

# Utilization of Iron Slag as Partially Replacement with Fine Aggrgate in High Strength Self-Compacting Concrete (HSSCC)

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**Abstract:-** lot of work within the field of normal mix concrete and Scc has been done in the last two decades. Utilization of different waste material from the different industries as the partial replacement of cement as well as aggregates both fine and coarse has been considered in the research work by different researchers as per their area of interest. No doubt use of Iron Slag has been in trend but only cement replacement is done with it. Research work in the replacing of Fine aggregate with iron slag in SCC has not been studied in detail. An aim was set to study the hardened properties and fresh properties of iron slag based HSSCC. Mix design of M60 grade of high strength self-compacting concrete is done as per EFNARC guidelines. Testing of rheological properties of HSSCC with U- Box, Slump Flow, L-Funnel, V- Box, apparatus were done. Testing of hardened properties of HSSCC for Split Tensile Strength, flexural strength, compressive strengths per Indian standard guidelines. Replacement of Fine aggregate (20, 30, and 40%) was done with iron slag and further addition of Alccofine and super plasticizer was done.

**Keywords-SCC,HSSCC, EFNARC, Iron Slag, Alccofine and super plasticizer**

## I. INTRODUCTION

Steel and Iron industries are always in a boom and the generation of slag is increasing from last 2 decades. It has become a major issue to dispose of the slag or utilization in a smart way. With a huge brain storming researchers have successfully explored the various alternatives to utilize the slag so that the developing countries can claim for the sustainable development. Iron slag could be a byproduct from the production of iron in an extremely furnace, found on the upper of the molten iron metal and processed a lot of for various treatments. Depending upon the different methods of treatment given to the flushed slag, it can be classified as Granulated Slag, Air Cooled Slag, and Expanded Slag.

Nowa days, the various forms of iron slag are being utilized in lightweight concrete, concrete masonry, road sub-base, soil cement, GGBFS cement, insulation, asphalt aggregates etc. Steel slag aggregate is also utilized in the asphalt, road base, and environment applications but due to less silica content, it is not blended with cement clinker. It is a very good barrier material which doesn't allow the heavy metals to leach out at waste disposal sites.

As per IS 456:2000[2],

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Concrete in the strength range 55-80MPa is graded as high strength concrete even M100 grade of concrete is also in trend and considered as high strength concrete. Increase in population and decrease in land available for construction has motivated structure designers to think of long span beams and long and heavy columns for tall structures, bridges as well as for off shore structures also. The design procedure of high strength concrete is totally different from the method followed for the design of normal concrete. Low water/cement ratio in the range 0.25-0.30 or even lower than that is the key technique of achieving the high strength of concrete and that is possible only with the addition of some water reducing chemicals called as plasticizer/super plasticizer. High levels of strength require the adding of some inanimate admixtures like silica fume, met kaolin etc. Scc is that the concrete that's able to flow underneath its own weight and fully fill formwork, even within the presence of reinforcement while not the necessity of any vibration while maintaining homogeneity [3]. Health issues like psychosomatic issues or hearing problems are no more seen caused at the work place. Although it was developed in 1986 in Japan but it is developed very slowly and being adopted in structures having congested reinforcement.

## II. MATERIALS

### CEMENT

Ultra tech Ordinary Portland Cement (OPC) grade 53 as per IS 269:2015 [26] taken from RMC plant ultra tech ltd, Mohali.

### COARSE AGGREGATE

Coarse aggregate of size 10mm sieve collected from Ultra Tech RMC Plant, Mohali. Testing of coarse aggregate for crushing value, water absorption, specific gravity, c and impact value confirms to IS 383:2016 .

### FINE AGGREGATE

Fine aggregate of size ranging 4.75mm to 150 microns collected from Ultra Tech RMC Plant, Mohali. Physical Properties of the fine aggregates and sieve analysis were done confirming to IS 383:2016

### ALCCOFINE

Alccofine 1203 is an innovative, ultra-fine material having low calcium silicate content. It has high initial rate of strength as it provokes the initial reaction during hydration. It also fritters away the waste calcium hydroxide that is generated during the formation of C-S-H gel.

### IRON SLAG

Iron slag was collected from Punjab Steels at Mandi Gobindgarh "The Steel City of Punjab" and grinded to Zone II of Fine aggregate as per Indian Standard 383:2016.

