Partial Replacement of Fine Aggregate by using Steel slag in concrete

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***Abstract*-** **Concrete is a widely used material in the world. Fine aggregate is an essential component of concrete. The most commonly used fine aggregate is natural river or pit sand. The global consumption of natural sand is very high due to the extensive use of concrete. In particular, the demand of natural sand is quite high in developing countries owing to rapid infrastructural growth. Therefore, the construction industries of developing countries are in stress to identify alternative materials to lessen or eliminate the demand for natural sand.**

The aim objective of this experimental work consists in:

•Substituting sand by granulated blast furnace slag.

•Utilizing the waste material (steel slag) in an effective manner.

The use of the method of substitution permits to improve the strength of the concrete, to increase the production of building materials and to protect the environment, it also gave an economic approach to the construction industry. The experimental results obtained show that the partial substitution of ordinary sand by slag gives better results compared with the ordinary concrete, but the full replacement of fine aggregates by slag products affect negatively the strength of concrete.

***Index Terms*-** **Concrete, Sand, Steel Slag.**

1. INTRODUCTION

Aggregates are the important constituents in concrete. They give body to the concrete, reduce shrinkage and effect economy. Since aggregates occupy 70-80 percent of the volume of concrete, their impact on various characteristics and properties of concrete is undoubtedly considerable.

All along in India, we have been using natural sand in concrete manufacturing. The infrastructure development such as highway projects, power projects and industrial developments have started now. Availability of natural sand is getting depleted and also it becoming costly. There is need for conserving resources and environment and for proper utilization of energy. Hence, there has to be an emphasis on the use of wastes and by-products in all areas including construction industry. As 75% of Concrete is composed of aggregates it is imperative that we look to maximize the use of waste as aggregate input in concrete making. Here in this work an attempt is made to utilize steel slag, a waste material from steel manufacturing industry in concrete as a partial replacement material for sand. Slag fines may be used as a substitute for sand without any deleterious effect. Volume stability, good sulphate resistance, and corrosion resistance to chloride solutions make reinforced slag concrete suitable for many applications.

2. MATERIALS & METHODOLOGY

2.1 A PREFACE ON STEEL SLAG

a) MATERIAL DETAILS

STEEL SLAG:

Slag is a byproduct of metal smelting, and hundreds of tons of it are produced every year all over the world in the process of refining metals and making alloys. Like other industrial byproducts, slag actually has many uses, and rarely goes to waste. Slag appears in concrete, aggregate road materials as ballast, and is sometimes used as a component of phosphate fertilizer. In appearance, slag looks like a loose collection of aggregate, with lumps of varying sizes. Slag is also sometimes referred to as cinder, in a reference to its sometimes dark and crumbly appearance.

Property	Value
Specific Gravity	3.2-3.6
Unit weight	1600-1920
Absorption	Up to 3%

Table 1: Physical Properties

Chemical Properties

The chemical composition of slag is usually expressed in terms of simple oxides calculated from elemental analysis determined by x-ray fluorescence. Virtually all steel slags fall within these chemical ranges but not all steel slags are suitable as aggregates. Of more importance is the mineralogical form of the slag, which is highly dependent on the rate of slag cooling in the steel-making process.

COARSE AGGREGATE

FINE AGGREGATE

Figure 1: Steel Slag, Fine and Coarse Aggregate

Steel slag is mildly alkaline, with a solution pH generally in the range of 8 to 10. However, the pH of leachate from steel slag can exceed 11, a level that can be corrosive to aluminum or galvanized steel pipes placed in direct contact with the slag

2.2 Determination of Specific Gravity

Apparatus required

Pycnometer, Balance, Weight box, Oven, Desiccators, Desired kerosene or any liquid with known specific gravity, Vacuum source, Thermometer.

Pycnometer is a glass jar to which a brass conical cap is screwed with a rubber washer. A 6mm diameter hole is provided in the brass cap.

Procedure

- Weigh the clean dry Pycnometer with its cap.
- Fill the Pycnometer one third full with cement and determine its weight after screwing the cap.
- Add kerosene to Pycnometer after removing the cap, until the Pycnometer to assist the removal of air and screw the brass cap.
- Add the kerosene till the Pycnometer is full. Remove remaining air by shaking after closing the screw top with one finger. Clean the outer surface of Pycnometer and then determine its weight.
- Empty the contents of Pycnometer and thoroughly wash it.
- Fill the Pycnometer with kerosene till the surface of kerosene is flush with the hold in the screw cap.
- Then weigh the Pycnometer.
- Note the temperature of kerosene.

