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Steel Slag to Improve the High Strength of Concrete

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Abstract: Steel slag is an industrial by-product of steel industry. It possesses the problem of disposal as waste and is of environmental concern. The results were compared with conventional concrete property can be maintained with advanced mineral admixtures such as steel slag powder as partial replacement of cement 0 to 40%. Experiments were conducted to determine the compressive strength; split tensile strength of concrete with various percentages of steel slag aggregate. Compressive strength of steel slag concrete with different dosage of slag was studied as a partial replacement of cement. From the experimental investigations, it has been observed that, the optimum percentage of steel slag for high strength concrete.
Key words - Concrete, steel Slag Powder, Compressive Strength, split tensile strength Flexural Strength, Optimum Replacement.

1. Introduction

The Ordinary Portland Cement (OPC) is one of the main ingredients used for the production of concrete. Unfortunately, production of cement involves emission of large amounts of carbon-dioxide gas into the atmosphere, a major contributor to the greenhouse effect and the global warming, hence it is inevitable either to search for another material or partially replace it by some other material. The search for any such material, which can be used as an alternative or as a supplement for cement should lead to global sustainable development and lowest possible environmental impact.

The successful incorporation of steel slag as an aggregate in construction products requires the consideration of certain issues. Firstly as steel slag is an industrial by product until recently disposed in landfill, the question is whether it is suitable for use in construction .Then the technical characteristics of the material are examining because due to its physicochemical properties steel slag requires special care, but can also provide maximum value if used for specific applications.

Steel making slag specifically slag generated from Electric Arc Furnace (EAFs), Basic oxygen furnace (BOFs), during the iron /steel making process has many important and environmentally safe uses. In many applications due to its unique physical structure, slag out performs the natural aggregate for which it is used as a replacement .Hence not only does slag offer a superior material for many construction , industrial, agricultural, and residential applications , but the uses of slag promotes the conservation of natural sources.

This paper presents the study of compressive strength and split tensile strength of M55 conventional concrete by replacing the o% to 40% of steel slag was added, tests were conducted on concrete cubes and cylinders to study compressive and split tensile strengths. The results are compared with the normal conventional concrete.

2. Materials Characteristics

2.1 initial tests

The chemical and physical properties of steel slag were examined and are stated in Table 1 and 2 [3]. The specific gravity of SSA was found to be 3.2, bulk density 2.54.

Table- 1 Chemical Composition of Steel Slag

Materials	**Mass (%)**
Fe	15-18
Sio_2	9-12
Al_2O_3	1.4-0.6
CaO	51-58
MgO	1-3
Fe_2O_3	10-13
MnO	4-5
S	0.13-0.1
P_2O_5	3.2-2.1
Na_2O	0.03-0.01
K_2O	0.04-0.01

Table 2.Physical Properties of Steel Slag

Properties	**%-age**
Water absorption	3
Crushing strength	29.5
Impact value	29
Los Angeles Abrasion	28

2.2. Fine aggregate

A concrete with better quality can be made with sand consisting of rounded grains rather than angular grains. River or pit Sand must be used and not Sea Sand as it contains salt and other impurities. By conducting Sieve Analysis, and compared with Grading table from IS 383-1970, Table 3, it was found that the sand used belongs to the Zone II.

Table 3. Properties of Fine Aggregate

Properties	**Value**
Fineness modulus	3.24
Specific Gravity	2.66
Size	Passing through 4.75mm sieve
Water absorption ratio	1%

2.3. Coarse Aggregate

The aggregate must be clean and free from impurities. The coarse aggregate used in this project is of the size 12.5mm.

