Behavior of Polymeric Fiber as an Alternative Reinforcement to Iron Wire Mesh in Ferro cement Elements under Flexural Load

M. M. Rahman, S. Sameen, R. Hafiza, and M. A. Sadeque

Abstract — This paper presents a relative comparison in properties between polymeric fiber reinforced ferrocement and conventional ferrocement under flexural load. The aim of this study is to investigate the influence of polymeric mesh, as a replacement of iron mesh, on properties of ferrocement. A series of ferrocement test specimens were cast, and characterized. Each specimen was prepared with single layer of mesh having 25 mm thickness. Hexagonal and expanded metal mesh, nylon 66 and polypropylene woven mesh were used in different test specimens, and effect of different reinforcement is determined. Assessment was carried out on the basis of compressive and flexural strength. Experimental result shows that polymer reinforcement has no adverse effect on the mechanical properties of the ferrocement specimens.

Keywords — crack width, ferrocement, flexural strength, polymer fiber

I. Introduction

FERROCEMENT is a type of thin wall reinforced concrete construction where usually hydraulic cement is reinforced with layers of continuous and relatively small diameter mesh. Mesh may be made of metallic material or other suitable materials. In the early 1940's, Italian Engineer-Architect Pier Luigi Nervi established the preliminary characteristics of ferrocement through a series of tests and pioneered the architectural use of this material [1]. Since then it has been extensively used in roof structures, water tanks, food storage, silos etc, besides being popularly used in boats and barges. Ferrocement material became popular for its light weight, easy labor and economic characteristics, but it has few shortcomings, for instance, in contact with corrosive species iron reinforcement may be corroded through electrochemical reactions that may lead to decrease in durability. Use of polymeric fiber as a replacement to conventional iron reinforcement can be considered to overcome such problems. Even, use of polymeric fiber in place of iron reinforcement may reduce the cost of the material and remove the threat of corrosion as well as will increase its durability. Previously, numbers of studies have been conducted on ferrocement, but comparatively little information is available on use of polymer fiber as reinforcement in cement-sand matrix.

Mansur and Paramasivam [2] studied the cracking behavior of ferrocement elements and predicted the ultimate strength of ferrocement in flexure using plastic analysis. Onet et al. [3] reported that Ferrocement elements have better performance under working loads and have very small crack widths with improved ductility. Jagannathan [4] showed in his works that, polymer reinforced ferrocement slab specimens absorb only about 50% of the impact energy absorbed by chicken mesh reinforced slab. Sakthivel and Jagannathan [5] showed that the energy absorption of fiber reinforced ferrocement slabs is higher than that of conventional ferrocement.

In view to study the feasibility of different types of polymeric fiber as replacement of iron mesh in ferrocemnt, this is first time in Bangladesh polymeric fiber reinforced ferrocement is developed using locally available materials. This is merely first step towards systematic study in the context of Bangladesh. First result of this study indicates that polymeric fiber replacing iron weir mesh is technically feasible.

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II. Experimental

A. Materials

The ferrocement test specimens were prepared using Portland Cement of type CEM 2, Sand, iron wire mesh and polymer fibers. All the materials were collected from local market.

The Portland cement used in this study is characterized in the laboratory with the following physical properties.

TABLE I
PHYSICAL PROPERTIES OF CEMENT

Test performed		Result
1. Fineness test		0.068%
2. Setting time		
	Initial	2 hours
	Final	3 hours
3. Compressive strength		
	7 day	15 MPa
	28 day	19 MPa

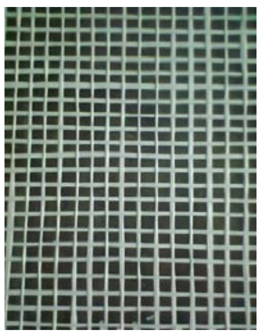
The locally available sand was collected from the localities Sylhet, Bangladesh, and characterized in the laboratory. Table 2 shows the sieve analysis of sand. Sands that passed through

2.36 mm sieve were used in the preparation of specimens in this experiment.

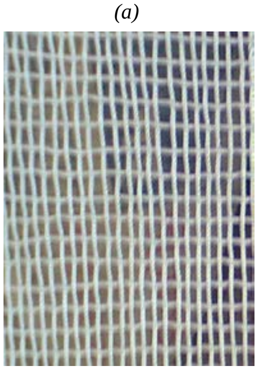
TABLE II
SIEVE ANALYSIS OF SAND

Sieve Size	% Passing by Weight
2.36 mm	94.14
1.18 mm	74.86
600 microns	39.26
300 microns	9.4
150 microns	1.8

Expanded metal mesh and hexagonal mesh for iron reinforcement have been used in this experiment. Polypropylene (PP) and Nylon 66 were used as polymer fiber reinforcement. These materials were selected because of their availability in the local market. Pattern of different reinforcement mesh is illustrated in Figure 1 and 2.

