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Slurry Infiltrated Fibrous Concrete (SIFCON) -A Review

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A B S T R A C T

The paper discusses the development of the slurry infiltrated fibrous concrete and its applications in the structural engineering over the past two to three decades. A review of prior research papers shows that the Slurry infiltrated fibre concrete having high compressive strength, high strain in compression, and better ductility showed. And its application in structures due to their high strength in compression, tension, and shear, toughness and ductility behaviour. This paper describes various material used as a replacement of cement like fly ash, GGBS, sand as well as methods used for determination of mechanical and durability properties of SIFCON by various researchers. The paper concludes by summarizing successes of the slurry infiltrated fibre concrete in the structural engineering and suggests areas in which, if they are employed innovatively, SIFCON composites could be used to great advantage.

Keywords: SIFCON, compressive strength, steel fibres, GGBS, fly ash, sand, matrix, Fibre reinforced concrete.

1. Introduction

Concrete is strong in compression but it is equally weak in tension. Hence, the use of plain concrete as a structural material is limited to situations where significant tensile stresses and strains do not develop. In the past study, attempts have made to impart improvement in tensile strength property of concrete members by using reinforcement in the concrete. Although, both these methods provide tensile strength to the concrete members but they do not increase the inherent tensile strength of concrete itself. In plain concrete structural cracks develop even before loading particularly due to drying shrinkage. It has recognized that the addition of small, closely spaced and uniformly dispersed fibres to concrete would act as a crack arrestor and would substantially improve its static and dynamic properties.

Today it is steel fibre, which is mainly used to reinforce concrete and overcome the problem of brittleness (Katzer 2006). The strength of composite largely depends on the quantity of fibres used. The increase in the volume of fibres increases the tensile strength and toughness of the concrete. But if a higher percentage of fibre i.e. more than 2% is used, it is likely to cause segregation and balling in concrete and in mortar. Slurry infiltrated fibre concrete (SIFCON) is a special type of fibre reinforced composite containing as much as 20% (by volume) of steel fibres (Lankard 1984). In conventional FRC, the fibre volume fraction is generally limited to about 2%. Mixing and placing becomes difficult if the fibre volume exceeds 2%. Hence, a different the first development of SIFCON was introduced by Lankard Materials Laboratory, Columbus, Ohio, USA, in 1979, by incorporating large amounts of steel fibres in steel fibre reinforced cement-based composites. Investigated and provided information about durability of SIFCON, mainly permeability, resistance to chloride penetration, freezing and thawing and drying shrinkage. Investigate the properties of durability of SIFCON under two categories that was slurry fibre and mortar fibre with different percentage of fibre (hooked or crimped) contents 7%, 9.5% and 12% by volume. In this research work not focused on replacement for sand and cement. (Gilani2007) An experimental investigation carried out to study the mechanical properties of fly ash based SIFCON by replacing cement with 10%, 20% and 30% of fly ash. Fibre content in SIFCON was varied from 6%, 8% and 10% they reported reduction in compressive strength when increased percentage of fly ash but at the same time positive response showed by fibre. In this they focused on mechanical properties of fly ash based SIFCON (Elavarasi2013). Yazici et al. (2010) reported the mechanical properties of SIFCON with various steel fibres and minerals admixtures. Experimental investigation showed that FA and GGBS replacement positively affected mechanical properties and fibre alignment is an important factor for superior performance however, GGBFS did not change the viscosity remarkably. Parameswaran et al. (1993) studied the mechanical properties of SIFCON they reported SIFCON specimens with 8 percent fibre content showed a fivefold increase in (hypothetical) ultimate flexural strength over companion plain mortar specimens. SIFCON specimens exhibited greater ductility and greater resistance to cracking and spalling of concrete, the abrasion resistance, impact resistance and the toughness indexes than normal FRM specimens, Yazici et al. (2006) carried out experimental work on mechanical properties of autoclave SIFCON with high volume fly ash.

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Test results indicate that Class C fly ash replacement has a positive effect on all mechanical properties of SIFCON in contrast to plain concrete and high- volume Class C fly ash mixtures are suitable for autoclave production of high strength SIFCON. Svermov et al. (2002) presented the work and result showed that the influence of different water/binder ratio, dosage of super plasticizer, limestone powder, viscosity agent and sand combinations on the rheological behavior of fresh cement slurry was investigated. SIFCON has more advantageous properties than conventional FRC. The crack propagation of SIFCON presents irregular multi crack phenomenon and the density of crack increases with the increase of fibre content. (Ipek 2014).

