FRP International

Fiber Reinforced Plastics

Spring, 1996 Volume IV, Issue 2

Society Profile – CSCE

In 1989, the Structures Division of the Canadian Society for Civil Engineering (CSCE) formed a new technical committee on the topic of advanced composite materials in civil engineering applications. The decision was conceived following a visit to the Swiss Federal Laboratories for Material Testing and Research (EMPA) in Zurich, where researchers were actively working on the use of advanced composite materials (ACM) for bridges and structures. The membership of the technical committee represents a good balance from the practicing, manufacturing and academic sectors. The mandate of the committee was, and continues to be, to investigate and, where found appropriate following investigation, to encourage the use of ACM in bridges and other structures. The major accomplishments of the committee were the publishing of two state-of-the-art books (Ref. 1 and 2) on the subject, the organizing of an international conference in 1992 (Ref. 3), which brought together many of the leading engineers in this field, and the organizing of a national lecture tour which was presented across Canada by several distinguished leaders in the field (Ref. 4). The efforts of the committee have been supported in large part by the Canadian Federal Government, which has a number of programs in place to assist in the development of new technologies in Canada. In 1992, with support from Industry Canada, a national network on ACM (the ACMBS Network of Canada) was established. The CSCE was appointed administrator of the network. The ACMBS Network encourages exchanges between its members through the creation of business alliances, market studies and support of research alliances. It sponsors conferences, short courses and technical missions, and promotes the creation of new engineering enterprises specializing in the field of ACM in bridges and structures. With national and international collaborations, several field projects using ACM technologies have been, and are being, constructed in Canada (Ref. 5, 6 and 7). Also, Canadian expertise has resulted in some of the world's first design specifications, these being in their final drafts, for the use of ACM for bridges and buildings.

Based on this proven record of collaboration among Canadian engineers and researchers, a new network under the Canadian Federal Government's program of the Networks of Centres of Excellence (NCE) was approved in July 1995 (Ref. 8), with headquarters at the University of Manitoba in Winnipeg. The network is called "Intelligent Sensing for Innovative Structures (ISIS Canada)". ISIS Canada will develop innovative systems that combine ACM, new fibre optic sensors and microchip technology for use in the design, reinforcement, and repair of civil engineering structures. These structures are classified as "smart" by virtue of their

(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 •

(continued from page 1)

integrated fibre optic structural sensing systems, and "innovative" through the use of advanced composite materials to make them light, yet strong, and long lasting. The wealth of sensing data generated from each structure, such as a bridge, will be intelligently processed and transmitted through telephone or satellite links to a central monitoring station, where it will be interpreted and the status of the structure evaluated. This central location will be able to remotely monitor the condition of potentially hundreds of structures, thereby eliminating the need for many costly site inspections. Moreover, the extensive use of advanced composite materials will substantially reduce the long-term maintenance, that has become a major source of frustration for the users, as well as a significant financial burden for both private sector and government.

The CSCE Technical Committee on the use of ACM bridges and structures is currently preparing a state-of-the-art report on the use of ACM for the repair of structures. The ACMBS Network has recently been extended to year 1998. With the creation of ISIS Canada and extension of the ACMBS network, engineers from industry and researchers at universities are networking together on the use of this new technology and materials for new construction, repair and rehabilitation of existing structures. The activities of ISIS Canada have started in earnest, bringing with it a surge in ACM research activities in Canada. The creation of the CSCE Technical Committee in 1989 led to the growth of Canadian expertise in this emerging field. This effort has brought innovative developments and prestige to Canadian efforts in ACM for structures and bridges.

References

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2. Mufti, A.A., Erki, M.A., and Jaeger, L.G., 1992. Advanced Composite Materials in Bridges and Structures in Japan, CSCE, Montreal, Quebec, 172 pp.

3. Neale, K.W. and Labossière P., 1992. Advanced Composite Materials in Bridges and Structures, Proceedings on the First International Conference, CSCE, Sherbrooke, Quebec, 705 pp.

4. Labossière P., 1994. Current and Future Applications of Advanced Composite Materials in Structural Engineering, 1994 CSCE National Lecture Tour in Structural Engineering. ACMBS Network of Canada, Montreal, Quebec, 44 pp.

5. Rizkalla, S. and Tadros, G., 1994. First Smart Highway Bridge in Canada, American Concrete Institute, Concrete International, Vol. 16, No. 6, pp. 42 - 44.

6. Fam, A.Z. and Rizkalla, S., 1995. Model Tests for Concrete Highway Bridges in Manitoba Fully Reinforced by CFRP Reinforcements, proceedings of the CSCE Annual Conference, Ottawa, Ontario, pp. 595-604.

