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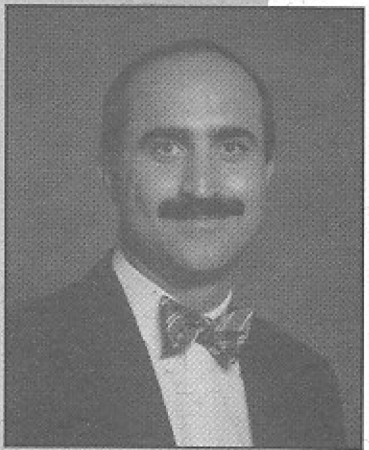
Guest Author – Dr. Mohammad R. Ehsani

Dr. Ehsani received his B.S., M.S., and Ph.D. degrees from the University of Michigan before joining the Faculty of Civil Engineering and Engineering Mechanics at the University of Arizona in 1982. For the past eight years, Professor Ehsani's research has focused on various approaches to the repair and strengthening of existing structures with FRP. Dr. Ehsani has served as a consultant on several projects dealing with the design of bridges and seismic retrofitting of concrete and masonry buildings. He has also worked extensively with the U.S. Army Corps of Engineers on the evaluation of seismic vulnerability and the rehabilitation of intake tower structures.



Dr. Mohammad R. Ehsani
Professor of Civil Engineering
University of Arizona

Dr. Ehsani is an active member of several American Concrete Institute committees and serves as the Chair of a subcommittee of the ACI Committee 440, which recently completed a comprehensive State-of-the-Art Report on FRP Reinforcement for Concrete Structures. A past Director of the Arizona Chapter of ACI, Professor Ehsani has also served as President of the Structural Engineers Association of Arizona. He is co-Chair of the First International Conference on Composites in Infrastructure which will be held in Tucson, Arizona in January 1996.

Recently, Dr. Ehsani served as a consultant for retrofitting a one-story unreinforced concrete masonry (URM) building shown in Figure (1). The building was retrofitted in the late 1980s by providing new steel columns and by tying the roof joists to the URM walls. However, in the 1994 earthquake, the wall located on the south side of the building was severely damaged. This is a common problem in most buildings which have been retrofitted. In older buildings, connections between the walls and floors are the weakest elements; once these elements are strengthened through seismic retrofitting, future earthquakes impose much larger loads on the walls, leading to the failure of these elements. Hence, there is a great need for simple techniques to strengthen URM walls.

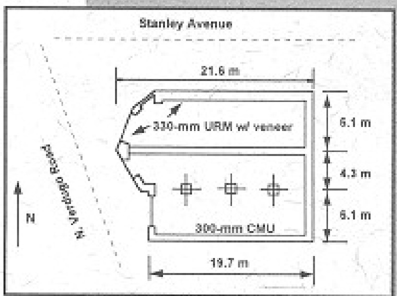


Figure 1. Plan of the damaged building

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Recognizing the limited capacity of URM walls in shear and flexure, a common solution is to attach a gridwork of steel rebars to the face of the existing wall and use shotcrete to increase the wall thickness from 150 to 200 mm. The additional weight increases the dynamic loads on the building, which in turn often requires strengthening of the foundation to support the heavier wall. In the case of this building, however, due to space limitations, this option was not available. As a result, it was decided to retrofit the wall by applying composite fabrics to both faces.

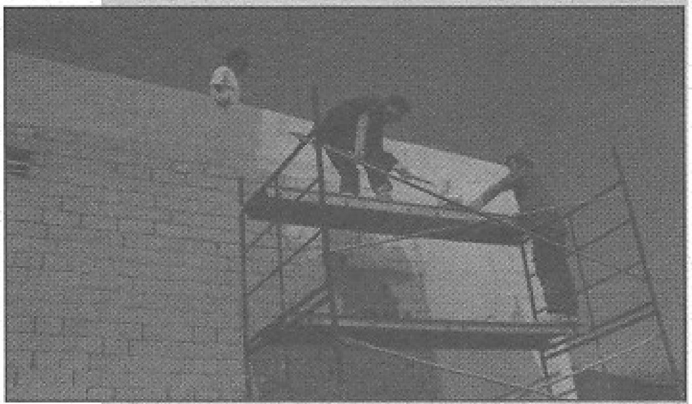

Figure 2. Application of composite fabrics to the URM wall (Courtesy of Structural Rehabilitation Corporation)

