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AN EXPERIMENTAL STUDIES OF MECHANICAL PROPERTIES OF CONVENTIONAL CONCRETE WITH FIBER REINFORCED CONCRETE

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ABSTRACT
Steel fiber reinforced concretes (SFRC) are typically prepared by adding the fiber along with the other concrete ingredients in the mixing operation. At fiber contents in excess of 2 volume percent, the SFRC becomes difficult or impossible to mix and place. In as much as improvements in concrete properties attributed to the fibers increase as a function of increasing fiber content, this situation places a limit on the ultimate property development in SFRC prepared using the premix approach. Recently, a procedure has been developed wherein steel fiber contents up to 20 volume percent have been provided. Slurry Infiltrated Fiber Concrete (SIFCCN) composites possess outstanding strength, ductility, and crack/spall resistant properties.
In the present project, it is aimed at to study a new type of material, termed SIFCON and to determine experimentally the strength characteristics of SIFCON with 8, 10 and 12% fibre volume fractions. The results obtained are studied and compared with values of strengths of Conventional SIFCON concrete.

1.INTRODUCTION

1.1 GENERAL

SIFCON is interesting development material having high quality and in addition huge pliability and far incredible potential for basic applications when unplanned burdens are experienced amid administrations. The framework in SIFCON has no coarse totals anyway it might contain fine (or) coarse sand and added substances, for example, fly cinder, smaller scale silica and latex emulsions. All steel fiber types to be specific straight, snared and creased can be utilized. SIFCON is fused by utilizing some measure of steel fiber in shape to frame exceptionally thick system of fiber. The system is then invaded with concrete based slurry or mortar. The fiber volume relies upon the fiber type and the vibration exertion required for appropriate compaction. Littler or shorter strands may pack denser than longer filaments and higher fiber volumes can be accomplished with watchful and adequate vibration.

1.2 Slurry Penetrated Sinewy Cement (SIFCON):

SIFCON is a high-quality, elite material containing a moderately high volume level of steel strands when contrasted with SFRC. It is additionally some of the time named as 'high-volume sinewy cement'. The source of SIFCON dates to 1979, when Prof. Lankard did broad investigations in his research center in Columbus, Ohio, USA and demonstrated that, if the level of steel strands in a bond network could be expanded generously, at that point a material of high quality could be gotten, which he initiated as SIFCON. While in customary SFRC, the steel fiber content for the most part differs from 1 to 3 percent by volume, it changes from 4 to 20 percent in SIFCON relying upon the geometry of the filaments and the sort of utilization. The way toward making SIFCON is additionally unique, as a result of its high steel fiber content. While in SFRC, the steel filaments are blended personally with the wet or dry blend of concrete, before the blend being filled the structures, SIFCON is made by penetrating a low-thickness bond slurry into a bed of steel strands 'pre-pressed' in structures/molds. The lattice in SIFCON has no coarse totals, however a high cementitious substance. Be that as it may, it might contain fine or coarse sand and added substances, for example, fly cinder, small scale silica and latex emulsions. The framework fineness must be planned in order to legitimately enter (penetrate) the fiber arrange put in the molds, since something else, vast pores may shape prompting a generous decrease in properties. A controlled amount of high-extend water-lessening admixture (super plasticizer) might be utilized for enhancing the streaming qualities of SIFCON. A wide range of steel strands, to be specific, straight, snared, or creased can be utilized. Extents of bond and sand for the most part utilized for making SIFCON are 1: 1, 1:1.5, or 1:2. Concrete slurry alone can likewise be utilized for a few applications. By and large, fly fiery debris or silica smolder equivalent to 10 to 15% by weight of concrete is utilized in the blend. The water-bond proportion shifts somewhere in the range of 0.3 and 0.4, while the level of the super plasticizer fluctuates from 2 to 5% by weight of concrete. The level of filaments by volume can be somewhere in the range of 4 to 20%, despite the fact that the current functional range goes just from 4 to 12%.Conventional steel fibre reinforced concrete (SFRC) is fabricated by mixing steel fibres with a concrete mix. The volume fraction of fibres is limited to less than two percent. The first high performance fibre reinforced concrete (HPFRC) fabricated by slurry infiltration technique with high fibre volume content was slurry infiltrated fibrous concrete (SIFCON), developed by Josifek et al. 1 The framework was not quite the same as should be expected FRC as in FRC, fiber volume more often than not fluctuates from 1 to 3 percent by volume though in SIFCON, fiber substance may run from 5 to 20 percent utilizing unique assembling methods. The network comprises of bond sand slurry or streaming concrete mortar. The way toward assembling is additionally unique. The SIFCON is set up by invading concrete slurry with high smoothness into a bed of pre-submitted filaments in request to accomplish a solid mass. Since, generally little length or potentially little perspective proportion is utilized to accomplish uniform fiber circulation, fiber volume part Vf , is massively expanded in this manner enhancing mechanical properties essentially.