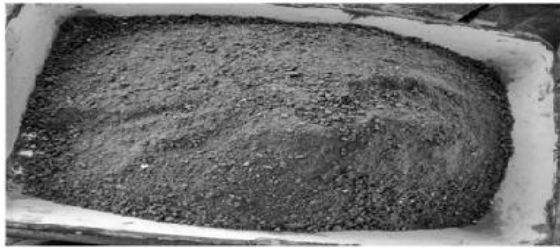


Figure 1 IRON SLAG GRINDED TO ZONE II

**Super Plasticizer**

Sika Visco Crete 5207 NS high performance super plasticizer admixture was used for high workability and reducing of water content. Various characteristics of Visco Crete 5207 NS given by Sika is given in the table 1.

Table 1 Properties of Super Plasticizer Visco Crete 5207 NS

Characteristic	Value
Appearance	Light Brown Liquid
Relative Density	1.12 at 25° C
pH	≥6
Chemical Base	Aqueous Solution of modified poly carboxylate

**MIX DESIGN:-**

The design of M60 grade of high strength SCC is done following the European Federation of National Associations Representing for Concrete Guidelines (EFNARCG).

**III. RESULTS AND DISCUSSION**

Different tests were organized to find the results of partial replacement of fine aggregate with iron slag in HSSCC. Fine aggregate was replacing with 20, 30, 40 % iron slag and fresh properties of HSSCC like L-Box ratio, V-Funnel, and U-Box value as well as the hardened properties like Split Tensile Strength, compressive strength, flexural strength were investigated. Mix design trials as well as the testing procedures are discussed in the previous chapter.

**FRESH PROPERTIES OF HSSCC**

The fresh properties of varied mixtures are summarized within the following table:

Table 2 Fresh Properties of HSSCC Mixtures

% Replacement of fine aggregate with iron slag	Slump Flow (mm)	U-Box (H2-H1)	L-Box (H2/H1)	V-Funnel (sec)	T-50 (sec)
0	765	24	0.89	11	2.90
20	725	26	0.85	12	3.23
30	682	27	0.83	13.5	4.07
40	661	28	0.82	15	4.53

**IV. HARDENED PROPERTIES**

**COMPRESSIVE STRENGTH**

The reference mix of HSSCC and other mixtures with 20, 30, and 40% replacement are tested for compressive strength on a CTM machine at curing age of 7, 14, and 28 day. All the results for a similar square measure shown within the table 14.

Table 3 Compressive Strength Tested on 150x150x150 mm Cubes

% Replacement of Fine aggregate with iron slag	Compressive strength (N/mm <sup>2</sup> )		
	7 days	14 days	28 days
0	41.77	61.66	68.70
20	46.73	65.67	71.79
30	52.55	69.70	75.65
40	54.15	73.45	78.33

The Compressive Strength of HSSCC with 0, 20, 30, 40% replacement of Fine aggregate with iron slag at 7 days result are shown in the Figure 1, at 14 days result are shown in the Figure 2, and at 28 days result are shown in the Figure 3.

