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Investigation on Carbon Fiber based Self- Compacting concrete by using various dispersing agents to check Resistivity and Conductivity

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ABSTRACT
Carbon fiber reinforced concrete (CFRC) has been measured as an ingeniously useful civil engineering material for self-monitoring buildings. However, the allotment of carbon fiber can significantly manipulate the performance of CFRC, especially their motorized and electrical properties. The main purpose of this research is to explore the effect of carbon fiber distribution on motorized and electrical properties of CFRC. For this purpose, the microstructure of all CFRSCC was observed via scanning electron micrographs (SEM) of the breakage surface.
The use of short pitch-based carbon fibers (1% of weight of cement), together with a dispersant, (chemical and mechanical), in self compacting concrete with fine and coarse aggregates resulted in a compressive strength increase of 22%, and a material price increase of 39%. The electrical resistivity reaches the minimum of 47.5Ω when surfactant and churner were used as dispersants. The fracture surface of the prepared CFRSCC was observed by scanning electron microscope.
KEYWORDS: pitch-based carbon fiber, methyl cellulose, surfactant, aero mix 400, mechanical churner, digital multi meter, electric paint, UTM machine.

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I. INTRODUCTION

The adding up of fibers to self-compacting concrete (SCC) may take benefit of its advanced performance in the fresh state to attain a more homogeneous dispersion of fibers, which is dangerous for a wider structural use of fiber reinforced concrete. Also, fiber Concrete is approved to be a reasonably brittle material when subjected to normal stresses and impact loads, where tensile strength is only about one tenth of its compressive strength. As a result, for these uniqueness, concrete member could not maintain such loads and stresses that generally take place, popular on concrete beams and slabs. In the beginning phase of fiber increment, steel and glass strands with calculation of straight and smooth were utilized, as these filaments create in flexibility, flexural quality and break strength of solid framework. The fundamental factors that precluded for this organization were fiber volume division and length/breadth. In any case, the difficulties confronted were unpredictability in blending and functionality. Strands that are long and at higher volume divisions were developed to ball during the expansion cycle. The cycle called 'balling' happens, makes the solid become hardened and a decrease in usefulness with expanded volume measurement of strands. This tends to impact the nature of cement and quality. The presentation of carbon filaments was gotten as an answer for increment concrete taking into account appealing its flexural and rigidity, which are another type of ring fastener that could combine Portland concrete in the holding with concrete frameworks The colloquialism of 'Fiber fortified cement' (FRC) is set up with concrete, different sizes of totals, which incorporate with independent, inconsistent strands. while, they are reasonably important while contrasted with related strands, for example, glass filaments or manufactured strands.

1.1 Self compacting concrete

Self-compacting concrete is also known as self-consolidating concrete, which has the tendency to fill up all the gapes in between reinforcement in mould without using an external mechanical vibrating machine. SC is also known as high performance concrete. It is an important development in the building industry.it is a kind of

concrete that can flow easily without using high volume of water-cement ratio. It can be used in initial stage at site. SC economizes the labour cost and is a durable/strong concrete. Progressive work in the evolution of ssc was broadcasted by OKAMURA and OUCHI in 1997.
Self-compacting concrete is popular by these reasons which are given below: -

- Quick construction.
- Economize the man power.
- Good surface finish.
- Good durability.
- comfortable placing.
- Lack of use of vibrating machine

1.2 **Properties of Self-Compacting Concrete**
The fresh and toughened properties are same as conventional concrete. It has been pragmatic that concert wise SCC is more competent than conservative concrete because of its fluidity. This can reach all possible corners of form shutter, without charitable any compaction efforts whereas in conventional concrete needs further effort for its compaction.

Fig 1: Key properties of fresh self-compacted concrete

1.3 **Carbon fiber in concrete**
Carbon fiber is a polymer and also known as graphite fiber. it is very strong material and light in weight. Carbon fiber is twice stiff steel. Carbon fiber is thinner than as human hair. It can be twisted like yarn to make clothe. It can be moulded and coated in resigns or plastic. Carbon fiber is a good conductor of electric current. It can pass electric current from one end to another end due to its electric current property. Carbon fiber is high in stiffness, high in tensile strength, light in weight, high in chemical resistance temperature tolerant to excessive eat and has low thermal expansion.

