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# Effects of Steel Slag on Durability Properties of Slurry Infiltrated Fibrous Concrete

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***Abstract*****: *Inthis research observed the properties of substitute of steel slag on slurry infiltrated fibrous concrete. Six series of test specimens were prepared using hook ended steel fibre with 0,2,3 and 4% volumes fractions along with 0 to 20 % steel slagsubstitute. All procedures on concrete subjected to fresh and hardened properties. For mechanical properties of concrete, compressive, splittingtingtensile and flexural tensile strength.Durability properties performed using the acidic attack test, sulfate attacktest and elevated temperature test. For workability properties to perform flowability, the passing abilitywas appraised using Slump flowand L-Boxtests. A fresh property depict the significant effect of changing steel slagsubstitute. Steel slag substitute along with 4% fibres showed that 25.73% compressive strength,20.34% splitting tensile strength,1.16% flexural strength improvement as compared to control specimen. Durability resultsuch as acid attack, sulfate attack for steel slag blend slurry infiltrated fibre concrete showed improvement over control specimen.***

***Index Terms*****: *Acid attack,Compressive strength, elevated temperature, Flexural tensile strength, Slurry infiltrated fibrous concrete, Steel slag,splitting tensile strength,Sulfate attack.***

## I. INTRODUCTION

Slurry infiltrated fibrous concrete (SIFCON) is a high - performance concrete with high fibre. It had high mechanical properties. It was found by Lankard in 1985 [1]. From 1990 to 2000 lot of work performed on the behaviour of SIFCON under various mechanical properties using various substitution, substitute of cement and fine aggregate [2]-[10].Investigated that the Compressive strength increased more significant than 35% when the steel fibres were added to the matrix by a volume fraction of 8%. The partial substitution of ordinaryportland cement to SF,15%, increased strength in compression by more than 20%. However, When samples were subjected to a elevated temperatures of 400 ° C for 2 h, its strength in compression decreased with the addition of silica fume. The weight loss was also higher when the silica fume was added [11]. This paper evaluates the effect of adding GGBFS to concrete at temperature increases between 200 and 350 º C; the mass loss is not very significant. Altering the hydrates permits the concrete microstructure to deteriorate, leading to an increase in unit of weight of concrete owing to the inclusion of steel slag aggregate. The compressive strength of that same steel slag aggregate, moreover concrete is marginally better than that of crushed limestone aggregate concrete, Very little significant growth throughout the flexure and splittingting tensile strength of both the steel slag aggregate concrete compared to the crushed calcareous concrete aggregate[12]. Investigated the plain sample burst at a temperature between 240 and 280 º C owing to narrow and uneven matrix pore structure as a result of fine particle-rich mix design. On the other hand, the explosion of the matrix phase due to high temperature obstructed by fiber inclusion (in the case of SIFCON). Therefore, the flexural strength has been noted through out the 300 º C condition. [13]. The addition of steel fiber to concrete significantly increased the abrasion resistance of concrete made with and without fly ash. Abrasion resistance was known to increase with increase of steel fiber volume fraction [14].The influences of fly ash, blast furnace slag, and low ash on flow attributes, density, and an evaluate compressive strength. The water capillary absorption attributes of mortar with reverence to moisture transport as well influence durability properties. Fresh concrete flow characteristics had been constant or reduced with such an increase in the substitute proportion of bottom ash fine aggregates. [15].The durability properties of concrete with basalt fibre presented in the work-related an abrasion resistance and fracture energy. The increase in fiber content and length has led to abrasion resistance; a strong relationship between abrasion resistance and flexural strength of control and high strength concrete [16]. Using a specific mould system, a pre-setting pressure was applied to the plastic (fresh) SIFCON. The application of pressure to fresh SIFCON minimizes the vacuum between the grains and increases the adherence between the micro-aggregates and the binder. This phenomenon between the matrix and the fibers is also the case. [17]. GGBFS (ground granulated blast furnace slag) increases the compressive, flexural and splitting tensile strength at 30% substitute level with steel fiber substitute from 6% to 10% [18]. The objective of present research work to check the. performance of locally available steel slag as construction material.
whether this is suitable for construction from mechanical strength point of view and durability point of view and it is beneficial for utilization of industrial waste in construction and infrastructural development.Application of industial waste in various activity in construction will reduce use of natural resources and it will help in reduction in carbon footprint.