After the wall surface was sandblasted and cleaned, a thin layer of a two-part epoxy was applied to the wall. The fabric, which was 915 mm wide and constructed primarily of E-glass, was pressed against the wet epoxy, as shown in Figure (2). The fabric included equal amounts of fibres in 0- and 90-degree directions, with a tensile strength of approximately 175 N/mm in each direction. The edges of the fabrics were overlapped so as to provide continuous reinforcement for the wall. A top coating of epoxy and a layer of ultraviolet-protective paint was also applied to the wall surface. The thickness of the wall was increased by only 5 mm as a result of the retrofit. The project was completed on time and at a cost savings of 30% compared to the conventional technique using shotcrete. This is the first reported field application of such a technique. The retrofitted wall at the completion of the project is shown in Figure (3).

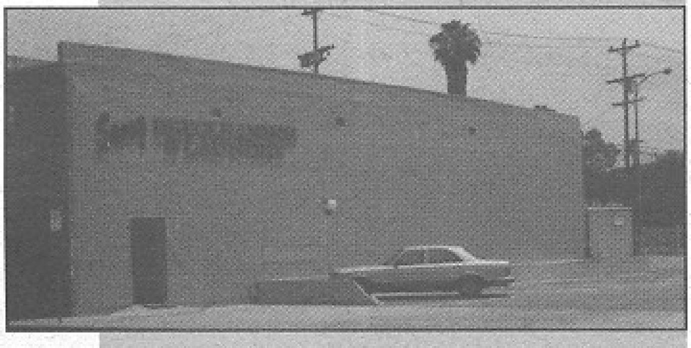

Figure 3. Strengthened URM wall at the conclusion of the project.

Research

FRP Composites for Repair of RC Structures

Beginning July 1, 1995, a project entitled: "Externally Bonded FRP Composites for Repair of RC Structures," was undertaken at The Pennsylvania State University. The project will have a duration of three years with funding from the National Science Foundation. The objective of this work is to provide the engineering science necessary for the implementation of externally bonded FRP reinforcement for the repair of concrete structures, except for the case of members subjected to compression where enhancement of strength and ductility is the result of lateral confinement of concrete (e.g., column wrapping). The material of interest consists of highly flexible sheets made of dry fibres or prepregs, i.e. pre-impregnated fibres, that can be adhered to a concrete surface after minimum surface preparation (e.g., cleaning/sealing/priming) by means of a polymeric resin. The fibres are of the high-strength and high-modulus category, such as carbon and aramid. The project consists of an experimental and analytical study based primarily on tensile RC specimens. Tests are conducted under quasi-static conditions after mechanical conditioning by means of repeated and sustained loading, and environmental conditioning by means of thermal cycling and exposure to aggressive environments to quantify the effects of externally bonded FRP reinforcement on concrete resistance to cracking, and to assess long-term strengthening performance. An important part of the durability study is to determine whether the presence of FRP reinforcement promotes/inhibits degradation of steel reinforcement in concrete.

The project will benefit greatly from the collaboration of the manufacturing and construction industry in the provision of suitable materials and making available field applications as a test bed for laboratory findings and verification of modelling.

For further information please contact Dr. A. Nanni at Penn State (Tel: 814-863-2084, Fax: - 4789; E-Mail: AXN2@PSUVM.PSU.EDU).

FRP for the Strengthening of Historic Masonry Structures

Research carried out over the past two years at the University of Patras, Greece, in the area of strengthening with FRP materials has focused on rehabilitation of historic masonry. The research efforts, led by Prof. Triantafillou, have aimed at developing and understanding two novel techniques for masonry rehabilitation using composites. In the first technique, old masonry buildings are strengthened using lightweight and corrosion resistant FRP tendons in the form of strips anchored to the masonry only at their ends. The strips, which may be applied in a reversible manner, are circumferentially applied on the external face of the building, in a color matching that of the surface, and are post-tensioned to provide horizontal confinement. Analytical and finite element calculations show that this method is very effective, especially when the ties are made of CFRP. The study has led to the development of optimum anchorages, and to the proposal of a design procedure within the framework of ultimate limit state design.

