Experimental Study on the Effectiveness of Ferrocement as a Permanent Form Work for Beams

Anisha G Krishnan[1], Allzi Abraham[2]

[1]PG Scholar, Department of Civil Engineering, SVNCE

[2]Assistant Professor, Department of Civil Engineering, SVNCE

Abstract: ***Ferrocement is a thin composite material made with a cement based mortar matrix reinforced with closely spaced layers of relatively small diameter wire mesh. The experimental study comprised of testing of three control beam specimens of dimension (200 X 300 x 1000) mm and three beam specimens with 25 mm thick ferrocement formwork. The control beams were reinforced with two numbers of 10 mm diameter bars and two numbers of 6 mm diameter bars on top and bottom with 6 mm diameter two legged stirrups at 200 mm c/c. The formwork consisted of a skeletal reinforcement of 6 mm diameter bar which provide shape and support for the mesh and one layer of chicken mesh having 0.88 mm diameter. The beams with ferrocement formwork were reinforced with two numbers of 10 mm diameter bar on top and bottom and were tied at the ends with 6 mm diameter stirrups. The effectiveness of ferrocement as a permanent formwork for beams was investigated in this study. The test results showed that the use of ferrocement formwork improve the load carrying capacity and crack resistance of the beams.***

Keywords: Ferrocement, Chicken mesh, Reinforced concrete

1. Introduction

Ferrocement is introduced by P L Nervi an Italian architect and engineer in 1940. Ferrocement has increased applications due to its properties such as strength, toughness, water tightness, lightness, ductility and environmental stability. Ferrocement can be fabricated in to any desired shape or structural configuration that is generally not possible with standard masonry, reinforced concrete or steel. Ferrocement can be cast in various shapes and forms even without the use of formwork. The thickness of ferrocement generally varies from 10 mm to 25 mm. High surface area imparts ductile characteristics to ferrocement even though mortar is weak in ductility.

Ferrocement is characterized by its enhanced resistance to cracking in comparison to reinforced concrete. Cracks in ferrocement are narrower and larger in numbers. The types of wire meshes generally used in ferrocement construction are welded steel wire mesh, X8 expanded steel wire mesh and chicken mesh. The wire meshes can be generally oriented in three ways such as zero degree orientation, forty five degree orientation and sixty degree orientation. The major limitation in ferrocement is the percentage of reinforcement. The reinforcement cannot be increased beyond certain limit. This limitation affects the strength of ferrocement and it cannot be employed where high impact or high loads are expected.

Ferrocement repairs and rehabilitation can be done in reinforced concrete structures to increase its strength. Ferrocement which can be made from non – formwork construction process is an advantage over other type of repairs and strengthening techniques. It enhances the crack resistance combined with high toughness. It imposes small additional weight on the structures. This material proves to be a cost effective solution for rehabilitation and general applications. Ferrocement overlay can be used to increase the ductility of masonry columns and walls.

Most of the concrete constructions are performed using wooden or steel temporary formwork. The steel formworks can be reusable but its cost is more than wooden formworks. The cost of formwork is a critical issue in the construction field. Hence it is essential to suggest an alternative material and technology for the formwork construction to replace the conventional materials and to reduce the cost. This study investigates the effectiveness of using ferrocement as a permanent formwork for the beams which are reinforced with single and double layers of chicken mesh.

2. Literature Survey

An experimental study on the strength of reinforced concrete beams retrofitted using ferrocement was conducted by Bansal et al., 2008[1]. Three types of wire mesh orientation such as zero degree orientation, forty five degree orientation and sixty degree orientation was used in the study. The results revealed that the percent increase in load carrying capacity of beams retrofitted by ferrocement with zero degree, forty five degree and sixty degree wire mesh orientation varies from 45.87 to 52.29 percent. Also forty five degree orientation showed greater load carrying capacity as compared to other orientation.

The performance chicken mesh on strength of beams retrofitted using ferrocement jackets was studied by Patil et al., 2012[4]. In the study reinforced concrete beams initially stressed to a fixed percentage of the safe load were retrofitted using ferrocement to increase the strength of beam in both shear and flexure. The chicken mesh is placed along the longitudinal axis of the beam. Two points loading is adopted for testing the specimens. The study concluded that the safe load carrying capacity of concrete beams retrofitted by ferrocement laminates is significantly increased with chicken mesh used for retrofitting.

