Experimental Investigation on Blended Fiber Reinforced Self-Compacting Concrete

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Abstract - *The paper presents an experimental study of self compacting concrete (SCC) by considering steel and natural fibers as effective reinforcements in hybridization. The influence of combinations steel fibers and natural fibers with different lengths and cross-sectional shape on the compressive strength and flexural behavior of SCC was investigated. Hooked end steel fibers with an aspect ratio 60 and banana fiber (musa sapientum) with an aspect ratio of 100 as natural fiber is taken for combinations. Volume fraction of fibers considered are 0.5%, 1% and 1.5% of volume of concrete mix. Ratio of volume of hybridization of fibers includes 1:1, 1:3 and 3:1(Natural: Steel) for the above percentage of fibers.*

Key Words: self-compacting concrete, hybrid mix of steel fibers, flexural tensile strength

1. INTRODUCTION

The use of SCC can shorten the time as well as decrease the costs of the building process. The incorporation of the randomly distributed steel fibers into brittle SCC improves its tensile parameters. The steel fibers can be effective in delaying propagation of micro- or macro-cracks according to geometrical parameters of fibers. Because of its technical benefits with the developments in new generation superplasticizers, self-compacting concrete has been widely used in construction industry.

Since that period, other fibers have been evaluated as reinforcement in concrete elements, but steel is still the most used fiber. Its popularity is associated with the fact that steel presents a good affinity with concrete, the ease of use, the high toughness and resistance to static and dynamic loads. Several categories of fiber reinforced concrete have been developed over the past three decades presenting different mechanical properties.

Fibers in the cement based matrix acts crack arrester, which restricts the growth of flaws in the matrix , preventing these from enlarging under load ,into cracks which eventually causes failure. Prevention of propagation of cracks originating from interior flaws, can result in improvements in static and dynamic properties of the concrete. Moreover the use of fibers alters the performance of fiber matrix composite after concrete has cracked, thereby improving ductility.

In India a great amount of waste is produced every day. Reuse of such waste materials in concrete constructions is happening nowadays. In southern part of India, material such as rice husk, coconut coir, sugarcane stems and banana stems are abundantly available as waste. Such materials have to be chosen and properly treated and introduced in concrete as additives to modify some of the properties of concrete. Here an attempt has been made, to investigate the possibility of using these waste materials as fibrous concrete composite material.

Extensive research work on FRC has established that combination of two or more types of fibers such as Steel fibers and natural fibers increase the overall performance of concrete composites. The beneficial effects of Banana fibers is to arrest the propagation of micro cracks in the elastic stage of concrete due to their lower modulus and increase fiber availability at a given volume fraction. It is important to have a combination of law modulus and modulus fibers to adjust the micro and macro cracks respectively.

Pajak et al.[1], incorporated randomly distributed steel fibers into brittle SCC improves its tensile parameters. The steel fibers can be effective in delaying propagation of micro- or macro-cracks according to geometrical parameters of fibers. To attract all types of cracks the fibers with different geometrical parameters should be used simultaneously.

Akcay et al.[2] studied the mixture design, workability, fiber dispersion/orientation, mechanical properties and fracture behaviour of hybrid steel fiber reinforced self-compacting concretes (HSFRSCCs) were investigated. The results of slump flow, Ubox, V-funnel and J-ring tests have shown that increasing the fiber content of the concretes slightly reduced the workability of HSFRSCC, and the main influencing factor on flowability is the geometry of fibres.

The addition of fibers, although did not change the final flowability, decreased the rate of flowability. The results from the experimental tests showed that the flexural strengths increased slightly with increasing strength of long fibers, whereas the splitting tensile strength remained unchanged.

Rambo et al. (2011) presented preliminary results of an experimental investigation on the mechanical behavior of self-consolidating concrete reinforced with hybrid steel fibers in the material and structural scale. the mechanical response was measured under tension and bending tests. In the flexural test, the movement of the neutral axis was experimentally determined by strain-gages attached to compression and tensile surfaces.

