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Experimental Study on the Ductile Characteristics of Light Weight Ferrocement Beams under Monotonic and Repeated Loading

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ABSTRACT: Light weight ferrocement elements are generally more ductile when compared to conventional reinforced Earthquake-resistance is dependent on good construction technique and additional reinforcement of the cement.The present work is concentrated on two major aspects, (i) Effect of blast furnace slag on crack & ultimate strength and (ii) 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 First crack & Ultimate Strength with replacement of slag by 0%,10%,20%&30% and second part of the work focusing the behavior of Light weight ferrocement beam under monotonic & Repeated loads with increased load for ductility performance. 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 for ductility performance.

KEYWORDS: Light weight ferrocement Beams, Blast furnace slag & Wire mesh.

I.INTRODUCTION

Light weight Ferro cement is a composite material made up of cement mortar and reinforcement in the form of layer of mesh. 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.

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.From the structural point of view, the conventional reinforced concrete materials are much used for load carrying elements when compared to the ferrocement materials due to lack of elaborate investigation works on the ferrocement materials and its use as a structural elements. One such area to be investigated for ferrocement elements are its ductility characteristics. Ductility is the ability of a structural member to absorb energy is an important factor which affects the overall performance of structural elements. This paper discusses the load vs. deflection characteristics, displacement ductility capacity of ferrocement Beam.

II. MATERIALS AND METHODS (RESEARCH SIGNIFICANCE)

Light weight Ferrocement elements are generally more ductile when compared to the conventional reinforced concrete elements due to the fact that, reinforcement is uniformly distributed over the entire section of the elements. But the post peak portion of the load- deflection curve of bending test of ferrocement elements reveals that the failure occur either due to mortar failure in compression or due to the failure of extreme layers of mesh . So, an attempt has been made to study the ductility behavior of ferrocement Beam with the ferrocement concrete materials and Blast furnace slag. It was also found that the increase of volume fraction of wire mesh reinforcement as a layer evenly distributed reinforcements has an influence on the load carrying capacity and cracking behavior of the ferrocement elements. The purpose of this paper is to investigate the effect of number of wire mesh reinforcement, and the effect of on the Blast furnace slag in ferrocement Beam. This paper provides information regarding (i) Deformation characteristics such as Load Deflection, (ii) Ductility factors such as Displacement ductility of ferrocement Beam.

III.EXPERIMENTAL INVESTIGATION

Variable Parameters

The primary variables considered in the Work included i) Number of Layer of square mesh reinforcements 4layers(2+2) and ii)Effect of Blast furnace slag in concrete by replacing sand by 0%, 10%,20%&30%. Under monotonic and repeated loading.

Test specimens

A total of 24 Number of specimens of Light weight ferrocement Beams were cast and are tested. 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 layered reinforcement), and the concrete mix with and without Blast furnace slag (0 and 30%). The specimens were designated as show in Table 1 shows the details of the varying parameters used in the Ferrocement Beam in the present investigation work. The supplementary specimens such as each three numbers of 70.6mm cubes with and without the Blast furnace slag were cast along with the Ferrocement Beams specimens and are tested for its compressive strength. Table: 2 gives the characteristic compressive strength of the 70.6mm size cubes .

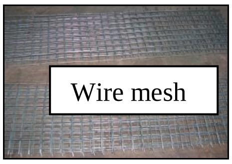
Table 1 : Ferrocement Beam details and varying parameters

No. of mesh layers	**Percentage replacement of B.F.S. of 1:2 cement mortar**			
	0	**10**	**20**	**30**
4	LMN41-0% LMN42-0% LMN43-0%	LMN41-10% LMN42-10% LMN43-10%	LMN41-20% LMN42-20% LMN43-20%	LMN41-30% LMN42-30% LMN43-30%
4	LRP41-0% LRP42-0% LRP43-0%	LRP41-10% LRP42-10% LRP43-10%	LRP41-20% LRP42-20% LRP43-20%	LRP41-30% LRP42-30% LRP43-30%

Table: 2 Characteristic compressive strength

SL.No	**Cube ID**	**BFS (%)**	**Average Compressive Strength (N/mm^2)**
1.	0% C1-3	0	45.41
2.	10% C1-3	10	64.82
3.	20% C1-3	20	56.12
4.	30% C1-3	30	45.02

Materials used and its properties



Cement

Table-3 Physical Properties of Cement

Physical property	Results obtained	IS specifications
Standard consistency (%)	30	Not specification
Initial setting time	45 mins	Not less than 30 mins
Final setting time	434 mins	Less than 600 mins
Fineness of cement	1.95%	Not more than 10%
Specific gravity	3.14	3.15
Compressive strength 28-days	44.10 N/mm2	43.0 N/mm2

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.

