



Studies on Light Weight Ferrocement Subjected to Axial Tension

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Abstract: Blast furnace slag, an industrial waste, causes environmental pollution due to the disposal by open site dumping. Slag has been utilised along with ferrocement to improve the strength characteristics. The main purpose of this work is to investigation effect of percentage replacement of sand by Blast Furnace Slag (BFS) and reinforcement with meshes under monotonic tensile loads. Encouraging results are obtained by the different combinations of these parameters. It has been observed that replacement of BFS increases the ultimate strength up to a certain value and later decreases with increase in replacement. Studies on lightweight ferrocement with sand replaced by foamed blast furnace slag (BFS) subjected to tension under slow cyclic loading have not been come across in literature. Hence it has been proposed to investigate on the stress-strain characteristics of lightweight ferrocement in tension. Further, ultimate strength is observed to vary directly with mesh content. In addition, the weak planes are generated normal to the mesh layer (as the tensile loading is done parallel to the mesh layer). The experimental results are plotted and analysed. This paper is proposed to increase the academic aspects in the field of ferrocement, which is scarce, in particular with blast furnace slag.

I. Literature Review

Application of Ferrocement to low cost housing has been receiving considerable attention recently [1]. A number of investigators have made experiments and analytical studies on normal ferrocement subjected to tension [2, 3, 4, 5, 6, 7 and 8]. These studies mainly attempt to determine the first crack strength, ultimate strength, modulus of elasticity, spacing and width of cracks and the influence of mesh wires on some of these properties. Application of lightweight ferrocement to housing was considered to increase the esthetics of structures due to its sleek design and thermal comforts.

Very few literature is available on lightweight ferrocement (sand replaced by foamed blast furnace slag) subjected to monotonic tensile load. Hence it has been proposed to investigate on the stress-strain characteristics of lightweight ferrocement subjected to monotonic tension. These results are expected to enhance the better understanding of the tensile behaviour of lightweight ferrocement and in the design of such members subjected to tensile forces.

Work on lightweight ferrocement subjected to monotonic and cyclic loading under compression has been reported by the authors [9, 10,11]. This paper presents some analysis of some experimental results with respect to BFS ferrocement specimens under monotonic tensile loading.

II. Experimental Work

Materials used: Ordinary Portland cement (43 grade), Blast furnace slag, River sand, wire meshes.

Table 1: Properties of the Materials used

Composition	% Present	Properties	BFS	River Sand
SiO ₂	30-33	Density (kN/m ³)	1.12	1.62
Al ₂ O ₃	20-22	Fineness modulus	4.90	2.78
CaO	33-35	Water absorption (%)	13.37	9.23
MgO	9-10	Specific gravity	2.36	3.28
S	Traces			
Others	3-5			

Blast furnace slag (BFS): The blast furnace slag used to replace sand is mixed in different proportions in concrete. The Physical properties of the river sand and lightweight aggregate (LWA) evaluated in the Laboratory and chemical compositions of LWA given by the supplier are as follows:

Wire meshes: Galvanised woven square meshes of 4 x 20 gauge size (0.78 mm average wire diameter at 6.35 mm nominal spacing) have been used and the stress-strain curve of GI wire mesh as shown in Fig 1

