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Experimental Investigation on Replacement of Steel Slag as Coarse Aggregate in Concrete

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Abstract : *This paper present the Experimental investigation carried out to evaluate the effects of concrete by replacing the normal coarse aggregate by steel slag on properties of concrete. Concrete is used more than any other material in the world so the use of concrete is unavoidable at the same time scarcity of aggregate is also increased nowadays. The industrial waste has been encouraged in construction industries because it contributes to reduce the usage of natural resources for many years by product such as fly ash, silica fume and steel slag were considered as waste materials. They have been successfully used in the construction industry for the partial and full substitution in concrete. In this study concrete of M20, M30, M40, M50 grades were considered for a W/C ratio of 0.55, 0.45 ,0.37, 0.32 respectively for the replacement of coarse aggregate 30% 60% and 100% by steel slag. This study revealed that there is a improvement in compressive strength 5 to 10% for all the grades of concrete. There is 4 to 8% increase in split tensile strength in all grades of concrete. The Flexural strength of concrete is increase about 2 to 6% for all the grades .steel slag can be use upto 60% replacement in all grades of concrete. Full replacement by steel slag decreases the strength considerably.*

Keywords*: industrial waste, steel slag, compressive strength, split tensile strength, flexural strength.*

1. INTRODUCTION

The aggregates typically account about 75% of the concrete volume and play a substantial role in different concrete properties such as workability, strength, dimensional stability and durability, Conventional concrete consists of sand as fine aggregate and gravel, limestone or granite in various sizes and shapes as coarse aggregate. There is a growing interest in using waste materials as alternative aggregate materials and significant research is made on the use of many different materials as aggregate substitutes such as coal ash, blast furnace slag and steel slag aggregate. This type of use of a waste material can solve problems of lack of aggregate in various construction sites and reduce environmental problems related to aggregate mining and waste disposal.

Steel slag is an industrial by-product obtained from the steel manufacturing industry. It is a non-metallic ceramic material formed from the reaction of flux such as calcium oxide with the inorganic non-metallic components present in the steel scrap. The use of steel slag reduces the need of natural rock as constructional material, hence preserving our natural rock resources, maximum utilization and recycling of by-products and recovered waste materials for economic and environmental reasons has led to rapid development of slag utilization.

In this study, it is proposed to utilize steel Slag as coarse aggregate in the production of M20, M30, M40, M50 concrete and at a different percentage of replacement 30%, 60%, 100%. Tests for compressive strength, replacement flexural strength, split tensile strength and water absorption test were conducted on the concrete.

2. MATERIALS

2.1 Cement

Ordinary Portland 53 grade cement with specific gravity 3.15 was used as the binder. The initial and final setting was 110 minutes and 260 minutes respectively.

2.2 Fine aggregate

Normal locally available sand is used for experiments, It is in zone 1.

Having a specific gravity	2.6
Bulk density	1770kg/cum
Water absorption	1%
Fineness modulus	2.64

2.3 Coarse aggregate

Locally available granite coarse aggregate is used specific gravity 2.67
Water absorption 0.65%
Bulk density 2100kg/cum
Impact value 13.5%

Crushing value 24.5%
Abrasion value 20.8%

2.4 Steel slag

Steel slag used here is basic oxygen furnace slag collected from jindal steel work pvt ltd, sandur village bellary district of the state of Karnataka, India.

