Design and Construction using Ferrocement technology

All over the World ferrocement is defined and designed as a form or type of RCC, which is basically thin layered. Due to it, its use was restricted to non-load bearing members lightly loaded structures, and structures having peculiar shape and size by which strength was achieved and also for architectural features which needed thin walled high strength/weight ratio materials. Ferrocement is homogeneous and ductile while RCC is heterogeneous and brittle. This is the major difference in the properties of the two materials and hence designing ferrocement as RCC or a form of RCC is neither rational nor justified.

Ferrocement is a novel material of construction, with its own unique mechanical properties typical characteristics and behavior. It has got its own unique identity and hence it must not be grouped or treated as a material having properties akin to RCC.

Until 1980 the use of weld meshes and chicken meshes made out of bars and rods having smaller diameter and closer spacing enmeshed in mortar was a well-established practice for reducing cracking and also achieving intricate forms and shapes. Thus its use was restricted to small size non-load bearing members like fins, small size tanks boats, pots containers and intricate items light weight elevation treatment architectural items which were essentially light weight and having low tensile stresses. Designing them as RCC, neglecting tension capacities made no difference as the tensile forces induced in them were also marginal. But when its use as a material for constructing large size structures was explored, limitations of treating ferrocement as RCC were realized.

The ability of this mortar based homogenous composite to take large tensile forces with very low crack widths even at high stresses in steel has made it possible to use the area above and below the NA to counter the tensile forces acting on the section.

This important property is not seen in RCC and which is why Ferrocement behaves in a completely different manner as from RCC and hence needs to be addressed also separately.

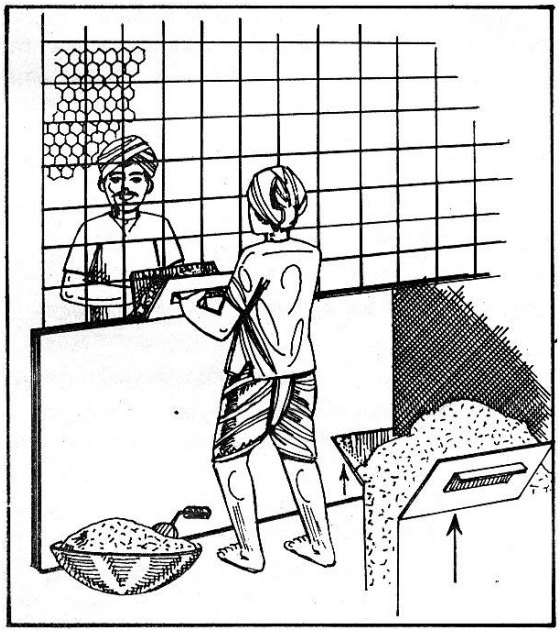
Ferrocement has now come out as a new material for structural applications in construction industry. It is no longer a technology for small lightly loaded architectural or cosmetic applications. Larger heavy duty structures need to take advantage of the tensile capacities of the composite to ensure lighter, yet safer and economical structures having an excellent strength to weight ratio. Ferrocement offers all of this to us.
It is also important to highlight the point that the new NBC code categorizes ferrocement as an

alternative material which can be used subject to providing analytical and field data and test reports. Further it stipulates that if it is to be used permission of the appropriate competent authority has to be taken till such time the code for the same is prepared and put in place.

We should have a realistic approach of treating ferrocement as a real two- phase composite. Its properties like high strengths, crack-control, and energy absorption capacity, strength through shape and design methods based on them will have to be elaborated. Thin walled construction, high strength to weight ratios, formation of hollow columns, beams, walls and floor by using thin walled plate-like elements and various novel methods of construction developed due to it, may be appreciated by users.

What is Ferrocement?

1.0 Introduction: Ferrocement is the composite of Ferro (Iron) and cement (cement mortar). Ferrocement can be considered as a type of thin walled reinforced concrete construction in which small-diameter wire meshes are used uniformly throughout the cross section instead of discretely placed reinforcing bars and in which Portland cement mortar is used instead of concrete. In ferrocement, wire-meshes are filled in with cement mortar. It is a composite formed with closely knit wire mesh tightly wound round skeletal steel and impregnated with rich cement mortar.



