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"Low Cost Housing Structure Using Steel and Ferrocement."

Ms. Shital Nagesh Bahirwade[1]
Dr. Prashant M. Pawar[2]
Dr. M. G. Deshmukh[3]
Mr. Ravikiran P. Jadhav[4]
Ms. K. W. Deshmukh[5]
[1]SVERI's College of Engineering, Pandharpur
[2]SVERI's College of Engineering, Pandharpur
[3]SVERI's College of Engineering, Pandharpur
[4]SVERI's College of Engineering, Pandharpur
[5]SVERI's College of Engineering (Polytechnic) , Pandharpur

Abstract. The increasing demand for affordable housing has prompted the exploration of alternative construction materials and methods to reduce costs while maintaining structural integrity and durability. This research presents the development of a low-cost housing structure utilizing a combination of steel and ferrocement. Steel, known for its strength and flexibility, is used as the primary framework, while ferrocement is a composite material made of wire mesh, cement mortar, and other additives forms the outer shell and walls. In this project ferrocement is provided with steel angles are provided. The panels are constructed for checking punching shear strength of ferrocement with steel panels for further studies. The study aims to demonstrate the feasibility of this innovative construction method as a viable solution for low-cost, sustainable housing.

Key words- ***Steel, Ferrocement, wire mesh***

1 Introduction

Ferrocement is a composite material made of a thin, dense layer of cement mortar reinforced with a network of wire meshes, often made of steel, to improve its strength and durability. It is commonly used in construction for various applications such as water tanks, boats, roofing, and low-cost housing. The inclusion of steel meshes increases the material's tensile strength, making it more resistant to cracking and impact compared to traditional reinforced concrete. It combines the properties of thin sections and high strength of steel. In addition it needs no formwork or shuttering for casting. Ferrocement is a very well known construction material for its superior tensile strength along with its light weight characteristic. Due to the closely and uniformly placed steel wire meshes, ferrocement shows flexibility and a better cracking behavior as compared to conventional reinforced cement concrete material.

Ferrocement possess many advantageous properties such as strength, toughness, water tightness, lightness, durability, fire resistance, and environmental stability which cannot be matched by any other thin construction material. The ferrocement panels may be used as a precast element or cast in site depending on the need. The handling of the ferrocement panels are simple and don't require heavy machineries for erection.

In this project ferrocement is provided with steel angles are provided. Also chicken meshes are provided at two layers in panels. The steel angles are provided at every corner or joint in structure. The panels are constructed for checking punching shear strength of ferrocement with steel panels for further studies. In this project is carried to develop a detailed architectural and structural design for the housing units, considering the use of ferrocement for walls, roofs, and potentially floors. Conduct structural analysis to ensure the safety and stability of the buildings, incorporating steel angles and other reinforcement as necessary. Ferrocement, a composite material consisting of cement mortar and layers of mesh or metal reinforcement, offers several advantages, including its strength, durability, and cost-efficiency. When coupled with steel angles, which can provide structural support and stability, this construction, approach becomes particularly promising for creating affordable and resilient housing units.

2 Objectives

The objective includes the following:

1. To develop a process to formulate steel and ferrocement based panels.
2. To fabricate various configuration steel and ferrocement based panels.
3. To test the strength performance of panels for punching shear.
4. To develop the methodology proposed panel structure for low cost housing.

3 Literature Review

The following is a summery of the research on steel with ferrocement technology. The research gaps are then determined using the literature review. The research articles are as follows:

H. H. Haynes et.al [1] presented the objective of the study to develop a multipurpose ferrocement construction panel which would satisfy a wide range of military needs at advanced bases. The study consisted of selecting a versatile panel configuration and then determining the flexural load carrying behavior of the panel. Additional work was conducted to study the durability of the ferrocement material in a corrosive environment.

N.Venkata Ramana [2] Reviewed on Punching Shear Strength of Slabs Slab is one of the component or element in the residential or industrial buildings. Many times the slabs are subjected to uniformly distributed loads and this case may consider in the design process also. Point loads and varying loads are also seen for slabs in special cases. Among many type of loads due to point loads the slabs may subjected to flexure and shear.

Nemkumar Banthia et.al [3] has provided technical information on physical and mechanical properties, design criteria and testing of ferrocement. The objectives are to promote the most effective use of ferrocement in terrestrial structure, provide architects and engineers with the necessary tools to specify and use ferrocement.

K. Vetri Aadithiya & Dr. P. Chandrasekaran **[4]** The construction of sandwich concrete slabs is an emerging trend in the field of Civil Engineering, where a thick, low strength, lightweight core infill is encased by a thin high performance face sheet. These slabs are widely accepted due to their high strength-to-weight ratio, reduced weight, and good thermal insulation characteristics. This article reviews on journals which have considered .