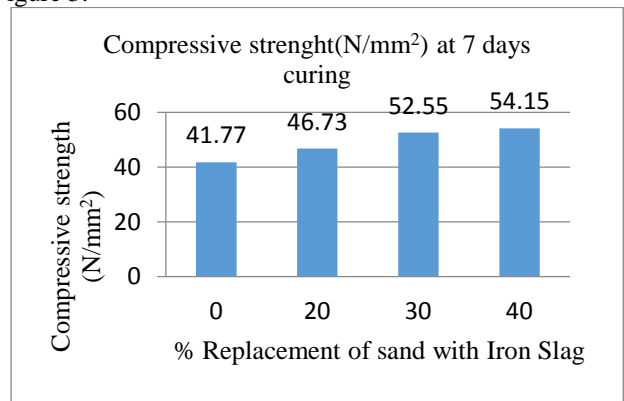


Figure 1 Compressive Strength at 7 days

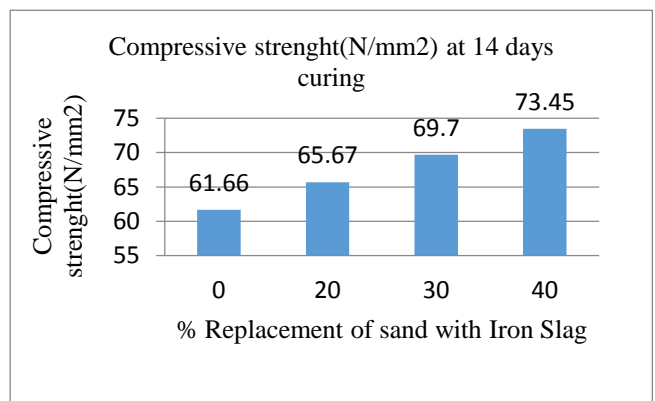


Figure 2 Compressive Strength at 14 days

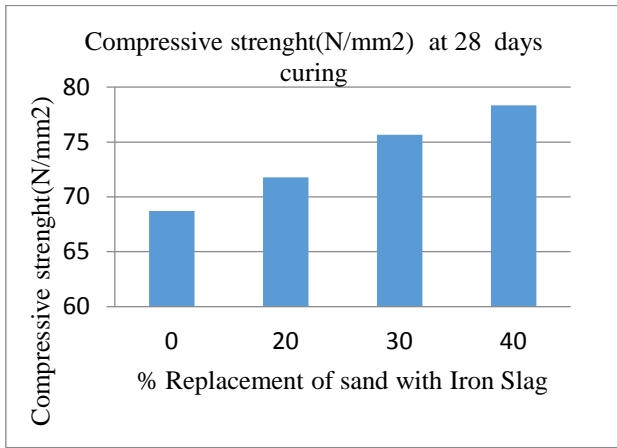


Figure 3 Compressive strength at 28 days

In the Figure 4 the comparison of Compressive strength of HSSCC with (0, 20, 30, 40) % replacement at 7, 14, 28 days curing. It has been observed that with increase in

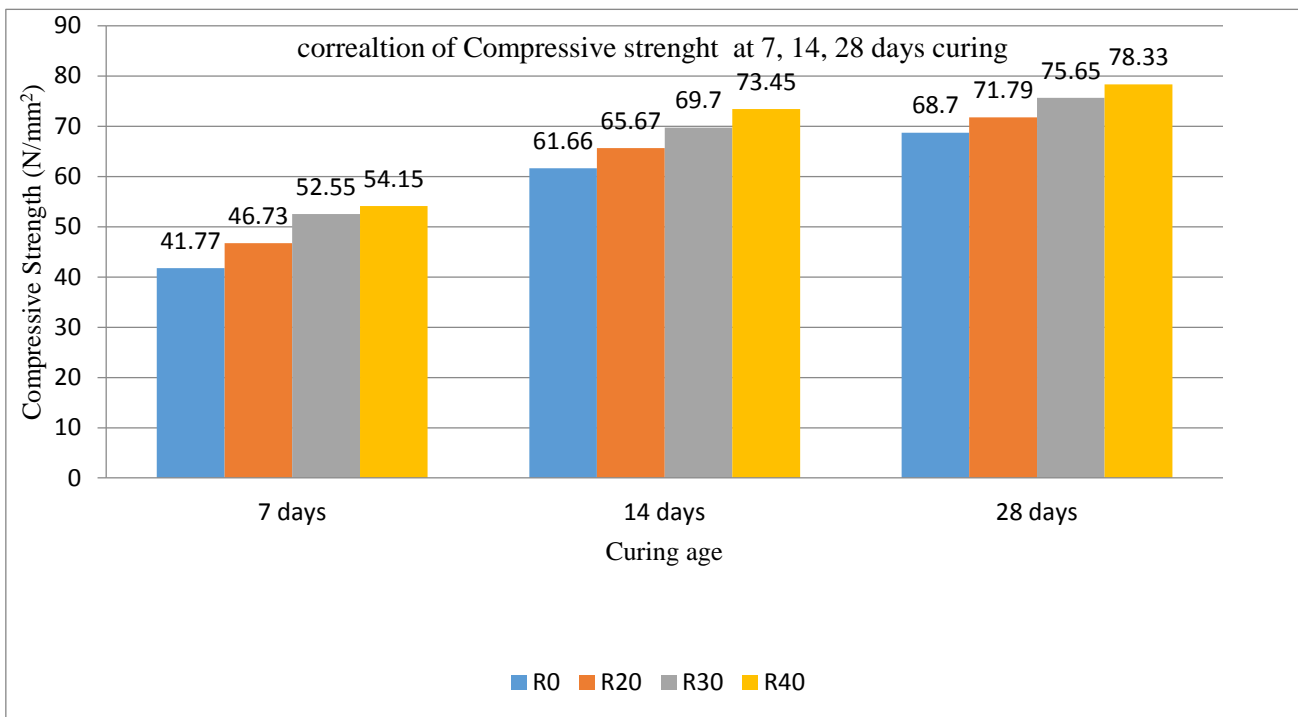


Figure 4 Compressive strength at 7, 14, 28 days

### Split Tensile Strength

To determine the split tensile strength of normal HSSCC and HSSCC containing iron slag cylinder size of 150x300 mm are used and total 36 cylinders were casted for testing. 3 cylinders for each mix group are casted and tested at each stage curing. Test results of Split Tensile Strength at 7, 14, 28days curing are shown in the table no .8

