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Study The Behaviour Bending Phenomenon of Ferrocement Slab Panels

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ABSTRACT

The fibrocement is a special type of reinforced concrete used for thin elements. It is made by cement micro concrete reinforced by continuous mesh layers from small diameter wires. The ferrocement is a building material with evident advantages for thin-walled members and spatial structures for this type of material. In this chapter describes the behaviour of ferrocement, advantages or disadvantages of ferrocement, quality and uses of ferrocement, objective of the thesis and organization of thesis.

Ferrocement serve as an innovative and low cost construction material. It has proven itself as an excellent material for low cost housing. Ferrocement possess high ductility and energy absorbing capacity and has been used both in terrestrial and marine environments as a structural grade material system, which competes favorably with reinforced concrete and other building materials (Hermosura and Austriaco, (1994); Ramli and Wahab, (1994); Arif et al., (1994); Naaman, (2006). Ferrocement is such a material that is slim, slender and also strong and elegant which provides a potential solution to roofing problems, with an history of ancient and universal method of building huts by using reeds to reinforce dried mud (wattle and daub).

The thickness of Ferrocement is in order of 10-25 mm and it uses rich cement mortar in which no coarse aggregates are used (J.R.Thirumal, (2012). In ferrocement the reinforcement consists of one or more layers of steel wire mesh which is continuous, small diameter steel wire or weld mesh netting. Ferrocement construction requires no skilled labor for casting, and employs only little or no formwork (Ferro 7, 2001). In ferrocement, there is no cracking of cement matrix since the load is taken over by wire mesh reinforcement immediately below the surface. (Desai, 2011). Ferrocement can be fabricated into any desired shape or structural configuration which is not possible with standard masonry, RCC or steel (Robles-Austriaco, 2006; Dongyen et al., 2006; Kondraivendhan & Pradhan, 2009).

INTRODUCTION

Ferro cement application continued up to 1960's decade, but its use declined, because man labor cost had been increasing and other competitors to thin walled components were developed. In the 1960's decade, Nervi's accomplishment simulated the beginning of other phase, the worldwide application of ferrocement, but mainly in the developing countries. This phase comes until the present days on age near 35 years. The most single property of ferrocement emphasized along its evolution has been related to its high structural performance which has allowed the application of the material in quite different constructions, from ship hulls to housing panels. However the world economy has been coming still more competitive and two words govern the industry: quantity and productivity. Amongst other properties, quality of a construction means durability, a satisfactory service life without special maintenance and repair. Productivity is strongly related to the cost of the product, and this latter almost ever is the final criterion of choice.

Ferrocement construction technology is being popularized throughout the world in countries like Canada, USA, Australia, New Zealand, United Kingdom, Mexico, Brazil, the former USSR, Eastern European countries, China, Thailand, India, 'Indonesia, and in other developing countries due to its uniqueness and versality (Shannag and Ziyyad, 2007). Small ferrocement tanks of less than 18.9 m3 (5000 gal) capacity were being factory built in New Zealand (Bulletin CP-10, 1968). The elevated water tanks of 47.3 m3 (12500 gal) capacity were successfully constructed in Bangladesh in 1989 (Mansur, 1990). Ferrocement silos can hold up to capacity of 10 metric tons (22400 lb) of grain/ food stuffs, fertilizer, cement and pesticide Ferrocement is more durable than wood/ timber and cheaper than imported steel. Small capacity ferrocement bins upto 3 metric tons which are cylindrical in shape, and size of 1.20 m (3.9 ft) in diameter and prefabricated in heights of 1 m (3.28 ft) is analyzed and successfully tested in India (Sharma et al. 1979) and the results have proved that ferrocement bins are less expensive than the bins made of steel, reinforced cement concrete (RCC) or aluminium.

