

# Flexural Behaviour of Ferrocement Slab Panels 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 behaviour of ferrocement flat panels subjected to two-point loading. Forty-eight ferrocement 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 and 50 mm.

**KEYWORDS:** Flat ferrocement panel, Wire mesh layers, Ultimate strength, and two-point loading.

## I. INTRODUCTION

### 1.1 General:

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.

### 1.2 Definition is ferrocement:

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 Nervi, 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.

### 1.3 Constituents of ferrocement:

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

**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.

### 1.4 Objective of Proposed 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 -:

- 1) Effect of number of mesh layers on the flexural strength of slab panels.
- 2) Effect of panel thickness on the flexural strength of slab panels.
- 3) To study the crack pattern for various samples

## II. EXPERIMENTAL PROGRAM

In order to study the strength and structural behavior and ultimate strength of ferrocement slab panels, a series of experiments have been carried out. This chapter includes the properties of the materials used, casting of ferrocement 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 forty-eight ferrocement slab panels under two-point loading. The primary variables were the thickness of panels and number of layers of meshes.

Cement:-The cement used in the tests was Ordinary Portland Cement (Grade 53) locally available

Fine Aggregate (Sand):-

Locally available clean and good graded fine aggregate was used after passing through I.S sieve 2.36 mm.

Crushed sand:-

Locally available clean and good graded crushed aggregate was used after passing through I.S sieve 2.36 mm Wire Mesh:-

Expanded steel meshes were used with 15x30mm opening used in the specimens.

Ordinary drinking water was used for mixing and curing of concrete. The water was clean and free from acids, alkalis and organic impurities.



Fig. 1. Typical Moulds of the Tested Specimens



Fig. 2. Casting of Cement Mortar

Table.1.Compressive Strength of mortar cubes

| Cube sample | Load taken (7 days) (kg) | Load taken (28 days)(kg) | Compressive Strength (7days) (N/mm <sup>2</sup> ) | Compressive Strength (28 days) (N/mm <sup>2</sup> ) | Average Compressive Strength (7 days) (N/mm <sup>2</sup> ) | Average Compressive Strength (28 days) (N/mm <sup>2</sup> ) |
|-------------|--------------------------|--------------------------|---|---|--|---|
| C1          | 13000                    | 22000                    | 26.53   | 44.89   | <b>25.85</b>   | <b>41.49</b>  |
| C2          | 12000                    | 21000                    | 24.49   | 42.85   |  |   |
| C3          | 13000                    | 18000                    | 26.53   | 36.73   |  |   |
| C4          | 14000                    | 22000                    | 28.57   | 44.89   | <b>28.57</b>   | <b>44.42</b>  |
| C5          | 13500                    | 21000                    | 27.55   | 42.85   |  |   |
| C6          | 14500                    | 22000                    | 29.59   | 44.89   |  |   |

**Flexural strength test: –**

To find the flexural or bending strength of the specimen, this test is carried out .Here the flexural strength was carried out by using two point loading test.