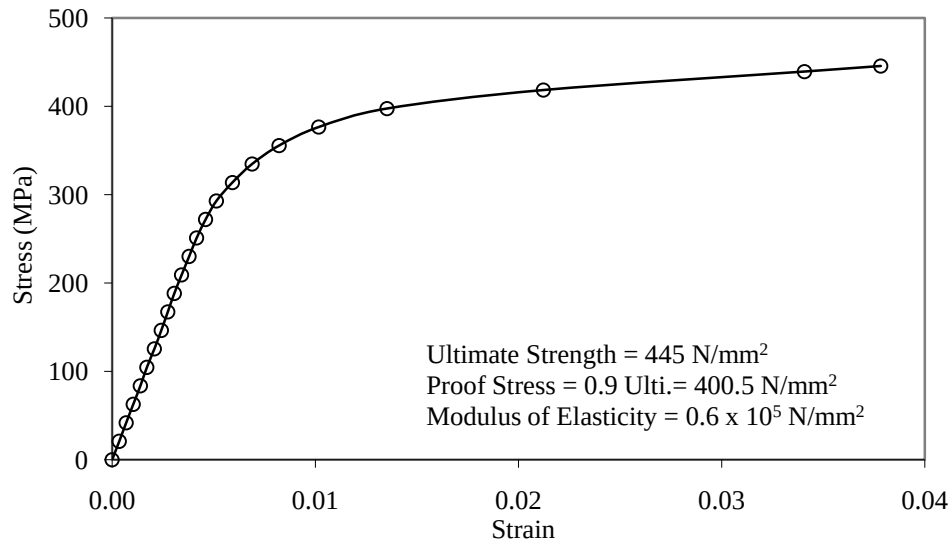


Fig. 1 - Stress-Strain Curve for GI wire under monotonic loading

Test specimens: The shape and size of the test specimens used in this study has a uniform thickness of 50mm and a width of 50mm constant over its central length of 300 mm. The width uniformly increases to 95 mm at each end over a length of 100 mm and the increase is “streamlined”. The ends of the specimen are 95 mm x 50 mm constant over a length of 100 mm. It was subsequently noticed that the “Streamlined shape” closely agreed with the one arrived at from an analytical study.

Casting of specimens: Parameters considered in this study are, the percentage of sand replacement and volume fraction of mesh wires. Four typical values of replacement of sand by lightweight aggregate (L.W.A.) viz., 0.0%, 20%, 35% and 70% by weight and five volume fractions of mesh wires in terms of number of mesh layers per specimen viz., 0, 2, 4, and 6 layers were considered. The different combinations of these parameters resulted in 16 different specimens Mortar used in this investigation had a mix proportion of cement to sand of 1:2 by weight with water-cement ratio of 0.50 and while casting the mesh layers were placed in the test specimen parallel to the direction of loading. Specimens were cast with suitable spacers were used in order to achieve uniform distribution for the wire mesh layers throughout the specimen thickness. Compaction was done by using vibrating table. On the basis of the percentage of sand replacement and volume fraction of mesh wire, specimens were cast in 16 groups. With each casting, 3 control cubes (a total of $16 \times 3 = 48$) of 70 mm nominal size were cast for the purpose of normalization.

Testing of specimens

The specimens were tested under slow cyclic loading; the unloading points were selected such that the intervals of 0.4Pu, 0.6Pu, 0.8Pu and if possible at Pu, Where Pu is the ultimate load carrying capacity of the specimen. Suitable steel frames were attached to the specimen at 200 mm gauge length. Tensile deformations were measured in gauge length by specially cast extensometer shown in plates 5.2 and 5.3, two dial gauges fixed between steel frames around tensile test specimen. For holding the specimens, friction grip bolts are used. These grip bolts have the advantages of applying tensile force without eccentricity and minimising stress concentration at the grips. To avoid slipping of specimen initially clamps were used to hold the grips against the face of the specimen and they are retained till the end of test. The shape of the specimen used and the grips adopted ensure the application of axial tensile force and failure of specimen in the central test section of 300 mm long, 50 x 50 mm cross section. The whole assembly of specimen with steel frames and the friction grips are held in between the cross heads of a universal testing machine. The load was applied in steps of 200 N for plain specimens and of 400 N for other specimens and strain readings were recorded.

