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Study and Cost Analysis of Ferrocement Panel for Affordable Housing

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Abstract—*Most developing countries are faced with problems of low standards of living, adject poverty, environmental degradation and housing shortage. Ferrocement technology has been established as environmentally friendly affordable cost technology. Ferrocement is a type of slim wall reinforced concrete panel where hydraulic cement is casted with closely spaced layers of continuous small diameter metel mesh.The current study shows the results of testing flat ferrocement panels armored with different number of layers of wire mesh. The main goal of this work is to compare flat ferrocement panel with conventional materials with respect to Strength, Time Cost for affordable cost housing. The no of layers used to study the flexural strength are two, three and four for a panels of size (900x300) with thickness 25 mm & three, four, five & six for wall panels of same size with thickness 40 mm were reinforced with expanded metal mesh. Panels were casted with cement mortar of mix proportion 1:1.70 with water cement ratio 0.38 and Polypropylene Fibrillated Fibers with dosage of 1% of total weight of cement. Panels were tested under UTM machine by two point loading system after curing period of 28 days. result shows that panels with more no of layers having higher flexural strength and less deflection compared with panels having less no of layers of mesh and construction of ferrocement structure is rapid and economical as compared with conventional material for affordable housing.*

1. INTRODUCTION

Ferrocement is a versatile structural constructional material possessing unique property of strength and serviceability. It is made with closely-knit wire mesh and mild steel reinforcing bars filled with rich cement mortar. Welded mesh may also be used in place of reinforcing bars. The materials required for making it namely cement, sand, wire mesh and mild steel reinforcing bars are easily available in most places. It is possible to fabricate in ferrocement a variety of structural elements which are thin, light, and durable and possessing high degree of impermeability. Ferrocement combines the lightness of steel and mould ability of concrete and can be cast to any shape.

Ferrocement is a construction material composed with a relatively thin and closely spaced layer of metal mesh, covering such binding agent like Cement morter. Because the building techniques are simple enough to be done by unskilled labor, ferrocement is an attractive construction method in areas where costs of labour are low. There is no need for the complicated formwork of reinforced cement concrete (RCC) construction, or for the welding needed for steel construction, everything can be done by hand, and no expensive machinery is required. The main difference between ferrocement and reinforced concrete is ferrocement is a thin composite made of cement matrix reinforced with closely spaced small diameter wire meshes instead of larger diameter rods and large size aggregates. The thickness of ferrocement generally ranges from 25 - 50 mm. The latest ACI Code encourages the use of non - metallic reinforcement and fibres.

2. CONSTITUENTS OF FERROCEMENT

The wall panel of ferrocement include the thick cement mortar which is planned as per the standard mix design procedures for mortar and concrete which includes cement, sand, wire mesh. water, and admixtures.

Cement: The cement to use is usually ordinary Portland. However, rapid hardening Portland cement may be used in cold climates. Sometimes a sulphate resistant Portland cement is used, either wholly or in part mixed with ordinary Portland against sulphate attack. If the cement is used with admixtures, care should be exercised in compatibility.

Water: Water should be potable, clean, and free from harmful salts or foreign materials which may impair the strength and resistance of the mortar.

Fine Aggregates: The importance of good, clean, well graded sand cannot be over emphasized if one is to make the high grade impervious mortar required.

Skeleton steel: It is provided to supports the steel wire mesh.The size of Skeleton steel is normally 6 to 8 mm of Fe 250 bars were used.

Wire mesh: Consists of galvanized steel wires of diameter 0.5 to 1.5 mm, spaced at 5 to 20 mm centre to centre Welded wire mesh has hexagonal or rectangular openings

Admixtures: admixtures are may be used in ferrocement for improvement in impermeablity, water reduction, air entrainment, which increases resistance to thawing and freezing.

3. PROPERTIES OF FERROCEMENT COMPOSITES

- Wire diameter varies between 0.5 to 1.5 millimeters
- Size of mesh ranges from 6 to 35 millimeters
- Per inch of thickness Maximum use of 12 layers of mesh Maximum 10 square inches per cubic inch in both directions.
- Steel cover 1.5 to 5 millimeters
- Maximum 8% volume fraction in both directions
- Thickness 6 to 50 millimeters
- Ultimate tensile strength is up to 34 MPa
- Compressive strength is up to 28 to 69Mpa
- Allowable tensile stress is up to 10 MPa
- Modulus of rupture is up to 55MPa

