Experimental Study on Ductile Characteristics of Light Weight Ferrocement Beam under Flexural Loading

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Abstract— The main investigation in this research work is to maintain the eco-balance by preventing the open site dumping of the Ground Granulated Blast furnace slag (GGBFS), a by-product in the process of cement production is an industrial waste, causing environmental pollution and prevention of sand mining by the replacement of Slag for fine aggregates in ferrocement. Sand mining has led to the danger of river-course change and causing floods. This replacement has been found to improve the strength characteristics of ferrocement and also makes it lightweight. This not only helps in construction of multi storied structures but also found to maintain thermal comfort. The main investigation is regarding the percentage replacement of sand by GGBFS and reinforcing with meshes. Light weight ferrocement is a composite material consisting of cement-sand mortar (matrix) along with light weight fine aggregate (In this work foamed granulated 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 concentrating on two major aspects, Effect of blast furnace slag on first crack and ultimate strength and Behavior of light weight ferrocement element under flexural loading. The first part of the present study has been focusing on the effect of ground granulated blast furnace slag (GGBFS) on ultimate strength with replacement of slag by 0%, 10%, 20%, 30%, 40% and 50% and second part of the work focusing the behavior of Light weight ferrocement beam with increased load.

Key words: Ferrocement Beam, Flexural Loading

I. INTRODUCTION

Light weight Ferrocement is a composite material consisting of cement-sand mortar (matrix) reinforced with layers of small diameter wire meshes and GGBFS. It consists of closely spaced, multiple layers of mesh or fine rods completely embedded in cement mortar. The mesh may be made of metallic or other suitable materials. Unlike conventional concrete, Ferro cement reinforcement can be assembled into its final desired shape and the mortar can be plastered directly in place without the use of a form which results in a flexible and strong enough ferrocement structures. 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.

In this work we were used Aluminium Powder as a foaming (aerating)agent for making concrete light weight. The density of light weight concrete varies from 300 Kg/m^3 to 1850 Kg/m^3. Aerated concrete is either cement or lime mortar, classified as lightweight concrete

The aim of this project is to investigate the effect of number of wire mesh reinforcement, and the effect of on the Granulated blast furnace slag in ferrocement Beam. This project provides information regarding (i) Deformation characteristics such as Load Deflection, (ii) Ductility factors such as Displacement ductility of ferrocement Beam.

II. OBJECTIVES

Specific objectives are as follows:

- Basic materials testing i.e. Cement, Sand, Granulated blast furnace slag(GGBFS) and wire mesh.
- Effect of blast furnace slag on first crack and ultimate strength of the light weight ferrocement beams.
- Percentage of slag as a replacement of sand in some quantity i.e.,10%,20%,30%,40% and 50%
- To produce aerated concrete with normal lightweight density which is between (1200-1600) Kg/m3
- Behavior of light weight ferrocement beams under flexural loading.

III. MATERIALS AND ITS PROPERTIES

A. Cement:

Ordinary Portland cement of grade 53 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 table 1.

Sl no.	Properties	Results	IS Specifications
1	Specific Gravity	3.08	-
2	Normal consistency	34%	-
3	Initial setting time	40 min	Not less than 30 minutes
4	Final setting time	190 min	Less than 600 minutes

Table 1: Tests on Cement

B. Fine Aggregate:

Good quality zone-II fine aggregate was used the various test results for fine aggregate are as shown in below. This sand is totally free from all impurity and organic matters. Experiment physical properties are obtained is shown in table 2.

Fineness modulus	3.164
Specific gravity	2.66
Bulk density(g/cc)	1.49

Table 2: Tests on Sand

C. Ground Granulated Blast Furnace Slag (GGBFS):

The blast furnace slag used to replace sand and it is obtained from JSW Bellary. It is non-metallic by product of steel manufacturing, consisting essentially of silicates and aluminium silicates of calcium that are developed in a molten condition simultaneously with iron in a blast furnace.

Constituents	Composition(%)

SiO_2	30-33
Al_2O_3	20-22
CaO	33-35
MgO	9-10
S	Traces
Others	3-5

Table 3 Tests on GGBFS:

Fineness modulus	3.93
Specific gravity	3.02
Bulk density(g/cc)	1.39

Table 4: Chemical Properties of GGBFS

D. *Aluminum Powder:*

The aluminium powder has been used as the gas-forming agent in producing slag cement based aerated lightweight concrete. The range of Al. Powder varies from 0.25% to 0.5% (99.7% pure) by weight of cement. We were taken 0.5% by weight of cement.

