Analysis of Curved Ferrocement Panel

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Abstract- *Prefabricated elements are used in construction industry as an alternative method to overcome the formwork problems and getting better quality control. The prefabricated elements made of reinforced concrete are very heavy and hard to transport, placing in position and to construct. Because of its good structural performance and low cost ferrocement is used in construction industry. Ferrocement is suitable for the construction of flooring/roof elements, precast elements, manhole covers, and construction of domes, vaults, grid surface and folded plates. It can also be used for construction of water tanks, boats, and silos. An experimental analytical and finite element analysis on flexural behavior of flat and curved ferrocement panels reinforced with varying number of wire mesh layers is presented. The Ansys analysis has been used to model the ferrocement panel for various span, mesh layer and thickness. The result obtained from FE analysis analytical and experiment work indicate that it has acceptable accuracy. Such models can thus be used as quick, simple, and inexpensive methods to calculate the optimal deflection of ferrocement channels for various spans and sizes of tensile reinforcement.*

Keywords- ferrocement; ANSYS; flexural strength; deflection; FE analysis.

I. INTRODUCTION

India has been identified as a developing economy which tends to give rise to a lot of infrastructure developments especially the building projects. RCC is most widely used in all over world because of its high load carrying capacity but the cost of cement and steel is increasing day-by-day. So, we require a substitute to concrete which gives same strength as that of RCC with low cost. In ferrocement, hydraulic cement mortar with closely spaced small diameter wire meshes is used. To improve certain characteristics of ferrocement various materials such as admixtures, silica fumes, fly ash and fibers are used. Generally, the thickness of ferrocement ranges from 20 – 50 mm. Ferrocement is a type of thin wall reinforced concrete commonly constructed of hydraulic cement mortar reinforced with closely spaced layers of continuous and relatively small size wire mesh which may be made of metallic or other suitable materials. Since ferrocement possess unique properties, such as high tensile strength-weight ratio, superior cracking behavior, lightweight, mold ability to any shape and certain advantages such as utilization of only locally available materials and semiskilled labor/workmanship, it has been considered to an attractive material and a material of good promise and potential by the construction industry. It has wide range of applications such as in the manufacture of boats, barges, prefabricated housing units, biogas structures, silos, tanks, and recently in the repair and strengthening of structures.

There are two approaches that can be taken in building with ferrocement one approach is to start with the individual components of steel reinforcing mesh, cement, and sand and build the structure in place from the ground up. The other approach is to use precast panels of ferrocement to the structure. Ferrocement is the best alternative to concrete and steel. Although the need for experimental research to provide the basis for design equations continues but by applying the FEM, can reduce the time and cost of otherwise expensive experimental tests, and may better simulate the loading and support conditions of the actual structure. Besides durability, there are other advantages of ferro—cement to the military. It is a very adaptable construction material. Structures of any shape can be built without the use of forms. Chicken wire is laid up into the desired shape and mortar is placed on. Ferro-cement is a nonflammable material, and this for some applications can be a very desirable feature. Military personnel not familiar with ferro-cement can build with the material when supervised by a knowledgeable person. This means that many men could be mustered to build defensive works, if necessary. Properties and application: Ferrocement is another type of reinforced concrete and which is unique with respect to content, behavior and suitability for structural application. The higher degree of sub division of the reinforcement and its uniform distribution in the matrix result in narrow uniformly spaced cracking load, rather than wider random cracking that is symptomatic of conventional reinforced concrete. The two-dimensional continuity of the reinforcement also imparts excellent resistance to disintegration and facilitates repair of damaged zones simply by re plastering. In real usage ferrocement is especially suited to sections less than about 76mm thick which placement and full compaction of concrete around conventional reinforcement with formwork on both sides is virtually unachievable.

II. EXPERIMENTAL PROGRAMME

A. Materials Used

Cement

Birla Super Gold Ordinary Portland Cement of Grade-53 was used for casting the ferrocement specimens.

Fine Aggregate

The locally available Crushed Sand, clean, well dried and good graded, was used throughout this research. The sand passing through 2.36mm I.S. sieve was used.

