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Comparative Study of Ferro-Cement Panel Using Welded Square Mesh and Expanded Mesh

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Abstract
The aim of this research paper is to study the ultimate and service behaviour of ferro-cement roof slab panels and the comparative study of panels via using welded square mesh and expanded mesh. The test results of four different panels of 20 mm thick having number of layers varying one to four presented. The parameters of study include: the effect of the percentage of wire mesh reinforcement by volume and the structural shape of the panels on the ultimate flexural strength, first crack load, crack spacing and load-deformation behaviour. The results indicate that the use of monolithic shallow edge ferro-cement beams with the panels considerably improves the service and ultimate behaviour of the panels, irrespective of the number of steel layers used.
Keywords: *Ferro-cement, Flexural strength, Lload-deformation, Ultimate flexural strength, first cracking load*

1. Introduction

A working definition of ferro-cement is ‘‘a thin shell of highly reinforced Portland cement mortar’’. Generally, Ferro-cement shells range from 10 to 25 mm in thickness and the reinforcement consists of layers of steel mesh, usually with steel reinforcing bars sandwiched midway between [1]. A large number of civil infrastructures around the world are in a state of serious deterioration today due to carbonation, chloride attack, etc. Moreover many civil structures are no longer considered safe due to increase load specifications in the design codes or due to overloading or due to under design of existing structures or due to 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. Ferro-cement over the years has gained respect in terms of its superior performance and versatility.
Ferro-cement has been used for repairing or strengthening existing reinforced concrete structures. It has also been used for sewer rehabilitation [2]. This principle of composite action between ferro-cement and an existing structure could be applied to new construction. Marine structure and motorway bridges subject to environmental effects can all benefit from this new concept.

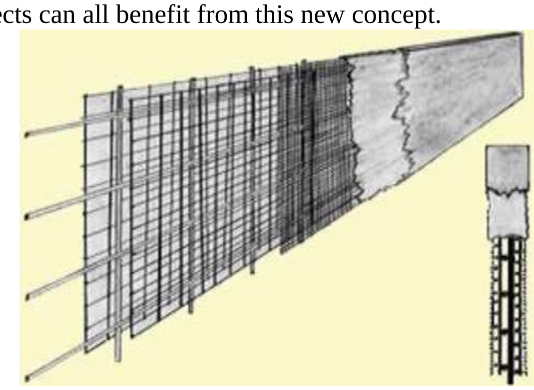

Fig. 1 Typical cross section of ferrocement structure

2. Experimental investigation

2.1 Materials

The cement used in the tests was fresh Ordinary Portland Cement (Grade 53) locally available. Locally available clean and good graded fine aggregate (River Sand) was used, after passing through I.S sieve 2.36 mm. Locally available clean and good graded crushed aggregate was used after passing through I.S sieve 2.36 mm. MS Square steel meshes were used with 19 X 19 mm opening used in the specimens having diameter 1.6 mm. The Expanded mild steel mesh was also used, it having wire diameter 1.6 mm. The opening of expanded mesh was 15 X 20 mm. Ordinary drinking water was used for mixing and curing of concrete. The water was clean and free from acids, alkalis and organic impurities.
Moulds were made from plywood of 16mm thickness. The moulds were fabricated in college workshop. The size of moulds is 550X200X20 mm. The moulds were oiled before casting of panels.

2.2 Mixing proportions

The mix proportion was 1:2 (Cement: Sand) with water to cement ratio of 0.40. Nine cubes (70 mm x 70 mm x 70 mm) were tested for specimens to obtain the average compressive strength (fcu). The specimens were cured by immersing in water for about 28 days. The average compressive strength of tested cube was 40 Mpa.

2.3 Casting of Panels

Different panels of thickness 20mm having number of mesh 1 to 4 have been casted. For Square and expanded type mesh total 24 panels have been casted. For every single thickness of panel there consist of 1 to 4 layers of mesh. For every mesh layer three specimens are casted. Moulds were made from plywood of 16mm thickness. The moulds were fabricated in college workshop. The size of moulds is 550X200X20 mm inner dimensions. The moulds were oiled before casting of panels.

2.4 Instrumentation and set up

The specimens were white colour in order to observe the cracks easily and they were placed on a simply supported base and each support was 50 mm apart from the edge of the specimen. The load was distributed on a two line load at one-third of clear span of the specimen. A dial gauge was placed at the bottom in the mid span to observe the deflection of the slab panels at each load increment. Cracking was carefully checked throughout the loading process and the corresponding cracking load is also noted.

