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Experimental Investigation of Ferrocement Panel Under Flexure By Using Expanded Metal Mesh

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Abstract-:

The present study describes the results of testing flat ferrocement panels reinforced with different number of wire mesh layer and variation in panel thickness. The main objective of these experimental tests is to study the effect of using different numbers of wire mesh layers and thickness variation on the flexural strength of flat ferrocement panels and to compare the effect of varying the number of wire mesh layers on the ductility and the ultimate strength of this type of ferrocement structure. In this study, all the specimens were divided into four groups to investigate the strength and behavior of ferrocement flat panels subjected to two-point loading. Forty eight Ferro-cement elements were constructed and tested. The used number of wire mesh layers is single, two, three and four layers; also thicknesses of panels are 20mm, 30mm, 40mm.

Keywords: Ferrocement; Wire Mesh, effect,Flexural Strength ,Ductility, Ultimate Strength, Layers,panels

1. Introduction

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. Ferrocement over the years have gained respect in terms of its superior performance and versatility**.** Ferrocement is a form of reinforced concrete using closely spaced multiple layers of mesh and/or small diameter rods completely infiltrated with, or encapsulated in, mortar. In 1940 Pier Luigi Nervy, an Italian engineer, architect and contractor, used ferrocement first for the construction of aircraft hangars, boats and buildings and a variety of other structures. It is a very durable, cheap and versatile material**.**

Constituents of Ferrocement :

Cement: The cement should be fresh, of uniform consistency and free of lumps.

Fine Aggregates: Normal weight fine aggregate clean, hard, and strong, free of organic impurities and deleterious substances and relatively free of silt and clay.

Water**:** Potable water is fit for use as mixing water as well as for curing ferrocement

Admixture**:** Chemical admixtures used in ferrocement serve purposes of water reduction, with strength and reduce permeability; air entrainment, which increases resistance to freezing and thawing; and suppression of reaction between galvanized reinforcement and cement.

Ferrocement Composite have**, T**hickness 6 to 50 mm Steel cover 1.5 to 5 mm, Ultimate tensile strength up to 34 MPa Allowable tensile stress up to 10 MPa, Modulus of rupture up to 55MPa, Compressive strength up to 28 to 69MPa.

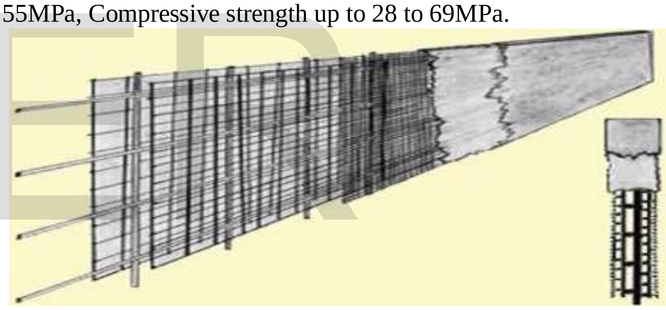

Figure 1. Typical cross section of ferrocement structure

2. Literature Review -:

Mohamad N. Mahmood Sura A. Majeed[1] carried out an experimental work on flat and folded ferrocement panels for studying their flexural behaviour. The panels tested for flexure are of size 380mm X 600mm with 20mm thickness for both flat as well as folded slab panels. The wire mesh used was mild steel galvanized welded wire mesh of 0.65 mm diameter and 12.5 mm square grid size. From his experimental work the author concludes that the cracking load was not significantly affected by the number of the wire mesh particularly for the folded panels. The also concludes thatthe flexural strength of the folded panel increased by 37 and 90 percent for panels having 2 and 3 wire mesh layers compared with that of single layer; while for the flat panel the percentage increase in the flexural strength using 2 and 3 layers is 65% and 68% compared with that of plain mortar panel.

S. Deepa Shri and R. Thenmozhi[2] carried out an experimental work on ferrocement panels for studying their flexural behavior

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by using polypropylene fiber. Silica fume is added to reduce the dosage of chemical admixtures needed to get required slump. It is well known that addition of fiber will generally improve the ductility, toughness, flexural strength and reduce the deflection of cementitious materials. In the present study, polypropylene fiber is added to the matrix and the dosage of fiber is taken as 0.3% by weight of cementitious materials. Weld mesh is arranged in different layers in ferrocement slab instead of reinforcement. Weld mesh of size 590 mm X 290 mm with grid size 20 mm X 20 mm and 1.2 mm dia. skeleton reinforcement is used for casting of ferrocement slabs. The slab panel size was 700mm X 300mm X 25mm and 30mm. The authors conclude that the load carrying capacity of SCC ferrocement slab panel with 0.3% fiber is larger compared to without fiber, delayed the first crack load, yield load and ultimate load compared to without fibers and there is an increase in strength with the increase of slab thickness.

