Behavior of Ferrocement Composite in Direct Tension by using Welded square mesh

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Abstract-Ferrocement is a special type of reinforced concrete, as it exhibits different behavior than that of the conventional reinforced concrete in performance, strength and application. Also it is superior in qualities like crack control, impact resistance and toughness. Ferrocement has very high tensile strength to weight ratio. Due to its nature, original brittle material gets converted to superior ductile composite. This project presents an experimental study on Tensile strength and behavior aspect of ferrocement in direct tension test. For this purpose total 36 panels are casted and tested for direct tension test. The main objective of these experimental tests is to study the effect of using different numbers of wire mesh as well as by using steel fibers by keeping constant thickness on the tensile strength of ferrocement. Test result shows that panels with more number of layers exhibits greater Tensile strength as that compared with same panels having less number of layers of mesh as well as panels with fiber mesh shows less elongation.

Index Terms- Ferrocement, wire mesh, specific surface, volume fraction, tensile strength, ultimate strength.

1. INTRODUCTION

Ferrocement is a slim and slender material but at the same time strong and elegant. It provides a potential solution to various problems in construction of different types of shapes of structures, also when light weight of structure is expected specially in case of earthquake prone areas as well as provides working solutions for repairs and rehabilitation works. Many civil structures are no longer considered safe due to overloading, under design of existing structures or lack of quality control. In order to maintain efficient serviceability, older structures must be repaired or strengthened so that they meet the same requirements demanded of the structures built today and in future. Ferrocement over the years have gained respect in terms of its superior performance and versatility. Considerable progress in research towards developing ferrocement as an efficient building material has been achieved in the last two decades. Its increase in use as a building material has motivated researchers and engineers to study ferrocement structural elements and formulates design guidelines for them.

The concept of embedding reinforcement into wet concrete to form reinforced concrete was first comes into existence due to a French gardener, Joseph Monier. In 1849, he had introduced a mesh of iron rods into large planting pots. Wilkinson, introduced reinforced concrete beams for buildings by using old mining ropes in the tension side of the beams as a reinforcement. J. L. Lambot made a concrete rowing boat by making use of wire network and interlaced thin rods as a reinforcement. This was the first application of Ferrocement. But for almost 100 years the concept of Ferrocement was almost forgotten. In the early 1940s, Pier Luigi Nervi observed uniqueness of Ferrocement. He noticed that ferrocement is thin, flexible, elastic, and exceptionally strong as well as capable of resisting impact. So after the Second World War, Nervi demonstrated ferrocement as a boat-building material. Later he combined reinforced concrete with the Ferrocement technique and constructed the famous Turin Exhibition Hall with a roof system which spans 91 m. Afterwards in October 1976, an important development was the founding of the International Ferrocement Information Center (IFIC) at the Asian Institute of Technology, Bangkok, Thailand. ACI Committee 549, Ferrocement and Other Thin Reinforced Products, was organized in 1974 and was given the mission to study engineering properties, construction practices, and practical applications of ferrocement and to develop guidelines for ferrocement construction. [1, 2]

Now a day Ferrocement is being widely used worldwide, especially in developing countries due to low labour cost and availability of basic material.

2. LITERATURE REVIEW

Application of ferrocement has been receiving considerable attention recently, as now a days everybody is looking for cost effectiveness as well as light weight construction.

Gangadharappa B. M. et al. [3] worked on Light Weight Ferrocement Subjected to Axial Tension , in which they have used Blast furnace slag with sand which is an effort towards prevention of pollution due to disposal of dangerous industrial waste. Galvanized woven square mesh of 4 x 20 gauge with

6.35 mm diameter of wire is used. Also replacement sand by BFS is kept in range of 0 %, 20 %, 35 %, 70 %. Five volume fraction had been used for total 6 layers. Mix proportion of 1 : 2 with water cement ration of 0.5 was finalized for this work. They got result as 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. Ultimate strength of specimen is found to be directly proportional to the number of mesh layers.

Sayyed Shoheb Navid et al. [4] refering to their observations it can be concluded that Tensile strength increase due to increase in contact area between wire meshes and mortar i.e. increases in specific surface of ferrocement.

