EXPERIMENTAL INVESTIGATION ON SELF COMPACTING CONCRETE CONTAINING IRON SLAG AS PARTIAL REPLACEMENT FOR FINE AGREGATE.

Submitted in partial fulfilment of the requirements

Of the degree of

MASTER OF TECHNOLOGY

in

CIVIL ENGINEERING

by

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2017

CERTIFICATE

This is to certify that this dissertation report entitled, "**SELF COMPACTING CONCRETE CONTAINING IRON SLAG AS PARTIAL REPLACEMENT FOR FINE AGREGATE"** is a bonafide work done by "**MIRZA NAJAM AL HASSAN BAIG, Reg. No.:- 11502710"** Student of Civil Engineering Department, Lovely Professional University, Phagwara, Punjab in partial fulfilment of the requirement for the Degree of Master Of Technology in Structural Engineering. This report has not been submitted to any other university or an institution for the award of any degree.

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DECLARATION

I, Mirza Najam AL Hassan Baig (11502710), hereby declare that the dissertation report entitled, **"SELF COMPACTING CONCRETE CONTAINING IRON SLAG AS PARTIAL REPLACEMENT FOR FINE AGREGATE"** is a bonafide and genuine research work carried out by myself under the guidance of **Mr. Navaneethan, Assistant Professor; Department of Civil Engineering, Lovely Professional University**, **Phagwara.**

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ABSTRACT

This study was conducted to find out the effect of partial replacement of fine aggregate by IRON SLAG and its effect on the fresh and hardened properties of self compacting concrete. The tests for the fresh properties of self compacting concrete where conducted immediately after the mixing of concrete and for the hardened properties at 7 days, 14 days & 28 days of curing. The mixture was prepared by replacing fine aggregate with Iron Slag in the ratio of 0%, 10%, 20 %, 30%, 40% & 50% by weight of fine aggregate .The effect of iron slag as a substitute for fine aggregate was determined on in this project. Iron slag is a material of low density as compared to fine aggregate but it doesn't affect the strength properties of concrete as found in this study.

From the experimental study, it is found that there is a decrease in workability (in view of fresh properties of Self compacting concrete) with the increase in replacement levels of fine aggregate with iron slag. It is also found that with the increase in replacement levels there is a significant increase in the hardened properties namely compressive, split tensile and flexural strength in the specimens at all curing ages. With 40% replacement of fine aggregate with iron slag which passed the workability criteria of Self compacting concrete, there is an increase of 19.86% in compressive strength, 16.66% in split tensile strength and 10.27% in flexural strength of the specimens after a curing period of 28 days as compared to the controlled mix (0% replacement). From the experimental findings, it is observed that iron slag is a good substitute for fine aggregate partially in SCC as it enhances the load carrying capacity of Self compacting concrete.

Keywords: Self compacting concrete (SCC), fresh properties of SCC, compressive strength, split tensile strength and flexural strength.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF SYMBOLS

SCC	Self Compacting Concrete
CA	Coarse aggregates
FA	Fine aggregates
OPC	Ordinary Portland cement
mm	Millimetre
Sec	Second
kg	Kilogram
%	Percent
kg/m^3	Kilogram per metre cube
MPa	Mega-Pascal

CHAPTER 1

INTRODUCTION

1.1.General

In this present world construction work is increasing everywhere on a huge scale and due to which our natural resources which are the essential ingredients our concrete are depleting enormously. In an attempt to save our natural recourses my dissertation work is based on partially replacing fine aggregate (sand) with iron slag in making Self Compacting Concrete. Literature survey indicates that there is only one published work relevantly related to use of iron slag in self-compacting concrete. Literature review was concentrated on use of slag in concrete as well as Self-compacting concrete.

1.2. Self Compacting Concrete

Self-compacting concrete (SCC) can be defined as a concrete which consolidates under its own weight with or without vibration. It facilitates and ensures proper filling and excellent structural performance of heavily reinforced congested members. A well designed SCC mix, has high deformability, excellent stability characteristics and does not segregate .Self-compacting concrete has been placed from heights more than 5 meters without segregation.

Lately, the demand of self-compacting concrete (SCC) has increased considerably. Superior Concrete, which incorporates high-fluidity concrete and high-strength concrete, must be created with cutting edge superplasticizers. At the point when utilized as a part of SCC, mineral admixtures can considerably reduce the amount of superplasticizer required to accomplish a given fluidity.

1.3 Iron Slag

Iron slag is an industrial waste material. It is a by-product of the iron and steel manufacturing process. Iron Slag is lighter than river sand is also brittle. Fineness modulus, unit weight specific gravity & water absorption by mass (%) of iron Slag are 2.38, 2000 kg/m^3, 2.5 & 18.54 %. Iron slag is glassy black in colour the major chemical composition and physical properties of slag are listed in the **Table 1.1**.

Table 1.1: Chemical composition of Iron Slag

Chemical proportions	**Percentage (%)**
Fe_2O_3	66.88%
SiO_2	6.98%
Al_2O_3	2.94%
CaO	0.8%
CO_2	22.4%

1.4. Advantages of using Iron Slag in SCC

1. Improves the strength properties of SCC.
2. Internal structure of concrete gets denser after inclusion of iron slag.
3. Increases the resistance to chloride ion penetration.
4. Improves pore refinement.
5. It decreases the permeability of concrete.

1.5. Advantages of SCC

1. The freedom of designing SCC is greater than normal concrete and therefore thinner sections of concrete can be made.
2. Improves the quality of concrete and reduction of onsite modifications.
3. It reduces the overall cost of construction.
4. Helps in faster construction.
5. It makes it easier for the introduction of automation into construction.
6. It helps in better placing to concrete and thereby results in cost saving through less use of equipments and labour.

