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Influence of Slag on Steel Fiber Reinforced Self Compacting Concrete (SFRSCC)

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Abstract: Self-compacting concrete is a type of concrete that gets compacted under its own self-weight. The addition of steel fibers increasing the ductility, toughness and reducing the cracks resulting material is steel fiber reinforced self-compacting concrete (SFRSCC). The increase strength in construction has brought heavy demand for ingredients of concrete such as cement and sand, and these materials are becoming costly and insufficient. With ever increasing environmental problems because of industrial waste products comes a great need to use these products in an appropriate manner to reduce health problems and environmental problems. Slag is a waste product of Ferro alloys industry. The study explores the influence of slag on SFRSCC. The objective is to replace the slag with coarse aggregates and to analyze the mechanical proper ties of SFRSCC. The experimental results reveal that substitution of natural aggregates with slag increases compressive strength, flexural and tensile strength.

Key Words: Steel Fiber Reinforced Self-Compacting Concrete (SFRSCC), Slag, Mix proportions, compressive strength, steel fibers.

1. INTRODUCTION:

Self-compacting concrete (SCC) is considered as a concrete which can be placed and compacted under its own self weight with little or no vibration effort, and which is at the same time cohesive enough to be handled without segregation or bleeding. It is used to facilitate and ensure proper filling and good structural performance of restricted areas and heavily reinforced structural members. SCC was developed by Okamura and Ozawa, around 1986, at the University of Tokyo and the large Japanese contractors. This is to be mainly used for highly congested reinforced structures in seismic regions. Recently, this concrete has gained wide use in many countries for different applications and structural configurations. SCC can also provide a better working environment by eliminating the vibration noise. There are many advantages of using SCC, especially when the material cost is minimized. Like any other concrete, SCC is also relatively strong in compression but weak in tension and shows little resistance to cracking and hence tends to be brittle. By the addition of fibers in concrete this weakness can be overcome. Considerable research on Fibre Reinforced Concrete (FRC) has shown that the addition of fibres to concrete makes it more homogenous and isotropic; and can significantly increase the tensile strength and ductility. When concrete cracks, the randomly oriented fibres arrest micro cracking and limit crack propagation thus substantially improving the toughness, tensile strength and ductility. The micro and macro-cracking processes described above can be favorably modified by adding short, randomly distributed fibres. SCC with randomly oriented steel fibres is called *Steel Fibre Reinforced Self Compacting Concrete* **(SFRSCC).**

Human is always innovative to meet his desire to be fulfilled. The scarcity of the natural aggregate has compelled researchers to think about the replacement option. The demand helped to replace coarse aggregate with slag in making **SFRSCC.**

The slag is the waste product of the ferroalloys industry. This low carbon slag is considered as third class hazardous waste and chemically composed of carcinogenic, such as Hexavalent chromium. By exposure to the environment, it creates health hazard to the human beings like problems in respiration and nervous system disorder. When the slag is dumped it pollutes the ground water. The slag can be easily eroded by the water and wind to contaminate the air and surface water. As per the survey conducted by EnSafe, Inc. (2002). A single ferroalloys industry produces 220,000 tons of low carbon slag per year. Due to the large scale use of ferroalloys in the market, slag may be increased to 12,000,000 tons per year. The slag may require a large place for dumping and this will create the pollution in the environment.

2. MATERIAL SPECIFICATIONS:

Ingredients of SFRSCC:

1. *Cement*: Ordinary Portland Cement-53 grade cement conforming to IS: 12269 is used. The different laboratory tests were conducted on cement to determine standard consistency, initial and final setting time, and compressive strength as per IS 4031.
2. *Fine aggregate:* Locally available Krishna river sand passed through 4.75mm IS sieve is used. The specific gravity 2.66 and fineness modulus of 2.72 were used as fine aggregate.
3. *Coarse aggregate:* Crushed granite aggregate available from local sources has been used. The coarse aggregates with a maximum size of 12mm having the specific gravity value of 2.78 and fineness modulus of 7.36 were used as coarse aggregate.
4. *Slag:* Slag conforming to IS: 383-1978 passing through 20mm sieve and retaining on 4.75mm sieve is used. The slag is composed of Calcium oxide 48%, silicon dioxide 25%, manganese oxide 11% and iron, sulfur, aluminum, chromium 16%. The Specific gravity of slag is 3.5. Impact value, crushing strength and water absorption values are 6.1%, 35.5% and 0.4%.

Table 1. Mechanical Properties of slag

Properties	**Slag**	**Natural Coarse Aggregate**
Specific Gravity	3.1	2.78
Impact value	6.50%	7.1%
Water absorption	0.40%	0.5%
Crushing Strength	35.51%	29.6%

5. *Steel Fibers:* Steel fibers [2] having 0.92mm diameter, aspect ratio 25 and ultimate strength 330N/mm^2
6. *Chemical Admixtures:* A polycarboxylic type super plasticizer (SP) (Structure 100) and viscosity modifying admixture (VMA) (Structure 480) Conforming to EN 934-2 Table 3.1 with the following properties in Table: 2 is used.

