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European Journal of Advances in Engineering and Technology, 2019, 6(7):60-66

Research Article ISSN: 2394 - 658X

Investigation on Mechanical and Durability Properties of Slurry Infiltrated Fiber Concrete (SIFCON)

Natchimuthu S.[1], Getu Woldu[2] and Bogale Gebre Mariam[3]

[1]*Associate Professor, New Horizon college of Engg- Bengaluru, India*
[2]*Research scholar, Faculty of Civil Engg, -AMIT, Arba Minch –Ethiopia*
[3]*Professor –AWIT, Arba Minch –Ethiopia*
natchisubramani@gmail.com

ABSTRACT

The construction industry is in need of finding cost effective materials for increasing the strength of concrete structures. Slurry infiltrated fibrous concrete (SIFCON) is one of the recently developed construction materials that can be considered as a special type of high-performance fiber reinforced concrete (HPFRC) with higher fiber content. An endeavor has been made in the present investigations to study the influence of addition of locally available material at different dosages to the total weight of concrete. An experimental program was carried out to investigate the compressive strength, flexural strength, Non-Destructive Test (NDT), such as rebound hammer test and ultra-sonic pulse velocity test, and durability test *such as sulfate attack. The investigations were done using cement-based mix and tests were carried out as per recommended procedures by appropriate codes. SIFCON specimens with 0%, 5%, 10% and 15% volume of fraction fibers and with aspect ratio (L/D) 20, 25 and 30were used in this study. Test results were presented in comparison of SIFCON with conventional plain concrete. The load carrying capacity of SIFCON specimen is found to be higher than conventional plain concrete and it also reduced crack width. SIFCON was found to have many differences from conventional plain concrete and fiber reinforced concrete. Regarding its mix constitute material, fresh SIFCON properties and hard SIFCON properties. Therefore, special standard test methods and compliance criteria should be prepared for this material.*

Key words: SIFCON, Compressive strength, Flexural strength, Aspect ratio, Sulfate attack

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INTRODUCTION

Slurry Infiltrated Fiber Concrete (SIFCON) was developed by David Lamkard [1] in 1979 as a high strength impact resistant material, which could be considered as a special type of fiber concrete with high fiber content. This composite can be considered as a special fiber reinforced concrete. Normally, fiber reinforced concrete contains 1-3% fiber by volume, whereas SIFCON contains 6-20% of fibers. The other major difference is in the composition of the matrix. In SIFCON, the matrix is made of flowing cement mortar slurry as opposed to aggregate concrete in normal fiber reinforced concrete. The casting process is also different for SIFCON. In most cases, SIFCON is fabricated by infiltrating a bed of pre-placed fibers with cement slurry. Slurry Infiltrated Fiber Concrete (SIFCON) composites possess outstanding strength, ductility, and crack/spall resistant properties [1]. Lankard presented the basic properties of SIFCON prepared with 12.5% of fibers such as load-deflection curve, ultimate compressive and flexural strengths, and impact and abrasion resistance. Naaman and Baccouche [2] Presented the shear response of dowel reinforced SIFCON. They observed that the shear strength of SIFCON is 10 times higher than that of the plain matrix. The behavior of reinforced concrete beams with SIFCON matrix was studied [2] and reported that use of SIFCON eliminates the need of shear stirrups in RCC beams.

APPLICATION OF SIFCON CONCRETE

SIFCON is one of the new materials developed in USA and it is a composite of cement based slurry and small length and closely spread fiber. The composite used successfully in a number of areas, like for applications where high strength or high ductility or both are needed. These include a large variety of earthquake resistant structures, military installations, explosive and penetration resistant structures.

METHODOLOGY

This research was carried out in laboratory to determine the mechanical and durability properties of the Slurry Infiltrated Fiber Concrete (SIFCON) and to show the effect of fiber content on the property of concrete with the use of different fiber length and aspect ratio that will provide an advantage of evenly distribution of fibers throughout the structure member and to obtain a concrete which has noticeable strength on flexure by the use locally available fiber.

The tests which carried out throughout the study were flow table test, compressive strength; flexure strength; non-destructive tests of hard concrete and the effect chemical on strength of SIFCON were studied. And finally discussion has made for each tests regarding with comparisons of plain (0%) concrete on the properties of concrete [3-11].