7. High resistance of SCC to segregation allows the elimination of macro defects, air bubbles and honeycombs which handicap the mechanical performance and structural durability of SCC.
8. It helps in improving the safety and also health on site through the elimination of vibrator use and thereby also helps in reduction of environmental noise on and around the site.
9. SCC improves the durability and reliability of concrete.
10. It reduces the wear and tear on form work due to elimination of vibrators.

1.6. Disadvantages of SCC

1. Requires precision in evaluation and monitoring of the constituent materials used.
2. It requires a number of trial batches in laboratory in designing it.
3. Its manufacturing cost is more than normal concrete.
4. Inflexible guidelines for the selection of materials used.
5. Lack of globally accepted test standards and mix design.

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CHAPTER 2

LITERATURE REVIEW

Gurpeet Singh et al.,(2016) In this experimental study the durability properties of SCC with replacement of iron slag with sand in levels of (0%, 10%, 25% & 40 %) were studied. In this study it was found that SCC using iron slag gave better strength and durability than normal SCC and thus can be used in SCC. The compressive strength of SCC with substitution levels of (10%,25% & 40%) where 4%, 13% & 21% (at 28 days) more as compared to controlled mix with slight increase in compressive strengths with time. It was also found that the water absorption of was SCC with iron slag was lesser than that of controlled mix. The chloride ion penetration was found to b good for SCC with iron slag, ultra sonic pulse velocity shows an excellent condition of SCC with iron slag, SEM images showed than internal structure of SCC gets denser with IRON SLAG.

Yeong~Nain Sheen et al.,(2015) in this experimental program, SCC was made using stainless steel oxidizing slag (SSOS) as replacement for coarse and fine aggregate with (0%, 50% &100%) replacement and stainless steel reducing slag (SSRS) as partial replacement for cement in levels of (0%, 10%, 20% &30%) with a fixed water to binder ratio of 0.4.Incorporating SSOS as aggregates and SSRS as cement replacements reduces the workability of SCC. It was found that that SCC containing stainless tell slag can enhance the hardening process resulting in shortening the setting time by 25 % and 36 % corresponding to 50% & 100% replacement of SSOS aggregates. Compressive strength of SSC (100% SSOS) is10-23% better than that of controlled mix and of (50%SSOS) SCC at 91 days.

Dinakar (2015) in this study the main objective was to design SCC with granulated blast furnace slag as replacement for cement in levels of 20-80%.it was found that SCC with strength in range of 30-100MPa at replacement levels of 20-80% can be made. The authors gave a methodology for design of SCC using GBFS.

The proposed procedure comprises of five stages, all of which depend on basic computations. The aggregate powder substance is settled in the initial step, the rate of slag is settled in view of the quality required and the proficiency (k) is resolved. In the third step the water to binders ratio required for building up the SCC is resolved. In the fourth step the quantities of coarse and fine aggregates are resolved utilizing the appropriate combined aggregate grading curves of DIN Standards.

At last the fresh properties of SCC are checked so as to see whether it falls in the limits given by ERNARC.

M.Valcuende et al.,(2014) in the experimental study the aim was to find the shrinkage of Self compacting concrete with time with replacement of sand by blast granulated furnace slag (GBFS) in levels of (0%,10%,20%,30%,40%,50% and 60%) with a water to binder ratio of 0.55.It was found that during the early days the compressive strength of SCC with replacements was almost equal as compared with the reference SCC but the strength increased with age of .This may be due to the slag reactivity. It was also found that higher the replacement levels, higher were the shrinkage levels of SCC as compared to the reference mix. The shrinkage was in the range of 4 -44 % when replacement levels where 10 -60%.

Her-Yung Wang et al.,(2013) in this study the properties of SCC made with a fixed water to binder ratio of 0.37 and replacement of cement by slag in the ratios of 0%,15% and 30% where studied. In this study it was found that the slump flow of SCC changed with the increase in substitution levels of slag for cement. The slump flow value for 15% replacement was found to be within design limits (550-700 mm).The compressive strength of samples with 15% substitution was found to be higher than the normal mix by almost 13 %.also it was also found that the shrinkage of SCC increased as the amount of slag used was increased, with the maximum shrinkage being in 30 % replacement.

Mehmet Gesoglu et al.,(2012) in this experimental program, the main aim was to check the properties of SCC with replacement of coarse aggregates with GGBS (as artificial coarse aggregate) in the replacement levels of (0%,20%,40%,60% & 100%), fly ash was added as a binder to impart desired fluidity to SCC. It was found that with the increase in substitution levels of GGBS the amount of superplasticizer used to achieve slump flow reduced. The compressive strength increased with all replacement levels of GGBS as compared to normal mix but the maximum value of compressive strength was achieved with 60% replacement.

Othmane Boukendakdji et al.,(2011) in this study the effect of two types of super plasticizers viz polycarboxylate based and naphthalene sulponate based with GBFS on SCC where studied. The GBFS replacement levels were in the levels of 0%, 15%, 20% and 25 %.the various tests conducted indicated that with the use of polycarboxylate based superplasticizer resulted in better workability and higher compressive strength than naphthalene sulponate based. Workability maintenance of around 45 min with 15 & 20 % of slag replacement was acquired using the polycarboxylate based superplasticizer.

