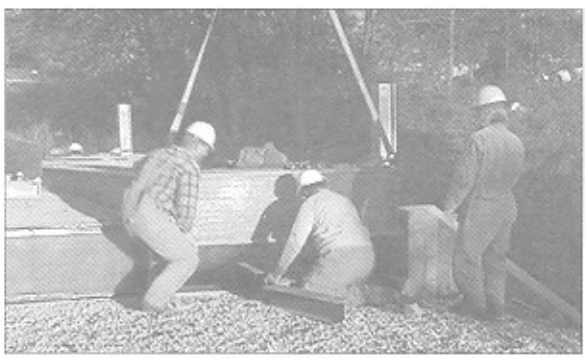
For more information, contact Dr. Robert Steffen at: robert.steffen@unh.edu.

## FRP Bridge Construction in Missouri

The University of Missouri-Rolla, in conjunction with the Department of Economic Development, the city of St. James, and its industry partners, is demonstrating the effectiveness of FRP composites in bridge construction by building four bridges. This includes FRP decks for three bridges and FRP-reinforced concrete for one bridge.

For more information, contact Ms. Danielle Stone at: stone@umr.edu.

*Figure 9: Installation of full-depth FRP bridge.*



## Fiber Reinforced Polymer Honeycomb

In January 1999, Infrastructure Composites International supplied five large-scale test panels to the Ohio Department of Transportation, the University of Kentucky, the University of Maine, and the US Army's Cold Regions Research Laboratory for performance evaluation. The tests included 10 million cycles. This system was selected, along with three other composite technologies, to replace the old decking on ODOT's Salem Avenue bridge.

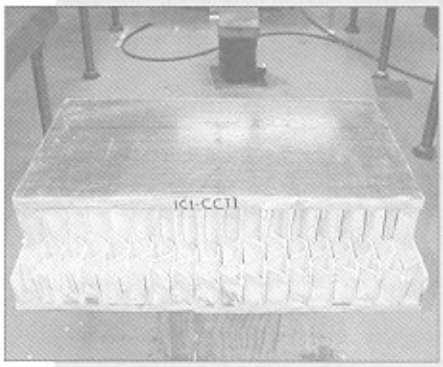



*Figure 10: Cross section of the deck panel following testing at the University of Kentucky.*

For more information, contact Larry Cox at: lcox@alink.com.

## Structural Verification & Testing of Martin Marieta Composite Bridge Deck

A carbon/fiberglass reinforced composite deck system is designed to replace existing steel gratings on the Schuyler Heim Bridge in Long Beach, California. Structural evaluation is being conducted at both the California State University-Fullerton under the direction of Professor Ayman Mosallam and at the University of California-Irvine under the supervision of Professor Medhat Haroun. The Martin Marietta Composites designed the hybrid bridge deck and ACME Fiberglass, Inc. fabricated the composite panels. The maximum design load is equivalent to HS25 load for one wheel plus 10% impact.

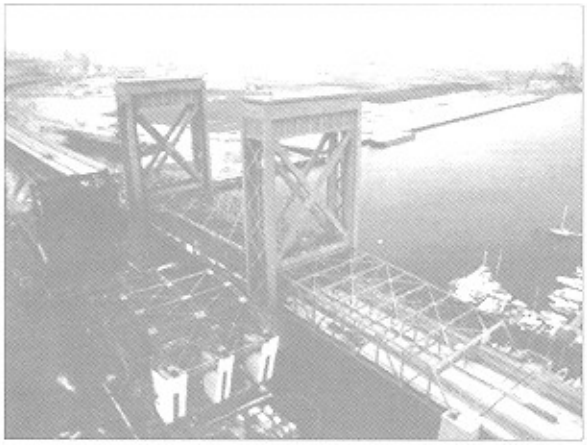


*Figure 11: The Schuyler Heim Bridge in Long Beach, California.*

For more information, contact Dr. Ayman Mosallam at: amosallam@fullerton.edu.

## Two New FRP Bridges in Japan

An experimental FRP highway bridge model, 8m length by 3.5m width, was designed and constructed by Public Works Research Institute. The design live load is a two-ton truck equivalent.

*Figure 12: Experimental FRP Bridge.*

Okinawa Prefecture constructed a pedestrian FRP bridge spaning over the road connecting the main Island to Ikeishima Island. The bridge was designed by Dr. Saeki and is 38m long and 3.5m wide.