Fig. 1: A usual cross-section of ferrocement panel

4. HISTORY OF FERROCEMENT

What we call today as R.C.C. construction material and Ferrocement, entered construction field simultaneously by mid-19th century. Mr. J. L. Lambot built a wire-reinforced boat in which reinforcement was in the form of a network of wires. However, since then, R.C.C. advanced as a full-fledged constructional material, time tested and design procedure formulated, though modified from time to time. On the other hand, ferrocement was forgotten almost for a century and took a small step in the middle of 20th century, when Mr. Pier Nervi devised the homogeneity property of ferrocement. Looking at the advantages and superiority of ferrocement over R.C.C., now the former should have squared up at least a century lag over the later. But in fact only some stray items like tanks, domes, etc. came in its shape. The physical property studied by Mr. Nervi was lost and once again, ferrocement got cutoff from major construction field. The obvious reason was design system for building system was used as non vulnerable construction material.

Whatever efforts were put in formulating these minor designs , they were on the basis of R.C.C. design, which is not considered as 'homogeneous' material as ferrocement is considered.This ferrocement was found on testing to have very little in common with normal reinforced concrete, however, since it possesses the mechanical characteristics of a completely homogeneous material. ACI Committee 549, Ferrocement and Other Thin Reinforced Products, was organized in 1974 and was given the mission to study and report on the engineering properties, construction practices, and practical applications and to develop guidelines for ferrocement Constructions.

5. DURABILITY OF FERROCEMENT

According to the ACI Committee, 'durability' is defined as 'ability to resist weathering action, chemical attack, abrasion, or any other process of deterioration', that is, durable concrete will retain its original form, quality and serviceability, when exposed to its environment. The various measures required ensuring 'durability' in conventional reinforced concrete is also applicable to ferrocement, since, ferrocement has almost the same type of ingredients/constituents, except, coarse aggregates and the use of smaller fine aggregates, than conventional concrete and a thin cross section. However, other unique factors, which affect durability, especially, the susceptibility to corrosion of ferrocement are:

1. Very small cover to the mesh reinforcement.

2. Very low cross sectional area of the mesh reinforcement wires.

3. Because of small wires being used The surface area of the reinforcement is high.

4. To prevent corrosion, Mesh reinforcement are galvanized, but the zinc coating can cause and produce hydrogen gas bubbles during hydration.

6. OBJECTIVES OF EXPERIMENTAL STUDY

This work focuses on the mechanical properties, materials, advantages, disadvantages, parameters, recommendations, practical design, research and development in ferrocement technology. And comparison of ferrocement panel with conventional materials for affordable cost housing. In order to achieve the aim, following objectives are identified:

a)To understand cost factor of ferrocement panel with Polypropylene Fibrillated Fibers compared with conventional materials.

a)Effect of number of layers of mesh on the flexural strength of ferrocement panels casted with Polypropylene Fibrillated Fibers.

c)To study the Effect of wall panels thickness on the flexural strength with Polypropylene Fibrillated Fibers.

7. EXPERIMENTAL WORK

The experimental program includes casting and testing of flat ferrocement wall panels under UTM Mashine for two-point loading. The primary variables were the thickness of panels 25mm and 40mm and number of layers of meshes ranging from 2 to 6 layers with Polypropylene Fibrillated Fibers.

MATERIALS USED-Cement Ordinary Portland Cement Zuari Cement (Grade 53), Sand -:Passing through 2.36 mm I. S. Sieve, Polypropylene Fibrillated Fibers with dosage of 1% of total weight of cement ,Water – Ordinary Drinking Water, Mesh Used –Expanded metal mesh of 1.2 mm Diameter.

8. MIX PROPORTION

Cement sand ratio (1:1.70).Water cement ratio (0.38) with Polypropylene Fibrillated Fibers dosage of 1% of overall weight of cement. A total of 11 cubes of size (70*70) of above proportion were casted and Compressive strength obtained is tabulated below

Table 1: Compressive strength at 28 day

Sr. No.	**Size of cube (mm)**	**No of days**	**Load at Failure (Kg)**	**Comp. Strength(N/mm²)**	**Avg**
1	70x 70	28	22870	48.11	
2	70x 70	28	25589	49.86	50.15
3	70x 70	28	23668	53.48	

Table 2: Details of panels to be casted

a.For 25 mm thick Panel with Polypropylene Fibrillated Fibers (1% cement)		
Panel thk	**Mesh Layer**	**No. of Panel**
	2	3
25 mm	3	3
	4	3
b.For 40 mm thick Panel with Polypropylene Fibrillated Fibers (1% cement)		
Panel thk	Mesh Layer	No. of Panel
	3	3
40 mm	4	3
	5	3
	6	3
Total Panels(a+b)		21

9. MIXING OF MATERIALS:

By mixing cement and sand The mortar was prepared with ratio of (1:1.70) with Polypropylene Fibrillated Fibers (1% cement) and water-cement ratio was maintained 0.38). to avoid harshness during casting mortar was prepared in two batches for one casting.

