SSRG International Journal of Civil Engineering Volume 8 Issue 3, 1-5, March 2021
ISSN: 2348 – 8352 /doi:10.14445/23488352/IJCE-V8I3P101 ©2021 Seventh Sense Research Group®

Experimental Investigation On The Strength Characteristics of Slurry Infiltrated Fibrous Ferrocement

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Received Date: 27 February 2021
Revised Date: 19 March 2021
Accepted Date: 03 April 2021

Abstract - *Ferrocement is a highly versatile and lightweight material having high cracking, ductility, and fatigue resistance. It is used for prefabricated residential units, industrial and marine structures. Slurry infiltrated fiber concrete (SIFCON) is a unique type of fiber concrete that consists of cement slurry. It is used for pre-stressed concrete beams. Slurry infiltrated fibrous ferro cement (SIFF) is a combination of SIFCON and ferrocement and can overcome the limitations of the later. SIFF can be used for the structures like runways in aerodromes, industrial flows, etc. This project deals with an experimental investigation on the strength characteristics of SIFF using flat steel fibers in 0.2%, 0.4%, 0.6% with replacement of metakaolin in 0%, 5%,10%, 15%, 20% by volume of cement. CONPLAST 430 superplasticizers which as an admixture used to reduce the water-cement ratio. The strength of concrete with replacement of flat steel fiber and metakaolin was observed, which exhibits good strength.*

Keywords - *Ferrocement, Fibers, SIFF, SIFCON, Metakaolin, CONPLAST430, and Superplasticizers.*

I. INTRODUCTION

Concrete is that the most ordinarily used man-made construction material. It is obtained by mixing cement, aggregates, and water (and sometimes admixtures) in the required proportions. In its hardened state, concrete should be strong, durable, and impermeable; among the various properties of concrete, compressive strength is considered to be the most important associated is taken as an index of its overall quality. Plain concrete has some disadvantages as follows low tensile strength, little resistance to crack propagation, and little brittle in nature.

During the manufacture of concrete, micro cracks develop in materials itself due to inherent volumetric and microstructural changes. Under load, virgin micro cracks develop at a low tensile strain, which on increased loading ultimately lead to uncontrolled growth of microcracks.

The inherent deficiency of the concrete material because of its low tensile strength can be overcome to a good extent by reinforcing plain concrete with strong, stiff steel fibers for long-term load carrying properties and performance.

Fiber reinforced concrete **(FRC)** is ordinary concrete containing discrete fibers of small diameter and short length, uniformly distributed in the matrix. The fibers act as crack arresters that restrict the growth of flaws within the matrix, dominant them from enlarging under stress into cracks that eventually cause failure. Due to its excellent cracks material with high resistance to cracking, high plastic strength and ductility can be obtained.

Slurry infiltrated fibrous concrete **(SIFCON)** can be thought of as replaced fiber concrete, with the placement of fibers in a form or mold on a substrate, as the initial construction step. The replaced fibers are subsequently infiltrated with fine-grained, hydraulic cement water-based slurry.

Ferrocement may know as a type of thin reinforced concrete construction where cement mortar matrix is reinforced with many layers of continuous and relatively small diameter wire meshes. While the mortar allows the mass, the wire mesh gives tensile strength and ductility to the material.

To get the advantages of both SIFCON and Ferrocement, and to overcome the limitations of the above to some extent, a new material called Slurry Infiltrated Fibrous Ferrocement **(SIFF)** is introduced, and it can be employed with assurance where high vibrations, high impacts, and high wear and tear are expected. In our project work, an experimental investigation on the strength characteristics of Slurry Infiltrated Fibrous Ferrocement (SIFF) is carried out by keeping fiber percentage as constant and varying the percentages of Metakaolin.

II. LITERATURE REVIEW

Sudhikumar 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 which of plastic fiber was 800 and 1600. The results indicated that lower facet ratios of steel, GI, and plastic fiber yield higher compressive strength, a better energy absorptive material that may end in higher flexural strength, toughness indices, and impact strength.

Yashar SHAFAEI (2012) carried out a study on fibers having length/aspect quantitative relation 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 also can seriously have an effect on the properties of SIFCON, where one can control the orientation easily. These properties are modulus of elasticity, flexural strength, stress-strain behavior, 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 kind and volume fraction of fibers to reach admirable energy absorption capacity and durability.

