F R P
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Guest Author Dr. R.M. Measures

Smart Structures – A Revolution in Civil Engineering

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Dr. Measures, a pioneer and world renowned researcher, succeeded in demonstrating that the marriage of fiber optic sensors, lasers, micro-electronics, integrated optics and artificial intelligence with the use of new advanced composite materials permits these materials to be made into Smart Structures. Such structures include a "built-in" fiber optic sensing system for determining the load, internal strain, deformation and temperature experienced during their working life. Professor Measures and his group demonstrated the potential use of this system by instrumenting a full scale aircraft wing with a structurally integrated fiber optic damage detection system as shown in figure 1.

Fiber optic sensors are excellent for this task as they are extremely small, light weight, highly resistant to fatigue and corrosion, immune to electrical interference, highly sensitive and have very large bandwidths. The unique feature of optical fibers is their use as "distributed sensors" in which each element of the optical fiber is used for both measurement and data transmission purposes.

The Fabry-Perot and the intracore Bragg grating sensors are the most attractive sensors for strain measurements. In the Fabry-Perot fiber optic sensor, a tiny cavity comprising of two mirrors formed within the optical fiber, serves as the sensing region. When strain or a change of temperature is impressed on the sensor, light within the cavity suffers a phase shift. A sensor based on this concept, comparable to conventional resistance foil strain gauges, is currently available commercially.

The Bragg grating sensor reflects light of essentially one wavelength due to strain or temperature variations imposed on the optical fiber. The high sensitivity of both types of sensors make it possible to use them with the short lengths needed for optical strain rosettes as shown in figure 2.

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Dr. Measures and his research group indicated that it may be possible to build a single optoelectronic chip that could demodulate and multiplex the sensing information from a large array of Bragg sensors. This would greatly simplify the structural interface and make an extremely user-friendly interconnect. This concept lends itself to free-space propagation from this structurally integrated optoelectronic interface which would allow a non-contact system so that no optical fibers or wires need be attached to the structure.

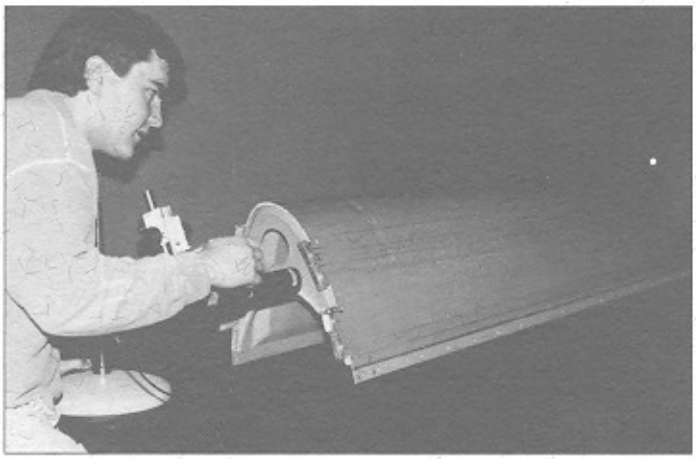

Figure 1:
First composite aircraft leading edge fabricated with a structurally integrated fiber optic damage detection system.

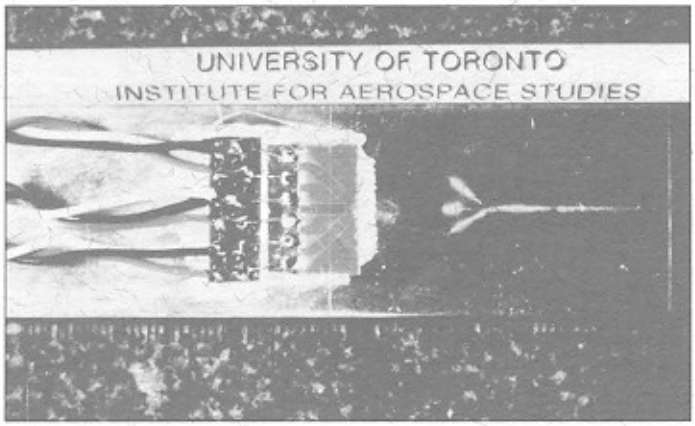

Figure 2:
Conventional foil strain to rosette on the left and new fiber optic strain rosette on the right.

