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Research paper



Effect of Fibre Content on Mechanical Behavior of Slurry Infiltrated Fibrous Concrete

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Abstract

Cement mortar or slurry is an essential material for production of Slurry Infiltrated Fibrous Concrete (SIFCON) structural components. However, there have been limited technical data available for deciding a suitable mix proportions and water cement ratio. For achieving a good quality of mortar mix or slurry with specific strength requirement and satisfactory level of workability for proper infiltration ability of cement slurry fibrebed. The preliminary study was carried out to select suitable mix and W/C from various mixes (1:1, 1:1.5 &1:2) and W/C (0.4, 0.45 & 0.5)on fresh and hardened properties of cement mortar. The optimum mix proportion and water cement ratio were obtained on workability (flow table test) and compressive strength of cement mortar are found to be as 1:1 and 0.40 respectively for fabrication of SIFCON. The main focus of this investigation on the behaviour of SIFCON contains various volume fraction of fibre content with an optimum mix(1:1) and W/C (0.4) under static loading. Hooked end steel fiber length of 30mm and tensile strength of 1050MPais used throughout the entire investigations. Cubes of 100 x 100 x 100mm for compressive strength and cylinders of 100mm diameter and 200mm height for split tensile strength were cast and tested at 3, 7 and 28 days. For flexural strength, three SIFCON beams of length 1200mm and cross section of 100mmx 200mm were cast and tested at 28 days under three point bending. The parameters like fracture energy, load deflection response, split tensile strength and compressive strength were found and compared the results with conventional mix. The test results observed that the strength performances were greatly improved due to addition of fibre by volume fraction in SIFCON matrix. Also developed the regression model from the experimental results to estimate the compressive and split tensile strength and compared the predicted values with the experimental values.

Keywords: *SIFCON, Compressive strength, Water cement ratio, Workability, Regression model, Fracture energy*

1. Introduction

Modern structural requirements demand materials that improve the basic properties of concrete such as ductility behavior, stiffness, strength characteristics, energy absorption, ultimate stiffness and abrasion resistance. Fibre reinforced concretes is prepared with various types of fibres have been found many structural applications. However, the ductility of fibre reinforced concrete mainly depends on the volume of fibre content which is used in the fabrication of composite concrete. The other factors such as fibre geometry, l/d ratio, fibre orientation and tensile strength are also influencing the performance of concrete. SIFCON is an excellent composite material possessing superior mechanical behaviour with larger energy-absorption characteristics. In fibre reinforced concrete, the volume of fibre content ranges between 1% to 3% by volume fraction, while in SIFCON the fibre volume ranges varies from 6% to 20%. The method of production of slurry infiltrated fibrous concrete is different from FRC. SIFCON is produced by infiltrating the mortar or slurry over a prepacked fibres bed.

SIFCON was created by Lankard in USA in the year 1983. The increased amount of fibre content in Slurry infiltrated fibrous concrete improves the toughness characteristics. [1] studied the basic mechanical properties like impact strength, flexural strength, load deflection behaviour compressive strength and abrasion resistance and concluded that the strength behaviour were improved due to increased volume of fibre content.

Halityazıcı 2010[2] investigated the effect of partial replacement of class C flyash and the fibre content on toughness and flexural strength of SIFCON and reported that the toughness and flexural strength were improved due to addition of fibre content and incorporation of higher percentage of partial substitution of flyash.[3] studied the elastic properties of SIFCON in compression and revealed that the stress-strain characteristics of hooked end fibres shows better performance than crimped fibres. [4] reported that the flexure and impact resistance of SIFCON and reported that the specimens exhibit superior ductility, resistance to cracking and spalling of mortar and also sustain heavy loads with larger deflections due to high volume of fibre content. [5] studied the performance of reinforced SIFCON slabs subjected to flexure and observed that the first crack strength and ultimate were increased with the addition of higher volume of fibre content than lower volume fraction of fibres. The stiffness behaviour of reinforced SIFCON slabs were superior than FRC and RCC slabs. [6] reported the performance of SIFCON two way slabs subjected to punching shear and concluded that the SIFCON slab specimens with conventional reinforcement exhibits higher shearing capacity than RCC and FRC slabs and also observed that the formation of first crack strength attained at 12% of fibre content. SudarsanaRao,(2010) [7], investigated the impact strength of SIFCON slabs contains various percentage of fibre content and found that the SIFCON slabs exhibits larger amount of energy absorption capacity than RCC and FRC. Among the reinforced and unreinforced SIFCON slabs, the greater energy absorption capacity was attained at 12% of fibre content than 8% and 10%

