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Editorial

Distress in structures much before their targeted design life has been a cause of great concern the world over with special science of distress diagnostics emerging as a very specialized important area of R&D. Retrofitting and strengthening have also been placed on sound scientific footing eliminating ad-hocism over the last few decades. The present issue deals exclusively with the issue of distress diagnostics and rehabilitation of structures.

The contributors include highly competent and leading professionals as well as academics. There are examples of damaged structures from Malaysia as well as new developments in the art of distress diagnosis. Post Rehabilitation Assessment has been specifically emphasized.

It is hoped that the readers would appreciate this special issue. We welcome your feedback.

Prof. Dr. D.N. Trikha
Chief Editor.

Damaged Building Structures and Structural Failures in Malaysia

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Malaysia is gearing towards achieving the status of a developed nation by the year 2020. In view of this, the government has invested substantially, particularly in public infrastructure, to develop the economy. This is to maintain Malaysia's competitiveness in the East Asia region, where our neighbours are growing at an impressive rate. The Public Works Department (PWD) Malaysia, being the main implementation agency for the government, has to ensure that defects and failures of infrastructure are avoided. Otherwise, the investment by the government will be jeopardised and more money wasted to remedy structural damages.

With respect to this, in Malaysia there are many reports of failures ranging from minor defects to catastrophic structural failures in the construction industry. Catastrophic failures are covered more extensively in the media compared to minor ones. However, minor failures on a cumulative basis may in effect have a greater adverse effect on the construction industry.

Ir.Dr.Wahid Omar

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Under the current practice, work by the main contractor is sometimes sub-contracted down one or more levels. The main concern is that the sub-contractor

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who eventually executes the work will have a much smaller profit margin than the main contractor who gets the job. As a result, they will find ways to cut corners when executing the work. This practice without proper control may lead to a potential cause for structural failures.

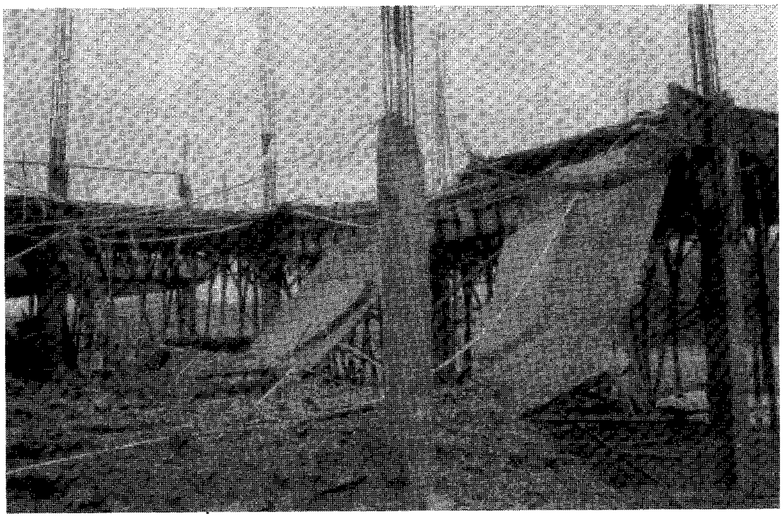

Figure 1 : The collapse of beams and slabs during construction of a building due to poorly constructed forms and temporary works.

Generally, in Malaysia, many structures are constructed from concrete cast at site, utilising the basic materials of cement and aggregates with formwork, which requires a large labour input. This unfortunately has resulted in many unskilled immigrant workers being employed in the construction sites as we lack a sufficient source of skilled labour.

Badly erected formwork including warped and bowed timber, leaks in formwork, poor workmanship, disorganised site conditions, and lack of site safety measures are a source of many problems, including structural defects and failures.

There is also a lack of competent and rigorous supervision of construction sites to control the quality on site. It is rare to find comprehensive quality assurance programmes being properly implemented on site to monitor quality of every detailed stage of construction. Compounding this shortcoming is the fact that sub-contractors are generally not aware of the potential hazards of shoddy work.

