REPLACEMENT OF FINE AGGREGATE BY STEEL SLAG

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ABSTRACT

In construction materials, concrete is the largest production of all other materials. Aggregates are the important constituents in concrete. 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. Steel slag is a waste product generated during the production of steel. These wastes are disposed in the form of landfills causes an enormous amount of land pollution. So for the increasing demand to protect the normal environment, especially in build-up areas, the needs to use these wastes are very important. Therefore, replacing all or some portion of natural aggregates with steel slag would lead to considerable environmental benefits. The utilization of waste materials from the industries has been continuously emphasized in the research work. The present work is to use steel Slag as replacement for fine aggregate. The M30 concrete with high volume steel slag replacement for fine aggregate are examined in the present study. According to material properties compressive strength, flexural strength and split tensile strength were found experimentally. The results were compared with conventional concrete property. The results showed that replacing about 0%, 25 % and 50% of steel slag aggregates by volume for natural aggregates will not do any harm to concrete and also it will not have any adverse effects on the strength and durability.

Keywords: Steel slag, Replacement of fine aggregate

I. INTRODUCTION

1.1 General

Concrete plays a critical role in the design and construction of the nation's infrastructure. Almost three quarters of the 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. The continues use of Natural Sand leads to the depletion of river beds results into the ecological imbalance. Availability of natural aggregates is getting depleted and also it becoming costly, therefore the replacement of natural sand by the waste industries by-products (Mineral admixtures) has been continuously emphasized during recent years. Natural sand is replaced by slag sand in various percentage.. In this study, therefore an attempt has been to study the effect of replacement of fine aggregate using steel slag on compressive strength, split tensile strength, flexural strength of concrete.

In this project slag from steel industry is used to replace for fine aggregate. Steel slag is a byproduct obtained either from conversion of iron to steel in a Basic Oxygen Furnace (BOF), or by the melting of scrap to make steel in the Electric Arc Furnace (EAF). Like other industrial byproducts, slag actually has many uses, and rarely goes to waste. It appears in concrete, aggregate road materials, as ballast, and is sometimes used as a component of phosphate fertilizer. This substance is produced during the smelting process in several ways. Firstly, slag represents undesired impurities in the metals, which float to the top during the smelting process. Secondly, metals start to oxidize as they are smelted, and slag forms a protective crust of oxides on the top of the metal being smelted, protecting the liquid metal underneath. When the metal is smelted to satisfaction, the slag is skimmed from the top and disposed of in a slag heap to age. Aging material is an important part of the process, as it needs to be exposed to the weather and allowed to break down slightly before it can be used.

Fig. 1 Steel slag

1.2 Scope

The original scope of this research was to investigate the properties of concrete with steel slag aggregates. The fresh and hardened properties of concrete were tested with steel slag aggregates. In addition to this research several tests were also included such as compressive strength, split tensile strength and the flexural strength of concrete with steel slag aggregates. For this research the percentage of the volume of natural aggregates normally used in concrete was replaced by steel slag. This replacement was done in 0%, 25%, 50% increments until all natural aggregates were replaced by the steel slag. Thus replacing the natural aggregates in concrete applications with steel slag would lead to considerable environmental benefits and would be economical.

1.3 Purpose.

The purpose of this research was to explore the feasibility of utilizing the steel slag as a replacement for natural aggregate in the concrete. Steel slag aggregates generally exhibit the potential to expand due to the presence of un-hydrated free lime and magnesium oxides which hydrate in humid environments. If such a product is used in the concrete, it influences both the mechanical and physical properties of concrete along with its durability. Researchers in the past have successfully incorporated this industrial byproduct as aggregates for hydraulically bound mixtures for road bases. The use of this material as a construction aggregate is being studied, and further research is on going in the United State.

