Application Summary Sheet 8

Title: Monitoring and Smart Composites

Target Audience: Civil and Structural Engineers

Keywords: Monitoring, instrumentation, transducer, strain gauges, smart materials.

Overview of application / summary:

Monitoring is a term used to describe the recording of diagnostic information on a structure, such as the differential settlement of foundations, or stress within an element such as a beam or column. Such information may be supplemented with periodic measurements, from surveying or levelling for example, or crack detection. Electronic monitoring usually involves the logging by computer of a number of instruments such as strain gauges, electro-levels or displacement transducers. Monitoring can be of benefit in building maintenance or construction control, providing information which can be used to avert potential problems. Monitoring can also be used to prove the reliability of innovative components or strengthening work , and the results taken into account for future designs.

A "smart" composite is a material with in built sensing capability. Because of the way in which FRP materials are manufactured and the nature of their application at the forefront of construction technology, composite materials lend themselves particularly to monitoring. FRP materials can readily incorporate fibre optic transducers to measure strain. Carbon fibres, because of their electrical conductivity, can be used as in built strain gauges.

<u>Impact of Application</u>

Financial:

Monitoring has an important role in the maintenance and safe design of structures, giving early warning of potentially costly problems.

Social:

Monitoring has a role in the safe design of structures and execution of construction work.

Engineering:

Results of monitoring and testing can be used to optimise future design and avoid problems both during construction and in service

Robustness:

Structural monitoring is an established engineering discipline in its own right with a long history, although it has fully benefited from recent advances in instrumentation, communication and computer technology.

Future developments and estimated time-scale:

Further development of "Smart" structures.

Where to get further information

Conferences and Websites:

Monitoring Seminar 1st Feb 2001 BRE, Watford, UK
general website www.bre.co.uk

3rd World Conference on Structural Control April 2002 Como Italy
http://www.3wcsc.jrc.it

Network on Structural assessment monitoring and control
http://www.samco.org/

ISIS Canada
http://www.isiscanada.com/

Products:

http://www.smartfibres.com/

Research:

Reliability Monitoring of CFRP Structural Elements in Bridges with Fiber Optic Bragg Grating Sensors
Brönnimann R, Nellen Ph M, Sennhauser U. (1999)
J. Intelligent Material Systems and Structures, 10(4), 322-329

Abstract: Cables made of carbon fiber reinforced polymer wires (CFRP) can replace the traditional steel cables in bridge construction with advantages of increased mechanical strength and resistance to corrosion. The integrity of such critical structural elements has to be guaranteed during their lifetime by inspection, preferably by continuous automatic monitoring. Fiber optical sensors based on Bragg gratings were used to monitor the prestressing strain of CFRP cables in bridges. The sensors were either adhered to the surface of the CFRP wires for the suspension cables, or directly embedded during the production process. Tests for the two applications were performed to validate

the suitability of the sensing systems. Results accumulated over three years on a stay cable demonstrate the reliability of those sensors.

Non-destructive characterisation of damage in pseudo-ductile hybrid FRP rods
Liang Y, Sun C, Ansari F. (2002)
3rd World Conference on Structural Control, 7-12 April 2002, Como, Italy

Abstract: FRP composites exhibit higher strength than steel; however, their stress-strain behaviour is linear-elastic all the way to failure. This is in contrast to the elasto-plastic and ductile behaviour of steel. Consequently, the energy release of beams with FRP tendons is mainly elastic and sudden, which is different from the inelastic energy consumed prior to failure of the beams prestressed by steel tendons. The paper describes the development of a pseudo-ductile hybrid FRP rod consisting of glass and carbon fibers. Two different hybrid forms were considered and the experimental results indicated the suitability of the core shell approach for manufacturing of the hybrid rods. The experimental program included tensile tests of the hybrid rod as well as non-destructive evaluation by way of a fiber optic acoustic emission sensor. The mechanical characteristics of the rods were pseudo-ductile with a definite yield point. The damage assessment methodology was capable of determining the location as well as the damage state in the material.

