EFFECT OF WIRE MESH AT DIFFERENT ORIENTATION ON THE STRENGTH OF FERROCEMENT REINFORCED CONCRETE BEAM

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ABSTRACT

Ferrocement, also referred to as ferro concrete or reinforced concrete, a mixture of Portland cement and sand applied over layers of woven or expanded steel mesh and closely spaced small-diameter steel rods rebar. Retrofitting techniques are used in field and out of all plate bonding technique is considered as the best. In this technique, the plates of different materials are bonded to the surface of structural member to increase its strength. Ferrocement sheets are most commonly used as retrofitting material these days due to their easy availability, economy, durability, and their property of being cast to any shape without needing significant formwork. In the present work, effect of wire mesh orientation on the strength of stressed beams retrofitted with Ferrocement jackets has been studied. The beams are stressed up to 75 percent of safe load and then retrofitted with Ferrocement jackets with wire mesh at different orientations. The results show that the percent increase in load carrying capacity for beam retrofitted with Ferrocement jackets with wire mesh at 0, 45, 60 degree angle with longitudinal axis of beam, varies from 45.87 to 52.29 percent. Also a considerable increase in energy absorption is observed for all orientations. However, orientation at 45 degree shows higher percentage increase in energy absorption followed by 60 and 0 degree respectively.

Keywords: Simply supported beam, Ferrocement, Jacket, wire mesh, orientation, retrofitting

INTRODUCTION

Ferro-cement is a relatively new construction material consists of wire meshes and cement mortar. It was developed by P.L. Nervi, an Italian architect in 1940. Ferro cement is widely used due to the low self weight, lack of skilled workers, no need of framework etc. Quality of Ferro-cement works are assured because the components are manufactured on machinery set up and execution time at work site is less. Maintenance cost of Ferro-cement is low. Ferro-cement construction has come into widespread use only in the last two decades.

Many experimental studies have been conducted in recent years to strengthen flexural members by using various materials. *Andrew and Sharma (1998)* in an experimental study compared the flexural performance of reinforced concrete beams repaired with conventional method and Ferrocement. They concluded that beams repaired by Ferrocement showed superior performance both at the service and ultimate load. The flexural strength and ductility of beams repaired with Ferrocement was reported to be greater than the corresponding original beams and the beams repaired by the conventional method.

Beams rehabilitated with Ferrocement jackets show better performance in terms of ultimate strength, first crack load, crack width, ductility and rigidity of the section. It was observed that the cracking and ultimate strength increases by 10 percent and 40 percent in case of rehabilitated beams, whereas these increases were 10-30 percent and 40-50 percent in case of composite sections. The jacketing increases the rigidity of the beams and lead to 37 percent and 29 percent reduction in deflection. The crack width of the composite beams and rehabilitated beams decreases on an average by 42 percent and 36 percent respectively.[*Nassif, H.H et al, 1998, Vidivelli, B. et al, 2001, Nasif, N.H. et al 2004*].

A Ferrocement shell improves the flexural behaviour of RCC beams, although there is no increase in the moment carrying capacity of under reinforced beams. However, the moment carrying capacity increased by 9 per cent and 15 per cent for balanced and over reinforced sections respectively [*Seshu, D.R., 2000*].

[*Kaushik, S.K. and Dubey, A.K., 1994*].

The addition of thin layer of ferrocement to a concrete beam enhances its ductility and cracking strength. Composite beams reinforced with square mesh exhibit better overall performance compared to composite beams reinforced with hexagonal mesh. An increase in the number of layers improves the cracking stiffness of the composite beams in both cases.

Paramasivam, P. et al (1994) studied the flexural behavior of reinforced concrete T-beams strengthened with thin ferrocement laminate attached to the tension face using L-shaped mild steel round bars as shear connectors. From the experimental investigation it was concluded that after strengthening the performance of the beam improved substantially in terms of strength, flexural rigidity and first crack load, provided the connectors are adequately spaced and the surface to receive the laminate roughened to ensure sufficient bond strength for composite action. Thus, Ferrocement is a viable alternative material for repair and strengthening of reinforced concrete structures. It has been accepted by the local building authority in Singapore for use in upgrading and rehabilitation of structures. The National Disaster Mitigation Agency (NDMA), Government of India, also accepted the use of Ferrocement for this purpose. The behaviour of Ferrocement in flexure depends upon various parameters such as mortar, type of wire mesh, orientation of wire mesh etc.; hence the behaviour of Ferrocement jackets.

