Study on Fresh and Mechanical Properties of Coconut Fiber Reinforced Self Compacting Concrete Enhanced with Steel Fibers

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***Abstract*— In Earth quake-prone regions, the ductile behavior of structures is a basic requirement. Among the natural fibers, coconut fibers have the highest toughness. In low-cost concrete structures, coconut fibers can possibly be utilized as reinforcement. Self-compacting concrete has a high flowability that under its own weight without any vibration or impact fills all the parts and chinks of the formwork. In this research, the effect of coconut fibers and hybrid combination of coconut fibers and steel fibers keeping low steel fiber content i.e., 0.5%by volume fraction on the fresh and hardened properties of Self Compacting Concrete is studied. Mix design strength of 20MPa is considered. Steel fiber reinforced self-compacting concrete at a volume fraction of 0.5% is produced for comparison. Slump flow diameter and time, and V-Funnel time tests were performed to look for the fresh properties. Mechanical properties such as compressive strength, split tensile strength and flexural strength were determined using cube specimen of 150mm, cylinder specimen of 150mm X 300mm and prism specimen of 100mm x 100mm X 500mm respectively. The experiment revealed that workability decreased with increase in fiber content. The hybrid fiber reinforced self-compacting concrete mixes showed congestion in flow section. Coconut fiber reinforced self-compacting concrete showed increase in compressive strength and flexural strength with increment in fiber content compared to normal self-compacting concrete and hybrid combinations. The hybrid mixes showed the increment in split tensile strength with increase in fiber content compared to coconut fiber reinforced self-compacting concrete and normal self-compacting concrete.**

Keywords*— Coconut fibers, Steel fibers, Normal self-compacting concrete (NSCC), Coconut fiber reinforced self-compacting concrete (CFRSCC), Steel fiber reinforced self-compacting concrete (SFRSCC) and Hybrid fiber reinforced self-compacting concrete (HFRSCC).

I. INTRODUCTION

Concrete is most extensively used construction material all over the world. The scope of concrete as a structural material has widened with the advancement of science and technology. Concrete is strong in compression and weak in tension. The ductile behavior of structures in the earthquake-prone regions is a basic requirement. This brittle nature can be overcome to some extent by the inclusion of fibers. There is a wide variety of fibers available in the market, but, however, most of the fibers are not cost effective. Natural fibers can possibly be utilized as reinforcement in the concrete structures. In many countries, natural fibers are cheap and locally available. Natural fibers are sisal, jute, coconut, bamboo, palm, cotton and sugarcane fibers. They are simple to handle and use because of their flexibility and low cost as compared to steel fibers.

As a substitute to steel or artificial fibers, researchers have used natural fibers in composites such as cement paste, mortar and concretes. Among the natural fibers coconut fibers is the toughest (Munawar et al. [1]) and capable of taking strains up to 4-6 times than other natural fibers. They are resistant to fungi, rot resistant, excellent insulation against sound and temperature, unaffected by moistness and wetness, tough and durable. Coconut fibers are removed from the external shell of the coconut. The common name of coconut fiber is coir. Coconut fibers are of two types, they are brown fibers extracted from mature coconut and white fibers are extracted from immature coconut. White fibers are smoother and finer and weak but brown fibers are strong and abrasive resistant. Depending upon the requirements, these fibers have different uses. Most commonly brown fibers are used in engineering applications.

