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Cost Analysis in the Construction Industry using Ferro-cement as a New Construction Material

Prathmesh Kadam[1], Omprakash Jha[1], Shrikrishna Shur[1], Kalpana Patil[2]

UG Students, Department of Civil Engineering[1]

Assistant Professor, Department of Civil Engineering[2]

JSPM's Rajarshi Shahu College of Engineering, Pune, Maharashtra, India

Abstract: *It is a composite structural material comprising thin sections consisting of cement mortar reinforced by a number of closely spaced layers of steel wire mesh. Application of Ferro- cement in construction industry is large due to the low self-weight, No need of more skilled labor, no need of formwork. Ferro-cement is generally used repairing, strengthening and retrofitting of the structures. Ferro-cement was firstly developed and used by Italian architecture. Different type of meshes is used in Ferro-cement such as, hexagonal wire mesh, Welded wire mesh, Woven wire mesh, expanded metal mesh, and three dimensional meshes. The desired shape may be built from a multi-layered construction of chicken wire, and if needed reinforced with steel wire or steel bars. Over this finished framework, an appropriate mixture of cement, sand and water is spread out. During hardening, the Ferro-cement is kept moist, to ensure the cement is able to set and harden. Quantity requirement of Ferro-cement in building construction is much less as compared to R.C.C. Therefore, dead load of Ferro-cement building is reduced by at least 50%. Consequently, the foundation cost gets reduced. Ferro- cement is sustainable construction material. The comparison of Cost-time for material used in construction industry in each material showed that the material which includes Construction method, new techniques, installation process is the most suitable alternative to the existing traditional method like reinforced cement concrete.*

Keywords: Ferro-cement, Metallic mesh, Lightweight structure, Sustainable construction material, Construction Cost and Time

I. INTRODUCTION

Ferro-cement is a thin composite made of a fully mortar matrix based on cement, reinforced with thoroughly spaced wire-mesh layers of small diameter. The mesh can be produced from steel or various appropriate materials to generate parts of little thickness, resilience and excessive robustness, and rigidity and high strength will be accomplished once correctly shaped. Ferro-cement is believed to be one of the distinctive techniques of construction that are now used throughout the globe. It is the cement material made of tightly spaced mesh layers in which the reinforcement is provided evenly throughout the material of Ferro-cement making it ductile from fragile. Ferro-cement has a high strength and serviceability that acts as a building material for several purposes. Compared to RCC, it functions as a homogeneous material having comparable characteristics in all directions. The mesh surface area in Ferro- cement is very large, which enables the mortar to properly bond with it, resulting in lesser cracks, exhibiting greater durability because of the same. It also has a much greater tensile strength and rupture module that helps to avoid cracks.

Similar skinny building material offers characteristics that do not match Ferro-cement's characteristics such as strength, toughness, water tightening, lightness, and durability. The bending behavior of Ferro-cement and concrete reinforced cement yields practically similar results. Ferro concrete is however regarded a hybrid material lies between reinforced concrete and stainless steel.

Ferro-cement can be considered a type of thin reinforced concrete construction in which large amounts of 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. Metallic mesh is the most common type of reinforcement. Meshes made of alkali-resistant glass fibers, and woven fabric made of vegetable fibers such as jute-burlap and bamboo, have also been tried as reinforcement.

Conventional reinforced concrete is combination of steel bars and concrete. Shuttering and scaffolding are quite essential. Ferrocement is a composition of weld mesh, mild steel angles or bars, chicken mesh and mortar. This mixture becomes a homogenous material and can be built in conditions and in any shape. Ferrocement is a very thin material that's why it becomes light in weight nature but its ductility is very high as compared to conventional RCC. Ferro-cement is defined as 'Cement mortar strongly bonded and encased in layers of fine wire meshes making it a homogeneous and ductile composite'. [1] According to Naval Ship R&D Center, 'Ferrocement consist of several layers of wire mesh reinforcing mortar of sand and Portland cement'.[2] All conventional material can be replaced by Ferrocement and material like steel, cement, timber, wood, clay, etc. can be saved to some extent. Production of steel and cement emits huge amount of greenhouse gases (GHGs) and harms the environment. That emission measured in terms of CO2. Carbon credit is a generic term for any tradable certificate or permit representing the right to emit one tone of carbon dioxide or mass of another greenhouse gas with a carbon dioxide equivalent to one tone of carbon dioxide [3]. Carbon credits are measured in units of certified emission reductions (CERs).

