FLEXURAL BEHAVIOURS OF RCC BEAM USING EMBEDDED SENSORS

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Abstract - *Structural health monitoring along with damage detection and assessment of its severity level in non-accessible reinforced concrete members using sensors becomes essential since engineers often face the problem of detecting hidden damage. Smart sensing technologies including the applications of fibre optic sensors, piezoelectric sensors, magneto restrictive sensors and self-diagnosing fibre reinforced composites, possess very important capabilities of monitoring various physical or chemical parameters related to the health and therefore, durable service life of structures. In particular, piezoelectric sensors and magneto restrictive sensors can serve as both sensors and actuators, which make SHM to be an active monitoring system .This paper reviews various literatures related to the study, of Flexural behaviours of reinforced concrete beam using sensors and conventional method. Three common Flexural behaviours are examined: (i) cracking of concrete (ii) Deflection (iii)Strain)*

Key Words: **Structural Health Monitoring, Flexural Behaviour, Damage detection, beams, sensors**

1. INTRODUCTION

Recent development of various experimental approaches that prevent sudden and total failures and reduce cost of inspection in Reinforced Concrete infrastructures has been emerged. Main objectives of this approach is real-time damage detection and Structural Health Monitoring (SHM) techniques. SHM aims to develop efficient methods for the continuous inspection and detection of various defects in Civil Engineering structural members. Even more, SHM is becoming extremely important in RC structures that are governed by shear mechanisms which lead to fragile and abrupt failure modes. Even minor incipient shear damage to deficient shear critical RC elements, such as beam–column joints, short columns and deep beams, could be the cause of catastrophic collapse. Inaccessibility of portions of structures, presence of unseen hair cracks, as well as material deterioration of some parts of the structure can lead to whole structure failure or some of its elements. Early prediction of this damage could help in increasing their life time and prevent unexpected modes of failure. To ensure structural integrity and safety, civil structures have to be equipped with Structural Health Monitoring (SHM), which aims to develop automated systems for the continuous monitoring, inspection, and damage detection of structures with minimum labour requirement. An effective SHM system can in real time, and online, detect various defects and monitor strain, stress, and temperature so that the optimum maintenance of the structures can be carried out to ensure

safety and durable service life. In general, a typical SHM system includes three major components: a sensor system, a data processing system (including data acquisition, transmission, and storage), and a health evaluation system (including diagnostic algorithms and information management). The first step to set up this system is to incorporate a level of stable and reliable structural sensing capability. So, this paper is mainly related to the first component of the SHM system: the sensing system formed by smart materials/sensors. Smart materials/sensors, such as fibre optic sensors (FOS), piezoelectric sensors, magneto restrictive sensors, and self-diagnosing fibre reinforced structural composites, possess very important capabilities of sensing various physical and chemical parameters related to the health of the structures..

2. LITERATURE REVIEW

(1) S Tejaswi , J Eeshwar Ram "FLEXURAL BEHAVIOUR OF RCC BEAMS" In this study flexural behaviour of RCC under various constrains is observed. For the experimental analysis simply supported beams of under reinforced, balanced and over reinforced sections are considered. The main objective of this study is to obtain the relation between loading and the corresponding deflection of a simply supported beam when it is subjected to a point load. In the present study stress-strain behaviour of Concrete and steel are taken as a base and the flexural behaviour of the material in various fibres

(2) C. G. Karayannis M.E. Voutetaki, Constantin E. Chalioris, Costas Providakis "DETECTION OF FLEXURAL DAMAGE STAGES RC BEAMS USING PIEZOELECTRIC SENSORS (PZT)" In this study, the potential of the detection of flexural damage state in the lower part of the mid-span area of a simply supported reinforced concrete beam using piezoelectric sensors is analytically investigated. Two common severity levels of flexural damage are examined: (i) cracking of concrete that extends from the external lower fiber of concrete up to the steel reinforcement and (ii) yielding of reinforcing bars that occurs for higher levels of bending moment and after the flexural cracking. Further, it is concluded that the closest applied piezoelectric sensor to the flexural damage demonstrates higher overall sensitivity to structural damage in the entire frequency band for both damage states with respect to the other used sensors. However, the observed sensitivity of the other sensors becomes comparatively high in the peak values of the root mean square deviation index