II. DISPERSION AND DISPERSING TECHNIQUES

The dispersing is mainly essential step in composite fabrication which could greatly affect the regularity and sensing behavior of smart concrete. The effectiveness of carbon fiber for improving the structural and efficient properties is greatly affected by the degree of fiber dispersion. good quality dispersion of carbon fibers is not only beneficial to the mechanical properties but also to the electrical performances due to the possible contact of carbon fibers, whereas the poor dispersal may exert negative influences on the mechanical and electric properties of the composite. Scattering of carbon strands in the concrete form stays an intriguing issue in the arrangement of carbon fiber strengthened concrete based composites (CFRC) on the grounds that it influences profoundly both the mechanical and electrical properties of the composites.

2.1 **Dispersing techniques**
Various dispersing techniques has been used which are given below: -

- M1-Normal/conventional concrete (>10mm)
- M2- carbon fiber and without dispersant (>10mm)
- M3-carbon fiber +surfactant (>10mm)
- M4-carbon fiber+surfactant+mechanical churner (>10mm)
- M5 A-crabonfiber+churner +methylcellulose (>10mm)
- M5B-carbon fiber+methylcellulose, without churner (>10mm)
- M6- carbon fiber without dispersant (<10mm)
- M7-carbon fiber+methyl cellulose +churner (<10mm)
- M8-crabon fiber+surfactant +churner (<10mm)

2.2 Why to select these techniques
These techniques are used to know the various effects of dispersing agents which are used in carbon fiber-based concrete. These techniques will give various results of carbon fiber concrete. Using of dispersing agents in concrete will show various effects in concrete. Various dispersing agents which are used are.

(I) Surfactant
(II) Methyl cellulose

Using of various types of dispersing agents will show the strength compression. Using of dispersing agents in carbon fiber will show the results which are compared without using dispersing of carbon fiber in concrete. Using of dispersing agents in carbon fiber will show effect of resistivity and conductivity as compared to without using dispersing agents.

2.3 Why carbon fiber?

Numerous sorts of studies have been completed on new and solidified properties of SCC. A few kinds of strands, for example, glass, steel have been utilized to deliver fiber strengthened scc.In correlation, restricted investigations were done to utilize carbon fiber in scc. Carbon filaments display a progression of remarkable properties of high quality, high modulus, high temperature obstruction, consumption opposition, weariness obstruction, creep obstruction, light weight, and electric conduction It is advantageous to deliver carbon fiber-strengthened concrete based composites (CFRC) by including short carbon filaments into concrete network. In the CFRC composites, carbon filaments are invaluable in their boss capacity to build the rigidity of concrete. They can improve both mechanical and electrical practices of the material just as the electromechanical and electromagnetic practices. They are additionally favorable in the overall substance latency. Corresponding to most practical properties, carbon strands are excellent contrasted with other fiber types.

III. MATERIAL PROPERTIES AND TEST METHODOLOGY

3.1**Material properties**

The various materials required for this project work include cement (43 grade) conforming to IS:269-1987, fine aggregates conforming to IS 383-1987.The fine aggregates were collected from Ganderbal and the coarse aggregates conforming to IS 383-1987 were also collected from Ganderbal. The origin of both fine and coarse aggregates is the river Sind. Ordinary Portland cement of grade 43 was used throughout the project. Crushed stone aggregates locally available were used with >10 mm and10mm down size. Fine aggregates also available locally has been used conforming to zone IV as per BIS. Short carbon fibers used were 5-7mm in length.

Fig2: Short pitch-based Carbon fiber

Fig 3 Mechanical churner

The dispersants used were chemical and mechanical. Chemical dispersants are methylcellulose and surfactants. The mass fraction of dispersant was in the amount of 0.5% by weight of cement. Aura mix 400, a water reducing agent was used in the amount of 2% by weight of cement. Besides this all, normal tap water was used in addition to the water reducing admixture.

3.1.1 **Portland cement**

Even though the entire materials that depart into the concrete mix are fundamental, cement is very often the most significant because it is generally the slight link in the chain. The task of the cement is initially of all to combine the sand and aggregates together and second to pack up the voids in between sand and aggregate particles to form a compact mass. It forms only about 20% of the total volume of the concrete mix. It is the dynamic; it is the dynamic portion of the binding means and the only scientifically restricted ingredient of concrete. Any variation in its magnitude affects the compressive strength of the concrete mix. The OPC is characterize into three evaluations, specifically 33 grade,43 grade,53 grade contingent on the quality of 28 days

Table 1 Recommended values by IS codes

S.NO.	Characteristics	Values obtained	Values specified by IS 12269-1987
1.	Specific gravity	3.12	
2.	Standard consistency	29	
3.	Initial setting time(min)	144	30(minimum)
4.	Final setting time(min)	350	600(maximum)

3.1.2 **Coarse aggregates**

The aggregate which is retained other than IS Sieve 4.75mm is known as coarse aggregate. The coarse aggregate is trodden gravel or stone obtained by devastating of gravel or inflexible stone. The usual utmost size is generally 10-20mm. The aggregates were tested as per IS:383-1970. Specific gravity and other properties of coarse aggregates be specified in table.