Ferrocement is an alternative to conventional RCC construction. Ferrocement technology is getting more attention because of its advantages such as light weight, water tightness, ductile, ease in construction and maintenance. Ferrocement application started with boats and now, various structures such as building, retaining wall, swimming pools, water tanks, domes, corrugated roof, etc. are being built with it. Ferrocement has another important advantage of reduction in CO2 emission. For sustainable development and prevention of environment, this feature of ferrocement, makes it more suitable for construction. However very less research work is done in this context and hence carried out research work for estimation of CO2 emission of ferrocement structure.

From the early history of ferrocement and through its subsequent evolution, the definition of ferrocement has been changing. Ferrocement can be defined as a type of reinforced concrete (RC) characterized by the small size of the reinforcement, which is wire mesh, and the aggregate, which is sand. The basic definition of ferrocement is given by ACI committee [1], however before and after this committee report, ferrocement has been defined with different researcher and committee [2–8].

However, there was insufficient application and research on ferrocement contraction between 1888 and 1942. An Italian engineer, Pier Luigi Nervi, carried out a series of experiments on ferrocement after that period. Based on the tests, it is observed that reinforcing concrete with layers of wire mesh produces a material possessing the mechanical characteristics of an approximately homogeneous material which is capable of resisting high impact load. Nervi also applied the ferrocement concept to civil engineering structures and used the idea of corrugation for the roofs of several significant structures including a roof system spanning98 m for the Turin Exhibition Hall. Ferrocement is now considered as a versatile, low-cost construction material with large potentials in many other areas, including housing applications. In many aspects, ferrocement is deemed to be an extension of RC, and it has relatively better mechanical properties and durability than conventional RC. Ferrocement use in the precast slab and composite precast slab applications. The utilizing of ferrocement in precast technology is highlighted regarding the mechanical and in-service properties. The advantages of ferrocement can be realized from its potential in precast and precast composite application. The flexibility of ferrocement provides for the design of panels that are thin, durable and have a high first crack load, which results in reduced construction time and total cost of the precast elements. Despite its thin structural form, ferrocement shows ductile behavior resulting in flexible transportation and erection options for the precast structures. Research conducted over the past decades demonstrates the advantages of ferrocement composite precast panels and suggests that new designs have the potential to overcome most of the precast and the precast composite structures' shortcomings. The use of ferrocement as a permanent formwork, concrete cover, precast slab, precast half slab and precast composite slab have proved its advantageous characteristics. Based on this review of research on ferrocement, it is evident that usage of the ferrocement should continue to be an important research focus for precast composite slab applications.

II. CONSTITUENTS OF FERROCEMENT

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

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

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

Fine Aggregates: The importance of good, clean, well graded sand cannot be over emphasized if one is to make the high-grade impervious mortar required. Skeleton steel: It is provided to supports the steel wire mesh. The size of Skeleton steel is normally 6 to 8 mm of Fe 250 bars were used.

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

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

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

III. HISTORY OF FERROCEMENT

What we call today as R.C.C. construction material and Ferrocement, entered construction field simultaneously by mid-19thcentury. Mr. J. L. Lambot built a wire-reinforced boat in which reinforcement was in the form of a network of wires. However, since then, R.C.C. advanced as a full-fledged constructional material, time tested and design procedure formulated, though modified from time to time. On the other hand, ferrocement was forgotten almost for a century and took a small step in the middle of20th century, when Mr. Pier Nervi devised the homogeneity property of ferrocement. Looking at the advantages and superiority of ferrocement over R.C.C., now the former should have squared up at least a century lag over the later. But in fact, only some stray items like tanks, domes, etc. came in its shape. The physical property studied by Mr. Nervi was lost and once again, ferrocement got cutoff from major construction field. The obvious reason was design system for building system was used as non-vulnerable construction material. Whatever efforts were put in formulating these minor designs, they were on the basis of R.C.C. design, which is not considered as 'homogeneous' material as ferrocements considered. This ferrocement was found on testing to have very little in common with normal reinforced concrete, however, since it possesses the mechanical characteristics of a completely homogeneous material. ACI Committee 549, Ferrocement and Other Thin Reinforced Products, was organized in 1974 and was given the mission to study and report on the engineering properties, construction practices, and practical applications and to develop guidelines for ferrocement Constructions.

