Investigation of Damage Level and Study on Load Deflection Characteristics of RCC Beam Using Smart Sensor

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Abstract - *Civil infrastructure leads the development of higher order structural safety during construction as well as during service life period. The integrity of safety and serviceability of structure can be investigated by advance structural health monitoring technique using smart sensors. This study has been made in identification of the damages occurring in the structure cause micro and macro cracks. These micro and macro cracks producing sound and vibration, this vibration is sensed by sensors. Using piezoelectric sensors sounds and vibrations are sensed the internal vibrations. Structural health monitoring and damage identification plays a major part to identify the behavior of structure during loading and damage of concrete. PZT (Lead Zirconate Titanate) sensor is used for sensing the vibration occurs during the damage, which works by converting the effect of cracks induced in the concrete beam in to electrical charge. The sensed damage level of structure can be observed by the advanced process of data acquisition system. Experimental study was conducted on beam specimen of size 1.0 m x 0.15 m x 0.15 m and the results were validated by the analytical study. From the interpretation of results it was clearly observed that increase in amplitude results in increasing the severity of damage level of RCC beam. The initial micro cracks were observed by minor fluctuation of amplitude while loading. By observing the health of the structure under loading the safety of the structure can be ensured by the alerting system, the catastrophic failure can be avoided.*

Key Words: Damage level, Data acquisition system, PZT, RCC beam, vibration

1. INTRODUCTION

Infrastructure developments are more important to play vital activities in the country development, it's highly focuses on the intense areas like high raised buildings and tall structures etc., the promotion of new technologies based on structural health monitoring and advance research leads to implement in the complicated structures. It's became cumbersome to understand the behavior of those structure under complex loading. To overcome most of the major problems in the buildings the multidisciplinary research are to be carried out. monitoring of structural health using sensors is a process of providing accurate and timely information based on the performance of an inherent structure.

The structural health monitoring is consists of following process, it gives digital signaling and also communicate the signal by wireless or any other media. It able to execute logical functions and instructions based on behavioral sensing of structure is monitored by sensors and those data were analyzed. It has greatly works to improve over all public safety and ensuring longer life span of the structure. As comparing to other sensors, PZT (Lead Zirconate Titanate) based sensors are becoming more popular because of their efficiency of monitoring the high raised structures. The PZT sensors are used as actuator or transducer to monitor concrete structures and to develop corresponding health monitoring system and damage identification strategies.

In recent years, the researches in testing techniques have been found to be very efficient for damage identification incase of micro cracks and macro crack detection and the health assessment of various structures. X. Feng et al.[1] investigated the Post-earthquake Damage Detection using Embedded Electro-mechanical Impedance Sensors for Concrete Dams. N. Kaur et al [2] Integrated Global Vibration and Low-Cost EMI Technique for Structural Health Monitoring of RC Structures Using Embedded PZT Patches. B. F. Spencer Jr et al.[3], reviewed the Industrial applications are at the present mostly found in civil engineering structures field and the integration of the detection and damage identification techniques into powerful, cost-effective and robust systems. G song, H gu et al.[4] investigated about the Concrete structural health monitoring using embedded piezoceramic transducers and studied about the investigation of reinforced concrete bridges and other large-scale civil infrastructures using piezoceramic transducer. S Na and H K Lee [5] presented a multi-sensing electromechanical impedance method for non-destructive evaluation of metallic structures. Suraj N. Khante et al [6] presented about the PZT Based Smart Aggregate for Unified Health Monitoring of RC Structures the work Non-Destructive Evaluation (NDE) technique for structural health monitoring by using smart materials. Constantin E. Chaliorisa et al [7] studied about Applications of smart piezoelectric materials in a wireless admittance monitoring system (wiams) to structures—tests in RC elements. Jinlei Zhao et al [8] investigated about the smart aggregate piezo ceramic patch combination for health monitoring of concrete structure the surface mounted piezoceramic patch combination is an effective tool for Monitoring health of concrete structures from the amplitudes of the recorded wave signals. P.Frojd et al., [9] studied about the Amplitude and phase measurement of continuous diffuse fields for structural health monitoring of concrete structures. Shi Yan et al., [10] investigated the development and application of a Structural Health Monitoring System Based on Wireless Smart Aggregates.