With Ferrocement it is possible to fabricate a variety of structural elements, may be used in foundations, walls, floors, roofs, shells etc. They are thin walled, lightweight,

durable and have high degree of impermeability. It combines the properties of thin sections and high strength of steel, in addition it needs no formwork or shuttering for casting.

Ferrocement have applications in all fields of civil construction, including water and soil retaining structures, building components, space structures of large size, bridges, domes, dams, boats, conduits, bunkers, silos, treatment plants for water and sewage.

1. 1 Definition of ferrocement

Ferrocement is defined in different ways by different organizations.

1) According to United Nations High Commissioner for refugees (UNHCR), ferrocement is defined as 'A thin walled construction consisting of rich cement mortar with uniformly distributed and closely spaced layers of continuous and relatively small diameter mesh (metallic or other suitable material).' (reference-UNHCR-Large ferrocement Water tank Manual July 2006)
2) ACI committee-549 describes it- 'Ferrocement is a form of reinforced concrete using closely spaced multiple layers of mesh and/or small diameter rods completely infiltrated with, or encapsulated, in mortar. The most common reinforcement is steel mesh' (reference – ACI 549.1R-93- Guide for the design, construction and repair of ferrocement)
3) Ferrocement can be defined as '*Cement mortar strongly bonded with and encased in layers of fine wire meshes, making it near to homogeneous with increased ductile properties*'**.**

1. 2 Historical background.

Ferrocement has a history of more than 170 years. It remained in background up to 1940. It has boomed as a construction material in the last two to three decades.

The idea of impregnating closely spaced wire meshes with rich cement mortar is similar to the Kood (कूड) type of age-old method of walling in which bamboo and reeds tied closely together are filled in with mud mixed with cow dung as a matrix. It is used in rural areas of India. Hence Ferrocement may be called as a modified form of Kood with standardized raw materials, systematic method of construction and reliable structural properties. Here the mesh is used in place of bamboo and reeds, and cement mortar instead of mud.

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

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

In 1972, National Academy of Science, U.S.A., established an Ad-hoc panel to study the use of ferrocement in developing countries. Its report on 'Ferrocement-Applications 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 effort has been made by many individuals and Institutions all over the world to develop ferrocement as a construction material.

At Asian Institute of Technology, Bangkok, Thailand "International Ferrocement Information Centre" was established and a "Journal of Ferrocement" is regularly published by it.

1. 3 Basic Methodology of forming Ferrocement members

A ferrocement structure is formed by fabricating the mesh reinforcement to the shape and size of the structure first and then mortared and cured. Method of forming a ferrocement element is as follows:

1) Welding skeletal steel framework.

A skeleton of steel bars is welded to the exact geometrical shape and size of the structure. This provides a rigid framework of the exact shape and size with correct line and level.

2) **Tying mesh reinforcement tightly over it to form cage.**

Weld mesh and fine wire chicken mesh is tied over this welded skeleton by stretching and tying technique. 'Tightly tying meshes' is the key point in ferrocement construction.

3) **Impregnating the mesh cage with rich cement mortar, finishing and curing.**

The stiff cement mortar is filled in the mesh layers by pressfill method. In pressfill method, the mortar is to be pressed inside the meshes from both the sides.

All these steps in construction are to be followed in sequence. On large size constructions, one can work simultaneously on all the three operations.

1. 4 Advantages of Ferrocement

Ferrocement has some basic advantages as follows-

1) **Increase in bond strength:**

The transfer of load from steel to concrete and vice versa takes place through bond between the two materials. The bond depends upon the bond-stress of concrete and the area of contact between the steel and concrete. Bond stress of concrete depends upon the grade of concrete. It is hardly 6 Kg per sq cm for M 15 concrete. The bond can be substantially increased if the contact area between steel and mortar is increased. In Ferrocement it is achieved by use of small diameter wires and mortar.