Table-4 Properties of Sand

Fineness modulus	2.85
Density (kN/m^3)	1.53
Water content (%)	0.5
Specific gravity	2.61

Table-5 Properties of BFS

Fineness modulus	3.58
Density (kN/m^3)	1.12
Water content (%)	0.05
Specific gravity	2.41
Grading zone	I

Water: Ordinary potable water was used for mixing. The mixing water should be fresh, clean, and potable.

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 as shown in Tables.

Table-6 Chemical Properties of BFS

Constituents	Compositions (%)
SiO_2	30-33
Al_2O_3	20-22
CaO	33-35
MgO	9-10
S	Traces
Others	3-5

Wire mesh

wire meshes have square openings 4x22 gauge (0.55 mm average dia at 4.17 mm c/c) are used. Meshes with square openings are available in welded or woven form. Welded-wire mesh is made out of straight wires in both the longitudinal and transverse directions.

CASTING & TESTING OF SPECIMEN

Casting of specimens

Parameters considered in this study are, the percentage of sand replacement and mesh wires. Four percentages of replacing sand by lightweight aggregate (L.W.A.) viz., 0%, 10%, 20% and 30% by weight and mesh wires in terms of number of mesh layers per specimen viz., 4 layers(2+2). A total of 24 ferrocement specimens have been cast. 3 specimens were cast at a time of dimension as shown in fig 2 & 3, using of teak wood moulds as shown in Fig 1. 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. A plate vibrator was used for compacting the specimens. Moulds were dismantled 24 hours after casting and cured under water up to age of 28 days. After curing the specimens were removed from water and kept in a cool and dry place till they were tested. All the specimens were white washed before applying the load to notice the cracks clearly. Three cubes were tested for their composition strength after testing each set of specimens in each group.

Instrumentation and Loading Procedures

All the specimens were tested in a 25kN- loading frame, which is fixed over a strong floor. The beams were simply supported with an effective span of 600mm c/c. Two point loads were applied transversely at one third distances from support using a cross beam. Along with it, 25kN capacity proving ring was used for the load application. Dial gauges of sensitivity 0.01mm were used to measure the deflection of the beams. The dial gauges were kept at mid span of the beam and other two were kept at one third distances from supports. In addition to deflectometer, the curvature meter was fixed at a specific gauge distance so as to measure the top and bottom strains. The behaviour of the beams was keenly observed from the beginning till collapse. The propagation of initial cracks due to the increase of load was also recorded. The loading was continued till the verge of collapse.

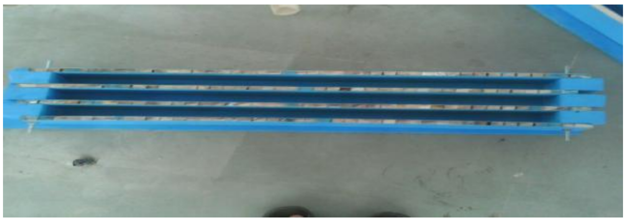


Fig.1 Teak wood mould

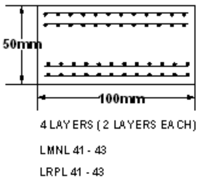


Fig 2 Details of Reinforcement in Specimen(2+2)

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Testing of Specimens

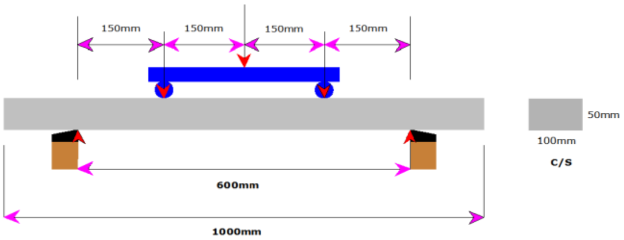

Fig 3 load & Dial Gauge points specimens

In each set six specimens were cast, out of which three specimens were tested under monotonic loading and other three under repeated loading. A reaction frame was fabricated for testing specimens under monotonic and repeated load as shown in figure 3.The specimen was seated in between two supports spaced 600mm apart canter to canter in reaction frame. Loading was applied from top upwards such that the tension face of specimen is on bottom as shown in fig 3. This was done to facilitate marking of cracks in the flexure zone. Rubber padding was used both that supports and at load points, to ensure that the load was applied uniformly across width of the specimen. Loads were applied at one fourth span points, ie at 150mm from supports using a mechanical screw jack of 250kN capacity through a distribution steel high beam shown fig 3.Applied load was measured using a proving ring of 50KN capacity.