2. LITERATURE:

2.1 Lankard (1984) expressed that Steel fiber fortified cements (SFRC) are normally arranged by including the fiber alongside the other solid fixings in the blending activity. Utilizing this premix approach, it is conceivable to join up to around 265 Ib/yd3 (2 volume percent) of fiber into the solid. At fiber substance more than 2 volume percent, the SFRC winds up troublesome or difficult to blend and place. In as much as the enhancements in solid properties ascribed to the filaments increment as an element of expanding fiber , this circumstance puts a farthest point on a definitive property advancement in SFRC arranged by the premix approach. As of late, a method has been produced wherein steel fiber con-tents up to 18 volume percent have been given in SFRC composites. The building properties of these exceptionally strengthened composites are talked about alongside various effective applications.

2.2**Yashar SHAFAEI (2012)** carried out study on fibres having length/aspect ratio of 80/60, 80/50, and 30/65 for approximate fiber amounts of 1%, 2%, 3% and 4% by the volume of concrete. Fiber orientation can also seriously affect properties of SIFCON where one can control the orientation easily. These properties are modulus of elasticity, flexural strength, stress strain behaviour, absorbed energy, impact energy, and water permeability (depth of water penetration). Finally the parameters are studied in comparison with conventional concrete. The results are analyzed to end up with optimum orientation and fiber type and volume fraction of fibres to reach admirable energy absorption capacity and durability.

2.2Sudhikumar et al (2014) carried out an experimental investigation on the strength characteristics of SIFF using 1% by volume of steel, GI and polypropylene fiber. The aspect ratios of steel and GI fibers used were 25, 38 and 50 and that of polypropylene fiber was 800 and 1600. The results indicated that with lower aspect ratios of steel, GI and polypropylene fiber yield higher compressive strength, a higher energy absorptive material which can result in higher flexural strength, toughness indices and impact strength.

3 METHODOLOGY AND MIX DESIGN.

3.1 PROPERTIES OF MATERIALS

3.1.1 CEMENT

Slag Cement used in this investigation is ACC conforming to bureau of Indian Standards(IS 8112:1989). The cement is fresh and uniform colour, consistency and free from lumps and foreign matter. The cement was tested for various properties as per IS 8112-1989. The properties of this cement are presented in Table-3.1.

