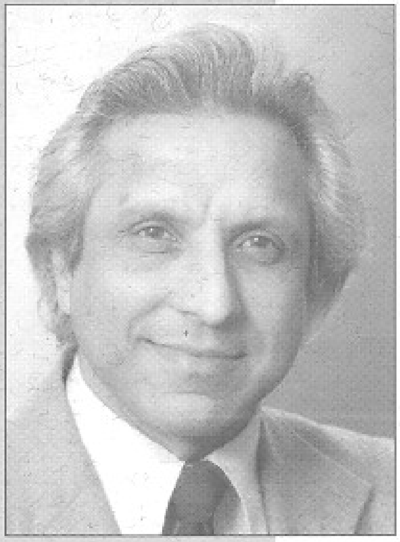
FRP
Fiber Reinforced Plastics
International

Winter, 1994 Volume II, Issue 1

Guest Author – Dr. Aftab Mufti, P.Eng., FCSCE, FEIC

Professor and Director,
Nova Scotia
CAD/CAM Centre



Fibre Reinforced Concrete (FRC) Bridge Deck Without Reinforcement/Parafil Anchor System For Wooden Bridge

Dr. Mufti is a professor of Civil Engineering at the Technical University of Nova Scotia (TUNS) in Halifax, Canada, and is the founding chair of the non-profit Advanced Composite Materials in Bridges and Structures Network of Canada (ACMBSN). This network brings together members from industry, government, and university, who share a common interest in promoting advanced composite materials (ACM) in civil engineering structures.

Dr. Mufti was one of the key persons to initiate interest in ACM for civil engineering structures in Canada through his founding work as Chair (1989 to 1993) of the Canadian Society for Civil Engineering (CSCE) Technical Committee on the Use of Advanced Composite Materials in Bridges and Structures. With support from Industry, Science and Technology Canada and External Affairs Canada, and working through the auspices of the CSCE, Dr. Mufti headed fact finding missions to Europe in 1990 and Japan in 1992. These visits resulted in two CSCE publications, the first of their kind ever published, on the state-of-the-art of ACM in civil engineering structures. In July 1993, with support from External Affairs Canada, Dr. Mufti organized and co-chaired a successful Canada Japan Workshop on ACM in bridges and structures.

Dr. Mufti is also active in ACM research, having recently collaborated on the development of an FRC bridge deck[1] which is devoid of steel reinforcement, as shown in Figure (1). He is currently working with researchers at the Ministry of Transportation of the Province of Ontario on the development of an anchorage system (shown in Figure 2) to be used with aramid ropes in order to prestress transversely

(continued on page 2)

In This Issue

(continued from page 1)

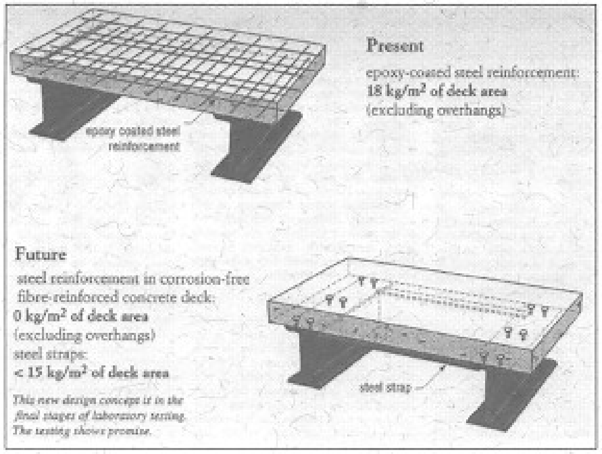


Figure 1. Present/Future bridge decks

laminated wood decking for bridges[2]. Dr. Mufti is a member of the Canadian Highway Bridge Design Code Technical Committee on ACM. He is also the founding director of the Nova Scotia CAD/CAM Centre at TUNS and Jodrey School of Computer Science at Acadia University.

