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Effect of Replacement of Fine Aggregate by Steel Slag Aggregates in concrete

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Abstract—*The construction industry is the largest consumer of natural resources which led to depletion of good quality natural sand. These situations led to us explore alternative materials and granulated slag a waste industrial byproduct is one such material identified for utilization of it as replacement of natural sand.*
The experimental investigation carried out to evaluation effects of replacing fine aggregate with that of slag, which is an industrial waste byproduct on concrete strength properties. The aggregates (sand and gravel) form the skeleton of the concrete, they occupy approximately 75% of its volume, and intervene directly on the physical and mechanical properties of concrete.
The main objective of this experimental work is: substituting sand by granulated blast furnace slag for different % replacement.
The use of this method of substitution permits to improve the strength of concrete, to increase the production of building materials and to protect the environment. The experimental results obtained shows that the partial replacement of sand by granulated slag gives better results compared with the ordinary concrete, but the full replacement of fine aggregate by slag affect negatively on strength of concrete.

Keywords*: Steel slag, Compressive strength, Flexural strength and Tensile strength.*

1. INTRODUCTION

Concrete used in construction are the most widely used material on earth after water. Many aspects of our daily life depend indirectly or directly on concrete. Concrete is a mix prepared by using various constituents like aggregates, water, cement etc. Concrete is different among major construction materials because it is designed specifically for particular civil engineering projects. Concrete is a composite material composed of granular materials like coarse aggregates embedded in a matrix and bound together with cement or binder which fills the space between the particles and glues those together. Design and construction of the nation's infrastructure critically depends up on concrete. The volume of concrete is composed of almost three quarter of aggregates. In future the availability natural aggregates get reduced; it becomes difficult to meet the global demand of concrete, so it is becoming more challenging task to find suitable alternatives to natural aggregates for preparing concrete.

During the manufacture of iron and steel the by-product produced is known as steel slag. The conversion of iron to steel produce significant quantities of steel slag as a major by-product formed in the basic steel making processes. The large volumes of industrial by-products and secondary materials are need of hour to produce concrete incorporating materials due to depletion of natural sand resources and strong demand for concrete. In this context fine steel slag material is used as alternative material in replacement for natural fine sand.

The steel slag generated from the conversion of iron to steel is poured into beds and slowly cooled under ambient conditions. The slag of crystalline structure is formed and hard lump slag is produced which can subsequently be crushed and screened. The crushing and screening of materials produces the aggregate is known as Steel Slag Aggregate (SSA).

2. MATERIALS

The materials used in the present study are discussed below.

2.1 Cement

In the present study 53 grade ordinary Portland cement (OPC) (confirming to IS 8112-1989) is used. Various physical properties such as standard consistency, specific gravity, fineness, initial and final setting time test were performed as per IS-4031 PART II-1988. The test results are tabulated in the Table 1.

Table 1: Physical properties of cement

SL.NO.	Physical Tests	Results
1	Fineness (%)	3
2	Standard Consistency (%)	27
3	Initial Setting time (min)	48
4	Final Setting time (min)	445
5	Specific gravity	3.15

2.2 Fine Aggregate

Commercially available river sand is used in the present experimental work. The specific gravity and water absorption test were conducted are shown in Table 2.

Table 2: Physical properties of fine aggregates

SL.NO.	Physical Tests	Results
1	Specific gravity	3.15
2	Water absorption (%)	0.55

2.3 Coarse Aggregate

Commercially available coarse aggregate is used in the present study. The Crushed stone aggregate were collected from the local quarry. Coarse aggregates used in the experimentation were 20mm and 10mm down size and tested as per IS 2386-1963 (I, II and III) specifications.

Table 3: Physical properties of coarse aggregates

SL No.	Physical Tests	Obtained values
1	Specific Gravity	2.60
2	Water Absorption	0.3%
3	Aggregate Impact Value	29%
4	Crushing Strength	29%
5	Los Angeles Abrasion	28%

2.4 Steel Slag

The source of the granular steel slag is from JSW Thoranagal Bellary. The test conducted for steel slag is show in Table 4.

Table 4: Physical properties of steel slag

SL.NO.	Physical Tests	Results
1	Specific gravity	2.65
2	Water absorption (%)	0.4

2.5 Water

Ordinary potable water free from organic content, turbidity and salts was used for mixing and for curing throughout the investigation.

3. EXPERIMENTAL PROGRAM

The experimental program is designed based on the percentage replacement of fine aggregate by steel slag to study the mechanical properties of concrete at different grades of concrete. The specimen prepared after replacement of fine aggregate by steel slag for 0, 25, 50, 75 and 100% are studied for compressive strength, flexural strength and tensile strength for curing period of 28 days.