Table -1 Different mix proportion and cube compressive strength of SIFCON

Component	**M_1**	**M_2**	**M_3**	**M_4**	**M_5**	**M_6**
Cement/ sand ratio	1:2	1:2	1:2	1:2	1:2	1:2
W/C ratio	0.55	0.5	0.45	0.55	0.55	0.5
Super plasticizer (%)	2.0	2.5	2.5	1.5	1	1.5
Flow measurement (mm)	272.5	255	220	265	240	250
Av. Compressive strength (MPa)	34.96	33.23	44.37	33.23	36.98	42.76

Keys: M_1-mix one, M_2-mix two, M_3-mix three, M_4-mix four, M_5-mix five, M_6-mix six

RESULT AND DISCUSSION

Strength of SIFCON concrete

Note: Plain:-fiber 0%; F5/20:- fiber 5% with aspect ratio 20; F10/20:- fiber 10% with aspect ratio 20; F15/20:- fiber 15% with aspect ratio 20.

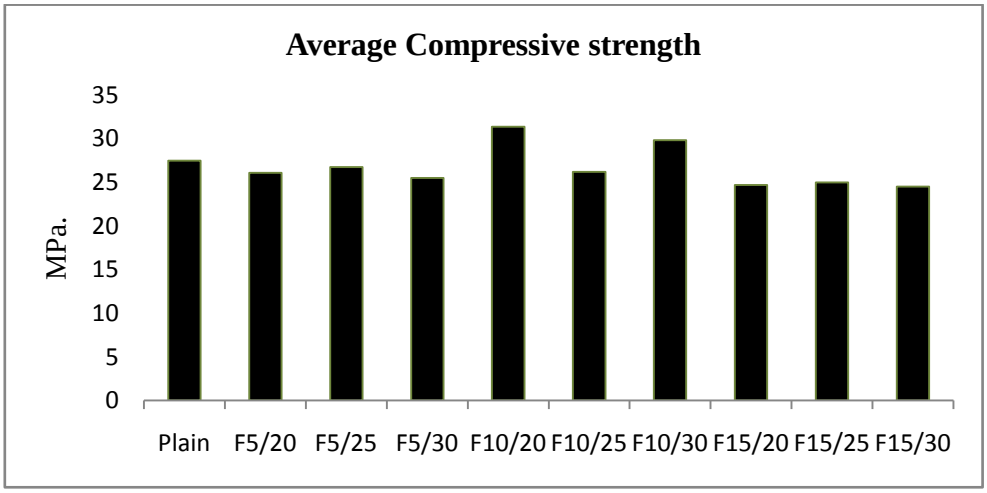

Fig. 1 Average compressive of SIFCON 7 day curing

The development of Compressive Strength with ages for the above different aspect ratio was plotted in the form of graph as shown in the above Figure. The cube compressive strength was observed as 31.36 N/mm^2 for 10% of fiber content and aspect ratio of 20 SIFCON concrete.

