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Experimental Study on Partial Replacement of Coarse Aggregate by Iron Slag in Cement Concrete (M_{25})

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Abstract : Iron slag is a waste by-product of steel industry. Basically it consists of aggregates which are bonded together by cement and water. Since the lifetime of many metal products can be longer than 10 years and sometimes longer than 50 years, these products for building and construction, there is an accumulation of metal in use since the beginning of the industry. As the disposal of this waste is posing serious problem to the environment it is better to use this type of material in making concrete so that a waste material can be disposed off by cleaner technology. This technique will also prevent degradation in environment. Iron slag which is generated in large quantities as waste is hardly being used in the preparation of concrete. Special quality control procedures may be required to address the lack of consistency in some properties such as gradation, specific gravity, and absorption found. Control concrete with 20%, 30%, 40% and 50% of coarse aggregate replacement by Iron slag were made. Blast furnace slag is mildly alkaline and exhibits a pH in solution in the range of 8 to 10. Although blast furnace slag contains a small component of elemental sulphur (1 to 2 percent), the leach ate tends to be slightly alkaline and does not present a corrosion risk. Concrete obtained by this method may have more self-weight than the conventional concrete, but it is expected to provide more strength than the conventional concrete.
Keywords : Iron slag, Compressive strength, Split tensile strength, Flexural strength.

1.0 Introduction

Concrete is most widely used material on earth after water. Many aspects of our daily life depends directly or indirectly on concrete. Concrete is prepared by mixing various constituents like cement, aggregates and water etc., which are economically available[1]. Concrete is unique among major construction material because it is designed specifically for particular civil engineering project.

Concrete plays a vital role in the design and construction of the nation's infrastructure. Almost three quarters of volume of concrete is composed of aggregates. To meet the global demand of concrete in the future, it is becoming a more challenging task to find suitable alternatives to natural aggregates for preparing concrete[2,3].

In an integrated steel plant, 2-4 tonnes of wastes (including solid, liquid and gas) are generated for every tonne of steel produced.

During the year 2015-16, VISL (Visvesvaraya Iron and Steel Limited, Bhadravati, Karnataka), DSP (Durgapur Steel Plant, Durgapur, West Bengal), and BSP (Bokaro Steel Plant, Bokaro, Jharkhand), reported production of BF slag as 25,548 tonnes, 8,16,020 tonnes and 16,14,000 tonnes respectively[4]. Therefore the use of alternative sources for natural aggregates is becoming increasingly important.

2.0 Experimental Setup

In this stage collection of materials required and data required for the mix design are obtained by sieve analysis and specific gravity. Sieve analysis is carried out from various fine aggregate and coarse aggregate samples and the samples which suits the requirement is selected. Specific gravity tests are carried out for fine and coarse aggregate[5]. The various materials used were tested as per Indian standard specification.

2.1 Materials

At present raw materials used for the concrete work are cement, fine aggregate, coarse aggregate, Iron slag and water.

2.1.1 Cement

The major raw material for the production of cement is clinker. Clinker is an artificial stone made by heating other raw materials in specific quantities to a very high temperature in a high temperature kiln. Portland cement is hydraulic cement made by finely pulverizing the clinker produced by calcinizing to incipient a fusion a mixture of argillaceous and calcareous materials[6]. It is a fine grey powder that is the most important ingredients of concrete, hence it is named cement concrete. Cement undergoes a chemical reaction with water and sets and hardens when it contacts with air or underwater.

Table 1 Properties of cement

Properties	**Values as per IS 1489 (Part 1) : 1991**
Initial setting time	30 min.
Final setting time	600 min.
Fineness	Not less than 300 m^2/kg
Specific gravity	3.15
Soundness	0.8%
Shrinkage	Not more than 0.15%
Compressive strength	33Mpa @ 28 days

Portland puzzolana cement (PPC), was used for the entire experimental investigation. The required quantity for this work was assessed and the entire quantity was purchased and stored properly in casting yard and used for the experimental investigation. The physical properties of the above tested according to standard procedure, conforms to the requirement of IS: 1489 (Part 1) – 1991[7]. Properties of cement is listed in Table 1.

2.1.2 Fine aggregate

Fine aggregate are usually sands from the river or the marine environment. Fine aggregates generally consist of natural sand or crushed stone with most particles passing through a 4.75mm sieve.

In India, river sand is preferred as a fine aggregate. Of late, the lack of availability of river sand has led to the use of artificial sands, especially in southern states such as Tamilnadu. Properties of fine aggregate is listed in Table 2.

