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STATE OF ART – REVIEW OF SLURRY INFILTRATED CONCRETE (SIFCON)

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ABSTRACT-Slurry Infiltrated Fiber Concrete (SIFCON) is a high-performance concrete used in structures exercising impact load during service. It is a special type of high performance fiber reinforced concrete (HPFRC). This consists of high strength fibers infiltrated with cement based matrix which differs from steel fiber reinforced concrete (SFRC).The addition of higher percentage of fibres ranges from 4-20% against the limit of 3% fibers in SFRC because of the balling effect of fibers. Matrix may be cement slurry or flowing mortar with sand passing through 1.18mm sieve. Fibers serves as an excellent crack arrestor, helps in reduction of stiffness degradation and increases cumulative ductility and energy absorption capacity. Sifcon is capable of sustaining higher loads with very less deflection and the regions with SIFCON are found to be intact after ultimate failure. It also helps in the reduction of shear reinforcement in the congested areas by its sufficient shear and bond strength. SIFCON has potential for applications such as beam column joints, repair and rehabilitation, retrofitting and explosive resisting structures. This paper presents reviews on SIFCON, its advantages and applications and concludes that SIFCON is superior to conventional concrete in terms of flexural, shear, axial tension and compressive strength. It details the experimental investigations and analytical computations in SIFCON.

Keywords- SIFCON, toughness, crack-bridging, blast loading, flexure.

I.INTRODUCTION

Slurry infiltrated fiber concrete (SIFCON) is a special fiber concrete, which mainly improves the ductility of concrete and is essential in developing high performance. In recent years SIFCON is profoundly used in construction of high rise buildings, off shore structures and mega structures due to its crack arresting and seismic resistant properties.Predominant durability and energy absorption properties of SIFCON shows the potential utilization territory in modern floors, reinforcing and retrofitting works, blast resistant military structures. It is found to be extremely resistive to higher temperature, thereby increasing the service life of the structures. The method of using steel fibers with cement matrix was first proposed by Haynes (1968). Later Lankard (1979) and several research scholars modified the method used by Haynes and proved that the use of steel fibers improves the strength of concrete and possess crack resistance property. The main difference between Fibre Reinforced Concrete (FRC) and SIFCON is the fiber content, matrix composition and casting process. In FRC 1-3% (by volume) fibers were mixed together in random and the specimen casting is followed. Whereas in SIFCON the volume of fiber 6-20% was preplaced in the mould and the cement matrix is infiltrated. In SIFCON the matrix is flowing cement mortar which infiltrates into preplaced fibre bed, whereas in normal fibre concrete the fibres are incorporated into wet or dry mix of concrete. The major type of materialscommonly used as fibres for the preparation of Slurry infiltrated fibre concrete are glass, steel, polypropylene, polyester, carbon and. It is evident that fibre matrix bond is significantly affected by mechanical properties of matrix, mineral additives, fibres type and length, fibre morphology, curing conditions, matrix strength. The incorporation of high fiber content increases the flexural stiffness, toughness and the crack propagation are reduced. SIFCON, when placed in plastic hinge regions and beam- column joints reduce the congestion of stirrup reinforcement thereby increasing the spacing of stirrups in beam column joints and in regions adjacent to beam column joints. Therefore,SIFCON is used in ductility needed places like pavement repairs, safe vaults, defense structures, repairs of bridge structure etc. SIFCON can also absorb considerable amount of energy, so it is used in structures subjected to impact and dynamic loading.