An experimental program was conducted by Fahmy et al., 2014[2] to evaluate the results of reinforced concrete beams consisting of precast permanent U shaped ferrocement forms filled with different types of core materials such as conventional concrete, autoclaved aerated lightweight concrete bricks, and recycled concrete. Similar investigations to examine the feasibility and effectiveness of using precast U shaped ferrocement laminates as a permanent forms for reinforced beam construction was done by Fahmy et al., 2005[3] and Tawab et al., 2012[5]. The results of these experiments showed that better crack resistance, high serviceability and ultimate loads, and good energy absorption could be achieved by using the ferrocement precast forms.

3. Methodology

The experimental phase of the study was distinctly divided in to definite sequences of works. The properties of materials used in this study were tested in the laboratory as per IS specifications and by using the test results mix design was done. The size of specimens was then suitably chosen and worked out the reinforcement details. The specimens were casted and tested after 28 days of curing.

3.1 Mix design and material properties

The U shaped permanent ferrocement formwork was produced by using mortar. The mortar consisted of ordinary Portland cement and sand with sand cement ratio 2 and water cement ratio 0.4. The concrete mix prepared for control beams and as the core of test specimens incorporating ferrocement formwork was in the proportion of 1:1.49:3.08 with water cement ratio of 0.5. Three concrete cubes of dimension 150 x 150 x 150 mm and three cylinder specimens of diameter 150 mm and length 300 mm were casted and tested after 28 days of curing to determine the compressive strength and split tensile strength of concrete. Single and double layers of chicken mesh were used for fabricating the U shaped permanent ferrocement formwork. The skeletal reinforcement for the U shaped ferrocement permanent formwork consisted of 6 mm diameter steel bars which provide shape and support for the mesh.

3.2 Preparation of test specimens

The concrete specimens were prepared in the proportion of 1:1.149:3.08 and water cement ratio of 0.5. Three reinforced concrete beam specimens have dimension 200 x 300 x 1000 mm were casted and which were taken as control beam specimens. The control beam specimens were reinforced with two numbers of 10 mm and 6 mm diameter bars on top and bottom with 6 mm diameter two legged stirrups at 200 mm c/c. The control beam specimens were kept for a curing period of 28 days before testing. The reinforcement details and beam specimens after casting were showed in Figure 1 and Figure 2 respectively.

Figure 1: Reinforcement for control beams

Figure 2: Control beams after casting

A frame was developed with 6 mm a diameter bar which is termed as skeletal reinforcement and it is covered with single and double layers of chicken mesh to form an open channel for the ferrocement formwork construction. The skeletal reinforcement covered with chicken mesh was showed in Figure 3.

Figure 3: Skeletal reinforcement covered with chicken mesh

The skeletal reinforcement having single and double layers of chicken mesh was then plastered with rich cement mortar of proportion 1:2 to get an overall thickness of 25 mm to the ferrocement formwork. The ferrocement formworks were kept for a curing period of 28 days. The ferrocement formwork after casting was showed in Figure 4.

Figure 4: Ferrocement formwork after casting

Cement slurry was applied inside the ferrocement formwork after 28 days of curing and then the reinforcement was placed inside the formwork. The reinforcement inside the ferrocement formwork consisted of four numbers of 10 mm diameter bars which were tied at the ends by using 6 mm diameter bars. No shear reinforcement was used in this case. The concrete was then poured and compacted in the ferrocement formwork. The beams with ferrocement formwork were kept for a curing period of 28 days. The specimens after casting were showed in Figure 5.

International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2013): 6.14 | Impact Factor (2015): 6.391

Figure 5: Beam with ferrocement formwork after casting

3.3 Test setup

The specimens were tested after 28 days of curing. The specimen having size 200 x 300 x 1000 mm was laid on loading frame of maximum capacity 100T. The test was conducted under two point loading condition. The span between the two supports was kept 800 mm. The testing arrangement was showed in Figure 6.

(a)

(b)

Figure 6: Testing arrangements of specimen

The load was applied on the specimen at an increment of 10 kN. The deflection on the specimen at every increment of load was noted by using LVDT. The first crack load and breaking load was noted for all the specimens. The difference in crack pattern in the control beam specimen and beam with ferrocement formwork was also noted.

4. Results

The flexural strength of control beam specimens and beams with ferrocement formwork were tested under two point loading condition.

4.1 Variation of deflection with load

The variation of deflection with increase in load was showed in Table 1.

