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Study on strength properties of concrete by partially replacement of sand by steel slag

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Abstract— *Natural aggregates are becoming increasingly scarce and their production and shipment is becoming more difficult. Steel slag is an industrial by product obtained from the steel manufacturing industry. Steel slag can be used in the construction industry as aggregates in concrete by replacing natural aggregates. Steel slag is currently used as aggregate in hot mix asphalt surface applications, but there is a need for some additional work to determine the feasibility of utilising this industrial by-product more wisely as a replacement for both fine and coarse aggregates in a conventional concrete mixture. Most of the volume of concrete is aggregates. Replacing all or some portion of natural aggregates with steel slag would lead to considerable environmental benefits. The primary aim of this research was to evaluate the strength of concrete made with steel slag as replacement for fine aggregates. For this present study M20 grade concrete shall be designed, Partial replacement of sand with steel slag will be made for varying percentages such as 10%, 20%, 30%, 40%, 50% by weight of sand. Studies on compressive strength, tensile strength, flexural strength would be made the optimum percentage of 30% of steel slag replacement.*

Key words: Steel Slag, Stress-Strain curve, Strength Properties.

I. Introduction

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).The molten liquid is a complex solution of silicates and oxides that solidifies on cooling and forms steel slag. It is a non-metallic product, consisting essentially of calcium silicates and ferrites combined with fused oxides of iron, aluminum, manganese, calcium and magnesium that are developed simultaneously with steel in basic oxygen, electric arc, or open hearth furnaces. The main constituents of iron and steel slags are silica, alumina, calcium, and magnesia, which together make about 95% of the total composition. Minor elements included are manganese, iron, sulphur compounds and traces of several other elements.

Some of the current uses of steel slag according to the National Slag Association (NSA accessed, 2008) are as follows:

- Steel slag is used as an ideal aggregate in hot mix asphalt
- It is also used for manufacture of Portland cement.
- It is used in base application, construction of unpaved parking lot as a shoulder material

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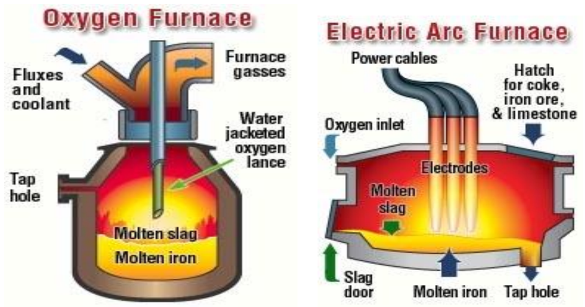

Fig 1 Schematic illustration of BOF and EAC

II. Materials

[1] CEMENT*:* The common OPC 53 grade cement is used. The physical properties of the cement tested according to standard procedure conform to the requirement of IS 12269: 1989.

Table 1 Physical properties of Cement

S.No	Characteristics	Value obtained experimentally
1	Standard Consistency	33%
2	Fineness (90 micron sieve)	3%
3	Initial Setting time	30 minutes
4	Specific gravity	3.0

[2] FINE AGGREGATE: Locally available river sand passing through 4.75mm sieve conforming to the recommendation of IS383-1970 was used.

Table 2 Physical properties of Fine Aggregate

S.No	Characteristics	Value obtained experimentally
1	Fineness Modulus	2.68
2	Specific gravity	2.68

[3] COARSE AGGREGATE: Locally available coarse aggregate retaining on 4.75mm sieve is used.

Table 3 Physical properties of Coarse Aggregate

S.No	Characteristics	Value obtained experimentally
1	Fineness Modulus	7.73
2	Specific gravity	2.59

[4] STEEL SLAG: *T*his steel slag can be used in the construction industry as aggregates in concrete by replacing

natural aggregates. Steel slag is obtained from Agni steels Private Ltd. Ingur, Tamil Nadu in fine form.

Table 4 Physical properties of Steel Slag

S.No	Characteristics	Value obtained experimentally
1	Fineness Modulus	2.97
2	Specific gravity	2.93

[5] WATER: It is used for casting and curing of specimens.

III. EXPERIMENTAL STUDY

In general, the mix design (M20) is arrived based on the physical properties of materials and according to with IS 10262:2009.

[1] *COMPRESSION STRENGTH TEST:* Totally 36 concrete cubes were casted and it is allowed for 7 days and 28 days curing. After drying, cubes were tested in Compression Testing Machine (CTM) to determine the ultimate load. . Replacement made for 0%, 10%, 20%, 30%, 40% and 50%. For this study the water cement ratio of 0.48 is maintained uniformly.

Fig 2 Compression strength test

Table 6 Compression strength of cubes

% of steel slag used	Average 7 days Compressive Strength (N/mm^2)	Average 28 days Compressive Strength (N/mm^2)
0	13.70	27.85
10	14.14	28.40
20	15.21	30.67
30	17.03	33.11
40	15.18	31.63
50	14.22	30.59

[2] *TENSILE STRENGTH TEST:* Totally 36 cylinders of M20 grade concrete were casted. Replacement made for 0%, 10%, 20%, 30%, 40% and 50%. For the study the water cement ratio of 0.48 is maintained uniformly.