Fig. 2. Dry Mixing

Fig. 3. Mixing of Mortar

10. CASTING OF PANELS

The panels were casted in Wooden moulds which were prepared to get a smooth finish. wooden batten were used to get accurate size moulds.. The Battens were placed on wooden platform (plywood) covered by thin metal sheet to avoid suction of water by wooden material. The steel mould prepared were properly oiled before casting.

Fig. 4. Fixing Of Thin metal Sheet On Plywood

Fig. 5. Final Moulding

The mesh pieces has cut down according to the size of panel letting a cover of 3 mm on both side of mesh (894*294).

Fig. 6. Mortar Placing (1st layer)

Curing: wall panels it was removed from mould after a period of 24 hours of casting.and palced in curing tank for curing for a period of 28 days.

Fig. 7. Curing of Panels

Testing: The wall panels were removed from tank for testing after curing of 28 days. The panels were placed on simple support on both ends leaving a space of 100 mm at ends. Two point loading system was installed at 200 mm from centre as shown. Testing was carried under UTM machine for flexure test.

Fig. 8: Two Point Loading System

After testing to calculate the flexural strength the panels were loaded UTM Machine for under two point loading and load and deflections were noted down

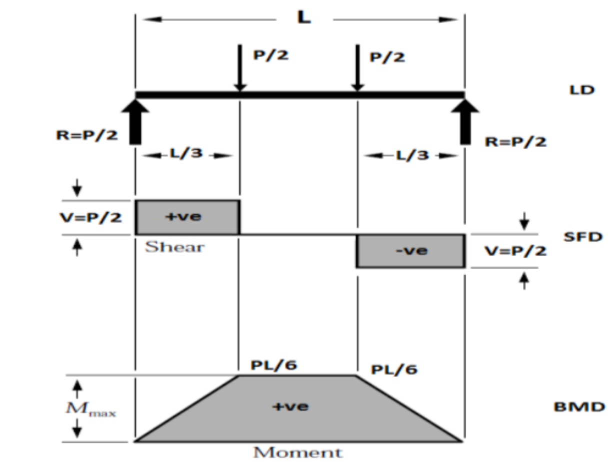

Fig. 9: Load, Shear and Moment Diagram

The bending strength were calculated using the Flexure formula M/I=σ/y thus σ=M/I * y Where:

M: Bending Moment, (N.mm)

y= D/2, (mm)

I: Moment of Inertia=bd³/12.

11. TEST RESULTS

Table 3. 25mm Panel with Polypropylene Fibrillated Fibers (1% cement)

Layers	Panel Name	Strength
		N/mm^2
2	25 2 1	42.62
2	25 2 2	43.91
2	25 2 3	44.23
3	25 3 1	42.3

3	25 3 2	41.02
3	25 3 3	44.55
4	25 4 1	42.3
4	25 3 2	45.83
4	25 3 3	45.19

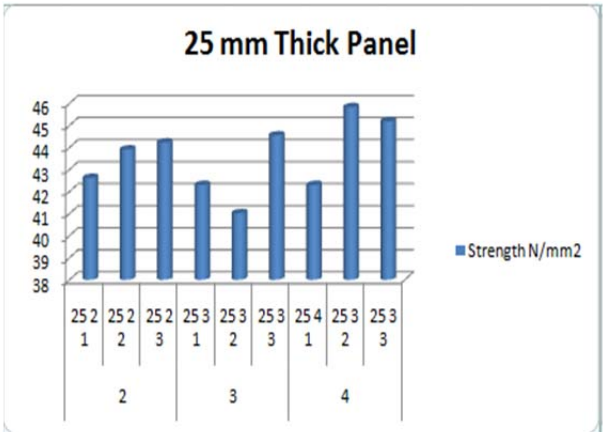

Fig. 10. Overall Results Of Flexure Test of 25 mm panel with Polypropylene Fibrillated Fibers (1% cement)

Table 4 40mm Panel with Polypropylene Fibrillated Fibers (1% cement)