Table 3.1 Properties of Cement

S.No.	Properties of OPC	Results
1	Specific Gravity	3.12
2	Fineness(%)	2
3	Normal Consistency (%)	32
4	Initial Setting Time (min)	224
5	Final Setting Time (min)	340
6	Soundness (LeChatlier expansion in mm)	2
7	Compressive Strength at	
	3 days	20.4 N/mm2
	7 days	31.0 N/mm2
	28 days	48.0 N/mm2

3.1.2 FINE AGGREGATE

Table 3.2 Grading of Fine Aggregates

I.S. Sieve designation	Percentage passing by weight for				Experimental results
	Grading Zone I	Grading Zone II	Grading Zone III	Grading zone IV	
10 mm	100	100	100	100	100
4.15 mm	90-100	90-100	90-100	95-100	99
2.36 mm	60-95	75-100	85-100	95-100	94
1.18 mm	30-70	55-90	75-100	90-100	64
600 micron	15-34	35-59	60-79	80-100	26
300 micron	5-20	8-30	12-40	15-50	8
150 micron	0-10	0-10	0-10	0-15	1

Table 3.3 Properties of fine aggregate

Sand conformed	Zone-II as per IS :383-1973
Fineness modulus	2.37
Specific gravity	2.51

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3.1.3 FIBERS

The present investigation aims at producing SIFCON with locally available fibers Accordingly, black annealed steel wire fibers of 1.0 mm diameter having unit weight of 7850kg/m³ were used. The fibers were cut to the required length of 50 mm by using shear cutting equipment giving an aspect ratio of 50. The ultimate tensile strength of fibre was 417 MPa. These black steel wires are commercially available and are generally used for binding the steel reinforcement in RCC works.

Table 3.4 Properties of fibre as supplied by manufacturer

Name	Value
Carbon	0.06
Manganese	0.39
Sulphur	0.23
Phosphorous	0.022
Silicon	0.19
Aluminum	0.022
Carbon Equivalent	0.13
Yield Strength N/mm2	331
UTS N/mm2	417
Grade	SAE 1008

3.1.4 WATER

Potable water from local resource was used for mixing and curing. Laboratory taps were used for SIFCON production. Water is the most important but the least expensive ingredient of concrete. A part of mixing water is utilized in the hydration of cement to form the binding matrix and the remaining water acts as a lubricant to make the concrete readily placeable.

3.1.5 SUPERPLASTICISER

Super Plasticizer, CONPLAST SP-**421 IC** from FOSROC chemicals was used as water reducing agent to required workability. The super plastisizer is Sulphonated Naphthalene Formaldehyde based and is a brown liquid instantly dispersible in water. In the present investigation super plastisizer is used only to improve the workability of the concrete. The properties of superplasticizer are given below

Properties of CONPLAST SP-421 IC

1. Specific gravity : 1.22 to 1.225 at 30^0c

2. Chloride content : Nill as per IS 456 and BS:5075

3. Air entertainment : Approximately 1% additional air is entrained.

Fig 3.2 Superplasticiser

3.2 MATRIX OF SIFCON

Practically, SIFCON does not contain coarse aggregate and the reason why SIFCON does not contain coarse aggregate is that coarse aggregates will not possibly pass through tiny spaces of fibers. The matrix contains cement, cement-sand, cement fly-ash, cement silica fume, cement sand fly, cement sand fly ash, cement sand silica fume strength and on the other hand, fly ash. The process of selecting suitable ingredients of concrete and determining their relative amounts with the objective of producing a concrete of the required strength, durability, and workability as economically as possible. The moulds were filled with 2, 4, and 6 per cents of fibers in layers and slurry was poured into respective moulds. Hand tamping is done with a tamping rod. Almost nine specimens were cast for each percent of fibers i.e. three cubes, three beams and three cylinders. The mix proportion is briefly given below in Table 3.5 indicating the mix proportion of sand, water cement ratio, dosage of each plasticizer for each volume of fiber. The specimens were finished smooth and kept under wet gunny bags for 24 hours after which they were cured for 7, 14 and 28 days.

