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STRENGTH PROPERTIES OF SLURRY INFILTRATED FIBROUS CONCRETE (SIFCON) PRODUCED WITH DISCRETE BAMBOO AND STEEL FIBRES

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ABSTRACT

This paper examined the comparison between the mechanical properties of slurry infiltrated fibrous concrete with short steel fiber and discrete bamboo. The differences in properties of the concrete with fiber, concrete without fiber and concrete with discrete bamboo was determined. Compressive and flexural strengths of concrete and slump were also determined. A total of six mix batches of concrete containing 0% (control), 1%, 2% and 3% of steel fiber and discrete bamboo was incorporated into concrete, while 0%, 0.5%, 0.75% and 1.0% of steel fibre and discrete bamboo by volume fraction of concrete were used for flexural strength test. The bamboo stripes were sun dried, cut in sizes ranging from 50-63mm in length and 4.4mm thick for easy mix with concrete while the steel fiber was 25mm in length and 0.4mm thick. The concrete prism used was 300mm x 100 mm x 100mm for compressive strength test and beam 350mm x 100mm x 100mm for flexural strength test.

A thickness of 10mm cement slurry was infiltrated into the beam prism while the remaining 90mm thickness was filled with concrete. Plain concrete without fiber or discrete bamboo served as control. The addition of steel fibre increased the strength of concrete.

Keywords: discreet bamboo concrete, steel fiber reinforced concrete, compressive strength, flexural strength.

1. INTRODUCTION

Slurry infiltrated fibrous concrete - SIFCON is a high-strength, high-performance concrete containing a relatively high volume percentage of fibre material as compared to conventional reinforced concrete. It is also sometimes termed as 'high-volume fibrous concrete HVFC. The origin of SIFCON dates to 1979, when Prof. Lankard carried out extensive experiments in his laboratory in Columbus, Ohio, USA and proved that if the percentage of steel fibres in a cement matrix could be increased substantially, then a material of very high strength could be obtained, which he christened as SIFCON. Considerable interest has developed in the reinforcement of cementitious materials with the dispersions of small diameter filament (fibres) as opposed to relatively thick steel bars used in conventional reinforced concrete (Udoeyo, 1993). Fibres have been used as construction materials for many centuries. The last three decades have seen a growing interest in the use of fibres in ready-mixed concrete, precast concrete, and concrete. Fibres made from steel, plastic, glass, and natural materials (such as wood cellulose and bamboo) are available in a variety of shapes, sizes, and thickness; they may be round, flat, crimped, and deformed with typical lengths of 6 mm to 150 mm (0.25 in. to 6 in.) and thicknesses ranging from 0.005 mm to 0.75 mm (0.0002 in. to 0.03 in.) (Figure-2). They are added to concrete during mixing. The main factors that control the performance of the composite material are: Physical properties of fibres and matrix and the strength of bond between fibres and matrix.

Fibre reinforced concrete was successfully used in variety of engineering applications, because of its satisfactory and outstanding performance in the industry and construction field. However, most of the engineers and researchers do not fully understand how and why the fibres perform so successfully. So, to recognize the usage of fibres in concrete, in these last four decades, most of the researches were done on mechanical behaviour of fibre reinforced concrete and the fibres itself. The fibre reinforced concrete in many applications is subject primarily to bending rather than axial loading, as this indicates the performance in flexure is remark as important. Johnston (1982) conducted tests by determining the factors influencing the flexural strength measurement on fibre reinforced concrete. He proposed that such parameters that affect the performance of the flexural were the loading mode in flexure, specimen's size, shape and span, fibre length, dimension of fibres and fibre volume fraction.

After 10 years, Johnston and Skarendahl (1992) conducted similar tests by examined 117 beams (150 x 100 x 750mm) under a three point loading with 5 types of steel fibres in amounts from 30 to 100 kg/m3. They concluded that the first-crack strength was primarily depends on the matrix characteristic, while secondary depends on fibre parameters such as type, size and amount. At the post cracking state, the toughness of concrete depends on the fibre type, amount and fibre aspect ratio. However, Tat *et. al* (1998) reported that the higher fibre concentration and longer fibres lead to better performance while bond stress between the matrix and

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fibres is a major influence to the flexural strength of fibre reinforced concrete.