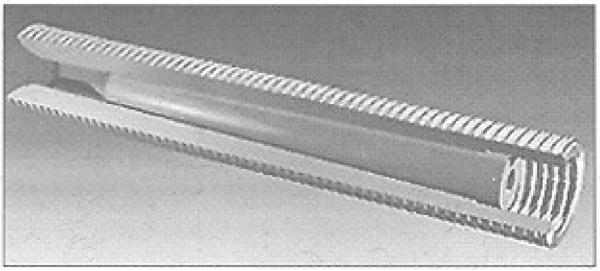


Figure 2. Anchor system for prestressed wooden bridges

References

1 MUFTI, A.A., L.G. Jaeger, B. Bakht, and L. Wegner. 1993. Experimental investigation of fibre-reinforced concrete deck slabs without internal steel reinforcement. Canadian Journal of Civil Engineering, Vol. 20, No. 3, pp. 398-406.

2 MUFTI, A.A., B. Bakht and J. Maheu. 1993. An example of the use of CAD/CAM in structures research. Proceedings of the 1993 Annual Conference of the Canadian Society for Civil Engineering, Vol. IV, pp 1-10.

FRP Research

Post-Stengthening Using Prestressed Carbon Fiber Sheets

In recent years, researchers at EMPA Dübendorf, Switzerland, have been working extensively on post-strengthening reinforced concrete members using light-weight carbon fiber reinforced plastic sheets. For certain structures it was found that there could be an advantage, in inducing a prestressing force in the sheets, particularly for serviceability. The results of this research have been compiled in the EMPA Research Report No. 224, by Dr. M. Deuring: "Post-strengthening of concrete structures with pretensioned advanced composites," 279 pages, (presently in German only). EMPA has also prepared an English and German language video cassette (VHS PAL or VHS NTSC) on this work. The video is available free of charge to universities.

For a free copy of the report or video, please contact Prof. Urs Meier, Swiss Federal Laboratories for Materials Testing and Research, EMPA, Überlandstr. 129, CH-8600, Dübendorf, Switzerland, Tel: 01-823-55-11 or FAX: 01-821-62-44.

Interest in "Smart Composites" Growing

There is growing worldwide interest in development and demonstration of "Smart Composites." This interest is driven in part by a desire of researchers, designers, government agencies and others to develop technology which would continuously monitor the structural performance and condition of primary load-bearing composites in applications such as pre-stressing/post-tensioning tendons in reinforced concrete, cable stays for bridge construction, bridge decks and structural girders. The current lack of long-term performance data, and absence of universally-accepted design protocols for composite materials, is hindering the demonstration of structural composites. Developing "smart" composites which could monitor their own performance would provide long-term data and early warning of premature failure, allowing the structure to be repaired or closed.

Technologies already under consideration include passive monitoring (imbedded strain gauges, optical fibers, etc.) as well as active "tagging" systems. The latter materials come to "life" in the event of unusual structural behaviour, providing a fail-safe warning. Some of the most advanced active tagging systems might trigger a protective response, such as deployment or activation of secondary or redundant structural mechanisms, or "self-healing" responses within the composite laminate itself.

The U.S. Army Corps of Engineers Construction Engineering Research Laboratories, Federal Highway Administration and leading composite research universities are already looking at ways to apply smart composite technology to infrastructure applications. The

(continued on page 3)

(continued from page 2)

newly-formed Composites Infrastructure Task Group (CITG) is actively seeking development contacts for their investigations. Parties with in-depth knowledge on the subject, please contact: Catherine A. Randazzo, Executive Director of the SPI /Composites Institute in New York City, Tel 212-351-5410 or FAX: 212-370-1731, or Douglas S. Barno in Granville, Ohio at Tel 614-587-1444 or FAX 614-587-2187.

Predicting Fracture in CGFRP

The relationship between strain, electrical resistance, and load has been measured for CGFRP (Carbon-glass fiber NEFMAC) by engineers at Shimizu Corporation in Japan. Typically, the strain of CGFRP increases linearly with load; however, it was found that the electrical resistance changes linearly as a function of the strain. After removing load, a large residual electrical resistance has been observed. The load and strain applied previously can be estimated by measuring this residual electrical resistance. This method appears to be a promising technique for predicting fracture of CGFRP (Figure 3). For further information, please contact Kenzo Sekijima, Shimizu Corporation, Japan, FAX: 81-36-437-260.