3.1 Compressive Strength Test

Concrete specimens of dimensions 150x150x150mm were prepared. They were tested on 2000 kN capacity compression testing machine as per IS 516-1959 as shown in Fig. 1.

The compressive strength is calculated by using the equation,

$F=P/A$

where,

F= Compressive strength of the specimen (in MPa).

P= Maximum load applied to the specimen (in N).

A= Cross sectional area of the specimen (in mm^2).

Fig. 1: Compression testing machine

3.2 Split Tensile Strength Test

Cylindrical specimens of diameter 150mm and length 300mm were prepared. Split tension test was carried out on 2000 kN capacity compression testing machine as per IS 5816-1999 as shown in Fig. 2.

The tensile strength is calculated using the equation,

$F= 2P/ (\pi DL)$

where,

F = Tensile strength of concrete (in MPa).

P = Load at failure (in N).

L = Length of the cylindrical specimen (in mm).

D = Diameter of the cylindrical specimen (in mm).

Fig. 2: Split tensile strength testing machine

3.3 Flexural Strength Test

Beam specimens of dimensions 100x100x500mm were prepared. During testing two point loading was adopted on an effective span of 500mm as per IS 516-1959.

Flexural strength is calculated using the equation,

F= PL/ (bd2)

where,

F= Flexural strength of concrete (in MPa).

P= Failure load (in N).

L= Effective span of the beam (500mm).

b= Breadth of the beam (100mm).

d= Depth of the beam (100mm).

Fig. 3: Flexural strength testing machine

4. RESULTS AND DISCUSSIONS

Compressive strength, tensile strength and flexural strength of concrete mixes of M20, M30 and M40 grade of concrete made by 0, 25, 50, 75 and 100% replacement of fine aggregate with slag aggregate was tested after 7, and 28 days of curing for the w/c ratio of 0.5, 0.45 and 0.40 respectively.

4.1 Compressive Strength Values

The results of compressive strength of various mix proportions of steel slag blended concrete measured at 7 days and 28 days of curing are given in Table 5 and 6 and shown in Fig. 4, 5 and 6.

Table 5: Compressive Strength for different replacement levels

Grade of Concrete	Compressive Strength (N/mm2)	Percentage Replaced		
		0%	25%	50%
M20	7 days	16.05	17.15	18.7
	28 days	29.4	31.89	30.3
M30	7 days	23.1	29.35	28.7
	28 days	39	44.25	41.04
M40	7 days	31.6	38.86	32.25
	28 days	46.3	47	46.2

Table 6: Compressive Strength for different replacement levels

Grade of Concrete	Compressive Strength (N/mm2)	Percentage Replaced	
		75%	100%
M20	7 days	19.64	18
	28 days	28.9	28.2
M30	7 days	27.7	23.2
	28 days	40.5	40.2
M40	7 days	31.11	31
	28 days	46.06	44.5

