

# Structural Health Monitoring for Concrete Structure using Impedance Chip



T. Jayachitra, Rashmi Priyadarshini

**Abstract:** *Structural Health monitoring plays a vital role in all generations for the safety of life and property. The method of Electromechanical Impedance (EMI) method and sensors are used in damage detection of civil and mechanical structures. The structure deteriorates due to ageing and environmental factors. This study represents the detection of damage in concrete structure using piezo electric transducer and EMI method. The piezo sensor is bonded to the concrete structure using epoxy resin and damage is created by using flexural testing machine. The force is applied using flexural testing machine at different KiloNewton. The output from the impedance chip is noted at undamaged state and at all levels of applied force. The impedance, admittance, conductance and susceptance curves are drawn with different levels of frequency. Root mean square deviation is also calculated for the detection of damage. The results conclude that Impedance chip is highly reliable and accurate in damage detection of concrete structure.*

**Keywords:** *Structural Health Monitoring; Electromechanical Impedance method; Impedance chip; Root mean square deviation; piezo sensors*

## I. INTRODUCTION

Civil and Mechanical structures starts degrading after years due to environmental factors and loading effects. Therefore monitoring of these structures is required at regular intervals of time to avoid damage to life and property. Structural Health Monitoring monitors the structure at all times to identify the existing damage, location and severity of damage[1]. In order to reduce the maintenance and repairing cost, Non Destructive Evaluation (NDE) technique is preferred. The most encouraging NDE is Electromechanical Impedance Technique (EMI). EMI technique works on piezoelectric property principle. When piezoelectric transducer is bonded or embedded in the civil or mechanical structure which is excited at suitable frequency range, any change in mechanical impedance of the structure is measured

as electrical impedance of the piezoelectric transducer [2]. EMI technique was first proposed by Liang et al. The result of Impedance method was compared with static and dynamic finite element approaches [3].

Different structures are chosen for experimentation of damage using EMI Technique. Structures like aluminium beam, concrete, steel etc were used [4]. Fabricio Guimarães Baptista et al evaluated the impedance measurement system on Aluminium structure and proved that the excitation signal influence the output impedance measurement [5]. Impedance Analyzers or LCR meter are used for measuring impedance. The cost of these components is high and the size is also bulk. Therefore, in order to minimize the cost and size, Impedance chip was used [6]. The Piezo sensors are embedded in different orientations and hydration of Reinforced concrete beam was monitored [7]. Naveet et al made a comparison study on bonded, embedded and metal wire transducer [8]. Piezo sensor and Impedance chip are used for detecting the damage in structures. Impedance (AD5933) is a precise Impedance converter which has frequency generator, analog to digital converter, DSP engine and temperature sensor. Excitation is provided by the frequency generator and processed by DSP engine. The real and imaginary data is obtained at each sweep frequency. The clock frequency of the impedance chip is 16MHz. The user defined software requires calibration at every time when it is restarted. 200 Kilo ohm resistance is added for circuit calibrations [9]. The only drawback in using impedance chip is repeatability. The output is repeatedly measured to measure the impedance. Using Impedance chip, damage was detected on bolted joint structure used for railway joints [10].

## II. METHODOLOGY

Concrete beam structure of size 500 x 100 x 100 mm is chosen for experimentation. Damage is induced in the structure by using flexural testing machine. Piezo electric transducer of Lead zirconate titanate patches are bonded in the structure and output is measured at full strength of the concrete beam. Then damage is created by applying the force using Flexural testing machine at different level in the concrete structure and the corresponding output is measured from Impedance chip. The concrete is placed in flexural testing machine and force is applied at 5KN and output is measured. Then the same process is repeated at 9KN, 12KN and 16KN. The concrete structure is fully damaged after the level of 20 KN. Fig 1 shows the Impedance chip and user define software of AD5933. Fig 2. shows the setup of concrete beam and Impedance chip. The damage is detected by measuring the Impedance, admittance, susceptance with frequency. The results are shown in section III.