CHAPTER 3

SCOPE OF STUDY

Normal Concrete needs vibration in order to expel the entrapped air and thus making it denser and homogeneous. Sufficient compaction is difficult to attain sometimes due to congested reinforcement, as a result of which Self Compacting Concrete was created in 1980's.SCC is an of late created idea in concrete technology. The advancement of SCC has denoted a gigantic stride toward effectiveness and working condition on development site. One impediment of SCC is its cost, associated with the usage of synthetic admixture and use of high volume of concrete. Over production of concrete has caused depletion of natural sand (Fine Aggregate).as a result of this depletion substitute materials are being researched upon as replacement of natural sand it is thusly fundamental to obtain such substance for concrete through legitimate mix proportions using modern by items, for instance, slag in this manner proficiently adding to worldwide maintainable advancement. The degree of slag as a substitute of natural sand in SCC was researched in this venture. At the point when SCC containing slag is utilized as a part of self-compacting concrete structures, the engineering properties of SCC can be can be improved significantly , and the waste asset namely Iron Slag used.

CHAPTER 4

OBJECTIVES

The aim of this study was

- To make self compacting concrete with replacement of fine aggregate by iron slag this reduced the cost considerably.
- To find out the optimum replacement levels of sand with iron slag this didn't alter the engineering properties of SCC.
- To find the effect of slag on the strength properties of SCC namely, compressive, tensile and flexural strength.
- To find out the effect of replacement by slag on workability, initial and final setting time of SCC mixes.
- To use iron slag which is a waste product and incorporate it in SCC which will slightly reduce its environmental pollution effects.

CHAPTER 5

MATERIALS AND METHODOLOGY

5.1 Material Used

The various materials used in this experimental study are as follows.

5.1.1 Cement

The cement used was taken from a local Khyber Cement Vendor and the cement used is OPC 43 grade with consistency (P) of 27%, initial setting time of 48 min and final setting time of 283 min with a specific gravity of 3.15.

5.1.2 Iron Slag

Iron Slag was collected from Vardhman Special Steels Ludhiana Punjab India. Iron slag was sieved to remove the larger particles and slag passing through 4.75 mm sieves was used in concrete. Iron Slag is lighter than river sand is also brittle. Fineness modulus, unit weight specific gravity & water absorption by mass (%) of iron slag are 2.38, 2000 kg/m^3, 2.5 & 18.54 %. Iron slag is glassy black in colour, the major chemical proportion of iron slag are listed in the **Table 5.1.**

Table 5.1: Chemical proportion of Iron Slag

Chemical proportion	Percentage (%)
Fe_2O_3	66.88%
SiO_2	6.98%
Al_2O_3	2.94%
CaO	0.8%
CO_2	22.4%

5.1.3 Aggregates

The coarse aggregate where 10-12 mm in size brought from a local crusher plant in Ganderbal J&K and fine aggregate river sand bought from a local vendor from the same place with fineness modulus 2.81 confirming to Zone I.

5.1.4 Water

The guidelines regarding quality of mixing water are that water should be fit for drinking. This water used should have an inorganic solids content less than 1000 ppm leading to a solid quantity of 0.05% of mass of binder when w/c ratio is provided in range of 0.5 resulting in a small effect on the strength. The w/c ratio used in this project is kept constant at 0.4.

5.1.5 Admixture

Auramix 400 high performance super plasticizer with low viscosity based on polycarboxyclic base was used in this project. This admixture has been developed for high pumpable concrete and SCC by Fosroc chemicals. It is light yellow coloured with PH of 6 .0 and 0 % chloride content.

5.2 Methodology

5.2.1 Mix Design

The mix design was selected by trial mixes the controlled mix achieved strength of 42.44 MPa at age 28 days. Fine aggregate(river sand) and was replaced with iron slag by mass in increments of 10 % (0 % - 50 %).Fixed quantities of Coarse Aggregate (C A) ,Cement , Admixture and W/C ratio i.e. 760 kg/m^3 , 550 kg/m^3, 1.2 % & 0.4 were used in the making the samples. The mix proportions of SCC are shown in the **Table 5.2**.

Table 5.2: Mix Proportions of SCC

Mix Constituents	SCC- CM	SCC – IS10	SCC – IS20	SCC – IS30	SCC – IS40	SCC – IS50
Cement (kg/m^3)	550	550	550	550	550	550
C A (kg/m^3)	760	760	760	760	760	760
Sand (kg/m^3)	960	864	768	672	576	480
Iron Slag (kg/m^3)	0	96	192	288	384	480
Iron Slag (%)	0	10	20	30	40	50
W/C Ratio	0.40	0.40	0.40	0.40	0.40	0.40
Admixture (%)	1.27	1.27	1.27	1.27	1.27	1.27

CHAPTER 6

EXPERIMENTAL SETUP

In this experimental study, total number of 54 cubes, 36 cylinders and 36 beams were casted in the laboratory. All the specimens were tested under CTM to study the compression behaviour of cubes.

6.1 Fresh Properties of SCC

The properties of SCC in fresh state were judged by checking the flowability, passing ability and filling ability of SCC for controlled mix and mix with replacement of slag with fine aggregates. The valuation of the fresh properties of SCC has been done by Slump Flow test, L Box Test & V Funnel Test. It was found that with the inclusion of iron slag in SCC there was a decrease in workability. All the fresh properties of SCC tested in this project are within the desired limits given by EFNARC except SCC – IS50.The results from the fresh properties of SCC are given in **Table 6.1 and shown in Figures 6.1 - 6.3.**

6.1.1 Slump flow

In case of this property the SCC mixes SCC – CM, SCC – IS10, SCC – IS20, SCC – IS30, SCC – IS40 exhibit slump flow in range of **764 – 670 mm** which is within the limits (650 -800 mm) given by EFNARC. These results indicate good deformability of these mixes**.** The mix SCC – IS50 exhibited a slump flow of **643 mm** which is slightly out of range as given by EFNARC.Intricate shape and sharp texture of iron slag as compared to fine aggregate (sand) plays a sound role in increasing the inter particle friction causing packing of concrete particles which thereby reduce the workability of SCC. The values of slump flow are shown in the tabular and graphical in **Table 6.1 and Figure 6.1**.