Reinforcing Mesh

Galvanized welded square mesh of diameter 1.6mm and grid opening of 20mm x 20mm was used for casting ferrocement specimens. Minimum cover of 4mm was provided from all sides of mold.

1. Diameter of mesh = 1.60 mm
2. Spacing of mesh = 20mm x 20mm
3. Ultimate tensile strength = 455 MPa
4. Yield strength = 450 MPa

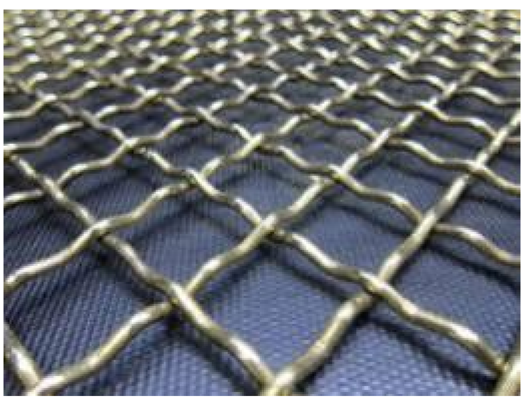

Fig. 1. Wire mesh

Water

For mortar mix preparation and curing of specimens, portable water was used. The water used was clean and free from organic impurities.

Admixture

PERMA PLAST PS-34 was used for water reduction, early strength of mortar and self-compacting. The procedure of adding admixture is very simple. First take required amount of admixture, mix it with water properly. Then add solution to dry mix.

B. Geometry of specimen

The ferrocement panels of dimension 550mm x 200mm x 20mm, 750 mm x 200 mm x 30mm, 900 mm x 200 mm x 40 mm and 1000mm x 200mm x 50mm with two and four number of layers of mesh were used. The reference number and designations of the tested elements are given table. The panels are constructed using the conventional ferrocement materials, which is composed of cement mortar and hexagonal wire mesh.

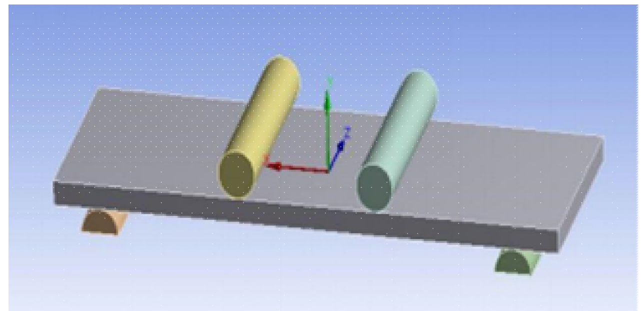

Fig. 2. FEM model of flat ferrocement panel

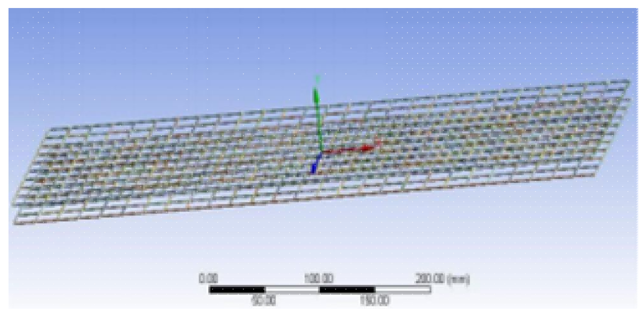

Fig. 3. FEM model of flat ferrocement panel

C. Experimental Setup

Universal Testing Machine was used to study the flexural behavior of ferrocement specimens. The specimens were tested under two-point loading condition. The specimens were placed on a simply supported base. Excess 50mm span was provided on either side of specimen and the center of the specimen was marked based on remaining span. Load was applied mechanically using hydraulic pressure under UTM. Dial gauge is installed to calculate the central deflection of the ferrocement slab due to applied load.

