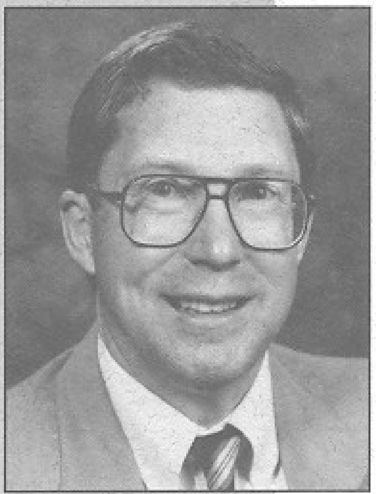
FRP International
Fiber Reinforced Plastics
Winter, 1995 Volume III, Issue 1

Guest Author – Charles W. Dolan

Dr. Charles W. Dolan was a principal in ABAM Engineers for nearly twenty years before returning to Cornell University for PhD. studies in Structural Engineering. His design projects have included the Walt Disney World Monorail, and the Dallas-Ft. Worth, Vancouver, British Columbia and Detroit, Michigan People Mover Systems. In 1986, he returned to Cornell University where he received his Doctorate in Civil Engineering, investigating the behaviour of Kevlar reinforced plastic strands as a prestressing material for concrete. He is currently a professor of Civil and Architectural Engineering at the University of Wyoming. Dr. Dolan participated actively in organizing the 1st International Conference on FRP Reinforcement for Concrete Structures and an NSF Workshop for research needs in FRP structures.



*Guest Author:
Charles W. Dolan,
P.E., Ph.D.
Professor,
Civil Engineering
Structures and Materials
University of Wyoming
Laramie, Wyoming*

Dr. Dolan's research identified several critical research and design areas needed for the development and commercialization of FRP prestressing tendons. These areas included anchorage of tendons, development of in-service long-term performance parameters, comparative performance of FRP tendons, and strain compatibility bases for design.

Dr. Dolan's research at the University of Wyoming (sponsored by NSF) deals with the design of the internal geometry of FRP anchorages to achieve the most effective prestressing forces that can be sustained by FRP tendons, as shown in Figure 1. In this case, the parabola is tangent to the tendon at the entrance to the anchor and has an exit angle of approximately 15º. The internal surface of the anchor is

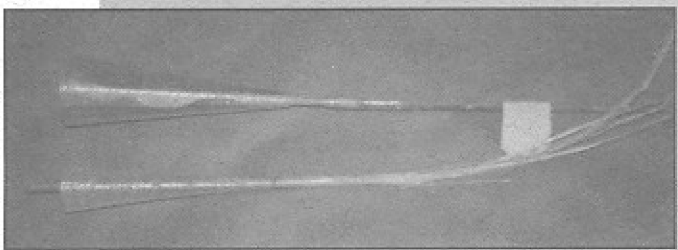


Figure 1. Central core from epoxy socketed conic and parabolic anchors

(continued on page 2)

In This Issue

• American Concrete Institute • American Society of Civil Engineers • Canadian Society for Civil Engineering • • Composite Institute • Japan Concrete Institute • ACMBS Network of Canada •

(continued from page 1)

greased to allow the anchor to slip and tighten around the resin core, therefore providing confining pressure on the FRP tendon.

Dr. Dolan's research work sponsored by the United States Army Corps of Engineers, is planned to provide comparative data describing the relative behaviour and long term performance of glass, aramid and carbon fibre-based tendons. These beams (shown in Figure 2) will continue to be loaded for several more months before they are tested to failure. The lack of comparative data is completely understandable, recognizing that each individual tendon has been developed for individual commercial interests. Nonetheless, for engineers to make intelligent choices on the selection of FRP prestressing, this comparative data must be available.

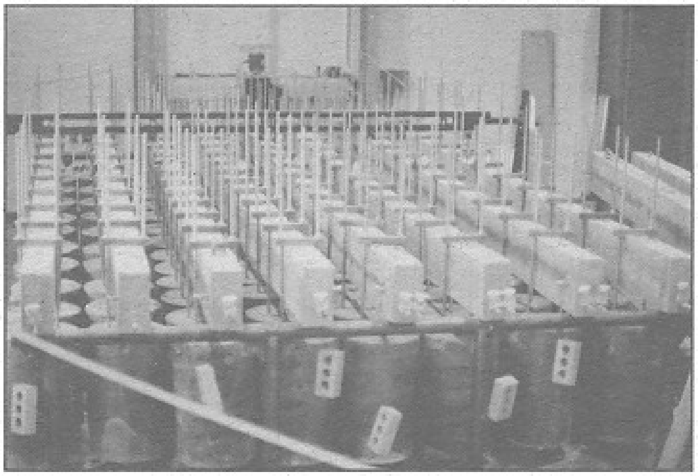


Figure 2. Creep and sustained load tests on FRP prestressed beams.

