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Prof. Nagataki is currently the chairman of the Concrete Committee of the Japan Society of Civil Engineering, the highest position in concrete engineering in this society. He was also responsible for organizing the present subcommittee on Continuous Fiber Reinforcing Materials (FRP); this subcommittee is currently working on producing a state-of-the-art report on the subject, and is also preparing the Japanese code recommendations for the design and construction of concrete structures using FRP rods. In addition, Prof. Nagataki is the chairman of the standards specifications committee for the design and construction of concrete structures. Prof. Nagataki received his Doctor of Engineering from the University of Tokyo in 1966 and he is a Fellow in the American Concrete Institute.

Although his current research is concentrated on high performance concrete, twenty years ago he and his research team published the results of pioneer research in the field of prestressing using glass fibre reinforced plastic (GFRP) rods. His paper was the first research paper published on this subject in Japan. The research included using beams prestressed by 9 mm GFRP rods, normally used at the time in the production of fishing rods. His research work proved to be a significant milestone in the use of FRP for prestressing special types of concrete structures, such as those for the linear motor car Maglev. Prof Nagataki's work also established the need for more extensive research in this field to improve the material's properties with respect to anchorage problems, shear strength of FRP rods, resistance to temperature, and brittle failure; after twenty years, these remain the most urgent research topics in this field.

In This Issue

Composite Structures

Longest Prestressed Concrete Bridge Using CFCC In Japan

The longest prestressed concrete bridge using Carbon Fiber Composite Cable (CFCC) in Japan, located at a golf course in Aichi Prefecture, has recently been completed. The bridge is a prestressed concrete rigid frame type, 110.0 m long with a clear span of 75 m, as shown in Figure (1). All the tendons used were CFCC, and the girder erection was accomplished by the cantilever erection method. Both internal and external cables were utilized in this bridge.

Internal cables were used to support the self weight loads during the erection stage, whereas external cables were placed to resist the kerb works and the live loads. To avoid any possible damage, the slope of the cables was restricted to 10 degree angles and the curvature was restricted to 8 meters in radius. Non-metallic ethylene sheaths were used. For external cables however, a straight-line arrangement was used between the front tip of the main girder and the abutment, taking into consideration the structural characteristics of the bridge. The external cables were protected by polyethylene pipes, without grouting.

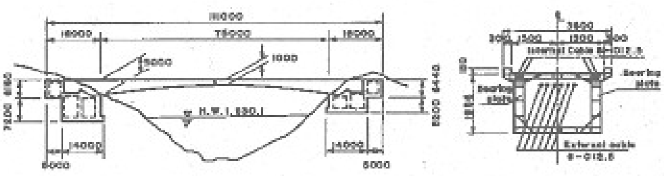

Figure 1. Cross section of the Tsukude Country Club Bridge

The main girder was divided into 23 blocks of 2.5 m to 3.5 m long, and the work commenced from both abutments by the cantilever erection method with the use of travellers. For both type of cables, six CFCC strands, with diameters of 12.5 mm each, were grouped into one multi-cable. Both types of cables were post-tensioned.

For further information, please contact Yoshiaki Imai or Fumio Seki, Civil Engineering Design Department, TAISEI Corporation, 1–25–1, Nishi Shinjuku, Shinjuku-ku, Tokyo 163–06, FAX: 81–3–3348–1147.

Advanced Waterfront Technology Demonstration Pier

The U. S. Army Corps of Engineers Construction Research Engineering Laboratories (USACERL) in Champaign, Illinois, the South Dakota School of Mines & Technology of Rapid City, South Dakota, the Naval Civil Engineering Laboratory (NCEL) in Port Hueneme, California and the Marine/Waterfront Task Group of the Composites Institute, New York, New York, are joining forces to build the world's largest waterfront demonstration pier at an NCEL site in Port Hueneme, California.

