FRP International

Fiber Reinforced Polymers

Autumn 1998 Volume VI, Issue 4

Notable Research Activity

Hokkaido University

Hokkaido University, the oldest university in Japan, is the leading university in Hokkaido, the northern island of Japan. The Division of Structural Engineering and Geotechnical Engineering at Hokkaido University is one of the major research institutions currently conducting research on fiber reinforced polymers (FRP) in Japan and organized the Third International Symposium on Non-Metallic FRP Reinforcement for Concrete Structures (FRPRCS-3) in Sapporo in 1997. The Division is rather unique since it combines fields of study in civil and architectural engineering, which are normally separated in Japan. The research activities started almost ten years ago and focused on the use of FRP bars and cables. Recently, the research emphasis shifted to the use of FRP for the repair and rehabilitation of structures.

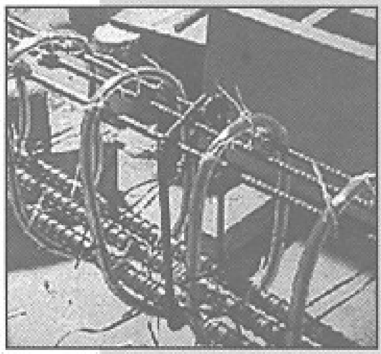

Figure 1. New flexible FRP bar

Research on FRP bars has included both carbon and aramid fibers for reinforcing concrete structures. Major research achievements focus on the shear strength and deformation of beams reinforced with FRP for shear and flexure, as well as the strength of FRP as affected by crack intersection and bend. The design method for "shear strength" proposed in the recommendations of the Japanese Society of Civil Engineers (JSCE) is based on the outcome of this group's activities. Current research is focused on bond properties of FRP and structural behavior of members retrofitted by FRP. Bond properties of carbon fiber sheet and bond stress-slip relationship were experimentally investigated and predicted by analytical models. FRP research at Hokkaido University includes the following topics:

- bond strength of FRP sheets under fatigue loads;
- tension stiffness of concrete in the presence of FRP sheets and steel reinforcement;
- fatigue strength of beams retrofitted with FRP sheets;
- shear strength of beams retrofitted with FRP sheets as shear reinforcement;
- the application of uncemented aramid fiber as external cables for retrofitting;
- prestressed continuous fiber sheets externally bonded to beams;
- the application of carbon fiber sheets for seismic retrofit of building structures.

Other research topics include the development of a flexible bar reinforcement fabricated with carbon and a new type of polyacetal fiber. The flexible bar reinforcement, used as

(continued on page 2)

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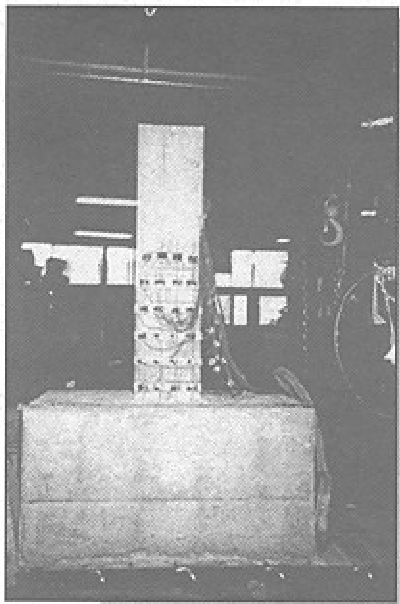

Figure 2. Test columns reinforced with the new flexible FRP bar

stirrups, is made from continuous carbon fiber encased in a plastic tube, as shown in Figure 1. Tubes filled with uncemented carbon fibers are placed and assembled together with ordinary steel reinforcement, then epoxy resin is injected into the tubes. This procedure allows bending of the carbon fiber bar reinforcement into any configuration. Experimental results show that these flexible reinforcements can be used effectively as shear reinforcement and that the ductility of the beams is improved. The new type of polyacetal fiber has a much higher ultimate strain (eight to nine percent) and costs significantly less than carbon and aramid fibers. The strength of the new fiber is adequate. The Young's modulus is, however, much smaller and is in the order of one tenth of carbon. Experimental results of tested columns using this new material shows ductile behavior even after development of major shear cracks as shown in Figure 2.

For further information, please contact Dr. Tamon Ueda by fax at +81-11-707-6582 or by e-mail at ueda@eng.hokudai.ac.jp.