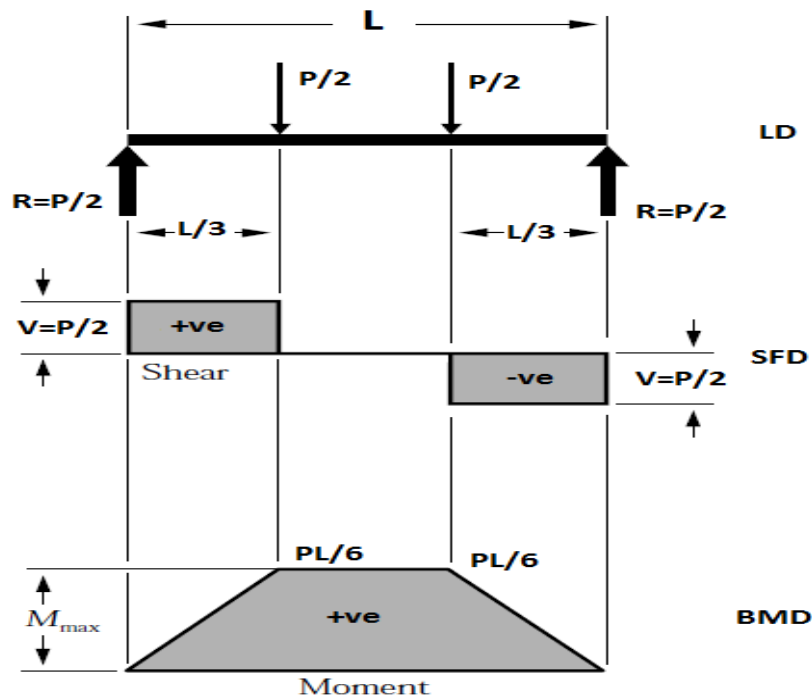


Fig. 3.

Table.2. Tested panel details

| Dimension of panels(mm) | Designation | Number of panels | Number of layers |
|-------------------------|-------------|------------------|------------------|
| 550x200x20              | E1          | 03               | 01               |
|                         | E2          | 03               | 02               |
|                         | E3          | 03               | 03               |
|                         | E4          | 03               | 04               |
| 550x200x30              | E1          | 03               | 01               |
|                         | E2          | 03               | 02               |
|                         | E3          | 03               | 03               |
|                         | E4          | 03               | 04               |
| 550x200x40              | E1          | 03               | 01               |
|                         | E2          | 03               | 02               |
|                         | E3          | 03               | 03               |
|                         | E4          | 03               | 04               |
| 550x200x50              | E1          | 03               | 01               |
|                         | E2          | 03               | 02               |
|                         | E3          | 03               | 03               |
|                         | E4          | 03               | 04               |

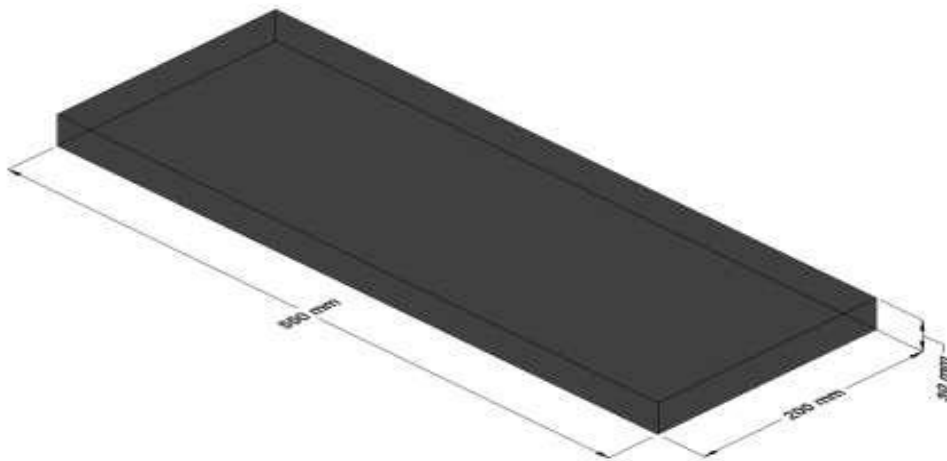


Fig. 4. Typical specimen of 30mm thick panel

### III. EXPERIMENTAL RESULTS

The parameters that had been investigated in this study are the effect of the thickness of the panels and number of wire mesh layers on the cracking load and ultimate flexural strength and to plot the load deflection curve for each panel. The test results of the samples at the age of (28 days) from the day of casting are presented in following tables and graphs;

