Journal of Advances in Science and Technology
Vol. 19, Issue No. 1, March-2022, ISSN 2230-9659

Ferrocement Construction Technology in Sustainable Construction

Mr. Balaji Balshankar[1]* Prof. R. B. Matkar[2]

[1] PG Student, M.E. (Civil Engineering), TSSM's, Padmabhooshan Vasantdada Patil Institute Technology, Pune

[2] Assistant Professor, Department of Civil Engineering, TSSM's, Padmabhooshan Vasantdada Patil Institute Technology, Pune

Abstract – It's a composite structural material made up of tiny sections of cement mortar strengthened by many layers of steel wire mesh positioned closely together. Ferrocement is widely used in the building sector due to its low self-weight, lack of trained labour, and lack of formwork. Ferrocement is commonly used in structural repair, strengthening, and retrofitting. P. L. Nervi, an Italian architect, was the first to create and use Ferrocement.

Hexagonal wire meshes, welded wire meshes, woven wire meshes, expanded metal meshes, and three-dimensional meshes are all employed in Ferrocement. A multi-layered chicken wire construction can be used to create the desired shape, which can then be reinforced with steel wire or steel bars if necessary. A suitable mixture of cement, sand, and water is spread over the completed framework. The Ferrocement is kept moist throughout hardening to ensure that it sets and hardens properly. In comparison to R.C.C., the quantity of Ferrocement used in building construction is substantially less. As a result, the dead load of a Ferrocement structure is decreased by at least 50%. As a result, the foundation cost is lowered. Ferrocement is a long-lasting building material. When the cost-time for each material used in the building industry was compared, it was discovered that the material that comprises. The most suitable alternative to the existing traditional approach, such as reinforced cement concrete, is the construction method, new techniques, and installation procedure.

Keywords— Ferrocement, Metallic mesh, Lightweight structure, Sustainable construction material, Construction Cost and Time

---------------------------------x---------------------------------

I. INTRODUCTION

Ferrocement 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. Ferrocement 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 Ferrocement making it ductile from fragile. Ferrocement 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 Ferrocement 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 Ferrocement's characteristics such as strength, toughness, water tightening, lightness, and durability. The bending behaviour of Ferrocement and concrete reinforced cement yields practically similar results. Ferro concrete is however regarded a hybrid material lies between reinforced concrete and stainless steel.

Ferrocement 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.

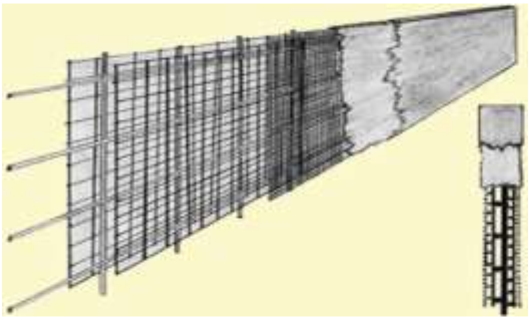

Fig 1: Typical cross section of Ferrocement structure

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. Ferrrocement 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 spanning 98 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. Within certain loading limits, it behaves as a homogeneous elastic material, and its elastic behavior is better than normal RC. The uniform distribution and high surface area to volume ratio of its reinforcement results in a better crack arrest mechanism and higher first crack load; moreover, ferrocement has better fire and heat resistance compared to RC [9–23]. The use of ferrocement technology seems to be an alternative to the current conventional systems. Ferrocement wall panels, precast ferrocement roofing elements, and ferrocement permanent formwork are few examples of ferrocement structural components being used in construction sector today.

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.

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 was used.

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

Admixtures: admixtures are may be used in ferrocement for improvement in impermeability, 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. However, other unique factors, which affect durability, especially, the susceptibility to corrosion of Ferrocement are:

- Very small cover to the mesh reinforcement.
- Very low cross sectional area of the mesh reinforcement wires.
- Because of small wires being used the surface area of the reinforcement is high.
- To prevent corrosion, Mesh reinforcement are galvanized, but the zinc coating can cause and produce hydrogen gas bubbles during hydration.