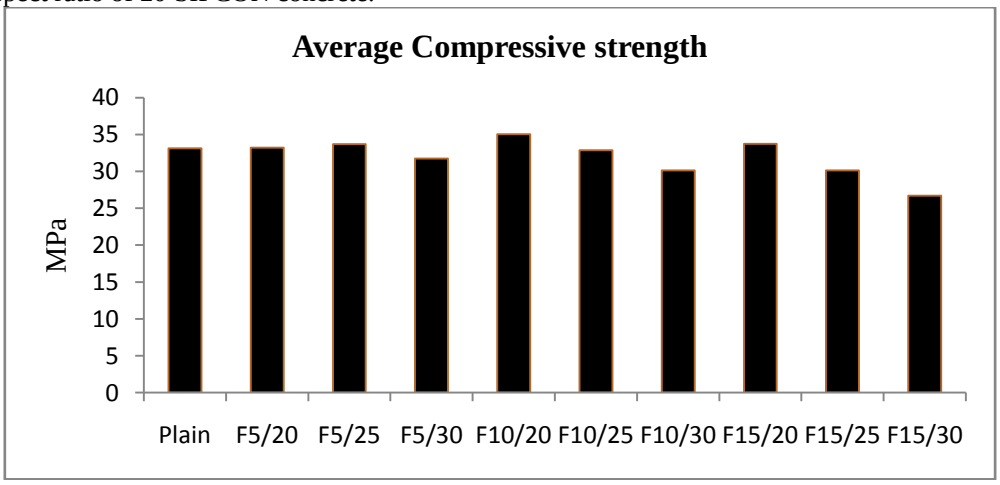

Fig. 2 Average compressive of SIFCON 14 day curing

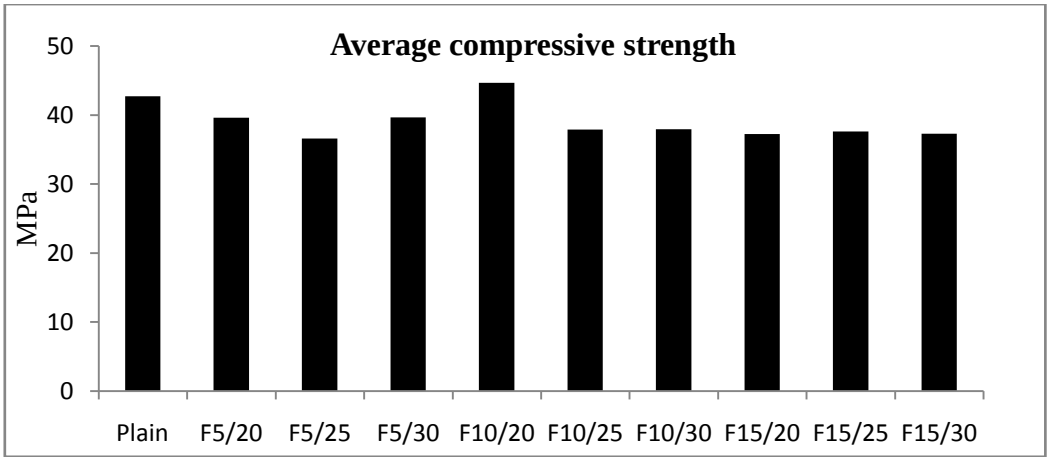

Fig. 3 Average compressive of SIFCON 28 day curing

Compressive Strength Depending on Aspect Ratio

The observations were made with reference to the effect of aspect ratio of fibers on the strength characteristics of slurry infiltrated fiber concrete. It was observed from the test results that presented. The compressive strength of slurry infiltrated fiber concrete with steel fiber goes on reducing as the aspect ratio of steel fiber increases. A higher value of compressive strength of 44.70MPa was observed for an aspect ratio 20 whereas a compressive strength of 42.76MPa was observed with an aspect ratio 25 and 30.