(3) V.P Roshan Ahamed1, Priyanka Dilip.P "EXPERIMENTAL AND ANALYTICAL ANALYSIS OF FLEXURAL BEHAVIOUR OF REINFORCED CONCRETE COMPOSITE BEAMS"In this paper, an experimental and analytical investigation on partial replacement of concrete below the neutral axis by light weight concrete is discussed. Experimental models of light weight composite beams were cast and tested in UTM of 600kN. Then modeling light weight concrete tensile layer in reinforced concrete prisms using a continuum-based finite element model test was conducted in ANSYS 16.1 and the experimental and analytical results were analysed and discussed

(4)R.Regupathi "DAMAGE DETECTION OF REINFORCEMENT CONCRETE BEAM USING EMBEDDED PIEZOCERAMICS TRANSDUCERS" The experimental effort for the damage assessment of concrete reinforcing beam using Embedded and surface bonded piezoelectric transducers based on the electromechanical admittance method. The experimental results provide clear evidence that piezoelectric lead zirconate titanate transducers are sensitive to damage detection in reinforced concrete (RC)beam from an early stage of the performed tests. Thus, the use of these sensors for monitoring and detecting concrete cracking by employing the electromechanical admittance approach can be considered as a highly promising structural health monitoring method.

(5)James Chilles, Ian Paul Bond "DESIGN OF AN EMBEDDED SENSOR, FOR IMPROVED STRUCTURAL PERFORMANCE" This paper identifies techniques for embedding slim sensors with comparatively large in-plane dimensions inside composite materials. The experimental study was complemented with finite element analysis, which identified the load paths within different embedment configurations and aided with the interpretation of the experimental results. The results show that with careful selection of sensor materials, geometry, embedding location and embedment technique, sensors can be integrated within composite structures without producing any significant reduction of mechanical performance.

(6)Mustaqqim Abdul Rahim1, Abdul Naser Abdul Ghani2, Muhammad Arkam Che Munaaim1, Zuhayr Md Ghazaly1, Ngah Ramzi Hamzah3 & Zulhelmi Zulkeflee " FLEXURAL BEHAVIOR OF REINFORCED CONCRETE BEAM EMBEDDED WITH LIGHTNING PROTECTION CABLE" The objective of this research is to investigate the flexural strength of concrete beam embedded with lightning protection cable, which the lightning strike were stimulated by high electric current equipment. As the result, the additional reinforcement added into the structure beam was increased the performance of the flexural strength and they are no structural performance effect to concrete beam.

(7)Youyuan Lu, Jinrui Zhang, Zongjin Li, Biqin Dong "CORROSION MONITORING OF REINFORCED CONCRETE BEAM USING EMBEDDED CEMENT BASED PIEZOELECTRIC SENSOR" In this study, the corrosion activities of reinforcement in concrete beams with or without cracks

under accelerated corrosion conditions were monitored using embedded cement-based piezoelectric composite sensors and the acoustic emission (AE) technique. It was found that cement-based piezoelectric sensors show a good capability in AE detection and the beam with cracks corroded much earlier than the case without cracking, consequently resulting in early deterioration.

(8)M. Sun,1 W. J. Staszewski,2 and R. N. Swamy "SMART SENSING TECHNOLOGIES FOR STRUCTURAL HEALTH MONITORING OF CIVIL ENGINEERING STRUCTURES" In this paper, the application of smart materials/sensors for the SHM of civil engineering structures is critically reviewed. The major focus is on the evaluations of laboratory and field studies of smart materials/sensors in civil engineering structures.

(9)Theeran KS, Jayaguru C "STRUCTURAL HEALTH MONITORING OF RC FRAME USING SMART SENSORS" This project has focused on utilizing the underlying PZT-structure electromechanical interaction for impedance based health characterization of concrete. The technique proposed is electromechanical impedance (EMI) technique, which involves a simplified empirical method to diagnose structural health using embedded self-sensing that under piezo-impedance transducers so called as Smart Sensing Aggregates (SSAs). For the result analysis, numerical approaches for determining the damage index are illustrated in this report. A detailed investigation on SHM of structural systems using SSAs will be carried out following

(10) Zhi Zhou and Zhenzhen Wang "AN EXPERIMENTAL INVESTIGATION ON FLEXURAL BEHAVIOR OF REINFORCED CONCRETE BEAMS STRENGTHENED BY AN INTELLIGENT CFRP PLATE WITH BUILT-IN OPTICAL FIBER BRAGG GRATING SENSORS" This paper proposes a novel end anchored self-sensing CFRP plate assembly with built-in optical fiber Bragg grating (FBG) sensor. The objective of the tests was also to gain a better understanding of the failure mode and the flexural behavior of RC beams strengthened with post tensioned CFRP plates taking into account the different strengthening methods, initial damage, and the dead load before strengthening. The experimental results showed that the developed CFRP plate with built-in FBG sensors not only can be the reinforcement of the RC structures, but also provide an effective way to monitor the full-range behavior of the CFRP plate with the excellent self-sensing property shown in the demonstration test.