Table 1: Load and corresponding deflection

Sl No	*Load (kN)*	*Deflection (mm)*		
		Control beam	*Beam with ferrocement formwork having single layer of chicken mesh*	*Beam with ferrocement formwork having double layers of chicken mesh*
1	10.574	0.65	0.17	0.12
2	20.574	0.75	0.27	0.19
3	30.574	0.86	0.38	0.27
4	40.574	0.93	0.49	0.38
5	50.574	1.05	0.58	0.50
6	60.574	1.14	0.69	0.62
7	70.574	1.25	0.75	0.72
8	80.574	1.35	0.90	0.81
9	90.574	1.37	0.95	0.88
10	100.574	1.42	1.02	0.93
11	110.574	1.48	1.12	1.01
12	120.574	1.62	1.22	1.08

From Table 1 it was clear that the deflection of control beam specimens were higher as compared to the beam with ferrocement formwork. Also there was a reduction in deflection in beam incorporating ferrocement formwork with double layers of chicken mesh as compared with single layers of chicken mesh. Table 2 showed the first crack load and braking load of different test specimens.

Table 2: First crack load and braking load

S No	Description	Control beam	Beam with ferrocement formwork having single layer of chicken mesh	Beam with ferrocement formwork having double layers of chicken mesh
1	First crack load (kN)	171.374	190.774	210.674
2	Braking load (kN)	196.574	256.174	320.574

Table 2 showed the variation in the first crack load and braking load of control beam specimens and beams with ferrocement formwork having single and double layers of chicken mesh. From the Table 2 it was clear that the increase in number of wire mesh layers result in increase of first crack load and braking load of specimens.

The beam incorporating permanent ferrocement formwork with double layers of chicken mesh can carry higher loads as compared to the control beams and the crack developed at the failure condition was also lesser in the case of beams with ferrocement formwork.

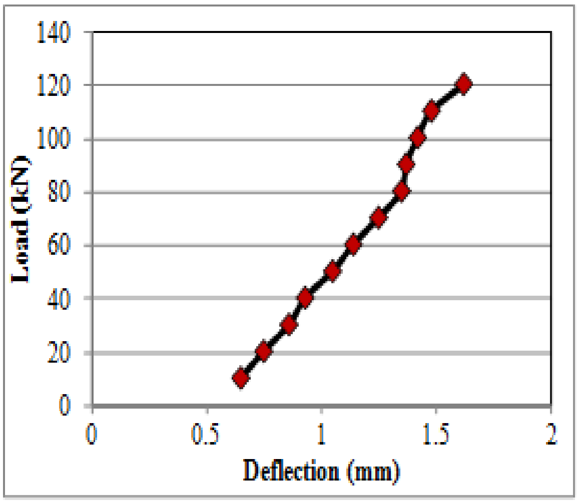

Figure 7: Load – deflection curve for control beam

Figure 7 showed the graphical representation of variation in deflection with increase in load. The deflection corresponding to 120.574 kN was 1.62 mm which was accurately measured by using a LVDT.

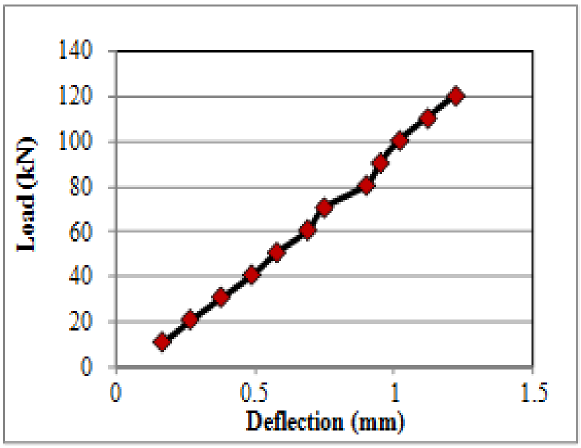

Figure 8: Load – deflection curve for beam incorporating ferrocement formwork with single layer of chicken mesh

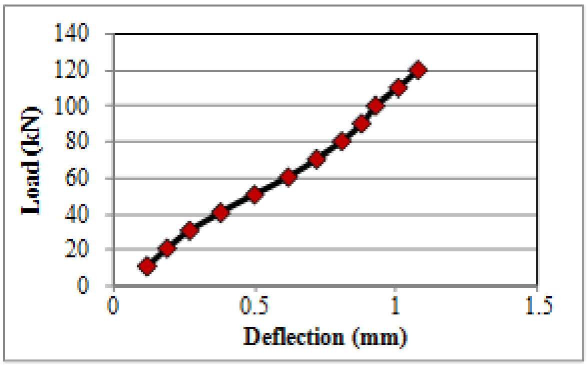

Figure 9: Load – deflection curve for beam incorporating ferrocement formwork with double layers of chicken mesh

Figure 8 and Figure 9 showed the variation in deflection of beam incorporating ferrocement formwork having single and double layers of chicken mesh with increase in load. The obtained deflection corresponding to load 120.574 kN in the two cases was 1.22 mm and 1.08 mm respectively. In the case of control beam the deflection corresponding to the 120.574 kN was 1.62 mm. There was a considerable reduction in deflection in the beams with ferrocement formwork as compared to the control beam.

