INTRODUCTION

1.1 INTRODUCTION:

It combines the properties of thin section and high strength of steel, mould ability of concrete, lightweight and ease of working of timber, high tensile strength capacity of pre-stressed concrete and crack control of fiber reinforced concrete. Ferrocrete can replace all these material. In addition it needs no formwork or shuttering for casting. In traditional method of construction columns and beam only take the loads but in this method walls also take the loads. Loads are taken by walls, roofs, hidden beams and columns at the same time. Performance of structure in tension as well in compression is improved as compared to the RCC. It acts as a complete homogeneous structure.

Compared to traditional methods, the site work is reduced to maximum percent, resulting in saving of time of construction all types of structure including multistoried building, space structures and large conduits can be easily constructed by using this method. Traditional building materials like stones, bricks and timber are completely eliminated. The thickness of walls has reduced from 9 inches to 3 inches. Pollution of air, water and noise is reduced to zero. Hence it is an eco-friendly method. It can be effectively used in earthquake prone zones. There is effective temperature and vibration control.

The sections are reduced and hence dead load and cost is reduced with it. Ferrocement is a unique method of constructing structures and buildings, in which Ferro cement Paneled Cavity walls and Ferro cement boxed hollow floors with inbuilt columns and hidden grid beams, stiffeners are fabricated, erected and casted simultaneously resulting in an integral construction of walls and floors with inbuilt three dimensional structural framework of columns, stiffeners and beams. Welded mesh, mild steel angles or bars are used for forming skeleton, while chicken-mesh, square mesh or expanded metal are used as mesh reinforcement. It is used as cavity walls, pipes, earthquake retaining structures, soil retaining structures, water retaining structures, etc. Ferrocement is the material of new millennium. it’s creating wonder in the construction industry. It is going to change total fundamentals in construction industry. Ferrocement is going to revolutionize the method of building structure, With minimum materials, simple skill and a full-proof method of construction.

It is the self quality conscious material with which one can build slim, slender but strong elegant structures. It is the dream material for the architects, at the same time it is the most appropriate material for rural applications. In construction industry it has got wide application and application at every corner of building. A little change in reinforcement pattern and what wonders it has worked out. A novel material named ‘Ferrocement’ is born and along-with it a new technology in construction industry is evolved. It has converted the heterogeneous brittle material like RCC into a homogeneous, ductile composite.

This is due to a small change of replacing steel bars by continuous meshes of fine steel wires. it has increased the bond between wires & mortar to such an extent that in tension wires break but won’t get pulled out of the matrix Up to the yield point of steel, the steel and mortar remain bonded together, and offer ductility to the composite. The structure may bend or deflect but won’t fail all of a sudden.

IT JUST LIKE A JOINT FAMILY BONDED TOGETHER WITH

AFFECTION & LOVE.

HISTORY OF FERROCEMENT

2.1 HISTORY:

Ferrocement has a history of more than 150 years. It remained in background up to 1940.It has boomed as a construction material in the last two three decades. Though Ferrocrete is called as a form of reinforced concrete, it is only in the term of grouping terms ‘Reinforced’ and ‘concrete’. It differs from conventional reinforced concrete by the manner in which the reinforcement is distributed in the matrix and is bonded with it. Closely spaced and thoroughly distributed continues fine wire mesh reinforcement in brittle matrix of cement mortar forms ferrocrete. The ingredients of ferrocrete remains strongly bonded together up to yield of steel wires and hence behave more like a homogenous and ductile material Structures of thinner sections are possible due to closely tied mesh reinforcement and micro concrete as matrix. Mesh tied tightly over skeletal steel also act as a formwork hence ferrocrete can be cast in ant complicated shapes and sizes.

Fig.no.1-First boat of Ferrocement constructed by Mr.J.L.Lambot

2.1.1 Initial Work:

Ferrocement in form of mesh reinforced cement mortar was used in Europe by Mr. J.L.Lambot in France. He constructed ferrocement rowing boat in 1848, in which reinforcement was in form of flexible form of woven wire mat and small size bars. He had patented this process.

In the early 1940, Nervi's of Italy used ferrocement for shipbuilding to overcome the shortage of steel plates in 2^{nd} world war. He also applied ferrocement techniques in buildings and houses and warehouses. Ferrocement has been used in construction of domes, roofs of stadiums, opera houses and restaurants in Europe. In spite of nerves demonstration of successful use of the material, no systematic studies were made till 1960, when its use a boat building material was made in Australia, UK and south East Asian countries.

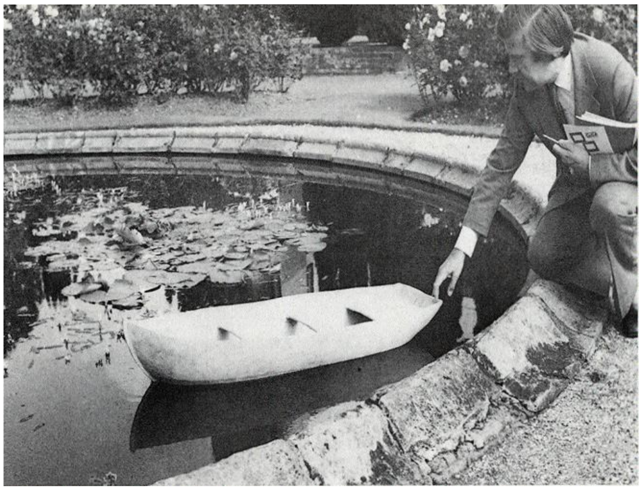

Fig. no. 2-.Mr.J.L.Lambot with his model boat

2.1.2 Recent Studies

In 1972, national academy of science, U.S.A., Established and Ad-hoc panel to study the use of ferrocement in developing countries. Its report on ‘ferrocement-application in developing countries’ was published in 1973. It gave impetus to systematic study of ferrocement in United States. This was followed by American concrete institute, establishing committee 549 on ferrocement in 1974. From then considerable efforts has been made by many individuals and institutions all over the world to develop ferrocement as a construction material.

Fig.no.3- Structure of Ferrocement in South Africa

LITERATURE REVIEW

In RCC method of construction slab, beam and column transfers the loads but in ferrocement method walls can also transfer the load. Loads are taken by walls, roofs, hidden beams and columns at the same time. Performance of structure in tension as well in compression is improved as compared to the RCC. It acts as a complete homogeneous structure. Compared to RCC, the site work is reduced to optimum percent, resulting in saving of time of construction. Multistoried buildings, space structures, various shapes of water tanks, retaining walls, domes, elevation treatment, silos, low cost houses, rehabilitation works, site cabins, manhole covers, rural applications, pipes, sewer lines and large conduits can be easily constructed by using this method. RCC building materials like stones, bricks and timber are completely eliminated. The thickness of walls has reduced from 9 inches to 3 inches. Pollution of air, water and noise is reduced to zero. Hence it is an eco-friendly method. It can be effectively used in earthquake prone zones. There is effective temperature and vibration control. The sections are reduced and hence dead load and cost is reduced with it.

TABLE: COMPARISION WITH R.C.C. STRUCTURE:

No.	Ferrocement	Reinforced Concrete
1	Thickness of member is 25 to 50mm.	Thickness of member is minimum 75mm.
2	Cement mortar	Cement Concrete.
3	Thin wires in the form of weld mesh (1-2 mm) and chicken mesh are used.	Steel bars greater than 6mm dia. spaced some distance apart.
4	High tensile strength, superior bond and shear strength.	Weak in tension, bond and shear.
5	Strength to weight ratio is Very High	Strength to weight ratio is very low in tension and compression
6	Tightly tight wire mesh act as forms for mortar casting. Filling is dense and compact	Formwork and shuttering are essential due to which honeycombing is formed.

