PERFORMANCE OF STEEL FIBER REINFORCED SELF COMPACTING CONCRETE

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Abstract:* Superior performances of Self-Compacting Concrete (SCC) in fresh state to achieve a more uniform distribution encourage the addition of fibers in concrete which is a motivation for structural application of fibre reinforced concrete. Steel fibre used in the Self Consolidating Steel Fibre Reinforced Concrete (SCSFRC) is to enrich the performance of the concrete material. But SCC has intrinsic low ductility and poor toughness which restrict the fields of application of SCC. The disadvantage of SCC can be avoided by reinforcing with randomly distributed discontinuous fibers. Implementing significant advantages in the supply of self-compacting concrete (SCC) is necessary because of the, negative features of SCC. Examples of these features are the ductility problem along with the very high cost of its constituted materials. It is now well established that one of the important properties of steel fibre reinforced concrete (SFRC) is its superior resistance to cracking and crack propagation. As a result of this ability to arrest cracks, fibre composites possess increased extensibility and tensile strength, both at first crack and at ultimate, particular under flexural loading; and the fibres are able to hold the matrix together even after extensive cracking. The net result of all these is to impart to the fibre composite pronounced post – cracking ductility which is unheard of in ordinary concrete. The transformation from a brittle to a ductile type of material would increase substantially the energy absorption characteristics of the fibre composite and its ability to withstand repeatedly applied, shock or impact loading. In our work we mainly focused on the comparison of mechanical properties like compressive strength, and flexural strength. Experimental work has been carried out to assess the compressive strength and flexural strength of concrete by varying quantities of fibres and the results were presented. It was observed that there is increase in compressive strength by 25.75% and increase in flexural strength by 19.47% of SFRSCC over normal SCC for the fibre content of 1.75%.
Keywords: Self Compacting Concrete, Fibers, Compressive Strength, Flexure Strength.

I. INTRODUCTION

Self-compacting concrete (SCC) is a flowing concrete mixture that is able to consolidate under its own weight. The highly fluid nature of SCC makes it suitable for placing in difficult conditions and in sections with congested reinforcement. Use of SCC can also help minimize hearing-related damages on the worksite that are induced by vibration of concrete. Another advantage of SCC is that the time required to place large sections is considerably reduced. Construction of durable concrete structures requires skilled labour for placing and compacting concrete. Self Compacting Concrete achieves this by its unique fresh state properties. Self consolidating concrete or self-compacting concrete is characterized by a low yield stress, high deformability, and moderate viscosity necessary to ensure uniform suspension of solid particles during transportation, placement (without external compaction), and thereafter until the concrete sets. In the plastic state, it flows under its own weight and homogeneity while completely filling any formwork and passing around congested reinforcement. In the hardened state, it equals or excels standard concrete with respect to strength and durability. When the construction industry in Japan experienced a decline in the availability of skilled labour in the 1980s, a need was felt for a concrete that could overcome the problems of defective workmanship. This led to the development of self-compacting concrete, primarily through the work by Okamura. A committee was formed to study the properties of self-compacting concrete, including a fundamental investigation on workability of concrete, which was carried out by Ozawa et al. at the University of Tokyo. The first usable version of self-compacting concrete was completed in 1988 and was named “High Performance Concrete”, and later proposed as “Self Compacting High Performance Concrete”. In Japan, the volume of SCC in construction has risen steadily over the years. Data indicate that the share of application of SCC in precast concrete industry is more than three times higher than that in the ready-mixed concrete industry. This is attributable to the higher cost of SCC. The estimated average price of SCC supplied by the RMC industry in Japan was 1.5 times that of the conventional concrete in the year 2002. Research studies in Japan are also promoting new types of applications with SCC, such as in lattice type structures, casting without pump, and tunnel linings.

1.1 MATERIALS FOR SCC

Mixture proportions for SCC differ from those of ordinary concrete, in that the former has more powder content and less coarse aggregate. Moreover, SCC incorporates high range water reducers (HRWR), Super-plasticisers in larger amounts and frequently a viscosity modifying agent (VMA) in small doses. The questions that dominate the selection of materials for SCC are:

- limits on the amount of marginally unsuitable

aggregates, that is, those deviating from ideal shapes and sizes,
- choice of HRWR,
- choice of VMA, and
- interaction and compatibility between cement, HRWR, and VMA. These are discussed below.

1.2 AGGREGATES

In the case of SCC, rounded aggregates would provide a better flow ability and less blocking potential for a given water-to-powder ratio, compared to angular and semi-rounded aggregates. Moreover, the presence of flaky and elongated particles may give rise to blocking problems in confined areas, and also increase the minimum yield stress (rheology terms are discussed in the next section). Incorporation of aggregate shape in the mixture design would enable the selection of appropriate paste content required to overcome these difficulties. It is possible that the highly flowable nature of SCC could allow a higher proportion of flaky aggregates compared to normal concrete. However, this aspect needs to be checked.