To alleviate the risk of a structural failure, there is now an urgent need for a paradigm shift from the conventional in-situ construction to a factory-based construction. This new option would also be more environmental friendly as the current construction practice has a detrimental impact on the environment. Currently this option is not so appealing to the contractor because of the perceived higher cost of construction involved. However, at the national level, this is a viable option because of the other costs associated with immigrant labour, including security costs in controlling the large influx of about 2 million immigrant workers and the rising social problems as a consequence of immigrant labour.

In this regard, the PWD Malaysia is promoting the use of modular component-based construction and prefabricated components in its works. With this approach, production of building components will be factory-based and this allows work to be carried out at a faster rate with assured quality and less potential for failure. It is hoped that in this manner the construction industry can be spurred to set up more plants to produce prefabricated components.

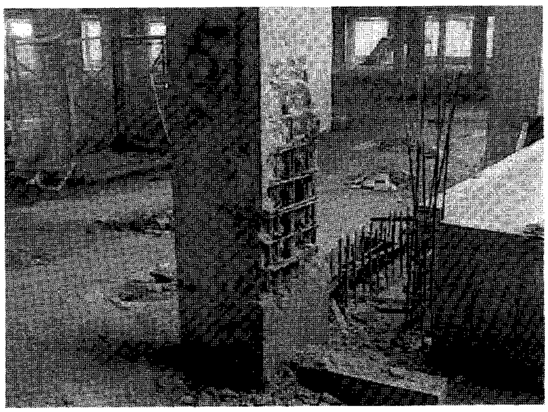

Figure 3 : The removal of honeycombs in a defective concrete column due to bad concreting practice at site

The potential for this innovation is not limited within Malaysia, as the Malaysian construction industry explores overseas markets, due to the higher value adding as a result of these products being used overseas.

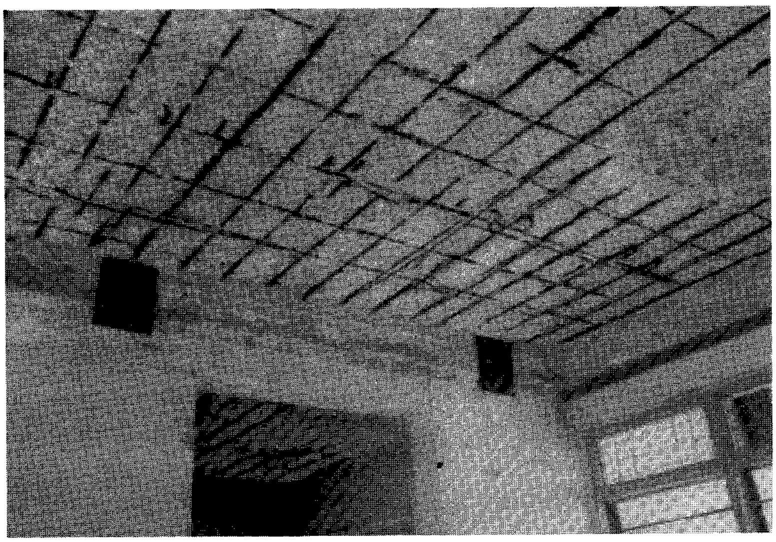

Figure 3 : Badly corroded reinforcement bars in concrete slab due to inadequate cover thickness

Damaged Bridge Structures and Failures in Malaysia

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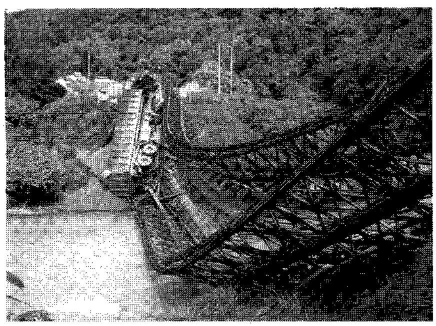
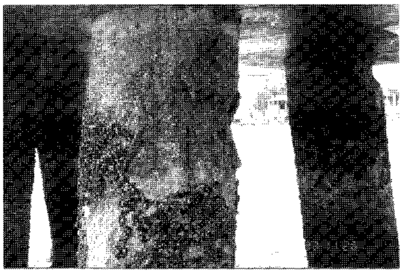
The Public Works Department (PWD) of Malaysia plays an important role in ensuring all existing and incoming bridge structures along its administrative roads are sound and safe to be used. The outcome of the studies done in 1986 and 1992 indicated that some bridges along Federal Routes in Peninsular Malaysia are experiencing structural and durability problems.