P. Paramasivam et al. [5] give thought on effect on Tensile strength of Ferrocement by placing bundled reinforcement near top, bottom and at midsection. In this study they have used galvanized wire mesh having grid size 8.5 mm^2 and wire diameter of 0.87 mm. The sand cement ratio of 1:5, water cement ratio of 0.45 and rapitard of 40ml for 10kg cement was adopted for experimental work. They concluded that by doing such arrangement of mesh there is improvement in crack control and hence durability of ferro-structures when subjected to direct tension.

Shehab Eldin M. Mourad [6] investigated the efficiency of confining plain concrete with different layers of welded Wire Fabric or Welded Wire Mesh in order to increase load carrying capacity. They used wire diameter of 0.94 mm and grid size of 12 mm x 12 mm of welded wire mesh. Mortar of cement sand ratio 1 : 2 with water cement ratio of 0.45 was selected for this job. In his work he found that Confinement of Plain concrete with Ferrocement jacket provides remarkable lateral confinement pressure which increases axial load carrying capacity.

3. OBJECTIVE OF STUDY

The main objective of these experimental tests is to study the effect of using different numbers of wire mesh as well as by using steel fibers by keeping constant thickness on the tensile strength of Ferrocement.

Various parameters considered in this study are as follows -:

- Effect of number of mesh layers on Tensile strength of composite
- Effect of steel fibers on the tensile strength of slab panels.

4. EXPERIMENTAL WORK

The experimental program includes preparing and testing of ferrocement panels under Universal Testing Machine (UTM) in direct Tension. The primary variables were the number of layers of meshes in panels and the use of steel fibers.

In this study, all the specimens were divided into two major groups (1) Ferropanel without fiber (2) Ferropanel with fiber and again sub divided into six groups each according to number of wire mesh layers used. The number of wire mesh layers used are single, two, three, four, five and six layer.

4.1 *Materials used for ferrocement specimen*

4.1.1 *Cement* - Cement Ordinary Portland Cement JK cement (Grade 43).

4.1.2 *Fine aggregates (sand)* - Uniformly graded sand, passing through 2.36 mm I.S. sieve, free of organic matter and deleterious substances, relatively free of silt and clay.

4.1.3 *Water* – Potable Water

4.1.4 *Admixtures* - Perma PC-202 (@ 1% of weight of cement) water reducing and self compacting admixture is used to enhance mix plasticity and to reduce water content.

4.1.5 *Reinforcement* - Galvanized Welded Square Mesh of 1.6 mm Diameter, (20 mm X 20 mm) mesh opening.

4.1.6 *Steel fibers* - Corrugated type with aspect ratio (l/d=57). 0.5% of total weight of material used.

4.1.7 *Mix proportion* – Cement sand ratio (1:1.75) by weight, Water cement ratio (0.38). We finalized mix design on trial and error basis. For this purpose control cubes of size (70 mm x 70 mm x 70 mm) were casted to achieve 50 Mpa compressive strength without fiber and 51 Mpa with steel fibers.

4.2 Test Specimen

The test specimens used in this study has a uniform thickness of 40 mm, as in case of tension the load carrying capacity is independent of specimen thickness because the matrix cracks before and does not contribute directly to composite strength. [1]

For 300 mm of central length, 50 mm width is kept constant. The width uniformly increases to 100 mm at each end over a length of 100 mm out of total 200 mm left out part on either ends. and the increase is "streamlined". The ends of the specimen are 100 mm x 50 mm constant over a length of 100 mm. [3,5,6,7,8] This is shown in Figure 1.