Few years later, Banthia and Dubey (2000) used Residual strength test method (RSTM) to measure the flexural toughness of fibre-reinforced concrete in terms of its post peak residual strength, which was investigated. This method has the ability to identify the influence of different fibre characteristics such as type, length, configuration, volume fraction, geometry, and the modulus of elasticity. The results were based on two set of testing. Test of set 1 was clearly stated that fibrillated polypropylene fibres provide a better toughness than monofilament polypropylene fibres. Test of set 2 noted that hooked-end steel fibres verified a better toughening strength than crimped steel fibres in fibre-reinforced concrete.

Some investigations were based on the effect of fibre content and damaging load on fibre reinforced concrete stiffness. Patton and Whittaker (1983) investigated on the steel fibre content for dependence of modulus of elasticity and correlation changes on damage due to load. They found out that there is approximately 3.3 percent increase over the modulus of elasticity of plain concrete for every 1.0% increase in fibre content by volume. Furthermore, the investigation shows that degeneration of stiffness starts at approximately 30 percent of the ultimate load before the first visible crack appears.

Rossi *et. al* (1987) analyzed that the effects of steel fibres on the cracking at both local level (behaviour of steel fibres) and global level (behaviour of the fibre/cement composite) were dependent to each other. The results of this analysis showed that 1.0% volume content of steel fibres could replace approximately 0.15% of flexural steel reinforcement.

Although fibre material was the same, there is some difference in behaviour of fibre reinforced concrete if the geometry of the fibres were different. Barros and Figueiras (1999) used two types of steel fibres in the fibre reinforced concrete for their research. These two fibres had similar tensile strength; however, their aspect ratio was different. Wang *et. al* (2000) recommended and encouraged the use of low cost waste fibre for reinforcement could lead to improved infrastructure with better durability and reliability, as these applications are reduced the solid waste from industrials and consumers.

2. MATERIALS AND METHOD

Sample preparation

The Bamboo stems shown in Figure-1 also called culms, consist of hollow sections called internodes which are interrupted by regularly spaced nodes, giving bamboo its jointed appearance was cut and sun-dry for four weeks to reduce the moisture content. The sun-dried stem was then cut into discrete sizes of about 63mm in length and 4.4mm in thickness, with the aid of cutting saw and knife.

Steel Fibre: Steel fibers are short, discrete lengths of steel with an aspect ratio (ratio of length to diameter) from about 20 to 100, and with several cross sections. Steel fibres shown in Figure-2 used for this project had hooked ends to improve resistance to pullout from a cement-based matrix, the fibre is 25mm in length and 0.4mm thick. Steel fibre was imported from Italy.

Cement: Ordinary Portland cement of grade 43 was used in this experiment conforming to IS-8112-1989 was locally and readily available.

Coarse aggregates (Granite): Machine crushed well graded angular granite aggregate of nominal size 12mm was locally sourced and used in this experiment.

Sharp sand: Locally available river sand of specific gravity 2.45 and fineness modulus 2.92 conforming to IS-383-1970 was used in the study.

Water: Locally available portable water free from impurities and conforming to BS 3148 (1989) was used in the concrete mix.

The materials, mixture proportions, manufacturing and curing of the test specimens are explained. Follow by description of types of samples, test parameters, and test procedures. Concrete prism of size 300mm x 100mm x l00mm was casted by using the percentage order of 0%, 1%, 2% and 3% on SFRC and DBRC for the compressive strength test while 0%, 0.5%, 0.75% and 1.0% on SFRC and DBRC was used for flexural test beam of 350mm x 100mm x 100mm. Six (6) samples was casted for each percentage for compressive test and Four (4) samples each for flexural test gives a total of 70 samples, 0% replacement served a control sample. In this study and the following tests were carried out:

a) Workability test
b) Compressive strength at 7, 14 and 28 days
c) Flexural strength test at 14 and 28 days

Figure-1. Bamboo fiber.

Figure-2. Steel fiber.

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3. RESULTS AND DISCUSSION

Table-1. Summary of SIFCON compressive test results.

Item	Curing period (Days)	Average compressive strength (N/mm²)	Strength Diff. (N/mm²)
0% Control	7	11.00	0.00
	14	13.50	2.50
	28	16.17	2.67
1% Steel Fibre	7	17.67	0.00
	14	18.83	1.16
	28	20.34	1.51
2% Steel Fibre	7	18.67	0.00
	14	20.17	1.50
	28	22.00	1.83
3% Steel Fibre	7	21.17	0.00
	14	21.84	0.67
	28	23.50	1.66
1% Bamboo	7	10.83	0.00
	14	12.00	1.17
	28	14.50	2.50
2% Bamboo	7	3.50	0.00
	14	4.50	1.00
	28	6.00	1.50
3% Bamboo	7	2.00	0.00
	14	3.50	1.50
	28	4.67	1.17

Table-2. Comparison of SIFCON compressive strength with 1% steel fibre to 1% discrete Bamboo.