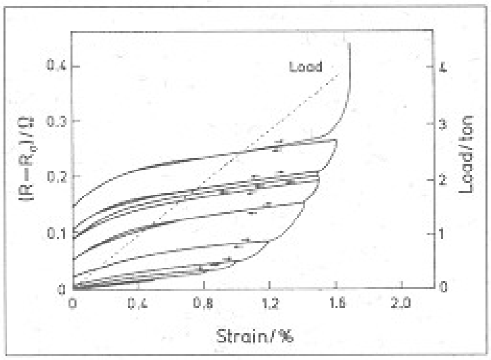


Figure 3. Changes in electrical resistance and load of CGFRP

Canada-Japan Joint Research On Fiber Reinforced Composites

The Natural Science and Engineering Research Council of Canada has recently approved a joint research project between the University of British Columbia (principal investigator Dr. N. Banthia), and The Civil Engineering Research Institute of the Hokkaido Development Bureau (principal investigator Mr. K. Sakai), under the auspices of the Japan Science and Technology Fund (JSTF). The three-year project is aimed at investigating the stress-rate and low-temperature sensitivity of fiber reinforced composites with both brittle and ductile matrices.

For further information please contact Dr. N. Banthia, Department of Civil Engineering, 2010-2324 Main Mall, University of British Columbia, Vancouver, British Columbia, Canada V6T 1Z4. Tel: 604-822-2637 or FAX: 604-822-6901.

Theses/Publications

TROTTIER, J.-F., 1993, Micromechanical and Macromechanical Toughness Characterization of Fiber Reinforced Cement Composites. Ph.D. Thesis. University of British Columbia, Vancouver, British Columbia, Canada V6T 1Z4.

HEFFERNAN, P.J., 1994, Behaviour of Reinforced Concrete Beams Strengthened with CFRP Sheets. M.Eng. Thesis. Royal Military College of Canada, Kingston, Ontario, Canada, K7K 5L0.

New Book

A new book entitled *Alternative Materials for the Reinforcement and Prestressing of Concrete* has been recently published by Blackie Academic & Professionals, an imprint of Chapman & Hill. In this book, edited by J.L. Clarke, an international panel of authors provides an authoritative overview of the subject, bringing together all aspects of the development of alternative reinforcing materials, and describing their properties and worldwide applications. The book serves as a comprehensive, up-to-date and valuable source of reference for civil and structural engineers involved in concrete design and construction, as well as materials researchers and advanced students. The following is a listing of the titles and authors for each chapter:

1. *The need for durable reinforcement* (J.L. Clarke, UK)
2. *Glass-fiber reinforcing bars* (M.R. Ehsani, USA)
3. *NEFMAC grid type reinforcement* (M. Sugita, Japan)
4. *Oriented polymer grid reinforcement* (G.R. Carter, UK)
5. *Parafil ropes for prestressing tendons* (C.J. Burgoyne, UK)
6. *Glass-fiber prestressing system* (R. Wolff and H. J. Miessler, Germany)
7. *Strengthening of structures with advanced composites* (U. Meier, M. Deuring, H. Meier and G. Schwegler, Switzerland)
8. *Aramid-based prestressing tendons* (A. Gerritse, Netherlands)

Cost is US$ 139.00 ($173.95 CDN). For orders, please contact Chapman & Hill, 29 West 35th Street, New York, NY 10001-2299, FAX: 800-248-4724.

