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Experimental Analysis On Self Sensing Characteristics Of M_{30} Concrete

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ABSTRACT: Self Sensing Concrete is artificially created concrete that has inbuilt ability to sense damage without any human intervention. Generally normal concrete does not conduct current to pass through it. Hence in order to conduct current in the concrete carbon fibres are added to the concrete matrix. Effective monitoring permits the control of working conditions of materials in the infrastructure and identification of behavioural parameters due to damages by application of load. Hence we can sense the amount of crack formed in the concrete structure through increase in electrical resistivity created within the concrete. The self sensing ability is achieved by correlating the variation of external stress or strain with the variation of electrical properties such as electrical resistance and conductivity.

This paper aims at the investigation of M_{30} concrete's sensitivity at 7 and 28 days. Cubes were casted with the proportion of 0.24%, 0.4%, 15% of carbon fibre, methyl cellulose and silica fumes respectively and the cracking patterns were sensed at 7 and 28 days with circuit connections consisting of Ammeter, Voltmeter and Regulated Power Supply (DC). The measurement of the electrical characteristics is completely monitored. The values of resistivity is compared with the conventional M_{30} concrete and the sensing characteristics are enhanced by wounding three layers of copper wires over the concrete cubes painted with nickel conductivity paints. Structural application of this project can be used in the power plants and also industrial plants in which structural health monitoring is essential.

INTRODUCTION

The present day constraints with construction field is the identification of proper methods for the evaluation of stresses in structures and also to check that they are cost effective. The invention of smart materials and sensors have ever increased the necessity to monitor in real time the behavior of critical structures like bridges, nuclear vessels, chemical storages etc.,The sensors are required to sense cracks in real time during static and dynamic loading for damage assessment with consequent action plan for remedies. They are further required to be low cost for instrumentation of huge structures. The existing sensors like strain gauges, fiber optic gauges, piezo electric, acoustic emission , Bragg grating etc., are not only costly but also suffer from poor durability and the requirement of trained personnel, transportation and erection problems. They also require expensive peripheral equipments like electronic and laser equipments.

But in this present experimental program with carbon fiber, carbon fiber itself is a sensor and does not require additional equipments except for a few simple instruments.Voltage and current were measured from the loaded specimen from which the electrical resistance was computed. The instruments used were normally available voltmeter, ammeter and a regulated D.C. power supply. Dial gages were used for measuring the deflections .In this present experimental procedure, experiments were conducted by casting mortar cubes with an addition of 0.24% of carbon fiber for increasing electrical resistance along with methyl cellulose, silica fume for enhancing fiber dispersion, silica fume for enhancing fiber matrix

OBJECTIVES

- To check the conductive ability of carbon fiber material when mixed with concrete
- Cast cubes and do the comparisons of 7,28 days curing,
- Copper wires are wounded perpendicular to the stress axis, by addition of Methyl Cellulose , carbon and Silica Fume and get their and Resistance vs Strain graphs and compare their performance

METHODOLOGY

Due to the weak bond between carbon fiber and the cement matrix, continuous fibers are much more effective than short fibers in reinforcing concrete. Experiments were conducted to assess the smart behavior of carbon fiber. Unlike other sensors like strain gauges, Fiber optic gauges etc., carbon fiber due to its smart property namely to conduct electricity, acts as a self sensing material and senses resistance changes .Hence it senses elastic resistance change and inelastic failures. Also carbon fiber possesses high flexural strength which is an added advantage.

The present work is to cast cubes and do the comparisons of 7,28 days curing, and copper wires are wounded in along and perpendicular to the stress axis, cubes are casted by addition of Methyl Cellulose , carbon and Silica Fume. Resistance Vs Strain graphs are obtained and compared with their performance

MATERIALS USED

CEMENT

Cement used in this project is OPC 53 grade, being a major constituent in binding the concrete matrix. The cement used for the study is tested for various parameters like fineness, setting time, soundness and specific gravity.

COARSE AGGREGATE

20mm coarse aggregates are used in the study and tested for various parameters like fineness, specific gravity and water absorption.

Fine aggregates

M sand is used as fine aggregates in the study and tested for various parameters like fineness, bulking and water absorption.

CARBON FIBER

Carbon fiber cement-matrix composites are structural materials that are gaining in importance quite rapidly due to the decrease in carbon fiber cost and the increasing demand of superior structural and functional properties. These composites contain short carbon fibers, typically 5 mm in length, as the short fibers can be used as an admixture in concrete (whereas continuous fibers cannot be simply added to the concrete mix) and short fibers are less expensive than continuous fibers. However, due to the weak bond between carbon fiber and the cement matrix, continuous fibers are much more effective than short fibers in reinforcing concrete. Surface treatment of carbon fiber (e.g. by heating or by using ozone, silane, and SiO2 particles or hot NaOH solution) is useful for improving the bond between fiber and matrix, thereby

Carbon fibers 5mm

improving the properties of the composite.

In the case of surface treatment by ozone or silane, the improved bond is due to the enhanced wet ability by water. Admixtures such as latex, methylcellulose and silica fume also help the bond.