2. Research significance

The main objective of the current study is to review and assess recent experimental results in the field of slurry-infiltrated fibrous concrete (SIFCON). The review study is focused on type of materials used in SIFCON, mix design, methods of preparation and definition of the main properties of SIFCON that have strong influence on structural behavior.

3. Preparation of SIFCON

Generally, SIFCON prepared by using a pre-placing technique in which first fibres placed in the casting mould then poured the slurry of cement on the rich fibre layers. The fibres placed in the mould by hand or by using fibre – dispersing units. The quantity of fibres that can be depends on an aspect ratio of fibre, geometry of fibre, and placement methods of fibres, increasing the fibre fraction if aspect ratios are low. The volume fraction can also be increased by using mild vibration. The fibre volumes typically range from 5% to 20%. In the fabrication of SIFCON the orientation of fibres is an important aspect. Flexural performance of SIFCON improved due to fibre orientation. The effect of fibre orientation on fracture energy is considerably higher than flexural strength. Ultrahigh performance can achieve with an improvement in the matrix phase low water/binder ratio, GGBS replacement and autoclave curing and with fibre orientation. This negative effect diminished when the matrix phase improved. On the other hand, the compressive strength of hardened slurry has been improved greatly in the case of random fibres. (Yazici et al.2010).

3.1 Constituent materials and mix proportions

The primary constituent materials of SIFCON are steel fibres and cement-based slurry. The slurry can contain only cement, cement and sand, or cement and other additives like Fly Ash, Silica Fume, GGBS, and Metakaolin. In most cases, high range water-reducing admixtures used in order to improve the flow ability of the slurry without increasing the water-cement ratio. In previous research generally used the cement slurry, rarely used addition of sand and otherCementous material. In the present day focused on researcher on new additives with economic consideration and without deterioration of strength and durability**.**

3.1.1 Steel fibres

The various types of fibres have investigated for use in SIFCON. These include fibres with hooked ends, crimped fibres, surface deformed fibres, and straight fibres (Gilani2007, Lankard 1984 Naaman1991, and Homrich 1987). The length-diameter ratios range from 60 to 100. Crimped and straight fibreshave also been used for some applications. Hooked-end steel fibres were used. Fibres are 30 mm long with the diameter of 0.75 mm. The aspect ratio and tensile strength of this fibre are 40 and 1,100 MPa; respectively. The length of each hook portion of the fibre is 4.5 mm. (Yazici et al.2010) Most common steel fibres have a length from 25 to 60mm, and a diameter ranging from 0.4 to 1 mm. Their aspects ratio (l/d), that is, the ratio of length over diameter or equivalent diameter, is generally less than 100, with a common range from 40 to 80 (Parameswaran et al.1993). Hooked ended steel fibre shown in figure1

3.1.2 Matrix

The matrix of SIFCON does not contain any coarse sand and aggregates. The matrix compositions observed in previous research works include cement, cement-fly ash, cement-silica fume, cement-sand-fly ash, and cement-sand-silica fume. Matrices containing filler materials were found to have better shrinkage characteristics. The matrix compositions investigated include cement-GGBS improvement on the flexural strength and fracture energy is between the 58 and 138% in I-GGBS matrix compared to the random fibre case. (Yazici et al.2010)

3.1.3 Mix proportions used in SIFCON

The main constituents of SIFCON matrix are cementitious material slurry and fibre fraction without adding coarse aggregate. The volume fraction of fibres could differ depending on the fibre placement technique and the fibre geometry. Only fines and should be used. If fly ash is used as an admixture, about 20% of the cement could be replaced with fly ash. If silica fume is used, the recommended dosage is 10% by weight of cement. The typical matrix strength varies from 9 to 13 ksi (60 to 90 MPa) (Sonebi et al.2005). The increase for fibres in SIFCON increasing the joint capacity of connected member in joint with 6 to 8 percent volume of fraction of fibre in SIFCON matrix particularly no crack visible observed at the 8 percent of volume fraction of fibres (Elnono et al.2009).

3.2 Engineering properties of SIFCON

The properties of slurry infiltrated fibre concrete (SIFCON) are discussed in the following subsection.