1.1 HISTORY OF FERROCEMENT

What we call today as R.C.C. construction material and Ferrocement, entered construction field simultaneously by mid-19th century. 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 of 20th 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 ferrocement is 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.

1.2 RELATED WORK

"Ferro cement is a type of thin wall reinforced concrete construction where usually hydraulic cement is reinforced with layers of continuous and relatively small diameter mesh" .

Joseph Aspdin introduced to the world Portland cement and patented it during 1824.Subsequent developments in material, higher burning temperature, continuousprocess rotary kiln etc., drastically improved the material and reduced the cost. A spate of buildings erected from 1835 onwards was of concrete but the concept of reinforcing the material was hardly around this period (John E Morgan 1998).

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 Hamilton S.B 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 Monier built large garden tubs (1849); Francois Coiquet (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 Bringnoles 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 „Ferciment" 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 trowler named "Rosy in I was built in HongKong. 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 centre 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.

1.3 PROBLEM DEFINITION

It has been seen that a significant amount of research has already been done in perspective of structure. The use of Ferrocement 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 Ferrocement. This study also explored and evaluated differences between constructions in India, by analysing the traditional material like RCC over Ferrocement. We reduce the cost and get more benefits using Ferrocement.

1.4 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.

1.5 OBJECTIVES

- To find the differences in cost by analyzing construction project cost between RCC structure and Ferrocement structure
- To find How much time need to complete one project using Reinforced concrete and Ferrocement material and to study Environmental Assessment Factors on ferrocement material
- 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 material.
- To study Effect on total project cost and benefits using Ferrocement material and advance construction techniques.

II. LITERATURE REVIEW

Kavita V. Desai, Dr. Deepa A. Joshi Review on Ferrocement an effective alternative for construction industry, International journal of innovation in engineering and technology (IJIET) Volume 6 Issue 2, December 2015

They looked into ferrocement, which is made up of weld mesh, mild steel angles or bars, chicken mesh, and mortar. This mixture solidifies into a homogeneous material that can be produced in any condition and shape. A review of research on ferrocement is offered in this study. Buildings, roads, dams, bridges, and other structures require millions of cubic metres of concrete. For that building, a lot of steel and cement were used. Steel and cement production generates a large amount of CO_2 and has a negative impact on the environment. It is necessary to replace that material in order to conserve the environment. All standard construction materials, such as RCC, bricks, lumber, steel, and so on, can be replaced with ferrocement, making construction more environmentally friendly. Following a review of the literature, it was determined that further research on Ferrocrete in the context of CO_2 emissions is required. They conclude that ferrocement is a viable alternative to traditional RCC building based on the approach described above. Ferrocement technology is gaining popularity due to its benefits, which include light weight, water tightness, ductility, and ease of construction and maintenance. Ferrocement was first used to make boats, but it is currently used to construct a variety of constructions including buildings, retaining walls, swimming pools, water tanks, domes, and corrugated roofs. Another significant benefit of ferrocement is that it reduces CO_2 emissions. This property of ferrocement makes it more suitable for building in terms of sustainable development and environmental protection. However, because there is a scarcity of study in this area, we conducted research to estimate CO_2 emissions from ferrocement structures.

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 Ferrocement 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 labour 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 moulds 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 fibres. 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 dirth 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 Ferrocement 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 labour 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. Utilizing locally available materials the design and fabrication of the structures have been made using .simple techniques. The cost of construction of Ferrocement structures has also been estimated on the basis of present cost of materials and labour. It is hoped that the observations made in this study will bring new idea in achieving wide acceptance of this technology for the construction of low-cost structures for farm uses.

III. RESEARCH METHODOLGY

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.