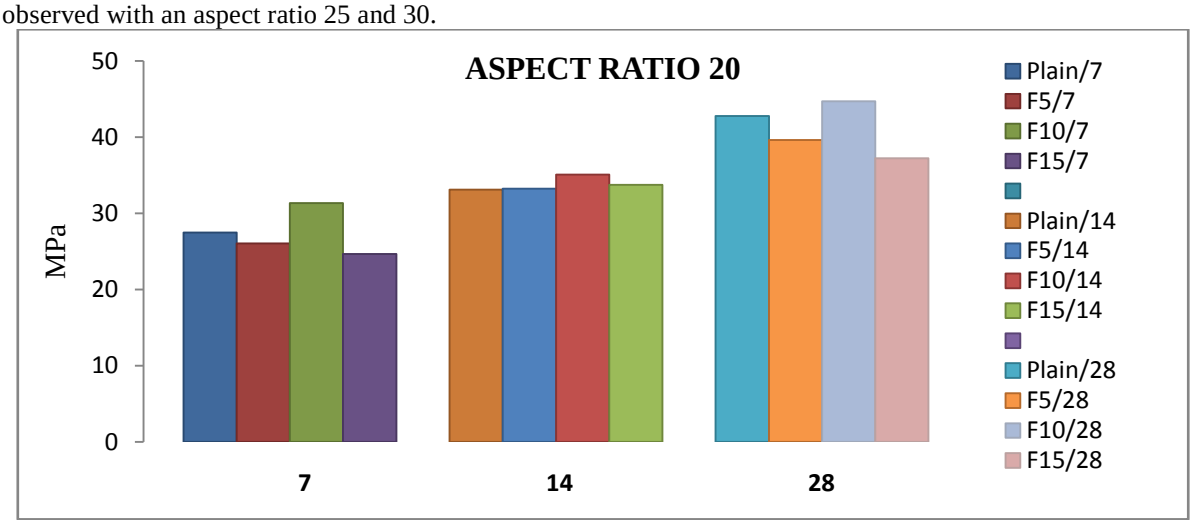

Fig. 4 Compressive strength for aspect ratio 20

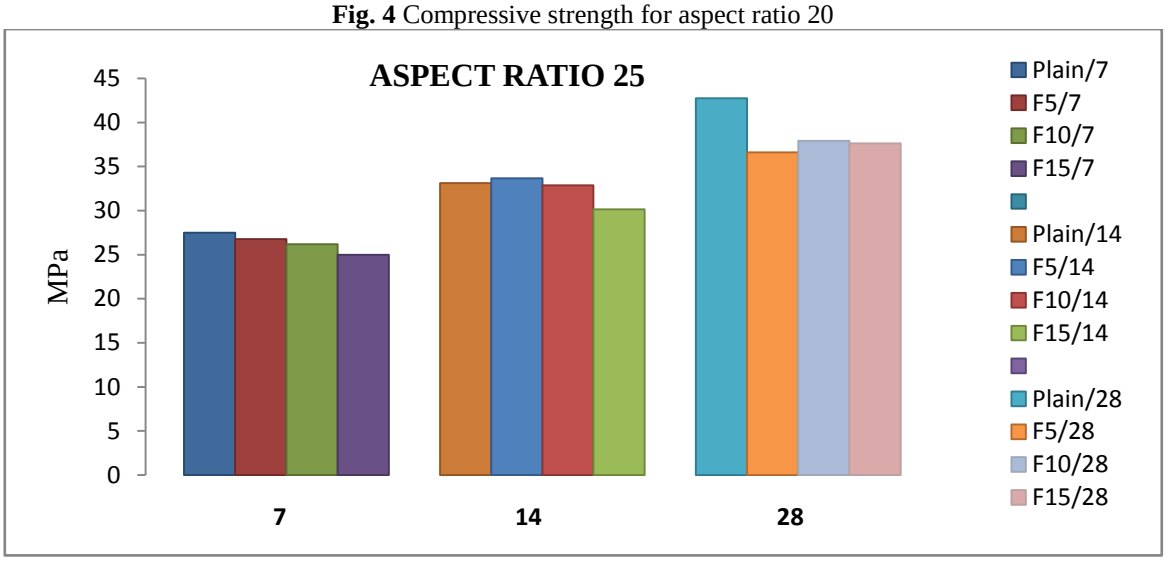

Fig. 5 Compressive strength for aspect ratio 25

Note: Plain/7:- fiber 0% with 7 days curing; Plain/14:- fiber 0% with 14 days curing; Plain/28:- fiber 0% with 28 days curing

