FRP

Fiber Reinforced Plastics

International

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Society Profile – ASCE

The first formal participation of ASCE in the emerging technology of synthetic structural composites was in 1962 when a small group of civil engineers met to consider the formation of a technical committee on plastics. Shortly thereafter, ASCE authorized the establishment of the *ASCE Committee on Plastics* within the Structural Division of the Society. In the early 1960's most American civil engineers were not interested in a construction material which sold by the pound since they were accustomed to thinking in terms of cost per ton of steel or per cubic yard of concrete. Also, designers did not feel comfortable specifying a structural material for which very little technical and performance information was available from manufacturers or suppliers.

In 1971, the Committee on Plastics moved from the Structural Division to the ASCE Technical Committee on Research and was renamed the Structural Plastic Research Council (SPRC). The goal of the SPRC was to publish a three-volume set of technical manuals describing the design of load-bearing members, the selection of appropriate materials, and the design of connections within a structure. Ongoing activities and objectives for promoting the use of structural plastics in the construction industry were also pursued by sponsoring technical seminars and encouraging the publication of timely papers related to the application, design, properties and economics of structural plastic systems in civil engineering projects.

A task force committee was appointed to oversee the solicitation of funds for the development of the manual, to select a contractor for the project and to monitor the work as it progressed. The contract cost for this document was approximately $135,000 and it was published in 1985. Development of the third manual, which deals with the design and anticipated performance of connections appropriate for laminates of structural plastics, was divided into two phases. Phase 1 was completed by the contractor in early 1993. The completion of Phase 2 has been delayed due to both technical and administrative issues. The anticipated cost of the third manual is approximately $100,000. Currently, considerations are underway to update and revise the Design Manual to reflect advances in available materials and analytical procedures since 1984.

In late 1988, ASCE management reorganized internal research activities and transferred administrative oversight of the SPRC to the Materials Division of the Society. Thus, the SPRC assumed the status of a technical committee within a principal technical division. In spite of the educational efforts by the SPRC for two decades and the production of

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two major guidelines for the selection of materials and design with structural plastics, the subject seemed to remain just an interesting curiosity among many of the members of ASCE.

In the early 1990's widespread interest in synthetic composites suddenly blossomed among the members of ASCE and other professional organizations with vested interests in constructed facilities. New faces appeared in seminars, short courses and technical meetings which focused on structural plastics. The membership of SPRC grew, new interests were introduced and hence it was desirable to broaden the scope of the committee into technical areas which had not been addressed previously. The name of the group was changed in 1992 to: *The Technical Committee for Structural Composites and Plastics (SCAP).* For more information, contact Fred C. McCormick, Professor Emeritus, University of Virginia, Charlottesville, Virginia.

ASCE Technical Committees

ASCE activities related to the composites and plastics material are carried out by three different committees operating under the Technical Activities Committee, as described below:

1. The Structural Composites and Plastics (SCAP) Committee in the Materials Division, chaired by Albert F. Dorris, is charged with advancing engineering knowledge and practice through stimulating and guiding research and assisting the financing of activities of its three subcommittees: Advanced Composite Reinforcements, Design Criteria for Adhesives and Connections, and Technology Transfer & Education. Prior to the formation of SCAP, these activities were carried out by the Structural Plastics Research Council which published two well-known ASCE Manuals: the Structural Plastics Selection Manual and the Structural Plastics Design Manual. SCAP currently has plans to develop a manual for adhesives and connections.

2. The Structural Composites and Plastics Standards Committee in the Building Standards Council, chaired by Max L. Porter, is charged with developing standards for design, fabrication, and erection of structural building elements made of composites materials.

3. The Advanced Composite Materials Committee in the Aerospace Division is charged with promoting the generation and transfer to technology on advanced composite materials for aerospace and civil engineering applications, including analytical and experimental endeavors such as processing and mechanics.

An effort is underway to coordinate the activities of three groups in the areas of Piling Systems, Stability, Connections, Material Properties, LRFD considerations, Tension Members, Panel systems, Dynamic Considerations, and Terminology and Definitions. Those interested in participating in any of the above ASCE committees may write to Ms. Megan Prosser, ASCE, Suite 600, 1015 15th Street NW, Washington, DC 20005.