Editor's Message

Welcome to the first issue of ***FRP International***! The concept for an FRP International newsletter began as one of the technical activities of the ACI Committee 440 on FRP to achieve advancement through knowledge. The newsletter will provide engineers, researchers and academics clear and international state-of-the-art knowledge and news in the rapidly changing and exciting field of FRP.

In addition to featuring a guest author, each issue will cover all news related to new products, industrial news, feature research and research news, conferences, meetings, symposiums, new publications and books in the field of FRP.

The support and efforts of the associate editors at ACI, ASCE, CSCE and JCI bring an international flavour to ***FRP International***. Until similar organizations can be identified in England and Europe, Dr. C.J. Burgoyne of Cambridge University and Mr. Arie Gerritse of Hollandesche Beton Groep have agreed to undertake the liaison responsibilities for ***FRP International***.

Your comments and questions are welcome and I invite you to submit news items for the second issue. The deadline is February 15, 1993.

- Sami Rizkalla

Codes and Design Criteria

JSCE Report on FRP

The Japan Society of Civil Engineers (JSCE) Committee on Continuous Fiber Reinforcing Materials (CFRM), initiated in 1989, completed its activities by holding a symposium on FRP, April 21-22, 1992 in Tokyo. The Committee published a technical report covering the following four topics:

1) Design concept for concrete members using CFRM;
2) Test methods for durability of CFRM;
3) Concept for durability of CFRM; and
4) A state-of-the-art report on CFRM for concrete structures.

English translation of the first three topics are published in the Concrete Library International, No. 19, 1992 published by JSCE. Copies can be purchased through JSCE, 1 Chome, Yotsuya, Tokyo 160 Japan, FAX: (81) 3-3355-3446.

Canadian Design Code for Advanced Composite Materials

Driven by the success of the Ontario Highway Bridge Design Code (OHBDC) in providing leading edge code to bridge designers, a new technical subcommittee on Advanced Composite Materials (ACM) has been established. The work of the committee is divided into five broad areas:

1) Fiber Reinforced Concrete (FRC) deck slabs for slab-on-girder bridges;
2) Fully, or partially, prestressed concrete beams with ACM (pretensioned, post-tensioned, internal/external, etc.);
3) Concrete slab bridges prestressed with ACM;
4) Stressed timber decks prestressed with ACM;
5) FRC barrier walls.

The subcommittee is seeking information to resolve the conflicting debates on the long term strength and the durability of aramid fibers, and the durability of glass fibers in concrete. Information or recommendations pertaining to these questions are invited by the subcommittee. Please send your response to Dr. Baidar Bakht, Research and Development Branch, Ontario Ministry of Transportation, 1201 Wilson Avenue, Central Bldg., Downsview, ON, M3M 1J8, FAX: (416) 235-4872.

ASCE Design Standards for Composites in Construction

An ad hoc task group of the ASCE Structural Composites and Plastics Committee (formerly SPRC), chaired by R.E. Chambers, recently submitted a proposal to the Standards Division to establish an activity to develop design standards for structural composite shapes used in civil engineering type structures. Other structural plastics and plastic pipes were also included in the proposal. The Management Group F of the Standards Division has endorsed and forwarded the proposal for review and approval by higher levels.

For additional information contact R.E. Chambers, Simpson Gumpertz & Heger Inc., 297 Broadway, Arlington, MA 02174, Phone: (617) 643-2000.

FIP Report on FRP

Federatione Internationale de la Précontrainte (FIP) Commission on Prestressing Steel and Systems published a state-of-the-art report entitled "High Strength Fiber Composite Tensile Elements for Structural Concrete", July 1992. The report includes properties of FRP, test procedures, principles of design and execution, and present and future fields of applications. The report summarizes the findings of a working group founded in 1988 by the FIP Commission on Prestressing Materials and Systems, chaired by Professor Rostasy. For further information contact Prof. Rostasy, Institute Für Baustaffe Massivbau und Brandschutz, Techn. Univ., Braunschweig, Beethovenstr. 52, 3300 Braunschweig, Germany, FAX: (49) 531-391-4573.

U.S.A. Pultrusion Centers

The University of Mississippi has one of only two full-size pultrusion operations in the United States, the other one being at Case Western Reserve University. The research activity focuses on optimizing the pultrusion process in the production of structural shapes. According to Dr. Robert M. Hackett, chairman of civil engineering at Ole Miss, researchers recognize that pultruded structural components are going to play an increasingly important role in the design and fabrication of major civil engineering structures. They will be working to produce substantial data that relate material properties to processing parameters which will be available and applicable for utilization in the development of all-important structural design standards for composite materials. Funding from the National Science Foundation in the amount of $545,550, and matching support from the State of Mississippi over the next three years, will provide significant support for these activities.