7	Nearly homogeneous	Heterogeneous
8	Simple in design	Complicated design
9	Structural behavior- Ductile	Structural behavior- Rigid

Table no.1-Comparision with R.R.C. structure

CONCEPT OF FERROCEMENT

4.1 FERROCEMENT:

Ferrocement is a composite material comprising rich cement which is highly reinforced with continuous and small diameter steel rods and wires. It may be defined as a sophistically designed well-proportioned cement based compound in which optimum quantity of suitably sized steel sections are evenly dispersed for achieving remarkable homogeneity, ideal monolithic properties, excellent strength and absolute impermeability. Its engineering properties, not only in compression but also in tension, bending and fatigue are far superior. Unlike RCC, its panels are quite thin. Its thickness is generally between 10mm to 40mm. It is light in weight and can be constructed to any shape of cross section. Hence, widely suited for Precast products. It is a structured construction material constituted by a thin layer of portland cement mortar reinforced with steel wire meshes of small diameter, transversally and equally distributed across its layers. A cement mortar of 37 pounds/cubic feet (600 Kg/m3) is used in order to obtain better results than reinforced concrete. From a structural point of view, ferrocement resistance is given by the geometrically folded shape parts. Ferrocement is a building material composed of a relatively thin layer of concrete, covering such reinforcing material as steel wire mesh. Because the building techniques are simple enough to be done by unskilled labor, ferrocement is an attractive construction method in areas where labor costs are low. Sand, cement, and water usually can be obtained locally, and the cost of the reinforcing material (steel rods, mesh, pipe, chicken wire, or expanded metal) can be kept to a minimum. There is no need for the complicated formwork of reinforced cement concrete (RCC) construction, or for the welding needed for steel construction. Virtually everything can be done by hand, and no expensive machinery is needed.

Ferrocement is a thin section material precast/cast insitu and fabricated in the form of panels or appropriate shapes and sizes consisting of light structural steel, wire mesh layers, high quality cement matrix, admixtures, super plasticizers, fibres etc. The high quality cement matrix has a ratio of 1:2 to 1:2.5 or so. The cost of ferrocement is not expressed in per tonne as it is not powder like cement nor is it expressed in per cubic metre; it is expressed as Rs2,500-5,000 per surface area or Rmt of column or beam. Ferrocement can be described as a modified form of reinforced cement concrete with elimination of coarse aggregate, large-size reinforcement, sometimes shuttering, but having quite different properties with increased strength.

Ferrocement is the best alternative to RCC and steel. It is strong, durable, waterproof, corrosion preventive and fireproof up to 750° C for long periods, say, 48 hours, which can be extended. Apart from rainwater harvesting, there are many applications. For instance, it can be used for insulation cost reduction and as a very effective material for disaster prevention.

Fig.No.4- Ferrocement KALASH

Fig.No.5-Home OfMr.Sachin Tendulkar In Pune

Fig.No.6-.Bed Room Of Ferrocement

DESIGN FEATURES OF FERROCEMENT:-

Theory of design of Ferrocement structure will be quite different and shall be modified from time to time for improvement as compared to present method of design of RCC pre- stressed concrete and steel construction with modification in software program. Tensile strength of concrete being negligible, it is not considered in design process while R.C.C. is designed for tension. As against this when Ferrocement is designed for tension, cement matrix highly bonded with steel gets elongated along with steel considerably. On further extension the cracks in width of microns developed and when near to yield the cracks may not reach the reinforcement thus least reason for corrosion .This is the feature even whenever there is tension during flexure and shear. Therefore ferrocement structures are far better than RCC structure. Very efficient when manufactured as Ferrocement Structural such as joists, plates and other structural for steel construction. Because of this feature ferrocement structure are corrosion resistant, crack resistant waterproof, ductile, energy absorbing and may be other aspect.

The surface of Ferrocement of has high skin strength whereas there is no such phenomena as regard RCC and Prestressed concrete.

Very high bond force on wire mesh reinforcement cause delayed reaction of depth of neutral axis when load increases to yield values. It attribute to crack-less deformation of high quality cement matrix to a large extent along with wire mesh reinforcement very near to yield .cracks found are of negligible width and depth to 15 to 30 microns very rare to reach surface or reinforcement .This enables ferrocement to large deformation at yield and no collapse. This feature is the reason for effective resistance to earthquake of high resistance to earthquake of high richter scale 7 to 8.

That is the mexico experience of 1999 earthquake of Richter scale 7.2 and 7.4 one after the other. Small dia. Wiremesh reinforcement and low cover are the assets of ferrocement. This is also the cause of high waterproof quality of ferrocement and also no repair phenomena. Ferrocement structure is most ductile and high energy absorbing.

5.1 SUITABILITY OF FERROCEMENT AROUND THE WORLD

With ferrocement Technology large span barrel roof, domes , floor have been constructed as early as 1940 . Irrigation structures such as aquaducts , gates have been constructed as early as about 1970. Vehicular bridges, footbridges have been constructed in 1970. Water storage tank, tower with storage of million liters have been constructed as early as 1970.

Ferrocement waterproofing has been carried out on roofs of Sydney operas in 1960 or so and other locations marine structures ,ships ,boats, barges, 200 meters. Long, 33 mtrs. Wide and 7 mtrs. Deep have been constructed during 1970 .Research on repairs of RCC structures has shown that Ferrocement is the best repairs and retrofitting material far better than any conventional polymers fiber wraps etc. with fire resistance up to 750®C .or more with durability for decades.

DESIGN OF FERROCRETE STRUCTURE

6.1 DESIGN, ANALYSIS AND OPTIMIZATION:

When we analyze structure, we assume that the dimensions of the structure members and the properties of the materials of which the structure is composed are known. Behavior of the structure in the form of stresses, strain and deflection etc. under given loading id studied by analysis. In designing a structure, geological configuration of the structure is determined to fulfill prescribed functions. We are at liberty to choose the form and the material of construction. The ferrocrete structures can be shaped in such a way that the full section of the member and the full strength of material can be utilized. Thus flexural members can be shaped as an arch to use higher compressive strength of concrete and the cross section of arch sharing the load. An optimum design of a structure is one in which the prescribed goals are achieved with the minimum cost. In ferrocrete strength can be achieved by giving an appropriate shape to the structure. Also due to high strength in tension and compression and strength-to-weight ratio optimum design of ferrocrete structure is very much possible.

6.2 DESIGN CONSIDERATIONS SPECIAL FOR FERROCRETE STRUCTURE:

It is already pointed out that ferrocrete is quite a different material of construction. The material characteristics of ferrocrete which affect the as follows:

a) Volume fraction of the reinforcement.

b) Specific surface of reinforcement.

c) Effect of types of mesh used.

d) Effect of orientation of mesh.

e) Effect of shape of mesh.

f) Three stage behavior of ferrocrete in tension.

g) Crack behavior.

h) Three stage behavior in flexure.

6.3 TYPICAL FEATURES OF FERROCRETE STRUCTURES:

Some Typical features of ferrocrete structures which affect their design are given below-

a) Ferrocrete is a thin walled structure.

b) Strength to weight ratio of ferrocrete in tension and compression is very high.

c) Strength of ferrocrete structure can be achieved by giving it an appropriate shape.

d) Ferrocrete casting needs no formwork.

e) Ferrocrete is prone to pre-casting.

6.3.1 Thin Walled Structure:

Ferrocrete structure is cast in form of thin walls. The walling thickness may vary from 20 to 50 mm. As the thickness is less, weight of ferrocrete walls gets reduced. Their values for different wall thicknesses are given below in table (a). Compare these weights with a 250 mm thick brick wall. For a wall height of 3.0m, a ferrocrete cavity wall, with two leaf walls each 25 mm thick, weighs only 375kg/m run while a 250 mm thick wall will weigh 1350 kg/m run.

Table: Weight of Ferrocement Walling For Various Thicknesses

Wall thickness (mm)	20.0	25.0	30.0	35.0	40.0	45.0	50.0
Weight per m^2 (kg)	50.0	62.5	75.0	87.5	100.0	112.5	125.0
Single wall 3m high (kg)	150.0	187.5	225.0	262.5	300.0	337.5	375.0
Cavity 3 m wall (kg)	300.0	375	450.0	525.0	600.0	675.0	750.0

Table no. 2- Weight of ferrocement walling for various thickness

6.3.2 Strength to Weight Ratio:

Strength of ferrocement in tension and compression are very high and due to thin walling their weights are very low. Hence the strength to weight ratio of ferrocrete, as compared to the other construction materials is the highest. Strength to weight ratios, for different walling materials in construction in compression, 1are calculated and tabulated in table 3.