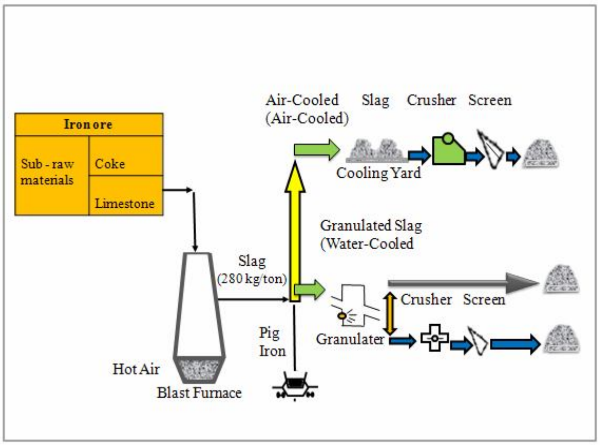


Figure 1 General Schematic view of blast furnace operation and Slag production

In the production of iron and steel, fluxes (limestone and/or dolomite) are charged into blast furnace along with coke for fuel. The coke is combusted to produce carbon monoxide, which reduces iron ore into molten iron product. Fluxing agents separate impurities and slag is produced during separation of molten steel as shown in figure 1. Slag is a nonmetallic inert waste byproduct primarily consist of silicates, alumino silicates, and calcium-alumina silicates. The molten slag which absorbs much of the sulfur from the charge comprises about 20 percent by mass of iron production Presently total steel production in India is about 72.20 Million Metric Tonnes and the waste generated annually is around 18 Million Metric Tonnes but hardly 25 % is being used mostly in cement production.

Table1-Chemical Composition of steel slag

Constituent	composition(%)
Aluminium oxide	1-3
Calcium oxide	40-52
Iron oxide	10-14
Magnesium oxide	5-10
Manganese oxide	5-8
Silica	30-35

Table 2 Physical properties steel slag

Physical properties	
Specific gravity	3.4
Fineness modulus	3.1
Water absorption	0.65%
Crushing value	29%
Impact value	17.3%
Loose bulk density	1848kg/cum
Compacted bulk density	2150kg/cum
Volume of voids	0.24%
Abrasion value	28%

2.5 Water

Portable drinking water having pH value of 7 and conforming to IS 456-2000 IS used for concreting as well as curing of specimens.

2.5. Mix design`

In this project American concrete institute ACI 211.4R-93 guideline is followed and results are shown in table 3.

Table-3 Design mix proportion for different grades of concrete

Grade of concrete	% of replacement of steel slag	w/c ratio	Water in lit	Cement kg/m^3	Sand kg/cum	Coarse aggregate kg/m^3	Steel slag kg/m^3
M20	0%	0.55	170	310	900	977	0
	30%				876.2	682.5	403.12
	60%				853.2	390	806.25
	100%				822.5	0	1343.75
	0%				888	977	0

M30	30%	0.45	160	356	864.2	682.5	403.12
	60%				841.2	390	806.25
	100%				810.5	0	1343.75
M40	0%	0.37	140	405	873	977	0
	30%				850	682.5	403.12
	60%				827	390	806.25
	100%				796.1	0	1343.75
M50	0%	0.32	136	422	748	1123	0
	30%				720.6	786	464.4
	60%				694.11	449	928.8
	100%				658.1	0	1548

4. EXPERIMENTATION

4.1 Compressive strength test

To determine compressive strength, six cubes of 150mm x 150mm x 150mm are casted for each grade M20, M30, M40, M50, and for each mix. Three cubes were tested for 7 days and next three cubes were tested for 28 days after curing. The compressive strength test was conducted accordance with the IS: 516-1957.

Figure-2 compressive strength testing machine

4.2 Split tensile strength test

Split tensile strength test is conducted at 28 day of curing. The specimen is having 150mm dia and 300mm length is prepared in two numbers for each grade M20, M30, M40, M50, and for each mix. The test was conducted accordance with the IS: 516-1957.

Figure-3 split tensile strength testing.

4.3 Flexural strength test

Flexural strength test is conducted at 28 day of curing. The prism specimen is having 100mm x 100mm sides 500mm length is prepared in two numbers for each grade M20, M30, M40, M50, and for each mix. The test was conducted accordance with the IS: 516-1957.

Figure-4 flexural strength testing set up.

a=distance between the line of fracture and to the nearer support.