The Annual Mandatory Bridge Inspection (AMBI) was introduced in 1995. The inspection results showed that most of the existing bridge damages are due to inadequate bridge opening, scouring, bad concrete quality, concrete deterioration, individual component failure and of insufficient structural capacity for current loading. A Weight Registration Order was gazette in 1987, as a result of the outcome of the 1986 National Axle Load Study. The current permissible axle load is 10 tons maximum with a maximum gross vehicles weight of 38 tons. This under capacity bridges were determined and listed to be replaced by year 2020. The determination of the structural capacity of existing bridges in Peninsular Malaysia is also one of the strategies on monitoring the existing federal bridge stocks.



Bridge at Ranau Buckled by a Heavy Loory



Pile badly damaged due to collision with a barge

Reinforced concrete bridges are the most common structures, which are about 80% of the total numbers. These bridges constructed prior to year 1970's have suffered in varying degrees of defects to the bridge components. Deterioration ranges from surface deterioration to the form of concrete spallings or extensive corrosion of the exposed reinforcement. Concrete tend to deteriorate fast in aggressive environments such as at coastal areas. Current remedy is to specify impermeable concrete or in less severe environment with a minimum grade of 40 N/mm2. Bridge expansion joints normally have a designed life of only for 5 years. PWD Malaysia is trying to minimize the usage of expansion joints by constructing integral bridge for a single span bridge and constructing continuous bridge structure over four to five number of spans.

Having multiple column piers and up stand piles over waterways also creates major problem for bridge maintenance with regard to trap of rubbish and debris. The Old Temerloh Bridge across Pahang River and the Old Nordin Bridge across Perak River experienced this problem which subsequently leads to total bridge collapse in the 1960's. Minimizing piers inside waterways is the best choice. However, there are no statistical data on the actual number of bridge failures. Public attentions have been captured by failures such as piles badly damaged by a sand barge at one pier of Kuala Kedah Bridge in 1993, a steel composite pedestrian bridge over Federal Route 2 brought down by a very high lorry at Midland Estate, Klang in 1994, although a 5.3m clearance was provided. Most recently in 2001, a bailey bridge at Ranau, Sabah buckled due to overloading by a lorry.

In general, PWD Malaysia will try to preserve the existing bridge structures by routine maintenance, rehabilitation or strengthening them. As prevention is better than cure, new structures are being designed as a very durable product for less future maintenance.

A collapsed single span steel buckle plate bridge structure due to scouring of abutment

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Distress Assessment of Concrete Using NDT

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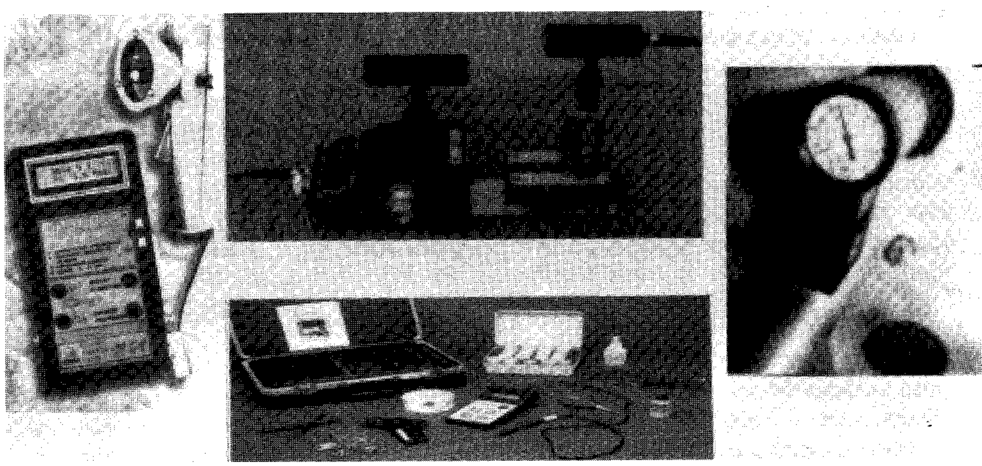
Most concrete structures are subject to some form of distress. Distressed concrete structures cannot perform their intended function or last their service lives. If the conditions are properly assessed at an early stage, suitable maintenance or strengthening strategy may be put in place so that their performance or service lives can be enhanced.