(11) Arooran Sounthararajah, Leslie Der Zhuang Wong, Nhu H.T. Nguyen, Ha H. Bui "EVALUATION OF FLEXURAL BEHAVIOUR OF CEMENTED PAVEMENT MATERIAL BEAMS USING DISTRIBUTED FIBRE OPTIC SENSORS" This paper aims to evaluate the reliability and accuracy of the estimation of flexural strains in cemented pavement material (CPM) beams using a distributed fibre optic sensing technique. Static and dynamic four-point bending tests were performed on CPM beams equipped with distributed fibre optic sensors (DFOSs) and a linear variable differential transducer (LVDT). Moreover, the evolution of the strain

profiles measured by DFOSs during the flexural tests clearly demonstrated the capability of DFOSs to detect crack initiation and propagation in CPM beams.

(12)Nobuhiro Okude1 , Minoru Kunieda2 , Tomoki Shiotani3 And Hikaru Nakamura "FLEXURAL FAILURE BEHAVIOR OF RC BEAMS WITH REBAR CORROSION AND DAMAGE EVALUATION BY ACOUSTIC EMMISSION" This paper presents an experimental investigation on the flexural failure behavior of RC beams having different weight loss of 0, 5, 10 and 30% due to corrosion. AE was also monitored during the loading tests of the deteriorated concrete beams.. It was concluded that such detected AE signals with lower frequency appear to be generated by de bonding behavior due to corrosion

(13) ZHU Jinsong1,2, GAO Change1, HE Liku "PIEZOELECTRIC-BASED CRACK DETECTION TECHNIQUES OF CONCRETE STRUCTURES: EXPERIMENTAL STUDY" Feasibility of a wave propagation-based active crack detection technique for non-destructive evaluations (NDE) of concrete structures with surface bonded and embedded piezoelectric-ceramic (PZT) patches was studied. In the experimental study, progressive cracked damage inflicted artificially on the plain concrete beam is assessed by using both lateral and thickness modes of the PZT patches. The results indicate that with the increasing number and severity of cracks, the magnitude of the sensor output decreases for the surface bonded PZT patches, and increases for the embedded PZT patches

(14) Lei li, Qingbin li , and Fan zhang "BEHAVIOR OF SMART CONCRETE BEAMS WITH EMBEDDED SHAPE MEMORY ALLOY BUNDLES "The behavior of smart concrete beams with embedded shape memory alloy (SMA) bundles is investigated in this study.. Experimental results indicate that the recovery force induced by SMA bundles is significant and controllable, the deflection generated by the SMA bundles at the middle span of the beam is about 0.44 mm, and the capability of resisting overload of each beam is about 2.98 kN (average). A relationship between SMA temperature and activating/inactivating time is also formulated. The conclusion is that SMA can be used in civil engineering structures either from a technological or economic aspect.

(15) Narayanan1, K. V. L. Subramaniam "DAMAGE ASSESSMENT IN CONCRETE STRUCTURES USING PIEZOELECTRIC BASED SENSORS" Piezoelectric based PZT (Lead Zirconate Titanate) smart sensors offer significant potential for continuously monitoring the development and progression of internal damage in concrete structures. Changes in the resonant behavior in the measured electrical conductance obtained from electro-mechanical (EM) response of a PZT bonded to a concrete substrate is investigated for increasing levels of damage. Changes in the conductance resonant signature from EM conductance measurements are detected before visible signs of cracking. The root mean square deviation of the conductance signature at resonant peaks is shown to accurately reflect the level of damage in the substrate. The findings presented

here provide a basis for developing a sensing methodology using PZT patches for continuous monitoring of concrete structures

(16) Weijie Li1, Qingzhao Kong, Siu Chun Michael Ho, Ing Lim, Y L Mo and Gangbing Song "FEASIBILITY STUDY OF USING SMART AGGREGATES AS EMBEDDED ACOUSTIC EMISSION SENSORS FOR HEALTH MONITORING OF CONCRETE STRUCTURES" This study conducts a feasibility study of using smart aggregates (SAs), which area type of embedded piezoceramic transducers, as embedded AE sensors for the health monitoring of concrete structures. The performance of embedded SAs were compared with the traditional surface mounted AE sensors in their ability to detect and evaluate the damage to the concrete structure. The results verified the feasibility of using smart aggregates as embedded AE sensors for monitoring structural damage in concrete.

