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DURABILITY PROPERTIES OF STEEL SLAG AS COARSE 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. Durability of concrete is the ability to resist the weathering action, chemical attack, abrasion, or any other process of deterioration. Durable concrete will retain its original form, quality, and serviceability when exposed to its environment. The durability tests to be done are water absorption test, Sulphate attack test and Sorptivity test.*

Key Words: Concrete, Steel Slag, Coarse aggregate, Compressive strength, Durability properties

1. INTRODUCTION

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.

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

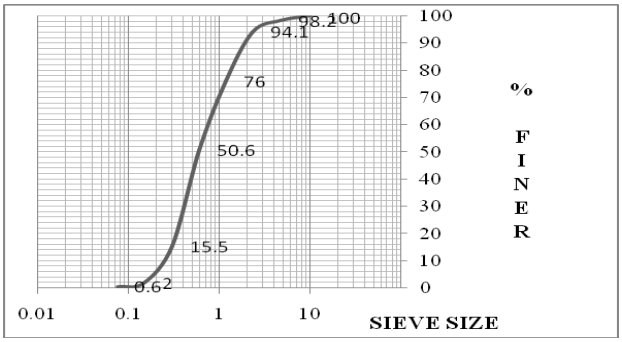

Fig 2.1 Sieve analysis of fine aggregate

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

4.3 Sorptivity test:

This test method is used to determine the rate of absorption of water by cement concrete by measuring the increase in the mass of a specimen resulting from absorption of water as a function of time when surface of the specimen is exposed to water.

The exposed surface of the specimen is immersed in water and water ingress of unsaturated concrete dominated by capillary suction during initial contact with water.

Rate of absorption, $I = \Delta m / (A \times \rho)$

where, Δm = change in mass of specimen (m2 – m1) in grams

m1 = initial mass of specimen in grams

m2 = final mass of specimen in grams, at the time t

A = exposed area of specimen in mm^2

ρ = density of the water in g/mm^3

Fig 4.1 Sorptivity test specimens

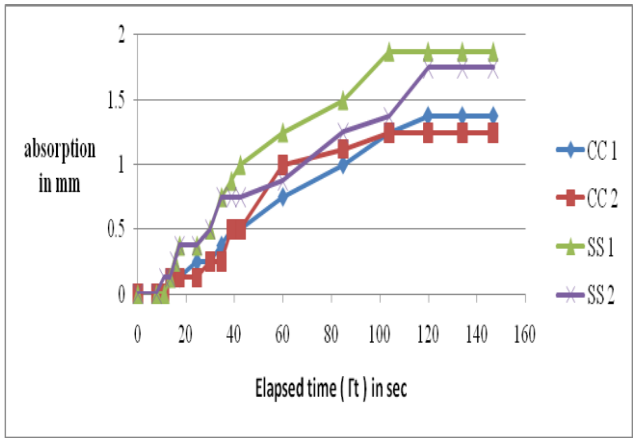

Fig 4.2 Rate of absorption of conventional and 45 % of steel slag

4.4 Sulphate attack test:

Sulphate attack on concrete is a chemical breakdown mechanism where sulphate ions attack components of the cement paste. The compounds responsible for sulphate attack on concrete are alkali-earth (calcium, magnesium) and alkali (sodium, potassium) sulphates that are capable of chemically reacting with components of concrete.

The resistance of concrete to sulphate attacks was studied by determining the loss of compressive strength of concrete cubes. The concrete cubes of 100mm x 100 mm x 100mm size was casted and after 28 days of water curing and dried for one day. The cubes were immersed in 5% of magnesium sulphate (MgSO4) by weight of water for 30 days. The concentration of sulphate water was maintained throughout the period. After 30 days immersion period, the concrete cubes were removed from the sulphate waters and after wiping out the water and girt from the surface of cubes tested for compressive strength.

Fig 4.3 sulphate attack of cubes

Table 4.3 sulphate attack test on concrete

Specimen	compressive strength of concrete before attack (N/mm^2)	Weight of specimen before attack in grams	Weight of specimen after attack in grams	compressive strength of concrete after attack (N/mm^2)	% loss in compressive Strength	Average % loss in compressive Strength
control	38.62	2.581	2.595	36.7	5.04%	4.31%
		2.532	2.576	37.27	3.57%	
45 % SS	39.09	2.434	2.541	35.32	8.62%	7.995%
		2.512	2.568	35.8	7.37%	

4.5 Water absorption test :

This test method determines the rate of absorption of water by hydraulic cement concrete by measuring the increase in the mass of a specimen resulting from absorption of water as a function of time when only one surface of the specimen exposed to water. The exposed surface is immersed in water and water ingress of unsaturated concrete dominated by capillary suction during initial contact with water.

Water absorption = (saturated weight – dry weight) / dry weight

Table 4.4 Water absorption on concrete

Specimen	Initial weight in grams	Final weight in grams	% of water absorption	Average % of water absorption
control	2520	2551	1.23	1.34%
	2493	2529	1.44	
45 % of steel slag	2431	2483	2.13	2.09%
	2392	2441	2.04	

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..
- Fresh, Hardened and durability properties of concrete was tested as per Indian standard provisions .
- 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.
- Durability properties of concrete shows slight decreases in compressive strength for sulphate attack test results due to pores present in steel slag .
- Rate of absorption of water gives better results.
- 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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