4.2 Crack pattern

The cracks developed on the specimens after conducting the two point loading test was showed in Figure 10, Figure 11 and Figure 12. Figure 10 showed the crack pattern developed on the control beam specimens at failure. More number of wider cracks was developed on the control beam specimens during loading. The width of cracks increases with increase in load application.

Figure 10: Crack pattern of control beam

Figure 11 and Figure 12 showed the crack pattern developed on the beams incorporating ferrocement formwork having single and double layers of chicken mesh. Lesser number of narrower cracks was developed on the beams incorporating ferrocement formwork. The number of cracks and crack width decreases with increase in number of wire mesh layers.

Figure 11: Crack pattern of beam with ferrocement formwork having single layers of chicken mesh

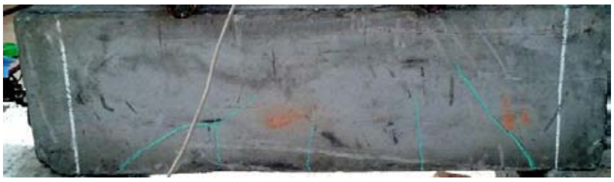

Figure 12: Crack pattern of beam with ferrocement formwork having double layers of chicken mesh

4.3 Crack width

The crack width of different beam specimens were observed during the investigation. Wider cracks were developed on control beam specimens than those of beams incorporating ferrocement formwork. The crack width developed on the specimens at failure was showed in Figure 13 and Figure 14.

Figure 13: Crack width on control beam

Figure 14: Crack width on beam incorporating ferrocement formwork

The beams incorporating ferrocement formwork could withstand higher loads and it also resists the cracks. At failure condition the cracks developed on beams with ferrocement formwork was narrower as compared with control beams.

5. Conclusions

Based on the results and observations of the experimental investigation presented in this study, the following conclusions could be drawn:

- The concrete beams incorporating permanent ferrocement formwork have high strength and crack resistance as compared to conventional reinforced concrete beams of the same dimension.
- Less steel weight was used in the beams incorporating ferrocement formwork, the beams attained higher first crack load and braking load in comparison to the control beams.
- The concrete beams incorporating U shaped ferrocement formwork reinforced with double layers of chicken mesh exhibited the highest first crack load and braking load as compared with beams incorporating U shaped ferrocement formwork reinforced with single layers of chicken mesh.
- With increase in number of wire mesh layers the deflection of beams got decreased.
- Wider cracks were developed in control beam as compared to beam with ferrocement formwork at failure.
- The dead weight of beams incorporating ferrocement formwork was less compared with control beams.
- The U shaped ferrocement formwork can be effectively used as a permanent formwork for beams because it improves the load carrying capacity and crack resistance of the concrete beams.

6. Future Scope

- The study may be extended by varying the number of chicken mesh layers to determine the strength variation of beams incorporating ferrocement formwork to that of control beams.
- The applicability of ferrocement formwork for columns may be investigated with different layers of chicken mesh.

References

[1] P.P. Bansal, M. Kumar, K.S. Kaushik," Effect of Wire Mesh Orientation on Strength of Beams Retrofitted using Ferrocement Jackets", International Journal of Engineering, 2, pp. 8-19.

[2] H.E. Fahmy, B.Y. Shaheen, A.A. Abdelnaby, A.B.M. Zeid, "Applying the Ferrocement Concept in Construction of Concrete Beams Incorporating Reinforced Mortar Permanent Forms", International Journal of Concrete Structures and Materials, 8,pp. 83-97.

[3] H.E. Fahmy, A.B.M. Zeid, B.Y. Shaheen, A.A. Abdelnaby, " A Viable Alternative for Construction of Concrete Beams", 30th Conference on Our World in Concrete & Structures,23-24 August 2005, Singapore.

[4] S.S. Patil, R.A. Ogale, A.K. Dwivedi, " Performance of Chicken Mesh on Strength of Beams Retrofitted using Ferrocement Jackets", IOSR Journal of Engineering, 2, pp. 1-10.

[5] A.A. Tawab, E.H. Fahmy, Y,B. Shaheen, " Use of Permanent Ferrocement Forms for Concrete Beam Construction", Journal of Materials and Structures, 45, pp. 1319-1329.

Author Profile

Anisha G Krishnan was competed the B Tech in Civil Engineering form Sree Buddha College of Engineering for Women, Elavumthitta in 2014 and M Tech form Sri Vellapally Natesan College of Engineering Mavelikkara in 2016. Now she is working in Sri Narayana Institute of Technology Adoor.