CARBON FIBER BASED SELF SENSING SMART CONCRETE FOR RESISTIVITY & CONDUCTIVITY

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Abstract: - To find an easy method to health monitor structures. Method: Self sensing or smart behavior has been observed in mortar or concrete with the addition of small amounts (0.2 to 0.5% by volume of cement) of short (5mm length) carbon fibers. It is seen that there is an increase in electrical resistance on loading up to crack propagation or fracture. On reaching the inelastic stage, the resistance change is not reversible. Findings: A method is developed which can be used in place of, often used strain gage technique or fiber optic technique for health monitoring of structures. There is an increase in resistance during fiber pull out in the elastic range. The change in elastic resistance was measured by a four-probe method and was seen to be reversible for elastic deformation. Also, the crack propagation and fiber breakage of the specimen can be identified by irreversible resistance change. The stress vs strain and resistance vs strain graphs when plotted show similarity. Application: This phenomenon can be made use of to find the real time weight of vehicles in traffic and finding stress values of a loaded structure.

Keywords:-asbestos, piezo resistivity, sensors

CHAPTER 1 INTRODUCTION

General:

Self compacting concrete or self consolidating concrete (SCC) is considerably new and excessively cohesive concrete that emerge beneath its own weight outwardly the use of vibration. SCC has the potency to fill all the notches completely in formwork and go around crowded or heavy reinforcement without segregation and bleeding (El-Dieb et al. 2011). The approach of SCC was first recommended by Okamura in 1986, and the sample was first progressed by Ozawa at university of Tokyo in 1988. Carbon fiber is used to enhance conventional concrete. The strength of structure is directly proportional to the degree of admixture (carbon fiber) added to the conventional concrete. Carbon fibers are electrically conductive hence they may also provide non structural functions I,e self-sensing (for sensing temperature change, demage percentage, strain etc) also it may sense electromagnetic reflection. Carbon fiber has got low density and high thermal conductivity. It can be used to reduce drying contraction. Because of its good thermal conductivity, high modulus of elasticity and light weight, it has been used in many projects. The diameter of carbon fiber is very small, hence it is difficult to distribute it uniformly which directly affects mechanical and electrical properties hence care has to be taken in proper uniform mixing of carbon fiber in concrete mix. The Dispersion of carbon fiber in carbon fiber-reinforced cementitious composite (CFRC) has got two steps . The first step is that the distributive system of carbon fibers is fairly distributed in the cement matrix, and the second step is that the carbon fibers are invariably distributed in the dispersant solution . The steps are compound physical , mechanical and chemical processes. The concept of smart concrete was first invented by Dr. DDL Chung. Due to temperature gradients, surface cracks can occur at very early ages in concrete structures in late 90's, because the hydration has just started it is possible that these cracks can heal with continuing hydration. Cracks endanger the durability of concrete structures as aggressive liquids and gasses may penetrate into the matrix along these cracks and cause damage. Consequently, cracks may grow wider and the reinforcement may be exposed to the environment. Once the reinforcement starts to corrode, total collapse of the structure may occur. Therefore, it seems obvious that inspection, maintenance and repair of concrete cracks are all indispensable. However, crack repair becomes difficult when cracks are not visible or accessible. Thus smart concrete utilizes a new sensor technology in which the material of which a structure is composed is itself the sensor. Dr. Chung discovered that by adding carbon fibers to concrete, the concrete itself became a sensor allowing the entire structure to conduct electricity. The concrete detected the stresses inside of itself and minute changes in stress were monitored.

Carbon fiber – uses and applications in concrete

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Dispersion and dispersion techniques

The Dispersion of carbon fiber in carbon fiber-reinforced cementitious composite (CFRC) has got two steps . The first step is that the distributive system of carbon fibers is fairly distributed in the cement matrix, and the second step is that the carbon fibers are invariably distributed in the dispersant solution . The steps are compound physical , mechanical and chemical processes.

Methyl cellulose

Methyl cellulose is a chemical compound derived from cellulose. It is used as an admixture in cement paste. It is dispersion resistant agent for concrete. It is used to improve the bond strength between cement and reinforcement. Methyl cellulose has got excellent thickening properties .

Surfactant

Surfactants are used in concrete to lower the interfacial tension between two liquids or between a liquid and a solid. Here surfactant act as wetting agent. It has been widely used to decrease the density of the concrete and to improve its thermal properties. The surfactant molecule help entrain air bubbles and stabilize them in the fresh cement paste. The most common chemical classification of surfactants is based on nature of the hydrophilic group, i. e., anionic (the surface –active portion of the molecule exhibits a negative charged) , cationic (surface-active portion bears positive charge) {lopez,A. I. T.}

Historical Perspective:

The concept of using fibers as reinforcement is not new. Fibers have been used as reinforcement since ancient times used in mortar and straw inmudbricks. In the 1900s, asbestos fibers were used in concrete. In the 1950s, the concept of composite materials came into being and fiber-reinforced concrete was one of the topics of interest. Once the health risks associated with asbestos were discovered, there was a need to find a replacement for the substance in concrete and other building materials. By the 1960s, carbon, glass (GFRC), and synthetic (such as polypropylene) fibers were used in concrete. Research into new fiber-reinforced concretes continues today.

