FRP International

Fiber Reinforced Polymers

Summer 1998 Volume VI, Issue 3

Notable Research Activity

U.S. Army Construction Engineering Research Laboratories

US Army Corps of Engineers
Construction Engineering Research Laboratories

The United States Army Construction Engineering Research Laboratories (CERL), located in Champaign, Illinois, is the lead laboratory in the Army for research to support sustainable military installations. CERL's research is directed toward increasing the Army's ability to more efficiently construct, operate and maintain its installations and ensure environmental quality and safety at a reduced life-cycle cost. The facilities support the Army's training, readiness, mobilization and sustainability missions.

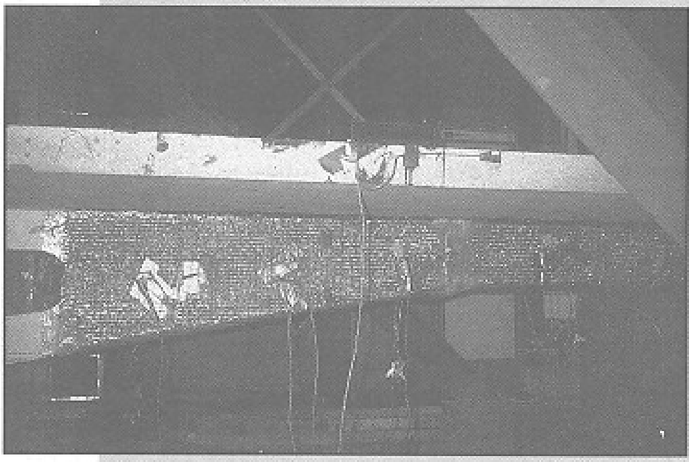

Figure 1. Repair of Precast Concrete Beam with GFRP

CERL works closely with its Army customers to develop quality products and services and to help customers implement new technologies. CERL's success in providing high quality products is the result of its ability to work with the university community and private industry. Under various contract arrangements, CERL actively works with over 30 major universities and private organizations in conducting research to support Army needs.

Four laboratories with CERL (Planning and Management, Utilities and Industrial Operations, Land Management, and Facilities Technology) executed a 72 million dollar research and development program in 1997. Examples of fiber reinforced polymer (FRP) research conducted by CERL in recent years include the following:

- In-place strengthening, repair or upgrade of concrete civil engineering structures using FRP composites (Figure 1).
- Strengthening of concrete masonry unit walls using FRP composites for the Tennessee Valley Authority (Figure 2).

(continued on page 2)

In This Issue

• American Concrete Institute • American Society of Civil Engineers • Canadian Society for Civil Engineering • • Composite Institute • Japan Concrete Institute • ACMBS Network of Canada • ISIS Canada •

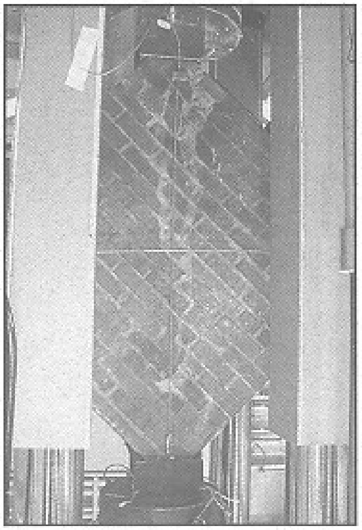

Figure 2. Repair of Masonry Structure with GFRP

- Development and demonstration of FRP composite fender, load-bearing and sheet-piling system.
- Demonstration of advanced composite cables for prestressing applications in concrete waterfront structures.
- Demonstration of FRP rebar on a full-scale concrete bridge deck.
- Development and demonstration of advanced design composite structural components.
- Composite grid/frame reinforcements for concrete structures.
- Seismic rehabilitation of unreinforced masonry walls (Figure 3).
- Tagged composite construction elements using ferromagnetic and magnetostrictive tags.
- Recycled plastic composite railroad ties.
- FRP composite gates and sheet piling for civil works structures.

CERL has been active in a wide variety of demonstration projects using FRP composites. These projects include:

- Strengthening damaged reinforced concrete beams using carbon FRP tendons in a condominium in South Florida.
- Piezoeletric path sensors applied to a carbon/epoxy upgrade under Navy Pier #11 at the Norfolk Naval Station.
- Carbon FRP tendons used for prestressing the concrete piles and deck slabs on a 12 m long pier section as part of the United States Naval Facilities Engineering Service Center Advanced Waterfront Technology Test Site in Port Hueneme, California.
- Plastic composite railway ties demonstrated in Pennsylvania, Colorado and Indiana.