For 20mm thick slab panel

Number of Panels= 3; Thickness of panels= 20mm; Number of Mesh layers = 1

Table.3. Test results for E1 (20mm) samples

| Load(kg) | Deflection(mm)               |                              |                              |
|----------|------------------------------|------------------------------|------------------------------|
|          | E11                          | E12                          | E13                          |
| 0        | 00                           | 00                           | 00                           |
| 20       | 0.05                         | 0.03                         | 0.05                         |
| 40       | 0.20                         | 0.22                         | 0.23                         |
| 60       | 0.45                         | 0.43                         | 0.44                         |
|          | First cracking load=<br>40kg | First cracking load=<br>40kg | First cracking load=<br>40kg |
|          | Max.Breaking load=<br>60kg   | Max.Breaking load=<br>60kg   | Max.Breaking load=<br>60kg   |

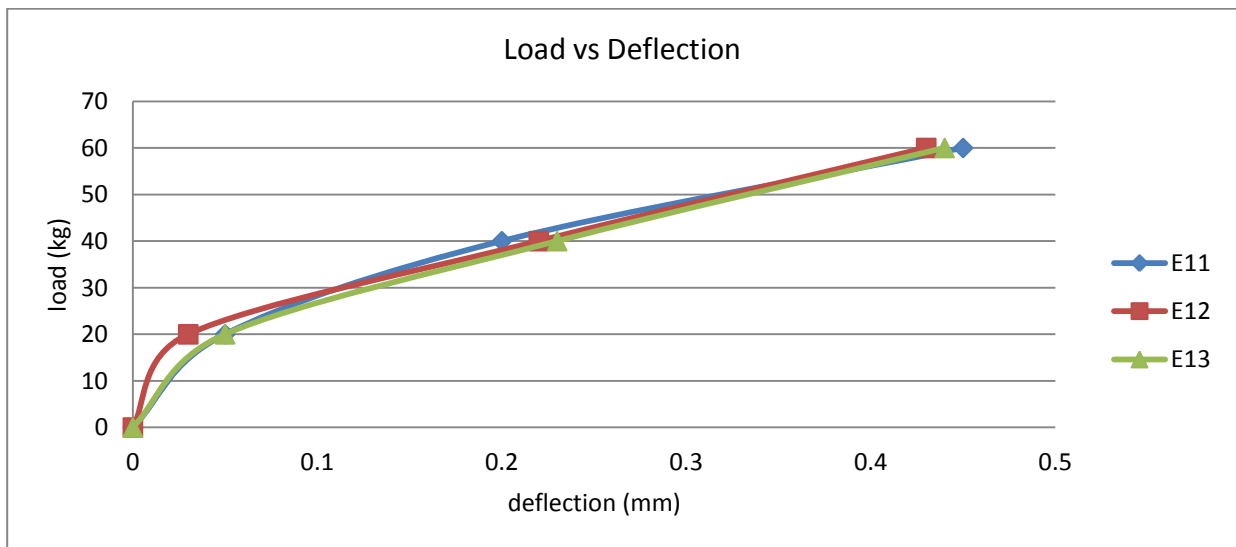


Fig. 5. Load-Deflection curves for E1 (20mm) panels

Number of Panels= 3; Thickness of panels= 20mm; Number of Mesh layers = 2

Table.4. Test results for E2 (20mm) samples

| Load(kg) | Deflection(mm)               |                              |                              |
|----------|------------------------------|------------------------------|------------------------------|
|          | E21                          | E22                          | E23                          |
| 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=<br>80kg | First cracking load=<br>80kg | First cracking load=<br>60kg |
|          | Max.Breaking load=<br>100kg  | Max.Breaking load=<br>100kg  | Max.Breaking load=<br>100kg  |