Specification	No.300	Aluminum	Min.99.3
Colour	Silver	Copper	Max.0.1
Particle size	Mesh 250	Iron	Max.0.4
Reactivity of Aluminum(%)	-	Silica	Max.0.2

Table 5: Specification and chemical composition of Aluminum powder

E. *Wire Mesh:*

Fig. 1: View of wire mesh

Galvanised woven square meshes of 4 x 22 guage size (0.55 mm average wire diameter at 4.17 mm nominal spacing) are used. Welded wire mesh is made out of straight wires in both the longitudinal and transverse directions. The tensile strength of the mesh is found as 435.86N/mm^2.

IV. METHODOLOGY

A. *Mix Compositions for Cubes:*

In this study, the experimental work has been carried out by keeping cement to sand (c/s) ratio constant i.e.,1:2 throughout the experiment. In this study the laboratory trials i.e.,based on compressive strength were carried out to determine an optimum water-to-cement (w/c) ratio within the range of 0.48 to 0.54. In this study the percentage of Aluminum powder has been used for making the foamed concrete. For fixing up the w/c ratio, the different percentage of Aluminum powder by weight of cement has been varied from 0.3% to 0.5%.

B. *Cube Specimens Preparation:*

A pre-foaming (dry) method was adopted to prepare foamed mortar. Mortar slurry was first prepared by mixing together the constituent materials of cement,GGBFS,sand, and water. The target density of the produced foamed mortar was 1200 ± 50 kg/m3.The fresh foamed mortar was poured into cube moulds with dimensions of 70.6*70.6*70.6 mm. After 24 h of casting, the specimens were demoulded and subjected to curing for 28 days until the day of testing. And these cubes are tested in the Universal Testing Machine(UTM) for compressive strength. The cubes of size 70.6*70.6*70.6mm, without foaming agent(Aluminum powder) were also casted for knowing the compressive strength but w/c ratio has been varied from 0.48 to 0.54. The compressive strength for a w/c ratio 0.48 and 0.5 without foaming agent gives more than other ratios. The compressive strength for an w/c ratio 0.5 gives the 4.25% and 11.56% more than that of the w/c ratios 0.52 and 0.54 respectively. So that we selected w/c ratio 0.5 as the optimum for our project work.

W/C	Percentage of Aluminum Powder					
	0.3		0.4		0.5	
	Compressive strength(N/mm^2)	Density in Kg/m^3	Compressive strength (N/mm^2)	Density in Kg/m^3	Compressive strength (N/mm^2)	Density in Kg/m^3
0.48	8.38	1143	8.53	1147	8.68	1196
0.5	9.03	1297	9.24	1280	9.89	1277
0.52	8.87	1287	8.69	1332	8.82	1183
0.54	8.3	1166	8.21	1197	8.52	1200

Table 6: Showing the cube compressive strength and density for different % of Al.powder

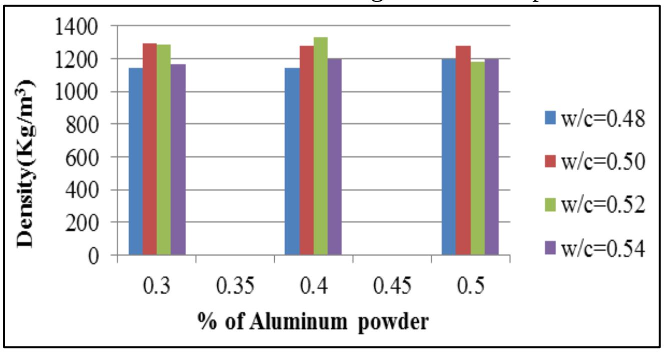

Fig. 2: Graph showing the density of aerated cubes for different water to cement ratio

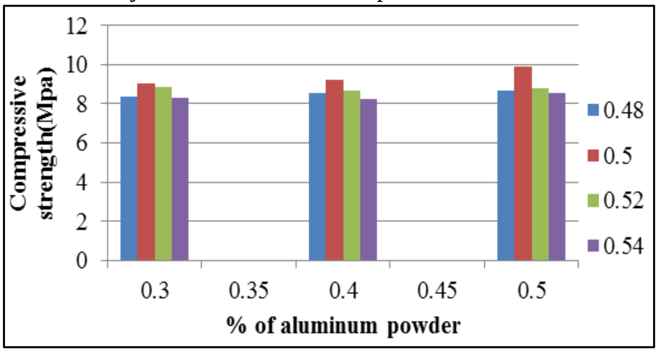

Fig. 3: Graph showing % of Aluminum powder Vs compressive strength for different w/c ratios

C. Casting of Beams:

Mortar used in this work has a mix proportion of cement to sand as 1:2 by weight with water-cement ratio of 0.5. The proportion of mortar is used in this work based on workability and cube strength of the mortar. For making concrete light weight Al.powder has been used in the mortar and which is taken 0.5% by weight of cement.