When ‘a’ is greater than 13.3cm
Flexural strength = pl/bd^2
Where p=flexural load in Newton
L=span of the beam.
B=breadth of the beam.
D=depth of the beam.
When ‘a’is less than 13.5cm, but greater than 11cm.
Flexural strength=$3pa/bd^2$

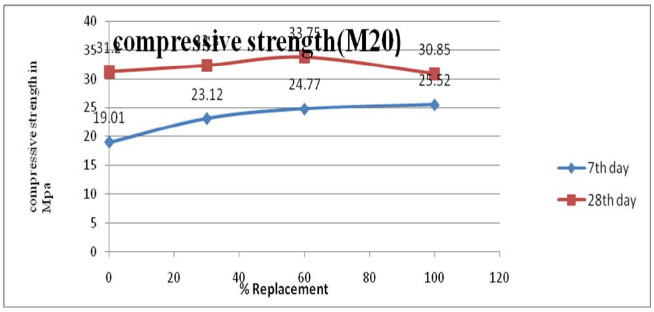
5. RESULTS AND DISCURSION

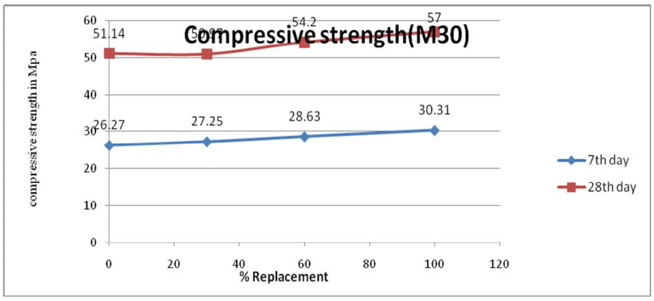
5.1 Compressive strength

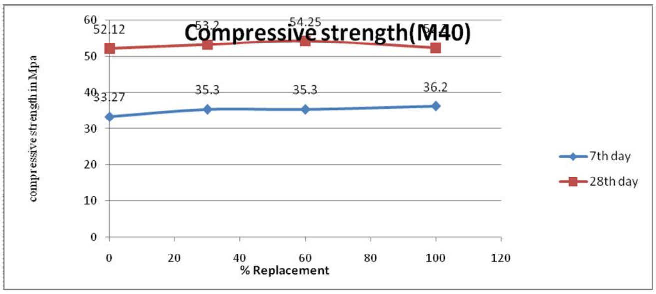
The result indicated that compressive strength is increased about 4 to 6% in all grade of concrete. But full replacement of steel slag reduces the strength in all grade of concrete and also at early ages there is rapid gaining of strength when steel slag is replaced.

5.2 split tensile strength of concrete

The test results indicate that split tensile strength is increases as the percentage of replacement increases in M20 and M40 grade and decrease at 100% replacement, where as in M30 and M50 grade decreases at 30% and increases at 60% then decreases at 100% as shown in figures-5.