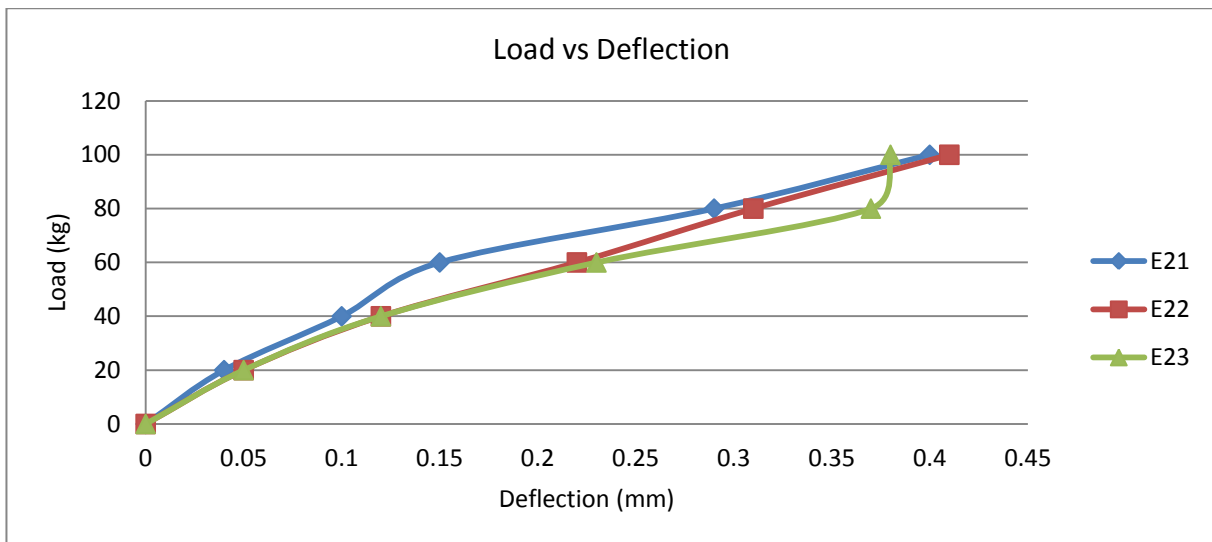


Fig. 6. Load-Deflection curves for E2 (20mm) panels

**Number of Panels= 3; Thickness of panels= 20mm; Number of Mesh layers =3**

Table.5. Test results for E3 (20mm) samples

| Load(kg) | Deflection(mm)             |                            |                            |
|----------|----------------------------|----------------------------|----------------------------|
|          | E31                        | E32                        | E33                        |
| 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 |
|          | Max.Breaking load= 140kg   | Max.Breaking load= 140kg   | Max.Breaking load= 120kg   |