Monitoring CFRP Reinforced Structures
Rolf Brönnimann, Philipp M. Nellen, and Urs Sennhauser (2002)
3rd World Conference on Structural Control, 7-12 April 2002, Como, Italy

Abstract: CFRP reinforced structural elements belong to a category of materials for which still limited long term experience exists, thus monitoring of such structures is essential to verify their performance. Of interest is the measurement of the strain state of CFRP for which various methods exist (resistance strain gauges, optical fiber sensors and direct resistance measurement). However, monitoring systems based on these methods drift and fail on periods shorter than the expected lifetime of the structural elements if not properly installed. The paper reports on embedding, reliability and lifetime investigations of sensors and monitoring systems.

Intelligent CRGFRP Composites with Self-Diagnostic Function for Preventing Fatal Fracture
Muto N., Yanagida h., Nakatsuiji T., Sugita M., Ohtsuka Y., Arai Y. and Saito Ch. (1994)
Sensors and Materials, 6(1), 45-62.

Abstract: CFGFRP (carbon fiber-glass fiber reinforced plastic) composites are materials with self-diagnostic function for preventing fatal fracture and detecting damage. When the carbon fiber bundles fracture, changes in the electrical resistance of the CFGFRP composites increase greatly. A large change in the electrical resistance can be conveniently used to prevent a fatal fracture by monitoring changes in the electrical resistance of the composite during loading.

Piezoelectric Patch Sensors for Structural Integrity Monitoring of Composite-Upgraded Masonry and Concrete Structures
Berman, J.B., R.F. Quattrone, A. Averbuch, F. Lalande, H. Cudney, V. Raju, and G.L. Cohen,
Technical Report, 01 Aug 1999, U.S. Army, Corps of Engineers, CERL, Champaign, IL, Report Number 99/72, ADANumver 369164.

Abstract: An acoustical impedance-based structural integrity monitoring technique employing piezoelectric (PE) patch sensor/actuators was used to detect real-time damaged introduced to composite-upgraded wall test specimens. Concrete and brick masonry wall sections externally upgraded with fiber-reinforced polymer (FRP) composite materials were subjected to various stresses in a load test machine. During the tests, the wall sections were periodically interrogated via the PE sensor/actuators and electrical impedance measurements were made at various frequencies. When damage was present, the impedance vs frequency signature changed. Furthermore, there was a marked difference between the signature pattern for loading and for debonding of the composite upgrade or cracking of the concrete/masonry substrate. This report includes details on the development of the impedance-based technique and documents a demonstration of the technology on a composite-upgraded pier at Norfolk, VA.

Health monitoring of composite plastic waterworks lock gates using in-fibre Bragg grating sensors
Bugaud, M. Ferdinand, P. Rougeault, S. Dewynter-Marty, V. Parneix, P. Lucas, D. (2000)
European conference on smart structures and materials; Micromechanics, intelligent materials and robotics 2000 Institute of Physics Publishing; 2000 (conference held July 1998 at Harrogate) Vol 9; No 3 , p322-327

General References:

In-service structural monitoring: a state of the art report.
Moss-R-M; Matthews-S-L (1995)
Structural-Engineer, v.73 no.2, p.23-31.

This paper presents a state of the art review of monitoring the in-service behaviour of structures. Much specialist monitoring as been undertaken in geotechnical and foundation engineering and his knowledge and expertise is now beginning to be applied to monitoring superstructures. Issues addressed in this paper include reasons for installing a monitoring scheme, under what circumstances and at what stage monitoring is appropriate, and the practical issues of how to proceed in terms of where instrumentation should be situated and what instrumentation and techniques should be used.

See also ISIS Canada (http://www.isiscanada.com/) guides on *Structural Health Monitoring* and *Use and Repair of Fibre Optic Sensors*