Sumesh Jain & Dr. R. S. Sharma [5] has studied on ferrocement an affordable housing material for low cost housing. Affordable housing projects are characterized by an increasing demand mainly due to urbanization. The selection of building materials should meet the needs of local conditions to improve quality of life for the most needed ones by building new structures and/or by improving existing structures. Ferro cement as a construction material attracted considerable attention from research workers, field applicators and economists.

Yousry B. I. Shaheen [6] has presented structural behavior of ferrocement channels slabs for low cost housing. This paper presents a new pre cast U-shape ferrocement forms reinforced with various types of metallic and non-metallic mesh reinforcement. This research was de-signed to investigate the feasibility and effectiveness of employing various types of reinforcing meshes in the construction of structural slabs incorporating permanent U-shape ferrocement forms as a viable alternative for conventional reinforced concrete slabs.

Swaptik Chowdhury [7] has presented Prospects of Low Cost Housing in India The paper presents work on low-cost and sustainable alternative building materials having advantages on areas such as India where concrete or steel housing is expensive. The project addresses the challenges and stereotypes of using these materials as a structural component for low-cost housing and their same capacity for adaptation to the broad spectrum of factors—physical, ecological, social, economic and technical—through different products developed which can dictate the production of the construction environment.

Chetana Londhe [8] has presented Ferrocement: Cost Effective & Sustainable Construction Material for Low Cost Urban Housing in India. Lower-income groups in India faces issues such as low living standards, poverty, and a housing shortage. The high cost of obtaining good quality residential houses for people living in slum area is a major impediment. As a result, to improve their quality of life, an environmentally sustainable method of precast ferrocement can be used, as it has the potential to eliminate this cost barrier. The primary goal of this study is to examine the parameters of precast ferrocement wall panels in terms of economic approach, construction time, and sustainability.

Sumesh Jain [9] has presented Ferrocement an affordable housing material for low cost housing Affordable housing projects are characterized by an increasing demand mainly due to urbanization. The selection of building materials should meet the needs of local conditions to improve quality of life for the most needed ones by building new structures and/or by improving existing structures. Ferro cement as a construction material attracted considerable attention from research workers, field applicators and economists. Its property of improved homogeneity compared to R.C.C. and reduced thickness made it possible to employ the material as substitute to timber, steel and asbestos cement as material.

3.1 Summary

In the literature was carefully reviewed and important things were learned from those papers. From the above literature, Ferrocement or Ferrocrete is light weight and thin walled construction in which thin wire mesh is used. It also gives effective use of ferrocement in terrestrial structure, provide architects and engineers with the necessary tools to specify and use ferrocement. Ferro cement is ideally suited for thin wall structures as the uniform distribution and dispersion of reinforcement provide better cracking resistance, higher tensile strength to-weight ratio, ductility and impact resistance.

4 Methodology

4.1 To develop a process to formulate steel and ferrocement based panels:

In this objective formulating steel and ferrocement-based panels involves a multi-step process that combines materials, design considerations, and construction techniques to create durable and versatile building components. These panels are commonly used in construction for their strength, versatility, and resistance to environmental factors. In this project step-by-step explanation of how to develop a process for formulating steel and ferrocement-based panels is given.

It includes steps such as material selection, mix design, structural design, reinforcement design and manufacturing, etc. In mix design appropriate ratio of cement, aggregates, water, and any additives or admixtures. In structural design the structural requirements of the panels based on the intended applications are determined.

4.2 To fabricate various configuration steel and ferrocement based panels:-

In this fabricating various configuration steel and ferrocement-based panels involves the hands on manufacturing process of creating these panels with different shapes, sizes, and designs to meet specific architectural or structural requirements.

It include panel design, material preparation, panel casting, formwork preparation, panel casting, mixing and pouring, demolding, curing, etc. In panel design the panels are designed for structural layout, considering factors such as load-bearing capacity, flexibility, and specific application requirements. In panel casting mix the concrete according to the optimized mix design and pour it into the prepared formwork and place the steel reinforcement within the concrete mix, ensuring proper positioning according to the design.

4.3 To test the strength performance of panels for punching shear:-

In this objective testing the strength performance of panels for punching shear involves assessing their ability to resist shear forces, which can occur at the connections or support points of the panels. This type of testing is crucial for ensuring the safety and structural integrity of panels used in construction.

First it include defining test objectives, sample preparation, instrumentation, testing set up, load application, load monitoring, failure criteria, data collection, post-test examination, data analysis, etc. Clearly define the objectives of the punching shear test. Consider factors such as the intended use of the panels, design specifications, and applicable industry standards. Prepare panel samples that are representative of the actual panels used in construction by ensuring that the dimensions and reinforcement details match the design specifications. Install strain gauges, displacement transducers, and load cells at critical locations on the panel to measure deformations and loads during testing. Apply loads to the panel in a manner representative of the expected loading conditions. Collect data on applied loads, displacements, and strains throughout the test. Record the point of failure and any visible signs of distress in the panel. Analyze the collected data to determine the ultimate punching shear strength of the panel.