AIJ Technical Papers

The annual meeting of the Architectural Institute of Japan was held in Tokyo, Japan, 2-5 September, 1993. Twelve technical papers referring to the use of Continuous Fiber Reinforcing Materials (CFRM) in buildings were presented. The topics presented varied from basic studies on properties of CFRM, to practical applications of CFRM in construction. The research topics and the authors are:

KOBAYASH et al, *Application of CFRM members to large scale structures (Part 1, Analysis and compression test program)*

FUJISSAKI et al, *Application of CFRP members to large scale structures (Part 2, Compression test results and discussion)*

SONOBE et al, *Experimental study on concrete frame reinforced with FRP reinforcement under horizontal loading (Part 1, Outline of study and trial design)*

TANIGAKI et al, *Experimental study on concrete frame reinforced with FRP reinforcement under horizontal loading (Part 2, Test results and discussion)*

FUKUYAMA et al, *Experimental study on concrete frame reinforced with FRP reinforcement under horizontal loading (Part 3, Test results and discussion)*

FUJISAWA et al, *Performance of concrete members reinforced with FRP bars (Part 7, Evaluation of Simple bond test)*

YONEMURA et al, *Performance of concrete members reinforced with FRP bars (Part 8, A formula to predict the bond and splitting strength)*

IRISAWA et al, *Fiber reinforced plastic mesh and woven texture (Part 1, Outline of flexural test and its result)*

ISHIBASHI et al, *Fiber reinforced plastic mesh and woven texture (Part 2, Effect of transverse bar and ultimate flexural strength)*

ODA et al, *Shear strengthening of existing reinforced concrete column by winding with aramid fiber (Part 1, Effectiveness of strengthening by basis experiments)*

OKAMOTO et al, *Compression tests of concrete column confined by braided FRP rods*

HATTORI et al, *Bonding shear test of circular RC columns confined in CFRC tube*

Figure (4) shows a classification according to materials of CFRM that were used in the above studies. Figure (5) shows a change in the number of papers related to CFRM that were presented at annual meetings of AIJ in the past 10 years. For further information on the above papers, please contact the Architectural Institute of Japan, 5-26-20 Shiba, Minato-ku, Tokyo 108, Japan, Tel: 81-3-3456-2051, or FAX: 81-3-3456-2058.

