Experimental Study of Particle Packing Analysis in Steel Slag Aggregate Concrete

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***Abstract*: This study presents an evaluation of steel slag aggregate concrete in comparison with the conventional natural aggregate concrete. Hardened concrete consist of more than 70% aggregate due to the high demand in building construction and the increase of the amount of disposed waste material, suppliers and researchers are exploring the use of alternative materials which could preserve natural sources and save the environment. Steel slag was used as an aggregate replacement in conventional concrete mixes. Steel slag which is mainly consists of calcium carbonate is produced as a by-product during the oxidation process in steel industry. Steel slag was selected due to its characteristics, which are almost similar to conventional aggregates and the fact that it is easily obtainable as a by-product of the steel industry. As a result, utilization of steel slag will save natural resources and clean environment and alsoThe results were compared with conventional concrete property can be maintained such as steel slag as partial replacement of cement 0 ,30%,60%,100%. Particle packing analysis is made to optimize the gradation of coarse aggregate which would decrease the cement requirement and increase the density of packing which would result in its improved performance in terms of strength and mechanical properties of concrete like compressive strength and flexural strength are studied here.**

Keywords: Compressive strength, Flexural strength, , Steel slag, Replacement.

I. INDRODUCTION

1.1 *GENERAL*

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 particular 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 those 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. Natural aggregates are obtained from natural rocks. They are inert, filler materials and depending upon their size they can be separated into coarse aggregates and fine aggregates. The coarse aggregate fraction is that retained on 4.75 mm (No 4) sieve, while the fine aggregates fraction is that passing the same sieve. According to some estimates after the year 2010, the global concrete industry will require annually 8 to 12 billion metric tons of natural aggregates (U.S.G.S and nationalatlas.gov, accessed Nov 2008).

1.2NEED FOR AGGREGATE REPLACEMENT

The aggregates typically account about 75% of the concrete volume and play a substantial role in different concrete properties such as workability, strength, dimensional stability and durability.

Conventional concrete consists of sand as fine aggregate and gravel, limestone or granite in various sizes and shapes as coarse aggregate. There is a growing interest in using waste materials as alternative aggregate materials and significant research is made on the use of many different materials as aggregate substitutes such as coal ash, blast furnace slag, steel slag aggregate. This type of use of a waste material can solve problems of lack of aggregate in various construction sites and reduce environmental problems related to aggregate mining and waste disposal. The use of waste aggregates can also reduce the cost of the concrete production (Kalyoncu, 2001; Farrand and Emery, 1995).

1.3NEED FOR OPTIMIZING AGGREGATE PACKING

From the production of concrete, cement is the most expensive material and can account for upto 60% of the total materials cost. Its manufacturing process is also the largest greenhouse gas contributor, and the most energy and resource intensive. Approximately 5% of global carbon dioxide emissions are attributed to the manufacturing of cement. The paste fraction of a concrete mix is usually 25% to 40% of the total volume. A portion of cement can be substituted by supplementary cementing materials (SCMs), but there is greater potential to reduce the cement content needed for concrete mixes by optimizing the combined aggregate gradation of mixes.

Optimizing the packing of the aggregate particles will improve concrete's:

i) Sustainability and cost by reducing cement content required;

Durability by decreasing its permeability and potential for drying shrinkage cracking;

1.4 USE OF STEEL SLAG AS AGGREGATE

Always, construction industry has been at forefront in consuming these waste products in large quantities. The consumption of Slag in concrete not only helps in reducing greenhouse gases but also helps in making environmentally friendly material. During the production of iron and steel, fluxes (limestone and/or dolomite) are charged into blast furnace along with coke for fuel. The coke is combusted to produce carbon monoxide, which reduces iron ore into molten iron product. Fluxing agents separate impurities and slag was produced during separation of molten steel. Slag is a nonmetallic inert waste byproduct primarily consists of silicates, alumina silicates and calcium-alumina silicates. The molten slag which absorbs much of the sulfur from the charge comprises about 20 percent by mass of iron production. As the aggregates can significantly control the properties of concrete, the properties of the aggregates have a great importance (Beshr*et al.*, 2003).Maslehuddinet *al.* (2002) have indicated that the durability of steel slag cement concrete was better than the same for crushed limestone aggregate.