The Road Engineering Association of Malaysia is developing a special guide to Bridge Inspection for the Malaysian road bridges. It has been primarily developed based on the existing Bridge Inspection Manual owned by the Jabatan Kerja Raya. The inspection guide, however, is largely dependent on visual inspections. The condition assessment of concrete bridges relies on the observations made by bridge inspectors, and for each observation of distress, a particular rating is given. The rating depends on the intensity and the extent of the distress. If, for example, a structure is rated 5, it must be demolished and replaced.

It is apparent that the use of NDT is useful to corroborate the results of the visual distress assessment. The extent, intensity and potential future distresses can be assessed using suitable NDT equipments. Distress of concrete structures due to honeycombs, delamination, degree of corrosion, depth of chloride penetration and internal cracks or voids is normally not visible, hence cannot be accurately assessed. In addition to assessing the extent of distress, some of the available NDT equipments may also provide strength estimation of the insitu concrete. It is essential however to understand the limitations of nondestructive test results because they are normally not deterministic.

Distress assessment of concrete structures basically uses physics of materials and their response to sound, electronic, chemical or electrical signals. Most of the materials response to these signals are generally predictable if they are put in ideal or controlled conditions. The sound or electronic signals passing through a concrete mass can be used to indicate the density, porosity, presence of voids or strength of the materials. However, insitu structures are not in ideal and controlled environment.

Factors such as construction defects, moisture content and surface conditions vary tremendously in structures. Most structures may also have more than one distress, hence, measurement using an NDT equipment for a specific purpose may not be ideal. In other words, the results obtained from NDT results are at best indicative. It depends a lot on the expertise of the technicians and the engineers involved in the measurement and interpretation of the test results. At UPM, there is an ongoing research to develop predictive models for different NDT test results for different distress in concrete structures. Equipments such as Ultrasonic Pulse Velocity, Impact-echo, Concrete Strength Tester, Chloride Penetration Tests, Pull-out Tests, Permeability Tests, Concrete Resistivity Tests and Coring Machines are currently available to carry out the study. For each equipment and each distress under different condition of exposures, a predictive model may be developed so that engineers may use them as reference or to calibrate the respective NDT equipments. The results obtained from the ongoing study have also been fed to a knowledge-based system on assessment of reinforced concrete bridges, which is being developed at UPM. The system should be able to identify the extent and intensity of distress, based on the signals outpu from the NDT results.



Some NDT equipment available at UPM

Post Rehabilitation Assessment

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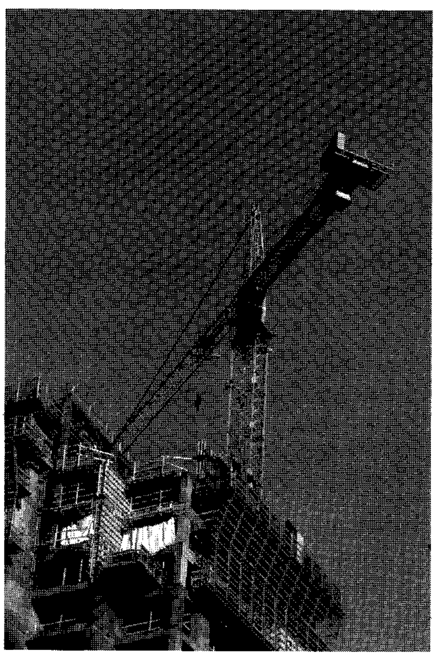
A rehabilitation /strengthening project requires a different strategy than the usual for its success. Firstly it is necessary that the investigations for distress (extent and nature) are entrusted to an independent authority other that the 'repair' contractor sothat the cause of distress is determined without consideration of financial gains. The repair contract should then include provisions for preparation of repair/rehabilitation scheme, its approval by appropriate authority and testing of repair materials prior to their use. As a third part of the strategy, the post rehabilitation assessment should be mandatory and left to a specialized agency with competence to carry out non-destructive tests (NDTs) as well as load testing of part or full structures.