Parameters considering in this study are the percentage of sand replacement and mesh wires. Six percentage of replacing sand by light weight aggregate (L.W.A) viz.,0%,10%,20%,30%, 40% and 50% by weight and mesh wires in terms of number of mesh layers per specimen 4 layers and 6 layers. A total of 12 ferrocement specimens have been cast. All specimens have a dimension of 100mm X1000mm with a thickness of 50mm each. The thickness of beam were kept constant and the parameters such as number of layers of wire mesh reinforcement (4 and 6 layered reinforcement), and the concrete mix with and without granulated blast furnace slag (0 and 50%). Specimens have been cast by using metal mould as shown in figure4.

Sl.no	Sand	GGBFS	Avg. Comp. strength(Mpa)
1	100%	--	7.35
2	90%	10%	9.75
3	80%	20%	9.42
4	70%	30%	8.71
5	60%	40%	7.41
6	50%	50%	7.11

Table 7: Showing the characteristic compressive strength for cubes for w/c ratio 0.5 by using Al. powder

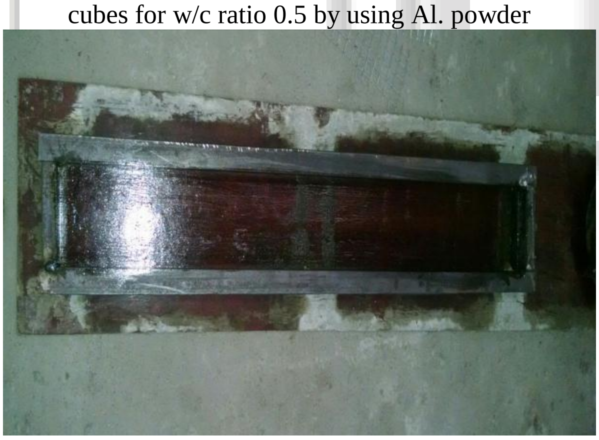

Fig. 4: Metallic Mould

Fig. 5: Casted Specimen

All the specimens are to be tested in a loading frame, which is fixed over a strong floor. The beams are simply supported with an effective span of 600mm c/c. Two point loading is applying transversely at one third distances from the support using a cross beam. Along with it, 25kN capacity proving ring will be using for the load application. Dial gauge of sensitivity 0.01mm will be using to measure the deflection of the beams. The dial gauge will be keep at mid span of the beam .During testing, these dial gauge will be reset when the deflection exceeded the range of gauge.

V. TESTING OF SPECIMEN

Fig. 6: Load and Dial Gauge Point Specimen

VI. FAILURE OF SPECIMENS

A. Cracking Behavior

All the Beams exhibit a fairly ductile behavior and the failure pattern is as shown in Figure: 8.1. The failure of Beam specimens results from the yielding of wire mesh reinforcement followed by the crushing of concrete. Initially fine flexural cracks appeared at the bottom of the specimen, with further increase in the load, regularly spaced vertical cracks were observed and they extended from the bottom of the specimen towards the top fibre. The load was increased up to ultimate stage and cracking pattern is observed.

Fig 7: Showing Cracking And Failure Pattern

VII. TEST RESULTS

sl. No.	Specimen designation	Load in KN		Deflection in mm			Ductility factor	Moment(KN-m)	
		Cracking (Wcr)	Ultimate (Wu)	Yield (d1)	Ultimate (du)	0.85*Wu (d2)	M_d=(d2/d1)	Cracking (Mcr)	Ultimate (Mu)
1	0%	2	4	1.04	2.14	3.4	3.26	0.15	0.3
2	10%	5	6	2.40	3.34	5.10	2.12	0.375	0.45
3	20%	3	5	1.80	2.6	4.25	2.36	0.225	0.375
4	30%	3	4	1.80	2.6	3.4	1.88	0.225	0.3
5	40%	3	4	1.6	2.4	3.4	2.12	0.225	0.3
6	50%	3	4	1.6	2.4	3.4	2.12	0.225	0.3