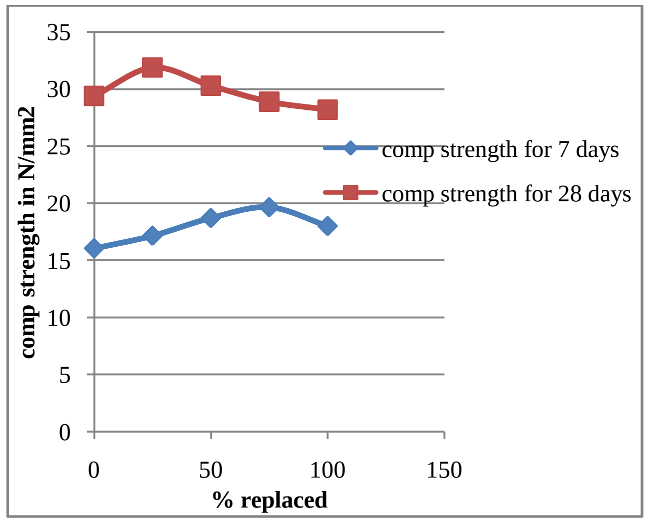

Fig. 5: Compressive strength for M20 grade concrete

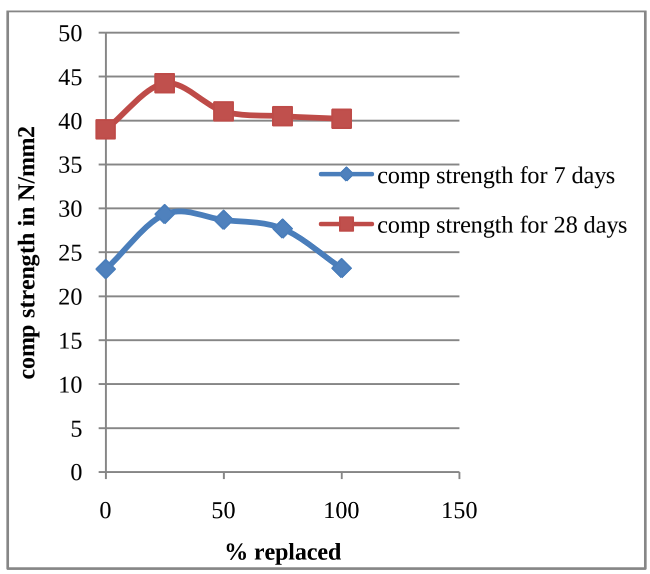

Fig. 6: Compressive strength for M30 grade concrete

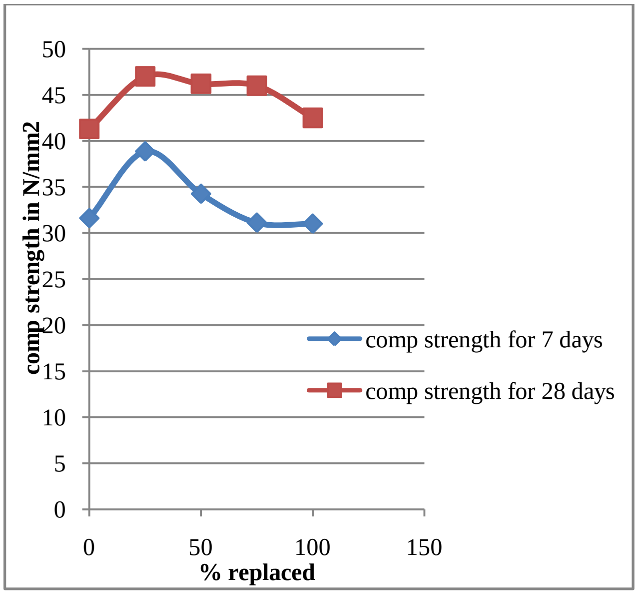

Fig. 7: Compressive strength for M40 grade concrete

- The results indicated that the compressive strength at 7 days was increased by 10% to 15% at 28 days in all the mixes.
- Optimum strength was found at the replacement level in-between 30 to 50%. Strength reduction was observed, 100% replacements of fine aggregate with granular slag reduces the strength by 7% to 10%.
- The results of mechanical properties show that the compressive strength of the concrete increases upto certain level of replacement.

4.2 Split Tensile Strength Values

The results of tensile strength of various mix proportions of steel slag blended concrete is measured for 28 days of curing is given in Table 7 and shown in Fig. 8, 9 and 10.

Table 7: Split tensile strength for different replacement levels

Grade of Concrete	Tensile Strength (N/mm2)	Percentage Replaced				
		0%	25%	50%	75%	100%
M20	28 days	2.15	2.68	2.5	2.4	2.21
M30	28 days	3.1	3.35	3.28	3.2	3.05
M40	28 days	3.19	3.37	3.41	3.3	3.16