Table 4 Split Tensile Strength tested on 100\*200 mm Cylinders

% Replacement of Fine aggregate with iron	Split Tensile Strength (N/mm²)		
	7 days	14 days	28 days
0	4.11	6.03	6.73
20	4.54	6.41	7.36
30	5.15	6.93	8.11
40	5.73	7.39	8.56

replacement percentage of Fine aggregate with iron slag, the compressive strength is increased at 7,14,28 days curing. At 7 days, the increase in compressive strength while comparing it with R0 was (10.61, 20.51, and 22.86) % with 20, 30, 40 % replacement of fine aggregate with iron slag . At 14 days, the increase in compressive strength of HSSCC with R0 mix proportion without iron slag was (6.11, 11.54, 16.05) % with 20, 30, 40 % replacement of fine aggregate with iron slag. At 28 days, the increase in compressive strength of HSSCC with R0 mix proportion without iron slag was (4.30, 9.19, 12.29) % with 20, 30, 40 % replacement of Fine aggregate with iron slag. With increase in curing, Hydration of cement produces alkali calcium hydroxide that reacts with reactive silica present in iron slag and gives stable calcium silicate that leads to lesser no. of voids and more compressive strength [22].

slag			
0	4.11	6.03	6.73
20	4.54	6.41	7.36
30	5.15	6.93	8.11
40	5.73	7.39	8.56

Figure no 5, Figure no 6, and Figure no 7 represents the Split Tensile Strength HSSCC with 0, 20, 30, and 40% iron slag at 7, 14, and 28 days. It is checked that the Split Tensile Strength increased with increase in % replacement of Fine aggregate with iron slag in HSSCC.