Table 3.5 Mix proportion of SIFCON

Mix	Water	Cement	Fine Aggregate (FA)	Volume of Fibre	Super Plasticizers
SIFCON-2	168	350	686		2100ml
	0.48	1.00	1.96	2%	0.6% by wt of Cement
SIFCON-4	168	350	686		2100ml
	0.48	1.00	1.96	4%	0.6% by wt of Cement
SIFCON-6	168	350	686		2100ml
	0.48	1.00	1.96	6%	0.6% by wt of Cement

3.3 PREPARATION AND CASTING OF TEST SPECIMENS

Standard cube specimens of size 150 x 150 x 150mm each for the determination of compressive strength, standard specimen of cylinders of size 150mm diameter and 300 mm height for split tensile strength and beam prisms of size 100 x 100 x 500 mm flexural strength respectively were cast to calculate the strength properties of SIFCON with 2%, 4% and 6% of fibre volume fraction. Moulds were cleaned and oiled properly. Care was taken that there were no gaps, so as to avoid the possibility of leakage from the slurry.

Table 3.6 Specimen cast for test on hardened SIFCON

S.No	Strength Properties	Specimens			Total Specimens Casted
		2%	4%	6%	
1	Compressive Strength, Rebound Hammer, Pulse Velocity Test	9	9	9	27
2	Split Tensile Strength	9	9	9	27
3	Flexural Strength	9	9	9	27

3.4 TESTS

Test specimens were casted for 2%, 4% and 6% of fibres with cement and coarse aggregate to arrive at the Strength characteristics. Study was also carried out to arrive at the increment of the flexural and tensile strength of Slurry infiltrated fibrous concrete. The strength properties and Non-destructive performance of 2%, 4% and 6% of fibre concrete mixes studied in this experimentation were as follows.

4. RESULTS AND DISCUSSIONS

Series of tests were conducted on SIFCON specimens to obtain the strength characteristics of SIFCON for application in civil engineering field. From the experimental investigation the values obtained have been discussed in the following sections to study the strength characteristics of SIFCON made with steel fiber (binding wire).

4.1 Compressive Strength

After 7 days, 14 days and 28 days of curing the specimens were taken out of the tank and air-dried. The compressive strength of concrete is determined by crushing 3 cubes of 150mmX150mmX150mm

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size at ages 7, 14 and 28 days in 300t Compression Testing Machine. The results of compressive strength of SIFCON are presented in Table 4.1 below and curves 4.1& 4.2.

Table 4.1 Values of Compressive Strength of SIFCON at 7, 14 and 28 days

Concrete Mix		Compressive Strength of SIFCON (N/mm²)	
	7 days	14 days	28 days
SIFCON 2%	21.11	24.27	29.19
SIFCON 4%	24.22	28.33	31.72
SIFCON 6%	27.11	32.52	34.44

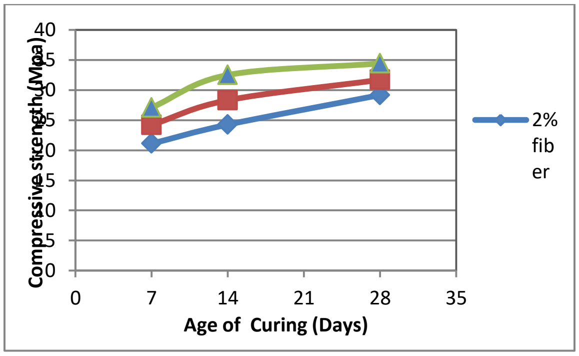

Fig 4.1 Variation of Compressive Strength of SIFCON with Age

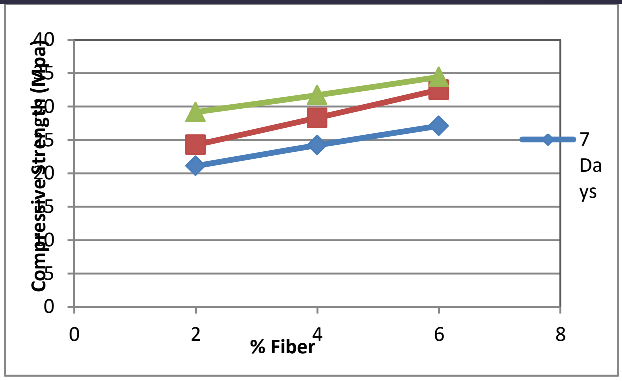

Fig.4.2 Variation of Compressive Strength of SIFCON with % Fiber

The increase in Compressive Strength of SIFCON is 8.60% for 6% fibre fraction and 17% for 4% fibre fraction when compared to 2% fibre fraction.