Naman and boccouche(5) presented the shear response of dowel reinforced SIFCON. They observed that the shear strength of SIFCON is 10 times above that of a plain matrix. The behavior of reinforced concrete beams with SIFCON matrix has been studied by Namanetal(6). They reported that the use of SIFCON eliminates the necessity of shear stirrups in RCC beams. The behavior of SIFCON below pure torsion has been presented by Balasubramanianetal(8). SIFCON with straight, crimped, and trough formed fibers has been prepared and investigated for torsional resistance.

Parameswaranetal(9) has studied the flexural behavior of SIFCON beam specimen under cyclic loading and reported that the flexural strength is 500 % more when compared with plain mortar specimens and 100% more to that of Ferro cement specimens.

In 1972, the National Academy of Sciences of the US of America set up an Adhoc Panel on the use of ferrocement in developing countries under the chairmanship of Prof. James P. Romualdi of Camegie-Mellon University, U.S.A. The report of the panel was first published in early 1973. As a result of the report, people became conscious of this material and began using it.

The ACI committee 549[1] has outlined Ferro cement as a "thin wall ferroconcrete commonly constructed of portland cement mortar reinforced with closely spaced small diameter wire mesh." The mix is generally of cement and sand mortar, wherever the wire mesh was having wide openings which make adequate bonding of mixture.

III. MATERIALS USED

Cement: The choice of the cement content depends on the strength requirements, exposure classes for durability, and the minimum amount of fine aggregate requires in the mix. The cement used for this project is ordinary Portland cement of 43-grade.

Fine Aggregate: The sand is of river sand screened and washed to get rid of all the organic and inorganic components. The specific gravity of sand is 2.68. Sand has been sieve in 4.75mm and retained in 150 microns. Sand is taken from the local construction area.

Coarse Aggregate: The coarse aggregate that is used for the concrete is 20mm of most size, and that they should be angular and well graded. It is taken from the local construction area. The particular gravity of the coarse combination is 2.83.

Flat Steel Fiber: Steel fiber for reinforcing concrete is defined as a short, discrete length of steel fibers with an aspect ratio. The flat steel fiber with an aspect ratio of 25mm was used. Flat steel fibers are collected from industry. Its appearance clear, bright, and flat steel fiber.

Metakaolin: The particle size of metakaolin is smaller than cement particles. It improves the properties of concrete and cement product. Metakaolin powder was bought from the shop. The specific gravity of metakaolin is 2.5, and its physical form is a white powder.

Super Plasticizers: It can be used in concrete to reduce the mixing water and W/C ratio inorder to increase the strength and improve the durability. The specific gravity of the superplasticizer is 1.22. It is in liquid form, and its color is brown.

Water: Water obtainable in the college campus conforming to the wants of water for concreting and curing as per IS: 456-2000.

IV. MIX DESIGN FOR M_{25} GRADE CONCRETE

Step 1: Design stipulations for proportioning

Grade Designation = M_{25}
Type of cement = O.P.C-43 grade
Maximum nominal size of aggregate = 20mm
Minimum cement content = 340 kg/m^3
Maximum cement content = 450 kg/m^3
Maximum water content = 0.42
Workability = 100mm slump
Exposure condition = Mild
Degree of supervision = Good
Type of aggregate = Crushed angular

Step 2: Test data for materials

Specific gravity
Cement = 2.85
Fine aggregate = 2.65
Coarse aggregate = 2.67
Water absorption
Fine aggregate = 1%
Coarse aggregate = 4.5%
Free moisture
Fine aggregate = Nil
Coarse aggregate = Nil
Sieve analysis
Fine aggregate = Conforming to zone-II of IS-383
Coarse aggregate =Conforming of table 2 of IS-383

Step 3: Target strength for mix proportioning

Using IS 10262:2009

F_{ck} = f_{ck}+1.65
= 31.6N/mm^2

Step 4: Selection of water cement ratio

Max w/c ratio =0.42
0.4<0.42
Hence ok

Step 5: Selection of water content

From table of IS 10262:2009
Max water content =186 lit
For 100mm slump =186+3/100x186
=191.6litre

Step 6: Calculation of cement content

w/c ratio =0.42
Cement content =191.6/0.42
=446.04 kg/m^3

Step 7: Proportion of volume of coarse aggregate and fine aggregate
Content From table 3
For zone 2 volume of coarse aggregate = 0.62
Volume of fine aggregate = 1 - 0.62
= 0.38