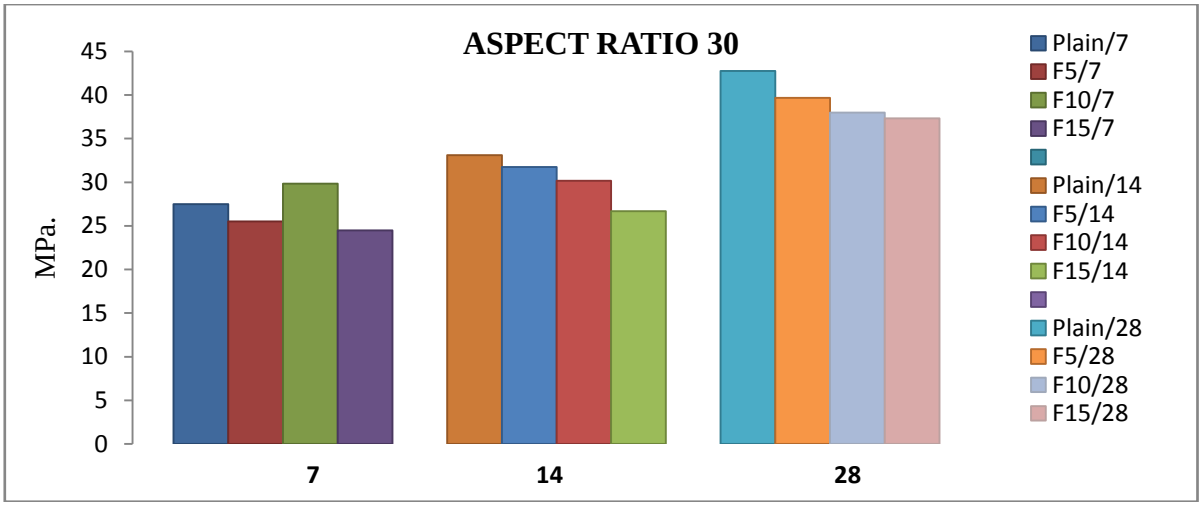

Fig. 6 Compressive strength for aspect ratio 30

Flexural Strength

For flexural strength test beam specimens of dimensions 160 X 40 X 40mm were casted (ASTM C-348) and the specimens were demoded after 24 hours of casting then were shifted to curing tank where they were allowed to cure for 7, 14.and 28 days. These specimens were tested under one point loading of Ma-Test Flexural testing machine. In each category three beams were tested and their average value is reported.

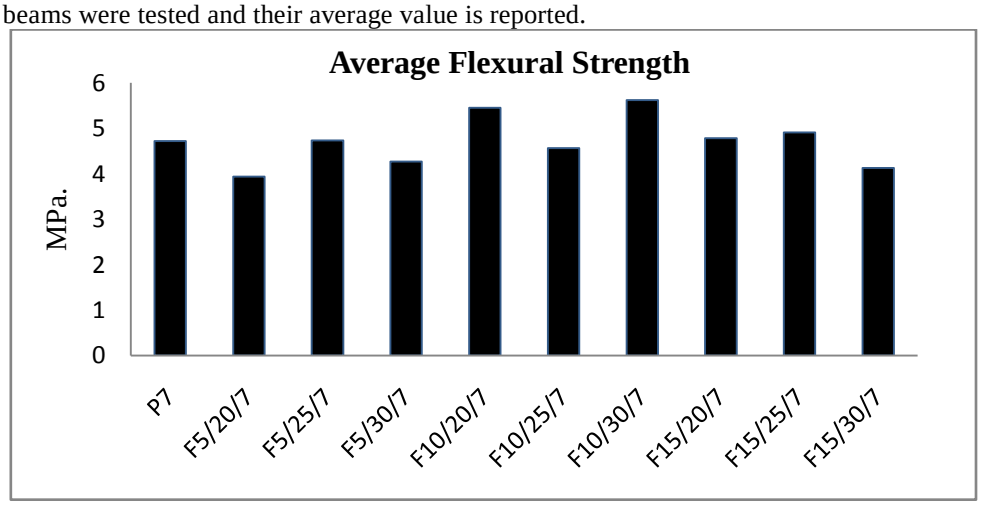

Fig. 7 Average Flexural strength of SIFCON 7 days curing

Note: Plain/14:-fiber 0% with 14 days curing; F5/20/14:- fiber 5% with aspect ratio 20 and 14 days curing; F10/20/14:- fiber 10% with aspect ratio 20 and 14 days curing; F15/20/14:- fiber 15% with aspect ratio 20 and 14 days curing.

