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Study on Strength and Durability characteristics of Hybrid 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 with an aspect ratio of 100 as natural fiber is taken for combinations. Volume fraction of fibers considered are 1% of volume of concrete mix. Steel fibers added with percentage of 0.5, 0.6, 0.7, 0.8 and banana fibres added with percentage of 0.5, 0.4, 0.3, 0,2 by volume of concrete.**

***Index terms*- Self-compacting concrete, hybrid mix of steel fibers, flexural tensile strength**

I.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 super plasticizers, 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 respectively.

Aslani et al.[1], performed experiments on SCC with steel, polypropylene (PP) and hybrid fibers. They found that the compressive strength of hybrid fibres is more than that of normal SCC fibers. They also concluded that compressive strength and modulus of rupture of fiber reinforced self compacting concrete decreases with time.

Akcay et al.[2] studied the mixture design, workability, fiber dispersion/orientation, mechanical properties and fracture behavior of hybrid steel fiber reinforced self-compacting concretes (HSFRSCCs) were investigated. The results of slump flow, U Box, 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 fibers.

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. (3) 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 fiber 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 fibers inclusion on the behaviour of Reactive Powder Concrete (RPC) columns. Micro steel fiber (MF) and deformed steel fibers (DF) were used. Steel fibbers were hybridized to produce hybrid steel fiber (HF). Finally, it was observed that the RPC specimens reinforced with HF showed delayed spelling 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.

II. EXPERIMENTAL PROGRAM

A. 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.

B. Fiber Proportion in SCC Mix

The designations 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 1.0 (N00/S100)	0.0	1.0
F 1.0 (N20/S80)	0.2	0.8
F 1.0 (N30/S70)	0.3	0.7
F 1.0 (N40/S60)	0.4	0.6
F 1.0 (N50/S50)	0.5	0.5

III. MATERIALS AND METHODS

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
2	Standard consistency (%)	31	26-33
3	Initial setting time(minutes)	44	Not less than 30
4	Final setting time(minutes)	348	Not greater than 600 minutes
5	Mortar Cube Compressive Strength of Cement (MPa)	55.9 MPa	>53MPa

2. Superplasticiser

The super plasticizer used was CONPLAST SP 430. The physical properties of superplasticizer are tabulated in table 3.

Table -3: Properties of Superplasticiser

SI No	Properties	Value (Given by Manufacture)
1	Appearance	Brown liquid
2	pH	>6
3	Relative Density	1.08 +0.01 at 25 C
4	Chloride ion content	0%
5	Alkali Content	<72

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
4	Density	$1.35 g/cm^3$

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	Mm
3	Aspect Ratio	60
4	Density	7.85 g/cm3
5	Specific gravity	2.9

IV. 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, which satisfied the requirements of EFNARC guidelines.

V. RESULTS AND DISCUSSIONS

A. Fresh Concrete Properties

As per EFNARC, 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	T 500	Slump-flow (mm)	L – box test (mm)
F 1.0	12	580	0.93
F 1.0 (N20/S80)	12.5	610	0.85
F 1.0 (N30/S70)	12.5	630	0.86
F 1.0 (N40/S60)	13	640	0.87
F 1.0 (N50/S50)	13	650	0.88

A. 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 1.0	51.13 MPa	8 MPa	11.6 MPa
F 1.0 (N20/S80)	45.80 MPa	6.81 MPa	11.09MPa
F 1.0 (N30/S70)	46.40 MPa	6.54 MPa	10.72MPa
F 1.0 (N40/S60)	47.10 MPa	6.40 MPa	10.54 MPa
F 1.0 (N50/S50)	48.10 MPa	6.30 MPa	10.25 M Pa

1. Compressive Strength Test

The result shows that hybridization plays a crucial role as it influences the strength substantially. The mix id F 1.0 (N50/S50) is found optimum.

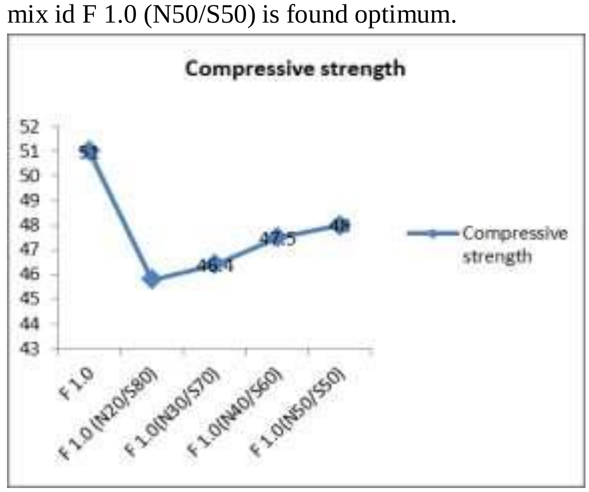

Fig -1: Compressive Strength of SCC

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 figure given below.