CARBON NANO TUBES

Carbon Nanotubes (CNTs) are incredibly strong hollow strings of carbon atoms that bond together in a tube or pipe-like fashion with unique properties which can be added to a multitude of materials to enhance durability or strength. CNTs could potentially be added to concrete or asphalt in a similar fashion to the way rebar reinforcement is used in modern construction, greatly increasing the structural strength and longevity of roads, foundations, load-bearing columns and walls, etc.

Carbon Nano Tubes

METHYL CELLULOSE
Methyl cellulose finds a major application as a performance additive in construction materials. It is added to mortar dry mixes to improve the mortar's properties such as workability, water retention, viscosity, adhesion to surfaces etc,.whereby, adding the methyl cellulose in the concrete which has carbon fiber

Methyl cellulose already will help carbon fiber to mix throughly mix with the concrete.

SILICA FUME
Effective use of the carbon fibers in concrete requires dispersion of the fibers in the mix. The dispersion is enhanced by using silica fume (a fine particulate) as an

admixture .A typical silica fume content is 15% by weight of cement. The silica fume is typically used along with a small amount of

methylcellulose for helping the dispersion of the fibers and the workability of the mix . Latex (typically 15± 20% by weight of cement) is much less effective than silica fume for helping the fiber dispersion, but it enhances the workability, flexural strength, flexural toughness, impact resistance, frost resistance and acid resistance . The ease of dispersion increases with decreasing fiber length .

Silica flume

CARBON CONDUCTIVE PAINT

Carbon Conductive ink is an ink that results in a printed object which conducts electricity. It is typically created by infusing graphite or other conductive materials into ink. Conductive inks can be a more economical way to lay down a modern conductive traces when compared to traditional industrial standards suchas etching copper from copper plated substrates to form the same conductive traceson relevant substrates, as printing is a purely additive process producing little to nowaste streams which then have to be recovered or treated

The carbon conductivity paint are used to joint all the carbon fiber particles to get more conductivity thereby increasing the accuracy of the results

REGULATED POWER SUPPLY

A regulated power supply is an embedded circuit; it converts unregulatedAC into a constant DC. With the help of a rectifier it converts AC supply into DC. Its function is to supply a stable voltage (or less often current), to a circuit or device that must be operated within certain power supply limits. The output from the regulated power supply may be alternating or unidirectional, but is nearly always DC bonding and Water reducing admixture naphthalene sulfonic acid for enhancing workability since the usage of carbon fiber decreased the slump.

MULTIMETER

A multimeter or a multimeter, also known as a VOM (volt-ohm- milliammeter), is an electronicmeasuring instrument that combines several measurement functions in one unit. A typical multimeter can measure voltage, current, and resistance. Analog multimeters use a microammeter with a moving pointer to display readings. Digital multimeters (DMM, DVOM) have a numeric display, and may also show a graphical bar representing the measured value. Digital multimeters are now far more common due to their cost and precision, but analog multimeters are still preferable in some cases, for example when monitoringa rapidly varying value

MIX PROCEDURE

Cement mortar cubes were cast to characterize the effect of carbon fiber and its combinations with mortar. Mortar with carbon fiber, Silica fume, methyl cellulose.(The carbon fibers used were of nominal length of 5mm and weighing 0.24% by weight of cement) . For the mortar containing methyl cellulose (0.4% by weight of cement), methyl cellulose was dissolved in water. After this, carbon fiber, methyl cellulose ,silica fume(15%) where mixed by hand for 2 minutes. Then this mix, cement, sand, and water were mixed in the mixer for 5 minutes. Then put into the cube mould (150x150mm)Curing .The specimen cubes were demoulded after one day and allowed to cure at room temperature for 7,28 days.

EXPERIMENTAL WORKS

The test was conducted as per IS 516-1959. In Universal Testing Machine (UTM). The cubes of standard size 150 mm x 150mm x 150mm were used to find the compressive Strength. The concrete cube was tested after the period of 7, 14 & 28 days of curing. The bearing surfaces of the resting machine shall be wiped cleanand any loose sand or other material removed from the surfaces of the specimen. Inthe case of cubes, the specimen shall be placed in the opposite sides of the cubes as cast that is not to the top and bottom. The axis of the specimen shall be carefully aligned with the center of thrust of the spherically seated platen No parking shall be used between the faces of the test specimen. The movable portion shall be rotated gently by hand so that uniform seating may be obtained. The load shall beapplied without shock and Increased continuously at a rate of approximately 140 kg/cm2 until the resistance of the specimen to the Increasing load breaks specimen shall then be recorded and the appearance of the concrete and any unusual features in the type of failures shall be noted.

$$\text{Compressive strength (MPa)} = \frac{P \times 100}{A}$$

P = Failure load of cube (KN)

A = cross sectional area of cube (22500 mm^2)

Therefore minimum three specimens should be tested at each selected age. If strength of any specimen varies by more than 15 per cent of average strength, results of such specimen should be rejected. Average of three specimens gives the compressive strength of concrete