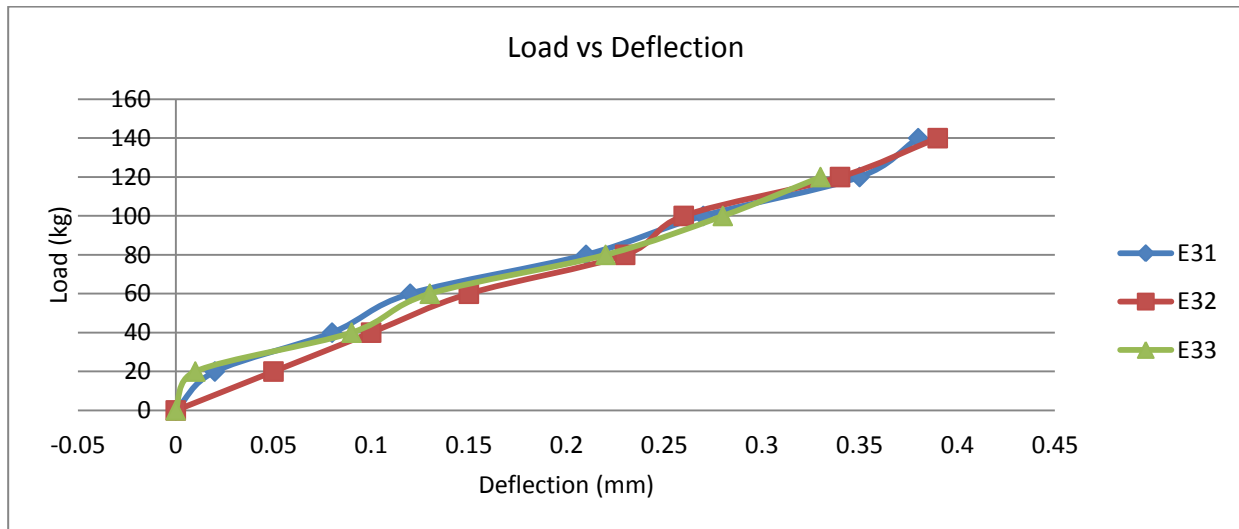


Fig. 7. Load-Deflection curves for E3 (20mm) panels

**Number of Panels= 3; Thickness of panels= 20mm; Number of Mesh layers =4**

Table.6. Test results for E4 (20mm) samples

| Load(kg) | Deflection(mm)                |                               |                               |
|----------|-------------------------------|-------------------------------|-------------------------------|
|          | E41                           | E42                           | E43                           |
| 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                          |
| 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=<br>140kg | First cracking load=<br>140kg | First cracking load=<br>140kg |
|          | Max.Breaking load=<br>160kg   | Max.Breaking load=<br>160kg   | Max.Breaking load=<br>160kg   |