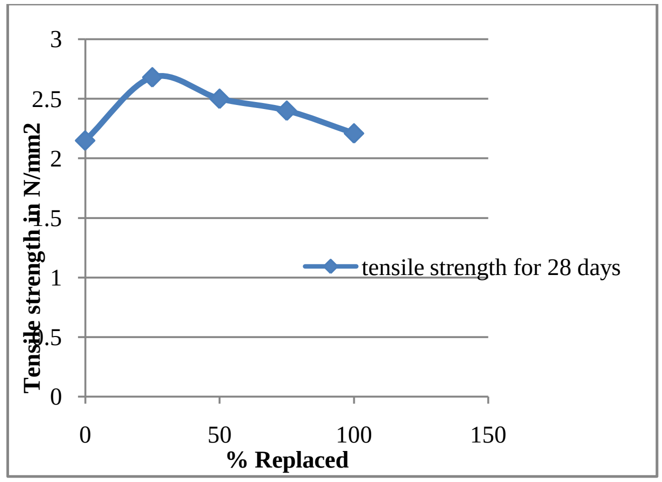

Fig. 8: Split tensile strength for M20 grade concrete

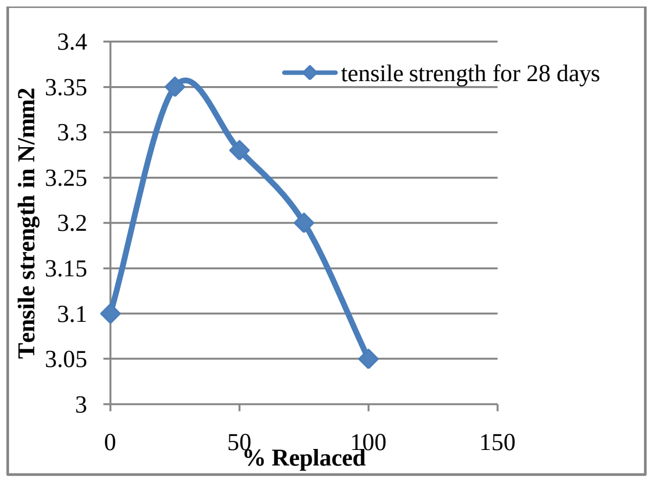

Fig. 9: Split tensile strength for M30 grade concrete

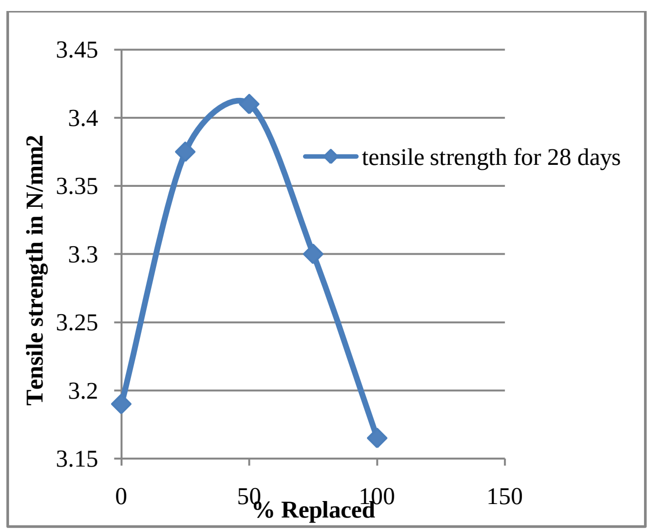

Fig. 10: Split tensile strength for M40 grade concrete

- The split tensile strength found improved by 6 to 8% at 25 to 50% replacement levels but it reduced by 8 to 10% at 100% replacements as shown in Fig.8, Fig.9 and Fig.10.
- The results of mechanical properties shows that the tensile strength of the concrete increases up to certain level of replacement.
- The optimum value was found in between the slag replacement proportion of 35% to 34% for fine aggregate and after that any further replacement of slag decreases the tensile strength.
- The increment of 15 to 20% was found in tensile strength of concrete as increase in grade of concrete.

4.3 Flexural Strength Values

The results of flexural strength of various mix proportions of steel slag blended concrete measured 28 days of curing is given in Table 8 and shown in Fig. 11, 12 and 13.

Table 8: Flexural strength for different replacement levels

Grade of Concrete	Flexural Strength (N/mm)	Percentage Replaced				
		0%	25%	50%	75%	100%
M20	28 days	3.865	3.97	3.85	3.8	3.65
M30	28 days	5.125	5.575	5.175	5.12	4.95
M40	28 days	4.785	5.035	4.855	4.78	4.72

