FRP International
Fiber Reinforced Polymers
Winter 1998 Volume VI, Issue 1

Notable Research Activity

The Magnel Laboratory for Concrete Research

The Magnel Laboratory for Concrete Research was founded at the Universiteit Gent in Belguim in 1926 by the late Prof. Magnel, who significantly contributed to the development of prestressed concrete in the 40's and 50's. His design methods were based on extensive experimental testing of full-scale concrete members. His text books were translated into several languages and he was involved in the design of the first prestressed concrete bridge in North America (the Walnut Lane Bridge in Philadelphia).

Under the direction of Prof. dr. ir. Luc R. Taerwe, the testing facilities include a 60 x 15 m strong test floor (Figure 1) and a stiff concrete box section with prestressed top and bottom slabs. The anchorage points, located at a grid distance of 1.2 m, can withstand vertical loads of 1000 kN. To date, the longest beams that have been tested to failure have had a span of 30 m.


Figure 1. Testing of GFRP Modular Panel.

In the past, research projects were performed on many aspects of structural concrete. For the last ten years, the main research topic has focused on the application of fiber reinforced polymer (FRP) for concrete structures. The following are some of the projects which have been investigated or are in progress:

- Structural behavior of concrete members post-tensioned with glass FRP cables of the former "Polystal" system.
- Material behavior, such as relaxation and transfer length, of ARAPREE bars and strips. The research also includes experimental and analytical models to study the influence of the transverse coefficient of thermal expansion on concrete, concrete cover and cracking.
- Long-term behavior of concrete slabs pre-tensioned with aramid FRP.
- Flexural behavior of concrete slabs reinforced with carbon FRP and glass FRP grids under service loading conditions and mode of failure, including punching shear.

(continued on page 2)

In This Issue

(continued from page 1)

- Strengthening of reinforced concrete beams with carbon FRP sheets in bending and shear; influence of the sheets on tension-stiffening and fire resistance.

These research projects were part of the BRITE/EURAM Program "Fibre Composite Elements and Techniques as Non-metallic Reinforcement of Concrete". This was a research program sponsored by the European Communities to which both research institutes and industrial companies contributed.

In order to establish guidelines for the design of concrete structures reinforced, prestressed or strengthened with FRP, a task group was established by CEB (Euro-International Committee for Structural Concrete) under the chairmanship of Prof. L. Taerwe. The group will continue its work under the new organization FIB (Fédération Internationale du Béton; International Federation for Structural Concrete), which is a merger of CEB and FIP (International Federation for Prestressed Concrete).

Other research projects deal with early age properties of concrete, high strength concrete, creep and shrinkage of concrete with recycled aggregates, optical fiber sensors, fatigue of bridge decks, life cycle analysis and biogenic sulfate attack of concrete.

For additional information, please contact Prof. dr. ir Luc Taerwe by e-mail at luc.taerwe@rug.ac.be.

Application

Field Application for FRP Dowels

The first major test for fiber glass dowel systems was installed in the fall of 1997. Isopolyester composite dowels produced by RJD Industries, Inc. of Laguana Hills, California, were installed in Iowa, Illinois and Wisconsin. The isopolyester composite bar is being evaluated along with other composites, epoxy-coated steel, solid stainless steel and hollow stainless steel filled with a cement-based mix. The Illinois and Wisconsin demonstrations are sponsored by the United States Federal Highway Administration, the Wisconsin Department of Transportation and the Market Development Alliance of the Composites Institute of the Society of the Plastics Industry. The Illinois site consists of portions of State Highway 59 in Naperville. The dowels were assembled on baskets before the concrete was cast as shown in Figure 2. The Wisconsin demonstration project uses portions of State Highway 29, west of Abbotsford. There are plans to have another site demonstration using three types of glass fiber reinforced polymer (GFRP) dowels at a highway in Winnipeg, Manitoba, in cooperation with ISIS Canada, the City of Winnipeg and the three producers.

Figure 2. Assembled GFRP Dowels Before Casting of Concrete.

For further information, please contact Mr. James P. McCallion of RJD Industries, Inc. by fax at 714-582-0995.