Formation of questionnaire

For this particular project, a questionnaire survey approach has been adopted to find the impact of various factors affecting the cost of project. The design philosophy of the questionnaire was based on the fact that it had to be simple, clear and understandable for the respondents and at the same time it should be interpreted well by the researcher.

Through literature survey

It has been seen that a significant amount of research has already been done in perspective of structure. The use of Ferrocement and their factors affecting the construction sector in india not so much data available for study. And hence, a preliminary research through various literatures throughout the globe led to the formation of a preliminary list consisting of factors affecting the project cost and time.

Through preliminary survey of the sites

After recognizing the basic factors through the literature survey, preliminary survey of various sites led to the understanding the nature and relative importance of those factors in the Indian working conditions. The survey co-related the effectiveness of global factors with respect to the Indian sites and also gave us and practical insight adding a few more factors, though they are area specific.

By talking to local experts

Due to varying environmental, social and economic changes, the effectiveness of the factors may also vary over the period of time, and due to the time constraint of the project, it's not feasible to cover all the aspects. And hence by talking to local experts, who are equipped with the practical knowledge of the situation, information required to verify the importance of a particular factor with respect to Indian working conditions can be achieved.

And hence, the factors affecting the construction cost and time were identified through the literature based on previous research, site survey and with input, revision and modifications by local experts.

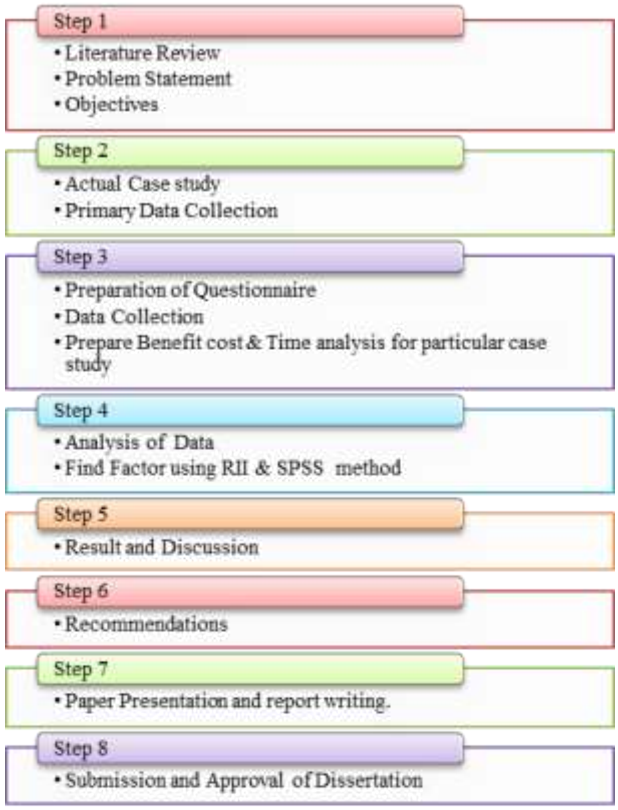

Figure: Methodology chart

V. DATA COLLECTION & 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:

√ Ferrocement elements undergo high deformations before collapse. It has high level of impact and cracking resistance, toughness and ductility.

√ The 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.

√ 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.

√ 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.

√ 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 / machinery for casting or lifting purposes. It is an economically feasible material and also suitable for developing countries in both urban and rural areas.

√ Due to less consumption of building materials and scaffolding items in ferrocement, (as compared to RCC), not much space is required for storing materials.

√ Ferrocement is most suitable for water-retaining structures due to water-tightness and impermeability.

√ 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:

√ 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.

√ 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.

√ 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.

5. Few suggestions of this study on ferrocement are that care should be taken to mix the cement mortar and apply to the reinforcing mesh as per the required technical specifications, and more emphasis should be paid in selection of a richer cement-sand ratio and lower water-cement ratio for the ferrocement mortars, as specified by the ACI Codes.

6. 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.