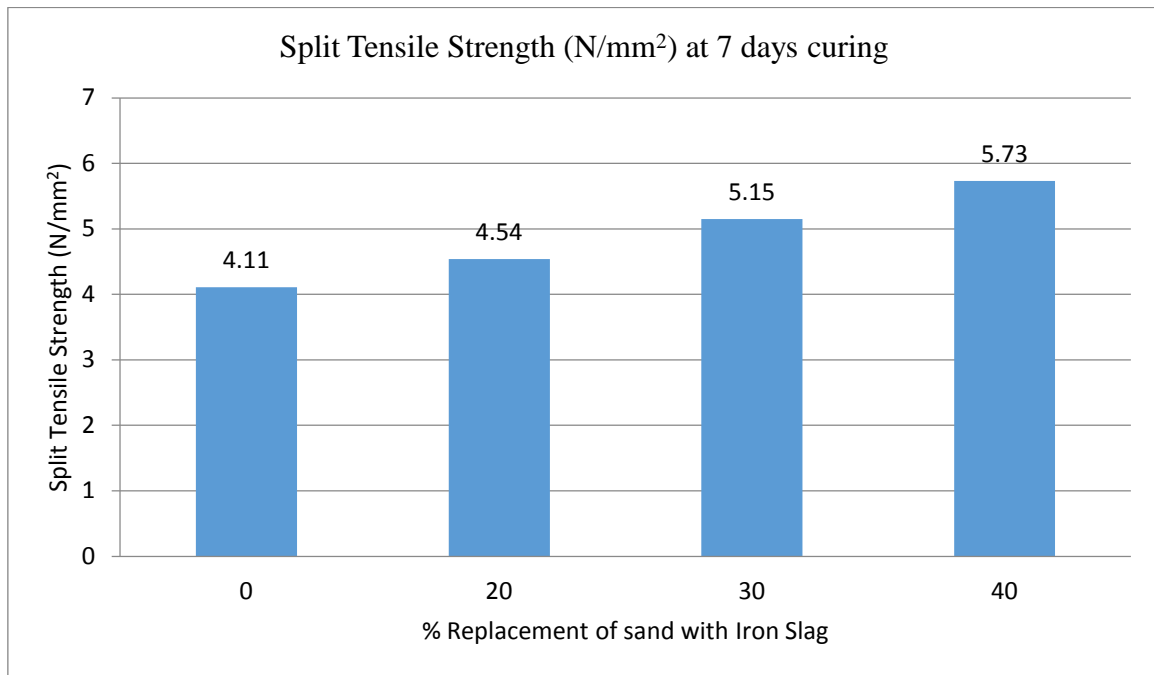


Figure 5 Split Tensile Strength at 7 days

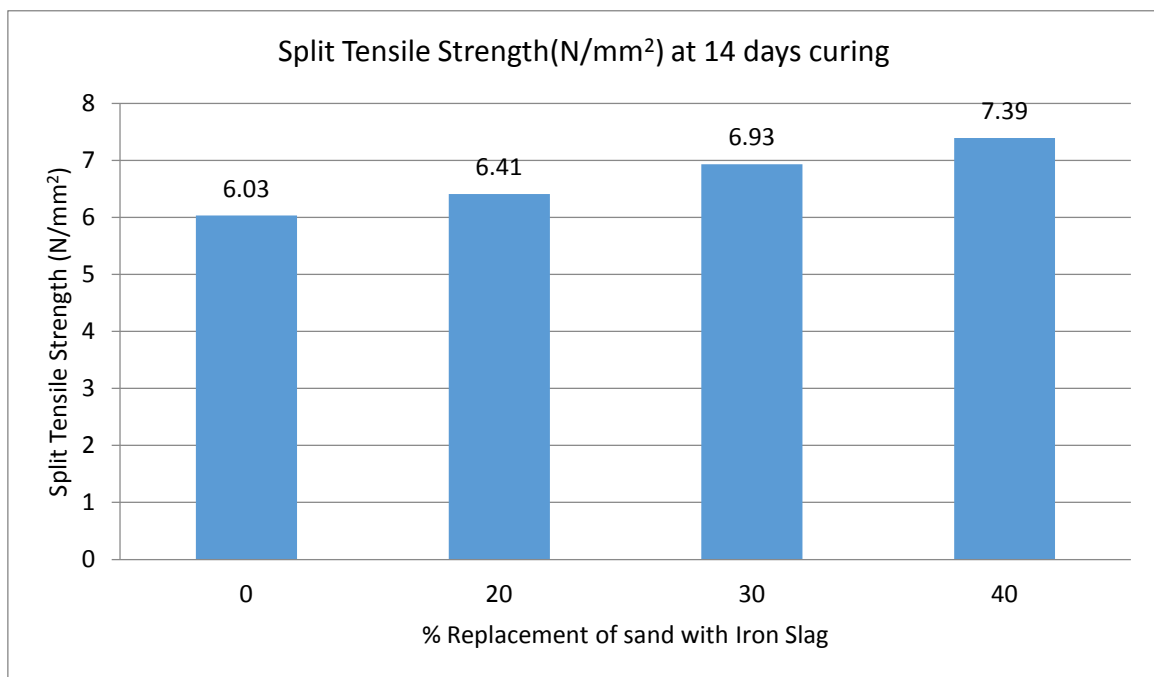


Figure 6 Split Tensile Strength at 14 days

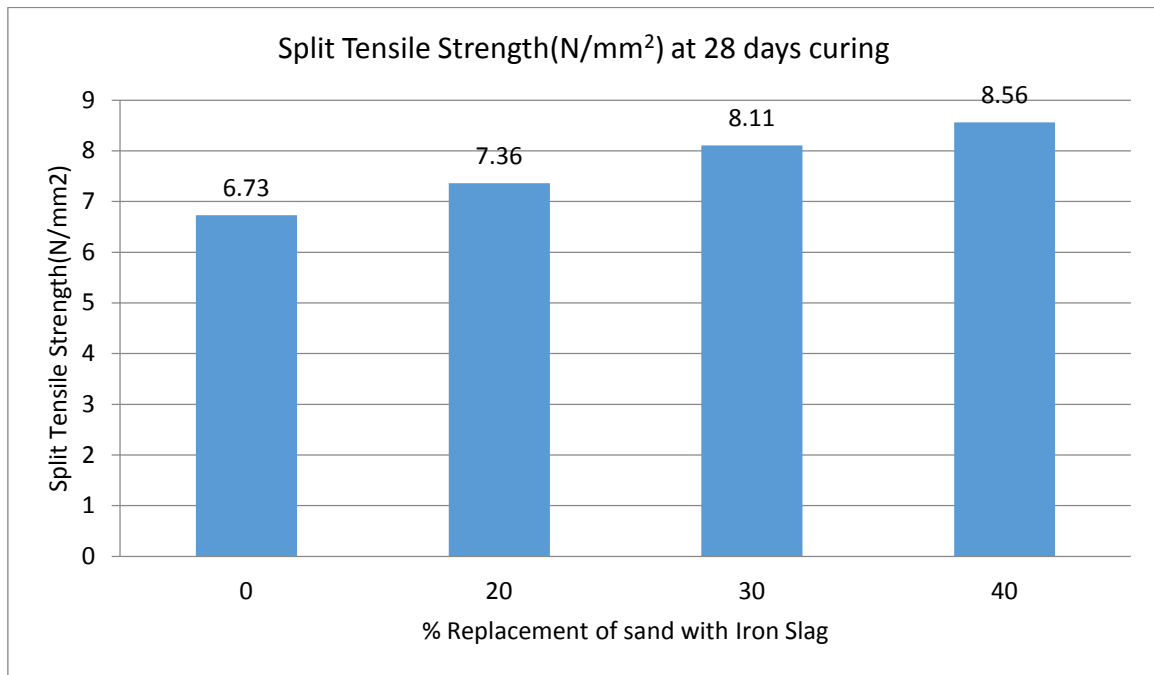


Figure 7 Split Tensile Strength at 28 days

It has been observed that at 7 days the HSSCC mixture containing 20, 30, and 40 % iron slag as fine aggregates gained (9.47, 20.19, and 28.27) % more Split Tensile Strength compared to HSSCC without iron slag . At 14 days, the gain in split tensile strength of HSSCC mixtures containing 20, 30, and 40% iron slag as fine aggregates as

compared to HSSCC without iron slag is (5.93, 12.99, and 18.40) % respectively. At 28 days, the HSSCC mixture containing 20, 30, and 40 % iron slag as fine aggregates gained (8.56, 17.02, and 21.38) % more Split Tensile Strength as compared to HSSCC without iron slag. The comparative results are shown in Table 8.