Particulars	Specific Gravity
Cement	3.15
Fine aggregate sand	2.66
Coarse Aggregate	2.75
Slag	3.85
Sand 90%+ Slag 10%	2.58
Sand 80%+ Slag 20%	2.61
Sand 70%+ Slag 30%	2.93
Sand 60%+ Slag 40%	3
Sand 50%+ Slag 50%	3.06

Table 3: Specific Gravity

2.3 MIX DESIGN

Design Specifications

1. Characteristic compressive strength (28 days) = 20 N/mm2
2. Maximum size of aggregate = 20mm (angular)
3. Degree of workability = 0.8 (compaction factor)
4. Degree of quality control = Good
5. Type of exposure = Mild

Test Data of materials

1. Specific gravity of cement = 3.15
2. Specific gravity of coarse aggregate = 2.75
3. Specific gravity of fine aggregate = 2.66
4. Water absorption of coarse aggregate = 0.5%
5. Water absorption of fine aggregate = 1.0%
6. Free surface moisture for coarse aggregate = Nil
7. Free surface moisture for fine aggregate = 2.0%

Design

1. Target mean strength of concrete

f_{ck} = f_{ck} + 1.65S

= 20 + (1.65X4)

= 26.6N/mm2

2. Selection of water-cement ratio

For 43 grade, w/c = 0.45

3. Selection of water and sand content

For 20mm maximum size of aggregate and sand conforming to grading zone II the water content per m3 of concrete is 186kg and sand content as % of total aggregate by absolute volume = 35%.

For change in value in w/c, compaction factor for sand belonging to zone

4. Determination of cement content:

$$\frac{w}{c} = \frac{Weight\ of\ Water}{Weight\ of\ Cement}$$

$$0.45 = \frac{186}{C}$$

C = 413.33 Kg/m^3

5. Determination of coarse & fine aggregate contents

Fine aggregate:

V = [w + c/s_c + (1/P x fa/S_{fa})] x [1/1000]

For 20mm size of aggregate, entrapped air = 2%

V = (100-2) = 98% = 0.98

0.98 = [186 + 413.33/3.15 + (1/0.325x fa/2.74)] X [1/1000]

980 = 293.36 + 1.123 fa

fa = 711.43 kg/m^3

Coarse aggregate:

Ca = [1-P/P] x fa X [Sca/Sfa]

= [1-0.325/0.325] X 611.43 x [2.81/2.74]

Ca = 1412.33 kg/m^3

413.33: 711.43: 1412.33

1: 1.62: 3.58

Result:

M20 = 1: 1.62: 3.58 and w/c = 0.45

3. EXPERIMENTAL PROGRAM

3.1 Mould Details

1. The cube specimens are having the size of 150x150x150 mm. They are made of mild steel plates and can be assembled / dissembled with the help of bolts and nuts.
2. The cylindrical moulds of size 150mm diameter and 300mm height were used for casting the specimen.
3. The prism moulds of size 100x100mm in cross section and 500mm long was selected for casting the specimens for flexure test.

Figure 2: Mould

3.2 Casting

Concrete with and without water proofing admixtures were casted for three numbers of each specimen. The inside of the mould was oiled to prevent adhesion of concrete.

3.3 COMPACTING BY VIBRATION

When compacting by vibration, each layer is vibrated by means of a suitable vibrating until the specified condition is obtained. After the top layer has been compacted the surface of the concrete is brought to the finished level with the top of the mould, using a trowel.

3.4 Curing

Casted Concrete was kept in the mould for one day. After the period of 24 hours, they were marked for later identification, and then the side planks of the mould were removed. All the specimens were removed from the mould platform and stored in the water for curing.

3.5 Test Specimens

The experimental program was designed to study the mechanical properties of concrete with partial replacement of fine aggregate by steel slag for M20 grade of concrete. The compressive strength of the cubes after replacing the fine aggregate by 10%, 20%, 30%, 40% and 50% with steel slag is studied after 28 days.