FRP Provides Solutions for Design/Construction Errors

Two double-ply carbon fiber reinforced polymer (CFRP) strips were used to strengthen the slab of a parking garage in order to correct a deficiency in the number of steel tendons used. Installation of the system involves filling all the defects of the concrete surface and preparing the surface with an epoxy primer. The primer is allowed to cure before applying the base coat of epoxy to the concrete surface. A pre-saturated CFRP sheet was placed and allowed to cure for one hour before applying a coat of epoxy resin in preparation for the second strip.

Due to the limited experience in design and construction using this system, as well as a lack of codes and standards, an on-site evaluation of the repair system for this project was conducted to provide contractors, engineers and the owner with a degree of comfort with respect to the system's performance. The structure was loaded, as shown in Figure 3, and the response was measured at different locations before and after strengthening to demonstrate the

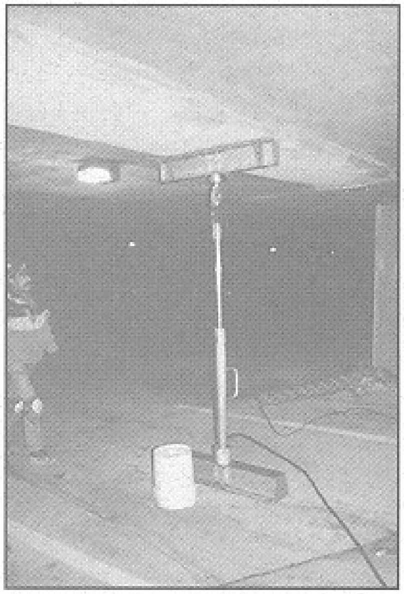


Figure 3. Loading System Used to Evaluate the Performance of CFRP Strips.

degree of strengthening added by the CFRP system. Test results indicated that fiber reinforced polymer technology is capable of correcting design/construction errors.

For further information, please contact Dr. A. Nanni of the University of Missouri-Rolla by fax at 573-341-4729 or by e-mail at nanni@umr.edu.

FRP Accommodates Changes in Original Plan

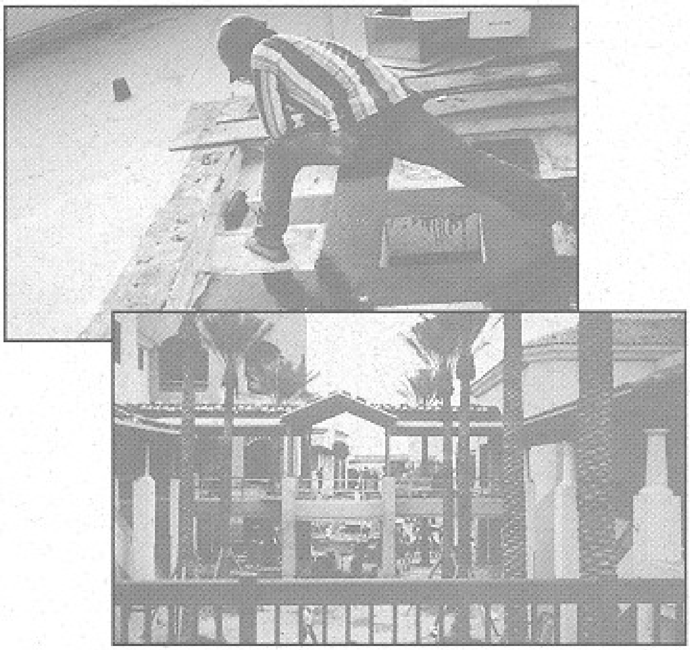


Figure 4. Strengthening of Slab Around the Openings.