In the second technique, the facades of old masonry buildings can be strengthened using CFRP laminates which are epoxy-bonded to the surface of the masonry, the laminates being parallel to the direction of the maximum principal tensile stresses, and thus serving the role of tensile reinforcement. The laminates are finally covered with a thin layer of plaster. Greek engineers regard this technique as a desirable alternative to the commonly-used reinforced concrete or shotcrete jackets, which not only add considerable weight to the structure and adversely affect the aesthetics, but are also inapplicable in the case of facades with arches. The first application of the technique to a 150-year old building in the historic centre of Patras is in progress, with partial funding from Hilti Corp. and the Swiss Federal Laboratories for Materials Testing and Research (EMPA).

For further information, please contact Prof. T.C. Triantafillou, phone (+30 61) 997764, Fax (+30 61) 9977694, e-mail ttriant@upatras.gr.

Smart FRP Reinforcement for Concrete

Researchers at The Pennsylvania State University are exploring the design, fabrication, and testing of smart, ductile, reinforcement rods based on hybrid fibre reinforced plastics. These smart rods are intended for use as safe tensile reinforcing elements (with or without pretension) for concrete structural members. Development testing was carried out on smooth, stand-alone, hybrid fibre rods manufactured in the Composites Manufacturing Technology Centre at Penn State by a low-cost pultrusion technique. A small volume fraction of electrically conductive carbon fibres was used to monitor the onset of damage by electrical means and to add stiffness to the rods. The type and placement of carbon fibres in the rods were chosen such that these fibres failed first, in a non-catastrophic manner, during tensile loadings. The remainder of the cross-section of the rods consisted of various combinations of higher ultimate strain glass, aramid, and polyvinyl alcohol fibres, designed such that one or more distinct groups of fibres failed sequentially before the final failure event.

Electrical and stress-strain behaviours of six different hybrid FRP rods have been evaluated to date. In all cases, the onset of progressive failure was effectively captured by electrical resistance monitoring. In addition, two of the material systems showed significant load carrying capability after failure of the carbon fibres. It was concluded that a small volume fraction of carbon fibres in a primarily glass-reinforced composite was the best material design for the objectives of this study, although ongoing studies will determine the appropriateness of polymer fibres as the primary load-carrying ones. Performance of the smart reinforcement when subjected to long-term loadings and temperature changes is still under investigation.

Industrial collaborators on this research project are Creative Pultrusions, Hercules, and Kuraray. Preliminary results of the investigation will be presented at the First International Conference on Composites in Infrastructure, to be held in Tucson, AZ, USA, on Jan. 15-17, 1996. For more information, please contact Prof. Charles E. Bakis, tel. 814-865-3178, e-mail ceb5@psuvm.psu.edu, add.: 227 Hammond Bldg. or Prof. Antonio Nanni, tel. 814-863-2084, e-mail axn2@psuvm.psu.edu, address: 104 Engineering Unit A at Penn State University, University Park, PA, 16802, USA.