In the present paper the effect of wire mesh orientation on the strength of the retrofitted beams is presented. The ultimate strength of the reinforced concrete beams, which failed due to overloading and were repaired using Ferrocement laminate, is affected by the level of damage sustained prior to repairing.

EXPERIMENTAL PROGRAMME

For experimental investigation , eight prototype beams of size 127mm x 227mm x 4100mm reinforced with two bars of 10 mm diameter in tension and two bars of 8mm diameter in compression were cast using the proportioned mix. Out of these eight beams, two were used as control beams (Type- A) and tested to failure to find out the safe load carrying capacity corresponding to the allowable deflection as per *IS:456-2000* i.e. span /250. The other six beams were stressed to 75 percent of the safe load obtained from the testing of the control beams and were then retrofitted with 15 mm thick Ferrocement jackets made with 1:2 cement sand mortar and w/c ratio 0.40 as shown in Fig. 2. The jacket was reinforced with single layer of 40mm x 40mm square welded wire mesh. The three wire mesh orientation viz. 0, 45, 60 degree were used in the Ferrocement jackets. The set of beams (two each) were divided into four categories depending upon the orientation of wire mesh in the jacket. Control beams were designated as type-A, whereas, beams retrofitted with welded wire mesh oriented at 0 degree were designated as type – B beams. Retrofitted beams having welded wire mesh oriented at 45 degrees and 60 degrees were designated as type – C and type-D, respectively.

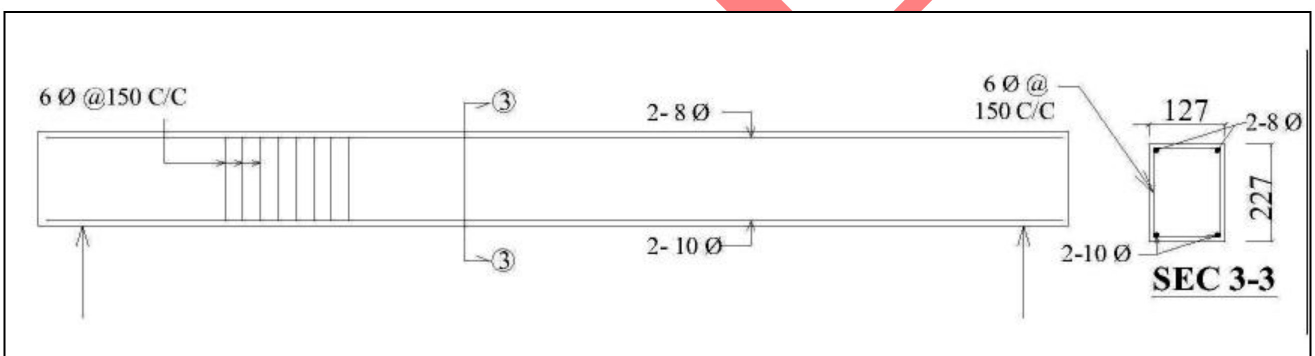


Fig. 1 Longitudinal and Cross-Section of Unretrofitted Under Reinforced Beams (All Dimensions are in mm)

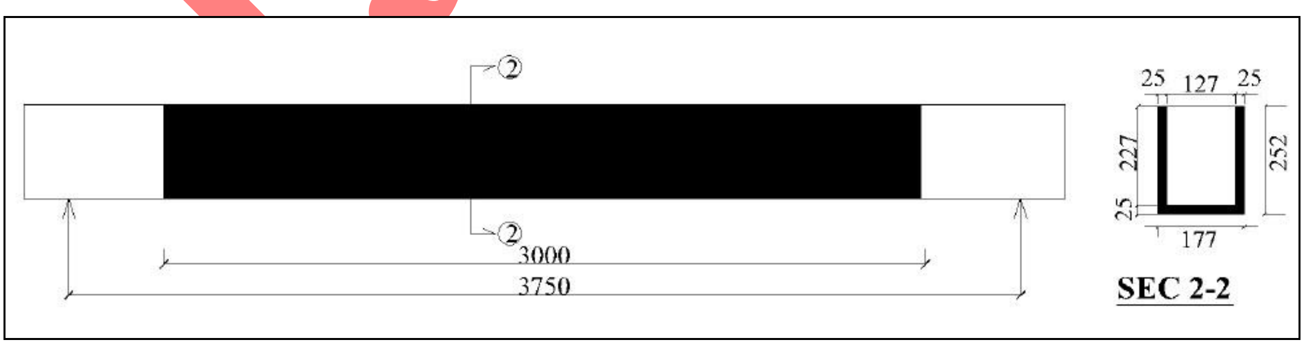


Figure 2: Longitudinal and Cross-Section of Retrofitted Beams

MATERIALS

The properties of various materials used in the experimental study are reported in Table.

