EXPERIMENTALLY INVESTIGATING THE STRUCTURAL INTEGRITY OF FOLDED FERROCEMENT PANELS ON VARYING NUMBER AND TYPE OF WIRE MESH LAYERS

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Abstract - *This study investigates the flexural behavior of folded ferrocement panels reinforced with square welded and woven mesh. Ferrocement, recognized for its enhanced elasticity and durability, is ideal for roofing systems, particularly in affordable housing initiatives in developing economies. The experimental analysis focuses on how the number and type of wire mesh layers affect the ultimate flexural strength and load-deflection characteristics of these panels. The findings indicate that panels with increased mesh layers exhibit superior flexural strength and reduced deflection. Specifically, panels reinforced with square woven mesh showcase better performance in terms of load capacity and stiffness com-pared to those with square welded mesh. Furthermore, combining different mesh types optimizes the structural response, demonstrating the potential of ferrocement panels in modern construction practices. This research contributes to the understanding of effective reinforcement strategies for enhancing the performance of ferrocement structures.*

Key Words: Folded Ferrocement Panels, Flexural Deformation, Wire Mesh

1. INTRODUCTION

The industrialization of construction technology has emerged as a highly accepted and preferred method in modern building construction to minimize onsite construction. This can be achieved through various strategies, including the utilization of advanced cement-based composites for structural applications, such as ferrocement. Ferrocement, a form of rein-forced concrete made with closely spaced mesh or small diameter rods encapsulated in mortar, offers a robust solution to roofing and structural issues, particularly in developing economies with high demand for affordable housing. The material, first utilized by Pier Luigi Nervi in the 1940s, is known for its superior performance and versatility, providing greater elasticity and resistance to cracking. The use of prefabricated ferrocement components not only enhances construction efficiency but also significantly reduces time, safety concerns, environmental impact, and overall costs. Refurbishment and strengthening of deteriorating civil infrastructures using such innovative materials ensure that older structures meet con-temporary safety and serviceability standards, making ferrocement a valuable material in modern civil engineering and construction.

1.1 Definition

The definition by ACI Committee 549 was: "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 materials or other suitable materials". In this definition, ferrocement is not confined to only steel wire mesh but other types of meshes as well. However, the definition ignores an important type of reinforcement currently in use in ferrocement, i.e. the combination of steel rods and wire mesh

1.2 Constituents of Ferrocement

The constituents of ferrocement include the hydraulic cement mortar which should be designed according to the standard mix design procedures for mortar and concrete which includes Portland cement, water, sand, wire mesh and admixtures.

1.2.1 Cement

The cement should be fresh of uniform consistency and free of lumps and foreign matter and of the type or grade de-pending on the application.

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1.1.2 Water

Potable water is fit for use as mixing water as well as for curing ferrocement.

1.2.3. Fine Aggregates

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

1.2.4. Wire Mesh

Steel meshes for ferrocement includes square woven or square welded mesh and chicken wire mesh of hexagonal shape and expanded metal mesh. Some mesh filaments are galvanized. Properties of the resulting ferrocement product can be expected to be affected by mesh size, type, ductility, manufacture and treatment

2. LITERATURE REVIEW

Vincent Prabakar Rajaiah, et.al, conducted an Experimental Study and concluded that the number of wire mesh layers did not significantly affect the cracking load but did improve the ultimate flexural strength and ductility. Folded panels with double wire mesh layers showed higher strength and reduced deflection compared to flat and trough panels, highlighting their potential for improved performance in construction applications.

Mohamad N. Mahmood et.al, investigated the flexural behavior of flat and folded ferrocement panels. They found that adding wire mesh layers significantly improved the flexural strength of both panel types, with folded panels performing better than flat ones. Specifically, folded panels with 2 and 3 wire mesh layers showed a 37% and 90% increase in flexural strength, respectively, compared to single-layer panels. Flat panels had a 65% and 68% increase in strength with 2 and 3 layers, respectively, compared to plain mortar panels. Additionally, more wire mesh layers enhanced the ductility and energy absorption of both panel types.

R. Jayasree et.al, conducted a comprehensive investigation into the flexural behavior of folded ferrocement panels vis-à-vis flat and trough panels, with an emphasis on load-carrying capacity, deformation, and energy dissipation capacity. The study revealed that augmenting the wire mesh layers significantly enhances the panels' load-carrying capacity, mitigates crack width, and retards crack propagation. The empirical results for various panel geometries and wire mesh layers were systematically compared with theoretical predictions.