Recently, a strip mall containing several restaurants and retail stores was constructed in South Florida. After casting of the reinforced concrete roof slab and completion of the interior work, the floor plan of one of the restaurants was changed and required relocation of the kitchen and its ventilation system. The slab openings for the ventilation system were also relocated. Structural concerns arose when several reinforcing bars were cut to make the openings. A number of options were considered to strengthen the edges of the openings and to control cracking around the corners. Existing duct work supported from the roof slab limited access to the area around the openings. In addition, the repair strategy needed to be implemented quickly to meet the project schedule. The MBrace composite strengthening system was selected as the most cost-effective and fastest solution. Carbon fiber sheets were installed on the top and bottom surfaces of the slab around the perimeter of the opening as shown in Figure 4.

For further information, please contact Mr. Gregg Blaszak of Structural Preservation Systems, Inc. by fax at 410-247-1136.

Isopolyester Protection for Concrete Columns

The California Department of Transportation (Caltrans) has decided to strengthen the 3,480 concrete columns of the Yolo County Causeway with a Snap-Tite™ isopolyester composite jacket as shown in Figure 5. CMI Inc. fabricates and installs the Snap-Tite™ system in the United States under license from NCF Industries, Inc. of Long Beach, California.

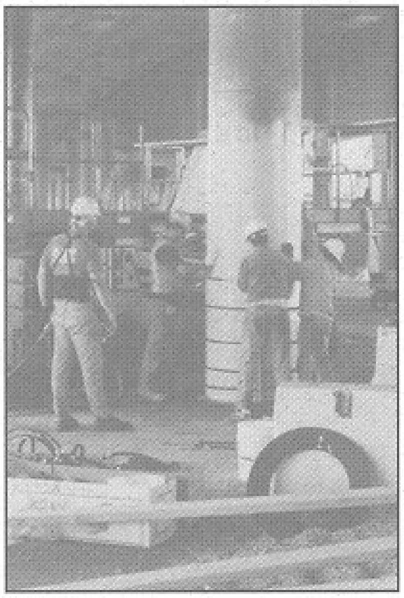


Figure 5. Snap-Tite™ Isopolyester for Concrete Columns.

Each Snap-Tite™ component is a single-seamed, cylindrical jacket that snaps onto the column. The column is cleaned and prepared with a special adhesive before placement of the jacket. Several jackets can be applied until the desired thickness for the job is achieved. An adhesive is applied between layers and the seams between the layers are staggered. Each nested jacket set is bound with belts until the adhesive cures. The Snap-Tite™ system increases concrete strength and overall ductility of the columns, as well as providing protection against severe weather conditions.

For more information, please contact Mr. Norman Fawley by fax at 310-602-0050.

Pier Cap Application

The Tyfo® SEH 51 System was used to strengthen severely corroded pier caps of the Manette Washington State Bridge as shown in Figure 6. The piers required epoxy injection prior to the strengthening process shown in Figure 7. Strengthening was required to increase the shear, flexural capacity and the ductility as specified by the Department of Transportation.

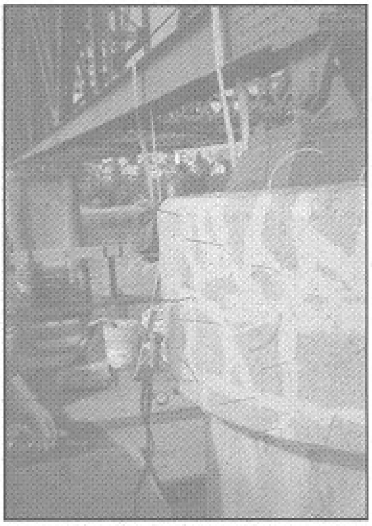


Figure 6. Epoxy Injection of the Pier Cap Prior to Strengthening.

For further information, please contact Fyfe Co. L.L.C. by fax at 619-642-0947 or visit their website at http://home.earthlink.net/~fyfeco/.