7. Vaughan Engineering, 1995. The Canadian FRC Bridge Deck – Demonstration Project, Salmon River Bridges, project brochure, Vaughan Engineering Associates Limited.

8. FRP International 1995. ISIS Canada Network of Centres of Excellence (ed. Rizkalla, S.), Vol. III, Issue 3, pp. 2 - 3.

Applications

The World's First Steel-Free Bridge Deck

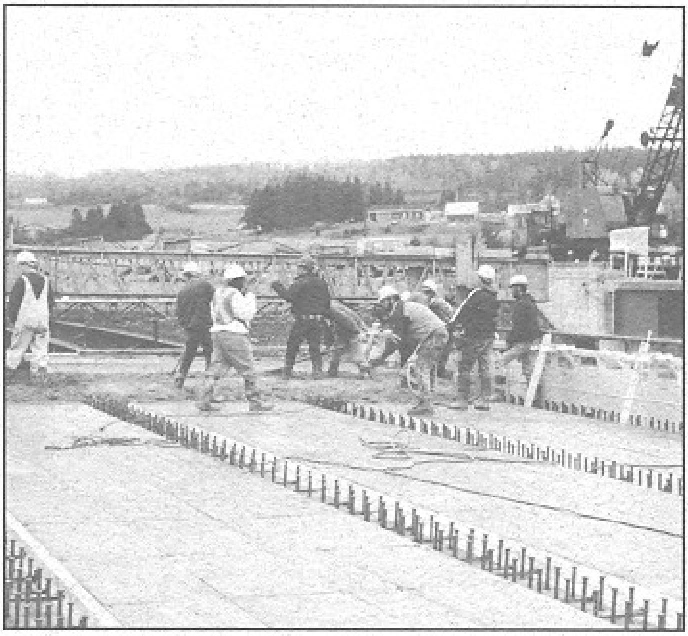


Figure 1. Salmon River Highway Bridge, Nova Scotia

The first highway bridge with a steel-free deck was constructed in late 1995 on Highway 104, over the Salmon River, near Kemptown, Nova Scotia. This innovative deck is composite with steel girders and comprises chopped, polypropylene fibre reinforced concrete, with 0.55 percent volume fraction of fibres. The top flanges of the girders are joined at regular intervals by steel straps, as shown in Figure 1. The bridge at Salmon River has four simply supported spans, each approximately 30 m in length. Three spans were constructed using conventional reinforced concrete design, while the fourth, on the west-bound side, uses the steel-free technology. The project represents a totally new and innovative approach to bridge deck design, including a new structural system. As the Salmon River bridge is the first field test of this new deck system, it will also be remotely monitored by fibre optic strain sensors as part of the ISIS Canada program.

Other technology of interest in this project is the use of fibre reinforced plastic (FRP) grid reinforcement in the curbs and parapets supporting the aluminum guardrails. The grid, manufactured by Autocon Composites Inc. of Ontario, was used because its strength is comparable to steel, without the potential for corrosion problems. The Salmon River bridge is owned by the Nova Scotia Department of Transportation and Public Works. For more information, please contact Dr. Mufti at (902) 420-7763, e-mail: mufti@tuns.ca.

CFCC for a New Road Bridge

Figure 2. Mukai Bashi Bridge, Japan

Mukai Bashi bridge is a new pretensioned prestressed concrete bridge constructed in Ishikawa prefecture in Japan. The bridge is 13.44 m in length and 12.13 m wide. CFCC and epoxy coated steel bars were used to overcome the corrosion problem of steel tendons due to salt spray. CFCC were used for both transverse and longitudinal prestressing. Two types of anchorages were used, the first being made from stainless steel. The second system allowed removal of the steel anchorage system after complete curing of the cement grout in the sheath as shown in Figure 2. Use of transverse CFCC was arranged to investigate their long-term behaviour in the field. For more information, please contact Mr. Kawamoto, Chief Engineer of the Civil Engineering and Development Department, P. S. Co. Ltd., by fax at 81-5391-6095.

Column Repairs

In November 1995, the University of Sherbrooke, Quebec, used FRP to strengthen and protect two reinforced concrete columns, located at the entrance of the university's Faculty of Administration as shown in Figure 3a and 3b. Columns were 12" (305 mm) in diameter and 13' (3.95 m) in length. Corrosion of the steel rebars of these columns led to extensive cracking and spalling of the concrete. The spalled concrete was replaced with a cement grout by a local building contractor. A team of graduate students from the Civil Engineering Department, under the supervision of Professor K. W. Neale and Professor P. Labossière, proceeded to install the FRP wrapping. The TYFO S composite system, courtesy of Composite Retrofit International Inc. of Montreal, was the FRP used. It consists of woven glass fibres and a two-component epoxy resin. The high strength of the composite wrap confines the concrete, thereby increasing the structural capacity of the columns. In order to improve the aesthetic quality of the columns, a finishing coat of the desired color and texture will be added this spring. For further information, please contact Dr. Labossière by fax at (819) 821-7134 or by e-mail at pjlab@vinci.gci.usherb.ca.

