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EXPERIMENTAL STUDY ON STRENGTH OF CONCRETE BY PARTIAL REPLACEMENT OF COARSE AGGREGATE BY STEEL SLAG (BLAST FURNACE SLAG)

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Abstract: *The Concrete is the third largest material consumed by human beings after food and water as per WHO. Concrete plays a vital role in the design and construction of the nation's infrastructure. Almost three quarters of the volume of concrete is composed of aggregates. These are obtained from natural rocks and river beds, thus degrading them slowly. This issue of environmental degradation ,and need for aggregates demands for the usage of any other alternative source.Thus the concept of replacement of coarse aggregate with steel slag seems to be promising. In this study an attempt is made to use steel slag, a by-product from steel industry as replacement for coarse aggregate in concrete. M30 grade of concrete was used. The aim of this project is to study on optimal replacement of steel slag by coarse aggregate in concrete results. Mix design is based on IS-456 and IS-10262-2009 and characteristic study of aggregate.*

Keywords: *Aggregates, Blast furnace slag, Compressive strength, Split Tensile Strength, Flexural Strength and durability characteristics.*

1. Introduction:

Concrete is a composite material composed mainly of water, aggregate, and cement. Usually there are additives and reinforcements included to achieve the desired physical properties of the finished material. When these ingredients are mixed together, they form a fluid mass that is easily moulded into shape. Over time, the cement forms a hard matrix which binds the rest of the ingredients together into a durable stone-like material with many uses Concrete is the most widely used man-made building material in the world, owing to its versatility and relatively low cost. 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 many countries, there is a scarcity of natural aggregate that is suitable for construction, whereas in other countries the consumption of aggregate has increased in recent years, due to increases in the construction industry. In order to reduce depletion of natural aggregate, artificially manufactured aggregate and some industrial waste materials can be used as alternatives.

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New by-products and waste materials are being generated by various industries. For many years, by-products such as fly ash, silica fume and steel slag such as energy optimized furnace slag is considered as waste materials. Concrete prepared with such materials showed improvement in workability and durability compared to normal concrete and has been used in the construction of chemical plants and under-water structures. .[6] discussed about Microwave Semiconductor Devices such as Tunnel diode, Gunn diode and valanche transit time devices and analyzes Monolithic Microwave Integrated Circuits (MMIC)

Over recent decades, intensive research studies have been carried out to explore all possible reuse methods. Construction waste, blast furnace, steel slag, coal fly ash and bottom ash have been accepted in many places as alternative aggregates in embankment, roads, pavements, foundation and building construction. More recently, strict environmental – pollution controls and regulations have produced an increase in the industrial wastes and sub graded by-products and it was estimated that the current production of steel slag (generally a mixture of lime, silicate and metallic ingredients) is around 41 million tones per annum in India, which can be used in concrete such as fly ash, silica fume, ground granulated blast furnace slag etc.

2. Experimental Investigation:

2.1. Material Used

The following materials are used for producing the high strength concrete.

2.1.1 Water

Water is needed for the purpose of hydration of cement and to provide workability during mixing and placing of concrete. For this study portable water pH value 7 and conforming to the specifications of IS 456-2000 is used for concreting as well as curing of the specimen

2.1.2. Cement

Cement is a binder, a substance that sets and hardens as the cement dries and also reacts with carbon dioxide in the air dependently, and can bind other material together. In this experiment ordinary Portland cement of 43 grade concrete used.

2.1.3. Fine aggregate

The fine aggregates serve the purpose of filling all the open spaces in between the coarse particles. Thus it reduces the porosity of the final mass and considerably increases its strength. Usually Natural river sand is used as a fine aggregate. The sand confirmed to grading zone II of IS 383-1970.

2.1.4. Coarse Aggregate

Optimum size of the coarse aggregate in most situations was about 20mm size was adopted. They generally possess all the essential qualities of a good building stone showing very high crushing strength, low absorption value and least porosity.

2.1.5. Blast Furnace Steel Slag

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In this study blast furnace steel slag is used which is collected from JSW SISCOL plant, mecheri, Salem.

Table 2.1: Properties of cement

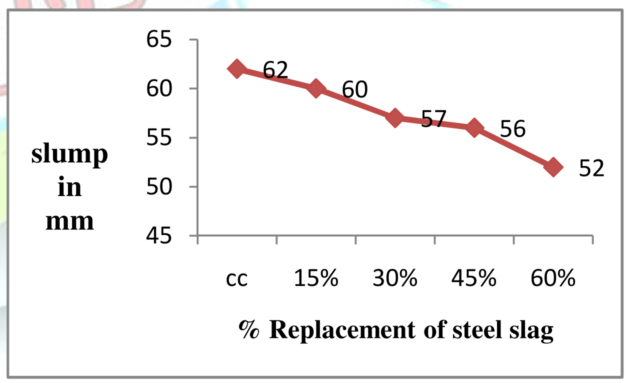
S.No	Description	Values
1	Specific gravity	3.15
2	Fineness (by sieve analysis)	2 %
3	Consistency	31 %
4	Initial setting time	40 minutes
5	Final setting time	250 minutes

Table 2.2: Properties of coarse aggregate

S.No	Description	Values
1	Specific gravity	2.5
2	Bulk Density	
	Partially compacted	1373 kg/m³
	Fully compacted	1680 kg/m³
3	Water absorption	0.25 %
4	Fineness modulus	2.89
5	Impact Value	15 %
6	Cushing Value	19 %
7	Abrasion Value	26.5

Table 2.3: Properties of Fine Aggregate

S.No	**Description**	**Values**
1	Specific gravity	2.64
2	Fineness modulus	2.76
3	Bulk Density	
	Partially compacted	1550 kg/m³
	Fully compacted	1760 kg/m³



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1	1.75	2.77	0.43

Table 2.4: Properties of Steel Slag

S.No	Description	Values
1	Specific gravity	2..6
2	Bulk Density	
	Partially compacted	1280 kg/m³
	Fully compacted	1450 kg/m³
3	Impact Value	25 %
4	Cushing Value	26.5 %

Table 2.1 shows the properties of cement are within the allowable limits. From Table 2.2 it was observed that the properties of coarse aggregate values satisfy the standards. Table 2.3 gives the properties of natural river sand. Table 2.4 is the properties of steel slag which has similar value of coarse aggregate.