Chee Ban Cheah and Mahyuddin Ramli[3] carried out an experimental work on HCWA (High Calcium Wood Ash) – DSF (Densified Silica Fume) high strength ferrocement panels for studying the flexural behaviour. Superplasticzer was used as a water reduction agent. A total of five layers of welded galvanised steel square mesh with a wire diameter of 1.05 mm and 13 mm spacing were provided as an internal reinforcement for each fabricated ferrocement panel. The Portland cement binder was partially replaced using HCWA at substitution levels of 0% 2%, 4%, 6%, 8% and 10% by total binder weight. Panel size used was 350mm X 125mm X 30mm for testing. From the experimental work the authors concludes that the use of HCWA at various levels of cement replacement up to 6% by total binder weight enhances the bulk density, compressive strength, flexural strength and Young's modulus of elasticity of mortar. Also concludes that there is a high tendency for thin ferrocement panels to fail in the pure bending mode upon being subjected to a flexural load.

Fahrizal Zulkarnain and Mohd. Zailan Suleiman[4] carried out an experimental work on ferrocement panels to study load and deflection characteristics, moments, crack widths, crack spacing, and the number of cracks when subjected to static flexure. The size of the test specimen was 125 mm x 350 mm x 30 mm, reinforced with 3 layer of square welded mesh of 1.0 mm diameter with opening of 12.0 mm x 12.0 mm. Three different polymer modification systems was employed in this study, namely styrene butadiene rubber latex (SBR), natural rubber latex (NR) and epoxy resin (ER), in their ability to increase the bond strength between mortar and reinforcement. The authors concludes that the results show that polymer modification has improved the mechanical properties of cement mortars, particularly their flexural strength. Also concludes that the first crack load of the polymer-modified and unmodified ferrocements shows higher predicted values than that of the experimental at 30 days of curing.

K. Sasiekalaa and R. Malathy[5] carried out an experimental work for studying flexural behaviour of ferrocement panels. The size of the slab panel was 500mm x150mm x 25mm. Silica fume and flyash was used as a partial replacement of cement by weight. Superplasticizer was also used as a water reduction agent. The galvanized chicken wire mesh was used as a reinforcement. From the flexure study parameters such as first crack load, ultimate load, maximum deflection, and crack pattern were observed. From the experimental work the authors concludes that Ferrocement panels with chicken mesh exhibit linear elastic behaviour up to the maximum load irrespective of the volume fraction of mesh reinforcement used. The authors also concludes that there is an increase in the load carrying capacity of the ferrocement panels with the increase in the volume fraction of the mesh reinforcement.

3. **Objective of experimental study –**

The main objective of this experimental work is to study the behavior of ferrocement panels under flexural loading in which expanded metal mesh has been used as a reinforcement. The various parameters considered in this study are as follows -:

a. Effect of number of mesh layers on the flexural strength of slab panels.
b. Effect of panel thickness on the flexural strength of slab panels.
c.Effect of volume fraction on the flexural strength of slab panels.

Experimental Work -:

The experimental program includes preparing and testing of forty eight ferrocement slab panels under two-point loading. The primary variables were the thickness of panels and number of layers of meshes. The materials used for the experimental work was as given below -:

Cement – Ordinary Portland Cement, Sand -:Passing through 2.36 mm I. S. Sieve, Crushed Sand -: Locally available

Water – Ordinary Drinking Water, Mesh Used – Expanded Metal Mesh of 15mm X 30mm opening and 1.8 mm thickness.

Mix Proportion Used -:

W/c Ratio : Cement : Sand : Crushed Sand
0.4 : 1 : 1 : 1

Table 1.Comp. test results for cube at the end of 28 days

Sr. No.	sectional Area (mm^2)	Load at Failure (N)	Comp. Strength (N/mm^2)	Average Comp. Strength (N/mm^2)
1	70 X 70	220000	44.89	44.40
2	70 X 70	210000	42.85	
3	70 X 70	220000	44.89	

Table 2.Details of panels tested under flexure with notations -:

Dimension of panels(mm)	Designation	Number of panels	Number of layers
550x200x20	E1	03	02
	E2	03	03
	E3	03	04