Dr. Dolan strongly recommended that researchers and designers should be examining the behaviour of structures reinforced by FRP materials based on their strain compatibility and strain capacity. Development of design guidelines based on stress levels is potentially dangerous because of the long-term creep rupture characteristics. Additionally, the stress capacity of FRP tendons can change with fibre volume and fabrication techniques; however, the strain capacity of composite tendons is generally quite well defined. Therefore, analysis and design, as well as definition of strength and performance criteria based on the strain compatibility of the tendons appears to be a more reliable and rational method of developing design parameters. This approach will allow the designer to quantify ductility and brittle behaviour of the composite structure.

FRP Research

Retrofitting Concrete Slabs with CFRP Laminates

The behaviour of pre-cracked pretensioned solid and voided slabs strengthened by carbon fibre reinforced plastic (CFRP) laminates were investigated, as shown in Figure 3. The project is sponsored by the Florida Department of Transportation and the U.S. Federal Highways Administration. The effect of CFRP laminates bonded to the soffit was evaluated in terms of flexural strength, deflection, cracking behaviour and failure modes. For further information, please contact Dr. M. Arockiasamy, Department of Ocean Engineering, Florida Atlantic University, FAX: (407) 367-3885, or Dr. M. El-Shawahy, State of Florida, Department of Transportation, FAX: (904) 488-6189.

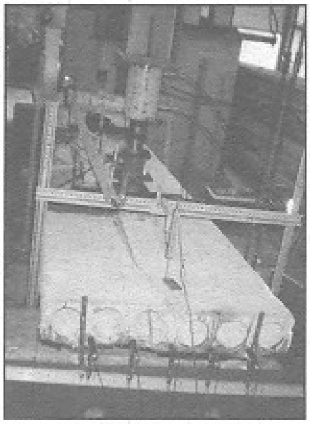


Figure 3. Tested slabs

FRC at Sub-Zero Temperatures

A joint study between Dr. Nemy Banthia of the University of British Columbia and Dr. Koji Sakai of Hokkaido Development Bureau, Sapporo on Stress-Rate Sensitivity of Fibre Reinforced cementatious Composites at Sub-Zero Temperatures has successfully entered its second phase in which instrumented impact tests are being conducted at very low temperatures on high fibre volume fraction cement composites. A new three-year collaborative project has been initiated between Dr. Banthia and Prof. Y. Ohama of Nihon University, to study repair mortars with polymer modification and hybrid fibre reinforcement. An additional joint study between Dr. Banthia and Prof. Arnon Bentur of the Building Research Institute, Technion, Israel, has been initiated to investigate the efficiency of various types of fibres in concrete through micromechanical bond-slip studies and fracture modelling.

For further information please contact: Dr. N. Banthia, Department of Civil Engineering, The University of British Columbia, FAX: 604 822 6901.
E-mail banthia@civil.ubc.ca.

(continued on page 3)

(continued from page 2)

Repair of Delaminated Highway Bridge Piers Using ACM — An Experimental Study

The Department of Civil Engineering at the University of Toronto is working in conjunction with the Research and Development Branch of the Ministry of Transportation of Ontario (MTO) on developing a repair technique for circular reinforced concrete piers with delamination that results from road salt spray. The principal objective of the project is to establish how FRP wrappings can be used in lieu of traditional patching techniques in order to provide long-lasting, cost-effective rehabilitation for highways bridges in Ontario. Experiments are being conducted to study a broad range of variables in potential repair techniques, including: type and quantity of FRP wrapping, the extent of surface preparation, the use of diffusion barriers to inhibit further corrosion, and the use of expansive grout. Reinforcing bars in the test specimens are being subjected to accelerated corrosion in order to simulate delamination observed in the piers of older highway bridges that have been sprayed with road salts for several decades. Delamination test specimens will be repaired with a variety of techniques and the performance will be assessed by monitoring continuing corrosion rates, lateral expansion, and structural resistance.