1.3 ADMIXTURES

SCC invariably incorporates chemical admixtures - in particular, a high range water reducing admixture (HRWRA) and sometimes, viscosity-modifying agent (VMA). The HRWRA helps in achieving excellent flow at low water contents and VMA reduces bleeding and improves the stability of the concrete mixture. An effective VMA can also bring down the powder requirement and still give the required stability. Moreover, SCC almost always includes a mineral admixture, to enhance the deformability and stability of concrete. Issues linked with the use of chemical admixtures are discussed in this section.

1.4 HIGH RANGE WATER REDUCERS

A number of studies have been conducted on the use of different types of HRWRAs with or without viscosity modifying agents in self-compacting concrete. These studies seem to indicate those that HRWRAs that work on the principle of 'steric hindrance' require a lower dosage compared to those based on 'electrostatic repulsion'. Stated in other words, acrylic copolymers (AC) and polycarboxylate ethers (PCE) are effective at lower dosages compared to suffocated condensates of melamine (SMF) or naphthalene (SNF) formaldehyde. At present, SNF-based admixture is priced lower (in India) than that based on AC and PCE In the opinion of the authors, SNF-based admixture seems to be preferable that based on PCE.

1.5 VISCOSITY MODIFYING AGENTS

The conventional method of improving the stability of flowing SCC is to increase the fines content by using a large amount of filler, reactive or inert. Of late, however, attempts are being made to reduce the fines content (and paste content) to the levels of normal concrete (in doing so, reducing the potential for creep and shrinkage) and use viscosity modifying agents (VMAs) to improve the stability. Current research shows that SCC produced with low powder content and VMA had similar fresh concrete properties as SCC with high powder contents produced without VMA.

1.6 ADMIXTURE COMPATIBILITY

A large amount of superplasticisers, typically SNF-based, is added to SCC to make it flowable at a reasonable water contents. There exists the problem of incompatibility between cement and HRWRA, which is generally felt acutely for mixtures having low water content. Jolicoeur and Simard have studied the interaction between SNF and cement. In concretes having low water content and high superplasticizer dosage, gypsum (present in cement) may precipitate out, causing a premature stiffening of the paste and consequent loss of slump. However, SCC mixtures typically may have a water content of 170 – 200 litres/m3 and the compatibility problems associated with low water contents may not arise.Sometimes superplasticizers are blended with retarders or lignosulfonates (which may have sugar in them), for slump retention in hot weather conditions. When a VMA is used along with such blended superplasticizers, concrete may not set for nearly twenty hours. This problem may be avoided by using pure SNF-based superplasticisers. The retarding effect of the VMA itself will be adequate for extending the slump retention time.

1.7 MIXTURE PROPORTIONING METHODS

Self-compacting concrete mixtures should be designed for a combination of filling ability, resistance to segregation, and ability to pass through and around reinforcement without blockage. The principles of producing SCC are shown in Figure 1.1 Correct selection of aggregate size and gradation, along with adjustments in paste rheology is essential for SCC. In the past, SCC mixtures have had high cementitious materials contents, providing a high degree of stability to the mixture. As a result, water contents of SCC mixtures were about 190 – 220 litres/m3. With the development of viscosity modifying agents specially suited for SCC applications, however, it has been possible to reduce the content of cementitious materials, bringing down the water contents to values closer to conventional concrete (160–190kg/m3).

1.8 BACKDROP REGARDING SELF-COMPACTING CONCRETE

Cement-based products are the nearly all plentiful of all man-made products and so are very essential design products, in fact it is more than likely that they'll go on to own similar value in the future. Nevertheless, these design and also anatomist products need to meet new and also larger demands. As soon as struggling with troubles of production, overall economy, top quality and also setting, weather resistant take on some other design products for instance plastic material, material and also timber. Just one direction within this advancement is usually to self-compacting concrete (SCC), some sort of improved product that will, devoid of additional compaction vitality, passes and also consolidates intoxicated by its bodyweight.

