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Experimental investigation on Fly ash based Slurry Infiltrated Fibrous Concrete (SIFCON) in Normal and Aggressive Environment

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Abstract: Slurry infiltrated fibrous concrete (SIFCON) can be considered as a special and advanced type of steel fibre reinforced concrete composite. SIFCON is produced by infiltrating a rich flowable cement slurry into the bed of preplaced fibres in the mould. The usage of rich mortar in production of SIFCON liberates excessive amount heat, which may cause shrinkage problems and lead to cracking. The cement is replaced with optimum quantity of fly ash in order to reduce the heat of hydration and to minimise the cracks which in turn improves the strength and durability characteristics of the composite. In this paper, an attempt has been made to investigate the mechanical properties of fly ash based SIFCON under normal and aggressive atmospheric conditions. An ordinary Portland cement was partially replaced by three different percentage of Class F fly ash (10%, 15% and 20%) in SIFCON slurries with incorporation of three different volume fraction of fibre content (2%, 4% and 6%). The test results indicated that the SIFCON specimen with 15% of FA and 6% of fibre content is found to be optimum both in normal and aggressive environmental conditions. Further, it is also found that the optimum mix yielded a compressive strength of 54.25 N/mm^2 under normal atmospheric condition whereas the same is 47.5 N/mm^2 under aggressive environment. It was also concluded that the incorporation of steel fibre content in the matrix developed the marginal increase in compressive strength.
Keywords: Fly ash, SIFCON, Aggressive environment, Compressive strength.

1.Introduction

The behaviour of SIFCON affected by four main factors such as slurry strength, fibre volume, fibre alignment and type of fibres. The available published literature on many design factors and strengthening of SIFCON is briefly reviewed.

HalitYazicietal[1] investigated the effects of steel fibre alignment and partial replacement of high volume mineral admixtures such as Flyash(FA) and Ground Granulated Blast Furnace Slag (GGBFS) on the mechanical properties of SIFCON. Ordinary Portland cement was partially replaced by 50% of FA or GGBS in SIFCON slurries and alignment of steel fibres in two different forms of orientation (random orientation and one direction orientation). Test results showed that replacement of FA and GGBS positively affected the strength characteristics but the incorporation of mineral admixtures enhances the durability characteristics and orientation of fibres alignment is an important factor for excellent performance of SIFCON. Sudarsana Rao et al.[2] studied the performance of Slurry infiltrated fibrous concrete two way slabs under punching shear. It is observed that the first crack strength was increased with increased percentage of fibre content in punching shear. Murat Tuyan et al.[3] investigated Pull-out behaviour of single steel fiber from SIFCON matrix and concluded that increasing the diameter of the fibre and improving the curing conditions increased matrix–fibre bond and an increasing bond strength. The pull-out toughness was increased by increasing embedded length of fibre. It has been observed that hooked end fibres have shown better interface bond compared to the smooth fibres. Sundarsana Rao et al.[4] studied the behaviour of slurry infiltrated fibrous concrete slabs under impact loading. The test was conducted by using impact testing machine with steel ball drop weight. The results reveals that SIFCON slabs with 12 % fibre content exhibits excellent performance in strength and toughness characteristics compared to Fibre reinforced concrete, Reinforced cement concrete and plain cement concrete slab specimens. JayeshKumar et al.[5] studied the experimental investigations on partial substitution of cement with fly ash in concrete mix design. Cement was partially replaced with flyash in the range of 0%, 10%,20%,30% and 40% for making concrete mix design normal and high strength concrete mix. The Compressive strength and split tensile strengths were decreased with increased percentage of flyash content, but cost of concrete decreased due to reduction of quantity of cement. . Arunachalam et al.[6] studied and performed the experimental investigation on high performance fly ash concrete in normal and aggressive environment. An Experimental investigation was conducted on mechanical properties of High strength Concrete with partial replacement of fly ash (25% and 50%) and without replacement of flyash (control specimen) under normal and aggressive environment. Iralda et al.[7] studied the action of atmospheric agents against reinforced concrete. In aggressive atmospheric conditions, more concentration of sulphates causes degradation of concrete structures and corrosion of steel reinforcement. This study concluded that to protect the reinforced concrete structures from the careful study of stability design, preventive measures. Jose Aguiar et al.[8] investigated on the performance of concrete in aggressive environment. Surface treatments act as a barrier between the surrounding and to prevent the entry of water and harmful substances into the concrete.