Effect of Fibers in Concrete:

Fibers are usually used in concrete to control cracking due to plastic shrinkage and to drying shrinkage. They also reduce the permeability of concrete and thus reduce bleeding of water. Some types of fibers produce greater impact–, abrasion–, and shatter–resistance in concrete. Generally fibers do not increase the flexural strength of concrete, and so cannot replace moment–resisting or structural carbon reinforcement. Indeed, some fibers actually reduce the strength of concrete. The amount of fibers added to a concrete mix is expressed as a percentage of the total volume of the composite (concrete and fibers), termed "volume fraction" (Vf). Vf typically ranges from 0.1 to 3%. The aspect ratio (l/d) is calculated by dividing fiber length (l) by its diameter (d). Fibers with a non-circular cross section use an equivalent diameter for the calculation of aspect ratio. If the fiber's modulus of elasticity is higher than the matrix (concrete or mortar binder), they help to carry the load by increasing the tensile strength of the material. Increasing the aspect ratio of the fiber usually segments the flexural strength and toughness of the matrix. However, fibers that are too long tend to "ball" in the mix and create workability problems. Some recent research indicated that using fibers in concrete has limited effect on the impact resistance of the materials. This finding is very important since traditionally, people think that ductility increases when concrete is reinforced with fibers. The results also indicated that the use of micro fibers offers better impact resistance to that of longer fibers

Benefits of Using carbon fiber in Concrete:

The use of carbon fiber in concrete can improve its properties. The benfits of using carbon fiber in concrete are as follows:

1. carbon fiber are generally disturbed throughout a given cross section whereas reinforcing bars or wires are placed only where required.
2. carbon fibers are relatively short and closely spaced as compared with contineous reinforcing bars of wires.
3. It is generally not possible to achieve the same area of reinforcement to area of concrete using carbon fibers as compared to using a network of reinforcing bars of wires.
4. carbon fibers typically do not significantly alter free shrinkage of concrete, however at high enough dosage they can increase the resistance to cracking and decrease crack width (Shah, Weiss and Yang 1998).
5. carbon Fibers are typically added to concrete in low volume dosages (often less than 1%), and have been show to be effective in reducing plastic shrinkage cracking.
6. carbon fiber reinforced concrete distributes localized stresses.
7. Reduction in maintanance and repair cost.
8. Provides tough and durable surfaces Reduces surface permeability, dusting and wear.
9. They act as crack arrestor.
10. Increases tensile strength and toughness.
11. Resistance to impact.
12. Resistance to freezing and thawing.

Objectives:

- To compare the electrical properties, compressive strength and workability of nominal/conventional and carbon fiber reinforced concrete.

  To achieve the above ojective, following mixes were prepared.
  - M1 – normal / conventional concrete.
  - M2 – carbon fiber reinforced concrete.

- To study the effect of varying size aggregates on conductivity of carbon fiber reinforced Concrete, compressive strength of carbon fiber reinforced concrete and workability of Carbon fiber reinforced concrete.

To achieve the above objective, following mixes were prepared.

Aggregates > 10mm

- M3- carbon fiber + surfactant
- M4 – carbon fiber + surfactant+methyl cellulose
- M5A –carbon fiber + methyl cellulose+ churner
- M5B – carbon fiber + methyl cellulose, without churner

Aggregates < 10mm

- M6 – carbon fiber + surfactant
- M7- carbon fiber + churner+methyl cellulose
- M8 – carbon fiber + surfactant + mechanical churner
- M9- carbon fiber + methyl cellulose , without churner

- To study the effect of carbon fiber dispersion on conductivity of carbon fiber reinforced Concrete , compressive strength of carbon fiber reinforced concrete and workability of carbon fiber reinforced concrete .

- To achieve the above objective , following dispersants were used
  - Surfactant
  - Surfactant + mechanical churner
  - Churner + methyl cellulose
  - Methyl cellulose, without churner

CHAPTER 2
LITERATURE REVIEW
Introduction:

Fiber reinforced concrete is a composite material and has gain popularity from last so many years .if we look into history Lankard was the person, who used fibers in 1997 and proved that the fiber reinforced concrete has high strength as compared to conventional concrete .He worked on carbon fiber concrete and done so many researches on it. Here are the some published literature available so far and carbon reinforced can be discussed as :-

Chung 1996 , conclude in her research that the sensing ability was present when the fibers were conducting (i.e., carbon) and absent when the fibers were non conducting (i.e., polyethylene).The sensing ability was absent when fibers were absent. The sensing ability occurred at low carbon fiber volume fractions which are associated with little effect of the fiber addition on the concrete's volume electrical resistivity. There was no maximum volume electrical resistivity required in order for the sensing ability to be present. The sensing ability was present when the carbon fiber volume fraction was as low as 0.2% – way below the percolation threshold, which was 1 vol.% or above, depending on the ingredients (e.g., silica fume vs. latex) used to help disperse the fibers. Fracture surface examination showed that the fiber were separate from one another. The presence of carbon fibers caused the crack height to decrease by orders of magnitude. For example, the irreversible crack height observed after deformation to 70% of the compressive strength was decreased from 100 to 1 mm by the addition of carbon fibers in the amount of 0.37 vol.%, even though the compressive strength was essentially not affected by the fiber addition.The presence of carbon fibers caused the flexural toughness and tensile ductility of the composite to increase greatly.

