Study on the Ductile Characteristics of Hybrid Ferrocement Slab

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Abstract

This paper presents the ductile characteristics of hybrid Ferro cement slab incorporating polypropylene fibres and GFRP sheet. A total of 9 slab have been tested under two point flexural loading. The size of the slab is 1000 mm(length) x1000 mm(width) x 60 mm(thickness). The parameters studied in this investigation includes the number of weld mesh layers, polypropylene fibres i.e (0.3%) and GFRP sheet. from the studies, it is observed that the load carrying capacity and deformation. The stiffness of the specimens with zero layer weld mesh is lower than that of the specimens with two layers and three layers bundled. Further, there is reduction in number of cracks with increase in fibre content.
Keywords: Ferrocement Slabs, GFRP Wrapping, Fibre Reinforcement, Ductility Factors, Crack Pattern

I. INTRODUCTION

The development of new technology in the material science is progressing rapidly. In recent two or three decades, a lot research was carried out throughout globe for how to improve the performance of concrete in terms of strength and durability qualities. consequently concrete has no longer remained as a construction material. A new material consisting of wire meshes and cement mortar called ferrocement. it is one of the construction materials which may be able to fill the need for building light structures. ferrocement composite consist of cement-sand mortar and single or multi-layers of steel wire mesh to produce elements of small thickness having high durability, and when properly shaped it has high strength and rigidity. These thin elements can be shaped to produce structural members such as folded plates, flanged beams, wall pane,. etc for use in the construction of cheap structures. Ferro cement elements are generally more ductile when compared to conventional reinforced concrete elements but post peak portion of load- deflection curve in bending test of Ferro cement elements reveals that failure occur either due to mortar failure in compression or due to failure of extreme layers of mesh. From the above discussions, it can be noted that, research work out on the ductile behavior of hybrid ferrocement slab with fibre. The present Investigation is aimed at to investigate the ductile behavior of hybrid ferrocement slabs with and without Considering the effect of fibres. Compared with the conventional reinforced concrete, ferrocement is reinforced in two directions; therefore, it has homogenous-isotropic properties in two directions. Benefiting from its usual high reinforcement ratio, ferrocement generally has a high tensile strength and a high modulus of rupture. In addition, since the specific surface of reinforcement in ferrocement is one to two orders of magnitude higher than that of reinforced concrete, larger bond forces develop with the matrix resulting in average crack spacing and width more than one order of magnitude smaller than in conventional reinforced concrete (Shah and Naaman 1997, Guerra et al 1978). Other appealing features of ferrocement include ease of prefabrication and low cost in maintenance and repair. Based on the abovementioned advantages, the typical applications of ferrocement are water tanks, boats, housing wall panel, roof, formwork and sunscreen (Nimityongskul et al 1980 and Kadir 1997).. Ferrocement over the years have gained respect in terms of its superior performance and versatility. Ferrocement is a form of reinforced concrete using closely spaced multiple layers of mesh and/or small diameter rods completely infiltrated with, or encapsulated in, mortar. In 1940 Pier Luigi Nervy, an Italian engineer, architect and contractor, used ferrocement first for the construction of aircraft hangars, boats and buildings and a variety of other structures. It is a very durable, cheap and versatile material.

II. EXPERIMENTAL INVESTIGATION

The experimental investigation consists of testing of nine hybrid ferrocement slabs. the Variables Considered In The Study(I) Numbers Of Welded Square Mesh Reinforcement.(ii) Percentage of polypropylene fibres in mortar.(iii) Number of GFRP layer wrapping. The details of experimental studies including characterization are presented below.

A. Materials Used

The materials that are used in this experiment are cement, steel fiber, fine aggregate, super plasticizer and water.

1) Cement:

OPC 53 grade cement from a single batch has been used throughout the course of the project work, properties of cement are shown in table 2.