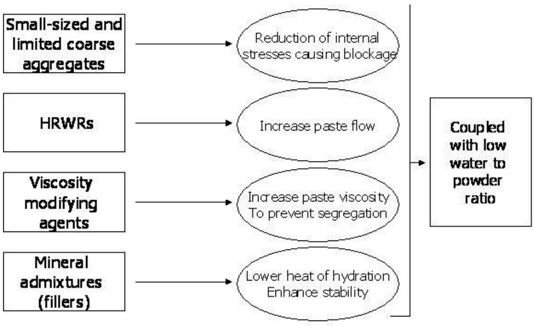

Figure 1.1 Principles of SCC mixture design

1.9 REQUIREMENT FOR SCC

Foundry fine sand and also reddish colored are like a magnet possesses pozzolanic houses hence increasing the holding houses and provides the higher quality durability concurrently this minimizes the charge problems. Plus minimizes this problems, Foundry squander disposal. Throughout disposal property turn out to be unproductive. It commences polluting the groundwater. Consequently it ought to be utilised in some helpful fashion. That might appeal in a pair of approaches Help out with getting better top quality of concrete. For countless years, the problem on the sturdiness of concrete set ups has become a major problem posed to be able to designers. To generate long lasting concrete set ups, ample compaction becomes necessary. Compaction intended for regular concrete is completed through vibrating. More than vibration can certainly result in segregation. Throughout regular concrete, it's tough to make certain homogeneous product top quality and also beneficial density in greatly strengthened places.

1.10 ECONOMY & TIME CUTTING DOWN:

- Their simple positioning increases the production as well as the price saving as a result of reduced tools and also labor tools.
- Reduction in wear of varieties, for that reason, this stretches the program living of varieties.
- Reduction in the number of member of staff. It minimizes the consumption of methods and also price, also thinking about a greater value for each cubic meter with the concrete.
- For the substantial fluidity, this specific concrete does not need any kind of vibrations in order that it will allow to avoid wasting vitality and also ensure appropriate price set up.
- Reduction of expenses and also manpower essential for patching finished precast aspects.
- It might enable the concrete dealer to deliver better uniformity in delivering concrete, which minimizes the interventions for the plant life or perhaps task sites.
- Building together with SCC isn't troubled by the proficiency on the workers, and also appearance and also agreement of reinforcing cafes on the set ups.
- SCC work with with design sites minimizes the possibility of accident through minimizing amount of cables essential for the functioning of compacting tools, hence, minimizes the workers settlement prices.
- It provides wide chance of using high-volumes of byproducts products. given that a greater level of powdered product becomes necessary intended for improving the cohesiveness and also minimizing the number of extremely plasticizer and also viscosity adjusting agencies.
- SCC is usually particular simply to regions where by it's nearly all necessary. These include areas where by entry to regular vibration is usually tough, or perhaps where by you will discover congested reinforcements.

1.11 INTRODUCTION OF STEEL FIBRES IN CONCRETE

The introduction of steel fibers in concrete is another issue of interest on the concrete technology. Steel fibers proved to have the potential to increase the post-cracking energy absorption capacity of cement based materials, enhancing the ductile character of concrete structures behavior, mainly of those with high redundant supports (Barros and Figueiras 1998).The advantages associated to the addition of steel fibers to concrete mixes may be joined with the ones resulting from the self-compacting ability concept in concrete, with the formulation of steel fiber reinforced concrete mixes exhibiting self-compacting ability. The resulting material is, in this work, designated by Steel Fiber Reinforced Self Compacting Concrete (SFRSCC) and, when compared to conventional concretes, presents clear technical advantages in terms of costs/benefits ratio. There exist, however, some drawbacks associated to the SFRSCC formulations, and the most relevant one is related to the strong perturbation effect produced by steel fibers on the flowing ability of fresh concrete. On one side, it is clear that the fluid properties of the fresh SCC formulations are beneficial for the inclusion and homogeneous dispersion of steel fibers. On the other side, steel fibers are rigid and, consequently, do not easily accommodate to the dynamically changing shape of the bulk paste located between the particles constituting the granular skeleton structure. As a result, the design procedure and the optimization technique followed to achieve self-compacting requirements must be sensible to the fiber content, as well as to the geometrical and material properties of the fibers. In the present work, the procedure followed to develop a cost effective and high performance SFRSCC is briefly described. A detailed exposition can be found elsewhere (Pereira 2006). The hardened SFRSCC performance. in terms of material and structural behavior at early ages is assessed. Compression and flexural tests were carried out with the objective of showing that it is possible to formulate relatively low-cost SFRSCC mixes, exhibiting good mechanical behavior and other relevant properties for structural applications. The developed composition was designed to be applied on the precasting industry, in the fabrication of façade lightweight panels. When compared to the solutions currently used,

SFRSCC has some advantages, such as: higher productivity and healthier labor conditions; initial and long term larger toughness; better quality control of the final products; lower costs (Barros et al. 2005b).
A smeared crack constitutive model, based on the material fracture parameters and implemented into a computer program (Azevedo et al. 2006) able to simulate the material nonlinear behavior of laminar concrete structures, was used to appraise its applicability on the simulation of the punching behavior of SFRSCC panels. The fracture parameters, required to describe the SFRSCC post-cracking constitutive law, were derived from an inverse analysis of the results obtained, for the same material and at the same testing age, at three-point flexural tests in notched prisms. To capture the structural softening behavior observed in the experimental punching tests, a softening diagram for both the out-of-plane shear components in the context of Mindlin shell finite elements theory was implemented.