Application

CFRP for Underestimated Loading Conditions

The design load for precast prestressed beams used for roofing of a concrete structure in Italy was underestimated in the original design. After erection, it was discovered that the beams did not meet state requirements for either the serviceability or ultimate limits. The beams were found to be cracked, even under the effect of the dead load, causing large deflections which could lead to rapid corrosion of the prestressing strand.

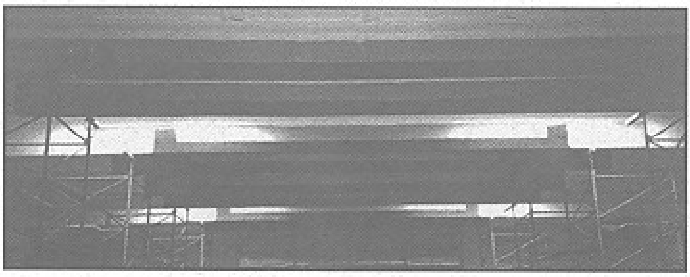

Figure 3. Flexural strengthening of prestressed beams in Italy

As a solution, the beams were strengthened using carbon fiber reinforced polymer (CFRP) pre-peg sheets, which were applied to the soffit of the beam's ribs. Before applying the CFRP sheets, a negative deflection was applied to the beams that annulled the pre-existing strain at the middle cross section of the beams and, consequently, closed the existing cracks. The CFRP sheets glued to the beams prevented cracks from opening under the dead load, thus making the beam's deflection similar to that of an uncracked beam. This behavior was observed during testing of the structure using water cushions. Figure 3 shows beams before repair. The equipment used to apply the negative deflections is not visible in the photograph.

For more information, please contact Prof. Antonio La Tegola by e-mail at lategola@axpmat.unil.it.

Underwater Applications of FRP

The longevity of reinforced concrete structures in salt-water splash zones is relatively low. A typical solution to corrosive damage is to demolish and replace the damaged members or to install additional piles.

The TYFO SW System, as shown in Figure 4, was used to enhance the performance of deteriorated piles. The piles are first cleaned by blasting or other methods, patched, and corners are rounded (for rectangular cross sections). After the section has been restored to a smooth, continuous surface, the composite (carbon fabric saturated with TYFO SW underwater epoxy) is applied to the pile surface. After the composite is applied to the piles, curing of the system requires that it be wrapped in plastic and allowed to cure for approximately 30 days. The TYFO SW formulation allows the composite to cure in water saturated or air environments, making it an excellent solution in tidal areas. After 30 days, the plastic can be removed with the system in a fully cured condition.

Figure 4. FRP sheets for deteriorated piles

For more information, please contact Duane Gee of Fyfe Co. LLC by fax at 619-642-0694.

Strengthening of Takatsuka Bridge in Japan

The Takatsuka Bridge on the Nishi Meihan Highway in Japan consists of 12 simply-supported pretensioned T-girders (Figure 5). Strengthening of this bridge was carried out by fitting with external cables to provide continuity of the structure.

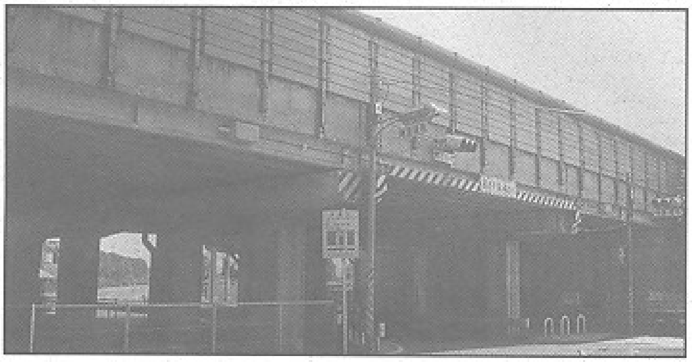

Figure 5. Takatsuka Bridge in Japan

Due to the limited space between the girders (780 mm), Technora rods were anchored by concrete blocks casted monolithically and prestressed perpendicularly to the bridge axis. The concrete blocks were cut after anchorage of the longitudinal cables, as shown in Figure 6, to minimize the prestress losses and provide better distribution of the external prestressing to each girder.

