Crack Detection In RC Beams Using Electrodes And Sensing Skin

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Abstract- *The crack detection in concrete structures will provide an early warning system and avoids the loss of property. The safety measures can be taken after detection of cracks to avoid human loss and loss of structures. Cracks can be detected by using ultrasonic wave technique, RFID technology, EIT technique and acoustic emission technique. These technologies are very costly and cannot implement for all structures due to economical issues. In this work conductive graphite paint which acts as sensing skin with materials like graphite electrodes and Arduino Uno R3 microcontroller installed with specially designed programs. The use of sensing skin and electrodes can detect the cracks in reinforced concrete sections and it helps to warn the engineers, supervisors, owners from upcoming threats.*

Keywords- Conductive Graphite Paint, Graphite Electrodes, Microcontroller.

I. INTRODUCTION

In reinforced concrete structures, concrete is most widely used material and it plays a vital role regarding durability of structure. Due to stresses, loads, environmental circumstances etc. cracks are developed in concrete. The cracks may form in any direction such as longitudinal, diagonal, transverse etc. There are many types of cracks which causes damage to the structures. The cracks in concrete adversely affect strength, durability and appearance of structures. In structures like Nuclear power plants, dams etc. a crack with smaller width can cause greater damage. The initial formation of crack does not lead to immediate deterioration of the structure but when it widens it creates a greater loss to life and property of structures. The crack detection in reinforced concrete concept is required to overcome these difficulties. Now days, the techniques which are in use for crack detection are EIT (Electrical Impedance Tomography) technique, Acoustic Emission technique, RFID (Radio Frequency Identification) technique and Inspection by using cameras.

II. LITERATURE REVIEW

Milad Hallaji, Aku Seppanen [6], The Sensing skin is applied on beam surface and 32 electrodes are placed. The four point bending method is used in this experiment. When the beam gets cracked, the sensing skin gets cracked. The EIT image shows the cracks in red line. EIT image will form immediately after crack formation.

E.A.Jiya and N.S.N.Anwar [9], they proposed microwave imaging technique to detect cracks. The antennas are placed on the surface of brick and the antennas are connected to multiplexer which transmit readings to workstation. Finite Differentiation time domain method is used in this research. The microwave imaging technique gives exact location of cracks. Small cracks of size 5mm can be detected. Crack can be detected in early stage of development.

Mohammad Pour-Ghaz, Amir Poursaee [7], they have compared three experimental methods to detect cracks in restrained ring specimens. The acoustic emission sensors, strain gauges, electrodes, conductive surface coatings are used. The conductive coating is applied on mortar surface. The sudden strain release in steel ring causes discrete increase in acoustic energy and increase in electrical resistance of conductive coating. The formation of crack also inspected visually. The conductive coatings and electrodes detect cracks only after they appear on surface but acoustic emission also provides information on damage development before the cracks are visible

III. METHODOLOGY

We have casted three beam specimens for laboratory testing. After curing period of 28 days, the conductive graphite paint is applied evenly on the surface of beam in two coats. The electrodes are placed in two pairs. The program is designed by using Embedded C language. The program is inserted to Arduino Uno R3 microcontroller by using Arduino 1.6.3 software. Then 5V current runs through the electrode pairs. According to Ohm’s law, Direct current flowing in a conductor is directly proportional to potential difference between its ends. Hence, when the surface of beam gets cracked, the conductive surface also gets cracked and resistance to current flow increases. Hence potential difference between electrode pairs increases. The results are shown on LCD and computer screen.

IV. MATERIALS

Cement

Cement used is Ordinary Portland cement. (OPC). In the absence of impurities, the color of cement is gray. Ordinary Portland cement (OPC) – 53 grade (Birla Shakti Cement) is used.

Fine Aggregate

Crushed sand is used which is also called as artificial sand. It is locally available in nearby area having specific gravity 2.63.

Coarse Aggregate

Natural coarse aggregate used which is locally available. Aggregates have specific gravity 2.79. The 20mm and 10mm size of aggregate were used in 60% and 40% respectively.

Water

Water should be free from acid, oils, alkalis, vegetables or other organic impurities. Soft water also produces weaker concrete. Water has two functions in concrete mixes. Firstly, it reacts chemically with the cement to form a cement paste in which the inert aggregates are held in suspension until the cement paste has hardened. Secondly, it serves as a lubricant in the mixture of fine aggregate and cement.

Conductive Graphite Paint

The Graphite conductive coating is an economical, acrylic paint that is used to create conductive, static free surfaces with excellent characteristics. Coated surfaces reduce electromagnetic or radio frequency interference (EMI/RFI). The graphite in the coat resists rubbing off to the touch. Further, the cured coat is designed to withstand large temperature changes without cracking. It has high Conductivity and low Surface resistivity. It is tough and durable coating and Rub off resistant.