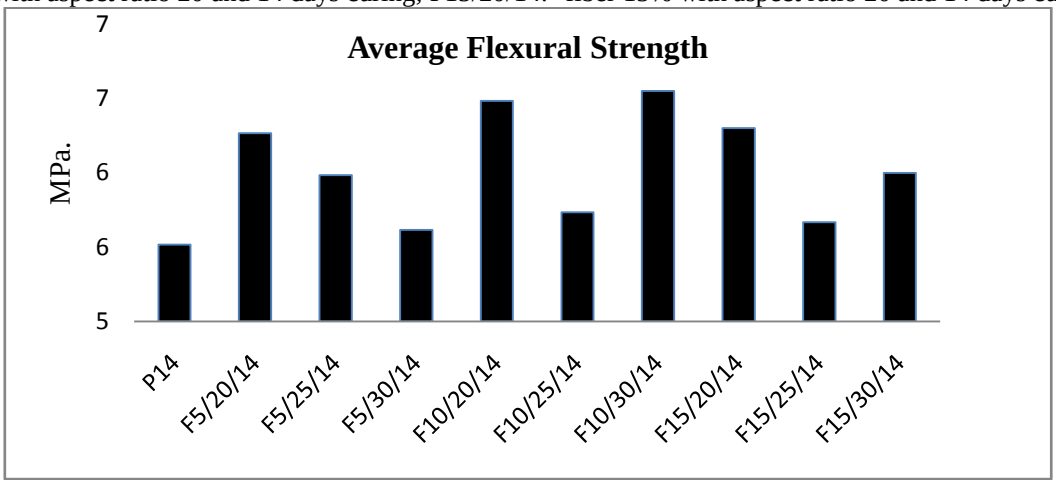

Fig. 8 Average Flexural strength of SIFCON 14 days curing

Note: Plain/28:-fiber 0% with 28 days curing; F5/20/28:- fiber 5% with aspect ratio 20 and 28 days curing; F10/20/28:- fiber 10% with aspect ratio 20 and 28 days curing; F15/20/28:- fiber 15% with aspect ratio 20 and 28 days curing.