Conferences and Meetings

PCI/ACI Seminar

On Tuesday, October 12, 1992, a PCI/ACI Seminar entitled: "Japanese Experience in Prestressed Concrete Bridge Construction Using FRP Tendons" was held at the Opryland Hotel in Nashville, Tennessee, during the 1992 PCI Convention and Exhibition. The seminar featured an introduction by A. Nanni (Pennsylvania State), six presentations by Japanese speakers, and a discussion led by C.W. Dolan (Wyoming University) and M. Shahawy (Florida DOT). The six presentations included state-of-the-art summary and design guidelines by Y. Tsuji (Gunma University), Japan's National project by M. Kanda (PWRI), and four industry reports (P.S. Concrete, Obbayashi, Sumitomo, and Mitsui). The meeting was very successful and generated high interest among the audience. Given the positive response, it is possible that PCI will consider taking an active roll in this subject. For further information contact Paul Johal, R&D Director, PCI, Phone: (312) 786-0300, FAX: (312) 786-0353.

ACI 440 Meeting

ACI Committee 440-FRP Reinforcement for Concrete Structures is organizing an FRP Symposium during the ACI Spring Convention, March 29-31, 1993, in Vancouver, Canada. The symposium will include 40 technical papers presented in six technical sessions on Monday, Tuesday and Wednesday. Abstracts of technical papers will be available at the symposium in a booklet form for a minimal cost. Proceedings of the symposium, including an additional 20 papers accepted for publication, will be available as ACI Special Publication in the summer of 1993. For more information contact ACI, Phone: (313) 532-2600, FAX: (313) 532-2600.

SAIE International Seminar/Exhibition

There is an interest in organizing an international seminar/exhibition in October, 1993, in Bologna, Italy, under the sponsorship of SAIE (Salone Internazionale dell'Edilizia). Details are not available at this time. For more information contact A. Di Tommaso, University of Bologna, Phone: (39) 51-644-3490, FAX: 3495.

Symposium on Composite Materials and Structural Plastics

The recent American Society of Civil Engineers (ASCE) Materials Engineering Congress held in Atlanta, Georgia, August 10-12, 1992, devoted a major portion of the technical program to a Symposium on Composite Materials and Structural Plastics in Civil Engineering Construction.

The symposium was organized by Larry Bank of The Catholic University of America, and sponsored by the ASCE Structural Composite and Plastics Committee. The symposium consisted of 24 papers in four sessions, entitled **State-of-the-Art: A 20 Year Overview of the Industry, Performance of Structural Plastic/Composite Structures, Composite Material Reinforcement for Concrete, and, Materials for Structural Strengthening.** Papers were presented by researchers from academia and by practitioners in the FRP industry. Approximately 50 people attended each session and participated in productive dialogue.

The papers presented at the symposium were published in the Proceedings of the Congress entitled **Materials - Performance and Prevention of Deficiencies and Failures**, edited by Thomas D. White of Purdue University. Copies of the volume (ISBN 0-87262-880-9) are available from ASCE headquarters in New York.

First International Conference on ACMBS-1

The First International Conference on "Advanced Composite Materials in Bridges and Structures, ACMBS-1" chaired by Dr. K.W. Neale of University of Sherbrooke, was held in Sherbrooke, Québec, Canada, October 7-9, 1992. The conference brought together 122 delegates from 14 countries to discuss and exchange information on advanced composite materials in construction applications. Sixty technical papers and three keynote lectures were presented. Copies of the 700+ page hardbound proceedings of ACMBS-1 are available by contacting Dr. K.W. Neale, Chair, ACMBS-1, Department de genie civil, Université de Sherbrooke, 2500 boulevard Université, Sherbrooke, Québec, Canada, J1K 2R1, FAX: (819) 821-7974.

The ACMBS-1 conference is the first in a series of international conferences to be hosted in Canada every four years and is sponsored by the Structure Division of the Canadian Society for Civil Engineering. The ACMBS-2 is scheduled to be held in Winnipeg, Manitoba, in 1996, and chaired by Dr. Sami Rizkalla, of the University of Manitoba, Canada.

TRB Meeting on FRP Composites

Two meetings on Structural FRP Composites will be held during the Transportation Research Board (TRB) annual convention in Washington, DC, on January 11, 1993.