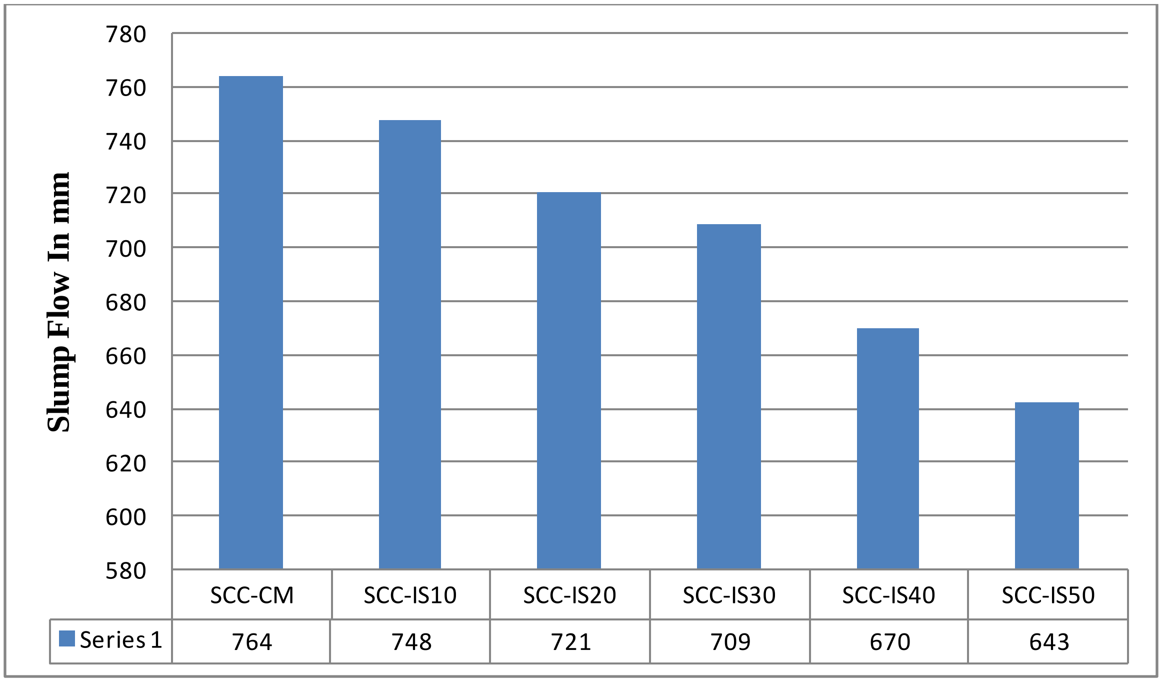


Figure 6.1: Variation of slump flow.

6.1.2 L Box:

In case of this property the SCC mixes SCC – CM, SCC – IS10, SCC – IS20, SCC – IS30, SCC – IS40 exhibit a passing ability in range of **0.94 – 0.82** which is with the limits (0.8-1) given by ERFNARC **.** The mix SCC – IS50 showed a passing ability of 0.73 which is slightly out of range as given by ERNARC (0.8 – 1).From these results we draw a conclusion that the increase in Iron Slag percentage there is an increase in the inter particle bonding which results in lowering the passing ability of SCC. The values of L BOX are shown in the tabular and graphical in **Table 6.1 and Figure 6.2**.

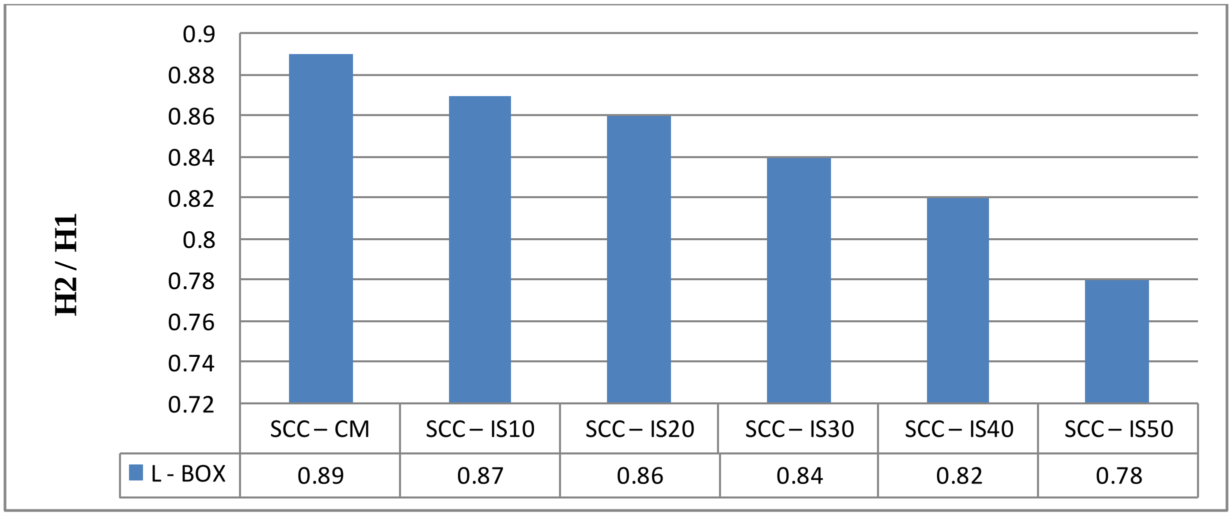


Figure 6.2: Variation of L Box test.