Rehabilitation of Clearwater Creek Bridge Using CFRP Sheets

In Alberta, Canada about 2,500 precast concrete bridges built in the 1950's and 60's are in urgent need of repair or strengthening. It will cost more than $150 million to repair or replace these bridges, even before taking into account the costs associated with interruptions to traffic and public inconvenience. A collaborative research project was developed last summer, the partners being the University of Alberta, Alberta Transportation and Utilities, Mitsubishi Canada, and Lafarge Construction and Materials, to study the construction and durability of using CFRP sheets to strengthen an existing concrete bridge. A three-span "Type G" girder bridge carrying almost 3,000 vehicles per day was chosen for the study. The "Type G" girders in the bridge had only a marginal shear capacity, which was expected to worsen as traffic loads increase and time takes its toll. All ten of the simply supported, Type G girders in the south span low beam were strengthened. The objective of this rehabilitation is to examine how effective this method will be in the field application of CFRP sheets, with the repaired bridge being exposed to real traffic loading and extremes of weather, an the program operating under realistic, limited budge constraints. The behaviour of the bridge and the CFRP sheets will be monitored visually and quantitatively for a projected period of 4 years. The construction phase of this rehabilitation project has been completed. An analysis of the initial cost of rehabilitation is being performed to compare the CFRP sheet rehabilitation method with various other rehabilitation methods, such as the traditional external steel stirrup reinforcement. This comparison, along with the performance of the strengthened bridge under controlled truck load tests and future accumulated durability data, will provide both a structural and financial measure of the efficiency of this method.

For further information, please contact Dr. Roger Cheng, University of Alberta, FAX: (403) 492-0249, Email: rcheng@civil.ualberta.ca.

Applications

Prestressed Concrete Panel by CFCC

A concrete panel prestressed with CFCC was adopted for the construction of a wall in the pier at Toyama-Fusiki harbor, Japan, in April 1995. The pier consists of poles and panels as the underwater structure, and deck as the superstructure. CFCC reinforced panels were installed at the waterline between the piles. The size of a panel is 1000 x 2800 x 90 mm. The number of panels used is 66. The wall dissipates the energy of the sea waves and is exposed to salt in the splash zone. The pier serves for the safe mooring of the sailing ship KAIOHMARU in the harbor, as shown in Figure (4).

For more information, please contact Mr. Kawata, manager of Technical Division, Tokyo Rope Co., Ltd., Fax 81-3-3242-7584.

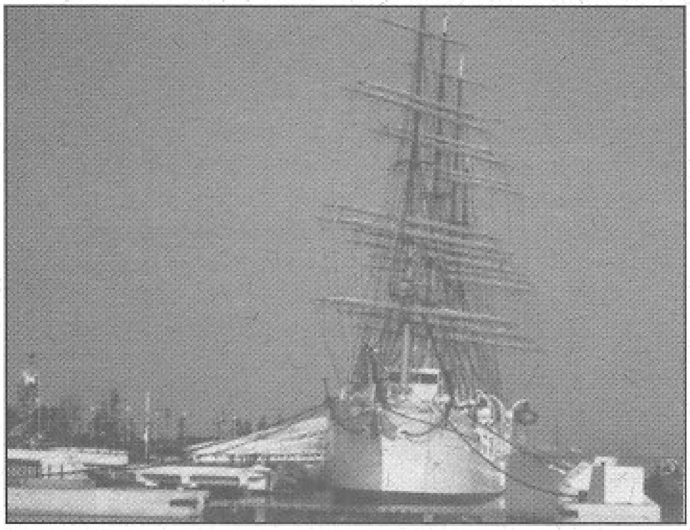

Figure 4. Concrete Panel prestressed by CFCC used in the pier in Toyama-Fusiki harbour, Japan.

NM Ground Anchor with CFCC

Zenitaka-Gumi, Kowa, Sekisui Chemical and Tokyo Rope jointly developed a permanent ground anchor system with CFCC in 1993. Since then, four commercial applications have been implemented. The tendon for the NM (New Material) anchor is composed of CFCC multi cables, a stainless steel terminal sleeve, and parts for the guide and free length spacing. A GFRP plate is used to distribute the pressure to the soil. The plate is attached to the tendon with a stainless steel bearing plate and nut as shown in Figure (5).

The system is light weight, easy to handle, and corrosion resistant, in addition to having the high loading capacity of conventional steel tendons.