Munawar et al. [1] characterized non-wood plant fibers based on their morphological, physical and mechanical properties. Their research showed that coconut fibers are the toughest fibers among natural fibers. Mechanical properties of inner and outer coconut fibers were evaluated experimentally by Abiola [2] and verified its results by using ABAQUS software. The author found that outer coconut fiber can resist higher stretching energy compared to inner fiber. Ramakrishna et al. [3] found that coconut fibers showed a decent rate of retaining its tensile strength when subjected to alternate wetting and drying and continuous immersion in water, saturated lime and NaOH. Baruah et al [4] studied the mechanical properties of plain concrete and fiber reinforced concrete. Synthetic, steel coconut and jute were used. This research found that all the properties of coconut fiber reinforced concrete improved. Majid Ali et al. [5] studied the influence of coconut fiber contents of1%, 2%, 3% and 5% by mass of cement and fiber length of 2.5, 5 and 7.5cms on mechanical properties of coconut fiber reinforced concrete. It is found that the fiber length of 5cm and content of 5% has the best properties. F.Bayramov et al. [6] worked on the optimization of steel fiber reinforced concretes to obtain more ductile behavior than plain concrete. The result showed that fiber volume fraction of 0.558% and an l/d ratio of 75.87 as optimum.

This paper presents the experimental work on the effect of coconut fiber and hybrid combination of coconut fiber and steel fiber keeping low steel fiber content i.e., 0.5%by volume fraction on the fresh and hardened properties of Self-Compacting Concrete. Mix design strength of 20MPa is considered. Steel fiber reinforced self-compacting concrete at a volume fraction of 0.5% is produced for comparison.

II. EXPERIMENTAL PROGRAM

Experiments were conducted to study the fresh and the mechanical properties of CFRSCC and hybrid mixes and to compare the results with NSCC and SFRSCC. Four mixes of CFRSCC with fiber content of 0.5, 0.75, 1.0 and 1.25% by weight of cement and four hybrid mixes keeping constant steel fiber content i.e. 0.5% by volume fraction and coconut content of 0.5, 0.75, 1.0 and 1.25% by weight of cement is produced. Steel fiber reinforced self-compacting concrete at a volume fraction of 0.5% is produced for comparison. Table-1 shows the mix designation of the experiment.

Table 1. Mix Designations

Mix Designation	**Fiber content**	
	Coconut Fiber	*Steel fiber*
NSCC	0	0
SFRSCC	0	0.5
CFRSCC1	0.5	0
CFRSCC2	0.75	0
CFRSCC3	1.0	0
CFRSCC4	1.25	0
HFRSCC1	0.5	0.5
HFRSCC2	0.75	0.5
HFRSCC3	1.0	0.5
HFRSCC4	1.25	0.5

A. Materials

Concrete mixes were produced using OPC 53 grade of specific gravity 3.14, locally available river sand conforming to zone II as per IS 383:1983 having specific gravity of 2.63 and coarse aggregate of maximum size 12mm with a specific gravity of 2.64. Fly ash having a specific gravity of 2.13 is used. High-performance superplasticizer(SP) based on polycarboxylic ether of a reputed brand is used to get suitable workability. Hooked end steel and Brown coconut fibers are used for this study and their properties are given in Table-2.

Table 2. Properties of fibers

Type of fiber	**Length (mm)**	**Diameter (mm)**	**Aspect ratio**
Hooked end steel fiber	35	0.55	64
Coconut fiber	50	0.25 (mean dia)	200

B. Mix Proportion

Following the guidelines of EFNARC [8] and using Nan-Su method [7] of mix design as a reference, trial mixes were conducted to produce SCC of strength of 20MPa. The following mix proportions were arrived based on the trial mixes.

Table 3. Mix proportion

Cement	**Fly Ash**	**Coarse aggregate**	**Sand**	**Water**	**SP**
320	84	821	968	182	3.26

C. Mixing procedure

Tilting drum mixer was used in preparing normal SCC. Cement and fly ash was added into the mixer and dry mixed for 60s. Then sand and coarse aggregates were added and dry mixed for another 60s. Water and superplasticizers were added and mixed for 3min. In case of coconut fiber reinforced SCC coconut fibers were thoroughly mixed with cementitious materials and above procedure are carried out. In case of hybrid mixes, steel fibers are sprayed into the mixer in small amounts to prevent balling after homogenization of above ingredients.