Applications

Composite Highway Bridge

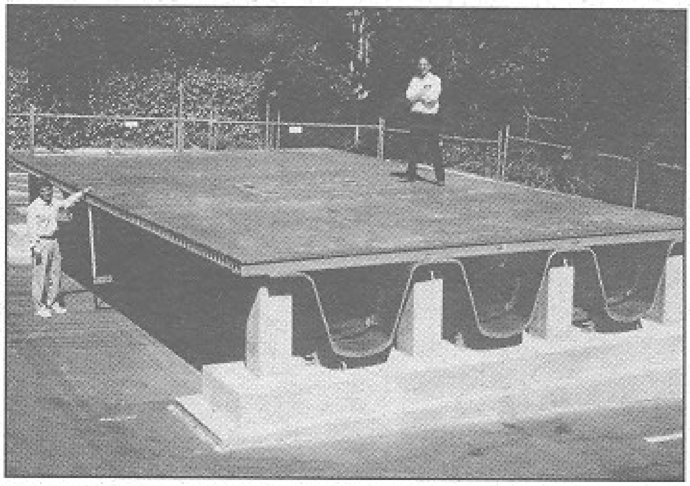

Figure 1. GFRP Highway Bridge.

Lockheed Martin's Palo Alto Laboratory successfully designed, built and tested a full-scale, 30-foot demonstration highway bridge. The design targeted simply supported bridges in the range of 120 foot-span category. The bridge utilizes two essentially repeating components—a deep U-shaped support beam superstructure and a top traffic bearing road deck, as shown in Figure 1. The components are fabricated by two commercial fiberglass fabricators. ACME Fibreglass (Hayward, CA) fabricated the 18 by 18 foot bridge deck panels shown in Figure 2, and Ron Moor Sailboats (Watsonville, CA) made the 30 foot support beams shown in Figure 3. Lockheed and two fabricators worked closely to tailor the particular fabric composition and resins to the individual company's process style. The bridges are tested under load simulating a variety of HS20-44 wheel loads to 72,000 lbs., temperature effect and the influence of various support conditions. For additional information, please contact Philip Underwood, fax (415) 354-5489.

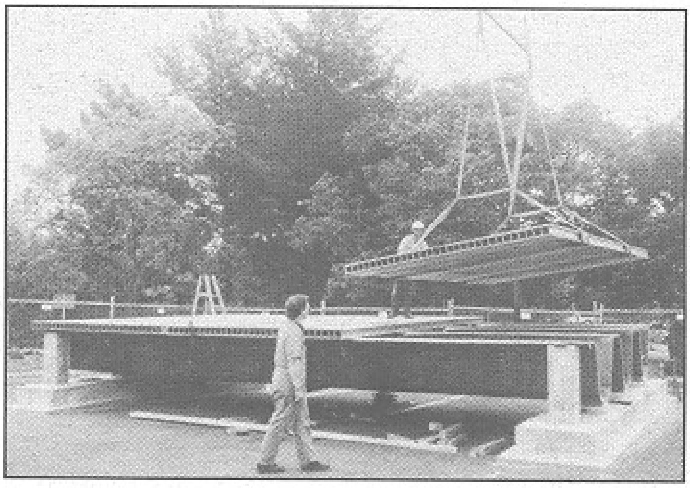

Figure 2. Fibreglass Bridge Deck.

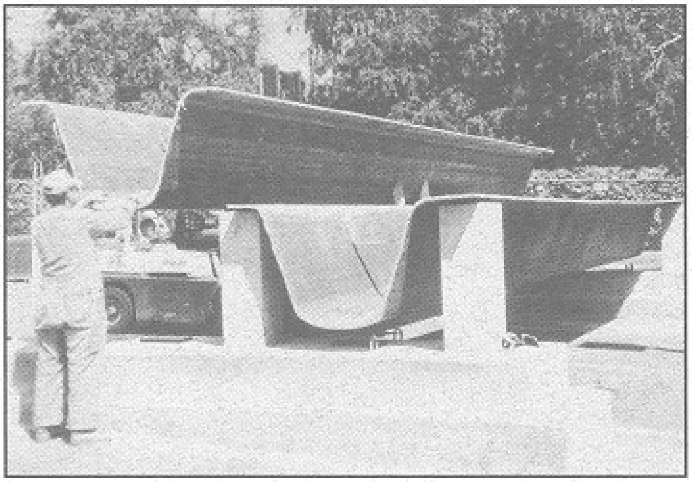

Figure 3. GFRP Bridge Beams.

