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Study the feasibility of CNT for potential use as sensor for smart concrete.

Darshan Parmar[1], Siddharth Shah[2], Smit Kacha[3]

[1]*Student, Department of civil engineering, Marwadi Education Foundation, Rajkot, Gujarat,*
[2] *Professor & Head, Civil Engineering Department, Marwadi Education Foundation, Rajkot, Gujarat,*
[3] *Asst.Professor, Civil Engineering Department, Marwadi Education Foundation, Rajkot, Gujarat,*

ABSTRACT - The piezo resistive properties of carbon nanotube/cement composites at different dose of CNT with respect to weight of cement is studied to explore the new and important advancement in the area of greatly sensitive strain sensors made from CNT to investigate its feasibleness as an inserted stress detector for common structures, for example, roads, buildings and bridges. The piezoresistive effect for any material is a variation in the electrical resistivity of that material when mechanical strain is applied. In this research paper, the ongoing significant advancement in the area of strain detector sensors made from the MWCNT by using its piezoresistive property is studied. The piezoresistive reactions of cement mortar moulds with various MWCNT injecting levels are considered. The MWCNTs were fully dispersed in water by using surfactants. Four probe electrical resistance method is used to measure the electrical resistance of CNT/cement composites moulds by using copper plate electrodes and also by using copper wires and graphs of displacement vs load and displacement vs fractional change in electrical resistance were plotted.

Key words - Multiwall Carbon Nanotube, Piezo resistance, cementitious material, strain, electrical resistance.

I. INTRODUCTION

A. Self Sensing Concrete

Self-sensing concrete has the capability to sense the conditions inside it and also the environmental changes. This includes stress, strain, crack, damage, temperature, and humidity. The self-sensing concrete has great potential in the fields of structural health monitoring and traffic detection.

B. Carbon Nano Tube (CNT)

CNT are allotrope of carbon with tube shaped nanostructure. A nanotube is a small, hollow, long, thin and solid tube with an outside dia in nanometer that is shaped from molecules, for example, carbon. Additionally, Nanotubes are hundred times stronger than steel. The ratio of length to diameter of nanotubes falls in the middle of 1:132,000,000. Its properties can be utilized in nanotechnology, eyesight, material skills, hardware and different fields of science. CNT has different applications (like in hardware, car, air transportation) that are now practically speaking and furthermore can change substance of development industry, the vehicle field, materials science enterprises, the space business and things related with step by step living. Nanotubes can be either single walled nanotubes (SWNT) or multi walled nanotubes (MWNT).

1) Single walled carbon nanotube (SWCNT): Single walled nanotubes have only a single layer of carbon nanotube. The range of tensile strength of SWNT varies from 13-53 GPa.

2) Multi walled carbon nanotube (MWCNT): They have multiple layers of carbon nanotubes around a single one. The strength of multi walled is greater than that of the single walled. The range of tensile strength for MWCNT is around 11-150 GPa.

C. Piezoresistive effect

The piezo resistive effect is a change in the electrical resistivity of a material when mechanical strain is applied. In which the electrical resistivity of a material is also known as its specific electrical resistance. the obstruction to current flowing through a conductor is called electrical resistance. Resistance's unit is Ω (ohm). (Volt per ampere).

The researchers have tried CNT as sensor in cementitious material for possible use in dynamic response measurements and structural health monitoring.**[1-3,4,6-10,12,13]** whereas k. s. Sathyanarayanan used carbon fibers for the same purpose.**[11]**cement paste moulds in rectangular shape was casted for experiment purpose.**[1,3-6,10,13]** the other researchers also casted cement mortar as well as cement concrete moulds.**[8,9,11]** f. ubertini casted cube of size 51 mm of cement paste.**[12]** in most of researches, the CNT content was ranging from 0.2% to 1% of weight of cement. Few researchers uses manual mixing followed by sonication process to disperse CNT in deionized water**[3-6,12,13]** and some uses proper dispersing agent with sonication process to fully disperse CNT in deionized water.**[1,8-11]** copper wires**[3,6,12]**, grid of copper wires**[1,2,4,13]** and copper plates[**5,8-11]** are used to act it as an electrode**.** Two probe method**[1-6,12,13]** and four probe method**[8-11]** are generally used to measure the electrical resistance of casted specimen. The specimens were kept into oven (65°C for 3 days and 110°C for another 3 days) for properly removal of moisture.**[3,8-10]** cyclic load**[8-11]** and dynamic load**[1-4,12,13]** was applied to specimen. The graphs of time vs fractional change in resistivity**[3,4,6];** load vs fractional change in resistivity**[1,2];** and both displacement vs load and displacement vs fractional change in resistivity**[8-11]** were plotted. It is seen that there is an increase in electrical resistance on loading up to crack propagation or fracture.**[7,11]**