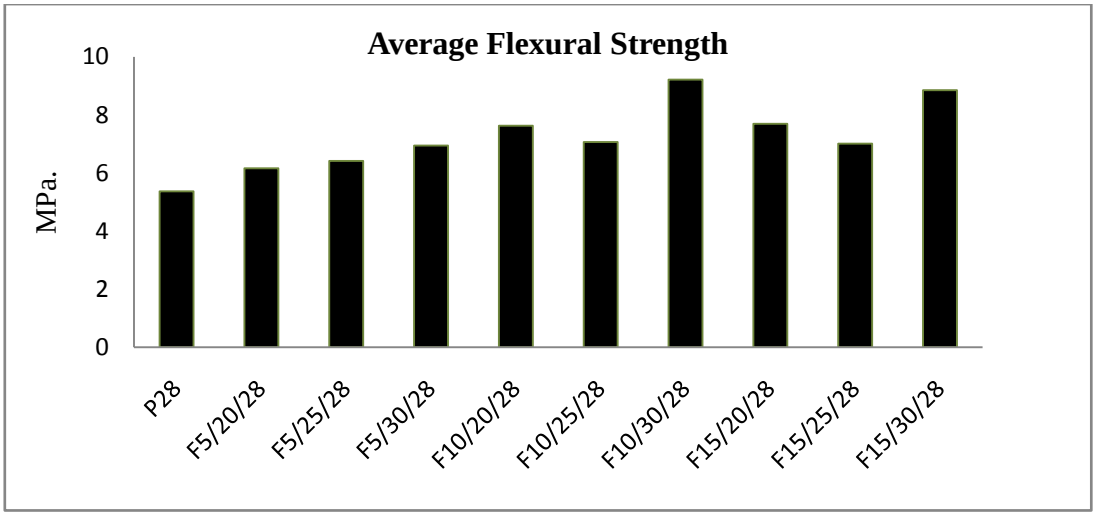

Fig. 9 Average Flexural strength of SIFCON 28 days curing

Rebound Hammer test

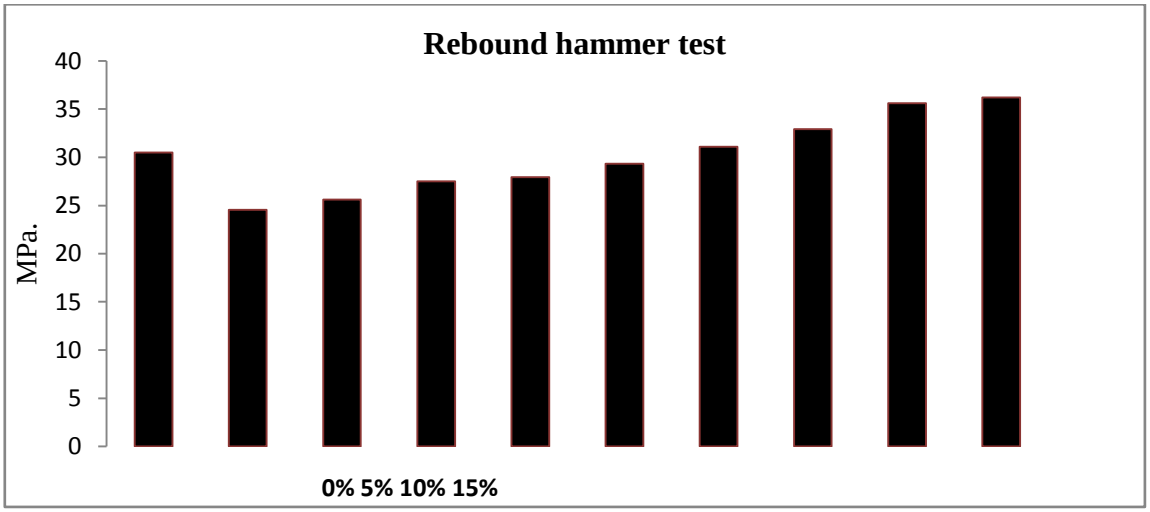

Fig. 10 Rebound hammers test result

The result indicated that the average compressive strength of SIFCON produced by rebound hammer test increases with the increase of fiber content and aspect ratio. The maximum average compressive strength of SIFCON specimen is 36.22 N/mm^2. Fiber content 15% and 30 of aspect ratio contributed to found the maximum average compressive strength of SIFCON.

Comparison of Destructive and Non-destructive tests

Destructive and Non-destructive tests were used for quality control and strength estimation of in laboratory and in situ of concrete respectively. These tests, being influenced in different and opposite mode from some fundamental parameters, allow to get outputs with least dispersions. Destructive test was determined its test output by crushing and destroyed the specimen. But, non-destructive test determine the output without affecting the performance of the specimen. The parameters which influence the velocity of propagation of ultrasound waves and rebound hammer test are; the entity of the load, the age of the concrete, the form and the dimension of the structure, the run length, the presence of metallic fibers, the ratio of water to cement, the state of strength, the temperature and the humidity of the concrete. In this paper the outputs of these methods were calibrated with the strength of cube specimens.

The maximum compressive strength of destructive test was 23.41% more when compared to the maximum compressive strength of non-destructive test. The test samples had the same curing days. But, the maximum compressive strength of destructive test determined with 10% fiber content and aspect ratio 20 and the maximum compressive strength of non-destructive test determined with 15% fiber content and aspect ratio 30.

Note: Plain:-fiber 0%; F5/20:- fiber 5% with aspect ratio 20; F10/20:- fiber 10% with aspect ratio 20; F15/20:- fiber 15% with aspect ratio 20.