Table: Strength to Weight Ratios of Various Walling Materials

Type of walling	Mix	Permissible loads (kg/sq.m)	Wall thickness (cm)	Load carried per m run (tons)	Weig ht per m run (kg)	Strength to weight ratio
Solid concrete	1:1.5: 3 1:2:4 1:3:6 1:4:8	35.0 31.0 20.0 11.0	15 15 15 15	52.50 46.50 30.00 16.50	1080 1080 1080 1080	48.60 43.05 27.77 15.28

I class brick work						
In cement mortar	1:3 1:4 1:6	10.0 9.0 5.5	23 23 23	23.00 20.70 12.65	1242 1242 1242	18.52 16.67 10.18
C.R. Masonry						
In cement mortar	1:4 1:6	11.0 5.5	37 37	40.70 20.35	2775 2775	14.67 7.33
R. R. Masonry						
In cement mortar	1:4 1:6	9.0 4.5	45 45	40.50 20.25	3375 3375	13.33 6.00

Type of walling	Mix	Permissible loads (kg/sq.m)	Wall thickness (cm)	Load carried per m run (tons)	Weight per m run (kg)	Strength to weight ratio
Block masonry in cement mortar. (1:3)						
Block strengths in kg/sq.cm	35	2.7	15	4.05	1080	3.75
	70	6.5	15	9.75	1080	9.03
	140	10.5	15	15.75	1080	14.58
Cavity wall in bricks in cement mortar (1:3) each leaf 100mm thick						
	10.0		0.67 (10+10)	13.34	1080	12.35
Cavity wall blocks in cement mortar (1:3) block strength 140kg/sq.cm						
	10.5		0.67 (10+10)	14.00	1440	12.90
Ferrocrete cavity wall each leaf 25 mm thick						
With mortar strength	M40	100	0.67 (2.5+2.5)	33.33	375	88.88
	M35	90	do	30.00	375	80.00
	M30	80	do	26.67	375	71.11
	M25	60	do	20.00	275	53.3

Table no. 3: Strength to weight ratios of various walling material

6.4 SAMPLE CALCULATIONS:

Consider the weight of wall of one floor height 3.0 m

1. **For the class brickwork in cement mortar, minimum wall thickness being 230 mm, weight of wall/m =3.0 X 1.0 X 0.23 X 1800 = 1242 kg.**

   (Density of brickwork being 1800 kg/cum)

   Load carrying capacity/m of wall = 23 X 100 X 10 = 23 tones.

   (Permissible direct compressive stress on brickwork being 10 kg/sq.cm)

   Hence the strength to weight ratio is 23,000/1242 = 18.5

2. **For the ferrocrete cavity wall of two leaves of 25 mm thick, per m length of wall the weight will be 2 X 0.025 X 2500 X 3.0 = 375 kg.**

   Load carrying capacity of the wall = 0.67 X (2.5 +2.5) X 100 X 90 =30.0 tons

   (To allow for the slenderness, the wall thickness is multiplied by 0.67)

   Hence the strength to weight ratio for ferrocrete wall is = 30,000/375 = 80.0

The table shows that even for very lean mortar mix of M 20, the ratio is more than that of any other walling material.

Even through the ferrocrete wall is thin it can be stiffened in both directions by providing ribs. Hence if the walls are specified on the basis of their strength, ferrocrete wall will be the cheapest substitute.

MATERIALS UESD FOR FERROCEMENT

Ferro-cement composite is a rich cement mortar matrix of 10 to 40 mm thickness with reinforcement volume of five to eight per cent in the form of one or more layers of very thin wire mesh and a skeleton reinforcement consisting of either welded mesh or mild steel thin bars. The proportions in terms of sand -cement ratio are normally 1: 1.5 or 1:2. The water cement ratio may vary between 0.4 to 0.5. Admixtures can be added for achieving improved workability, reduced permeability and increased durability.

The skeleton steel can comprise of welded wire fabric of 3 to 4 mm diameter wires welded at 80 to 100 mm center to center. Steel should be uniformly distributed along the thickness and length. The wire mesh consist of galvanised wire protected against corrosion the diameter of the wire being 0.5 to 1.5 mm. Meshes with hexagonal openings are sometimes referred to as Chicken wire mesh. The hexagonal wire mesh is cheaper but structurally less efficient than the mesh with square openings because the wires are not oriented in principal stress directions. Meshes with square openings are available either in the form of welded wire mesh or in oven form.

7.1 MATERIALS USED IN FERROCEMENT CONSTRUCTION

7.1.1 Frame rods

7.1.2 Rod reinforcement

7.1.3 Mesh reinforcement

7.1.4 Staples and lacing wire

7.1.5 Welding rods

7.1.6 Cement

7.1.7 Sand

7.1.8 Admixtures

7.1.9 Jointing compounds

7.1.10 Water

7.1.1 Frame rods

The ideal rod to use is a cold worked high yield (CWHY) rod to British Standard (B.S) 4461 although both plain bars and deformed bars may be used. The latter maybe more difficult to use when welded by inexperienced people. The requirement of steel grade and minimum

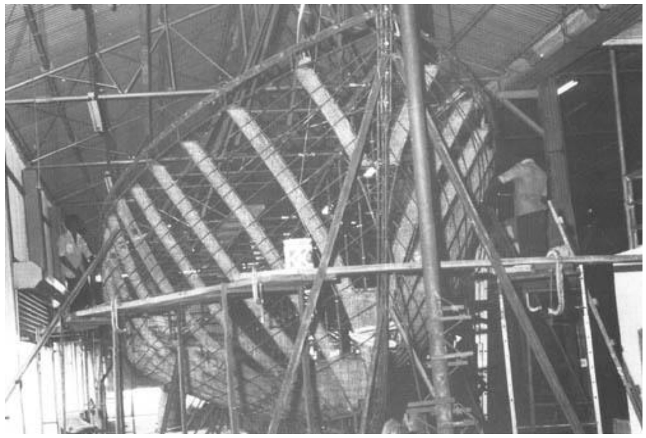

Fig no.7-Frame rods provided for construction of boat

yield point will depend on the construction method employed, but will have sufficient tensile and yield strength and ductility and other properties essential for good construction. All reinforcement should be free from contamination, grease and mill scale. While not objected to, light corrosion should be wire brushed to remove the rust.

7.1.2 Rod reinforcement

For use in the hull shell, deck floors, bulkheads and stiffening webs or girders; ideally should be a semi-bright hard-drawn (SBHD) rod of 6 and 8 mm diameter for concrete reinforcement to BS 4482. Mild steel rod to BS 15 may also be used but in practice will require closer frame spacing or support to prevent being bentout of shape during construction and/or distortion by welding.

7.1.3 Mesh reinforcement

The ideal mesh is a 13 x 13 mm x 19 gauges (1 mm) welded mesh to BS 4482. Although meshes of 18-22gauge can be used, 19 gauge will prove to be the best from a practical point of view. In colder, less humid climates, it may be used ungalvanised; in semi-tropical/tropical it will need to be galvanised. A specification for welded mesh: Initially rod used in the manufacture of welded wire mesh is a low carbon content (0.15% max by weight) rimming steel with the carbon concentrated in the centre. The rod used in the manufacture of the wire mesh is hard-drawn from 'X'size down to 19 gauges (1 mm), hot rolled (perhaps copper washed) passed through separate soap and then welded. It is then passed through the galvanising process. (The rod has a very low silicon value.)