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## II. EXPERIMENTAL INVESTIGATION

### A. Materials

The Ordinary Portland Cement 53 grade used in this research work corresponded to IS 12269-1989[19] having a specific gravity of 3.15 and a fineness of 3200cm2/gm. The steel slag was obtained from the local steel manufacturing company. The steel slag with pozzolana's general requirements confirms IS 456-2000[20].The fine aggregate's specific gravity 2.56. Hook ended steel fibres confirms to ASTM A820 TYPE II [21]. The fibres length 35mm and diameter 0.6mm and tensile strength 1100 MPa according to specification. The water used in preparing, mixing and curing of SIFCON specimens was potable water obtained from drinking water source. For workability improvement superplasticizer CONPLAST SP-430 conforming toASTMC-494-F[22], HRWR agent used. Adding of superplasticiser is 1% of total powder content.

### B. Samples Preparation and Methods

Mix development of slurry infiltrated fiber concrete slurry built on the packing density principle. OPC, 2 mm fine aggregate, steel slag, superplasticizer and steel fibres. Steel slag has partially replaced 0, 10 and 20 % for fine aggregate. A fiber has preplaced the volumetric substitution for 2, 3 and 4 % in the mold. The amount of fiber test based on packing density method [23,24].Matrix preparation for all experimental research has taken in the ratio of one part of cement and one part of fine aggregate with partial steel slag substitution. A slump flow test was used as a concrete workability measure and was carried out in accordance with the guidelines in ASTM C1611 [25].

Table 1. illustrate the outcomes for slump flow and L-box test for the severalpartial substitute levels of steel slag. Seventy-two cubic specimens 100 ×100 ×100 mm, 100 ×100 ×500 mm prism and cylindrical specimen 100 ×200 mm were cast and tested to determine the compressive, flexural tensile and splittingting tensile strength of slurry infiltrated fibrous concrete including steel slag as per IS 516-1999[26]. Durability studyon slurry infiltrated fibrous concrete is worked out by using an Acidic attack, Sulfate attack and Elevated temperature test and size of samples were used 100 ×100 ×100 mm.

**Table1.Slump flow(*df*)and L-box test(H2/H1)on SIFCON**

| Type of Mix | Steel slag % | Fibre % | $d_f$(mm) | H2/H1 |
|---|---|---|---|---|
| M 102 | 10 | 2 | 630 | 0.80 |
| M 202 | 20 | 2 | 635 | 0.82 |
| M 103 | 10 | 3 | 590 | 0.86 |
| M 203 | 20 | 3 | 570 | 0.90 |
| M 104 | 10 | 4 | 565 | 0.86 |
| M 204 | 20 | 4 | 550 | 0.86 |

### C. Testing of Specimens

The compressive andsplittingting tensile strength of slurry infiltrated fibrous concretehaving three different percentage of fibre content with and 0,10 and 20 % steel slag were conducted on a digital compression testing machine having the capacity of 3000kN.The flexural performance of SIFCON conducted on Universal Testing Machin having a capacity of 1000kN.All the above test conducted byIS 516-1999[26].The arrangement of testing as shown in Fig.1.