Composite Tanks

Xerxes Corporation of Minneapolis, Minnesota has been a pioneer in the use of composites for the infrastructure. Composite underground petroleum storage tanks (USTs) (shown in Figure 4) were first introduced in 1964 to replace rusting steel USTs. There have been over 350,000 fiberglass tanks sold in the United States and the number grows each year as customers become more environmentally aware. Interest in composite tanks is high outside the USA, as well. ZC Composites, Inc., in Canada has been a very successful Xerxes' licensee for years and the Japan Steel Works, Ltd. is the newest licensee. Underground storage tanks are an excellent use of composites because the unique molding and manufacturing allows parts consolidation, the light-weight allows the use of smaller lifting equipment and the corrosion resistance avoids rust. For additional information contact Terry Jensen at telephone (612) 887-1828.

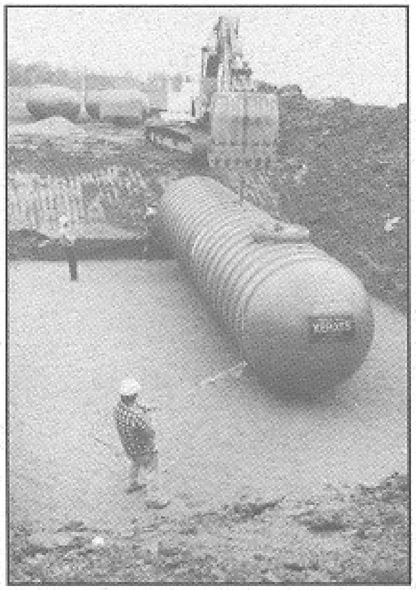

Figure 4. Installation of tank.

FRP Bridges

1. *Point Bonita Lighthouse Bridges, San Francisco, CA:* Two E-glass/isophthalic polyester resin pedestrian bridges spanning 35'-0" and 70'-0" have recently been completed in Golden Gate National Park by E.T. Tectonics, Inc., allowing the reopening of the trail to the historic Point Bonita Lighthouse. Overlooking the Golden Gate Bridge, these bridges will again allow access to the famous landmark and the wonderful views of San Francisco and the surrounding area. The bridges were designed for 100 psf live load and 40 psf uplift due to the extreme wind conditions on the point (Figure 5). Constructed of C8x2-3/16"x3/16"x3/8" and 2"x2"x1/2" square tube sections, the bridges were assembled off site in a parking lot area approximately 1/2 mile from the site and then air lifted by helicopter to the site. This was due to the dangerous site conditions which required installation into the Marin Headland Bluffs (sheer drop off of 120'-0"). The client, the Golden Gate National park Association, wanted the bridges to match an existing suspension bridge which leads south to the lighthouse. White pultruded sections were used.

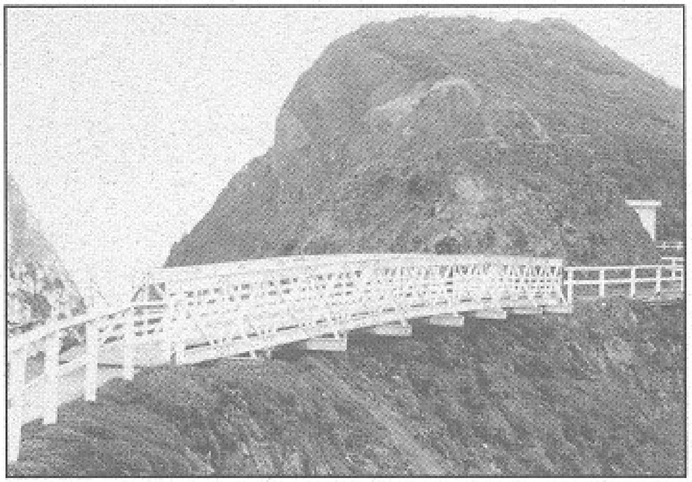

Figure 5. Point Bonita Bridge.

2. *Haleakala National Park Bridges, Maui, Hawaii:* Two E-glass/isophthalic polyester resin pedestrian bridges spanning 40'-0" and 80'-0" designed by E.T. Tectonics, Inc., are currently being constructed at Haleakala National park in Maui, Hawaii. The bridges will provide park visitors access to pristine locations on the Haleakala Volcano which are presently inaccessible. The bridges were designed for 60 psf live load, 20 psf wind load, and seismic zone 2 conditions. Pultruded sections for two bridges were provided by Creative Pultrusions, Inc., of Alumbank, PA. Fabrication of the bridges was done by Structural Fiberglass, Inc., of Bedford, PA.