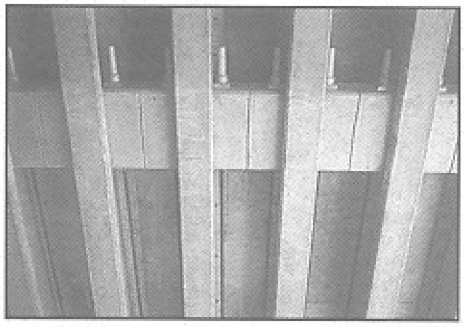

Figure 6. External prestressing using FRP cables

For more information, please contact Mr. Hiroshi Nakai of Sumitomo Construction Co., Ltd. by fax at +81-3-3353-6656 or by e-mail at hironky @ sumiken.co.jp.

FRP Bridge Deck

The United States Highway Innovation Technology Evaluation Centre (HITEC) is currently evaluating the replacement of deteriorated bridge decks with new fiber reinforced polymer (FRP) decks. Currently, two types are being evaluated and produced in Raleigh, North Carolina. Both types use a pultrusion process. The FRP composite bridge decks are non-corrosive and have high strength, high stiffness to weight ratio, and potential cost savings over the conventional concrete deck slab. The United States Federal Highway Administration expects to re-deck 18,000 bridges by the year 2005. A typical Superdeck Composite Bridge Deck is shown in Figure 7.

For more information, please contact Creative Pultrusions, Inc. by telephone at 814-839-4186 or by e-mail at crpul@pultrude.com.

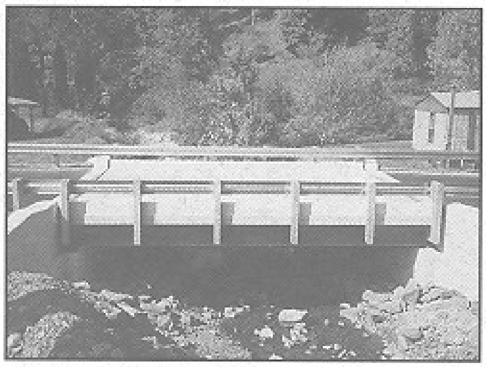

Figure 7. Typical Superdeck composite bridge deck

Electromagnetically-free Structure

Aramid fiber reinforced polymer (FRP) reinforcements were used to reinforce the slabs, beam and columns of a 8.35 m X 8.1 m floor area and 4.7 m high structure as shown in Figure 8. Reinforcing the entire building with Arapree bars made it possible to have an electromagnetically-free environment for a special laboratory in Japan. Prefabricated Arapree square ties were used for the columns.

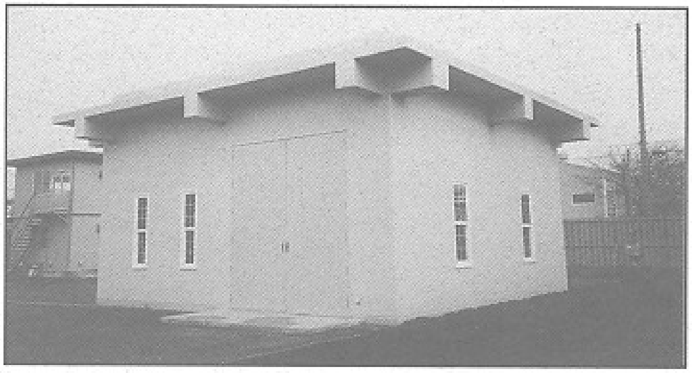

Figure 8. Electromagnetic-free laboratory in Japan

For more information, please contact Mr. H. Nakamura of Tokyu Construction Co., Ltd. by fax at +81-427-63-9504.

Rehabilitation of Lee Road Bridge in Atlanta, Georgia

A high-performance carbon fiber reinforced polymer (CFRP) material was recently applied to an overpass in metro Atlanta, Georgia. The reinforcement is used to strengthen and extend the life of the bridge. The rehabilitation of the bridge is part of a research project funded by the Georgia Department of Transportation in cooperation with the United States Federal Highway Administration.