Curing period (Days)	0% Control (N/mm²)	1% Steel Fibre (N/mm²)	1% Bamboo (N/mm²)
7	11.00	17.67	10.83
14	13.50	18.83	12.00
28	16.17	20.34	14.50

Table-3. Comparison of SIFCON compressive strength with 2.0% steel fibre to 2.0% discrete Bamboo.

Curing period (Days)	0% Control (N/mm²)	2.0% Steel Fibre (N/mm²)	2.0% Bamboo (N/mm²)
7	11.00	18.67	3.50
14	13.50	20.17	4.50
28	16.17	22.00	6.00

Table-4. Comparison of SIFCON compressive strength with 3.0% steel fibre to 3.0% discrete Bamboo.

Curing period (Days)	0% Control (N/mm²)	3.0% Steel Fibre (N/mm²)	3.0% Bamboo (N/mm²)
7	11.00	21.17	2.00
14	13.50	21.84	3.50
28	16.17	23.50	4.67

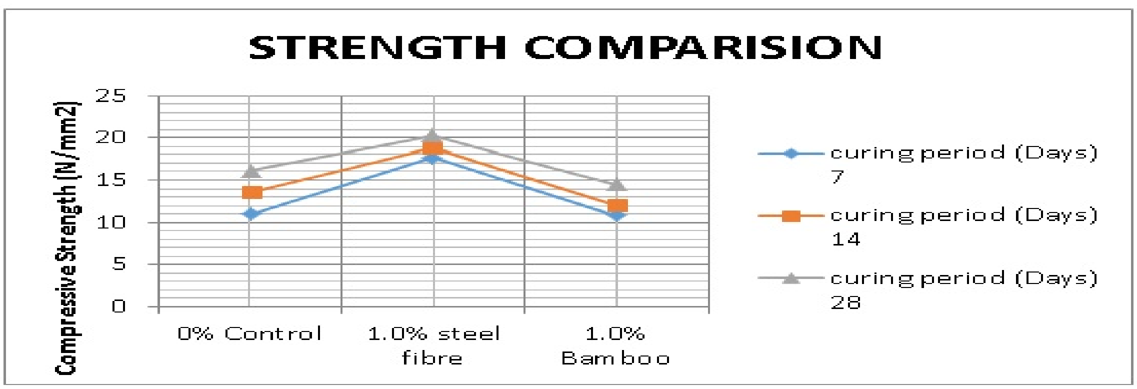

Figure-3.

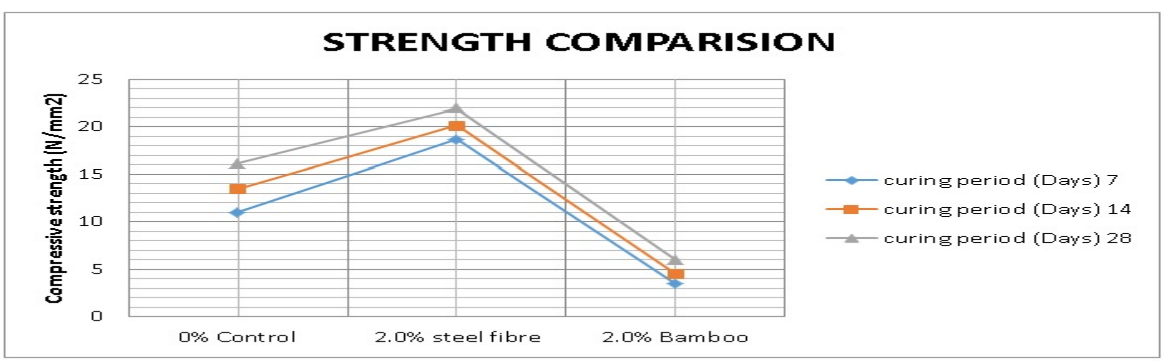

Figure-4.