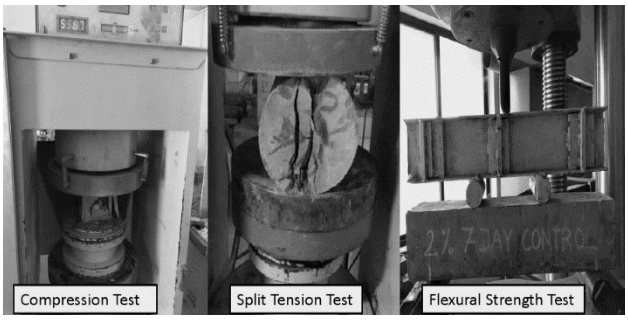

**Figure 1.Testing Arrangements**

The durability properties are determined by the use of chemical test (acid attack, sulfate attack) and elevated temperature test[ 27,28]. Chemical tests (acid attack, sulfate attack) were tested for a total period of 28-dayssays. Five percent concentration of hydrochloric acid was taken as a medium for testing. Concrete(SIFCON)100 mm samples with a mild solution of hydrochloric acid were dissolved in the container. A magnesium sulfate solution (MgSO4) was prepared in which 5% concentration of magnesium sulfate has been taken as a medium for testing.Then the 100 mm size samples that were cured for 28-days were immersed in this solution. After 28-days of exposure to the solution, the cubes were removed from the solution and dried on the surface. The cube surfaces were cleaned, scrubbed and dried weights were found on the final surface.

## III. RESULT AND DISCUSSION

### A. Compressive Strength

The compressive strength of SIFCON samples containing 4 % of steel fibres content and, 10 % substitute of steel slag with sand.Fig.2 depict the detail illustration of a variation of compressive strength regarding 7-days and 28-days curing age. Similar inclinations have been observed for 7-days and 28-days for curing age. Fig.2 illustrates that the compressive strength of SIFCON with steel fibers 4 % with 10% steel slag subtitution for fine aggregate shows a higher compressive strength of 70.76 MPa. In other words, SIFCON with 4% of steel fibres depict higher compressive strength; the percentage increase in compressive strength is 25.73%.

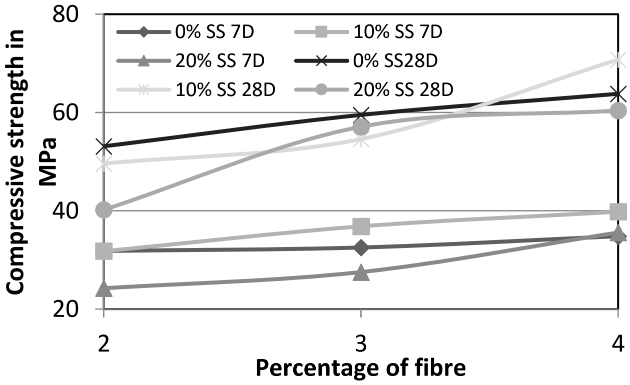

**Figure 2.Variation of Compressive Strength of SIFCON with Steel Slag and Steel Fibre**

### B. Splitting Tensile Strength

Fig.3 depict the 7-days and 28-days splittingting tensile strength of SIFCON specimens containing 2- 4% of steel fibre content to the 10-20 % substitute of steel slag with sand. The Splitting Tensile strength of SIFCON samples containing 4 % of steel fibres content to the 10 % substitute of steel slag with sand.Fig.3 depict the detail illustration of a variation of Splitting tensile strength concerning 7-days and 28-days curing age. Similar inclinations have been observed for 7-days and 28-days for curing age. Fig.3 depict that the Splitting Tensile strength of SIFCON with steel fibres goes on increasing up to the 4-percentage addition of steel fibres with 10 % of steel slag. A higher Splitting Tensile strength of 10.41MPa observed for 4% addition of steel fibres to SIFCON with steel slag.