For more information contact Dr. Seishi Meiarashi at: mei@pwri.go.jp.

*Figure 13: Pedestrian Bridge in Okinawa, Japan.*

## Timber Bridge Strengthening

In order to accept larger truck loads, the 1930-built Timber Bridge in La Riviere, Manitoba, was evaluated by Wardrop Engineering and Vector Construction Group. While the flexural capacity of the superstructure was acceptable, the horizontal shear capacity of the stringers was the limiting factor. A strengthening system was adopted based on results of tests conducted by ISIS Canada at the University of Manitoba. The system consists of Glass Fiber Reinforced Polymer (GFRP) rods installed in vertical holes drilled equally spaced along the stringers. A two-component epoxy resin was injected to provide the required bond between the GFRP rods and the stringers. Preliminary load testing shows that the maximum deflection of the stringers has been substantially reduced along with increase in shear capacity.

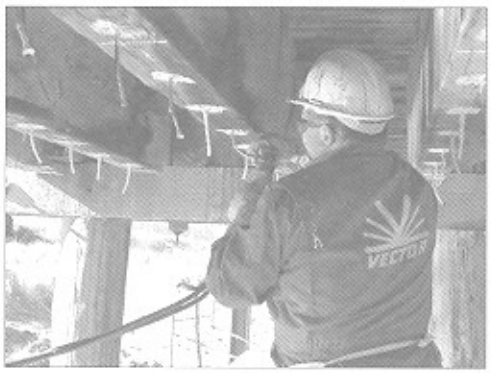


*Figure 14: Injection of epoxy resin that provides the bond between the installed GFRP rods and stringers.*

For more information, contact Leo Mancs at: leom@vectorgroup.com.

## Development of ICBO, ES Evaluation Certified Program

The California State University at Fullerton, under the direction of Professor Ayman Mosallam, has established the first internationally recognized program for International Conference of Building Officials Evaluation (ICBO/ISO) acceptance criteria (AC125, AC85, AC89) as well as California Department of Transportation for FRP Composite Repair and Rehabilitation Systems.

For more information, contact Dr. Ayman Mosallam at: amosallam@fullerton.edu.

## Sandwich Wrapping Confining System (SWCS)

A Sandwich Wrapping Confining System (SWCS) for strengthening rectangular columns is developed to replace the conventional FRP wrapping system with two FRP faces separated by a light incompressible core. The core of the sandwich structure is used as a spacing device, creating a structure with great bending and axial stiffness. Unlike the conventional FRP system, which has only axial stiffness, the SWCS has both axial and flexural stiffness.

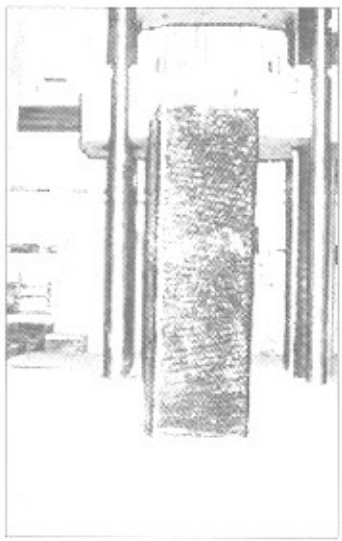


*Figure 15: Column strengthened with SWCS.*

For more information, contact Dr. Tarek Rizk at: t_rizk@ltu.edu.

## FRPs as Strengthening Materials

A four-year research program on the fundamental behavior of FRP-strengthened RC beam-column joints is approaching the stage of completion in the Department of Civil Engineering at the University of Patras, Greece. Extensive, nearly full-scale testing of joints under simulated seismic loading as well as analytical modeling has demonstrated that properly placed FRP sheets may provide substantial strength enhancement in shear-critical beam-column joints.

For more information, contact Dr. Thanasis Triantafillou at: ttriant@upatras.gr.