The comprehensive understanding and detailed design method of contemporary ferrocement is provided by (Naaman, 2000). However, the rapid development in reinforcing meshes 11 and matrix design requires continuous research to characterize the new material and improve the overall performance of ferrocement. Thus far steel meshes have been the primary mesh reinforcement for ferrocement, but recently fiber reinforced plastic (FRP) meshes were introduced in ferrocement as a promising alternative to steel meshes (Al-Farabi, et al, 1993, Al-Sulaimani,1994). Compared with steel, FRP materials possess some remarkable features such as lightweight, high tensile strength and inherent corrosion resistance. However, unlike steel that has an elastic-plastic stress-strain relationship, FRP materials behave elastically up to failure, thus do not yield and lack ductility.

1.4 ADVANTAGES OF FERROCEMENT

Ferrocement is advantageous technology for developing countries due to following reasons:

- It can be molded into any desired shapes.
- Raw materials are readily available in most countries.
- The skills for ferrocement construction can be acquired easily.
- Heavy plant setup and machinery are not required in ferrocement construction.

In case of damage, it can be repaired easily. Being labor intensive, it is relatively inexpensive in developing countries

MATERIALS TESTING

Cement

Cement is the most important, active component in mortar and usually has the highest unit cost. Thus, its selection and proper use are important in obtaining most economical balance of properties desired for any particular mixture. It fills up voids existing in the fine aggregate and makes the mix impermeable Good quality cement should satisfy all the requirements as per I.S. specifications. The amount of cement required for a given mix should be in a range of minimum and maximum amount for the given grade as per the IS code provision.

Portland cement, also referred to as Ordinary Portland Cement (OPC), is the most important type of cement and is a fine powder produced by grinding Portland cement clinker. OPC is classified into 3 grades namely 33 Grade, 43 Grade, 53 Grade depending upon the strength of 28 days. The specification for the cement of any grade is given by the various IS codes. IS 8112:2013 provides the specification of the OPC 43 Grade.

Ordinary Portland Cement (OPC) of 43 Grade from a single lot was used throughout the research work. The physical properties of the cement are determined from various method of physical test for cement (IS 4031) and the requirement, conforming to IS 8112:2013.

Table 3.1: Physical Properties of Cement

Characteristics	Values Obtained Experimentally	Value Specified By Is 8112:2013	Method Of Test Ref.
Specific Gravity	3.15	-	IS 4031 part 11
Standard Consistency	35	-	IS 4031 part 4
Initial Setting Time (minutes)	48mins	Not to be less than 30 minutes	IS 4031 part 5
Final Setting Time (minutes)	264mins	Not to be greater than 600 minutes	IS 4031 part 5

Table 3.2: Chemical Composition of Cement

Parameters	% by Weight Test Results	Recommended Values as per IS 8112: 2013
Silica, SiO_2	21.24	17-25
Alumina ,Al_2O_3	5.19	3-8
Iron Oxide , Fe_2O_3	7.05	0.5-6
Lime, CaO	61.32	60-67
Magnesia, MgO	2.38	0.1-4
Sodium Oxide, Na_2O + Potassium Oxide, K_2O	0.17	0.5-1.3
Loss on ignition, LOI	2.68	5
Sul. anhydride, SO_3	2.29	3.5
Chloride	-	0.1

3.2.2 Fine Aggregates

Aggregate occupy a large volume in concrete mixture and give dimensional stability to mortar. In ferrocement only fine aggregate (sand) is used particle size less than 4.75mm. Sand consists of small angular or rounded grains of silica and is commonly used as the fine aggregate in cement mortar it fills the existing voids and reduces shrinkage and cracking of mortar. It helps in hardening of cement by allowing the water through its voids. To form hard mass of silicates, as it is believed that, some chemical reaction takes place between silica of sand and constituents of cement. The fine aggregates assist the cement paste to prevent the possible segregation. The aggregate must be proper in shape, clean hard and well graded. The aggregates which pass through 4.75mm IS sieve are termed as fine aggregates.

The fine aggregates used are procured locally from two places and were conforming to grading zone II. Sand 1- Yamuna Sand, Sand 2- River Sand (Ganga River Sand). They are free from silt and clay particles. Sieve analysis and physical properties of fine aggregates are tested as per IS: 383 and result are shown in tables.

