Experimental study on light weight ferrocement beam under monotonic and repeated flexural loading
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ABSTRACT

Light weight ferrocement is a composite material consisting of cement-sand mortar (matrix) along with light weight fine aggregate (In this work foamed blast furnace slag is employed as light weight fine aggregate) as a replacement of sand in some quantity reinforced with layers of small diameter wire meshes. The present work is concentrated on two major aspects, Effect of blast furnace slag on first crack and ultimate strength and Behavior of light weight ferrocement element under monotonic & repeated flexural loading. The first part of the present study has been focused on the effect of blast furnace slag (BFS) on ultimate strength with replacement of slag by 0%, 10%, 20% and 30% and second part of the work focusing the behavior of Light weight ferrocement beam under monotonic load and repeated load with increased load. The results obtained from this work is expected to be useful in determining the strength and ductility of light weight ferrocement beam subjected to similar types of forces and thus will help toward designing ferrocement elements to withstand monotonic and repeated flexural loading.

Keywords: Light weight ferrocement, blast furnace slag (BFS), wire mesh.

1. Introduction

Light weight Ferrocement is a composite material consisting of cement-sand mortar (matrix) reinforced with layers of small diameter wire meshes and BFS. It consists of closely spaced, multiple layers of mesh or fine rods completely embedded in cement mortar. Usually steel bars are used in addition, to form a steel skeleton, which helps in retaining the required shape of the ferrocement components until the cement mortar hardens. It differs from conventional reinforced concrete primarily by the manner in which the reinforcement is arranged within the brittle matrix. Since its behavior is quite different from that of conventional reinforced concrete in performance, strength and potential applications, it is classed as a separate material. Light weight ferrocement has high resistance against cracking; also many of its engineering properties such as toughness, fatigue against resistance, and impermeability etc. are improved when compared to reinforced concrete. In India, light weight ferrocement is used often because the constructions made from it are better resistant against earthquakes. Earthquake-resistance is dependent on good construction technique and additional reinforcement of the cement.

1.1 Earlier works

Investigations related to mechanical properties of ferrocement elements under monotonically with increased loading (Desayi P et. al and Naaman A.E et. al) and fatigues have been
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reported (Balaguru P. et. al., 1951) and some design procedure has been suggested based on the results of such studies. Both first crack and ultimate moment increases with increasing matrix grade (decreasing w/c ratio)( Walkus B.R,1986) and increasing volume fraction of reinforcement have been reported(Suresh G.S et. al., 2007 ). No information has been available on the response of light weight ferrocement structure subjected to monotonic and repeated loading. In this work matrix grade increase and volume fraction is increasing by taken as 6 layer wire mesh and study the behaviour of light weight ferrocement beam.

2. Objectives of the present work

Specific objectives of this paper are as follows:

1. Basic materials testing i.e. Cement, Sand, Blast furnace slag(BFS) and wire mesh.
2. Effect of blast furnace slag on first crack and ultimate strength of the light weight ferrocement beams.
3. Behavior of light weight ferrocement beams under monotonic and repeated flexural loading.

2.1 Materials used and its properties

Cement
Ordinary Portland cement of grade 43 conforming to IS: 8112-1989, which was stored in a cool and dry place before used. Physical properties of cement is found given in the table1.

<table>
<thead>
<tr>
<th>Physical property</th>
<th>Results obtained</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compressive strength 28-days</td>
<td>44.10 N/mm²</td>
</tr>
</tbody>
</table>

Sand
Fine aggregate used in the light weight ferrocement is taken from Narsipura river bed near Kudala sangama. This river sand is totally free from all impurity and organic matters. Experiment physical properties are obtained is shown in table 2.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fineness modulus</td>
<td>2.85</td>
</tr>
<tr>
<td>Density (kN/m³)</td>
<td>1.53</td>
</tr>
<tr>
<td>Water content (%)</td>
<td>0.5</td>
</tr>
<tr>
<td>Specific gravity</td>
<td>2.61</td>
</tr>
</tbody>
</table>

Blast Furnace Slag (BFS)
The blast furnace slag used to replace sand was obtained from Visvesvaraya Iron and Steel Plant, Bhadravathi. It is non-metallic by product of steel manufacturing, consisting essentially of silicates and aluminum silicates of calcium that are developed in a molten condition simultaneously with iron in a blast furnace. It is mixed in different proportions in mortar. The chemical composition of this BFS given by the supplier and the physical properties are found by experiment as shown in table 3 and table 4.
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Table 3: Properties of BFS

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fineness modulus</td>
<td>3.58</td>
</tr>
<tr>
<td>Density (kN/m3)</td>
<td>1.12</td>
</tr>
<tr>
<td>Water content (%)</td>
<td>0.05</td>
</tr>
<tr>
<td>Specific gravity</td>
<td>2.41</td>
</tr>
<tr>
<td>Grading zone</td>
<td>I</td>
</tr>
</tbody>
</table>

Table 4: Chemical Properties of BFS

<table>
<thead>
<tr>
<th>Constituents</th>
<th>Compositions (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO2</td>
<td>30-33</td>
</tr>
<tr>
<td>Al2O3</td>
<td>20-22</td>
</tr>
<tr>
<td>CaO</td>
<td>33-35</td>
</tr>
<tr>
<td>MgO</td>
<td>9-10</td>
</tr>
<tr>
<td>S</td>
<td>Traces</td>
</tr>
<tr>
<td>Others</td>
<td>3-5</td>
</tr>
</tbody>
</table>

Water

Ordinary potable drinking water free from organic matter, silt, oil, sugar, chloride and acidic material was used for mixing.