TEST RESULTS AND OBSERVATIONS

Load vs. Deflection curves

Behavior of Average of three Specimens for each percentage of Blast Furnace Slag replacement under monotonic load, represented by the load deflection curves show in fig 4

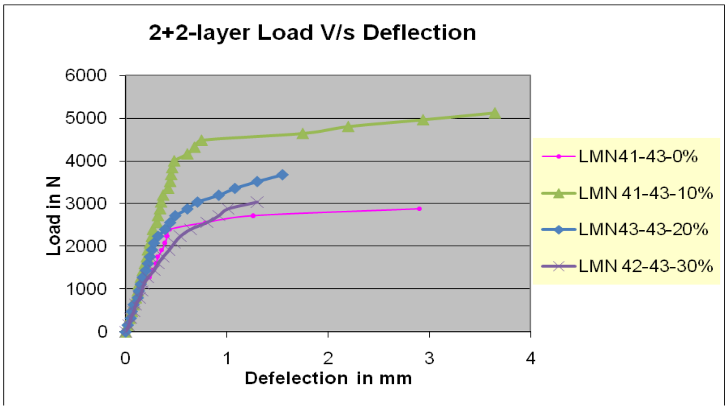

Fig 4: Load Vs Deflection

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. & second is horizontal portion near ultimate showing an increase in deflection.

Fig 5 – Failure of Specimens in 0% replacement of BFS

Cracking behaviour

All the Beams exhibit a fairly ductile behavior and the failure pattern is as shown in Figure: 5 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.

Behavior of Average of three Specimens for each percentage of Blast Furnace Slag replacement under repeated load, represented by the load deflection curves show in fig 6