Plans call for the construction of an Advanced Waterfront Technology Test Bed (AWTTB) with overall dimensions of 20 ft. in width by 160 ft. in length. Structural composites will be used throughout the test pier for reinforcing prestressed concrete piling, pile caps and decking. One 20 ft. by 20 ft. section of the pier will feature an all-composite deck capable of handling 221 kips concentrated load on a 2.5 ft by 2.5 ft area. The balance of the pier will demonstrate half-scale segments of experimental composite structural concepts such as soffit plates and king and queen posts.

The overall installation will also demonstrate a wide variety of off-the-shelf composite products such as railings, gratings, ladders, catwalks, pier utilities, lighting poles, pipe hangers, and electrical and equipment enclosures. These products will be installed on the AWTTB pier and monitored as part of a program to develop new guide specifications for composite marine/waterfront applications. For additional information, contact the Composites Institute offices in New York, Tel: (212) 352–5410, FAX: (212) 370–1731.

JSCE Award for the Stress-Ribbon Footbridge

Kajima Corporation received the Japan Society of Civil Engineers Award in 1991 for the Birdie Bridge. The 54.5 m Birdie Bridge, Figure (2), located at the Southern Yard Country Club in Ibaragi Prefecture and built by Kajima, is the world's longest stress-ribbon footbridge built with FRP. LEADLINE was used in the ground anchors retaining the abutments, and pre-and post-tensioned ARAPREE was used in the bridge slab. The permanent formwork of the structure was constructed using CFCC reinforcement and vinylon (KURALON) fiber reinforced concrete.

Figure 2. Birdie Bridge in Southern Yard Country Club, Ibaragi

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Durashield Panels

In recent years, "all-fibreglass" buildings for computer testing, calibration of electronic equipment and EMI-RFI testing have been constructed using DURASHIELD Fibreglass foam core building panels as roofing, rooftop enclosures, and enclosures for chemical processes. Using DURASHIELD panels, 24 inch EXTREN I-beams and FIBREBOLT fasteners, MMFG designed and fabricated an all-fibreglass building for the John Fluke Manufacturing Company of Everett, Washington in 1991(Figure 3). Only a forklift was used to erect the panels, and since construction, the building has functioned well in the extreme Washington weather without requiring painting or other maintenance.

For more information, please contact Morrison Molded Fiberglass, Western Regional Sales Office, 9227 Haven Avenue, Suite 330, Rancho Cucamonga, CA 91730, USA. Tel: (714) 941-1875, FAX: (714) 941–8265.

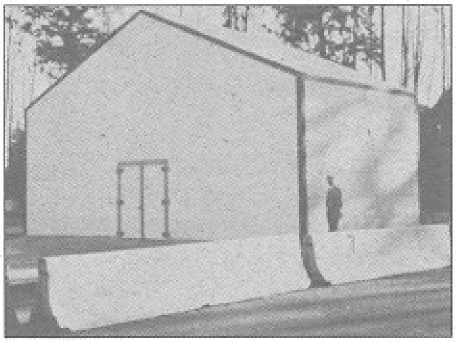

Figure 3. Durashield construction in Everett, Washington

FRP for Bridge Repairs

A consortium of St. Louis researchers and business people, led by Dr. J.L. Kardos, Chair of the Washington University Department of Chemical Engineering, has proposed helping the defense industry by using the composite materials developed for military hardware to repair and earthquake retro-fit bridges. The Composites for Civil Structures was formed in 1991 with members from Washington University, McDonnell Douglas Corp., Production Inc., Zoltek Corp. and Missouri Advanced Technology Institute, combining impressive manufacturing and research expertise in carbon fiber technology. Faced with 125,000 structurally deficient bridges in the U.S., the consortium estimates that up to 100,000 new jobs could be created with large-scale use of composite materials for bridge repairs. Between $20 to $30 million in US federal funds over a six-year period will permit the consortium to gain access to the $50 billion annual market for bridge repairs, and the consortium would be self-sustaining at the end of the six years.

For more information, please contact Tony Fitzpatrick, Washington University in St. Louis, Tel: (314) 935–5272.