4.2 SPLIT TENSILE STRENGTH

The tensile strength is one of the basic and important properties of the concrete. The concrete is not usually expected to resist the direct tension because of its low tensile strength and brittle nature. However, the determination of tensile strength of concrete is necessary to determine the load at which the concrete members may crack. The cracking is a form of tension failure.The split tensile strength test was conducted on cylinder specimens of size 150mmX300mm size made with 2%, 4% and 6% fiber volume fraction. The results of split tensile strength of SIFCON with various percentage volume fibre fractions at 7, 14 and 28 days are prepresented in Table 4.2 and Figs.4.3 and 4.4 below.

Table 4.2 Values of Split Tensile Strength SIFCON at 7, 14 and 28days

Concrete Mix	Split Tensile Strength of SIFCON (N/mm^2)		
	7 days	14 days	28 days
SIFCON 2%	1.52	1.98	2.85

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SIFCON 4%	2.84	3.46	4.19
SIFCON 6%	3.00	.3.78	5.35

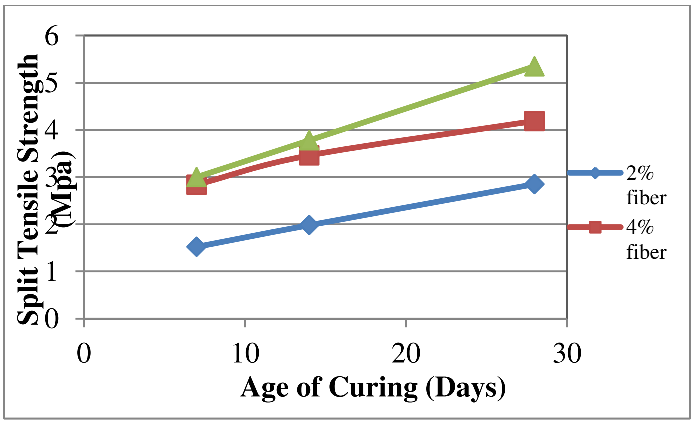

Fig 4.3 Variation of Split Tensile Strength of SIFCON with Age

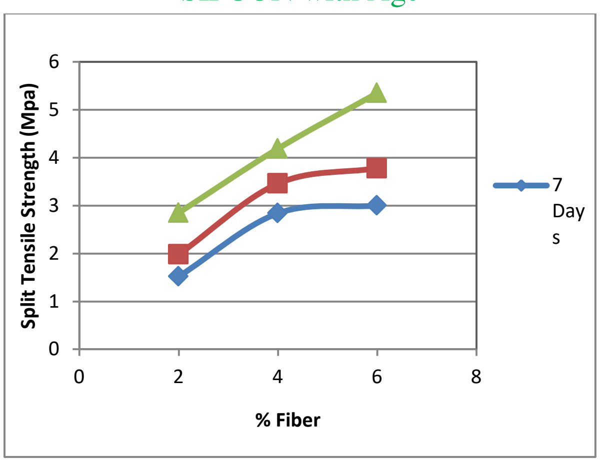

Fig.4.4 Variation of Split Tensile Strength of SIFCON with % Fiber Fraction

4.3 Modulus of Rupture Strength

The modulus of rupture strength of SIFCON was determined by crushing 3 prisms of size 100mmX100mmX500mm each by loading them at middle third points at 7, 14 and 28 days of curing. The results of modulus of rupture strength of SIFCON are presented in Table 4.3 and curves 4.5 and 4.6 below **Table 4.3 Values of Modulus of Rupture Strength of SIFCON at 7, 14, 28 days**