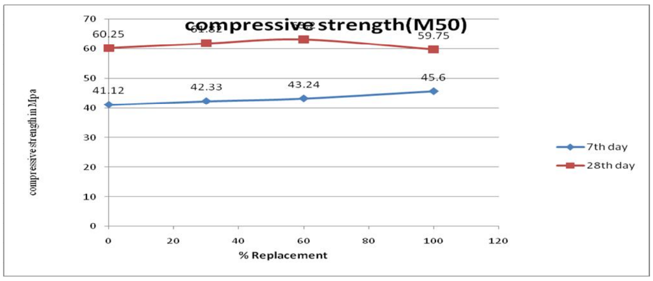
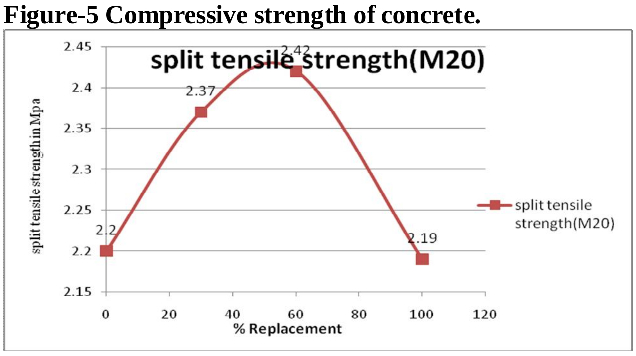
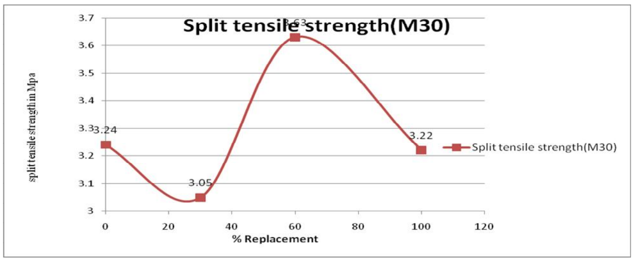
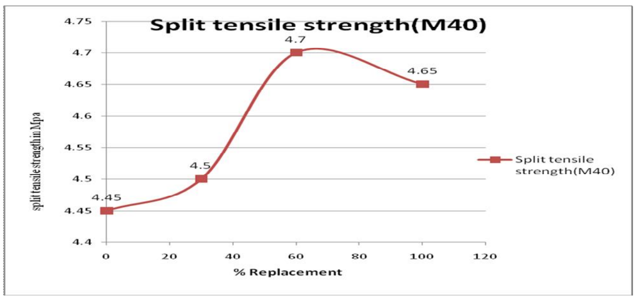


Figure-5 Compressive strength of concrete.







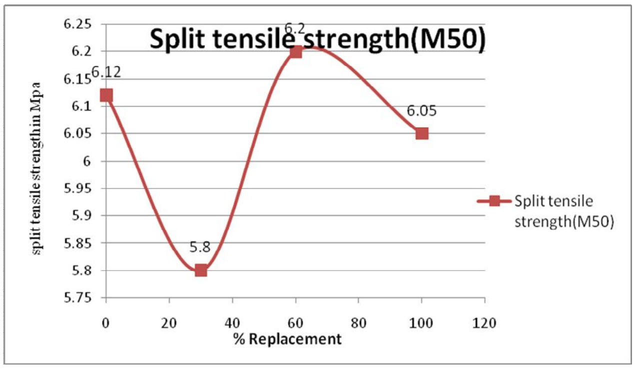
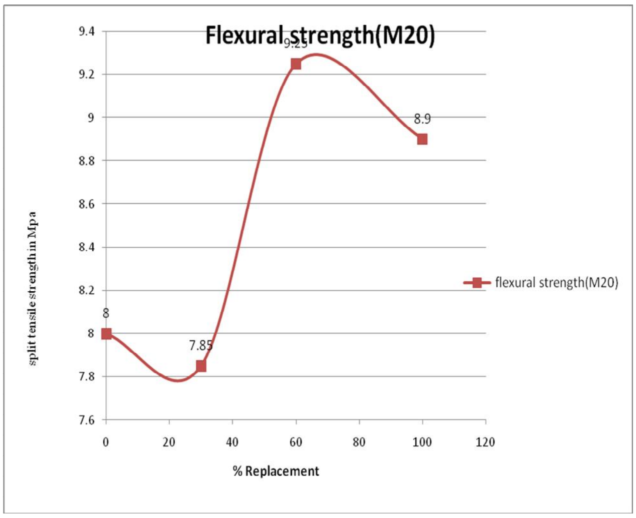
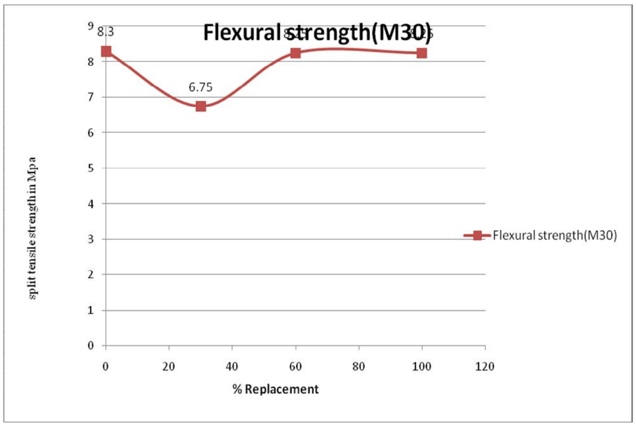