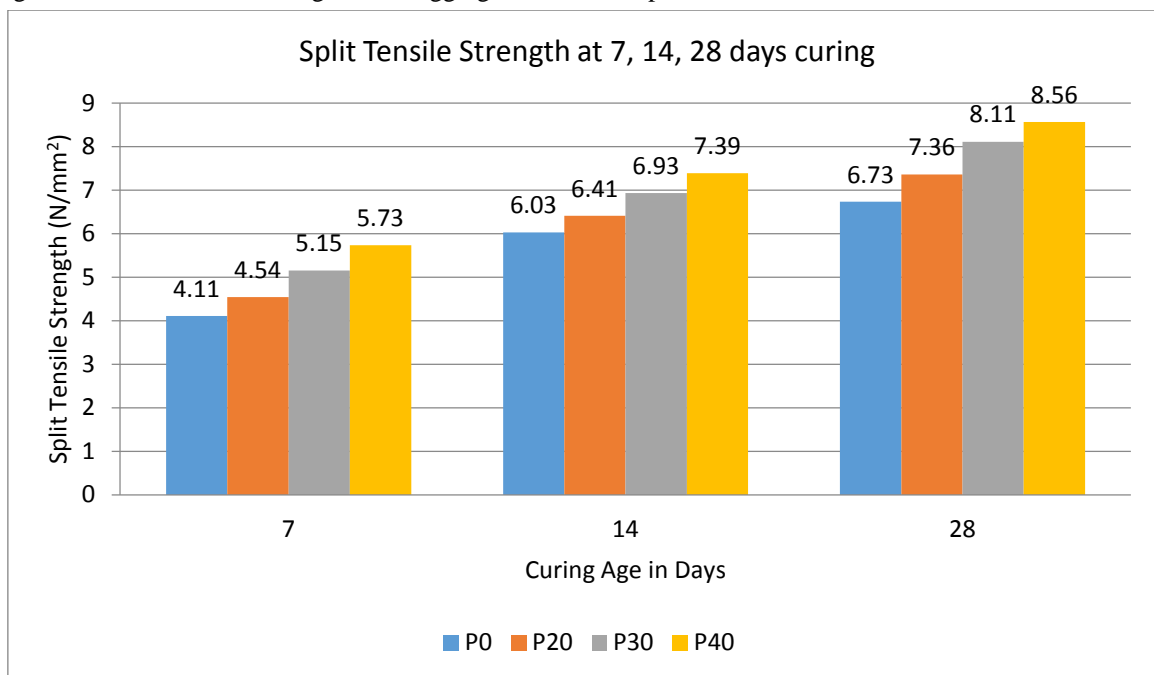


Figure 8 Split Tensile Strength at 7, 14, 28 days

### FLEXURAL STRENGTH

It is tested on beams of size 100×100×500 mm (IS: 516-1959). 3 Beam samples of each mix group are casted and tested at different curing age. 36 beams are casted and put in the curing tank. All testes of flexural strength at 7, 14 and 28day results are shown in Table no.5

# Utilization of Iron Slag as Partially Replacement with Fine Aggregate in High Strength Self-Compacting Concrete (HSSCC)

Table 5 Flexural Strength tested on 100\*100\*500 Beams

%Replacement of Fine aggregate with iron slag	Flexural Strength (N/mm <sup>2</sup> )		
	7 days	14 days	28 days
0	3.97	4.78	6.13
20	4.32	5.11	6.88
30	4.98	5.50	7.13
40	5.11	6.03	7.37

A similar trend like Split Tensile Strength and compressive strength. Split Tensile Strength is followed in this also i.e. the flexural strength goes on increasing with curing age and increase in % replacement of Fine aggregate with iron slag up to 40%. Figure no. 9 represents the flexural strength of HSSCC containing 0, 20, 30, 40% iron slag as fine aggregates at 7 days. Figure no.10 represents the flexural strength of HSSCC with 0, 20, 30, 40% replacement of Fine aggregate with iron slag at 28 days. Figure11 shows the flexural strength of HSSCC mixtures at 28 days.