II. EXPERIMENTAL PROCEDURE

A. materials and preparation of specimen

The ordinary Portland cement (OPC) and well graded fine aggregates were used to prepare moulds of cement mortar of size 15cm*5cm*5cm in a ratio of 1:3 cement to sand. The MWCNT (multi wall carbon nanotube) of diameter ranges from 20 to 40 nm and length of 5 to 15 micrometer were reinforced into cement mortar moulds. The MWCNT were properly dispersed into distilled water. Use of surfactants was applied to properly disperse the MWCNT into a water. Multi walled carbon nanotubes and surfactants were first dried mixed for 5 mins in a clean glass beaker and then required quantity of distilled water is added into mixture of MWCNT and SDS. This mixture is required to sonicate in a sonicator machine for 40 to 50 mins. This dispersed CNT added distilled water is used to prepare cement mortar moulds. The prepared mortar was casted in 15*5*5 cm wooden oiled moulds. The water to cement ratio was kept at 0.4 and CNT dosage was of 0.2 % of weight of cement. After 24 hours of casting, the moulds were demolded and kept for curing for 28 days.

To eliminate the effect of polarization, in which the electrical resistance of prepared cement mortar moulds were continuously increasing over time without applying load, the prepared moulds were kept into oven at 65°C for 3 days and 110°C for another 3 days for proper removal of moisture from mould.

B. measurement of electrical resistivity

Two types of electrodes namely copper wire of 2 mm dia and copper plate of 2 mm thickness were used to measure electrical resistivity of prepared moulds. Two different types of methods were used to measure electrical resistivity i.e. two probe method and four probe method.

To measure the electrical resistivity of mould by using two probe method, either two copper wires of 2 mm dia or two copper plates of size 50mm*15mm*2mm were used as shown in figure 1 and 2.

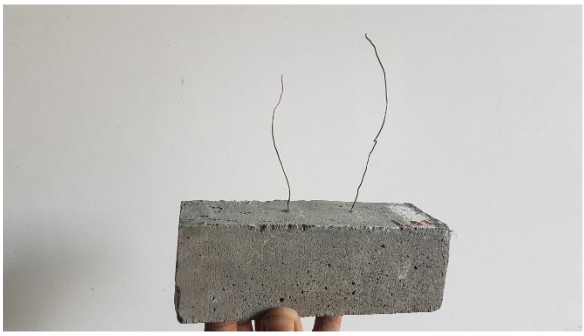

Fig. 1. Cement mortar mould with two copper wires

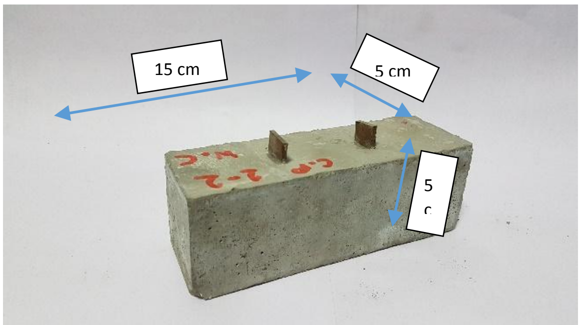

Fig. 2. Cement mortar mould with two copper plates

Also to measure the electrical resistivity of prepared moulds by using four probe method, either four copper wires of same dia or 4 copper plates of same size were used as shown in figure 3 and 4. After observing and analyzing the both method by using "E4980AL Precision LCR Meter" with copper wires and copper plates, the accurate results were noticed in four probe electrical resistance method with copper wires. Around 40 Nos. of cement mortar moulds reinforced with MWCNT at 0.2% of wt. of cement including 4 copper wires were prepared for test. After 28 days of curing, the moulds were kept in oven at 65°C for first three days and at 110°C for another three days to eliminate the effect of polarization.