1.12 OBJECTIVE OF THE WORK

The objective of this study is to optimize the Steel Fiber Reinforced Self Compacting Concrete (SFRSCC) in the fresh and in hardened state. But the literature indicates that some studies are available on plain SCC but sufficient literature is not available on SFRSCC with different mineral admixtures. Hence an attempt is made in this work to study the mechanical properties of both plain SCC and SFRSCC.

II. MATERIALS AND METHODOLOGY

For the present study ordinary Portland cement of 53 Grade, Natural sand from river Godavari (Paithan) confirming IS 383-1970 along with potable water and natural aggregates were used for preparation of concrete. The super plasticizer used for the present study was supplied by the manufacturer Sika India Pvt. Ltd., Mumbai complies IS: 9103- 1999. The viscosity modifying agent (VMA)was also supplied by the manufacturer Sika India Pvt. Ltd. Dramix steel fibers conforming to ASTM A820 type-I are used for experimental work. Dramix RC - 80/60 - BN are high tensile steel cold drawn wire with hooked ends, glued in bundles & specially engineered for use in concrete. Fibers are made available from Shakti Commodities Pvt. Ltd., New Delhi. Fly Ash (FLA) which is available in dry powder form and is procured from Dirk India Pvt. Ltd., Nashik. It is available in 30Kg bags, colour of which is light gray under the product name "Pozzocrete 60" was used for the present study.

2.1 ORDINARY PORTLAND CEMENT OF 53 GRADE

Cement can be defined as the bonding material having cohesive & adhesive properties which makes it capable to unite the different construction materials and form the compacted assembly. Ordinary/Normal Portland cement is one of the most widely used type of Portland Cement. The name Portland cement was given by Joseph Aspdin in 1824 due to its similarity in colour and its quality when it hardens like Portland stone.Portland stone is white grey limestone in island of Portland, Dorset.

2.2 AGGREGATES

Natural aggregates: By far the most widely used aggregates for nano-composites are naturally occurring. Usually these are ceramic materials whose crystalline structure is extremely directional, allowing it to be easily separated into flakes or fibers. The nanotechnology touted by General Motors for automotive use is in the former category: a fine-grained clay with a laminar structure suspended in a thermoplastic olefin (a class which includes many common plastics like polyethylene and polypropylene). The latter category includes fibrous asbestos composites (popular in the mid-20th century), often with matrix materials such as linoleum and Portland cement. In-situ aggregate formation: Many micro-composites form their aggregate particles by a process of self-assembly. For example, in high impact polystyrene, two immiscible phases of polymer (including brittle polystyrene and rubbery polybutadiene) are mixed together. Special molecules (graft copolymers) include separate portions which are soluble in each phase, and so are only stable at the interface between them, in the manner of a detergent. Since the number of this type of molecule determines the interfacial area, and since spheres naturally form to minimize surface tension, synthetic chemists can control the size of polybutediene droplets in the molten mix, which harden to form rubbery aggregates in a hard matrix. Dispersion strengthening is a similar example from the field of metallurgy. In glass-ceramics, the aggregate is often chosen to have a negative coefficient of thermal expansion, and the proportion of aggregate to matrix adjusted so that the overall expansion is very near zero. Aggregate size can be reduced so that the material is transparent to infrared light.

2.3 SUPER PLASTICIZER

Superplasticizers, also known as high range water reducers, are chemical admixtures used where well-dispersed particle suspension is required. These polymers are used as dispersants to avoid particle segregation(gravel, coarse and fine sands), and to improve the flow characteristics (rheology) of suspensions such as in concrete applications. Their addition to concrete or mortar allows the reduction of the water to cement ratio, not affecting the workability of the mixture, and enables the production of self-consolidating concrete and high performance concrete. This effect drastically improves the performance of the hardening fresh paste. The strength of concrete increases when the water to cement ratio decreases. However, their working mechanisms lack a full understanding, revealing in certain cases cement-super plasticizer incompatibilities. The addition of super plasticizer in the truck during transit is a fairly new development within the industry. Admixtures added in transit through automated slump management systems, such as Verifi, allows concrete producers to maintain slump until discharge without reducing concrete quality.

