INTRODUCTION

In recent years, Structural Health Monitoring (SHM) has garnered attention in civil engineering applications. Degradation, cumulative structural damage or poor material resistance are common reasons for the failure of conventional concrete structures such as dams and bridges which undergo different levels of load, fatigue or corrosion. All of these parameters can be termed as distress in a structure. Monitoring the distress is essential in order to prevent the collapse of a structure and loss of life. While there are several sensors available for structural health monitoring, they are expensive, degrade with time and also detect distress in a small area. Hence there is a need to develop a material which has the ability to detect distress on its own, continuously with time and over a larger area. This provides the motivation for the development of self-sensing concrete.

Concrete is a very poor conductor of electricity. However, by the addition of a nano material called CNT (Carbon nanotubes) in the matrix of concrete, the electrical conductivity increases. Uniform dispersion of carbon nanotubes is critical, in order to achieve better electrical conductivity. This is achieved by dispersing CNTs in an aqueous solution of surfactant (aids in dispersion and provides a protective coating around CNTs) in an ultrasonic sonicator. This solution is mixed with the constituents of cement concrete to create an electrically conductive specimen. We pass electricity through this specimen and observe the variation of electrical resistance with the applied load. These results can be used to interpret cracks in concrete and set threshold limits for the progressive and sudden failure of the specimen. These threshold limits are used to develop an IoT (Internet of Things) system by using Arduino Uno and a GSM module. This system is used to send a warning message to a control station when the structure is under distress.

No compromise is anticipated in the mechanical properties of concrete with the additions of additives such as CNTs. On the contrary, an increase in the compressive strength of concrete was observed by the addition of CNTs. Curing also plays an important role in enhancing the electrical properties of concrete as there is densification of the microstructure of concrete which observed in the SEM images. A densified microstructure aids CNTs to develop better contact and hence better conductivity. The electrical resistance of concrete decreases with the increase in applied load. Use of a super plasticizer densifies the microstructure of concrete and thus increases the
electrical conductivity of concrete. By the implementation of IoT, this method of structural health monitoring can be constantly monitored throughout the lifespan of the structure. With early detection of distress in the structure, the structure can be rehabilitated and thus major disasters may be averted.

Failure of structures due to overloading, high impact load loading and aggressive environmental condition, continuous maintenance is necessary for the structures like highways, bridges and dams. Early detection of these types of damage can protect the structures from deteriorating, sudden collapse and also adds to the safety of public. Different structural health monitoring methods have been developed to check the safety and performance of the structures (such as fibre optic sensors, piezoelectric sensors) which holds shortcoming of higher cost and less effectiveness. Therefore, in recent years, many researches led to the development of self sensing composite.

Self sensing is the property by which a material can sense its own conditions such as stress, strain, damage, temperature, and so on. The methodology of this project is based on the concept of nanotechnology. It may have the potential to engineer concrete with superior properties through the optimization of material behaviour and performance needed to significantly improve mechanical performance, durability and sustainability.

The fundamental concept of this project is based on the strain or stress parameters. Due to varying load, cracks are formed inside the concrete structure, which deforms the nano materials inside the conductive medium. Whenever there is a stress or strain in the concrete composite, it causes the change in the conducting property of the nano material inside the concrete, which is proportion to the load applied. The external electrical arrangement which is made to measure the change in conductivity is used for monitoring the structure. Self monitoring implies that whenever there is a change in the crack pattern of the concrete structure for varying load, an external signal in the form of noise or message is created to alert detection of flaws and cracks inside the structure as a warning before collapse. Thus, the whole material acts as sensor which is long lasting compared to other health monitoring techniques.

To achieve the conducting property, different materials are used such as Carbon fibre, Carbon black and carbon nanotubes. The sensing ability depends on the type, amount and the uniformity in distribution of the conducting material. In this research paper, carbon nanotubes (CNTs) are used for flow of electricity in cement composite for structural health monitoring. In cement composite, carbon nanotubes act as conductive network for electrical current which helps to measure the change in electrical parameters for varying load. Since carbon nanotubes acts as an effective filler material, it also helps to reduce the micro and nano level cracks inside the concrete enabling the improved mechanical properties.
LITERATURE REVIEW
Coppala Luigi, et. Al., Electrical Properties of Carbon Nanotubes Cement Composites for Monitoring Stress Conditions in Concrete Structures - Applied Mechanics and Materials Vol. 82 (2011) pp 118-123 – 2011 – Use of surfactant decreases the density of the specimen. Combination of defoamer and surfactant is ineffective in removal of trapped air. Piezo resistive property is high when the CNT content was 0.1% of the weight of cement.

M.S. Konsta-Gdoutos and E.E. Gdoutos - Specimens in CNTs have higher Young's modulus when compared to that of normal cement paste. It is noted in his study that Modulus of elasticity has increased by 45%. Flexural strength increased by 25% for CNT concentration of 0.8%.