Properties of Portland Pozzolana Cement			
S.No	**Characteristics**	**Test Value**	**As per IS:1489 (Part-1)**
1	Standard Consistency	34	-
2	Fineness of Cement as retained on 90micron sieve (%)	0.5	<10
3	Setting Time Initial Final	 84 300	 >30 <600
4	Specific Gravity	3.07	-
5	Compressive Strength (MPa) 1. 7 Days 2. 28 Days	 30.0 43.0	 22.0 33.0
6	Soundness (mm)	2.0	<10

Properties of Fine Aggregate		
S.No	**Characteristics**	**Value**
1	Specific Gravity	2.52
2	Bulk Density loose (kN/m^3)	14.8
3	Fineness Modulus	2.36
4	Water Absorption	2.67

Properties of Coarse Aggregate			
S.No	**Characteristics**	**Value**	
		CA-I	**CA-II**
1	Maximum Nominal Size	12.5	4.75
2	Specific Gravity	2.68	2.7
3	Fineness Modulus	7.45	6.21
4	Water Absorption	1.45	1.643

	Properties of Steel Bars & Steel Mesh Wires			
S.No	**Diameter of Bar/ Mesh Wire (mm)**	**Yeild Strength (N/mm^2)**	**Ultimate Strength (N/mm^2)**	**Elongation (%)**
1	12	452.00	584.00	23.00
2	10	470.00	580.00	20.00
3	8	445.00	555.00	23.00
4	6	442.42	612.70	32.90
5	2.4	400	511.36	02.52

TESTING ARRANGEMENT

All the eight simply supported beams were tested with an effective span of 3.75 m. Two concentrated loads were applied at 1m spacing for testing (see Fig -3). The beams were tested using hydraulically operated jacks connected to a data acquisition system through the load cells. With an increase in load the deflection in the beam was noted using three dial gauges placed at the quarter span points.

