Experimental Investigation On Concrete By Partial Replacement Of Fine Aggregate Using Steel Slag

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Abstract*- Steel slag is an industrial by product obtained from the steel manufacturing industry. It is produced in large quantities during the steel-making operations which utilize Electric Arc Furnaces (EAF). Steel slag can also be produced by smelting iron ore in the Basic Oxygen Furnace (BOF). Steel slag can be used in the construction industry as aggregates in concrete by replacing natural aggregates. Natural aggregates are becoming increasingly scarce and their production and shipment is becoming more difficult.*

For this present study M_{40} concrete will be designed. Partial replacement of sand with steel slag will be made for varying percentages such as 10%, 20%, 30%, 40%,50%,and 60% of weight of sand. Studies on compressive strength, tensile strength, flexural strength and experimental investigation and the strength of concrete attain optimum value at a particular replacement percentage of natural aggregates by steel slag.

Keywords*-* Steel slag ; Compressive Strength ; Flexural Strength .

I. INTRODUCTION

Concrete is the most widely used material on earth after water. Many aspects of our daily life depend directly or indirectly on concrete. Concrete is prepared by mixing various constituents like cement, aggregates, water, etc, which are economically available. Concrete is unique among major construction materials because it is designed specifically for civil engineering projects. Concrete is a composite material composed of granular materials like coarse aggregates embedded in a matrix and bound together with cement or binder which fills the space between the particles and glues them together. Concrete plays a critical role in the design and construction of the nation's Infrastructure. Almost three quarters of the volume of concrete is composed of aggregates. To meet the global demand of concrete in the future, it is becoming a more challenging task to find suitable alternatives to natural aggregates for preparing concrete.

1.1 Applications of steel slag

Some of the current uses of steel slag according to the National Slag Association (NSA accessed, 2008) are as follows:

- Steel slag is used as an ideal aggregate in hot mix asphalt (HMA) surface mixture application due to its high frictional resistance and skid resistance characteristics. The cubical nature of steel slag and its rough texture provides more resistance than round, smooth and elongated aggregates.
- It is also used in making Stone Matrix Asphalt (SMA) because the particle-to-particle contact of the aggregate does not break down during the manufacturing, laying down, or compaction process.
- It is also used for manufacture of Portland cement.
- It is used in base application, construction of unpaved parking lots, as a shoulder material, and also in the construction of embankment.
- It is also used in agriculture because it has minerals like iron, manganese, magnesium, zinc and molybdenum which are valuable plant nutrients.
- It is environment friendly. During the production of cement, the CO is reduced as slag has previously undergone the calcination process.
- Steel slag aggregates are used for soil stabilization or soil improvement material and for remediation of industrial waste water run-off.

1.2 Need for Research:

River sand used as fine aggregate in concrete becoming very scarce. The cost of construction becoming uneconomical due to excessive cost of transportation from natural sources. The purpose of this study is to find out the suitable material for replacement of fine aggregate in concrete and explore feasibility of utilizing the steel slag produced by steel mills in Tamil Nadu region as a replacement for natural aggregate in the concrete. Steel slag aggregates generally exhibit the potential to expand due to the presence of unhydrated free lime and magnesium oxides which hydrate in humid environments. If such a product is used in the concrete, it enhances both the mechanical and physical properties of concrete along with its durability.

II. EXPERIMENTAL PROGRAMME

2.1. Materials used

2.1.1. Aggregates and cement

The cement used should confirm to IS specifications. There are several types of cements are available commercially in the market of which Portland cement is the most well known& available everywhere. OPC 53 grade was used for this study. The physical properties of the cement tested according to standard procedure conform to the requirement of IS 12269: 1989.

Locally available river sand passing through 4.75mm sieve conforming to the recommendation of IS383-1970 is used.

Coarse aggregates to be used for production of concrete must be strong, impermeable, durable & capable of producing a sufficient workable mix with minimum water cement ratio to achieve proper strength. Locally available coarse aggregate retaining on 4.75mm sieve is used.

2.1.2. Steel slag

Steel slag is an industrial by-product obtained from the steel manufacturing industry. It is produced in large quantities during the steel making operations which utilize Electric Arc Furnace (EAF). Steel slag can also be produced by smelting iron ore in Basic Oxygen Furnace (BOF). This steel slag can be used in the construction industry as Aggregates in concrete by replacing natural aggregates. Natural aggregates are becoming increasingly scarce and their production and shipment is becoming more difficult. In this study Steel slag with specific gravity 3.10 is used for replacement of fine aggregates.

2.2 TEST ON MATERIALS:

2.2.1. Specific Gravity

Specific gravity of aggregate is made use of in design calculations of concrete mixes. With the specific gravity of each constituent known, its weight can be converted into solid volume and hence a theoretical yield of concrete per unit volume can be calculated.