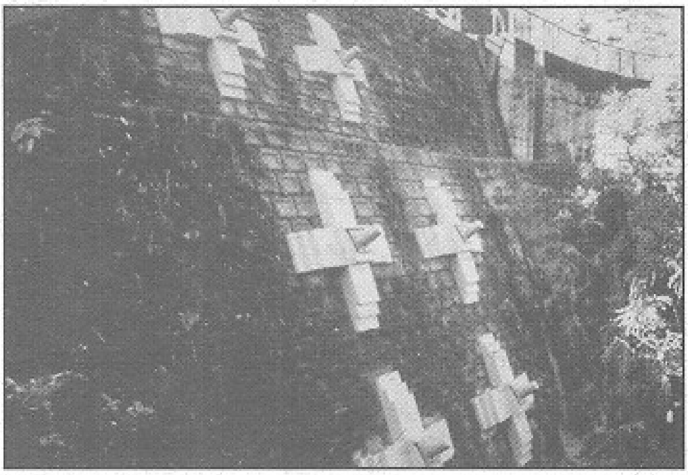

Figure 5. NM Ground Anchors, cited in Toyama, Japan in 1994. Tendons are 17.5m, 14.5m and 11.0m in length and 30 tons each in loading capacity.

For more information, please contact Mr. Kawata, manager of Technical Division, Tokyo Rope Mfg. Co., Ltd., Fax 81-3-3242-7584.

Rehabilitation Following Earthquake Disaster

Extensive repair work is demanded for reinforced concrete (RC) structures damaged by the Southern Hyogo Prefecture Earthquake on January 17, 1995 in Japan. Among the various methods of repair, seismic retrofitting using Carbon Fibre (CF) stands superior to the others in time-saving efficiency and ease of handling. In the earthquake affected

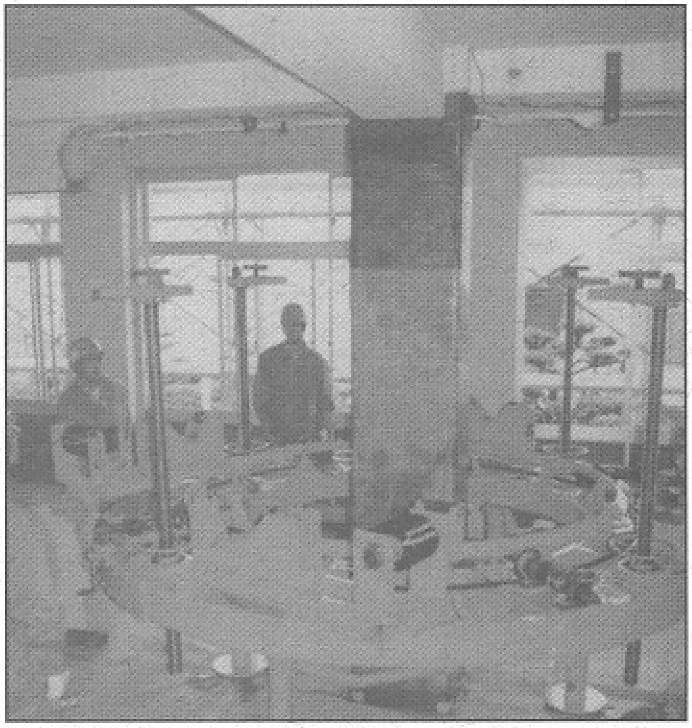

Figure 6. Rehabilitation using CF Strands.

areas, CF-retrofitting has been used in approximately 50 cases, including buildings columns and beams, railways and highways bridge piers, platforms in railway stations, a radio-communication tower, and tunnels.

There are two ways to apply CF on to a concrete surface. One is the winding of strands consisting of more than 10,000 CF filaments. Figure (6) shows a case of reinforcing of a building column using such CF strands. The other method is to apply CF sheets as shown in Figure (7) for a railway bridge pier. The efficiency and the construction technique of CF-seismic-retrofitting have been thoroughly researched in the last decade and it is expected that their use will be extended to existing RC structures in Japan.

Figure 7. Rehabilitation using CF Sheets.

ACM Dock

A 12 meter long and 1.3 meter wide ACM dock, shown in Figure (8), was built by Faroex Ltd., Gimli, Manitoba, Canada to study the feasibility of using pultruded box shape fibreglass composite sections manufactured by Faroex in the construction of these types of structures and pedestrian bridges.