2 Experimental investigations

2.1 Materials used

Cement, fine aggregate, fibre and water (normal and aggressive environment) were used in casting of concrete. The main significance of this investigation is carried out to know the properties and behaviour of fly ash based SIFCON under normal and aggressive atmospheric conditions. The specifications and properties of various materials which is used for production of flyash based SIFCON are as follows.

2.1.1 Cement

Ordinary Portland cement of 53 grade confirming to IS 12269 was used. The specific gravity of the cement as 3.15 as per IS-2720 (Part – 3). The initial setting and final setting time of cement were found as 30 minutes and 300 minutes respectively as per IS- 4031 (Part – 5). The chemical composition of cement was presented in Table 1.

Table 1 Chemical composition of cement and fly ash

S.No.	Chemical Composition (%)	Cement	Fly Ash
1	Silica (SiO_2)	21.8	58.3
2	Alumina (Al_2O_3)	6.6	31.7
3	Ferric oxide (Fe_2O_3)	4.1	5.9
4	Calcium oxide (CaO)	60.1	2.0
5	Magnesium oxide (MgO)	2.1	0.1
6	Sodium oxide (Na_2O)	0.4	0.8
7	Potassium oxide (K_2O)	0.4	0.8
8	Sulphuric anhydride (SO_3)	2.2	0.2
9	Loss on Ignition (LOI)	2.4	0.3

2.1.2 Fine aggregate

Locally available river sand passing through 4.75mm IS sieve was used for making SIFCON slurry. The specific gravity of the sand is found to be 2.65.

2.1.3 Fibres

Hooked end steel fibres with diameter 1.00 mm and length of 30 mm giving aspect ratio of 30 was used. Fibres were disbursed in the form of random manner. The main significance of fibre in slurry utilizing two mechanisms, one is spacing mechanism and another one is crack bridging mechanism.

2.1.4 Class F Flyash

Fly ash particles are generally spherical in shape and range in size from 0.5 µm to 300 µm. Chemical composition of fly ash was presented in Table1. The burning of harder, older anthracite and bituminous coal typically produces Class F fly ash contains less than 20% lime (CaO).

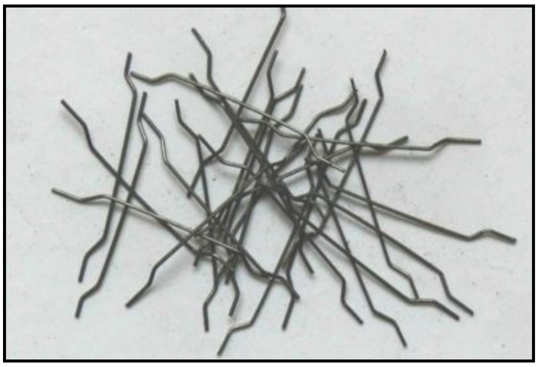

Fig.1 Hooked end Steel fiber

Fig.2 Cubes in curing

2.1.5 Water

Fresh water available from local source was used for casting and curing of SIFCON, conforming to IS: 456-2000. Water with two different qualities were used for casting and curing of SIFCON specimens to stimulate normal and aggressive environmental conditions. The first quality of water which is suitable for making concrete was used for casting and curing of specimens under the normal atmospheric condition and the second one is not suitable for concreting, fresh water containing certain considerable amount of ammonium sulphate and sodium chloride to make the water more aggressive and the same water was used for curing of specimens. Table 2 showed the amount of solids added to fresh water to make it more aggressive according to IS 3025.