Chen PW 2002, in her registered patent describes about a new strain/stress sensor based on the concept of reversible crack opening in a composite material. Dr.Chung concludes that Mortars containing 0.2%—4.2% by volume of short carbon fibers and concretes containing 0.2%—1.1% by volume of the fibers are capable of providing non destructive in-situ structural integrity monitoring and stress/strain sensing via electrical probing. Without the fibers, or With polyethylene fibers instead of carbon fibers, the desired sensing ability is not observed. Fractional increases in the electrical resistivity along the stress axis by up to a value of 21 (i.e., 2100%) during compressive loading to failure, up to 0.053 (i.e., 5.3%) during tensile loading to failure, and up to 0.184 (i.e., 18.4%) during flexural loading to failure are observed in the mortars. The Weaker effect during tension or flexure is due to the much lower ductility under tension than compression. Similar effects are observed in the electrical resistivity perpendicular to the stress axis. The effects are similar for different relative humilities during curing

Wen S, Chung DDL,states that the presence of electrically conductive fibers in thecement-based material is necessary for the piezoresistivity to be sufficient in magnitude and in reversibility. In the absence of conductive fibers, the piezoresistivity is weak and has substantial irreversibility, if at all observable, as shown in the case of cement-based materials without fibers (Cao et al., 2001) and with non conductive (polyethylene) short fibers (Chen and Chung, 1996b). Although conductive fibers are important for piezoresistivity, they are preferably discontinuous (around 5mm in length, unless stated otherwise), due to the low cost of short fibers compared to continuous fibers and the amenability of short fibers for incorporation in the concrete mix by mixing, and are typically used at a volume fraction below the percolation threshold, which refers to the volume fraction above which the fibers touch one another to form a continuous electrical path. The fibers are not the sensors; they are an additive for rendering significant piezoresistivity to the cementbased material, which is the sensor. A low fraction of fibers is preferred for the purpose of maintaining low cost, high workability and high compressive strength.

Wang X, Fu X, Chung DDL:- Compared two samples of Cement Paste Containing0.36 Vol% Short Carbon Fibers in one sample and 0.5 Vol.% Short Carbon Fibers in the other . she found that resistivity increased upon tension and decreased upon compression, as observed for cement paste containing 0.72 vol.% carbon fibers. The piezoresistivity results for cement paste containing 0.5 vol.% short carbon fibers (15 diameter) However, the resistivity change and strain were more reversible, both under tension and compression. the piezoresistivity results for cement paste containing 0.5 vol.% short carbon fibers (15 mm diameter) showed that the resistivity increased with tensile strain and decreased with compressive strain, such that the effect was totally reversible, except for an irreversible increase at the end of the first compression cycle. The resistivity variation was much less noisy and much more reversible than that observed for the two carbon fiber cement pastes. She concluded that the fiber pull-out is activated by straining and accompanies crack opening. The reverse, fiber push-in, accompanies crack closing. As the amount of fiber pull-out (<1 mm) is negligible compared to the fiber length (5 mm), the fiber– matrix interface area is essentially not affected by the fiber pull-out, but the fiber–matrix contact resistivity is increased upon fiber pull-out, thus causing the overall resistivity of the composite to increase. The reversibility of the fiber pull-out is associated with the reversibility of the crack opening. This reversibility is made possible by the fact that the fiber bridges the crack. The crack volume increase alone just cannot explain the large increase in electrical resistance. In order for a short fiber composite to have strain sensing ability using the abovementioned mechanism, the fibers must be more conducting than the matrix, of diameter smaller than the crack length and be well dispersed. Their orientations can be random and they do not need to touch one another (i.e., percolation is not needed).

Wang X, Fu X, Chung DDL:- These authors in this paper states that Damagesensing, which is to be distinguished from strain sensing, has also been achieved by using short carbon fiber in concrete [4,6,22,23]. It is mainly based on the notion that damage causes some breakage of the brittle carbon fibers, thereby resulting in an irreversible increase in the resistivity. Spatially resolved sensing of both strain and damage has also been achieved [26] by using an array of electrical contacts, with the outermost contacts for passing current and the remaining contacts used in pairs for measuring the voltage.

Sabapathi and Achyutha (1989) Stress- strain characteristics of carbon fiber reinforced concrete under compression. Cube compressive strength and Initial Tangent Modulus Elasticity were obtained and equation for stress-strain relation was also proposed.

Ganesan and Ramana Murthy (1990) ascertained the stress-strain behaviour of short, confined, reinforced concrete column with and without carbon fibers. The volume fraction of 1.5% with aspect ratio of 90 of carbon fiber was used. The variable of the study was percentage reinforcement of lateral reinforcement. The strain at peak loads was increased to certain extent.

Balaguru and Shah (1992) have reported that the fibers that are long and at higher volume fractions were found to ball up during the mixing process called balling and causes the concrete to become stiff and causes reduction in workability with increase volume dosage of fibers. This has a tendency to influence the quality of concrete and strength.

Shah, Weiss and Yang (1998) used the carbon fibers to increases the resistance to crack. Carbon fibers typically do not significantly alter free shrinkage of concrete, however at high enough dosage they can increase the resistance to cracking and decrease crack width.