2) **Bond area increase:**

Increase in bond area will result in more adhesion between steel and mortar, making it behave more like a homogeneous material and which has become very strong in tension due to increase in bond.

3) **Dispersion of steel wires:**

Ferrocement is formed by tying together a number of layers of continuous wire meshes. Volume of steel percentage is very large, may be up to 8 percent. Also the mortar cover over the meshes is hardly 3 to 5 mm. Hence throughout the body of the composite, the wire reinforcement is fully dispersed. This leads Ferrocement to become more homogeneous. It results in improving the properties of Ferrocement in tension, flexure, impact resistance and crack resistance.

4) **Crack control:**

Meshes are fully bonded to mortar and spaced very near to the surface of Ferrocement. Such closely spaced fine wires, very near to the surface of Ferrocement, act as crack arrestors.

5) **Equal strength in both directions:**

The continuity and placement of equal mesh reinforcement in both directions make Ferrocement to achieve equal strength in two directions and to become strong in resisting diagonal tensions due to shear.

6) **Containment of mortar matrix in mesh layers:**

In Ferrocement, layers of wire meshes tightly tied together are impregnated with cement mortar. The matrix is held by the meshes in between and is contained by them.

7) **Formless construction:**

Tightly tied meshes in ferrocement can hold wet cement mortar when it is pressfilled in them. The consistency of cement mortar is very thick with very low water cement ratio. It won't come out of the meshes. Thus casting of Ferrocement does not need any formwork or shuttering. The other advantage of this aspect is no honeycombing will occur in pressfilling, as the mortaring is done in front of your eyes.

If the mesh is tied loosely or water cement ratio is not maintained to thick consistency or over-sanding is done, the mortar will flow down and will not be held by the meshes.

8) Strength through shape:

Ferrocrete structures are thin walled and may be hardly 25 to 50 mm in thickness. Hence to take care of slenderness and buckling, Ferrocement is shaped in different forms to achieve its strength.

9) Lightweight, homogeneous and versatile material

Ferrocement structures have high equal strength in both directions. It can be moulded in any shape and size. Ferrocement is homogeneous, easy to work and can be made available in thin sections.

10) High strength to weight ratio:

Being a thin walled structure of high strength, strength to weight ratios in tension and compression of ferrocement are very high. Hence thin sections can take higher loads.

1. 5 Comparison of RCC and Ferrocement

Ferrocement composite has different features than Reinforced cement concrete. Features like thickness of products, matrix used in products, reinforcement, strength, structural behaviour etc. on which they are differentiated, is given in Table No. 1

Table No. 1. Comparison of RCC and Ferrocement

Sr. No.	Features	Reinforced Cement Concrete	Ferrocement
1	Thickness	Minimum 75mm	Thin walled, 25 to 50 mm.
2	Matrix material	Cement concrete	Rich cement mortar
3	Reinforcement	Steel bars > 6mm diameter Spaced distance apart	Continuous fine wire mesh dispersed throughout the body of the structure.
4	Strength	Weak in tension, bond and shear	High tensile strength, superior bond and shear strength.
5	Tensile strength	4-6 Kg/sqcm	80-90 Kg/sqcm
6	Strength to Weight Ratio	15 to 50	45 to 90

7	Casting process	Formwork and shuttering are quite essential. Due to forms honeycombing is likely to occur.	Tightly tied wire-meshes act as supporting mortar casting. Filling is dense and compact, no honeycombing.
8	Composition	Heterogeneous	Nearly Homogeneous
9	Gain of strength	Due to size, shape and reinforcement	Due to shape of the structure
10	Structural Behaviour	Rigid	Non rigid

Ferrocement Society of India:

Ferrocement Society (India) has done a lot of work in Design, Development and Construction of Large Size Structures in all fields of Civil Engineering. It has taken out Ferrocement from the Shackles of Laboratory investigations and developed its direct applications in fields for all types of structures.