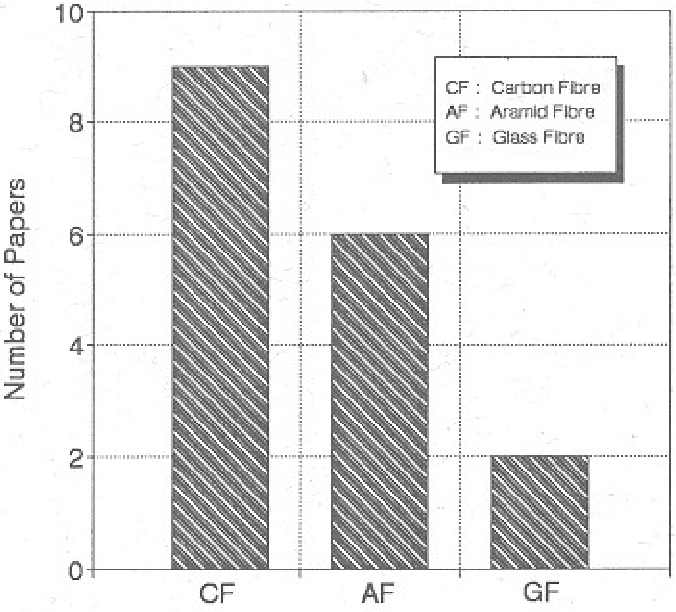


Figure 4. Classification according to materials

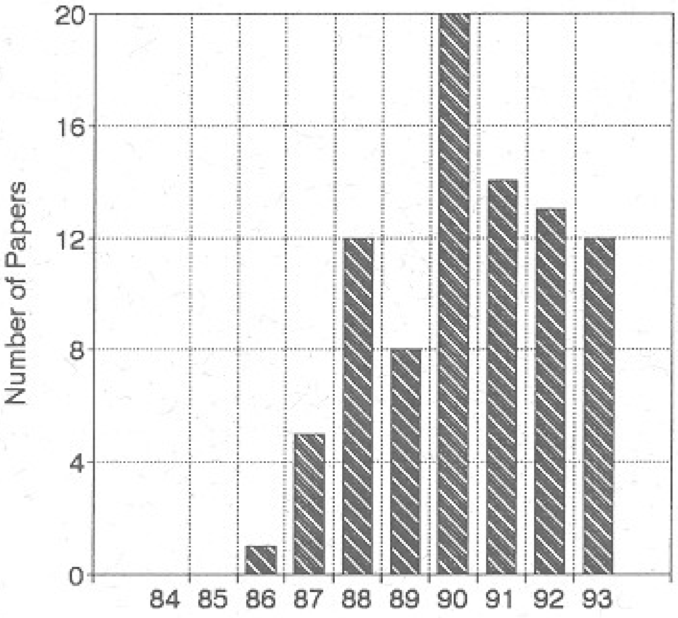


Figure 5. The number of papers related to different materials in last 10 years

Conferences

ICCE/1 In New Orleans, LA

The First International Conference on Composites Engineering (ICCE/1) will be held in the Sheraton Hotel, 28-31 August, 1994 in downtown New Orleans, Louisiana. The Conference will emphasize applications of composites and will facilitate the interaction between basic and applied research in high-quality international meetings.

Extended abstracts may be submitted as soon as possible to Professor David Hui, University of New Orleans, Department of Mechanical Engineering, New Orleans, LA 70148, Tel: 504 -286-6192, or FAX: 504-286-5539. The extended abstract should be formatted on a regular size 8 ½" x 11" single sheet, two-sided, where each side has a two column format for a total of four columns.

CI's 49th Annual Conference

Rebuilding the 21st Century U.S. Infrastructure... with Composites

The 49th Annual Composites Institute Conference and EXPO '94 will focus on the worldwide movement intended to develop a new generation of composite civil engineering structures for the infrastructure. The event will be held 7-9 February, 1994 at the Cincinnati Convention Centre in Cincinnati, Ohio.

Six special sessions, plus hundreds of exhibits featuring composite structures, piping, products for electrical transmission and distribution, waterfront structures, and composite reinforcements for concrete, will make this event one of the most important conferences of the year for civil engineers interested in learning more about the rapidly-growing field of structural composites.

Events for civil engineers, government officials, contractors and owners include a special version of CI's popular half-day intensive workshop, "Introduction to Composites" on Monday morning, 7 February, 1994. This course has been certified for a 1/2 continuing education unit (0.5 CEU) by the International Association for Continuing Education and Training.

The afternoon of Monday, 7 February, features the flagship event of the conference, "Building the 21st Century U.S. Infrastructure...with Composites." James W. Poirot, President of the American Society of Civil Engineers (ASCE), and Harvey Bernstein, President of the Civil Engineering Research Foundation (CERF), will share their perspectives on the immediate and long-term opportunities for structural composites in rebuilding the U.S. infrastructure. Senior representatives of the American Concrete Institute (ACI and Society of American Military Engineers (SAME) will participate in an informative, open panel discussion.

On the morning of Tuesday, 8 February, a panel of experts from the U.S. Navy, American Associate of Ports Authorities, PIANO, and others will discuss revolutionary developments in waterfront and offshore engineering using composites. The keynote speaker for this session will be John J. Cecilio, Chief Engineer, Navy facilities Engineering Service Center (NFESC). On Tuesday afternoon, 8 February, Major General John Sobke, Deputy Commander, U.S. Army Corps of Engineers, will be the keynote speaker for a session focussing on structural composites for the land-based facilities of the infrastructure.

On Wednesday, 9 February, morning and afternoon technical sessions will feature 18 state-of-the-art technical papers presented by researchers, civil engineers and composite organizations.

Additional conference information, including brief descriptions of the seminars, sessions and papers of particular interest to civil engineers, as well as registration forms and housing information are available from the Composites Institute office in New York City, Tel: 212-351-5410 or FAX: 212-370-1731.