Fig. 4. Two-point bending test

III. FINITE ELEMENT ANALYSIS

A general-purpose code, Ansys FEA which is a finite element based software and a powerful tool to investigate the behavior of the proposed ferrocement panel, was applied in this study. Several elements are available which can be used to model. Better satisfying the boundary conditions along the elements borders and closer results of analytical and experimental models, were considered for modeling the mortar of ferrocement and reinforcement reinforced concrete in this program. It had three degrees of freedom at each node (translations in the nodal X, Y, and Z directions). The ferrocement mortar was modeled with concrete characteristics using elastic modulus of (Ec) 15 GPa and Poisson's ratio of 0.2 and these values for reinforcement were 200 GPa and 0.3 respectively. Curved panel having same geometry as that of flat panel with camber height 20, 30, 40 and 50mm was used for the analytical and FE analysis.

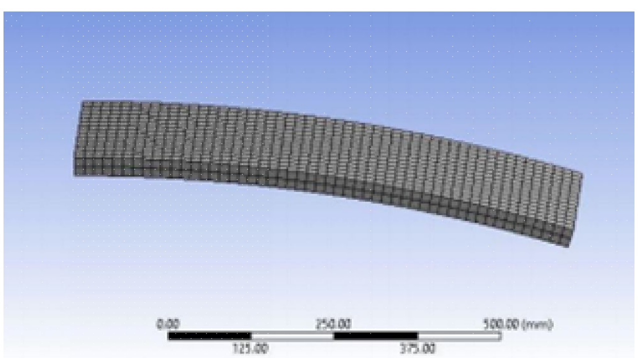

Fig. 5. FEM model of curve ferrocement panel

IV. ANALYTICAL STUDY

Energy method is used to calculate the central deflection of curved slab due to point load. The equation is given by

Where,
P = Applied force
h = Span of ferrocement
d = Camber height
E = Young's modulus
A = Cross sectional area of slab
I = Moment of inertia

V. RESULTS

Load deflection from the lateral edge of the ferrocement panel under flexural strength under two-point loading in the experimental and FE model is shown in Table. Although various parameters can affect load deflection, only the linear load is applied in the FE model. Comparison between the developed FE model of the channel and the findings from the experimental model suggested that the two models yielded similar trends. As regards the ferrocement panel there is no vibration used in construction operations the variant of modulus of elasticity is sensitive to FE model. Therefore, with a reliable factor of safety and optimal designing the trend may be acceptable. The deflection calculated for the curved ferrocement panel is similar to the deflection obtained from finite element analysis.

The result obtained from experimental, finite elemental and analytical analysis is summarized below