Fig. 3. Cement mortar mould with four copper wires

Fig. 4. Cement mortar mould with four copper plates

C. experimental tests

The three point bending test was performed on prepared cement mortar moulds in which, the mould were supported from the both ends and point load was applied gradually at the center by using CBR apparatus as shown in figure 5. Dial gauge was used to measure the displacement at the center with accuracy of 0.01 mm.

To measure the change in electrical resistivity with respect to applied load, two digital multimeter were used. Electrical resistivity is equal to voltage divided by current.

$$R = \frac{v}{a} \qquad (1)$$

Where,

R = resistivity (ohm, Ω)
v = voltage (volt, V)
a = current (ampere, A)

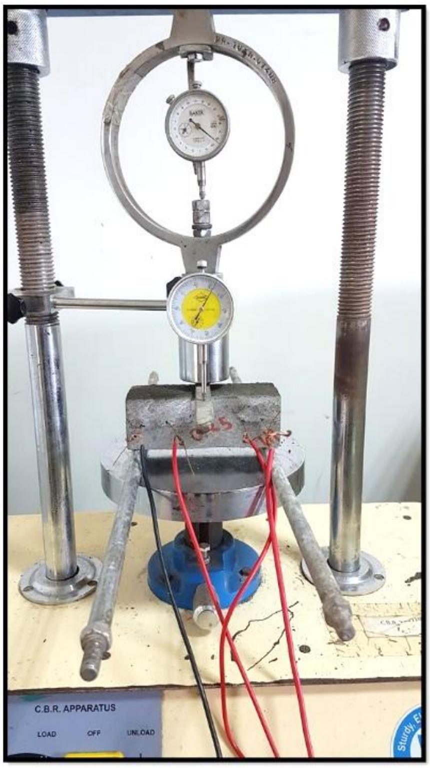

Fig. 5. Three point bending test

Fig. 6. Experimental setup for measuring electrical resistance

III. RESULTS AND DISCUSSION

The primer task of the current study was to study ‘‘damage sensing under bending’’ by performing three-point bending test of cement mortar mould with addition of multiwall carbon nanotube of 0.2% weight of cement. Data of load, voltage and current were noted at every displacement of 0.1 mm. after getting the results, the graphs of displacement vs load and displacement vs fractional change in resistivity was plotted.

The fractional change in resistivity is obtained by dividing the difference in values of resistivity each time and initial resistivity.

$$\text{Rn} = \frac{Rt - \text{R0}}{\text{R0}} \qquad (2)$$

Where,

Rn = fractional change in resistivity (%)
Rt = measured resistivity during the test
R0 = initial resistivity

Readings of Rt was obtained by using two digital multimeter by taking readings of voltage and current using equation 1.

The graph in fig. 7 shows the typical change in electrical resistance measured during three point bending load for mortars modified with carbon nanotubes at 0.2 % of wt. of cement.

The load-displacement behavior of mortar as well as fractional change in electrical resistivity is shown in graph in Fig. 7. x axis shows the readings of displacement whereas on y axis, the left side shows the readings of load and right side shows fractional change in electrical resistance as explained in equation 2. The failure occurred at load of 1.98 kn having displacement of 0.78 mm. From fig. 7, the material's response can be categorized into two main segments. In first segment, that is from occurrence of displacement to 0.7 mm of displacement, there is normal change in electrical resistance, whereas in second segment, that is displacement from 0.7 mm to 0.78 mm there is sudden dramatic increase in electrical resistance.