Table 4. Properties of Coarse Aggregate

Properties	**Value**
Fineness modulus	4
Specific Gravity	2.64
Size	Passing through 16 mm and retaining in 12.5mm sieve
Water absorption ratio	0.50%

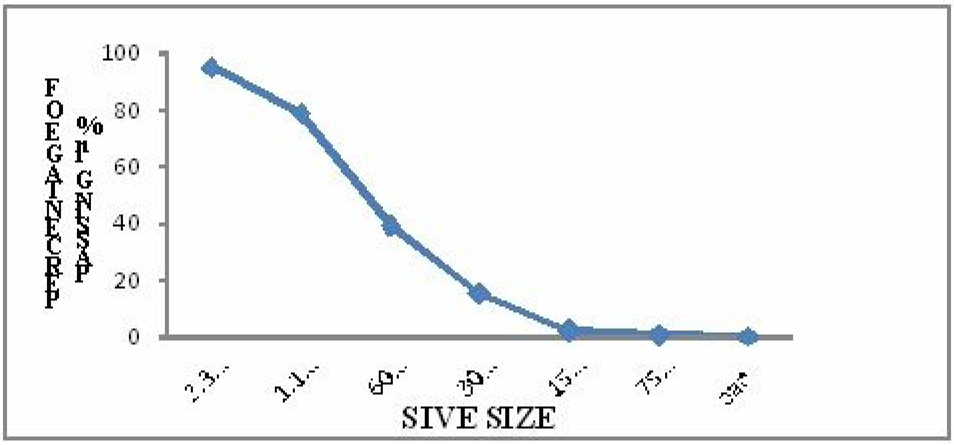

Figure 1 Particle Size Distribution in Sand

2.4. Mix proportioning

A single batch of ordinary Portland cement (OPC), M55-grade, was used in this study. Steel slag was collected from the steel industry, JSW steels, mature, Salem, Tamilnadu, India. It was crushed down to 20 mm size for use as a coarse aggregate in concrete. The sand used in concrete was local river sand and the natural coarse aggregate was 12.5 mm crushed granite [6]. The study is for replacing natural coarse aggregate (NCA) with steel slag aggregate (SSA) for pavement concrete. The concrete mix selected is M55 and is proportioned as per Indian Roads Congress [7].

Land quarried sand passing through ASTM sieve No. (4.57mm) conforming to zone II classification of ACI method was used as fine aggregate. The sand has a fineness modulus of 4. Tap water was used for the preparation of specimens. All the concrete mixes were designed for similar workability with a slump of 65 mm. The water content was kept constant to 176.63 kg for the desired slump in all the mixes to have similar workability. The water–cement ratio (w/c) used to be 0.32. The fresh density of concrete was then obtained as per guidelines specified by the ACI method of mix selection to be 2380Kg/m3 Mix design is as shown in Table5 Quantity of ingredients per cu.m. of M55 Concrete origin were used in the Concrete mix ratio =1: 0.97: 2.02 (Cement: FA: CA: Water-cement ratio). To satisfy the overall grading requirement of coarse aggregate (8)

Table-5 Concrete mix proportions

Water	**Cement**	**Fine Aggregate**	**Coarse Aggregate**
176.63 kg	552kg	536.64 kg	1113.84 kg
0.32	1	0.97	2.02

3.Experimental Details

3.1 Details of test Specimen

Concrete cubes of size 150 x150 x 150 mm, were cast for compressive strength tests and Cylinders, 100 x 300 mm, were cast for splitting tensile strength test and to determine the flexural strength, 100 x 100 x 500 mm prisms were cast. All specimens were denuded 24 hours after casting, and then cured for 28 days.