2.4 VISCOSITY MODIFYING AGENT

The key function of a VMA is to modify the rheological properties of the cement paste. The rheology of fresh concrete can be mainly described by its yield point and plastic viscosity: The yield point describes the force needed to start the concrete moving. Yield point is related to the workability of the concrete and may be assessed by tests such as the slump value (EN 12350-2).Plastic Viscosity describes the resistance of a concrete to flow under external stress. Viscosity is caused by internal friction. The speed of flow of concrete is related to its plastic viscosity as shown in the diagram below and may be assessed by the T500 time during a slump flow test (prEN 12350-8) or by the time to flow through a V Funnel (prEN 12350-9). High viscosity, slow speed of flow Low viscosity, fast speed of flow. process of viscosity modifying agent shown in figure 2.1 The balance between the yield point and the plastic viscosity is key to obtaining the appropriate concrete rheology. VMA's change the rheological properties of concrete by increasing the plastic viscosity but usually cause only a small increase in the yield point. Admixtures which decrease the yield point are called plasticizers and are often used in conjunction with a VMA to optimise the yield point.

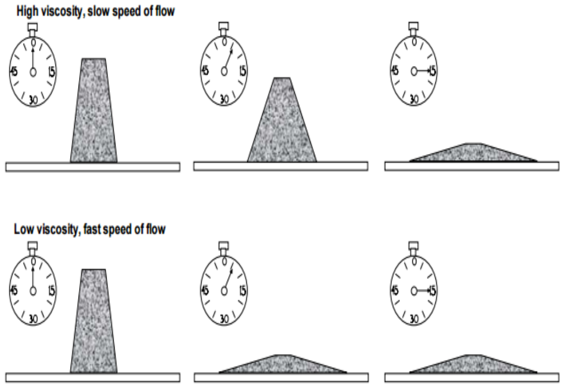

Figure 2.1 Indicating process of viscosity modifying agent

2.5 DRAMIX STEEL FIBERS

The most common uses for stainless steel fibers is in the field of the electrical and textiles industry such as anti-radiation cloth, thermal resistant fabric, and anti-static brushes. Many people also use stainless steel fibers in weaving. Increasingly common today are stainless steel fibers in clothing, including radiation protection for pregnant women. Stainless steel yarns are woven, braided, and knit into many industrial fabrics. For additional variety, stainless steel yarns are twisted with other fibers such as wool, nylon, cotton, and synthetic blends to produce yarns which add novelty effects to the end cloth. Stainless steel and other metal fibers are used in communication lines such as telephone lines and cable television lines. Stainless steel fibers are also used in carpets. They are dispersed throughout the carpet with other fibers so they are not detected. The presence of the fibers helps to conduct electricity so that the static shock is reduced. These types of carpets are often used in computer-use areas where risks of electrostatic discharge are much greater. Other uses include tire cord, missile nose cones, work clothing such as protective suits, space suits, and cut resistant gloves for butchers and other people working near bladed or dangerous machinery.

2.6 FLY ASH

Fly ash, also known as "pulverised fuel ash" in the United Kingdom, is one of the coal combustion products, composed of the fine particles that are driven out of the boiler with the flue gases. Ash that falls in the bottom of the boiler is called bottom ash. In modern coal-fired power plants, fly ash is generally captured by electrostatic precipitators or other particle filtration equipment before the flue gases reach the chimneys. Together with bottom ash removed from the bottom of the boiler, it is known as coal ash. Depending upon the source and makeup of the coal being burned, the components of fly ash vary considerably, but all fly ash includes substantial amounts of silicon dioxide (SiO2) (both amorphous and crystalline), aluminium oxide (Al2O3) and calcium oxide (Ca O), the main mineral compounds in coal-bearing rock strata.

2.7 METHODOLOGY

After performing all required tests on the ingredients of concrete such as cement, sand, coarse aggregates etc. mix design for SCC was done.

Mix Design For SCC:-

Rational method is used for mix design of M-30 grade of concrete. The optimum percentage of fly ash to give maximum compressive strength was achieved by making trial mixes with fly ash at a constant interval of 3% by weight of cement. The trial mixes were made for fly ash from 12% to 36%. The compressive strength went on increasing up to 33% at it decreased at 36%. The maximum compressive strength was achieved at 33%. Hence, fly ash at 33% by weight of cement was added to concrete in this experiment. Figure 2.3 shows the SCC Mix Design Procedure.