7. This study also recommends that fibers may be added as additional reinforcement in ferrocement into the matrix composition for crack-control and resistance against local loads. Synthetic fibers (such as nylon, poly-vinyl chloride, polyolefin, polyvinyl alcohol, polyethylene and polypropylene) can be used in ferrocement instead of steel fibers so as to avoid corrosion.

8. 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 behaviour 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 repair and strengthening techniques; enhanced crack resistance combined with high toughness.

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. Step 4: Applying cement mortar on the reinforcing wire-mesh by hand or through spraying (similar to guniting/shotcreting methods)

Step 5: Provide necessary curing for 28 days. Alternatively, ferrocement membrane protective layer can be carried out. In this, layers of closely spaced wires can be used on to the RCC surfaces to prevent crack widening. The cement matrix is in proportion of about 1:2 and has admixtures which reduce shrinkage and develop early high strength. The matrix is vibrated locally using light vibrating tools. Finish of the membrance is just like plaster.

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 alround 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.

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*

Chiken Mesh: *Galvanized Chicken Wire Mesh With A Hexagonal Opening Of Size 12mm And A Wire Thickness Of1.29mm Is Generally Used.*

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*

Fig 2: Ferrocement construction materials

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.
6. Manpower can be easily trained at site.
7. Improved structural performance.
8. Cost reduction, 15-50% cheaper than conventional techniques.
9. Less maintenance.
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 labors 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 spelling of matrix cover.
- Delamination of extreme tensile layer.
- Labour demanding therefore excessive labour cost.

Parameters	yes	No	Other
A] Resource Management:			
1)Raw material:-			
□ Reinforcement steel stored separately as per bars of different diameter, length, and grade wise with proper labeling.	Yes		
□ Weld-mesh roll is opened in the reverse direction of its curvature.	Yes		
□ After cutting chicken mesh the ends of wires are folded back immediately.	Yes		
□ Cement is fresh, free from lumps & stored in dry condition.	Yes		
□ Aggregates/Sand is clean, free from organic matter and relatively free from clay and silt.		No	
□ Water is fresh, clean, and potable.		No	
□ Admixture stored in covered storage area, cool, dry place, away from sunlight.			Other
2)Equipment and tools:-			
□ Calibration of weighing balances satisfactorily done.	Yes		
□ All required sieves available are in satisfactory condition.	Yes		
□ Condition of steel/mesh bending, cutting, welding machines satisfactory.		No	
□ Condition of mortar mixer machine satisfactory	Yes		
□ Availability of tools like piers, hooks, trowels, plumb with satisfactory condition.	yes		
3)Testing and documentation-			
□ Testing of cement as per inspection testing plan(ITP) satisfactory	Yes		
□ Testing of sand/fine aggregates as per inspection testing plan(ITP) satisfactory		No	
□ Testing of steel as per inspection testing plan (ITP) satisfactory.	Yes		
□ Brand/make/age of admixtures as specified.	Yes		
□ Testing of mesh as per inspection testing plan (ITP) satisfactory.			Other
□ Testing of mortar as per inspection testing plan (ITP) satisfactory.	Yes		
B] Site supervision:			
1)Pre-work:-			
□ Working details is available in drawing.	Yes		
□ All material as specified is easily available and accessible.	Yes		
□ For cast in situ markings are properly done as specified.	Yes		
□ Starting point marked.	Yes		
2)During work-			
□ Steel and mesh cutting and tying done satisfactory.	Yes		
□ Mortar bed (thickness and mix proportion) as specified.		No	
□ Use of mortar mix within 60 minutes of preparation.	Yes		
□ Curing of precast panels done satisfactory.	Yes		
□ Joints of panels filled with mortar satisfactory.	Yes		
3)After work-			
□ All precast panels in level as per thickness.	Yes		
□ Surface ready for plaster	Yes		
C] Finished quality:			
□ Quality of joint filling found ok.	Ok		
□ No damages observed in precast panels.			other

CASE STUDY

Project Detailed:

Structure Type: Residential Building Construction

Construction Type: Ferrocement house

Name of the project: Meerai, Nigdi, Pimpri chinchwad

Location: Nigdi, Pimpri chinchwad

Completion period: 8 Months

Construction Type: Ferrocement panel

No. of Floor: Ground only

Contractor Name: Mr. Tilekar

Authority Engineer: Mr. Purandar

Local Authority: Pimpri chinchwad Municipal Corporation, Pune

Questionnaire

The questionnaire design process progressed in a collaborative manner. It was divided into two categories: respondent profile and various parameters impacting construction cost and time required to complete specific tasks using RCC and Ferrocement materials.

Questions in the respondent profile were designed to gather information such as job title, work experience, current and/or prior work locations, and contact information. It was investigated; these survey questions were crucial to the research since they analyzed personal qualification issues from a variety of diverse profiles from various places.

The set of questions was designed with the goal of determining the factors/sources that influence the cost savings achieved by employing Ferrocement on the job site. The responses were to be based on the respondents' understanding, expertise, and experience, and to be tied to a specific project.

This straightforward and straightforward strategy was chosen to produce a list of cost-affecting components. The influence of each element was assessed using a five-point scale ranging from 1 to 5. Questions can be found on the annexure page. The following numerical impact values are ascribed to the rating of the respondents:

- Strongly agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

Revisions to the Pilot Survey and Questionnaire:

A pilot study was conducted to improve the questionnaire portion. This portion included the identification of several causes, data gathering, and data findings. The application of this part aided in the formulation of a better survey.

A total of 25 questionnaires were issued to various building construction organizations' labourers, contractors, architects, owners, project managers, valuators, and project engineers.

i. A questionnaire should always begin with the organization's general information.

ii. Some aspects have nothing to do with building. They should be changed or eliminated.

iii. Some aspects should be altered to make them more appropriate and consistent.

iv. Additional information should be added to some factors.

v. Repetitive factors with similar meanings should be eliminated.

vi. Some factors should be altered to provide a clearer sense of importance and comprehension.

SPSS SOFTWARE VERSION 4.4

IBM SPSS Software was used to analyze the survey questionnaires. SPSS Statistics is a statistical analysis software programme. The original name of the software was Statistical Package for the Social Sciences (SPSS), which reflected the target market. It's a Windows-based tool that allows you to enter data, analyze it, and create tables and graphs. It can handle vast volumes of data and conduct all of the analysis discussed in the text, as well as many others.

In social science, it is a widely used programme for statistical analysis. Market researchers, health researchers, survey firms, the government, education researchers, marketing groups, data miners, and other professionals use it. The programme is used to enter all of the responses from the questionnaires. The variables or questions are first put in the data view, and then the responses are entered into the software. From the various data entered into the software, frequency is calculated, which is then used to calculate the relative importance factor.

Viewing SPSS data

The results of the Questioner Survey were recorded in an excel spreadsheet. SPSS presents data in a spread sheet-like format after it has been opened. The excel file was saved as a data file. In the spread sheet, look at the values and other information.

Data analysis with SPSS:

In its Data Editor window, SPSS can open any type of data and show it along with its metadata in two pages. We may compute the frequency in our data, which contains a variable that holds respondents' responses to a ferrocement-related inquiry, by going to Descriptive Statistics. Pie charts are also picked for better understanding and deeper study.