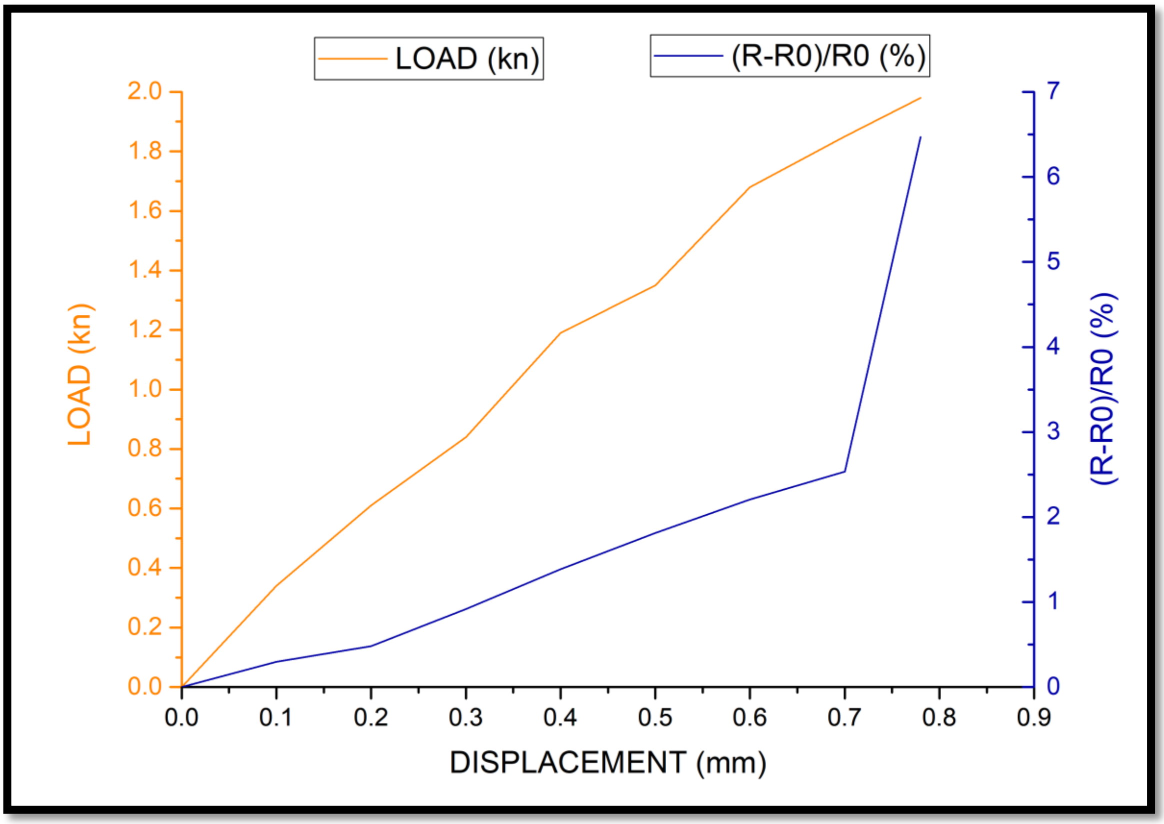

Fig. 7. Change in electrical resistance during three point bending test

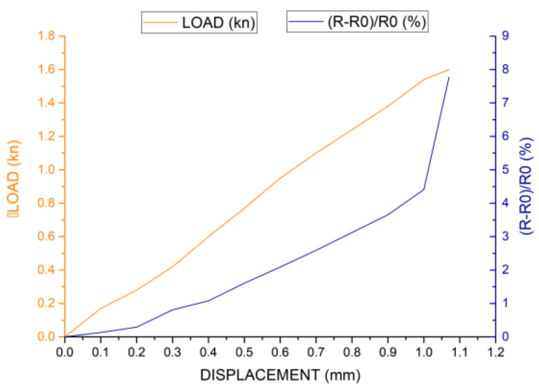

Fig 8 (a)

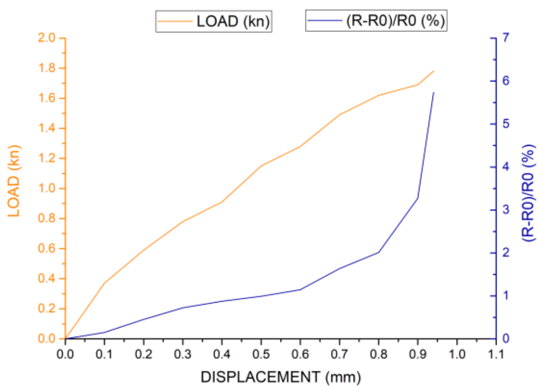

Fig 8 (b)