The Lee Road Bridge over Interstate 20 in Douglas County suffers from cracks in its concrete deck. A research team led by Dr. Abdul-Hamid Zureick, a professor at Georgia Institute of Technology's School of Civil and Environmental

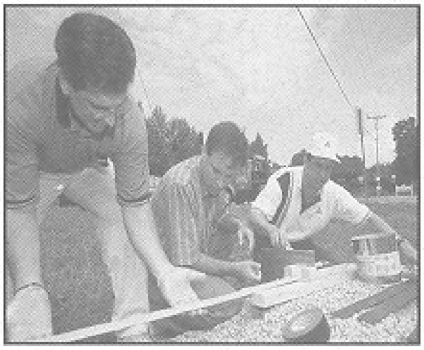

Figure 9. Research team of Georgia Institute of Technology

Engineering, hopes that the strips of CFRP will extend the bridge's life by at least five to ten years (Figure 9). They are monitoring the bridge closely to gather durability data.

For more information, please contact the Research News and Publication Office of the Georgia Institute of Technology by fax at 404-894-6983.

CFRP Ground Anchor

A total of 102 carbon fiber reinforced cables (CFRP) were recently used as ground anchors to stabilize a steep slope over the Kasupe Tunnel of National Road Route 229 in Hokkaido, Japan. The construction work was undertaken as emergency disaster prevention by the Hokkaido Development Bureau. The construction site is located in close proximity to the Japan Sea and has a very steep slope, which required a non-corrosive material to minimize the protective cover and a lightweight material to install the ground anchor without the use of machinery. The CFRP rods used were Leadline, supplied by Mitsubishi Chemical Corporation of Japan, and the cables were installed by Chemical Grouting Co., Ltd., also of Japan (Figure 10). The CFRP ground anchors shortened construction time.

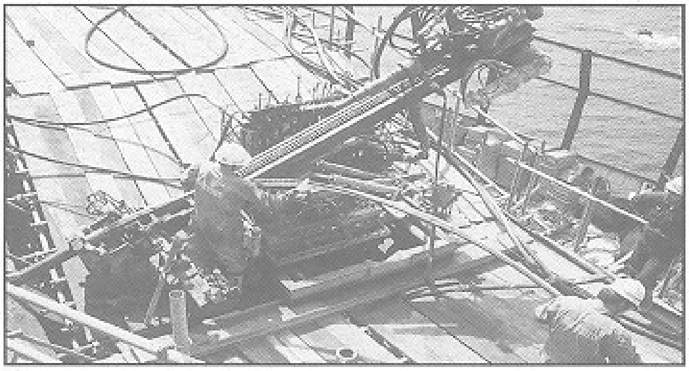

Figure 10. Installation of CFRP ground anchors in Japan

For more information, please contact Mr. K. Yagi by e-mail at KCP0148@cc.m-kagaku.co.jp.

FRP for Restoration of Historic Bridge in Oregon

The Horsetail Creek Bridge, built in 1913 and located on the beautiful Scenic Highway in the Columbia Gorge in Oregon, was retrofitted using fiber reinforced polymers (FRP) to increase the flexural and shear capacity of the bridge. Conventional repair methods were not considered for the bridge due to its historic nature, limited funding and time restrictions.

Figure 11. Horsetail Creek Bridge in Oregon, U.S.A.

As a result of preliminary strengthening design, four commercially-available FRP systems were pre-approved for possible use. The project was awarded to Fyfe Corporation of San Diego, California. After initial restoration of the concrete surface, carbon FRP laminates were glued to the tensile zones of the beams to increase their flexural capacity. The shear strength was increased using several layers of glass FRP laminates with a thickness of 5 mm at the critical locations. The thin composite strips received a specially-designed finishing cover to match the color, texture and appearance of the original concrete (Figure 11).

Horsetail Creek Bridge is the first structure in Oregon to be retrofitted with advanced composite materials. The bridge utilizes fiber optic sensors to monitor its performance and will provide invaluable data on the long-term behavior of the FRP composites (Figure 12).

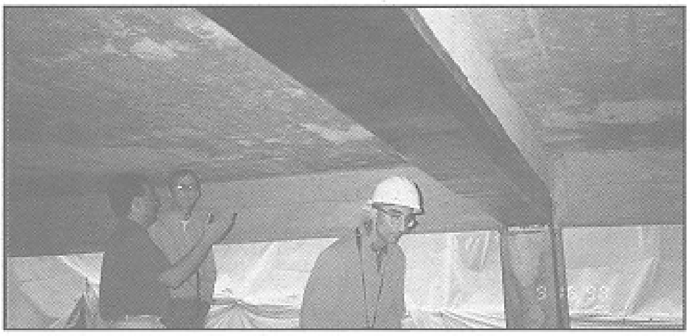

Figure 12. Flexural strengthening of the bridge beams of Horsetail Creek Bridge

For more information, please contact Dr. Damian Kachlakev by fax at 541-737-3052 or by e-mail at kashlada@engr.orst.edu.