Table 2Properties of coarse aggregates

S.NO.	Characteristics	Value
1.	Color	Grey
2.	Shape	Angular
3.	Size	>10mm
4.	Specific gravity	2.72
5.	Water absorption	2.35

3.1.3 Fine aggregates (Natural sand)

The aggregates mainly of which surpass throughout 4.75mm IS Sieve are known as fine aggregates. The aggregates mainly of which surpass throughout 4.75mm IS Sieve are known as fine aggregates. The fine aggregates resulting from natural breakdown of rocks and which has been deposited by streams is used. According to size, the fine aggregate may be defined as coarse, medium and fine sands. Depending upon the constituent part size allocation IS:383-1970 has divided the fine aggregates into four grading zones (Grade I-IV). The grading zones become gradually finer from grading zone I-IV. In this experimental program, fine aggregate was in the vicinity procured and confirmed to Indian Standard Specifications IS: 383-1970.

Table 3 Physical properties of fine aggregates –Natural sand

S.NO.	Characteristics	Value
1.	Specific gravity	2.68
2.	Fineness modulus	2.62
3.	Water absorption	0.9

3.1.4 Water

Water is a significant constituent of solid, which not just vigorously partakes in the hydration of concrete yet in addition adds to the usefulness of new concrete. Concrete is a blend of composite intensifies, the impact of concrete with water prompts its setting and solidifying. All mixes present in the concrete are anhydrous however when carried into connect with the water they get hydrolyzed, framing hydrated mixes. The two chief elements of water in the solid blend are to result hydration and liven up usefulness.

3.2 Admixtures

3.2.1 Carbon fiber

The short pitch-based Carbon fibers are used for this work.

Properties

- Carbon fiber has extremely high tensile strength
- It has a low thermal expansion.
- It is a light weight substance having stumpy density.
- It is a excellent conductor of electricity.
- It can wear a high resistance.
- High stiffness.
- High chemical resistance.
- High temperature tolerance.

Dosage

- 1 % by weight of cement.

3.2.2 Surfactants (sodium dodecylbenzene sulphurated, C18H29NaO3S)

Surface active agents play an important role as dispersing, foaming, wetting, cleaning agents.

Uses

•To decrease the water cement ratio and thus increasing the compressive strength and density of concrete.

Dosage

•0.5 % by weight of cement.

3.2.3 Methyl cellulose Uses

- To increase the tensile strength by up to 72%
- To increase the shear bond strength with carbon fiber. The bond strength increases with increase in methyl cellulose content.

Dosage

•0.5% by weight of cement

3.2.4 Aura mix 400, water reducing agent

Uses

- This greatly improves cement dispersion. At the begin of the assimilation process an electrostatic dispersion occurs but the cement particles capability to break up and disperse. This mechanism significantly reduces water demand in flowable concrete.
- It combines the properties of water reduction and workability preservation. It allows the production of high-performance concrete
- Reduces shrinkage and creep
- Increased durability **Dosage**
- 2% by weight of cement