Layers	Panel Name	Strength N/mm^2
3	40 3 1	17.25
3	40 3 2	16.12
3	40 3 3	16.5
4	40 4 1	23
4	40 4 2	21.12
4	40 4 3	21.75
5	40 5 1	20.25
5	40 5 2	24.87
5	40 5 3	22.62
6	40 6 1	25.11
6	40 6 2	25.81
6	40 6 3	26.6

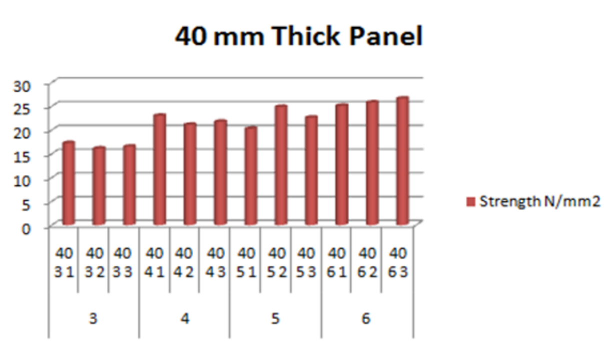

Fig. 11. Overall Results Of Flexure Test with Polypropylene Fibrillated Fibers (1% cement)

12. COST ANALYSIS

Cost Factor Of Ferrocement Panel Compared With Brick Masonry.

Table 5. Cost of brickwork work and Plastering (3.048m^3)

Sr. no.	Description	Qty	Rate	Amount
1	Bricks	5146	7	36022
2	Cement	16	350	5600
3	Sand	0.7483	5500	4115
Total cost of brickwork				**45737**
Sr. no.	**Description**	**Quantity**	**Rate**	**Amount**
1	Cement	10 bags	350	3500
2	Sand	0.491 Brass	5500	2700
Total cost of plastering				**6200**

Table 6: Cost analysis of roofing and labour

Sr. no.	Description	Quantity	Rate	Total Amount
1	Labour (brickwork)			
	1) Skilled	1	700	1300
	2) Unskilled	2	300	
2	Labour (plastering)			
	1)Skilled	2	500	1600
	2)Unskilled	2	300	
3	Bhisti	1	150	150
4	Fitting(Roofing)	2	500	1000
5	Carpenter	2	500	1000
Total cost of laboring = 1300 + 1600 + 150 + 1000 + 1000 =				**5050**
Sr. no.	**Description**	**Quantity**	**Rate**	**Total Amount**
1	G.I. sheet	4	600	2600
2	Angles(12ft.- ,21Kg)	3	756	2268
	Per Kg.-36 rupees			
3	Rivets and bolds	15	7	105
Total cost of roofing = 2600 + 2268 + 105				**4973**
Sr. no.	**Description**	**Quantity**	**Rate**	**Total Amount**
1	Door with frame	1	4000	4000
2	Window with frame	1	1200	1200
Total cost of Door and window = 4000 + 1200				**5200**

Total cost of Brickwork = 67160 Rs.

Table 7: Cost of ferrocement for room (3.048m^3)

Sr. No.	Description	Nos	Cost (Rs.)	Total cost (Rs)
1	Ferrocement panels	132	(125x132)	16500

2	Scaffolding-			
I.	Props	10	10 x 20	200
I.	Spans	6	6 x 15	90
I.	Base cannel	4	4 x 650	2600
3	Roofing materials-			
I.	G. I. Sheet	4	4 x 600	2400
I.	Angles (Length 3.65m) (Weight-21Kg)	3	3 x756	2268
I.	Rivets and bolts	15	15 x 7	105
4	Openings-			
I.	Door	1	1 x 4000	4000
I.	Window	1	1x1200	1200
5	Labors-			
I.	Skill	2	2 x 2 x 700	2800
I.	Unskilled	3	3 x 2 x 300	1800
Total construction cost of ferrocement panels				**33963**

13. CONCLUSIONS

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

1.as the number of layers of metal mesh increases the flexural strength of ferrocememt panel increases.

2. the pattern of stress vs strain graph of 25 mm thick panel is similar to stress strain graph of concrete. and the pattern of stress-strain graph of 40mm thick panel is similar to stress-strain graph of steel materials. so it concludes that in 25 mm panel fails due to concrete failure and 40 mm panel fails due to expanded metal mesh failure.

2.Increase in thickness of slab panels and increase in mesh layer, central deflection of slab panel goes on reducing.

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

6.The cost of ferrocement panel construction is approximately half than cost of construction of conventional brickwork.

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