Study on the Strength Characteristics of Concrete using Iron Slag as Fine Aggregate

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Abstract— Although iron and steel slag is still today considered waste and is categorized in industrial waste catalogues in most countries in the world, it is most definitely not waste, neither by it sphysical and chemical properties nor according to data on its use as valuable material for different purposes. Moreover, since the earliest times of the discovery and development of processes of iron and other metals production, slag as by-product isused for satisfying diverse human needs, from the production of medicines and agro-technical agents to production of cement and construction elements. Iron and steel making slag are by products of their on making and steel making processes. Todate, these types of slag have been widely used in cement and as aggregate for civil works. There port presents an investigation of mechanical and durability properties of concrete by adding iron slag as replacement of sand in various percentages. There sults show that the strength properties of concrete increase significantly when sand is partially replaced by iron slag.
Key words: Concrete, Iron Slag, Fine Aggregate

I. Introduction

The history of the use of iron and steel slag dates back a long way. European Slag Association (2006) has reported about the earliest reports on the use of slag, where in it is mentioned that Aristotle used slag as a medicament as early as 350 B.C. All through history use of slag has ranged from the novel to the usual including: cast cannon balls in Germany (1589), wharf buildings in England (1652), slag cement in Germany (1852), slag wool in Wales (184armored concrete in Germany (1892) slag bricks made from granulated slag and lime in Japan (1901) according to Iron and Steel (2007). In the past, the application of steel slag was not noticeable because enormous volumes of blast furnace slag were available. Through awareness of environmental considerations and more recently the concept of sustainable development, extensive research and development has transformed slag into modern industrial product which is effective and beneficial. The American Society of Testing and Materials (ASTM) (1999) defines blast furnace slag as “the non-metallic product consisting essentially of calcium silicates and other bases that is developed in a molten condition at the same time with iron in a blast furnace.” Slag was considered to be essential in the production of iron, but once it served its purpose in refining the metal, it was strictly a nuisance with little or no use. The usefulness of slags was realized with the first ore smelting process. The use of slags became a common practice in Europe at the turn of the 19th century, where the incentive to make all possible use of industrial by-products was strong and storage space for by-products was lacking. Shortly after, many markets for slags opened in Europe, the United States, and elsewhere in the world.

II. Objective of Study

The objective of the present work is to study the effect of partial replacement of one of the slags viz. Iron slag. It is proposed to partially replace fine aggregates with iron slag and find its effect on the strength characteristics of concrete. Three percentage levels of replacement i.e. 15, 30 and 45 percent are considered for partially replacing sand with iron slag. M20 concrete grade is initially designed without replacement and subsequently sand is partially replaced with iron slag.

A. *Material and methodology*

The properties of material used for making concrete mix are determined in laboratory as per relevant codes of practice. Different materials used in present study were cement, coarse aggregates, and fine aggregates, in addition to iron slag. The aim of studying of various properties of material is used to check the appearance with codal requirements and to enable an engineer to design a concrete mix for a particular strength. The description of various materials which were used in this study is given below:

III. Test Methods

The procedure of methods used for testing cement, coarse aggregates, fine aggregate and concrete are given below:

A. *Specific Gravity*

Specific gravity is ratio of the weight of a given volume of a substance to the weight of an equal volume of some reference substance, or equivalently the ratio of the masses of equal volumes of two substances.

B. *Sieve Analysis for Coarse and Fine Aggregates as per IS: 2386 (Part I) – 1963*

The sieve analysis is used for the determination of particle size distribution of fine and coarse aggregates by sieving or screening.

C. *Compressive Strength of Concrete*

Cube specimens of size 150 mm x 150 mm x 150 mm were taken out form the curing tank at the ages of 7,28 and 56 days and tested immediately on removal from the water (while they were still in the wet condition). Surface water was wiped off, the specimens were tested. The position of cube when tested was at right angle to that as cast. The load as applied gradually without shock till the failure of the specimen occurs and thus the compressive strength was found.

Fig. 1: Compressive strength test

The quantities of cement, coarse aggregate (20 mm), fine aggregate, iron slag and water for each batch i.e. for different percentage of iron slag replacement was weighed separately. The cement and iron slag were mixed dry to a uniform colour separately. The coarse aggregates were mixed to get uniform distribution throughout the batch. Water added to the mix. Firstly, 50 to 70% of water was added to the mix and then mixed thoroughly for 3 to 4 minutes in mixer. Then the concrete was filled into the cube moulds and then get vibrated to ensure proper compaction. The surface of the concrete was finished level with the top of the mould using trowel. The finished specimens were left to harden in air for 24 hours. The specimens were removed from the moulds after 24 hours of casting and were placed in the water tank, filled with potable water in the laboratory.

D. Split Tensile Strength of Concrete

The split tensile strength of concrete is determined by casting cylinders of size 150 mm X 300mm. The cylinders were tested by placing them uniformly. Specimens were taken out from curing tank at age of 7, 28 and 56 days of moist curing and tested after surface water dipped down from specimens. This test was performed on Universal Testing Machine (UTM). The magnitude of tensile stress (T) acting uniformly to the line of action of applied loading is given by formula

$T= 0.637P/dl$

Where,

T = Split Tensile Strength in MPa

P = Applied load,

D = Diameter of Concrete cylinder sample in mm.