Table 2 Properties of fine aggregate

Properties	Values
Specific gravity	2.74
Fineness modulus	3.35
Water absorption test	1.20%
Bulk density	1820 kg/m^3

2.1.3 Coarse aggregate

Coarse aggregate are major ingredients of concrete. They provide rigid skeleton structure for concrete, and acts as economical and space fillers. They contribute to the both stiffness and durability to the concrete. Generally coarse aggregate are derived from the mineralogical composition of rock. The environmental exposure to which rocks has been subjected and the method of crushing employed to get the different sizes. In India crushed rock is used as coarse aggregates.

Machine crushed stone with angular shape was used as coarse aggregate. Properties of coarse aggregate is listed in Table 3.

Table 3 Properties of Coarse aggregate

Properties	Values
Specific gravity	2.74
Fineness modulus	7.54
Water absorption test	1.83%
Bulk density	1800 kg/m^3

2.1.4 Water

An important ingredient of concrete is water as it chemically participates in the reaction with cement to form the hydration product, C-S-H gel. The strength of cement mortar depends mainly from the binding action of the hydrated cement paste gel. A higher w/c ratio will decrease the strength, durability, water – tightness and other related properties. The quantity of water added should be the minimum for chemical reaction of hydrated cement, as any excess of water would end up only in the formation of undesirable voids (capillary pores) in the hardened cement paste[8,9]. The strength of cement paste is inversely proportional to the dilution of the paste. Hence, it is essential to use as little paste as possible consistent with the requirements of workability and chemical combination with cement.

Quantity and quality of water is required of water is required to be looked very carefully. The water used for making concrete should be free from undesirable salts that may react with cement and admixtures reduce their efficiency. Silts and suspended particles are undesirable as they interfere with setting, hardening and both bond characteristics.

Water conforming to requirement of BIS: 456- 2000 is found to be suitable for making cement mortar[7,10]. It is generally stated that water fit for drinking is fit for making cement mortar. For the present investigation, portable water supplied by the neighbouring Municipality was used for casting and curing the specimens.

2.1.5 Iron slag

Iron slag is a by-product of iron and steel (fig.1). Steel cannot be prepared in the Basic Oxygen Furnace (BOF) or in an Electric Arc Furnace (EAF) without making its by-product steel slag. In a blast furnace, crude or pig iron is made by a stripping the oxygen and other impurities from iron ore by means of high- temperature reactions with reducing agents (mainly carbon) and fluxes. The impurities and fluxing agents both to form a liquid silicate melt called iron or blast furnace slag. The non-metallic product, consisting essentially of silicates and alumina silicates of calcium and of other basis that is developed in a molten condition simultaneously with iron in a blast furnace.Properties of iron slag is listed in Table 4.

Table 4 Properties of iron slag

Properties	Values	Range as per code IS: 383-1970
Specific gravity	2.74	2.30 – 2.90
Bulk density	1800	1280 – 1920
Fineness modulus	2.35	2.10 – 3.20
Water absorption	3	0 – 8
Flakiness index	53.90%	-
Elongation index	4.5	-
Impact strength	8.3%	-
Crushing strength	2.95%	-

Fig. 1 Iron slag

3.0 Mix Design

Conventional concrete mix of grade M_{25} has been designed based on Indian Standard Recommended Guidelines IS: 10262-2009. The proportion and quantities of various materials for the concrete mix have been presented in Table 5.

Table 5 Mix design

Water (kg/m^3)	Cement (kg/m^3)	Fine aggregate (kg/m^3)	Coarse aggregate (kg/m^3)
197	438	709	1108
0.45	1	1.62	2.53

4.0 Material Test Result

4.1 Fresh concrete

4.1.1 Workability

Workability is the property of the fresh concrete for determining the effort required to manipulate a freshly mixed quantity of concrete with minimum loss of homogeneity. Workability is necessary to obtain a maximum compaction to a possible density. The test result of slump cone is mentioned in Table 6.

Table 6 Slump cone test result

S.No	Description	Values
1	Slump value of conventional concrete	25mm
2	Slump value of (20%) Replacement concrete	30mm
3	Slump value of (30%) Replacement concrete	40mm
4	Slump value of (40%) Replacement concrete	45mm
5	Slump value of (50%) Replacement concrete	55mm

Slump test (fig.2) is used to determine the workability of fresh concrete, slump test as per IS 1199-1959 is followed. The apparatus used for doing slump test are slump cone and tampering rod.