The fields covered are-

1) Water and Soil retaining structures,
2) Buildings from foundations to roofs
3) Space structures like domes, pyramids, shells of all types- geometric or organic in shape.
4) Precast Spun pipes and cast-in-situ large size egg-shaped conduit of size 3600mm dia and 700m long
5) Large silos- capacity 750 cubic meters, Digesters- of capacity 420 cubic meters, settling tanks, effluent treatment plants for industries and communities
6) Arch faced dams- for spans of 30m and height water 2.0meters
7) Thermally insulated houses with inbuilt RCC frame-work embedded in Ferrocrete Cavity walls and Hollow floors – Built a Bungalow of 5000 sq ft plinth area
8) Earthquake resisting structures- Box like integrally cast structures with shear walls and stiffened diaphragms with wide-flange columns and beams embedded in cavity walls and hollow floors
9) Parabolic Linings to canals and rejuvenating of old culverts with internal ferrocrete lining.

10) Two storied Building on Black Cotton Soils on floating foundations
11) Retrofitting and rehabilitation of heritage structures
12) Precast walling and floor panels with joints as structural members like columns and beams
13) Precast ferrocrete forms as open boxes for columns, channel section for beams of spans 6 to 8 m, thin ribbed slabs as centering plates used as lost formwork for 30,000 sft of the fourth floor of a college building.
14) 30mm thick ferrocrete slab resting on ribs is provided for 5000 sft roof of a hospital building.
15) Petal tank 60ft dia and 18ft height with shell roof over it to store 1200 cubic meters of water.
16) Soil retaining walls of 6 to 10 m height and lengths varying from 100 to 200 meters
17) Innovative system of constructing structures, replacing conventional system of RCC framework with filler walls in it, is evolved in which saving of material, labour and time is more than 50%. One can earn carbon credits by using it. A number of buildings are built by using this system.

Recent developments:

1) Subject of "Ferrocrete Technology" is introduced in University of Pune (India) at Graduate and Postgraduate level

2) Number of ME and Ph D students are working in projects of practical applications in field

3) Research work is undertaken on

a) Ferrocrete to replace prestressed concrete with 3-D mesh reinforcement
b) Ferro-Geo-crete with Geopolymer Mortars as matrix to replace steel sections
c) Ferro-foam-crete with Foamed mortar a matrix to replace timber planks
d) Precast ferrocrete ribbed stiffened panels to build pavements overnight
e) Factory-on-wheels to manufacture precast products at the work site for mass-scale housing
f) Substitute for Portland Cement by use of Geopolymers.
g) Zero-friction high-strength pipes- plastic pipes out-coated with ferrocrete

4) Ferrocement Society has organized 5 National Conventions FS 2011, FS 2013, FS 2015, FS2017 and FS2019 in which about 150 papers from members all over India are presented and published in form of proceedings.

5) Work on BIS Specifications for Ferrocrete is in progress. A committee is already formed.

6) **Books on Ferrocrete Technology –**

a) "A Green Revolution in Construction Industry- Ferrocrete Technology" by Dr B N Divekar-A book giving introduction of technology which can be easily understood by a common man -already published

b) "Ferrocrete technology –A Construction Manual" written by Dr B N Divekar - already published

c) Book on "Design of Ferrocrete Structures" by DR B N Divekar is published. In it, designs of Ferrocrete structures based on specific surface and volume fraction of meshes and split tensile strength of mortar are developed and used as the design parameters

d) Writing of book on "Build with Ferrocrete" by Dr Divekar is in progress.

e) Hand-book on "Ferrocrete Technology" is published by MERI (Government of Maharashtra).

f) Specifications of various ferrocrete items- drafting is in progress.

7) Work-shops on Ferrocrete Technology with Demo – About 126 workshops are already organised in Engineering/ Architecture Colleges and Government organizations.

8) Consultation is offered in Design and Construction of ferrocrete Structures.

9) "India Ferrocement Information Center" is established with about 500 references and made available for research students.

10) Training programs for Entrepreneurs and Technicians are organized for budding engineers.

11) Number of papers on ferrocrete technology are written and published by our members in national and international conferences.

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