



EXPERIMENTAL STUDY ON MECHANICAL AND DURABILITY PROPERTIES OF HIGH PERFORMANCE CONCRETE REPLACING COARSE AGGREGATE BY FERRO SLAG AGGREGATES

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ABSTRACT

The main objective of this research is to find out alternative materials for concrete to meet the demands of coarse aggregate for the upcoming years, to provide adequate strength at minimum cost, to make the eco-friendly structures. Use of ferro slag a waste industrial by-product of iron and steel production provides great opportunity to utilize it as an alternative to normally available aggregates (coarse). In this research, ferro slag is used and M60 grade concrete of W/C ratio 0.28 was used respectively for the replacement of 0 to 100% coarse aggregate by ferro slag aggregate for find out the optimum ratio of steel slag. In this study, a mix ratio of 1: 1.2: 2.4 is used in conventional mix. Initial optimization of ferro slag aggregate for replacing the natural coarse aggregate was find with 7 and 28 days strength. Test on compressive strength and non-destructive test at 7 and 28 days were conducted. It was concluded that possible optimum replacement of slag material was found to be 40%. Split Tensile Strength and Flexural Strength and durability characteristics were carried out for conventional and optimum concrete mix to study the properties of concrete with ferro slag.

Keywords

Aggregates, Blast furnace steel slag, Compressive strength, Nondestructive test, Split Tensile Strength, Flexural Strength and durability characteristics.

1. INTRODUCTION

Concrete is the largest production as construction materials. The increase in demand for the ingredients of concrete is met by partial replacement of materials by the waste materials which is obtained by means of various industries. The utilization of industrial waste or secondary materials has encouraged for the production of cement and concrete in construction field. New by-products and waste materials are being generated by various industries. For many years, by-products such as fly ash, silica fume and ferro slag were considered as waste materials. Concrete prepared with such materials showed improvement in workability, strength and durability compared to normal concrete and has been used in the all type of construction. Nowadays, intensive research studies have been carried out to explore all possible reuse methods.

This paper represents about the experimental investigation of the possibility of using ferro slag in various percentage as coarse aggregate substitute in cement concrete. The attempt has made to investigate the characteristic of ferro slag concrete for various parameters like compressive strength, quality of concrete and load carrying capacity. For thousands of years sand and gravel have been used in construction of roads and building. Today, demand for sand and gravel continues to increase in construction industries. Excessive in stream sand-and-gravel mining causes the degradation of sub surface and surface flow of rivers. In stream mining lowers the stream bottom, which may lead to bank erosion and the reduction of sub surface water.

2. EXPERIMENTAL INVESTIGATION

2.1 Materials Used

The following materials were used for producing high strength concrete.

2.1.1 Water

Water is needed for the purpose of hydration of cement and to provide workability during mixing and placing of concrete. For this study, potable water having pH 7 and other water quality parameters conforming to IS 456-2000 standards was used for concreting as well as curing of the specimens.

2.1.2 Cement

Cement is a binder, a substance that sets and hardens as the cement dries and also reacts with carbon dioxide in the air, and can bind other materials together. In the present experiments ordinary Portland cement of 53 grade conforming to IS 1489 (Part-1):1991 specifications were used in the preparation of concrete mixes.

2.1.3 Fine Aggregate



The Fine aggregates serve the purpose of filling all the open spaces in between the coarse particles. Thus they reduce the porosity of the final mass and considerably increase its strength. Usually natural river sand is used as fine aggregate. In the preparation of concrete mix, sand conforming to grading zone II of IS 383-1970 was used.

2.1.4 Coarse Aggregate

Optimum size of the coarse aggregate in most situations was about 20 mm. They generally possess all the essential qualities of a good building stone showing very high crushing strength, low absorption value and least porosity. Testing of coarse aggregate was done as per IS 383-1970 procedures. The guidelines of coarse aggregate crushing value was tested as per IS 9376-1979, and its impact value was tested as per IS 9377-1979 standards.

2.1.5 Ferro Slag And Super-Plasticizer

Ferro slag used in the preparation of concrete mixes was here is collected from JSW SISCOL Plant, Mecheri, Salem. Super-Plasticizer CONPLAST (430) was used to increase the workability of the concrete mix. Its specific gravity was 1.21.

Table 1. Properties of Cement

Sl.No	Properties or Parameters	Values
1	Specific gravity	3.15
2	Standard consistency	29%
3	Fineness (by sieve analysis)	4.60%
4	Initial setting time	30 minutes

Table 2. Properties of Coarse Aggregate, Fine Aggregate and Ferro Slag

Sl.No	Properties or Parameters	Coarse Aggregate	Fine Aggregate	Ferro Slag
1	Specific gravity	2.75	2.64	2.93
2	Bulk density	1765.0 kg/m ³	1668.0 kg/m ³	1682.0 kg/m ³
3	Water absorption	0.5%	1%	-
4	Fineness modulus	6.45	2.76	-
5	Impact value	13.33%	-	14.5%
6	Crushing value	17.3%	-	23.3%
7	Abrasion value	26.5	-	-

As can be seen from Table 1, the properties of cement are within the allowable limits. From Table 2 it was observed that the properties of coarse aggregate, and ferro slag are more or less similar.