Rehabilitation of Sainte-Émélie-de-l'Énergie Bridge in Québec

The Sainte-Émélie-de-l'Énergie Bridge was built in 1951 according to H20 truck loads and consists of four simply-supported reinforced concrete T-beams. According to the new code in Canada, the flexural and shear capacities of the beams should be increased by 35 and 20 percent, respectively.

The repair work began in September 1998 using CarboDur plates (carbon fibers) for flexural strengthening and SikaWrap (glass fibers) for shear strengthening, as shown in Figure 13. A total of 66 sensors, including 28 electric gauges, 10 thermocouples and 28 optical fibers, were used to monitor the behavior before and after the repair was completed. The work was carried out in collaboration with the Ministry of Transportation of Québec.

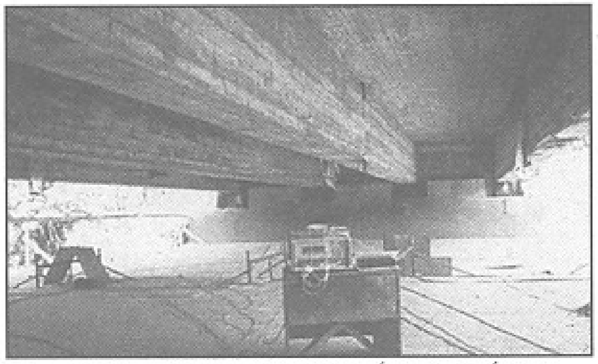

Figure 13. Strengthening of the Sainte-Émélie-de-l'Énergie Bridge in Canada

For more information, please contact Dr. Pierre Labossière, ISIS Canada, University of Sherbrooke, by fax at 819-821-7974.

Strengthening of Bridge Deck with Carbon Fiber Sheet

Carbon fiber sheet was used to strengthen the bridge deck slab of Mitatebashi Bridge in Tokyo, Japan. The slab was non-composite with steel plate girders. The purpose of strengthening is to increase the capacity of the bridge to match the demand for increases in the live load. The strengthening work was carried out after repairing the cracks by resin injection. Two layers of high modulus Tonen Tow Sheet were bonded in both longitudinal and transverse direction to enhance the fatigue resistance. Acrylic urethane resin was used for top coating, as shown in Figure 14. The construction area was 900 square meters and construction time was about four months.

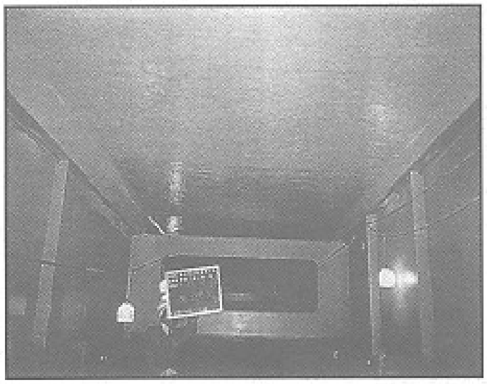

Figure 14. Strengthening of the deck slab of Mitatebashi Bridge in Japan

For more information, please contact Mr. Toshiya Maeda of Shimizu Corporation by e-mail at maeda@civil.shimz. co.jp.

Strengthening of Airport Parking Garage

Work has just been completed on one of the largest fiber reinforced polymer (FRP) strengthening projects in North America. The MBrace carbon fiber strengthening system, manufactured by Master Builders, was used to increase the shear capacity of 5,200 precast prestressed double-tee beam stems at the Pittsburgh International Airport parking garage, as shown in Figure 15. After cracks were observed in the stems of several of the double tees, an engineering investigation was initiated. Shear deficiencies were identified and load tests performed on four of the beams. Several strengthening options were considered, including externally bonded FRP systems. Factors in the selection of the MBrace system included its comparatively low installation costs, rapid installation time, minimal economic impact to a revenue-generating garage, and aesthetics. The 34,000 square meters of carbon fiber sheet used on the job was installed in just over four months by the joint venture of Carl Walker Construction and Structural Preservation Systems, Inc. In-situ load testing, using an innovative frame, was used to rapidly verify the installed behavior of the MBrace system.