A cautionary note with reference to using galvanised materials in the construction before casting is applicable at this stage. The reason for care is that it may be possible to build in a fault into the hull through the interaction of the zinc on the mesh and the remaining steel, in the moisture of the setting mortar, causing hydrogen bubbles between the mortar and the steel, and reducing bond between the mortar and steel. Galvanised mesh which has been exposed to weather for some time prior to use may have less effect on the structure as a precaution, by adding 300 parts per million by weight added to the casting water, of chromium trioxide (chromic oxide) the problem can be neglected.

Chromium trioxide must be handled with caution as it ishighly toxic to the skin and especially to the eyes. The crystals must be kept from moisture until they areactually added to the mixing water (approximately 66 gto 200 litres.)Other mesh types which may be used are hexagonal mesh and, to a lesser extent, woven square mesh. Classification societies may need evidence of how the alternate meshes are used, in what direction they lay, and the combination of meshes that can or may be used. Using expanded mesh in certain forms of construction may also be acceptable but is rarely employed other than in a construction using moulds.

Types of wire mesh are:

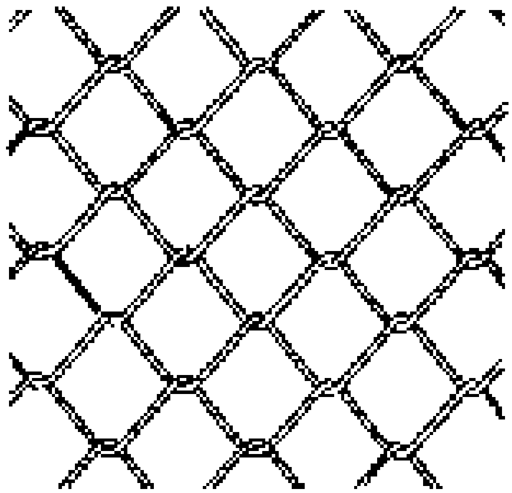

Fig. No. 8- Hexagonal wire mesh

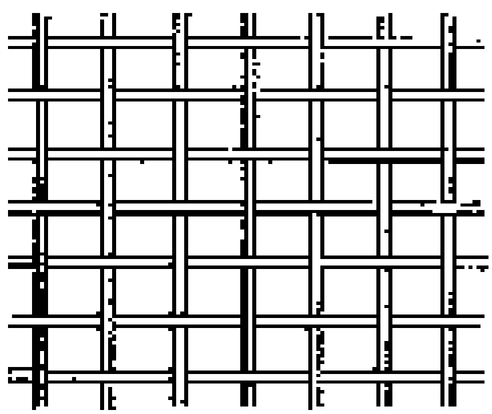

Fig. No. 9- Welded wire mesh

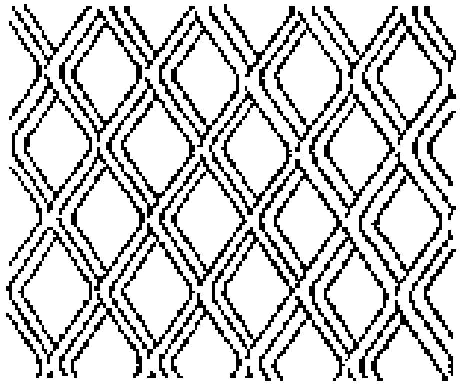

Fig. No 10-. Expanded metal mesh

7.1.4 Staples and lacing wire

Staples and lacing wire are best made from 1.6 mm or16 gauge plain degreased annealed mild steel lacing wire. This can be purchased in 25 kg reels and cut on suitable jig to provide either 30 mm or 40 mm length staples to suit single and double rod construction, with the legs of the staples set at a width to suit the size of mesh being used.

Fig. No 11- Staples and lacing wire

7.1.5 Welding rods

The normal gauge of welding rod required will be 10swg or 3.25 mm, although small quantities of other gauges will also be used. Welding rods are of generalpurpose, all angle type, and should be cared for incompliance with the manufacturer's advice and good practice.

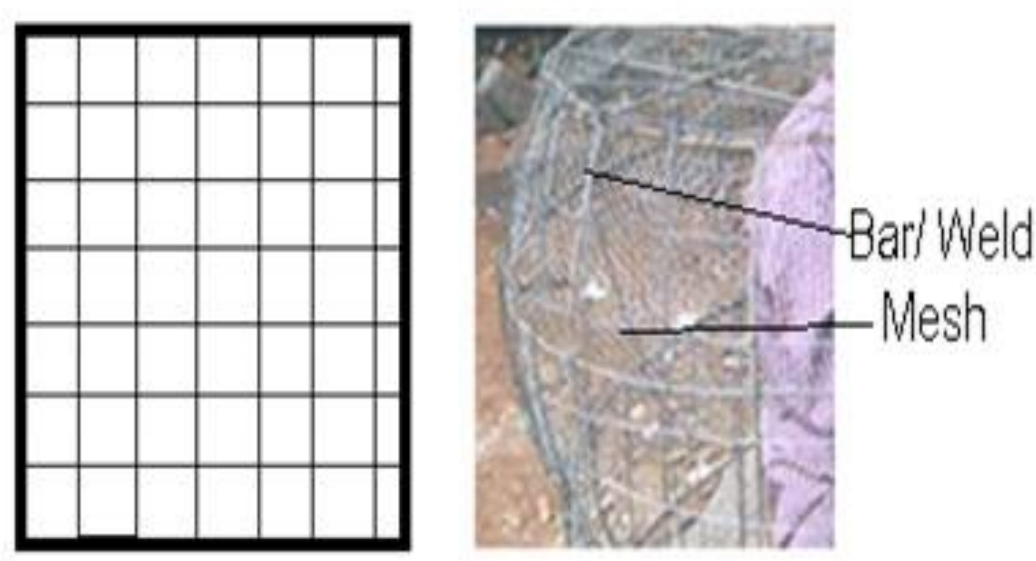

Fig. No.12-Welding rods

7.1.6 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, although as most vessels are protected by marine paints and antifouling, its use is hardly necessary. If the cement is used with admixtures, care should be exercised incompatibility.

Fig. No. 13- OPC cement

All cements are to be to BS 12 or equivalent local standard. In some underdeveloped countries it may be necessary to obtain a certificate of the materials composition and date of manufacture, where there is the likelihood of low quality and, perhaps, adulteration between point of manufacture and delivery. This may mean that the cement has to be picked up by the yard's transport and a reliable person checks there is no problem in delivery. Ideally the cement will be no more than three weeks old and delivery accomplished two to three days before use. Other cements may be considered providing they offer adequate strength, density, and uniform consistency.

7.1.7 Sand

The importance of good, clean, well graded sand, cannot be over emphasized if one is to make the high-grade impervious mortar required for boat building. The sand will be of a siliceous nature. The sand is notto contain sulphates, pyrites, or other chemically active

Fig. No.14- Sand free from crystalline materials.

Substances in such amounts that the mix is harmed. If sea sand is used, it is to be washed free of any saline compositions. (It is always preferable to use non-saline river sand.) The sand should not contain loose clay or clay which adheres or covers the sand grains. The sand is not to contain humic acid or organic materials in quantities that may be detrimental. Preferably, the sand should be 'sharp' and not contain non-crystalline minerals. The sand should be stored in as dry a place as possible and so that water content is evenly balanced. The sand should be protected against pollution.

7.1.8 Admixtures

There is such a wide range of admixtures available today that one cannot make recommendation without first testing those chosen. If they are to be employed, care and discretion should be exercised at all times. Selected grade of pore sealing compound and plasticizer may be added to the mortar to be used for construction of ferrocement structures

- Three main criteria should be considered when applying admixtures:

a) Is the strength of the mortar increased or decreased?

b) The effect of the admixture on the steel reinforcement.

c) Practicality of use on site and supervision of exact mixing quantities.

7.1.9 Jointing compounds

With the advent of new methods for joining concrete, far more jointing compounds are available for making ‘wet' joints in cement structures. It is always best to carry out tests on

Fig. No. 15- Joining Compound (Epoxy Polysulphide Resin)

The potential system before use. For joints in hull construction and repair, a two component epoxy polysulphide resin gives an excellent bond. If this is not obtainable, a cement grout applied judiciously will give better results than some PVA glues that are commonly available to the building construction industry.