2) Fine aggregates:

Only fine aggregate is used in Ferrocement the aggregate consists of well graded fine aggregate (sand) that passes a 4.75 mm sieve. and since salt-free source is recommended, sand should preferably be selected from river-beds and be free from organic or other deleterious matter. Good amount of consistency and compactibility is achieved by using a well- graded, rounded, natural sand having a maximum top size about one-third of the small opening in the reinforcing mesh to ensure proper penetration. The moisture content of the aggregate should be considered in the calculation of required water.

3) Super plasticizer:

Super plasticizer used in the present investigation is FOSROC CONPLAST SP430. and the details of super plasticizer is given in table.1.

4) Polypropylene Fiber:

Having specific gravity 0.90 -0.91 gm/cm3 because of its low specific gravity ,polypropylene yields the greatest volume of fibre for a given weight. This yield means that the polypropylene fibre provides good and bulk cover, while being lighter in weight. Polypropylene is lightest of all fibres and is lighter than water. It is 34% lighter than polyester and 20% lighter than nylon.

5) Water:

Potable water was used in the present investigation for both casting and curing. the water used for mixing cement mortar should be fresh, cleanand fit for construction purposes; the water of pH equal or greater than 7 and free from organic matter—silt, oil, sugar, chloride and acidic material.

B. Properties of Ferrocement Composites

1) Wire diameter 0.5 to 1.5 millimeters
2) Size of mesh opening 6 to 35 millimeters
3) Maximum use of 12 layers of mesh per inch of Thickness
4) Maximum 8% volume fraction in both directions
5) Maximum 10 square inches per cubic inch in both directions
6) Thickness 6 to 50 millimeters
7) Steel cover 1.5 to 5 millimeters
8) Ultimate tensile strength up to 34 MPa
9) Allowable tensile stress up to 10 MPa
10) Modulus of rupture up to 55MPa
11) Compressive strength up to 28 to 69Mpa

Table – 1
Technical data of super plasticizer CONPLAST SP430 as supplied by FOSROC chemicals

Sl no.	*Characteristics*	*Value*
1	*Colour*	*Brown liquid*
2	*Alkali content*	*Typically less than 1.5g Na_2O equivalent/litre of admixture*
3	*Chloride content*	*Nil as per IS:9103-1999*
4	*Specific gravity*	*1.20 to 1.22 at 30^0C*

Table – 2
Mix proportions

Cement sand Proportion	*1: 2*
Water cement ratio	*0.45*
Polypropylene fibres	*0.3% by weight of cement*
super plasticizer	*0.5% by weight of cement*

III. TEST SPECIMENS

A total of 9 specimens of ferrocement slabs were cast and are tested. All the specimens have a dimensions of 1000mm*1000mm with a thickness of 60mm each. The thickness of slabs were kept constant and by varying numbers of layers of meshes, numbers of FRP layers and the slabs with and without polypropylene fibre totally accounts for 9 slab specimen. The specimens were designated as A0,A2,A3,B0,B2,B3,C0,C2,C3. The supplementary specimens such as six numbers out of which three are with and another three without polypropylene fibres of size 70mm*70mm cubes were cast along with the ferrocement slab and are tested for compressive strength.

A. Preparation of Mortar

Mortar was prepared by calculating the exact amount of cement sand and water. At the first the cement sand were dry mixed. For addition of water, initially 75% of water is added to the dry mix and mixed thoroughly. Admixture such as super plasticizer with dosage of 0.5% by weight of cement is added with remaining 25% of water and its added to the mixer and is mixed thoroughly for about ten minutes and polypropylene fibre with dosage of 0.3% by weight of cement is added to the mixture and mixed properly, Finally the mortar is prepared.

