TO STUDY THE PROPERTIES OF SELF COMPACTING CONCRETE USING IRON SLAG AS PARTIAL REPLACEMENT OF FINE AGGREGATE

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Abstract: This study has been done to study the properties of self compacting concrete using iron slag as partial replacement of fine aggregate. To study the effect of iron slag on the two main and essential properties of concrete, strength and workability. To check the workability of concrete Slump Flow, J-Ring, V Funnel and L Box test are done. And for compressive strength cube test has been done. It has found that the compressive strength of concrete increases with increase in iron slag percentage. Iron slag has some cementitious properties which help in increasing the compressive strength of concrete. But it has negative impact on the workability, the workability of concrete decreases with increase of iron slag percentage due to the increase in the friction between the rough surfaces iron particles. The main producer of iron slag is iron and steel manufacturing plants. This experimental study is done to find out the future possibilities, to use iron slag in self compacting concrete as a partial replacement of fine aggregate. SCC mixes were designed and fine aggregates were replaced with 0, 10, 20, 30, 40 and 50% iron slag.

Keywords: Iron Slag, Self Compacting Concrete, Strength, Workability

INTRODUCTION

Iron slag is the co-product from the reduction of iron ores to produce molten iron and molten slag. It is mixture of silicon dioxide and metal oxides. It contains oxides of silicon, aluminum, carbon, calcium as main component. During the last year 2017-18 annual iron slag production in India is about 23.39 lakh tonnes[1]. Out of which a large amount of slag is disposed in open land which is very hazardous for living creatures and very harmful for the environment. These dumps have very bad effect on their surrounding and on the land where they are disposed off. Therefore reusing them instead of disposing is a good and eco friendly step. With yearly increase in the production of iron slag, it is necessary to find method for its disposal, using it in concrete is a solution. And use of iron slag in place of naturally available aggregates has two benefits , first, it provide a good way of disposing off by reusing it, and second, help us in reducing mining of materials which is good for environment and a good step towards sustainable development. The main properties of concrete, such as strength, durability and serviceability, depend mainly on the properties and the quality of the materials that are used in preparing it. Therefore, the use of waste materials, such as iron slag, in concrete may have positive effect.

Concrete is a very important component of construction. And proper compaction is necessary for concrete to gain its full strength. Compaction becomes a big issue where dense reinforcement is used or where uses of vibrator are very difficult. In such places self compacting concrete is used. Self Compacting Concrete is concrete having high flowability, high deformability, low yield stress and good resistance against segregation and bleeding. Concrete is a mixture of different material like cement, coarse aggregate, fine aggregate, super plasticizer etc. There is no need of compaction or use of vibrator for compaction of self compacting concrete. For making self compacting concrete it is necessary to use superplasticizer to make it highly flowable and to increase its passing ability. For making good and economical concrete, proportion of materials of concrete should be selected properly. Self compacting concrete is very much affected by properties of material. For the proper selection of material, properties of material should be known and a proper mix design should be made. To determine the properties of material many tests are done in laboratory as per IS Code. There are different IS Code for different material and for different test. On the basis of these code tests are done and results are obtain. And on the basis of these obtained result mix design are obtain as pre IS 10262:2009[28]. Generally small size coarse aggregate is used. In self compacting concrete coarse aggregate content is lower than the fine aggregate. And always tried to increase the paste content. Low water cement ratio is selected. Large amount of superplasticizer is used. Some viscosity modifying agents are also used.

MATERIAL

1.CEMENT

OPC-43 has been used for this study.

Table 1 Physical Properties of OPC-43

Characteristics	Test Result	Recommended Value (As per IS 8112:1989)[30]
Fineness	95%	≥90%
Consistency	30%	
Initial Setting Time	115 minute	30 minute (Minimum)
Final Setting Time	225 minute	600 minute (Maximum)
Compressive Strength 3 Days 7 Days 28 Days	 29 N/mm^2 39 N/mm^2 48 N/mm^2	 23 N/mm^2 33 N/mm^2 43 N/mm^2

2. FINE AGGREGATE

Locally available aggregates passing through 4.75mm sieve and retained on .7mm sieve are used as fine aggregate .The test procedures area as per IS383:1970[27] is carried out to determine the properties of Fine Aggregate.

Table No. 2 Physical Properties of Fine Aggregate

Characteristics	Test Value	Recommended Value
Grading Zone	Zone II	
Fineness Modulus	3.11	
Specific Gravity	2.69	2.65-3.0
Silt Content	2.48%	5%

3. COARSE AGGREGATE

Locally available aggregate of 10 mm is used
Having specific gravity 2.7.