7.1.10 Water

Material	Flexural strength N per sq mm	Modulus of elasticity N per sq mm X 10^5	Density in kg per cubic meter
Timber	8.0 to 8.5	0.06 to 0.12	500 to 10000

Mixing water should comply with the requirements of BS 3148. Water should be potable, clean, and free from harmful salts or foreign materials which may impair the strength and resistance of the mortar.BS 3148 gives details of testing water for concrete by comparing the properties of concrete made with any particular sample of water with those of an other wise similar concrete made with distilled water; therefore the tests will usually be performed in a laboratory.

Table: Flexural Properties of Materials:

Table no. 4- Flexural properties of material

Ferrocrete	**10.0 to 25.0**	**0.30 to 0.50**	**2500**
Reinforced concrete	2.7	0.22	2300 to 2400
Steel	150	2.0	7850

Table: Comparison of First Class Brick Wall with Ferrocrete Cavity Wall.(Per 10 Sq. meter of Walling)

Item	Brickwork with plaster on both sides	Ferrocrete cavity wall with plaster on both sides
Cement	6,64 bags	6.34 bags
Sand	1028 liters	444 liters
Mason	4	3
Labour	7	4
Bricks	1250	---
Steelbars Weld mesh Chicken mesh	---	23.4 kg 20 sq m 40 sq m

Table no. 5-Ccomparison of first class brick wall with ferrocement cavity wall (per 10 sq. meter of walling)

Table: Weights and Lengths of Steel Bars

Bar dia. Mm	Area mm^2	Weights kg/m.	Length of bar in m per 100 kg.	No. of 10 m bars per 100 kg.
4	12.56	0.099	1010	101.0
5	19.64	0.154	649	64.9
6	28.27	0.220	454	45.4
8	50.26	0.390	256	25.6
10	78.54	0.620	160	16.0

12	113.10	0.887	112	11.2

Table no. 6- Weights and lengths of steel bars

Table: Quick Guide for Mortar Mix by Weight for Various Types Of Sand

Mix by weight	**Sand in kg**	**Sand in litres per bag of cement**		
		Dry	River	Wet
		Density kg /m^3		
		1600	1800	2000
1:1.0	50	31.25	27.77	25.00
1:1.5	75	46.87	41.67	37.50
1:2.0	100	62.50	55.55	50.00

1:2.5	125	78.12	69.44	62.50
1:3.0	150	94.00	83.33	75.00
1:4.0	200	125.00	111.00	100.00

Table no.7- **Quick Guide For Mortar Mix By Weight For Various Types of sand**

Table: Surface area and volume of steel wires per meter run

Bars Dia.mm	**Dia. mm**	**Perimeter mm**	**Surface area Mm^2/m run**	**Cross-sect Area Mm^2**	**Volume per m run Mm^3**
10	10	31.415	31415	78.54	78540
8	8	25.132	25132	50.266	50266
6	6	18.849	18849	28.274	28274
4	4	12.566	12566	12.566	12566
Wire Gauge					

10	3.175	9.97	9970	7.920	7920
12	2.157	7.90	7900	4.960	4960
14	1.994	6.26	62601	3.120	3120
16	1.588	4.98	4980	1.980	1980
18	1.257	3.95	3950	1.240	1240
20	0.996	3.13	3130	0.779	779
22	0.794	2.49	2490	0.495	495
24	0.629	1.97	1970	0.310	310
26	0.498	1.56	1560	0.195	195

Table no.8- Surface area and volume of steel wires per meter run

Table: Specific Surface Of-Meshes Sr (Total) In Mm2/ M3 X 10-3

Wire gauge	**Specific surfaces for meshes of opening size (mm x mm)**							
	opening sizes of mesh mmxmm	13x13	19x19	25x25	50x50	75x75	100x100	150x150

	length of wires long + trans	156	108	82	42	28.66	22	15
	surfaces of wires area mm^2/m length							
10	9970	155.53	107.67	81.75	41.87	28.57	21.73	14.75
12	7900	123.24	85.32	64.32	33.18	22.64	17.38	11.85
14	6260	97.65	67.61	51.33	26.27	17.94	13.77	9.39
16	4980	77.69	53.78	40.83	20.91	14.27	10.95	7.47
18	3950	61.62	42.67	32.39	16.59	11.32	8.69	5.92
20	3130	48.83	33.80	25.67	13.14	8.97	6.88	4.69
22	2490	38.84	26.87	20.42	10.46	7.13	5.48	3.73
24	1970	30.73	21.27	16.15	8.27	5.64	4.33	2.95
26	1560	24.33	16.85	12.77	6.55	4.47	3.43	2.34

Table no. 9- Specific surface of meshes sr (total) in sq.mm./

Wire mesh used	
Wire diameter	0.5 to 1.5 mm
Types of meshes	Chicken meshes , square mesh , expanded metal
Size of mesh openings	6-25 mm
Numbers of mesh layers	Up to 5 layers per cm thickness
Volume friction of reinforcement	Up to 8 % in both directions
Specific surface of reinforcement	Up to 4 sq.cm per cubic cm in both directions
Intermediate skeletal steel	
Type	Wire fabric weld mesh rods and strands
Diameter	3 to 10 mm
Grid size	50 to 150 mm
Typical mortar compositions	Any type depending on applications
Cement sand ratio	1 to 2.5 by weight, 1.5 to 4 by volume
Water cement ratio	0.4 to 0.6 by weight
Grading of fine aggregates	Passing 2.36 mm with fineness modules 2.4 to 2.5

Composite properties	
Thickness	6 to 50 mm
Steel cover	1.5 to 5.0 mm
Ultimate tensile strength	Up to 34.5 MPa
Allowable tensile stress	Up to 10.3 MPa
Modulus of rupture	Up to 55 MPa
Compressive stress	27.6 to 68.9 MPa

Table no. 10-: Salient features of ferrocement

Table: Weight Of Skeletal Bars Per M^2 Of Panel For Various Spacing Of Bars (Calculation Based On A Panel Size Of 3.0 X 3.0 M)

Spacing of bars size (mm X mm)	**weight in kg per m^2 of panel for bar diameter**					
	4 mm	5 mm	6 mm	8 mm	10 mm	12 mm
75 X 75	0.90	1.40	2.00	3.55	5.65	8.08
100X100	0.68	1.06	1.52	2.69	4.27	6.11
150X150	0.46	0.72	1.03	1.82	2.89	4.14
200X200	0.35	0.55	0.78	1.39	2.21	3.16

300X300	0.24	0.38	0.54	0.95	1.51	2.16
50X0500	0.15	0.24	0.34	0.61	0.97	1.38

Table no.11- Weight of Skeletal Bars Per M^2 Of Panel For Various Spacing of Bars (Calculation Based On A Panel Size Of 3.0 X 3.0 M)

Table: Grading Of Sand

Sieve size ASTM	Particles size	Grading limit % passing
4	4.75 mm	95 to100
8	2.36 mm	80 to 100
16	1.18 mm	50 to 85
30	600 microns	25 to 60
50	300 microns	10 to 30
100	150 microns	2 to 10

Table no. 12- Grading of sand

Table: Cement Mortar Mix By Volume

Mix by volume	Cement liters	Dry sand liters
1:10	666	666

1:1.5	533	800
1:2.0	444	888
1:2.5	380	952
1:3.0	333	1000
1:4.0	267	1066

Table no. 13- Cement mortar mix by volume

IS 383-1970 for coarse aggregate from natural sources should be referred to for specification of natural resources

METHOD OF CONSTRUCTION

8.1CRUSHED SAND OR MANUFACTURED SAND:

Crushed sand is good substitute for natural sands. It is manufactured from quarried rock, by bringing down its particle size in the range of 4.75 to 150 microns. Crushed sands have two important features; one is its gradation and second and the second is its particle size. crushed sands are successfully used for various grades of concrete from M15 to M40.