3. OBJECTIVES OF EXPERIMENTAL STUDY

A lot of work has been done to study the behavior of flat ferrocement panels but investigation of the behavior of folded ferrocement panels with length longer than one meter is very limited. The aim of this present work is to study the effect of varying the number and type of steel wire mesh layers on the flexural behavior of folded ferrocement panels (Square Woven Mesh with one and two Layer, Square Welded Mesh With one and two Layer and Combination of a Layer of Square Woven and Square Welded), to obtain the ultimate flexural strength and the load deflection behavior.

The various parameters considered in this study are as follows: -

1. Effect of number of mesh layers on the flexural strength of folded ferrocement panels.

2. Effect of varying the type of wire mesh layers on the flexural strength of folded ferrocement panels

4. EXPERIMENTAL WORKS

The experimental program involved preparing and testing folded ferrocement slab panels under two-point loading conditions, focusing on the number and type of wire mesh layers as the primary variable. In constructing folded ferrocement panels, Materials included Ordinary Portland Cement (Grade 53), its conforming (IS: 12269 –1987). The Physical properties of the cement are reported in Table 1.

Table -1: Properties of Cement

Properties	Test Values	Limit
Specific Gravity	3.11	3.10 to 3.16
Consistency (%)	30.2	25 to 35
Fineness Modulus (%)	3.33	0 to 10
Initial Setting Time (Min)	33	>30
Final Setting Time (Min)	270	<600

Sand passing through a 2.36 mm I.S. sieve and the Physical Properties are reported in Table 2.

Table -2: Properties of Sand

Properties	Test Values	Limit
Specific Gravity	2.69	2.5 to 3.0
Fineness Modulus (%)	3.57	2.0 to 4.0
Water Absorption (%)	1.24	0 to 2.0

Potable water, Square Welded and Woven meshes with 1.6 mm diameter wires and opening sizes of 20 mm x 20 mm and 10 mm x 10 mm, respectively, are secured to 6 mm diameter reinforcement bars. These bars create the primary skeletal steel framework, which serves as a base for attaching finer wire meshes. For 2000 mm length of the panels, four 6 mm diameter bars run longitudinally, while four folded 6 mm diameter bars are positioned at 500 mm intervals. This reinforcement design ensures the structural integrity and robustness of the ferrocement panels. The mortar mix proportion of 1:2:0.35 exhibits excellent workability. Specifically, the cement-sand ratio is 1:2 and the water-cement ratio are 0.35. Twenty-seven mortar cubes, each of dimensions 70 mm x 70 mm x 70 mm, were cast using this proportion. These cubes underwent a 28-day curing period under pond curing conditions. The compressive strength of the mortar, determined on the 28th day, was 38.2 MPa.

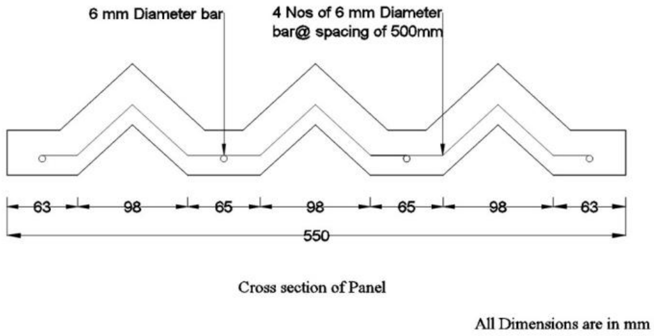

Fig -1: Cross Section Dimension of the Slab Panel

The typical cross-section of the folded panel was designed considering practical feasibility such as mold preparation, casting processes, and laboratory testing facilities. The panel spans 2000 mm, optimized for flexural failure mode. A total of five panels were cast and subjected to two-point loading to induce pure flexural bending. All panels were tested in a slab testing frame under simulated simply supported conditions, with loads applied symmetrically via concentrated line loads. A 50-ton capacity Hydraulic Jack was utilized for load application, and deflection at the panel's center was measured using a Dial Gauge with a precision of 0.01 mm and a 50 mm range. To facilitate crack tracing, panels were coated with white cement. Incremental load application was employed, and deflection was recorded continuously until failure.