Armelin and Banthia (1998) worked on the carbon fiber reinforced concrete .They used the carbon fibers of hooked ends ,30mm long &0.5 diameter .The pull out test of single fiber was conducted at embedment length at different inclination angles 0,22.5,45 and 67.5°. He used two fiber content of 0.75% & 1.5% by volume. Armelin and Banthia concluded that the pull out of individual fibers was related to overall toughness performance of SFRC under flexural loading & also depends upon variation of fiber density arrangement.

Neelamegam and Gopalkrishnan (2000) They Research on the micro crack stress induced in Dramix carbon Fiber Reinforced Concrete (DSFRC),by using UPV (ultrasonic Pulse velocity Technique) .They prepared different specimens &test on them ,They subjected the specimens under compressive loading &determine the micro crack stress. They prepare the specimens with varying percentages of fibers 0.5%, 1.0%, 1.5% by volume .The UPV reading were noted at different compressive stress levels in the concrete sample at different intervals (3, 7, 14, 28 days).The authors found that the FRC shows higher micro-crack initiation as compared to plain concrete .The test showed that 1% of volume fraction of Dramix Carbon fibers increases the mechanical properties of concrete.

Gupta (2001) Gupta did his experimental work on the crimped round carbon round Carbon fibers and did his experimental investigation. He proposed the linear relationship between flexural strength and splitting tensile strength and also the relationship of split tensile strength with compressive strength.

Antoine E. Naaman (2003) Emphasized technical background behind the development and design of a new generation of carbon fiber used in cement. The fiber are used to provide optimal properties, compatibility with a given matrix. The fibers are used to achieve optimal properties in terms of shape, size and mechanical properties.

Yin et al (2003) The Experimental work of Yin and his team was the effect of polymer sheets on concrete .The authors Concluded that on addition of fiber reinforced polymer sheets improves the structural strength & shows high strength towards load.

Ghugal Y.M. (2003) They have presented the results of the experimental investigation of various strengths of carbon fiber reinforced concrete (SFRC). Variables considered in the research work are various strengths and fiber volume fractions. Various strengths considered for investigation are compressive strength, flexural strength, split tensile strength, bond strength and shear strength. Concrete mix of M30 grade and crimped carbon fibers with aspect ratio 50 are used. The fiber volume fraction is varied from 0.5% to 4.5 % at an interval of 0.5% by weight of cement. Standard test specimens for compressive strengths, split tensile strength, flexural strength and push-off specimens for shear strength were cast and water cured for 7 and 28 days. All the test specimens were tested according to relevant Indian Standards and standard test procedures available in the literature wherever applicable. All the strengths are found to be increasing continuously with increase in fiber volume fraction. The experimental results obtained for various strengths are modeled in terms of the material properties of matrix, fiber and compressive strength. The mathematical expressions developed for various strengths are presented. The inclusion of carbon fiber in to the normal concrete showed the excellent strength performance in this investigation compared to the normal concrete.

Kaushik (2005) Kaushik used carbon fibers of 0.6 x 2.0 x 50 mm in his experimental study using fiber volume fraction 1.5% and 2.0%, each of the fiber volume fraction containing mixed carbon fibers. The result of the author was that the variation in the distribution of fatigue life of SFRC was more as compared to plain.

CHAPTER 3 METHODOLOGY

EXPERMINTAL PROCERDURE:

Tests of cement

- Standard/Normal consistency test
- Initial & final setting time test
- compressive strength test
- specific gravity test

STANDARD CONSISTENCY TEST

- Consistency test is used to find out the water to be mixed with cement.
- It is necessary to find the consistency because amount of water present in the cement paste may effect the setting time.
- Standard consistency os indicated by the vicat plunger reading 5 to 7mm from the bottom of mould

PROCEDURE

- Take 400g of cement and place it in a bowl or tray.
- Now Assume standard consistency of water is 28% and add the same quantity of water in cement and mix it.
- Mix the paste thoroughly within 3-5 minutes.
- Now fill the paste in Vicat mould correctly any excessive paste remained on Vicat mould is taken off by using a trowel.
- Then, place the VICAT mould on Glass plate and see that the plunger should touch the surface of VICAT mould gently.
- Release the Plunger and allow it to sink into the test mould.
- Note down the penetration of the plunger from the bottom of mould indicated on the scale.
- Repeat the same experiment by adding different percentages of water until the reading is in between 5-7mm on the Vicat apparatus scale.

OBSERVATION TABLE

Type of grade of cement	Weight of cement	Percentage of water added	Vol. of water added	Penetration of needle from the bottom
Opc 43 grade	400g	28	112	13
Opc 43 grade	400g	29	116	9
Opc 43 grade	400g	30	120	7

INTIAL AND FINAL SETTING TIME TEST

- Initial setting time is that time period between the time water is added to cement and time at which 1 mm square section needle fails to penetrate the cement paste, placed in the Vicat's mould 5 mm to 7 mm from the bottom of the mould.
- Final setting time is that time period between the time water is added to cement and the time at which 1 mm needle makes an impression on the paste in the mould but 5 mm attachment does not make any impression.