K.G. Hiraskar and ChetanPatil (2013), investigated the use of blast furnace slag as aggregates in concrete. The results showed that it has properties similar to natural aggregates and it would not cause any harm if incorporated into concrete. The research was encouraging, since they show that using blast furnace slag as coarse aggregates in concrete has no negative effects on the short term properties of hardened concrete.

Mohammed Nadeem1, Arun D. Pofale (2012), studied on replacement of coarse and fine aggregate in concrete by slag. Concrete of M20, M30 and M40 grades were considered for a W/C ratio of 0.55, 0.45 and 0.40 respectively for the replacements of 0, 30, 50, 70 and 100% of aggregates (Coarse and Fine) by slag. Whole study was done in two phases, i.e. replacement of normal crushed coarse aggregate with crystallized slag and replacement of natural fine aggregate with granular slag. The investigation revealedimprovement in compressive strength, split tensile and flexure strength over control mixes by 4 to 8 %. The replacement of 100 % slag aggregate (coarse) increased concrete density by about 5 to 7 % compared to control mix. The study concluded that compressive strength of concrete improved by 4 to7 % at all the % replacements of normal crushed coarse aggregate with crystallized slag.

Anastasiou and Papayianni, (2006), investigated on using steel slag aggregates in concrete and found out that the 28 day strength was increased by 21% with replacement of natural aggregates, while there was no increase in the setting time of concrete mixtures.

Manso and Gonzalez (2004), studied on durability of the concrete made with Electric Arc Furnace slag as an aggregate was done and the results showed that it was acceptable. The concrete mixes using conditioned EAF slag showed good fresh and hardened properties and acceptable behavior against aggressive environmental conditions. It was observed that the compressive strength was similar to that of traditional concrete. The durability was slightly lower than conventional concrete. The concrete had good physical and mechanical properties, but results showed that special attention should be paid to the gradation and crushing process. The results showed that the high porosity of EAF slag aggregates affects concrete resistance to freezing and thawing but improvements in the field could be possibly obtained by adding air entraining admixtures.

Maslehuddin, et al, (2003), compared steel slag and crushed limestone aggregate. They studied the mechanical properties and durability characteristics of steel slag aggregate concrete in comparison with limestone aggregates. Abrasion resistance, specific gravity, water absorption, chemical soundness, alkalinity, concentration of chloride and sulfates were tested and compared with lime stone aggregates. Shrinkage and expansion characteristics of steel slag and sand cement mortar specimens were evaluated and length was measured at periodic intervals. Compressive strength of steel slag aggregates increased with the proportion of coarse aggregates from 31.4 MPa with 45% coarse aggregates to 42.7 MPa with 65% coarse aggregates. The flexural strength and split tensile strength also increased while the water absorption capacity was reduced. Shrinkage of steel slag exposed to a dry environment was similar to limestone aggregate.

1.5 OBJECTTIVES

The objective of this research was to find combined aggregate gradations, using Steel slag aggregate, which will significantly reduce the amount of cement required by 10% to 15% without compromising concrete properties. To achieve this objective, several optimization techniques were being applied to typical M 40 design. These techniques include:

II. MATERIALS

2.1 Concrete

The concrete used for casting the specimens was designed for strength of 40 M. The Mix proportioning of ingredients are presented in Table 1.

Table 1 Mi Proportioning of Ingredients

Mix	Mix Description	Fine Aggregate kg	Coarse Aggregate kg	Steel Slag kg	Cement Content kg	W/C Ratio
1	Control	545.29	1185.78		425.78	0.45
2	Steel Slag Coaise Aggregate	545.29	-	1521.37	425.78	0.45

2.2.Experimental Programme

Cube specimens of sizes 150 x 150 x 150 mm and prism specimens of size sizes 700 x 150 x 150mm made of

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concrete with cement, fine aggregate and coarse aggregate with following replacements of waste material (steel slag).

- Concrete with Coarse aggregate70% and steel slag30% (30%)
- Concrete with Coarse aggregate 40% and steelslag 60% (60%)Concrete with Coarse aggregate 0% and steel slag 100% (100%)

2.1.1 Cement

The cement used in this study of steel slag concrete was OPC Grade 43. The specific gravity result of cement test was 3.15

2.1.2 Coarse Aggregate

Locally available natural aggregates were used to manufacture specimens for the control mix to be compared with that of the proposed mixes. The specific gravity result of aggregate was 2.74.