Doo-Yeol Yoo et al. [4] investigated the implications of fiber hybridization on the flexural behavior of ultra-high-performance concrete (UHPC). Test results indicated that the hybrid use of long and medium-length fibers effectively improved the flexural performance in terms of post-cracking strength, deflection capacity, toughness, and cracking behavior, whereas the hybrid use of long and short fibers generally decreased the performance.

In a study conducted by Algin and Ozen [5], The use of basalt fibre in the production of self-compacting concrete (SCC) has been studied to identify how the fresh and hardened properties of SCC are affected by the addition of fiber. The results reveal that the use of basalt fiber decreases the workability but improves the mechanical properties of SCC.

Hadi and Tikrite [6] investigated experimentally the influence of steel fibres inclusion on the behaviour of Reactive Powder Concrete (RPC) columns. Micro steel fibre (MF) and deformed steel fibres (DF) were used. Steel fibres were hybridized to produce hybrid steel fibre (HF).Finally, it was observed that the RPC specimens reinforced with HF showed delayed spalling of concrete cover more than the RPC specimens that included MF and DF.

Senthilkumar et al.[7], dealt with the mechanical properties of sisal fiber and the several factors influencing the mechanical properties of its polymer composites, such as fiber loadings, fiber length, fiber architecture, chemical treatments and hybridization by incorporating different natural/synthetic fiber/fillers or additive, according to the application and strength requirements.

2. EXPERIMENTAL PROGRAM

2.1 Test Specimens

The cube moulds of size 150mm x 150mm x 150mm, cylindrical moulds of size 150mm diameter and 300mm height and beam moulds of size 100mm x 100mm x 500mm length were selected for casting the specimens for compression test, split tensile test and flexural test of the blended fiber reinforced SCC.

2.2 Fiber Proportion in SCC Mix

The designation of various mixes are shown in the table given below;

Table -1: Mix ID Table

Mix ID	Volume fractions of fibers	
	Natural fiber	Steel fiber
F 0.0	0.0	0.0
F 0.5	0.0	0.5
F 1.0	0.0	1.0
F 1.5	0.0	1.5
F 0.5 (N25/S75)	0.125	0.375
F 0.5 (N50/S50)	0.25	0.25
F 0.5 (N75/S25)	0.375	0.125
F 1.0 (N25/S75)	0.25	0.75
F 1.0 (N50/S50)	0.5	0.5
F 1.0 (N75/S25)	0.75	0.25
F 1.5 (N25/S75)	0.375	1.125
F 1.5 (N50/S50)	0.75	0.75
F 1.5 (N75/S25)	1.125	0.375

3. MATERIALS AND METHODS

3.1 Cement

The cement used is OPC 53 grade.The tests were conducted according to Indian Standard recommendations [12].The physical properties of cement are tabulated in Table 2.

Table -2: Physical Properties of Cement

Sl No.	Properties	Value	Recommended Value
1	Specific gravity	3.15	3.10 to 3.16 [13]
2	Standard consistency (%)	31	26-33 [11]
3	Initial setting time (minutes)	44	Not less than 30 [12]
4	Final setting time (minutes)	348	Not greater than 600 minutes [12]
5	Mortar Cube Compressive Strength of Cement (MPa)	55.9 MPa (672hrs)	>53MPa (672hrs)

3.2 Superplasticiser

The super plasticizer used was MasterGlenium SKY 8233. The physical properties of superplasticizer are tabulated in table 3

Table -3: Properties of Superplasticiser

SI No	Properties	Value (Given by Manufacture)
1	Appearance	Light Brown liquid
2	pH	≥ 6
3	Relative Density	1.08 ± 0.01 at 25^0C
4	Chloride ion content	<0.2%
5	Magnesium oxide (MgO)	1.62

3.3 Banana Fiber

The physical properties and image of banana fiber are given below.

Table -4: Physical Properties of Banana Fiber

SI No	Properties	Values
1	Length	25mm
2	Diameter	0.25 mm
3	Aspect Ratio	100
	Density	1.35 g/cm^3
	Youngs modulus	43.5 GPa

3.4 Steel Fiber

Hooked end steel fibers are used and the physical properties of steel fiber are given in the table given below.