Compared to natural sands, the crushed sands have the following special features

a) Fines passing 75 micron sieve are restricted. The deleterious material like clays, silts, inorganic and organic salts contained in natural sands affect the strength and durability of concrete. They are also cause cracking and discolouring to the finished plaster surface. They are eliminated in crushed sand.

b) The basic composition of particle sizes of natural sands hardly confirms with the gradation desired in the mix design. In crushed sands, sands of different particle sizes are available which can be blended to the desired gradation curve.

c) The spherical shape of particle sizes of natural sand offers less surface area for the cement to cover, as compared to the cubical shape of the crushed sand. Hence cement consumption is more in crushed sand.

d) Natural sand needs sieving. Sand available in market contains 15 to 25 % oversize particles which are of no use at site.

e) To remove clay, silt and deleterious matter natural sand needs washing.

f) The fines in crushed sand, passing 75 microns, are within limit of 20% as specified in IS-383-1970.This fraction results in efficient aggregate packing and denser concrete mix.

This increases efficiency in void filling in ultra-fine of cement paste,closes the capillaries and decreases permeability of concrete.

8.2 WATER:

The mixing water should be fresh, clean and potable. It should be free from organic matter, silt, oil, sugar, chlorides and acidic materials. Water should pH more than or equal to 7.0 salt water is not acceptable but chlorinated water will do.

8.3 ADMIXTURES

Chemical Admixtures In Ferrocrete Serve Four Purpose:

a) Water reduction which increases the strength and reduces the permeability. It can be achieved by using superplasticisers.

b) Waterproofing compounds may be used to get watertight structures.

c) Air entraining agents increases the resistance to freezing and thawing.

d) Suppression of galvanic action between galvanized steel and cement is achieved by using chromium trioxide approximately 300 parts per million, in mixing water.

8.3 PROPORTIONING OF CEMENT MORTAR:

Normally rich cement mortar of mix proportions of (1:1.5) to (1:4) by volume, are used in Ferrocrete. When sand contents increased, its water requirement goes up to maintain the same workability. To obtain strong, dense and mortar of such a consistency, which can easily penetrate the layers of meshes, trial mixes should be taken.

Fineness modulus of sand, water cement ratio and the sand cement ratio for the mix should be determined and used. Due to discussion of wires throughout the body of Ferrocrete, problem of shrinkage is not there. Depending upon the method of application of mortar; its plasticity plays an important role. Normally the slump of cement mortars should not exceed 50 mm to provide stiff mortar mix, which can penetrate meshes. For most applications, the 28 days compressive strength of moist cured cement mortars should be less than 35 Mpa.

8.4 PRACTICAL HINTS FOR PROPORTIONING AND MIXING OF CEMENT MORTARS:

a) A simple field test to find out stiff consistency of mortar is to form a ball of the mortar in hand, and when tossed up it should retain its shape.

b) Another practical testis, when the trowel is inserted in the heap of the mix, it should stand erect. It is called Khada Phavada test by the mason in India.

c) To check silt content in sand, mix it with water, put it in the glass, shake it and allow it to settle. The thickness of the layer of the silt collected over sand will show percentage silt content in sand approximately.

d) Another simple test to check silt content, is to rub the wet sand on the palms of hand, the hands will get spoiled if the silt content is high.

e) To correlate the mix proportions by volume , note that one bag of cement weights 50 Kg and has volume 35 liters with bulk density of 1.40 densities of dry , river and wet sands are approximately 1600,1800 and 2000 kg per cubic meter.

f) One medium sizes ghamela when filled in to its brim, with level surface, contains about 6 to 8 liters of sand.

g) A good homogeneous cement mortar mix has uniform gray cement-colour and smooth texture. All sand particles are fully covered with cement paste.

A Quick Guide for Various Mortar Mixes by Volume Measure And By Weight Is Given In Tables below:

Table: Cement Mortar Mix by Volume (Dry Mix Of Mortar = 1.33 X Wet Mortar Mix) (Quantities Per Meter^2 Of Wet Mortar)

Mix by volume	Cement liters	Dry sand liters
1:1.0	666	666
1:1.5	533	800
1:2.0	444	888
1:2.5	380	952
1:3.0	333	1000
1:4.0	267	1066

Table no14- Cement mortar mix by volume

Table: Quick Guide for Mortar Mix by Weight for Various Types of Sand

Mix by weight	Sand in kg	Sand in liters per bag of cement		
		Dry	River	Wet
		Density kg /m^3		
		1600	1800	2000

1:1.0	50	31.25	27.77	25.00
1:1.5	75	46.87	41.67	37.50
1:2.0	100	62.50	55.55	50.00
1:2.5	125	78.12	69.44	62.50
1:3.0	150	94.00	83.33	75.00
1:4.0	200	125.00	111.00	100.00

Table no. 15- Mortar mix by weight

8.5 JOB REQUIREMENT OF SKILLED WORKERS:

Skilled workers required for fabricating the skeleton, fitter to tie mesh and mason for mortaring.

8.5.1 Welder

For welding skeletons, a welder with knowledge of spot welding and line welding is sufficient. No special high-tech welding is involved and hence any ordinary welder will serve the purpose.

8.5.2 Fitter

For tying the mesh, any fitter, with a training of few hours, can undertake the job.

8.5.3 Mason

For mortaring, the mason needs training in press filling mortar in the mesh layers .generally the masons are trained to plaster the walls by splashing mortar on them. It should be emphatically stressed, that mortaring of Ferrocrete is not plastering, but it is impregnating the meshes with mortar. Any mason can pick up this skill within no time.

8.5.4 Tools, Plants and Machinery

The Equipment Required Fabricating and Cast Ferrocrete Structures is Given Below:

Generally fabrication, welding and tying of Ferrocrete cage is undertaken in factories. the work left at site is only mortaring, finishing and curing. For precasting of Ferrocrete products the plants and machinery required are given in separate chapter.

8.5.5 For Fabrication and Welding Of Bar Skeleton

For cutting, straitening and bending of bars tools of a cutter are adequate. For small jobs a shearing chisel and a heavy hammer will serve the purpose but for large scale works, shear cutting machine should be preferred. A single phase welding transformer will suffice the need of spot and line welding of bar skeleton. All the welder's tools with safety measures will be required.

8.5.6 for Tying Mesh on Bar Skeleton

For cutting meshes, weld meshes cutters and chicken mesh cutters are used. For binding the mesh to bars, pliers and hooks are required . For stretching and tightening the mesh, mesh pullers in form of screw drivers are preferred. Stretching and tying mesh tightly is very monotonous, tedious and time consuming job. It needs meticulous workers to finish it properly.

8.5.7 for Mixing the Mortar

On small jobs, hand mixing is done, and all the tools of mason are used for it. For major jobs, a mortar mixer is preferred. A mortar mixer with spiral blades or paddles inside stationary drum or a pan type of mixer can be used. A rotating drum mixer with fins fixed to the sides is not recommended. Mortars should be mixed in batches, in such a way that the mortar mixed in a batch should be used within an hour of its mixing. Retempering of the mortar should be prohibited.

8.5.8 for Mortaring the Structures

As stressed earlier, mortaring does not mean plastering the meshes. The mortar is to be pressed inside the meshes. in hand working, plate trowels are used in addition to all the tools required by a mason. A vibro-press developed by the author assures full penetration of the mortar in the mesh layers and results in dense mortar filling. For large works guniting may be adhered to, with complete guniting system. A small size brush coater may be developed and tried as an alternative. For curing of Ferrocrete structures, continuous moist curing is essential. Being thin walled structures, ferrocrete gets dried early and hence an extra precaution is required in curing it. For precast products curing by sprinklers or by immersion in water is adhered too.

8.5.9 For Handling Ferrocrete Item

For handling, hoisting and erection of small size particles like water tanks, a chain pulley block with a hoisting pole are used. A small capacity crane may be used to handle precast product.