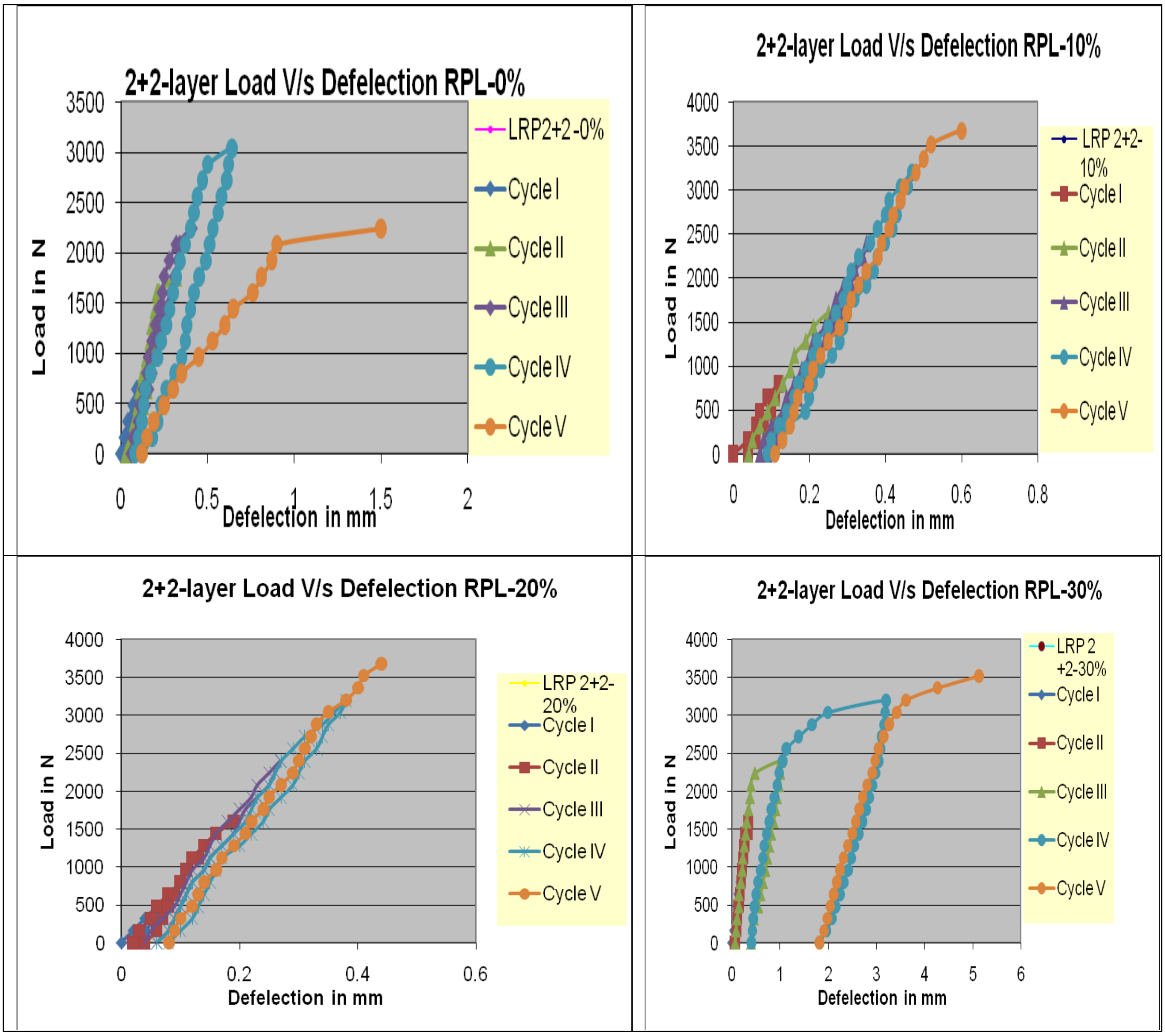

Fig 6: Repeated Load (N) Vs Deflection(mm)

Form all the specimens under repeated loading, the Load-Deflection curves shown in fig6, 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

DUCTILITY PERFORMANCE

The ability of a member to deform without a significant loss of its strength is known as ductility. One method of quantifying ductility is by using the ductility factor (displacement ductility index) as defined by the ratio of ultimate deflection to the deflection at yielding of tensile reinforcement and the ratio of ultimate curvature to the curvature at yielding. Ductility Index, based on the failure state, where the failure load may be considered as equal to 85% of the ultimate load in the descending part of the load- deflection curve, is also of interest in some cases, especially in seismic design. The displacement ductility factors based on yielding of steel and ultimate stage are shown in Table: 7 & Table: 8. It can be seen that displacement ductility factor varied from 4.32 to 6.6 and varied from 6.4 to 7.2 for ferrocement Beams under monotonic & repeated load respectively. From the test results, the Beam with the 10% BFS exhibits lowers ductility ratios.

T able: 7 Experimental result values under monotonic loading

SL No	**Specimen Designation**	**Load at (N)**		**Moment in (N-m)**		**Deflection in mm**			**Ductility factor(Md) =(d2/d1)**
		Cracking (Wcr)	**Ultimate (Wu)**	**Cracking (Mcr)**	**Ultimate (Mu)**	**Yield (d1)**	**Ultimate (du)**	**0.85 *Wu(d2)**	
1	LMN41-43-0%	2560	2880	192	216	0.22	0.79	2.9	13.08
2	LMN41-43-10%	3680	5120	276	384	0.34	1.75	2.2	6.4
3	LMN41-43-20%	3040	3840	228	288	0.28	1.55	2.55	9.02
4	LMN41-43-30%	2720	3680	204	276	0.27	1.68	3.52	12.64

Table: 8 Experimental result values under Repeated loading

SL No	**Specimen Designation**	**Load at (N)**		**Moment in (N-m)**		**Deflection in mm**			**Ductility factor(Md) =(d2/d1)**
		Cracking (W_{cr})	**Ultimate (W_u)**	**Cracking (M_{cr})**	**Ultimate (M_u)**	**Yield (d_1)**	**Ultimate (d_u)**	**0.85 *Wu(d_2)**	
1	LRP41-43-0%	2240	2560	168	192	0.19	0.97	1.32	6.69
2	LRP41-43-10%	2560	4640	192	348	0.31	0.54	0.88	2.82
3	LRP41-43-20%	2240	3520	168	264	0.26	0.71	1.08	4.16
4	LRP41-43-30%	2080	3200	156	240	0.24	0.9	1.34	5.53

IV.CONCLUSION

From the results of the experimental study reported herein, the following conclusions can be drawn.

1. The compressive strength of the 10 % replacement of BFS mortar is about 30% higher than that of the conventional mortar.
2. Replacement of 10% of BFS has shown increase in crack & Ultimate strength and other replacement of 20 % and 30 % of Blast furnace slag has shown decreases in marginal.
3. The light weight ferrocement specimens could sustain greater number of repetitions.
4. The 30% replacement BFS light ferrocement Beams shows the same ductility ratio than that of the conventional ferrocement Beams. & Beam with the 10% BFS exhibits lowers ductility ratios.
5. The BFS ferrocement Beams also show a good load and moment carrying capacity

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