3. CONCRETE MIX DETAILS

Two sets of mixes were prepared for M₆₀ grade concrete. First Mix was ordinary conventional concrete. Second mix replacing ferro slag for coarse aggregate. Two sets of 3 cubes were tested for compressive strength, one set at 7 days and another set at 28 days.

Table 3. Concrete Mix Ratio

Cement	Fine Aggregate	Coarse Aggregate	Water	Super plasticizer
1	1.2	2.4	0.28	1%

4. TESTING DETAILS

4.1. Non- Destructive Test

4.1.1. Rebound Hammer Test

Rebound hammer test was conducted for all the mixes for both 7 days and 28 days for M60 grade of concrete. 3 specimens were cast for each replacement of ferro slag aggregate for coarse aggregate. The value for each trial increases the percentage of steel slag (0, 10%, 20....up to 100%).



Fig 1 : Rebound Hammer Test

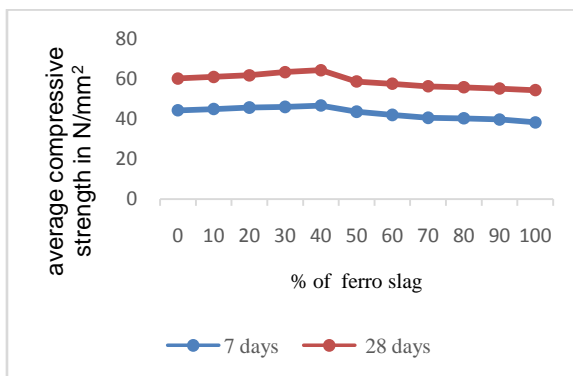


Fig 2 : Compressive Strength from Rebound Hammer

The values of average compressive strength at 7 days and 28 days, determined through rebound hammer test, are plotted against percentage of ferro slag, and are shown in Figure 2.

4.1.2. Ultrasonic Pulse Velocity Test

In ultrasonic pulse velocity test, three methods are there. In this paper, direct method is used. The test was conducted for all the mixes for both 7 days and 28 days for M60 grade of concrete. Three specimens were cast for each replacement of blast furnace steel slag aggregate.

From the following table 4, the quality of concrete is determined with reference to the velocity obtained.

Table 4 . Quality of concrete using UPV

Pulse velocity(km/sec)	Concrete quality (Grading)
Above 4.5	Excellent
3.5 to 4.5	Good
3 to 3.5	Medium
Below 3	Doubtful



Fig 3 : Ultrasonic Pulse Velocity test

Table 5. Ultrasonic Pulse Velocity Test Results

Mix Id	% of Coarse Aggregate	% of Ferro Slag	Quality of Concrete	
			7 Days	28 Days
M0	100	0	Excellent	Excellent
M1	90	10	Excellent	Excellent
M2	80	20	Excellent	Excellent
M3	70	30	Excellent	Excellent
M4	60	40	Excellent	Excellent
M5	50	50	Excellent	Excellent
M6	40	60	Excellent	Excellent
M7	30	70	Good	Good
M8	20	80	Good	Good
M9	10	90	Good	Good
M10	0	100	Good	Good

4.2. COMPRESSIVE STRENGTH TEST

In this test, six cubes (150 mm x 150 mm x 150 mm) were cast for each trial mix of M₆₀ concrete. For each mix three specimens after 7 days and another set of three specimens after 28 days of curing were tested for their compressive strength, using 2000 kN capacity compression testing machine.



Fig 4 : Compressive Strength Test

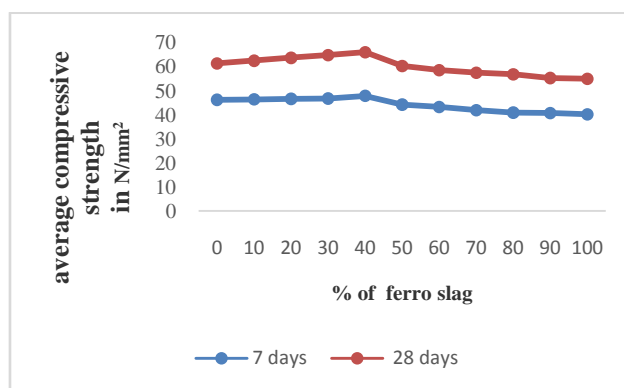


Fig 5: Compressive Strength test result from CTM

The values of Compression strength test for conventional concrete and ferro slag concrete was determined and shown in figure 5.