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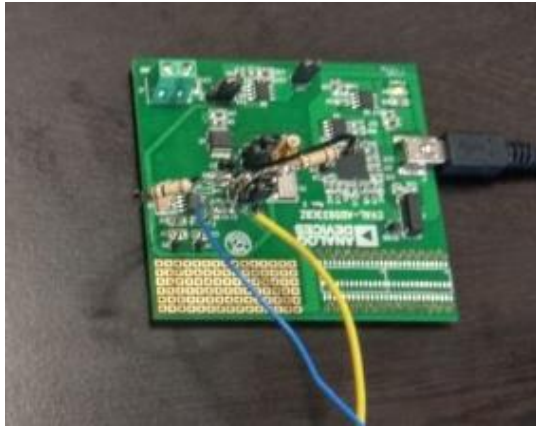


Fig. 1. Impedance chip and User Defined software of AD5933

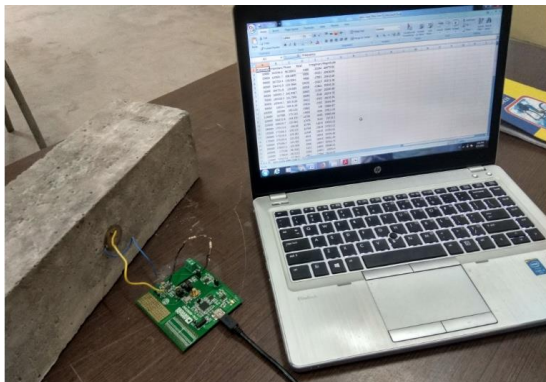


Fig. 2. Experimental setup of concrete structure

### III. RESULTS

The impedance is measured at the undamaged level and considered as base signature. Then the force is applied on the concrete using flexural machine at 5KN, 9KN, 12KN and

16KN and the corresponding output from the Impedance chip is measured. Fig 3 to Fig 6 represents the impedance, admittance, conductance, susceptance versus frequency. The damage state is identified by peaks when compared with the undamaged state. The result indicates that the impedance increases as the level of damage increases. Root mean square deviation (RMSD) is calculated by

$$RMSD\% = \sqrt{\frac{\sum_{i=1}^n (Y_i - X_i)^2}{\sum_{i=1}^n X_i^2}}$$

Where  $X_i$  represents the baseline conductance signature for  $i=1,2,\dots,n$ , where  $n$  is the number of observation and  $Y_i$  represents the conductance signatures due to damage. Fig 7 represents RMSD indices comparison between undamaged state and damaged state. The RMSD is less in 5KN and it increases at 12KN and this indicates that the damage is detected when the applied force is more than lesser one. Then at further increase in the application of force the RMSD is reduced. The damage in the concrete is detected at 5KN. Table-I show the various parameters like impedance, admittance, conductance and susceptance at undamaged state and different levels of damaged state.