The two supporting trusses are assembled by pultruded box beams made of E glass and polyester. The truss beams are formed from an assembly of box beams that are dowelled together at the connection points by 13mm fibreglass dowel pins. Each joint is also connected by means of epoxy adhesive. The combination of dowel pin and adhesive is used to overcome the abrasion which commonly occurs in the dowel pin areas under the cyclical loadings which are often encountered in this type of structure.

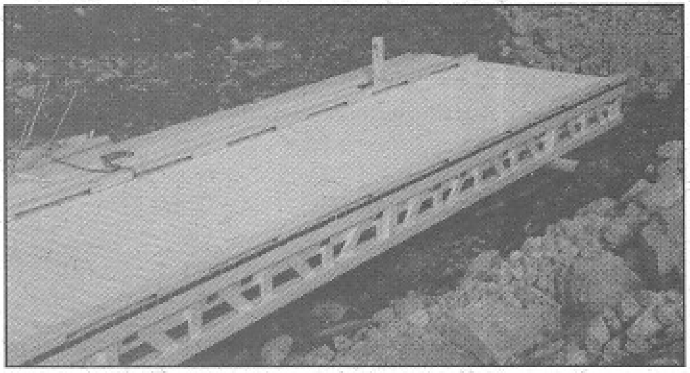

Figure 8. ACM Deck, Gimli, Manitoba, Canada.

The deck is made using the same box shape beam and similarly dowelled and glued into place. To provide optimum traction, the exposed surfaces of deck surface protection were provided with a painted finish.

The structure was evaluated for strength and stiffness before being used as a dock structure. The glued and dowelled joints in the structure will be evaluated on site under the action of the cyclic movements from wave action.

For more information, please contact Ken Church at Faroex Limited, Tel: (204) 642-8897 and FAX: (204) 642 7542.

Shank Castle Footbridge, Cumbria, United Kingdom

Shank Castle Footbridge crosses the Rae Burn River at a remote woodland location approximately 10 miles north of Carlisle. The bridge is a simply supported structure with a span width of 12 m and a deck width of 0.76 m, as shown in Figure (9). It is one of a series of standard footbridges designed by Maunsell Structural Plastics for Designer Composites Technology. The design used a limit state design method linked to a special manufacturing specification for the pultruded glass reinforced plastic components. All components used in construction of the footbridge form part of Maunsell Structural Plastics Advanced Composite Construction System (ACCS) for which Designer Composites Technology is the exclusive license holder. Components are bonded together using an epoxy adhesive.

Figure 9. Shank Castle Footbridge.

A glass reinforced plastic bridge was selected as an alternative to timber in this case because of it durability, low weight, color flexibility and ease of construction. The total weight of the bridge, including hand railing, is 660 kg (55 kg/m).

The beam was manufactured off site, incorporating a non-skid deck surfacing. It was then delivered by road as far as was possible in such a remote location. Specially made trolleys were used to complete the delivery through the surrounding woodland.

Ropes and winches were used to lift the beam on to the purpose-built abutments. The bridge was completed by the addition of glass reinforced plastic hand railing. The application of the ACCS provides a Class 2 fire resistance rating and a reliable life to first maintenance of at least 30 years. The long-term performance of the ACCS has been proven by a research program undertaken at the University of Surrey.

For further information, please contact either Allan E. Churchman or Peter R. Head, 0181-663-6565, Fax 0181-663-6723.

ACM Building

The world's first advanced composite multi-story building constructed using the Maunsell Structural Plastics Advanced Composite Construction System (ACCS) was commissioned by the client as an alternative to conventional site accommodation for the Government's Agent team on the Second Severn Crossing project.

The system consists of high quality interlocking pultruded glass reinforced panels which are bonded together to form a membrane structure in which walls, floors and roof provide complete structural integrity without additional framework, as shown in Figure (10).