II. LITERATURE REVIEW

TABLE I
LITERATURE REVIEW

S. NO	TITLE	AUTHOR	COUNTRY	YEAR	A,E, N	TYPE OF LOADING	VARIABLES	REMARKS
1	Steel fibers as shear reinforcement in beams	G.Batson, E.Jenkins and R.Spatney	U.S.A	1972	A,E	Two point loading	Type of fiber, percentage of steel fiber, spacing of fiber and shear span ratio	Experimental results revealed that replacement of vertical stirrups by steel fibers increase shear strength. This case prevails when shear span ratio less than 3.
2	Behaviour of slurry infiltrated fiber concrete (SIFCON)	P.Balaguru	U.S.A	1987	E	Monotonic, cyclic and reverse cyclic loading	Fiber length, fiber volume content and type of slurry.	SIFCON possess high ductility in flexure, direct shear, axial tension and compression with optimum fiber content 8%.
3	Slurry infiltrated fiber concrete (SIFCON)	David R. Lankard	U.S.A	1987	E	Static, Third point loading	w/c ratio, fiber volume, aspect-ratio	This study concludes that SIFCON increases the strength of about 80-100% and energy absorption capacity of about 200-400% over ordinary concrete. The type of fiber available needs further research.
4	Behaviour of high volume fiber content mortar in flexure	V.S Parameswaran, T.S Krishnamoorthy and K.Balasubramanian	India	1990	E	Static and cyclic load	Fiber volume, fiber length, aspect ratio, mix proportion, mode of vibration, water-cement ratio and percentage of superplasticizer	Test results indicate that specimen with straight fiber 30mm length and fiber volume 8% shows high flexural strength.
5	Durability of fiber reinforced mortar	K.Kosa, A.E Naaman and W.Hansen	Japan	1991	E	Four point loading	Mortar mix, dimension of crack-induced specimen, composite type and exposure condition.	All the sifcon specimens tend to exhibit limited reduction in toughness and strength after 10 months severe corrosive environment.
6	Shear properties of slurry infiltrated fiber concrete	M.L Wang and A.K Maji	U.S.A	1994	E	Static, Four point loading	Diameter of specimen, fiber aspect ratio, orientation of fibers	The size of the Sifcon specimens for the torsion test should be at least three times the fibre length.
7	Flexural strength of reinforced concrete T-beams with steel fibers	Ramzi B.Abdul-Ahad and Omer Qarani Aziz	Iraq	1999	A,E	Two point loading	Percentages of steel bars and steel fibers.	An experimental result shows that over reinforced concrete beam is economical instead of using steel fibers in T-beams compression zone.

8	A quantitative study on the surface crack pattern of concrete with high content of steel fiber	An Yan, Keru Wu, Xiong Zhang	Republic of Korea	2002	E	Static loading	Fiber content	Quantitative study reveals that the increase of fiber content relatively increases the density of crack. Fractal dimension can characterize the crack pattern and it is responsible for the increase of compressive, bending strength and toughness index.
9	Autoclaved sifcon with high volume class C fly ash binder phase	HalitYazici, Huseyin, Serdar Aydin and Bulent Baradan	Turkey	2006	E	Static loading	Steel fiber volumes and different ratios of flyash	FA replacement at 10% fiber volume provides good result when compared to FAO matrix. Results indicate that silica fineness and lime content increases strength.
10	Flexural strength of reinforced concrete beams with and without steel fibers	Shailendra Kumar	India	2006	A,N	Two point or single point loading	Steel fiber volume, aspect ratio, presence and absence of steel fibers.	The semi-empirical equation proposed predicts the ultimate flexural strength of steel fibrous concrete beams. Flexural strength characteristic curve gives the beam properties.
11	Response of SIFCON Two-way slabs under impact loading	H.Sudarsana Rao, Vaishali G.Ghorpade, N.V Ramana and K.Gnaneswar	India	2010	A,E	Impact loading	Fiber volume, mode of vibration, mix proportion, water -cement ratio, type of slab, presence and absence of reinforcement in SIFCON and FIBER reinforcement slab	SIFCON slab with reinforcement shows superior strength compared to fiber concrete slab, R.C.C and P.C.C slab.
12	Normal strength steel fiber reinforced concrete subjected to explosive loading	Mohammed Alias Yuaof, Norazmar, Ariffin, FquziMohd Zain, Risby and CP Ng	Malaysia	2010	E	Explosive loading	Volume of steel fibers, type of specimen, length of hooked end steel fiber in SFRC panel	Steel fiber concrete containing 1.5% volume of fibers shows significant resistance to explosive loading when compared to normal reinforced concrete.
13	Role of flyash in high performance concrete	Mr. G.S Thirugnanam, Dr. P. Govindan	India		E	Cyclic loading	With and Without fly ash	Investigation on rate of fly ash indicates that addition of fly ash reduce the ultimate load carrying capacity and energy absorption capacity.
14	Study on flexure behavior of slurry infiltrated fibrous concrete (SIFCON)	Mr. R.Harish, S.Karthik and T.Devaraj	India	2012	E	Reverse Cyclic loading	Type of beam	Study reveals that load carrying capacity and first crack load of SIFCON beams was 1.77 times and 2.33 times more than conventional RC beam.
15	Slurry	Kuldeep	India	2012	E	Monotonic	Fiber length,	Results show that tensile,