8.6 METHODSOF CONSTRUCTION:

As the section is thin (10mm to 50mm thick) high level quality control is required at every step. During fabrication, the main section of structure may be of steel bars which are welded together. On this skeleton are tied several layers of welded /woven meshes. The skeleton should be strong enough to support the meshes in correct geometric position and take the load of mortar and force applied during the process of filling in. Irrespective of the method used the object is to fill the mortar into the mesh without leaving any voids. Mortar filling may be done either manually or by guniting. Vibrators may also be used for compaction. For associated units in-situ method of construction is suitable – e.g. retaining wall, swimming pools, costal lining, etc. For mass production of standard units precasting will be useful. Most of the construction in ferrocement does not need formwork, but temporary propping may be require while the mortar gains enough strength to load of structure. Curing should be done for about 7 to 15 days for complete chemical reaction between cement and water.

8.6.1 Armature System

In this method the skeleton steel is welded to the desired shape on either side of which are tied several layers of stretched meshes. This is strong enough, so that mortar can be filled in by pressing for one side and temporarily supporting from the other side. Filling in of mortar can also be administered by pressing in the mortar from both sides. In this method the skeleton steel (bars) are at the centre of the section and as such they add to the dead weight of without any contribution to strength.

8.6.2 Closed mould system

Several layers of meshes are tied together against the surface of the mould which holis them in position while mortar is being filled in. The mould may be removed after curing or may remain in position as a permanent part of the finished structure. If the mould is to be removed for reuse, releasing agent must be used.

8.6.3 Integrated Mould System

Using minimum reinforcement any integral mould is first constructed to act as a frame work .On these mould layers of meshes are fixed on either side and plastering is done onto them from both Sides. As the name suggests, the mould remains permanently as an integral part of the finished structure (E.g. double-T section for flooring, roofing etc.) Precautions should be taken to have firm connection between the mould and the layers filled in later, so that the finished product as a whole integral structural unit.

8.7 SOME PRECAUTIONS TO BE TAKEN DURING CONSTRUCTION:

1) All reinforcement should be free of dirt, grease, rust, etc.

2) Take cement, sand and water by weight

3) Avoid use of moist sand, if volumes basis is used. This sand may have a bulking up to 15 to 20%

4) Quantity of mortar required is generally small. Hence smaller batching should be used in place of usual 50kg.Bag basis.

5) Use freshly mixed mortar within about 1 hour to avoid setting of morter.in any case keeps the mortar moving on mixing platform.

COST ANALYSIS

9.1 COST ANALYSIS:

The model house was constructed at premises of institution of engineers, Nagpur centre under the instructions of the government of Maharashtra in October 1995. The problem placed before me was of constructing 5000 houses per year, for economically weaker sections of society. If the low cost houses are constructed with conventional method then along with low cost the quality of construction also goes down to unacceptable levels. I had therefore, with the help of Indian concrete institute, Nagpur centre& the institution of engineers, Nagpur centre developed a precast ferro-cement house, which was built in 1995 and still stands the test of time in spite of very rough use. The complete program of pre casting all the components and then erection was done within a period of 21 days. The erection was done manually as no cranes like hydras were available in those days. In view of manual handling it was seen that the weight of each precast component was specifically kept below 150 kgs.

9.2 MAIN USE:

When we discuss low cost housing the main issue is the low cost. The second main issue is the technology to be used, which is ferrocement in this case.

9.3 LOW COST HOUSING CONCEPT:

Low cost Housing is concept which deals with the effective budgeting and following of techniques which help in reducing the cost of construction through the use of locally available materials along with improved skills and technology without sacrificing the strength, performance and life of structure. There is huge misconception that low cost housing means only sub-standard works and they are constructed using cheap & low quality building materials. The fact is that low cost housing is done by planned management of resources. Economy is also achieved by postponing finishing works or implementing them in phases.

9.4 LOW COST + HOUSING:

The low cost is a relative term. It only means that the cost of 'B' is lower than 'A'. But when you use it in term of housing in India, it means the lowest possible cost of permanent house.

- Low cost housing is always releted with the economically weaker sections of society OR the lowest strata of the society.
- Hence, whenever you plan a low cost house, it should mean that the structure should have a life of about 25 years.
- It should not be a temporary structure, that cannot withstand even the commonest vagary of weather like heavy rains, heavy winds. If the structure cannot withstand the common weather hazard then the cyclones and seismic stresses will simply destroy the structure.

9.5 LOW COST HOUSING – COST FACTOR

- The building construction cost can be divided into four parts namely ;
- Building material cost : 45 to 50 %
- Labour cost : 25 to 30 %
- Contractors profit is 20 %
- Taxes are 5 %
- Now in low cost housing, building material cost is less because we try to make use of the locally available materials and also the labour cost can be reduced by properly making the time schedule of our work. Cost reduction is achieved by selection of more efficient material or by an improved design.

9.6 COST FACTOR ACTIVITY GROUP WISE:

- Earth work
- Concrete work
- Reinforced concrete work
- Reinforcement work
- Masonry OR walling work
- Doors & windows work
- Steel fabrication work
- Flooring work
- Roofing work
- Plastering work
- Painting work
- Sanitary & plumbing work
- Waterproofing work

9.7 AREAS OF REDUCTION IN COST :

- Reduces plinth area by using thinner wall cocept.Ex.150 mm thick solid concrete block wall.
- Use locally available material in an innovative form like soil cement blocks in place of burnt brick.
- Use energy efficient materials which consume less energy like concrete block in place of burnt brick.
- Preplan every component of house and rationalize the design procedure for reducing the size of the component in the building.
- By planning each and every component of a house the wastage of materials due to demolition of the unplanned component of the houses can be avoided.
- Each component of the house shall be checked from utility point.

➢

➢ **Use of eco-friendly thinner material & reduces the dead weight of the building in following areas:**

- **Plinth**

  It is suggested to adopt 1ft. height above ground level for the plinth.
- **Walling**

  Wall thickness. Of 6 to 9’’ is recommended for adoption in construction of walls all-round the building and 3 to 41/2’’ for inside walls.
- **Rat-trap bond wall**

  It is a cavity wall construction with added advantages of thermal comfort and reduction in the quantity of bricks.
- **Concrete block walling**

In view of high energy consumptions of burnt brick it is suggested to use concrete block (block hollow and solid) which consumes about only 1/3 of the energy of the burnt bricks in its productions.

- **Doors and windows –**

  It is suggested not to use wood for doors and windows and in its place concrete or steel sections frames shall be used for achieving saving in cost up to 30 to 40 %. Similarly for shutters commercially available block boards, fiber or wooden practical boards etc. shall be used for reducing the cost by about 25 %.

9.8ADDITIONAL COST REDUCTION AREAS:

9.8.1 Lintels and chajjas

The traditional R.C.C. lintels which are costly can be replaced by brick arches for small spans and save constructions cost up to 30 to 40 % over the traditional method of construction. By adopting arches of different shapes a good architectural pleasing appearance can be given to the external wall surfaces of the brick masonry.

9.8.2 Roofing

Normally 4.5’’ (115mm) thick R.C.C slabs are used for roofing of residential building. By adopting rationally designed in-situ construction practices like filler slab and precast elements the construction cost of roofing can be reduced by about 20 to 25 %.

9.8.3 Filler slabs

They are normal RCC slabs where bottom half (tension) concrete proportions are replaced by filler materials such as bricks, tiles, cellular concrete blocks.etc. These filler materials are so placed as not to compromise structural strength in replacing unwanted and nonfunctional tension concrete, thus resulting in economy. These are safe, sound and provide aesthetically pleasing pattern ceiling and also need no plaster.

9.8.4 Jack arch/floor

They are easy to construct, save on cement and steel, are more appropriate in hot climates. These can be constructed using compressed earth blocks also as alternative to bricks for further economy.