The first committee meeting, Monday 9:00 a.m., will be held in the executive room of the Omni Shorham Hotel. The second meeting on "Structural Applications of Fiber Reinforced Plastics" will be held the same day at 1:00 p.m. in the Idaho Room, Sheraton, Washington Hotel. For further information contact Mr. Craig Ballinger, CBA, 314 Ayito Road S.E., Vienna, VA 22180, FAX: (703) 938-1252.

FRP Research

Current NSF Projects in FRP

The National Science Foundation (NSF) supports research to enhance the development of knowledge basic to progressive design, construction, maintenance and operation of safe, long-lived, efficient, and economical civil infrastructure systems. High performance materials, including FRP and composite materials, are key elements of these research efforts. The following lists some examples of NSF grants in FRP and composite materials used in civil infrastructure systems.

- F.G. Yuan (North Carolina State University), "Theoretical and Experimental Studies of Failure in Anisotropic Curved Layered Structure".
- L.C. Bank (Catholic University of America), "The Influence of Transverse Material Properties on the Design and Performance of Pultruded FRP Structures".
- D. Darwin (University of Kansas), "Engineering Foundation Conference: Composite Construction II".
- C.W. Dolan (University of Kansas), "Anchorage for Synthetic Prestressing Tendons".
- V.C. Li (University of Michigan), "Fracture Testing Technology for Advanced Ceramic and Cementations Matrix Based Composites".
- A. Nanni (Pennsylvania State University), "Lateral Confinement of Concrete using High-Strength Fiber Reinforcement".
- R.H. Plant (Virginia Polytechnic Institute), "Dynamic Behavior of Inflatable Dams".
- M.D. Rao (Michigan Technological University), "Damping Capacity of Adhesively Bonded Structural Joints (in Composites and Composites to Metal)".
- Lawrence Bank (Catholic University of America), "Analysis and Design of FRP Grating/Concrete Composite Structural Slabs".
- Antonio Nanni (Pennsylvania State University), "Development of Hybrid (FRP and Steel) Reinforcement".
- Thanasis Triantafillou (Massachusetts Institute of Technology), "Innovative Strengthening Techniques with Composite Materials".
- Hota V. GangaRoo (West Virginia University), "Government-Industry-University Workshop on Polyner Matrix Composites in Construction".
- Hamid Saadatmanesh (University of Arizona), "Strengthening of Concrete Columns with Fiber Composites".
- Abdul H. Zureick (Georgia Institute of Technology), "Behavior of Axially Loaded Pultruded Fiber Reinforced Composite Columns".
- Faramarz Gordamnejad (University of Nevada-Reno), "A New Polymer Matrix Composite Material System with a High Thermal Conductivity".
- Robert M. Hunter (Yellowstone Environmental Science), "Polymer System for In-Situ Rehabilitation of Pipelines".
- G. Eric Johansen (E.T. Techtonics), "Prestressed Kevlar-E-Glass Structural Systems".
- Joseph M. Plecnik (California State University, Long Beach), "Adaptation of Composite Materials to Infrastructure Applications".

For further information contact Ken P. Chong and John B. Scalzi, Program Directors, National Science Foundation (NSF), Washington, D.C. 20550.

Canadian FRP Research

The Canadian Society for Civil Engineering (CSCE) Technical Committee on the Use of Advanced Composite Materials in Bridges and Structures identified potential topics for a concentrated research effort into the use of advanced composite materials in civil engineering structures. These topics have a number of components and include several universities and research institutions. The research topics and the lead persons are:

- Parking Structures: Dr. S.H. Rizkalla, University of Manitoba, and Mr. John Crimi, Autocon, Ontario;
- Long-Term Material Properties: Dr. P. Ellyin, University of Alberta;
- Enclosure Systems: Dr. A.G. Razaqpur, Carleton University, Ottawa, and Dr. D.R. Morgan;
- Rehabilitation and Repair: Dr. K.W. Neale, Université de Sherbrooke, Québec, and Dr. M.A. Erki, Royal Military College of Canada, Ontario; and
- Bridges: Dr. G. Abdel-Sayed, University of Windsor, Ontario.

Other research activities at Canadian universities include:

- Research in the field of carbon fiber concrete at the University of British Columbia led by Dr. Banthias;
- Bridge deck slabs containing randomly dispersed polypropylene at the Technical University of Nova Scotia by Dr. A. Mufti;
- Bolted connections for fiber-reinforced composite structural members at the University of Manitoba by Dr. Sami Rizkalla.