4. Results and Discussion

The experiment was conducted to find the difference in increased compressive strength and split tensile strength; when the steel slag is replaced with fine aggregate. The tests were conducted on 7th, 14th and 28th days. For that we followed all the procedures as per ACI code specifications

The shape of steel slag is fine grained particles and highly angular. It has rough surface texture. The aggregates of steel slag have high bulk density and specific gravity with moderate water absorption capacity. Properties of Steel Slag (Bulk density=2. 54 , Specific Gravity= 3.2 , Water absorption Up to 3%)

Table 6 Slump test for Fresh concrete

W/C Ratio	Percentage of Water	Volume of water in ml	Slump in mm
0.32	35%	1400	65

Table 7 Compacting Factor

S.No	W/C Ratio	Weight of partially compacted cylinder (W2) in Kg	Weight of partially compacted cylinder (W3) in Kg	Weight of partially compacted concrete (W_2-W_1) in Kg	Weight of Fully compacted concrete (W_3-W_1) in Kg	Compacting Factor
1	0.3	15.660	16.220	9.28	9.84	0.96

Compacting Factor = 0.96

4.1. Tests for hardened concrete:

To evaluate the performance of different mix used in this work, following strength test were performed.

1. Compressive strength 2.Split tensile strength 3.Flexural Strength

4.2. Compressive strength

The compressive strength of concrete is one of the most important properties of concrete. Comparative strength if M55 grade of concrete for the full replacement of sand by crushing was found. In this test 150x150x150mm concrete cubes were cast, by using 55 Mpa concrete. The compressive strength of concrete cubes with 0%, 10%, 20%, 30%, 35%, 36%, 37%, 40% replacement with steel slag aggregate were determined The mixing was done by cubes were remolded and placed under water and cured for 28 days. Then the cubes were tested for their crushing strength at 7, 14 and 28 days. As per ACI 211.4R load was applied at the rate of 140kN/min. The result showed that percentage of steel slag increase with compressive strength increased.

Strength of hardened concrete:

Table. 8 Compressive strength of concrete

S.No	Percentage of Steel Slag	7 days in Compressive strength in Mpa	14 days in Compressive strength in Mpa	28 days in Compressive strength in Mpa
1	0%	40.44	48.88	61.7
2	10%	41.78	49.55	55.1
3	20%	49.77	57.03	61.99
4	30%	54.43	60.81	65.92
5	35%	56.58	60.66	68.74
6	36%	56.66	61.25	70
7	37%	55.1	58.66	66.66
8	40%	48.74	52.51	57.84

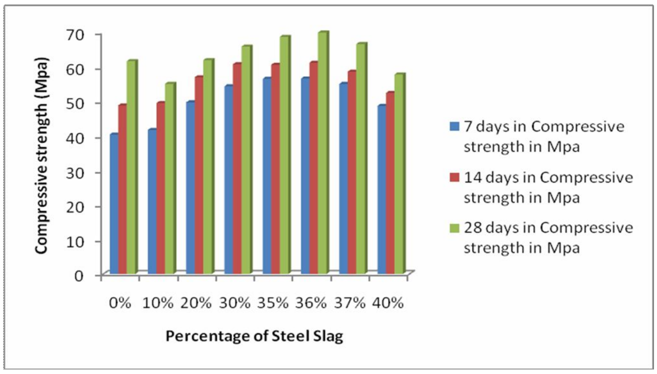

Figure 2 Comparisons of Compressive strength in Concrete

4.3. Split Tensile Strength

The tensile strength of concrete was obtained indirectly by split tensile test, where the compressive line loads were applied along the opposite generators of a concrete cylinder placed with its horizontal axis between the platens of compressive testing machine. Due to such applied line load, a fairly uniform tensile stress is induced over nearly two-third of the loaded diameter [2]. The stress induced will split the cylinder vertically into two halves. The magnitude of tensile strength was calculated using the Equation 1.