The University of Toronto faculty research team includes John Bonacci, Nataliya Hearn, Voula Pantazopoulou, Michael Thomas, and Shamim Sheikh.

For further information please contact Dr. J. Bonacci, Department of Civil Engineering, University of Toronto, FAX: 416 978 6813, E-mail bonacci@civil.utoronto.ca.

Simulation of Rolling Wheel Loads on an FRC Deck Slab

A steel-free fibre reinforced concrete (FRC) deck slab has been developed by researchers at the Technical University of Nova Scotia. Static load testing of this slab was described in FRP International Autumn 1994 (Vol II, Issue 4). The Ministry of Transportation of Ontario (MTO) commissioned the fatigue testing of full-scale models of FRC deck slabs under rolling wheel loads at Carleton University. Figure 4 shows the cross-section of the test model, which had a simply supported span of 4.2 m. A sequential wheel load system involving four stationary load pads was used to simulate rolling wheel loads.

Figure 5 shows the patterns of the dynamic loading sequence on the four loading pads. The outcome of the testing confirms that the FRC deck slab under repeated wheel loads eventually shakes down to an elastic and stable structure. The test specimen was able to sustain without damage 4 million passes of a 98 kN load, confirming that it has ample fatigue capacity.

For further information please contact A.P.S. Selvadurai, McGill University, FAX: (514) 398-7367

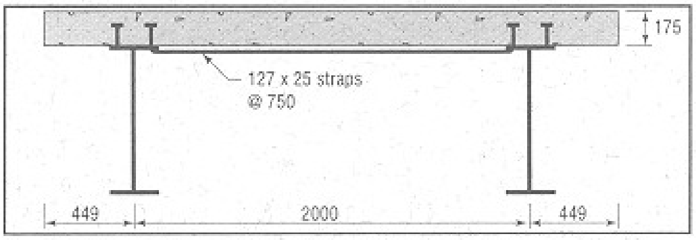


Figure 4. Cross-section of the FRC deck slab test model

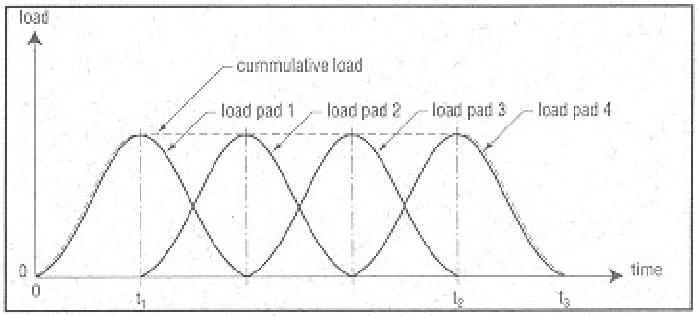


Figure 5. Patterns of the dynamic loading sequence – FRC deck slab

Composite Structures

World's First ACM Lift Bridge

The latest example of using Advanced Composite Materials, ACM, for bridge construction is the first ACM lift bridge over the canal at Bonds Mill historical canal in the United Kingdom. The case of assembly requirements is met by building the bridge deck using the ACM system created by Maunsell Structural Plastics Ltd. of Beckenham, Kent, UK, and is marketed by Designer Composite Technology Ltd of Alton, Hampshire, UK.

(continued on page 4)

(continued from page 3)

The ACCS is a highly versatile modular construction system comprised of isopolyester composite components that are complex in design but simple to use. Relatively unskilled workers can quickly assemble and install an ACCS structure with no special tools or lifting equipment. Assembly is by a combination of mechanical interlocks and adhesive bonding.

The system is comprised of parts made by pultrusion, a composite fabrication process that produces linear profiles with a constant cross section. The reinforcement in the ACM parts are fibreglass. The resin is an isopolyester with UV inhibitors to increase resistance to outdoor exposure.

Isopolyester resin, supplied by Amoco Chemicals, Chicago, USA, provides very good physical properties, corrosion resistance and ease of processing at a lower cost that such resins as vinyl ester, epoxy and modified acrylic.