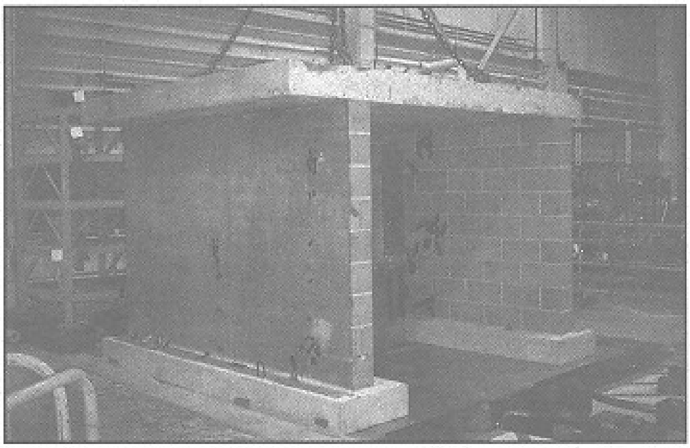

Figure 3. Tri-Axial Shake Table Test of Walls Repaired with GFRP

For more information, please contact Orange Marshall at 1-800-USA-CERL or by e-mail at o-marshall@cecer.army.mil, or visit the USA CERL website at www.cecer.army.mi.

Application

Column Strengthening at the Swiss National Museum

Non-destructive evaluation of the load-bearing strength of a limestone column in the Swiss National Museum revealed a large discontinuity in an inclined plane. A carbon fiber reinforced polymer (FRP) hoop reinforcement, using Sika strip with high stiffness, was selected to prevent slippage. A spiral-shaped groove was chiseled out of the column; the strip was bonded into the groove and mechanically anchored at each end (Figure 4). The remaining depth of the groove was refilled such that the refurbished areas had almost the same appearance as the limestone itself. The strengthened column was more cost effective in comparison to its complete replacement despite the labor-intensive retrofitting.

Figure 4. Strengthening of a Limestone Column

For more information, please contact Dr. Martin Deuring by fax at +41-52-121-4484.

FRP/Concrete Composite Marine Piling

Fiber reinforced polymer (FRP)/concrete piles were used to build the United States Navy Degaussing Pier in Ingleside, Texas. Lancaster Composite achieved the required strength of the piles using high-strength, corrosion-resistant glass fiber reinforced polymer (GFRP) tubes with a chemically prestressed, expanding concrete core. In August 1997, piling from Lancaster Composite was used for four different load-bearing and fendering applications in the walkway and slip (Figure 5).

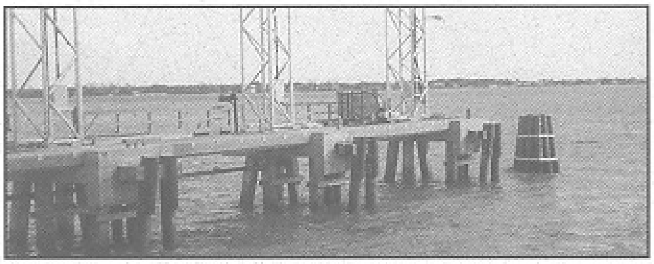

Figure 5. FRP Marine Piles

For more information, please visit the Lancaster Composite website at http://ourworld.compuserve.com/homepages/lanc_comp.

Strengthening of Skew Bridge in Canada

In 1996, CH2M Gore & Storrie Limited, with the assistance of ISIS Canada, put a material testing program together at the University of Calgary to review the strengthening effects of carbon fiber reinforced polymer (CFRP) strips on existing bridge beams. In 1997, CH2M Gore & Storrie Limited was appointed by the City of Calgary to strengthen the bridge carrying Country Hills Boulevard over the Deerfoot Trail in north-east Calgary.

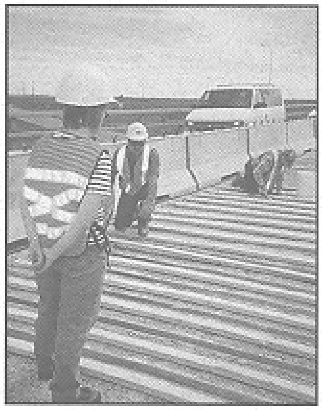

Figure 6. Repair of Country Hills Boulevard Bridge in Calgary, Alberta

One of the main problems with the bridge was that its thin deck would be over-stressed in lateral bending under full CS-750 loading. Conventional strengthening with the addition of reinforcement would have required breaking into the deck in strips, adding reinforcement, and re-concreting each strip.

Sika Carbodur strips were installed in eight areas of slab found to be in need of strengthening. Strips were installed at 500 mm centres. The hydromilled deck surface was rough and an initial levelling course of Sikadur 30 with sand aggregate was trowelled on. After one day, strips were applied (Figure 6.)