INITAL SETTING TIME TEST

- ake 400 g of cement and prepare a neat cement paste with 0.85P of water by weight of cement.
- Gauge time is kept between 3 to 5 minutes. Start the stop watch at the instant when the water is added to the cement. Record this time (t_1).
- Fill the Vicat mould, resting on a glass plate, with the cement paste gauged as above. Fill the mould completely and smooth off the surface of the paste making it level with the top of the mould. The cement block thus prepared is called test block
- Place the test block confined in the mould and resting on the non-porous plate, under the rod bearing the needle.
- Lower the needle gently until it comes in contact with the surface of test block and quick release, allowing it to penetrate into the test block.
- In the beginning the needle completely pierces the test block. Repeat this procedure i.e. quickly releasing the needle after every 2 minutes till the needle fails to pierce the block for about 5 mm measured from the bottom of the mould. Note this time (t_2).

FINAL SETTING TIME TEST

- For determining the final setting time, replace the needle of the Vicat's apparatus by needle with an annular attachment.
- The cement is considered finally set when upon applying the final setting needle gently to the surface of the test block; needle makes an impression thereon, while the attachment fails to do so. Record this time (t_3).

initial time

final time

CALCULATION

- Initial setting time=t_2-t_1
- Final setting time=t_3-t_1,
- Where,
- t_1=Time at which water is first added to cement
- t_2=Time when needle fails to penetrate 5 mm to 7 mm
- from bottom of the mould
- t_3=Time when the needle makes an impression but the attachment fails to do so.

OBSRVATION TABLE

- Type of cement= OPC 43 grade
  - Date of test = 26/02/2019
  - Water required for normal consistency
    - = 0.85P
    - = 0.85 X 30%
    - = 0.255
  - Weight of cement = 400gm
  - Water to be added = 400 X 0.255
    - =102 gm
- Initial setting time (limit minimum 30 minutes) = 144 minutes
- Final setting time (limit maximum 600 minutes) = 350 minutes

SPECIFIC GRAVITY TEST

- Specific gravity of cement is tested in order to know the various atmospheric effects on the moisture content of cement.
- Mix design is based on the value of specific gravity of cement as 3.15.

APPARATUS

Specific gravity bottle, kerosene, cement.

PROCEDURE

- Weight of empty specific bottle (W1)
- Weight of specific gravity bottle + cement (W2)
- Weight of specific gravity bottle + kerosene + cement (W3)
- Weight of specific gravity bottle + kerosene (W4)
- Weight of specific bottle + distilled water (W5)

CALCULATION

- SPECIFIC GRAVIY OF KEROSENE (SK) =
  (W4-W1) / (W5-W1)
- SPECIFIC GRAVITY OF CEMENT (SC) =
  (W2-W1) X SK / (W4-W1)-(W3-W2)

OBSERVATION TABLE

AVERGAE SPECIFIC GRAVITY OF CEMENT = (3.17+3.08)/2=3.12

COMPESSIVE STRENGTH TEST OF CEMENT

APPARATUS REQUIRED

- 200 gm of cement
- 200 gm of ist grade standard sand (passing through 2mm & retained on 1mm sieve)
- 200 gm of 2nd grade sand (passing through 1mm retained on .5mm sieve)
- 200 gm of 3rd grade sand (passing through .5 mm sieve retained on 0.09mm)
- Mould.

- Vibrating machine.
- CTM (compressive testing machine)

PROCEDURE

- Make cement paste with standard sand.
- The amount of water should be (P/4 +3) % of combined weight of cement & sand where P = normal consistency water
- The mixing time should be 3-4 minutes.
- Now adjust the mould on vibrating machine and set vibrating time 120 seconds.
- Now start machine & start pouring paste to mould.
- After pouring temp 25 times to paste by tamping rod to adjust the paste.
- When machine stop take out mould from the machine.
- Now remove the mould the spacemen is now ready.
- Make 9 specimen of cement paste.

  3 for 3 days testing

  3 for 7 days testing

  3 for 28 days testing

- Take entire specimen in water & take out from water on testing time
- On testing day take specimen & put this on compressive testing machine.
- Apply load from machine & note the load on which the specimen are fail.
- Cubes should be made up of 75mm x 75mm x 75mm dimension.

Smart Behaviour of carbon fiber

Unlike other sensors like strain gauges, fibre 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.

Experimental Programme

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 volume of cement).

Mix Procedure

For the mortar containing methyl cellulose (0.4% by weight of cement), methyl cellulose was dissolved in water. After this, carbon fiber, the defoamer (0.13 volume percent) and the fibres were stirred by hand for 2 minutes. Then this mix, cement, sand, and water were mixed in the mixer for 5 minutes.

Curing Procedure

The specimen cubes were demolded after one day and allowed to cure at room temperature for 7 days.

