Experimental Study on Ferrocement Channel Units Under Flexural Loading

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Abstract—*Ferrocement is often believed to be a form of reinforced concrete. However, in spite of the similarities between the two materials there are still major differences, indicating that ferrocement requires a separate study to establish its structural performances. On the other hand, although a large amount of research has been carried out on ferrocement, its flexural and shear behavior is still not fully understood.*

This report deals with the shear strength of simply supported ferrocement rectangular beam subjected to two points loading. Limited literature is available on the shear behavior of ferrocement elements. However, studies on the shear response of ferrocement assume importance to understand the material behavior. It is observed that increase in the volume fraction of the mesh reinforcement (number of layers of mesh) and specific surface area of reinforcement increased the shear capacity of the member. The flexural behavior is predominant and design of the elements based on flexure is sufficient.

Various authors have studied shear behavior of ferrocement on different specimens such as box beams, panels, and plates. The ANSYS software used for finite element analysis (FEM) of beam. In the present study an attempt is made to observe behavior of ferrocement beam in shear and bending behavior of ferrocement beam. The stress intensity is determined using FEM and compared with the available test results and analytical calculations.

I. INTRODUCTION

Ferrocement is a type of building materials made up of a relatively thin layer of cement mortar reinforced with layers of continuous uniformly distributed wire mesh. The ACI Committee 549 [1] defined ferrocement as “a type of thin wall reinforced concrete commonly constructed of hydraulic cement mortar reinforced with closely spaced layers of continuous and relatively small diameter wire mesh”. The cementing mix consists of cement and sand mortar while the reinforcement steel wire mesh has openings large enough for adequate bonding of the mixture. The uniform dispersion of the steel wire mesh and the close distribution of its opening transform the usually weak and brittle mortar mixture into a high performance building material distinctly different from normal reinforced concrete. This steel wire mesh is also responsible forferrocement structures to have greater tensile strength and flexibility which is not found in ordinary concrete structures. It possesses higher tensile strength to weight ratio and a degree of toughness, ductility, durability and cracking resistance considerably greater than those found in other conventional cement based materials [2]. Since ferrocement is made of the same cementations materials as reinforced concrete structure (RC), it is ideally used as an alternative strengthening component for rehabilitation work on any RC structures.

The most widely used construction materials in today’s world would be concrete and steel combined to make reinforced concrete as can be seen in most building construction. However, the first known example of the usage of reinforced concrete started with the construction of boats when Joseph Lambot of France began to put metal reinforcing inside concrete in 1840s. That was the birth of reinforced concrete and from there subsequent developments followed. The technology at that period could not accommodate the time and effort needed to produce meshes of thousands of wires. Instead, large rods were used to make what is now called standard reinforced concrete. One of the greatest assets of ferrocement is its relatively low unit cost of materials but in countries which demand higher cost of labor, the usage of ferrocement is not economical. For countries where unskilled, low-cost labor is availableand can be trained, and as long as a standard type of construction is adhered to, the efficiency of labor will improve considerably, resulting in a reduced unit cost. With these conditions, ferrocement proves to be a more favorable option thanother materials used in construction, all of which have a higher unit material cost and require greater inputs of skilled labor. The primary worldwide applications of ferrocement construction to date have been for tanks, roofs, silos and mostly boats. In this paper, the flexural behavior of beam strengthened with ferrocement laminate will be investigated. The result from the testing of ferrocement strengthened beam will be compared to a control beam to have a clearer insight into the advantages of using ferrocement. The cracking behavior and ultimate load carrying capacity will be highlighted in this paper.

II. REVIEW OF LITERATURE:

The strengthening of reinforced concrete beams using ferrocement laminates attached onto the surface of the beams has been carried out by Paramasivam, Lim and Ong [2]. In the research, they have come to the conclusions that the addition of ferrocement laminates to the soffit (tension face) of the beams tested statistically substantially delayed the first crack load, restrained cracks from further widening and increased the flexural stiffness and load capacities of the strengthened beam. The improvements in mid-span deflection and load capacities are lower in beams where the composite action was lost between the original beam and the strengthening ferrocement laminates. Thus, it is suggested that the surface of the beam to receive the ferrocement laminate to be roughened and provided with closely spaced shear connectors in order to ensure full composite action.

The flexural behavior of reinforced concrete slabs with ferrocement tension zone cover had been investigated by Al-Kubaisy and Jumaat [7]. Their research proves that reinforced concrete slabs with ferrocement tension zone cover are superior in crack control, stiffness and first crack moment compared to similar slabs with normal concrete cover. Deflection near serviceability limit was significantly reduced in specimens with ferrocement cover.

Research has shown that ferrocement is effective for strengthening purposes for various types of reinforced concrete members such as beams, columns and slabs in terms of increasing the flexural strength, crack control as well as deflection. Columns reinforced with ferrocement jacket also had increased shear strength and higher ductility. Construction costs will be slightly higher with ferrocement cover but this is greatly offset by the money spent on repairing damaged structures caused by cracking or spalling of normal concrete cover. In addition to that, ferrocement allows the existing conventional concrete material and practices to be used and thus, is more practical as a strengthening material compared to others. The usages of ferrocement and its advantages compared to a normally reinforced beam is an interesting topic for further investigation. The short-term behavior, cracking load as well as cracking behavior could be analyzed further to gain more understanding of the advantages of ferrocement.