Fig. 1: mixing of polypropylene fibres in mortar

The mesh pieces were cut down according to the size of panel leaving a cover of 50mm on both side of mesh of size (900*900mm) as shown in figure below

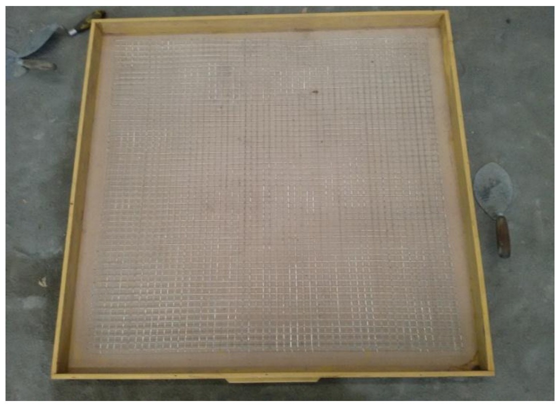


Fig. 2: Pieces of welded square mesh (spacing 20*20mm, 1.2mm diameter)

B. Casting

A wooden mould of size 1000mm*1000mm*60mm were oiled before casting to avoid sticking of mortar. Firstly at bottom mortar is placed for about 6mm thickness and above this the wire mesh of size 900mm*900mm to ensure minimum clear cover of 50mm on each side of the reinforcement is placed inside the mould care should be taken that the wire mesh should be strengthen to a plane surface by pressing with fingers and above this mortar is placed and another wire mesh is placed the procedure is continued for a three layer, two layer, and zero layer finally, the surface are being levelled to get a uniform surface finishes following fig 3 .shows casting slabs.

Fig. 3: casting slab

C. Curing and Application of GFRP Layers

The specimens cast were left in the moulds for a period of 24 hours. After 24 hours Specimens were demoulded from the mould carefully and immediately placed under water in a curing tank and were allowed to cure under water for a period of 28 days. After the period of 28 days, the ferrocement slabs were taken out of the curing tank, dried and out of nine slabs for three slabs such as C0, C2&C3 at the bottom surface of the slab is made rough using of wire brush. GP resin twice by weight of the FRP sheets is being applied using the brush on the bottom surface of the slab and the sheets are pasted and are pressed along the edges of the slabs. FRP wrapped slabs are being kept for a period of 2 days and are allowed to get dried before the testing of slabs. All the slabs were tested under monotonic loading in two point flexure to evaluate the following:

- Deformation characteristics.
- Ductility of Hybrid Ferrocement slabs
- Modes of failure

Fig. 4: curring of slab

Fig. 5: Application of GFRP layer

D. Instrumentation and Loading Procedures

All the specimens were tested in a loading frame, which is fixed over a strong floor. The slabs were simply supported with an effective span of 800mm c/c. Two point loads were applied transversely at one third distances from support using a steel plate. Along with it, capacity proving ring was used for the load application. Dial gauge of sensitivity 0.01mm were used to measure the deflection of the slabs. The dial gauge were kept at mid span of the slab i e deflectometer to measure the deflection of the slab. The behaviour of the slab 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. 6: Testing of slab specimen