(17)M.R. Esfahania, M.R. Kianoushb, A.R. Tajaria "FLEXURAL BEHAVIOUR OF REINFORCED CONCRETE BEAMS STRENGTHENED BY CFRP SHEETS" This paper investigates the flexural behaviour of reinforced concrete beams strengthened using Carbon Fibre Reinforced Polymers (CFRP) Sheets. The effect of reinforcing bar ratio ρ on the flexural strength of the strengthened beams is examined. From the results of this study, it is concluded that the design guidelines of ACI 440.2R-02 and ISIS Canada overestimate the effect of CFRP sheets in increasing the flexural strength of beams with small ρ values compared to the maximum value, ρ max, specified in these two guidelines

(18) Vishesh Kakwani ,Siddharth Patel, Mohammed Tohfafarosh Sunil Jaganiya "STRUCTURAL HEALTHMONITORING USING PIEZO CERAMIC BASED SMART AGGREGATE" In this project, an innovative piezoceramic based approach is developed for the structural health monitoring of various structures. The piezo-electric property of the PZT is used for Structural Health Monitoring and Damage detection. A ceramic based piezoelectric material PZT (Lead Zirconate Titanate) and piezoceramic based disc is used for compressive and seismic stress monitoring. Hence, both the properties will be used alternatively in actuator and sensor. The results will be used for damage analysis and categorization.

(19) Haichang Gu, Yashar Moslehy, David Sanders, Gangbing Song and Y L Mo "MULTI-FUNCTIONAL SMART AGGREGATE-BASED STRUCTURAL HEALTH MONITORING OF CIRCULAR REINFORCED CONCRETE COLUMNS SUBJECTED TO SEISMIC EXCITATIONS" In this paper, a recently developed multi-functional piezoceramic-based device, named the smart aggregate, is used for the health monitoring of concrete columns subjected to shake table excitations. Experimental results showed that the acceleration level can be evaluated from the amplitude of the dynamic seismic response; the damage statuses at different locations were evaluated using a damage index matrix; the first modal frequency obtained from the white noise response decreased with increase of the damage severity.

(20) Yee Yan Lim, Kok Zee Kwong, Willey Yun Hsien Liewand Chee Kiong Soh "NON-DESTRUCTIVE CONCRETE STRENGTH EVALUATION USING SMART PIEZOELECTRIC TRANSDUCER—A COMPARATIVE STUDY" In this paper, a semi-analytical model of surface bonded piezoelectric (lead zirconate titanate) based wave propagation (WP) technique was developed for strength evaluation of mortar with different mix, throughout the curing process. The performance of the WP technique was then compared to the electromechanical impedance technique and other conventional techniques, such as the ultrasonic pulse velocity (UPV) test and the rebound hammer test. Results showed that the WP technique performed equally well as the conventional counterparts. A separate study was finally conducted to verify the applicability of this technique on heterogeneous concrete specimen. With the inherent capability of the WP technique in enabling autonomous, real-time, online and remote monitoring, it could potentially replace its conventional counterparts, in providing a more effective technique for the monitoring of concrete strength.

3. CONCLUSIONS

Smart materials/sensors are a new development with enormous potential for SHM of civil engineering structures. Some of them are currently being applied in the field, while others are being evaluated under laboratory conditions. SHM system must possess the comprehensive abilities to detect positions and severity of damages. However, until now lots of studies about applications of smart sensors/smart materials in SHM of civil engineering are related to the basic sensing abilities of smart sensors. That is, some damages within structures can be monitored directly using data from sensors, while others can only be detected indirectly through special diagnostic methods. Civil engineering structures are usually very large. So, many sensors are equipped to make structures sense their health conditions. The technology of SHM is growing, and new technologies are introduced every year, even though many questions remain to be answered. In this study ,we found how to apply SHM methods to civil infrastructures and components to improving on traditional approaches by using sensors

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