CFCC for Prestressed Concrete Pier

At Fukuoka prefecture in Japan, CFCC (Carbon Fiber Composite Cable) was used for a prestressed concrete pier constructed by the Coastal Development Institute of Technology. This pier replaced an old one suffering extensive salt-injury damage. The construction method used consisted of laying precast concrete slabs with CFCC tendons on the beams, arranging steel bars and casting concrete as an overlay on the top of the CFCC slab. As a result, the pier becomes the composite structure. The slabs were pretensioned using CFCC, and they were post-tensioned using CFCC on site, as shown in Figure (4).

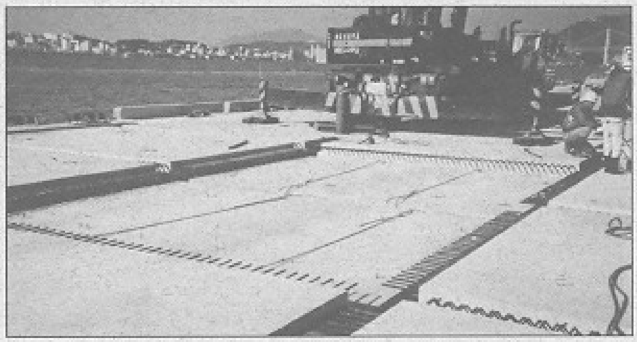

Figure 4. Overhead view of the laid CFCC slabs

New Committees and Task Forces

New Composites Coordinating Council

In a bold move towards the future of structural composites in civil engineering, the Civil Engineering Research Foundation (CERF), in Washington, D.C. has undertaken the task of organizing a new National Coordinating Committee (NCC) for high performance composites used in infrastructure construction. CERF is the research arm of the American Society of Civil Engineers (ASCE).

The new American NCC will identify and coordinate end-use market needs, R&D, demonstration projects, and technology transfer with the goal of achieving widespread commercial use of structural composites in civil engineering and infrastructure repair by the end of the decade. The NCC encourages active participation by all leading construction and composites industry influence factors, including ACI, ASCE, NSPE, ASME, SACMA, SAME, SAMPE, government labs and agencies, universities, etc. Industry experts consider this new model of inter-agency cooperation to be one of the most important developments in recent years.

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Presently, a steering committee chaired by Dr. Gregg McKenna of the National Institute of Standards & Technology (NIST) is developing a seven-to-ten year research plan. A national forum is planned to permit review and revision of the plan before it is submitted to participating organizations and the American federal government for approval and funding. For additional information about the new CERF National Coordinating Council, please contact Dr. Gregg McKenna at Tel: (301) 975–6752 or Carl Magnall at CERF, Tel: (202) 842–0555, FAX: (202) 789–2943.

New Infrastructure Task Group

The Composites Institute, a 425-member organization serving the composites industry, is forming a new "Composites Infrastructure Task Group" (CITG). With J. Rich Alexander of PPG Glass Fibers serving as chairman, the mission of this task group will be to focus composite industry resources on a number of recently-identified opportunities for structural composites in civil engineering and infrastructure construction. CITG plans to team up with other leading civil engineering trade and professional organizations including the American Society of Civil Engineers (ASCE), American Concrete Institute (ACI), Civil Engineering Research Foundation (CERF), government laboratories, universities and others to conduct research & development as well as demonstration projects to promote wide-spread acceptance of structural composites.

One of CITG'S most important priorities will be to support the research and testing of composite reinforcements for concrete, including dowel bars, reinforcing rods, prestressing and post-tensioning tendons as well as cable stays. Other application development efforts will focus on all-composite bridge decks, stay-in-place formwork and support provision to ongoing research programs. Although the group was only formed in mid-August, there is already a high level of program activity.

Participation in the Composites Institute Task Group program activities is limited to individual or organization members of the Composites Institute who enroll in and subscribe to the new group. For information about joining the Composites Institute, contact their New York offices at Tel: (212) 351–5410, FAX: (212) 370–1731. To learn more about the new Composites Infrastructure Task Group, contact Douglas S. Barno, CI's market development specialist at Tel: (614) 587–1444, FAX: (614) 587–2187, or Richard D. Rodriguez, CITG's marketing sub-committee chairman at Tel: (919) 990–7831, FAX: (919) 990–7749.