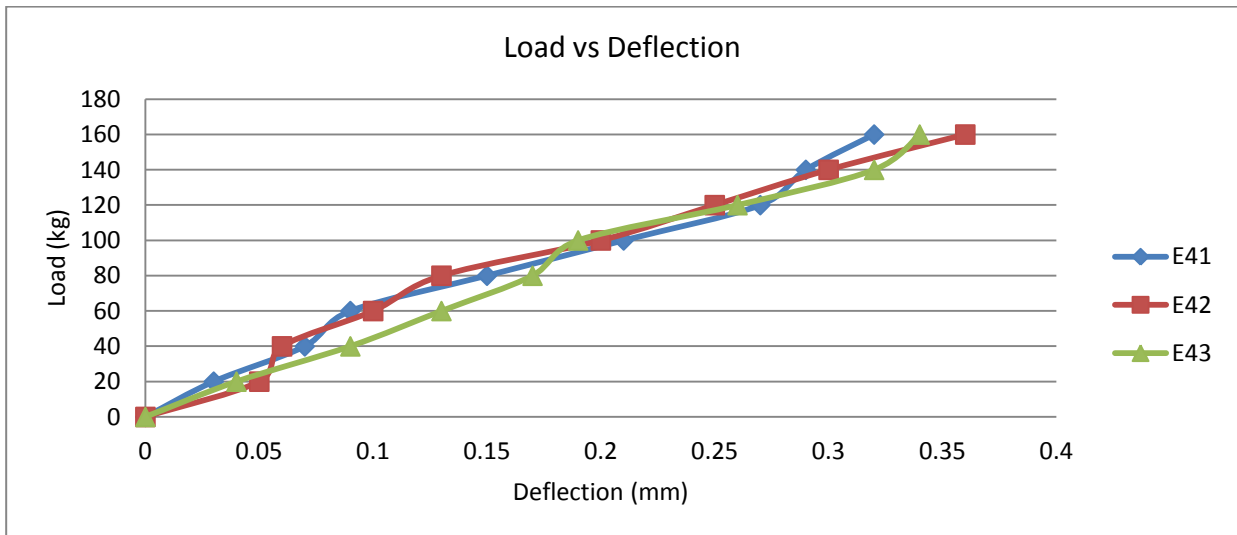


Fig. 8. Load-Deflection curves for E4 (20mm) panels

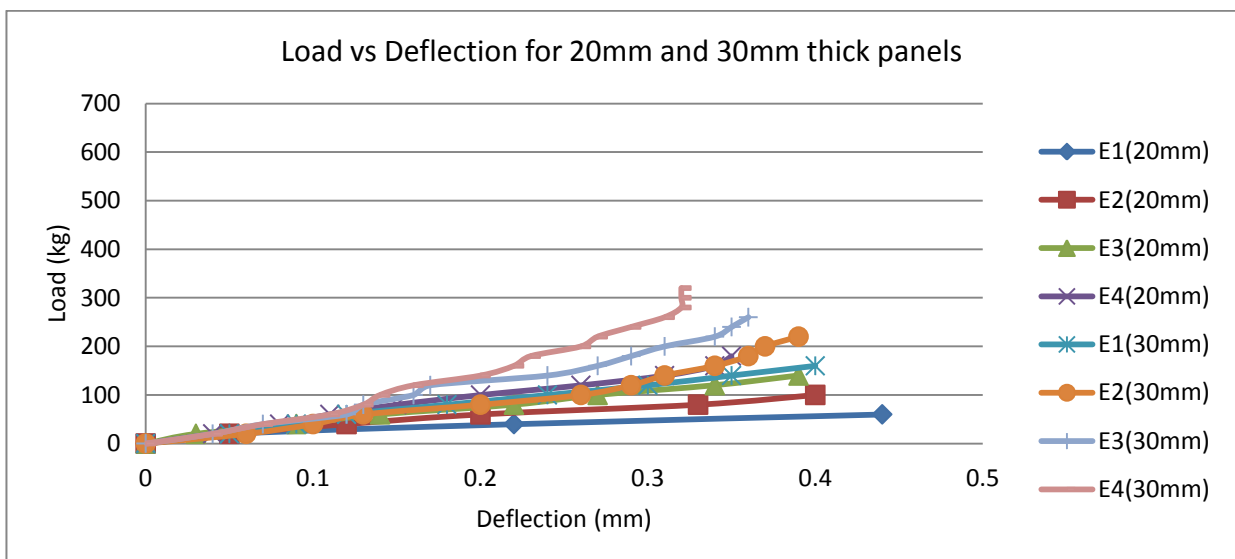


Fig. 9. Load-Deflection curves for (20mm and 30mm) panels



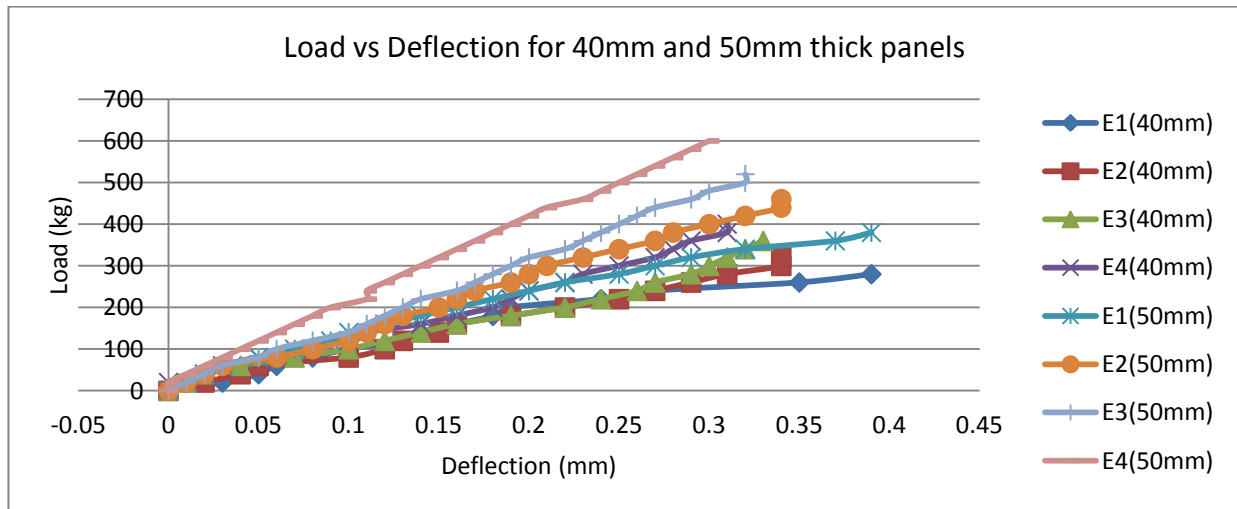


Fig. 10. Load-Deflection curves for (40mm and 50mm) panels

Table.7. Flexural strength of ferrocement panels of 550 mm x 200 mm dimension

| Specimen and size | Panel Number | Cracking Load (N) | Ultimate Load (N) | Flexural strength at cracking load $\sigma_{cr} (\frac{N}{mm^2})$ | Flexural strength at ultimate load $\sigma_{ult} (\frac{N}{mm^2})$ |
|-------------------|--------------|-------------------|-------------------|---|--|
| E1(20mm thick)    | E11          | 392.4             | 588.6             | 2.212   | 3.319  |
|                   | E12          | 392.4             | 588.6             | 2.212   | 3.319  |
|                   | E13          | 392.4             | 588.6             | 2.212   | 3.319  |
| E2(20mm thick)    | E21          | 784.8             | 981               | 4.425   | 5.531  |
|                   | E22          | 784.8             | 981               | 4.425   | 5.531  |
|                   | E23          | 588.6             | 981               | 3.319   | 5.531  |
| E3(20mm thick)    | E31          | 1177.2            | 1373.4            | 6.638   | 7.745  |
|                   | E32          | 981               | 1373.4            | 5.531   | 7.745  |