Aging, deterioration and extreme events such as natural and man-made disaster like earthquake, sudden blasting can take a toll on high raise buildings. The structural health monitoring using smart sensors reduces the regular monitoring and it gives the relevant accurate and timely information through programming. The experimental study has been carried out on RCC beam specimen of size 1.0 m x 0.15 m x 0.15 m and the results were validated by the analytical study. Piezoelectric sensor is used for sensing the vibration occurs during the damage that works by converting the effect in to electrical charge. The sensed damage level of structure can be observed by the advanced process of data acquisition system.

2. EXPERIMENTAL SETUP

2.1 Specimen casting

The Reinforced Cement Concrete of beam size 1000mm x 150mm x 150mm was cast with the mix ratio of M25 grade of concrete. The water-cement-sand-aggregate weight ratio of the concrete mix was 0.45 : 1 : 1.46 : 2.82. To avoid brittle failure of the concrete beam during the two-point loading test, two numbers of longitudinal steel bars of 10mm diameter were placed at the tension zone and two numbers of longitudinal bars were placed at the compression zone and the stirrups of size 8mm diameter were used and 25mm cover blocks provided for the specimen.

2.2 Circuit setup

Arduino is open software which shows the platform used for the building electronic projects it consist of both physical programmable circuit board. It is referred as a micro controller and a piece of software that runs on the computer used to write and upload the computer coding to the physical board. The PZT was programmed using arduino software and the program was uploaded to the micro processor. The arduino UNO was powered from a USB cable from the computer. The power fluctuation in the PZT was controlled by using 1 mega ohm resistor. The resistor resists the flow of excess power supply. Figure 1 shows the set up of arduino board and the pins are connected in the bread board.

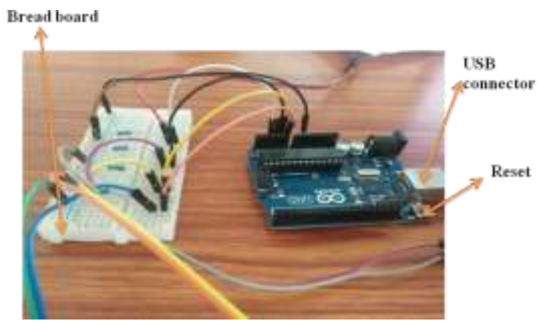

Fig -1: Circuit setup

2.3 Digital data acquisition system (DDA)

The PZT sensors placed at the surface of the Reinforced Cement Concrete specimen. The process the signal receiving from the structure by applying the mechanical energy was converting the results into electrical energy in terms of digital numerical values. The received signal from the sensor is due to the vibration of the structure. The digital values result in terms of amplitude in voltage and time in seconds. Figure 2 shows the process of energy conversion using advanced digital data analysis technique.

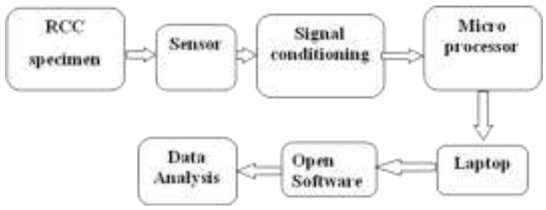

Fig -2: Digital data acquisition system

3. TESTING PROCEDURE

3.1 Numerical Analysis

The Numerical analysis of the RCC beam was done to find the critical points. After knowing the critical points, the sensors were placed at the critical points equal to the same distance on both sides of the RCC beam. This setup is helpful to monitor the micro and macro cracks even at the real time structures. In future this will be useful to locate the crack at high rise buildings. Figure 3 shows the Numerical analysis of the beam.

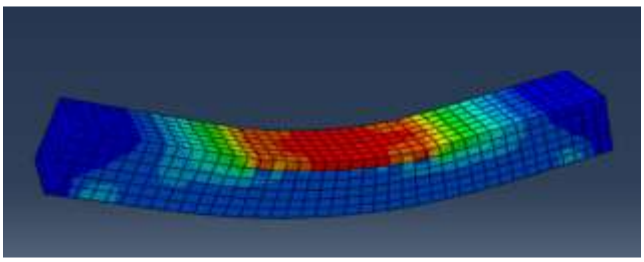

Fig -3: Numerical Analysis of RCC beam

3.2. Laboratory set up

Simply supported RCC beam were subjected to pure bending by application of two point loading at L third distance. One end of the beam was treated as hinged and other was roller, so the beam was simply supported. Test is carried out in UTM loading capacity of 2000 kN. Loading arrangements was made for two point loading, the load were applied at the distance of 333.33mm i.e. L/3 distance on either side of the mid span of the beam. The load has been monitored through a high accuracy set up, in this case, mid span deflection was measured using dial gauges of least count 0.01mm. Figure 4 shows the testing set up for two point loading.

