BOND STRENGTH AND FLEXURAL BEHAVIOUR OF RCC BEAM OF STEEL SLAG AGGREGATE IN CONCRETE

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Abstract - *The use of concrete has increased in their wide spread application in construction. Many materials can be reused in concrete in different form. Every constituent of concrete can be replaced with waste material so as to produce a Green concrete. For sustainable development we have taken an initiating activity to minimize the exploitation of natural aggregate by replacing it with steel slag. Steel slag was selected due to its properties, which are almost similar to conventional aggregates and it is easily obtainable as a by-product of the steel and iron industry. However, waste stabilization have investigated into alternative reuse techniques and disposal routes for slag. In this work, an experimental study is made on the partial replacement of coarse aggregate by Steel Slag in concrete. The properties of Steel slag and conventional materials were studied. The work was conducted on M30 grade mix designed by IS 10262-2009 and IS 456-2000. The replacement of coarse aggregate by steel slag in the range of 15%, 30%, 45% and 60 % and tested its compressive strength. Pull out strength test was carried out for conventional concrete and optimum percentage of steel slag. The flexural strength of the concrete was determined according to Indian Standard 516:1959. Reinforced concrete beams of length 1000 mm, with a cross-section of 100 mm x 150 mm were casted. The flexural test was carried out in loading frame with capacity of 100 KN.*

Key Words: Concrete, Steel Slag, Coarse aggregate, Pull out strength test and flexural strength.

1. INTRODUCTION

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1.1 General

Concrete is a composite material composed mainly of water, aggregate, and cement. The increase in demand for the ingredients of concrete is met by partially replacing the building materials by the waste materials which is obtained by means of various industries. Aggregate is the main constituent of concrete, occupying more than 70% of the concrete matrix. In order to reduce depletion of natural aggregate, artificially manufactured aggregate and some industrial waste materials can be used as alternatives. Concrete prepared with such materials showed improvement in workability and durability compared to normal concrete and has been used in the construction works.

1.2 Steel Slag

Slag is a by-product generated during manufacturing of pig iron and steel. Primarily, the slag consists of calcium, magnesium, manganese and aluminum silicates in various combinations. Basic oxygen furnace slag is formed during the conversion of hot metal from steel. In this process the hot metal is treated by blowing oxygen to remove carbon and other elements that have a high affinity to oxygen. The slag is generated by the addition of fluxes, such as lime stone and dolomite that combine with silicates and oxides to form liquid slag. Basic oxygen furnace slag has increased skid resistance and high level of strength described by the impact- and crushing value compared to natural rocks and thus makes it an ideal aggregate for road constructions and surface layers for high skid resistance.

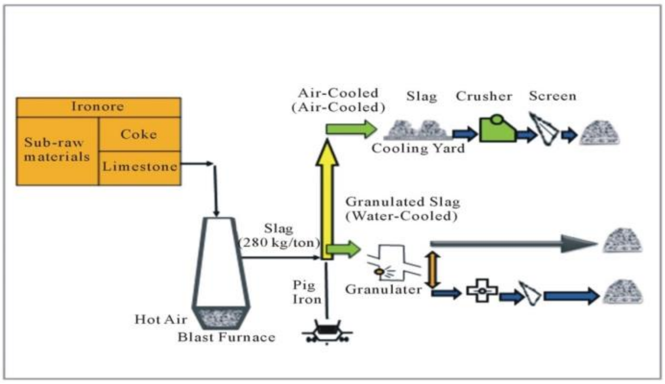

Fig 1 Schematic view of blast furnace operation

2. PROPERTIES OF MATERIALS

2.1 Cement : Ordinary Portland Cement (43 grade) was used for making concrete mixes. The cement used was fresh and without any lumps. Testing of cement was done as per IS 8112-1989. The various tests that were conducted on cement and the results obtained are tabulated in table 2.1

Table 2.1 Physical properties of Cement

S.No	Characteristics	Values obtained	Standard Values
1	Specific Gravity	3.12	-
2	Consistency	31	26-32
3	Initial setting time	43 Min	Not less than 30 Min
4	Final setting time	252 Min	Not more than 600 Min
5	Fineness	2%	<10 %

2.2 Fine Aggregate

The natural river sand used for the experimental program was locally procured. The sand was first sieved through 4.75 mm sieve to remove any particles greater than 4.75 mm and will be used for casting all the specimens. Properties of fine aggregate used in experimental work are tabulated in table 2.2.