The Bonds Mill bridge weighs 6.5 tonnes (14,300 lbs) - 4.5 tonnes (9,900 lbs) of composite and 2 tonnes (4,400 lbs) of steel supports for a mechanism that lifts the bridge to allow canal boats to pass. Since the system is based on lightweight composites, the lifting mechanism is simpler and less expensive than a traditional lifting tower with counterweight. Light weight also permits the re-use of existing foundations with little modification, as shown in Figure 6.

For further information contact James E. Thorpe, FAX: +44 (81) 663-6723.

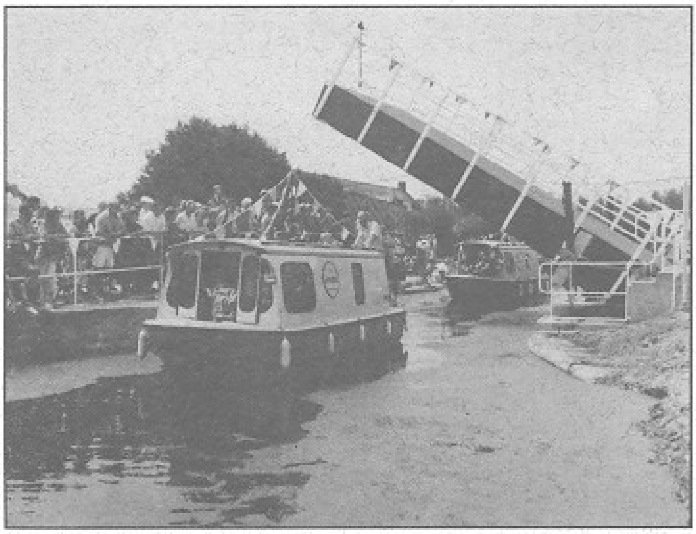


Figure 6. The first ACM lift bridge over the canal at Bonds Mill, UK

• Isopolyester Pipeline Structures

In August 1994 an isopolyester composite pipeline was installed around the quarters and work platforms of the offshore structure of the Gulf of Mexico, as shown in Figure 7. The pipeline will supply seawater to contain the blaze and allow the personnel to evacuate.

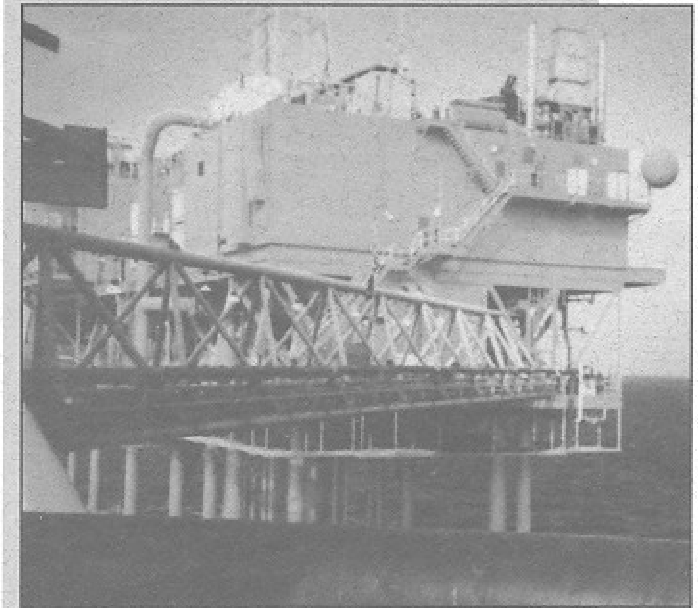


Figure 7. The isopolyester composite pipeline for the offshore structure in the Gulf of Mexico.

The pipeline system was designed, fabricated, and installed by Specialty Plastics, Inc., of Baton Rouge Louisiana. This installation of Fibrebond 20-FW-HV composite pipe and fitting is part of an emerging trend in the Gulf of Mexico where drilling sites have traditionally used steel pipe for firewater mains. The isopolyester pipes were fabricated using excellent resin for seawater applications up to 160°F (70°C), to meet all the performance requirements and are economical alternatives to metals.

The corrosion resistance of the interior surface is improved by applying a resin-impregnated, 2-mil (0.05 ml) thick layer of C-veil to the mandrel. The exterior of the pipe is coated red to designated the pipes' function as the firewater main. The colour is achieved by a gel coat applied with a synthetic fabric veil to provide a resin-rich, corrosion resistant surface. This exterior surface finish provides resistance to "fibre bloom" for up to 10 years.