Table -5: Physical Properties of steel Fiber

SI No	Properties	Values
1	Length	30 mm
2	Diameter	0.5 mm
3	Aspect Ratio	60
4	Density	7.85 g/cm^3
5	Specific gravity	2.9

4. MIX DESIGN

There is no standard method for SCC mix design and many academic institutions, ready-mixed, precast and contracting companies have developed their own mix proportioning methods. In this study, the mix design procedure was carried out by using modified Nan Su method [9], which satisfied the requirements of EFNARC guidelines.

5. RESULTS AND DISCUSSIONS

5.1 Fresh Concrete Properties

As per EFNARC [20], SCC can be classified on the basis of slump-flow as SF1, SF2 and SF3, viscosity as VS1/VF1 and VS2/VF2 and on passing ability as PA1 and PA2. Fresh properties of mixes were tabulated in Table

Table -6: Fresh properties of SCC

Mix ID	T500 (s)	Slump-flow (mm)	L – box test (mm)
F 0.0	4.5	680	0.99
F 0.5	6	660	0.96
F 0.5 (N25/S75)	6	665	0.94
F 0.5 (N50/S50)	6.5	660	0.94
F 0.5 (N75/S25)	8	675	0.89
F 1.0	12.5	590	0.93
F 1.0 (N25/S75)	12	610	0.86
F 1.0 (N50/S50)	13	650	0.88
F 1.0 (N75/S25)	13	660	0.74
F 1.5	16.5	480	0.89
F 1.5 (N25/S75)	15	510	0.765
F 1.5 (N50/S50)	14.5	540	0.85
F 1.5 (N75/S25)	14.5	560	0.83

5.2 Hardened Self Compacting Concrete Properties

The respective results for the hardened self compacting concrete properties are in the table given below, along with their corresponding mix ID.

Table -7: Hardened properties of SCC

Mix ID	Compressive Strength	Split Tensile Strength	Flexural Strength
F 0.0	38.15 MPa	3.49 MPa	5.50 MPa
F 0.5	41.9 MPa	4.46 MPa	9.25 MPa
F 0.5 (N25/S75)	39.93 MPa	4.08 MPa	8.75 MPa
F 0.5 (N50/S50)	38.13 MPa	3.56 MPa	7.75 MPa
F 0.5 (N75/S25)	36.13 MPa	3.97 MPa	6.75 MPa
F 1.0	51.13 MPa	7.95 MPa	11.58 MPa
F 1.0 (N25/S75)	48.10 MPa	6.81 MPa	11.09 MPa
F 1.0 (N50/S50)	45.80 MPa	6.30 MPa	10.25 MPa
F 1.0 (N75/S25)	41.06 MPa	6.10 MPa	8.65 MPa
F 1.5	55.93 MPa	9.92 MPa	14.25 MPa
F 1.5 (N25/S75)	52.10 MPa	9.65 MPa	13.92 MPa
F 1.5 (N50/S50)	49.35 MPa	9.28 MPa	12.83 MPa
F 1.5 (N75/S25)	42.60 MPa	8.50 MPa	11.75 MPa

5.2.1 Compressive Strength Test

The variation of compressive strength at 28 days of curing for various mix id is graphed and plotted, shown in Fig.3.