Fig -2. A

Fig -2. B

Fig -2. C

Fig -2. D

Fig -2. E

Fig -2. A – E - Casting Methodology of the Folded Ferrocement Panel

Fig -3. A

Fig -3. B

Fig -3. A – B- Testing Setup of the Folded Ferrocement Panel under Two-point line loads to get pure flexural bending

Table -3- TEST RESULTS OF SQUARE WOVEN -1

Sl no	Load		Deflection		
	Tonne	Newton	Left (mm)	Centre (mm)	Right (mm)
1	0	0	0	0	0
2	0.25	2500	0.44	0.53	0.44
3	0.5	5000	0.77	0.94	0.85
4	0.75	7500	1.62	1.8	1.5
5	1	10000	3.25	4.16	3.3
6	1.25	12500	4.5	6	4.6
7	1.5	15000	6.11	8.65	6.2
8	1.75	17500	9.85	11.49	9.57
9	2	20000	13.18	16.23	13.82
10	2.25	22500	17.84	20.2	17.75

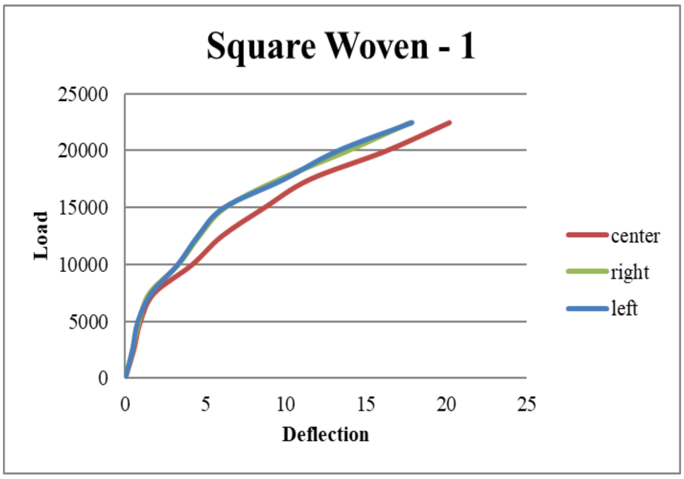

Chart -1: Load Vs Deflection Curve of Square Woven 1.

Table -4- TEST RESULTS OF SQUARE WELDED 1

Sl no	Load		Deflection		
	Tonne	Newton	Left (mm)	Centre (mm)	Right (mm)
1	0	0	0	0	0
2	0.25	2500	0.59	0.62	0.61
3	0.5	5000	1	1.08	0.98
4	0.75	7500	1.37	1.52	1.36
5	1	10000	1.8	1.99	1.79
6	1.25	12500	2.76	3.31	2.77
7	1.5	15000	4.77	5.51	4.84
8	1.75	17500	7.09	8.21	7.2
9	2	20000	8.64	10.04	8.81

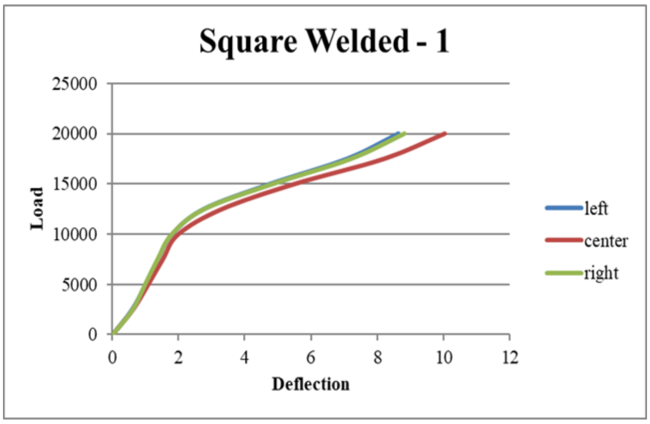

Chart -2: Load Vs Deflection Curve of Square Welded 1.