Nature of Repairs	Repair Techniques	Assessment Procedures
1. Repairs of non-structural cracks	Sealing of cracks Bonding of repair materials to the old concrete	Permeability test Pull-off Test UPV Test
2. Repair for poor/contaminated concrete, honey combed/delaminated concrete	Replacement by well compacted salt free concrete	Rebound Hammer Test Core Test Permeability Test Chloride Test UPV Test
3. Repairs for cover depth	Jacketing/adding concrete	UPV Test Cover Meter
4. Repairs for structural cracks (a) Cracks caused by non-functioning of bearings	Set the bearings right & seal	As for non-structural cracks
(b) Cracks caused by bad design, over-load	Jacketing Plate bonding External prestressing	Theoretical Analysis Load Test
5. Repairs for Corrosion	Cleansing of steel & sealing	UPV Chloride Test Potential Test

Figure 1

Post rehabilitation assessment depends on the nature of repairs/rehabilitation carried out. Although each repairs/ rehabilitation project requires a project specific assessment procedure, certain general guide-lines can be formulated as shown in figure 1.



Load tests are however prohibitively expensive and time consuming. If it is possible to estimate reasonably correctly the strength of materials, reinforcement details and dimensions, theoretical analysis based on simplified methods like grillage analysis or finite strip method give a fairly accurate assessment of the global behaviour; otherwise a more rigorous finite element method has to be employed.

Load tests require simulation of live loads by means of water, sand, concrete blocks or metal weights which are applied in a gradual incremental manner (to avoid sudden failures) till test load is reached. The load is sustained for 24 hours and creep deformations are recorded. The structure is gradually unloaded. The load-deflection curve thus obtained gives the most accurate assessment of the rehabilitated structure.

To conclude, post rehabilitation assessment is a specialist job which can lead to legal disputes. A carefully planned strategy needs to be evolved to avoid legal hassles and to protect public infrastructure.

Fiber Optic Sensors for Real-Time Monitoring of Concrete Structures

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Reinforced concrete engineering, although highly advanced in materials and in the structural analysis and design, is deficient in its evaluation techniques for concrete strength and structural integrity. Most of the methods used are destructive. Various non-destructive methods for testing concrete have been developed. Optical fibers, because of their small size, can be embedded within concrete without affecting its properties and used as sensible, but rugged, transducers of mechanical perturbations. In this respect, fibers have the ability to provide high resolution temparature and strain measurements, detect the onset and growth of cracks, as well as to monitor creep and thermal stresses.

The basic physical principle (shown in Figure 1) behind embedded fibers to characterize the state of a composite material is that light sent through the fiber has either its intensity, phase, or polarization altered by changes in the mechanical state of the surrounding host. This can ultimately be used to provide "real time"information on the state of a specific concrete structure or member by means of a built-in damage and evaluation system based on a grid of optical fibers embedded within the structure at the time of construction. Figure 2 shows an example of a bridge fixed with fibre optic sensors.

Nondestructive, in-situ, testing of concrete properties will also be possible,for instance,its relative strength,its modulus of elasticity,or whether a batch was thoroughly mixed and properly poured and cured. Engineers and inspectors can return over the years to probe the internal condition of the concrete without damaging it, simply by connecting external equipment to the connectorized ends of the embedded fiber sensor. This is particularly useful in buildings located in seismic regions,and in constructions requiring a high degree of safety and reliability as is the case with hospitals, auditoriums, bridges, dams, and others.