Figure 6. Handicap Access Bridge at Catholic University.

3. Handicap Access Ramp/Catholic University, Washington D.C.: A 40'0" E-glass/isophthalic polyester resin handicap access ramp was recently completed at Catholic University in Washington, D.C., as shown in Figure 6. The ramp provides handicap accessibility to the University's Engineering School, Pangborn Hall. The structure was designed by E.T. Tectonics, Inc., of Philadelphia, PA using the PRESTEK Truss System. The ramp was designed for 100 psf live load and 20 psf wind load. Fabrication was done by Structural Fiberglass, Inc., of Bedford, PA. For more information: E.T. Tectonics, P.O. Box 40060, Philadelphia, PA 19106.

Large CFRP stay cables at the Stork Bridge in Winterthur, Switzerland

Since 1980 the Swiss Federal laboratories for Materials Testing and Research, EMPA, have been developing CFRP cables for cable-stayed and suspension bridges. They are produced as assemblies of parallel CFRP wires. The key problem facing the application of CFRP cables, and thus the impediment to their widespread use in the future, is design of the anchorage system. EMPA has been developing CFRP cables using a conical resin-cast termination. The evaluation of the casting material to fill the space between the metallic cone of the termination and the CFRP wires was the key to the problem. This casting material, also called load transfer media (LTM), has to satisfy multiple requirements:

- The load should be transfered without reduction of the high long-term static and fatigue strength of the CFRP wires due to the connection.
- Galvanic corrosion between the CFRP wires and the metal cone of the termination must be avoided. It would harm the metal cone. Therefore the LTM must be an electrical insulator.

The best design approach was found to be the use of a gradient material for the LTM. At the load side of the termination the modulus of elasticity is low and continuously increases until reaching a maximum. This design eliminated the shear peak within the anchorage. The LTM is composed of aluminium oxide ceramic (AJ_2O_3) granules with a typical diameter of 2 millimeters. All granules have the same size. To obtain a medium modulus the granules are coated with a thin layer. To reach a high modulus the granules are filled into the socket without any coating. With this method the modulus of the LTM can be designed tailor-made. The holes between the granuoles are filled by vacuum-assisted resin transfer molding with epoxy resin:

Many parallel wire bundles were tested at EMPA under static and fatigue loading. The results proved that the anchorage system described is very reliable. The static load carrying capacity generally reaches 92% of the sum of the single wires. This result is very close to the theoretical capacity. Fatigue tests performed on bundles with 19 and 241 wires showed superior performance of CFRP under cyclic loads. The anchorage system is patented and EMPA gave in December 1995 the worldwide exclusive license to BBR Ltd., Zurich.

In March 1996 two CFRP cables will be applied for the first time on a cable stayed vehicular bridge with 124 m span (Figure 7) in Switzerland. The ultimate load of each cable is 12 MN. Each cable is assembled out of 241 parallel CFRP wires of 5 mm diameter. The length of each cable is 35 m. The cables were fabricated by EMPA in cooperation with BBR Ltd and StahTon AG, Zurich. The mass of the cable per meter is only 7.3 kg (5 times lighter than steel). EMPA will perform remote monitoring measuring the cable loads and the displacement of the LTM in the anchorage cone.

Goal of this pilot project is to build up confidence of bridge owners in the use of advanced composite materials for primary structural components.

For further information contact: Urs Meier, Swiss Federal Laboratories for Materials Testing and Research, EMPA, FAX: +41 1 821 65 44, E-Mail: urs.meier@empa.ch.

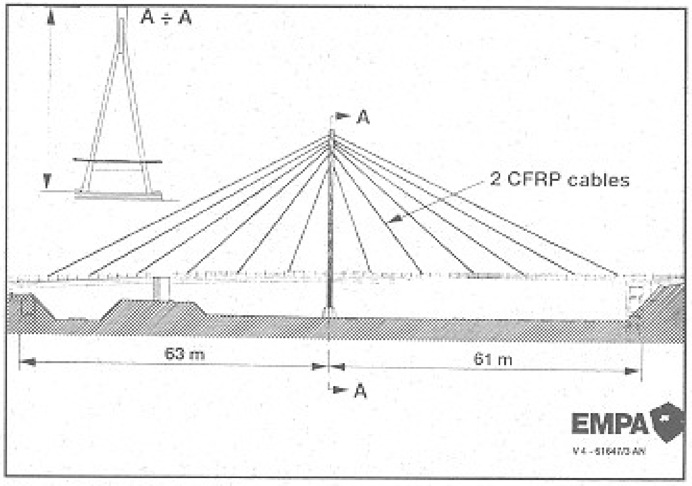

Figure 7. Stay Cable Bridge.