For the test specimens, 43 grade ordinary Portland cement, natural river sand and coarse aggregate, steel slag from steel plants is being utilized. The maximum size of the coarse aggregate was limited to 20mm. A sieve analysis conforming to IS 383 – 1970 was carried out for both fine and coarse aggregates. The concrete mix proportions of M20 (1:1.62:3.58) with the water cement ratio of 0.45 was used.

The concrete mix design was proposed to achieve the compressive strength of 20MPa after 28 days curing, in case of cubes. The flexural strength and the split tensile strength of the specimens were also tested. The concrete cubes, concrete beams and concrete cylinders for conventional as well as other mixes were casted. Each layer was compacted with 25 blows using 16mm diameter rod.

3.6 Test Procedure

The specimens are tested to find out the mechanical properties. The concrete cube specimens were placed over the Compression Testing Machine and the load was gradually applied till the failure of the specimen. The ultimate load was noted down as collapse load and compressive strength was calculated.

The beam is placed on Electronic Universal Testing Machine to find out the flexural strength for various proportions. The split tensile strength test was carried out with concrete cylinders in Compression Testing Machine for each type of concrete specimens.

3.6.1 NDT Testing

Non-destructive Testing have been in use for about few decades. It is now considered as a powerful method for evaluating existing concrete structures with regard to their strength and durability apart from assessment and control of quality of hardened concrete.

Schmidt’s Rebound Hammer Method

- Schmidt’s Rebound Hammer developed is one of the commonly adopted equipment for measuring the surface hardness.
- It consists of a spring control hammer that slides on a plunger within a tubular housing.
- When the plunger is pressed against the surface of the concrete, the mass rebound from the plunger. It retracts against the force of the spring.
- The hammer impacts against the concrete and the spring control mass rebounds, taking the rider with it along the guide scale.
- By pushing a button, the rider can be held in position to allow the reading to be taken. The distance travelled by the mass, is called the rebound number. It is indicated by the rider moving along a graduated scale.
- Each hammer varies considerably in performance and needs calibration for use on concrete made with the aggregates from specific source.
- The test can be conducted horizontally at any intermediate angle.

Figure 3: NDT Testing

3.7 Results & Discussion

%replacement of sand by steelslag in concrete	Compressive Strength (N/mm2)	Split TensileStrength (N/mm2)	FlexuralStrength(N/mm2)
0	20.48	1.923	1.71
10	20.59	1.343	1.75
20	21.18	1.887	4.125
30	27.85	2.122	6.25
40	32.15	2.404	6.75
50	17.18	2.934	7.25

Table 4: Test Results of Concrete Specimens for percentage replacement Of Fine Aggregate by Steel Slag