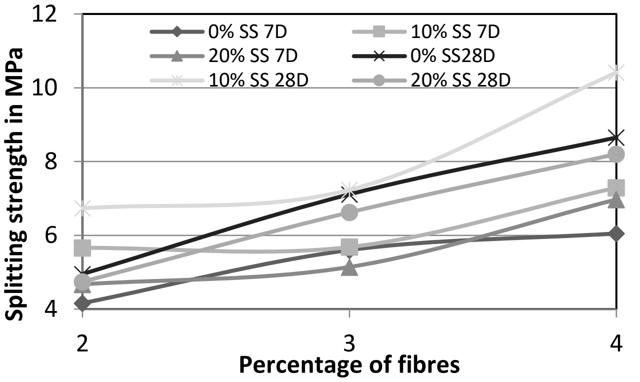

**Figure 3. Variation of Splitting Tensile Strength of SIFCON with Steel Slag and Steel Fibre**

### C. Flexural Strength

Fig.4 depict the 7-days and 28-days Flexural tensile strength of SIFCON specimens containing 2- 4% of steel fibre content to the 10-20 % substitute of steel slag with sand. The Flexural Tensile strength of SIFCON samples containing 4 % of steel fibres content to the 10 % substitute of steel slag with sand.Fig.4 depict the detail illustration of a variation of Flexural Tensile strength concerning 7-days and 28-days curing age. Similar trends have been observed for 7-days and 28-days for curing age. Fig.4 depict that the Flexural Tensile strength of slurry-infiltrated fibre-concrete with steel fibres goes on increasing up to the 4-percentage addition of steel fibres with 10 % of steel slag. A higher Flexural Tensile strength of 18.29MPa observed for 4% addition of steel fibres to slurry infiltrated fibre-concrete with steel slag.

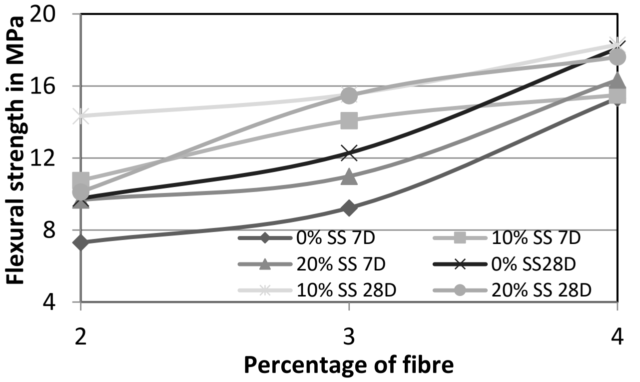

**Figure 4. Variation of Flexural Tensile Strength of SIFCON with Steel Slag and Steel Fibre**

### D. Acid attack test

The effect of HCl concentration on the compressive strength. From the Fig.6 it is clear that compared to all other mixes the strength loss is maximum for the control mix, i.e. 13.82 %. Comparing the strength corresponding to 28-days acid exposure the rate of strength loss was found to be maximum for control mix. By the addition of steel slag and steel fibres, the sulfate resistance of 20 %, 28-days mix was improved.

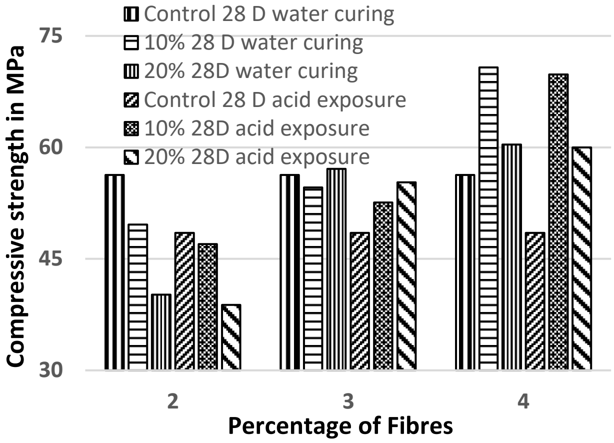

**Figure 5. Compressive Strength of SIFCON with Steel Slag and Steel Fibre under water and acid curing**

From the acid attack test to determine the deterioration of concrete.Fig.6 depict that more loss of weight in control concrete as compare to another mix. Loss of weight under acid attack depict linear decrement toward M204.