Research

Research at Georgia Institute of Technology

Since 1986, Professor A. Zureick of the School of Civil Engineering at Georgia Institute of Technology has been researching the strength of fiber-reinforced polymeric structures for use in new construction and in the rehabilitation of aging infrastructure. The program has involved testing of fiber-reinforced polymer structural components and systems of various dimensions under static and dynamic loads in adverse environmental conditions. Current projects at Georgia Tech are:

1. Accelerated Test Methods to Determine the Long-Term Behavior of FRP Composite Structures: Funded by the Federal Highway Administration (FHWA), see Figure 8. The purpose of this study is to provide researchers with common test methods, acceptable to the highway bridge design community, that can measure FRP structural behavior so that design criteria and data may be developed for existing materials, and to provide the industry with an accepted test method for evaluating composites custom-designed for highway bridges.

2. Development of an Innovative Technique for Processing Large Structural Shapes: This work, conducted with Morrison Molded Fiber Glass (MMFG) Company, is funded under the Advanced Technology Program (ATP) from the United States Department of Commerce, National Institute of Standards and Technology. The objective of this work is the development of innovative design and manufacturing techniques to produce new optimized deep composite structural members.

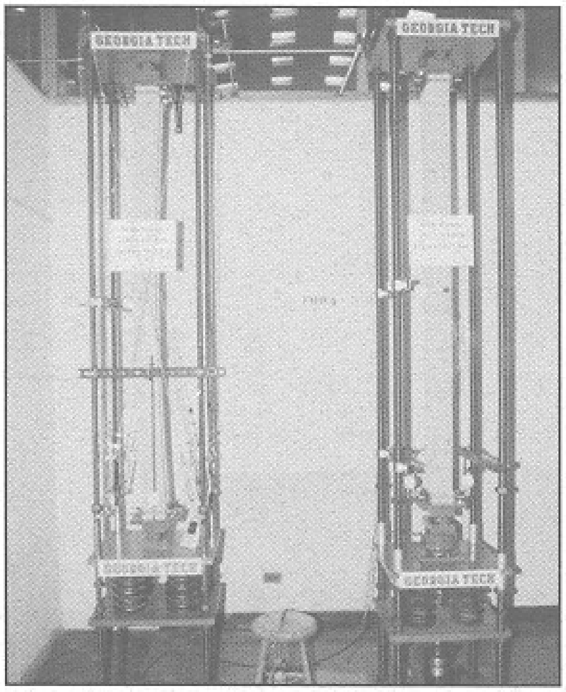

Figure 8. Creep testing of Pultruded Columns.

3. Development of Fiber-Reinforced Polymeric Deck for Offshore Structures: This work addresses a rigorous study of material properties, analytical techniques, and processing science of fiber-reinforced polymer decks. Full-scale tests are to begin in February 1996 with the objective of demonstrating these high value components for maritime platforms, portable ports, highway and pedestrian bridges.

4. Bridge Repair & Strengthening Methods Using Advanced Composites: The objective of this work is to develop and demonstrate advanced composite systems for in-place strengthening, repair, and upgrade of two bridge decks located in Gilmer County, Georgia. These two decks show varying degrees of deterioration and thus will provide an excellent opportunity to test the effectiveness of the repair techniques for a wide range of actual field conditions.

Research in Australia

Since 1993, the University of New South Wales, Australia, has been conducting research in FRP reinforcement for concrete and some results obtained by Scanning Electron Microscopy are shown in Figure 9. Currently, a team of five (Dr. N. Gowripalan, Professor R.I. Gilbert, Mr. X.W. Zou, Mr. Y.K. Chadian and Ms. H.M. Mohamed), in the Department of Structural Engineering of the School of Civil Engineering is conducting research on aramid (AFRP) and carbon (CFRP) fibre based materials. This research project includes the following areas.