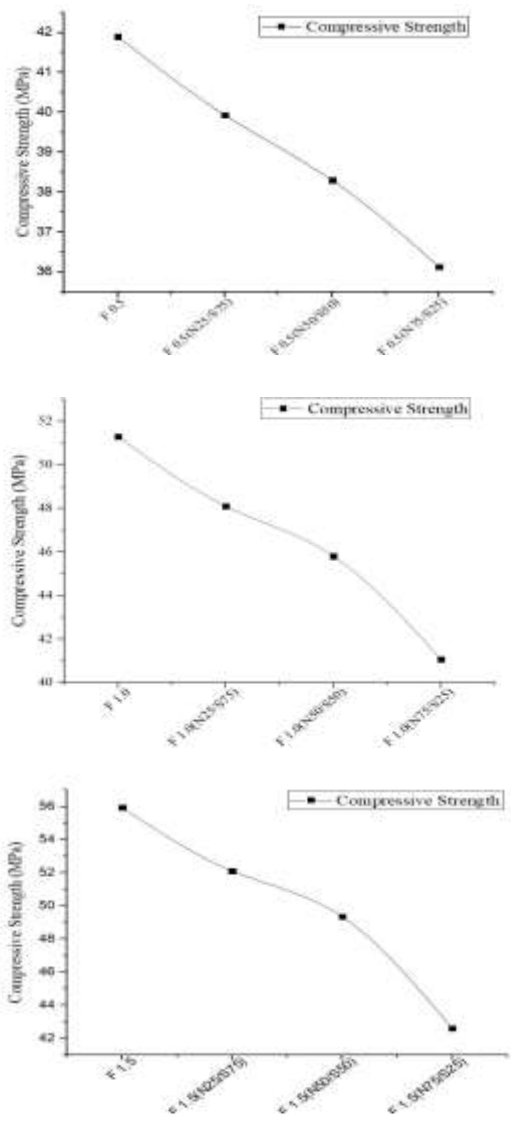

Fig -1: Compressive Strength of SCC

The result shows that percentage increase in the compressive strength is higher with the addition of fibres. However, hybridization plays a crucial role as it influences the strength substantially. The mix id F 0.5 (N50/S50) is found optimum under the category of compressive strength sacrificing 3.77 percentage strength to that of mix id F 0.5, however increasing the profit margin by replacing 50 percent of the steel fibres by natural fibre in a concrete volume mix of 0.5 percentage fibre imparted in the mix.

Similarly mix id F 1.0 (N25/S75) and F 1.5 (N50/S50) is found most optimum, sacrificing 3.03 and 3.83 percentage substituting 25 percentage of steel fiber with natural fiber in 1.0 percent SCC fiber concrete mix and 50 percentage of steel fiber with natural fiber in 1.5 percent SCC fiber concrete mix respectively.

5.2.2 Flexural Strength Test

Flexural strength, also known as modulus of rupture, or bend strength, it's the stress at which a material yield in a flexure experiment. The variation of flexural strength at 28 days curing for different concrete composition in the figures given below.

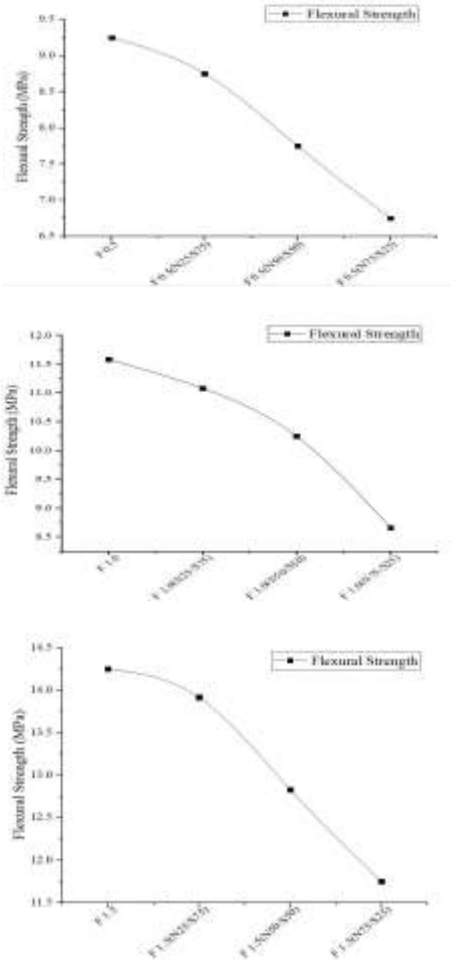

Fig -2: flexural Strength of SCC

The mix id F 0.5 (N75/S25) is found optimum under the category of flexural strength, sacrificing 5.4 percentage strength to that of mix id F 0.5. Similarly the mix id F 1.0 (N50/S50) by 11.48 percentage and F 1.5 (N75/S25) by 2.31 percentage to that of mix id F 1.0 and F1.5 can chosen optimum.