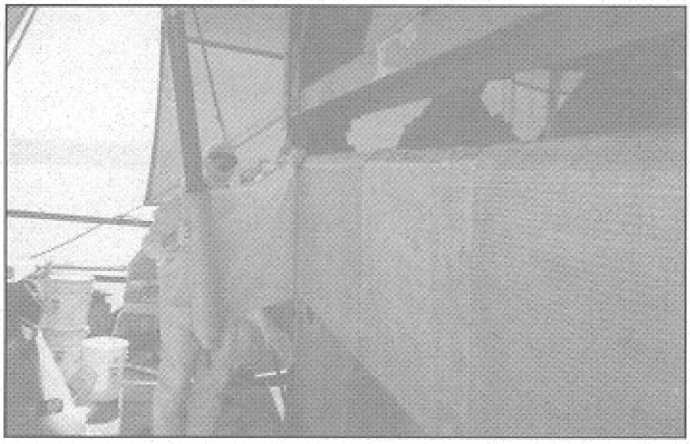


Figure 7. Repair of the Pier Caps of Manette Bridge in Washington State.

Strengthening of Office Building

Fiber reinforced polymer (FRP) sheets were used to increase the specified live load from 50 psf to 120 psf of a two-way post-tensioned flat slab of an office building in North Carolina. The carbon fiber reinforced polymer (CFRP) sheets were installed without interfering with existing mechanical piping and the alarm system, as shown in Figure 8. Multiple FRP sheets were installed between all columns in the positive moment area and in the negative moment zones, where required. A total of 14,000 square feet of the MBrace FRP system was used in this project which was completed under budget and ahead of schedule. Structural Preservation Systems, Inc. (SPS) was the contractor on this project.

For further information, please contact Mr. Jay Thomas by fax at 410-247-1136.

Figure 8. Installation of CFRP Sheets Without Interference with Existing Mechanical System.

FRP for Beam-Column Joints

The pier of the Highland Drive Bridge on Interstate 80 in Salt Lake City was retrofitted with carbon fiber reinforced polymer as shown in Figure 9. The rehabilitation of the bridge pier included wrapping of the columns, cap beam-column joints and the cap beam haunches with carbon fiber composites. The freeze-thaw action, and heavy use of de-icing salt, had created severe corrosion problems in the pier of the bridge. Preliminary estimates of the pier's as-built capacity showed that, for gravity loads, the pier seemed to perform adequately. However, due to severe corrosion, the actual capacity of the cap-beam was believed to be much less than what the original drawings would indicate. As far as response to earthquake loads, it was obvious that the pier would experience severe damage in the event of a major earthquake. Calculations confirmed that one composite layer is required in the $+45^{o}$ direction and another in the -45^{o} direction. The cap beam was wrapped with carbon fiber sheets at 90^{o} around the beam-ends, and at 45^{o} at the beam-column joint.

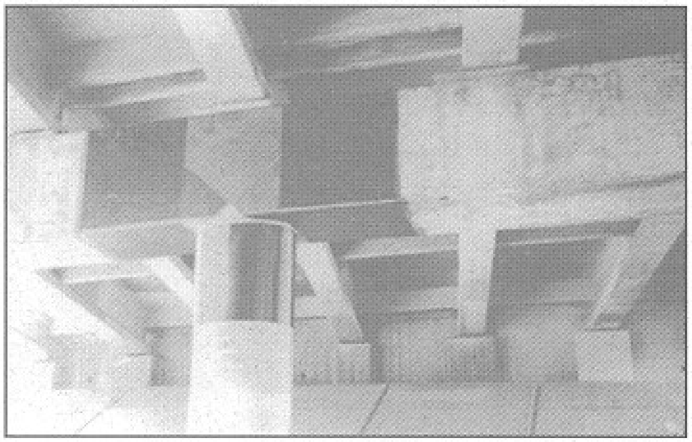


Figure 9. CFRP Retrofit of Beam-Column Joint at Highland Drive Bridge.

Experiments carried out at the University of Utah and at Utah State University verified the analytical predictions, which indicated doubling of the ductility and a significant increase in shear strength. The economics of the construction, which took only one week for the Interstate 80 Bridge pier, are competitive to conventional repair methods.

For further information, please contact Dr. C. Pantelides by fax at 801-585-5477 or by e-mail at chris@civil.utah.edu.