E. Crack patterns

The following figure and shows some of the crack pattern of specimens

Fig. 7: crack pattern on the surface

Fig. 8: crack pattern on the edge

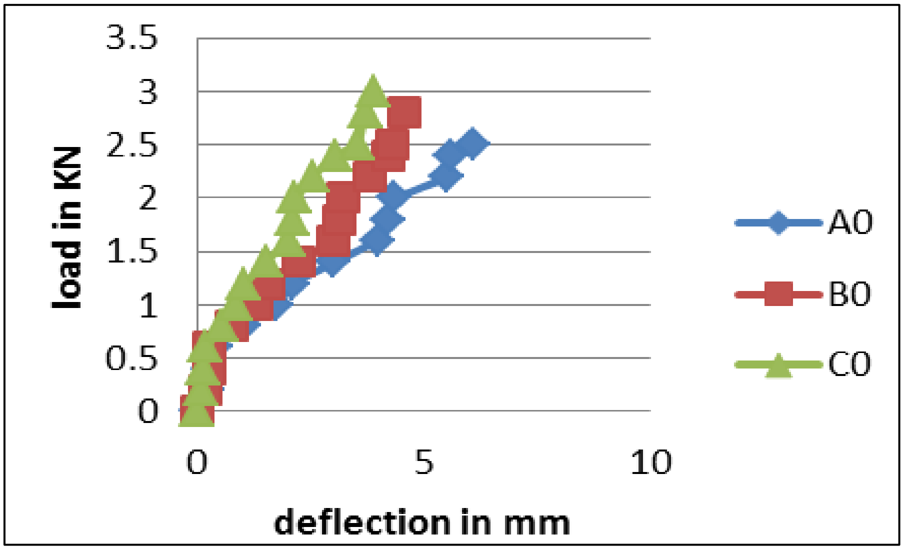
IV. RESULTS AND DISCUSSIONS

Table – 3
Test results on cubes

Sl no	Size in mm	Load at failure (kg)	Compressive strength in (N/mm^2)	average
Without polypropylene fibres				
1	70*70	20,000	40.04	40.84
2	70*70	20,000	40.04	
3	70*70	21,200	42.44	
With polypropylene fibres				
4	70*70	18,800	37.63	43.43
5	70*70	24,300	48.64	
6	70*70	22,000	44.04	

Table – 4
Test results of slab specimens

Load (KN)	Deflection (mm) A0	Deflection (mm) B0	Deflection (mm) C0
0	0	0	0
0.2	0.22	0.165	0.11
0.4	0.28	0.27	0.14
0.6	0.39	0.29	0.19
0.8	1.04	0.78	0.52
1	1.75	1.31	0.87
1.2	2.09	1.56	1.04
1.4	3.02	2.26	1.51
1.6	4	3.0	2.0
1.8	4.22	3.16	2.11
2	4.34	3.25	2.17
2.2	5.52	3.81	2.54
2.4	5.60	4.2	3.04
2.5	6.09	4.32	3.56
2.8		4.56	3.70
3.0			3.92
1st crack	5.52	4.2	3.56
Max.load	3000	2800	3000

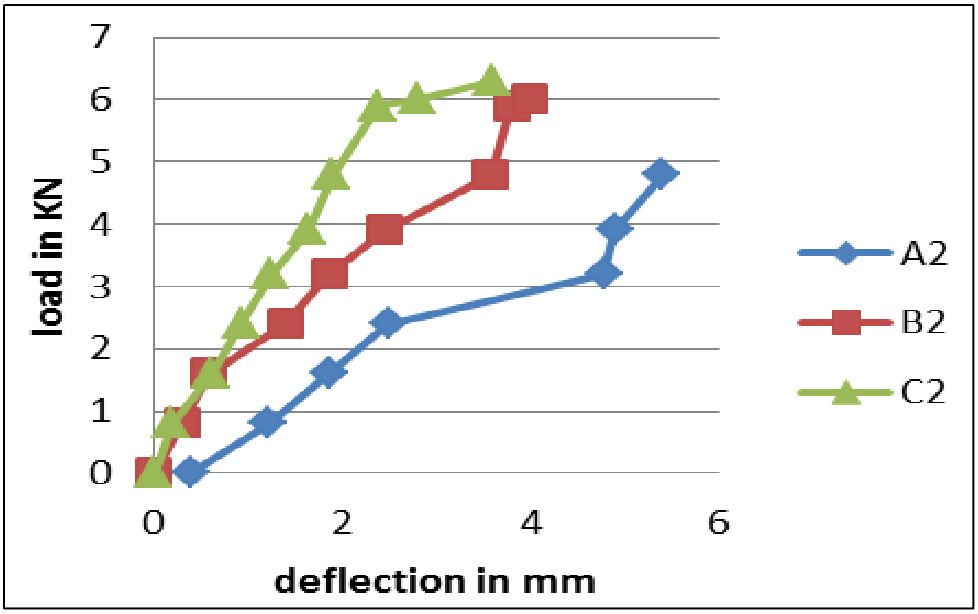


Graph 1: Load v/s deflection (40mm zero layer)

Where
A0: Slab specimen with zero layer wire mesh in the absence of polypropylene and Frp sheet.
B0: Slab specimen with zero layer wire mesh in the presence of polypropylene and in the absence of frp sheet.
C0: Slab specimen with zero layer wire mesh in the presence of polypropylene and Frp sheets.