Figure 1. Conductive Graphite Paint

Graphite Electrodes

The graphite electrodes are generally known as Carbon electrodes. The size of carbon electrode is 35x10x3 mm. The material which is used in this carbon electrode is electro-graphite. It has excellent quality control & ISO 9001 certified. These electrodes are much cheaper than other type of electrodes.

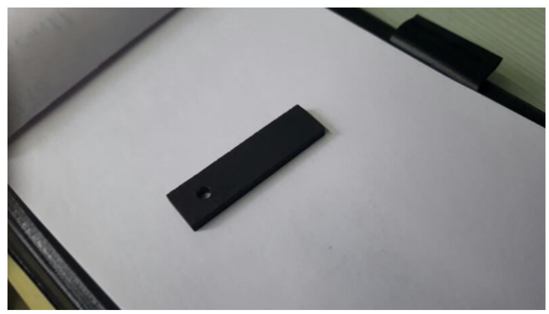

Figure 2. Graphite Electrode

V. EXPERIMENTAL PROGRAM

Arduino Uno R3 Microcontroller

Arduino Uno R3 is a microcontroller board based on ATmega328P datasheet. This is 10-bit microcontroller. The sensors will read the voltage readings from 0-5V and microcontroller converts these values to ADC value from 0-1023 units. It has 14 digital input and output pins of which 6 can be used as outputs, 6 analog inputs and 16 MHz quartz crystal, USB Connection, power jack, reset button. It contains everything needed to support the microcontroller, simply connected it to a computer with a USB cable. This microcontroller starts its working when connected to laptop using USB. In some cases the sensor requires more electricity to operate, hence power connector is provided to connect adapter. The reset switch is provided to refresh the system. The LCD is connected to 7, 8, 9, 10, 11, 12 digital outputs. The electrode pair 1 is connected to analog output named as

A1. The electrode pair 2 is connected to analog output labeled as A2. The buzzer is connected to pin no.2.

Figure 3. Arduino Uno R3 Microcontroller

Casting

Three beams of size 750x150x150 mm are casted. The M25 concrete grade is used and main steel of 10 mm diameter and stirrups of 6 mm diameter are used at 65mm c/c. The curing is done for 28 days.

Application of Conductive Graphite Paint

After curing for 28 days, the beam specimens are taken out from curing tank. After 24 hours, the first coat of conductive graphite paint is applied on the surface of beams using painting brush. The first coat of conductive graphite paint is allowed to dry for two hours. After that the second coat of conductive graphite paint is applied on surface of beam.

Experimental Setup

The four point flexure test is carried out on Universal Testing Machine (UTM). The graphite electrodes are fixed on the surface of beam by using stick tape. The electrodes are placed in two pairs. Electrode pair 1 is fixed at lower section of beam surface and electrode pair 2 is fixed at upper section of beam surface. The distance between electrode pair 1 and electrode pair 2 is 600 mm. The electrode pair 1 is connected to analog output A1 on Arduino Uno R3 microcontroller and electrode pair 2 is connected to analog output A2 on Arduino Uno R3 microcontroller. The LCD is connected to 7, 8, 9, 10, 11, 12 digital outputs. The buzzer is connected to pin no. 2. The Arduino Uno R3 microcontroller is connected to laptop by using USB cable. Now the Arduino 1.6.3 software is started in laptop. The laptop provides current supply to Arduino Uno R3 microcontroller. Now current runs through the conductive paint by electrode pairs. This measures voltage reading between the pairs of electrode and the initial values of voltage between electrode pairs 1, 2. The sensor reads the voltage value from 0-5V. Then the microcontroller converts that analog value to digital value i.e. ADC value. The sensor reads the voltage value from 0-5V and microcontroller converts that value in 0-1023 units because we have used 10 bit microcontroller. If voltage value is 5V then its ADC value will be 1023 units and anything less than 5V will be a ratio between 5V and 1023. This ADC value will be shown on LCD screen. The initial ADC values of voltages which are shown on LCD are note down. These initial ADC values of voltages are set in the program. According to Ohm's Law "The potential difference i.e. Voltage across an ideal conductor is proportional to the current flowing through it i.e. V= IR, where 'V' is potential difference between two points which include Resistance 'R' and 'I' is current. The minimum value of the voltage difference for a small crack in our computer program is 15 units. For example, if the initial ADC value of voltage between each electrode pair is 500 units. Whenever there is small crack on the beam surface the ADC value increases by 15 units i.e. it crosses 515 units, message is shown on the screen that there is a crack between certain pair of electrode. Whenever there is crack between any of the electrode pair 1 and electrode pair 2, then the value of voltage between that electrode pair will rise only and thus we will come to know that there is crack near that electrode pairs. The message will be shown on LCD that "There is a crack in between certain electrode pair and buzzer will start beeping.