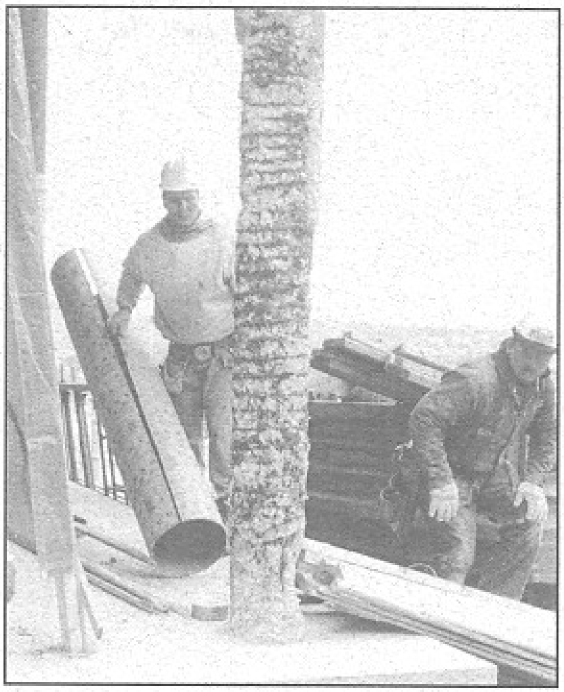
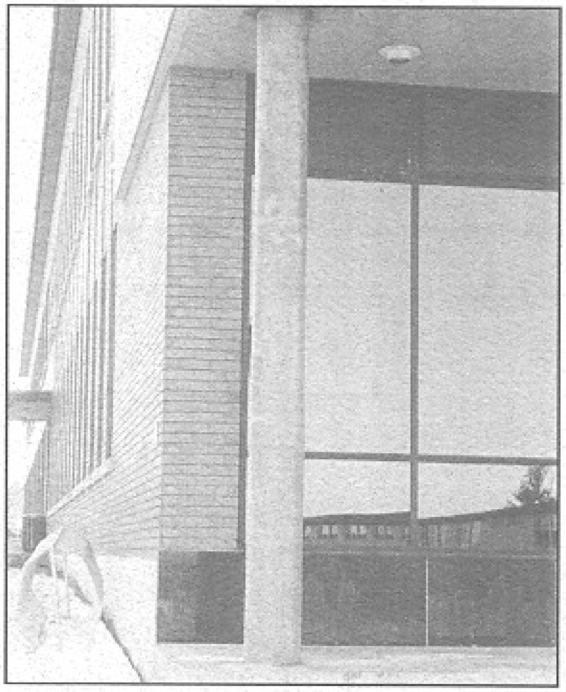


Figure 3a and 3b. Repair of Column at University of Sherbrooke (Before and After)



Phenolic Grating Provides Lightweight Decking Offshore

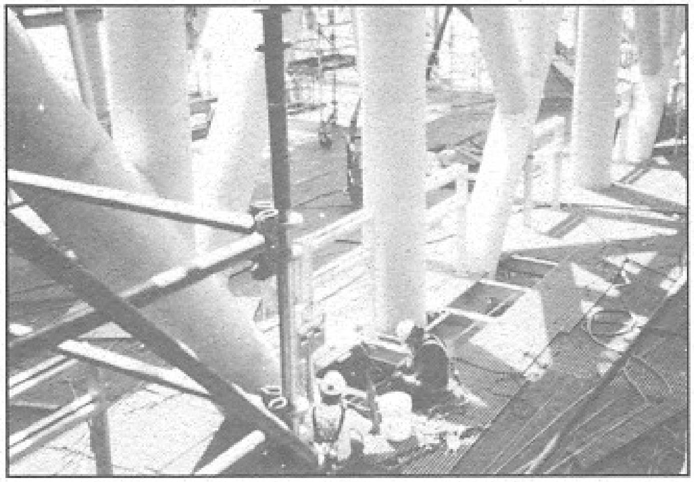


Figure 4. Shell Mars Tension Leg Platform, Gulf of Mexico

DURAGRID® phenolic grating, developed by MMFG, provides the weight savings necessary for floating tension leg platforms, as well as fire resistant safety with low smoke and low toxic fume emissions as shown in Figure 4. Over 80,000 square feet of phenolic grating has been fabricated for primary modules on the Shell Mars tension leg platform and another 75,000 square feet will be used on the nearly identical Ram Powell platform. This is apparently just the beginning of what may be an international boom in offshore platform construction for deep water drilling. Innovative technologies are required to meet the challenges of the offshore oil industry's move to develop record deep oil production, and to reduce the weight which is a key design feature for these types of projects. Phenolic grating is pultruded using fibreglass reinforced phenolic and offers the following properties: one quarter the weight of steel, thermally non-conductive, high strength and impact resistance. With an indefinite maintenance-free product life, phenolic grating also eliminates the continual repainting and rust removal maintenance required for such an environment. It has been estimated that the use of advanced composites on the decks of the new generation of tension leg platforms could save up to 25 percent of the construction cost of the deck. For more information, please contact Vickie Clark by fax at (540) 645-8132.