Design model for CFRSCC

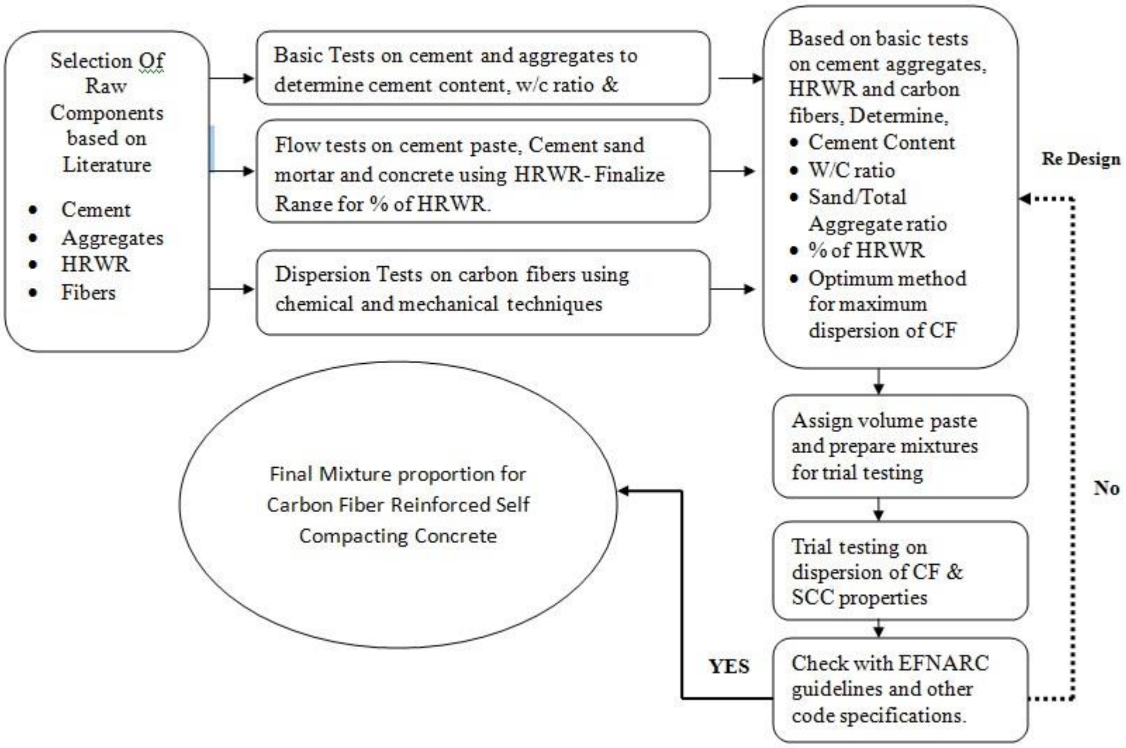

Fig 4 Design model for CFRSCC

3.3 Preparation of Materials

All materials shall be brought to room temperature, preferably 27±3^{0}c before commencing the results. Samples of aggregates for each batch of concrete shall be of the desired grading and shall be in the air-dried condition.

Mixing

The main object of mixing concrete is to obtain a uniform and easily workable concrete paste. Properly calculated quantities of the concrete ingredients were taken. These compositions were mixed thoroughly in a laboratory batch mixer to get a homogenous mixture.

I: 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.

II: 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.

III: M3-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

IV. M4-carbon fiber +surfactant (>10mm)

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

V: M5-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 molds, a vibrator was used to decrease the amount of air bubbles.

VI: M6-carbon fiber + methylcellulose, 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.

VII: M7- Normal concrete (<10mm)

All the ingredients are fed before mixing is started, especially true for water which must be added simultaneously with sand, cement and coarse aggregates (<10mm).

VIII: M8-crabon 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.

IX: M9- 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 I min. Then this mixture, cement, sand, water and the water reducing agent were mixed in the mixer for 5 min.

X: M10-carbon fiber + methyl 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

IV. EXPERIMENTAL PROGRAMS

4.1 Determination of fresh properties

Filling ability is the ability of SCC to flow horizontally and vertically under its self- weight. The slump flow was determined by measuring the diameter of the concrete spread in two perpendicular directions (D1, D2), where D1 is the largest diameter of the flow patty. The shape was lifted upward and the solid was permitted to stream. The droop stream estimation was taken after the spread of the solid totally halted. Droop stream esteems ought to be in a range between 550 to 800mm.

Fig 5 Slump Flow

4.1.1 Segregation resistance test

Isolation obstruction or dependability is an essential property of SCC. It is characterized as the capacity of the solid to stay reliable and uniform during blending, transport, and setting. Dependability influences the solidified properties, for example, quality and strength. There are a few strategies to quantify the isolation opposition of SCC including segment isolation, infiltration, and sifter security tests. The isolation opposition can likewise be

subjectively surveyed dependent on visual perceptions.
In this examination the isolation opposition of SCC was outwardly evaluated regarding the visual strength list (VSI).

4.1.2 Visual stability index (VSI)

In this study, the VSI of SCC was determined by observing the visual quality of the concrete mix in the slump flow test. Each concrete mix was given a VSI value, which indicated the stability of the CFRSCC. The index value varied from 0 to 3 to describe the degree of concrete stability.

4.2 Determination of Mechanical Properties

For pressure testing of concrete, 150mm solid shapes were utilized. All the blocks were tried in surface dry condition, subsequent to clearing out the surface. The tests were completed after the example has been focused in the testing machine. Stacking was proceeded till the example fizzles and perusing was noted down from the programmed Universal Testing Machine. The ultimate load divided by the cross-sectional area of the specimen is equal to the ultimate cube compressive strength. $\mathbf{f_c = P/A}$

4.3 **Experimental Setup for electrical measurement and procedure.**

To ensure the trustworthy measurements in the variation of resistivity with varying percentages of carbon fibers, the selection of an appropriate electrical configuration is very imperative. The self-sensing performance of composite materials was quantified by the concept of piezo resistivity i.e. by measuring the fractional change in electrical resistance when the specimen was subjected to loading. The method employed for the measurement of this resistance with the application of load in this study was based on two probe method. In the two-probe measurement, when two wires get nearer in get in touch with each other or when a wire is close to any electrical module or device, the current experiences a considerable resistance as it tries to pour from one contacting face to the next which is simply referred to as Resistance.