For further information, please contact
Kevin Schmit, Project Engineer, Specialty Plastics, Inc., FAX: (504) 752-2757.

New Products

FRPH Structural Systems

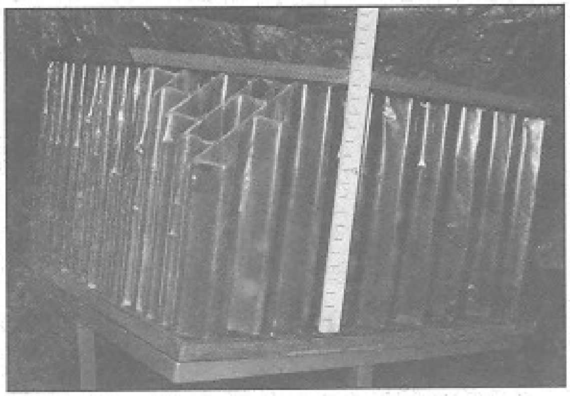


Figure 8. Fibre-reinforced-polymer honeycomb (FRPH) structural systems

Fibre-reinforced-polymer honeycomb (FRPH) structural systems are a sandwich composite consisting of two fibre reinforced polymer (FRP) skins separated by an FRP honeycomb core as shown in Figure 8. The FRPH structural element is planned to be used in replacing a highway bridge deck in the U.S.A. The system is developed by Core Craft Technologies Inc. and currently commercialized by Industrial Honeycomb Structures Inc. and its subsidiary, Mega Marine Structures Inc. FRPH structural elements is an innovative concept which provides significant reduction in cost, labour and weight, in addition to the advantage of a corrosion-free system for a variety of structures such as bridge decks and marine structures.

For further information, please contact Mr. Robert Cohen, FAX: (303) 430-9135.

Vinylester PSI Fiberbar

The PSI fiberbar, produced by Polystructures, Inc., Little Rock, AR, U.S.A., is made up of 70% e-glass and 30% vinylester resin. The bar is covered with a nexus veil to protect the fibres and wrapped with strands of E-glass at a 45º angle to provide spiral indentation to enhance the bond strength characteristics of the product, as shown in Figure 9. PSI Fiberbar is produced in standard bar sizes from 6.3 mm to 28.6 mm diameter.

The company produced similar products using S-glass, Aramid fibre and carbon fibre. The products have been tested and used for several projects including hospital MRI installations, radar installations and power conditioning facilities.

For further information, contact Mr. Bob Curd, FAX: (501) 375-1277.

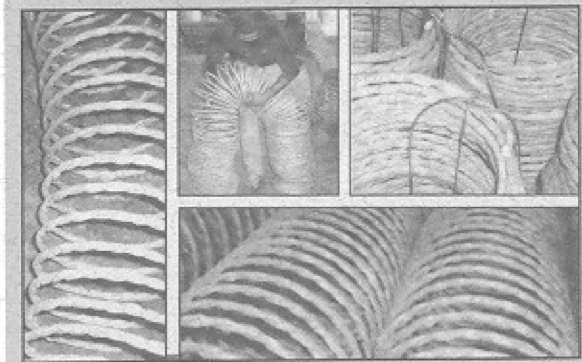


Figure 9. The PSI FIBERBAR, produced by Polystructures, Inc.

C-Bar Reinforcing Rods

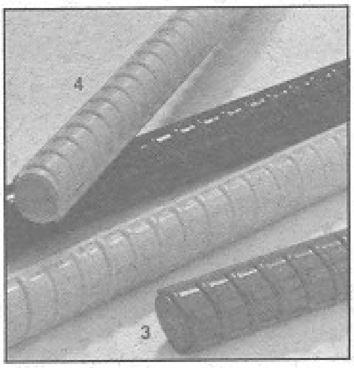


Figure 10a. C-BAR™ Reinforcement

Marshall Industries Composites has recently introduced a new generation of FRP reinforcements, called C-BAR™ (Figure 10a and b) with the following characteristics:

- C-BAR™ reinforcing rods are non-corrosive, non-metallic and non-conductive
- Tensile strength in more than twice that of steel, yet is four times lighter than steel
- Consistent modulus of elasticity
- Deformation patterns are the same as with steel

(continued on page 6)

(continued from page 5)