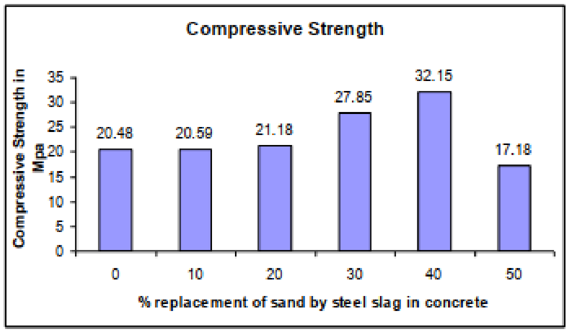

Figure 4: Average Compressive Strength of Cubes in MPa for M20 Grade

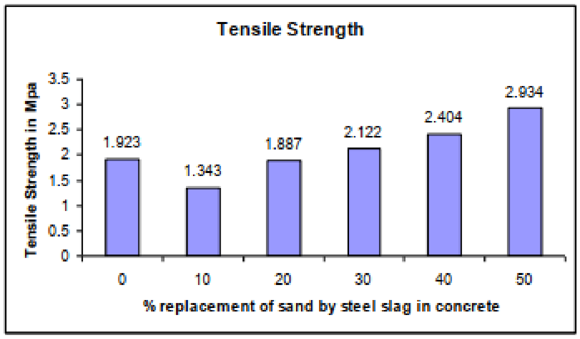

Figure 5: Average Split Tensile Strength of cylinder in MPa for M20 Grade

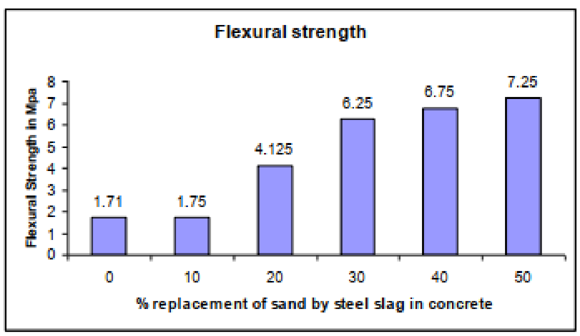

Figure 6: Average Flexural Strength after 28 days in MPa for M20 Grade

%replacement of sand by steel slag inconcrete	Compressive Strength (N/mm2)					
	7 Days		14 Days		28 Days	
	Cube	Cyl	Cube	Cyl	Cube	Cyl
0	14	14.3	16	16	19	18
10	15.3	15	17	17	20	20
20	16	17	18	19	21	22
30	18.3	18	20	23	23	25
40	20	20.6	23	25	28	30
50	14	18.3	15	15	18	18

Table 5: Results of NDT testing

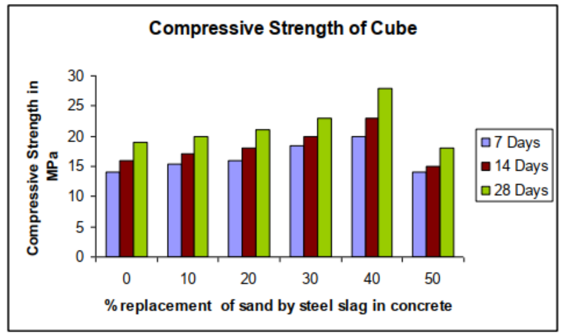

Figure 6: Average compressive strength of Cube (NDT Testing) after 7 and 14 days in MPa for M20 Grade

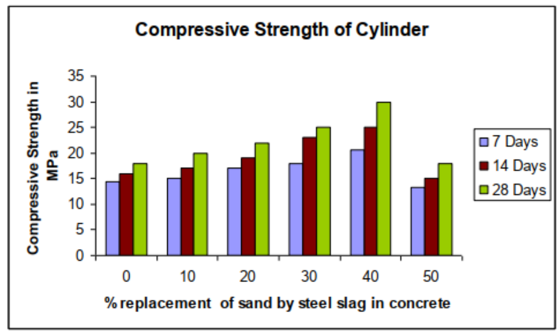

Figure 7: Average compressive strength of Cylinder (NDT Testing) after 7 and 14 days in MPa for M20 Grade

Discussion

The compressive strength of concrete cube at 10% replacement of sand by steel slag is about 20.59 N/mm2, for 20% the compressive strength is 21.18 N/mm2, for 30% the compressive strength is 27.85 N/mm2, for 40% the compressive strength is 32.15 N/mm2 and for 50% the compressive strength is 17.18 N/mm2. Therefore the compressive strength goes on increasing upto 40% replacement of sand by steel slag and then decreases. This has been also proved by the NDT Testing for both cube and cylinder.

The tensile strength of concrete specimen at 10% replacement of sand by steel slag is about 1.343 N/mm2, for 20% the tensile strength is 1.887 N/mm2, for 30% the tensile strength is 2.122 N/mm2, for 40% the tensile strength is 2.404 N/mm2 and for 50% the tensile strength is 2.934 N/mm2.The tensile strength increases from 1.343 N/mm2 to 2.934 N/mm2.Therefore the tensile strength goes on increasing with the replacement of sand by steel slag.

The flexural strength of concrete specimen at 10% replacement of sand by steel slag is about 1.75 N/mm2, for 20% the flexural strength is 4.125N/mm2, for 30% the flexural strength is 6.25 N/mm2, for 40% the flexural strength is 6.75 N/mm2 and for 50% the flexural strength is 7.25 N/mm2.The flexural strength increases from 1.75 N/mm2 to 7.25 N/mm2.Therefore the flexural strength goes on increasing with the replacement of sand by steel slag.

4. CONCLUSION

After conducting all the tests on the specimen, it has been observed that 40% replacement of fine aggregate with steel slag proved to be good in Compression. Tensile strength and Flexural strength goes on increasing with the replacement of fine aggregate by steel slag.

Cost Effective
Now a day the market rate of 1 m3 of sand is Rs.450.But for our mix design the rate comes around Rs.152.By replacing the sand by steel slag, the rate is about Rs.91 and thus Rs.61 is saved. Therefore it is cost effective.

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