In this study the electric contacts on the concrete cube specimens were made by two copper wires wound along the surface of specimen in two layers as seen in figure. A highly precise digital multimeter was connected to the copper wires to record the change in resistance measurements digitally. The multimeter worked on the basis of the concept mentioned above in eq.2. Resistance measurements were all made at a DC current in the range of 500µA to 10A.

Fig 6 digital multimeter

V. RESULT AND DISCUSSIONS:

5.1 Properties of fresh CFRSCC

Table 4: Properties of fresh CFRSCC

Mix	Method	Flow diameter (mm)	Segregation index
M1	Normal concrete	650	1
M2	Carbon-fiber, without dispersant	560	2
M3	Carbon fiber +surfactant +churner	662	0
M4	Carbon-fiber+ surfactant	590	1
M5	Carbon-fiber+ methyl celluloses with churner	480	2
M6	Carbon-fiber+ methyl-cellulose, without churner	380	>2
M7	Normal concrete	545	1
M8	Carbon-fiber+ surfactant +churner	580	0
M9	Carbon-fiber without dispersant	493	2
M10	Carbon-fiber +methyl- cellulose +churner	541	2

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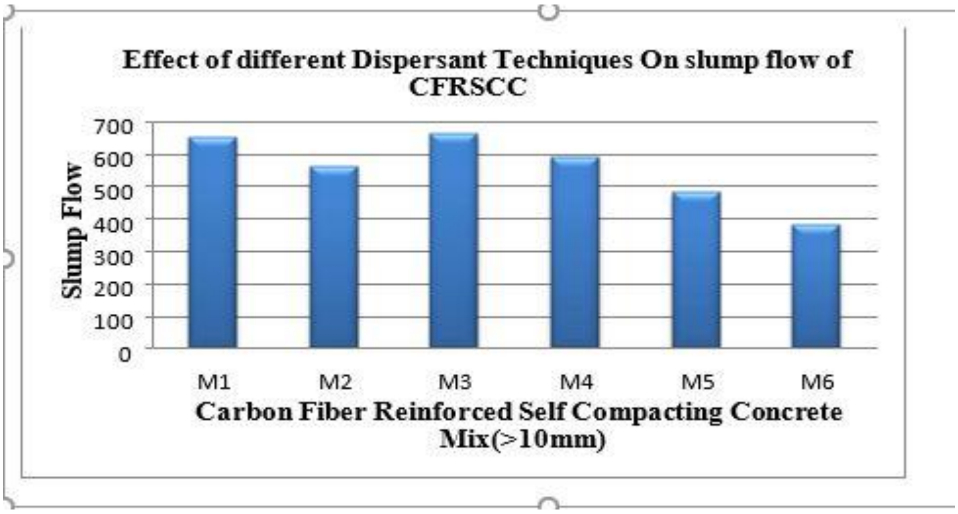

Fig: 7 effect of dispersant techniques on slump flow

5.2 **Compressive strength**

Table 5: Compressive strength test

Mix	Method	Compressive strength(N/mm2)	
		14th Day	28th Day
M1	Normal concrete	24	28.3
M2	Concrete with carbon fiber	26.35	30.2
M3	Carbon-fiber +surfactant+ churner	28.4	34.3
M4	Carbon-fiber+ surfactant	25.7	29.9
M5	Carbon-fiber+ +methyl cellulose, with churner	22	26.2
M6	Carbon-fiber+ methyl-cellulose, without churner	21.08	24.8
M7	Normal concrete	16.5	19.2
M8	Carbon-fiber+ surfactant +churner	19.21	22.6
M9	Carbon-fiber without dispersant	18.09	21.8
M10	Carbon-fiber +methyl cellulose+ churner	15.81	18.6

The compressive strength results of different CFRSSCs and control mixtures are summarized in table. Mixture 3 provided the highest compressive strength of 34.35 MPa at the age of 28 days while mixture 6 had lowest compressive strength of 28.2 MPa in case of the series 1of CFRSCC mixtures. Furthermore, the highest 28 days compressive strength of 24.6 MPa was achieved for Mixture M8 and the lowest 28 days compressive strength of 20.5 MPa was obtained for Mixture M10 in case of series 2 of CFRSCC mixtures.