Composite Structures

Aramid FRP Rods For Precast Irrigation Channel

Aramid FRP Technora rods were used in the renovation of irrigation channels in Saga Prefecture, Japan, by the Ministry of Agriculture, Forestry and Fisheries in 1993. The precast system was used to reduce construction time and minimize labour costs. The precast units consist of L-shaped blocks linked by Aramid FRP Technora rods, to provide a corrosion-proof environment as shown in Figure (6). Irrigation channels are frequently constructed in weak ground in alluvial plains and easily deform from the uneven subsidence. Selection of Aramid FRP rods was based on their ability to deform easily, following the ground deformation, and their high tensile strength, in addition to their non-corrosion characteristics.

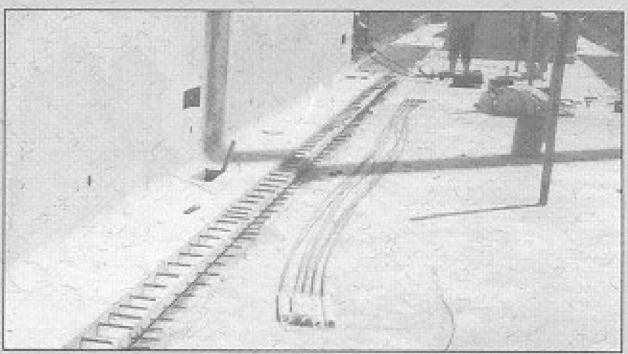


Figure 6. Aramid FRP Technora Rods being installed

Aramid Pilot Ropes Used For Kashi & Kaikyo Bridge In Japan

A Kashi & Kaikyo bridge currently under construction to connect Honshu, Awaji and Shikoku islands in Japan, is the largest suspension bridge in the world. The bridge is 3910 m long with a centre span of 1990 m. The main towers rise about 300 m above sea level. Aramid fibre ropes were used as pilot cables to examine the erection using a helicopter, as shown in Figure (7a), instead of a ship. Aramid fiber ropes were selected due to their light weight and strength. The Aramid fiber ropes used were made of 800,000 filaments which were bound and covered with urethane resin. It took 30 minutes to extend the cable between the two main towers shafts shown in the Figure (7b).

Figure 7a.
Helicopter guiding Aramid pilot rope

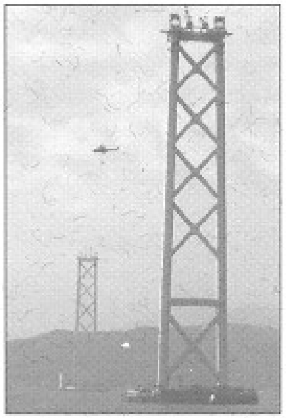


Figure 7b.
Towers of the Kashi-Kaikyo Bridge, Japan

FRP-Reinforced Precast Stair Treds Installed

At the Catholic University of America in Washington D.C., a new entrance using FRP-reinforced concrete has been constructed at the school's engineering building. The old entrance was found to be unsafe due to corrosion of steel re-bar, and was subsequently demolished.

Catholic University faculty members Larry Bank and Russell Gentry suggested the use of FRP re-bar in the precast concrete stair treads leading into the building. Facilities project manager Richard Weil agreed to use the new material in the stair treads and Creative Pultrusions agreed to supply the FRP re-bar at no cost. The general contractor, Hitt Construction, and a local precaster, Arban Precast, agreed to cast the stair treads for the front entrance and an additional 10 stair treads, for testing in the Catholic University Structural Engineering Laboratory.

The stair treads have been installed and are performing well. Ongoing tests are verifying the static and fatigue strength of the stair treads. The durability and structural performance of the stair treads will be monitored and compared with "control" specimens that are reinforced with epoxy-coated steel reinforcement.

For more information please contact Dr. Russell Gentry, FAX: (202) 319-4499, email: gentry@pluto.ee.cua.edu.