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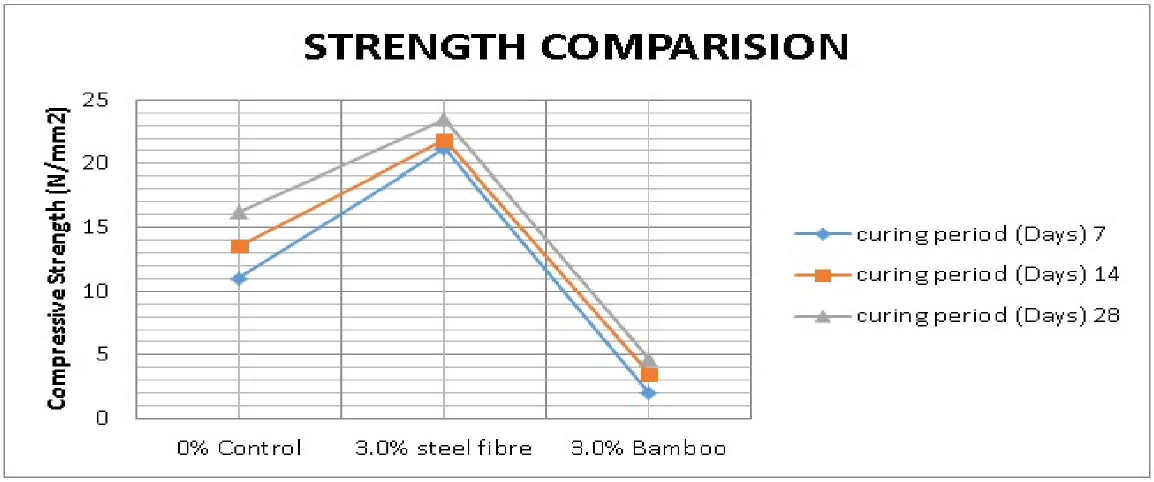

Figure-5.

Table-5. 28-Days flexural strength.

	Sample	Mass of prism (kg)	Initial Load (KN)	Final Load (KN)	Initial deflection (mm)	Final deflection (mm)	Flexural strength (N/mm²)	Average flexural strength (N/mm²)
0% Control	1	8.30	2.5	12.5	0.35	1.02	6.56	6.56
	2	8.25	2.5	12.5	0.38	1.04	6.56	
0.5% SF	1	8.45	2.5	15.0	0.42	1.14	7.88	7.88
	2	8.49	2.5	15.0	0.45	1.10	7.88	
0.75% SF	1	8.57	2.5	17.5	0.27	1.19	9.19	9.19
	2	8.60	2.5	17.5	0.25	1.22	9.19	
1.0% SF	1	8.65	2.5	20.0	0.45	1.65	10.5	10.5
	2	8.75	2.5	20.0	0.43	1.75	10.5	
0.5% DB	1	8.29	2.5	12.5	0.21	0.52	6.56	6.56
	2	8.40	2.5	12.5	0.20	0.42	6.56	
0.75% DB	1	8.18	2.5	10.0	0.18	0.37	5.25	5.25
	2	8.19	2.5	10.0	0.15	0.32	5.25	
1.0% DB	1	8.10	2.5	7.5	0.12	0.18	3.94	3.94
	2	8.08	2.5	7.5	0.10	0.22	3.94	

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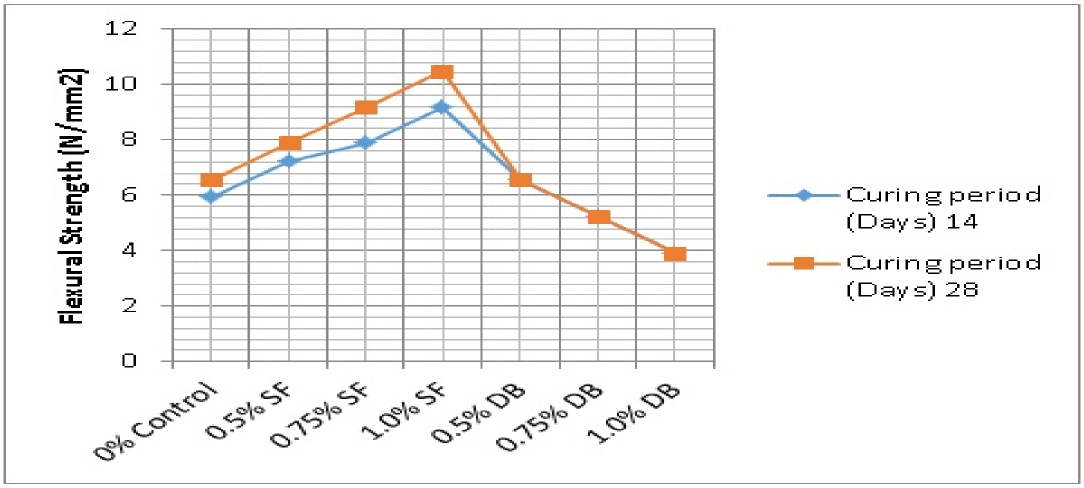

Figure-6. Graph of SIFCON flexural test with control, steel fibre and discrete Bamboo.