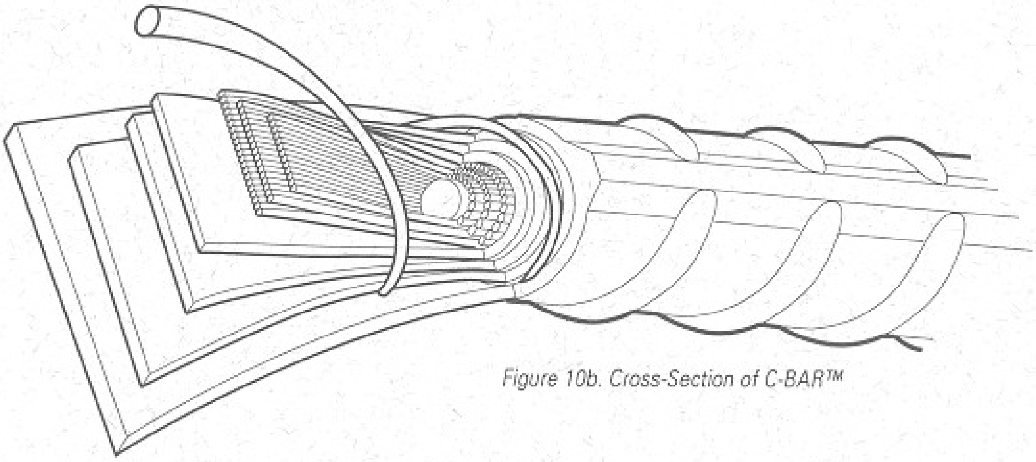


Figure 10b. Cross-Section of C-BAR™

- Quality assurance traceable through lot-coding
- Available in prefabricated ACI standard angles and bends
- Multiple patents on the technology pending
- Coefficient of thermal expansion more similar to concrete than that of steel

For further information, please contact
Dr. Salem Faza,
Director of Marketing and Engineering,
Marshall Industries Composites,
FAX: (419) 229-2598.

• Seapile™ Composite Marine Piling

The SEAPILE™ Composite Marine Piling is a new piling for dock construction introduced by Seaward International, Inc. Made from recycled plastic and drawing upon technology especially developed for this application, the SEAPILE™ offers the dock designer and facilities manager an alternative to traditional creosoted timber piles for fendering purposes (Figure 11).

SEAPILE™ Composite Marine Piling is:

- Environmentally Friendly
- Made from recycled plastics
- Impervious to marine borers
- A one-piece unit
- Non-magnetic when reinforced with fibreglass
- Covered by a tough outer skin

SEAPILE™ International, Inc. can provide driving accessories to aid in the installation of the SEAPILE™.

SEAPILE™ is manufactured in a continuous process, so one-piece pilings can be made in virtually any length. The plastic compound is made of Duralin™ Plastic, a matrix composed of 100% recycled resin and designed by Seaward chemists and engineers for its strength and ability to bond with the structural elements of the pile. It is also resistant to ultraviolet light, chipping and spalling and is impervious to marine borers. The structural elements that help to form the piling can be either steel or fibreglass. When reinforced with fibreglass, the SEAPILE™ exhibits a non-magnetic signature and is one hundred percent recyclable.

For further information, please contact
Seaward International, Inc., Clearbrook, VA, USA,
FAX: (703) 667-7987.

CONFERENCES

- **The SPI Composites Institute 50th Annual Conference and Expo '95** in Cincinnati, Ohio, **30 January to 1 February 1995.**

  Contact the Composites Institute, 355 Lexington Ave. New York, NY 10017. TEL: (212) 351-5410. FAX: (212) 370-1731.

- **Third Annual Wilson Forum on Existing and Potential Application of Concrete Materials in the Infrastructure,** Crown Sterling Suites, Santa Ana, CA, **20-21 March 1995.**

  Contact Norma Anders, FAX: (916) 989-1714.

- **Fibre Reinforced Concrete Second University - Industry Workshop,** International Plaza Hotel & Conference Centre, Toronto, Ontario, Canada. **26-29 March 1995.**

  Contact Dr. N. Banthia, FAX: (604) 822-6901.

- **Tenth ASCE Engineering Mechanics Conference,** University of Colorado, Boulder CO, USA, **21-24 May 1995** - Session on Non-Metallic Reinforcement for Concrete Structures.