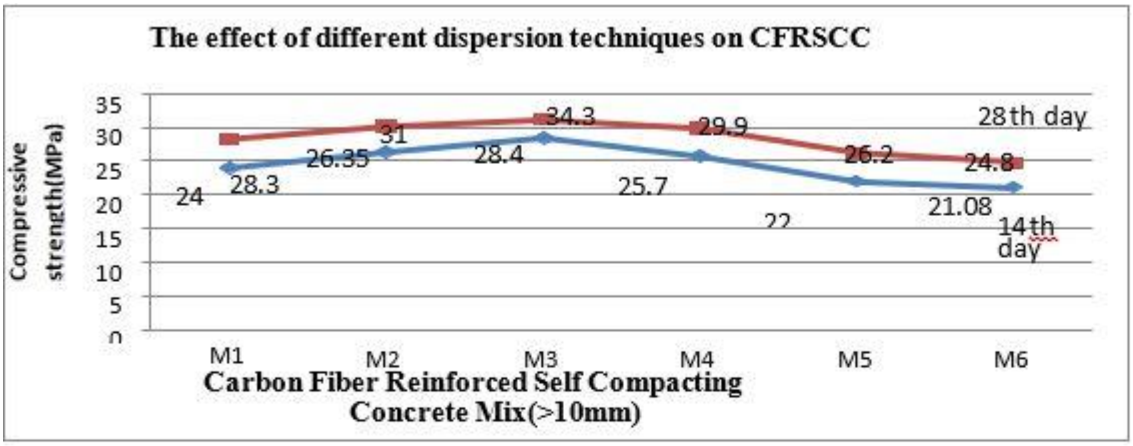

Fig: 8: Comparison of compressive strength of CFRSCC

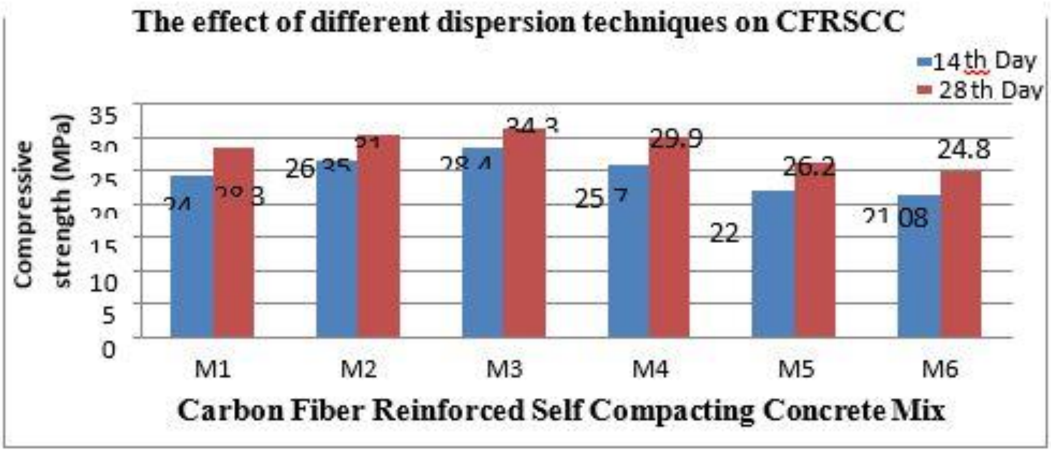

Fig: 9 Effect of different dispersion techniques on compressive strength of CFRSCC (>10mm**)**

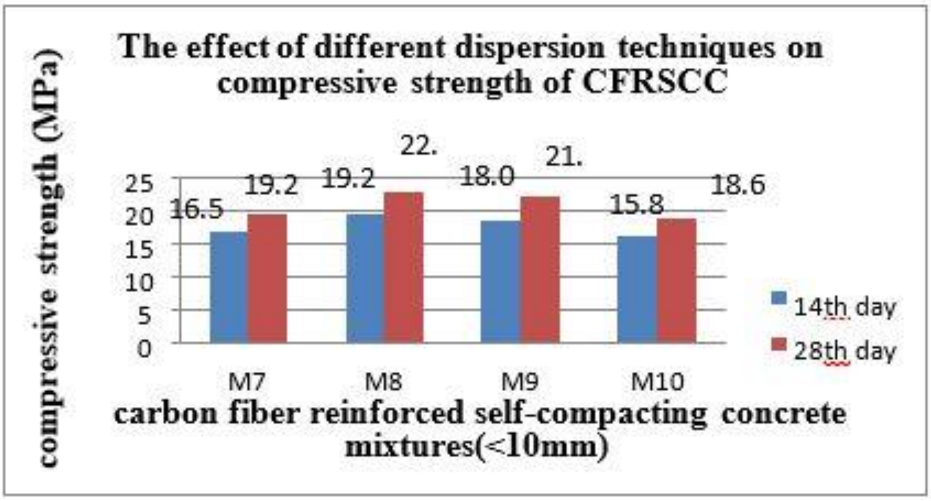

Fig: 10 Effect of different dispersion techniques on compressive strength of CFRSCC (<10mm)