2.5 Volume friction and Specific Surface

The volume fraction of reinforcement is the ratio of volume of reinforcement to the volume of composite. [3-4]

Vr = (N.π.dw2)/(2 .h . D)

Where: N : Number of meshes, dw: Diameter Of mesh wire, h : Thickness of Panel , D : Spacing between mesh wires

The specific surface of reinforcement is the total lateral surface area of the reinforcement divided by total volume of composite; that is the surface area of bounded reinforcement per unit volume of composite.[3-4]

$$S_r = \frac{4 X Vr}{dw}$$

Where: V_r = Volume fraction of reinforcement, d_w= Mesh of wire diameter

Table 1: Volume Fraction and Specific Surface of Reinforcement

Size	Panel Name and Number	No of Mesh Layers	Mesh of Wire Dia (mm)	Square Mesh		Expanded Mesh	
				Volume Fraction (Vr) %	Specific Surface of Reinforcement for Square Mesh	Volume Fraction (Vr) %	Specific Surface of Reinforcement for Expanded Mesh
550X200X20	20-S-1	1	1.6	1.057	0.0001	1.178	0.0295
	20-S-2	2	1.6	2.115	0.0503	2.357	0.0589
	20-S-3	3	1.6	3.173	0.0754	3.535	0.0884
	20-S-4	4	1.6	4.230	0.1005	4.713	0.1178

2.6 Test Program

To study the strength and structural behaviour and ultimate strength of ferrocement slab panels, a number of experiments have been carried out. This includes the properties of the materials used, casting of ferro-cement slab panels, and preparation of samples, testing procedure, description of the testing instrument and the geometry of the specimens.

The experimental program includes preparing and testing of ferrocement slab panels under two-point loading. The primary variables were the thickness of panels, number of layers of meshes and different type of meshes (Square Welded and Expanded).

The specimens were white colour in order to observe the cracks easily and they were placed on a simply supported base and each support was 50 mm apart from the edge of the specimen. The load was distributed on a two line load at one-third of clear span of the specimen. A dial gauge was placed at the bottom in the mid span to observe the deflection of the slab panels at each load increment. Cracking was carefully checked throughout the loading process and the corresponding cracking load is also noted.

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Fig. 2 Flexural test setup

3. Testing Result

3.1 Load VS Deflection Graphs

Cracking load, ultimate cracking load & flexural strength of each panel has been studied. The load VS deflection curve of each panel has been drawn and elastic modules of each matrix has been calculate. The test results of the samples at the age of (28 days) from the day of casting. Panels were placed in sunlight for 4 hours for drying before testing.
The graph shows the load vs deflection curve,