D. Test methods

Fresh concrete was filled into the slump cone and V-Funnel instruments for workability measurements such as slump flow diameter and time (T_{500}), and V-Funnel time. For evaluating the mechanical properties of the concrete mixes considered, the following tests were conducted. They are,

- Compressive strength test by casting cube specimen of size 150mm,
- Split tensile strength test by casting cylinder specimens of size 150mm diameter and 300mm length, and
- Flexural strength test by casting prism specimens of 100mm x 100mm x 500mm dimension.

They were de-moulded after 24h and kept for curing for respective periods.

III. RESULTS AND DISCUSSION

A. *Fresh Properties*

Table 4. Workability test results

MIX	FLOW (mm)	Flow time T_{500}(sec)	V-FUNNEL (sec)
NSCC	740	3	6.3
SFRSCC	725	3.5	8
CFRSCC1	730	4	9.2
CFRSCC2	700	4	10.8
CFRSCC3	650	4.5	14
CFRSCC4	600	4.5	BL
HFRSCC1	680	4.5	10
HFRSCC2	670	5	12
HFRSCC3	600	6	BL
HFRSCC4	575	6	BL

To evaluate the fresh properties of the concrete mixes two types of tests were considered i.e. slump flow and V-Funnel. Table-4 show the results of fresh properties of the concrete mixes considered. The tests revealed that workability decreased as the fiber content increased. The slump flow diameter decreased with increment in fiber content. Time taken by the slump flow to reach 500mm diameter (T_{500}) is below 8s. V-Funnel showed congestion in the flow section for mix CFRSCC4 and for hybrid mixes as shown in table. It was observed that with increase in fiber content the flow was non-homogenous. Flow diameter was not circular and cluster of materials remained at the center of spread after the removal of slump cone.

B. *Mechanical Properties*

Table-5 show the results of the mechanical properties such as compressive strength (fc), split tensile strength (fst) and flexural strength (fcr) of the concrete mixes considered respectively.

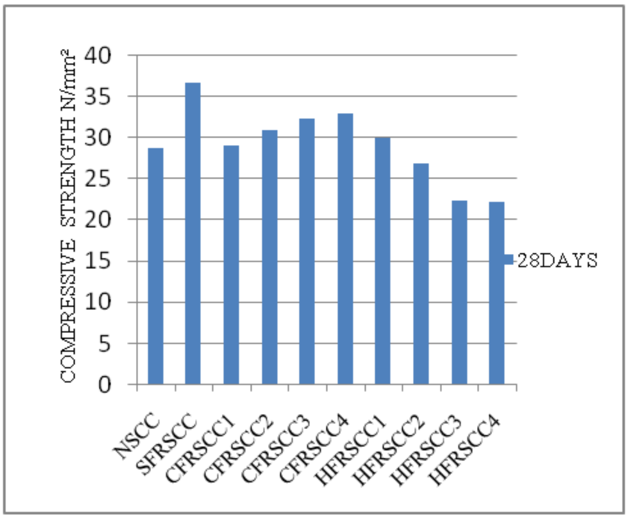
Table 5. Strength test results

MIX	fc (Mpa)	fst (Mpa)	fcr (Mpa)
	28Days	28Days	28Days
NSCC	28.80	1.99	6.5
SFRSCC	36.71	3.44	7.42
CFRSCC1	29.12	2.33	7.08
CFRSCC2	31.01	2.23	7.17
CFRSCC3	32.38	2.24	7.83
CFRSCC4	32.90	2.22	8
HFRSCC1	30.025	3.78	7.58
HFRSCC2	26.85	2.76	7.42
HFRSCC3	22.41	2.90	7.08
HFRSCC4	22.26	3.21	6.92

- *Compressive strength*

The chart-1 show the compressive strength results of the concrete mixes. CFRSCC mixes showed increase in compressive strength and hybrid mixes showed a decrease in compressive strength with increase in fiber content. The percentage increase in compressive strength with reference to NSCC is 27.5% in SFRSCC, 14% in CFRSCC4 and 4% in HFRSCC1. HFRSCC4 showed 22.7% decrease in compressive strength compared to NSCC. No mix showed significant improvement than SFRSCC.