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550x200x30	E4	03	02
	E5	03	03
	E6	03	04
550x200x40	E7	03	02
	E8	03	03
	E9	03	04

Details of Flexural Strength -: The flexural strength test under two point loading was conducted on all the panels. During the testing loads and the corresponding deflections are noted down

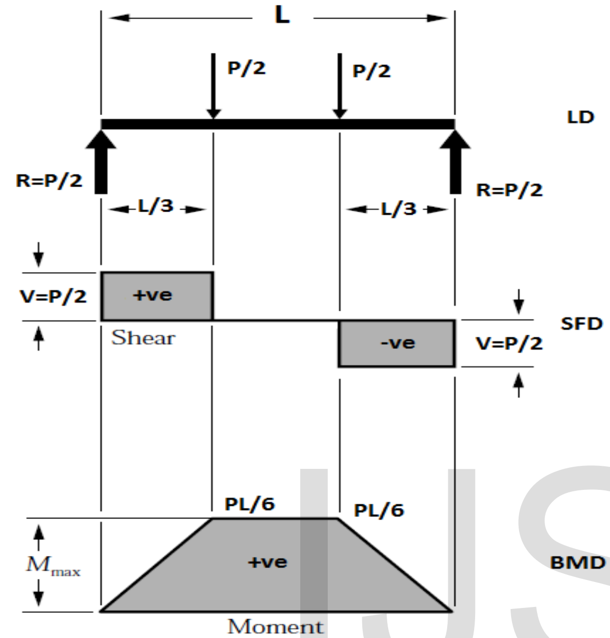

Figure 2. SFD and BMD Distribution

and are presented here in the forms of tables and graphs. The flexural strenght was also calcuted and shown here.

The bending strength was calculated by using the following formula -:

$$\frac{M}{I} = \frac{\sigma}{y}, \qquad \sigma = \frac{M}{I} y$$

Where:
M: Bending Moment, (N.mm)
y= D/2, (mm)
I: Moment of Inertia= $BD^3/12$, (mm^4)

Figure 3. Flexural Strength Test

4. Test Results -:

Table 3. Test results for Sample E1, Thickness of panels = 20mm ; Number of Mesh layers = 2

Load(kg)	Deflection(mm)		
	E11	E12	E13
0	00	00	00
20	0.04	0.05	0.05
40	0.10	0.12	0.12
60	0.15	0.22	0.23
80	0.29	0.31	0.37
100	0.40	0.41	0.38
	First cracking load= 80kg	First cracking load= 80kg	First cracking load= 60kg

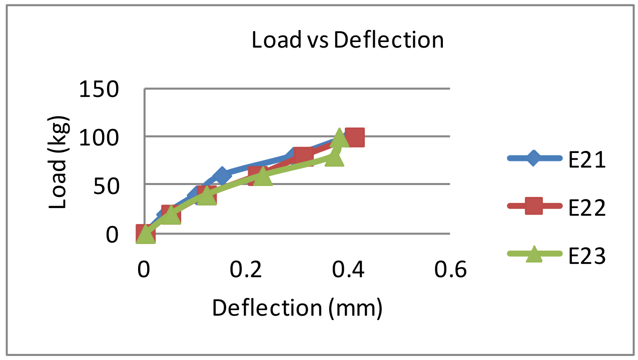

Table 4. Test results for Sample E2, Thickness of panels = 20mm ; Number of Mesh layers = 3

Load(kg)	Deflection(mm)		
	E21	E22	E23
0	00	00	00
20	0.02	0.05	0.01
40	0.08	0.10	0.09
60	0.12	0.15	0.13
80	0.21	0.23	0.22
100	0.27	0.26	0.28
120	0.35	0.34	0.33
140	0.38	0.39	
	First cracking load= 120kg	First cracking load= 100kg	First cracking load= 100kg

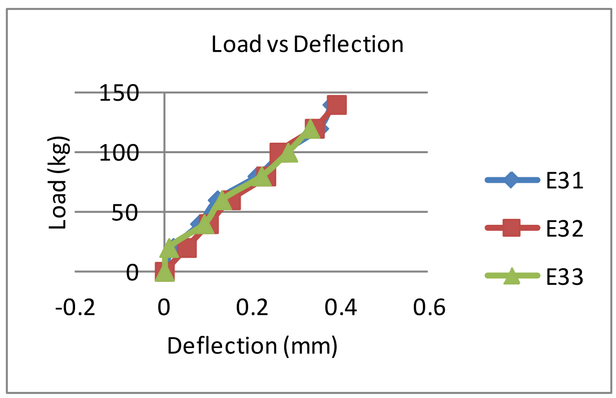

Table 5. Test results for Sample E3, Thickness of panels = 20mm ; Number of Mesh layers = 4