Table -5- TEST RESULTS OF SQUARE WOVEN 2

Sl no	Load		Deflection		
	Tonne	Newton	Left (mm)	Centre (mm)	Right (mm)
1	0	0	0	0	0
2	0.25	2500	0.25	0.29	0.26
3	0.5	5000	0.48	0.56	0.51
4	0.75	7500	0.97	1.18	1.02
5	1	10000	1.58	1.99	1.65
6	1.25	12500	3.32	3.96	3.15
7	1.5	15000	4.55	5.31	4.25
8	1.75	17500	6	6.92	6.43
9	2	20000	7.4	8.48	7.62
10	2.25	22500	9.49	10.68	9.23
11	2.5	25000	19.35	22.58	19.45
12	2.75	27500	26.84	32.49	26.6

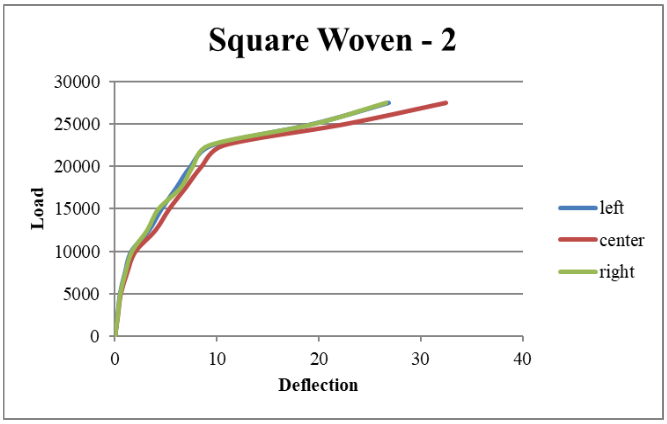

Chart -3: Load Vs Deflection Curve of Square Woven 2.

Table -6- TEST RESULTS OF SQUARE WELDED 2

Sl no	Load		Deflection		
	Tonne	Newton	Left (mm)	Centre (mm)	Right (mm)
1	0	0	0	0	0
2	0.25	2500	1.07	1.37	1.13
3	0.5	5000	1.49	1.89	1.48
4	0.75	7500	3.09	3.7	3.13
5	1	10000	4.37	5.12	4.35
6	1.25	12500	5.89	6.84	5.94
7	1.5	15000	7.34	8.56	7.42
8	1.75	17500	11.52	13.42	11.12
9	2	20000	14.42	20.74	14.6

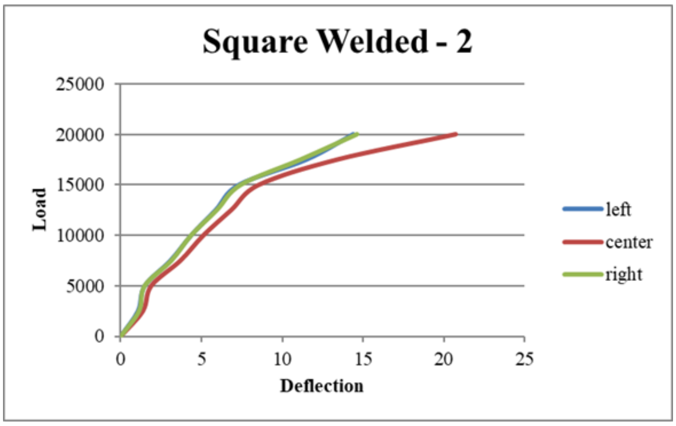

Chart -4: Load Vs Deflection Curve of Square Welded 2.

Table -7- TEST RESULT OF SQUARE WOVEN 1 + SQUARE WELDED 1

Sl no	Load		Deflection		
	Tonne	Newton	Left (mm)	Centre (mm)	Right (mm)
1	0	0	0	0	0
2	0.25	2500	0.18	0.21	0.18
3	0.5	5000	0.39	0.45	0.36
4	0.75	7500	0.98	1.09	0.83
5	1	10000	2.25	2.61	2.1
6	1.25	12500	3.96	4.59	3.7
7	1.5	15000	4.82	5.63	4.65
8	1.75	17500	6.32	7.3	6.06
9	2	20000	7.44	8.67	7.18
10	2.25	22500	10.22	11.98	9.95
11	2.5	25000	12.45	13.88	12.45

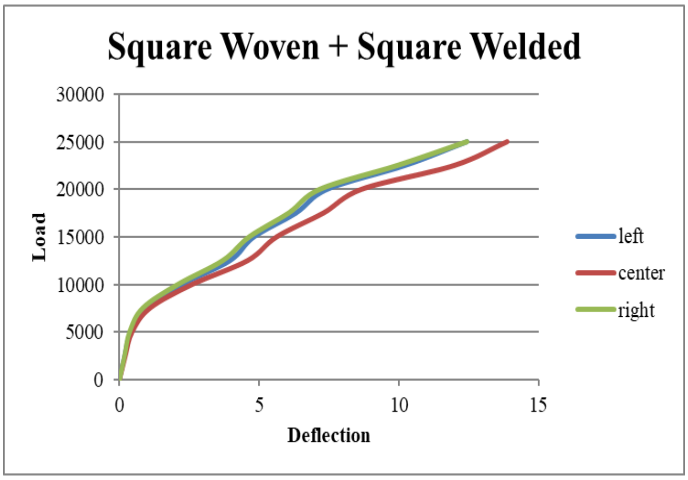

Chart -5: Load Vs Deflection Curve of Square Woven 1+ Square Welded 1.