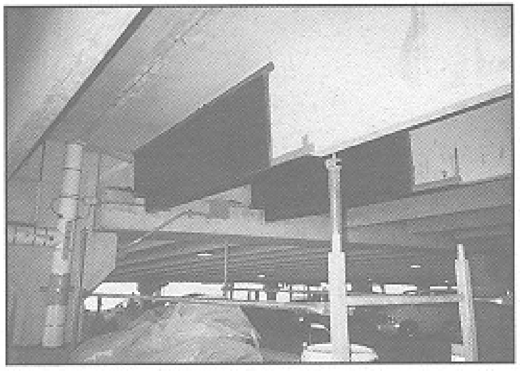

Figure 15. Shear strengthening of prestressed double-tee beams

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

FRP for Sanze Bridge in Japan

Route 7, running along the Japan Sea, is a notorious area subjected to heavy sprays of salty water. The Sanze Bridge is the first fiber reinforced polymer (FRP) bridge built under the direct control of the Ministry of Construction. The project was proposed by the Sakata Work Office of the Tohoku Regional Construction Bureau.

While the old bridge was supported by T-shaped girders, the new one is supported by two-span pretensioned simply-supported hollow girders to minimize the surface area subjected to the influence of salt (Figure 16). The bridge measures 44.8 m in length and is 18.8 m in width. Carbon fiber composite cables (CFCC) were used for the four outside girders.

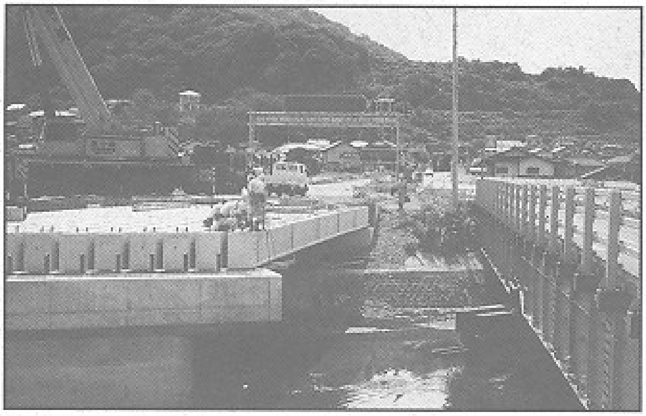

Figure 16. CFCC used for prestressing the Sanze Bridge in Japan

For further information, please contact Mr. Yasuo Isozumi of the Showa Concrete Industry Co., Ltd. by fax at +81-22-225-1202.

Research

Strengthening with NEFMAC

A testing program conducted at the Gunma University in Japan showed that high elastic modulus carbon fiber NEFMAC is effective in increasing the load-carrying capacity of reinforced concrete systems. The project is sponsored by DPS Bridge Works Co., Ltd. and NEFCOM Corporation in Japan.

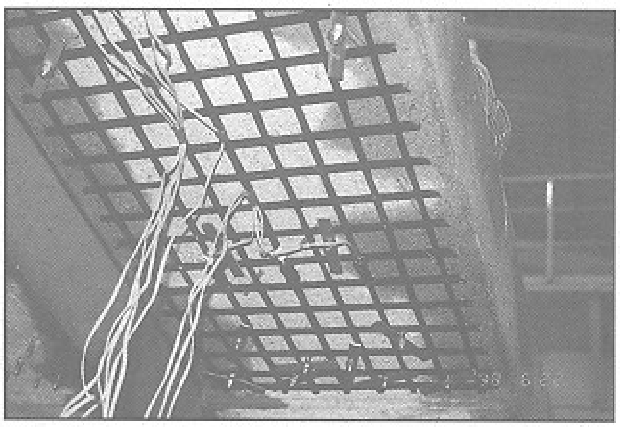

Figure 17. NEFMAC for strengthening RC slabs

A total of 27 beams with a span of 2.6 m were used to investigate flexural and shear behaviors of reinforced concrete beams strengthened by reinforcing materials and polymer mortar (Figure 17). The parameters of the testing program included (a) type of reinforcement (reinforcing steel bars and NEFMAC), (b) construction methods of polymer mortar (grouting and trowelling), (c) numbers of anchor bolts, and (d) surface conditions of the concrete. Test results showed that flexural crack width can be reduced to the same level as one of reinforcing steel bars by using NEFMAC. The flexural capacity is also greatly increased. Overall, the tests showed that NEFMAC is an effective reinforcement to strengthen severely damaged reinforced concrete beams.