Load(kg)	Deflection(mm)		
	E31	E32	E33
0	00	00	00
20	0.03	0.05	0.04
40	0.07	0.06	0.09
60	0.09	0.10	0.13

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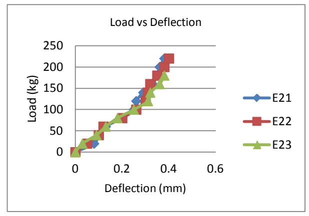
80	0.15	0.13	0.17
100	0.21	0.20	0.19
120	0.27	0.25	0.26
140	0.29	0.30	0.32
160	0.32	0.36	0.34
	First cracking load= 120kg	First cracking load= 140kg	First cracking load= 120kg



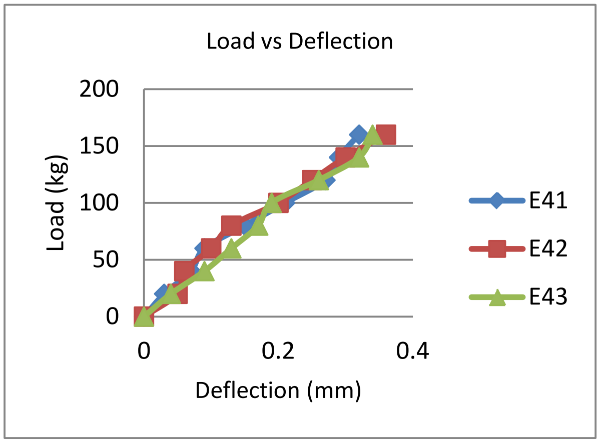


Table 6. Test results for Sample E4, Thickness of panels = 30mm ; Number of Mesh layers = 2

Load(kg)	Deflection(mm)		
	E41	E42	E43
0	00	00	00
20	0.08	0.05	0.03
40	0.10	0.10	0.09
60	0.13	0.12	0.13
80	0.20	0.20	0.18
100	0.25	0.26	0.25
120	0.26	0.30	0.31
140	0.29	0.31	0.32
160	0.33	0.32	0.36
180	0.35	0.35	0.38
200	0.36	0.38	
220	0.38	0.40	
	First cracking load= 180kg	First cracking load= 180kg	First cracking load= 160kg

Table 7. Test results for Sample E5, Thickness of panels = 30mm ; Number of Mesh layers = 3

Load(kg)	Deflection(mm)		
	E31	E32	E33
0	00	00	00
20	0.05	0.02	0.03
40	0.07	0.04	0.09
60	0.12	0.09	0.14
80	0.13	0.10	0.16
100	0.19	0.12	0.15
120	0.20	0.13	0.17
140	0.25	0.21	0.24
160	0.29	0.26	0.25
180	0.30	0.29	0.28
200	0.31	0.32	0.30
220	0.32	0.34	0.34
240	0.33	0.36	0.35
260	0.35		0.36
	First cracking load= 240kg	First cracking load= 200kg	First cracking load= 220kg

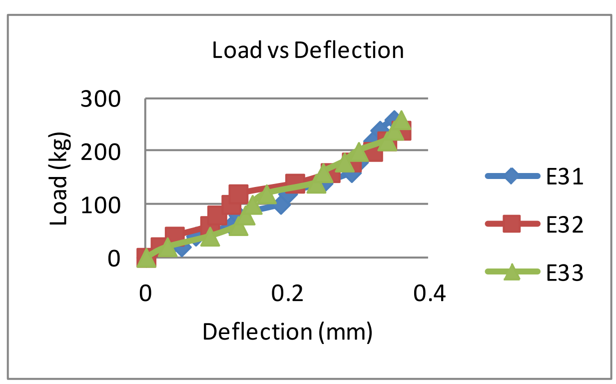


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Table 8. Test results for Sample E6, Thickness of panels = 30mm ; Number of Mesh layers = 4

Load(kg)	Deflection(mm)		
	E41	E42	E43
0	00	00	00
20	0.05	0.03	0.03
40	0.08	0.04	0.07
60	0.12	0.08	0.12
80	0.13	0.10	0.14
100	0.15	0.12	0.15
120	0.17	0.14	0.17
140	0.19	0.21	0.20
160	0.21	0.22	0.22
180	0.22	0.23	0.24
200	0.24	0.27	0.25
220	0.26	0.29	0.26
240	0.27	0.31	0.28
260	0.29	0.32	0.30
280	0.31		0.33
300	0.32		
	First cracking load= 260kg	First cracking load= 240kg	First cracking load= 240kg