4. IRON SLAG

Collected from a steel rolling mill. It is mixture of silicon dioxide and metal oxides. It contains oxides of silicon, aluminum, carbon, calcium as main component.

Table No.3 Chemical Compound of Iron Slag [1]

Chemical Compound	% of Chemical Compound
Iron Oxide (Fe_2O_3)	1.4
Silicon Dioxide (silica) (SiO_2)	33
Aluminum oxide (alumina) (Al_2O_3)	22.4
Calcium oxide (lime) (CaO)	33
Sulfur Trioxide (SO_3)	22.40
Magnesium Oxide (MgO)	9.8

5. ADMIXTURE

Polycarboxlate Ether Superplasticizer is chemical admixture used to increase the workability of concrete. It reduces the water cement ratio without negatively affecting the workability. And superplasticizer also helps in reducing the cement content by reducing the water content. IS 9103:2007[29] is referred.

Table No. 4 Properties of Superplasticizer

Properties	
Specific Gravity	1.15
Chlorides	Nil
Nitrates	Nil
Sulphates	0.5%
Appearance	Straw Coloured liquid
Freezing point	+5 ºC Material can be reconstituted by agitating at 30 ºC.
Role in Concrete	Improves workability and flow properties of concrete.

EXPERIMENTAL PROCEDURE

Six Mixing batches are prepared in this study first is normal without any addition of iron slag and rest five mixes are of partial replacement of fine aggregate with iron slag at different percentage which are 10%, 20%, 30%, 40%, 50%. Iron slag is added by weight of fine aggregate. To check the workability (passing and filling ability of self compacting concrete) of mixes V Funnel, L-Box, Slump Flow, J-Ring tests are done. And to check the compressive strength of concrete, cube of 150x150x150 mm were casted and cured for period of 7days and 28 days.

Table No.5 Mix Design

Cement	w/c	Fine Aggregate	Coarse Aggregate	Superplasticizer
1	0.45	2.476	1.815	0.01

Table No. 6 Mix Proportion

Trail	Cement (kg/m^3)	w/c ratio	Fine Aggregate (kg/m^3)	Coarse Aggregate (kg/m^3)	Admixture (kg/m^3)	Iron Slag (kg/m^3)
Normal Mix	423	0.45	1047.38	767.83	4.23	0
Mix(10%)	423	0.45	942.642	767.83	4.23	104.76
Mix(20%)	423	0.45	867.904	767.83	4.23	209.47
Mix(30%)	423	0.45	733.166	767.83	4.23	314.236
Mix(40%)	423	0.45	628.428	767.83	4.23	418.996
Mix(50%)	423	0.45	523.69	767.83	4.23	523.69

For making concrete, while mixing, first, coarse aggregate, fine aggregate, iron slag and cement was poured in mixer and machine was started to rotate and material was allowed to mix dry. After few minutes' water was added in mix in two installments, in first installment half of water was poured in to the mixer, in second installment rest of the water mixed with Superplasticizer was applied. And the machine was allowed to rotate for few minutes. After the fresh mix was prepared, the properties of fresh concrete were checked, workability of self compacting concrete was checked. First Slump flow test was done, after that J Ring, L-Box and V Funnel tests were done and the readings were recorded. And after that, to check the compressive strength of concrete cubes were casted and allowed to cure for 7days and 28 days. Three samples for each 7 day and 28 day was prepared. For every mix proportion this processes is repeated.

RESULT AND DISCUSSION

WORKABILITY

With increase in percentage of Iron Slag the workability of concrete decreases which also result in decrease in the ability of concrete of passing and filling which is essential for self compacting concrete. To check these properties V Funnel, L-Box, Slump Flow, J-Ring tests are done.

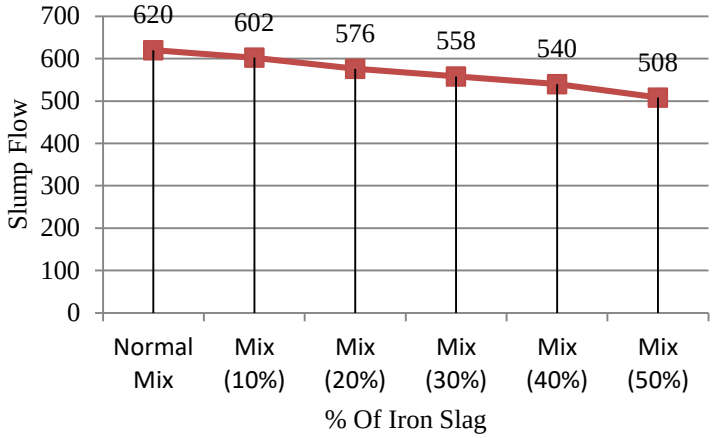
It was found that the workability of concrete is decreasing with the increase of iron slag. We know that water cement ratio play important role in workability, with increase of iron slag cementitious content in concrete also increasing which reduces the water cementitious ratio and decreases the workability of concrete. In many research is has been found that use of iron slag negatively affect the workability of concrete for every type of replacement whether it is replacement with fine aggregate or with cement or with coarse aggregate.