Percentage changes in weight of the test specimens are shown in Fig. 6 depict that weight loss is greater for the test specimens of Mix CON, which contained a cement sand and fibres, than for the specimens of Mix Ml02. Weight loss of the test specimens for the, Mix M202, is greater than that of the specimens for the Mix M103, Mix M203 (Fig. 6). As shown in Fig. 6, the weight loss is slightly greater for the test specimens of Mix M104.

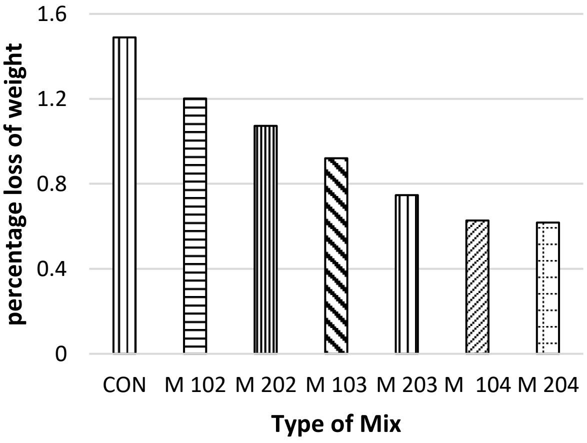

**Figure 6. Percentage loss of weight under acid attack**

### E. Sulfate attack test

From the Fig.7 it is clear that compared to all other mixes the strength loss is maximum for the control mix, i.e. 7.05%. Comparing the strength corresponding to 28-days sulfate exposure the rate of strength loss was found to be maximum for control mix. By the addition of steel slag and steel fibres, the sulfate resistance of 10 % 28-days mix was improved as compared with the control concrete mix. Overall compressive strength decreased with exposure period in a sulfate solution.

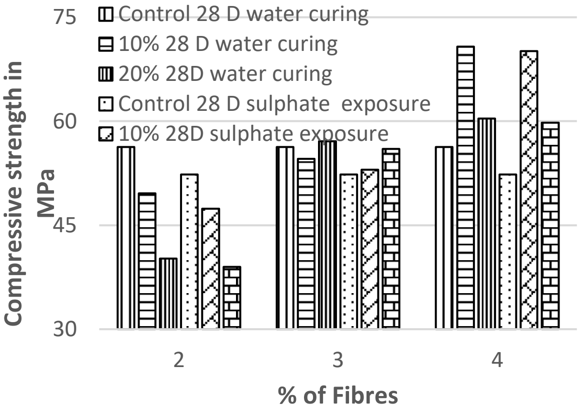

**Figure 7. Compressive Strength of SIFCON with Steel Slag and Steel Fibre under water and sulfate curing**

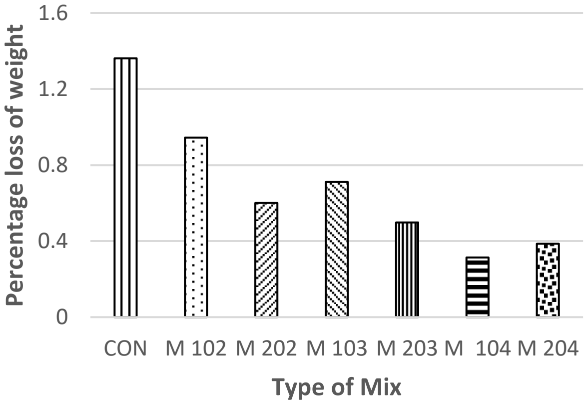

**Figure 8. Percentage loss of weight under sulfate attack**

Fig.8 depict that percentage loss of weight for control and steel slag mix M102-M204.weight loss under sulfate attack depict more in M102 mix as compared to another mix excluding control mix.