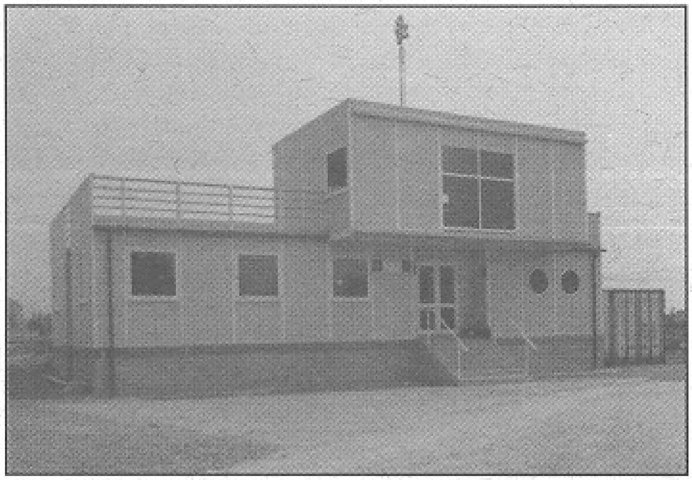

Figure 10. Advanced Composite Site Office Building.

The office provides space for eight staff and a large meeting room for 20 people on the first floor. Good thermal insulation and fire-resistance are key features of the building design. Panels are insulated to a high standard and double-glazed windows have been fitted. In critical areas, panels meet Class 0 fire regulation specifications, with a fire resistance of at least 30 minutes when tested in accordance with the relevant British Code.

The advanced Composite Construction System provides rapid, cost-effective, high quality construction, even in locations where access is difficult. Future applications of the system are envisaged particularly for disaster relief, since the flat-packed buildings can be rapidly erected and earthquake-resistant multi-story buildings are ideal for seismic areas.

For further information, please contact either Allan E. Churchman or Peter R. Head, 0181-663-6565, Fax 0181-663-6723.

FRP for the Strengthening of Concrete and Masonry

Structural Preservation Systems, Inc. (SPS), and Tonen Corporation of Japan have teamed up to provide carbon fibre sheet strengthening technology for concrete and masonry. This repair system offers ease of application, versatility, durability, and economy to the repair market.

SPS and Tonen have made available FORCA Tow Sheet materials, technology and installation services to solve complex concrete and masonry repair problems in a cost-effective manner.

FORCA Tow Sheet has been shown to provide superior excellent reinforcement/protection and cost advantages compared to conventional strengthening. This strengthening system, consisting of continuous carbon fibre sheet and impregnation resins affixed to the surface of concrete and masonry structures, has found widespread use with hundreds of field applications, including repairs on bridge beams, retaining walls, utility poles, slabs, chimneys, tunnels and other structures requiring strengthening, stabilization or seismic upgrade.

For more information, please contact Jay Thomas, 410-247-1016, Fax 410-247-1136.

CFRP Reinforced for Concrete Poles

Solutions for replacing the steel reinforcement of centrifugally cast concrete poles (Hume process) are currently being studied at EMPA Dubendorf together with SACAC Lenzburg, an industrial partner, in Switzerland.

The major problem of galvanized steel lightning and power transmission poles is the severe corrosion of the outer surface, already present after only 12 years of service, which leads to expensive maintenance activities. The reinforced conconcrete poles employed today are resistant up to a point. The poles are constructed with a 25-30 mm thick concrete cover to the steel rebars and spiral shear reinforcement. This results in excessive weight.

The replacement of steel by carbon fibre reinforced plastic reinforcements, which are not affected by corrosion, is forseen to lead to corrosion-resistant and lighter poles, because of the saving of the thick concrete cover. The 25 times higher specific strength of CFRP will still further increase this weight saving and increase structural efficiency.

Furthermore, the use of high strength concrete, with a compressive strength higher than 100 Mpa, could result in an additional weight reduction of the poles.

The first part of this research program dealt with the search for and testing of an adequate shear reinforcement for replacement of the steel wire spirals. This was found in filament wound CFRP grids and epoxy impregnated, loosely braided, carbon fibre sleeves. Torsional testing of CFRP grid reinforced spun concrete pipes was performed in order to study the shear behaviour of the reinforcement. Induced compression forces were carried by the high strength concrete struts, while the perpendicular CFRP ties carried the tension stresses. Torsional failure of the pipes occurred by tensile failure of the CFRP ties in the principal tensile stress direction at 77-95% of the truss model calculated moment. The sudden failure is shown in Figure (11).