Fig 3 Tensile strength test

Table 7 Tensile strength of cylinders

% of steel slag used	Average 7 days Tensile Strength (N/mm^2)	Average 28 days Tensile Strength (N/mm^2)
0	1.44	3.35
10	1.51	3.47
20	1.58	3.59
30	1.67	3.77
40	1.60	3.44
50	1.46	3.42

[3] FLEXURAL STRENGTH TEST*:* Totally 36 prisms of M20 grade concrete were casted. Replacement made for 0%, 10%, 20%, 30%, 40% and 50%. For the study the water cement ratio of 0.48 is maintained uniformly.

Fig 4 Flexural strength test

Table 8 Flexural strength of prisms

% of steel slag used	Average 7 days Flexural Strength (N/mm^2)	Average 28 days Flexural Strength (N/mm^2)
0	1.47	2.93
10	1.49	3.07
20	1.60	3.08
30	1.87	3.20
40	1.60	2.67
50	1.59	2.40

[4] STRESS-STRAIN CURVE*:* Totally 6 cylinders of M20 grade concrete were casted. Replacement made for 0%, 10%, 20%, 30%, 40% and 50%. For the study the water cement ratio of 0.48 is maintained uniformly.

Fig 5 Compression test with longitudinal compressometer

Table 9 Stress-Strain

% of steel slag used	Ultimate load kN	Stress N/mm^2	Longitudi-nal Strain	Longitudi-nal Deflection mm
0	270	15.31	0.00467	1.40
10	240	13.59	0.00567	1.70
20	251	14.27	0.00533	1.60
30	253	14.21	0.00567	1.70
40	238	13.47	0.00733	2.20
50	256	14.49	0.00567	1.70

IV. Result and Discussions

The results obtained from the experimental investigations are shown graphically. All the values are average of the three specimens tested. The compression strength of cubes, split tensile strength of cylinders, flexural strength of prisms and stress strain curve for cylinders are shown in fig 6, fig 7, fig 8 and fig 9 respectively.

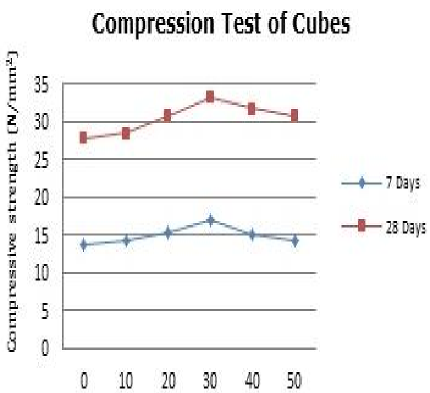

Fig 6 Compression strength

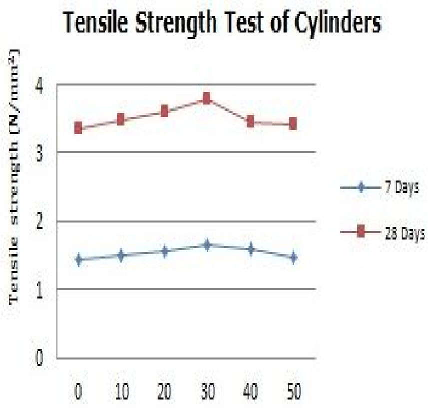

Fig 7 Split tensile Strength

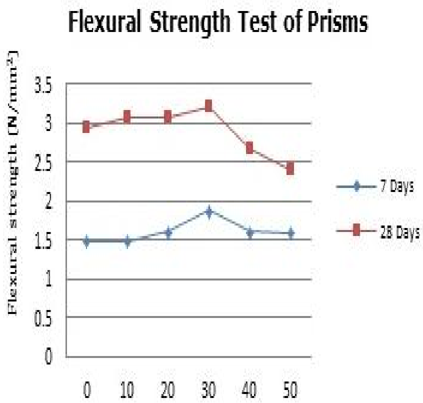

Fig 8 Flexural Strength

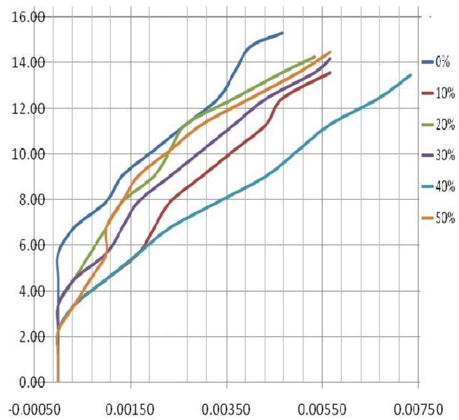

Fig 9 Stress-Strain Curve (Graph)

V. Conclusion

- The compressive strength increase with increase in percentage of steel slag up to 30% by weight of fine aggregate
- The enhancement in compressive strength is about 25% for 7 days curing and 18.85% for 28 days curing
- The split tensile strength increases with increase in percentage of steel slag up to 30% by weight of fine aggregate
- The enhancement in split tensile strength is about 15.97% for 7days curing and 12.53% for 28 days curing

- The flexural strength increases with increase in percentage of steel slag up to 30% by weight of fine aggregate
- The enhancement in flexural strength is about 27.2% for 7days curing and 9.21% for 28 days curing
- From the results of compressive strength, split tensile strength and flexural strength of 7 days and 28 days curing, 30% replacement of fine aggregate by steel slag is the optimum percentage of replacement of M20 grade concrete and decreases considerably in further replacement of slag in concrete.
- From stress-strain curve (graph) 30% steel slag replaced M20 concrete is similar to that of M20 conventional concrete.

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