Research

Concrete Repairs Using Sprayed FRP

The Department of Civil Engineering at the University of British Columbia (UBC) and GU Industries, Aldergrove, British Columbia, have teamed up to develop techniques to repair concrete structures using sprayed fibre reinforced plastics. The 3 to 5 mm thick FRP layer produced using spraying techniques has a two-dimensional random distribution of 6 mm long fibres of glass, or other types, in a polymeric matrix. Preliminary trials have indicated that it is possible to obtain reasonably high fibre volume fractions, and significant improvements to both the strength and ductility of concrete as a result of the coating. The ease of application (Figure 5) makes this a particularly attractive technique for repair and rehabilitation at sites where access is restricted. Additional data will be presented at the Second International Conference on Advanced Composite Materials in Bridges and Structures (ACMBS-II) in Montreal, August 11 to 14, 1996. For more information, please contact Dr. Nemy Banthia, UBC, by fax at (604) 822-6901 or by e-mail at banthia@civil.ubc.ca.

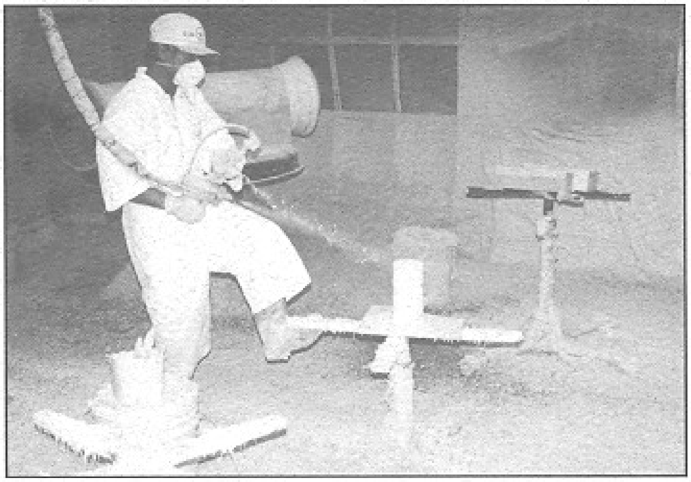
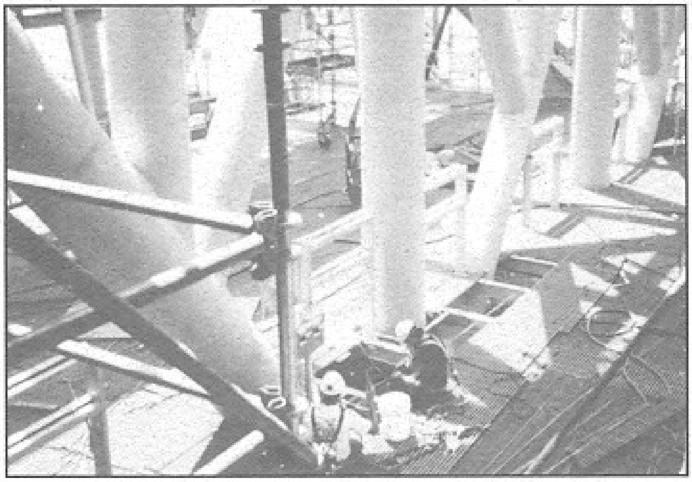


Figure 5. Sprayed Fibre Reinforced Plastic for Repair

Pultruded Composite for Causeways

AEPCO Inc., in conjunction with The Catholic University of America's Civil Engineering Department, has been awarded a contract by the Naval Surface Warfare Center, Carderock Division, to develop a pultruded composite design for military causeways (floating barges). The principal objective is to establish how pultruded composites can be utilized in lieu of the current high-maintenance, labour-intensive, corrosion-vulnerable, steel-based causeway design. Analyses will be performed to explore the durability, stability, operational effectiveness, and life cycle costs of a pultruded composite causeway system versus the current military causeway system. Once an acceptable design is achieved, the proposed pultruded composite causeway sections can be used as "building blocks" for improved offload systems (roll-on/roll-off discharge facilities), causeway ferries or floating piers, high sea state container transfer systems, and air cushion vehicle landing platforms, for both the military and commercial industry. For further information, please contact Dr. Lawrence C. Bank of the Department of Civil Engineering, The Catholic University of America, by fax at (202) 319-4499 or e-mail at bank@cua.edu.