## The Texas GFRP-Bar Reinforced Concrete Bridge Deck

Top mat GFRP reinforcing bars have been incorporated in the concrete deck of the Sierrita de la Cruz Creek Bridge near Amarillo, Texas. This is the first application of embedded FRP reinforcement in Texas civil infrastructure. The federal TEA-21 In-

*Figure 16: Workers place the bridge deck concrete through and over the GFRP-bar mat.*

novative Bridge Research and Construction Program (IBRCP) has funded all associated additional costs of using the innovative GFRP material in this structure. TxDOT performed the bridge design, including the GFRP-bar reinforced concrete deck.

For more information, contact Mr. Timothy Bradberry at: tbradber@dot.state.tx.us.

## Concrete Arch Wrapping

The Woodland Viaduct Bridge in Westchester County, California, is a 75-year-old concrete open-spandrel arch. Due to severe deterioration of the superstructure, and vulnerability to seismic events, it was decided to replace all columns on the arches, using a pin connection for the new columns and wrapping the arches with fiber-reinforced-polymer composites. The Tyfo® Fibrwrap® System provided the confinement

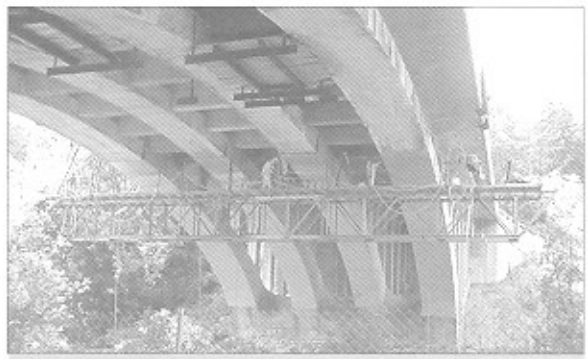


*Figure 17: Installation of Tyfo® System fy FCI*

necessary to increase the ductility of the arches and enable them to survive a design seismic event.

For more information, visit: www.fyfeco.com.

## Continuing Acceptance of Composites in the Infracture Market

A suspension bridge in Wheeling, West Virginia, was recently renovated with FRP grating manufactured by Strongwell (Bristol, Virginia). The bridge, which spans more than 1,000 feet above the Ohio River, was outfitted with more than 8,000 square feet of grating. This project exemplifies the continuing acceptance of composites in the infrastructure market.

For more information, contact Mr. Daniel Pulliam at (540) 645-8143.

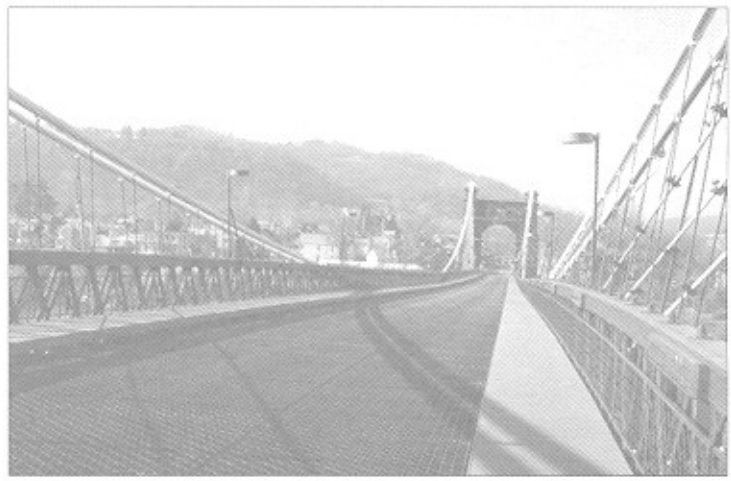


*Figure 18. FRP grating placed on Wheeling Bridge.*

## Trippling Bearing Capacity of Concrete Floor

A reinforced concrete floor system in a building at the Antwep Zoo in Belgium was seriously degraded, and required strengthening to increase the capacity from 5 kN/m$^2$ to 15 kN/m$^2$. Conventional CFRP laminates strengthening was not possible due to limits on the compressive concrete stress. A Balsa wooden beam was placed between the concrete and the CFRP tensile reinforcement to increase the lever arm between the tensile reinforcement and concrete compression zone to reduce the applied stresses.

For more information, contact Dr. S. Matthys at: Stijn.Matthys@rug.ac.be.

*Figure 19: Beam strengthening at Antwep Zoo.*

## Product Selection Guide for Bridge Applications Available

The MDA, a non-profit trade organization representing the FRP composites industry has published a powerful reference tool for the engineer seeking a working knowledge of composites and its use in replacement or retrofitting of bridge structures. This technical compendium offers extensive information on products and showcases numerous field installations. Download the 250+ page guide by visiting: www.MDAcomposites.org.