Testing Procedure

For Compression testing, specimens were prepared by using 70mmx70mmx70mm and 50mmx50mmx50mm size. During compressive testing upto 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 method and the current output and voltage output were measured using a voltmeter and an ammeter and the fractional change in resistance computed at each loading stage. Prior to the test, cubes were painted in four layers with silver paint at a interval of 10 mm. Copper wires were wound around the layers and these were connected to the R.P.S., voltmeter and ammeter. The middle two copper wires from cube were connected to the two probes of the voltmeter. The positive end of ammeter was connected to positive end of R.P.S and negative end of R.P.S was connected to one end of cube. The negative end of ammeter was 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 ammeter and the middle two contacts in voltmeter give the voltage. Resistance was computed using

$$R=E/I$$

Testing was performed in different cycles of loading in fractions of KN, up to failure and the readings were taken at each stage. 10 from compression test for the cases of 1. Difference between 50 mmx50 mmx50 mm and 70 mmx70 mmx70 mm cubes 2. Copper wires are wounded in along and perpendicular to the stress axis. 3. Comparisons of 7, 14, 28 days curing. It is seen from the plots that the results in case 1. 50mm cube is much better than 70 mm cube because the cube size is minimum due to threshold value. In case 2. 50 mm cube with copper wires wounded along stress axis is better than wires wounded in perpendicular to stress axis. In case 3. 50 mm cube with 7 days curing is better than the 14 and 28 days curing. It essentially means that it is quite possible to predict the stress values in the field using the carbon fiber, silica fume and methyl cellulose combination It is also seen that once the stress vs strain and Resistance vs Strain (R-Ro/Ro where Ro is the initial resistance) graphs are drawn using a cube compression test, Field experiments can be conducted to get actual stress values. Thus health monitoring of structures can be carried out using this simple procedure.

BENEFITS

TEMEPATURE SENSING

The sensing of temperature is needed for thermal control, energy conversation, hazard mitigation and operational control. Concrete structures that benefit from temperature sensing include buildings (for temperature regulation and energy saving), as well as highways, bridges and airport runways (for hazard mitigation and deceing). Temperature sensing is conventionally , achieved by thermometers , thermistors and thermocouples in the form of devices that are attached to or embedded in a concrete structure . however the use of concrete itself for temperature sensing reduces the cost, enhances the durability and allows the sensing function to exist throughout the structure.

DAMAGE SENSING

Self-monitoring of damage (whether due to stress or temperature, under static or dynamic conditions) has been achieved in continuous carbon fiber polymer-matrix composites, as the electrical resistance of the composite changes with damage42-56. Minor damage in the form of slight matrix damage and/or disturbance to the fiber arrangement is indicated by the longitudinal and through-thickness resistance decreasing irreversibly, caused by the increase in the number of contacts between fibers. More significant damage in the form of delamination or interlaminar interface degradation is demonstrated by the through-thickness resistance (or more exactly the contact resistivity of the interlaminar interface) increasing with the decrease in the number of contacts between fibers of different laminae. Irreversible increase of the longitudinal resistance highlights major damage in the form of fiber breakage.

TEMEPERATURE SENSING FOR CONTINOUS CARBON FIBER

Continuous carbon fiber epoxy-matrix composites provide temperature sensing by acting as thermistors59,60 and thermocouples61. The thermistor function stems from the reversible decrease of the contact electrical resistivity at the interface between fiber layers (laminae) with temperature. From the (negative) slope of the Arrhenius plot, which is quite linear, the activation energy can be calculated. This is the energy for an electron jumping from one lamina to another. Electronic excitation across this energy enables conduction in the through-thickness direction. The electron jump primarily occurs at points where there is direct contact between fibers of adjacent laminae. This direct contact is possible because of the flow of the epoxy resin during composite fabrication and due to the slight waviness of the fibers42. The thermocouple function originates from the use of n-type and p-type carbon fibers (obtained by intercalation) in different laminae.

FLOOR HEATING SENSING

Systematic development of an electrically heatable cement-based composite, prepared by admixing a few volume percent of chopped carbon fibers without a need of adding further heating elements, is observed. The optimal volume content of carbon fibers is determined to range from 1 to 2 volume percent, if 3 mm long and 7 mm thick carbon fibers are being used. By applying an electrical current to the composite material, a temperature rise suitable for heating rooms and walls can be induced. By screening matrix properties empirically, show that carbon fiber reinforced cement based screed exhibits the best conductivity (and thus the best performance as floor heating material) if carbon fibers having an aspect ratio of about 400 (7 mm in diameter and 3 in length) are being used. Based on percolation theory, the fibre volume content suitable for electrical resistance heating is found to be 1 to 2 vol. % of carbon fibers. A permanent heating of carbon fiber reinforced composite at 60^0 C for 4 weeks causes no measurable loss of strength, although additional long term experiments should be performed to verify the long-term stability. All performed tests prove that a cement-based screed, suitable and applicable for in-situ electrical heating, can be fabricated by admixing 2 vol. % of carbon fibers into the composite and using graphite or silver electrodes for contacting purposes. Furthermore, it is shown that embedding a grid of electrodes into fibre reinforced cement plate opens up the possibility to heat selected areas of the plate up to 100^0C by applying an AC voltage of 12 V. Further studies on smart heating plates are needed to demonstrate that this concept can be scaled up and thus is suitable for similar plates exceeding dimensions of several meters. Although electrical energy is high priced for heating purposes compared to wood, oil or gas, higher energy costs of the presented heating system can be compensated by a higher operating efficiency, since only desired areas can be heated. Additionally, the heated areas can always be changed just by reconnecting the grid of electrodes in the floor plate (e.g. when furniture is rearranged) which makes the system highly flexible. The simplicity of only admixing carbon fibers to a cement mixture and the absence of additional heating elements provide low system pricing. Thus carbon fiber reinforced cement-based composites can be stated as a suitable concept for floor and wall heating purposes.