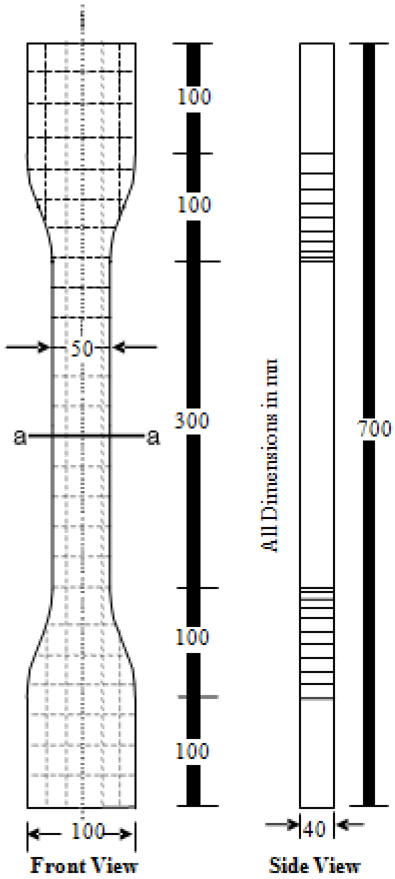

Figure 1: Size of test Specimen

4.3 Preparation of mortar

Mortar was prepared by calculating the exact amount of cement sand and water. Initially cement and sand were mixed dry. Admixture of 1 % of weight of cement is mixed thoroughly with water and then added to dry mix. Steel fibers with dosage of 0.5 % of total volume of composite were added. 50 % of steel fibers were added in dry mortar and remaining 50 % after mixing of water for homogenous mix.

4.4 Preparation of wire mesh specimen

Mesh pieces were cut down according to the size of panel leaving a cover of 3 mm on each side of panel by using wooden mould, as it was really a tough task to cut down wire mesh specimen of required shape. Initially rectangular shape was prepared and then streamlined shape was finalized by using wooden mould which is shown in figure 2 and 3.

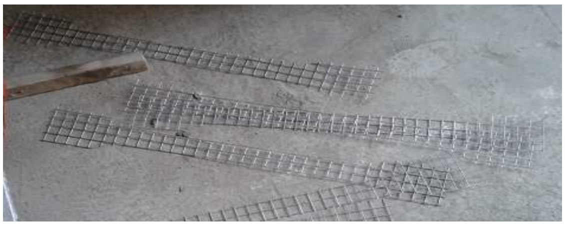

Figure 2: Wooden mould prepared for specimen mesh cutting

Figure 3: Wire mesh specimen after cutting

4.5 Casting

While casting the mesh layers were placed in the test specimen parallel to the direction of loading. Specimens with varying no. of layers of mesh as well as varying usage of steel fibers were casted.

Specially prepared steel moulds were properly oiled before casting. At bottom a layer of mortar was applied of thickness 2-3 mm followed by layer of welded square mesh and again followed by layer of mortar. The procedure continues for placing rest of the layers of mesh so that uniform distribution of mesh can be achieved. While casting panels 10 mm dia. oiled steel pipe pieces were inserted at both ends of panel for attaching grips at the time of testing. This is shown from figure no. 4 to figure no 8.

Figure 4: Laying mesh in mould

Figure 5: Fixing mesh in mould properly

Figure 6: Placing mortar in mould

Figure 7: Fixing pieces of steel pipe for anchorage

Figure 8: Casting of specimen

4.6 Curing

After 24 hours specimen were removed from mould and kept for curing in normal water for next 28 days. This is shown in figure 9.

Figure 9: Curing of specimens

4.7 Testing

After removing specimen from curing tank white wash was applied to the panels to get clear indication of the cracks during testing. Direct Tension test is carried out on digital UTM of 200 kN capacity. For holding specimens special attachments were used. To hold specimen properly 10 mm diameter bars are used to connect specimen with UTM so that it was possible for us to apply tensile force without eccentricity due to which stress concentration is minimized. The load was applied in a direction parallel to the mesh layers. The rate of loading is kept such that test is completed in about 15 minutes. [2]

Figure 10: Experimental setup for Tension test

5. TEST RESULTS AND DISCUSSIONS

Table No.1 – Test results of Square mesh without steel fibers (S)

Sr. No.	No. of layers	Volume fraction of Mesh	Specific surface	Average Ultimate Load (N)	Average Ultimate elongation (mm)	Tensile Strength (Mpa)
S-1	1	0.502	1.256	4320	4.53	1.73
S-2	2	1.005	2.512	6947	4.60	2.78
S-3	3	1.507	3.768	9423	5.50	3.77
S-4	4	2.010	5.024	10700	7.20	4.28
S-5	5	2.512	6.28	13170	7.70	5.27
S-6	6	3.014	7.536	13700	8.00	5.48