The structural behavior of ferrocement is different from conventional reinforced concrete. The dispersion of small diameter steel wires closely and uniformly in the entire volume of the ferrocement element improves many engineering properties like impact resistance, fatigue resistance, tensile strength, toughness and flexural strength. In ferrocement, there is a combined action of steel and mortar in tension zone even after cracking. Thereby, the tensile strength of mortar is improved due to close spacing of wires. The presence of steel phase improves the deformation characteristics of other phase i.e., mortar. Thus, ferrocement is defined as a two-phase composite material, the steel phase acting as the reinforcement phase and mortar phase as the matrix.

IV. RELATED WORK

To overcome the low tensile strength of concrete, attempts were made to reinforce it using bronze rods and strips. But the higher rate of thermal expansion of bronze caused cracking. A note on the history of reinforced concrete in buildings by describes the early use of armatures of embedded iron in masonry and to reinforce brick work; within a short period, use of reinforced concrete was put under use. Joseph Monnier built large garden tubs (1849); Francois Coquet (1852) cast concrete around an ion skeleton within timber shuttering; William Wilkinson a new castle builder took out a patent in 1854 for embedding in floors or beams of concrete a network of flat iron bars (John E Morgan 1998).

In the same period Joseph Louis Lambot and horticulturist living on his estate at Miraval near Brignoles in Var experimented with plant pots, seats and tubs made of meshes and plastered with sand and cement mortar replaced his rotting rowing boat. He called this material as „Ferrocement" in a patent, which he took in 1852. Lambot"s row boats still now available in Brignoles Museum in France.

There was very little application of true ferrocement construction between 1888 &1942 when Pier Luigi Nervi began a series of experiments on ferrocement. He observed that reinforcing concrete with layers of wire mesh produced a material possessing the mechanical characteristics of an approximately homogeneous material capable of resisting high impact. After the Second World War Nervi demonstrated the utility of ferrocement as a boat building material

In 1945, Nervi built the 165-ton Motor Yatch “Prune” on a supporting frame of 6.35mm diameter rods spaced 106mm apart with 4 layers of wire mesh on each side of rods with total thickness of 35mm.It weighed 5% less than a comparable wooden hull &cost 40% less at that time.

In 1947, Nervi built first terrestrial ferrocement structure was due to the corrugations of the wall &the roof which were 44.45mm thick.

In 1948 Nervi used ferrocement in first public structure, the Tutrin Exhibition building, the central hall of the building which spans 91.4m, was built of prefabricated elements connected by reinforced concrete arches at the top &bottom of the undulations. In 1958, the first ferrocement structure a vaulted roof over shopping Centre was built in Leningrad in Soviet Union. In 1971 a ferrocement trawler named “Rosy in I was built in Hong Kong. It had an overall length of 26m &is claimed to be the world’s longest ferrocement fishing boat.

In 1972, the National Academy of Sciences of the United States of America set up an Adhoc Panel on the utilization of ferrocement in developing countries under the chairmanship of

In 1974, the American Concrete Institute formed committee 549 on ferrocement. ACI Committee 549 first codified the definition of ferrocement in 1980, which was subsequently revised in 1988, 1993 and 1997(Naaman A.E, 2000).

In 1975, two ferrocement aqueducts were designed &built for rural irrigation in China.

In 1976, the International Ferrocement Information Centre (IFIC) was founded at Asian Institute of Technology, Bangkok, Thailand. The center is financed by the United States Agency for International development, Government of New Zealand, International Development Research Centre of Canada. In 1978, an elevated metro station of 43.5mx1.6m in size with continuous ferrocement roofing was erected in Leningrad.

In 1979, RILEM (International Union of Testing &research Laboratories of materials &structures) established a committee (48- FC) to evaluate testing methods for ferrocement.

In 1984, ferrocement was used in the construction of a shaking table of large-scale earthquake simulation facility at the state university of New York at Buffalo. The International Ferrocement Society (IFS) formed a Committee (IFS-10-01), the recommendations of which were published as "Ferrocement Model Code" (FMC) in January2001.The definition in the above model code reflects the advances in ferrocement and past experiences too.

V. PROBLEM DEFINITION

It has been seen that a significant amount of research has already been done in perspective of structure. The use of Ferro-cement and their factors affecting the construction sector in India not so much data available for study.

This study attempted to determine how much profit and efficiency of construction projects could be increased using Ferro-cement. This study also explored and evaluated differences between constructions in India, by analyzing the traditional material like RCC over Ferro- cement. We reduce the cost and get more benefits using Ferro- cement.