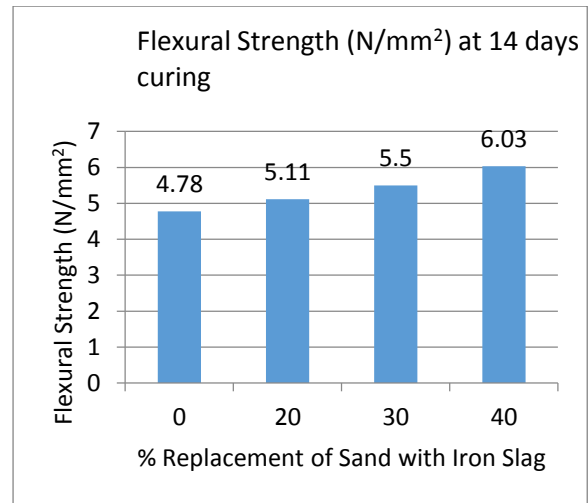


Figure 10 Flexural Strength at 14 days

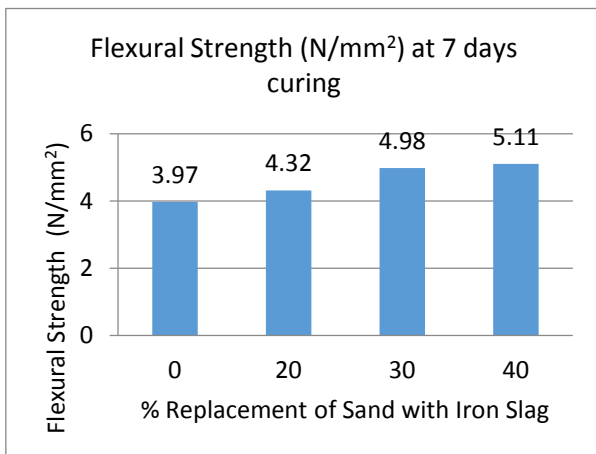


Figure 9 Flexural Strength at 7 days

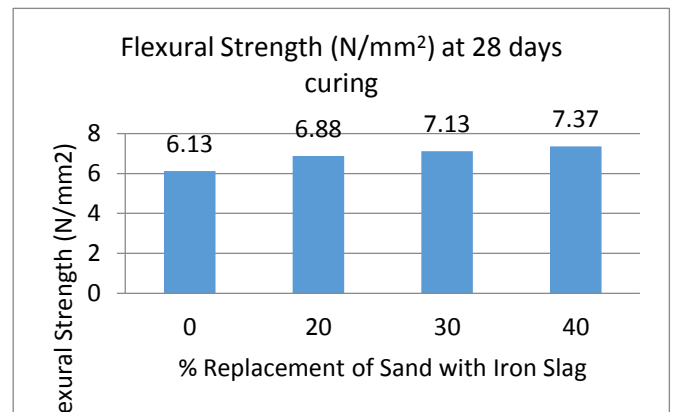


Figure 11 Flexural Strength at 28 days

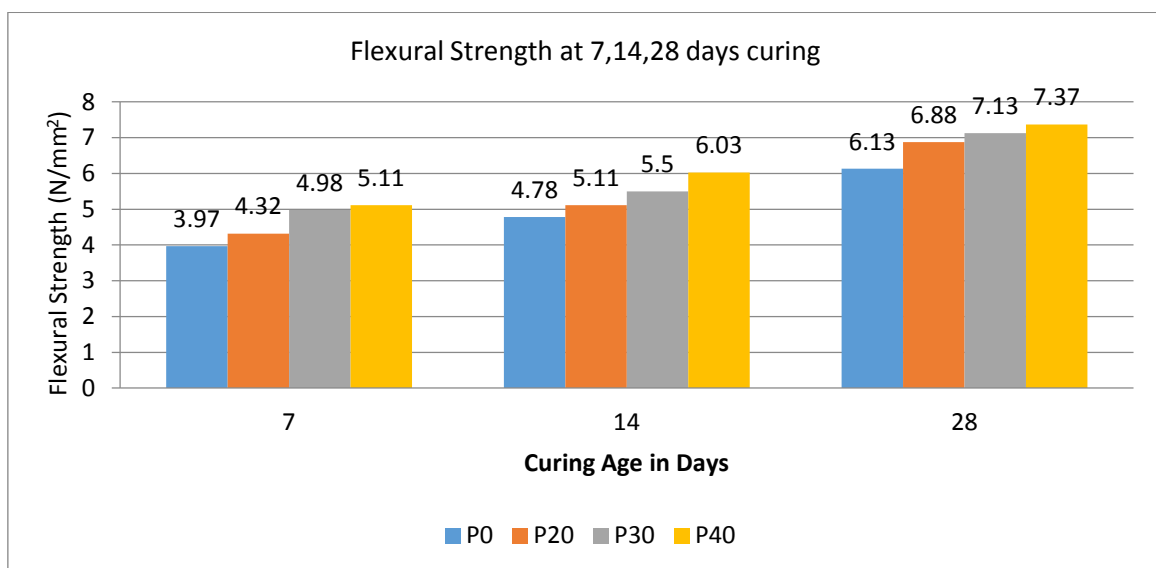


Figure 12 Flexural Strength at 7, 14, 28 days

Figure 12 represents flexural strength at all curing ages with (0, 20, 30, 40) % Fine aggregate replacement with iron slag . It is observed that at 7 days age, HSSCC containing 20, 30, 40 % iron slag as fine aggregates gained (8.10, 20.28, and 22.31) % more flexural strength than HSSCC without iron slag. At 14 days age, HSSCC containing 20, 30, and 40 % iron slag as fine aggregates gained (6.46, 13.09, and 20.73) % more flexural strength than HSSCC without iron slag. At 28 days age, HSSCC containing 20, 30, and 40% iron slag as fine aggregates gained (10.90, 14.03, and 16.82) % more flexural strength than HSSCC without iron slag.

## V. CONCLUSION

After summarizing the investigation work on the impact of iron slag as partially replacement of fine aggregate M60 grade of HSSCC. It includes assorted findings the study.

- Test results show that there's decrease in slump flow, L-Box, U-Box and values with increase in 20% replacement of Fine aggregate with Iron slag and V-Funnel time increased with increasing 40% of iron slag. a lot of granular and rough texture of iron dross will increase the put down particle friction that decreases the on top of aforesaid values, ultimately decreasing the workability.
- It is concluded that HSSCC with iron dross as fine aggregates need slightly a lot of quantity of chemical admixture to form it workable enough.
- Observed data conclude that there's hike altogether hardened properties of HSSCC that's split tensile strength, compressive strength and flexural strength of M60 grade of self-compacted concrete with 40% replacement of Fine aggregate with iron slag
- There is no adverse result of substituting fine aggregate and iron slag on strength parameters of HSSCC.
- Increase altogether strength parameters of HSSCC makes iron slag a helpful candidate to exchange Fine aggregate up to 40% and any increase in replacement is studied.

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