Table No.2 – Experimental values for composite of Square mesh with steel fibers (SF)

Sr. No.	No. of layers	Volume fraction of Mesh	Specific surface	Average Ultimate Load (N)	Average Ultimate elongation (mm)	Tensile Strength (Mpa)
SF-1	1	0.502	1.256	5027	2.27	2.01
SF-2	2	1.005	2.512	7707	4.57	3.08
SF-3	3	1.507	3.768	10720	5.03	4.29
SF-4	4	2.010	5.024	12120	5.70	4.85
SF-5	5	2.512	6.28	14987	7.43	5.99
SF-6	6	3.014	7.536	16013	7.97	6.41

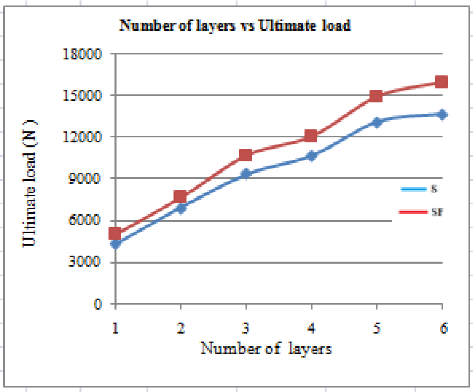

Figure 11: (a)

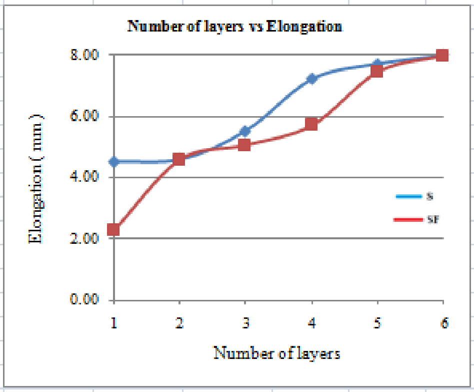

Figure 11: (b)

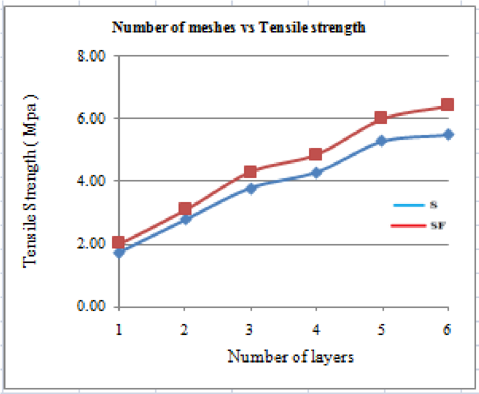

Figure 11: (c)

Figure 11: (a) – Graph of Number of layers Vs Ultimate load for Specimen without fiber and Specimen with fiber.
Figure 11: (b) – Graph of Number of layers Vs Elongation for Specimen without fiber and Specimen with fiber.
Figure 11: (c) – Graph of Number of layers Vs Tensile Strength for Specimen without fiber and Specimen with fiber.

After referring table no. 1 and 2, graphs 11(a), 11(b) and 11(c) have been plotted. Results shows that ultimate load carrying capacity, elongation as well as tensile strength of ferrocement is directly proportional to the number of mesh layers used. This is due to tensile strength of wires of specimen. As Tensile strength is directly related to volume fraction of reinforcement which depends on number of mesh layers provided in ferrocement along the loading direction. This effect is observed in both categories of the specimens.

Typical cracking patterns in direct tension test –

Figure 12: Failure pattern of specimen

In case of failure of specimens, cracks always appeared either in the normal or near normal direction to the loading as shown in figure 12.

CONCLUSION

Ultimate load carrying capacity, elongation as well as tensile strength of ferrocement composite is directly proportional to the number of mesh layers used. On other side elongation at failure also increases when volume fraction increases. Usage of steel fibers increase load carrying capacity as well as tensile strength by about 10 to 17 % of strength of specimens without steel fibers.

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