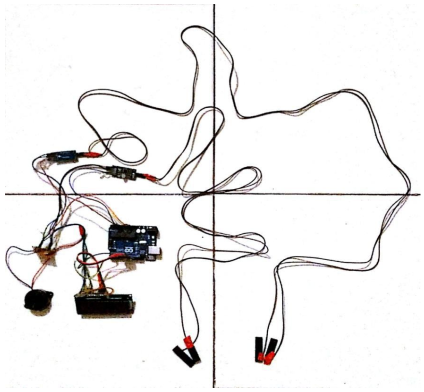

Figure 4. Assembly of Microcontroller, LCD, Buzzer, Electrodes

Testing

Three beams are designated as B1, B2, and B3. The Universal Testing Machine is used for testing of three beam specimens for crack detection. The four point flexure test is used for testing. After experimental setup the loading is applied gradually and readings shown on LCD are note down.

Figure 5. Experimental Setup

VI. RESULTS AND DISCUSSION

The testing of three beam specimens has given us readings regarding cracks. The LCD displays readings of ADC values of voltages between two electrode pairs. The readings per 2 seconds are recorded in Arduino 1.6.3 software.

Table 1. ADC Readings of voltages for B1 during testing

For Beam 1			
Electrode Pairs	Initial Reading	Final Reading	Remark
1	259	326	Crack Detected
2	193	277	Crack Detected
Load : 73.17 kN			

Table 2. ADC Readings of voltages for B2 during testing

For Beam 2			
Electrode Pairs	Initial Reading	Final Reading	Remark
1	729	802	Crack Detected
2	620	648	Crack Detected
Load : 80.46 kN			

Table 3. ADC Readings of voltages for B3 during testing

For Beam 3			
Electrode Pairs	Initial Reading	Final Reading	Remark
1	161	1008	Crack Detected
2	138	138	No Crack
Load : 78.70 kN			

The Table 1 shows the ADC readings of voltages from two electrode pairs on B1. The initial ADC readings of voltages between electrode pair 1 and 2 are 259 units and 193 units respectively. These initial voltage readings are different from each other because resistance varies with paint thickness. The crack is formed on beam surface under the load of 73.17 kN. The final ADC voltage readings are 326 units and 277 units respectively for electrode pair 1 and electrode pair 2 respectively. The current flow between both electrode pairs is obstructed. Hence the resistance to conductivity increased. The message shown on LCD is “Crack 1 and Crack 2”. The diagonal cracks are formed on surface of beam as shown in Fig. 6.

Figure 6. Cracks on surface of B1

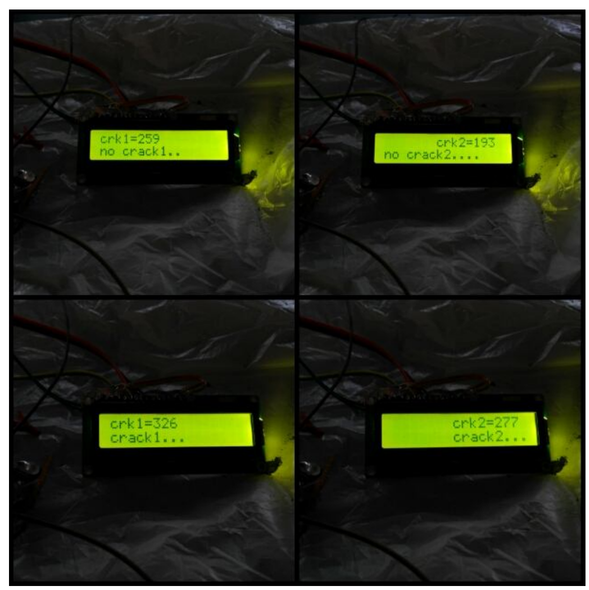

Figure 7. ADC readings of voltages from B1

B2 beam had very rough surface. Hence the conductivity of graphite paint is less as compared to other beams. At Electrode pair 1, the initial ADC reading of voltage is 729 units and at electrode pair 2 initial ADC reading of voltage is 620 units. The crack is formed on the surface of beam under the load of 80.46 kN. When the crack is formed the resistance to current is increased, hence ADC voltage value also increased to 802 units for electrode pair 1. At Electrode pair 2, the initial reading is 620 units and final reading is 648 units. The LCD displays "Crack 1 and Crack 2". Table 2 shows the ADC readings of voltages from two electrode pairs on B2. The flexural crack is formed on surface of beam as shown in Fig 8.