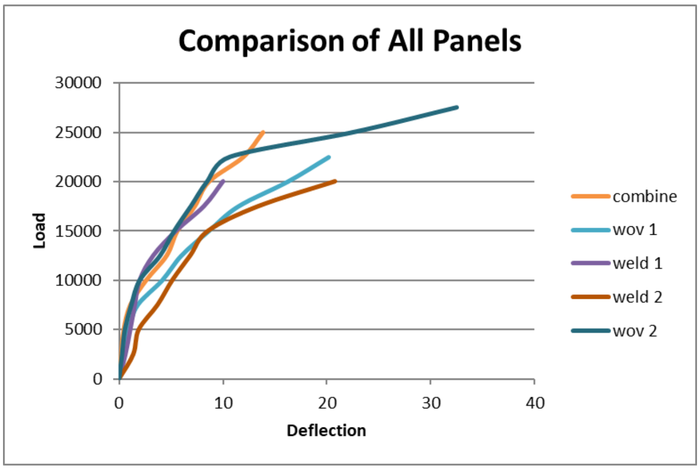

Chart -6 Load Vs Deflection Curve – Comparison of All Panels.

Table 3 to 7, Shows the experimental results of Square Woven 1, Square Welded 1, Square Woven 2, Square Welded 2 and Combination of Square Woven 1 and Square Welded 1 respectively. In which the data clearly shows that the deflection at centre gradually increases. Similar deflection is observed with negligible variation at right and left deflection readings

5. Conclusions and comments

5.1 **Flexural Strength and Deflection**: Panels with more wire mesh layers, whether square woven or square welded, exhibit higher flexural strength and lower deflection. For instance, panels with two layers of square woven mesh (Square Woven 2) and square welded mesh (Square Welded 2) show significantly higher load-bearing capacity and reduced deflection compared to panels with a single layer (Square Woven 1 and Square Welded 1).

5.2 **Comparison of Mesh Types***:* Both square woven and square welded mesh types enhance the flexural strength of the panels. However, the specific performance varies slightly between the two types. For example, at a load of 20000 Newtons, the deflection for Square Woven 2 is 7.4 mm at the left dial gauge, while for Square Welded 2, it is 14.42 mm, indicating that the woven mesh may provide better resistance to deflection under similar loads.

5.3 **Combined Mesh Layers:** Panels reinforced with a combination of square woven and square welded mesh layers (Square Woven 1 + Square Welded 1) also show improved performance, with deflection values falling between those of the individual mesh types. This suggests that combining different mesh types can be an effective strategy to optimize the flexural behavior of ferrocement panels.

5.4 **Load-Deflection Behavior:** The load-deflection curves indicate that panels with more layers of wire mesh can sustain higher loads before significant deflection occurs. This is evident from the progressive increase in deflection with increasing load, where panels with more mesh layers show a more gradual increase in deflection.

In summary, increasing the number of wire mesh layers in folded ferrocement panels significantly enhances their flexural strength and reduces deflection, with both square woven and square welded mesh types contributing positively to the overall performance. Combining different mesh types can further optimize the structural behavior of these panels.

- **Square Woven Mesh**: Offers better performance in terms of lower deflection and higher stiffness, making it more suitable for applications requiring higher flexural strength and reduced bending.
- **Square Welded Mesh**: While still effective, it shows higher deflection under similar loads, indicating slightly lower stiffness compared to woven mesh.

Overall, square woven mesh panels exhibit superior performance in terms of flexural strength and deflection resistance compared to square welded mesh panels. Combining both types of mesh can optimize the structural behavior of ferrocement panels

ACKNOWLEDGEMENT

I express my deepest gratitude to God for the guidance, strength, and blessings that allowed me to complete this project

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