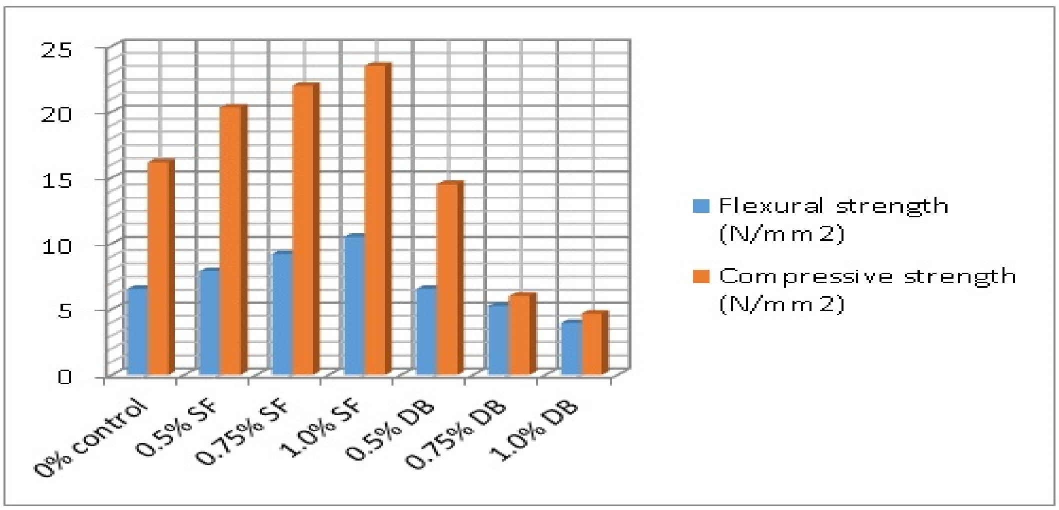

Figure-7. Comparison of compressive and flexural strength at 28 days.

From Table-1 above, it was discovered that only 0% SIFCON (Control), 1.0% SIFCON (SF), 2.0% SIFCON (SF), 3.0% SIFCON (SF) and 1.0% SIFCON (DB) showed no significant result but, 0% SIFCON (Control), 1.0% SIFCON (SF), 2.0% SIFCON (SF), 3.0% SIFCON (SF) showed an appreciable strength at 28 days.

Hence, there is no indication that discrete bamboo improved the strength of SIFCON sample but the addition of steel fibres increased the strength of SIFCON sample. There is appreciable increase in strength of SIFCON with steel fibre while the strength of SIFCON with discrete bamboo decreases as the percentage of bamboo in the concrete increases.

The graph in Figure-6 showed that addition of steel fibre to SIFCON increased the tendency to resist failure in bending while the strength decreased (diminished) for discrete bamboo.

Compressive strength of 1.0% SIFCON with (SF and DB) ranged from 67-77% while, the flexural strength ranged between 23-33%. It shows that the result obtained from the compressive strength is more than twice the percentage of flexural strength.

SIFCON beams with SF as shown in the graph of Figure-7 can withstand higher loads hence gives appreciable crack before final failure while SIFCON beams with DB experienced sudden failure.

4. CONCLUSIONS

Conclusions drawn based on the results of this study:

- Addition of steel fibres increased the compressive and flexural strength of SIFCON, the increase in compressive and flexural strength of steel fibre concrete was attributed to the capability of steel fibre to delay the unstable development of micro cracks as well as limiting the propagation of that micro cracks and its effect on concrete.

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- Addition of discrete bamboo decreased the compressive and flexural strength of SIFCON, the decrease in compressive and flexural strength of discrete bamboo concrete was attributed to the inability of discrete bamboo to delay the unstable development of micro cracks.
- This study has discovered that the samples tested were able to withstand an appreciable load before failure because of infiltration of slurry into the concrete.

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