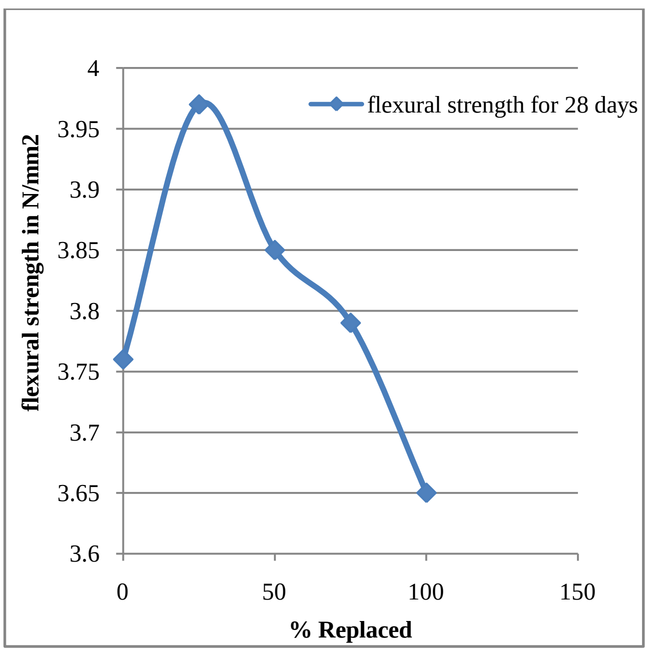

Fig. 11: Flexural strength for M20 grade concrete

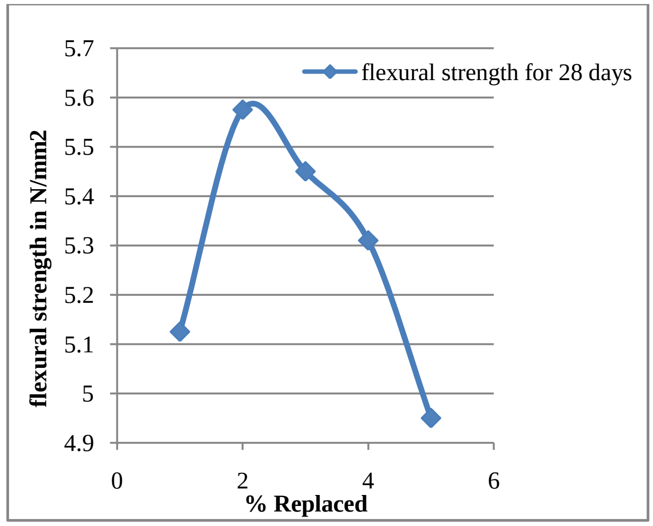

Fig. 12: Flexural strength for M30 grade concrete

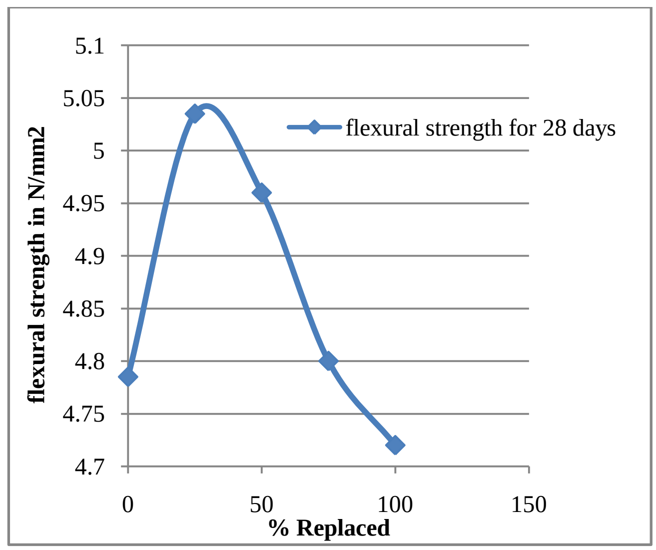

Fig. 13: Flexural strength for M40 grade concrete

- The flexural strength found improved by 6 to 8% at 25% replacement levels but it reduced by 8 to 10% at 100% replacements as shown in Fig.5.7, Fig. 5.8, and Fig. 5.9.
- The results of mechanical properties shows that the flexural strength of the concrete increases up to certain level of replacement.
- The optimum value was found in between the slag replacement proportion of 25% to 35% for fine aggregate and after that any further replacement of slag decreases the flexural strength.

5. CONCLUSIONS

This work relates the use of waste steel slag as a fine aggregate for M20, M30 and M40 grade of concrete and recommends the approval percentage level for use of concrete in replacement of fine aggregates. This approval is important because the compressive, flexural and tensile strength increase up to certain level of replacements.

- The results indicated that the compressive strength at 7 days was increased by 10% to 15% at 28 days in all the mixes. Optimum strength was found the replacement level in-between 30 to 50%. Strength reduction was observed at 100% replacements of fine aggregate with granular slag and the reduction in the strength is by 7% to 10%.
- The flexural strength and tensile strength were found improved by 6 to 8% at 25% replacement levels but it reduced by 8 to 10% at 100% replacements.
- Total substitution of sand by slag reduces the strength of concrete by 30%; this may be due to improper adjustment of slag particles.
- The increment of 15 to 20% was found in all the strength of concrete as increase in grade of concrete.
- The strength is increased, because of increase in unit weight of concrete due to incorporation of slag.
- Reduction in strength at higher replacement level is due to rough surface of slag aggregates, this requires finer material to overcome this frictional force and improve the strength.
- The compressive strength, tensile strength and flexural strength of the concrete increase at partial replacement level and decrease at full replacement of concrete.
- The strength gain is long term by replacement of fine aggregates by steel slag in concrete.
- The mass utilization of waste material like steel slag as partial replacement material of fine aggregates in concrete helps in reduction of cost of construction and proves to be socially beneficial by reducing the stocks of slag in the plants which is health hazards.
- The increment of 15 to 20% was found in flexural strength of concrete as increase in grade of concrete.

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