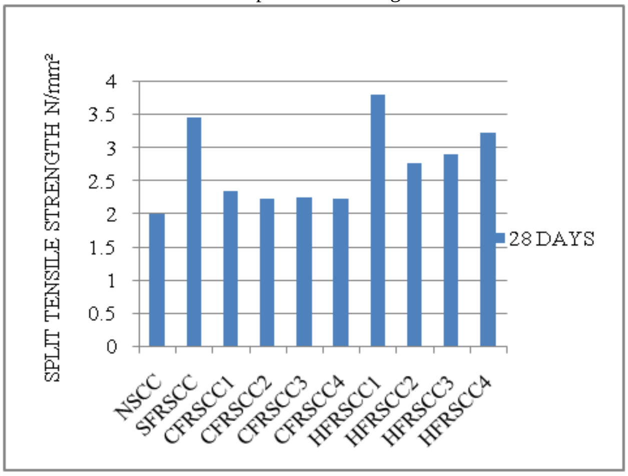
Chart 1 Compressive strength results



- *Split Tensile strength*

The chart-2 show the Split tensile strength results of the concrete mixes. The percentage increase in tensile strength with reference to NSCC is 73% in SFRSCC, 17% in CFRSCC1 and 90% in HFRSCC1. HFRSCC1 showed 10% increase in tensile strength compared to SFRSCC. Hybrid mixes showed a decrease in tensile strength with increase in fiber content.

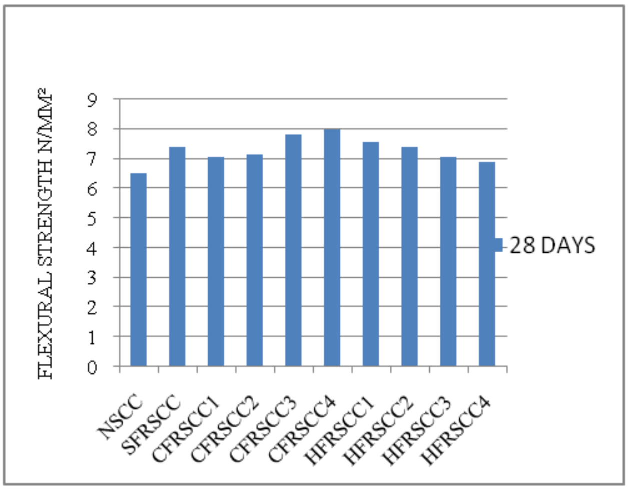
Chart 2 Split tensile strength results



- *Flexural strength*

The chart-3 show the Flexural Strength results of the concrete mixes. The percentage increase in flexural strength is 14% in SFRSCC, 23% in CFRSCC4 and 16% in HFRSCC1. CFRSCC showed increase and HFRSCC showed a decrease in flexural strength with increase in fiber content. CFRSCC4 showed 7.8% and HFRSCC1 showed 1% increase in flexural strength compares to SFRSCC.

Chart 3 Flexural strength results



IV. CONCLUSIONS

In the present study, efforts have been made to study the fresh and mechanical properties of CFRSCC and Hybrid mixes and to compare the results with NSCC and SFRSCC. Following are the conclusions drawn from the present study.

- Workability decreased with increase in fiber content. The flow was not homogenous and a cluster of materials remain at the center of spread as fiber content increased.
- With an increment in coconut fiber content, there was an increment in compressive strength compared to NSCC. Hybrid mixes showed a decrease in compressive strength with increment in fiber content. Both mixes showed a decrease in compressive strength when compared to SFRSCC.
- HFRSCC1 showed significant improvement in split tensile strength and it was more than the SFRSCC.
- CFRSCC showed significant improvement in the flexural strength compared to NSCC and SFRSCC. Hybrid mixes did not show any significant improvement.
- From the considered mixes, CFRSCC3 and HFRSCC1 showed the good mechanical properties and acceptable fresh properties.

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