Step 8: Mix calculation

Volume of concrete = 1m3
Volume of cement

$$= \left[\frac{\textit{Mass of cement}}{(\textit{Specific gravity of cement} \times 1000)} \right]$$

= 446.04/(2.85x1000)
= 0.156 m^3

The volume of water

$$= \left[\frac{\textit{Mass of water}}{(\textit{Specific gravity of water} \times 1000)} \right]$$

= 191.6/(1x1000)
= 0.191 m^3

Volume of chemical admixture = 1.75 litres/m^3
Volume of all in aggregate = [a-(b+c+d)]
= [1-(0.156+0.191+0.004)]
= 0.649 m^3

Mass of coarse aggregate
= 0.649x0.62x2.67x1000
=1074.35 kg/m^3

Mass of fine aggregate
= 0.649x0.38x2.65x1000
= 653.54 kg/m^3

Volume of cement
=446.04kg/m^3

Step9: Mix proportion
Table:1 Mix proportion

Water	Cement	Fine Aggregate	Coarse Aggregate
191.6	446.04	653.54	1074.35
0.42	1	1.46	2.40

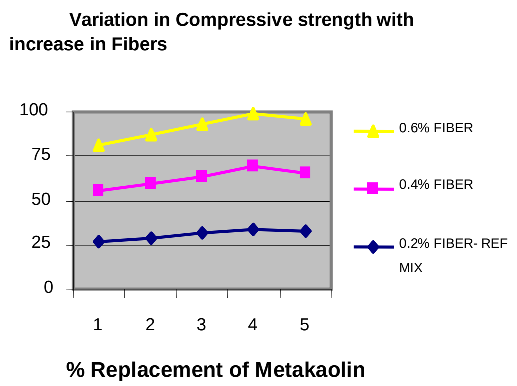
V. RESULT & CONCLUSION

A. COMPRESSIVE STRENGTH

Table:2 Ref mix : (0.2% fiber) with w/c=0.42

% Replacement of Metakaolin	Compressive strength(N/mm²)			% Increase/decrease of compressive strength w.r.t ref.mix	
	Ref mix	0.40 %	0.60 %	0.40 %	0.60 %
0	25.95	27.98	25.2	2.03	-0.75
5	28.85	29.78	28.34	0.93	-0.51
10	30.85	31.56	28.79	0.71	-2.06
15	33.3	34.29	32.12	0.99	-1.18
20	31.75	32.76	29.65	1.01	-2.1

Fig 1 COMPRESSIVE STRENGTH OF M25 GRADE OF CONCRETE

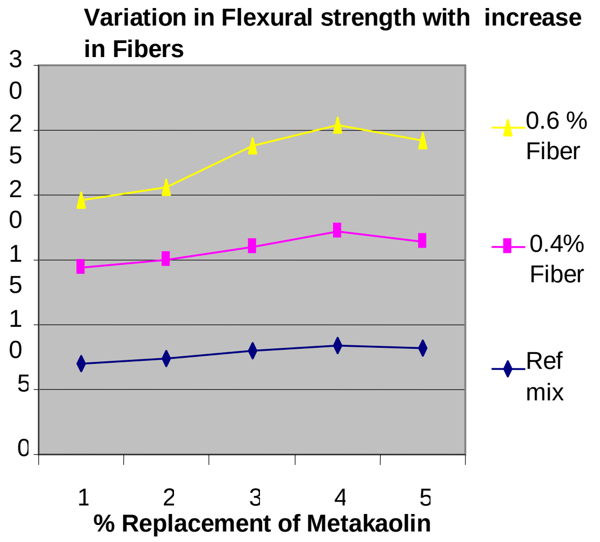


B. FLEXURAL STRENGTH

Table: 3Ref mix : (0.2% fiber) with w/c=0.42

% Replacement of Metakaolin	Flexural strength(N/mm²)			% Increase/decrease of flexural strength w.r.t (Ref.mix)	
	Ref mix	0.40 %	0.60 %	0.40 %	0.60 %
0	6	7.15	5.2	1.15	-0.8
5	8.5	7.4	5.35	-1.11	-3.15
10	8	8.05	6.7	0.05	-1.3
15	8.75	8.7	8.05	-0.05	-0.7
20	7.85	8.14	7.7	0.29	-0.15