6.1.3 V - Funnel:

There was increase in passing time as the percentage of iron slag level was increased .The results from this test show that the mixes SCC – CM, SCC – IS10, SCC – IS20, SCC – IS30, SCC – IS40 had a FILLING ability time of (10 – 12 sec)which is within the limits by EFNARC (8 - 12 sec). The mix SCC – IS50 showed a filling ability Time of 16 s which is out of range as given by ERNARC (8 – 12 sec). The values of slump flow are shown in the tabular and graphical in **Table 6.1 and Figure 6.3**.

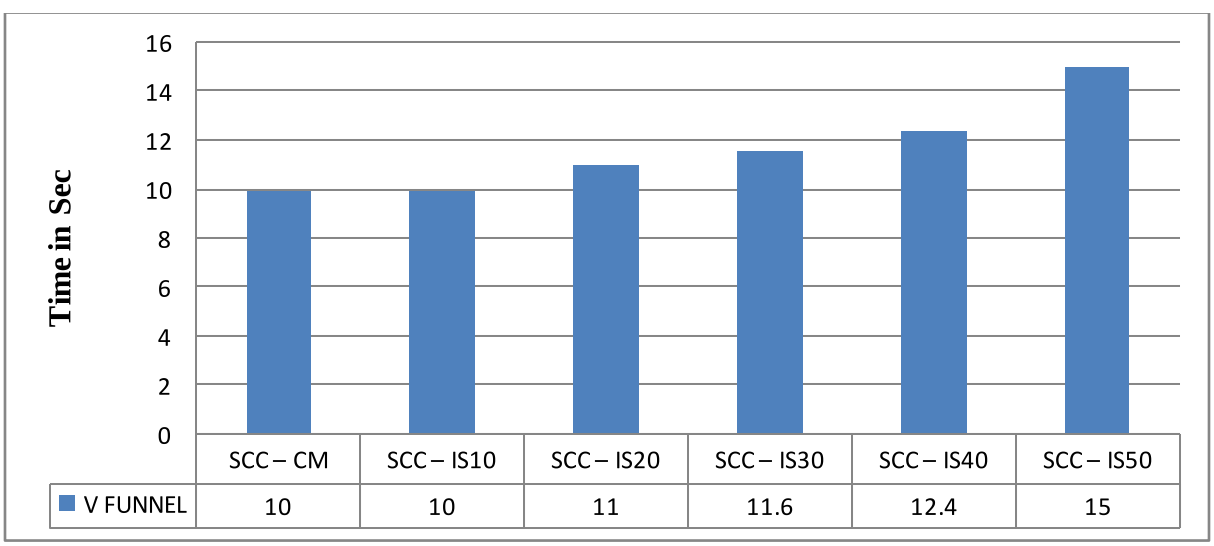


Figure 6.3: Variation of V Funnel time.

Table 6.1: Fresh properties of SCC.

MIXTURE	Slump Flow mm	L – Box (H2/H1)	V – Funnel (sec)
SCC – CM	764	0.89	10
SCC – IS10	748	0.87	10
SCC – IS20	721	0.855	11
SCC – IS30	709	0.83	11.7
SCC – IS40	670	0.81	12.4
SCC – IS50	643	0.78	16

6.2 Experimental Work

6.2.1 Cubes

In this study, total numbers of 54 cubes were casted. The moulds were of size 150 mm×150 mm×150 mm. First the moulds where cleaned, lubricated and after that filled with concrete. Every specimen was tested under CTM to determine the compressive strength. These cubes were tested after 7,14 and 28 days. All the specimens were cured in the curing tank. For determining the average strength of the cubes after 7 days, 3 sample cubes were tested and their average value was taken and same was done for the compressive strength after 14 days and 28 days.

6.2.2 Rectangular Beams

Total numbers of 36 rectangular beams were casted. The moulds were having cross-section of 100mm×100mm×500mm as shown in the figure 4. All these rectangular moulds where cleaned, lubricated and after that filled with concrete. Every specimen was tested under CTM to determine the Flexural strength. These beams were tested after 7 days, and 28 days. All the specimens were cured in the curing tank. For determining the average strength of the beams after

7 days, 3 sample beams were tested and their average value was taken and same was done for the flexural strength after 28 days.

6.2.3 Cylinders

Total numbers of 36 cylinders were casted. The moulds were having cross-section of 150 mm × 300 mm. All these cylinders where cleaned, lubricated and after that filled with concrete. Every specimen was tested under CTM to determine the tensile strength. These cylinders were tested after 7 days, and 28 days. All the specimens were cured in the curing tank. For determining the average strength of the cylinders after 7 days, 3 samples were tested and their average value taken and same was done for the tensile strength after 28 days.