|                   | E33          | 981               | 1177.2            | 5.531   | 6.638  |
| E4(20mm thick)    | E41          | 1373.4            | 1569.6            | 7.745   | 8.851  |
|                   | E42          | 1373.4            | 1569.6            | 7.745   | 8.851  |
|                   | E43          | 1373.4            | 1569.6            | 7.745   | 8.851  |
| E1(30mm thick)    | E11          | 1373.4            | 1569.6            | 3.433   | 3.924  |
|                   | E12          | 1373.4            | 1569.6            | 3.433   | 3.924  |
|                   | E13          | 1177.2            | 1373.4            | 2.943   | 3.433  |
| E2(30mm thick)    | E21          | 1765.8            | 2158.2            | 4.414   | 5.395  |
|                   | E22          | 1765.8            | 2158.2            | 4.414   | 5.395  |
|                   | E23          | 1569.6            | 1765.8            | 3.924   | 4.414  |
| E3(30mm thick)    | E31          | 2354.4            | 2550.6            | 5.886   | 6.376  |
|                   | E32          | 1962              | 2354.4            | 4.905   | 5.886  |
|                   | E33          | 2158.2            | 2550.6            | 5.395   | 6.376  |
| E4(30mm thick)    | E41          | 2550.6            | 2943              | 6.376   | 7.357  |
|                   | E42          | 2354.4            | 2550.6            | 5.886   | 5.886  |
|                   | E43          | 2354.4            | 2746.8            | 5.886   | 6.867  |