SAND 1: Yamuna Sand:

This type of sand is not mostly used because the production of sand decreases. The physical properties and sieve analysis of the Yamuna sand as tabulated in given table 3.3 & 3.4.

SAND 2: River Sand (Ganga Sand): is procured from river streams and banks and is fine in quality unlike pit sand. This type of sand has rounded grains generally in white-grey color. The physical properties and sieve analysis of the river sand as tabulated in given table 3.5 & 3.6. River sand has many uses in the construction purpose such as plastering.

Table 3.3: Physical Properties of Yamuna Sand

Characteristics	Experimental values
Type	Uncrushed(natural)
Grading Zone	II
Fineness modulus	2.59
Specific gravity	2.62

Table-3.4 Sieve Analysis Data of Yamuna Sand Sample

S.No.	IS-Sieve (mm)	Wt. Retained (gm)	%age Retained	%age passing	Cumulative % retained
1	4.75	8	0.8	99.3	0.7
2	2.36	57	5.7	94.2	6.5
3	1.18	137	13.7	86.4	20.1
4	600 µ	240	24.00	75.9	44.2
5	300 µ	418	41.8	58.3	85.9
6	150 µ	119	11.9	88	97.9
7	Pan	21	2.1	**SUM**	**255.0**
TOTAL		**1000**	**1000**		**FM=2.55**

Table 3.5: Physical Properties of Fine Aggregate

Characteristics	Experimental values
Type	Uncrushed(natural)
Grading Zone	II
Fineness modulus	2.3
Specific gravity	2.65

Table-3.6 Sieve Analysis Data of River Sand (Ganga River) Sample

Is Sieve	% Of Passing Of River Sand Sample	Cumulative % retained
4.75	99	0.00
2.36	90.70	9.30
1.18	98.30	11.00
600 µ	80.90	30.1
300 µ	47.80	82.3
150 µ	54.50	97.7
Pan	SUM	230.4
	FM	**2.30**

3.2.3 FLY ASH

Fly ash is a thermal Industrial waste (by product of coal) and defined as a fine powder of mainly spherical, glassy particles as shown in figure 3.4. Investigations were made on fly ash procured from NTPC Yamuna. The fly ash was used to replace a certain percentage of the cement. The chemical & physical composition as given by the supplier is shown as in table 3.7 & 3.8.

Table 3.7 Chemical Properties of Fly ash

Parameters	(%) Permissible value as per IS 3812-2003
$(SiO_2+Al_2O_3+Fe_2O_3)$	71.0 min
Magnesia, MgO	0.6 max
Sodium Oxide, Na_2O	1.6 max
Potassium Oxide, K_2O	-
Loss on ignition, LOI	1.7 max
Sul. anhydride, SO_3	0.4 max

Table 3.8 Physical Properties of Fly Ash

S.NO.	Particulars	(%) Permissible value as per IS 3812-2003
1	Fineness Specific Surface (cm2/gm)	3100 min
2	Residue on 45 micron (wet sieving)	33 max
3	Soundness expansion by auto clave, %	0.9 max

3.2.4 Silica Fume

The silica fume used in the present work is supplied by NTPC Yamuna as shown in figure 3.5 and the chemical properties of silica fume as shown in given table 3.9. Silica fume is highly reactive pozzolanic material and is a byproduct from the production of silicon or Ferro- silicon metal. It is composed from the flue gases from electric arc furnaces. Silica fume is very fine powder, with particles about 100th times minor than average cement grain. It is available in a water slurry form. It is used at 5% to 12% by mass of supplementary cementitious materials for concrete structures that requires high strength

Table 3.9 Chemical Properties of silica fume

Silica Fume	ASTM-C-1240
SiO2	86% min
LOI	7% max
Moisture	2%
Pozz Activity Index	106% min
Sp Surface Area	>15 m2/gm
Bulk density	540 to 710
+45	9% max

3.2.5 Water

The potable water is generally considered satisfactory for mixing and curing of concrete. Accordingly potable water was used for making concrete available in material testing laboratory.

3.2.6 Wire Mesh

Stainless steel wire mesh offers excellent acid resistance, alkaline resistance, heat resistance, and also high tensile strength as shown in figure 3.7.