CHAPTER 7

RESULTS AND DISCUSSION

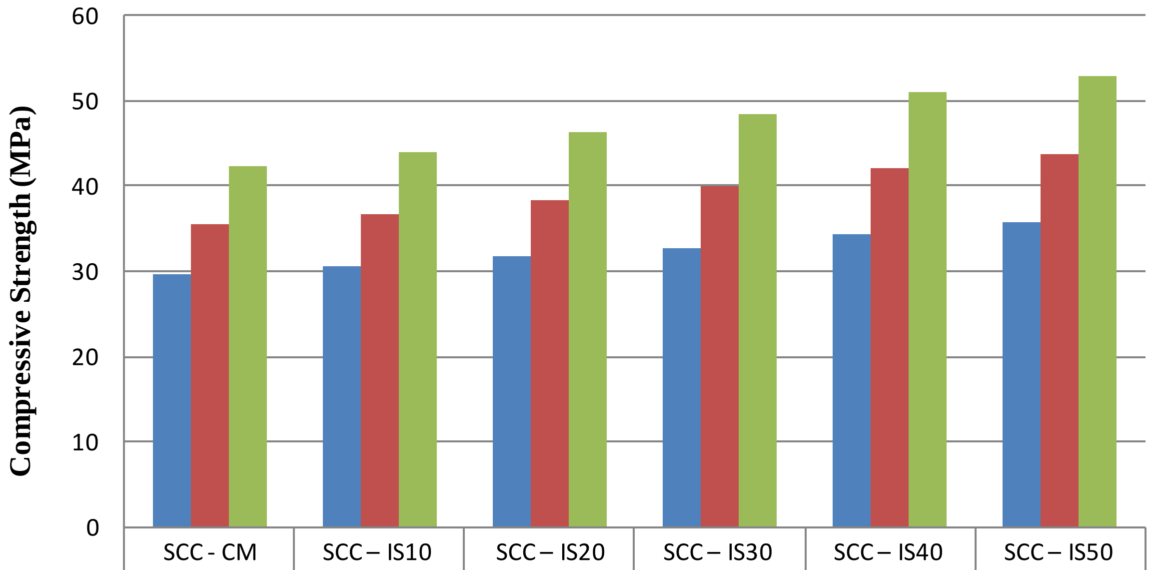
7.1. Compressive Strength

To determine the precise compressive strength of cubes an average of three samples were taken for every reading. The testing of specimens has been performed after curing of 7 days, 14 days and 28 days for both controlled as well as for cubes where fine aggregates were partially replaced with iron slag. The results of compressive strength obtained in this project are shown in **Table 7.1**.

From **Table 7.1**, its clear that there is an increase of 2.71% , 6.25% , 9.36% , 13.41 % & 16.8 % of compressive strength in cube specimens after 7 days , 3.13, 7.45 ,11.40 ,15.63 ,18.9 % at 14 days & 3.32% ,8.33% ,12.58% ,16.75% ,19.86 % at 28 days as compared to control mix .

Table 7.1: Compressive strength of cubes after 7 days, 14 days and 28 days.

MIX	Compressive Strength (Mpa)			Average Compressive Strength (Mpa)		
	7 days	**14 days**	**28 days**	**7 days**	**14 days**	**28 days**
SCC - CM	30.1	36	43	29.7	35.5	42.44
	29.4	33.3	42.32			
	29.6	37.2	42			
SCC – IS10	31	36.2	44	30.53	36.65	43.90
	30.9	37.9	45.3			
	29.7	35.85	42.44			
SCC – IS20	32	39	46.7	31.68	38.36	46.30
	32.7	38.8	46			
	30.34	37.3	46.2			
SCC – IS30	33	40.02	48	32.77	40.07	48.55
	34.3	41	49.15			
	31.01	39.01	48			
SCC – IS40	35	42.6	51.14	34.3	42.08	50.98
	34	42	50.6			
	33.9	41.64	51.2			
SCC – IS50	36	44	53.9	35.7	43.80	52.96
	35.7	44.1	52.7			
	35.2	43.3	52.28			



	SCC - CM	SCC – IS10	SCC – IS20	SCC – IS30	SCC – IS40	SCC – IS50
7 Days	29.7	30.53	31.68	32.77	34.3	35.7
14 Days	35.5	36.65	38.36	40.07	42.08	43.8
28 Days	42.44	43.9	46.3	48.55	50.98	52.96

Figure 7.1: Variation of compressive strength of cubes after 7, 14 and 28 days

The load carrying capacity of specimens with partial substitution of Fine Aggregate with iron slag is more than that of controlled specimens. From table 7.1 it is clear that the Load carrying capacity of Self Compacting Concrete cubes is increasing with the substitution of iron slag as fine aggregate 19.86 % after 28 days curing. At 28 days the increase in strength percentage of Replaced mixes is found to be more than that of controlled mix. This is because with the increase in age reactive silica which is found in Iron Slag reacts with the alkali calcium hydroxide produced by hydration of cement forming calcium silicate and aluminate hydrate which results in filling the voids in the interfacial zone of concrete and thus improves the Compressive Strength of Concrete.

7.2. Split Tensile Strength

To determine the precise Split Tensile strength of cylinders an average of three samples were taken for every reading. The testing of specimens has been performed after curing of 7 and 28 days for both controlled as well as for cylinders with partial replacement of Fine aggregates with iron slag. The results of Split tensile strength obtained in this project are in **Table 7.2**.

Table 7.2 Split Tensile Strength of cylinders after 7 and 28 days.

Mixture	Split Tensile Strength (Mpa)	
	7 days	28 days
SCC - CM	1.6	2.85
SCC – IS10	1.81	2.94
SCC – IS20	1.94	3.20
SCC – IS30	2.00	3.29
SCC – IS40	2.18	3.42
SCC – IS50	2.29	3.65

At 7 days curing the increase in split tensile strength the mixtures SCC – IS10. SCC – IS20, SCC – IS30, SCC – IS40, SCC – IS50 containing iron slag in percentage levels of (10-50%) gained 11.6 % , 17.5% , 20% , 26.6% & 30.13% more split tensile strength than Controlled mix .At 28 days curing the increase in split tensile strength of the mixes SCC – IS10. SCC – IS20, SCC – IS30, SCC – IS40, SCC– IS50 containing iron slag in the same percentage as above gained 3.06% , 10.95% , 13.37 % , 16.66 % & 21.9 % more split tensile strength than that of controlled mix. Thus it can be said from Split tensile strength tests that there is an increase in split tensile strength with the increase in replacement levels of sand by iron slag. This is also due to the enhancement in the bonding of concrete due to iron slag and also due to the reduction in the void content of SCC.