	infiltrated fibrous concrete (SIFCON)	Dagar				and high-amplitude cyclic loading	type of loading	compressive, flexural and shear strength is higher in SIFCON compared to plain concrete. The length of fiber does not affect the shear strength.
16	Pull-out behaviour of single steel fiber from FIBER matrix	Murat Tuyan and HalitYazici	Turkey	2012	E	Static loading	Type of hooked fibers, embedded length of hooked fibers, curring methods, slurry design, diameter of steel fibers.	An experimental result indicates that hooked-end steel fibers has higher peak load compared to smooth steel fibers. Autoclaved curing with increase in diameter and embedded length of fiber provides higher strength.
17	Flexural behaviour of slurry infiltrated fibrous concrete (SIFCON) composite beam	K.Parthiban, K.Saravanarajamohan and G.Kavimukilan	India	2014	E	Static loading	Sifcon volume ratio, type of specimen	The addition of SIFCON in conventional concrete, FRC, RCC improves the load carrying capacity, energy absorption and toughness.
18	Experimental study on slurry infiltrated fibrous concrete with sand replaced byM-Sand	M.Gopala Krishnan	India	2014	E	Static loading	Percentage of fiber	Increase in strength of cubes and cylinders is observed due to the M-Sand replacement
19	The effect of pre-setting pressure on the flexural strength and fracture toughness of SIFCON during the setting phase	MetinIpek, Mecbure Aksu, Kemalettin Yilmaz and MuctebaUysal	Turkey	2014	E	Compression pressure	Pressure levels, length and diameter of steel fiber, size of quartz sand and powder	Flexural strength, fracture toughness and unit weight were increased when 3Mpa pre-setting pressure was applied.
20	Strength and behaviour of SIFCON with different types of fibers	ArunAniyan Thomas, Jeena Mathews	India	2014	E	Static, Two-point loading	Volume and type of fibers	Results shows the optimum fiber content of about 5% steel fiber greatly influence the strength of SIFCON specimen
21	Flexural behaviour of fly ash based slurry	Sini Pavithran, D. Elavarasi and Dr. K.	India	2015	E	Static loading	Fiber volume	Experimental results concludes that the concentration of fiber in SIFCON beams increases the load carrying capacity,

	infiltrated fibrous concrete	Saravana Raja Mohan						flexural strength and energy absorption
22	Behaviour of Steel fiber reinforced high strength concrete filled FRP tube columns under axial compression	TianyuXie, TogayOzbakkaloglu	Australia	2015	E	Static loading	Type of concrete,type of steel fibres, fiber volume fraction, fiber aspect ratio	Concrete filled FRP tubes with hooked end fibers proved high compressive strength and ultimate strain.
23	Use of precast SIFCON laminates for strengthening of RC beams	Yogesh.N. DhamakMadhukarR. Wakchaure	India	2015	E	Static	Volume fraction of fibers, laminate confinement	Increase in stiffness, ductility and energy absorption capacity was proved in sifcon laminated specimens.
24	Flexural strength properties of slurry infiltrated fibrous concrete beams using miraculous berry fiber as reinforcement	OlufemiS. Awogboro, Oladipupo S.Olafusi, FestusA.Olutoge,Issac B.Oni		2015	E	Static	Volume of slurry, concrete	Miraculous Berry fiber replacement has proved higher flexure strength, sustained high deflection and less crack width
25	Flexural performance of SIFCON composite subjected to high temperature	Ahsanollah Beglarigale, CaglarYalcinakaya, HuseyinYigiter,Halit Yazici	Turkey	2016	E	Static	Curing temperature	Flexural strength is 5-25 times higher at 300^0C but reduction in the cross section of steel fibers, decrease in flexural strength and destruction of C-S-H structure at elevated temperatures above 300^0C

Where, A-Analytical; E- Experimental; N-Numerical

III. DISCUSSION

In this detailed investigation about SIFCON, it is evident that addition of SIFCON in conventional concrete reduces the crack propagation thus increasing load carrying capacity with minimum displacement. SIFCON-RCC-Composite shows high strength compared to conventional RCC beam. The failure pattern is similar in all SIFCON beams. It is evident that flexural crack is followed by diagonal cracking of specimen and a similar failure pattern is observed in all Sifcon beams. The diagonal crack becomes discontinuous at some point due to bridging effect on the application of impact or explosive load. The crack-bridging mechanism is able to resist the heavy load thus increasing the energy absorption capacity (toughness value).

IV. CONCLUSION

From the detailed investigation carried on the SIFCON, the following conclusions are drawn out.

1. The load carrying capacity of reinforced SIFCON beam is much greater than fiber reinforced beam and conventional reinforced beam.
2. Volume of fiber, type of fiber, orientation of fiber are the main parameters that governs the flexural, toughness, shear and tensile strength.
3. Failure in SIFCON is due to improper bonding between fibers and matrix.
4. Addition of silica fume increases the strength.
5. SIFCON can be used in structures subjected to impact loading.

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