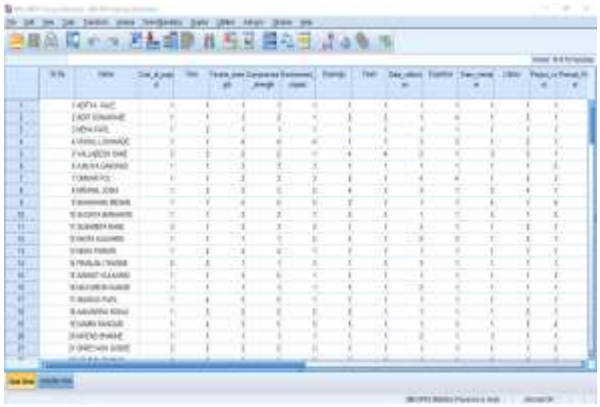

Figure3: SPSS Data View

SPSS Variable View:

An SPSS data file always has a second sheet called variable view. It shows the meta-data associated with the data. Meta-data is information about the meaning of variables and data values. In Variable View, different columns are displayed. Each line corresponds to a variable. A variable is simply a quantity of something, which varies and can be measured, such as height, weight, number of children, educational level, gender and so forth.

SPSS Output Window:

After clicking Ok, a new window opens up, SPSS output viewer window. It holds a nice table with all statistics on all variables we chose. Output Viewer window has a different layout and structure than the Data Editor window we saw earlier. Creating output in SPSS does not change our data in any way; unlike Excel, SPSS uses different windows for data and research outcomes based on those data.

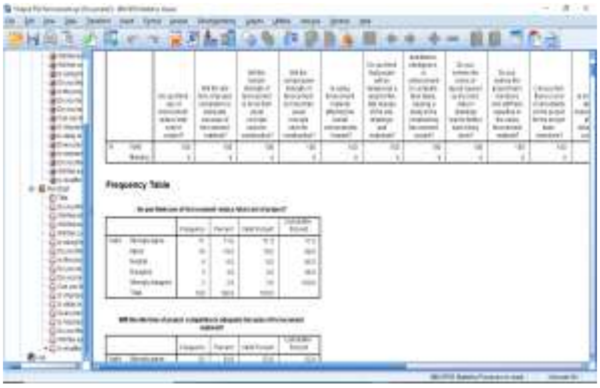

Fig.4: SPSS output window

Method RII (Relative Importance Index)

This study's sample size is quite modest. As a result, in order to generate meaningful results, the analysis merged all groups of respondents (clients, consultants, contractors, and regulatory boards).

Frequencies and the Relative Importance Index were used to analyze the data (RII). For data analysis in this project, the Relative Importance Index technique is applied.

This method is used to assess the relative impact of various factors influencing waste output on building sites. SPSS software was used to do the data analysis. The frequency (fi) of the response category index for the cause and effect components was calculated using SPSS. Using the frequency data for each response category provided by SPSS, the relative importance index (RII) for each element was determined.

The questionnaire was evaluated using a three-point likert scale ranging from 1 to 5, with 1 representing not at all, no, most of the time, and yes, and 5 meaning not at all, no, most of the time, and yes, respectively. The data was analyzed using a procedure to calculate the Relative Important Index (RII). The significance of several factors is ranked, and the Relative Importance Index is calculated (RII)

$$RII = \Sigma W / A * N$$

Where

W denotes the respondents' weighting of each component.

$$\sum W = 5 \times W5 + 4 \times W4 + 3 \times W_3 + 2 \times W_2 + 1 \times W_1$$

A represents the most significant weight (i.e. 5)

N is the total number of people who responded (N=100).

The relative importance of the components could be compared using these rankings. To offer an overall picture of the aspects of material management in the Indian construction industry, each specific cause RII perceived by all respondents should be used to assess the general and overall rankings.

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.

ACKNOWLEDGMENT

We express our sincere thanks to PG coordinator **Prof. U J Phatak** for his continuous support. We also thankful to our Head of Department of Civil **Dr. R. R. Sorate** For support

REFERENCES

[1]. Ferrocement Model Code, by IFS Committee 10-01 (2011) International Ferrocement Society, Asian Institute of Technology, Bangkok, Thailand.

[2]. Paul BK, Pama RP (2012) Ferrocement, International Ferrocement Information Centre, Publication No 149, AIT, Bangkok, Thailand.