Table 1 - Some SIFCON slurry and mortar mix design from the literature.

Researcher	SIFCON Composition Cement	Fine Sand	W/c Ratio	Fly Ash	Silica Fume	GGBS	SP
Gilani 2007	1	-	0.40	-	-	-	-
	1	1	0.40	-	-	-	0.012
Ipek et al. 2014	1	0.87	0.3	-	0.30	-	0.4
Svermova et al.2002	1	1	0.45	-	-	-	0.9
	1	1	0.45	0.10	-	-	0.015
Elavarasi et al.2013	1	1	0.45	0.20	-	-	0.015
	1	1	0.45	0.30	-	-	0.015
Parameswaran et al.1993	1	1	0.375	0.20	-	-	0.030
	1	1.5	0.375	0.20	-	-	0.050
	1	1.15	0.390	-	0.15	-	0.043
Yazici et al.2006	1	1.08	0.490	0.20	0.15	-	0.043
	1	1.005	0.65	0.40	0.15	-	0.043
	1	0.932	1.01	0.60	0.15	-	0.043
	1	0.99	0.42	-	-	-	0.0091
Yazici et al.2010	1	0.825	0.85	1	0.20	-	0.0078
	1	0.97	0.85	-	0.20	1	0.0065

3.2.1 Unit weight

The unit weight of SIFCON is typically higher than conventional concrete and normal FRC because of the relatively heavy weight of the high fibre content. For a slurry unit weight of 1920 kg/m^3, the addition of steel fibres results in an increase in density varies from 2160 to 3130 kg/m^3, for steel volume fraction ranging from 5 to 20 volume percent.

3.2.2 Compressive strength of SIFCON

SIFCON recognized for its high compressive strength. The highest compressive strength reported for SIFCON is 210 MPa. The composite is also very ductile as compared to a plain matrix. The compressive behavior of SIFCON investigated using both cast and cored cylinders, and the variables investigated included (Van *et al.*1991, Svermova *et al.*2002 and Van *et al.*1991)

(a) Fibre orientation effect - parallel and perpendicular to the loading axis. b) Fibre geometry - hooked ends, crimped, and deformed.

(c) Matrix composition - plain cement matrix, matrix containing sand or fly ash, silica fume, GGBS or their combinations.

Table 2 shows the range of compressive strengths obtained for various SIFCON matrix mix proportions and Table 3 present properties of different types of fibres used in SIFCON. An increase in matrix strength resulted in an increase of SIFCON compressive strength. Fibre geometries showed less influence than matrix strength. An increase in matrix strength results in an increase of SIFCON compressive strength. Replacement of manufactured sand (M-sand) in mortar SIFCON gives the better compressive strength as compared to natural sand (Krishnan *et al.*2014).

3.2.2.1 Stress-strain behavior in compression

Even though SIFCON has typically higher compressive strength than normal concrete, its uniqueness is much more important in the area of energy absorption, ductility and toughness. A great energy absorbing capacity and a ductile mode of failure, make SIFCON suitable and perfect for applications involving impact, blast, and earthquake loading. Fibre alignment also affected the compressive strength of SIFCON greatly. (Yazici *et al.*2010) This behavior is quite different from conventional fibre-reinforced concrete. In the case of oriented fibre placement, two different loading types were applied in uniaxial compressive test; loading parallel to the fibres and perpendicular to the fibres.

Table 2 - Slurry mix design and compressive strength values (Gilani 2007, Elavarasi *et al.*2013 and Yazici *et al.*2006)

Mix No.	Constituents	Relative Weight of Constituents	Water –Cementitious ratio	Strength Range (MPa)
1	Type 1 cement	1		
	Fly ash	0	Water/Cement	53.52
	Water	0.40		
	Superplasticizer	0.012		
2	Type 1 cement	1		48.20
	Fly ash	10		
	Silica fume	0	Water/(Cement +Fly Ash)	
	Water	0.45		
	Superplasticizer	1.5		
3	Type 1 cement	1		

	Sand Fly ash Water Superplasticizer	1 20 0.45 1.5		45.42
4	Type 1 cement	1		
	Sa nd Fl y as h W ate r Superplasticizer	1 30 0.45 1.5	**Water /(Cement+Fly Ash)**	39.70
5	Type 1 cement Sand GGBS Wa ter Fly As h Silica Fume Superplasticizer	1 0 0.5 0.42 0.06 0.1 0.065	**Water/(C.M+GGBS+F.A+S.F)**	77-101