Concrete Mix	Flexural Strength of SIFCON (N/mm^2)		
	7 days	**14 days**	**28 days**
SIFCON 2%	4.63	5..32	5.50
SIFCON 4%	6.22	7.34	8.06
SIFCON 6%	10.82	12.25	12.42

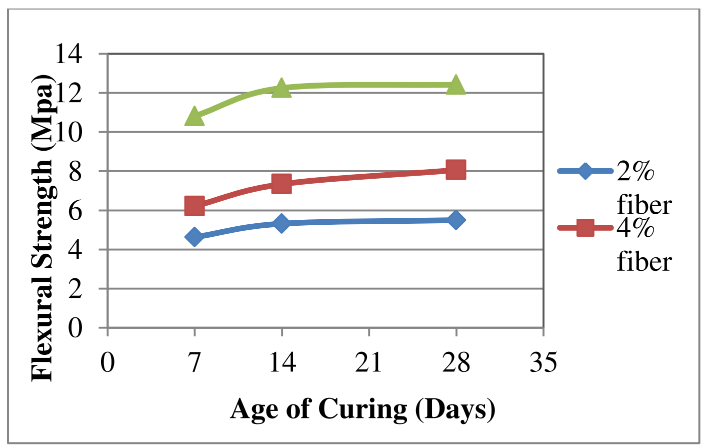

Fig.4.5 Variation of Flexural Strength of SIFCON with Age

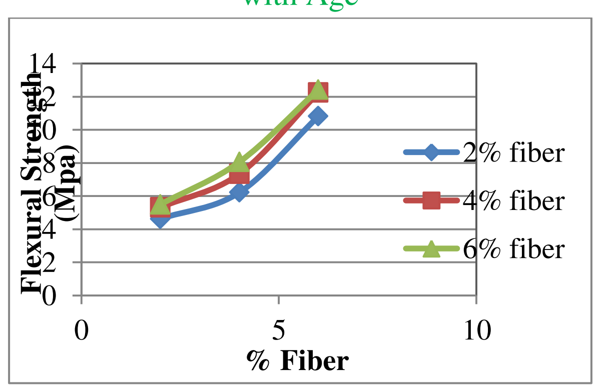

Fig.4.6 Variation of Flexural Strength of SIFCON with % Fiber Fraction

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Figs. 4.5 and 4.6 show the values of modulus of rupture strength at the age of 7, 14 and 28 days of curing. The results show an increase of modulus of rupture strength by adding 2%, 4% and 6% fiber volume fraction. Using steel fibres, the modulus of rupture strength achieved are 5.50, 8.06 and 12.42N/mm^2 at 28 days respectively. The results indicate that the increase in initial modulus of rupture strength is observed to be maximum when compared to lateral strength. From Figs. 4.5 and 4.6, it is seen that SIFCON specimens exhibit greater ductility, fewer cracks, and less spalling of concrete during the tests than normal specimens. It may also be of interest that the ultimate modulus of rupture strength obtained from the tests is in the range of 19 to 37 N/mm^2.

4.4 REBOUND HAMMER TEST:

Non-destructive testing can be applied to both old and new structures. For new structures, the principal applications are likely to be for quality control or the resolution of doubts about the quality of materials or construction. The testing of existing structures is usually related to an assessment of structural integrity or adequacy. These tests include a) Rebound Hammer Test and b) Ultrasonic Pulse Velocity test.