VI. NEED FOR CONSTRUCTION

Construction Management is the method by which the project planning, Project cost, design and construction phases of a project are treated as integrated tasks. The interaction between construction costs, benefits, environmental impact, quality and completion schedules are carefully examined so as to realize the project in the most economical time frame. This study includes questionaries' survey in which we can find out the factor affecting the construction cost which directly related with material use in construction projects. the factors affecting the construction cost and time were identified through the literature based on previous research.

VII. AIMS AND OBJECTIVES

- To find the differences in cost by analysing construction project cost between RCC structure and Ferro-cement structure
- To minimize energy costs / waste without affecting production & quality and to minimize environmental effects and to identify the source of wastes for specifically chosen activities at a construction site and relate them to the waste generate in construction industry using both materials.
- To study Effect on total project cost and benefits using Ferro- cement material and advance construction techniques.

VIII. LITERATURE REVIEW

Lakhan Murari, Elson John, Review on Study on performance of prefabricated ferrocement columns and wall panels, international journal of engineering research and science and technology (IJERST), Special Issue, Vol. 3, No. 1, April 2016

In this paper they studied about performance of fabricated Ferro- cement column and wall panels. Ferrocement wall panels of size 1 m x 1 m with 5 cm and 2.5 cm thickness and Ferrocement Hollow columns of size 0.20 m x 0.20 m x 1 m and 0.25 m x 0.40 m x 1 m with 0.03 m thickness load were casted and tested in laboratory and their failure load was studied. Hollow section, column with infill PCC and normal column were casted in order to compare their failure. In this paper they also include cost comparison, for cost comparison of ferrocement columns and normal RCC column and wall panels, material cost was taken as the common tool for comparison. If we take the total cost including labor cost, form work cost etc. into account, the initial cost for prefabricating the ferrocement elements will be higher compared to RCC elements. But in the long run the total cost of prefabricated element will be less than the cast in-situ elements. This is because the same form work and molds can be used for many times. For comparison wall panels of sizes 1 m x 1 m x 0.05 m and columns of size 0.20 m x

0.20 m x 1 m and 0.25 m x 0.40 m x 1 m were taken. They estimate that RCC wall panel cost is 757.25 Rs. And Ferrocement wall panel cost was 467.65. Based on results obtained from the study, it can be concluded that the prefabricated ferrocement columns and wall panels may be used for the construction of low-rise buildings and it is also cheaper compared to RCC elements of similar size.

Ganesh A. Choughule, N. N. Morey, Study and Cost Analysis of Ferrocement Panel for Affordable Housing, Journal of Basic and Applied Engineering Research, Volume 3, Issue 10; July- September, 2016

In this Paper they studied affordable housing using ferrocement panel. As they know about the main difference between ferrocement and reinforced concrete is ferrocement is a thin composite made of cement matrix reinforced with closely spaced small diameter wire meshes instead of larger diameter rods and large size aggregates. The thickness of ferrocement generally ranges from 25 - 50 mm. The latest ACI Code encourages the use of non - metallic reinforcement and fibers. They conclude that as the number of layers of metal mesh increases the flexural strength of Ferrocement panel increases. The no of layers used to study the flexural strength are two, three and four for panels of size (900x300) with thickness 25 mm & three, four, five & six for wall panels of same size with thickness 40 mm were reinforced with expanded metal mesh. Panels were casted with cement mortar of mix proportion 1:1.70 with water cement ratio 0.38 and Polypropylene Fibrillated Fibers with dosage of 1% of total weight of cement. Panels were tested under UTM machine by two-point loading system after curing period of 28 days. The cost of ferrocement panel construction is approximately half than cost of construction of conventional brickwork. result shows that panels with more no of layers having higher flexural strength and less deflection compared with panels having less no of layers of mesh and construction of ferrocement structure is rapid and economical as compared with conventional material for affordable housing.

A.S. Burakale, P.M. Attarde, Mayuri D. Patil, Ferrocement Construction Technology and its Applications, International Research Journal of Engineering and Technology (IRJET), Volume: 07, Issue: 07, July 2020

In this paper they studied that ferrocement is an innovative material and the ready availability of materials and ease of construction make it suitable in developing countries for housing, and water and food storage structures. Ferrocement is found to be a suitable material for repairing or reshaping the defective RCC structural elements and enhancing its performance. The applications of ferrocement are capturing almost all the fields of civil engineering but there is a dirt of research backing and a rationale design base to construction of ferrocement structures. As the performance of ferrocement is greatly dependent on the characteristics of the reinforcing mesh, there is a need to determine and specify an optimum range of properties for the mesh, such as wire spacing, wire diameter, and the characteristics of the mesh system. This is only a review study and experimental research on new building materials for use in ferrocement construction or combinations of meshes and fibers are needed. The standard methods of ferrocement construction and effect of shape due to which novel forms are generated have to be researched upon and benefits brought out. Considering the unique features, ferrocement will no doubt be one of the most important structural alternatives for RCC and a repair material in the future and thus has a great potential for developing and developed countries alike.