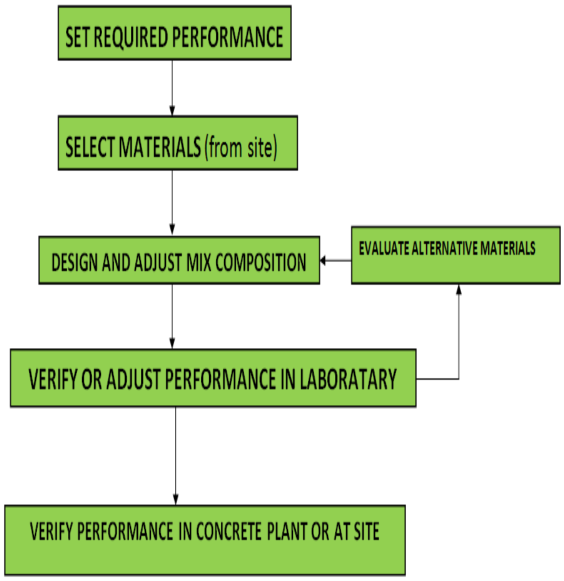

Figure 2.3 SCC Mix Design Procedure

At the end after performing the entire test following mix proportion was used for the present study. The quantities of ingredient materials and mix proportions as per EFNARC guidelines are shown in the Table 2.1.

Table 2.1 Quantity of Materials per Cubic Meter of Concrete

Material	Proportion by Weight	Weight in Kg/m3
Cement	1	450.00
F.A	2.19	985.5
Fly Ash	0.34	153
C.A(<12mm)	1.79	805.5
W/C	0.41	184.5

After finalizing the proportion of ingredients following mix proportions with different designations according to Steel Fiber content were used. The details are shown in Table 2.2

Table 2.2 Mix Designations Used

S.NO	MIX DESIGN-ATION	FlyAsh (%)	STEEL FIBER CONTENT (%)	W/C ratio
1	M0	34.0	0.0	0.41
2	M1	34.0	0.5	0.41
3	M2	34.0	1.0	0.41
4	M3	34.0	1.25	0.41
5	M4	34.0	1.5	0.41
6	M5	34.0	1.75	0.41
7	M6	34.0	2.0	0.41
8	M7	34.0	2.25	0.41
9	M8	34.0	2.5	0.41
10	M9	34.0	2.75	0.41
11	M10	34.0	3.0	0.41

The specimens used were cubes, beam specimens. Dimensions of each test specimen are as under:
Cube: 100 mm x 100 mm x 100 mm
Beam: 100 mm x 100 mm x 500 mm
Above specimens were used to determine the compressive strength test and flexural strength test respectively.

III. TEST RESULTS AND DISCUSSION

3.1 Compressive Strength Test on Cube

A cube compression test was performed on standard cubes of plain and SFRSCC of size 100 x 100 x 100 mm after 7 days and 28 days of immersion in water for curing. Results are shown in Table 3.1, Table 3.2 and graphical presentation between compressive strength and percentage fiber volume fraction is shown in Figure 3.1 to Figure 3.8.

Table 3.1 Compressive Strength of Normal SCC and SFRSCC, MPa

S.NO	% OF STEEL FIBER	COMPRESSIVE STRENGTH (f_{cu}) MPa		% VARIATION IN COMPRESSIVE STRENGTH OVER CONTROL MIX	
		7 Days	28 Days	7 Days	28 Days
1	0.0	35.56	45.64	00.00	00.00
2	0.5	35.76	48.42	0.620	6.093
3	1.0	36.93	50.34	3.855	10.257
4	1.25	37.04	52.15	4.164	14.268
5	1.5	37.86	54.96	6.470	20.426
6	1.75	38.93	57.39	9.478	25.752
7	2.0	39.50	61.76	11.084	35.329
8	2.25	39.69	63.83	11.618	39.865
9	2.5	40.85	65.90	14.881	44.402
10	2.75	41.98	68.98	18.060	51.152
11	3.0	43.15	70.05	21.351	53.497

