Flexural Behavior of Reinforced Concrete Beams with Ferro Cement Lost Forms

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Abstract—The Flexural behavior of reinforced concrete beams with Ferrocement lost forms was experimentally investigated. The test includes six Ferrocement beams and two control beams of M30 grade is used to compare the strength with ferrocement beams. The purpose of study is to observe the performance of the tested beams, modes of failures and so on. Mid span deflection, crack width, crack propagation and crack spacing were measured during the course of test. The Flexural strength properties of these Ferrocement beams are evaluated and compared under the four point Static and Cyclic loading systems. The results shows that the Ferrocement beam can obviously increase the load bearing capacity when compare to the control beam. This performance shows that the Ferrocement lost forms is efficient method in corrosion resistance, weather proofing and esthetic characteristics.

Key words: Ferrocement Lost Forms, Deflection, Crack Width, Flexural Strength, Load Bearing Capacity, Static and Cyclic Loading

I. INTRODUCTION

Ferrocement is a wire mesh reinforcement embedded with mortar. This is durable and efficient material. Due to their thinness, Ferrocement elements can be used as roofing/flooring elements to cover large spans. “Ferrocement is a type of thin wall reinforced concrete commonly constructed of hydraulic cement mortar reinforced with closely spaced layers of continuous and relatively small size wire mesh”. The Endeavour looked as a better idea to prevent shrinkage cracking and control of early thermal contraction right after placing the fresh concrete in the formwork. Concrete is characterized by brittle failure, the nearly complete loss of loading capacity, once failure is initiated. This characteristic, which limits the application of the material, can be overcome by the inclusion of layers of steel meshes. The main objective of this experimental work is to study the behavior of RC beams with Ferrocement under flexural loading in which welded square mesh has been used as reinforcement and copper slag is also used for replacing the Fine aggregate. The Grade of M30 was used. The various parameters considered in this study are as follows :- a) Effect of using 50% of copper slag instead of Fine aggregate b) Effect of using addition of 10% of Microsilica and 40% of GGBS for the replacement of cement. The beam specimens are tested for static and cyclic loading to study their flexural behaviour.

II. MATERIALS

A. Copper Slag

Copper slag is a by-product created during the copper smelting and refining process. As refineries draw metal out of copper ore, they produce a large volume of non-metallic dust, soot, and rock. Collectively, these materials make up slag, which can be used for a surprising number of applications in the building and industrial fields. To produce every ton of copper, approximately 2.2-3.0 tons of copper slag is generated as by-product material and is used as replacement for sand in the construction industry. The blasting media manufactured from copper slag brings less harm to people and environment than sand. The product meets the most rigid health and ecological standards.

B. GGBS

Ground granulated blast furnace slag is one of the greenest of construction materials. It is a non-metallic product consisting essential silicates and aluminates of calcium and other bases. Its only raw material is a very specific slag that is a by-product from the blast furnaces manufacturing iron. GGBS essentially consists of silico and alumino silicates and other bases that are developed in molten condition. The chemical composition of oxides in GGBS is similar to that of Portland cement but the proportions vary. GGBS cement is routinely specified in concrete to provide protection both sulphate and chloride attack.

III. EXPERIMENTAL WORK

The experimental program includes preparing and testing of flat ferrocement slab and ferrocement beam under two-point and four-point loading. The primary variables were the two layers of meshes with different mix proportions and the use of copper slag instead of fine aggregate, addition of microsilica and GGBS for the replacement of cement.

A. Preparation of Mesh

1/2 inch and 1 inch mesh was cut according to the required dimensions. The meshes were straightened using wooden hammers. Hooks were used for tying the bending wires. Slab size of $600*300$ mm were sandwiched together using binding wires of $1$ mm for checking the flexural strength and Beam size of $850*150*100$mm were used.

B. Preparation of Mortar

Mortar was prepared by calculating the exact amount of cement, sand and water by considering the appropriate mix design and water-cement ratio. At first the cement and sand were mixed dry. Water is gradually added to the dry mix and is mixed.

C. Casting

Ferrocement slabs and beams were cast using the mould system. The mortar is applied from one side through several layers of mesh, held in position against the surface of a closed mould. The mould is treated with mould releasing agents. In this method, the mortar is applied from one side.
D. Curing
Ferrocement slabs and Ferrocement beam specimens were cured in a fresh water tank for a period of 28 days. The slabs were laid to rest vertically in the upright position, resting on the longer side and the beams were laid in horizontal position.