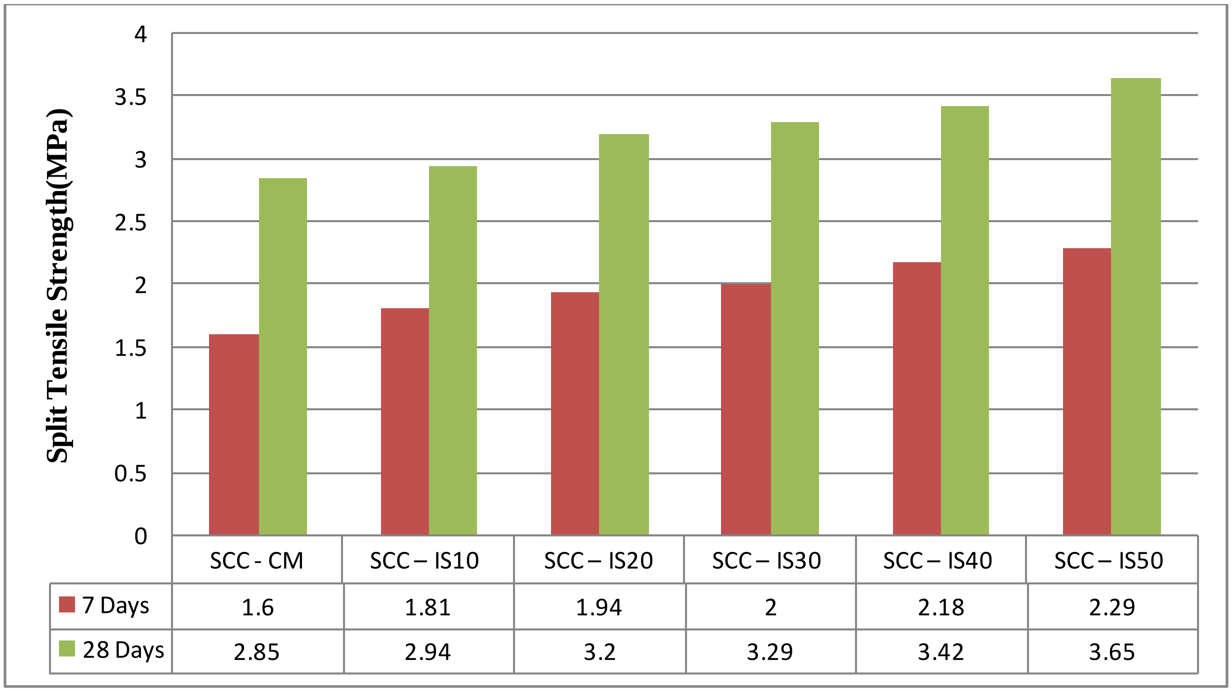


Figure 7.2: Variation of Split Tensile Strength of cylinders after 7days, and 28 days.