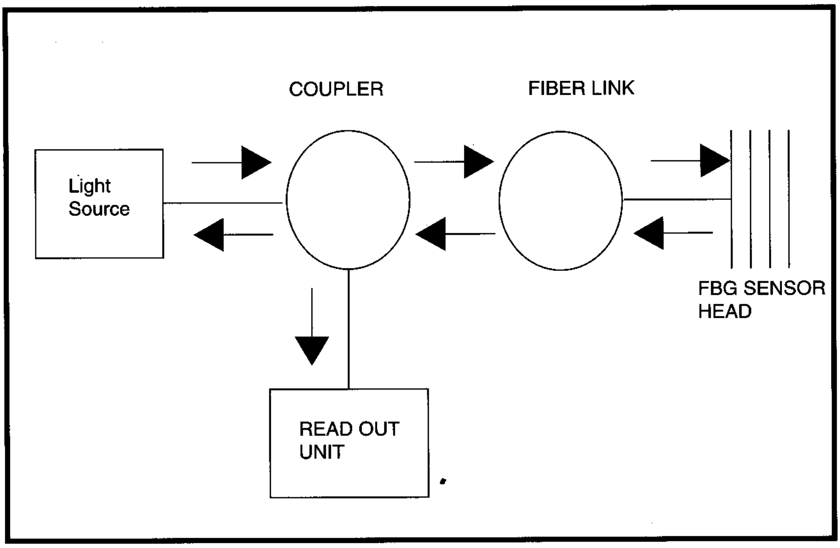

Figure 1 - Fibre Bragg Grating Sensor System

The fundamental applications envisioned for this new technology can be grouped in three main areas as follows: 1)structural monitoring and damage evaluation, 2)experimental stress analysis and, 3)management and control of systems and service installations in buildings.The first area studies the incorporation of single-and multi-mode fibers within structural concrete members such as beams,columns,arches or shells, so that concrete curing, stress, strain, deflection, bending, cracks and creep can be measured and monitored individually,as well as the deflection and bending of structure as a whole.In the field of experimental stress analysis,fibers would make sensitive and versatile sensors for the measurement of mechanical characteristics of structural members in experimental studies.The third set of applications considers that lighting,electric power,security,fire alarms and other building services can be run more efficiently and economically using fiber optic sensors to monitor the state of affairs of

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INDUSTRIALISED BUILDING SYSTEM 2003

Global Trends in Research, Delevopment and Construction

** September 2003

1st ANNOUNCEMENT AND CALL FOR PAPERS

Theme and Objective:

The construction industry has for many years maintained the time-tested but labour intensive traditional approach in construction and investing little in research and development. As the K-economy enters its stride into the new millennium, technological advances shall play a major role in changing the competitive work environment in the construction industry. Concurrently, as the demand for production and quality increases, the construction industry must indulge itself in innovations and be supportive of new technological techniques in construction. It is believed that the implementations of Industrialised Building System (IBS) in most countries have endured the high expectations from consumers.

Hence, the 3-Day International Conference on Industrialised Building System shall be an opportunity for the sharing of experiences in areas related to research, development and construction.

The theme for this Conference IBS2003, is **Global Trends In Research, Development and Construction.** IBS2003 is to provide a platform for the interaction amongst experts, researchers, designers, builders, developers and policy makers from all over the world for appraisal of latest developments in Industrialised Building Systems and for the identification of further programmes for the propagation of industrialized construction as the preferred mode of quality construction.

We invite papers related to the following areas in IBS:

- Innovations in IBS
- Structural Analysis and Design
- System Development (Super Structures, Substructures and Jointing systems)
- Modular Coordination
- Design Codes and Standards
- Construction Methods and Problems
- Development of New Materials
- Architectural Aspects and Designs
- Government Policies
- Environment Issues and Social Aspects
- Legal and Financial Issues
- Robotics and Automation
- Studies on Labour Reduction & Quality Enhancement
- Smart and Intelligent Features

Key Dates:

- Deadline for abstracts (about 300 words) *30 November 2002*
- Notification of provisional acceptance *31 December 2002*
- Deadline for submitting camera ready manuscript *31 March 2003*
- Notification of acceptance of manuscript *31 May 2003*

Registration:

- Conference Fees: **RM500.00 / US$150.00** per person
- Payable to: **Bendahari Universiti Putra Malaysia**

General Information and Enquiries:

- Please contact:

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43400 Serdang, Selangor, Malaysia
Tel & Fax: 00603 8941 3402
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HOUSING and CONSTRUCTION news

Congratulations....