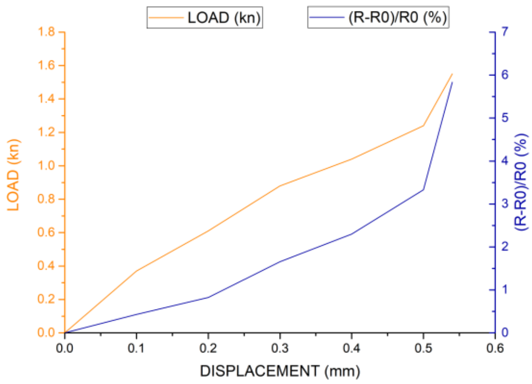

Fig 8 (c)

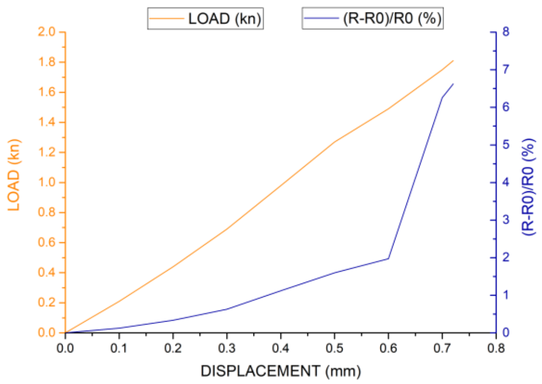

Fig 8 (d)

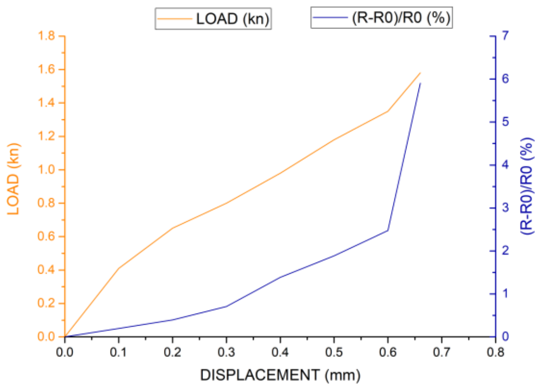

Fig 8 (e)

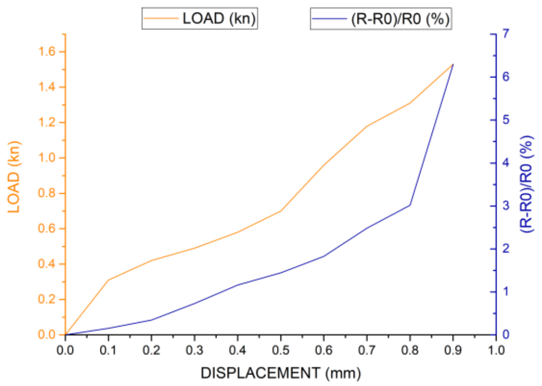

Fig 8 (f)

Fig. 8 Different graphs of change in electrical resistance during three point bending test

The fig. 8 shows different graphs plotted after performing three point bending test. the displacement vs load and displacement vs fractional change in electrical resistivity's value for different cement mortar moulds can be noted from above graphs. The sudden change in electrical resistance was observed just before the failure of moulds. Which shows that whenever there is any such type of dramatic change of electrical resistance of an element, the failure of particular element can be predicted.

IV. CONCLUSION

Cement mortar moulds modified with carbon nanotubes at 0.2 % by weight of cement was prepared and their strain and damage sensing potential in the area of greatly sensitive strain sensors made from CNT to investigate its feasibleness as an inserted stress detector for common structures was investigated. Sodium dodecyl sulfate as a dispersing agent was found effective and, proper dispersion of CNT in distilled water was achieved. Two methods namely two probe electrical resistance method and four probe electrical resistance method was studied by using copper wires and copper plates as electrodes. After analyzing the both method the four probe electrical resistance method with four copper wires was found accurate compare to other method. Also the piezo resistive behavior of cement mortar moulds modified with CNT was studied and graphs of displacement vs load and displacement vs fractional change in resistivity were plotted. Where before failure of moulds, the sudden dramatic increase in electrical resistance was observed. which acts as a sensor by predicting the failure of particular element and can be effectively use for structural health monitoring for various common structures like residential houses, multi storied buildings, brides etc..

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