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fibre content. Farnam 2010 8 [8] investigated experimentally the triaxial compressive performance of SIFCON and reported that the improvement of poisons ratio and triaxial compressive strength due to increased volume of fibre content and confining pressure than HPFRC and HSC. [9] investigated the shearing properties of slurry infiltrated fibrous concrete (SIFCON) subjected to pure torsion and found that the shear strength was increased due to addition of fibre content and fibre orientation [10] investigated the bond strength of SIFCON and concluded that the pull out strength was developed due to interlinking between the matrix and fibre due length and geometry of also the pullout toughness was improved due to increasing length of fibres embedded into the matrix. [11] studied the behavior of restrained SIFCON two way slabs in punching shear -2and the results revealed that the SIFCON slabs with 12% of fibre content exhibits superior performance such as failure loads crack patterns and deflections than all other slabs. Also developed the regression models for estimating the punching shear.[12] investigated the load deflection response, toughness indices, resilience, ultimate load, first crack load, and concrete and found that the hooked end fibres shows better performance than crimped fibres.[13] investigated thethe influence of partial substitution of silica fume for cement and fibre content in high strength concrete and concluded that due to partial substitution of silica fume and addition of fibre in high strength concrete improves the toughness characteristics.

2. Experimental Investigations

2.1 Materials

The following materials were used throughout the entire experimental work and the chemical and physical properties of materials were studied as per IS code.

Cement
Cement grade of 53as per IS 12269 [14] was used. The initial setting time of 30 minutes and final setting time 340 minutes. The specific gravity is 3.1.

Fine aggregate
Locally available river sand passing through 4.75mm sieve conformed to IS: 383-1970 [15]. The specific gravity was found to be 2.62 which isused as a fine aggregate.

Steel fibre
Hooked end steel fibre length of 30mm and having a diameter of 1mm was used. The fibres were oriented in a random manner.

Super plasticizer
CONPLAST- 420, a high range water reducing admixture has been used for improving the infiltration ability into the fibre bed.

Water
Fresh and clean potable water which is available from local sources was used for casting and curing.

2.2 Mix Proportions

The mix proportions of SIFCON mixes are presented in Table 1. The various other factors like fibre type, fibre orientation, l/d ratio, slurry strength etc. influencing the performance of SIFCON.

Table 1: Mix proportion of SIFCON mixes

Sl.No.	Type of mix	Mix proportions	Volume of fibre	W/C	SP	Mode of compaction
1.	PCC	C:FA:CA (1:1:2.8)	-	0.39	-	Hand
2.	SIF6	Cement and sand (1:1)	6%	0.4	2%	Hand
3.	SIF8	Cement and sand (1:1)	8%	0.4	2%	Hand
4.	SIF10	Cement and sand (1:1)	10%	0.4	2%	Hand

2.3 Casting and Testing of Specimens

The methodology adopted for the present study is as follows:
The preliminary study was carried out on fresh and hardened properties of cement mortar by conducting workability (flow table test) and compressive strength test for selecting the suitable mix proportion from various mixes 1:1, 1:1.5 and 1:2 with varying W/C of 0.4, 0.45 and 0.5.
The main focus of this paper investigated the influence of fibre content in SIFCON on split tensile, compressive and flexural strength were investigated. Initially, fibres were prepacked into the mould and a constant cement slurry mix 1:1 with W/C of 0.4 is prepared and poured into the packed fibre bed. Manual compaction was done to ensure the infiltration of slurry into fibre bed. The specimens were demoulded after 24 hours and kept in water for 3, 7 and 28 days.

3. Results and Discussions

3.1 Effect of mix proportions and water cement ratio

Workability test
Workability of cement mortar was conducted by using flow table test. Fig.1 shows the workability of different mix proportions of cement mortar with three different W/C ratios. From the test results found that the flow percentage was increased with increasing W/C and cement with increasing amount of cement. The optimum mix proportion was found to be 1:1.

Compressive strength
Fig.3 shows the compressive strength of different mixes of cement mortar at 28 days. From the test results observed that the strength decreases with increasing water cement ratio at all mixes. The compressive strength of all mixes with W/C 0.4 shows slightly higher than 0.45 and 0.5. It was observed that the optimum water cement as 0.40.