Seismic Strengthening of Keiyo Highway Bridge Piers

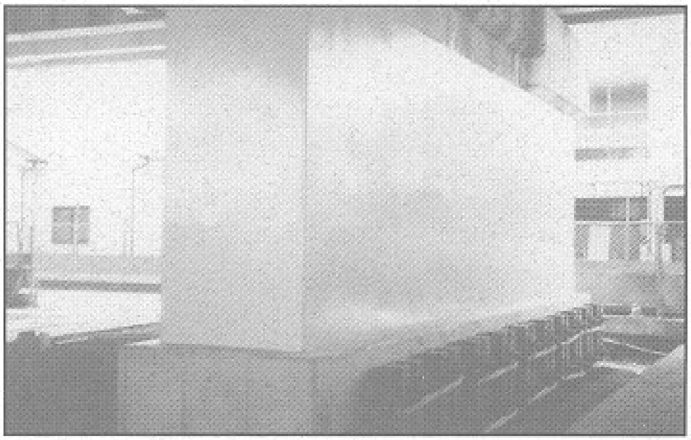


Figure 10. Strengthening of Keiyo Highway Piers by AFRP Rods.

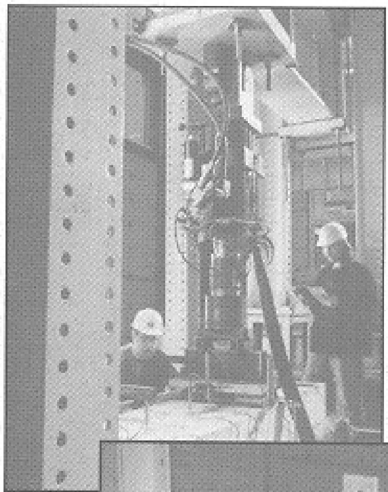
Seismic strengthening of the wall-type piers of the Keiyo Highway, in the vicinity of Funabashi City, was carried out with the aramid wall strengthening (AWS) method in which the piers were prestressed with aramid fiber reinforced polymer (AFRP) using Technora rods. This technique, which is applied to the wall-type bridge pier where the ratio of the vertical to the horizontal cross section of the piers is three or more, involves retrofitting the piers with steel sheets and prestressing them with AFRP rods laid in line with the thickness of the wall as shown in Figure 10. Using AFRP prevented buckling of the steel sheets and provided confinement of the concrete which improved both the bending and shear strength of the member. The work involved the strengthening of 29 piers using a total of 524 cables. This new seismic strengthening technique was developed in association with the Japan Highway Public Corporation.

For more information, please contact Mr. Masaya Kamiyoshi by fax at +81-3-3506-4127.

Research

FRP Dowels

Smooth, round and non-corroding glass fiber reinforced polymer (GFRP) dowel bars are currently being produced by three manufacturers in the United States; namely, Glasforms, Inc., RJD Industries, Inc. and Creative Pultrusions, Inc. GFRP dowels are replacing epoxy-coated bars which are susceptible to corrosion causing lock-up of the joints and resulting in deterioration and spalling of the concrete at the joint location. The commercially-available dowel bars are 1.5" (38 mm) in diameter with unidirectional GFRPs offering a very high fatigue strength. The smooth surface of the bars allows expansion and contraction of the concrete at the joint due to temperature changes.



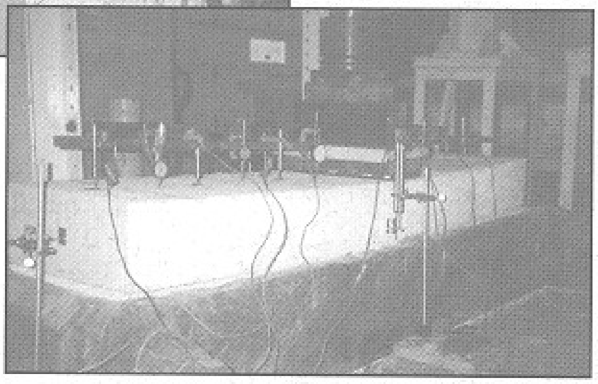


Figure 11. Testing of GFRP Dowels at the University of Manitoba.