$\Sigma_{Sp} = 2P/\square DL$ ---------------1
Σ_{Sp}=split test strength of concrete in N/mm2
P=crushing load in N
D=diameter of the cylinder in mm
L= length of the cylinder in mm

Table 9 Split Tensile Strength in Concrete

S.No	Percentage of Steel Slag	7 days in split tensile strength in Mpa	14 days in split tensile strength in Mpa	28 days in split tensile strength in Mpa
1	0%	4.38	4.81	5.5
2	10%	4.73	5.16	5.8
3	20%	5.09	5.5	6.22
4	30%	5.44	6	6.65
5	35%	5.8	6.22	6.86
6	36%	6	6.43	7.07
7	37%	5.5	6.15	6.71
8	40%	4.52	5.23	6.36

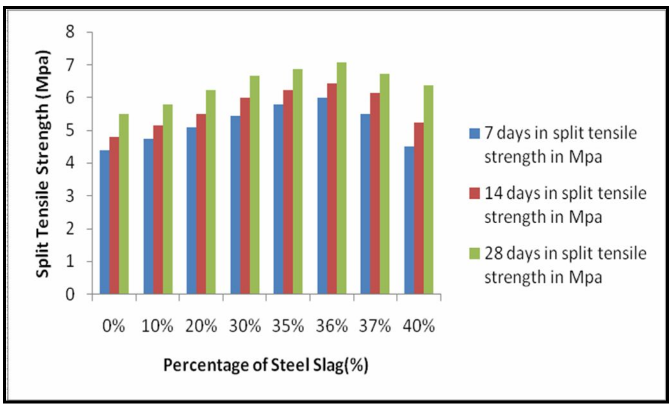

Figure 3 Comparison of Split Tensile Strength in Concrete

4.6. Flexural strength test:

The flexural strength test was conducted on beam specimens by manual flexural strength testing machine. The beams were tested on 7, 14, 28 days after curing in fresh water at 27*C. The variation of flexural strength with different percentage of replacement of cement by different admixtures. The values of flexural strength for different level of replacement of cement is given in the table and the graph is given in Figure are respectively**.**

Table 10 Flexural Strength in Concrete

S.No	**Percentage of Steel Slag**	**7 days in Flexural strength in Mpa**	**14 days in Flexural strength in Mpa**	**28 days in Flexural strength in Mpa**
1	0%	2.83	2.91	3.4
2	10%	2.94	3.23	3.7
3	20%	3.09	3.3	4.22
4	30%	3.54	4	4.65
5	35%	3.6	4.36	4.76
6	36%	4	4.58	5.02
7	37%	3.5	4.98	4.85
8	40%	2.62	3.65	4.49

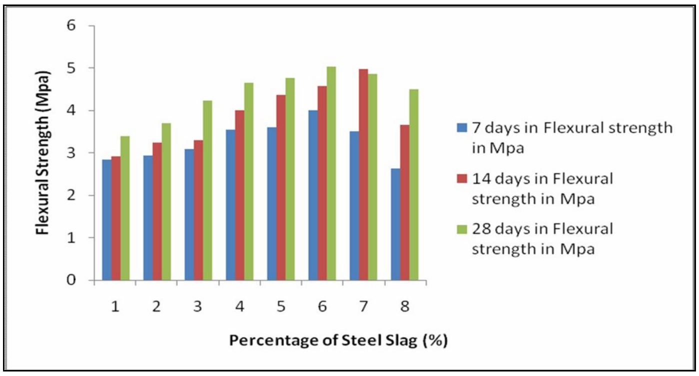

Figure 4 Comparison of Flexural Strength in Concrete

5. Conclusion

The influence of high strength steel slag performance in concrete in this study and the following findings is concluded:

This work relates the use of steel slag, a waste cheap material used as fine aggregate in M55 grade concrete and recommends and approval of the materials for use in concrete as replacement material for fine aggregates .The partial substitution of natural aggregates permits a gain of compressive, tensile and flexural strength and modulus of elasticity of concrete up to an optimum value of replacement. It has been observed that up to 36% replacement of fine aggregate with steel slag to be good in Compression, as well as in Tension, whereas the concrete properties with equal proportion of steel slag and conventional fine aggregate confirmed to be inefficient. The benefits can also obtained by cost reduction, social benefits , mass utilization of waste material is possible in construction by using steel slag as a partial replacement material for fine in concrete.

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