ACC Club of Japan

Founded in 1991, the ACC Club of Japan promotes the development and applications of carbon fiber, aramid fiber, and other new composite materials in the construction industry. Currently the membership consists of 48 general contracting and prestressing companies, along with 11 associate members consisting mainly of materials manufacturers. Within the ACC Club there are six specialty committees, representing CFCC, Arapree, Technora, FiBRA, LEADLINE, and NEFMAC. Through the Japan Society of Civil Engineers, the ACC Club is commissioning research in this area. The ACC Club will be an exhibitor at the FIP Symposium '93 in Kyoto.

For more information, please contact Tatsuhiko Iwasaki, Secretariat of ACC Club, A.M. Engineering K.K., Koga Bldg., 2–3–14 Muromachi Nihombashi Chuo-ku, Tokyo 103. Tel: 81-3–3231-0690, FAX: 81–3–3241–292.

IABSE Working Group on FRP

The International Association for Bridge and Structural Engineering (IABSE) has formed a technical committee, called Case Histories of the Use of New Materials in Structural Engineering, under the chairmanship of Dr. Baidar Bakht, Ministry of Transportation of Ontario, Canada. The objective of this technical committee is to report periodically on the existence of demonstration structures built with new synthetic materials, such as carbon, aramid and glass fibres, and to record their long term performance with a view to reporting on this aspect as well. The first report of the technical committee is expected within the next year. For further information please contact: Dr. Baidar Bakht (WC2), Ministry of Transportation of Ontario, Structures Research Office, 1201 Wilson Avenue, Downsview, Ontario, Canada M3M 1J8, FAX: (416) 235 4872.

New Publications

Japanese Guidelines for FRP Concrete Structures

Since 1988, the Ministry of Construction of Japan and the Association of Composite Materials Using Continuous Fiber for Concrete Reinforcement (CCC) of Japan have been collaborating on a set of design and construction guidelines for concrete structures reinforced with FRP. The guidelines also include a state-of-the-art report on FRP grid and textile reinforcements. The guidelines will be available in 1994, through the Building Research Institute, Ministry of Construction. For more information, please contact Dr. Hirosi Fukuyama, Building Research Institute, Ministry of Construction, 1-Tatehara, Tukuba Ibaraki 305, Japan, Tel: 81-2-9864-2151, FAX: 81–2–9864–2989.

FRP Reinforcement for Concrete Structures: Properties and Applications

This new book, edited by A. Nanni, makes a further contribution to advancing knowledge and acceptance of FRP composites for concrete reinforcement. The articles are divided into three parts. Part I introduces FRP reinforcement for concrete structures and describes general material properties and manufacturing methods. Part II covers a three-continent perspective of current R&D, design and code implementations, and technical organizations' activities. Part III presents an in-depth description of commercially available products, construction methods, and applications. The work is intended for engineers, researchers, and developers with the objective of presenting them with a world-wide cross-section of initiatives, representative products and significant applications.

Contents: Part I – Introductory Topics: FRP reinforcement for prestressed and non-prestressed concrete structures (A. Nanni); FRP reinforcement, materials and manufacturing (C.E. Bakis). Properties of FRP reinforcements for concrete (L.C. Bank).

Part II – International Perspective: A Canadian perspective on R&D, design/codes and technical committees (M.A. Erki, S. H. Rizkalla); FRP developments and applications in Europe (L.R. Taerwe); An overview of R&D in Japan (Y. Sonobe); FRP developments in the United States (C. Dolan).

Part III – FRP Reinforcement Products. Part III.a: 1-D Reinforcing Systems: Glass FRP reinforcing bars for concrete (S.S. Faza, H.V.S. GangaRao); Properties and applications of vinylon FRP Rod [CLATEC Rod] (M. Okazaki); CFCC [Carbon FRP Cable] (N. Santoh); Testing and application of prestressed concrete beams with CFRP tendons (T. Katou, N. Hayashida); TECHNORA; an aramid FRP rod (K. Noritake, R. Kakihara, S. Kumagai, J. Mizutani); FiBRA (T. Tamura); Glass fiber prestressing system (R. Wolff, H. J. Miesseler); PARAFIL ropes for prestressing applications (C.J. Burgoyne).