GRFP Structures In China

Glass fiber reinforced plastic (GFRP) application started in China in 1983. The first GFRP cable-stayed pedestrian bridge, shown in Figure (8), was completed in 1986, followed by six GFRP projects including five bridges with different construction systems and a spherical vault structure. The recently completed spherical vault has a span of 14.2 m and a height of 4.25 m. A GFRP sandwich system was used to provide the required strength and stiffness. For further information please contact Professor Guodong Tang, Chengdu University of Science and Technology, P.O. Box 610065, Chengdu, PR China, FAX: (86) 28-582-670.

Figure 8.
GFRP Cable-stayed bridge in China

Precast Prestressed Concrete Floating Bridge

Precast, prestressed concrete bridge at Takahiko-three-Country Golf Course is the first floating bridge with FRP materials in Japan (Figure 9). Taking into account the environmental conditions, (the pontoons would be in contact with water), and the fact that they were to be floating structures, FRP materials were used in all positions as durable and light weight substitutes for conventional reinforcement bars and prestressing tendons in the concrete reinforcements and anchor ropes.

The bridge length is 56.36 m and the width is 4.00 m. This bridge consists of six pretensioned pontoons, cast-in-place abutments located at the bridge ends, anchor blocks for mooring and supporting blocks, as shown in Figure (10). The abutments are used due to insufficient water depth near the pond shore to support floating structures. The weight of anchor blocks for mooring is enough to anchor the bridge in position.

FiBRA FA 13 was used for the pre-tension tendons on the side walls of the precast boxes, while FA 15 was used for the post-tension tendons to connect the 6 precast boxes. These were delivered in the form of coils cut into the required lengths.

FiBRA RA 7 was used as a substitute for reinforcement steel in the floor slabs and walls orthogonal to the side walls. They were delivered to the site after being processed into meshes at the factory to facilitate the on-site work.

Clatec Rod 10D was used as a substitute for the side wall reinforcement steel (stirrups). These were subjected to heat treatment (100 to 110° C) and processed into continuous spirals prior to delivery to facilitate the on-site work, as in the case of the FiBRA RA 7.

For more information, please contact Masamichi Tezuka, Oriental Construction Co. Ltd., FAX: 81-285-83-0021.

Figure 9. Takahiko-three-Country Golf Course Floating Bridge

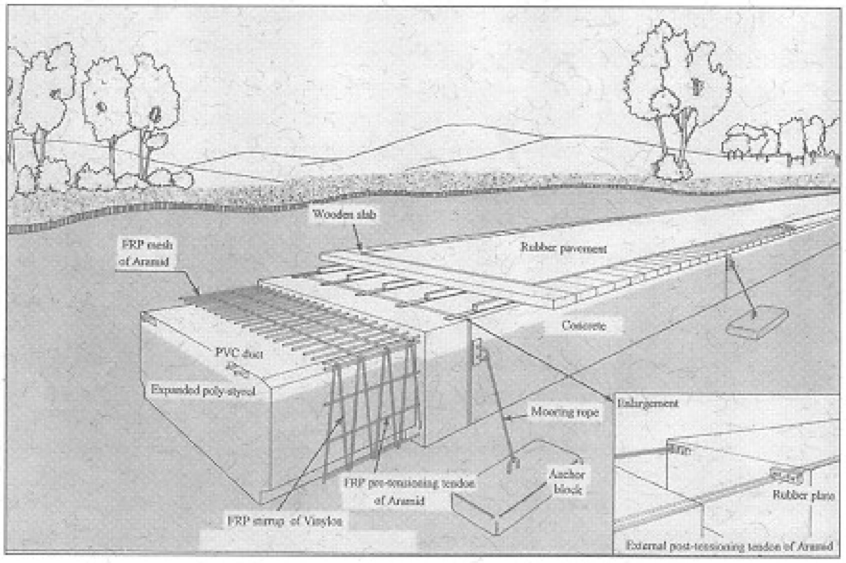


Figure 10.
Cross section of the floating bridge

GFRP Reinforcements In USA

The University of Alabama Birmingham Medical Centre which was completed in 1991 and the National Institute of Environmental Health Sciences, currently under construction at the Research Triangle Park, N.C., used glass fiber reinforced plastic (GFRP) reinforcement bars for the concrete structure supporting their Magnetic Resonance Imaging (MRI) Facilities. This type of structure is highly sensitive to magnetic fields: therefore, the use of ferrous metals are restricted due to their magnetic characteristics. Stainless steel has been used and is still in use as reinforcements; however, their cost is estimated at twice the cost of GFRP materials.