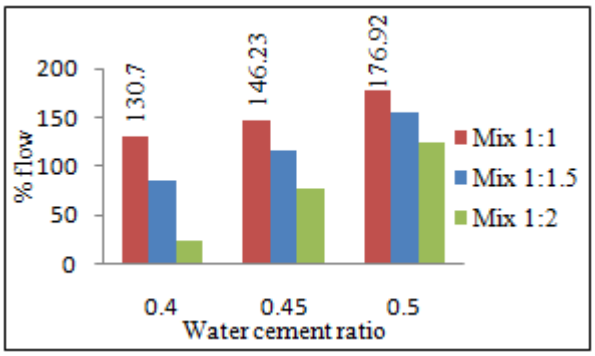

Fig. 1: W/C vs % of flow

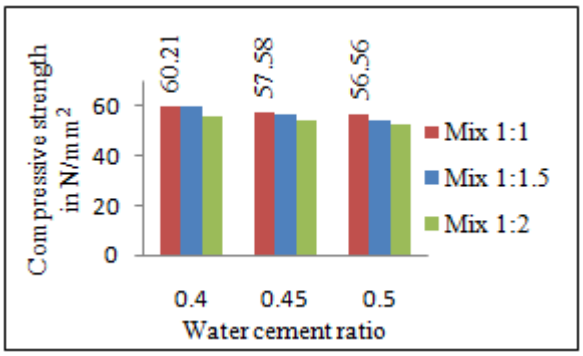

Fig. 2: W/C vs compressive strength

3.2 Effect of Fibre Content in SIFCON

Compressive strength

From the test results revealed that the compressive strength of SIFCON matrix increased due to addition of higher volume of fibre content. The maximum compressive strength was attained at 10% of fibre content as 65.5N/mm^2 compared to all other mixes. The strength improvement due to higher volume of fibre content gives better interlocking between the matrix and fibre. The strength of SIFCON contains 10% of fibre volume was getting increased by 24% compared to conventional mix.

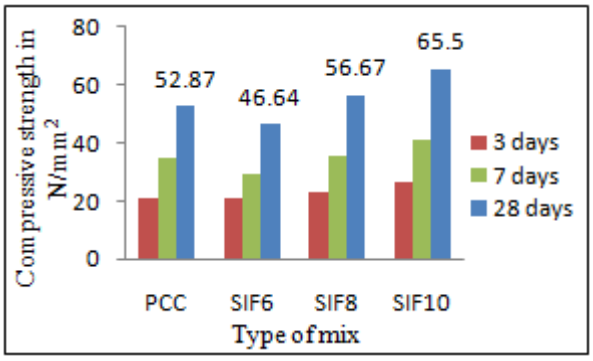

Fig. 3: compressive strength of various mixes

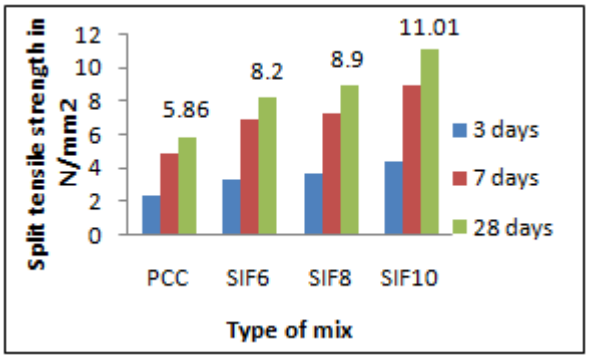

Fig. 4: Split tensile strength of various mixes

Split tensile strength

Fig.4 shows the split tensile strength of different mixes. Split tensile strength of SIFCON matrix containing 6%, 8% and 10% fibre content increased by 40%,51.8% and 87.8% respectively compared to conventional mix (PCC). It is clearly shows that the split tensile strength was increased with increased fibre content by volume fraction. This may be attributed due to better fibre bridging mechanism between the matrix.

Regression models for strength

Developed the regression model from the results for estimating the strength characteristics slurry infiltrated fibrous concrete incorporation of various percentage of fibre content. Linear regression technique is adopted for developing the regression model. The linear regression model is in the form of

y = ax+b- eqn. (1)

Where y and x are dependent independent variables, a and b are regression coefficient. a&b can be determined from linear regression model based on least square method. The suggested linear equation for predicting the strength characteristics at 28 days were obtained from the following expressions

y = 4.715x + 18.55 - eqn. (2) -Compressive strength

y = 0.702x + 3.75 - eqn. (3)- Split tensile strength

The estimated values from regression models were compared with experimental test results of SIFCON containing various volume of fibre content on compressive strength as shown below in fig.4(a). Similarly, the split tensile strength experimental results were compared with the predicted values as shown fig.4(b). It is clearly observed that the developed linear regression models were satisfied to predict the strength characteristics of SIFCON containing volume fraction of fibre content.

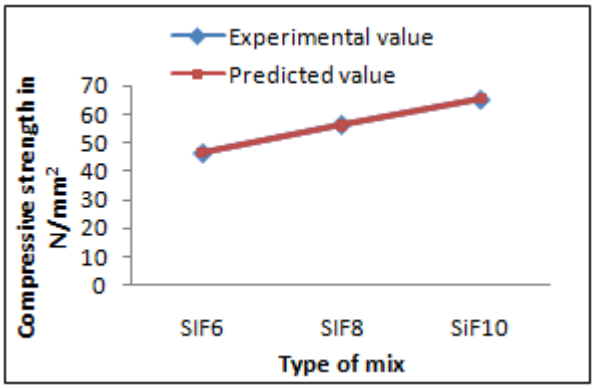

Fig. 4(a): Comparison of experimental and predicted values (Compressive strength)