Table 8: Experimental values under flexural loading for 4 layer wire mesh

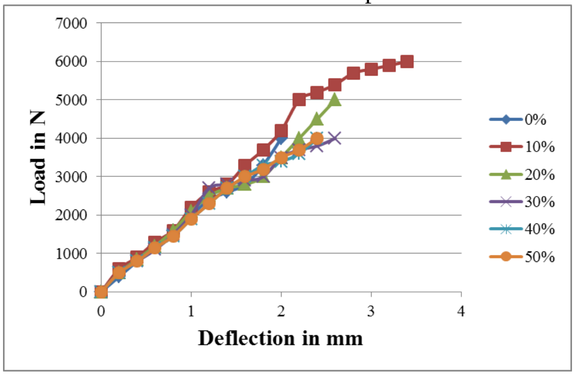

Fig 8: Graph showing the Load (N) Vs Deflection (mm) for 4 layered wire mesh

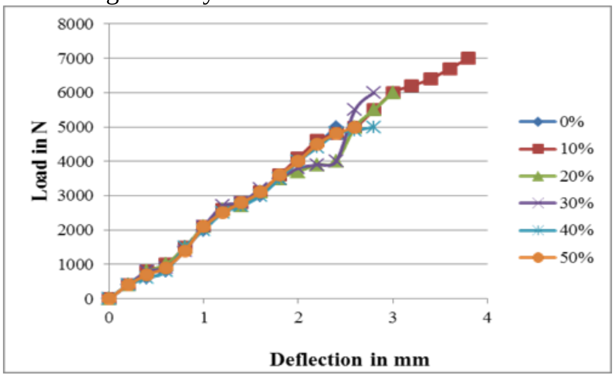

Fig. 9: Graph showing the Load (N) Vs Deflection(mm) for 6 layered wire mesh

sl. No.	Specimen designation	Load in KN		Deflection in mm			Ductility factor	Moment(KN-m)	
		Cracking (Wcr)	Ultimate (Wu)	Yield (d1)	Ultimate (du)	0.85*Wu (d2)	M_d=(d2/d1)	Cracking (Mcr)	Ultimate (Mu)
1	0%	3	5	1.5	2.5	4.25	2.83	0.225	0.375
2	10%	6	7	3	3.8	5.95	1.98	0.45	0.525
3	20%	4	6	2.3	2.9	5.1	2.21	0.3	0.45
4	30%	4	6	2.3	2.9	5.1	2.21	0.3	0.45
5	40%	4	5	2.1	2.7	4.25	2.02	0.3	0.375
6	50%	4	5	2.1	2.7	4.25	2.02	0.3	0.375

Table 9: Experimental values under flexural loading for 6 layer wire mesh

VIII. DISCUSSIONS

- From table 6 the compressive strength for w/c=0.5 and also for 0.5% of AL. Powder gives 12.23%,10.81%,and 13.85% more than that of the water to cement ratios 0.48,0.52 and 0.54 and also we reached our target density 1200kg/m3.
- From table 7 the compressive strength for w/c=0.5 by using Al. Powder for 10% and 20% replacement of GGBFS gives 25% more than that of the 0% replacement of GGBFS.
- From table 8 the 10% and 20% replacement of GGBFS carries more load and good moment carrying capacity.
- From table 9 the 10% replacement of GGBFS carries more load and good moment carrying capacity and 10% replacement of GGBFS exhibit lowers ductility ratios.

IX. CONCLUSIONS

- Replacement of GGBFS helps in reducing weight of the structure and thus improving its earthquake resistance. Use of GGBFS also avoids environmental hazards due to open dumping of GGBFS and overuse of natural sand which has led to serious problems at the river beds and delta regions. It also improves the thermal comfort in the building.
- By using GGBFS as a replacement of sand for the preparation of concrete as they are waste and economical to use.
- The compressive strength of the 10% replacement of GGBFS mortar is about 25% higher than that of the 0% replacement of GGBFS.
- Replacement of 10% of GGBFS has shown increase in crack and ultimate strength and other of 20%,30%,40% and 50% of GGBFS has shown decrease in marginal.
- Increase in percentage of aluminum powder in making aerated concrete decreases the density of mortar so 0.5% is the optimum value to reach our target density 1200kg/m^3.
- The ultimate strength of ferrocement beams increases with the increase of number of mesh layers for all replacement percentage of GGBFS used.
- The ductility ratio for 10% replacement of GGBFS shows lower value for both 4 layered wire mesh and 6 layered wire mesh than that of the other replacements 20%,30%,40% and 50% of GGBFS used.
- The GGBFS ferrocement beams also show a good load carrying capacity.

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