4.4 To develop the methodology proposed panel structure for low cost housing:-

Developing a methodology for a proposed panel structure for low-cost housing involves creating a systematic approach to designing, manufacturing, and constructing affordable and durable housing units. The objective is to optimize cost efficiency without compromising safety and quality. In this research a step-by-step explanation of how to develop such a methodology is given.

It includes various steps such as site analysis, structural design, material selection, cost estimation, fabrication process, construction, testing and quality control.

For low cost housing structure first analyze the characteristics of the target building site, including climate, soil conditions, and local building regulations. Then design the panel structure for adequate load-bearing capacity and stability. Optimize the use of materials to balance strength and cost. Choose cost-effective and locally available materials that meet the project requirements. Conduct a detailed cost estimation for the proposed panel structure, considering materials, labor, and construction processes. Then Develop a methodology for fabricating the panels, considering efficiency and scalability. Implement quality control measures during the fabrication process to ensure consistency. Develop a step-by-step construction methodology that is simple and can be executed by local labor with minimal skills.

5 Developing Model of Low Cost Housing

1. Design Phase

- **Site Selection and Analysis**: Identify the site, considering soil type, climate, and available resources. Plan the layout, incorporating light steel frames and ferrocement panels for walls, roofing, and flooring.


Fig 4.1 Site selection & layout

2. Materials

- **Steel**: Lightweight, prefabricated sections (strips & angles) for the frame.
- **Ferrocement**: A composite of cement, sand, water, and layers of wire mesh.
- **Other Materials**: Cement mortar (1:3 ratio of cement to sand), reinforcements, and connectors.


Fig 4.2 Materials

3. Steel Frame Construction

- **Fabrication**: Prefabricate the steel frame elements based on the design.
- **Structural Calculations**: Ensure the steel frame supports the expected loads, considering local building codes and safety

factors.

- **Assembly**: Assemble the steel framework on-site using welding. Ensure proper alignment and level using plumb lines and spirit levels.
- **Anchoring**: Fix the steel frame to the foundation using anchor bolts.

Fig 4.3 Steel frame construction

4. **Ferrocement Panel Preparation**

- **Mortar Application**: Mix cement mortar 1:3 ratio with a water-cement ratio of 0.45. Apply the mortar over the wire mesh uniformly, ensuring complete penetration.
- **Curing**: Cure the panels for at least 7–14 days to achieve proper strength.

Fig 4.4 Mortar application

5. **Roofing**

- Use ferrocement slabs or lightweight panels for roofing.
- Reinforce with additional chicken mesh necessary for longer spans.

6. **Finishing**

- Apply a waterproofing coat to the walls and roof.
- Add exterior plaster, paint.
- Install doors, windows, and utilities.

Fig 4.5 Finished work

6 Ferrocement panel with steel

The Ferrocement precast infill panels of size 1m X 1m. It consist of steel mesh of size 1m X 1m. The outer to outer dimensions of the proposed roofing system works out to be 1m X 1m. The reinforcement details along with slab cast are depicted in Figs.

1 and 2, respectively. Ferrocement panels, Cement mortar Mix (1:3 = Cement: sand) with water cement ratio of 0.45 (IS 13356:1992) is prepared.

Fig.6.1 Ferrocement panel using steel

Fig. 6.2 Mortaring

Fig.6.3 Ferrocement panel using steel

7 Result

Sample	Details	No of radial cracks	Average Crack Width (mm)	Ultimate punching load in N
Panel 1 with steel mesh	(100x100x8) CM	4	1.05	4624

Panel 2 with steel mesh	(100x100x8) CM	3	0.95	5110
Panel 3 without steel mesh	(100x100x8) CM	7	1.6	2622

8 Conclusion

Experimental conclusion of low cost housing using steel and ferrocement

- The average crack width in panels with steel mesh was notably smaller than in the panel without steel mesh. This indicates that steel mesh effectively mitigates crack propagation and limits crack width.
- The ultimate punching load for panels with steel mesh was higher (4624 N for Panel 1 and 5110 N for Panel 2) compared to the panel without steel mesh (2622 N).
- The inclusion of steel mesh enhanced the structural integrity, demonstrating its effectiveness in distributing stress and improving the overall durability of the panels.
- Incorporating steel mesh in concrete panels significantly improves their punching resistance, reduces crack propagation, and limits crack widths. This highlights the crucial role of reinforcement in enhancing the structural performance and durability of concrete elements under punching loads.
- Steel mesh reinforcement is recommended for applications requiring improved crack resistance and higher load-carrying capacities.
- Ferrocement reinforced with steel mesh offers an affordable, durable, and sustainable solution for low-cost housing. Its cost-effectiveness, ease of construction, and excellent structural performance make it a promising alternative for addressing the housing needs of low-income communities while promoting sustainability and resource efficiency.

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