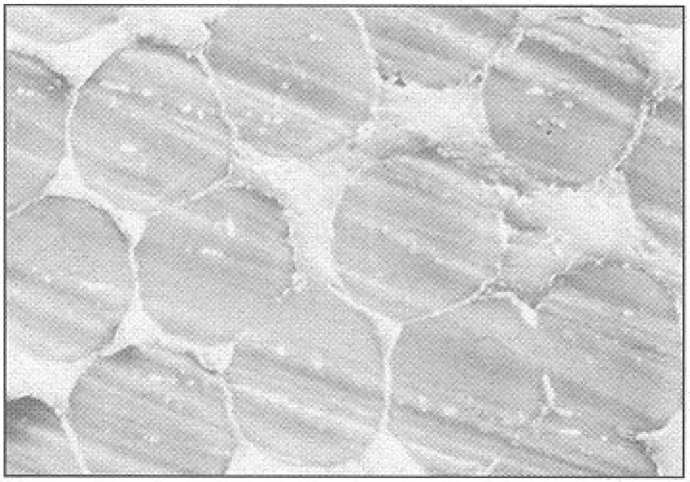
Figure 9. Scanning Electron Microscopy of Arapree tendon.

1. Short-term material properties such as characterization of the surface of FRP and bond stresses. 2. Long-term material properties such as relaxation and stress-rupture of AFRP and CFRP tendons. 3. Short-term structural behavior under slow cyclic loading of pre-tensioned beams with AFRP and CFRP tendons. 4. Long-term structural behavior under sustained loading of pre-tensioned beams with AFRP and CFRP tendons. 5. Durability related problems of AFRP in concentrated alkaline, acidic and salt solutions and in other harsh environments such as high temperature treatments.

Funding has been provided by the Australian Research Council Grants and industry. There is only one type of FRP bar produced locally, made of glass fibers, by Applied Research of Australia (AROA) Pty Ltd. in South Australia. These GFRP bars are extensively used as rock anchors and possibilities exist for them to be used as reinforcement in concrete structures in the future. The bars contain 74-78% of glass fibre by volume and are produced by a pull forming process that can give a higher fibre volume fraction than the pultrusion process. The bars (with deformations on the surface) are usually 1200 mm long (or 2400 mm by special order) with nominal diameter of 20 mm, and threaded at one or both ends to facilitate a anchorage. Currently, there are two types of FRP tendons available in Australia and these are imported from Germany, Italy or Japan. They are: 1. AFRP Bars (Arapree) - Manufactured by Sireg, Italy and supplied by Akzo-Nobel, Australia and 2. CFRP Bars (Leadline) and Carbon fibre sheets (Replark) - Manufactured by Mitsubishi Chemicals Corporation, Japan and supplied by Sumitomo Australia Ltd.

Concrete Constructions Group Pty Ltd. which is one of the largest groups in Australia, and firms such as Carbon Fibre Composites Pty Ltd., are keen to promote the use of FRP reinforcement for concrete structures in Australia. For example, the use of carbon fibre sheets (Replark) has been demonstrated in the rehabilitation of Sydney Opera House walkways by Concrete Constructions Group Pty Ltd. For further information contact Dr. N. Gowripalan at telephone +61-2-385 5146, fax +61-2-385-6139, School of Civil Engineering, University of New South Wales.

Thermal Compatibility of Concrete and Composite Reinforcement

The Catholic University of America has been awarded a grant to study the thermal compatibility of plastic composite reinforcements and concrete (Figure 10). If the two materials prove to be thermally incompatible, the bond between them may be degraded by long-term exposure to temperature fluctuations. The transverse isotropy of composite reinforcements may exacerbate considerations of thermal incompatibility. Due to the lack of transverse reinforcement of the matrix material, the transverse coefficient of thermal expansion (CTE) of longitudinally reinforced composite rebar is typically much higher than its longitudinal CTE. This may create significant bursting-type stresses within concrete members reinforced with composite reinforcement. To quantify the influence of this potential thermal incompatibility and to verify manufacturer's claims regarding the thermal compatibility, the longitudinal and transverse CTE of composite rebar will be measured. The effect of bursting stresses caused by transverse expansion of the composite reinforcement in concrete will be explored using beam specimens with varying levels of clear cover over the composite reinforcements. This research is sponsored by the U.S. National Foundation. For more information, contact Dr. Russell Gentry, The Catholic University of America, (202) 319-4382.