For more information, please contact Frank Laquinta by fax at 403-279-0514.

CFCC for Pedestrian Bridge

Carbon fiber composite cables (CFCC) were used as external tendons for two precast prestressed concrete slab pedestrian bridges installed in the courtyard of the Technology Research Center of Fujita Corporation. These bridges are passageways connecting the third floors of the research building and the experiment building. CFCC tendons were designed to represent an image of string structures (Figure 7). The prestressed concrete slab is 2.2 m wide, 16.12 m long and 0.35 m thick. Two 21.8 mm CFCC tendons were used for each bridge.

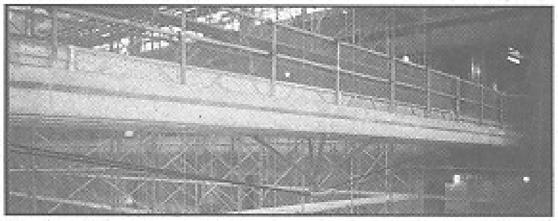

Figure 7. Pedestrian Bridge in Japan

For further information, please contact Tsuyoshi Enomoto of Tokyo Rope by fax at +81-3-3242-7584 or by e-mail at enomotot@ho.tokyorope.co.jp.

FRP for Temporary Piles

Carbon fiber NEFMAC mesh reinforced temporary concrete piles, 22 m in length, used to provide support for existing buildings in Tokyo, Japan, during construction of a new railway tunnel for the Japan Railway Construction Corporation. The new tunnel will run through the centre of Tokyo to the newly-developed seaside city centre. The carbon-type NEFMAC C-16 with a grid spacing of 200 mm (Figure 8) was used. Its low strength in the direction perpendicular to the fibers allowed easy cutting of the tunnel by the cutter bits of the shield machine.

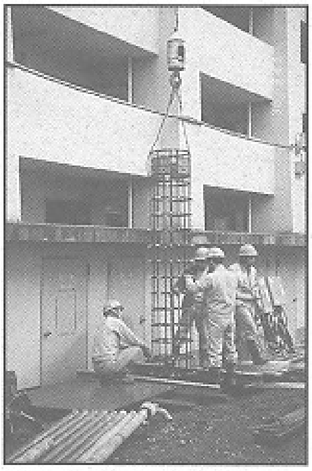

Figure 8. NEFMAC Mesh for Temporary Piles

For more information, please contact the NEFCOM Corporation by fax at +81-3-3254-9210.

The Church of Meissen

The wooden roof truss of the Church of Meissen, built in 1447 (Figure 9), was heavily damaged by deterioration of the joints. Extensive deformations in the framework resulted in large cracks in the masonry between the load-bearing longitudinal walls and the connected vault. Carbon fiber reinforced polymer (CFRP) pin straps, developed by the Swiss Federal Laboratories for Materials Testing and Research (EMPA), were selected as bracing elements in combination with stainless steel end anchorages. The major reason for this choice was the low thermal expansion in the longitudinal direction. This results in a reduced crack opening displacement in the masonry following temperature changes. In addition, reversibility requirements favored the selection due to the discreet end anchorage. The elastic properties of the strap element were measured and used in combination with strain measurements to control the prestressing level of the bracing.

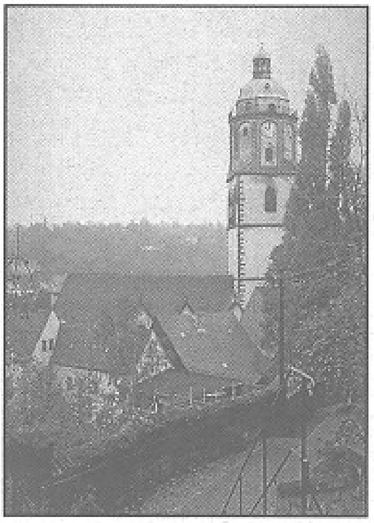

Figure 9. Repair of Church of Meissen

For further information, please contact Prof. Urs Meier by fax at +41-1-821-6244 or Olaf Kempe by fax at +49-3521-412420.

Rehabilitation of Structures in California

Fyfe Co. saturation is used to impregnate Tyfo® materials with Tyfo® epoxy to increase the shear and flexural strength, as well as ductility of severely damaged structures in Malibu, California (Figure 10). Special anchorage details were used in this project to achieve a complete bond of the material to the concrete surface.