- Maximum use of 2 layers of mesh and size is 350x350mm
- Size of mesh opening 10x10 mm

Fig. 3.6 Wire Mesh

3.3 MIXING, CASTING AND CURING OF FERROCEMENT

The materials like cement, sand was proportioned in required quantities and dried mixed. The ratio of cement and sand adopted is 1:1.5 for same mixes fly ash and silica fumes were measured according to the required percentage and added to the dry mix. Necessary care has to be taken to prevent balling effect of fibers. The water is measured and added to the mix. Proper mixing is done with the help of mixer. Firstly conventional mix is prepared by using cement, fine aggregate and water in proportion of 1: 1.5: 0.40 in the concrete mixer as shown in figure 3.7. Then for other mixes cement is replaced by fly ash and silica fumes by 10% and 6% by weight of cement respectively.

The casting of ferrocement cubes is started by using metal mould of size 70.6×70.6×70.6mm First of all entire mould is cleaned and oiled so that cubes can be easily removed from the moulds after 24 hours. Place the entire quantity of mortar into the mould and tamp the mould using 12mm diameter tamping rod 25 times. Place the mould on the vibrator. Vibrate the cube for a period of two minutes. Remove the mould from vibration and keep it in a dry area, top surface of the cube is finished properly, repeat the process for casting of other cubes. Demould the cubes after 24 hours and transfer them into the curing tank. Total seventy two numbers of ferrocement cubes are casted and cured for a period of 7days, 14days, 21days and 28 days.

3.3.0 Detail of cube casted

Table 3.10 mix of Ferrocement

S.no.	Size of cube	Type of sand	w/c ratio	No. of cube
1.	70.6×70.6×70.6	Yamuna sand	0.40	12
2	70.6×70.6×70.6	River sand	0.40	12

Table 3.11 Modified mortar 1 (with 10% fly ash, 6%silica fumes)

S.no.	Size of cube	Type of sand	w/c ratio	No. of cube
1.	70.6×70.6×70.6	Yamuna sand	0.34	12
2.	70.6×70.6×70.6	River sand	0.34	12

Table 3.12 Modified mortar 2 (with 10%flyash, 8%silica fumes)

Fig: 3.:Mixture of material & Mixer

The casting of slab panels is started by using wooden mould of size 400 x 400 x 40 mm. First of all entire mould is oiled so that slabs can be easily removed from the moulds after 24 hours. Initially a layer of the mortar was placed of 10 mm thickness then first layer of wire mesh is placed over the finished mortar. Before casting the slab the wire mesh must be fabricated as shown in figure 3.8 and after it 20 mm mortar is laid and properly finished. Then the second layer of wire mesh is placed. Finally the top cover of 10 mm of mortar is spread and top layer of slab surface is finished properly as shown in figure 3.9. Total seventy two numbers of ferrocement slabs are casted and cured for a period of 7days, 14days, 21days and 28 days.

3.3.1 Details of Panels Casted

Table 3.10 mix of Ferrocement

S.no.	Size of panel	Type of sand	w/c ratio	No. of wire mesh layers	No. of panels
1.	400x400x40	Yamuna sand	0.42	2	12
2.	400x400x40	River sand	0.42	2	12

Table 3.11 Modified mortar 1 (with 10% fly ash, 6%silica fumes)

S.no.	Size of panel	Type of sand	w/c ratio	No. of wire mesh layers	No. of panels
1.	400x400x40	Yamuna sand	0.34	2	12
2.	400x400x40	River sand	0.34	2	12

Table 3.12 Modified mortar 2 (with 10%flyash, 8%silica fumes)

S.no.	Size of panel	Type of sand	w/c ratio	No. of wire mesh layers	No. of panels
1.	400x400x40	Yamuna sand	0.34	2	12
2.	400x400x40	River sand	0.34	2	12

CONCLUSION

Concrete or mortar is very strong in compression but weak in tension so use steel wire mesh to increase the tensile strength and durability of the ferro-cement mortar. Fly ash and silica fume are used to fill the pores and effect on the durability of mortar mix. Different proportions of the fly ash and silica fume are used in the mortar and determine the flexural strength and compressive strength.