Phenolic Grating Provides Lightweight Decking Offshore



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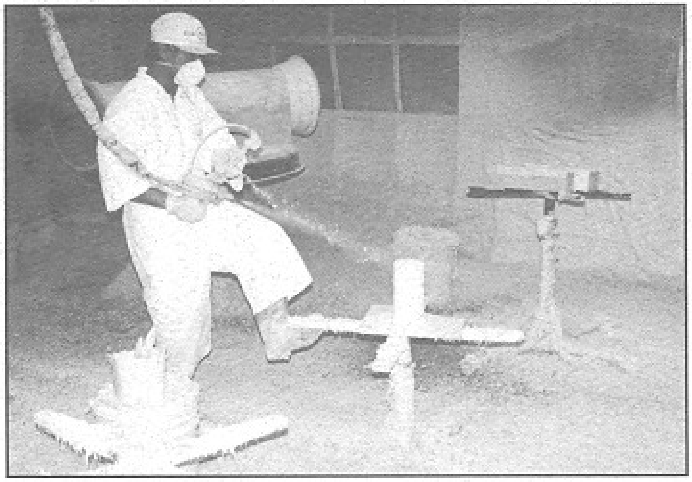

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Research in Japan

Current research activities in Japan are focusing on the following areas:

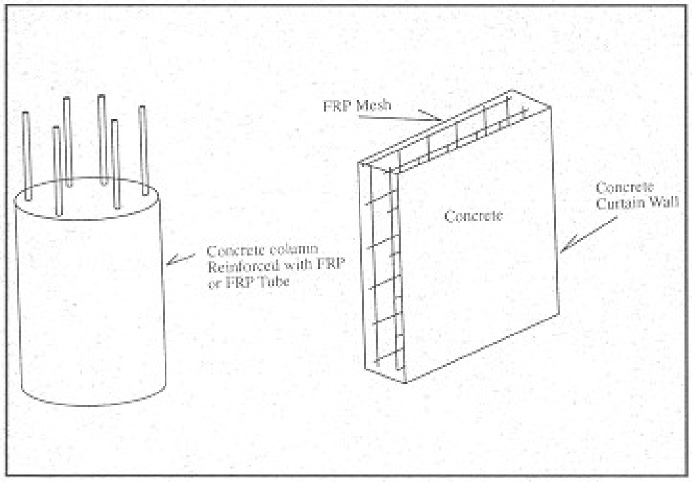

Figure 6. Precast Concrete Reinforced by FRP

1. Development of high-performance concrete panel elements using continuous fibres: Using continuous and uniformly distributed FRP reinforcements is proposed to improve performance, particularly the ductility, for certain applications such as curtain walls, concrete forms and, in general, precast members as shown in Figure 6. FRP could be used in the form of tube as outer skin for columns with or without longitudinal reinforcements.

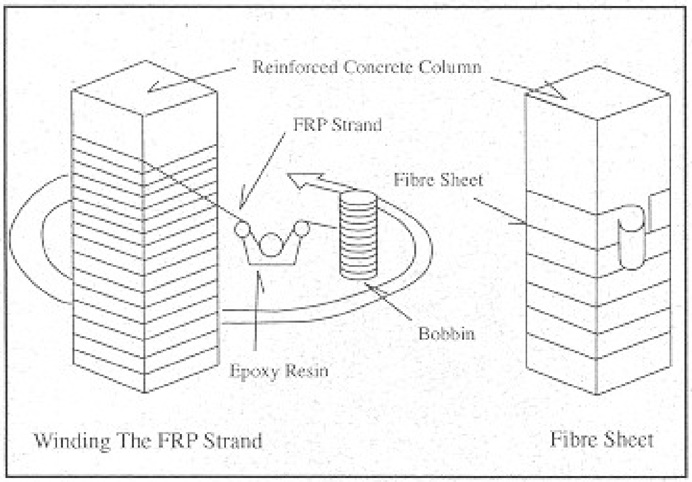

Figure 7. Repair and Strengthening of Building

2. Use of FRP for seismic repair of RC buildings due to earthquake damage or strengthening of an existing building against future earthquakes: The application includes winding strands around RC members or using fibre sheets, or tapes to RC members as shown in Figure 7. These methods prove to be more effective, economical and introduce considerable savings in construction time in comparison to methods using steel or concrete jackets. This technique has been used in several buildings damaged by the Hyogo-Ken Nanbu Earthquake which occurred in January of this year.