APPLICATIONS

10.1: HOUSING APPLICATIONS

Ferrocement has found widespread applications in housing particularly in roofs, floors slabs and walls. Ferrocement is considered as sustainable housing technology for developing countries attested by the increasing number of easily built and comfortable ferrocement houses. Ferrocement houses utilizing local materials such as wood, bamboo or bush sticks as equivalent steel replacement have been constructed in Bangladesh, Indonesia and Papua New Guinea. Precast ferrocement elements have been used in India, the Philippines, Malaysia, Brazil, Papua New Guinea, Venezuela and pacific for roofs, wall panels and fences. In Sri Lanka, a ferrocement house resistant to cyclones have been developed and constructed. A pyramid dome over a temple in India and numerous spherical domes for mosques in Indonesia have been constructed with ferrocement. The choice was dictated by low self weight, avoidance of formwork and availability of unskilled labour. Figure shows one of the examples of the house built using ferrocement structures.

Fig. No.16- A typical ferrocement house

10.2: MARINE APPLICATIONS:

Ferrocement has been adapted to traditional boat designs in Bangladesh, China, India, Indonesia and Thailand due to timber storages. In china, 600 ferrocement boat-manufacturing units produce annual capacity of 600,000 to 700,000 tonnages. Ferrocement boats are divided into four categories according to usage: farming boats, fishing boats transport boats and working boats. In countries like Hong Kong, India, Malaysia, Philippines, Sri Lanka and Thailand. Ferrocement boats generally conform to western standards. In Hong Kong, India and Sri Lanka, most of the ferrocement crafts constructed are used as mechanized fishing trawlers while in Korea, as fishing boats. In addition the south east fisheries development centre, Philippines, has used ferrocement for these purposes. In Africa, ferrocement boat yards have been successfully established in Kenya, Sudan and Malawi. The boatyards are now self-supporting under the management of local staff trained by the consultants. The objectives of these boatyards are to provide rural fisherman opportunities to explore the fishable grounds to increase their income. Figure shows the Ferrocement boat.

Fig. no.17- A typical ferrocement boat

10.3 AGRICULTURAL APPLICATIONS:

Agriculture provides the necessary resource for economic growth in developing countries. The use of ferrocement technology can contribute towards solving some of the production and storage bins in Thailand, India and Bangladesh to reduce losses from attack by birds, insects, rodents and moulds. Thailo, a conical ferrocement bin; was designed and first constructed at the Asian Institute of Technology (AIT), Bangkok, Thailand. Storage capacities range from 1to10 tons. These bins have proved to be structurally sound and construction has provided adequate protection to the produce against rodents, insects and bird attacks. The bin costs well within the means of farmers. Besides, this type of silo also can hold up to 5000 gallons (22.7m^3) of drinking water. In Ethiopia, underground pits are the traditional method of gain storage. It has been found that when the traditional pits is lined with ferrocement and provided with an improved airtight lid, a hermetic and waterproof storage chamber can be achieved.

10.4 WATER AND SANOTATION APPLICATIONS:

Ferrocement can be effectively used for various water supply structures like well casings for shallow well, water tank, sedimentation tank, slow sand filters and for sanitation facilities like septic tank, service modules and sanitary bowls. Some findings indicated that ferrocement tanks are less expensive than steel or fiberglass tanks. The reasons why ferrocement is cheaper are:

- Ferrocement is an feasible material for the construction of water storage
- Flexibility of shape, freedom from, corrosion, possibility of hot storage, relative lack of maintenance, and ductile mode of failure are important advantages of ferrocement over other materials
- Ferrocement tanks require less energy to produce than steel tanks.

Ferrocement water tanks of 20 to 2000 gallons (0.09 to 9m^3) capacity are mass-producing in India. Bamboo-cement well casings have been built in Indonesia to prevent contamination of the water.

10.5 MISCELLANEOUS APPLICATIONS:

Ferrocement is proving to be a technology that can respond to the diverse economic, social and cultural need of human being. Ferrocement has been used to strengthen older structures, a medium for sculpture and many other types of structures. Ferrocement as a medium for sculpture proves its versatility and the unlimited dimension to which it can be used. Ferrocement in art is an exciting development and it opens a new horizons. Figure below shows a typical sculpture made from ferrocement. Some of the sculptures are described in figures shown below:

Fig. no.18- Sunshade and irrigation canal lining

Fig no.19- Canoe

Fig no.20- Chairs and tables **Fig no.21- Mushrooms for decorative purpose**

ADVANTAGES AND DISADVANTAGES

11.1 ADVANTAGES:

(1) The advantages of a well built ferro-cement construction are low weight, maintenance costs and long lifetime in comparison with steel constructions. However, meticulous building precision is considered crucial here. Especially with respect to the cement composition and the way in which it is applied in and on the framework.

(2) When a Ferro-cement sheet is mechanically overloaded, it will tend to fold instead of crack or rupture. The wire framework will hold the pieces together, which in some applications (boat hull, ceiling, and roof) is an

advantage. A Ferro-cement construction has 10 to 25% of the weight of a comparable construction made of bricks.

(3) In Ferro-cement while mortar provides the mass, the wire mesh imparts tensile strength and ductility to the material. In terms of structural behavior it exhibits very high tensile strength-to-weight ratio and superior crack resistant performance.

(4) The distribution of small diameter wires over the entire surfaces provides very high resistance against cracking. Moreover many other engineering properties, such as toughness, fatigue resistance, impermeability are considerably improved.

(5) Ferrocement can be shaped in any form.

(6) It can be formed into sections less than 25 mm (1 inch) thick and assembled over a light framework

(7) The material is very dense, but structures made from it are light in weight.

(8) It is also rot- and vermin-proof, impervious to worms and borers, and watertight.

(9) Ferrocement is more versatile than RCC and can be formed into simple or compound curves. In contrast, RCC construction is cast in sections and needs extensive and very solid formwork to support the weight of the concrete.

11.1.1 More Advantages At A Glance Are Follows:

(1) It is highly versatile and can be formed into almost any shape for a wide range of uses;

(2) Its simple techniques require a minimum of skilled labor;

(3) The materials are relatively inexpensive, and can usually be obtained locally;

(4) Only a few simple hand tools are needed to build uncomplicated structures;

(5) Repairs are usually easy and inexpensive;

(6) No Maintenance is necessary;

(7) Structures are rot-, insect-, and rat-proof, and non-flammable;

(8) Structures are highly waterproof, and give off no odors in a moist environment;

(9) Structures have unobstructed interior room and structures are strong and have good impact resistance.

11.2 DISADVANTAGES:

(1) Structures made of it can be punctured by forceful collision with pointed objects.
(2) In corrosive environments (for example, sea water) it is often observed that after several decades the reinforcing materials become corroded.
(3) Fastening with nails or by welding is not possible.
(4) The large amount of labor required for ferrocement construction is a disadvantage in countries where the cost of unskilled or semi-skilled

labor is high. Tying the rods and mesh together is especially tedious and time consuming.

(5) The main disadvantage of ferrocement for smaller structures and boats is its high density (2400 kg/[m.sup.3], 150 pounds/cubic foot). Density is not a problem, however, for larger structures (for example, large domes, tanks, and boats over 12 m long). Large, internally-unsupported domes and curved roofs have been built that could not have been constructed with other materials without elaborate ribs, trusses, and tie rods.

CONCLUSION

12.1 CONCLUSION:

It was realized that it will save considerable time which is most important aspect in the present day life. Therefore we Engineers, have to be very vigilant to maintain the technologies sustainable by modifying materials, methodology, systems etc. With the advent of new technology, the sustainability may change totally. The form of Technology may change as it has happened in the case of Ferrocement Technology.

The imminent change to save the resources is development of geopolymer concrete which will not require use of cement at all and shall be making profuse use of fly ash, blast furnace slag, copper slag etc. At the same time it will be much superior with many features than the present day concrete. This will also apply to Ferrocement Technology. However there are still areas of applications where ferrocement is not widely eased, such as structural components, like main beam, column etc. this may be due to insufficient understanding on the behavior of ferrocement. Hence more research will still have to be done. This present research will contribute to the enrichment of information and understanding on this subject.