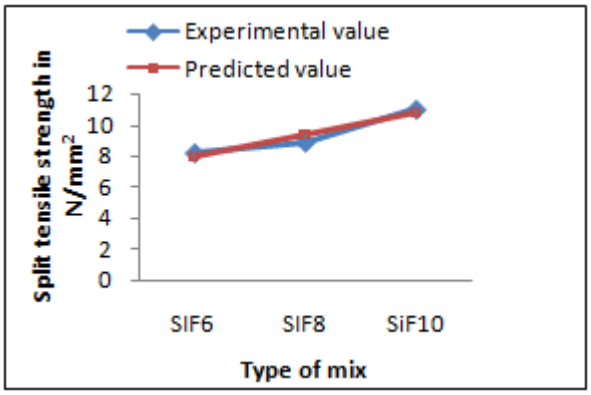

Fig. 4(b): Comparison of experimental and predicted values (Split tensile strength)

Load Deflection response

Fig.5 shows the load deflection response of different mixes. The ultimate load carrying capacity of SIFCON specimens were higher than RCC specimen, because SIFCON exhibits excellent ductile characteristics. This increase may be attributed to improved matrix bond linked with the formation of less porous zone. The toughness was calculated area under load deflection curve. The toughness was increased with increased volume of fibre content, because the higher amount of fibre content in SIFCON improves the ductile behavior.

Fracture energy

Fig.6 shows the fracture energy of different mixes. The fracture energy was calculated from the following expressions

Fracture energy G_f= W + mg ∂ (L´ /L) /A ---------- eqn. (4)

(Eqn.4 based on RILEM50-FMC Committee of Fracture Mechanics of Concrete 1985)

Where G_f - fracture energy (N/m)

W – area under load deflection curve upto ultimate stage

∂ - deflection at ultimate stage

L and L ´ – length and span length of the beam

A –area of cross section of the beam

Fracture energy depends on the area under load deflection curve. Fracture energy of SIFCON shows excellent performance due to high volume of fibre content compared to RCC. Among the SIFCON matrix, the maximum fracture energy was attained at 10% of fibre content than all other mixes. The improvement of bond strength between the matrixmay be due to the increased volume of fibre content. in the matrix.

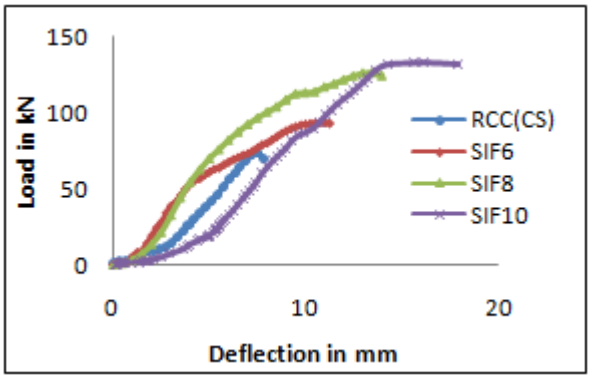

Fig. 5: Load deflection curve

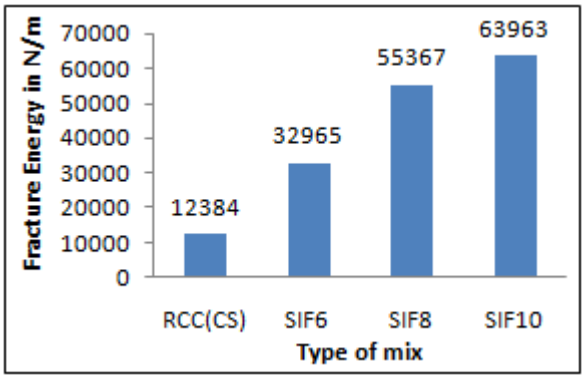

Fig. 6: Fracture energy of different mixes

4. Conclusions

The major conclusions were drawn from the experimental investigations as follows:

- The optimum mix proportion and W/C of cement mortar are found to be 1:1 and 0.4 respectively.
- The compressive and split tensile strength of SIFCON containing 10% of fibre content attained maximum strength compared to all other mixes. this performance may be due to densification of matrix improves bond strength and pull out behavior of fibre.
- The improvement of ultimate load carrying of SIFCON containing high volume of fibre content. This behavior may be attributed to the stronger interface zone between binder and fibers which improves the bond strength and reduces the progress of micro-cracks which leads to flexural failure.
- The fracture energy of SIFCON containing 10% of fibre content by volume fraction is higher than all other mixes. This improvement may be due to the formation denser microstructure and bond strength between the matrix and fibres.
- Based on the experimental results, regression models were suggested to evaluate the strength performance. The predicted values were satisfied with the experimental results obtained.

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