This study recommends ferrocement as the best alternative material to RCC and also a construction material of the future due to its properties/ advantages. And also recommended that Ferro-cement also use for repair work

A.S.M. Abdul Awal, M. Siddikur Rahman and M. Bellal Hossain, Development of ferrocement technology for low-cost farm structures, J. Bangladesh Agri! Univ. 2(2): 343-349, 2004 In this paper, unlike other sophisticated engineering constructions, ferrocement requires minimum of skilled labor and utilizes readily available materials. The basic materials needed for ferrocement constructions are wire mesh, sand, cement, water, and mild steel rod as skeletal reinforcement. Structures that have been identified and made in this project are some of many that can be constructed for farm uses using ferrocement technology. The results obtained have demonstrated that utility and economy can both be achieved using very simple techniques utilizing readily available materials. It is expected that the observations made here in this research will bring new concept in gaining wide acceptance of ferrocement for the construction of low-cost but strong and durable structures for farm uses. The present study is an attempt to familiarize ferrocement technology for the construction of low-cost structures for farm uses. The selected structures that have been identified for farm uses are storage structure, cattle trough, irrigation and drainage canal lining, and manhole cover.

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IX. RESEARCH METHODOLOGY

Research Methodology will be designing a questionnaire survey by which we can find out the factor affecting the construction cost which directly related with material use in construction projects.

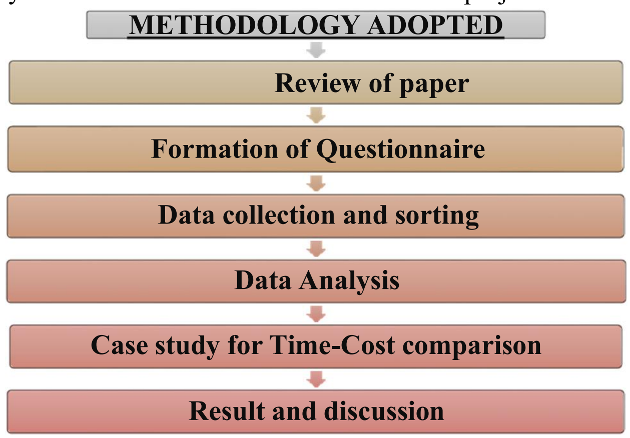

Figure 1: Methodology chart

Roofing = 900 Rs.
Consider Room size: 10ft. × 10ft.
No. of ferrocement channel required = 8 Cost of channels required =8×900 =7200 Rs.
Cost of gap filling between channels and installation=1000Rs. Total cost required for 100sq. ft. =8200 Rs.
Therefore, Total cost using ferrocement channel roofing system = 82 Rs./sq. ft
Total cost using conventional (R.C.C) roofing system = 125 Rs. /sq. ft Therefore % saving = 35%
Calculations For Ferro-cement as per SSR Walls
Total Area of Ferro-Cement construction = 2335.77 Sq. Ft Cost Required for Ferro-Cement construction = 82 Rs. / Sq. Ft Total Cost = 2335.77 x 82 = 1,91,533.14 Rs.
Contingences is 10% = 19,153 Rs. Add on Profit 20% = 42,137.2 Rs.
Total Cost for Ferro-Cement Construction in Walls = 2,52,823.34 Rs. Roofing
Cost For Roofing = 125 Rs. /Sq. Ft Total Roofing Area = 1044.1 Sq. Ft Total Cost for Roofing = 1,30,512.5 Rs. Contingences is 10% = 13,051.25 Rs.
Total Cost for Ferro-Cement Construction in Roofing = 1,43,563 Rs.
Total Cost Required for 1044.1 Sq. Ft Ferro-cement Construction = 3,96,386.34 Rs

X. DATA COLLECTION AND ANALYSIS

1. Ferrocement is an innovative material and has a number of structural applications which includes earth-retaining walls, swimming pools, underground and overhead water tanks, where water-tightness is a requirement. Ferrocement is also used in construction of corrugated roofs, hyperbolic paraboloid shell structures, domes and housing structures. Ferrocement thin elements are used in facades, sunscreens and curtain walls, and the architectural beauty and grandness of the building is enhanced due to its sleek nature.
2. This study recommends ferrocement as the best alternative material to RCC and also a construction material of the future due to its following properties/ advantages:
   a. Ferrocement elements undergo high deformations before collapse. It has high level of impact and cracking resistance, toughness and ductility.