Table 3 - Reported fibre properties

Fibre Type	Length (mm)	Diameter (mm)	Aspect Ratio, (l/d)	Vf (%)	(Vf.l/d)
Deformed (Abdollahi et al.2012)	30	0.30	100	5-6	500-600
Crimped (Elavarasi et al.2013)	50	1.00	50	6-10	300-500
Black annealed steel wire(Rao et al2010)	50	1.00	50	8-12	400-600
Hooked (Krishnan et al.2014)	30	1.00	30	4-9	120-270
Straight round steel fibres (Van et al.1991)	30	0.40	75	6-8	450-600
Straight round steel fibres (Van et al.1991)	40	0.40	100	6-8	600-800
Hooked (Yazici et al.2010)	30	0.75	40	25	1000

3.2.3 Tensile strength of SIFCON

The tensile strength of SIFCON is about three times the strength of the plain matrix. (Elavarasi *et al*.2013, Elnono *et al*.2009) Table 4 presents the tensile strengths for various combinations of SIFCON matrix compositions, fibre types and fibre volume fractions. A matrix of SIFCON containing silica fume, fly ash shows that higher strength than plain matrix. As comparison with fly ash by silica fume and matrix, containing silica fume provides higher strength. Water cement ratio of matrix of SIFCON also affects the tensile strength of SIFCON. Lower the water cement ratio increased the tensile strength of SIFCON. Tensile strengths are greater for fibre volume fractions higher than 10 % compared to volume fractions lower than 10 %. The tensile strength of SIFCON can exceed 20 MPa, compared to the plain matrix of 7 MPa (Elavarasi *et al*.2013, Elnono *et al*.2009). Tension tests consisted of uniaxial tensile tests on dog bone-shaped prism specimens. Tensile strength of SIFCON has been investigated for about 9 matrixes shown in the Table 4 ranged from5 ksi (34.5 MPa) to 6.7 ksi (46.23 MPa) for the fibre volume fraction (v_f) ranged between 12to 27percent, and fibres primarily parallel to the loading axis (Naaman *et al*.1991).

3.2.3.1 Stress-strain behavior in tension

As in the case of compression, SIFCON exhibits high ductility in the tension mode. Typical stress-strain curves obtained using hooked ended steel fibre types and volume fractions.

Table 4 - Results of tension tests (Naaman *et al.*1991)

Matrix	Fibres	Vf percent	f' ksi(MPa)	E, ksi(MPa)
Mortar 1	30mm deformed	27.0	5.0(34.50)	9100(62790)
		23.9	4.6(31.74)	6500(44850)
Mortar 2	30mm deformed	23.9	4.5(31.05)	10900(72210)
		23.9	5.6(38.64)	8000(55200)
Mortar3	30mm deformed	23.9	3.7(25.53)	8300(57270)
		22.8	6.3(43.47)	6300(43470)
Slurry	30mm deformed	27.0	4.6(31.74)	10200(70380)
		27.0	5.0(34.50)	8300(57270)
Mortar1	30 mm hooked	15.6	5.6(38.64)	4400(30360)
		15.6	4.9(33.81)	3500(24150)
Mortar2	30 mm hooked	16.7	7.0(48.30)	4600(31740)
		16.7	5.2(35.88)	4000(27600)
Mortar3	30 mm hooked	16.4	5.5(37.95)	4600(31740)
		16.4	5.8(40.02)	4400(30360)
Slurry	30 mm hooked	15.6	4.8(33.12)	3200(22080)
		16.7	4.6(31.74)	5000(34500)
Mortar2	50 mm hooked	12.2	5.4(37.26)	4600(31740)
		12.2	6.7(46.23)	4500(31050)

3.2.4 Flexure strength of SIFCON

Table 5 presents the flexure strengths for four fibre lengths and various fibre contents together with the compressive strengths of slurry obtained using cube specimens.

(a) The flexural strength of SIFCON is an order of magnitude greater than the flexure strength of normal fibre-reinforced concrete.

(b) For a constant fibre length, the flexure strength increases with the volume fraction of fibre only up to a certain limit. After certain fibre content, the bond strength decreases because of the lack of matrix in between the fibres, thus reducing the flexure strength. The optimum fibre content seems to be in the range of 8 % to 10 %.