Slump flow test shows the decrease in workability with increase of iron slag percentage. This test help in determining the concrete is self compacting concrete or not. It can be seen in table no. 7 and figure 1 that with increase in the percentage of iron slag the flow properties of concrete is decreasing at percentage 3% for 10% iron slag, 7% for 20% iron slag, 10% for 30% iron slag, 13% for 40% iron slag, 18% for 50% iron slag.

Table No. 7 Slump Flow

	Flow (mm)
Trail Mix	620
Mix (10%)	602
Mix (20%)	576
Mix (30%)	558
Mix (40%)	540
Mix (50%)	508

Figure 1. Graphical Representation of slump flow

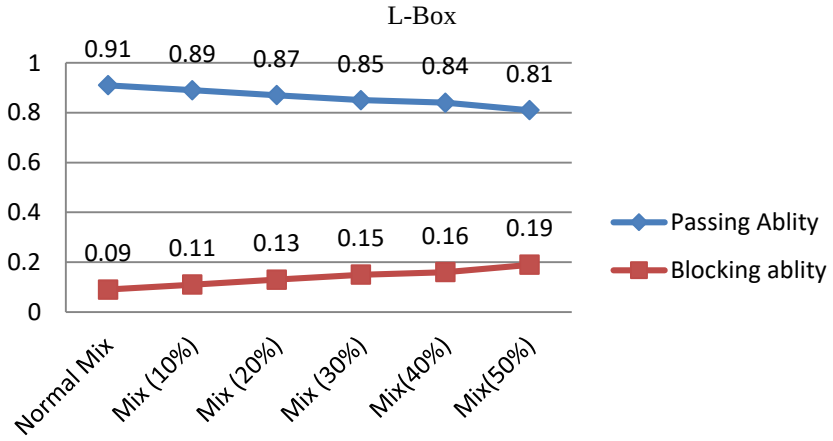


L Box shows the passing ability of concrete. L Box result shows that passing ability of concrete is decreasing with increase of percentage of iron slag. It can be seen in table no. 8 and figure 2 that with increase in the percentage of iron slag the passing ability of concrete is decreasing at percentage 3% for 10% iron slag, 4.4% for 20% iron slag, 6.6% for 30% iron slag, 7.7% for 40% iron slag, 11% for 50% iron slag.

Table No.8 L-Box

	P_L	B_L
Trail Mix	0.91	0.09
Mix (10%)	0.89	0.11
Mix (20%)	0.87	0.13
Mix (30%)	0.85	0.15
Mix (40%)	0.84	0.16
Mix (50%)	0.81	0.19

Figure 2. Graphical Representation of L Box

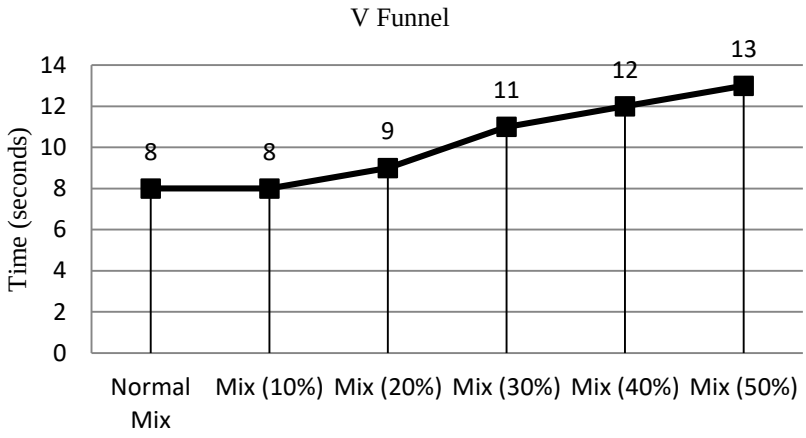


V Funnel shows the flowability of concrete. Result shows increase in time with increase in increase of percentage of iron slag. That means flowability is decreasing. It can be seen in table no. 9 and figure 3 that with increase in the percentage of iron slag the flow time of concrete is increasing percentage 0 % for 10% iron slag (remain same for 10% slag), 12.5% for 20% iron slag, 37.5% for 30% iron slag, 50% for 40% iron slag, 62.5% for 50% iron slag.