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   - **b.** he ferrocement structures are thin and light-weight compared to conventional reinforced concrete. Hence there is considerable reduction in self-weight of the structure and saving in foundation cost. Transportation cost is also less.
   - **c.** Ferrocement can be fabricated into any desired shape or configuration. Pre-casting is suitable for thin ferrocement elements, and mechanized methods can be adopted in case of mass production of ferrocement components.
   - **d.** Partial or complete elimination of formwork is possible. Hence there is considerable saving in the cost of formwork, particularly for curved or complicated/ complex shapes/ structures, which is not possible with RCC construction.
   - **e.** Ferrocement construction is simple and quick and does not require highly skilled labour; and the labourers can also be easily trained for this job. Also, it does not require any heavy equipment
   - **f.** Machinery for casting or lifting purposes. It is an economically feasible material and also suitable for developing countries in both urban and rural areas.
   - **g.** Due to less consumption of building materials and scaffolding items in ferrocement, (as compared to RCC), not much space is required for storing materials.
   - **h.** Ferrocement is most suitable for water-retaining structures due to water-tightness and permeability.
   - **i.** Ferrocement structures can be easily maintained, and also repaired in the event of structural damage without any major problems.

3. This study recommends ferrocement as a repair material due to the following reasons:

   - **a.** Ferrocement is suitable for repair works in boats, water tanks, swimming pools, sewer lines etc. Ferrocement is also suitable for repair or rehabilitation/restoration of ancient or heritage building structures. The repaired elements can withstand long years without cracking.
   - **b.** Ferrocement repair to old/deteriorated RCC structure is cheaper and quicker than demolition of such structures and reconstructing them. Ferrocement patch repair techniques help in easy bonding of old and the new layers, and patches also do not show up in ferrocement as the layers easily merge with each other.
   - **c.** Less or no formwork construction processes is involved in ferrocement repair methodology.

This study is of the opinion that ferrocement jacketing method of confining reinforced concrete columns is one of the most suitable methods to enhance its load-carrying capacity and strength.

1. As there are only limited studies on corrosion in ferrocement, it is recommended by the present authors, that in order to prevent corrosion, new meshes manufactured of stainless steel, plastic, PVC, or any other non-metallic mesh reinforcement may be explored as reinforcement in ferrocement. But the structural load carrying capacity and other characteristics of these elements, using such new materials, are to be ascertained through experimental studies.
2. This study also recommends that fibres may be added as additional reinforcement in ferrocement into the matrix composition for crack-control and resistance against local loads. Synthetic fibres (such as nylon, poly-vinyl chloride, polyolefin, polyvinyl alcohol, polyethylene and polypropylene) can be used in ferrocement instead of steel fibres so as to avoid corrosion.
3. In order that ferrocement is to become an accepted building material, this study strongly recommends that considerable research on new reinforcing materials should be done. The two different concepts of ―Ferrocement using Wire/ Weld Meshes and Engineered Cementitious Composite using Discontinuous Fibers‖ can be combined and a new material may be developed to provide a hybrid composite with improved properties. Experiments may be conducted on such ferrocement composite elements to study the flexure, impact and punching, ductility, and cracking behavior of ferrocement elements.

Ferrocement Construction Process

As thin structural elements, ferrocement has been used in numerous applications ranging from engineered structures to architectural applications such as sheets, boards, shells, hulls, and also sandwich type construction using thin skins, and constructions where the reduction of self-weight, improved water permeability and development of very fine crack widths are essential.

