Analysis of Ferro-Cement Insulation Sandwich Wall Pannel

Ujjval Pratap Singh[1], Govind Sharma[2], Anoop Kumar[3], Mr.Shakti Kumar[4]
[1, 2, 3] Dept of Civil Engineering
[4]Asst. Prof., Dept of Civil Engineering
[1, 2, 3, 4] Bansal Institute of Engineering and Technology Lucknow, India

Abstract- *Ferrocement is a thin composite construction comprised of a rich cement-based mortar mixture and a variety of wire meshes. Ferrocement is a versatile building material that is widely used in developing countries for real estate, sanitation, water resources, etc. This project's major goal is to design an affordable insulation-resistant residential construction system for both urban and rural growth. Ferrocement methods decreased structural load, cost, and time by at least 30% to 50%. Due of the locally accessible materials and the necessary labour, it is durable and affordable. Studying the impact on samples cast using single and double layers of welded mesh is the major goal of this investigation. Ferrocement has various design attributes, including flexural strength, split resistance, tiredness resistance, toughness, and affect resistance. It is a highly flexible material. It is assessed how much energy will be needed to maintain the structure using the existing construction method and the suggested ferrocement construction approach. Conclusion: The current approach (ferrocement green spaces-housing system) is capable of creating homes that are incredibly energy efficient.*

Keywords- cement, sand .stone dust, wire mesh, light weight, thermocol

I. INTRODUCTION

Urban development is a significant energy consumer, or another way to put it is that it is a fundamental cause of environmental pollution. As a result, it is important to understand the relationship between various elements, including building materials made of natural and manufactured materials, renewable energy sources, and depleted energy sources. Since the 3Rs (reduce, reuse, and recycle) are the foundation of any green building, ferro-cement sandwich wall panels should be used. Steel and cement are combined to form ferrocement, or ferro-cement mortar. Ferrocement is a type of thin-walled reinforced concrete building where Portland cement mortar is used in place of concrete and small-diameter wire meshes are employed uniformly across the cross section rather than discretely placed reinforcing bars. Wire-meshes are filled with cement mortar in ferrocement. It is a composite made of densely woven wire mesh, tightly twisted steel skeletons, and rich cement mortar. Ferrocement may be used to create a range of structural components, including shells, walls, floors, roofs, and foundations. They feature a high level of impermeability, thin walls, low weight, and durability.

The impacts of climate change are being felt in every corner of the planet. With 280 heat wave days across 16 states in 2022, India had the highest in a decade [8]. From tropical to moderate to alpine in the south, India has an astounding variety of climatic zones. According to the Indian Meteorological Department, the country's yearly average temperature has risen by 0.56 degrees and will keep rising.After a long day at work, a man needs a suitable thermal environment to regain energy. The first variable and most significant environmental component affecting human comfort is air temperature.[1-5]

The horizontal surface of a structure that enables interaction between indoor and outdoor areas and receives the highest amount of solar radiation is the roof. The comfort range for the temperature of the room is 26°C to 32.5°C, while the relative humidity range is from 17.5% to 92.5%, according to field study carried out at Lucknow, India [6-7]. By using thermal protection techniques, an inert environment may be created that is both healthful and energy-efficient. Ferrocement is a desirable roofing material. It is necessary to provide insulation from heat in buildings because it has a stronger resilience to thermally induced stresses than other materials such cellular concrete and hollow blocks.[7-10]

II. MATERIAL USE

A. Cement-

As cement is a generic term, it may be used to describe any substance. There are several varieties of cements that are used in the construction and building fields or to solve certain problems. Portland cements make up the most bulk of the concrete used today, despite the fact that the molecular structure of these cements can vary considerably.

[10-12]

Fig.1 Cement (PPC)

Fig.2 Standard Consistency & Setting time

Table No. 1. Properties Portland pozzolana cement (PPC).

S no.	Characteristics	Value
1.	Specific gravity	3.3
2.	Standard consistency	32%
3.	Initial setting time	75 minutes
4.	Final setting time	250 minutes
5.	Fineness	6.5 %

B Fine Aggregate-

SAND-; The best place to find sand is in riverbeds. It should be devoid of organic material and other harmful elements, and silt and clay should be present in very small amounts. By employing a well-graded, rounded, natural sand, consistency and compaction are effectively increased.