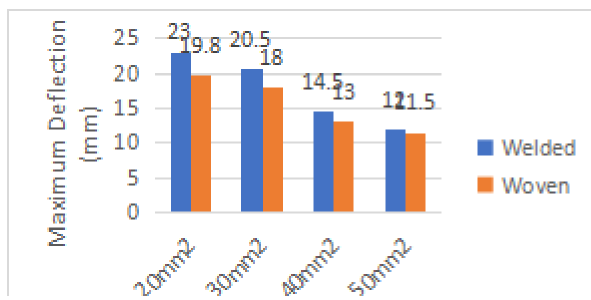

Figure 6 Deflection for flat ferrocement panel

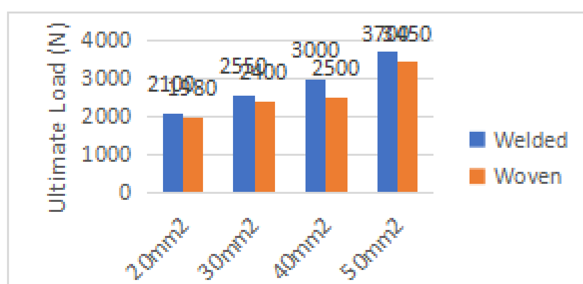

Figure 7 Maximum load for flat ferrocement panel

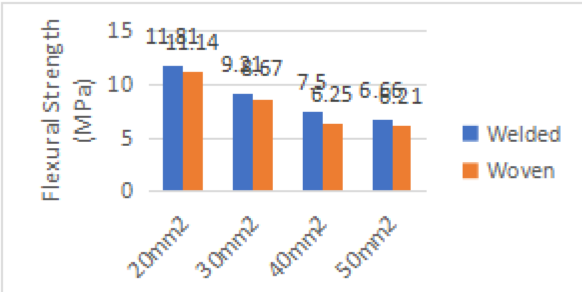

Figure 8 Flexural Strength for flat ferrocement panel

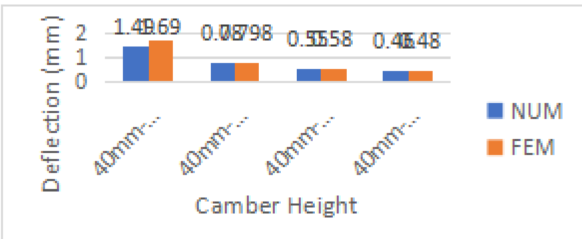

Figure 9 Deflection for 40mm thick curved panel

Table 1 Results for flat ferrocement panel

Serial No.	Specimen name	Thickness of specimen (mm)	Number of layer of mesh	Volume Fraction of Mesh (Vr)	Ultimate Load (N)	Maximum deflection (mm)	Flexural Strength (MPa
1	20mm2-Wl	20	2	2.02	2100	23	11.81
2	20mm2-Wo	20	2	2.02	1980	19.8	11.14
3	30mm2-Wl	30	2	1.35	2550	20.5	9.21
4	30mm2-Wo	30	2	1.35	2400	18	8.67
5	40mm2-Wl	40	2	1.005	3000	14.5	7.5
6	40mm2-Wo	40	2	1.005	2500	13	6.25
7	50mm2-Wl	50	2	0.804	3700	12	6.66
8	50mm2-Wo	50	2	0.804	3450	11.5	6.21
9	30mm4-Wl	30	4	2.7	3800	21.3	13.72
10	30mm4-Wo	30	4	2.7	3500	18	12.64
11	40mm4-Wl	40	4	201	5000	17.3	12.5
12	40mm4-Wo	40	4	2.01	4600	16.5	11.5
13	50mm4-Wl	50	4	1.61	6550	14.3	11.79
14	50mm4-Wo	50	4	1.61	6100	14.2	10.98

Table 2 Deflection of curved panel (2-layer)

Sr. No.	Specimen	Load (N)	Deflection (mm)	
			Numerical	FEM
1	20mm-20	2860	0.59	0.63
2	20mm-30	3240	0.394	0.41
3	20mm-40	3620	0.33	0.33
4	20mm-50	3800	0.30	0.32
5	30mm-20	3050	0.98	1.1
6	30mm-30	3430	0.58	0.62
7	30mm-40	3780	0.43	0.434
8	30mm-50	4160	0.37	0.38
9	40mm-20	3650	1.49	1.69
10	40mm-30	3940	0.78	0.798
11	40mm-40	4300	0.55	0.58
12	40mm-50	4600	0.46	0.48
13	50mm-20	4320	1.92	2
14	50mm-30	4550	0.97	1.1
15	50mm-40	4830	0.64	0.72
16	50mm-50	5230	0.48	0.54

Table 3 Bending Stress for curved panel (2-layer)

Sr. No.	Specimen	Load (N)	Bending Stress (MPa)	
			Compression	Tension
1	20mm-20	2860	13.2	7.4
2	20mm-30	3240	12.73	6.72
3	20mm-40	3620	12.6	6.65
4	20mm-50	3800	12.3	6.6
5	30mm-20	3050	10.1	6.16
6	30mm-30	3430	9.6	5.4
7	30mm-40	3780	9.5	5.1
8	30mm-50	4160	9.4	4.9
9	40mm-20	3650	8.2	5.5
10	40mm-30	3940	8.15	4.8
11	40mm-40	4300	8.12	4.5
12	40mm-50	4600	8.1	4.3
13	50mm-20	4320	7.5	5.17
14	50mm-30	4550	7.48	4.6
15	50mm-40	4830	7.46	4.2
16	50mm-50	5230	7.45	3.9

Table 4 Deflection of curved panel (4-layer)