Fig -4: Two point loading set up with sensors

4. RESULT AND DISCUSSIONS

The PZT sensor is used to detect the damage of the structure like micro and macro cracks in this experiment. The incipient cracks can be identified by monitoring. The output of the sensor was obtained by Arduino board as a digital value. while applying load the minor cracks were identified with respect to plotting a graph between time in micro seconds and Amplitude in voltage. The graph is plotted directly from the obtained results by taking amplitude in y axis and time in x axis. The results can be taken either way by giving alerting system and also can take digital values. The live monitoring can be possible with the help of Arduino code and to form alerting system with few micro controllers. The incipient crack in concrete matrix was immaculately predicted by the voltage reading which was obtained by sensor and read as digital value by Arduino programming. Table 1 shows that time in minutes which was converted from micro seconds the values directly obtained through program coding. This value was obtaining while the mechanical energy generate electrical energy. S1, S2, S3, S4 are the PZT1, PZT2, PZT3, PZT4 respectively which placed at the two faces of RCC beam. The load value in kN was obtained from UTM machine for comparing the damage level with load. This will be helpful for the future references.

Table -1: Damage level of the beam

Time in Minutes	Load (kN)	S1	S2	S3	S4
0	0	0	0	0	0
1	7.2	0	0	0	0
2	24.65	0.06	0	0	0.01
3	38.45	0.05	0.07	0	0
4	54	0	0.07	0	0
5	74.75	0	0	0.05	0
6	80	0	0	0	0

Chart 1 show that the Level of Damage in Reinforced Cement Concrete beams with respect to time and amplitude. The incipient crack occur at the amplitude of 0.01V at 24.65 kN was recorded at PZT4 i.e. S4 sensor. Then the developing crack was monitored and recorded, by the respective sensors simultaneously using micro processor. The maximum amplitude recorded in S2 at 0.07 V it shows that the maximum crack recorded at the second sensor. In real time monitoring, it depends upon the critical section where we can place the sensors. . From the graph it shows that usage of PZT can be used to predict the compressive strength and the damage level. Once the peak amplitude is achieved the voltage drops shows the poor strength of concrete against load.

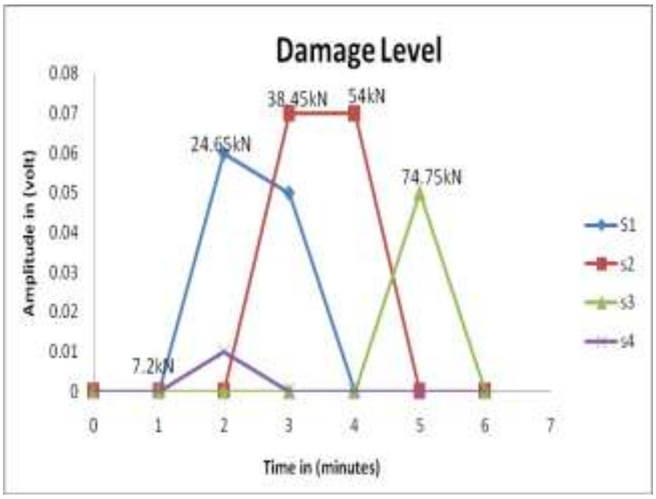

Chart -1: Damage level of RCC beam

5. CONCLUSION

It is concluded that from the experimental work that continuous health monitoring of structure is possible, with proposed cost effective technique. It carried out that the Damage level can be proposed economically by using PZT sensor. Health monitoring of the concrete structure is a simplest task to detect incipient damages using Arduino programmed coding. This method can be implement in high rise buildings, in additional the alert indication can also be possible while increase in damage level of the structure. It also denotes the predicted location of crack at a high rise building, based on the sensor which is fixed in RCC-beam.

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