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

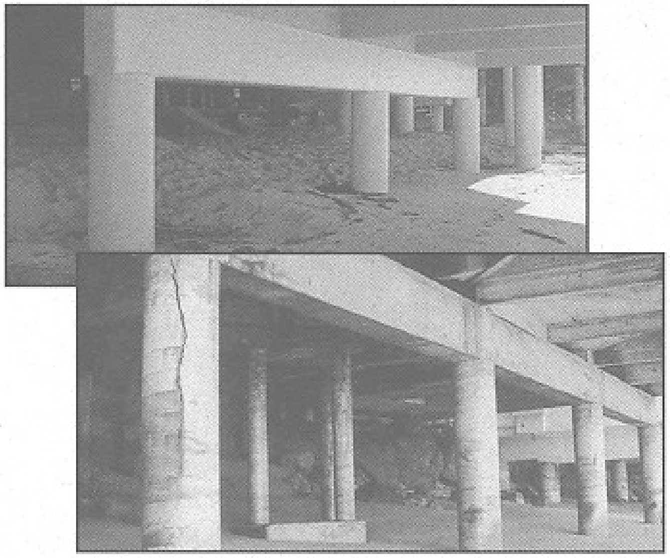

Figure 10. Rehabilitation of Continuous Beam and Column in Malibu, California

FRP/Concrete Composite Signposts

The New York City Department of Transportation redesigned its bus stop signs using state-of-the-art composites technology to create aesthetically pleasing signs that are user-friendly, durable and theft-proof. In September 1997, facing frequent impacts, corrosive snow/salt, losses to an active scrap metal market and a demanding public, the New York City Department of Transportation mounted 3,000 all-composite sign systems on Lancaster Composite's "CP40" posts (Figure 11). Lancaster Composite's Federal Highway Administration-approved signpost is flexible, offers permanent colour, will not corrode and cannot be resold as scrap.

For further information, please visit Lancaster Composite's website at http://ourworld.compuserve.com/homepages/ lanc_comp.

Figure 11. FRP Signposts

Research

Low-Cost, Lightweight Metal/CFRP Hybrid Beams

Aluminum/carbon fiber reinforced polymer (CFRP) beams have been studied at the Swiss Federal Laboratories for Materials Testing and Research (EMPA) in Switzerland and at the Shonan Institute of Technology in Japan as a low-cost alternative to all-composite designs for the replacement of metals in lightweight structures.

Hybrid beams combine two classes of materials in a mechanically appropriate way: aluminum webs provide shear stiffness and ductility, while mostly CFRP flanges ensure bending stiffness and low mass. Figure 12 shows a typical loading curve of a hybrid and an aluminum beam, as measured in small-scale tests.

Hybrid beams are produced by adhesively bonding semi-finished sections such as extruded aluminum and pultruded unidirectional CFRP sheets. A thin layer of glass fiber reinforced polymer (GFRP) can be intercalated for stress transfer and to avoid corrosion problems at the interface. The assembly does not require the complex equipment needed for processing advanced composite parts. Applications are foreseen in transportation, industrial robots and lightweight civil engineering structures.

For more information, please contact Dr. Patrick Kim by e-mail at pkim@center. shonan-it.ac.jp.