Table No.9 V Funnel

	Time (second)
Trail Mix	8
Mix (10%)	8
Mix (20%)	9
Mix (30%)	11
Mix (40%)	12
Mix (50%)	13

Figure 3. Graphical Representation of V Funnel

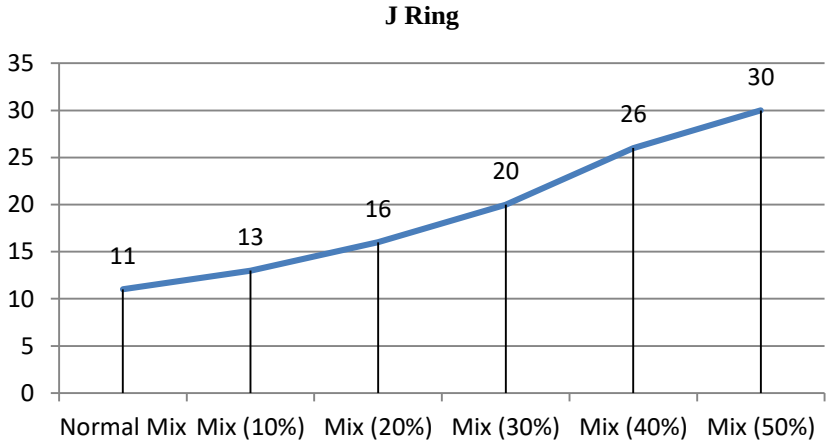


J Ring Test is used to determine the passing ability of concrete. Result shows increase in J Ring Value which means decrease in passing ability of concrete. It can be seen in table no. 10 and figure 4 that the J Ring value is increasing with increase in the percentage of iron slag the passing ability of concrete is decreasing.

Table No. 10 J Ring

	Slump Flow (mm)	**J Flow (mm)**	**J Ring Result (mm)**
Trail Mix	620	610	11
Mix (10%)	602	589	13
Mix (20%)	576	560	16
Mix (30%)	558	538	20
Mix (40%)	540	514	26
Mix (50%)	508	478	30

Figure 4. Graphical Representation of J Ring



Iron slag contains silica and lime. Silica and lime both have cementitious property. By increasing the percentage of iron slag the amount of silica and lime is also increasing therefore the cementitious content in concrete is also increasing. With increase of cementitious content the ratio of water to cementitious content decreases. Decrease in water cementitious ratio, means decrease in water content, means decreases in the workability of concrete.

Table No.11 Workability of Mixes

Trail	Cement (kg/m^3)	w/c ratio	Fine Aggregate (kg/m^3)	Coarse Aggregate (kg/m^3)	Admixture (kg/m^3)	Iron Slag (kg/m^3)	Slump Flow (mm)	L-Box	V Funnel (seconds)	J Ring
Normal Mix	423	0.45	1047.38	767.83	4.23	0	620	0.91	8	11
Mix(10%)	423	0.45	942.642	767.83	4.23	104.76	602	0.89	8	13
Mix(20%)	423	0.45	867.904	767.83	4.23	209.47	576	0.87	9	16
Mix(30%)	423	0.45	733.166	767.83	4.23	314.236	558	0.85	11	20
Mix(40%)	423	0.45	628.428	767.83	4.23	418.996	540	0.84	12	26
Mix(50%)	423	0.45	523.69	767.83	4.23	523.69	508	0.81	13	30