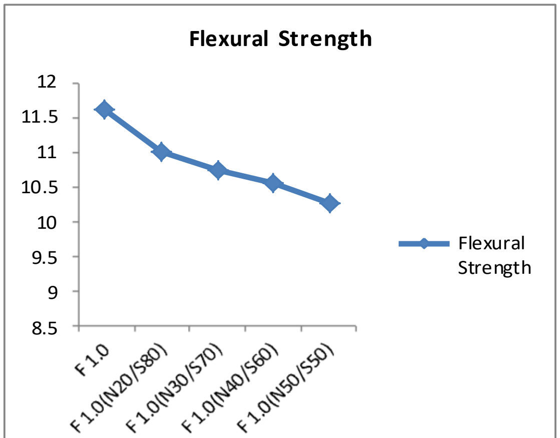

Fig -2: flexural Strength of SCC

The mix id under the category of Flexural strength F 1.0 (N20/S80) can be chosen optimum.

3. Split Tensile Strength Test

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

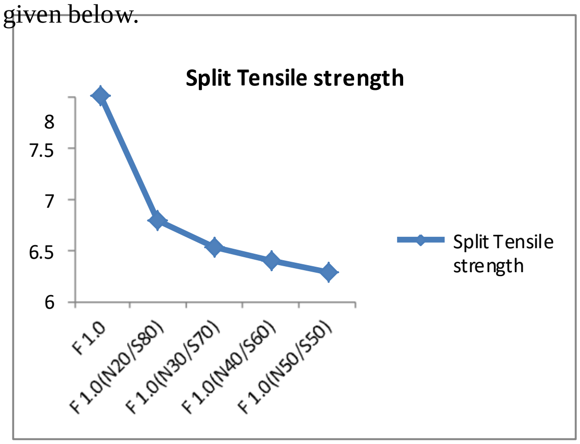

Fig -3: Split Tensile Strength of SCC

In split tensile strength, the strength gets influenced by dosage of fibers for reinforcement. The mix id F 1.0 (N80/S20) is found optimum under the category of split tensile strength.

VI. DURABILITY TESTS

1. Acid Attack Test

Tests were carried out according to ASTM G20-8 to obtain weight loss of different type of concrete. Acid test results are shown in table 6.4. from result it will be observed that 28 days hydrochloric attack to the concrete decrease the weight loss on various proportions of concrete compared to conventional concrete.

Table -8: Acid Attack Test Results

Types of concrete	Average weight		Loss in Kg	% Loss
	Before Acid Attack	After Acid attack		
1% SFRC	8.74	8.712	0.028	0.32%
20% N + 80% S	8.684	8.654	0.03	0.35%
30% N + 70% S	8.666	8.638	0.028	0.32%
40% N + 60% S	8.652	8.629	0.023	0.27%
50% N + 50% S	8.64	8.62	0.02	0.23%

4. Sulphate attack test:

Tests were carried out according to ASTM G20-8 to obtain weight loss of different type of concrete. Acid test results are shown in table 6.3. From result it will be observed that 28 days sulphate attack to the concrete decrease the weight loss on various proportions of concrete to conventional concrete.

Table -9: Sulphate Attack Test Results

Types of concrete	Average weight		Loss in Kg	% Loss
	Before Acid Attack	After Acid attack		
1% SFRC	8.84	8.82	0.02	0.22%
20% N + 80% S	8.825	8.8	0.025	0.28%
30% N + 70% S	8.78	8.766	0.014	0.15%
40% N + 60% S	8.76	8.744	0.016	0.18%
50% N + 50% S	8.63	8.612	0.018	0.20%

VII. CONCLUSION

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 1.0 (N50/S50) is found most optimum under the category of compressive strength
- The mix id F 1.0 (N80/S20) is found optimum under the category of flexural strength.
- The mix id F 1.0 (N80/S20) is found optimum under the category of split tensile strength.
- The durability of concrete with addition of steel and banana fiber is to be checked for the future scope.

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