Fig. 2 Slump cone

4.1.2 Compaction factor

The compaction factor measures the degree of compaction achieved by a standard amount of exerted work. The test result of compaction factor is mentioned in Table 7.

Table 7 Compaction factor test result

S.No	Description	Values
1	Compaction factor of conventional concrete	0.90
2	Compaction factor of (20%) Replacement concrete	0.88
3	Compaction factor of (30%) Replacement concrete	0.87
4	Compaction factor of (40%) Replacement concrete	0.87
5	Compaction factor of (50%) Replacement concrete	0.86

4.2 Hardened concrete

4.2.1 Compressive strength

The compressive strength test is the most common test conducted because most of the desirable characteristic properties of concrete and the structural design purpose are qualitatively related to compressive strength. The test was conducted in compression testing machine as per the specifications given by IS under normal room temperature. The capacity of compressive testing machine was 20 tonnes. The cubes were properly held in position such that the load is applied uniformly over the surface. The load was applied gradually until the ultimate load is reached. The ultimate load was noted and the compressive strength was calculated using the formula and result has been showed in Fig.3

$$\textbf{Comp. strength} = \frac{\textbf{ultimate load}}{\textbf{cross section area}} \, \textbf{N}/\textbf{mm}^2$$

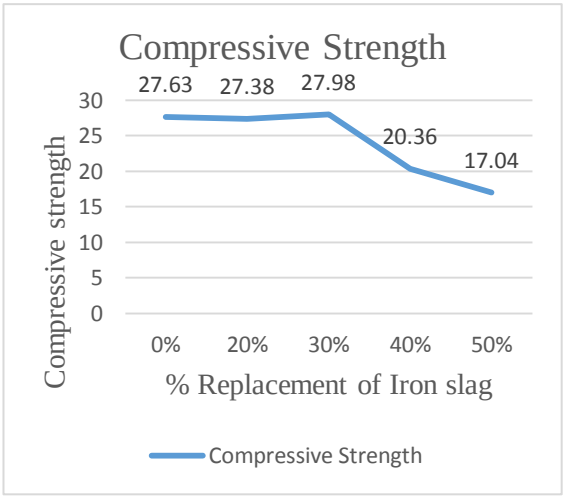

Fig. 3 Compressive strength result

Fig. 4 Compressive strength

4.2.2 Split tensile strength

According to split tensile strength, the cylinders were dealt with circumferential load and the result were obtained using formula. The result has been showed in Fig.5

The split tensile strength is given by the formula $^{2p}/_{\pi DL}$ and the stress value is obtained.

P is the ultimate load at which the cylinder brakes.

D and L are the diameter and length of the cylinder.

Split tensile strength = $^{2p}/_{\pi DL}$ $^{N}/_{mm^2}$

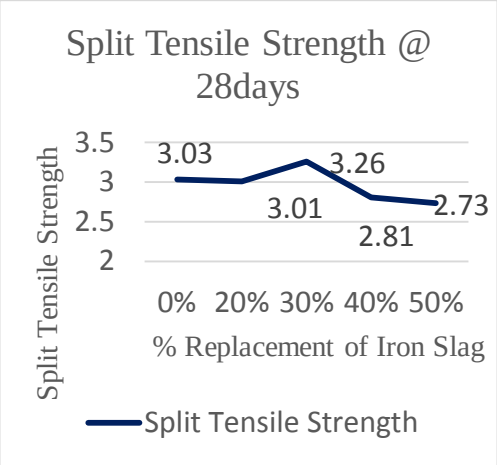

Fig. 5 Split tensile strength result

Fig. 6 Split tensile strength

4.2.3 Flexural strength

The testing machine shall be provided with two steel rollers, 30 mm in diameter, on which the specimen is to be supported, and these rollers shall be so mounted that the distance from centre to centre is 70 cm for 15.0 cm specimens. The load shall be applied through two similar rollers mounted at the third points of the supporting span. The load shall be divided equally between the two loading rollers, all rollers shall be mounted in such a manner that the load is applied axially and without subjecting the specimen to any torsional stresses or restraints.The test result has been showed in Fig.7.