Other recent projects exploiting the non-magnetic characteristics of GFRP, are numerous compass calibration pads at airports in the USA. Aircraft use these areas, which are specifically oriented in relation to the earth's magnetic field, for adjustment of on-board navigation equipment. Coming issues of *FRP International* will present specific projects.

For further information, please contact Mr. Philip Catsman, Corrosion Proof Products, Inc., Tel: 402-359-2269.

First Canadian Smart Highway Bridge

Construction of the first concrete highway bridge in Canada prestressed by FRP tendons, was completed and the bridge opened to traffic on 15 November, 1993. The Beddington Trail/Centre Street bridge in Calgary, Alberta, shown in Figure (11), is a two-span continuous skew bridge, with 75 feet and 63 feet spans consisting of 13 bulb-tee section, precast prestressed concrete girders in each span. Carbon fiber composite cables, CFCC, 5/8" in diameter produced by Tokyo Rope, Japan, were used to pretension four girders while the other two girders were pretensioned using two 3/8" diameter Leadline rod tendons produced by Mitsubishi Kasei. Fiber optic Bragg grating strain and temperature sensors were used to monitor the behaviour during construction and under serviceability conditions. The 4-channel Bragg grating fiber laser sensing system was developed at the University of Toronto Institute for Aerospace Studies. Before construction of the bridge, an experimental program was conducted at the Structural Engineering and Construction R & D Facility, University of Manitoba, to examine the behaviour of 1:3.3 scale model beams pretensioned by the same size of anchorage of the two different types of tendons used for the bridge. For detailed information please contact Dr. S. Rizkalla, University of Manitoba, Winnipeg, Manitoba, Canada R3T 5V6, FAX: 204-275-3773.

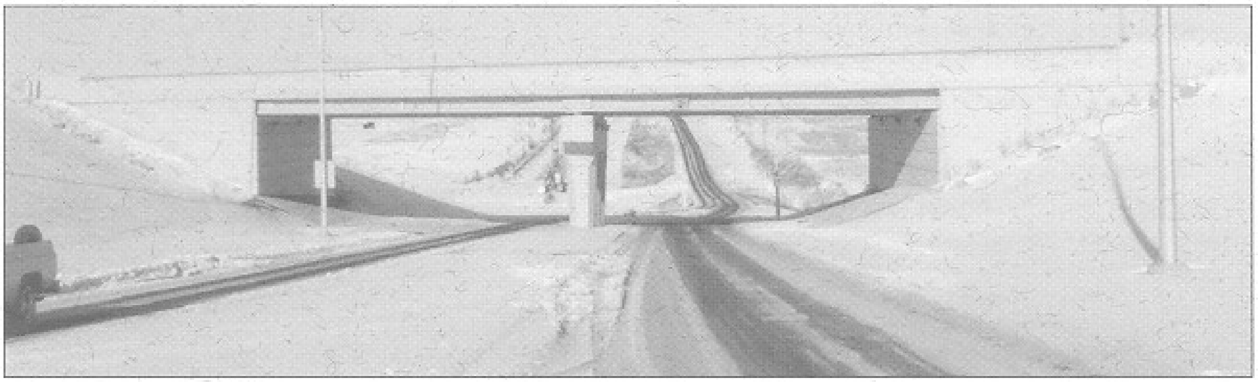


Figure 11. Beddington Trail/Centre Street Bridge, Calgary, Canada

Faculty of Engineering
Room 350 Engineering Bldg.
University of Manitoba
Winnipeg, Manitoba
R3T 5V6

STAMP

To:______________________________