Following are the conclusions which are coming from the results obtained in the experimental study.

- The combination of fly ash and silica fume which are used in different proportions increase the durability of mortar mix.
- Percentage of silica fume also increases the flexural and compressive strength of specimen as compared to the conventional mix.
- The increment in flexural strength is 11% of ferro-cement panels containing badarpur sand, flyash and 8% silica fume. In case of Ganga sand it increases by 9%.
- The increment in compressive strength is higher of ferrocement cube containing Badarpur sand, flyash and 8% silica fume compare to Ganga sand.
- Combination of badarpur sand using fly ash and silica fume shows greater effect for increasing the quality as comparing to river sand.

LITERATURE REVIEW

Flexure strength, compressive strength, ductility and durability of ferrocement have been investigated by many researchers. Study on the effect of replacement of cement by materials like flyash and silica fumes has also been done to gain equal or more strength.

A large number of experimental and analytical studies dealing with ferrocement structural elements, having various shapes and sizes, subjected to different loading conditions are reported in literature.

2.2 FERROCEMENT

Hussain,W (1991) [1],presented extensive data on the cracking and strength behavior of thin ferrocement sheets of 10mm thickness in flexure. Cement replacement by 50% to 70% fly ash and inclusion of super plasticizer can produce mixes of excellent flow characteristics and adequate early strength that can further ease the construction process and enable incorporation of short discrete fibers without difficulties of Fabrication. The inclusion of fibers increases stiffness, decrease deflection and shows large ductility at failure. Small opening meshes exercise better cracking control than large opening meshes. However, incorporation of fibers in the mix modifies this pattern as large result in substantial reduction in crack spacing and crack widths compared with conventional ferrocement. For structural applications of ferrocement, deflection is a Major design limitation. Fiber ferrocement along with layers of mesh can increases stiffness of the composite and reduces deflection at all stages of loading. The measured Crack spacing and crack width can be satisfactorily predicted by the method proposed in this work.

Ohama et al., (1992) [2],compared the durability of polymer-ferrocement with conventional ferrocement. The polymer-ferrocement, using styrene- butadiene rubber Latex, is prepared with various polymer-cement ratios, and tested for accelerated carbonation, chloride ion penetration and accelerated corrosion. It is concluded that the carbonation and chloride ion penetration depth of polymer-ferrocement decreases markedly with an increase in polymer-cement ratio regardless of exposure and immersion periods, and are strongly affected by polymer-cement ratio and water-ratio and water cement ratio. The corrosion inhibiting property of polymer-ferrocement is remarkably improved with an increase in polymer-cement ratio. As in the case of conventional reinforced concrete, the mechanical properties of Ferrocement depend to a large extent on the properties of the cementitious matrix and the reinforcing steel. The apparent tensile properties of ferrocement represent a significant departure from that of ordinary reinforced concrete in that the dispersed reinforcement changes the observed cracking pattern.

S. DeepaShri et al., (1995) [3], performed an experimental work on ferrocement panels for studying their flexural behavior by using polypropylene fibers. Silica fume is added to reduce the dosage of chemical admixtures needed to get required slump. It is well known that addition of fibers will generally improve the ductility, toughness, flexural strength and reduce the deflection of cementitious materials. In the present study, a polypropylene fiber is added to the matrix and the dosage of fibers 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% fibers is larger compared to without fibers, delayed the first crack load, yield load and ultimate load compared to without.
- There is an increase in strength with the increase of slab thickness. Hybrid reinforced ferrocement specimens could sustain the larger deflections both at yield and ultimate loads compared to the SCC ferrocement specimens.
- Many micro cracks are formed before failure of the specimens, indicating more energy absorption and ductility. The stiffness of the specimens with 2-layers bundled weld mesh is lower than that of the specimens with 3 layers bundled.

Dr. S.K. Kaushik (1997) [4], investigated the behavior of eight simply supported concrete steel and concrete ferrocement composite slabs of span 1.5m and 3.0 the

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