II. MATERIALS AND METHODOLOGY

The basic tests are conducted on various materials like OPC53 grade cement, fine aggregate, coarse aggregate and steel slag to check their suitability for making concrete. The experimental investigation has been carried out on the test 3 specimens of Cubes, Cylinders, and Beams each to study the strength properties as a result of replacing fine aggregate by Steel slag in various percentages namely 0%, 25% and 50% of steel slag. Specimens are cast as per mix design and the tests are conducted after proper curing, the tests are compressive strength of cubes (150mm x 150mm x 150mm), split tensile strength of cylinders (150mm x 300mm) and flexural strength of beam (100mm x 100mm x 500mm). From the studies, optimum results are found out and compared with the conventional concrete.

2.1 Cement

Ordinary Portland cement of 53 grade conforming to IS: 8112 – 1989 was used. Its specific gravity was 3.15.

2.2 Fine aggregate

Natural river sand with fraction passing through the 4.75 mm sieve and retained on 600 µm sieve was used and tested as per IS: 2386. The fineness modulus of sand used was 2.81 with a specific gravity of 2.74.

2.3 Coarse aggregate

Crushed granite coarse aggregates of 20mm size were used. The specific gravity was 2.74.

2.4 Steel Slag

Steel slag is a byproduct obtained either from conversion of iron to steel in a Basic Oxygen Furnace (BOF), or by the melting of scrap to make steel in the Electric Arc Furnace (EAF).

TABLE 1 Physical properties of steel slag

Sr no.	Designation	Properties
1	Colour	Light to dark brown
2	Shape	Highly angular
3	Bulk density	1911.11 kg/m3
4	pH (in water)	8
5	Combustibility	Non-combustible
6	Surface Texture	Rough
7	Specific gravity	2.93

TABLE 2 Chemical properties of steel slag

Sr no.	Constituent	Composition (%)
1	Calcium Oxide (CaO)	40 - 52
2	Silica (SiO2)	10-19
3	Iron Oxide (FeO)	10-40
4	Manganese Oxide (MnO)	5-8
5	Magnesium Oxide (MgO)	5-10
6	Alluminium Oxide (Al2O3)	1-3
7	Phosphorous Oxide (P2O5)	0.5-1

III. FRESH CONCRETE

Following test were conducted on fresh concrete.

- Slump Test
- Compaction Factor Test

IV. HARDENED CONCRETE

Test which are conducted on hardened concrete are as follows,

- Compression test
- Splitting tensile test
- flexural strength test

The test which conducted on hardened concrete are given below.

4.1 Compressive Strength of Concrete.

Totally 9 concrete cubes were casted and it is allowed for 7 days and 28 days curing. After drying, cubes were tested in Universal Testing Machine (UTM) to determine the ultimate load. Replacement made for 0%, 25% and 50 %. For this study the water cement ratio of 0.45 is maintained uniformly.

Fig.2 Compression strength test under UTM

After performing test on cubes of M30 grade of concrete under Universal Testing Machine (UTM) for varying percentage of steel slag by volume of fine aggregate results obtained are as given below

TABLE 3. Compressive strength

% of steel slag used	7 days Compressive Strength (N/mm^2)	28 days Compressive Strength (N/mm^2)
0	26.81	56.85
25	29.96	59.68
50	16.32	54.02

4.2 Split Tensile Strength of Concrete.

Totally 9 cylinders of M20 grade concrete were casted. Replacement made for 0%, 25% and 50%. For the study the water cement ratio of 0.45 is maintained uniformly. The splitting tensile strength of the concrete specimens was tested at 7 and 28 days under Universal Testing Machine (UTM).

Fig. 3 Split Tensile strength test for cylinder

After performing Split Tensile strength test on cylinder of M30 grade of concrete under Universal Testing Machine (UTM) for varying percentage of steel slag by volume of fine aggregate results obtained are as given below

TABLE 4. Split Tensile strength of cylinder

% of steel slag used	7 days Tensile Strength (N/mm^2)	28 days Tensile Strength (N/mm^2)
0	2.04	3.75
25	2.45	3.98
50	2.83	3.89

4.3 Flexural strength of Concrete

The flexural strength test was conducted on beam specimens in Universal testing machine. All beams were tested under three point loading method. The fracture indicates in the tension surface within the middle third of span length.