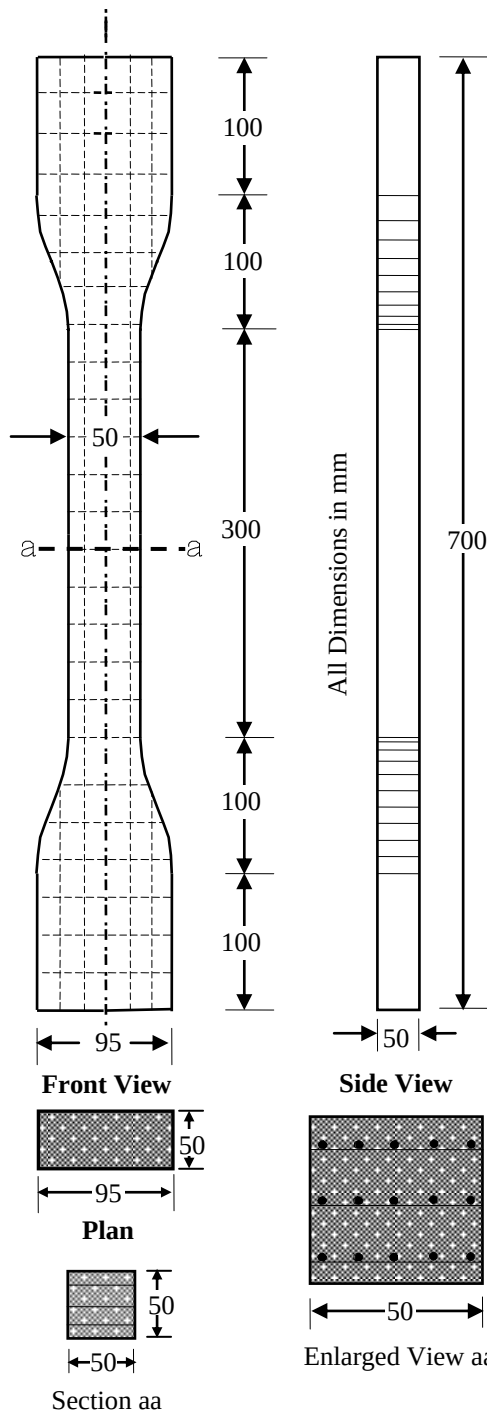
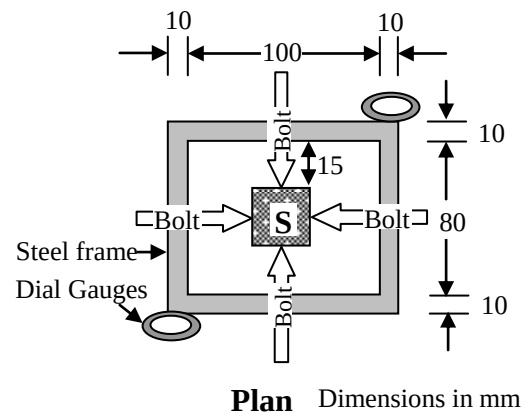


Fig. 2. Test Specimen



Plan Dimensions in mm

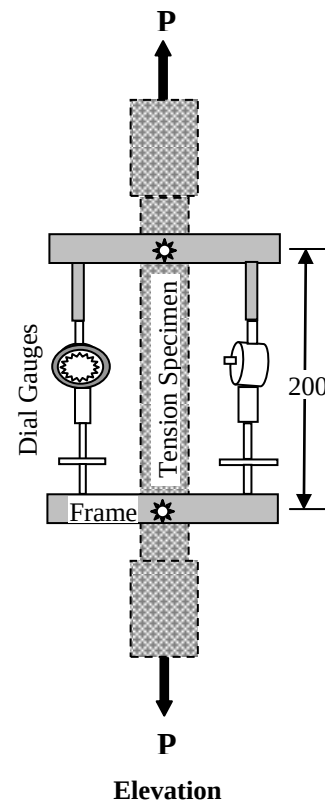


Fig. 3. Extensometer

During testing strains, crack pattern and ultimate load were recorded. Since the strains were measured on the two sides of the specimen, the average of the two dial gauge readings at each stage of loading was taken to represent the deformation between the gauge points of the specimen. (Experimental values of the ultimate tensile strength of the specimen σ_w , and strain at ultimate ϵ_{cu} , are given). Companion cubes were tested in compression and their compressive strengths σ_{cu} have been calculated and given in table-5.3