Structural Applications

Ferrocement can be used in various structural members subjected to different type of stresses. As a compression member, hollow columns with horizontal stiffeners can be cast in ferrocement. Columns or walls in concrete, RCC, stone or brickwork can be encased in ferrocement to increase their strength due to confinement. Members subjected to membrane stresses like shells, domes, pyramids can be cast in ferrocement very easily; and being a homogenous material, full section of member is utilized in resisting the membrane stresses. A ferrocement hyperbolic paraboloid shell structure was constructed by the student chapter of the American Society of Civil Engineers at Funded by the International Development Research Centre of Canada, two prototype cylindrical water tanks for the collection of rainwater were designed, constructed, and tested for use in the rural areas of the Philippines. A greater use could be made of ferrocement in water-retaining constructions and other similar constructions where crack width is a design criterion. Because of its very small crack widths under service load and it superior extensibility, ferrocement provides excellent leakage characteristics for applications in water tanks; moreover, should pressure increase, ferrocement stretches to allow higher leakage and acts as a safety valve, thus, it does not fail

Roofing Applications

Ferrocement appears to be an economic alternative material for roofing; and flat or corrugated roofing system is quite popular. Ferrocement roofing materials can be factory mass-produced in prefabricated form, a process best suited to the concentrated demands of the urban area, or it also can be fabricated in-situ in villages. Construction of hundreds of ferrocement roofs for poorer areas of Mexico has been well documented; and large ferrocement roofs have also been constructed in Italy spanning with a thickness of 30 mm. The use of ferrocement as roofing for large span structures with internal ribs has been successful in many European and South American countries. Domes have been constructed in Jordan using thick ferrocement with internal ribs.

Need for Repair of RCC Structures

Some major reasons for the deterioration of RCC structures are cracking (due to incorrectly made construction joints, poor compaction, segregation, poor curing and high-water content) and spalling (due to corrosion in the reinforcement bars accelerated by a lack of adequate cover). The cracks in the concrete may be developed due to wrong design of structure or due to poor quality of materials used, and this will facilitate internal corrosion of steel reinforcement used in RCC elements; the cracks in course of time deepens up due to increase in corrosion and subsequently, peeling of concrete cover or spalling of concrete takes place. Use of proper repairing materials and methods of damaged or deteriorated RCC structures is a necessity not only to serve the intended service life but also assure the safety of buildings value: Ferrocement Repair Techniques A good repair improves the function and performance of structures, restore and increase its strength and stiffness, enhances the appearance of the concrete surface, provides water tightness and prevents ingress of the aggressive species to the steel surface durability. Ferrocement repairs and rehabilitation can be done in RCC structures to increase the strength of columns, beams and slabs up to 30% as well as contribute towards prevention of crack formation. Ferrocement which can be made from non- formwork construction processes is an advantage over other types of repairs and strengthening techniques; enhanced crack resistance combined with high toughness, its rapid constructions with no heavy machinery involved, small additional weight it imposes, and considering an economical aspect of rehabilitation, this material proves to be a cost-effective solution for rehabilitation and general applications.

The ferrocement material is a waterproof system and does not allow the penetration of water and atmospheric gases. It can totally replace deteriorated/ damaged RCC with reduction in dead load.

Ferrocement Repair Methodology

It is generally noticed that corrosion of RCC structures most commonly takes place in the main reinforcement in slabs, beams and columns and the stirrups, where proper cover is not maintained and where reinforcement is exposed in the cover area. Patchwork repair can be done using ferrocement to the damaged concrete surfaces in slabs, beams and columns to restore the original strength of the RCC. Ferrocement patch repair method can be carried out in columns, bottom and middle portions of beams, soffit of slabs, etc. and following are the repairing steps recommended in the previous studies

- Step 1: Breaking open the damaged spalled cover or the affected zone or the cover of RCC elements (such as beams or columns) with the help of a chisel and hammer.
- Step 2: Exposing the original reinforcing bars and scraping of corrosive layers of reinforcement and applying anticorrosive paints (if any) or cutting and replacing the corroded reinforcement.
- Step 3: Roughening the concrete surface, and placing chicken and/or galvanized wire/ weld mesh in position and the mesh should get fixed/ embedded to original slab/beam/column reinforcement. Use skeletal reinforcement, if required.

Ferrocement Confinement

Ferrocement confinement is done around defective circular or square/rectangular RCC columns in order to enhance the strength, ductility and energy absorption capacity of existing concrete columns. A jacketing layer of 30 mm is created around the RCC columns with ferrocement is done in order to increase its load carrying capacity.

This confinement work also protects the existing reinforcement, provides water tightness and prevents ingress of the aggressive species to the surface of original concrete or steel surface. Ferrocement not only increases the performance/ function of structures but also enhances the appearance of the existing RCC structure. The repair in the structural elements using ferrocement can withstand for long years without cracking provided the mortar used is of proper proportion using good quality materials, and the wire mesh is of anti-corrosive coating type

Properties of Ferrocement

Ferro cement is a type of a reinforced concrete haring large amount of smaller diameter wire meshes are needed, these wires are metal wire and sometimes other type of suitable material can be used sand, cement, mortar mix and quantity of reinforcing material decide the strength of ferro cement.