The Modulus of rupture calculated using the equation;

R= PL/BD

Where:

R = The Modulus of Rupture. (MPa)

P = The Maximum applied load indicated by the testing machine (N)

L = The span length.(mm)

b = The average width of the specimen at the fracture.(mm)

d = The average depth of the specimen at the fracture (mm)

Fig.4 Flexural strength of beam.

After performing Flexural strength test on beam of M30 grade of concrete under Universal Testing Machine (UTM) for varying percentage of steel slag by volume of fine aggregate results obtained are as given below,

TABLE 5 Flexural strength of beam

% of steel slag used	7 days Tensile Strength (N/mm^2)	28 days Tensile Strength (N/mm^2)
0	50.30	64.45
25	63	78.75
50	77.10	71.02

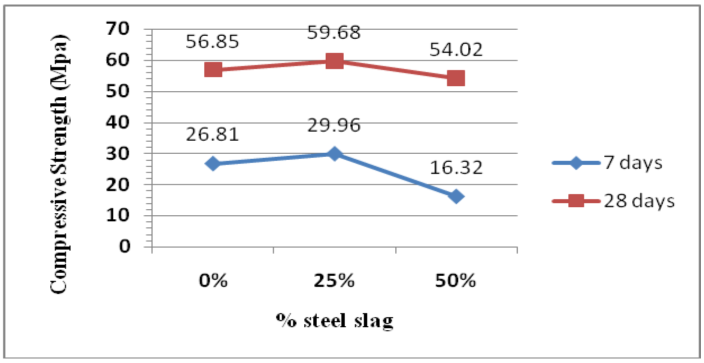

Fig. 5 Compressive strength of concrete

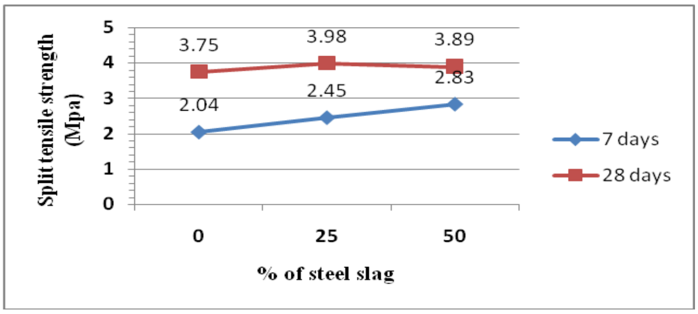

Fig 5 Split tensile strength of concrete

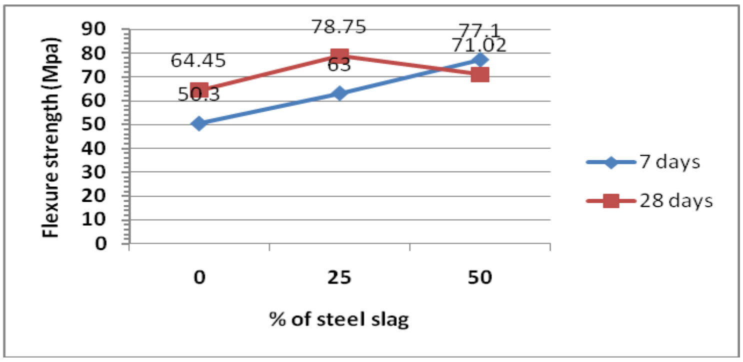

Fig.6 Flexural Strength of concrete

V. CONCLUSION

The compressive strength increases with increase in percentage of steel slag by 25% by weight of fine aggregate

The compressive strength decreases after 25% replacement of steel slag.

The split tensile strength increases with increase in percentage of steel slag by 25% by weight of fine aggregate.

The flexural strength increases with increase in percentage of steel slag by 25% by weight of fine aggregate.

From the results of compressive strength, split tensile strength and flexural strength of 7 days and 28 days curing, 25% replacement of fine aggregate by steel slag is the optimum percentage of replacement of M30 grade concrete and decreases considerably in further replacement of slag in concrete.

Eco-friendly and Mass utilization of waste material is possible in construction by using steel slag as partial replacement material for partial replacement in concrete.

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