Table – 5
Slab thickness 40mm 2 layers of wire mesh

LOAD (KN)	*Deflection (mm)*	*Deflection (mm)*	*Deflection (mm)*
	A2	*B2*	*C2*
0	*0*	*0*	*0*
0.8	*0.39*	*0.29*	*0.19*
1.6	*1.22*	*0.59*	*0.61*
2.4	*1.86*	*1.39*	*0.93*
3.2	*2.49*	*1.86*	*1.24*
3.9	*4.78*	*2.46*	*1.64*
4.8	*4.90*	*3.58*	*1.90*
5.9	*5.4*	*3.80*	*2.39*
6.0		*4.0*	*2.80*
6.3			*3.60*
1st crack	*4.78*	*3.58*	*2.39*
Max.Load	*6400*	*7200*	*6400*

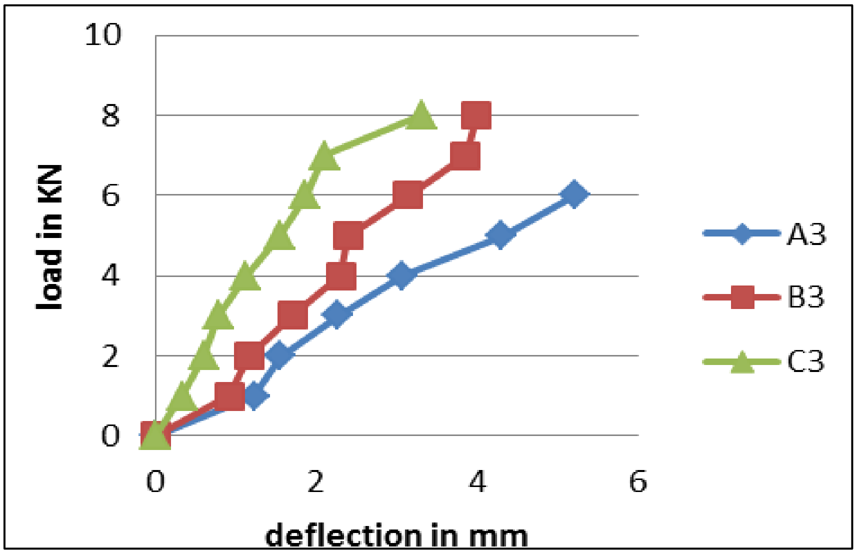


Graph 2: Load v/s deflection (40mm 2 layer)

Where
A2: Slab specimen with two layer wire mesh in the absence of polypropylene and Frp sheet.
B2: Slab specimen with two layer wire mesh in the presence of polypropylene and in the absence of frp sheet.
C2: Slab specimen with two layer wire mesh in the presence of polypropylene and Frp sheets.

Table – 6
Slab thickness 40mm 3 layers of wire mesh

Load (KN)	*Deflection (mm) A3*	*Deflection (mm) B3*	*Deflection (mm) C3*
0	*0*	*0*	*0*
1	*1.23*	*0.92*	*0.34*
2	*1.56*	*1.17*	*0.61*
3	*2.27*	*1.70*	*0.78*
4	*3.08*	*2.31*	*1.13*
5	*4.31*	*2.40*	*1.54*
6	*5.21*	*3.15*	*1.87*
7		*3.86*	*2.1*
8		*4.0*	*3.32*
1st crack	*4.31*	*3.15*	*3.32*
Max.Load	*8000*	*8000*	*8000*



Graph 3: Load v/s deflection (40mm 3 layers)

Where
A3: Slab specimen with three layer wire mesh in the absence of polypropylene and Frp sheet.
B3: Slab specimen with three layer wire mesh in the presence of polypropylene and in the absence of frp sheet.
C3: Slab specimen with three layer wire mesh in the presence of polypropylene and Frp sheets.