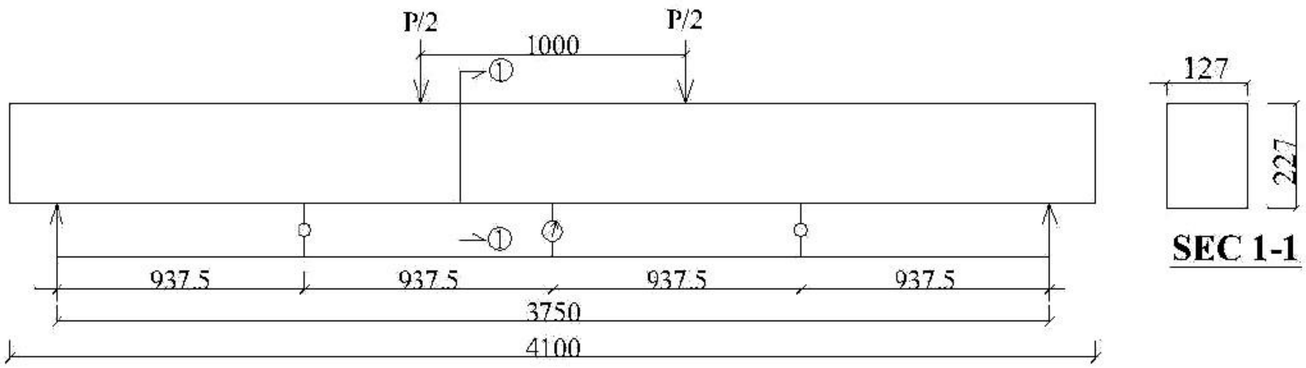


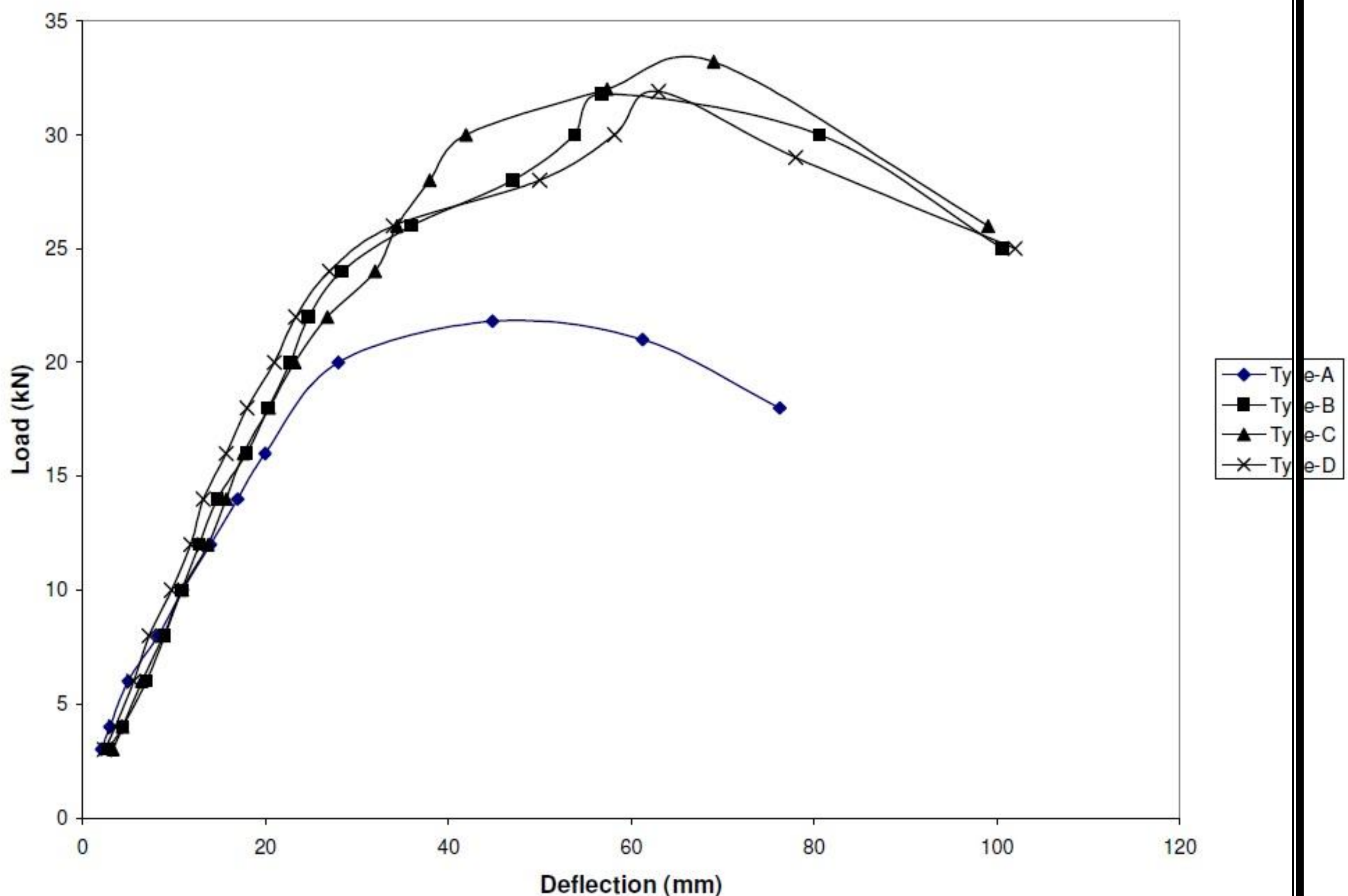
Fig. 3: Loading Arrangement for Testing of all Beam Specimens
(All Dimensions are in mm)

Retrofitting Process

Firstly the surface of beam is cleaned. After cleaning the surface, the cement slurry is applied as bonding agent to the surface of beam. After the application of bonding agent retrofitting of beam is done by applying 15mm thick cement mortar on the three faces as Ferrocement jackets having wire mesh at different orientation. The beams are cured for 7days before testing. Then with same procedure as of control beam, testing of beam is done in order to calculate ultimate load and corresponding deflections.