Due to a lack of codes and standards for this new material, a comprehensive research program is currently in progress by ISIS Canada at the University of Manitoba as shown in Figure 11. The program includes testing of a 10" (250 mm) concrete pavement slab representing a section of highway pavement. The specimens include two dowels and the joint was tested under an equivalent AASHTO track design loading area. The slab is supported by simulated subgrade.

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

Hybrid FRP-Concrete Columns

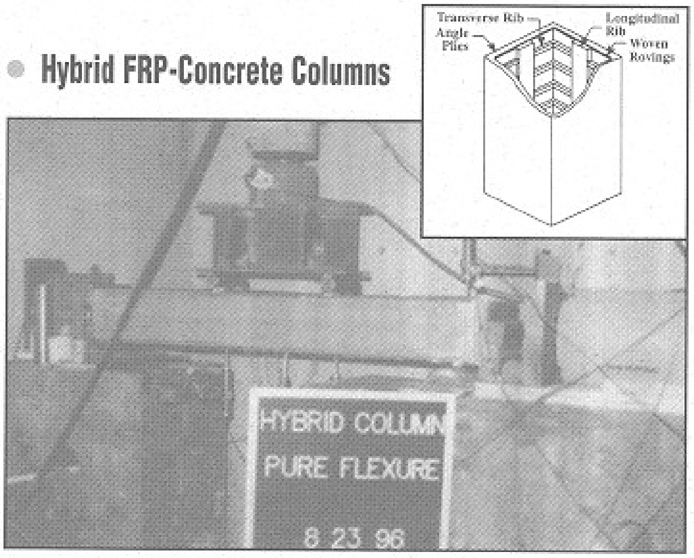


Figure 12. Hybrid FRP-Concrete Columns.

One of the most efficient applications of fiber reinforced polymer (FRP) is in the form of hybrid construction with concrete, which optimizes the use of materials based on their mechanical properties. Structural systems with pseudo-ductile characteristics can be developed by utilizing a full-section enclosure of concrete with or without internal reinforcement. A new concrete-filled FRP tube (CFFT) is developed in which the tube is the pour form, protective jacket, confining mechanism, and shear and flexural reinforcement as shown in Figure 12. Extensive experimental and analytical studies at the University of Central Florida and the Structural Research Center of the Florida Department of Transportation indicate significant strength and ductility for CFFT columns and beam-columns of circular or square sections. CFFTs can be used as cast-in-place or precast piles or columns. A new confinement model for FRP composites has also been developed. The project is sponsored by the Florida Department of Transportation and the National Science Foundation.

For more information, please visit the University of Southern Florida's website at http://bader.engr.ucf.edu/staff/mirmiran.htm.

Products

US-Japan Joint Venture

Toray Industries Inc. in Japan recently announced an investment plan of slightly more than seven billion yen to build a polyacrylonitrile (PAN) carbon fiber plant in the United States. The plant, capable of producing 1,800 tons of PAN carbon fiber a year, is expected to become operational in 1999. Demand for carbon fibers as a reinforcing material in consumer products and civil engineering projects is expected to grow to 21,000 tons in 2005 compared to 11,000 tons produced in 1996.

Toray Carbon Fibers America will be established with a start-up capital of 45 billion dollars. The company headquarters and the plant will be located at the Decatur, Alabama, plant of Monsanto Co. At the plant, acrylic long fibers shipped from Japan will be processed into carbon fibers. The products will be marketed in the United States.

News received from the Canadian Embassy in Japan.

FRP for Wastewater Treatment Reactor

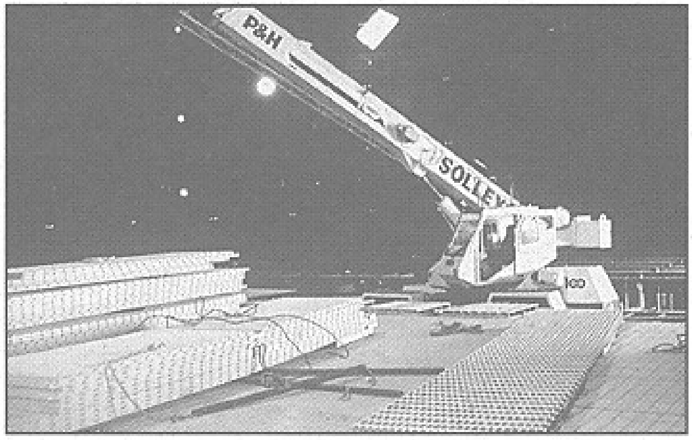


Figure 13. Composite Grating for Wastewater Treatment Reactor.