Part III.b: 2-D and 3-D Reinforcing Systems: NEFMAC – Grid type reinforcement (M. Sugita); Three dimensional fabric reinforcement (H. Nakagawa, M. Kobayashi, T. Suenaga, T. Ouchi, S. Watanabe, K. Satoyama); New three-dimensional FRP reinforcement (T. Yonezawa; S. Ohno; K. Inoue; T. Fukada; R. Okamoto).

Part III.c – External Reinforcing Systems: FRP bonded sheets (U. Meier, M. Deuring, H. Meier, G. Schweler); A retrofitting method for reinforced concrete structures using carbon fiber (Y. Kobatake, K. Kimura, H. Katsumata).

If you are interested in the above publication, send your order to your usual supplier or to: Elsevier Science Publishers, P.O. Box 211, 1000 AE Amsterdam, The Netherlands; or in the USA and Canada; Elsevier Science Publishing Co. Inc., P.O. Box 945, Madison Square Station, New York, NY 10160–0757. Price: Dfl 340.00 (US$ 194.25).

Workshops

Canada-Japan Workshop Held in Ottawa

A highly successful Canada-Japan Workshop on the use of advanced composite materials in bridges and structures was held 28–30 July 1993, in Ottawa, Canada. The Workshop was hosted by the Nova Scotia CAD/CAM Centre, the Canadian government's Japan Science and Technology Fund, and the Advanced Composite Materials in Bridges and Structures Network of Canada. The major objectives of the workshop were to define research and business areas for enhanced science and technology in the use of advanced composite materials in bridges and structures, and to foster cooperation between Canadian and Japanese universities, public and industrial organizations, and practising engineers.

Figure 5. Canada-Japan Workshop participants

There were four working groups organized to discuss R&D and human resources development, design concepts, FRP rods and tendons, and other ACM products. The Canadian delegates learned that Japanese companies working in the field of ACM for civil engineering construction have organized three important associations in Japan, namely the Association of Composite Materials Using Continuous Fiber for Concrete Reinforcement (CCC), with over 30 corporate members, the Advanced Composite Cable Club (ACC), with over 50 corporate members, and the Carbon Fibre for Civil Application (CCA), with over 120 corporate members. Among the many significant exchanges at the workshop, it was agreed that the Advanced Composite Materials in Bridges and Structures Network of Canada and these Japanese associations would regularly exchange information about their activities. A group photo of the Canadian and Japanese delegates is in Figure (5).

FRP Research

U.S. Corps of Engineers Awards Composites Research Grants

The U.S. Army Corps of Engineers Headquarters recently announced that it has awarded two major research grants to investigate the use of structural composites in civil engineering and infrastructure applications to two universities and the Marine/Waterfront Task Group (MWTG) of the SPI Composites Institute. The awards are part of the Corp's 1993 Construction Productivity Advancement Research (CPAR) program. The CPAR program is a unique partnership in which Corps laboratories join forces with university and industry partners. Of a total of 12 grants awarded in 1993, two of the largest involved structural composites. Under the leadership of Robert D. Sweet of Creative Pultrusions, Inc., Chairman of the CI Marine/Waterfront Task Group, a total of three CPAR proposals were submitted for 1993. Two of the three proposals submitted were approved.

The first CPAR proposal, "Development and Demonstration of Composite Piling and Sheet Pile," partners the Corps of Engineers Construction Engineering Research Laboratories (USACERL) in Champaign, Illinois with Rutgers University in New Brunswick, New Jersey and the Marine/Waterfront Task Group of the Composites Institute in New York. This project will be conducted in three phases over a three year period. The total value of the project is $2.55 million.