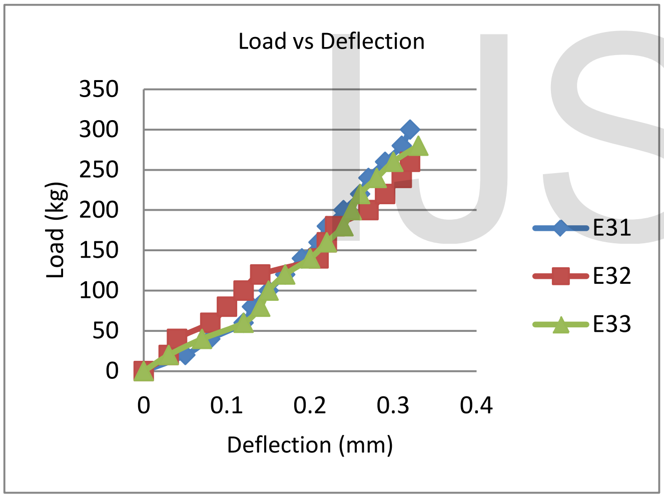

Table 9. Test results for Sample E7, Thickness of panels = 40mm ; Number of Mesh layers = 2

Load(kg)	Deflection(mm)		
	E21	E22	E23
0	00	00	00
20	0.01	0.01	0.02
40	0.02	0.02	0.06
60	0.03	0.03	0.09
80	0.09	0.08	0.11
100	0.10	0.11	0.13
120	0.11	0.13	0.14
140	0.13	0.15	0.15
160	0.14	0.17	0.17
180	0.17	0.21	0.18
200	0.20	0.24	0.20
220	0.23	0.27	0.23
240	0.25	0.29	0.25
260	0.27	0.32	0.26
280	0.28	0.35	0.29
300	0.35		0.32
320			0.34
	First cracking load= 260kg	First cracking load= 250kg	First cracking load= 270kg

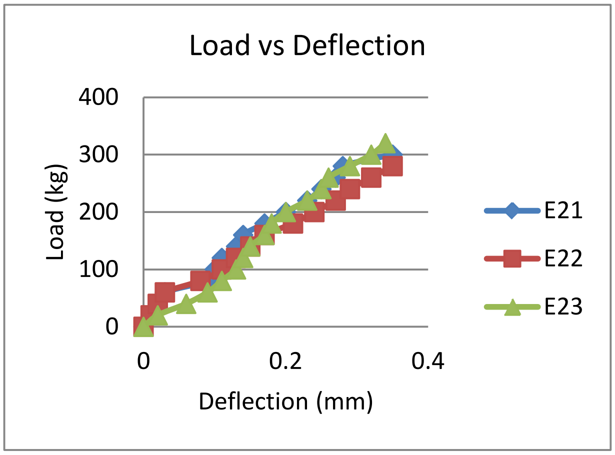

Table 10. Test results for Sample E8, Thickness of panels = 40mm ; Number of Mesh layers = 3

Load(kg)	Deflection(mm)		
	E31	E32	E33
0	00	00	00
20	0.00	0.01	0.00
40	0.03	0.02	0.01
60	0.04	0.03	0.05
80	0.05	0.07	0.08
100	0.07	0.11	0.10
120	0.09	0.13	0.12
140	0.10	0.15	0.15
160	0.14	0.17	0.17
180	0.17	0.21	0.18
200	0.20	0.24	0.20
220	0.23	0.25	0.23
240	0.25	0.26	0.25
260	0.27	0.28	0.26
280	0.28	0.29	0.29
300	0.29	0.30	0.30
320	0.30	0.31	0.31
340	0.31	0.32	0.32
360		0.33	
	First cracking load= 320kg	First cracking load= 330kg	First cracking load= 300kg