Table: 2 Properties of Chemical Admixtures

Chemical admixture	Specific Gravity	pH	Colour	Dosage (l/m3)	Component
SP	1.01	6.3	Opaque	1- 4	Polycarboxylic Ether
VMA	1.06	6.4	Light yellow	0.5-2	Aqueous dispersion of microscopic silica

3. METHODOLOGY:

1. Mix Proportions: There is no standard method for SCC mix design and many pre cast and contracting companies have developed their own mix proportioning methods. Okamura's method, based on EFNARC [3] specifications, was adopted for mixed design. Different mixes were prepared by varying the amount of coarse aggregate (from slag), fine aggregate, and water powder ratio, steel fibers [2] (1%), SP and VMA. After several trials, SCC mix satisfying the test criteria was obtained. The details of the design mix are given in Table-4.

2. Tests on Fresh Concrete:

a. *Slump Flow:* The slump flow test is used to assess the horizontal free flow of SCC in the absence of obstructions. On lifting the slump cone, filled with concrete, the concrete flows. The average diameter of the concrete circle is a measure for the filling ability of the concrete. The time T_{50cm} is a secondary indication of flow. It measures the time taken in seconds from the instant the cone is lifted to the instant when horizontal flow reaches diameter of 500mm.

b. V-Funnel Test: The flow ability of the fresh concrete can be tested with the V-funnel test. The funnel is filled with about 12 liters of concrete and the time taken for it to flow through the apparatus is measured. Further, T_{5min} is also measured with V-funnel, which indicates the tendency for segregation, wherein the funnel can be refilled with concrete and left for 5 minutes to settle. If the concrete shows segregation, the flow time will increase significantly. According to Khayat and Manai [5], a funnel test flow time less than 6s is recommended for a concrete to qualify for an SCC

c. L-Box: The passing ability is determined using the L- box test. The vertical section of the L-Box is filled with concrete, and then the gate lifted to let the concrete flow into the horizontal section. The height of the concrete at the end of the horizontal section is expressed as a proportion of that remaining in the vertical section (h_2/h_1). This is an indication of passing ability. The specified requisite is the ratio between the heights of the concrete at each end or blocking ratio to be ≥ 0.8.

d. U-Box: The test is used to measure the filling ability of self-compacting concrete. The apparatus consists of a vessel that is divided by a middle wall into two compartments. An opening with a sliding gate is fitted between the two sections. Reinforcing bars with nominal diameters of 13 mm are installed at the gate with centre-to-centre spacing's of 50 mm. This creates a clear spacing of 35 mm between the bars. The left hand section is filled with about 20 liter of concrete then the gate lifted and concrete flows *upwards* into the other section. The height of the concrete in both sections is measured.

Table-3 Acceptance Criteria for SCC as per EFNARC

Test	Range	Result
Slump flow(mm)	650-800	715mm
V-Funnel (sec)	6-12	7.1sec
U-Box Value (h_2/h_1)	0-30	26
L-Box(h_2/h_1)	0.8-1.0	0.94

Table-4 SFRSCC Mix Proportions with Slag

Particulars	Quantity(Kg/m3)
Cement	456 Kg/m^3
Coarse aggregate	1188.34 Kg/m^3
Fine aggregate	560.04 Kg/m^3
Water(Lt/m^3)	191.5 lit/m^3
Super Plasticizer (Lt/m^3)	1-4 lit/m^3
VMA(Lt/m^3)	0.5-2lit/m^3
Steel Fibers	80 Kg/m^3

4. PREPARATION AND CASTING OF SPECIMEN:

The following mixing sequence was arrived after several trials for optimizing the workability. All the ingredients were first mixed in dry condition in the concrete mixer for one minute with slag as fine and coarse aggregate. Then 70% of calculated amount of water was added to the dry mix and mixed thoroughly for one minute. The remaining 30% of water was mixed with the super-plasticizer and viscosity-modifying agent and was poured into the mixer and mixed for five minutes. At this stage, 20% by weight of the water mixed with super plasticizer was poured into mixer and mixed for four minutes. Then, 10% by weight of water mixed with viscosity modifying agent was poured into the mixer and mixed for one minute. Later required quantities of steel fiber were sprinkled over the concrete mix and mixed for one minute to get a uniform mix. Thus, the total mixing time was 7 minutes.

In making SFRSCC with slag the proportion of slag is varied from MIX-0, MIX-20, MIX- 40, MIX-60, MIX-80 and MIX-100. MIX-60 represents preparation SFRSCC with 60% of Slag and 40% of natural aggregate. Concrete moulds are cleaned properly and the screws are tightened to make sure that no slurry will escape through the joint. After tightening, the moulds are oiled properly for easy striping of the specimen.