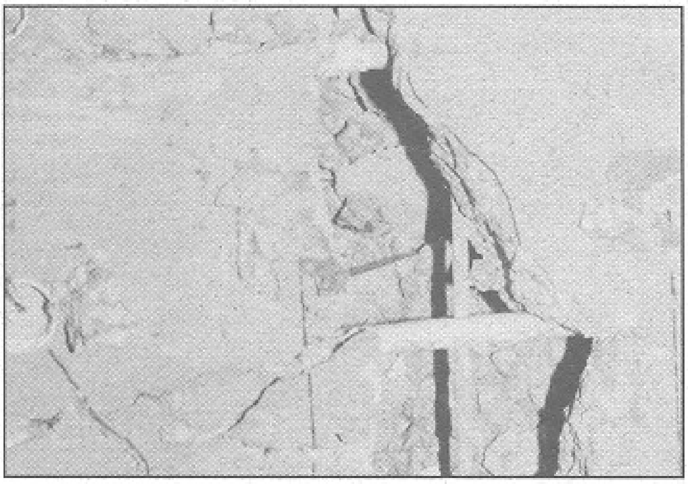

Figure 10. FRP rebar in concrete.

Major Durability Study

The U.S. Navy's Naval Facilities Engineering Services Center (NFESC) plans to conduct a three-year study to compare the long-term durability of various types of thermosetting FRP composites in actual marine environment operating conditions. Although the Navy is aware of testing which has been performed over the years by other organizations including the landmark Gibbs & Cox studies, their own work will be the "prime factor in helping to develop FRP composite specifications for future Naval Facilities Command (NAVFAC) shore facility purchasing decisions". A wide range of test sites have been selected including Florida, Hawaii, Puerto Rico and Alaska. Durability testing plans include water absorption, temperature behavior and sunlight, as well as attachment by marine organisms and attack by aggressive agents. The Navy plans to purchase commercial stock shapes FRP sheets, rods, bars, channels, etc. in a variety of resins and reinforcements. Individuals or organizations interested in having their materials evaluated as part of the Navy's program should contact Dr. Thomas Novinson at NFESC in Port Hueneme, California at fax: (805) 982-1074, telephone (805) 982-1056.

Design Competition Finals

The Civil Engineering Research Foundation (CERF) received nearly 100 entries in its 1996 Innovation Awards competition. A proposal, "Use of Fiber-Reinforced Polymer Reinforcing and Prestressing for Long-lasting Concrete Bridges" has been selected as one of the four finalists in the Innovative Concepts category. This proposal was developed through collaboration between the American Concrete Institute (ACI), Craig Ballinger & Associates, Composites Institute's Market Development Alliance, Lawrence Technological University, Marshall Industries Composites, Mitsubushi Leadline, Owens-Corning Corporation, Precast/Prestressed Concrete Institute (PCI) Searward International and South Dakota School of Mines and Technology. Features include composite tendons for post-tensioned decking, composite reinforcing bars. The Innovative Applications Award recognizes the contribution of an organization or collaborative team who can demonstrate innovative approaches in design, materials or construction practices. One entry in the competition is the design of a 270 foot long, four-lane H@-25 wheel loading vehicular bridge to be built in Columbus, Indiana. The winner of the hotly contested competition will be announced at CERF's International Research Symposium, February 5, 1996 at the Sheraton Washington Hotel.

New Publication is a "PIP"

The Composites Institute's Market Development Alliance has just published a major new study of FRP composite applications in civil engineering and construction. This 91-page full color book, titled "FRP composites in Construction Applications: A Profile in Progress" profiles the use of composites in a wide range of commercial applications. Topics covered include primary and secondary structures, marine/waterfront structures, repair, durability, corrosion resistance, electrical and telecommunications, as well as emerging technology. Also included is a summary of CI Product Showcase competition winners which highlights new products developed for the construction industry. To obtain a copy of Profiled in Progress, please send a written request to John P. Busel, Manager of Market Development at the Composites Institute, 355 Lexington Avenue, New York, New York or fax (212) 370-1731.

Composites Industry Gathers in Cincinnati

In just a few weeks, the eyes of the composites world will be in Cincinnati, Ohio. The 51st Annual Composites Institute Conference and EXPO'96 will be held February 5 to 7, 1996, at the Cincinnati Convention Center. The theme of this year's event is "Vision, Innovation and Opportunity...Build a Better World with Composites". Nearly 25 technical and market development sessions will focus on new developments in materials, processes and applications, along with hundreds of exhibitors. This show is the largest industry event of the year and will attract thousands of composites experts from around the world. For additional information, please contact the Composites Institute at 355 Lexington Avenue, New York, New York, 10017, telephone (212) 351-5410 or fax (212) 370-1731.