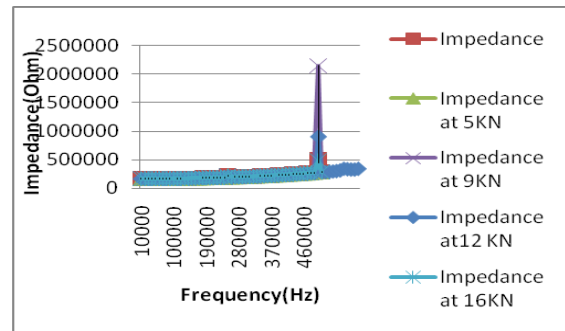


Fig. 3. Impedance signature at different frequency range

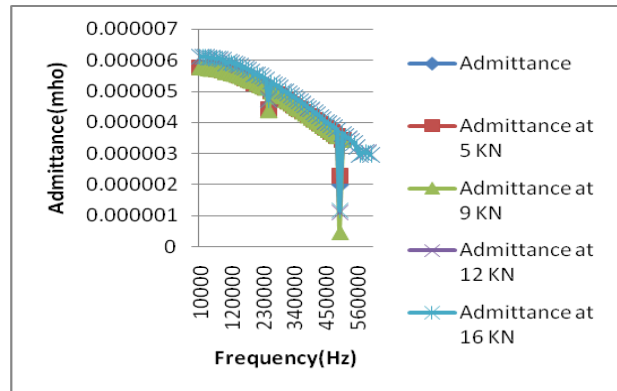


Fig. 4. Admittance signature at different frequency range

Table- I: Results of various parameters with respect to different damage state

Parameters	Undamaged state	Force at 5KN	Force at 9KN	Force at 12KN	Force at 16KN
Impedance(ohm)	5.05E+05	4.42E+05	2.15E+06	9.04E+05	4.89E+05
Admittance(mho)	1.97E-06	2.26E-06	4.64E-07	1.11E-06	1.15E-06
Conductance(mho)	0.0019	0.00084	0.0012	0.0017	0.00199

Susceptance(Siemens)	0.0013	0.00093	0.00097	0.00278	0.0011
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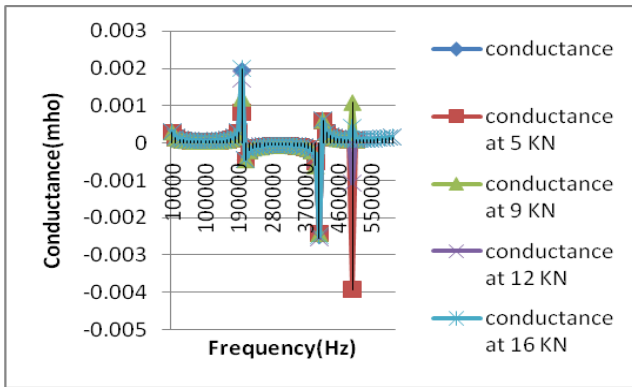


Fig. 5. Conductance signature at different frequency range

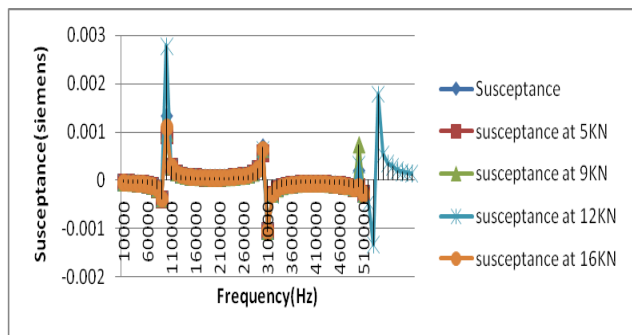


Fig. 6. Susceptance signature at different frequency range

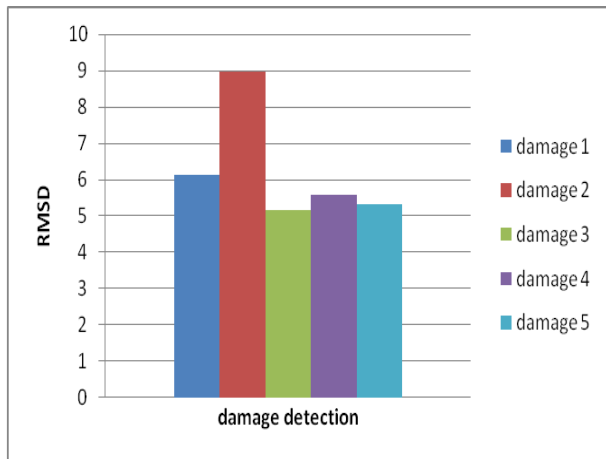


Fig. 7. RMSD comparison between undamaged and damaged structure

IV. CONCLUSION

The objective of this paper to check the strength of concrete using low cost Impedance chip. In this evaluation, Impedance chip is used to detect the damage in concrete structure. The result identifies that the Impedance chip is highly reliable and accurate in detecting the damages in the structure but repeatability process is required in the output measurement.

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