5. TESTS ON HARDENED CONCRETE:

a. ***Compressive Test***:

Cubes sizes were 150mm x 150mm x 150mm. Test being conducted using the compressive strength machine.

$$compressive\ Strenght = \frac{\text{Applied Load (N)}}{\text{Area of Cube (mm2)}}$$

b. ***Split Tensile Strength of Concrete***:

The cylinder sizes were 150mm x 300 mm. Test being conducted using the compressive strength machine. The spilt tensile strength (Ft) is calculated using the following expression.

$$Ft = \frac{2P}{3.14 * D * L}$$

Ft = spilt tensile strength in N/mm2
P = applied load in N
D = diameter in mm

L = length in mm

c. ***Flexural Strength of Concrete***:
The sizes were 100mm x 100mm x 500 mm. Test being conducted using the flexural strength machine The flexural strength (fp) is calculated using following expression

$$Fp = \frac{PL}{B * D2}$$

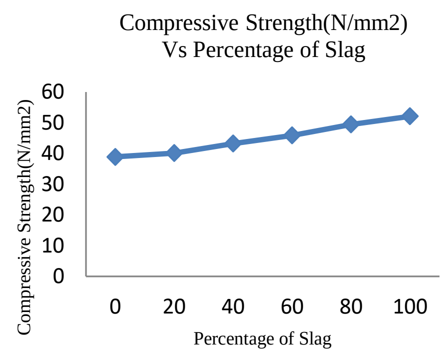
Fp = flexural strength in N/mm2
P = applied load in N
B = breadth in mm
D = depth in mm
L = length in mm of the span on which was supported

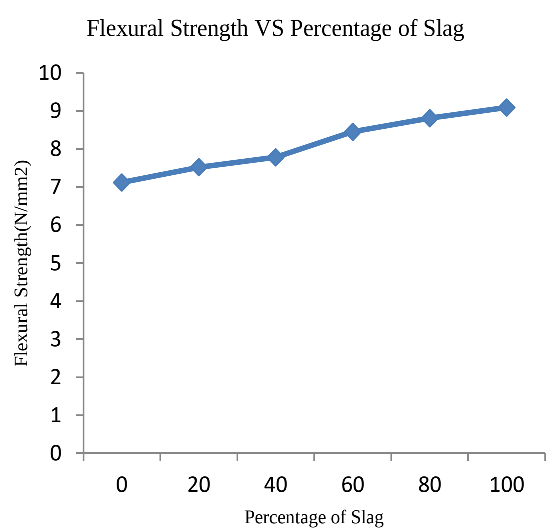
5. RESULTS AND DISCUSSION:

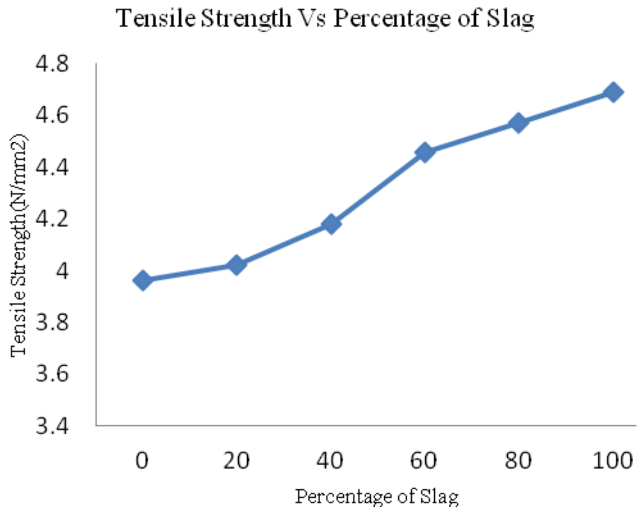
The percentage increase in weight of cube with respect to slag percentage is shown in below Table 5. When the natural aggregate is replaced by 20%, 40%, 60%, 80% and 100% with slag, the percentage increase is 0.749%, 2.334%, 3.753%, 4.904% and 6.028% respectively. So when the natural aggregate is replaced completely by slag, dead load will be increased only by 6.028%, which is very nominal. So there is absolutely no problem in using slag in the construction field as a replacement of natural aggregate.

Table 5 Different Mixes and their Properties

Mix Designation	MIX-0	MIX-20	MIX-40	MIX-60	MIX-80	MIX-100
Natural Aggregate (%)	100	80	60	40	20	0
Slag (%)	0	20	40	60	80	100
Weight (Kg)	7.95	8.01	8.14	8.26	8.36	8.46
Compressive Strength (N/mm^2)	38.89	40.12	43.23	45.9	49.46	52.12
Flexural Strength (N/mm^2)	7.12	7.52	7.78	8.45	8.81	9.09
Tensile Strength (N/mm^2)	3.96	4.02	4.18	4.46	4.57	4.69







6. CONCLUSION:

Based on the experimental research and behavior studies of the Steel Fiber reinforced Self-Compacting Concrete (SFRSCC) with Slag the following conclusions can be drawn.

- The workability increases with increase in the percentage of slag in place of normal coarse aggregate.
- The weight of the cube increases with increase in the percentage of slag as coarse aggregate. The increase is nominal, so the concrete with slag can be used in structural works.
- Compressive strength of concrete increases with increase in the percentage of slag, so it is better to design compression members with it.
- The flexural strength and tensile strength increased with increase in the percentage of slag as coarse aggregate.

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