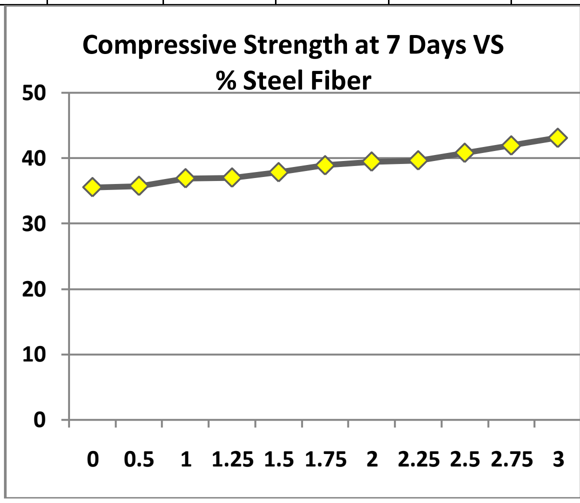

Figure 3.1 Graph between Compressive Strength at 7 days vs % Steel Fibre

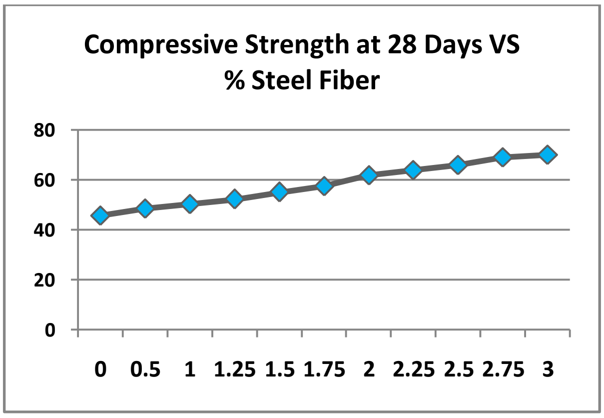

Figure 3.2 Graph between Compressive Strength at 28 days vs % Steel Fibre

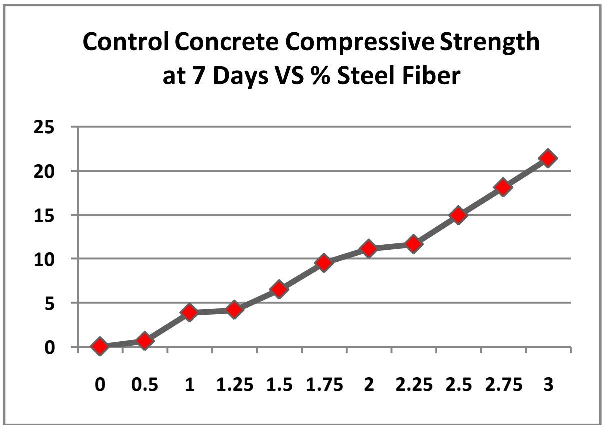

Figure 3.3 Graph between Control Concrete Compressive Strength at 7 days vs % Steel Fibre

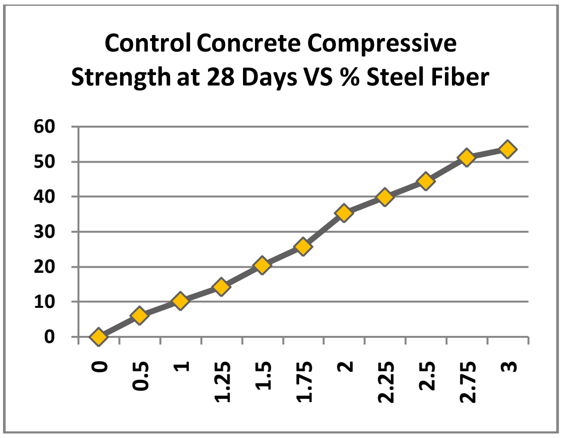

Figure 3.4 Graph between Control Concrete Compressive Strength at 28 days vs % Steel Fibre

4.2 Flexural Strength Test on Beam:

Table 3.2 Flexural Strength of Normal SCC and SFRSCC, MPa

S.NO	% OF STEEL FIBER	COMPRESSIVE STRENGTH (f_{cu}) MPa		% Variation in Compressive Strength over control mix	
		7 Days	28 Days	7 Days	28 Days
1	0.0	4.32	5.30	0.000	0.000
2	0.5	4.47	5.56	3.49	4.92
3	1.0	4.64	5.87	7.43	10.78
4	1.25	4.75	5.95	9.98	12.29
5	1.5	5.03	6.14	16.48	15.88
6	1.75	5.42	6.33	25.53	19.48
7	2.0	5.46	6.45	26.46	21.74
8	2.25	5.61	6.49	29.94	22.50
9	2.5	5.75	6.69	33.18	26.28
10	2.75	6.03	6.98	39.68	31.77
11	3.0	6.12	7.15	41.77	34.98