For more information, please contact Prof. Yukikazu Tsuji of Gunma University by fax at +81-277-30-1601 or by e-mail at tsuji@ce.gunma-u.ac.jp.

Moment Redistribution in RC Structures Reinforced with FRP

The researchers at the Department of Material Science at the University of Lecce in Italy have investigated the entity of the moment redistribution phenomenon in reinforced and prestressed concrete structures reinforced with fiber reinforced polymer (FRP) bars. The research work included formulation of analytical models capable of taking into account the progressive tension micro-cracking of FRP-reinforced structures and evaluate the ductility required to satisfy the compatibility of the design redistribution. The research includes a field application of an industrial structure floor using a hollow core slab where FRP reinforcements are used for the negative moment zones, as shown in Figure 18.

For more information, please contact Prof. Antonio La Tegola of the University of Lecce by e-mail at lategola@axpmat.unil.it.

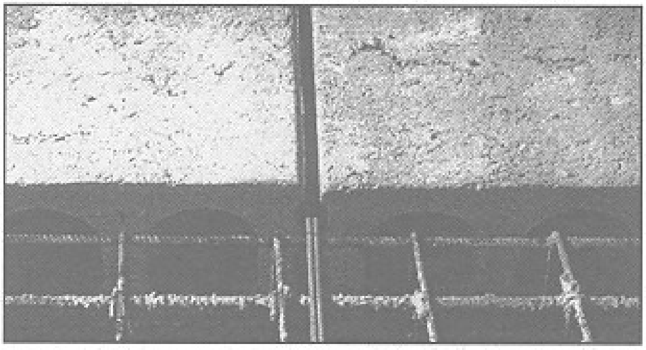

Figure 18. FRP reinforcements for negative moment zones

Field Test of RC Bridge Piers Strengthened with FRP

In-situ lateral load tests of two bridge bents were conducted by the University of Utah on Interstate 15 to determine the strength and ductility of an existing concrete bridge and the improvements that can be achieved using a fiber reinforced polymer (FRP) composite retrofit as shown in Figure 19. The design of the composite was developed based on rational guidelines for the columns, cap beam, and cap beam-column joints to provide a specific displacement ductility. Good

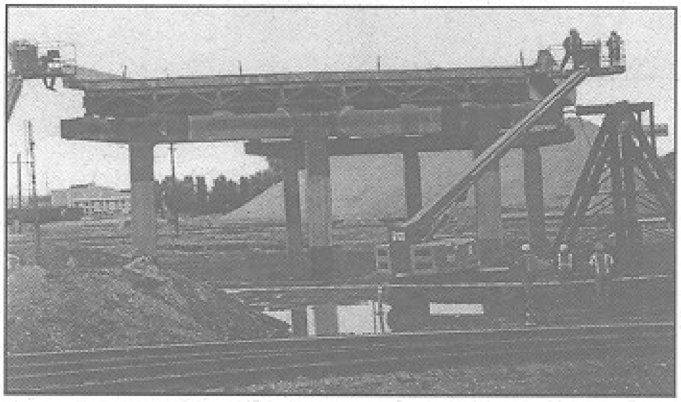

Figure 19. Field testing to evaluate strengthening bridges with FRP

correlation between analytical and experimental results was observed which included the yield level of the members, the peak lateral load, and the location of plastic hinges. The composite was able to strengthen the cap beam-column joints effectively and increased the shear stresses to 35 percent. The retrofitted bent reached a displacement ductility of ten, which was twice that of the as-built bent, while the peak lateral load capacity was increased by 18 percent.

For more information, please contact Prof. Chris Pantelides of the University of Utah by fax at 801-585-5477 or by e-mail at chris@civil.utah.edu.

Publications

Durability of Fiber Reinforced Polymer (FRP) Composites for Construction

The First International Conference on Durability of Composites for Construction (CDCC'98) was held in Sherbrooke, Quebec, Canada, August 5 to 8, 1998. Proceedings of the conference, containing 58 reviewed papers by a distinguished international scientific committee, are available at a cost of $120 US (including shipping and handling).

For more information, please contact the CDCC'98 Secretariat by fax at 819-821-7974.