COMPRESSIVE STRENGTH

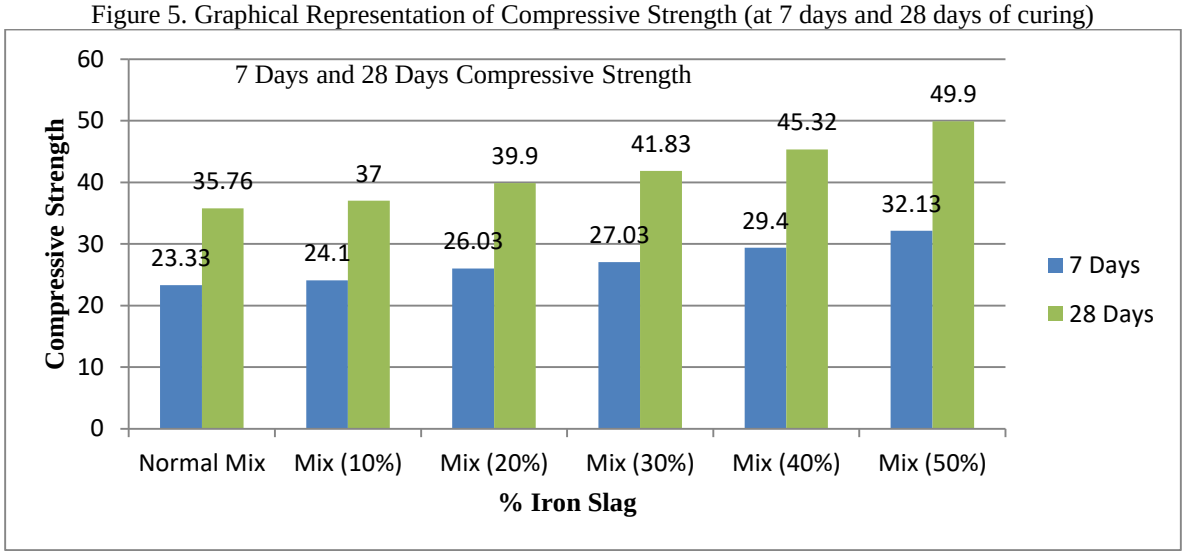
Figure 5 shows the increase in compressive strength of concrete at all percentages of partial replacement at 7 and 28 days. Compressive strength of normal mix is 23.33 N/mm^2 and 35.76 N/mm^2 at 7 and 28 days. And compressive strength of mixes with partial replacement at 7 and 28 days are 24.1 N/mm^2 and 37 N/mm^2 for 10% replacement, 26.03 N/mm^2 and 39.9 N/mm^2 for 20% replacement, 27.03 N/mm^2 and 41.83 N/mm^2 for 30% replacement, 29.4 N/mm^2 and 45.32 N/mm^2 for 40% replacement and 32.13 N/mm^2 and 49.9 N/mm^2 for 50% replacement. Compressive strength of concrete increases with increase of slag. At 7 days and 28 days of curing there is an increase of 4%, 11%, 16%, 26%, 36% for 10%, 20%, 30%, 40%, 50% iron slag replacement.

Addition of silica in concrete increases the compressive strength of concrete because it has cementitious property. And in iron slag 33% of the all chemical compound is silica which may be the reason of increase of compressive strength. In many researches it has been shown that lime also have a cementitious property, which is also present in iron slag at amount of 33% of the all chemical compound. It may also be the reason for increase in compressive strength. It may be possible that silica and lime both help concrete to increase its compressive strength.

Table No. 12 Compressive strength at 7days of curing

Trail	Cement (kg/m^3)	w/c ratio	Fine Aggregate (kg/m^3)	Coarse Aggregate (kg/m^3)	Admixture (kg/m^3)	Iron Slag (kg/m^3)	Compressive Strength (N/mm^2)(7 Days)	Compressive Strength (N/mm^2)(28 Days)
Normal Mix	423	0.45	1047.38	767.83	4.23	0	23.33 N/mm^2	35.76 N/mm^2
Mix(10%)	423	0.45	942.642	767.83	4.23	104.76	24.1 N/mm^2	37 N/mm^2
Mix(20%)	423	0.45	867.904	767.83	4.23	209.47	26.03 N/mm^2	39.9 N/mm^2
Mix(30%)	423	0.45	733.166	767.83	4.23	314.236	27.03 N/mm^2	41.83 N/mm^2
Mix(40%)	423	0.45	628.428	767.83	4.23	418.996	29.4 N/mm^2	45.32 N/mm^2
Mix(50%)	423	0.45	523.69	767.83	4.23	523.69	32.13 N/mm^2	49.9 N/mm^2

Figure 5. Graphical Representation of Compressive Strength (at 7 days and 28 days of curing)



CONCLUSIONS

1) Workability of the self compacting concrete decreases with increase of iron slag. Values of V Funnel, J-Ring have been increased and values of L-Box, Slump Flow, tests have been decreased.
2) With increase of iron slag cementitious content in concrete also increasing which reduces the water cementitious ratio and decreases the workability of concrete
3) Compressive Strength of concrete increases with increase of iron slag. There is increase of compressive strength (at 7 days of curing) by 4%, 11%, 16%, 26%, 36% for 10%, 20%, 30%, 40%, 50% iron slag replacement.
4) At 28 days compressive strength of concrete increases by 3%, 11%, 17%, 26%, 38% for 10%, 20%, 30%, 40%, 50% iron slag replacement.
5) Presence of silica and lime in iron slag are may be the reason for the increases of compressive strength of concrete. With the increases in the amount of iron slag silica and lime is also increasing and resulting in increase of strength of concrete.

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