Sr. No.	Specimen	Load (N)	Deflection (mm)	
			Numerical	FEM
1	30mm-20	4450	1.25	1.44
2	30mm-30	4980	0.73	0.85
3	30mm-40	5320	0.53	0.59
4	30mm-50	5900	0.45	0.53
5	40mm-20	5540	2.03	2.14
6	40mm-30	5950	1.07	1.22
7	40mm-40	6450	0.74	0.87
8	40mm-50	6740	0.56	0.62
9	50mm-20	6880	2.8	2.92
10	50mm-30	7230	1.41	1.5
11	50mm-40	7570	0.89	0.94
12	50mm-50	7940	0.67	0.69

Table 5 Bending Stress for curved panel (4-layer)

Sr. No.	Specimen	Load (N)	Bending Stress (MPa)	
			Compression	Tension
1	30mm-20	4450	9	14.75
2	30mm-30	4980	7.76	14
3	30mm-40	5320	7.1	13.9
4	30mm-50	5900	6.98	13.48
5	40mm-20	5540	8.34	12.35
6	40mm-30	5950	7.36	12.27
7	40mm-40	6450	6.72	12.18
8	40mm-50	6740	6.5	12.1
9	50mm-20	6880	8.24	11.9
10	50mm-30	7230	7.3	11.8
11	50mm-40	7570	6.6	11.62
12	50mm-50	7940	6.1	11.4

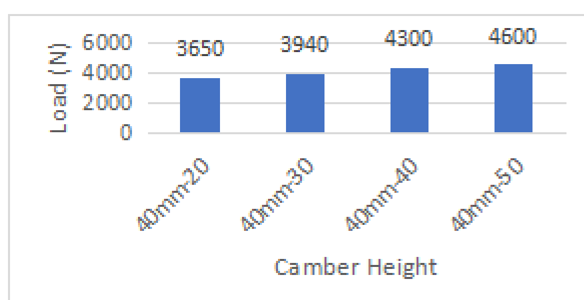

Figure 10 Maximum load for 40mm thick curved panel

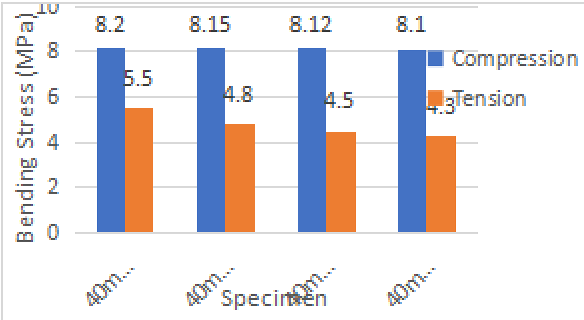

Figure 11 Bending stress for 40mm thick curved panel

VI. DISCUSSION

From the above table, it can be observed that the factor experimental data to the FEM data is in the range of 1 to 1.2. It is noted that welded mesh ferrocement panel has more load carrying capacity than that of the woven mesh ferrocement panel. When the number of mesh layers increase the load carrying capacity, final deflection and flexural strength of the ferrocement panel also increases. But while increasing thickness of the panel the final deflection and the flexural strength of the ferrocement panel decrease. This is due to the higher moment of inertia due to the increase in thickness. In curved panel it's also observed that when the camber height of the panel increase the flexural strength of the panel decreases and the load carrying capacity increases.

VII. CONCLUSION

1. The load carrying capacity and flexural strength of welded ferrocement flat panel is more than that of the woven ferrocement panel.
1. Deflection obtained from analytical equation and FE analysis is within the limit of allowable error so the analytical equation is suitable calculating deflection of ferrocement curved slab.
2. In curved slab, increase in camber height causes increase in load carrying capacity and decrease in flexural strength.
3. Increase in camber height of curved panel caused decreases in deflection of panel due to load.
4. With increase in thickness, flexural strength decreases and load carrying capacity of the ferrocement panel increases.
5. The load carrying capacity and flexural strength of ferrocement panel increases with increase in volume fraction of reinforcement.

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