(a) *(b)*




(c) *(d)*

Fig. 1 Types of mesh. (a) Hexagonal iron mesh, (b) Woven PP, (c) Woven Nylon 66 (d) Expanded Metal mesh

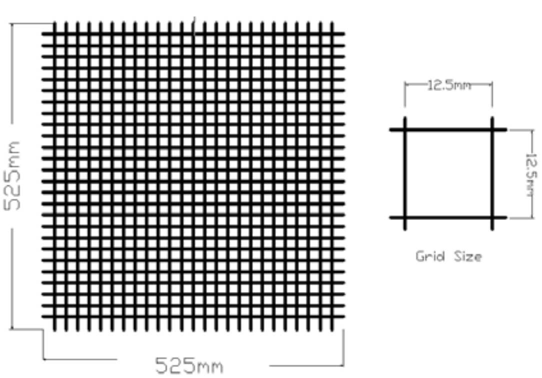


Fig. 2 Polymeric reinforcement details

B. Test Specimens

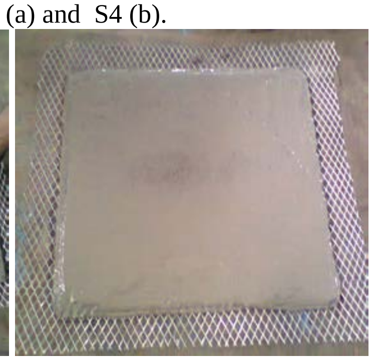
The experimental investigation consisted of casting and testing of four series of ferrocement slabs (S1, S2, S3, S4). The test was carried out with two specimens of each series. The dimensions and details of the specimen slabs are shown in table III.

TABLE III
SPECIMEN DETAILS

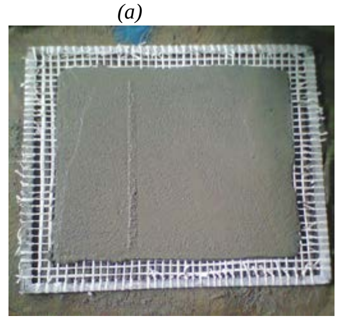
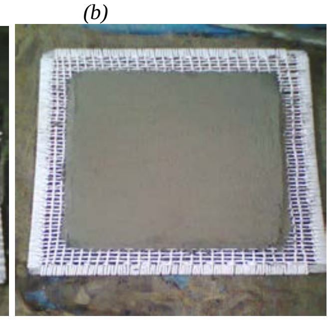
Specimen ID	Types of mesh used in specimens	Thickness mm	Specimen Size
S1	Expanded metal	25	525 mm × 525 mm
S2	Hexagonal	25	525 mm × 525 mm
S3	Polypropylene	25	450 mm × 450 mm
S4	Nylon 66	25	450 mm × 450 mm

C. Sample Preparation

All specimens were cast in moulds of steel. Four samples were prepared using four different types of mesh in single layer. Mortar was prepared with cement-sand ratio of 1:2 and water cement ratio of 0.45. The two types of iron mesh were collected from local market. The locally available polymer fibers were woven in form of mesh with 12.5 mm spacing. During the preparation of a specimen, a layer of mortar of 6.25 mm thick was cast at first, following the placement of one layer mesh above it and the second and final layer of mortar was then placed above the mesh, as shown in figure 3.1 below. After 24 hours of moulding, the specimens were kept under water for curing for 28 days. To carry out the flexural test, specimens of 150 mm × 525 mm and 150 mm × 450 mm were cut from the ferrocement slab S1, S2 and S3, S4 respectively. These test specimens were then named as S1(a), S1(b) , S2 (a), S2 (b), S3 (a), S3 (b) , S4 (a) and S4 (b).