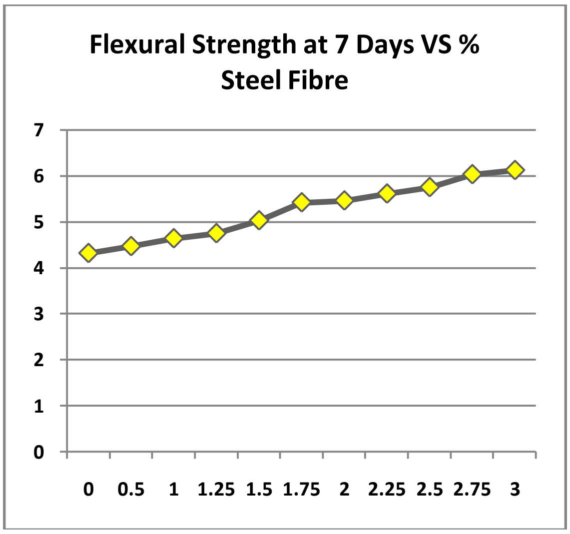

Figure 3.5 Graph between Flexural Strength at 7 days vs % Steel Fibre

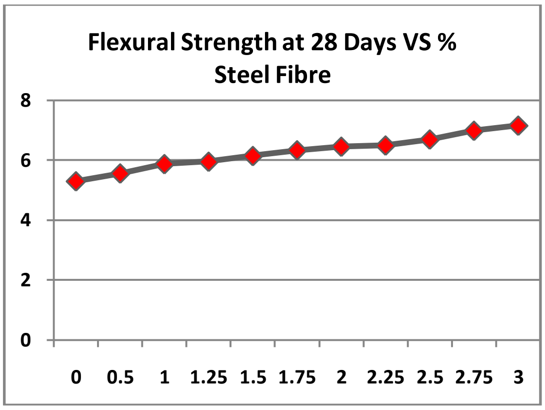

Figure 3.6 Graph between Flexural Strength at 28 days vs % Steel Fibre

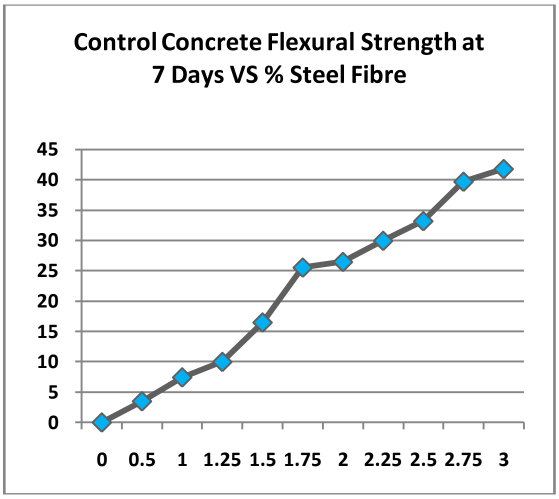

Figure 3.7 Graph between Control Concrete Flexural Strength at 7 days vs % Steel Fibre

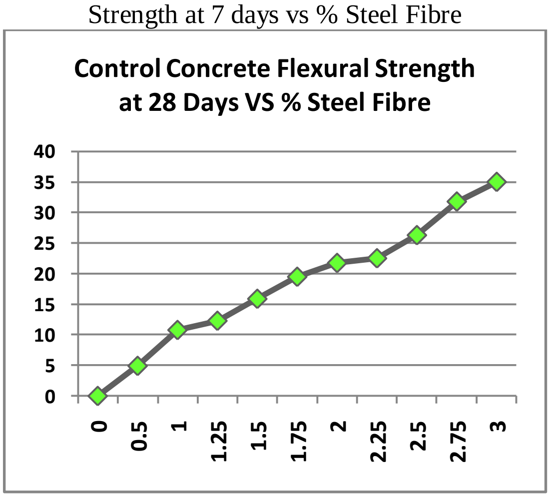

Figure 3.8 Graph between Control Concrete Flexural Strength at 28 days vs % Steel Fibre

DISCUSSION ON TEST RESULTS:

Results of compressive strength are shown in Table 3. It indicates the optimum volume fraction of fibers which gives maximum strength at 28 days is 3.0%. The percentage increase in strength at this volume fraction of fibers over normal SCC at 7 and 28 days is 21.351% and 53.497% respectively. Cracks occur in microstructure of concrete and fibers reduce the crack formation and propagation. Also fly ash improves the microstructure of concrete. Here, this might be the reason for the enhancement of compressive strength. From above Table 4, it is observed that the flexural strength increases with increase in fiber content up to 3.0%. The maximum values at 7 and 28 days are 6.12 and 7.15 respectively.

IV. CONCLUSION

Following conclusion are drawn based on the result discussed above

1. In general, the significant improvement in various strengths is observed with the inclusion of Hooked end steel fibres in the plain concrete. However, maximum gain in strength of concrete is found to depend upon the amount of fibre content. The optimum fibre content to impart maximum gain in various strengths varies with type of the strengths.
2. In general the compressive strength and the flexural strength increase with increase in the percentage of fibre content.
3. In addition to the compressive strength and the flexural strength on the concrete split tension test was also performed on the SFRSCC the results of which are not mentioned in the paper (because the scope is limited to compressive and flexural strength of the SFRSCC) and it was found that the split tensile strength went on increasing with the addition of fibers. The optimum fiber content for increase in split tensile strength is 1.75% and percentage increase is 24.49% of SFRSCC over normal SCC.
4. The increase in compressive strength is 25.75% and increase in flexural strength is 19.47% of SFRSCC over normal SCC for the fibre content of 1.75%.
5. Satisfactory workability was maintained with increasing volume fraction of fibers by using super plasticizer.
6. With increasing fiber content, mode of failure was changed from brittle to ductile failure when subjected to compression and bending.

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