  Contact: Dr. Richard N. White, School of Civil and Environmental Eng'g. Cornell University, Ithaca, NY FAX: (607) 255-4828.

- **"Journées Européens des composites" Conference and Exhibition (JEC)** CNIT Paris-la-Defense, Paris, France. **26-28 April 1995.**

  Contact Centre de Promotion des Composites, FAX: +33 (1) 4763-5739.

- **40th International SAMPE Symposium and Exhibition,** Anaheim Convention Centre and Anaheim Hilton Hotel, CA. **8-11 May 1995.**

  Contact Dr. Gerald Bailey, FAX: (619) 464-9902.

- **Second International Symposium on Non-Metallic (FRP) Reinforcement for Concrete Structures,** Universiteit Ghent, Belgium, **23-25 August 1995.**

  Contact: Dr. Luc Taerwe, Universiteit Ghent, Dept of Structural Eng'g. Technologiepark-Zwijnaarde 9, B-9052 Gent, Belgium, FAX: +32 (9) 264-5845, E-mail: beton@mecairis.rug.ac.be.

- **IABSE - Extending the Lifespan of Structures,** San Francisco, CA, USA, **23-25 August 1995.**

  Contact: IABSE Secretariat, ETH-Hönggerberg, CH-8093 Zurich, Switzerland, FAX: +41(1) 371-2131.

- **9th International Conference on Mechanics of Composite Materials,** Riga, Latvia, Sweden, **17-20 October 1995.**

  Contact: Secretariat, FAX: +46 (31) 772-2296.

- **Second Symposium on High Temperature And Environmental Effects On Polymeric Composites,** sponsored by ASTM Committee D-30, Norfolk, Virginia, **14-16 November 1995.**

  Contact Dr. A. Zureick, FAX: (404) 894- 0211.

- **The First International Conference on Composites in Infrastructure (ICCI '96)** Tucson, Arizona, USA. **15-17 January 1996.**

  Abstracts; 250 words by 1 February 1995 to:
  Prof. M. Ehsani, University of Arizona,
  FAX:: (602) 621-1443;
  Dr. Saadatmanesh, FAX: (602) 621-2148.
  E-mail: baltes@bigdog.engr.arizona.edu.

- **2nd International Conference on the Use of Advanced Composite Materials for Bridges and Structures,** Winnipeg, Manitoba, Canada, **11-14 August 1996.** Deadlines: Oct. 1, 1995 for 300 word abstract.

  Contact: Dr. S. 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,** Tokyo, Japan, **Summer 1997.** Deadlines: t.b.a.

  Contact: Dr. T. Uomoto, Institute of Industrial Science, University of Tokyo, 22-1 Roppongi, 7-Chome, Minato-ku, Tokyo 106, Japan.

Theses

Brooks, R.J., 1993.
Finite Element Modelling and Analysis of the Lateral Buckling Tests of Tip Loaded, Pultruded GRP, I-section Cantilevers, M.Sc. Thesis, Engineering Department, Lancaster University, Lancaster, United Kingdom.

Drimoussis, Efrosini H., 1994.
Shear Strengthening of Concrete Girders Using Carbon Fibre Reinforced Plastic Sheets, M.Sc. Thesis, University of Alberta, Edmonton, Alberta, Canada. Supervisor: J.J. Roger Cheng.

Nadipelli, M. 1994.
Experimental Investigation of Local Buckling and Failure of Pultruded Fiber Reinforced Plastic Beams, MS Dissertation, Department of Civil Engineering, The Catholic University of America, Washington, DC, U.S.A.

Svecova, D. 1994.
Serviceability and Strength of Concrete Parking Structures Reinforced by Fibre Reinforced Plastics, M.Eng. Thesis, Carlton University, Ottawa, Canada. Supervisor: Dr. A. Razaqpur.

Tao, S.,1994.
Bond of Glass Fiber-Reinforced-Plastic Reinforcing Bars to Concrete, Ph.D. Dissertation, Dept. of Civil Engineering and Engineering Mechanics, The University of Arizona, Tucson, AZ, U.S.A.

Jin, L.,1994.
Seismic Retrofit and Design Recommendations for Reinforced Concrete Bridge Columns, Ph.D. Dissertation, Dept. of Civil Engineering and Engineering Mechanics, The University of Arizona, Tucson, AZ, U.S.A.

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

STAMP

To: ______________________________