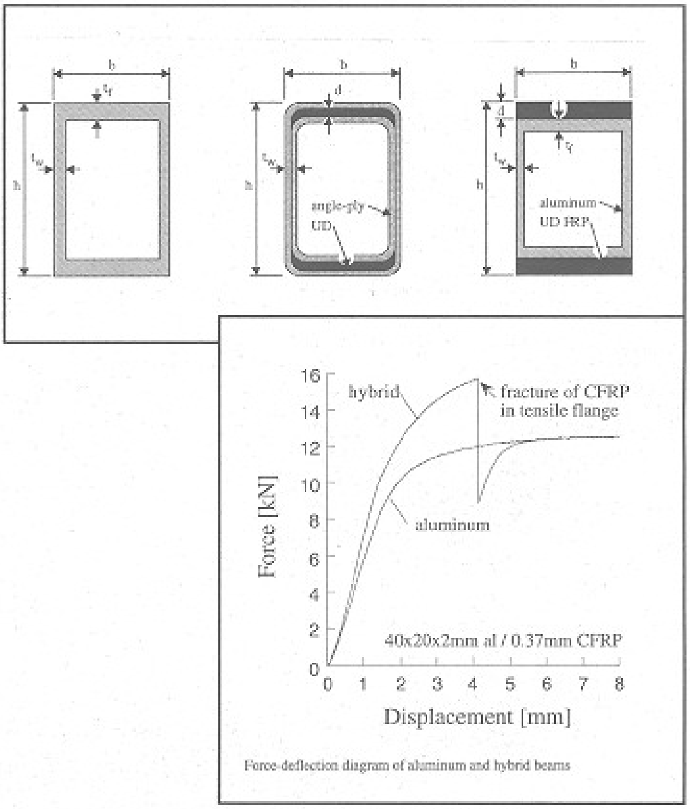

Figure 12. Metal/CFRP Hybrid Beams

FRP Research in Italy

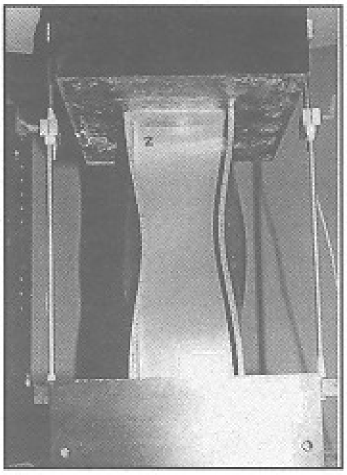

Figure 13. Buckling of FRP Columns in Italy

The Department of Structural Analysis and Design at the University of Naples "Federico II" in Italy links the old tradition of structural engineering with innovative research in the field of fiber reinforced polymer (FRP). Research activities are mainly devoted to new design methods for structures under seismic loading, to innovative materials and systems, to the use of advanced techniques for both new construction and for the repair and rehabilitation of existing structures. Experimental and theoretical studies are in progress to examine the structural and bond behavior of reinforced beams strengthened with FRP bars and sheets, as well as buckling of FRP structural shapes (Figure 13). A field of particular interest is the use of the advanced composites in the retrofitting of historical buildings.

For more information, please contact Prof. Edoardo Consenza by e-mail at consenza@unina.it.

Anchorage for FRP Using HEM

A new anchorage method using highly expansive material (HEM) has been developed by Prof. T. Harada at Nagasaki University and Prof. T. Idemitsu at the Kyushu Institute of Technology, Japan. The method has been designed for all types of fiber reinforced polymer (FRP) having various shapes and sizes without stress concentrations. The pressure induced by the expansive material transfers a stress of 50 MPa to the tendons. The main component of HEM is CaO. This anchorage is useful for post-tensioning type anchorages and as an anchorage for tension tests of FRP. The anchor length for a carbon fiber reinforced polymer (CFRP) strand with a 12.5 mm diameter is only 200 mm. Test results of long-term loading for seven and one-half years using CFRP strand (12.5 mm) with 1 m length measured losses of prestressing force in the range of only three to six percent. However, when the length of CFRP strand is 10 m long, the loss of prestressing force is negligible for practical applications. The fatigue characteristics of CFRP strand (12.5 mm) using HEM anchorage has excellent advantages over epoxy resin anchorage. As one of the applications of HEM anchorage, a multi-cable tendon system with six CFRP strands has been developed as a "Ground Anchoring Method" in Japan. Figure 14 shows pouring of the HEM slurry into the stainless sleeve of a ground anchor.

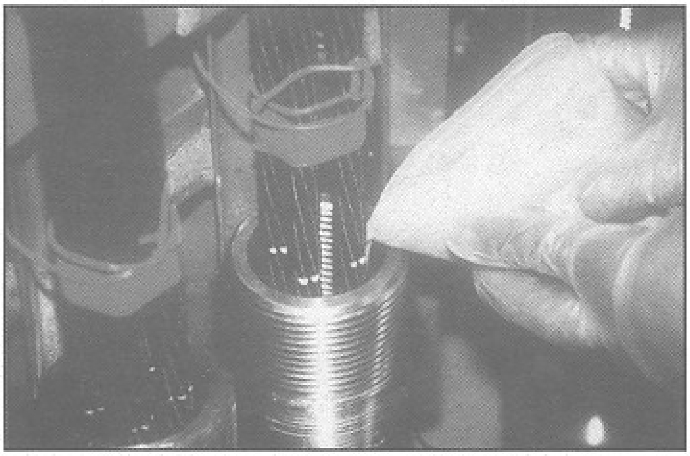

Figure 14. Proposed Ground Anchorage Sleeves

For further information, please contact Prof. T. Harada of Nagasaki University by fax at +81-95-848-9637 or by e-mail at harada@st.nagasaki-u.ac.jp.

Composite Bridges

Grontmij Advies, Techniek POLYMARIN and AKZO NOBEL joined forces to investigate the opportunities for using fiber reinforced polymer (FRP) modules in bridges. The investigation primarily focused on the development of bridges for pedestrians and cyclists. FRP materials were selected due to their advantages of being of lightweight, easily portable and rapidly assembled, and a corrosion-resistant alternative to steel bridges (Figure 15). The composite action of the design optimizes the use of this material for the force-distribution in the superstructure of the bridge. A section of the bridge, a main girder consisting of one longitudinal reinforced polymer beam with a concrete deck 10 m long and 0.8 m in width, was tested at the Stevin Laboratory of the Technical University of Delft in the Netherlands (Figure 16).