The SCC (SELF COMPACTING Reinforced Concrete) is a composite material consists of ordinary portland cement, aggregate and carbon fibers. Normal plain concrete is a brittle weak in tension. In order to solve this problem fibers are added, it comes under the category of carbon fiber reinforced concrete .The carbon fiber reinforced concrete consists of cement, fine aggregates, coarse aggregates and carbon strip fibers. The specimens were prepared and the strength is to be checked after 7 days and 28 days. The test were conducted on both plain concrete and fiber reinforced concrete. It was seen from the experimental programe that the compressive strength, flexural strength increases upto the optimum dosage of 1%.The experimental procedure consists of following steps:

Material used in carbon fiber reinforced concrete taken from,

Testing the properties of SCC material,

Making the different concrete mixes for trial purpose,

Casting of specimens,

Curing of specimens for testing,

To conduct the compressive strength test on SFRC mix,

To conduct the split tensile strength test on SFRC mix,

To conduct the flexural strength test on SFRC mix,

Testing of Specimens:

The following tests have been carried on various specimens:

- Compressive strength test
- Resistivity Test

WATER ABBSORBTION TEST OF COARSE AGGRIGATES

PROCEDURE :

The sample should be thoroughly washed to remove finer particles and dust, drained and then placed in the wire basket and immersed in distilled water at a temperature between 22 and 32ºC.

After immersion, the entrapped air should be removed by lifting the basket and allowing it to drop 25 times in 25 seconds. The basket and sample should remain immersed for a period of 24 + ½ hrs afterwards.

The basket and aggregates should then be removed from the water, allowed to drain for a few minutes, after which the aggregates should be gently emptied from the basket on to one of the dry clothes and gently surface-dried with the cloth, transferring it to a second dry cloth when the first would remove no further moisture. The aggregates should be spread on the second cloth and exposed to the atmosphere away from direct sunlight till it appears to be completely surface-dry. The aggregates should be weighed (Weight 'A').

The aggregates should then be placed in an oven at a temperature of 100 to 110ºC for 24hrs. It should then be removed from the oven, cooled and weighed (Weight 'B')

PROCEDURES OF MAKING CARBON FIBER BASED CONCRETE CUBES BY USING AND WITH OUT USING DISPERSING AGENTS OF VARIOUS AGGRIGATE SIZES.

1:- M1-Normal/conventional concrete (>10mm)

A mixer was used for mixing. Concrete in the ratio of 1:1.5:1.7 is taken. All the ingredients are fed before mixing is started, especially true for water which must be added simultaneously with sand, cement and coarse aggregates.

01	Temprature	13 degree celcius
02	Humidity	44%
03	Flow value	0
04	Seggregation	0
05	Bleeding	0

2:- M2- carbon fiber and without dispersant (>10mm)

A mixer was used for mixing. Concrete in the ratio of 1:1.5:1.7 is taken . Carbon fibers first were mixed in the mixer directly for about I min. Then this mixture, cement, sand, water and the water reducing agent were mixed in the mixer for 5 min.

01	Temprature	20 degree celcius
02	Humidity	31%
03	Flow value	0
04	Seggregation	0
05	Bleeding	0

3. M3-Carbon fiber +surfactant (Dispersion agent) >10mm

For the case of concrete containing surfactant, surfactant was dissolved in water and then fibers were added and satirred by hand for about 2min. Then this mixture, cement, sand, water and water reducing agent were mixed in the mixer for 5min.

01	Temprature	20 degree celcius
02	Humidity	31%
03	Flow value	0
04	Seggregation	0
05	Bleeding	0

4:-M4 carbon fiber+ surfactant+ mechanical churner.>10mm

In this case, surfactant was dissolved in water and then fibers were added and dispersed with the help of a mechanical churner for about 2min. Then this mixture, cement, sand, water and water reducing agent were mixed in the mixer for 5min.

01	Temprature	20 degree celcius
02	Humidity	31%
03	Flow value	0
04	Seggregation	0
05	Bleeding	0

5:- M5A-crabonfiber+churner +methylcellulose (>10mm)

Here methylcellulose was used .First methylcellulose was dissolved in water and then fibers were added and dispersed by the churner for about 2min. Then this mixture, cement, sand, water and water reducing agent were mixed in the mixer for 5min. After pouring the mix into oiled moulds, a vibrator was used to decrease the amount of air bubbles.

01	Temprature	20 degree celcius
02	Humidity	31%
03	Flow value	0
04	Seggregation	0
05	Bleeding	0

6:-M5B carbon fiber+methyl cellulose without churner (>10mm)

Methylcellulose was used as dispersant. First methylcellulose was dissolved in water and then fibers were added. This solution was mixed for about one min.Then this mixture, cement, sand, water and water reducing agent were mixed in the mixer for 5min.

01	Temprature	21 degree celcius
02	Humidity	25%
03	Flow value	Better than M3
04	Seggregation	0
05	Bleeding	0

7:-M6- carbon fiber without dispersant (<10mm)

In this mix <10mm size aggregates were used. Concrete in the ratio of 1:1.5:1.7 is taken . Carbon fibers first were mixed for about 1 min. Then this mixture, cement, sand, water and the water reducing agent were mixed in the mixer for 5 min.