The second CPAR is, "Development and Demonstration of Advanced Hybrid Composite Structurals." Participants are USACERL, West Virginia University's Constructed Facilities Center in Morgantown, West Virginia and the Marine/Waterfront Task Group of the Composites Institute. The program will be implemented in four phases over a three-year term; total project value is approximately $1.6 million.

For additional information, contact the Composites Institute in New York at Tel: (212) 351–5410, FAX: (212) 370–1731 or the appropriate university.

Long-Term Behaviour of FRP Bridges

The Federal Highway Administration (FHWA) has recently awarded a grant to Georgia Tech, Catholic University, and Penn State University to develop accelerated test methods for determining the long-term behaviour of fiber-reinforced polymer (FRP) composites for bridges. The purpose of the study is to provide future researchers with common test methods, acceptable to the highway bridge design community, that can measure FRP structural behaviour so that design criteria and data may be developed for existing materials. These test methods will also provide the industry with an accepted test method for evaluating composites custom-designed for highway bridges. The major thrusts for this plan are: to develop tests for four different mechanical and environmental loading conditions; to perform both destructive and non-destructive mechanical testing; to perform chemical analysis of deteriorated FRP materials; and to develop mathematical models that can predict the long term behaviour of FRP materials and structures.

To accomplish the objective, a team of internationally known researchers in the areas of structural engineering, mechanics, design and testing of both FRP and FRP/Concrete hybrid materials, highway bridge design and construction, non-destructive testing, and polymer chemistry has been assembled from three different universities that have a history of pioneering research in the area of FRP structures. The research at each institution will be lead by three co-principal investigators: Dr. A. Zureick (Georgia Tech), Dr. L. C. Bank (Catholic U.) and Dr. A. Nanni (Penn State) (see Figure 6). The co-principal investigators will be jointly responsible for all phases of the proposed research. However, they will provide leadership in different areas, each of which falls into an area of expertise of one of the PI's of the project.

Figure 6. Investigators Lawrence Bank, Antonio Nanni, and Abdul-Hamid Zureick

Test methods for the environmental loading of stand-alone FRP materials and FRP/concrete hybrid materials will be the primary responsibility of Dr. Lawrence Bank at Catholic University. Here the concern will be with irreversible material degradation, damage and deterioration in the presence of adverse exposure, and environmental conditions. Test methods for the mechanical loading of stand-alone FRP composite material structures will be the primary responsibility of Dr. Abdul-Hamid Zureick at Georgia Tech. This will include creep tests, cyclic tests, fatigue tests and impact. The effects of temperature and moisture fluctuations that do not cause irreversible material degradation will be considered in this sub-study. The methods for the mechanical characterization of FRP/concrete hybrid structural materials will be the primary responsibility of Dr. Antonio Nanni at Penn State. The focus of this sub-study is to characterize the mechanism of interaction between FRP reinforcement and concrete for both prestressed and non-prestressed

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systems. The mechanical performance of the interface between the two materials affects bond strength and slip, stress concentration in the FRP, and mode of failure of the system.

Georgia Institute of Technology is serving as the contracting institution, and Dr. Zureick is serving as the overall Project Manager. For additional information please contact: Dr. Abdul-Hamid Zureick, Georgia Institute of Technology, School of Civil Engineering, Atlanta, GA 30332, TEL: (404) 894–2294, FAX: (404) 894–2278 E-mail: abdul.zureick@ce.gatech.edu.

NMI Projects On FRP Reinforcement

The National Maglev Initiative (NMI) is a partnership between American federal government agencies and the private sector to determine the potential for Maglev transportation in the U.S.A. Some of the funds made available by Congress to assess the technical feasibility of Maglev systems have been and are now being used to support research in the area of FRP reinforcement for Maglev guideways.

A short-term project is currently underway at Penn State to evaluate the performance of selected tendon-anchor systems in terms of ease and reliability of the prestressing operation (including prestress losses due to anchor slip), and to determine the stress field in a selected tendon-anchor system by finite element modelling. Tendon-anchor systems from companies in Europe (Linear Composites, NDI and SIREG), Japan (Mitsubishi Kasei, Mitsui Construction, Teijin/Sumitomo Construction, and Tokyo Rope), and the U.S. (NEPCO) will be included in the project.