Wire mesh

Galvanised woven square meshes of 6 x 20 gauge size (0.55 mm average wire diameter at 4.17 mm nominal spacing) have been used. The tensile strength of the mesh is found as 435.86 N/mm².

![Figure 1: View of wire mesh](image)

3. Casting and testing of specimens

Casting specimens
Parameters considered in this study are the percentage of sand replacement and mesh wires. Four percentage of replacing sand by light weight aggregate (L.W.A) viz., 0%, 10%, 20%, and 30% by weight and mesh wires in terms of number of mesh layers per specimen 6 layers is selected by previous experimental study. A total of 24 ferrocement specimens have been cast. 6 specimens were cast at a time of dimension as shown in figure 2 and 4 and using of teak wood moulds as shown in figure 2. The layer of mesh was held in position at required spacing in the moulds by means of suitable aluminum spacers, which were removed while casting. In each casting about 3 mortar cubes 70.6 of mm side were also cast as control specimens. Three cubes were tested for their compressive strength after testing each set of specimens.

![Figure 2: Teak wood mould](image)

**Table 5:** Light Weight Ferrocement Beam details and varying parameters

<table>
<thead>
<tr>
<th>No. of mesh layers</th>
<th>Percentage replacement of B.F.S. of 1:2 cement mortar</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>LMN61-0% LMN62-0% LMN63-0%</td>
</tr>
<tr>
<td>10</td>
<td>LMN61-10% LMN62-10% LMN63-10%</td>
</tr>
<tr>
<td>20</td>
<td>LMN61-20% LMN62-20% LMN63-20%</td>
</tr>
<tr>
<td>30</td>
<td>LMN61-30% LMN62-30% LMN63-30%</td>
</tr>
</tbody>
</table>

![Figure 3: Details of Reinforcement in Specimen](image)
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Testing of Specimen

Figure 4: Details of Demec and Dial Gauge points specimens

In each set three specimens were cast and they were tested under monotonic loading. A jack is used for testing specimens under monotonic loading as shown in figure 3. Two points loading was applied at one fourth span points, ie at 150mm from supports using a mechanical screw jack of 100kN capacity through a distribution steel high beam. Applied load was measured using a proving ring of 50 KN capacities. Deflections and strains on mortar surfaces at various levels across the depth of the specimens in pure flexure zone were recorded during testing of ferrocement elements under monotonic and repeated flexural loading. Deflections were measured at mid points. For measuring deflections at these points, dial gauges of 25mm range with least count of 0.01mm were used. During testing, these dial gauges were reset when the deflection exceeded the range of gauges. Strain on mortar surface of specimens were measured by demec (dемountable mechanical) gauge over demec points fixed to the mortar surface with an adhesive. Surface strains were measured on top and bottom edges of the specimens and at other levels of specimen across the depth. Strain were measured on both the faces of specimen over gauge length of 200mm and least count of demec gauge was 1x10^{-5}.

4. Result and discussion

Behavior of average of three specimens for each percentage of slag replacement under monotonic load, represented by the load-deflection curves show in figure 5

Figure 5: Monotonic Load (N) vs Deflection (mm)
For all the specimens under monotonic loading, the load deflection curves show generally two portions. The first portion is a rising portion up to first crack load and second is horizontal portion near ultimate showing an increase in deflection.

**Figure 6:** Failure of specimens in 10% replacement of BFS

Behavior of average of three specimens for each percentage of slag replacement under repeated load, represented by the load deflection curves show in figure 7

**Figure 7:** Repeated Load (N) vs Deflection (mm)
Form all the specimens under repeated loading, the load-deflection curves shown in figure 7, the 10% of slag replacement specimens carry a more load compare to other replacements & it is felt that increase in stiffness in the initial cycles may be due to the closure of shrinkage cracks present in the specimens before loading. Behavior of average of three specimens for each percentage of slag replacement under monotonic load & repeated loading represented by the moment curvature curves show in figure 8.

Figure 8: Moment vs Curvature
Form all the specimens under monotonic and repeated loading, the moment curvature curves shown in figure 8, the 10% of slag replacement specimens carry a more moment compare to other replacements.

5. Conclusion

Based on the experimental investigations the following conclusions were drawn,

1. It can be observed that, the first crack and ultimate strength increases up to 10% replacement of sand, and then decreases with the increased percentage of sand replacement.
2. The light weight ferrocement specimens having increased wire mesh (Volume fraction) could sustain greater number of repetitions, compared to the plain light weight ferrocement specimens because of their greater strain carrying capacity.
3. Light weight ferrocement beams have good moment of resistant under both monotonic & repeated loading.
4. The mesh wires are found to be more effective in increasing the margin between first crack and ultimate flexural strengths.

6. References


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