Table 2 Amount of solids added to make aggressive atmosphere

S.No	Solids	Amount limit for normal water	Amount used for aggressive water
1	Sulfate	400mg/l	600mg/l
2	Chloride	500mg/l	700mg/l
pH values		Not less than 6	4.2

2.1.6 **Super plasticizer**

Super plasticizer is also known as high range water reducers which is used to improves the workability of mix and flow ability of SIFCON slurry into the bed of preplaced fibres. CONPLAST- 430, a high – range water reducing agent has been used.

2.2 Mix proportions

The mix proportions of flyash based slurry infiltrated fibrous concrete specimens were presented in Table 3. Water binder ratio as 0.5 was used. High range water reducing admixture was added to the mix for improving flow ability into the bed of preplaced fibre and workability of slurry.

Table 3 Mix proportions of SIFCON specimens

S.No.	Type of mix	Mix proportion	Replacement of cement with flyash	W/C ratio	Dosage of superplasti-cizer	Mode of vibration
1.	SIFCON-2 NA	1:1	10%	0.5	1.5%	Table vibrator
2.	SIFCON-4 NA	1:1	15%	0.5	1.5%	Table vibrator
3.	SIFCON-6 NA	1:1	20%	0.5	1.5%	Table vibrator
4.	SIFCON-2 AA	1:1	10%	0.5	1.5%	Table vibrator
5.	SIFCON-4 AA	1:1	15%	0.5	1.5%	Table vibrator
6.	SIFCON-6 AA	1:1	20%	0.5	1.5%	Table vibrator

***NA – Normal Atmosphere** ***AA- Aggressive Atmosphere**

2.3 Casting of specimens

The cubes of size 100 x 100 x 100 mm were casted and tested for determining the compressive strength of SIFCON specimens under normal and aggressive environmental conditions. The moulds were placed on a levelled surface and oil was applied on the sides to remove the specimens easily from the mould. The steel fibres were packed in the mould upto full depth and light external vibration was done during fibre placement for getting random orientation. Fine grained flyash based cement slurry was poured into the prepacked fibre bed with subsequent infiltration of the slurry aided by vibrator to ensure the infiltration of slurries into the bed of prepacked fibre. High range water reducing admixture was added to the slurry to improve the flowing ability of infiltration and workability of mixed slurry. The cube specimens were demoulded after 24hours of casting and cured in water for 28 days under normal and aggressive environment. After curing the specimens were taken out wiped the surfaces and kept air.

2.4 Testing of the specimens

2.4.1 Compressive Strength

The compression test has been conducted using Compression testing machine capacity of 3000kN shown in figure 4. Cubes of size 100 x100 x100mm were casted and tested at the age of 28 days of curing under normal and aggressive conditions. The specimens were placed in the testing machine and load was gradually applied till the failure of the specimens and noted down the breaking load for determining compressive strength of the specimen.

Fig.3 Testing of Cubes

Fig.4 Crack pattern of Cubes

3. Results and Discussions

The results of compressive strength of fly ash based SIFCON specimens were noted down for both normal and aggressive atmospheric conditions. The Fig.5 and Fig.6 shown the graphical representations of the compressive strength of SIFCON specimens with different combinations of fly ash and fibre content under normal and aggressive atmosphere. The test results indicated that the SIFCON specimen with 15% of FA and 6% of fibre content is found to be optimum both in normal and aggressive environmental conditions. Further, it is also found that the optimum mix yielded a compressive strength of flyash based SIFCON specimens under aggressive condition was slightly decreased by 14% when compared to SIFCON under normal atmosphere. It was clearly observed that the strength of SIFCON specimen was increased due to the increased percentage of fibre content both in normal and aggressive environment.