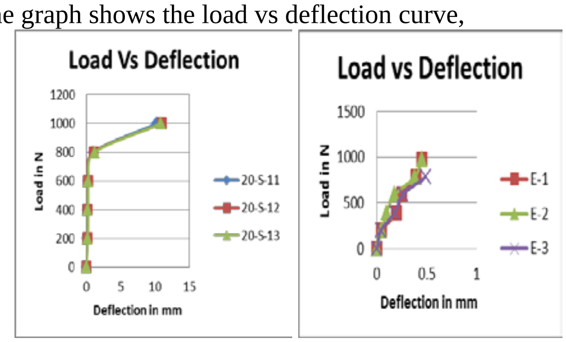

Fig. 3 load VS Deflection 20 mm thick 1 layer Square and Expanded

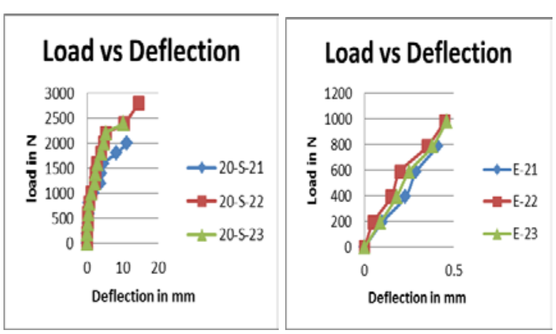

Fig. 4 load VS Deflection 20 mm thick 2 layer Square and Expanded

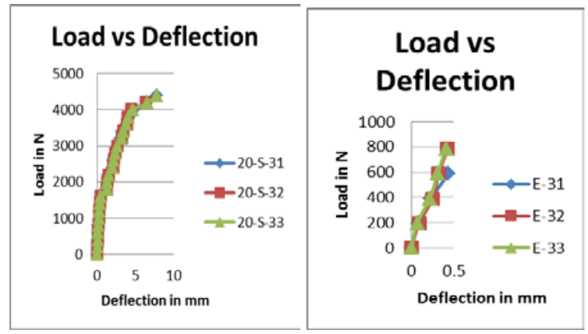

Fig. 5 load VS Deflection 20 mm thick 3 layer Square and Expanded

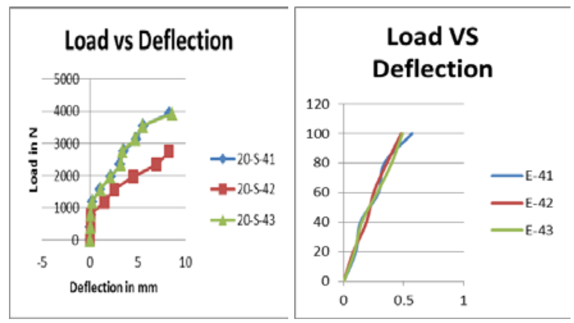

Fig. 6 load VS Deflection 20 mm thick 4 layer Square and Expanded

3.2 Load VS Deflection Graphs

On the basis of load vs deflection curves the elastic modules of the Ferrocement matrix is calculated. To calculate the stress in the each layer of the panel the Analysis methods for bending under service loads is used. The stresses at each layers has been calculated.
The stress at bottom layer of the panel is calculated by the formula.[3]

$$\sigma_{mtop} = \frac{M\left(\frac{h}{2}\right)}{I_{(tr)uncracked}}$$

Where: M= Moment leading to cracking, $I_{(tr)uncracked}$= Moment of inertia just before cracking , h=Thickness of panel
The stress at bottom layer of the panel is calculated by the formula.

$$\sigma_{mtop} = \frac{M_{service} X C}{I_{(tr)cracked}}$$

Where: $M_{service}$ = Maximum service moment, C = Neutral axis of bending, $I_{(tr)cracked}$=Moment of inertia of transformed cracked section
Stresses at each layer are calculated by:

$$\sigma_{ri} = n \frac{M(\frac{h}{2}-d_i)}{I_{(tr)uncracked}}$$

Where: $I_{(tr)uncracked}$ = Moment of inertia just before cracking, h=Thickness of panel, M= Moment leading to cracking, d_i=Distance of reinforcing mesh from extreme to fibre, n= Moduli ratio

The stresses at the different layers have been calculated for the square and expanded mesh.

Table 2: Stress at each mesh layers and Curvature of section just before cracking for panels for expanded mesh

Slab Thickness & layers	M_{cr} N.mm (x 10^3)	σ_{r1} N/mm^2	σ_{r2} N/mm^2	σ_{r3} N/mm^2	σ_{r4} N/mm^2	$\sigma_{m\,(Bottom)}$ N/mm^2	E_c (GPa)	Φ_A (m^{-1})
20-E-1	29.43	-6.302	------	------	------	2.2	15.636	0.014
20-E-2	59.129	-13.81	-59.126	------	------	3.75	16.269	0.0232
20-E-3	88.28	20.9	7.845	-20.9	------	5.68	16.906	0.0335
20-E-4	103.005	24.01	7.983	-8	-24.01	6.524	17.543	0.03718

Table 3: Stress at each mesh layers and Curvature of section just before cracking for panels for square mesh

Slab Thickness & layers	Mcr N.mm (x 10^3)	σ_{r1} N/mm2	σ_{r2} N/mm2	σ_{r3} N/mm2	σ_{r4} N/mm2	$\sigma_{m\,(Bottom)}$ N/mm2	Ec (GPa)	Φ_A (m-1)
20-S-1	58.860	-25.740	------	------	------	3.890	16.020	0.025
20-S-2	103.005	40.308	-40.308	------	------	6.099	16.920	0.036
20-S-3	161.865	36.838	16.162	-36.838	------	7.460	30.840	0.033
20-S-4	235.440	65.025	26.010	-26.010	-25.150	14.013	24.860	0.056

4. Conclusion

After recording the results obtained from flexure test it was found that the strength increases with increase in the number of mesh layers for both panels. Square mesh panels behaves much batter in all parameters than expanded mesh

The square mesh used panels gives better results than expanded mesh in flexure.

From the observed readings it is found that for square mesh used panels there is continuously increase in flexural strength as 35% to 45% compared to expanded mesh panels.

Panels cast using square mesh sustain 40 to 50% moment than panels cast from expanded mesh for one layer.

For panel thickness, as volume fraction and specific surface area increases, the flexural strength of panel increases.

The square mesh cast panels shows stiffness and higher cracking moment than the expanded mesh panels.

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