Suitable steel frames are attached to the specimen at 200mm gauge length. Tensile deformations were measured in gauge length by specially designed extensometer, two dial gauges fixed between steel frames around tensile test specimen. Friction grip bolts are used to hold the specimens to have the advantage of applying tensile force with out eccentricity and to minimise stress concentration at the grips. To avoid slipping of specimen, clamps were used to hold the grips against the face of the specimen. The shape of the specimen

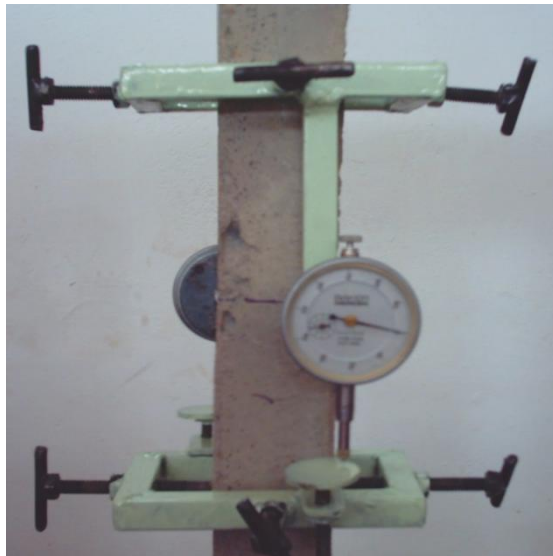


Plate 1. Arrangement of Test Specimen



Plate 2. Tension test specimen in UTM

used and the grips adopted ensure the application of axial tensile load and failure of specimen at the central test-section. The whole assembly of specimen and steel frames is as shown in Fig 3. The friction grips are held in between the cross heads of a universal testing machine. The load is applied in steps of 200 N for plain specimens and of 400 N for other specimens and strain readings are recorded as shown in plate 1 & 2. Crack pattern and ultimate load are also recorded. Since the strains were measured on the two sides of the specimen, the average of all the two readings at each stage of loading was taken to represent the deformation between the gauge points of the specimen.

Table 1 - Experimental Values of Specimens Tested in Monotonic Tension

Sl. No.	Designation of Mix	Ult. Ten. Stress of Wire (σ_{su}) N/mm ²	Volume Fraction of Mesh = $V_f \times 10^{-2}$	Control Cubes		Test Specimens		Normalised Value = $\frac{\sigma_{tu}}{\sqrt{\sigma_{cu}}}$
				Ultimate load (kN)	Ultimate Stress (σ_{cu}) N/mm ²	Ultimate Tensile Load (kN)	Ultimate Tensile Stress (σ_w) N/mm ²	
1	2	3	4	5	6	7	8	9
1	A 0-0	445	0.000	245.00	49.00	4.25	1.70	0.24
2	A 0-2		0.235	248.80	49.76	7.35	2.94	0.42
3	A 0-4		0.475	242.50	48.50	8.50	3.40	0.49
4	A 0-6		0.707	247.00	49.40	10.50	4.20	0.60
5	A 20-0	445	0.000	210.00	42.00	4.50	1.80	0.28
6	A 20-2		0.235	207.50	41.50	7.15	2.86	0.44
7	A 20-4		0.475	205.00	41.00	8.40	3.36	0.52
8	A 20-6		0.707	204.00	40.80	9.90	3.96	0.62
9	A 35-0	445	0.000	148.00	29.60	3.60	1.44	0.26
10	A 35-2		0.235	150.50	30.10	5.80	2.32	0.42
11	A 35-4		0.475	157.00	31.40	7.15	2.86	0.51
12	A 35-6		0.707	157.50	31.50	8.45	3.38	0.60
13	A 70-0	445	0.000	125.00	25.00	2.75	1.10	0.22
14	A 70-2		0.235	125.20	25.04	5.20	2.08	0.42
15	A 70-4		0.475	126.00	25.20	6.10	2.44	0.49
16	A 70-6		0.707	124.50	24.90	7.25	2.90	0.58