5.2.3 Split Tensile Strength Test

The variation of split tensile strength at 28 days curing for different concrete composition in the figures given below.

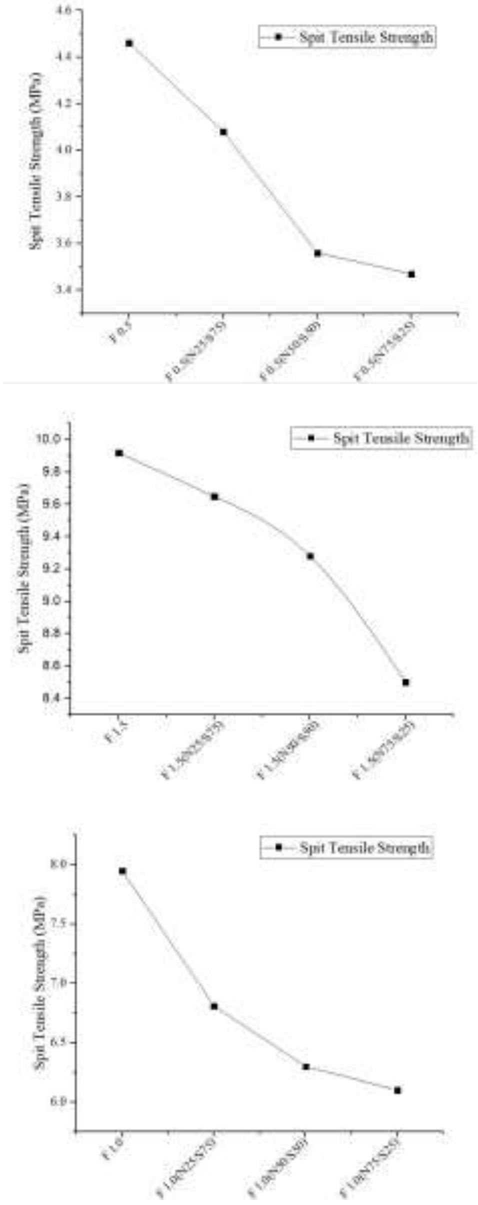

Fig -3: Split Tensile Strength of SCC

In split tensile strength, the strength gets influenced by dosage of fibers for reinforcement. The mix id F 0.5 (N75/S25) is found optimum under the category of split tensile strength ,sacrificing 8.52 percentage strength to that of mix id F 0.5. Similarly the mix id F 1.0 (N75/S25) by 14.34 percentage and F 1.5 (N75/S25) by 5.2 percentage to that of mix id F 1.0 and F 1.5 can chosen optimum.

6. CONCLUSIONS

The experimental results indicate that the natural fibers have a good capability of using it as a reinforcement material along the steel fibers imparted at specified percentages. In flow/passing ability experimental techniques, it proved that mix with low fiber content had better workability. From the investigation, due to hybridization of natural fiber with the steel fiber, it is seen that the natural fiber had a crucial role especially in the category of split tensile strength and flexural strength parameters. The following conclusions are drawn from the experimental results.

- The mix id F 0.5 (N50/S50) is found optimum under the category of compressive strength to that of mix id F 0.5. Similarly mix id F 1.0 (N25/S75) and F 1.5 (N50/S50) is found most optimum in comparison to mix id F 1.0 and F 1.5 respectively.
- The mix id F 0.5 (N75/S25) is found optimum under the category of flexural strength to that of mix id F 0.5. Similarly mix id F 1.0 (N50/S50) and F 1.5 (N75/S25) is found most optimum in comparison to mix id F 1.0 and F 1.5 respectively.
- The mix id F 0.5 (N75/S25) is found optimum under the category of split tensile strength to that of mix id F 0.5. Similarly mix id F 1.0 (N75/S25) and F 1.5 (N75/S25) is found most optimum in comparison to mix id F 1.0 and F 1.5 respectively.

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