Table 4.4 Comparison of In-situ Compressive Strength with the Age of Concrete obtained from Rebound Hammer Test

Concrete mix	In situ compressive strength (N/mm2)	
	7 days	28 days
SIFCON 2%	16.27	20.44
SIFCON 4%	16.13	20.64
SIFCON 6%	15.90	61.92

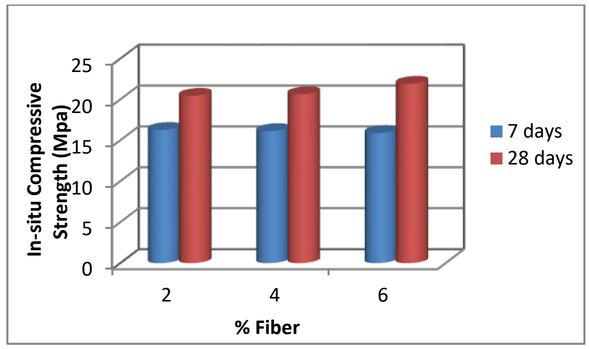

Fig.4.7 Comparison of In-situ Compressive Strength of SIFCON with % Fiber Fraction

4.5 ULTRASONIC PULSE VELOCITY:

Table 4.5 presents the overall results of Ultrasonic Pulse Velocity conducted on specimens made with 2%, 4% and 6% fiber volume.

Table 4.5 Comparison of Ultrasonic Pulse Velocity with the Age of Concrete

Concrete mix	Ultrasonic Pulse Velocity (m/sec)	
	7 days	28 days
SIFCON 2%	5417	5465
SIFCON 4%	5495	5571
SIFCON 6%	5603	5737

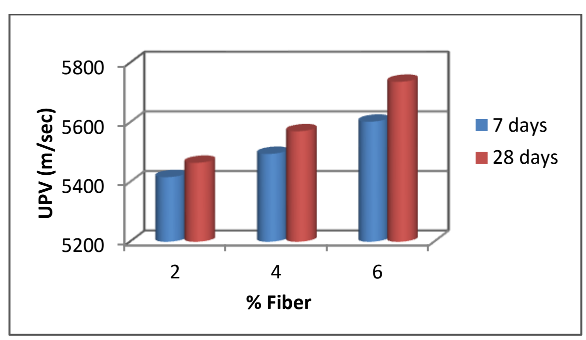

Fig.4.8 Comparison of Ultrasonic Pulse Velocity of SIFCON with Fiber Fraction

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5.CONCLUSIONS

The Following conclusions can be drawn based on the experimental study conducted on the strength characteristics of slurry infiltrated fibrous concrete.

1. Slurry infiltrated fibrous concrete produced with binding steel wires shown higher compressive strength, Split tensile strength and modular rupture strength
2. Small addition of fibers into slurry infiltrated fiborous concrete (0% fibers) can enhance the strength characteristics.
3. From the experimental study, it can be said that strength properties of SIFCON significantly increased as the percentage fibre volume fraction increases. The strength characteristics of SIFCON with 6%fibre fraction shown more strength than other two fibre fractions.
4. Amongst 2, 4 and 6 % of fibre volume fractions, 6% fibre fraction showed the maximum values in Compression, Split tensile and and Modulus of Rupture Strength. This is due to the higher volume fraction of fibres used in the specimen.
5. The increase in Compressive Strength of SIFCON with 4% of fibre fraction is 8.7% at 28days when compared to SIFCON with 2% of fibre fraction. Similarly SIFCON with 6% of fibre fraction is 17% at 28days when compared to SIFCON with 2% of fibre fraction.
6. The increase in Split Tensile Strength of SIFCON with 4% of fibre fraction is -25.61% at28days when compared to SIFCON with 2% of fibre fraction. Similarly SIFCON with 6% of fibre fraction is 87.71% at 28days when compared to SIFCON with 2% of fibre fraction.
7. The increase in Modulus of Rupture Strength of SIFCON with 4% of fibre fraction is 46.55% at 28days when compared to SIFCON with 2% of fibre fraction. Similarly SIFCON with 6% of fibre fraction is 125.81% at 28days when compared to SIFCON with 2% of fibre fraction.
8. The insitu strength of concrete obtained by rebound hammer test is found to be good indicating quality of concrete is good without ansy voids.

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