L =Length of Concrete cylinder sample in mm.

Fig. 2: Split tensile strength test

The quantities of cement, coarse aggregate (20 mm), fine aggregate, iron slag and water for each batch i.e. for different percentage of iron slag replacement was weighed separately. The cement and iron slag were mixed dry to a uniform colour separately. Fine aggregate was mixed to this mixture in dry form. The coarse aggregates were mixed to get uniform distribution throughout the batch. Water added to the mix. Firstly, 50 to 70% of water was added to the mix and then mixed thoroughly for 3 to 4 minutes in mixer. Then the concrete was filled into the cylindrical moulds and then get vibrated to ensure proper compaction. The surface of the concrete was finished level with the top of the mould using trowel. The finished specimens were left to harden in air for 24 hours. The specimens were removed from the moulds after 24 hours of casting and were placed in the water tank, filled with potable water in the laboratory.

E. Sulphate Resistance Test

Tests performed for checking the sulphate resistance of concrete, produced using iron slag as partial replacement for sand, in this work are compressive strength test after immersing the cube specimen in 50g/l of magnesium sulphate solution(as per per ASTM C1012) for 7, 28 and 56 days. Before immersing them in sulphate solution, specimens are cured for 28 days in water under normal temperature.

Cube specimens of size 150 mm x 150 mm x 150 mm were taken out from the magnesium sulphate solution at the ages of 7, 28 and 56 days and tested immediately on removal from the solution (while they were still in the wet condition). Surface solution was wiped off before testing the specimens for compressive strength. The position of cube when tested was at right angle to that as cast. The load was applied gradually without shock till the failure of the specimen occurs and thus the compressive strength was found.

	MIX DESIGN (M20)	
A) Test data for materials		
(i)	Specific gravity of cement	3.12
(ii)	Specific gravity of coarse aggregates	2.57
(iii)	Specific gravity of fine aggregates	2.43
(iv)	Zone of fine aggregates	II
(v)	Water absorption of coarse aggregates	0.43%
(vi)	Water absorption of fine aggregates	0.89%

The mix proportions obtained for the various mixes cast are tabulated in Table 3.7

Mix Designation	Water (W) kg/m3	Cement (C) kg/m3	Fine Aggregates(FA) kg/m3	Iron Slag (IS) kg/m3	Coarse Aggregates (CA) kg/m3	Ratio of W:C:FA:IS:CA
M20	180	360	573.86	0.00	1233.54	0.5:1:1.59:0:32
M20	180	360	516.48	57.38	1233.54	0.5:1:1.43:0.15:3.42
M20	18	360	459.088	114.	1233.	0.5:1:1.27:

	0			772	54	0.31:3.42
M20	18 0	360	401.702	172. 158	1233. 54	0.5:1:1.11: 0.47:3.42

Table 1: Proportions of Concrete Mixtures

F. Summery

The properties of concrete of different ratios compared with normal concrete. A concrete mix prepaid with the replacement of fine sand by iron slag in different ratios (15%, 30% and 45%). The number of cubes and cylinders casted respectively for each test and different tests like compressive strength test, tensile strength test and sulphate resistance test performed after 7days, 28 days and 56 days of curing.

IV. Conclusions

- After adding 15% iron slag in the mix, there is an increase in compressive strength with 26% after 7 days, 50% increase after 28 days and 43% increase after 56 days as compared to the control mix. By adding 30% and 45% iron slag , there is large amount of increase in percentage i.e. 68%, 91%, 78% and 125%, 113% , 87% after 7, 28 and 56 days respectively.
- The Compressive strength tends to increase with increase percentages of iron slag in the mix.
- The early age strength gain is higher as compared to later ages if 45% of fine aggregate is replaced by iron slag.
- The Split tensile strength also tends to increase with increase percentages of iron slag in the mix.
- After adding 15% iron slag in the mix, there is increase in split tensile strength with 24% after 7 days, 9% increase after 28 days and 25% increase after 56 days. By adding 30% and 45% iron slag , there is large amount of increase in percentage ie 37%, 19%, 46% and 40%, 25% , 29% after 7, 28 and 56 days respectively.
- At early age presence of more amount of iron slag as sand replacement in concrete is beneficial for improving the strength characteristics.
- The compressive strength of 15% iron slag specimens when immersed in 50g/l MgSo4 solution gives more strength than standard mix value when immersed in water at 7, 28 and 56 days. But when the percentage of iron slag increase to 30% and 45%, the compressive strength of the mix tends to decrease when compared with the compressive strength of specimen cured in water at same ages.
- The strength loss will be much larger if the concrete is immersed in the solution for a larger period of time, the extent needs to be investigated.
- 15% slag is optimum from the consideration of resistance to sulphate attack as observed from the experimental results.

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