|                |     |        |        |       |       |
|----------------|-----|--------|--------|-------|-------|
| E1(40mm thick) | E11 | 2550.6 | 2746.8 | 3.585 | 3.861 |
|                | E12 | 2354.4 | 2746.8 | 3.309 | 3.861 |
|                | E13 | 2354.4 | 2746.8 | 3.309 | 3.861 |
| E2(40mm thick) | E21 | 2550.6 | 2943   | 3.585 | 4.137 |
|                | E22 | 2354.4 | 2746.8 | 3.309 | 3.861 |
|                | E23 | 2746.8 | 3139.2 | 3.861 | 4.413 |
| E3(40mm thick) | E31 | 2943   | 3335.4 | 4.137 | 4.688 |
|                | E32 | 3335.4 | 3531.6 | 4.688 | 4.964 |
|                | E33 | 2943   | 3335.4 | 4.137 | 4.688 |
| E4(40mm thick) | E41 | 2943   | 3335.4 | 4.137 | 4.688 |
|                | E42 | 3335.4 | 3531.6 | 4.688 | 4.964 |
|                | E43 | 2943   | 3335.4 | 4.137 | 4.688 |
| E1(50mm thick) | E11 | 3335.4 | 3727.8 | 3.002 | 3.355 |
|                | E12 | 3335.4 | 3531.6 | 3.002 | 3.178 |
|                | E13 | 3139.2 | 3531.6 | 2.825 | 3.178 |
| E2(50mm thick) | E21 | 3335.4 | 3727.8 | 3.002 | 3.355 |
|                | E22 | 3335.4 | 3531.6 | 3.002 | 3.178 |
|                | E23 | 3139.2 | 3531.6 | 2.825 | 3.178 |
| E3(50mm thick) | E31 | 4708.8 | 5101.2 | 4.238 | 4.591 |
|                | E32 | 4512.6 | 4905   | 4.061 | 4.415 |
|                | E33 | 4708.8 | 4905   | 4.238 | 4.415 |
| E4(50mm thick) | E41 | 5493.6 | 5886   | 4.945 | 5.298 |
|                | E42 | 5297.4 | 5689.8 | 4.768 | 5.121 |
|                | E43 | 5493.6 | 5689.8 | 4.945 | 5.121 |

**Table.8. Avg.flexural strength of ferrocement panels of 550 mmx200 mm dimension**

| Test group and Thickness (mm) | Compressive strength (28 Days) $N/mm^2$ | Avg.flexural strength at cracking load( $\sigma_{cr}$ ) $N/mm^2$ | Avg.flexural strength at ultimate load( $\sigma_{ult}$ ) $N/mm^2$ |
|-------------------------------|---|--|---|
| E1(20mm)                      | 42.95                                   | 2.212  | 3.319   |
| E2(20mm)                      | 42.95                                   | 4.056  | 5.531   |
| E3(20mm)                      | 42.95                                   | 5.900  | 7.376   |
| E4(20mm)                      | 42.95                                   | 7.745  | 8.851   |
| E1(30mm)                      | 42.95                                   | 3.2696   | 3.7603  |
| E2(30mm)                      | 42.95                                   | 4.2506   | 5.068   |
| E3(30mm)                      | 42.95                                   | 5.3953   | 6.2126  |
| E4(30mm)                      | 42.95                                   | 6.0493   | 6.7033  |
| E1(40mm)                      | 42.95                                   | 3.401  | 3.861   |
| E2(40mm)                      | 42.95                                   | 3.585  | 4.045   |
| E3(40mm)                      | 42.95                                   | 4.3026   | 4.780   |
| E4(40mm)                      | 42.95                                   | 4.3206   | 4.780   |
| E1(50mm)                      | 42.95                                   | 2.943  | 3.237   |
| E2(50mm)                      | 42.95                                   | 2.943  | 3.237   |
| E3(50mm)                      | 42.95                                   | 4.179  | 4.4736  |
| E4(50mm)                      | 42.95                                   | 4.886  | 5.180   |

**Crack pattern**

Referring to figures, it can be concluded that all the samples were failed in bending because the cracks are vertical. The cracks started from the extreme fiber at the bottom and continued vertically upward until the failure reached. Most of the samples failed under the line load and a number of them failed at the mid span



Fig. 11. Top view of crack pattern for 20mm and 30mm thick panel



Fig. 12. Typical Top view of crack pattern for 40mm and 50 mm thick panel



Fig. 13. Typical side view of crack pattern for 40mm and 50mm thick panel

#### **IV.CONCLUSION**

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

1. The flexural loads at first crack and ultimate loads depend on number of reinforcing mesh layers used in ferrocement. As increase in thickness and number of mesh layer, flexural strength of slab panel goes on increasing.
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, central deflection of slab panel goes on reducing.
5. Curvature of section just before cracking is goes on increasing with increase in the number of mesh layers.

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