3. Concrete Mix Details

Five sets of mixes are prepared for M_{30} grade concrete. First Mix is ordinary conventional concrete. Other mixes replacing steel slag for coarse aggregate in 15%,30%,45%,60% respectively.

Table 3.1: Mix Ratio

Cement	Fine aggregate	coarse aggregate	Water

4. Testing details:

4.1.1. 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.

Fig 4.1

4.2. Compressive Strength Test:

To determine the compressive strength, six cubes (150mm x 150mm x 150mm) were cast for each trial mix of M30 concrete for each mix and three samples were tested after 7 days and next three samples were tested after 28 days of curing. 7 and 28 days cube compressive strength test was conducted. Compressive strength tests were carried out using 2000KN capacity compression testing machine.

Figure 4.2: Compressive Strength Test

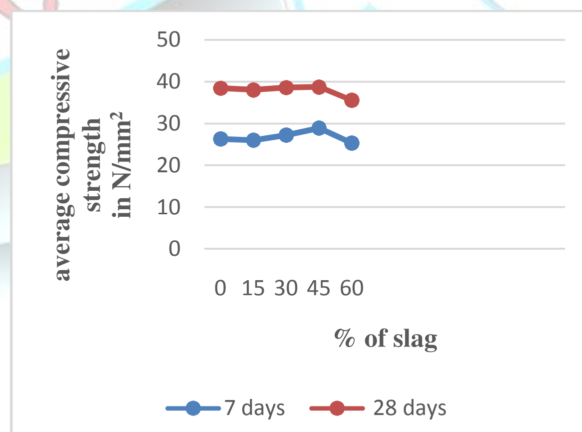

Figure 4.2. Compressive Strength test result

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4.3. Split Tensile Strength Test

The test was conducted as per IS 5816:1999. For tensile strength test, cylindrical specimens of dimension 100 mm diameter and 300 mm length were cast. In each mix, three cylinders were cast and tested and their average value was taken. The split tension test was conducted by using digital compression machine having 2000 kN capacity.

Figure 4.3: Split tensile Test

Split tensile strength was calculated as follows:

Spilt Tensile strength (MPa) = 2P / π DL
Where,
P = Failure Load (kN)
D = Diameter of Specimen (100 mm)
L = Length of Specimen (300 mm)

Test Results of splitting tensile strength for conventional and optimum percentage of steel slag concrete of M_{30} grade concrete as shown in table 4.3, below.

Table 4.3: Test Results of Split Tensile Strength

S.No	Specimen	Average Split tensile strength in (Mpa)7 days	28 days (Mpa)
1.	Conventional	3.09	3.92
2.	15%	2.97	3.73
3.	30%	3.01	3.83
4.	45%	3.4	4.02
5.	60%	2.83	3.53

4.4. Flexural strength test

For Flexural strength test, prism specimen of 100 mm X 100 mm X 500 mm was cast. For conventional and optimum mix, three prisms were cast and tested with two point load was applied and their average value was reported.

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Figure 4.4. Flexural Strength test

A beam specimen is placed in the ultimate testing machine of 2000kN capacity for testing. The Flexural strength is calculated by using the formula,

$$\sigma = P\, l / bh^2$$

Where,
P = load in Newton shown in dial gauge
l = length of prism in mm i.e. 500 mm
b = breadth of prism i.e. 100 mm
h = height of prism i.e. 100 mm.

Table 4.4: Test Results of Flexural Strength

S.NO	Mix ID	Average flexural strength in (Mpa)
1.	Conventional	5.14
2.	15%	4.98
3.	30%	5.05
4.	45%	5.18
5.	60%	4.84

5. Results & Discussion:

From graph 4.2, it was noticed that the compressive strength gradually increases as the percentage of steel slag is increased up to 45% replacement. After replacement of 45% compressive strength is gradually decreased. Hence we can conclude that complete replacement of coarse aggregate with energy blast furnace slag has reduced the compressive strength in concrete.

The compressive strength for M30 grade of concrete is shown in Graph 4.2, as above. As the curing days increases the strength also increases. This compressive strength test result also similar to the rebound hammer test.

From split tensile strength test, flexure strength test and also durability test results shows, the blast furnace steel slag aggregate concrete is better than the conventional concrete.

6. Conclusion:

1. Steel slag, an industrial waste by-product obtained from manufacture of steel can be identified as an alternative to natural aggregates for concrete production.
2. The properties of steel slag is similar to the Coarse aggregate.

3. The use of steel slag as replacement of coarse aggregate in concrete is beneficial for the better workability.
4. No major difficulty in handling the concrete with steel slag.
5. The compressive strength of concrete can be improved.
6. The optimum percentage of steel slag was found to be 45 %.
7. Overall, the performance of steel slag was found to be satisfactory for structural

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