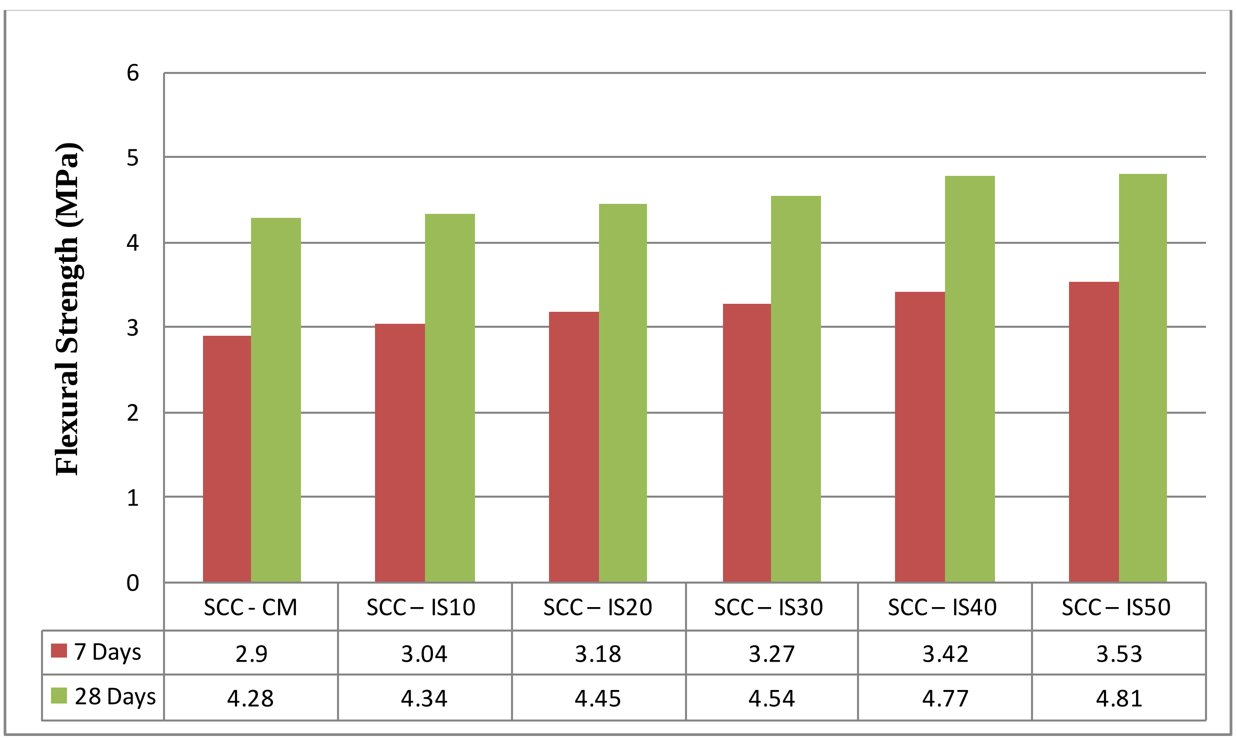
7.3. Flexural Strength

To determine the precise flexural strength an average of three samples were taken for every reading. The testing of specimens has been performed after curing period of 7 and 28 days for both controlled as well as for beams with partial replacement of Fine aggregates with iron slag. The results of flexural strength obtained in this project are in **Table 7.3**.

Table 7.3 Flexural Strength of beams after 7 and 28 days.

Mixture	**FLEXURAL STRENGTH (Mpa)**	
	7 days	28 days
SCC - CM	2.90	4.28
SCC – IS10	3.04	4.34
SCC – IS20	3.18	4.45
SCC – IS30	3.27	4.54
SCC – IS40	3.42	4.77
SCC – IS50	3.53	4.81

Flexural Strength test results as shown in the **Table 7.3** shows similar increment in flexural strength as is the case of compressive and split tensile strength. At 7 days curing the increase in flexural strength in the mixtures SCC – IS10. SCC – IS20, SCC – IS30, SCC – IS40, SCC – IS50 containing iron slag in percentage levels of (10-50%) gained 4.6 % , 8.8% ,11.31% , 15.2 % & 17.84 % more split tensile strength than Controlled mix. At 28 days curing the increase in split tensile strength of the mixes SCC – IS10. SCC – IS20, SCC – IS30, SCC – IS40, SCC– IS50 containing iron slag in the same percentage as above gained 1.38 % , 2.72 % , 5.72 % , 10.27% & 11.01 % more split tensile strength than that of controlled mix. Thus it can be also said from flexural strength tests that there is an increase in flexural strength with the increase in replacement levels of sand by iron slag. This is also due to the enhancement in the bonding of concrete due to iron slag and also due to the reduction in the void content of SCC. The percentage increase in flexural strength increases with the increase of replacement levels (10-50%). Under the flexure loading, the cracks are initiated in the interfacial zone. Due to strengthening of this zone by the replacement of fine aggregate with iron slag increases the resistance to cracks propagation thereby increasing the flexural strength.



	SCC - CM	SCC – IS10	SCC – IS20	SCC – IS30	SCC – IS40	SCC – IS50
7 Days	2.9	3.04	3.18	3.27	3.42	3.53
28 Days	4.28	4.34	4.45	4.54	4.77	4.81

Figure 7.3: Variation of Flexural strength of beams after 7days, and 28 days.

CHAPTER 8

CONCLUSION AND FUTURE SCOPE

Conclusion

This experimental study was conducted to investigate the usefulness of using iron slag as a partial replacement for Sand (F A) in SCC. Experiments were conducted by partially replacing sand (F A) in different proportions from the tests it was found out that iron slag is a good option for partial replacement of sand (F A) in production of SCC of grades up to M 50. Based on the analysis of the results obtained from my experimental study the following conclusions can be drafted:

1. Results show that with the increase in substitution levels of fine aggregate with iron slag resulted in decrease in the fresh properties of SCC. Intricate shape and sharp texture of the iron slag particles plays a significant role in increasing the interparticle friction which thereby reduce the fresh properties of SCC. Therefore it can be stated that with the increase in iron slag content results in decrease in the workability of SCC.
2. From the test results it is found that with the increase in replacement levels of iron slag with fine aggregate there is a increase in the overall strength of concrete be it compressive, tensile or flexural strength.
3. Maximum increase in compressive strength is 16.75%, split tensile strength is 10.27 % and flexural strength is 16.66 % for Mix SCC – IS40 with 40 % replacement of F A with iron slag at 28 days as compared to the controlled mix.
4. With the increase in substitution level of sand with iron slag (>40 %) results in increase in the w/c ratio or increase in the admixture percentage (in view of workability) as the fresh properties of SCC decreased.
5. The optimum substitution level of replacement of fine aggregate with iron slag is 40% which results in higher strength and which also passes the criteria of limits of fresh properties of SCC given by EFNARC.

Future scope of study

As a reasonable other option to Fine aggregate Iron slag can be used in SCC as found in our research. As found from the results there is an increase in overall strength of concrete be it compressive, tensile or flexural strength at all replacement levels. Trail mixes should be designed so that the replacement levels above 40 % pass the workability criteria and the fresh properties of SCC. Also the effect of partially substitution of sand with iron slag should be checked for different zones of ZONE II, III & IV and research should be done on how much improvement in strength is achieved in SCC with these zones of F A .the effect of improvement in strength by replacing Zone IV F A partially with iron slag can be studied so that the finer Zone IV sand can also be used. Furthermore a design mix of SCC with replacement levels of F A with Iron slag can also be done so it's easy for the manufacturing Companies of SCC to incorporate Iron Slag in SCC and also help other researchers in the research process in this field. This will result in utilization of this waste product and thus save our environment from some pollution.

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