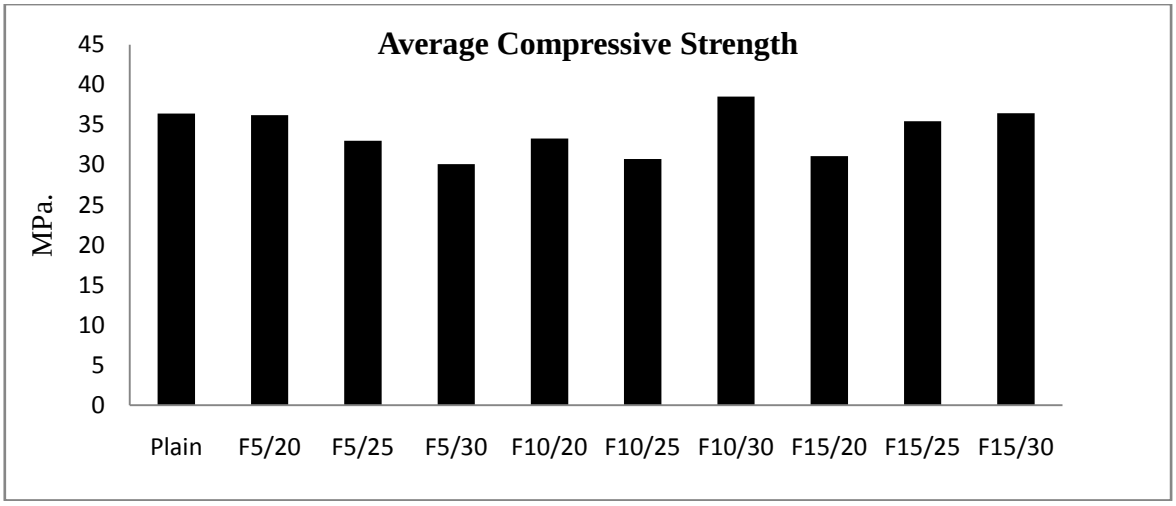

Fig. 11 Sulfate attack test result

The maximum average compressive strength of SIFCON concrete after attack by Magnesium Sulfate was 38.53 N/mm^2 that concrete which had 10% of fiber content and aspect ratio 30. So the result indicated that the resistance of sulfate attack of SIFCON concrete increases with increasing of fiber length or aspect ratio.

CONCLUSIONS

This experimental research carried out to investigate various mechanical and durability properties of slurry infiltrated fiber concrete (SIFCON). A straight type of steel fiber was incorporated in three different volume percentages by weight of cement and three different aspect ratio of fiber, and one type of matrix of mixture, slurry was investigated. The following conclusions were derived based on the obtained results.

The compressive strength of SIFCON concrete was increases up to a certain limit of fiber content then decreases after this certain limit. SIFCON specimens with 10 percent fiber content at 28 days of curing increased by 4.53% in compressive strength over plain mortar specimens. Fibers with an aspect ratio of 20 were found to contribute more to the compressive strength of SIFCON than those with an aspect ratio of 25 and 30.

The flexural strength of plain concrete can be improved clearly by incorporating SIFCON and the addition of steel fiber in conventional concrete results in improvements in strength and ductility under static loading.

Incorporating steel fibers in high aspect ratio resulted in reduced compressive strength when compared with plain mortar specimen. But, low aspect ratio of fiber shows better resistance of compressive strength than plain mortar specimen. Fiber with an aspect ratio of 20 was contributed to found more compressive strength than plain mortar specimen, 25 aspect ratio and 30 aspect ratio.

The rebound hammer reading of concrete are affected by factors such as smoothness of surface, size and shape of specimen, moisture condition of the concrete, type of cement and coarse aggregate. The results showed that the rebound hammer reading and compressive strength increases with increases of fiber content and density of SIFCON concrete specimens.

Concrete is a heterogeneous material. The amounts of voids, the w/c ratio, the aggregate type and others variables affect the concrete strength. The results showed that the quality of SIFCON concrete depending on the quality criterion of concrete classification was medium quality concrete.

- The effect sulfate on SIFCON concrete depends on the concentration of fiber content and concentration of sulfate. The result shows that SIFCON specimens with 10 percent of fiber content produces 38.53 N/mm2 compressive strength after sulfate attack. A fiber with aspect ratio of 30 was contributed to found more compressive strength than plain mortar specimen, 20 of aspect ratio and 25 of aspect ratio.
- Generally speaking, Addition of steel fibers increased the compressive and flexural strength of SIFCON, the increase in compressive and flexural strength of steel fiber concrete was attributed to the capability of steel fiber to delay the unstable development of micro cracks as well as limiting the propagation of that micro cracks and its effect on concrete.

RECOMMENDATIONS

The recommendations made below are proposed based on the findings of this experimental study.

- SIFCON is a material with many differences from both conventional concrete and fiber reinforced concrete, especially regarding its composition. Therefore, special standard test methods and compliance criteria should be prepared for this material.
- To ensure the density and surface finishing of SIFCON, coarse aggregate with maximum size of 19 mm should be included in the mix.
- Using maximum possible steel fiber content is always recommended to achieve a better performance

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