[3]. Shah SP, Balaguru PN (1984) Ferrocement Concrete Design and Technology 2nd Edn,

Swamy RN, Surrey University Press, London, UK.

[4]. Kaushik SK (2014) Research and Development on Ferrocement. Asia Pacific Scenario, Proceedings Second Asia Pacific Symposium on Ferrocement, Roorkee, India.

[5]. Naaman AE (2016) Ferrocement and Thin Reinforced Cement Composites: Four Decades of Progress, Proceedings 8th International Symposium and Workshop on Ferrocement and Thin Reinforced Cement Composites. Bangkok, Thailand, February 6(8): 3-21.

[6]. Nervi PL (2016) Structures FW Dodge Co, New York, USA.

[7]. Hermosura NK, Austriaco LR Research on Ferrocement Housing Global Perspective. Journal of Ferrocement 24(1): 1-6.

[8]. Ramli M, Wahab I (2009) Ferrocement in Affordable Housing Construction: The Malaysian Experience. Journal of Ferrocement 24(1): 17-21.

[9]. Arif M, Akhtar, S, Masood A, Basit S, Garg M, et al. (2011) Flexural Behaviour of Fly ash Mortar Ferrocement Panels for Low Cost Housing. Journal of Ferrocement 31(2): 125-135.

[10]. Kaushik SK, Pankaj, Akhtar S, Arif M (2012) Experimental Investigations on Ferrocement Plates using Super plasticized Fly Ash Mortar. Journal of Ferrocement 32(2): 97-107.

[11]. Alexander D (1989) Factors Influencing the Durability of Ferrocement. Journal of Ferrocement 19(3): 215-222.

[12]. Masood A, Arif M, Akhtar S, Moyeen A (2003) Performance of Ferrocement Panels in Different Environments. Cement and Concrete Research 33: 555-562.

[13]. Akhtar S, Quraishi MA, Arif M (2009) Use of Chemical Corrosion Inhibitors for Protection of Metallic Fibre Reinforcement in Ferrocement Composites. Arabian Journal for Science and Engineering 34(2C): 107-113.

[14]. Akhtar S, Md Daniyal, Quraishi MA (2015) A Review of Corrosion Control Methods in Ferrocement. Journal of Steel Structures and Construction

[15]. Kavita V. Desai, Dr. Deepa A. Joshi Review on Ferrocement an effective alternative for construction industry, International journal of innovation in engineering and technology (IJIET) Volume 6 Issue 2, December 2015

[16]. 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

[17]. 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

[18]. 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

[19]. 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

[20]. Sridevi Kumarasamy, A. Sudhahar, D.L. Venkatesh Babu, R. Venatasubramani, Experimental and numerical analysis of Ferrocement RC composite, GRAĐEVINAR 69 (2017) 10, 915-921

[21]. WRD Handbook Chapter No. 1, Ferrocement Technology Maharashtra Engineering Research Institute, Nashik 422004, India

[22]. Journal of Ferrocement, ISSN-0121 17&9 Vol. 12, No. 3, July 1982

[23]. M.A. Saleem and M. Ashraf, Low Cost Earthquake Resistance Ferrocement Small House, Pak. J. Engg. & Appl. Sci Volume2, 2008

[24]. S.F. Ahmad, Sarosh H. Lodi, and Juneid Qureshi., " Shear Behaviour of ferrocement thin webbed sections ", Cement and Concrete Research, Vol. 25, No. 5, pp. 969-979, 1995

[25]. Chandra Sekhar Rao T, Gunneswara Rao T D, Ramana Rao N V and Ch Rambabu , "An Experimental Study on Ferrocement Box-Beams Under Flexural Loading", International Journal of Emerging Technology and Advanced Engineering, Vol. 2, No. 9, pp. 138-144, ISSN 2250-2459, 2012

Corresponding Author

Mr. Balaji Balshankar*

PG Student, M.E. (Civil Engineering), TSSM's, Padmabhooshan Vasantdada Patil Institute Technology, Pune