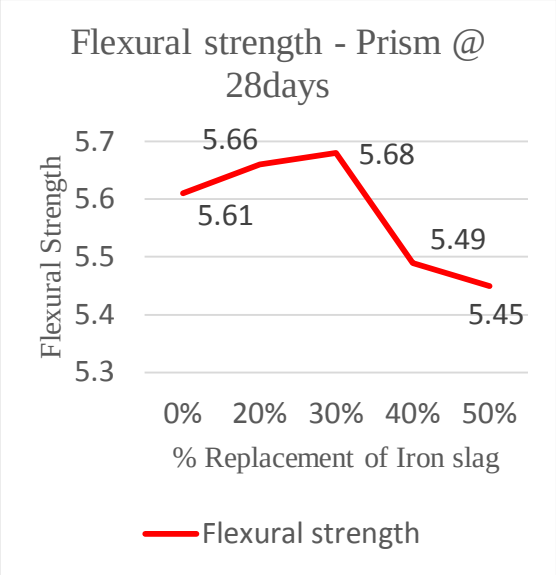

Fig. 7 Flexural strength

Fig. 8 Flexural strength

5.0 Conclusion

The specimen were casted with the partial replacement of Coarse aggregate by Iron slag with the replacement of 20%, 30%, 40% and 50%

- Comparing to the conventional concrete, Partial replacement of iron slag in concrete increases for 30% by 1.3% and decreases for 20%, 40%, 50% by 0.9%, 26%, 38% respectively for cube compression strength.
- Comparing to the conventional concrete, Partial replacement of iron slag in concrete increases for 30% by 7.6% and decreases for 20%, 40%, 50% by 0.66%, 7.3%, 10% respectively for split tensile strength.
- Comparing to the conventional concrete, Partial replacement of iron slag in concrete increases for 20% and 30% by 0.9%, 1.25% and decreases for 40%, 50% by 2.14%, 2.85% respectively for flexural strength.

6.0 References

1. P. Vignesh Kumar, R. Ranjith Kumar "An Experimental Study on Partial Replacement of Coarse Aggregate by Iron Slag with Polypropylyne Fiber" International Journal of Science and Research (IJSR) ISSN (Online): 2319-7064, Volume 5 Issue 3, March 2016Paper ID: 1031603
2. P. Sateesh Kumar, VVS. Sarma , N. VidyaSagarLal "Study on Behaviour of Concrete Mix Replacing Fine Aggregate with Steel Slag at Different Properties" International Journal of Engineering Research and Applications (IJER) ISSN: 2248-9622, Vol. 5, Issue 11, (Part - 4) November 2015, pp.39-46

3. ChetanKhajuria, RafatSiddique"Use of Iron Slag as Partial Replacement of Sand to Concrete" International Journal of Science, Engineering and Technology Research (IJSETR), Volume 3, Issue 6, June 2014
4. KandukuriAnitha, Dr.P.SriChandana, Ph.D"Experimental Studies on Ferrous Slag as a Replacement of Fine Aggregate in Conventional Concrete" International Journal & Magazine of Engineering, Technology, Management and Research ISSN No: 2348-4845, Volume No: 2 (2015), Issue No: 11 (November)
5. PremRanjan Kumar, Dr.Pradeep Kumar T.B "Use of Blast Furnace Slag as an Alternative of Natural Sand in Mortar and Concrete" International Journal of Innovative Research in Science, Engineering and Technology (IJIRSET)ISSN (Online): 2319 – 8753 ISSN (Print):2347 – 6710.Vol. 4, Issue 2, February 2015
6. Khalid Raza, Apoorv Singh, R. D. Patel "Strength Analysis of Concrete by Using Iron Slag as a Partial Replacement of Normal Aggregate (Coarse) in Concrete" International Journal of Science and Research (IJSR) ISSN (Online): 2319-7064, Volume 3 Issue 10, October 2014, Paper ID: OCT14103
7. Dhanasri K, Kishore Kumar M "Performance of Concrete by replacing Coarse Aggregate and Fine Aggregate with Blast Furnace Slag and Crusher Dust"International Journal of Innovative Research in Science, Engineering and Technology (IJIRSET) ISSN: 2319-8753Vol. 2, Issue 12, December 2013
8. Sindhu.A.E, Karthikeyan.N"Effect of Replacing Sand with Cast Iron Slag on Compressive Strength of Concrete" International Journal of Science and Engineering Research (IJ0SER), Vol 4 Issue 6 June-2016 3221 5687, (P) 3221 568X
9. D. Satish Kumar, L.R. Manjunath, M.C. Nataraja, MarutiramKaza and S.M.R. Prasad "Urgent need for a new aggregate standard"
10. T.S.Thandavamoorthy" Feasibility of making Concrete with Iron Slag Scrap as Coarse Aggregate" Construction Engineering Volume 4, 2016, doi: 10.14355/ce.2016.04.001

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