Table – 8
Experimental results

slab ID	*load at (N)*		*deflection in mm*			*ductility factor (Md) = (d2/d1)*
	yield load	*Ultimate load (Wu)*	*Yield (d1)*	*ultimate (du)*	*0.85*Wu (d2)*	
A0	*2200*	*2500*	*5.52*	*6.09*	*2.12*	*0.38*
A2	*3900*	*5900*	*4.78*	*5.4*	*5.01*	*1.05*
A3	*5000*	*6000*	*4.31*	*5.21*	*5.10*	*1.18*
B0	*2400*	*2800*	*4.2*	*4.56*	*2.38*	*0.57*
B2	*4800*	*6000*	*3.58*	*4*	*5.10*	*1.42*
B3	*6000*	*8000*	*3.15*	*4*	*6.8*	*2.15*
C0	*2500*	*3000*	*3.56*	*3.92*	*2.55*	*0.72*
C2	*5900*	*6300*	*2.39*	*3.6*	*5.35*	*2.24*
C3	*7000*	*8000*	*2.1*	*3.32*	*6.8*	*3.23*

V. DISCUSSIONS

Table 3 shows that the compressive strength of hybrid ferrocement slabs without polypropylene fibres and with polypropylene fibres. From results it is observed that the compressive strength at 28 days curring of hybrid ferrocement slabs with polypropylene fibres content of 0.3% is increased by 40% with compressive strength of conventional concrete plain.

Table 4 shows the test results of ferrocement slabs specimen A0 with zero layer wire mesh in the absence of polypropylene B0 in the presence of polypropylene and in the absence of frp sheet.and C0 in the presence of polypropylene and Frp sheets.Graph1 shows the corresponding load deflection behavior of different three slabs from the test results it is observed that the ultimate load carriying capacity in flexure is 75% is more for B0 compared to A0 and 50% more for C0 compared to A0 slab.

Table 5 shows the test results of ferrocement slabs with double layer mesh the Graph2 shows the corresponding load v/s deflection behavior of HFS it is observed that the load carrying capacity is more in case of B0 and C0 compared to A0 in the same way Table 8 shows the test results of ferrocement slabs with three layer Graph3 shows the load deflection curve having more load carryting capacity of slab C0 compared to B0 ,A0 slabs.

From the test results it is observed that the ultimate load carrying capacity in three layer weld mesh HFS with 0.3% fibre content is increased by 25% in comparison with double layer weld mesh of ferrocement slab without GFRP layer.

By studying the crack patterns it is observed that the appearance of the first crack is slower in case of three layer weld mesh ferrocement slab with fibre and GFRP sheet in comparison with double layer weld mesh with 0.3% fibre content and without fibrous ferrocement slabs .

VI. CONCLUSION

1) The flexural load at first crack and ultimate loads depend on number of reinforcing mesh layers used in ferrocement.
2) Increasing in numbers of layers from 2 to 3 significantly increase the ductility and capability to absorb energy of the slabs.
3) Presence of polypropylene fibre reduces the cracks and protects the corners of slab and increase the abrasion resistance, reduce the seepage of water.
4) Addition of super plasticizer will results in achieving self-compacting concrete and thus which reduce up to 40% of water. It also helps in placing of mortar which can easily flow by its own Wight without any vibration.
5) The compressive strength of cubes with presence of polypropylene fiber which increase about 40% as compared to conventional cube specimens.
6) The gfrp wrapped ferrocement slabs shows the higher ductility than that of the conventional ferrocement slabs due to the fact that, better confinement is being provided by the wrapping in the tension zone of the slabs. The wrapping acts as an external reinforcement and takes load in the tensile zone after the concrete fails.

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