Investigation on Strength of Concrete Containing Steel Slag Aggregates as Partial Replacement of Sand
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Abstract:
Concrete, which is the major producing material in construction field? The important constituents in concrete are the aggregates, which imparts better properties to the concrete. Due to the depletion of natural fine aggregate, it has become more challenging task to find the suitable alternatives to fine aggregate by waste by product of various industries. Steel slag is one of the waste material obtained from the various steel industries. Hence an attempt has been made to assess the possibility of using steel slag. It is used as a partial replacement of fine aggregate on the basis of particle size after performing sieve analysis using IS 10262-2009.In this study, the fine aggregate is partial replaced with the steel slag by 0%, 10%, 20%, 30% and 40% .The Compression strength, Flexural strength and Split tensile strength tests were conducted. Therefore, the optimum strength is obtained at 30% replacement of steel slag.

Keywords: Steel slag, Conplast sp430, Compressive strength, Flexural strength, Split tensile strength, CTM, UTM.

I. INTRODUCTION
1. General
Concrete is a substantially produced material. It plays very important role in design and construction of infrastructures of the nation. It’s mix is prepared using aggregates, it has become more challenging task to find the suitable alternatives to natural aggregates as because depletion of natural fine aggregate which resulting in ecological imbalance. In India, the conventional concrete is produced by using natural sand from river beds as fine aggregate. Dwindling sand resources possess the environment problem and hence government restrictions on sand quarrying resulted in scarcity and significant increases in its cost. Such cost can be reduced through the use of locally available alternative materials to the conventional ones normally used in concrete work of interest to this research is are alternative to sand. The world wide consumption of sand as fine aggregate in concrete in concrete production is very high and several developing countries have encountered some stain in the supply of natural sand in order to meet the increasing needs of infrastructural development in recent years to overcome the stress and demand for river sand in the construction industries have identified some alternatives namely Quarry dust, manufactured sand, limestone and steel slag etc. Steel slag is one of the by-products of the steel manufacturing industry which is obtained from the impurities in the metals or ores that are being treated by the process either from Basic Oxygen Furnace or by Melting of Scrap to make steel in the Electric Arc Furnace. It consists of mostly mixed oxides of elements such as silicon, sulphur, phosphorous and aluminum ash and products formed in the reactions such as lime stones during smelting process slag is produced in several ways firstly, it represents undesirable impurities in the metals which float on the top during the smelting process. Secondly, a metal gets oxidized as they are smelted. A protective crust of oxide formed by slag on the top of metal which has been smelted, by this slag protects the liquid metal underneath. Slag is taken from the top of a metal which is smelted to satisfaction and the slag disposed of in a slag heap to age. Aging material is an important process as it needs to be exposed to the weather and allowed to break slightly before its use Therefore, it has been estimated that in India approximately thousand million tonnes of slag is generated, so for that research is needed to utilize this major by-product of steel industry as one of the constituent in concrete production. By the use of steel slag in construction it preserves the natural fine aggregate.

![Figure 1. Steel Slag](image)

1.1 Objectives
a. To test the properties like compressive strength, Split Tensile strength and Flexural strength by replacing 0%, 10%, 20%, 30% and 40% of steel slag with fine aggregate
b. To compare the workability of conventional concrete with the steel slag concrete by conducting the slump test.

2. MATERIAL AND METHODOLOGY
For making the concrete basic tests are conducted on various materials like OPC43 grade cement, fine aggregate, coarse aggregate, steel slag to check suitability. To study the strength properties as a result of replacing fine aggregate by steel slag
in various percentage such as 0%, 10%, 20%, 30%, and 40% of steel slag. The experimental investigation has been carried out on the three test specimens of specimen were casted as per mix design of 1:2:4 with the water cement ratio of 0.4 and the tests are conducted after decorous curing.

The material used are:

a. Cement: Ordinary Portland cement of 43 grades conforming to IS 8112-1989 was used.

b. Fine aggregate: Manufactured sand with fraction passing the 4.75mm sieve and retained on the 600micron sieve was used and fineness modulus of 4.04 with the specific gravity of 2.64 was used.

c. Coarse aggregate: Crusted granite coarse aggregate of 20mm downsize were used and the fineness modulus of 4.32 with a specific gravity of 2.63 was used.

d. Steel slag: It is by-product obtained either from conversion of iron to steel in a Basic Oxygen Furnace or by the melting of scarp to make steel in the Electric Arc Furnace.

e. Superplastisizer: Conplast sp430 is Superplastisizer, which significantly reduces the water demand in the concrete mix and provides the strength gain at early age.

2.1 Fresh Concrete
The slump test was conducted on fresh concrete and the slump value obtained is 25mm.

2.2 Hardened Concrete
In this experimental investigation work, a total of 45 number of concrete specimens like cubes (150 x 150 x 150 mm), cylinders (150x300mm), and beams (100x100x500mm) were casted.