Table 4 Compressive strengths of SIFCON under normal and aggressive Atmosphere

Sl.No.	% of Fly Ash	Average compressive strength of			Average compressive strength of		
		Fiber 2%	Fiber 4%	Fiber 6%	Fiber 2%	Fiber 4%	Fiber 6%
1	10	31.34	42.05	50.09	24.42	34.15	43.88
2	15	33.32	45.82	54.25	28.25	40.56	47.50
3	20	31.23	42.17	48.99	22.08	32.82	42.64

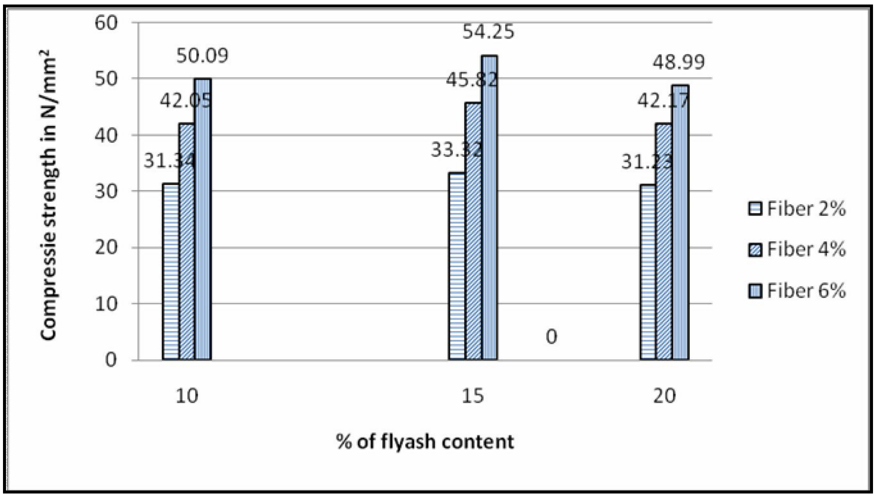

Fig.5 Compressive strength vs % of fly ash under normal atmosphere

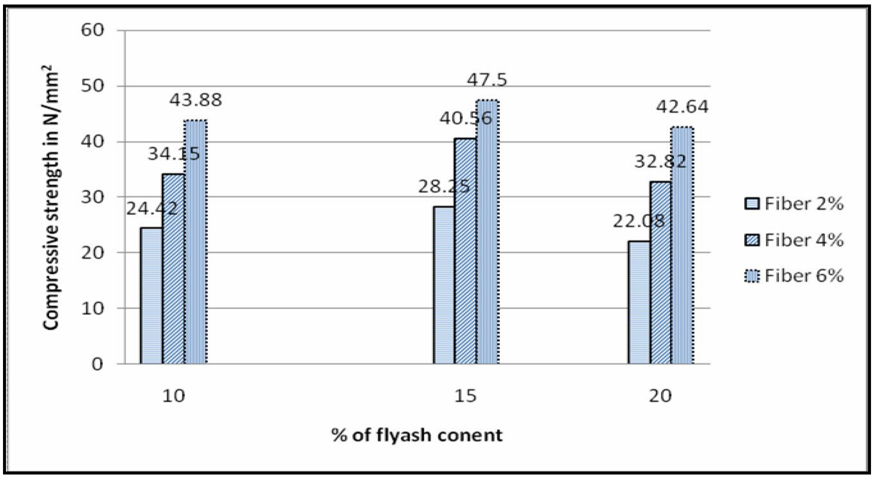

Fig.6 Compressive strength vs % of flyash under aggressive atmosphere

4. Conclusions

Based on the results obtained from the experimental study, the following conclusions have been presented

1. The excessive replacement of cement with fly ash reduces the compressive strength of SIFCON under both normal and aggressive environment, but due to the incorporation of increased percentage of steel fibres developed the marginal increase in compressive strength.
2. The best combination of percentages of replacement of cement with fly ash observing the above graphs and tables is 6% of fibre with 15% of flyash replacement were performed well under normal atmosphere when compared to the aggressive atmosphere.
3. The compressive strength of fly ash based SIFCON was increased with 6% of fibre content under both normal and aggressive condition. Hence it is clear that the compressive strength was increased by incorporation of fibre content with high volume fraction(6%) When compared with fibre content of 2% and 4% by volume fraction.

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