For more information contact: A. Nanni, Penn State, Tel: (814) 863–2084, FAX: (814) 863–4789 or E. O'Neil USACE-WES, Tel: (601) 634–3387, FAX: (601) 634–3242.

FRP Research In Japan

The Japanese Ministry of Construction Public Works Research Institute has been pursuing research on the use of FRP products as tensioning materials for prestressed concrete bridges, within the frame work of the Ministry's research project entitled "Development of New Base Materials Utilisation Techniques in Construction Projects". Ten private companies are also involved in this research.

This series of studies was carried out over the four years from April 1989 to March 1993, under the following headings:

- The performance required of FRP tensioning materials (April 1989-March 1991)
- Investigation of the qualitative characteristics of FRP tensioning materials (April 1989-March 1991)
- Study in sheaths for prestressed concrete beams using FRP tensioning materials (April 1990-March 1992)
- Study of anchoring methods for FRP tensioning materials (April 1990-March 1992)
- Study of durability performance of prestressed concrete beams using FRP tensioning materials (April 1990-March 1993)
- Study of load-bearing performance of prestressed concrete beams using FRP tensioning materials (April 1990-March 1993)

A range of tests were performed in pursuit of these studies, using two types of carbon FRP, two types of aramid FRP and a type of glass FRP.

The ultimate aim of this project is to produce a set of draft guidelines on design and construction using FRP tensioning materials, which is now almost complete in Japanese and English versions.

The results of the entire series of tests will be announced at the FIP International Conference to be held in Kyoto, Japan in October of this year.

FHWA Research for Roadside Safety Structures

The American Federal Highway Administration (FHWA) Design Concepts Research Division, is currently investigating FRP Materials for roadside safety structures. These structures in general include guardrail type barriers, crash cushions, signs and lighting supports. This investigation—initiated in 1990 by FHWA—is currently staffed with Government employees, contract employees, and a three-year cooperative agreement with the Catholic University of America (CUA) in Washington, D.C.

The research in this area concentrates on laboratory

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testing and computer (finite element) simulation to evaluate the behaviour of various glass FRP materials. The ultimate goal is the development of a complete FRP guardrail system. As a part of this effort, small scale drop weight impact tests have been conducted at the FHWA Turner-Fairbank Highway Research Centre (TFHRC) in McLean,Virginia. Samples from commercially available pultruded material, as well as samples made from a vacuum bag lay-up process at CUA, have been tested to optimize matrix static tests on the materials considered. In addition, volume fraction testing has been performed to give complete fiber, resin and filler content and fiber structure information for each.

In the next two years, both FHWA and CUA will continue this research in each of these areas:

- Laboratory static testing and pendulum impact testing of FRP specimens on a one-third scale of the current guardrail.
- Computer simulation of the impact FRP materials, including rail/post/soil interactions and design studies.
- Fabrication of optimized FRP rail structures by a vacuum bag lay-up at the CUA lab and eventually the pultrusion process.
- Development of connections for FRP rail structures.
- Full scale crash testing at the FHWA Federal Outdoor Impact Laboratory (FOIL)

For more information, contact Mr. Martin Hargrave, Research Engineer, FHWA McLean, VA, 22101, FAX: (703) 285–2379 or Dr. Lawrence Bank, CUA, Washington, D.C. 20064, FAX: (202) 319–4499.

M.Sc. Theses

The following are some theses recently completed at Penn State University Department of Architectural Engineering related to FRP research:

BRADFORD, N.M., "The Strength and Ductility Enhancement of Concrete Members Subjected to Lateral Confinement Using FRP Materials," M.Sc. Thesis, 1993.

HENNEKE, M.J., "Evaluation of Hybrid Reinforcement (FRP Rod with Steel Core)," M.Sc. Thesis, 1993.

NORRIS, M.S., "Lateral Confinement of Concrete Using FRP Reinforcement," M.Sc. Thesis, 1993.

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