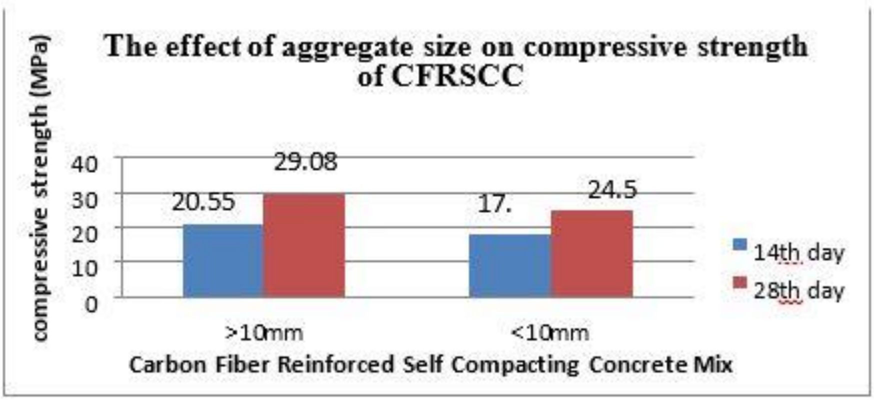

Fig: 11 Effect of different dispersion techniques on compressive strength of CFRSCC (>10mm)

5.3 Effect of aggregate size on compressive strength of CFRSCC

The larger aggregate particles result in greater increase in crack surface than smaller particles and, thus, require more energy for crack propagation. Thus, concrete with larger aggregate has a higher degree of matrix-aggregate interlock, resulting in an increase in the energy required for crack propagation

5.4**Resistivity test Aggregate size >10mm**

Table 6: Resistivity test

Mix	Method	28h day
M1	Normal concrete	0.4MΩ
M2	Concrete with carbon fiber	1.53KΩ
M3	Carbon-fiber +surfactant+ churner	61Ω
M4	Carbon-fiber+ surfactant, without churner	87Ω
M5	Carbon fiber methylcellulose, with churner	12KΩ
M6	Carbon-fiber+ methylcellulose, without churner	66KΩ
M7	Normal concrete	89MΩ
M8	Carbon-fiber+ surfactant +churner	131Ω
M9	Carbon-fiber without dispersant	225Ω
M10	Carbon-fiber +methyl-cellulose +churner	226KΩ