STONE DUST-; The finest kind of aggregate is called stone dust. Usually, crushed stone produces it as a byproduct. The difficulty you might have purchasing it is really partially caused by this mistake. Calculating how much water is needed should take the aggregate's moisture content into account.[12-15]

Fig.3 Stone dust

Table No. 2 Properties of Stone Dust

S.NO.	PROPERTIES	OBTAINED
1	Fineness Modulus	2.60
2	Specific gravity	2.40

C Water-:

The pH level of the mixing water should be near to 7.0; salt water is not suitable, but disinfected drinking water will suffice. It should be uncontaminated with organic debris, silt, oil, sugar, chlorides, and acidic elements.

Fig .3 water

D. INSULATION MATERIAL (Thermocol) –:

It is a flexible styrene material that can take on a variety of forms. It is created by the chemical styrene, which also gives rise to the synthetic thermocol polymer known as polystyrene. It acts as an insulator for heat.

Fig. 4 thermocol

E. Wire Mesh-:

Following the removal of the aperture, the mesh was cut in line with the measurement. Steel wire meshes are assumed to be the primary mesh reinforcement. This comprises meshes that are square welded or woven.[16-19]

Fig. 5 wire mesh

III. SCOPE & OBJECTIVE

Ferro cement is a lightweight, strong composite material that may replace heavier materials in structural components. The findings of this study will encourage the usage of the unique approach for manufacturing lighter composites wall components. The research is undeniably a step in the right approach towards manufacturing high-quality products.

The research is virtually experimental in character. The current study focuses on the creation of an optimal, high workability, and high performance mortar that can be poured during the casting of ferrocement skin boxes over the aerated concrete in a single operation. The mortar's performance was evaluated in terms of compressive strength, strength development, water absorption, and unit weight. In order to identify the optimum curing regimes for sandwich specimens, samples were cured in three curing regimes: water, air, and natural weather. The use of slag as a cement alternative in mortar to save costs is also considered.

IV. CASTING OF SPECIMENS

Before casting specimens, we must first prepare the mould to the necessary form and size. Moulds are constructed from 12mm thick plywood with the assistance of external supports. For the preparation of cement mortar, each item was weighed, and 20% additional was added to account for loss and shrinking of the mortar. For mixing the components, a mixer machine is used; the mixer is cleaned beforehand and maintained moist in order to prevent the absorption of water supplied to the concrete. The mixer will be filled with fine aggregate (fine sand and stone dust) first, followed by cement. The water is then progressively added to get a consistent mix. The final cement mortar has a consistent look.

The mortar is then transferred to the moulds. The initial layer of mortar was poured with a trowel up to one-eighth (1/8) of the thickness necessary, i.e. 20mm, for the casting of wall panels. The steel mesh was then installed, followed by another layer of cement (15mm thickness) on top. A thermocol layer of 80 mm thickness is put between the mortar for insulation purposes. This was done to ensure that the steel mesh was evenly distributed across the mortar layers.

Fig. 6 Costing of sample

Finally, the levelled surface is polished equally so that no water collects in any one place of the wall panel. After 24 hours after casting, the sample is immersed in a water container for 28 days. As a result, the exposed layer is kept from drying off. These are wetted on a regular basis. During the curing process, the surface of the panel cannot remain dry even for a brief length of time.

Following the curing time, specimens are gently transferred without causing any damage to be tested on a loading frame.

Fig. 7 Sandwich panel

V. EXPERIMENTAL WORK AND RESULTS

The panel, which measured 700x150x150 mm, was subjected to compression and flexural testing.[5]The tests were carried out in compliance with the rules established by the Bureau of Indian Standards. The panel's compressive and tensile strength tests were performed at 7 and 28 days after curing.

Mix Proportion-

The mortar mix percentage ranges for ferrocement use are 1 : 4 sand/cement ratio by weight and 0.30 to 0.5 water-cement ratio by weight. The amount of water utilised should be as little as possible while yet being compatible. To guarantee adequate penetration, well-graded, rounded natural sand and stone dust with a maximum top size roughly one-third the smallest gap in the wire mesh system is typically used. Sand going through a 1.16 mm sieve has produced good results in a variety of practical applications. The blend should be as stiff as possible while yet allowing complete mesh penetration.