Fig 2 FLEXURAL STRENGTH OF CONCRETE



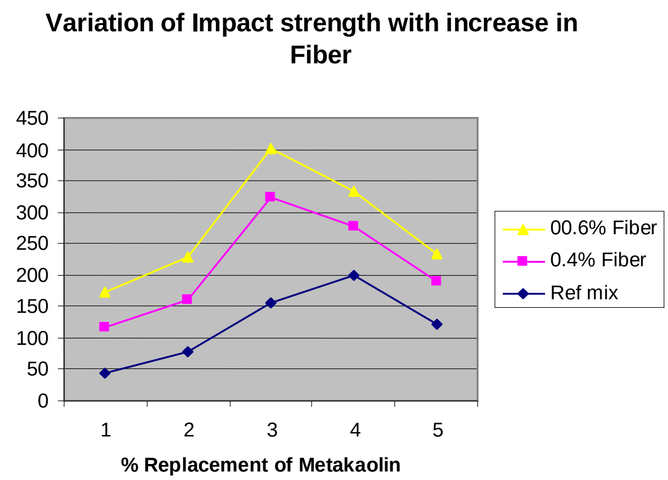
C. IMPACT STRENGTH

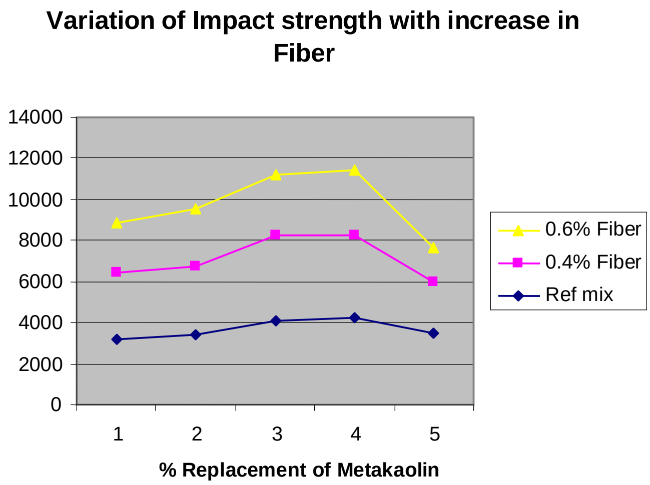
Table: 4 Ref mix : (0.2% fiber+1WM+1CM) with w/c=0.42

% Replacement of Metakaolin	Impact strength(N/mm²)					
	0.2% Fiber(ref.mix)		0.40%		0.60%	
	First crack	Final failure	First crack	Final failure	First crack	Final failure
0	44.48	3146.9	72.78	3313	55.6	2413
5	77.84	3424.96	83.4	3324.6	66.72	2779.2
10	155.68	4092.16	168.96	4136.2	77.84	2990.4
15	200.16	4270.8	77.84	3980.16	55.6	3201.3
20	122.32	3513.2	66.72	2490	44.48	1634

% Replacement of Metakaolin	% Increase/decrease of Impact strength w.r.t (ref.mix)			
	0.40%		0.60%	
	First crack	Final failure	First crack	Final failure
0	63.62	5.27	25	-23.32
5	7.14	2.91	-14.28	-33.45
10	8.53	1.07	-50	-26.92
15	-63.11	-6.8	-72.2	-25.04
20	-45.5	-29.12	-63.63	-53.48

Fig 3 IMPACT STRENGTH WITH INCREASE IN FIBER





CONCLUSION

The compressive strength of SIFF increases with the increase in % of fibers up to 0.4% by volume and with 15% replacement of cement with metakaolin. The compressive strength of SIFF is 2.72% higher as compared to the reference mix (0.2% fibers). The flexural strength increases with the increase in % of fibers up to 0.4% by volume and with 15% replacement of cement with metakaolin. The flexural strength of SIFF 3.52% higher as compared to the reference mix (0.2% fibers). The impact energy increases with an increase in % of fibers up to 0.4% by volume and with 10% replacement of cement with metakaolin. The Impact energy of SIFF is 8.53% higher for the first crack and 1.07% higher for final failure as compared to the reference mix. Thus **0.4%** of steel fibers and **15%** replacement of cement with metakaolin is recommended for maximum compressive strength, flexural strength, impact strength.

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