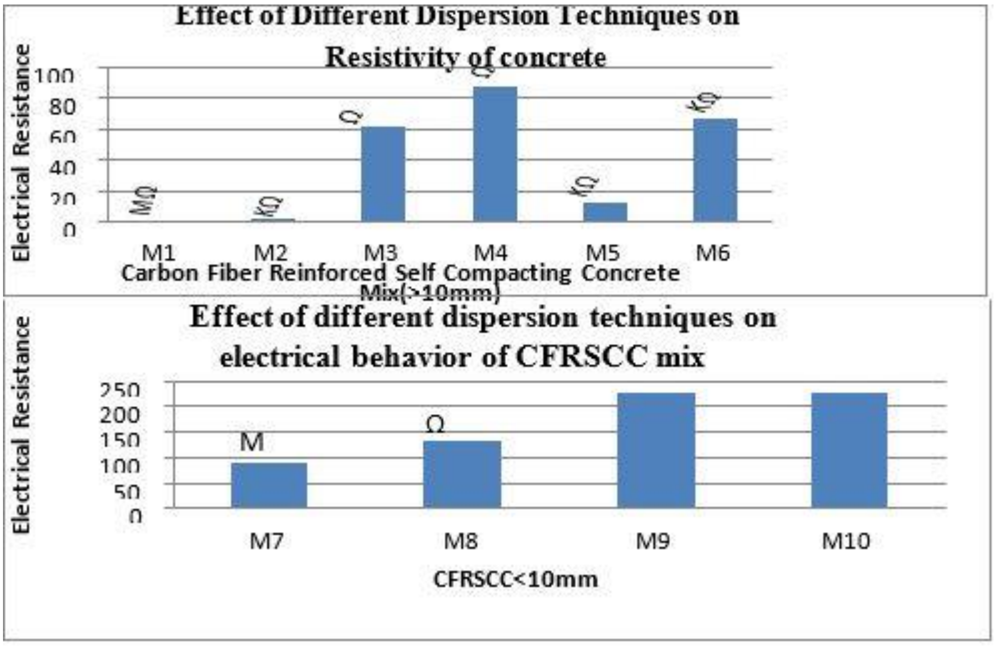

Fig:12 Effect of Different Dispersion Techniques on Resistivity of concrete

It is clear from the graph that resistivity is decreased by the addition of carbon fiber. Also, dispersion effects can be analyzed from the graph. The lower resistivity is attained by the addition of surfactant. This lower resistivity is attained due to greater degree of fiber dispersion provided by surfactant along with the churner. The use of both surfactant and churner results in electrical resistivity This is an outstandingly low resistivity value compared to those of other dispersion techniques. when carbon fibers are uniformly dispersed in the cement matrix, they can contact or overlap each other to form a conductive network. To show clear overlap of carbon fibers in the cement matrix, two SEM images of CFRC samples are provided.

Microstructure Behavior

The morphology and microstructure of the fractures of CFRC samples was observed and analyzed via scanning electron microscopy (SEM)

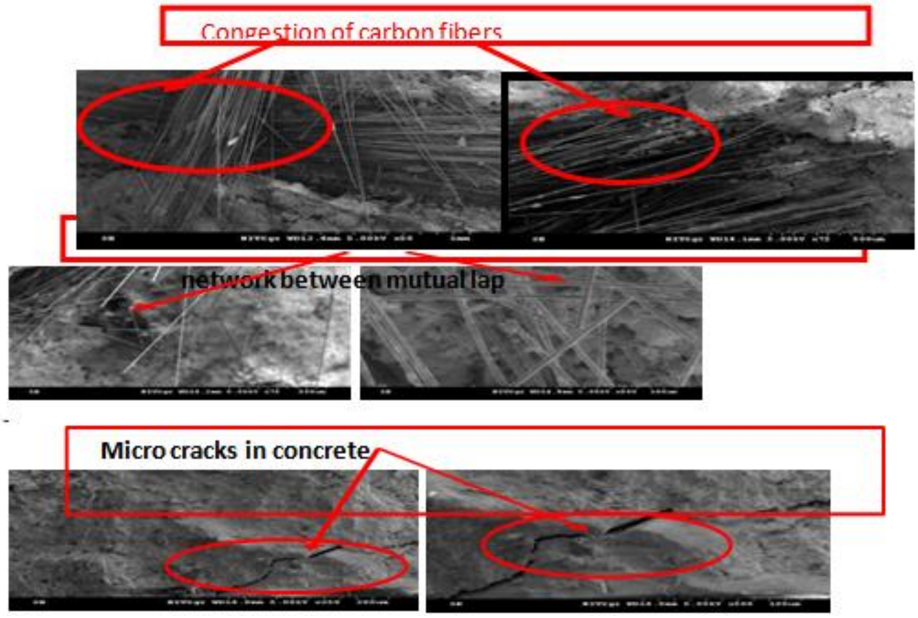

Fig:13 Micro cracks in concrete

The microstructure of the fracture surface for different CFRSCCs and control mixtures was observed through SEM as shown in Figs Clearly, carbon fibers were well distributed in the cement matrix Good dispersion of carbon fibers is not only beneficial to the mechanical properties but also to the electrical performances owing to the possible contact of carbon fibers with one another, whereas the poor dispersion may exert negative influences on the mechanical and electrical properties of the composites when carbon fibers are uniformly dispersed in the cement matrix, they can contact or overlap each other to form a conductive network

VI. CONCLUSION

Based on the test results of this study on CFRSCC and associated discussion, the following conclusions are drawn:

- Carbon fibers affected the filling ability and segregation resistance of SCC mixtures.

Maximum flow diameter of 662mm was attained for M3 due to better dispersion technique.

- CF are very effective in improving the electrical behavior of concrete composite. Electrical resistivity drastically decreased. This is attributed to good dispersion of fibers.
- The highest level of compressive strength was achieved for M3 CFRSCC mix due to better dispersion of fibers dispersed with surfactant and churner that contributed to enhance to the crack bridging. Hence, M3 mix is considered to be the optimum method for maximum dispersion of carbon fibers.
- Scanning Electron Micrographs of the fractured concrete specimen revealed that carbon fibers were distributed in SCC without any fiber clumping or fiber balling in M3 mix. However, for other mixes many carbon fibers came very close to each other and the congestion of the fibers occurred.

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