Table 2.2 Physical properties of Fine Aggregate

S.No	Characteristics	Values obtained
1	Type	River Sand
2	Specific Gravity	2.7
3	Fineness modulus	2.36
4	Bulk density (fully compacted)	1763.6 kg/m^3
5	Grading zone	II

2.3 Coarse Aggregate and Steel Slag

Locally available coarse aggregate having the maximum size of 20 mm were used in the present work. Testing of coarse aggregate was done as per IS : 383- 1970.

Steel Slag is the mostly available solid waste material obtained from steel making process which can be used in concrete in the form of coarse aggregate partially. For this study work Steel Slag was collected from Jindal Steel Works, Mecheri. The properties of coarse aggregate and Steel Slag are tabulated in table 2.3

Table 2.3 Physical properties of Coarse Aggregate and Steel Slag

S.No	Characteristics	coarse aggregate	Steel slag
1	Type	Angular	crushed
2	Specific Gravity	2.52	2.62
3	Fineness modulus	2.985	2.85
4	Crushing value	19%	27.60%
5	Impact value	15.03%	24.93%
6	Water absorption	0.26%	2.43%

2.4 Water

Water is an important ingredient of concrete as it actively participates in the chemical reaction namely hydration with cement. Potable tap water available in the laboratory with pH value 7 and conforming to the requirements of IS: 456 -2000 was used for mixing concrete and curing the specimen as well.

3. MIX DESIGN

The concrete mix M30 grade was designed as per IS 10262-2009 and IS 456 for the conventional concrete and then followed by the replacement of coarse aggregate with steel slag.

Materials	Cement	Fine aggregate	Coarse aggregate	Water
Mix proportion (kg/m^3)	390	699.10	1108.7	172
Mix ratio	1	1.79	2.840	0.44

4. Test Results:

4.1 Slump cone test

Slump test is conducted on fresh concrete of different mix proportions. Fig 4.1 shows the variation of slump value of concrete using steel slag.

Table 4.1 slump value

S.No	% replacement of slag	Slump value	Degrees of workability
1	control	64 mm	Medium
2	15 %	61 mm	Medium
3	30 %	58 mm	Medium
4	45 %	56 mm	Medium
5	60 %	52 mm	Medium

4.2 Compressive strength test :

The compressive strength on concrete was performed as per IS 512-1959 codal provisions.

Table 4.2 Compressive strength of control and various proportions of steel slag

S.No	% replacement of slag	Compressive strength (N/mm^2)	
		7 days	28 days
1	control	26.52	**38.65**
2	15 %	26.01	38
3	30 %	27.35	38.65
4	45 %	29.12	**39.09 (optimum)**
5	60 %	25.52	35.72

4.2 Split tensile strength test:

The split tensile strength test is the standard test, to determine the tensile strength of the concrete in indirect way and could be performed in accordance with IS : 5816-1970. A test cylinder of concrete specimen of diameter 100 mm and length of 200 mm is placed horizontally between loading surfaces of compression testing machine.

This method consists of applying a diametric compressive force along the length of the cylindrical specimen. This loading induces tensile stresses on the plane containing the applied load. Plywood strips are used so that load is applied uniformly along the length of the cylinder.

$$\text{Split tensile strength} = \frac{2P}{\pi d l} \ (N/mm^2)$$

Where, P = Ultimate load (N)

d = Diameter of the specimen (mm)

l = Length of the specimen (mm)

Table 4.3 Tensile strength of control and 45 % of steel slag

Specimen	load in Tons	Tensile strength N/mm²	Average tensile strength (N/mm²) at 28 days
control	12.5	3.9	3.9
	12.5	3.9	
45%	13	4.06	4.06
	13	4.06	

4.3 Pull out strength test :

This test is carried out on the cylinder to determine the local bond strength of concrete with reinforcing bar and could be performed in accordance to IS : 2770 (Part -1) 1967. In this test, a bar of diameter 12 mm is kept at centre in cylindrical mould of diameter 100 mm and length 200 mm, before filling the concrete in the mould.