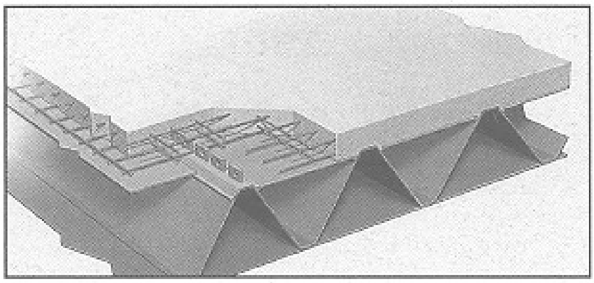

Figure 15. Concrete/FRP Composite Bridges

For further information, please contact Nico Tiemessen of Grontmij Verkeer and Infrastructure by fax at +31-30-220-50-84.

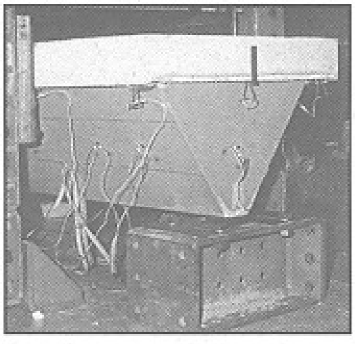

Figure 16. Testing of Bridge Modules at Technical University of Delft

FRP Research in France

For several years, a group of private companies, universities, and official French laboratories have been developing a new process for strengthening and repairing civil engineering structures using TFC®. Carbon fiber cloth (TFC) is very flexible and bonds easily to the external surface of concrete structures using epoxy resin. Current research includes durability, effect of thermal cycling, static testing, cyclic loading and numerical simulation of structures strengthened with the material, as well as seismic testing for retrofitting tests using a three-dimensional vibrating table (Figure 17). The research is being conducted at the LCPC-Paris and LREP-le Bourget, LMT Cachan Research Laboratories, in cooperation with Freyssinet International, Soficar (carbon fiber manufacturer) and Ato Findley (epoxy manufacturer).

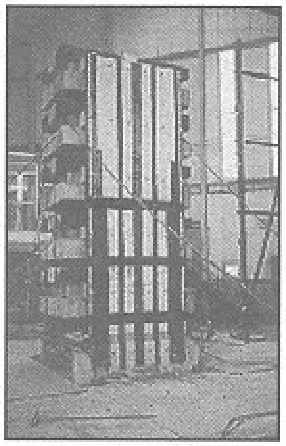

Figure 17. Testing of Bearing Walls in France

For more information, please contact Mr. Jean Luyckx of the Société des Fibres de Carbone by fax at +33-1-48-85-62-02.

Extension of ISIS Canada

Funding of the Canadian Network of Centres of Excellence on Intelligent Sensing for Innovative Structures (ISIS Canada) has been extended until the year 2002 and is qualified to apply for an extension to the year 2009. The network recently underwent an in-depth review by six world-renowned experts from the United States and Europe who were appointed by the Canadian Federal Government. The network focuses on innovative structural systems using fiber reinforced polymer (FRP) materials for the rehabilitation of structures and fiber optic sensors for monitoring structures. The network's newsletter and annual reports are available free-of-charge.

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

Products

FRP Geogrid NESTEM

Shimizu Corporation and Asahi Glass Matex have developed geogrid NESTEM (a new system for reinforcing soil by fiber synthetic material). This new grid is made of glass fiber reinforced polymer (GFRP) composed of high strength continuous glass fibers impregnated with vinylester resin and formed into a grid shape (Figure 18). It is classified as a geogrid which is one of the geotextiles to be used for reinforcing earth. NESTEM is very light and superior in mechanical properties such as high strength and high stiffness. The grid also has superior resistance against chemicals. NESTEM is used to reinforce embankments, soil walls and road bases.

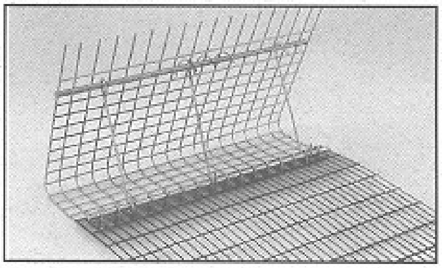

Figure 18. FRP Geogrid NESTEM

For more information, please contact Dr. Eiji Ogisako, of Shimizu Corporation by e-mail at ogisako@sit.shimz.co.jp.