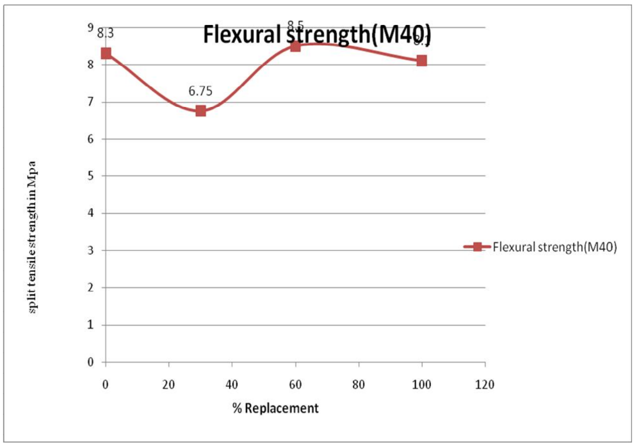
Figure-6 Split tensile strength of concrete.

5.3 Flexural strength of concrete

The test results indicate that split tensile strength is increases as the percentage of replacement increases in all the grades of concrete, flexural strength is maximum at 60% replacement of steel slag and full replacement decreases the strength in all grade shown in figures-7.







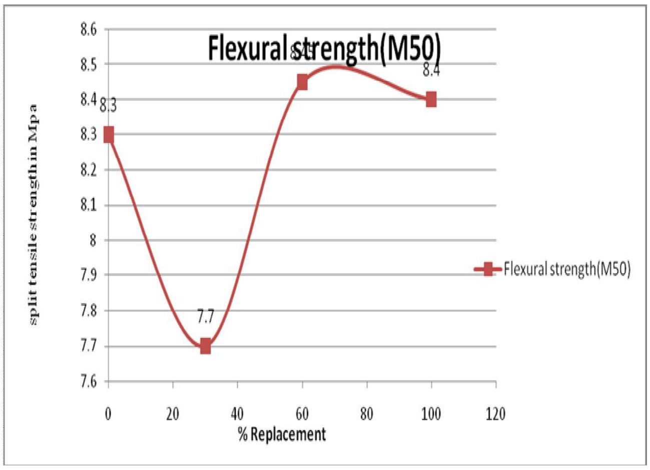


Figure-7 Concrete flexural strength

6. CONCLUSION

a. The use of steel slag as replacement of coarse aggregate in concrete is beneficial for the better workability and strength it imparts up to 60% replacement level.

b. The study concluded that compressive strength of concrete improved by 4 to7 % at all the grade of concrete at 60% replacement of normal crushed coarse aggregate with steel slag.

c. In comparing with M20, M30 and M40, M50 grade of concrete, M50 attains maximum strength compared to all grade of concrete.

d. With higher level of replacement of CA with SSA 100% there was a slight bleeding and segregation tendency. Therefore, it is recommended that up to SSA 60% can be used as replacement of coarse aggregate.

e. It could be said that 100% replacements of crushed coarse aggregate with steel slag enhanced concrete density by 5 to 7% in all the concrete mixes. The improvement in density was due to the higher unit weight of steel slag which is 9% heavier than natural aggregate.

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