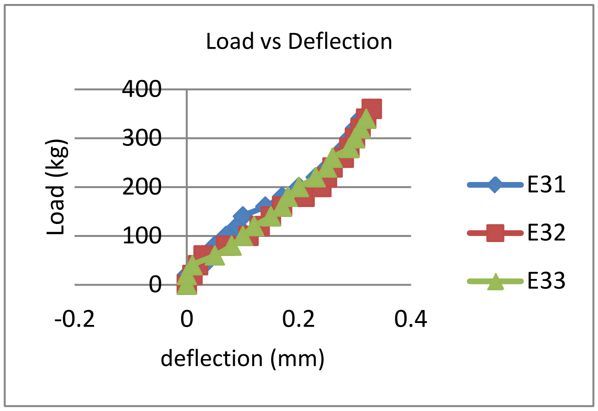

Table 11. Test results for Sample E9, Thickness of panels = 40mm ; Number of Mesh layers = 4

Load(kg)	Deflection(mm)		
	E41	E42	E43
0	00	00	00
20	0.00	0.00	0.00
40	0.02	0.02	0.01
60	0.03	0.03	0.02
80	0.05	0.06	0.04
100	0.06	0.09	0.07
120	0.09	0.10	0.11
140	0.10	0.11	0.12
160	0.12	0.13	0.15
180	0.15	0.14	0.17
200	0.17	0.16	0.20
220	0.18	0.17	0.21
240	0.19	0.19	0.22
260	0.20	0.21	0.23
280	0.22	0.23	0.24
300	0.24	0.24	0.25
320	0.27	0.26	0.26
340	0.28	0.27	0.27
360	0.29	0.29	0.28
380	0.30	0.33	0.30
400	0.31		0.31
	First cracking load= 320kg	First cracking load= 340kg	First cracking load= 330kg

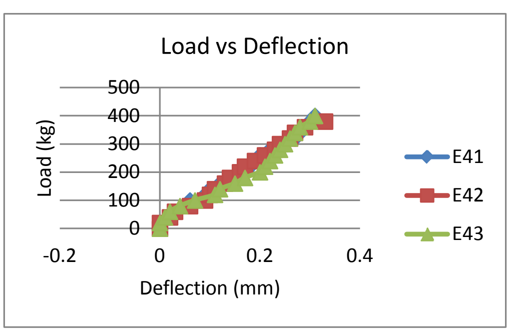

Table 12. Flexural Strength of ferrocement panels of 550 mmx200 mm dimension

Specimen and size	Panel Number	Cracking Load (N)	Ultimate Load (N)	Flexural strength at cracking load σ_{cr} $(\frac{N}{mm^2})$	Flexural strength at ultimate load σ_{ult} $(\frac{N}{mm^2})$
E1(20mm thick)	E21	800	1000	4.50	5.625
	E22	780	990	4.39	5.572
	E23	770	990	4.33	5.567
E2(20mm thick)	E31	1200	1400	6.75	7.875
	E32	1000	1300	5.625	7.313
	E33	1000	1350	5.625	7.594
E3(20mm thick)	E41	1200	1600	6.75	9.000
	E42	1400	1500	7.875	8.438
	E43	1200	1400	6.75	7.875
E4(30mm thick)	E21	1800	2200	4.50	5.500
	E22	1800	2100	4.50	5.250
	E23	1600	2150	4.00	5.375
E5(30mm thick)	E31	2400	2600	6.00	6.500
	E32	2000	2500	5.00	6.250
	E33	2200	2600	5.50	6.500
E6(30mm thick)	E41	2600	3000	6.500	7.500
	E42	2400	2900	6.000	7.250
	E43	2500	2900	6.250	7.250
E7(40mm thick)	E21	2600	3000	3.656	4.137
	E22	2500	3000	3.515	4.218
	E23	2700	3200	3.796	4.499
E8(40mm thick)	E31	3200	3400	4.499	4.780
	E32	3300	3600	4.639	5.061
	E33	3000	3450	4.218	4.850
E9(40mm thick)	E41	3200	4000	4.499	5.624
	E42	3400	3900	4.780	5.483
	E43	3300	3800	4.639	5.342

Conclusion -:

Based upon the experimental test results of the ferrocement panels the following conclusions can be drawn :

1. The flexural loads at first crack and ultimate loads depend on number of reinforcing mesh layers used in ferrocement panel.
2. Increasing the number of layers of wire mesh from 2 to 4 layers significantly increases the ductility and capability to absorb energy of the panels. Increase in number of mesh layers improves the ductile behavior of ferrocement slabs.
3. Increasing the thickness also affected the final breaking load for slab panels. Therefore increasing the thickness of ferrocement panels from 20 mm to 50 mm significantly increases the ductility and capability to absorb energy the panels.
4. Increase in thickness of slab panels and increase in mesh layer,

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central deflection of slab panel goes on reducing.

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