(c) The optimum fibre volume seems to decrease with an increase in fibre length. For the same fibre volume, longer fibres provide a slight increase in flexure strength.

3.2.4.1 Behavior under flexure loading

In the most field applications, SIFCON is subjected to bending stress, at least partially. Hence, the behavior under flexure loading plays an important role in field applications. Flexure tests have been conducted using SIFCON beams both under static and cyclic loading.

The effects of both fibre alignment and matrix phase on flexural strength of composites presented in test results showed that flexure strength increases significantly with fibre orientation and using with mineral admixture. For instance, flexure strength of hardened control slurry is only 4.4 MPa while this value reaches up to 47 MPa in case of the random fibres and 55 MPa for oriented case. Furthermore, replacement of cement with FA or GGBS positively affected the flexure strength. Flexural strength of both FA50 and GGBS50 composites are over 70 MPa for random fibres and over 80 MPa for oriented fibres. (Yazici *et al.*2010) SIFCON specimens with 8 percent fibre content showed a fivefold increase in (hypothetical) ultimate flexural strength over companion plain mortar specimens and a two-fold increase over normal FRM specimens with 2 to 4 percent fibre content. Higher fibre percentages also gave higher ultimate flexural strength for the same aspect ratio. (Parameswaran et *al* 1993) With the increasing amounts of steel fibres, the flexural strength and toughness improved for all mixtures. For instance, the flexural strength (Yazici *et al.*2006)

Table 1 -Flexural strength of SIFCON (Yazici et al.2010, Parameswaran et al 1993)

Types of Fibre	Fibre (length/dia.) (mm)	Fibre Volume (%)	Aspect Ratio	Maximum Flexural Strength (MPa)
Straight round steel fibres	30/0.4	6	75	32.4
	40/0.4	6	100	28.8
	30/0.4	8	75	40.8
	40/0.4	8	100	36.8
hooked steel fibres	30/0.55	2	55	20-24
	30/0.55	6	55	32-38
	30/0.55	10	55	40-55
hooked steel fibres	30/0.75	25	40	55
	30/0.75	16	40	47

3.2.4.2 Load-deflection behaviour in flexure

The load-deflection behavior of a SIFCON is quite different from the load-deflection behavior of typical FRC beams. The curves have a relatively short linear elastic response and a considerable plateau at the peak. The beams can also sustain a high percentage of peak loads (more than 80 % of peak load) even at large deflections.

3.2.5 Behaviour under Shear

The shear strength parameter of Fibre reinforced concrete has been studied (Van *et al.*1991) but the equation of shear strength in FRC does not perform accurately for shear strength prediction in SIFCON. Shear tests on SIFCON have been performed with direct, double shear specimens, direct shear specimen's torsion specimens (Balaguru *et al.*1987 and Naaman *et al.*1995), and specimens under combined tension and shear (Van *et al.*1991). Each of these tests was performed with various proportions of cementitious materials with addition of super plasticizer slurry strengths, different fibre volume of fibre fraction (Vf) and aspect ratio reinforcement indexes (l/d), and fibre types.

3.2.6 Bond Strength of SIFCON

The bond characteristics of reinforcing bars embedded in SIFCON has investigated (Hamza 1992). The SIFCON was prepared with 5 % of hooked steel fibres of 50 mm long and 0.5 mm diameter. The compressive strength of SIFCON was 61.4 MPa. Based on the test results conducted in those studies, Pull- out peak load increased with the increase in embedded length of fibre. Peak load of hooked-end steel fibres was higher than those of smooth steel fibres. Debonding toughness of hooked-end fibres increased with compared to smooth steel fibres. The fibre–matrix interface bond depends dramatically on the physical properties of the fibre. It was observed that as the diameter of fibre increased, interface bond between fibre and matrix increased. Pull-out peak load decreased for equal length fibres as the aspect ratio of fibre increased. Curing conditions affected the fibre–matrix interface bond significantly. It was also determined that bond strength between fibre and matrix increased as the curing condition improved. (Tuyan et al.2012)

3.3 Durability of SIFCON

A very few literatures information available on durability aspect of SIFCON with addition of pozzolanic material as Fly ash, Silica Fume, GGBS, and Metakaolin. The only available information was solely about drying shrinkage and resistance to freezing and thawing. Water absorption, and chloride penetration the following sections present the available results of those two aspects of SIFCON durability.