(a) *(b)*

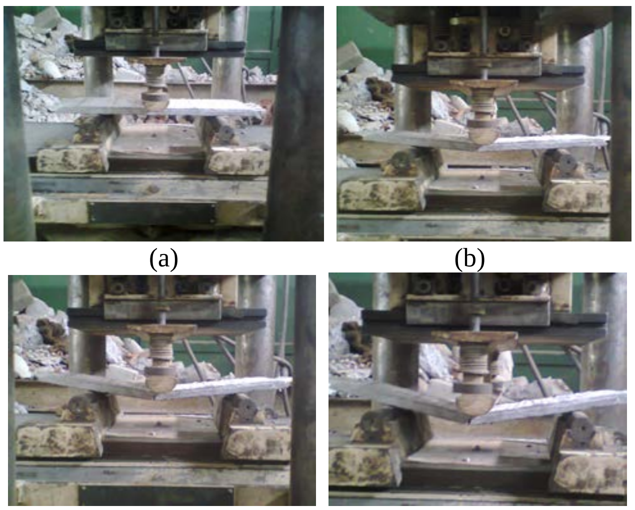



(c) *(d)*

Fig. 3 Test specimens (a) preparation of ferrocement slabs (b) specimen with expanded metal mesh, (c) PP mesh, (d) nylon 66 mesh.

D. Flexural Test

A special flexure loading frame was exclusively fabricated for testing the slab panels and a detail of the test specimen set up is shown in Figure 5. In order to test the slabs on a one point loading, over an effective span of 275mm, the centre of the line of the panel and the roller supports were marked and ferrocement panel was seated on the bottom rollers. Loading was applied manually through a hydraulic jacking arrangement to cause downward deflection. The load was given through the jack in small increments. The loading was continued till the ultimate failure of the slab panels is reached.



(a) (b) (c) (d)

Fig. 4 Flexural test method (one point load) from initial to ultimate load situation

E. Methods

The modulus of rupture is the ultimate strength determined in a flexure test. The modulus of rupture for each sample was evaluated using the following equation.

$$R= 3PL/2bd^2$$

Here, R= Modulus of Rupture, P= ultimate Load, L= span, b= average width of specimen, d= average depth of specimen.

III. Results And Discussions

A. Compressive Strength

Compressive strength of the mortar specimens was evaluated according to ASTM standard using Universal Testing Method (UTM). The test results are illustrated in the following table. Test result shows that maximum compressive of the mortar after 28n days curing is as high as 46 MPa

TABLE IV
Compressive Strength Test Result

Days	Compressive Strength(Mpa)
3 Days	14.0
14 Days	29.0
28 Days	46.0

B. Flexural Strength

Flexural strength of ferrocement specimens of four different compositions was determined using UTM following ASTM standard methods. 8 specimens of 150 mm × 450 mm size, each with single layer of reinforcement, were used in the flexural test. The results are shown in table 5. From the results, it is found that the modulus of rupture of ferrocement specimens with PP mesh is almost similar to that of the specimens with metal mesh as reinforcement. Nylon reinforced ferrocement exhibited modulus of rupture as high as 19 MPa.

TABLE V
MODULUS of RUPTURE

Specimen ID	Type of Reinforcement	Modulus of Rupture (Mpa)
S1(a)	Expanded Metal mesh	16.99
S1(b)	Expanded Metal mesh	14.86
S3(a)	PP Woven Mesh	14.86
S3(b)	PP Woven Mesh	15.29
S4(a)	Nylon 66 Woven Mesh	17.84
S4(b)	Nylon 66 Woven Mesh	19.11

The two ferrocement specimens reinforced with hexagonal wire mesh were cracked into two pieces after the test specimens were cut out from the 525 mm^3 specimen.

C. Effect of Polymer mesh

It was observed that the width of crack developed in the polymer reinforced ferrocement was less than that of the metal mesh ferrocement. Table 6 shows the crack width of different specimens which was developed after flexural test. Greater crack width indicates high percentage elongation of reinforcement and less bonding between the mesh and cement-sand matrix. Similarly, small crack width represents less percentage elongation and better bonding quality between the mortar and the mesh. Ferrocement has become popular over concrete because of its smaller crack width, and here the results have shown that the crack width of ferrocement with polymer reinforcement is much less than the conventional ferrocement itself.

TABLE VI
Crack Width Of Tested Samples

Specimen ID	Types of Mesh used as reinforcement	Average crack width (mm)
S1 (a)	Expanded metal	2.0
S1 (b)	Expanded metal	2.2
S3 (a)	Polypropylene	0.5
S3 (b)	Polypropylene	0.45
S4 (a)	Nylon 66	0.8
S4 (b)	Nylon 66	1.0

Fig. 5 Crack in Tested Specimens

IV. Conclusion

This study indicates that the use of polymer fiber mesh as reinforcement in ferrocement in replacement of iron is technically feasible. This study also shows that polymer fiber reinforcement has no adverse effect on the flexural behavior of ferrocement and on the bonding between mortar matrix and mesh.

From this study it can also be presumed that, as polymer inherent a very good insulating property, use of polymer fiber as mesh in ferrocement will increase the thermal and sound insulation properties of the material.

Acknowledgment

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