# STRUCTURAL HEALTH MONITORING USING PZT A REVIEW

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**Abstract— Due to the involution of damage occurring in the structure it is difficult to monitor structural health. Electromechanical Impedance technique (EMI) is used for the damage detection in the structural member experimental results are obtained by the applying piezoceramic patches surface bonded and embedded PZT (Lead Zirconate Titanate) patchs are used for the detection of structure failure. This papers reviews online strength gain monitoring of early age concrete is detected with the help of EMI sensing technique. By using this methods detection s well as location, severity estimation is also possible. The piezoceramic materials performs the both works sensor as well as actuator. The proposed method of damage detection are quit effective and sensitive to concrete.**

**Keywords - Structural Health Monitoring,Non Destructive Evalution,EMI techniques,Damage detection,PZT**

## Introduction

Civil infrastructures need timely inspection for the assessment of their integrity and stability for the future benefit of the human society, life safety and cost effectiveness. Their safe and economical performance stands a high benefit for the society, because it stabilizes financial management and safety. In general, their performance contains a large number of uncertainties because they are often subjected to traumatic natural disasters and intensive usage. To overcome these challenges, many organizations and independent research bodies comes up with new techniques for full scale performance assessment and behavioral interpretation of structures, which is termed as structural health monitoring (SHM).The term SHM originated in the early of 19th century, quite before it had been widely used for practical applications including various non-destructive techniques and evaluation (NDT&E). Basically, SHM denotes the process of acquisition, validation and interpretation of a set of structural data, collected from the structure at different times to facilitate life time risk management decisions. Health monitoring is typically used to track and evaluate the performance, symptoms of operational incidents and anomalies due to deterioration or damage during operation and after extreme events. For any kind of structures, including civil, aerospace, and mechanical engineering infrastructure, SHM is the process of detecting damage, while the structure is in service. In contrast to SHM, the non-destructive evaluation (NDE) techniques, such as dye penetrant inspection, magnetic inspection, eddy-current inspection, radiography, and ultrasonic inspection are performed while the system of interest in service. The ultimate achievement of SHM can be categorized into two aspects; one is "real-time", which enables the SHM system to obtain immediate response of the structure and hence measures the health of structure. The academic research community is greatly attracted towards vibrational response of structures using smart materials or conventional sensors to identify the modal characteristics, which are sensitive to structural damages. PZT (piezoelectric lead zirconate titanate) is actuator-driven system. It is an individual piezoelectric transducer which serves both as sensor & actuator when PZT patch is attached to or embedded inside the structure. When PZT is stressed it produces electric charge. Conversely when an electric field is applied the PZT produces mechanical strain.In EMI technique PZT patch is bonded to the host structure. The change in the electrical admittance of the PZT patch is monitored & compared to a baseline electrical impedance measurement. If damage is present in the host structure then there is change in the structural mechanical impedance. Then it can be detected whether there is structural damage or not.

## Literature Remark

Included herein a brief literature survey on various method available for structural health monitoring of RC structure.

**Suresh Bhalla and CheeKiong Soh[15],** paper presents a new method of damage diagnosis by means of changes in the structural mechanical impedance at high frequencies. The proposed structural impedance based damage detection methodology was varied using the test data obtained from a model RC(Reinforced Concrete) frame subjected to base vibrations. The test structure was a two-storey portal frame, made of RC. In this paper the test loads were applied in the form of vertical base motions of varying frequencies and amplitudes. The buildings are normally subjected to such base motions during earthquakes and underground explosions.The proposed method has higher sensitivity to damage as compared to the existing approaches.

The paper given by **NaveetKaur& Suresh Bhalla[10],** investigates the effect of the adhesive bond and the related parameters on the energy harvesting capability of thin PZT patches operating in surface-bonded/embedded configurations bonded onto RC structures.Towards this end, a numerical model is generated for a real-life sized simply supported RC beam instrumented with (a) surface bonded piezo-sensor (SBPS), and (b)embedded PZT patch.This paper has presented a numerical approach to perform a parametric study to investigatethe effect of various parameters, including PZT patch's geometricparameters, the adhesive layer's thickness and the stiffness on thepower generated by it.