01	Temprature	21 degree celcius
02	Humidity	25%
03	Flow value	Better than M3
04	Seggregation	0
05	Bleeding	0

8:-M7-carbon fiber+methyle cellulose +churner(<10mm)

Here methylcellulose was used .First methylcellulose was dissolved in water and then fibers were added and dispersed by the churner for about 2min. Then this mixture, cement, sand, water and water reducing agent were mixed in the mixer for 5min.

s.no.	Wt. of cement (kg)	Wt. of sand (kg)	Wt. of coarse aggregates (kg)	Admixture %	Carbon fiber %	W/C ratio	Dispersant %
1	9	13.5	15.3	1	2	0.42	0.05

01	Temprature	23 degree celcius
02	Humidity	35%
03	Flow value	Better than M4
04	Seggregation	0
05	Bleeding	0

01	Temprature	23 degree celcius
02	Humidity	35%
03	Flow value	Better than M4
04	Seggregation	0
05	Bleeding	0

9:-M8-Carbon fiber+surfactant +churner (<10mm)

In this case, surfactant was dissolved in water and then fibers were added and dispersed with the help of a mechanical churner for about 2min. Then this mixture, cement, sand, water and water reducing agent were mixed in the mixer for 5min.

Curing procedure:

The specimens were remoulded ater I day and then allowed to cure at room temperature for , 14, 28 and 56 days

CHAPTER-4 ANALYSIS OF RESULTS AND DISCUSSION

Introduction

The experimental investigation on SCC with carbon fiber at constant percentage while using different design mix techniques. The experiments for compressive strength, resistivity were conducted. The curing time for compressive strength was 28 days and 56 days and for the resistivity the curing time was 14 days and 28 days.. The observed values are shown in the tables below.

Compressive Strength Test

In this test specimen was taken from the curing tank after the time period of 28 and 56 days. By this we calculated the compressive strength after 28 & 56 days. Specimen were tested on 200 tons capacity of UTM .The specimen is placed centrally between the two compression plates, such that the centre of moving head is vertically above the centre of specimen. Load is applied on specimen by moving the movable head. The load and corresponding contraction are measured at different intervals. Load is applied until the specimen fails. The strength is determined by conduct of a compression test .The load is applied gradually at the constant rate 14 N/mm^2 .Unit of failure of specimen takes place .This test was performed as per IS code 516-1959. Following data was collected for different design mixes.

RESISTIVITY:

DISCUSSION:

Compressive strength:

The compressive strength test was conducted as per IS516-1959 on different specimen. For the plain SCC the compressive strength was 19.2 N/mm^2 and 22.2N/mm^2 for curing period of 28 and 56 days respectively while using the aggregates of size less than 10 mm diameter. However when carbon fiber and surfactant was added to the concrete, the compressive strength increased to 22.6 n/mm2 and 24.6 N/mm^2 for curing of 28 and 56 days respectively. Also when carbon fiber was added in presence of methyl cellulose to the concrete with the help of churner the compressive strength was noted as 18.6 N/mm2 and 20.5 N/mm^2 for the curing of 28 and 56 days respectively.

The compressive strength of plain SCC when cured for 28 and 56 days was 28.3 and 35 N/mm^2 respectively when using the aggregates of size greater than 10 mm diameter. When carbon fiber was added to it strength was noted as 30.2 N/mm^2 and 36.25N/mm^2 .In addition to this when carbon fiber was added with surfactant in presence of churner, the compressive strength was 31.2 and 38.35 N/mm^2 for 28 and 56 days respectively. However when carbon fiber was added in presence of surfactant and methyl cellulose without churner, the compressive strength was 24.8 and 28.2N/mm^2 for the curing period of 28 and 56 days respectively.

Resistivity:

The determine the electrical property of concrete, resistivity test was conducted .the resistivity of plain SCC WAS 0.47 and 0.97 mΩ for 14 and 28 days respectively when aggregates of size more than 10 mm diameter was used and when carbon fiber was added the resistivity was observed as 1.53 and 4.18 kΩ. Also when carbon fiber was added in presence of surfactant with the help of churner, the resistivity was 61Ω and 47 Ω for 14 and 28 days respectively. However when carbon fiber was added with surfactant and methyl cellulose the resistivity was observed a 12kΩ and 6.8kΩ but when added without churner the resistivity was observed as 66kΩ and 49 k Ω for 14 days and 28 days respectively.

When the concrete was made of aggregates of size less than 10 mm diameter, the resistivity was for plain SCC was 89 m Ω and 186m Ω and when carbon fiber was added with surfactant in the churner, the resistivity was 131 Ω and 110 Ω for the curing period of 14 and 28 days respectively. However when the carbon fiber was added without dispersant the resistivity was 255Ω and 223 Ω when cured for 14 and 28 days respectively and when carbon fiber was added with methyl cellulose in churner the resistivity was observed 226kΩ and 189 kΩ for and 14 and 28 days respectively.

CHAPTER 5
CONCLUSIONS

- On adding carbon fiber, surfactant and methyl cellulose, the compressive strength increased and it was observed that maximum strength was attained when concrete was mixed with surfactant and carbon fiber cured for 56 days.
- From the different resistivity experiments it was observed that plain SCC had maximum resistivity. However when this concrete was mixed with carbon fiber and other dispersants the resistivity decreased because of the conductivity nature of carbon fibers and least of its value was observed when concrete was mixed with carbon fiber, surfactant with the help of churner.

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