III. Results and Discussions

Mode of Failure and Cracking of Specimens

Failure of the plain specimens (without wire mesh and sand replacement) has occurred within the gauge length. This implies that, the use of streamlined specimens and friction grips working on the lazy tone principle has worked satisfactorily. In case of specimens with wire meshes, the load was applied in a direction parallel to the mesh layers, the cracks always appeared either in the normal or near normal direction to the loading as shown in plate 3.

Effect of BFS on ultimate strength:

The effect of sand replacement by BFS on ultimate strength is shown in Fig. 4. For all wire mesh contents used in this investigation, replacement of 20% of BFS has shown increase in ultimate strength which further decreases with 35% and 70% of BFS. Increase in ultimate strength for 20% replacement may be attributed to secondary reactions of chemicals present in BFS. Higher content of these chemicals have not influenced the ultimate strength.

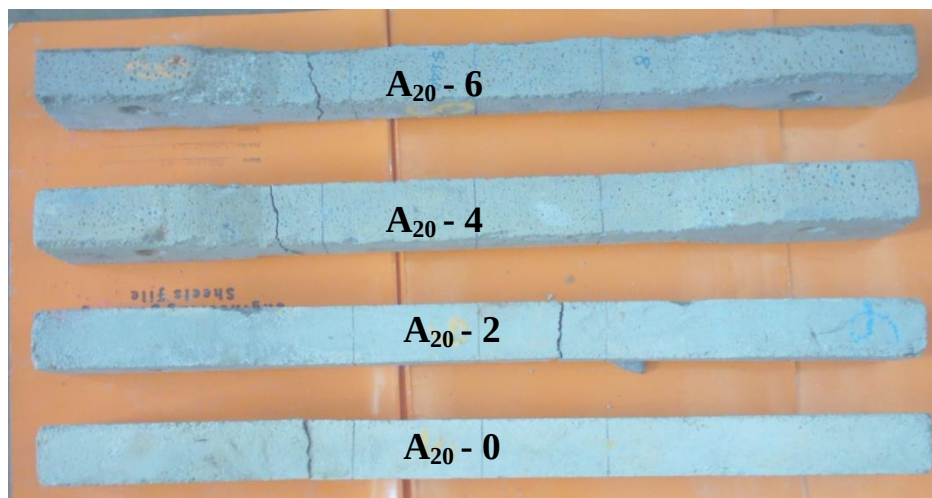


Plate 3. Specimens with 20% replacement of

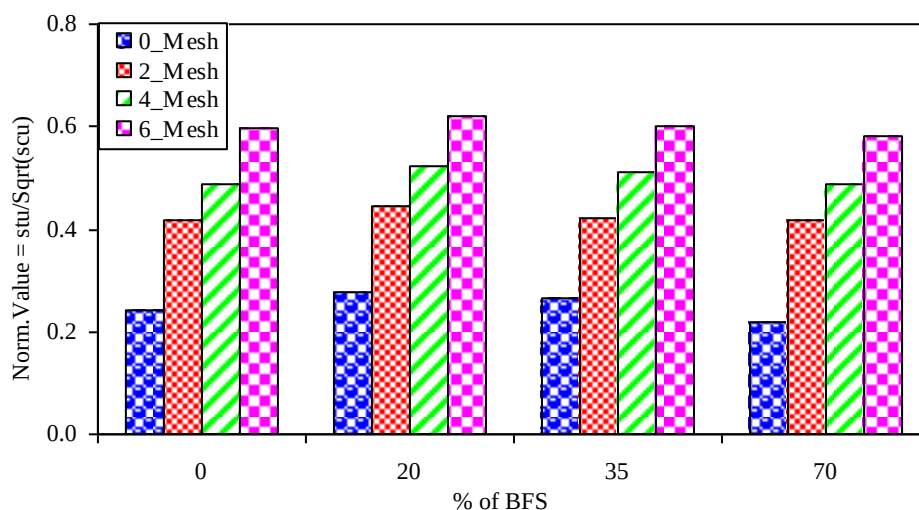


Fig. 4 - Effect of BFS on Mesh Layers in Monotonic Tension

Effect of mesh content on ultimate strength

Increase in mesh content increases the normalized ultimate strength. This may be due to tensile strength of wires used in the mesh. This effect is observed in all the specimens with different percentage of replacement of sand by BFS as shown in Fig. 5.

From the stress-strain curves shown in Fig 6 it has been observed that the replacement of BFS has no significant effect on the initial tangent drawn to the stress-strain curve.