Shivani Mehta, Hardik Solanki has highlighted in his study that Strength of mortar mix with CNTs embedded is greater than that of normal mortar. Nanotubes increase the electrical properties of mortar. Uniform dispersion of nanotubes is necessary for efficient electrical conductivity.

Literatures suggest that addition of CNTs improves conductivity of the specimen. Electrical resistance varies with load making the material piezo resistive. Optimum content of CNTs was found to be 0.1% of the weight of cement. All mechanical properties can be increased by the addition of CNTs. Efficient dispersion CNTs is essential to ensure uniform conductivity. Surfactants play the role of protection of CNTs during dispersion. Use of Super plasticizer improves the conductivity of the specimen.

MOTIVATION
• Modern day methods use embedded sensors which are localized to a point.
• These sensors degrade with time and exposure to harsh environments.
• Sensors cannot detect internal and external distress in concrete structures simultaneously.
• Development of a material which can detect distress by itself.

PROBLEM DEFINITION
1. To make cement/concrete matrix electrically conductive by the addition of MWCNTs.
2. To study the mechanical properties of CNT cement/concrete composite such as compressive and flexural strength.
3. To study the electrical resistivity behavior of CNT cement composite for varying load and correlate it with the distress in the massive concrete structures.
MATERIALS AND METHODS

a) Mix proportions
Cement : Fine aggregates = 1 : 3
Water : Cement ratio = 0.5
CNTs = 0.1 % of weight of cement
Surfactant = 1 gram / 250 mL of water

b) Comparison of compressive strength of cement mortar with CNT and without CNTs
Weigh the required amount of CNTs. Dissolve the surfactant in water using a magnetic stirrer (Amount of water should be equal to the amount required to maintain the water cement ratio) Pour CNTs into the solution. Solution is stirred again. Disperse CNTs using an ultrasonic sonicator for 1 hour. Mix cement, sand and the solution using a Hobart mixer. Cast three cement mortar cubes with CNTs. Cast another three normal cement mortar cubes. Demould after 24 hours. No curing adopted. Specimens tested after 28 days. 30 % increase in strength was observed.

Casting of beams with CNTs: Mix dispersed CNTs with cement mortar mix and cast beams of size 40 mm x 40 mm x 160 mm.Insert electrodes into the beam with equal spacing from both ends and connects wires to them. Demould the specimen after 24 hours. One beam with CNT mortar composite was cast. No curing was adopted to study the effect of curing on electrical conductance. Curing was adopted by spraying water on further specimens.

c) Testing the electrical properties of the beam with varying load: A single beam was subjected to flexure test after 7 days of curing. The variation in electrical parameters with respect to the load was checked. Since flexural testing led to sudden failure and propagation of cracks was not observed, three beams were tested for compression after 28 days of curing using a CBR machine. Making all the necessary electrical arrangements, the beam was loaded at a constant rate and the corresponding dial reading, current reading and voltage drop was noted down. Effect of curing on electrical conductivity was studied as well and it was seen that the resistance was too high for an uncured specimen. Since a super plasticizer (SP) provides more cement particles and removes flocs, 3 more specimens were cast using 0.8% SP of the weight of cement. This led to the assumption that the conductivity would increase with the use of SP.

Implementation of INTERNET OF THINGS [IoT]

Current sensor and voltage sensors are connected to Arduino UNO. The data from the sensors is fed into Arduino Uno. After tabulation of data, threshold value is set. The Arduino board is then programmed in such a way that a message is sent using a GSM module when resistance exceeds the threshold value.
RESULTS: Results and observations from the analysis are

- The electrical conductivity was decreasing without curing.
- SEM, XRD and EDAX data suggested that the formation of CSH gel was too low for specimen to conduct.
- Hence, it was decided to cure the specimen by spraying water on the specimen daily.
- There is an increase in the compressive strength of mortar by addition of 0.1% of CNTs.
- The variations in electrical conductivity can be interpreted
- The data obtained from Arduino Uno and by manual testing for a particular specimen are similar. The pattern observed in the above graph holds true for all the specimens. From this graph, the peaks are correlated and correspond to threshold limits for different levels of distress (Initiation of cracks, propagation of cracks and absolute collapse) and were interpreted as the indication of levels of distress. Arduino Uno is programmed to send a warning message to the control station when the specimen reaches these threshold limits of distress.

CONCLUSION

Increase in the compressive strength of mortar by addition of CNTs was found to be 35%. SEM data suggests that micro level cracks maybe arrested. From the tests conducted it is seen that the electrical resistance varies with load. It was observed that curing the specimen is essential to enhance electrical conductivity. SEM, XRD and EDAX data suggested that the formation of CSH gel is essential for continuity to be present in the specimen so that it conducts electricity.

REFERENCES


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