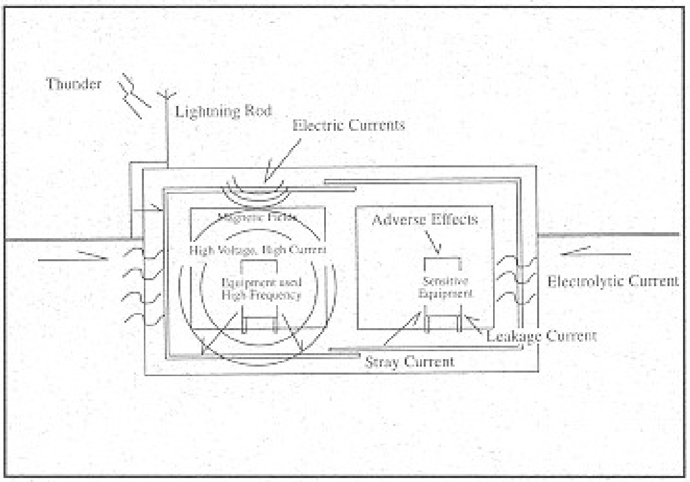

Figure 8. Use of FRP Solution for Electricity-related Problems

3. Use of FRP reinforcements as a solution of electricity-related problems arising from the use of steel reinforcements: Examples include electrolytic corrosion of steel reinforcements in the vicinity of power plants and transformer stations. FRP are proposed to be used as reinforcements in areas where steel reinforcement could pose problems related to stray and leakage currents to computers and other sensitive equipment, or structures sensitive to magnetic fields, as skematically shown in Figure 8. For further information on any of these research activities, please contact Professor Mutsuyoshi by fax at 81-48-858-3556 or by e-mail at mutuyosi@p.mtr.civil.saitama-u.ac.jp.

NEFMAC Grids for Shear Reinforcement

Recent tests at the Royal Military College of Canada (RMC) in Kingston, Ontario, have shown that shear reinforcement can be effectively provided by NEFMAC FRP grids without the need for bent FRP stirrup. Beams, 4 m in length and reinforced for shear with conventional steel stirrups and with NEFMAC grids, manufactured by Autocon Composites Inc. of Toronto, were tested to failure. Constructing the beams with the NEFMAC grids required less labour for preparation and installation of the reinforcement. Also, it is expected that the use of NEFMAC grids for shear reinforcement could be more economical than FRP rectangular stirrups that need to be prefabricated to conform to the specific dimensions of the application, precluding last minute design changes. Additional analytical and experimental work on models tested to failure in shear is required to develop design guidelines for the proposed concept. For more information, please contact Dr. Marie-Anne Erki by fax at (613) 541-6599 or by e-mail at erki_m@rmc.ca.

Structural Composites Research at the University of Surrey

Under the direction of Professor Len Hollaway, who heads the Composite Structures Research Unit at the Department of Civil Engineering, current research includes experimental and numerical analysis in the following fields:

1. Strengthening of Reinforced and Prestressed Beams: The research includes testing of reinforced and prestressed concrete beams strengthened by carbon fibre composites either unstressed or prestressed at the time of bonding. Sixty reinforced concrete beams strengthened by fibre composite plates have been tested with spans varying from 1 m to 18 m. The study has led to the development of optimum anchorages for the plates and a numerical approach for the analyses. The program included two projects. The first project, known as ROBUST, is an EPSRC-DTI Structural Composites LINK program and is being undertaken by a consortium of seven industrial firms and two academic partners. The project is led by Mouchel and Partners, consulting engineers, West Byfleet, Surrey, United Kingdom. The second project is EPSRC, funded in collaboration with two industrial firms (investigators – H. Garden and R. Quantrill).

2. Characterization of the Maunsell Structural Plastics Advanced Composite Construction System (ACCS): Investigative work is being completed on the ACCS plant, 20 of which have been formed into two box beams loaded in the natural environment under a four point loading system over an 18 m span. The test lasted ten months to characterize the material and structural system under load and exposed to the natural environment. In addition, a 2.2 m length of this box beam section was simply supported and placed under a 100 kN pad concentrated load of area, 300 mm X 300 mm, to determine the transfer of the load into the structure. This pad load represented a concentrated wheel load (investigator – J. Lee).

3. Optical Fibres for Composite Materials: The research includes development of smart composite materials based on embedment of a sensor system into the host material during fabrication. Fibre optic sensors have been considered to be the prime candidate for internal structures and condition monitoring of composite materials. The research considers polarimetric strain sensors to measure strain in GFRP loaded composites. The embedded sensor has the potential capability of sensing strain and structural behaviour (Investigator – M. Hadijprocopiou).

For more information, please contact Professor Len Hollaway by fax at 01-48-345-0984.