Purified Isophthalic Acid (PIA) produced by Amoco Chemical was used to fabricate a composite grating for the Decatur Wastewater Treatment Reactor in Alabama, U.S.A. PIA is a primary component in the isopolyester resin used for the grating located at the bottom of the reactor to support the thermoplastic media in which waste-digesting micro-bacteria grow. The isopolyester resin protects against chemical and hydrolysis attack as the grating is constantly submerged in the wastewater solution. The 24 m diameter, cylindrical reactor for the Decatur wastewater system used one layer of composite grating to support a 3 m high stack of biodigestion media called "packing". The Dynaform® pultruded grating is supplied by Composite Structures International Inc. of Dallas, Texas, which makes the grating's lineal composite parts by the pultrusion process as shown in Figure 13. During pultrusion, composite structures pull isopolyester resin-impregnated glass fiber reinforcements through a die that forms a lineal profile with a constant cross section. When the resin cures to a hard state, the fibers are encapsulated in the isopolyester matrix to create a structural composite.

For further information, please contact Ken Berg by fax at 972-250-1530.

Associations

CF Kenkyo

Carbon Fiber (CF) Buildings (Ken) Conference (Kyo) was originally founded in December 1995, but it dramatically expanded its activity and membership through participation in a three-year comprehensive technical development project by the Japan Ministry of Construction. Currently, CF Kenkyo's membership consists of about 190 companies including general and repair contractors and manufacturers of carbon fiber sheet, resin and finishing materials nationwide. The major goals of CF Kenkyo include: (1) promoting strengthening and repair with adhesively-bonded carbon fiber sheets, (2) educating engineers and workers, and (3) developing quality standards, specifications and installation guidelines for carbon fiber sheets in the construction industry, as a result of the sponsored research to the Japan Association for Building Research Promotion (JABRP).

For more information, please contact Mr. Tatsuo Ando by fax at +81-3-3453-8008.

Carbon Fiber Repair and Reinforcement Research Association (CFRRA)

The Carbon Fiber Repair and Reinforcement Research Association (CFRRA) was formed in July 1994 at the request of the Japan Ministry of Construction to establish and develop technology for repair and reinforcements for civil engineering applications using carbon fiber sheets. CFRRA consists of 21 members who include three suppliers (Tonen, Toray and Mitsubishi Chemical Corporation), five consulting firms and 13 construction companies including five major contractors (Obayashi, Shimizu, Taisei, Kajima and Takenaka). The technical activities of CFRRA are organized by four committees (Bridge Superstructures, Bridge Substructures, Buildings and Tunnels). The main activities of CFRRA include promotion of technology, development of design and application manuals, and collaboration in research between universities and government. CFRRA is currently active in developing seismic design techniques for bridges using carbon fiber sheets.

For more information, please contact Mr. Masahiko Uemura by fax at +81-3-5778-5074.

Committees

ACI Committee 440

ACI Committee 440 is one of the most dynamic and active committees of the American Concrete Institute (ACI). There are 11 subcommittees, 50 voting members, 58 associate members and 9 consulting members. Current activities of the subcommittees include the following:

- Guidelines for selection, design and installation of fiber reinforced polymer (FRP) systems for externally strengthening concrete structures. Subcommittee 440-F, chaired by R. McCullough.
- Design guidelines for concrete members reinforced by FRP. Subcommittee 440-H, co-chaired by S. Faza and A. Nanni.
- Design guidelines for concrete members prestressed by FRP. Subcommittee 440-I, chaired by C. Dolan.
- State-of-the-art report on stay-in-place FRP structural composite form. Subcommittee 440-J, chaired by S. Iyer.
- FRP material characteristics. Subcommittee 440-K, in collaboration with ASTM Committee D20.18, co-chaired by S. Faza and B. Benmokrane.
- FRP student education. Subcommittee 440-G, chaired by S. Ahmad, organizes an annual student competition on concrete beams reinforced by FRP. This year, 15 universities participated.
- Subcommittee 440-E on professional education is producing notes for short courses on all FRP aspects in slide format. This subcommittee is chaired by C. Goodspeed.
- Subcommittee 440-D on FRP research will produce a white paper on research needs. The subcommittee is chaired by M. Porter.
- A state-of-the-art report on FRP reinforcement for concrete structures, published as ACI 440R-96, is currently available. The report was produced by Subcommittee 440-C, chaired by M. Ehsani.

ACI Committee 440 has a web page which can be reached at http://www.aci-int.org/committees/440.htm.

ACI Committee 440, along with other societies, sponsor this "FRP International" newsletter.

There will be two sessions at the ACI Fall Convention in Los Angeles on

- seismic repair and retrofit of structures with fiber composites, chaired by M. Ehsani.
- design guidelines for concrete structures reinforced and prestressed by FRP, chaired by A. Nanni.

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

Conference Announcement

FRPRCS-4

The Fourth International Symposium on Non-Metallic (FRP) Reinforcement for Concrete Structures (FRPRCS-4) will be held in conjunction with the Fall Convention of the American Concrete Institute, October 31 to November 5, 1999, in Baltimore, Maryland, U.S.A. The Symposium is jointly sponsored by ACI Committee 440 (Fiber Reinforced Polymer Reinforcement) and ACI Committee 423 (Prestressed Concrete). A total of 13 technical sessions have been devoted to this topic and a symposium publication is scheduled to be available for the conference participants. The Technical Committee is soliciting abstracts for publication and/or presentation at FRPRCS-4 in Baltimore. Abstracts of between 200 and 400 words will be accepted on the following subjects:

- Properties of FRP reinforcement.
- Manufacturing and quality control of FRP reinforcement.
- Performance of concrete structures using FRP reinforcement.
- FRP repair and strengthening systems.
- The use of FRP in masonry structures.
- Bond, durability and compatibility of FRP reinforcement in concrete structures.
- Case studies of FRP reinforcement design and implementation.
- Code and standards development of FRP reinforcement.

All abstracts should be sent to:

Dr. Antonio Nanni
Chairman, FRPRCS-4 Technical Committee
V & M Jones Professor
Department of Civil Engineering
University of Missouri-Rolla
Rolla, Missouri 65409-0030
Telephone: 573-341-4553
Facsimile: 573-341-4729
E-mail: frprcs4@umr.edu

Abstracts will be received up to October 15, 1998. E-mail submission of abstracts is encouraged. Authors will be notified of acceptance of abstracts and provided instructions for preparation of camera-ready final papers by December 1, 1998. Final papers must be received no later than March 1, 1999. All final papers will be peer reviewed under the guidelines established by the American Concrete Institute. Authors will be notified of acceptance for publication and for presentation by April 1, 1999. Corrected papers must be received by April 30, 1999.

Conferences

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, 1998, Bologna, Italy. For further information, please visit the conference website at http://www.unibo.it/goon/icpic/main.htm.

First International Conference on Computational Methods for Smart Structures and Materials, September 21 to 23, 1998, Rome, Italy. For further information, please contact the Conference Secretariat by fax at +44-170-329-2853.

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 fax at 248-848-3701.

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

International Association for Bridge and Structural Engineering (IABSE) Symposium, August 25 to 27, 1999, Rio de Janeiro, Brazil. For further information, please visit the Symposium Secretariat's website at http://www.iabse.ethz.ch.

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.

Fourth International Symposium on Non-Metallic (FRP) Reinforcement for Concrete Structures (FRPRCS-4), in conjunction with the American Concrete Institute 1999 Fall Convention, October 31 to November 5, 1999, Baltimore, Maryland, U.S.A. For further information, please contact Dr. A. Nanni by e-mail at frprcs4@umr.edu.

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