### F. Elevated temperature test

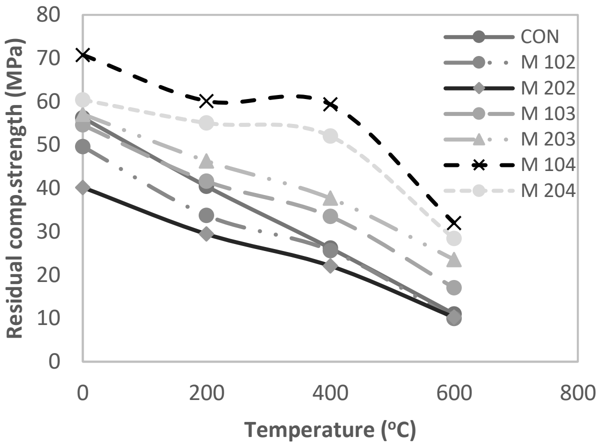

**Figure 9. Residual compressive strength after exposure to 200,400 and 600 °C**

Fig.9 depict the residual strength of control concrete at varying temperatures 0 -600oC.The figures showthat for sixtypes of the mix (irrespectiveof partial substitute level of steel slag and steel fibres), M104 higher residual strength compared to that other samples. All mixes showing good resistance up to 200oC after 200-600oC showing spalling of concrete. It is observed more reduction in compressive strength beyond 400oC. Steel fibres in SIFCON have a significant effect on improving compressive strength. The compressive strength of SIFCON at 200ºC was not compromised, performed exceptionally well.

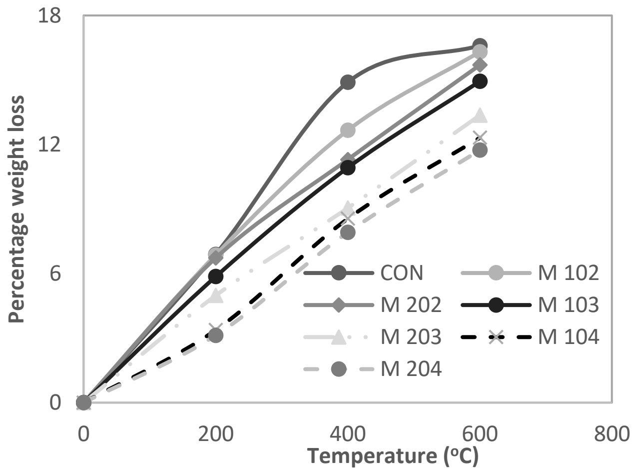

**Figure 10. Weight losses of different SIFCON mixtures**

The loss in weight (percent) calculated as follows:

$$Lossinweight\ (\ percent\ ) = \frac{Initialweighting - finalweighting}{Initialweighting} \times 100$$

Fig.10 illustrated the percentage weight loss after exposure to 200,400 and 600 °C. In the above figure depict that loss of weight more observed in control concrete as compare with another six mixes.Experimental investigationdepict less weight loss in M204 at 600oC.

**Figure 11. Durability testing on SIFCON**

Fig.11 shows that the graphical representation of durability testing on SIFCON, it includes control sample after elevated temperature,PH testing unit for measuring acidic level water,sample after acid curing,sulfate curing and sample testing after sulfate curing.

## IV. CONCLUSION

The reduction in compressive strength with exposure period in a sulfate solution.

The reduction in compressive strength with exposure period in 3% sulfuric acid solution.

As the percentages of fibre in slurry infiltrated fibrous concrete go on increasing the flexural strength and ductility go on increasing. In the present study, the slurry infiltrated fibrous concrete has attained higher flexural strength and higher ductility values at 4% addition of steel fibres with 10 % steel slagsubstitute for sand.

SIFCON gives better result after exposure to extreme temperature as compared to normal concrete. At 600°C the control specimens cannot be with stand. Some fine cracks developed on the surface of the specimen, and it is observed by visual observation.

Optimum level of partial substitute of steel slag for fine sand upto 10% and its show good significance in development of compressiveand flexural strength.

The loss of steel slag SIFCON weight decreased as the percentage of steel slag increased.

The performance of chemical attacks on SIFCON steel slag is significantly better than CON concrete results. The better results of SIFCON steel slag in acidic conditions than others of CON concrete can be related to the low calcium content of the original material.

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