**Dansheng Wang et al[5]**presents a new damage detection method is proposed based on electromechanical admittances (inverse of impedance) of multiple PZT patches and a damage index, namely, cross-correlation coefficient (CC).In the studies, three PZT patches were bonded to the surface of a plain concrete beam with certain intervals. By measuring the electromechanical admittance signals of each PZT in different frequency ranges, the occurrences of several crack damage of a plain concrete beam were monitored; the damage locations and severities of the plain concrete beam were also determined. It is also found that the numerical and experimental results were also compared.It can be concluded that the proposed damage detection method was quite effective and sensitive to concrete. From the experimental study it can be found that when damage on the surface of a concrete beam is presented the electromechanical admittance curve of a PZT transducer near the damage obviously changes, and the damage index CC for the PZT transducer is much smaller than those for other PZT sensors.

**Chris G. Karayannis et al[2]** presents an experimental effort for the damage assessment of concrete reinforcing bars using bonded piezoelectric transducers and the implementation of an integration analytical approach based on the electromechanical admittance method. Tests are performed in (i) single steel reinforcing bars with predefined and artificially induced damages corresponding to two different damage states and (ii) steel reinforcing bars embedded in typical large scale reinforced concrete beams subjected to flexural load at two different loading levels (before and after yielding) that inevitably cause two different damage levels. The damage of the embedded steel bars in the concrete beams after yielding is the result of excessive elongation of the bars due to yielding caused by flexural deformation of the beams.The experimental program includes data acquisition of current intensity curves for healthy and damaged bars as detected by the test instrumentation and implementation of the adopted admittance-based procedure to evaluate damages at different levels.

**C. P. Providakis et al[3]** gives an integration approach based on both electromechanical admittance methodology and guided wave propagation technique is used to evaluate the artificial damage on the examined longitudinal steel bar. Two actuator PZTs and a sensor PZT are considered to be bonded on the examined steel bar.The admittance of the Sensor PZT is calculated using COMSOL 3.4a. Fast Furrier Transformation for a better evaluation of the results is employed. An effort for the quantification of the damage detection using the root mean square deviation (RMSD) between the healthy condition and damage state of the sensor PZT is attempted.

**Seunghee Park et al[17]** presents the results of experimental studies on PZT-based active damage detection techniques for nondestructive evaluations (NDE) of steel bridge components. Both impedance and Lamb wave methods are considered for damage detection of lab-size steel bridge members.Two types of experimental studies have demonstrated that the current active damage detection system in conjunction with both the impedance and Lamb wave methods is able to detect incipient structural damage, such as cracks or loose bolts on steel bridge components. In addition, advanced signal processing and pattern recognition techniques such as continuous wavelet transform (CWT) and support vector machine (SVM) have been clearly found to be very effective to improve the damage detection capability of the current system.The current system can be readily applied to real-world steel bridge structures, since it is not sensitive to changes in ambient conditions such as boundary conditions, traffic loadings, or operational vibrations by providing a high frequency excitation of the PZT patches used as co-located actuators sensors.

**M. Moix-Bonetet al[8]** focuses on the mechanical durability of DuraAct™ piezoelectric patch transducers, which have been co-bonded on Carbon-Fiber Reinforced Polymer (CFRP) plates. The samples were tested in quasi-static and cyclic loading conditions at different loading levels. The degradation of the Dura Act™ piezoelectric transducers is assessed by means of three monitoring methods: The electro-mechanical impedance spectrum, the charge issued from the direct piezoelectric effect when the piezoelectric transducers undergo mechanical deformation and the guided ultrasonic waves sent and received by the transducers. The piezoelectric wafer active sensors(PWAS) used in this project are DuraAct™ piezocomposites. The durability of DuraAct™ is studied by [7n] with 4-point bending tests under quasi-static as well as cycling loading.

**Sumedha Moharana & Suresh Bhalla[16]** in this paper The analytical derivation of continuum based shear lag model covered aims to provide an improved and more accurate model for shear force interaction between the host structure and the PZT patch through the adhesive bond layer, taking care of all the piezo, structural and adhesive effects rigorously and simultaneously. This paper has rederived the coupled admittance signature based on the continuous variation of displacement (hence, the related piezo induced strain) and charges over the PZT patch. This is more accurate and realistic shear lag model for the impedance based SHM for the EMI technique.The continuum based signatures are qualitatively better match with experimental observations. The effect of the adhesive mass and the PZT mass simultaneously has also been investigated, which shows negligible impact on overall performance.