For further information on the research activities in Canada, contact the Associate Editor, Dr. M.A. Erki.

Modular FRP Concepts for Bridge Deck Replacement

The School of Civil Engineering at Georgia Tech was recently awarded an FHWA grant "Modular FRP Concepts for Bridge Deck Replacement". Led by

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Dr. A. Zureick, a team of researchers in the areas of composite analysis and design, construction, and manufacturing has been assembled from academia and industry to develop analytical methods for FRP bridge decks and provide recommendations for the design of future experimental specimens based on manufacturing and construction considerations. Analytical methods will be developed for use at the material, structural element, and whole bridge levels which will be consistent with civil engineering-type structural analysis, and mechanical and aerospace composite design analysis.

CPAR Projects

South Dakota School of Mines and Technology was awarded a Construction Productivity Advancement Research Program (CPAR) project of $340,000 for two years by the US Army Corps of Engineers. The project consists of building an offshore structure at Port Hueneme (Navy research facilities in California). The structure is made of prestressed concrete piles with graphite cables to support a composite prestressed deck system. The deck and cross beams will be prestressed with graphite and S-2 fiberglass cables. The length of piles is 45 feet. The deck is 15 feet wide and 60 feet long. For further information contact Dr. Iyer at SDSM&T, FAX: (605) 394-6131.

The Constructed Facilities Center at West Virginia University was also awarded a CPAR project of $400,000 for three years by the US Army Corps of Engineers. The project consists of the design, construction and monitoring of a concrete bridge deck reinforced with fiber reinforced plastic (FRP) rebars. The concrete bridge deck is 32 feet wide, 55 feet long and will be built at Blacksville, West Virginia. For further information contact Drs. Faza or GangaRoo, at CFC, FAX: (304) 293-5024.

New Publications

The Canadian Society for Civil Engineering Technical Committee on the Use of Advanced Composite Materials in Bridges and Structures has recently published, ***Advanced Composite Materials in Bridges and Structures in Japan, a Task-Force Report***, edited by A.A. Mufti, M.A. Erki, and L.G. Jaeger, CSCE 1992, pp. 172. ISBN 9-921303-40-8.

This is a companion report to ***Advanced Composite Materials with Applications to Bridges*** (Canadian Society for Civil Engineering 1991). The new book updates the rapid progress that is being made in the use of advanced composite materials (ACM) for civil engineering structures in Japan. ACM have been targeted for use principally in new bridges and cladding for high-rise building structures. The cost (includes postage and taxes) for Canadian orders is $25, and outside Canada is $35.

Advanced Composite Materials in Bridges and Structures, Proceedings of the 1st International Conference on Advanced Composite Materials in Bridges and Structures, edited by K.W. Neale and P. Labossiere (CSCE 1992, pp. 705, ISBN 0-921303-41-6) is available for $70 (Cdn).

To place orders for any of the above three publications, please contact the Canadian Society for Civil Engineering Head Office, 2050 Mansfield, Suite 700, Montreal, Québec, H3A 1Z2, Phone: (514) 842-5653, FAX: (514) 842-8123.

Canadian Composite Centre

The Canadian government announced that the Composite Materials Centre (CMC) of Saint-Jerome Inc., north of Montreal, will receive federal funding of $2.3 million from the Ministry of Industry, Science and Technology Canada (ISTC) under the Technology Outreach Program (TOP). The funds will be used to expand existing CMC's production and laboratory equipment, and to support CMC's ongoing efforts to identify and develop technologies strategic to the future of the composite materials industry. The Centre occupies an area of 40,000 sq.ft. (3716 sq.m.) with a total investment in the plant of more than $10 million. CMC employs 20 full-time staff, of which 17 are engineers and technicians educated and experienced in composite materials technologies. To date, CMC has completed over 300 client projects working with companies of all sizes.

Completed Composite Structures

World's First Major FRP Bridge

The western world's first major all plastic bridge has just been completed at Aberfeldy in Scotland. It is a 64m main span cable stayed bridge. The deck and towers are constructed from interlocking cellular glass reinforced plastic pultrusions which are glued together. The stay cables are parallel lay ropes (Parafil) made from Kevlar yarns. The structure was designed by Maunsell Structural Plastics and built in a period of a few weeks over the summer by students from Dundee University. The GRP pultrusions were developed originally for bridge enclosures. A number of bridges in the UK have been fitted with these enclosures to reduce corrosion, and hence maintenance requirements. The designer of this system, Peter Head, Technical Director of Maunsell, will be writing future articles for this newsletter.