Figure 8. Crack on surface of B2

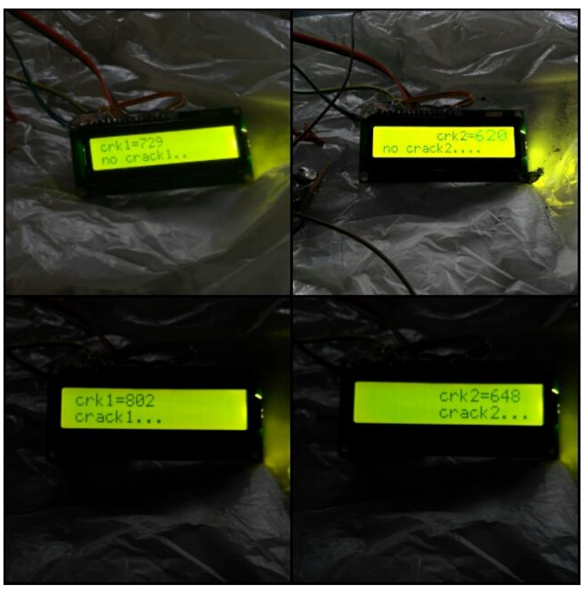

Figure 9. ADC readings of voltages from B2

Table 3 gives ADC readings of voltages from two electrode pairs on B3. The initial ADC readings of voltages between electrode pair 1 and 2 are 161 units and 138 units respectively. The crack is formed under the load of 78.70 kN. The flexure crack is formed at electrode pair 1 and the crack is not propagated towards electrode pair 2 as shown in Fig. 10. The voltage reading gets increased due to increase in resistance. Hence final ADC voltage readings are 1008 units and 138 units for electrode pair 1 and electrode pair 2 respectively. The LCD displays "Crack 1 and No Crack 2".

Figure 10. Crack on surface of B3

Figure 11. ADC readings of voltages from B3

VII. CONCLUSION

1) The results indicate that application of sensing skin and electrode is a promising method to detect cracks in Structure.
2) The location of cracks in concrete structure can be detected. The results are continuously showing in the software Arduino 1.6.3.
3) The system gives indication of crack formation by beeping alarm.

REFERENCES

[1] Mohammad Pour-Ghaz, Timothy Barrett; Tyler Ley, Nicholas Materer, Allen Apblett and Jason Weiss (2015), Wireless Crack Detection in Concrete Elements Using Conductive Surface Sensors and Radio Frequency Identification Technology, Journal of Materials in civil engineering, vol. 26, pp 923-929.

[2] Milad Hallaji, Mohammad Pour-Ghaz (2014), A new

sensing skin for qualitative damage detection in concrete Elements: Rapid difference imaging with electrical resistance tomography, NDT&E International, vol. 68, pp 13-21.

[3] Hiromasa Chigusa, Yasutoshi Makino, Hiroyuki Shinoda (2009), Large Area Sensor Skin based on Two-Dimensional Signal Transmission Technology, SICE-ICASE, pp 4867-4869.

[4] Tsung-Chin Hou and Jerome P. Lynch (2009), Electrical Impedance Tomographic Methods for Sensing Strain Fields and Crack Damage in Cementitious Structures, Journal of Intelligent Material Systems and Structures, vol. 20, pp 1363-1379.

[5] Prasanna Kalansuriya, Rahul Bhattacharyya and Sanjay Sharma (2013), RFID Tag Antenna-Based Sensing for Pervasive Surface Crack Detection, IEEE, vol. 13, pp 591-599.

[6] Kambiz Raoufi, Mohammad Pour-Ghaz, Amir Poursaee and Jason Weiss (2011), Restrained Shrinkage Cracking in Concrete Elements: Role of Substrate Bond on Crack Development, Journal of materials in civil engineering, vol. 23, pp 895-902.

[7] Mohammad Pour Ghaz, Amir Poursaee, Robert Spragg, Jason Weiss (2011), Experimental methods to detect and quantify damage in restrained concrete ring specimens, JACT, vol. 9, pp 251-260.

[8] Aku Seppanen, Milad Hallaji, Mohammad Pour Ghaz (2014), Electrical impedance tomography-based sensing skin for quantitative imaging of damage in concrete, Smart Materials and Structures, vol.23, pp 1-13.

[9] E.A.Jiya, N.S.N.Anwar, M.Z.Abdullah (2016), Detection of cracks in Concrete Structure using Microwave Imaging technique, IJMST, vol. 2016, pp 1-6.

[10] IS-10262 (2009), Concrete Mix Proportioning guidelines, Bureau of Indian Standards.