2.1.3 Steel Slag

Steel slag was obtained from local Steel industries in Pudhucherry. Steel slag was obtained in lumps which was then crushed manually into smaller fractions and then sieved to required size. No special treatment was made prior to use. They were packed in sacks and stored in the laboratory under dry condition.. specific gravity results of steel slag aggregate were 3.42.

III.TEST SPECIMENS

3.1. Casting of Test Specimens

In this test, size of the cubical specimen 150 mm, size and size of the prism 100 mm X 100 mm X 500 mm were used. The casting of mould .

Concrete were cast based on the mix ratios. Conventional method of concrete batching and mixing was done. The weighing of the ingredients viz., Cement, fine aggregates, coarse aggregates were made just prior the beginning ofproducing concrete.The fresh concrete was then cast into the mould immediately after mixing without any delay. Each layer was given strong manual roding. Each layer received nearly 25 manual strokes.

Curing of testing specimen

3.2 Testing of Specimens

The specimens were tested for their compressive strength and flexural strength.

3.2.1Compressive Strength Test

Out of many test applied to the concrete, this was the almost important which gives an idea about all the characteristics of concrete. By this single test one judge that whether Concreting has been done properly or not. For cube test specimen cubes of 15 cm X 15 cm X 15 cm and These specimens are tested by compression testing machine after 7 days curing and 28 days curing. Load was applied until failure of specimens. Load at the failure divided by area of specimen gives the compressive strength of concrete. Compressive strength test was shown in Fig.5. Compressive strength = (P/A)F.

3.2.2 Flexural Strength Test

Flexural strength is one measure of the tensile strength of concrete. It was a measure of an unreinforced concrete beam or slab to resist failure in bending. It is measured by loading 700mm x150mm x 150 mmconcrete beams. The flexural strength is expressed as Modulus of Rupture (MR) in psi (MPa) and is determined by standard test methods ASTM C 78 (third-point loading) or ASTM C 293 (center-point loading). Flexural strength test was shown in Fig.7. Flexural Strength of Concrete Flexural MR is about 10 to 20 percent of compressive strength depending on the type, size and volume of coarse aggregate used. However, the best correlation for specific materials is obtained by laboratory tests for give materials & mix design

Flexural strength =$(3PL/bd^2)$

Fig.7 Flexural Strength Test

IV. EXPERIMENTAL RESULTS AND DISCUSSION

The standard specimens were tested at both 7 and 28 days. Initially cubical specimens were put to compressive strength test in order to get optimum number of proportions. This was not unusual as compressive strength has fundamental importance in the design of concrete mixtures. The entire test resultsstated above was obtained as average value of three test specimens under each mixes considered. Casting and testing of specimens were with due care confined to a possible extent with the standards.

COMPARISON BETWEEN NORMAL & DIFF. VOL slag

Volume of Steel Slag	Volume of Coarse aggregate	Cube Compressive Strength at 7 Days (N/mm^2) (Average Values)
Controlled Concrete (0%)	Controlled Concrete (0%)	22.52
30%	70%	24.18
60%	40%	23.29
100%	_	20.55

5. CONCLUSION

Replacing STEEL SLAG for (30%, 60%, and 100%) is done for M40 grade of concrete. The test results shows that the replacement of steel slag aggregate upto 60% by weight and coarse aggregate has considerably increases the physical and mechanical properties of concrete. By use of this waste, the construction cost reduces by 40%. The saving will be more if the industrical waste availability is at industrical company. This also reduces the burden of dumping the wastes and slag in the earth so as to reduce the environmental pollution. The mechanical properties of concrete like compressive strength and flexural strength are studied here shows considerable increase in strength.

Durability test shows no variation for different replacement s of steel slag.

From this work it was found that 100% replacement of conventional aggregate with steel slag aggregate was not found to yield better strength, when conventional aggregate ratio was given. With modified aggregate sizes and ratio, based on aggregate packing analysis, better strength results was obtained both cases of conventional and steel slag aggregates.

- Steel slag coarse aggregate gave up to,
  - o Compressive strength of steel slag concrete increases in 6 % compared to the conventional coarse aggregate concrete.

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