Various Tested Done on Sandwich Panels Determine its Properties

- Water Absorption Test
- Density Test
- Compressive Strength Test
- Flexural Strength Test
- Rebound Hammer Test

Water Absorption Test-

A water absorption test is performed to assess how much water is absorbed under certain situations. Water absorption is affected by factors such as the kind of plastic used, the additives utilised, the temperature, and the period of exposure. The data gives light on the materials' performance in wet or humid settings.

Percent Water Absorption = [(Wet weight - Dry weight)/ Dry weight] x 100

Table No. 3 water absorption test.

Panel no.	Wet weight (kg)	Dry weight (kg)	Water absorption (%)
1.	25.69	24.30	5.72
2.	26.40	24.74	6.70
3.	25.32	24.50	3.35

Density (Unit Weight) Test-

The term "unit weight" or "density" refers to the weight of an item per unit volume. When expressed in terms of weight (KN/m3), it is normally referred to as density, while when expressed in terms of mass (kg/m3), it is typically referred to as density.

Density (kg/m3) = Mass (kg) / Volume (m3)
Volume = 0.700×0.150×0.150
$=1.57\times10^{-2}$ m3

Table No. 4. Density of panel.

Panel no.	Weight of panel (kg)	Volume of panel (m^3)	Unit weight (kg/m^3)
1.	24.34	1.57×10^{-2}	1545.40
2.	24.74	1.57×10^{-2}	1575.80
3.	24.50	1.57×10^{-2}	1560.50

Compressive Strenth Test-

Rebound Hammer Test,The rebound hammer test is a non-destructive mortar test that provides a practical and quick assessment of the compressive strength of the cement mortar .

Fig. 8 Rebound hammer test

Table No. 5. Rebound hammer test.

Panel no	Compressive strength after 7 days (N/mm^2)	Compressive strength after 28 days (N/mm2)
1.	10.50	18.75
2.	12.25	19.00
3.	13.0	17.50

Table No. 6. Compressive strength of Sample at 28 days.

Panel no.	Size	Load at failure (KN)	Comp. strength ($N\backslash mm^2$)
1.	700×150×150	20.465	22.669
2.	700×150×150	23.200	26.038
3.	700×150×150	27.295	30.634

Flexural Strength Test-

Panels were taken from water after 28 days. To be clear, a white wash was added to the evidence of fissures caused by bending under service stress on the panel. Panels were tested for flexibility using a universal testing equipment. Panels were put on supports with a 50 mm gap at both ends. As indicated, a two-point loading system is mounted 150 mm from the centre. At the bottom of each panel, a dial gauge is used to record the deviation in mm at each loading stage [21].The panel was loaded in two points to calculate flexural strength, and the load and deflection were meticulously recorded. The flexural strength was calculated using the equation shown below.

$$F = PL/(bd2)$$

Where;

F = Flexural strength of sample in (Mpa)
P = Failure load in (N)
L = Effective span of panel (700)
B = Breadth of the panel (150)
D = Depth of the panel (150)

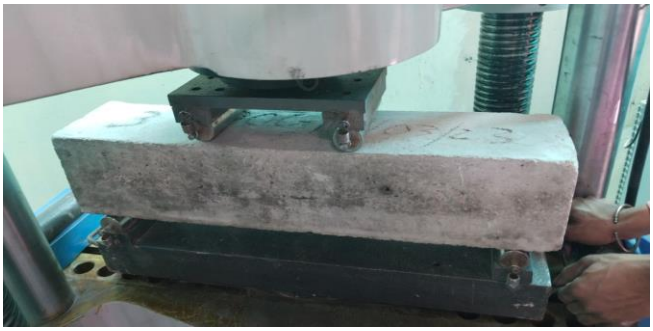

Fig. 9 Flexural test

Table No 7. Flexural strength of panels

Panel no.	Braking load (KN)	Deflection (mm)	Flexural Strenth (N/m^2)
1.	20.465	20.06	3.6
2.	23.200	13.07	4.0
3.	27.295	10.72	4.7

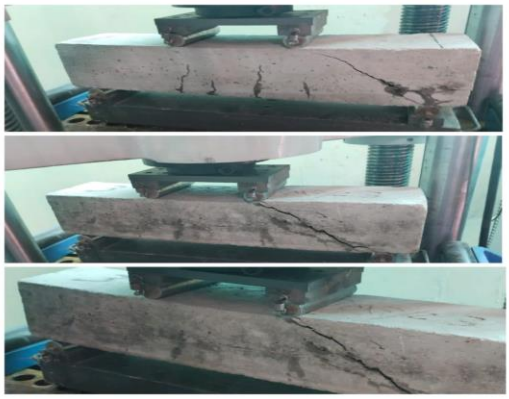

Fig . 10 Braking point of sample

Fig. 11 Dimension Measurement

VI. CONCLUSION

The paper focuses on the qualities of sandwich wall panels. The use of a thermal insulation center with metallic wire layers improves the properties of prefabricated wall panels. Based on the trial results, the following conclusions may be drawn:

- Panels, although exceptionally strong and lightweight, are perfect for a wide variety of building applications as compared to alternative construction methods;
- This minimises the cost and greatly shortens the creation time. In the creation of new low energy, low cost, environmentally and economically sustainable housing sandwich wall panel is the best product for re-housing and the development of industrial construction in the twenty-first century.
- It has been discovered that installing as part of construction panels allows for high levels of thermal efficiency. When compared to previous approaches, this technology consumes less energy in heating loads.
- Because the conventional way of producing brick or stone masonry is more labor-intensive, the difficult sandwich wall proved to be more expensive than the technology-based sandwich wall. Sandwich wall panels proven to be a low-cost construction method. Ferrocement might be a viable alternative to RCC in basic lighting construction.

REFERENCES

[1] Joel Bernstein, "Ferrocement: Application in Developing Countries, National Academy of Science, Washington D.C. Feb 1973, pp 40-45.

[2] M.Saleem, "Flexural Behavior of Ferrocement Sandwich panels", Cement Concrete Composites, Jan-1991pp 21-28.

[3] A .E. Naaman, "Bending behavior of mortar reinforced with steel meshes and Polymeric fibers", Cement and Concrete Composites, 1995 pp-327-338.

[4] ACI Committee 549, "State-of-the-Art Report on Ferrocement", ACI 549R-97, American Concrete Institute, 1997pp 24.

[5] ACI Committee 549, "Guide for the Design, Construction and Repair of Ferrocement", ACI 549.1R-93, American Concrete Institute, 1999pp 27

[6] P.Paramasivam, " Ferrocement structural applications", 26th conference on Our World in Concrete and Structures at Singapore, on August 27-28, 2001, pp 99-107.

[7] S.Wang "Bending response of hybrid ferrocement plates with meshes and fibers" Journal of Ferrocement, Vol-34, Jan-2004, pp 275-287.

[8] M.Jamal Shannag "Flexural response of Ferrocement with fibrous Cementitious Matrices" Construction and Building materials, 2007 pp 1198-1205.

[9] A. Saleem, "Low Cost Earthquake Resistant Ferrocement Small House", Pak. J. Engg. & Appl. Sci. Vol. 2 Jan 2008, pp 59-63.

[10] P.B.Sakthivel, "Ferrocement construction technology and its application-A Review", The International Conference on Structural Engineering ,Construction and Management at Kandy, Sri Lanka on December 15-17,2011, pp 2-12.

[11] R.Thenmozi "An Experimental investigation on the flexural behavior of scc ferrocement slabs incorporating fibers" IJEJT, Vol-4 May-2012, pp 2146-2157.

[12] A. Jagannathan "Study of flexural behavior of ferrocement slab reinforced with PVC coated weld mesh" IJERD, Vol-1, July-2012, pp 50-57.

[13] S. K. Patra, "Ferrocement – A Review'', IJERT Vol. 2 Issue 10, October – 2013, pp 562-565.

[14] V. Halhalli, "Shear and Flexural Behavior of Ferro Cement Deep Beams'', IJRET Nov- 2013, pp 85-90.

[15] R. Phalke "Flexural Behaviour of Ferrocement Slab panels using welded square mesh by incorporating steel fibers" IJRET,Vol-3,May-2014,pp 756-763.

[16] da Silva, A. R. C., Proença, S. P. B., Billardon, R., Hild, F. "A Probabil istic Approach to Predict Cracking in Lightly Reinforced Microconcrete Panels". Journal of Engineering Mechanics, 130(8), pp. 931–941, 2004 https://doi.org/10.1061/(ASCE)0733-9399(2004)130:8(931)

[17] Kaushik, S. K., Gupta,V. K., Anuj, S. K. "Behavior and Performance of Composite Ferrocement Brick Reinforced Slabs". Journal of Ferroce ment, 21, pp. 215–222. 1991. Review of Research on the Application of Ferrocement in Composite Precast Slabs 2018 62 4 1037

[18] Naaman, A. E. "Ferrocement and Thin Fiber Reinforced Cement Com posites: Looking Back, Looking Aheade". In: Seventh International Sym posium on Ferrocement and Thin Reinforced Cement Composites. pp. 3–16. Singapore. 2001.