Specific gravity of fine aggregate is 2.66
Specific gravity of Coarse aggregate is 2.86
Specific gravity of Cement is 3.12

2.2.2. Mix design

As per IS10262-2009 the concrete mix design prepared for M40 grade concrete the water cement ratio is taken as 0.40 from IS10262-1982 for maintain workability.

2.2.3 Mix Proportion

Table 1.1 Mix Ratio

Cement	Fine aggregate	Coarse aggregate	W/C
465	569.41	1232.3	186
1	1.22	2.65	0.4

2.3 Preparation of Concrete Cubes

For this study, experimental work involves casting of concrete cubes of size 150mm X 150mm X 150mm for determination of compressive strength for 7 days and 28 day. Totally 36 cubes were casted. Cubes were casted for various percentage of replacement of fine aggregate with steel slag. Replacement made for 0%, 10%, 20%, 30%, 40% and 50% 60%. For the study the water cement ratio of 0.40 is maintained uniform.

2.3.1 Mixing

The concrete for designed mix is mixed homogeneously by means of hand mixing.

2.3.2 Casting of Cubes

Before casting the cubes the entire mould is oiled. So the cube can be easily removed from the mould after the desired period. The concrete is filled in the cube three layers and each layer tamped evenly by tamping rod.

2.3.3 Pond Curing

On ponding flat surface such as pavements and floors, concrete can be cured by ponding. Earth or sand dikes around the perimeter of the concrete surface can retain a pond of water. This method is commonly used in the laboratory for curing concrete test specimens.

2.4 TESTING OF SPECIMENS

2.4.1 Compressive Strength Testing

The concrete cubes after casting allow 7 days and 28 days curing. After the curing cubes were allow to one day drying. The cubes are tested by means of compression testing machine (CTM) to find the ultimate load.From the ultimate load, the compressive strength is obtained by the following formula,

Compressive strength = Load/Area (N/mm^2)

Table 1.2 28 days Compressive Test Result

Specimen Name	% of steel slag used (%)	Average Compressive Strength (N/mm2)
C0	0	47.85
C1	10	48.40
C2	20	50.67
C3	30	53.11
C4	40	51.63
C5	50	50.59
C6	60	49.08

Fig 1.1 Compression Test

2.4.2 Tensile Strength Test

The concrete cylinder after casting is allowed for 7 days and 28 days curing. After the curing cylinder were allowing for drying. After drying cylinder are tested in compression testing machine (CTM) to determine the ultimate load. From the ultimate load, the tensile strength is obtained by the following formula,

Split tensile strength = $\frac{2P}{\pi LD}$**(N/mm^2)**

Fig 1.2 Split Tensile Test

Table 1.3 28 Days Split Tensile Strength:

Specimen Name	% of steel slag used (%)	Average Split Tensile Strength (N/mm2)
S0	0	3.65
S1	10	3.77
S2	20	3.89
S3	30	3.97
S4	40	3.34
S5	50	3.12
S6	60	3.09

2.4.3 Flexural Strength Test

For this study, experimental work involves casting of concrete prisms of size 50cm x 10cm x 10cm for determination of flexural strength for 7 days and 28 days curing. Totally 36 prisms of M_{40} grade concrete were casted. The mix design procedure for M_{40} grade concrete is shown in Appendix-I. Cylinders were casted for various percentage of replacement of fine aggregate with steel slag. Replacement made for 0%, 10%, 20%, 30%, 40% and 50% 60%. For the study the water cement ratio of 0.40 is maintained uniformly.

Flexural strength = $\frac{3pa}{bd^2}$ **(N/mm^2)**

Fig 1.3 Single point loading for Prism

Table 1.4 Flexural Strength Result

Specimen Name	% of steel slag used (%)	Average Flexural Strength (N/mm2)
F0	0	4.53
F1	10	4.67
F2	20	4.87
F3	30	4.96
F4	40	4.77
F5	50	3.99
F6	60	3.92

III. CONCLUSION

- It is obvious that compressive strength increases with increase in percentage of steel slag up to 30% by weight of fine aggregate
- The enhancement in compressive strength is about 22% for 7days curing and 11% for 28 days curing
- It is obvious that split tensile strength increases with increase in percentage of steel slag up to 30% by weight of fine aggregate
- The enhancement in split tensile strength is about 22.5% for 7days curing and 9% for 28 days curing
- It is obvious that flexural strength increases with increase in percentage of steel slag up to 30% by weight of fine aggregate
- The enhancement in flexural strength is about 22.8% for 7days curing and 10.15% for 28 days curing
- Further stress-strain curve for 30% slag replaced M_{40} concrete is similar to that of M_{40} conventional concrete
- The specific gravity is almost same both for the natural river sand and steel slag. The variation in cost when compared with normal concrete to 30% of replacement for 1 m3 is about Rs. 200.
- Hence it can be concluded on whole that, by utilizing this type of industrial by product as major constituent of concrete by effective proportioning, we can reduce the cost of construction and also reduce the environmental impact.

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