HRC wishes to congratulate one of our members, Dr. Ashrabov Anvar Abbasovich for his promotion to Professor. Best wishes and congratulations!

Forthcoming events

5 August 2002

2nd Research Executive Meeting of the National Research Programme on Affordable Quality Housing.

The meeting will be hosted by Universiti Putra Malaysia, Serdang, Selangor.

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variables of interest (temparature,pressure,current,etc). Furthermore,integration of all the information supplied by the different fiber sensors into a single processing center within the same facility could result in a "smart" building.

In order to implement these ideas,a fundamental understanding of the fiber-host interaction is needed. To perform the function of internal temparature/strain sensor, fibers must be embedded in the uncured concrete mix,and a good bonding must exist at the interface between fiber and cement host. This presents two major problems: a)the introduction,without damage of the fibers into a plastic, aggregate-filled, and mechanically vibrated medium; and b)the chemical durability of the fibers in the water-rich,highly alkaline environment of a cement paste.

Interface bonding is obtained between concrete and fibers by virtue of the shrinkage that takes place during curing,caused by the loss of moisture with a decrease in the volume of the mix of about 0.05 percent. In addition,there will be some mechanical keying and constriction caused by the crystal growth of the hydrated calcium alumino silicates. This later effect might be also detrimental to the performance of the fibres, so alkali-resistant coatings with an adequate compliance should be used to protect the fibres.

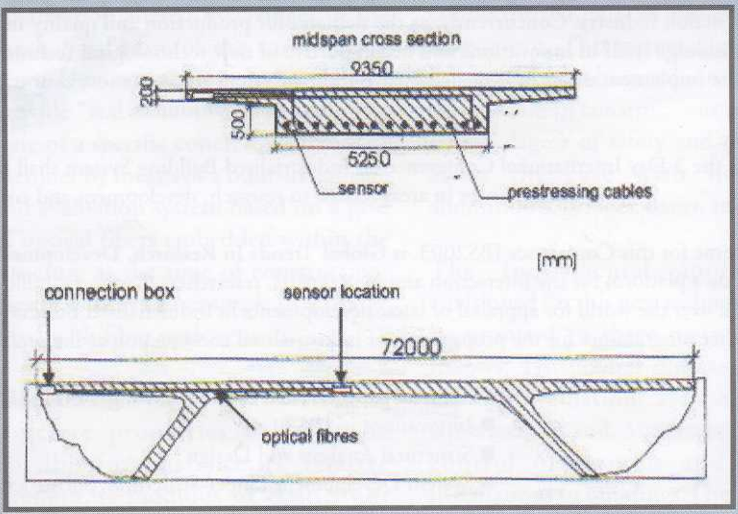

Figure 2 - Prestressed concrete bridge and sensor locations

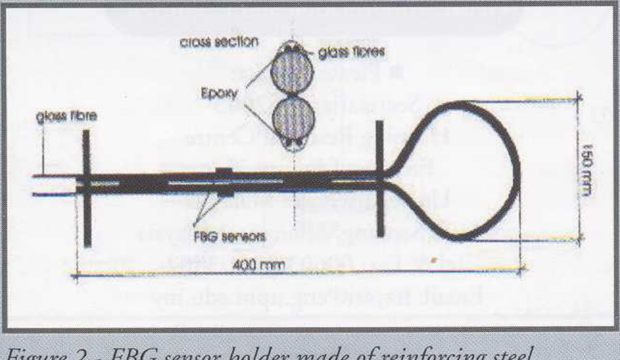

Figure 2 - FBG sensor holder made of reinforcing steel

Finally, to summarize, Fiber optic sensing technology offers the possibility of nondestructive, in-situ, measurement of the temparature, strain, stress and deformation of structures made of reinforced concrete. Novel applications for concrete buildings are envisioned in the analysis and evaluation of structural integrity, and in the management and control of buildings services. However,in order to achieve this ultimate goal,experimental research is needed to investigate the feasibility of the ideas outlined in the article.