IV. TESTING ON FERROCEMENT SLAB
The slab panels were removed from curing tank after a period of 28 days. White wash was applied to the panels in order to get clear indication of cracks due to bending under service loads. Panels were tested for flexural strength under universal testing machine. The panels were placed on support leaving a space of 50 mm from both ends. Dial gauge was placed below the panel to record the deflection in mm each stage of loading. Cracks are then marked during each loading and corresponding central deflection is also noted down.

A. Flexural Strength on Slab

![Fig. 1: Flexure test on Ferrocement slab](image1)

![Fig. 2: Crack pattern on Ferrocement Slabs](image2)

<table>
<thead>
<tr>
<th>S. NO</th>
<th>MIX</th>
<th>F.S 1 (KN)</th>
<th>F.S 2 (KN)</th>
<th>GGBS &amp; M.S (KN)</th>
<th>C.S (KN)</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>1:1.5</td>
<td>4.88</td>
<td>4.08</td>
<td>3.00</td>
<td>2.6</td>
</tr>
</tbody>
</table>

Table 1: Flexural Test Results

V. TESTING ON FERROCEMENT BEAM

A. Materials
The materials used in the mix design were Ordinary Portland Cement (OPC), river sand and potable water. Beam specimens were made with M30 grade concrete Water binder ratio of 0.4 and 0.3% of Glenium B233 superplasticiser was used to impart better workability. Fe 500 grade steel was used for longitudinal reinforcement and for stirrups.

B. Preparation of Ferrocement Beam

![Fig. 3: Beam mould](image3)

![Fig. 4: Mould with ferrocement](image4)

![Fig. 5: Filled with cement mortar](image5)

![Fig. 6: Insert Reinforcement cage](image6)

![Fig. 7: Ferrocement Beam](image7)

C. Test Specimen Details
Two numbers of reinforced concrete beams with Ferrocement lost forms and Normal control beams of
M30grade were cast and tested. The span of the beam was 850 mm and of size 150 mm x 100 mm. Out of the four specimens tested, two specimens were cast with Ferrocement and two specimens were cast with Controlled beams. Four specimens were tested at 28th day from the date of casting. For strengthening the beam Ferrocement beam is compared with the Controlled beam.

D. Test Set-Up

The testing was carried out in a loading frame of 100T capacity. All the specimens were white washed in order to facilitate marking of cracks. Demec gauges were used to measure the strain at compression zone and tension zone and three dial gauges were fixed which is used for measuring deflections at several locations one at mid span, two directly below the loading points which is shown in Figure 8. The beams were subjected to four-point loading under a load control mode. The development of cracks was observed and the crack widths were measured.

![Experimental set-up for the test specimens](image)

E. General Observation

Vertical flexural cracks were observed in the constant-moment region and final failure occurred due to crushing of the compression concrete with significant amount of ultimate deflection. Crack formations were marked on the beam at every load interval at the tension steel level. It was noticed that the first crack always appears close to the mid span of the beam. The crack widths at service loads for ferrocement beam is 2mm. The first crack occur at 45KN load and the failure of the ferrocement beam occurs at 76KN for the static load and for the cyclic load the failure occur at 75KN.

![Crack patterns of Ferrocement Beam](image)

VI. TEST RESULT AND DISCUSSIONS

- Based on the flexural test results, the observed behavior of the Ferrocement beam and slab are as follows.
- The observed ultimate load for cracking of ratio 1:1.5 for Ferrocement Slab are 4.88KN, 4.08KN, 3.00KN and 2.56KN for FS1, FS2, GGBS & Microsilica and Copper slag for Static Loading.
- The observed ultimate load for cracking of ratio 1:1.5 for Ferrocement Beam is 76KN for Static Loading and 75KN for Cyclic Loading.
- The number of cracks developed in slab at first cracking is 4, 2, 3 and 6 for ratio 1:1.5
- The crack spacing at ultimate load for Ferrocement slab are 47mm, 70mm, 120mm and 75mm respectively for the Static Loading.
- The crack width and crack propagation for Ferrocement Beam is 2mm and 134mm and for Controlled Beam is 2.5mm and 140mm.
- The observed ultimate load for Controlled Beam is 59 KN for static loading and 55 KN for Cyclic Loading.

VII. CONCLUSIONS

The Flexural Behavior of Reinforced Concrete Beams with cement mortar Ferrocement Lost Forms has gained more strength of mix ratio 1:1.5 when compared to the Normal Controlled Beams of M30 Grade of mix ratio 1:2.15:3.64.

REFERENCES