**Ricardo Z. M. da Silveira et al[13]** conducted a comparative experimental analysis of the main installation methods of the sensors in the electromechanical impedance technique, which are the direct installation, the magnetic coupling, and using aluminum foils. Tests with the three installation methods were carried out on aluminum structure sand the results were compared using the electrical impedance signatures and damage indices. The experimental results indicate important features of each method relative to the feasibility for detection of structural damage.its concluded that conventional method is the most sensitive to damage at lower frequencies. In contrast, the magnetic and MWBEMI methods indicate a higher sensitivity to high frequencies, but the damage indices are significantly lower compared to the conventional method. This study was carried using an excitation signal with fixed amplitude.

**Suresh Bhalla and CheeKiong Soh**[14]This series of two papers present a new simplified methodology to diagnose structural damages by means of surface bonded piezo-impedance transducers. The first part introduces a new PZT–structure electroelastic interaction model based on the concept of “effective impedance.” The proposed formulations can be conveniently employed to extract the mechanical impedance of any “unknown” structural system from the admittance signatures of a surface bonded PZT patch.present a methodology to quantify structural damage using the extracted impedance spectra of the structure on the basis of an equivalent system approach. can be used in numerous other applications, such as predicting the system’s response, energy conversion efficiency, and system power consumption.Part II of this paper will present a procedure to extract the mechanical impedance of the structure by means of experimental conductance and susceptance signatures.

**Andrei N. Zagrai and Victor Giurgiutiu**[1]studied, the E/M impedance method was used to identify the structural dynamics and the presence of damage in circular plates. An analytical expression, which accounts for both axial and flexural vibrations of a plate, was derived and validated through a set of experiments. The experimental results show good matching with the theory. Additional acoustic experiments were conducted to assess the presence of damage in circular plates for particular set of boundary conditions. Some damage metrics were suggested to analyze the frequency spectrum obtained. The results show the changes in the E/M impedance spectrum due to damage presence.

**Vijay Kumar Sonkar**[18]studied the damage detection properties of PZT on concrete slabs, simply supported reinforced concrete slabs with piezoelectric patches attached to their surfaces and the Electromechanical Impedance method (EMI) was adopted for research. Healthy and damage condition were designed to test the impedance values at different frequency bands. Frequency band is 50KHz to 300KHz in step 200. The numerical and experimental studies verify that the EMI technique can accurately predict changes in the amount of damage in reinforced concrete slabs. The damage index changes regularly with the distance of damages to the sensor. This relationship can be used to determine the damage location. The newly proposed damage index Ry/Rx is accurate in determining the damage location.

**Xianyan Hu et al**[19] studied the damage detection properties of PZT on concrete slabs, simply supported reinforced concrete slabs with piezoelectric patches attached to their surfaces. Five kinds of damage condition were designed to test the impedance values at different frequency bands. Consistent rules are found by calculation and analysis. Both the root mean square deviation (RMSD) and the correlation coefficient deviation (CCD) damage indices are capable of detecting the structural damage. The slab plane was divided into four parts, with each part has one piezoelectric attached to the center of the surface. The test was conducted in four separate frequency bands. Along with the increase of the degree of damage, when the depth of the damage was more than 1/2 the thickness of the slab, the damage indices would have a larger growth, and the two different kinds of indices show consistent rules and they could monitor the amount of damage of reinforced concrete slabs well.

## Concluding Remark

Ceramic Piezoelectric materials and especially PZT (Lead Zirconate Titanate)have successfully adopted in ND evaluation methods of RC elements.Sensitivity of a new type of embedded active PZT sensor in the structural damage detection is investigated.It is concluded that embedded PZT sensors are sensitive to structural damage.Experimental results indicates the transducers have different sensitivities to damage detection and the sensitivity varies significantly with the frequency range.This EMI method can be used for the monitoring of long term performance of structure and structural behaviors when subjected to natural disasters, such as wind and earthquake.

## Acknowledgment

It is our proud privilege and duty to acknowledge the kind of help and guidance received from several people in preparation of this paper.it wouldn’t have been possible to prepare this paper without their valuble help,cooperation and guidance.

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