New Products

Security Guard Using CFGFRP

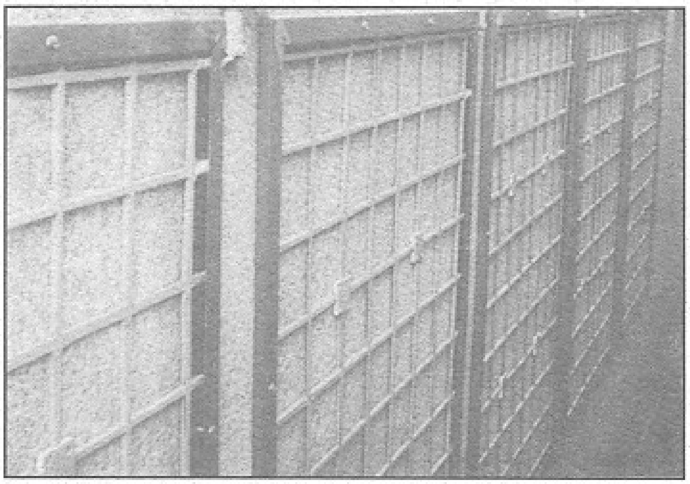

Figure 9. Use of "Bright Guard" Reinforcement for Concrete Walls

Sogo Security Services Co. Ltd., Shimizu Corporation and Professor Hiroaki Yanagida, Faculty of Engineering at the University of Tokyo, have developed new security goods called "Bright Guard" using CFGFRP (Carbon Fibre-glass Fibre Reinforced Plastics) of hybrid composites. CFGFRP composites have been commercially developed for "NEF-MAC" produced by Shimizu Corporation. Bright Guard is constructed in concrete walls of bank buildings as shown in Figure 9. Bright Guard utilizes the conductivity of carbon fibre to trigger an alarm when an intruder tries to penetrate a wall reinforced with this system. Due to the induced elogation, the output voltage level will exceed a preset threshold level and activate the alarm system. Bright Guard has been constructed in the wall of a building at Yokohama (February 1994), Nagano (March 1995) and Kobe (May 1995) in cooperation with Sogo Security Services Co. Ltd. For more information, please contact Minoru Sugita of the Ohsaki Research Institute at 81-3-3508-8011 or by fax at 81-3-3508-2196.

New Code

The Canadian Highway Bridge Design Code (CHBDC), planned to be published in late 1996, is the successor of the three editions of the Ontario Highway Bridge Design Code. The CHBDC has a new section dealing with the design of fibre reinforced structures. The provisions of this section, developed by a technical committee of ten engineers from Canada, Japan and Germany, relate to the design of (a) prestressed concrete beams and slabs; (b) concrete slabs and deck slabs with fibre reinforced plastic; (c) fibre reinforced concrete deck slabs of slab-on-girder bridges; (d) stressed wood decks; and (e) barrier walls. A paper has been prepared which introduces the draft provisions of this section of the CHBDC with a view to receiving comments and feedback from engineers who are familiar with the materials under discussion. The paper will be presented at the Second International Conference on Advanced Composite Materials in Bridges and Structures (ACMBS-II) to be held in Montreal, August 11 to 14, 1996. For further information, please contact Dr. Baidar Bakht by fax at (416) 235-4872 or e-mail at bakhtba@epo.gov.on.ca.

Publications

1. ACI State-of-the-Art Report on Fibre Reinforced Plastic Reinforcement for Concrete Structures as reported by ACI Committee 440, see Figure 10.

2. Design Guidelines for FRP Prestressed Concrete Members, edited by Building Research Institute, Japanese Ministry of Construction, July 1995.

3. Guidelines for Structural Design of FRP Reinforced Concrete Building Structures, edited by Building Research Institute, Japanese Ministry of Construction.

For more information regarding publications number 2 and 3, contact Professor Mutsuyoshi by fax at 81-48-855-9361.


ACI 440R-96

State-of-the-Art Report on Fiber Reinforced Plastic Reinforcement for Concrete Structures

Reported by ACI Committee 440

american concrete institute

Figure 10. ACI 440R-96 Report

Awards

CERF Awards

The Civil Engineering Research Foundation (CERF) of the American Society of Civil Engineers has announced the 14 finalists of its 1996 Innovation Awards Program, ten for the applications category and four for the concept category. Seven out of 14 finalists use composites and fibres. Among them were the "Steel-free Bridge Deck" innovation by R. MacDonnell of Vaughan Engineering, Dr. A. Mufti of the Nova Scotia CAD/CAM Centre, and Dr. B. Bakht of the Ontario Ministry of Transportation; HDR Engineering of Omaha for their Sherbrooke Pedestrian/Bikeway Footbridge using reactive powder concrete (RPC) technology; Maunsell Structural Plastics Ltd. of the United Kingdom for their advanced composite structural system (ACCS) with pultruded FRP, plus separately for their SPACES bridging system; Oregon State University and the Wood Science and Technology Institute for their FiRP (tm) reinforced glulams with pultruded plates of carbon and aramid fibres (winner in the concept category); Sumitomo Construction Co. Ltd. for development and applications of aramid fibre tendons (co-winner in the Applications Category); Lawrence Technological University of Michigan for the use of fibre reinforced plastic reinforcing and prestressing for long-lasting concrete bridges; and the University of California, Division of Structural Engineering, for a carbon shell space truss bridge.