Committees

JCI Technical Committee on FRP

The Technical Committee on Continuous Fiber Reinforced Concrete in the Japan Concrete Institute (JCI) completed its three-year research project in March 1998 under the direction of Prof. K. Maruyama of Nagaoka University of Technology. The 25 members were from universities, research institutes and construction companies in Japan. The first working group dealt with design equations and testing methods of continuous fiber reinforcing materials (CFRM) and continuous fiber reinforcing (CFR) concrete structures. The second group surveyed recent research progress and applications of retrofitting of existing structures using continuous fiber sheet. The third group proposed a comprehensive life-cycle assessment system of CFR concrete structures to evaluate their advantages. The final report was published in English for international use.

For further information, please contact Dr. T. Shimomura of Nagaoka University of Technology by e-mail at takumi@nagaokaut.ac.jp.

JSCE Committee on Retrofit

The 1995 Great Hanshin Earthquake and the recent revision of the design loads for highway bridges triggered the necessity to retrofit existing bridges and structures. The Japan Society of Civil Engineers (JSCE) set up a Sub-Committee on Retrofitting Design under the Concrete Committee (307 Committee) in 1996. The committee is chaired by Dr. Tamon Ueda of Hokkaido University and consists of 41 members from both industry and university. After two years of activity, the committee presented its report which includes:

- Performance-based design system for retrofit (a tentative draft).
- Design examples in accordance with the draft design system.
- Survey of current retrofit practices.

The committee focused its investigation on the major retrofitting methods in Japan; namely, the methods using external cables, wrapping/jacketing with sheet/plate and concrete wrapping/jacketing. Continuous fiber cemented with resin fiber reinforced polymer (FRP) is the major material for both the external cable and externally bonded sheet/plate. Latest information on retrofitting design with FRP reinforcement, such as the design for flexure, shear, ductility and anchorage, is compiled. The survey results indicate the establishment of a rational design system for retrofit is long overdue. At present, JSCE is preparing the retrofit design part of the JSCE Specification for Concrete Structures, based on the works of the 307 Committee.

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

Publications

A Look at the World's FRP Composites Bridges

The market development alliance of the Composite Institute recently published a comprehensive list of bridges constructed throughout the world in the last 25 years where fiber reinforced polymer (FRP) composites have been specified. The guide chronicles the history and progress of FRP composite materials in bridge engineering by focussing on global installation.

To obtain a copy, please contact Mr. John Busel by e-mail at jbusel@socplas.org.

Manual for Design and Construction of Prestressed Concrete Highway Bridge Using FRP Materials (Fourth Edition)

The ACC (Advanced Composite Cables) Club of Japan published the first edition of the "Manual for Design and Construction of Prestressed Concrete Highway Bridge using FRP Materials" in March 1992. After the Japan Society of Civil Engineers (JSCE) published "Recommendation for Design and Construction of Concrete Structures using Continuous Fiber Reinforcing Materials" in September 1996, this manual was revised to conform to the recommendation of the JSCE and to add some newly-developed FRP materials in April 1998. The Chairman of the task committee of the ACC Club is Mr. Motohiko Suzuki of Oriental Construction Co. Ltd.

The manual deals with eight kinds of FRP materials of the ACC Club; namely, CFCC (Tokyo Rope), Leadline (Mitsubishi Chemical), NACC Strand (Nippon Steel), ARAPREE (Nitto Shinko), COMPOSE (Ube-Nitto Kasei), FiBRA (Shinko Wire), Technora (Teijin) and NEFMAC (NEFCOM). The manual is only written in Japanese, but it will be useful for practising engineers who are engaged in the design or construction of concrete structures using FRP materials.

For more information, please contact Mr. Tatsuhiko Iwasaki, Secretariat of the ACC Club, by fax at +81-3-3242-7584.

Workshops

International Research on Advanced Composites in Construction (IRACC)

The IRACC-98 workshop was held in conjunction with the European Conference on Composite Materials (ECCM-8), June 6, 1998, in Naples, Italy. Major deliberations of the workshop included the following:

- The critical function of IRACC is to provide timely information on research and development and the implementation of composites in construction.
- IRACC secretariat will maintain the web page and will solicit updates for the International Research-in-Progress document.
- Themes of interest are discussion/comparison of national codes and design guidelines; sharing of successful and unsuccessful experiences or problems encountered with the use of fiber reinforced polymer (FRP) materials; coordination of a research database; organization of technical sessions on specific subjects during the conference at the venue of the IRACC meeting (suggested themes are construction documents and specification protocols for FRP projects).
- Proposed future workshops in 1999 are Sunday, May 9, 1999, Cincinnati, Ohio, U.S.A., in conjunction with the ICE'99/ASCE Materials Congress, and October 1999 in Baltimore, Maryland, U.S.A., in conjunction with FRPRCS-4/ACI Fall Convention.