RESULTS AND DISCUSSION

First, the two control beams were tested to failure. The load corresponding to an allowable central deflection of 15 mm (span/250) was obtained from load deflection curve as 12.89 kN. The remaining six beams were stressed to 75 percent of this average safe load i.e. 9.50 kN. Subsequently the retrofitting of beams using different orientations of wire mesh in the Ferrocement jackets was carried out. These retrofitted beams were then loaded to failure and the data was recorded in the form of load and deflection. Table 5 presents this data for the control beams and beams retrofitted using specified wire mesh orientations. Fig 4 shows the load deflection behaviour at the mid span points of the control as well as beams retrofitted with different wire mesh orientations. It is observed from the curves in Fig 4 that with an increase in load there is a considerable increase in deflection for all the beams. It was also noted that the spacing of cracks was 45mm in case of beams retrofitted with wire mesh at zero degree as compared to beams retrofitted with wire mesh at 450 , for which it was 85mm. The spacing increased to 108 mm for 60-degree orientation. This shows that the distribution of stress with wire mesh at zero degree is better



. Figure 4: Load V/S. Deflection Curve At Mid Span For Control Beam And Beams Retrofitted With Wire Mesh At Different Orientations

It is also observed that corresponding to the serviceability requirement of 15 mm deflection, the load increased from 12.89 kN for the control beam to 14.32 kN, 13.35 kN, 15.51 kN for type B, C and D retrofitted beams, respectively.

It is also observed from the curves that the deflection at the centre at maximum load is maximum in the case of beams retrofitted with wire mesh at 45 degrees, which is 68.95mm as compared to those with wire mesh at zero degree, for which it is 56.62mm, and for 60 degree, for which it is 63.87 mm.

S.No	**TYPE-A (Control Beam)**			**TYPE-B (Wire mesh at 0^0)**			**TYPE-C (Wire mesh at 45^0)**			**TYPE-D (Wire mesh at 60^0)**		
	Load (kN)	**Deflection at (mm)**		**Load (kN)**	**Deflection at (mm)**		**Load (kN)**	**Deflection at (mm)**		**Load (kN)**	**Deflection at (mm)**	
		L/2	**L/4**		**L/2**	**L/4**		**L/2**	**L/4**		**L/2**	**L/4**
1	3	2.12	1.22	3	2.82	1.80	3	3.37	2.12	3	2.43	1.84
2	4	3.07	1.83	4	4.41	3.02	4	4.42	3.00	4	3.58	2.40
3	6	5.12	3.05	6	7.03	4.89	6	6.52	4.50	6	5.61	3.16
4	8	8.32	5.07	8	9.00	6.47	8	8.88	6.00	8	7.30	4.24
5	10	10.98	7.04	10	8.89	7.76	10	10.90	7.74	10	9.76	4.87
6	12	14.50	9.21	12	12.82	9.22	12	13.85	9.26	12	11.85	6.00
7	14	17.00	11.22	14	14.92	10.54	14	15.77	11.45	14	14.23	7.75
8	16	20.11	13.50	16	17.95	13.42	16	17.63	13.96	16	15.75	9.84
9	20	28.13	19.01	18	20.37	15.38	18	20.45	16.76	18	18.00	11.96
10	21.8	44.85	33.40	20	22.76	16.90	20	23.22	17.52	20	21.02	13.72
11	21	61.27		22	24.69	18.55	22	26.80	21.00	22	23.33	15.01
12	18	76.28		24	28.42	20.24	24	32.02	25.11	24	27.04	17.50
13				26	36.03	24.02	26	34.40	28.04	26	34.00	24.02
14				28	47.08	32.04	28	38.00	31.45	28	50.03	36.36
15				30	53.83		30	41.95	35.02	30	58.20	41.54

16				31.8	56.62		32	57.37	40.20	31.9	63.86	45.51
17				30	80.63		33.2	68.95	42.84	29	78.00	
18				25	100.62		26	99.04		25	102.00	

Table-5 : Deflection values for control beam and retrofitted beam at various load

CONCLUSIONS

Based upon the test results of the experimental study undertaken, the following conclusions may be drawn:

1. The beams retrofitted with wire mesh at different orientations do not de-bond when loaded to failure.
2. The failure of the composite is characterized by development of flexural cracks over the tension zone.
3. The spacing of cracks is reduced for retrofitted beams indicating better distribution of stress.
4. Wire mesh orientated at 45 degree for retrofitting the stressed beams has the highest load carrying
   capacity as compared to control beam as well as the other beams retrofitted using different orientations.
5. After retrofitting, all the test specimens showed reduced crack widths, large deflection at the ultimate load.

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