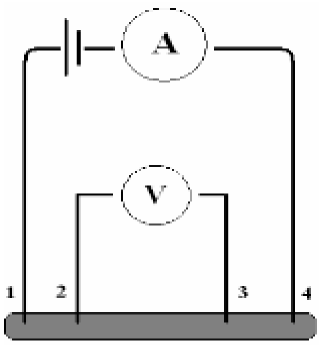
FOUR PROBE METHOD

For Compression testing , specimens were prepared by using 150x150 mm size. During compressive testingupto fracture the strain was measured by the cross head displacement in a Servo displacement controlled UTM 100T capacity . Voltage input from a Regulated power supply (R.P.S.) was given to the cube using four probe circuit and the current output and voltage output were measured using amultimeter and the fractional change in resistance computed at each loading stage. Prior to the test, cubes were painted in four layers with carbon conductive paint at a interval of 10mm. Copper wires were wound around the layers and these were connected to the R.P.S,multimer . The middle two copper wires from cube were connected to the two probes of the multimeter. The positive end of voltmeter was connected to positive end of R.P.Sand negative end of R.P.S. was connected to one end of cube. The negative end of multimeterwas connected to another end of Cube.This is the Four probe method of measuring resistance. From the voltage and current values obtained at each stage of loading, the resistance is calculated. The outer two contacts give the current value in multimeter and the middle two contactsin multimeter give the voltage.

R=E/I,R is the obtained resistance

Ri is the difference in resistance or final resistance

RESULT AND DISCUSSION



PROPORTION OF CONCRETE INGREDIENT

Table Proportion Of Concrete Ingredient

1.	Characteristic compressive strength required in the field at 28 days grade designation	M 30
2.	Type of Cement 53 Grade confirming to IS 12269	OPC
3.	Maximum Nominal size of aggregate	20 mm
4.	Shape of coarse aggregate	Angular
5.	Workability required at site	100 mm (slump)
6.	Type of exposure the structure will be subjected to (as defined in IS: 456)	Moderate

CONCRETE MIX PROPORTIONS

Table: concrete mix proportions

MATERIALS	VOLUME (kg/m3)	WEIGHT (gm/cube)	RATIO
Cement	394	1070	1
Fine aggregates	732	1670	1.56
Coarse aggregate	1139	3093	2.89
Water	197		
W/C ratio	0.50		
Carbon fiber		2.56	
Methyl cellulose		4.28	
Silica fume		160.5	

COMPRESSION STRENGTH OF NORMAL CONCRETE:

SEVEN DAYS CURING

Table: 5.4 compression strength of normal concrete(7days)

S. NO	CUBES	APPLIED LOAD(N)		COMPRESSION STRENGTH (N/m3)	
		7 days	28 days	7 days	28 days
1.	CUBE 1	468	702	20.8	31.2
2.	CUBE 2	486	778	21.6	34.6
3.	CUBE 3	461	679	20.5	30.2

COMPRESSION STRENGTH AND RESISTANCE OF SELF SENSINGCONCRETE:

SEVEN DAYS CURING

Table: 5.6 compression strength and resistance of self sensingconcrete(7 days)

S.NO	CUBES	STRAIN %	V	I	Ri (Ω)	R (Ω)	R* (Ω)
1.	CUBE 1	• 20 %	5.86	5	1.62	1.18	0.27
		• 60 %	3.20	5	1.62	0.64	0.60
		• 80 %	1.38	5	1.62	0.27	0.83
2.	CUBE 2	• 20 %	5.92	5	1.62	1.18	0.27
		• 60 %	3.40	5	1.62	0.68	0.58
		• 80 %	1.56	5	1.62	0.32	0.80
3.	CUBE 3	• 20 %	5.68	5	1.62	1.13	0.30
		• 60 %	3.03	5	1.62	0.60	0.62
		• 80 %	1.12	5	1.62	0.22	0.86

TWENTY EIGHT DAYS CURING

Table: 5.6 compression strength and resistance of self sensingconcrete(28 days)

S.NO	CUBES	STRAIN %	V	I	Ri (Ω)	R (Ω)	R* (Ω)
1.	CUBE 1	20%	6.86	5	1.62	1.32	0.18
		60%	3.80	5	1.62	0.76	0.53
		80%	2.26	5	1.62	0.45	0.72
2.	CUBE 2	20%	6.92	5	1.62	1.38	0.14
		60%	4.12	5	1.62	0.82	0.52
		80%	2.48	5	1.62	0.49	0.69
3.	CUBE 3	20%	5.82	5	1.62	1.16	0.28
		60%	4.01	5	1.62	0.80	0.50
		80%	2.08	5	1.62	0.41	0.74

Self sensing conductive concrete exhibit high conductivity and hence sense their own crack by gradual increase in strain percentage of concrete and their corresponding resistance is found and hence cracks can be analysed. Therebyconductive ability of the concrete can be done in the M30 grade and amount of crack has been analysed without tedious way and thereby in future it can be used in the core structure in power plants and other industrial plants

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