III. EXPERIMENTAL PROGRAMME:

A. *Description of test specimen:*

Three ferrocement beams of channel section of Grade M30 were cast for the experimental testing carried out in the laboratory. The beam were measured 2400 mm in length with cross section of size 150 mm×150 mm. Two the beams were cast using the same reinforcement which is 4 bar of 6 mm diameter for bottom steel reinforcement and one beam was cast with 2 bars of 6mm. diameter for bottom reinforcement. All three samples have 2 bars of 6 mm diameter as a top reinforcement. In ferrocement laminate, square wire mesh with 1.6 mm diameter and spacing of 20 mm was used.

B. *Material properties:*

Cement and natural sand were used in making the ferrocement mortar in the ratio of 1:3 with a water/cement ratio of 0.55 and admixture. The cement used was ordinary Portland cement complying with IS 12269 specifications .The sand used was river sand conforming IS 650-1991. For reinforcement, a wire mesh with closely spaced wires was used in the ferrocement slabs tested. The galvanized wire mesh had a diameter of 1.6 mm and a spacing of 20 mm. The frame on which the wire mesh was stretched was made of 6 mm diameter mild steel bars having yield strength of 250 N/mm2. The cement and the sand were mixed using the mixer for about 5-8 min. The mortar was designed to give 28 day strength of about 30 N/mm2. The wire mesh had to be tied to a framework made from mild steel bars with a diameter of 6 mm. The reinforcement framework (6 mm diameter) was first fabricated and the wire mesh was tied to it, making a relatively strong cage. In case of channel sections, the framework formed by two steel bars, tow in top and two in bottom of the integral edge beam, separated by 300 mm center to center. The beam was then cast in a mould made of wood. A layer of mortar not exceeding 10 mm was first placed in mould and the reinforcement cage was placed followed by a second layer of mortar. Due to the small thickness of the panel, the wire mesh was placed almost at mid thickness.

Fig. 1: Testing of ferrocement beam Channel section

Nomenclature	Span (m.)	Reinforcement property
A2-1 (Single Point load)	2.2	Welded mesh -1.6mm dia. 20mm spacing. MS-2#6mm dia.
B4-1(Single Point load)	0.9	Welded mesh -1.6mm dia. 20mm spacing. MS-4#6mm dia.
C4-1(Single Point load)	2.2	Welded mesh -1.6mm dia. 20mm spacing. MS-4#6mm dia.
C4-2(Two point load)	2.2	Welded mesh -1.6mm dia. 20mm spacing. MS-4#6mm dia.

Table 1: Details of reinforcement the beam section

Practical difficulties were met when trying to disperse the reinforcement mesh in a uniform pattern through the depth of the slab. With each beam, three 70.7x70.7x70.7 mm concrete cubes were cast to determine the mortar compressive strength and the mortar modulus of rupture. After 2-3 days, the slabs and the cubes were removed from the moulds and were kept under water until the day of testing. The slabs were covered with wet sacks for about 28 days. The compressive strength, flexural strength and the ultimate load tests were then conducted. Following table shows test results of compressive strength of cube :

Sr. no.	Failure load (KN)	Stress in MPa
1	20.2	40.15
2	17.1	34.2
3	18.5	37
	Average	37.12

IV. RESULTS AND DISCUSSION

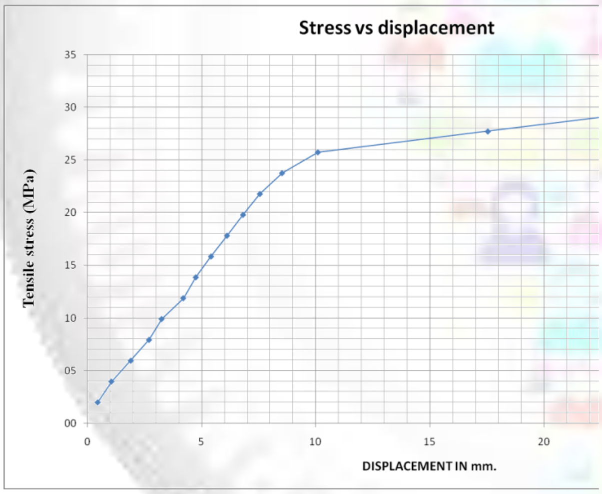
The salient features of the test results are shown in table 3.

The strain distribution along the depth of the units was linear upto the cracking load in all the members i.e. (small and large beams). The load deflection curves of all the specimens have indicated linear behavior up to about cracking load. The observed first cracking moment increases with increase in the number of layers of wire mesh (volume fraction of the reinforcement). After the cracking, the load deflection curves deviated from linearity and become non-linear. As the applied approaches to ultimate load, several new cracks were formed at finite spacing. The specimen is then maintained approximately, the same load level with the increasing deflection, but crack continue to penetrate deep into the top layers of specimens.

Sr. no .	Designation of specimen	% Vf of mesh	First cracking load (KN)	Ultimate load (KN)	Moment (KN.m.)
1	A2-1	1.9	13	15	7.5
2	B4-1 (shear failure)	1.9	24	28	4.2
3	C4-1	2.01	15.7	17.7	9.7
4	C4-2	2.01	26	28	11.9

Table 3: Beam flexure Test results

At this stage crushing of the matrix was observed on the compression zone. Further increase in deflection was associated with a drop in the applied load.



V. CONCLUSIONS

The ferrocement channel sections show flexural strength more than 30 Mpa.As compared to flexural strength of RCC ,ferrocement behaves better in flexure. The thickness of ferrocement components being as small as 25 mm, these components are light weight still have better structural behavior. Thus ferrocement structural components can be used in place of RCC .These components can be used as lost form. This can make light weight structures and good finish, better strength. This analogy can change conventional design of RC elements.

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