3.2.1 Drying shrinkage strain

The low shrinkage of SIFCON compared to plain slurry is probably due to the high fibre content, as well as to the nature of the reinforcing bed, in which the fibres form contacts with each other, generating a fibre interlock effect (Bentur *et al.*1990). Generally, the addition of sand reduces the shrinkage of thematrix considerably. Hence, SIFCON made with cement-sand mortar observed that less shrinkage strain than in which the slurry by only cement. The drying shrinkage test has performed on unreinforced slurry and various percentage of volume of fibre fraction used. The different types of fibre viz. hook ended steel fibre and crimped fibre with 7%, 9.5% and 12 % used. (Balaguru *et al.*1992)

3.2.2 Freezing and thawing resistance of SIFCON

The durability of SIFCON under freezing and thawing has evaluated previously in only one study (Kendzulak 1986). The investigation was conducted using the rapid freeze-thaw procedure similar to the one recommended in ASTM C 666, Procedure. Half of the slurry cubes disintegrated in the freeze-thaw chamber where none of the SIFCON prism specimens disintegrated. However, there was considerable scaling on the SIFCON surfaces. After the freeze- thaw cycles, the specimens were tested in flexure. Because of the scaling, the flexural strength reduced considerably. The reduction in strength ranged from 26 % to 43 % compared to control specimens. (Svermova *et al.*2002). It has observed that from the previous study when increased in fibre content, then decreased in shrinkage. Moreover, the multiple micro cracks developed on the surfaces of slurry-infiltrated fibre concrete found due to the shrinkage. Consequently, slurry SIFCON specimens experienced 50 % to 100 % less shrinkage than mortar SIFCON. For the effect of fibre shape on the drying shrinkage, it has observed that specimens made with hooked fibres showed less shrinkage when compared to those made using crimped fibres. (Gilani2007) The weight loss, if any, is due to surface scaling in specimens because of the deterioration effect caused by repetitive freezing and thawing. According to the test procedure, the specimen considered to have failed if its weight loss exceeded 5.0 %(ASTM C 666- 1997).

3.2.3 Resistance to Chloride penetration

Corrosion of steel reinforcement, caused primarily by chloride attack, is one of the major causes of deterioration of reinforced concrete structures. SIFCON should be more susceptible to problems related to chloride penetration because, when compared to concrete, it has almost no protecting cover and it includes high quantities of steel fibres distributed throughout the SIFCON element. In spite of their relatively higher absorption, all investigated SIFCON matrices showed lower total chloride ion contents by mass of cement when compared with the control concrete. This resulted from the combined effect of the high concentrations of steel fibres, and the high cement contents (40 % to 70 % compared with only 20 % in concrete). (Gilani 2007)

3.2.4 Resistance to water absorption

Deterioration of concrete structures is generally caused by penetration of aggressive agents (sulphates, chlorides, moisture, CO2) into the concrete interior. Thus, concrete durability is strongly related to the quality of its cover, which corresponds to the first few centimeters of material below the surface of the structure. Porosity and permeability are widely recognized durability indices; since they quantify the resistance of the material against penetrating agents (Lankard 1984), the high-water content in slurry SIFCON increases the permeability. SIFCON, in general, has very high absorption capacities that range from 2 to 5 times of the control concrete absorption, depending on the matrix composition. Inclusion of steel fibres reduces the absorption. The higher is the fibre content, the lesser is the absorption. (Gilani 2007)

4. Conclusion

Following critical observations have been made from the above literature review of Slurry infiltrated fibre concrete (SIFCON).

1 The major part of the study on the SIFCON based on strength oriented.

2 Some researcher has made the investigation on replacement of cement and fine aggregates and tried to achieve the economy.

3 Limited literatures are available on durability based on the SIFCON.

4 Some researcher has been made the investigation on durability study only on slurry infiltrated fibre concrete (SIFCON) and slurry infiltrated fibre concrete (SIFCON) with sand

5 In this above research work, there is no any work performed on abrasion resistance, RCPT (Rapid chloride permeability test) and water permeability, acid resistance and Impact resistance test on Slurry infiltrated fibre concrete with various pozzolanic materials with the replacement of fine aggregate and cement.

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