For detailed information about ECCM-8 and its proceedings, please visit the conference website at http://www.eccm98.etruria.net.

Documents and updates on IRACC activities are available by visiting IRACC website http://www.iper.net/co-force/iracc.htm.

For further information, please contact Dr. Antonio Nanni by e-mail at nanni@umr.edu.

Theses

Bonfiglioli, B. "Use of Optical Fibres in Monitoring of Strengthening with FRP for Structural Elements", M.Sc thesis, 1998, University of Bologna. Supervised by Prof. A. Di Tommaso, Prof. P. Bassi, Dr. M. Arduini and Dr. O. Manfroni.

Burdine, Eric. "Stiffening Steel Stringers Bridges with Carbon Fiber Reinforced Polymers", M.Sc. thesis, 1997, West Virginia University. Supervised by Prof. H. GangaRao.

Craigo, Carl. "Transverse Bending Tests of Modular FRP Compsite Deck", M.Sc. thesis, 1998, West Virginia University. Supervised by Prof. R. Lopez-Anido.

El-Hacha, Raafat. "Strengthening of Concrete members with Advanced Composite Materials", M.Sc. thesis, 1997, Concordia University. Supervised by Dr. M. El-Badry.

Wight, R.G. "Strengthening Concrete Beams with Prestressed Fiber Reinforced Polymer Sheets", Ph.D. thesis, 1998, Queen's University. Supervised by Profs. M. Green and M.A. Erki.

Conferences

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.

International Conference on Advanced Composites, December 15 to 18, 1998, Hurghada, Egypt. For further information, please visit the conference website at http://www.eng.auburn.edu.icac.

Composites: Innovations and Structural Applications, February 23 to 25, 1999, Sydney, Australia. For further information, please visit the University of New South Wales' website at http://www.materials.unsw.edu.au/.

SPIE 6th Annual International Symposium on Smart Structures and Materials, March 1 to 5, 1999, Newport Beach, California, U.S.A. For further information, please visit the SPIE website at www.spie.org/info/ss/.

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.

The Second Middle East Symposium on Structural Composites for Infrastructure Applications, April 26 to 29, 1999, Hurghada, Egypt. For further information, please contact Dr. Ibrahim Mahfouz by telephone or fax at 202-291-7187.

Fourth Annual ISIS Canada Conference, May 6 to 8, 1999, Toronto, Ontario, Canada. For further information, please contact Dr. Sami Rizkalla by e-mail at rizkall@cc.umanitoba.ca.

Fifth ASCE Materials Engineering Division Congress, May 10 to 12, 1999, Cincinnati, Ohio, U.S.A. For further information, please contact Prof. L. Bank by e-mail at matcong5@engr.wisc.edu.

SAMPE'99, May 24 to 27, 1999, Long Beach, California, U.S.A. For further information, please contact SAMPE IBO by e-mail at sampeibo@aol.com.

Canadian Society for Civil Engineering 27th National Conference, June 2 to 5, 1999, Regina, Saskatchewan, Canada. For further information, please visit the conference website at http://www.gov.sk.ca/hiways/conference/csce/csce.htm.

Fifth International Conference on Composites Engineering (ICCE/6), June 27 to July 3, 1999, Florida. For more information, please contact Prof. David Hui by fax at 504-280-5539.

12th International Conference on Composite Materials (ICCM-12), July 5 to 9, 1999, Paris, France. For further information, please visit the conference website at www.iccm12.org.

Structural Faults and Repair'99, July 6 to 8, 1999, London, England. 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.

Fracture of Polymers, Composites and Adhesives, September 13 to 15, 1999, Les Diablerets, Switzerland. For more information, contact the Conference Secretariat by fax at +44-0-1865-843958 or by e-mail at a.richardson@elsevier.co.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 Fibre Reinforced Polymer (FRP) for Reinforced 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.

Composites: Application of Materials Chemistry and Physics to Interfaces for Micro-Macro-Properties, October 31 to November 5, 1999, Lake Louise, Alberta, Canada. For further information, please contact Professor Patrick S. Nicholson by e-mail at nicholsn@mcmaster.ca.

Third International Conference on Composite Science and Technology, January 11 to 13, 2000, Durban, South Africa. For further information, please contact Professor S. Adali by e-mail at adali@eng.und.ac.za.

Third International Conference on Advanced Composite Materials for Bridges and Structures (ACMBS-III), August 2000, Ottawa, Ontario, Canada. For further information, please contact Dr. Razaqpur by e-mail at grazaqpur@ccs.carleton.ca.

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