After filling the concrete the cylinder is kept for curing along with the bar. Then, local bond strength is calculated by applying pullout force by universal testing machine, on reinforcing bar against cylinder up to failure. The load is applied without sock and increasing continuously at a rate such that stress increases on the bar against the cube is at a rate of 180 kg/min.

$$\text{Bond stress} = \frac{P}{\pi d l} \ ((N/mm^2)$$

Where, P_u = Ultimate load (N)

d = Diameter of the specimen (mm)

l = Embedded length of the specimen (mm)

Fig 4.1 Pull out strength test specimens

Table 4.4 Bond stress of concrete

Specimen	Ultimate load (KN)	Ultimate bond stress (N/mm²)
Control	59.1	15.67
45% of steel slag	56.2	14.90

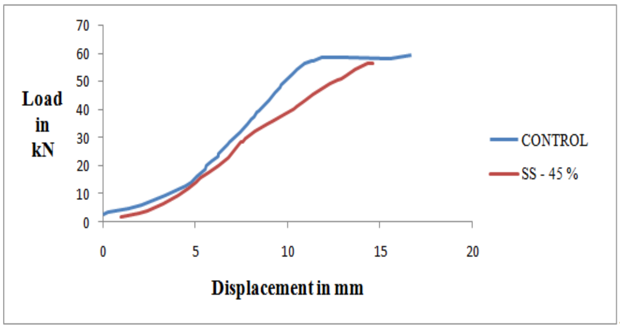

Fig 4.2 Load vs Displacement curve on bond strength

4.4 Flexural strength of RCC beam

The flexural strength of the concrete was determined according to Indian Standard 516:1959. Reinforced concrete beams of length 1000 mm, with a cross-section of 100 mm x 150 mm were casted. The reinforcement provided at top and bottom of the beam is 2 nos- 10mm diameter and 8 mm diameter with 2 legged stirrups @ 160 mm c/c spacing are provided. The beams were cured for 28 days.

The bearing surfaces of the supporting and load rollers are wiped clean .The specimen is then placed in the machine in such a way that the load is applied to the uppermost surface as cast in the mould.

The load is applied until the specimen fails and the maximum load applied to the specimen during the test is recorded. Flexural strength of concrete is calculated by using the formula,

Flexural strength = P L / b*d2 (N/mm2)

Where,

P = Ultimate load (N)

L = Length of specimen (mm)

b = Breadth of specimen (mm)

d = Depth of specimen (mm)

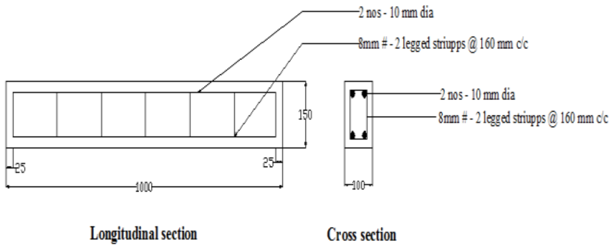

Fig 4.3 Reinforcement details of RCC beam

Fig 4.4 Experimental setup for RCC beam

Fig 4.5 Crack pattern of control beam

Fig 4.6 Crack pattern of 45 % of steel slag

Table 4.5 Flexural strength of RCC beams

Specimen	Ultimate load in kN	Ultimate moment (kNm)	Maximum deflection in mm	Flexural strength (N/mm²)	Stiffness (kN/mm)
Control	51.1	17.03	12.6	21.57	4.05
45 % of SS	48.9	16.3	8.5	20.64	5.752

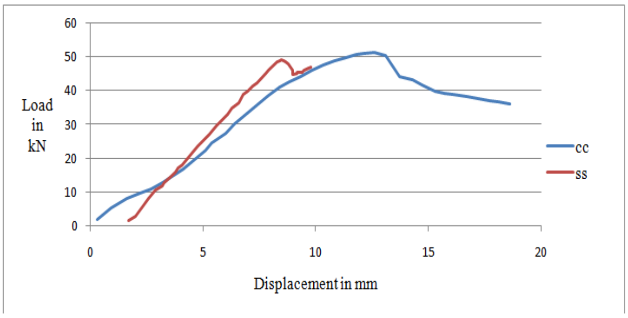

Fig 4.7 Load vs Displacement curve

5. CONCLUSION

- Through literature review, it was concluded that the use of steel slag as replacement of coarse aggregate is beneficial and an effective construction material.
- The properties of steel slag is similar to the coarse aggregate.
- The concrete mix is designed according to Indian standard specifications..
- Workability of concrete decreases as increase in percentage of steel slag increases.
- The optimum percentage of replacement to coarse aggregate with steel slag was found to be 45 % with medium workability.
- The compressive strength of concrete tends to increases gradually as increase in percentage of steel slag and it gives better bond strength.
- The moment carrying capacity of RCC beam for control was found to be 17.03 kNm with deflection of 12.6 mm and for 45 % of steel slag was 16.30 kNm with deflection of 8.5 mm.
- Overall, the performance of steel slag was found to be satisfactory for structural and steel slag can be recognized as new construction material.

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