University Theses

Abdelrahman, A., 1995. *"Serviceability of Concrete Beams Prestressed by Carbon Fibre Reinforced Plastic Tendons"*, PhD., University of Manitoba, Winnipeg, Manitoba, supervised by S. Rizkalla.

Baumert, M.E., 1995. *"Low Temperature Behaviour of Reinforced Concrete Beams Strengthened with CFRP Sheets"*, M.Sc., Queen's University, supervised by M.F. Green and M.A. Erki (Royal Military College).

Domenico, N., 1995. *"Bond Characteristics of CFCC Prestressing Strands in Pretensioned Concrete Beams"*, M.Sc., University of Manitoba, Winnipeg, Manitoba, supervised by S. Rizkalla.

Fam, A., 1995. *"Carbon Fibre Reinforced Plastics Prestressing and Shear Reinforcements for Concrete Highway Bridge"*, M.Sc., University of Manitoba, Winnipeg, Manitoba, supervised by S. Rizkalla.

Nitereka, C., 1995. *"Renforcement des poutres par des lamelles composites: analyse non linéaire par élément finis"*, M.Sc., l'Université de Sherbrooke, Directeur: P. Labossière.

Picher, F., 1995. *"Confinement de cyllindres en béton par des composites carbone—époxy unidirectionnels"*, M.Sc., l'Université de Sherbrooke, Directeur: P. Labossiére.

Yantha, P., 1995. *"Static and Dynamic Behaviour of a GFRP Prototype Vehicle Bridge"*, M.Eng., Royal Military College of Canada, supervised by M.A. Erki and M.F. Green (Queen's University).

Conferences

SPI Composites Institute's 51st Annual Conference and Expo '96, February 5-7, 1996, Cincinnati Convention Centre, Cincinnati, Ohio, contact Bruce or Patricia Lesli, Tel: (212) 865-5067, FAX: (2121-666-6406.

The First International Conference on Composites in Infrastructure (ICCI '96), Tucson, Arizona, USA, 15-17 January 1996. Contact Prof. M. Ehsani, University of Arizona, FAX: (602) 621-1443; Dr. Saadatmanesh, FAX: (602) 621-2148, Email: baltes@bigdog.engr.arizona.edu.

SPIE's 1996 Symposium on Smart Structures and Materials, Catamaran Resort Hotel, San Diego, California, 25-29 February 1996. Contact the International Society for Optical Engineering, FAX: (360) 647-1445.

4th Annual Wilson Forum, Existing and Potential Applications of Composite Materials in the Infrastructure, San Francisco, California, 11-12 March 1996, FAX: (916) 989-1714.

ACI '96 Spring Convention, Hyatt Regency Denver, 14-19 March 1996, Contact ACI in Detroit, FAX: (313) 538-0655.

International Conference on Marine Applications of Composite Materials, Melbourne, Florida, 19-21 March 1996, FAX: (407) 951-9464.

41st International SAMPE Symposium and Exhibition, 25-28 March 1996, Anaheim, California, Contact Doris Weaver, FAX: (818) 332-8929.

JEC – Journées Européenes des Composites conference and Exhibition, CNIT Centre, La Defense, Paris, France, 24-26 April 1996. Contact the Centre for Promotions of composites, FAS: 33-1-40-59-85-46.

7th European Conference on Composite Materials (ECCM-7), Brittania International Hotel, UK, 14-16 May 1996, Contact Cathy Pearcey, Tel: +44 (171) 235-1391; FAX: +44 (171) 823-1638.

17th International SAMPE Europe Conference Exhibition, Messe Basel and the Le Plaza Hotel, 28-30 May 1996, Contact Prof. U. Meier, EMPA, Tel: +41 (1) 823-5511; FAX: +41 (1) 821-6244.

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

2nd International Conference on the Use of Advanced Composite Materials for Bridges and Structures, Montréal, Québec, Canada, 11-14 August 1996. Contact: Dr. S.H. Rizkalla, Faculty of Engineering, University of Manitoba, Winnipeg, MB R3T 5V6, FAX: (204) 261-5465.

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

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