XI. MATERIALS

The Following Materials Are Used in This Work:

1. Ordinary Portland Cement (43 Grade)
2. Fine Aggregate
3. Chicken Meshes-Hexagonal Opening
4. Water
5. Steel According to the Design
6. Binding Wire
7. Admixtures

Cement: Some of The Properties of The Cement Are:
Specific Gravity = 3.15, Standard Consistency =34%, Initial Setting Time = 40mins Compressive Strength = 52.16 N/Mm2

Fine Aggregate: Fine Aggregate Used Are Passing Through 4.75 Mm Is Sieve with A Specific Gravity Of 2.62

Chicken Mesh: Galvanized Chicken Wire Mesh of Size 12mm

Water: Potable Drinking Water Was Used for Mixing and As Well As for Curing Other Constituent Elements Are as Follows:

Steel – Generally the Diameter of Steel Used Is From 3 Mm To 10 Mm but Generally 6 Mm Diameter Steel Is Most Commonly Used.

Binding Wire – Binding Wire Of 18 To 24 Gauges Is Used.

Admixtures – For increasing the workability, minimizing water use and reducing the setting time of cement admixtures are added. Equipment required for ferrocement construction

- Nails
- Hammer
- Plumb Bob
- M.S. Plane
- Steel Cutter
- Chisel
- Wire Brush
- Spade
- Showel
- Sieve
- Wheel Barrow

Ferrocement as Sustainable Construction Materials

The low material cost, labor intensity and semi-skilled labor requirements make ferrocement is the most promising alternative materials for housing. The constituent materials of ferrocement are easily available and are quite inexpensive. The fabrication technique of ferrocement is quite easy and common people could be trained in a short time to learn the skill. Advantages of ferrocement as a construction material may be summarized as follow:

1. Very high -quality control.
2. Pre-Fabricated products.
3. Easy production and installation.
4. Shading devices to provide shading and day lighting to the building (use light weight and low-cost environmental element). 5. Fast construction.
5. Manpower can be easily trained at site.
6. Improved structural performance.
7. Cost reduction, 15-50% cheaper than conventional techniques. 9. Less maintenance.
8. 10. Reduction in dead weight, 50-75% lighter than conventional techniques

Advantages of Ferro Cement

- Required materials are readily available.
- It can be used for large construction work.
- Minimum skilled labours are required.
- Light weight members due to smaller thickness.

- Most suited for high levels of prefabrication.
- Highly versatile material hence can be fabricated in any desired shape.
- It is having high tensile strength and flexural strength.
- It is highly durable, crack resistant and water resistant.
- Due to its ductile behaviour, it can be used in earthquake resistance.
- Have good impact resistance and toughness.
- Construction with this is easy, less weight and lasts long.
- It requires low maintenance

Disadvantages of Ferrocement

- It fails in compression due to absence of mass concrete.
- Liable to corrosion due to bad compaction.
- Because of distinctive shapes trouble in construction.
- Frequently suffers from intense spalling of matrix cover.
- Delamination of extreme tensile layer.
- Labour demanding therefore excessive labour cost.

XII. CONCLUSION

Ferrocement panel, which is a thin and lightweight component, being an emerging technology in the construction field, has many advantages when compared to that of conventional methods of reinforcements.

This review has summarized that ferrocement is a versatile but unharnessed material. The ease of construction with mere materials makes it suitable for low-cost light construction especially in developing countries. The applications of ferrocement in both cast in situ as well as precast construction have been explored in all areas of civil engineering but there is a dearth of enough research and a coded rationale for design. The standardization of procedures and applications as load bearing and non-load bearing elements is lacking. The regulatory authorities need to publish the codes as for reinforced concrete structures. The performance of ferrocement elements greatly depends on the number and characteristics of the reinforcing mesh, fillers, and mortar mix. Optimum ranges for these parameters need to be specified. The light weight sandwich panels offer a good potential towards good energy efficiency and disaster resilience. This review study emphasizes more experimental research with sustainable building materials, combinations of meshes, fibers and fillers. Considering the economics, simplicity and versatility, ferrocement can prove to be a potential alternative to RCC in elemental light construction.

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