4.3. SPLIT TENSILE STRENGTH TEST

For tensile strength test, cylindrical specimens of dimension 100 mm diameter and 300 mm length were cast. In each mix, three cylinders were cast and tested and their average value was taken. The split tension test was conducted by using digital compression machine having 2000 kN capacity.

$$\text{Split Tensile strength (MPa)} = 2P / \pi DL$$

Where,

P = Failure Load (kN)

D = Diameter of Specimen (100 mm)

L = Length of Specimen (300 mm)



Fig 6: Split tensile Test

Table 6 .Test Results of Split Tensile Strength

S.No	Mix ID	Average Split tensile strength in (Mpa)
1.	S0	5.44
2.	S40	6.97

Test Results of splitting tensile strength for conventional and optimum percentage of ferro slag concrete of M₆₀ grade concrete as shown in table 6

4.4. FLEXURAL STRENGTH TEST

For Flexural strength test, prism specimen of 100 mm X 100 mm X 500 mm was cast. For conventional and optimum mix, three prisms were cast and tested with two point load was applied.



Figure 7: Flexural Strength test

A beam specimen is placed in the ultimate testing machine of 2000kN capacity for testing.

$$\sigma = P l / bh^2$$

P = load in Newton

l = length of prism in mm i.e. 500 mm

b = breadth of prism i.e. 100 mm

h = height of prism i.e. 100 mm.



Table 7. Test Results of Flexural Strength

SI.NO	Mix ID	Average flexural strength in (MPa)
1.	S0	5.31
2.	S40	6.78

Table 7 shows the values of average flexural strength of conventional concrete (S0) and ferro slag aggregate concrete (S40).

4.5. SULPHATE ATTACK

Sulphate attack on concrete has been reported from many other parts of the world. 100mm x 100 mm x 100mm size cube specimens are taken out from the curing tank after 28 days. Then 5% sodium sulphate is mixed per liter of ordinary water. Then Cubes are immersed in the sulphate solution for 60 days. After that the cubes are taken out from the sulphate solution and kept dried. Then the specimens are tested and compressive strength of the specimen was calculated.

Table 8. Loss of compressive strength of specimen subjected to sulphate Attack

mix id	Average compressive strength at 28 days (MPa)	Decrease in compressive strength at 60 days (MPa)
S0	61.2	60.96
S40	65.8	65.63

4.6. CHLORIDE ATTACK

Chloride attack is primarily caused by corrosion of reinforcement. To test the effect of chloride on concrete, 100mm x 100mm x 100mm size conventional and ferro slag aggregate concrete cubes were cast and kept at a room temperature. After 24 hours the specimens were cured in clean fresh water for 28 days. After curing the cubes were immersed 60 days in sodium chloride solution and tested for their compressive strength and thereby durability was assessed.

Table 9. Loss of compressive strength of specimen subjected to Chloride Attack

Mix ID	Avg. compressive strength at 28 days	Decrease in Compressive strength (MPa)
S0	61.2	60.7
S40	65.8	65.61

4.7. HYDRO CHLORIC ACID TEST

To test the effect of hydrochloric acid on concrete, 100mm x 100mm x 100mm size conventional and ferro slag aggregate concrete cubes were cast and kept at a room temperature. After 24 hours the specimens were cured in clean fresh water for 28 days. After curing the cubes were immersed in HCL Acid and tested for their decrease in compressive strength after acid attack as shown in table 4.7.

Table 10. Loss of compressive strength of specimen subjected HCL Acid Attack

Mix ID	Average compressive strength at 28 days	Decrease in Compressive strength (MPa)
S0	61.2	60.2
S40	65.8	65.56

5. RESULTS & DISCUSSION

From figure 2, it was noticed that the compressive strength gradually increases as the percentage of ferro slag is increased up to 40% replacement. After replacement of 40% compressive strength is gradually decreased. Hence we can



conclude that complete replacement of coarse aggregate with ferro slag has reduced the compressive strength in concrete.

From the UPV results, shows that the quality of concrete is come under excellent while increasing the steel slag up to 60%. While increasing the replacement of ferro slag above 60% quality of concrete is comes under good.

The compressive strength for M60 grade of concrete is shown in figure 2, as above. As the curing days increases the strength also increases. This compressive strength test result also similar to the rebound hammer test.

From split tensile strength test, flexure strength test and also durability test results shows, the ferro slag aggregate concrete is better than the conventional concrete.

6. CONCLUSION

1. In rebound hammer test, the compressive strength of the concrete was increased about 5 to 7% at 7 days curing and 7.5% is increased at 28 days curing, while replacement of 40% of ferro slag compare to the conventional concrete.
2. In ultra-sonic pulse velocity test, the quality of concrete was excellent up to 60% replacement of ferro slag aggregate.
3. The compressive strength of the concrete was increased about 3 to 8% at 7 days and 28 days curing, while replacement of 40% of ferro slag compare to the conventional concrete.
4. From the result above 40% replacement of coarse aggregate with ferro slag, the compressive strength of concrete decreases linearly.
5. Split tensile test results of cylinder at 28 days have been observed. S40 is 28.12% higher than the control mix.
6. Optimum ferro slag replacement shows higher flexural strength results compare to the conventional mix at 28 days. S40 is 27.7% higher than the control mix.
7. The durability characteristics such as resistance to sulphate attack, resistance to chloride attacks and resistance to acid attack of steel slag concrete are better than that of the controlled mix concrete
8. The chloride acid resistance of ferro slag concrete is significantly better than that of natural aggregate. ferro slag concrete is Eco-Friendly.

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