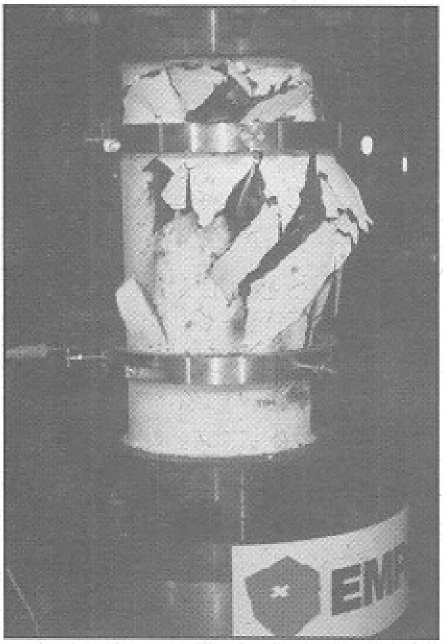

Figure 11. Concrete failure at 100 MPa.

For future information, please contact Giovanni Terrasi, at EMPA, Fax: 0041-1-823-4010, e-mail: giovanni.terrasi@empa.ch.

Society News

JCI has just set up the new committee on FRP Reinforcement. The chair is Prof. Kyuichi Maruyama (Nagaoka University of Technology) and the members are from JSCE and AIJ. The objectives are:

1) to establish design methods for FRP,
2) to investigate and study the application of FRP to repair and strengthen existing concrete structures; and,
3) to investigate the possibility of future applications of FRP.

The term of the committee's activity is 2 years. The committee will be responsible for the third FRP International Conference.

ACMBS Network Technical Mission to Francophone Europe

The ACMBS Network of Canada, with the support of Industry Canada, sponsored a technical mission that visited France, Switzerland and Belgium, from 23 April to 5 May 1995. The Mission, headed by Dr. Pierre Labossière from the Université de Sherbrooke, visited research institutions and universities, builders and contractors, field applications, and producers of composite materials. The Mission coincided with the Journées européennes de composites, the most important commercial exhibition in this field in Europe, held every year in Paris. In total, fourteen companies or institutions were visited. Most of the discussions held during the Mission dealt with the properties of the products and the opportunity to develop standards to guide the design of practical applications by engineers. It was noteworthy that repair and rehabilitation of existing structures with carbon fibre sheets is now commercially viable in Switzerland, and that in Switzerland over 100 structures have been repaired, or are slated for repair with these sheets. A bilingual, French and English, report of the Mission has been published by the ACMBS Network of Canada; copies may be obtained upon request from Dr. Aftab A. Mufti, Chair of the ACMBS Network of Canada, Fax: 902-422-8380, e-mail: mufti@tuns.ca.

University Theses

M'Bazaa, I., 1995, *Flexural Reinforcement of Reinforced Concrete Beams Using Composite Material Sheets: Optimization of Sheet Length (In French).* M.A.Sc. Université de Sherbrooke, Sherbrooke, Québec. Supervisor: P. Labossière.

Missihoun, M., 1995, *Flexural Reinforcement of Reinforced Concrete Beams Using Composite Material Sheets: Optimization of Fibre Orientation (In French).* M.A.Sc. Université de Sherbrooke, Sherbrooke, Québec. Supervisor: P. Labossière.

Aubert, M.M., 1995, *Analysis and Design in the Linear Elastic Range of RC Flexural Members Externally Bonded with FRP Sheets.* M.Sc., The Pennsylvania State University, University Park, PA. Supervisor: A. Nanni

Conferences

ACI 95 Fall Convention, Montreal, Bonaventure Hilton & Radisson Gouverneurs, Québec, Canada, 5-10 November 1995.

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.

International Conference on Fibre Reinforced Structural Plastics in Civil Engineering. Indian Institute of Technology, Madras, India, 18-20 December 1995.

The 75th Annual Transportation Research Board Meeting, Washington, DC, 7-11 January 1996. Contact Clifford MacDonald, FAX: (612) 736-7496.

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, FAX: 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 Chiyoda-ku, Tokyo 102, Japan.

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