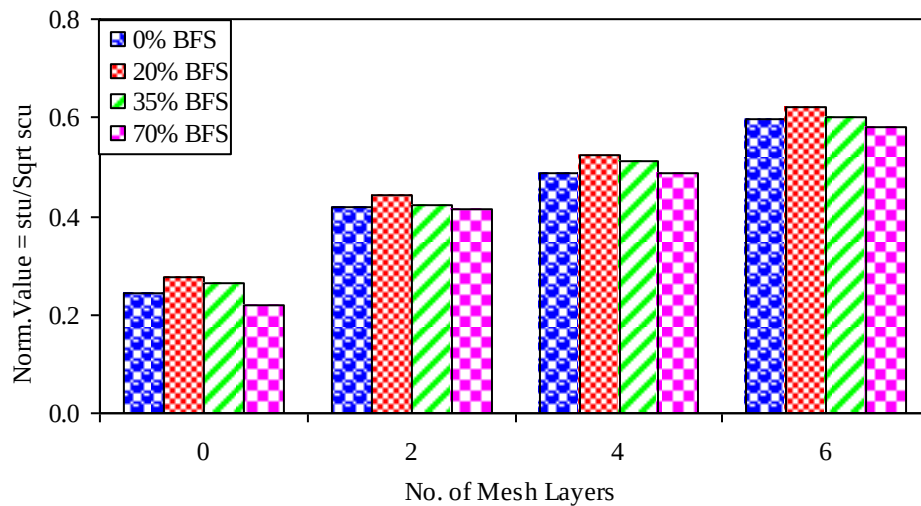


Fig. 5 - Effect of Mesh Layers on % of BFS in Monotonic Tension

Effect of BFS on Young's Modulus

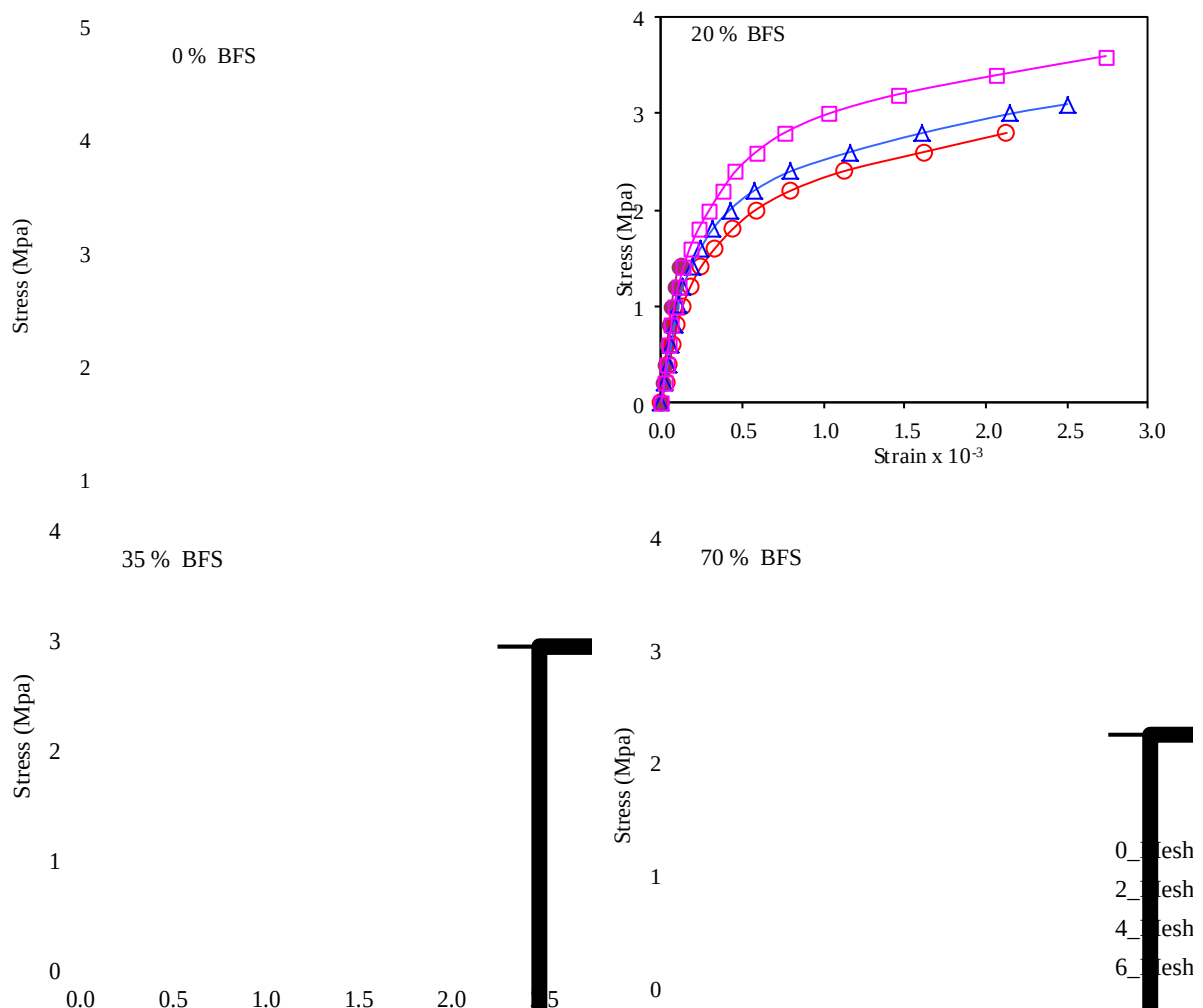


Fig. 6 Experimental Stress-Strain Curves in Monotonic Tension

IV. Conclusions

The major initiative taken up by the governments at the international level in creating an eco-friendly environment across the globe is of prime concern of this research work. This research is an effort towards the prevention of pollution caused due to the disposal of such dangerous industrial waste, Blast furnace slag that has been considered to be utilised in ferrocement. Research includes the parametric variation of percentage

replacement of sand by BFS and reinforcing with number of steel wire meshes. With the existing experimental investigation, following conclusions are drawn.

Replacement of 20% of BFS has shown maximum increase in ultimate strength and further increase in replacement of BFS to 35% and 70% has shown decrease in ultimate strength. Increase in ultimate strength for 20% replacement may be attributed to secondary reactions of chemicals present in BFS. Increase in the chemicals contents of LWA has not influenced the ultimate strength.

Ultimate strength of specimen is found to be directly proportional to the number of mesh layers per specimen for all replacement percentages examined. Detailed investigation required on the influence of chemicals is being worked out.

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