Aramid FRP for Prestressed Concrete Berth

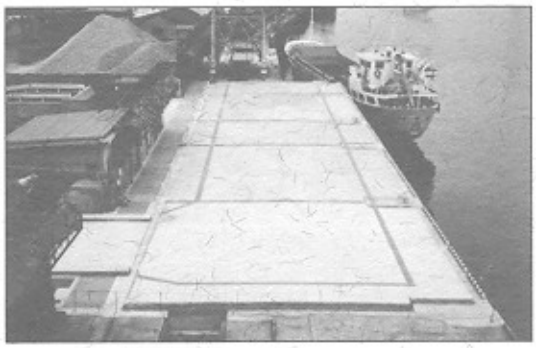


Figure 3

Aramid FRP rods were used for a prestressed concrete berth constructed by Sumitoma Construction Co. Ltd. in Japan. Aramid FRP "Technora" and "Arapree" rods were used for simply supported prestressing hollow girders used for the barge shown in figure 3. For further information contact Mr. Shin-ichiro Kumagai, Civil Engineering Division, Sumitomo Construction Co., Ltd., 13-4, Araki-cho, Shinjyuku-ku, Tokyo 160 Japan, Phone: (03) 3225-5132, FAX: (03) 3353-6656.

NEFMAC for Floor Slabs

NEFMAC (New Fiber Composite Material for Reinforcing Concrete) was used as grid reinforcements for a floor slab of concrete structures in the Antarctic continent. For more information, please contact Ken-ichi Sekine, NEFCOM Corporation, 2-23, Kanda Awaji-cho, Chiyoda-ku, Tokyo 101, Phone: (03) 3254-9209, FAX: (03) 3254-9210.

Now, NEFMAC is patented in several countries and is available according to fibers. A Canadian company, Autocon, has recently been granted an exclusive license to manufacture and sell NEFMAC. For further information contact Mr. John Crimi, FAX: (416) 743-6383.

Fiberglass Spire High Point on Atlanta Skyline

The 37 feet tall, all-fiberglass Spire installed October 30, 1991, atop the new 55 story C&S building is the golden high point on the Atlanta skyline. The tallest building in Atlanta (1025 feet tall) is topped with a gold leaf clad fiberglass Spire (fabricated of fiberglass structural shapes and plate), that will house communications antennae as shown in the figure 4.

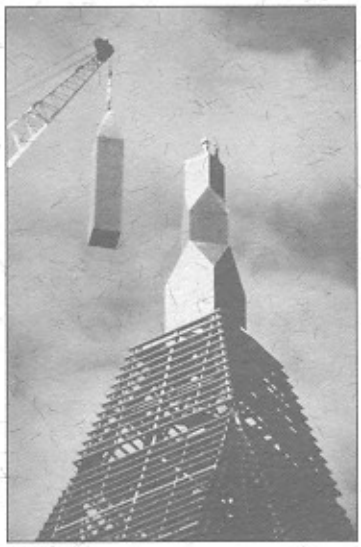


Figure 4

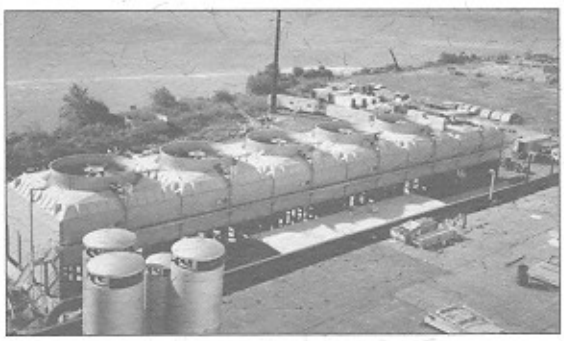
All fiberglass Spire materials were specially manufactured by Morrison Molded Fiber Glass Company (MMFG) in Bristol, Virginia. The Spire is 6 feet square at the bottom (and ascends 6 feet square for 26 feet) gradually tapering to a point 11 feet long. The Spire sits on a 50 feet tall steel structure clad in 1 inch fiberglass foam core panels.