The tests were conducted on hardened concrete are as follows:

a. Compression strength test
b. Split Tensile Strength test
c. Flexural strength test

da. Compression Strength Test:
Totally 15 numbers of concrete cube specimens (150x150x150mm) were casted and it is allowed for 7 days and 28 days curing. To determine the ultimate load cubes were tested in compression testing machine (CTM), after drying. Replacement of the fine aggregate was made by 0%, 10%, 20%, 30% and 40% of steel slag.

The Compression strength is calculated by using formula:

\[ C = \frac{P}{A} \times \frac{1}{N/mm^2} \]

Where,  
- \( P \) = maximum applied load in N
- \( A \) = area of specimen in mm²

After performing test on cube M25 grade of concrete under compression testing machine (CTM) for varying percentage of steel slag by weight of fine aggregate, the results obtained are as given below:

<table>
<thead>
<tr>
<th>% of Replacement</th>
<th>7 days avg compressive strength (N/mm²)</th>
<th>28 days avg compressive strength (N/mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>19.6</td>
<td>25.85</td>
</tr>
<tr>
<td>10</td>
<td>20.08</td>
<td>26.16</td>
</tr>
<tr>
<td>20</td>
<td>24.2</td>
<td>28.33</td>
</tr>
<tr>
<td>30</td>
<td>25.7</td>
<td>34.88</td>
</tr>
<tr>
<td>40</td>
<td>24.85</td>
<td>26.16</td>
</tr>
</tbody>
</table>

b. Split Tensile Strength Test:
Totally 15 numbers of concrete cylinder specimens (100x100x300mm) were casted and it is allowed for 7 days and 28 days curing. To determine the ultimate load cylinders were tested in compression testing machine (CTM), after drying. Replacement of the fine aggregate was made by 0%, 10%, 20%, 30% and 40% of steel slag. The Split Tensile strength is calculated by using formula:

\[ S = \frac{2P}{\pi DL} \times \frac{1}{N/mm^2} \]

Where,
- \( P \) = maximum applied load in N
- \( D \) = Diameter of the specimen in mm
- \( L \) = Length of the specimen in mm

![Figure 2. Compression strength for cube under CTM](image)

![Figure 3. Split tensile strength for cylinder under CTM](image)
After performing test on cylinder M25 grade of concrete under compression testing machine (CTM) for varying percentage of steel slag by weight of fine aggregate, the results obtained are as given below:

Table 2: Split Tensile strength results

<table>
<thead>
<tr>
<th>% of Replacement</th>
<th>7 days avg Split tensile strength (N/mm²)</th>
<th>28 days avg. Split tensile strength (N/mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1.6</td>
<td>2.91</td>
</tr>
<tr>
<td>10</td>
<td>1.5</td>
<td>2.64</td>
</tr>
<tr>
<td>20</td>
<td>1.97</td>
<td>3.47</td>
</tr>
<tr>
<td>30</td>
<td>2.3</td>
<td>3.8</td>
</tr>
<tr>
<td>40</td>
<td>1.7</td>
<td>2.8</td>
</tr>
</tbody>
</table>

Figure 4. flexural strength for beam under UTM

c. Flexural Strength Test:
Totally 15 numbers of concrete beam specimens (100x100x500mm) were casted and it is allowed for 7 days and 28 days curing. To determine the ultimate load, beams were tested in universal testing machine (UTM), after drying. Replacement of the fine aggregate was made by 0%, 10%, 20%, 30% and 40% of steel slag.

The Flexural strength is calculated by using formula:

\[ F = \frac{PL}{BD^2} \quad \text{N/mm}^2 \]

Where,

- P = maximum applied load in N
- L = the span length in mm
- B = width of the specimen in mm
- D = depth of the specimen in mm

After performing test on beam M25 grade of concrete under universal testing machine (UTM) for varying percentage of steel slag by weight of fine aggregate, the results obtained are as given below:

Table 3: Flexural strength results

<table>
<thead>
<tr>
<th>% of Replacement</th>
<th>7 days avg Flexural strength (N/mm²)</th>
<th>28 days avg. Flexural strength (N/mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2.4</td>
<td>4.75</td>
</tr>
<tr>
<td>10</td>
<td>2.2</td>
<td>5.7</td>
</tr>
<tr>
<td>20</td>
<td>2.93</td>
<td>6.45</td>
</tr>
<tr>
<td>30</td>
<td>3.52</td>
<td>6.8</td>
</tr>
<tr>
<td>40</td>
<td>2.97</td>
<td>6.2</td>
</tr>
</tbody>
</table>

3. CONCLUSION

1. The uses of steel slag as a partial replacement for sand which impact strength up to 30% replacement. Where higher level replacement leads to segregation and bleeding.

2. The results of compressive, split tensile and flexural strength test have indicated that the strength of concrete increases with respect to the percentage of steel slag added by weight of fine aggregate up to 30% replacement level.

3. The addition of steel slag definitely reduces the porosity of concrete and makes the concrete impermeable.

4. Replacement of steel slag increases the self weight of concrete specimens to the maximum of 30%.

4. REFERENCES