# Theses

Jahic, J., "Mechanical Behavior of Pultruded Composite Materials under Elevated Temperature Conditions," MME Thesis, California State University, Fullerton, May 2000. Supervised by Drs. J. Kreiner and A. Mosallam.

Liu, X., "A Linear and Nonlinear Numerical Investigation on Static Behavior of Pultruded Composite (PFRP) Portal Frame Structures," MME Thesis, California State University, Fullerton, May 2000. Supervised by Drs. A. Mosallam and J. Kreiner.

Marano, S., "Experimental Investigation of the Viscoelastic Behavior of Composite Laminates Bonded to a Substrate Under Dry and Wet Conditions," MME Thesis, California State University, Fullerton, May 2000. Supervised by Drs. A. Mosallam and J. Kreiner.

Slenk, J., "Experimental Assessment of Residual Tensile Strength of Graphite Epoxy Woven Laminates After Impact," MME Thesis, California State University, Fullerton, July 2000. Supervised by Drs. J. Kreiner and A. Mosallam.

Neely Jr., W., "Evaluation of the In-Service Performance of the Tom's Creek Bridge," MSCE Thesis, Virginia Tech., December 2000. Supervised by Drs. Tommy Cousins and Jack Lesko's.

De Lorenzis, L., "Near Surface Mounted FRP Rods," MSc. Thesis, Department of Civil Engineering, The University of Missouri - Rolla, Rolla, MO. June, 2000. Supervised by Dr. A. Nanni.

Simpson, P., "Australian Research into Composite Bridges," PhD Thesis, University of Southern Queensland, Toowoomba, Queensland, Australia, June 2000.

# Conferences

- **CFA - Composites 2001 Annual Conference & Trade Show.** October 3 - 6, 2001, Convention Center, Tampa, Florida, U.S.A. Please visit: www.cfa-hq.org.
- **Fifth National Science Foundation Workshop on Bridge Research in Progress**, Minneapolis, Minnesota, U.S.A., October 8-10, 2001. Contact: Dr. Carol K. Shield at 612-625-5522; email: ckshield@tc.umn.edu.
- **ACI Fall Convention**, Dallas, Texas, U.S.A., October 28-November 2, 2001. Please visit: www.aci-int.org.
- **33rd International SAMPE Technical Conference**, Seattle, Washington, U.S.A., November 4-8, 2001. Please visit: www.sampe.org.
- **11th International Conference on Composite Structures**, Victoria, Australia, November 19-21, 2001. Please visit: www.eng.monash.edu.au/iccs11.
- **International Conference on Science and Technology of Composite Materials**, Mar del Plata, Argentina, December 10-12, 2001. Email: sapsampe@fi.mdp.edu.ar.
- **9th International Conference on Fibre Reinforced Composites**, Newcastle, United Kingdom, March 26-28, 2002. Please visit: www.ncl.ac.uk/ccme.
- **SAMPE Europe, 23rd International Conference**, Paris, France, April 9-12, 2002. Email: cardamone@stesalit.com.
- **ACI Spring Convention**, Detroit, Michigan, U.S.A., April 21-26, 2002. Please visit: www.aci-int.org.
- **Second International Conference on Durability of FRP Composites for Construction**, Montreal, Quebec, Canada, May 29-31, 2002. Please visit: www.gci.usherb.ca/cdcc2002.
- **6th International Conference on Short & Medium Span Bridges**, Vancouver, British Columbia, Canada, July 31 - August 2, 2002. Please visit: www.bridgeconference.com.
- **The First *fib* Congress, Concrete Structures in the 21st Century**, Osaka, Japan, October 13- 19, 2002. Email: fib2002@jpcea.or.jp.
- **ACI Fall Convention**, Phoenix, Arizona, U.S.A., October 27-November 1, 2002. Please visit: www.aci-int.or.
- **ACI Spring Convention**, Vancouver, British, Columbia, Canada, March 27 - April 4, 2003. Please visit: www.aci-int.org.




Department of Civil Engineering
161 Oliver H. Raymond Building
University of Kentucky
Lexington, KY 40506-0281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