University Theses

Grieef, S., 1996. *"GFRP Dowel Bars for Concrete Pavement"*, M.Sc., University of Manitoba, supervised by S.H. Rizkalla.

Masmoudi, R., *"Flexural Behaviour and Design of Concrete Beams Reinforced with FRP Rebars"*, Ph.D., University of Sherbrooke, supervised by B. Benmokrane and co-supervised by O. Chaallal.

Michaluk, C. 1996. *"Flexural Behaviour of One-Way Concrete Slabs Reinforced by Glass-Fibre Reinforced Plastic Bars"*, M.Sc., University of Manitoba, supervised by S.H. Rizkalla.

Conferences

International Technology Transfer Day, "Fibre Reinforced Plastics (FRP) in the Construction Industry", Bologna, Italy, June 8, 1996. Please contact Dr. Marco Arduini, University of Bologna, by fax at 39-51-638-7503.

IRACC'96, International Research on Advanced Composites in Construction and Seminar on Fibre Reinforced Plastics (FRP) in Construction, Bologna, Italy, June 8 to 11, 1996. Please contact Dr. Marco Arduini, University of Bologna, by fax at 39-638-7503.

The First Middle East Workshop on Structural Composites for Infrastructure Applications, Sharm El-Sheikh, Egypt, June 14 and 15, 1996. For information, please contact Dr. A. Mosallam or Dr. A. Hadi Hosni by fax at (714) 773-3916.

Composite Construction III, Irsee, Germany, June 9 to 14, 1996. Contact Dale Buckner, Department of Civil Engineering, Virginia Military Institute, Lexington, VA, by fax at (703) 464-7618.

Third International Conference on Composites Engineering, New Orleans, Louisiana, July 21 to 27, 1996. Please contact David Hui, Department of Mechanical Engineering, University of New Orleans, New Orleans, LA 70148 or by fax at (504) 286-6652.

ACI 1996 Fall Convention, New Orleans, Louisiana, November 3 to 8, 1996. Contact American Concrete Institute, P.O. Box 19150, 22400 West Seven Mile Road, Detroit, MI 45219 or by fax at (313) 538-0655.

Second International Conference on the Use of Advanced Composite Materials for Bridges and Structures, Montréal, Québec, Canada, August 11 to 14, 1996. Please contact Dr. S.H. Rizkalla, Faculty of Engineering, University of Manitoba, Winnipeg, MB R3T 5V6, or by fax at (204) 261-5465.

20th International British Plastics Federation Composites Congress '96, Hinckley Island Hotel, Leics, England, September 11 and 12, 1996. Please contact Susanne Wolf by fax at 44-17-1457-5045.

ASCE Annual Convention, Washington, D.C., November 11 to 13, 1996. Contact Delon Hampton, Convention Chair, at (202) 898-1999.

The Seventh International Conference and Exhibition – Structural Faults and Repair '97, Edinburgh, Scotland, July 8 to 10, 1997. The theme of the event is extending the life of bridges, concrete buildings and civil structures. Send abstract before August 9, 1995, to Professor M.C. Forde, Civil Engineering Construction, Department of Civil Engineering, University of Edinburgh, The King's Building, Edinburgh Eh9 3JL, Scotland, UK, or by fax at 31-452-8596.

1997 International Conference on Engineering Materials, Citadel Ottawa, Hotel, Ottawa, Canada (covers repairs and rehabilitation materials and FRP materials), June 8 to 11, 1997. Please contact Akthem Al-Manaseer at Bradley University, Peoria, IL, USA, by fax at (309) 677-2867.

Third FRP International Symposium on Non-Metallic (FRP) Reinforcement for Concrete Structures, Sapporo, Japan, October 14 to 16, 1997. Contact: Secretariat FRPRCS-3, Japan Concrete Institute, TBR - 708, 5-7 Kojimachim Chiyoda-ku, Tokyo 102, Japan.

Dept. of Civil Engineering
Room 353A Engineering Bldg.
University of Manitoba
Winnipeg, Manitoba
Canada R3T 5V6

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