ACC Club Projects (Volume 2)

The Advanced Composite Cables (ACC) Club of Japan recently published the second volume of "ACC Club Projects Using New Materials" to highlight over 100 cases in 1998. The volume includes the latest 33 applications, which are classified into the following eight fields: high-durability bridges, marine structures, water courses and underwater structures, non-magnetic or non-electro-conductive structures, buildings, ground anchors, and underground structures. The publication also provides the characteristics of the eight types of fiber reinforced polymer (FRP) materials of the ACC Club and a list of the projects in Japan and abroad.

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

Eighth ACC Club Conference

The eighth technical conference of the Advanced Composite Cables (ACC) Club of Japan was held in Fukuoka on November 24, 1998. The main theme was "Development of Materials for the 21st Century, Propagation of Fiber Reinforced Polymer Reinforcement (FRP) for Construction Field". Members of the ACC Club presented the following eight construction field applications using FRP reinforcements:

- CFCC for prestressed concrete bridge girders in ocean environment.
- Arapree for electromagnetically-free interference laboratory.
- Technora for seismic strengthening of reinforced concrete piers.
- FiBRA for rock bolts.
- Leadline for ground anchors of a seaside cliff.
- NEFMAC for repair of box girders of a highway bridge.
- NACC strand for temporary catwalks of Kurushima Bridge.
- COMPOSE for tendons of precast bridge girders.

The fourth edition of the "Manual for Design and Construction of Prestressed Concrete Highway Bridge Using FRP Materials", published by ACC Club, was also introduced at the conference.

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

Theses

Gentilini, D. "Strengthening of Concrete and Hollow Tiles Mixed Floors with Innovative Composites (FRP) - Tests and Numerical Simulations", M.Sc. Thesis, 1998, University of Bologna. Supervised by Prof. A. Di Tommaso, Dr. M. Arduini and Dr. O. Manfroni.

Hassan, T. "Behaviour of Concrete Bridge Decks Reinforced with FRP", M.Sc. Thesis, 1999, University of Manitoba. Supervised by Dr. Sami Rizkalla.

Tumialan, J. G. "Concrete Cover Delamination in Reinforced Concrete Beams Strengthened with CFRP Sheets", M. Sc. Thesis, 1998, University of Missouri-Rolla. Supervised by A. Belarbi and A. Nanni.

Conferences

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 web-site 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.

International Composites Expo'99 (ICE'99), May 10 to 13, Cincinnati, Ohio, U.S.A. For further information, please contact Peggy Stabach of the Composites Institute by telephone at 914-381-3572, extension 267.

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.

The 8th Canadian Conference on Earthquake Engineering (CCEE), June 13 to 16, 1999, Vancouver, British Columbia, Canada. For further information, please contact the CCEE Conference Secretariat by fax at 604-822-6901 or by e-mail at 8ccee@civil.ubc.ca.

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.

Advances in Structural Engineering and Mechanics (ASEM'99), August 23 to 25, 1999, Seoul, Korea. For further information, please visit the conference website at http://asem99.kaist.ac.kr.

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 Fiber 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.

Structural Engineering Convention: Incorporating Polymer Composites in Construction, November 23 to 27, 1999, Mumbai, India. For further information, please contact Mr. Yogesh by e-mail at desai@civil.iitb.ernet.in.

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.

American Concrete Institute 2000 Spring Convention, March 26 to 31, 2000, San Diego, California, U.S.A. For further information, please contact ACI International by fax at 248-848-3701.

Fifth Annual ISIS Canada Conference, May 3 to 6, 2000, Montréal, Quebec, Canada. For further information, please contact Dr. Sami Rizkalla by e-mail at rizkall@cc.umanitoba.ca.

Second International Conference on Fatigue of Composites, June 4 to 7, 2000, Blacksburg, Virginia, U.S.A. For further information, please contact Mrs. Sheila Collins by fax at 510-231-9187 or by e-mail at shcolli4@vt.edu.

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.

American Concrete Institute 2000 Fall Convention, October 15 to 20, 2000, Toronto, Ontario, Canada. For further information, please contact ACI International by fax at 248-848-3701.

Sixth International Conference on Deterioration and Repair of Reinforced Concrete in the Arabian Gulf, October 23 to 25, 2000, Manama, Bahrain. There is a $10,000 (US) prize for the best paper. Deadline for abstracts is March 1, 1999. For further information, please contact the Bahrain Society of Engineers, P.O. Box 835, Manama, Bahrain.

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