Fiberglass was selected for this application because it is transparent to electromagnetic waves, corrosion resistant, strong, and is lightweight. The lightweight feature allows the entire prefabricated 37 feet high structure to be lifted into place by an erection crane - eliminating the high cost of a helicopter lift.

For more information contact Noreen Wray, Director/Advertising and PR, Morrison Molded Fiber Glass Company, 400 Commonwealth Ave., Box 580, Bristol, VA 24203-0580, Phone: (703) 645-8077.

Unilite FRP - Structure Cooling Tower

Ceramic Cooling Tower Company recently introduced its latest Generation of Cooling Towers centred around its Pultruded Composite Structure known as Unilite® Structural Concept. The pultruded composite members designed, engineered and manufactured by Ceramic specifically for use in Cooling Towers, represent an important advancement in materials technology.



The Unilite® Structural Concept is a state-of-the-art system which uses five basic pultruded composite shapes to provide a cost effective and superior alternative to wood, concrete or metal. The basis of the Unilite® Patented Structural System is the Unicolumn, with its unique Tic-Tac-Toe Profile. It has an extremely high load carrying capability, thus minimizing the number of vertical columns required in the tower structure.

The design has achieved superior strength-to-weight ratios compared to steel and concrete, as well as permanent color and superior UV- and Corrosion-Resistance Properties.

New Products

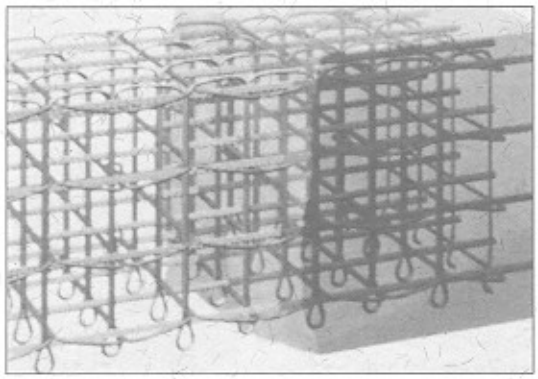


Figure 5 3-D Fabric used for curtain wall

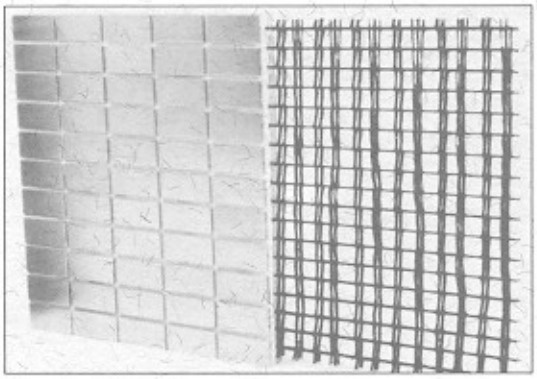


Figure 6 3-D Fabric

Commercial Link for Parafil Ropes

Parafil ropes were developed by Linear Composites in England and are made with a core of Kevlar or polyester yarns within a polyethylene sheath. The system has been used in prestressed concrete and stay cable applications. Linear Composites have now linked up with the VSL group, based in Berne, Switzerland, to offer Parafil ropes to the structural engineering industry for prestressed concrete, rock anchor and cable stay applications. VSL will provide technical assistance to designers of such structures and also provide the jacking systems when the ropes are installed. For further information contact Dr. Franz Zahn, VSL International, Konizstrasse 74, P.O. Box 7124, 3001 Berne, Switzerland.

Three-Dimensional Fabric

A three-dimensional woven fiber fabric developed by Kjima Co. of Japan, was used for reinforced concrete (figure 5), and as tile for a curtain wall (figure 6) in a 23 story building in Japan. The 3D fabric is a woven carbon or aramid fiber impregnated with epoxy into fiber strands. For further information contact Mr. Hiroaki Nakagawa, Kajima Corporation, Kajima Technical Research Institute, Japan, FAX: (0424) 89-2892.

Flexible and Rigid FiBRA

Two types of FiBRA are currently produced by changing the type of resin. The flexible type is convenient for prestressed tendons (figure 5), and the rigid type is used as a reinforcement (figure 6). In Japan, FiBRA rods were used as reinforcements of prestressed concrete beams in a three-story construction provided with a base isolation system under the first floor slab. For further information, please contact Tomia Tamura, Research & Development Division, Mitsui Construction Co. Ltd., 3-10-1, Iwamoto-Cho, Chiyoda-Ku, Tokyo, 101 Japan, FAX: (03) 5821-7640.

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