[19] Paul, B. K., Parma, P. R. "Ferrocement". International Ferrocement Info Center, Bangkok: 1978.

[20] Swamy, R. N. "New Reinforced Concretes". Blackie, London. 1984.

[21] Chithambaram, S. J., Kumar, S. "Flexural behaviour of bamboo based ferrocement slab panels with flyash". Construction and Building Materi als, 134, pp. 641–648. 2017. https://doi.org/10.1016/j.conbuildmat.2016.12.205

[22] Yardim, Y., Waleed, A. M. T., Jaafar, M. S., Laseima, S. "AAC-concrete light weight precast composite floor

slab". Construction and Building Materials, 40, pp. 405–410.2013.https://doi.org/10.1016/j.conbuildmat.2012.10.011

[23] Yerramala, A., Ramachandurdu, C., Desai, V. B. "Flexural strength of me takaolin ferrocement". Composites Part B: Engineering, 55, pp. 176–183. 2013. https://doi.org/10.1016/j.compositesb.2013.06.029

[24] Greepala, V., Nimityongskul, P. "Structural integrity of ferrocement pan els exposed to fire". Cement and Concrete Composites, 30(5), pp. 419–430. 2008. https://doi.org/10.1016/j.cemconcomp.2007.08.007

[25] Pama, R. P., Intaragumhaeng V, P. B. "Study of Tensile cracks and bond slip in ferrocement". Ferrocement materials and applications, SP-61, pp. 43–79. Detroit. 1979.

[26] Lilia, R.-A. "Evolution of Ferrocement". In: Seventh International Sym posium on Ferrocement and Thin Reinforced Cement Composites. Singa pore. 2001.

[27] Naaman, A. E. "Ferrocement and laminated cementitious composites". Materials and Structures, 33(2), pp. CO3-CO3. 2000. https://doi.org/10.1007/BF02484171

[28] Huq, S., Pama, S. R. "Ferrocement in Tension: Analysis and Design". Journal of Ferrocement, 8(3), pp. 143–167. 1978.

[29] Naaman, A. E. "Design Predictions of Crack Width in Ferrocement". Ferrocement-Materials and Applications, 61, pp. 25–42. 1979.

[30] de Robinson, J. R. Cours de Beton Arme –de I'Ecole nationale des ponts et Chaussess. Paris, Dunod. 1964.

[31] Akhtaruzzaman, A. K. M., Pama, R. P. "Cracking Behavior of Ferroce ment in Tension". Journal of Ferrocement, 19, pp. 101–108. 1989.

[32] Yardim, Y., Lalaj, O. "Shear strengthening of unreinforced masonry wall with different fiber reinforced mortar jacketing". Construction and Build ing Materials, 102(Part 1), pp. 149–154. 2016. https://doi.org/10.1016/j.conbuildmat.2015.10.095

[33] Nguyen, H. T., Thanh, N. H. "The Water-Demand And Gap-Volume Of Aggrgate For Ferrocement". Periodica Polytechnica Civil Engineering, 33(1–2), pp. 85–106. 1989.

[34] Rao, A. K., Gowdar, C. S. K. "A Study of Behaviour of Ferrocement in Direct Compression". Cement and Concrete,10, pp. 231–237. 1969.

[35] Rao. P. K. "Stress-Strain Behavior of Ferrocement Elements under Com pression". Journal of Ferrocement, 22(4), pp. 343–352. 1992.

[36] Arifa, M., Pankaj, Kaushik, S. K. "Mechanical behaviour of ferrocement composites: An experimental investigation". Cement and Concrete Com posites, 21(4), pp. 301–312. 1999. https://doi.org/10.1016/S0958-9465(99)00011-6

[37] Logan, D., Shaw, S. P. "Moment Capacity and Cracking Behavior of Fer rocement in Flexure". ACI Journal Proceedings, 70(12), pp. 799–804. 1973. https://doi.org/10.14359/7137

[38] Kumar, S. G. V., Sharma, P. C. "Investigation of the Ultimate and First Crack Strengths of Ferrocement in Flexure". Indian Concrete Journal,