Flexural performance of ferrocement based on sustainable high-performance mortar

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Abstract— **These characteristics can be affected by the materials used, the composition of the mix, the degree of mechanical bond between the plaster and the supporting surface, and the quality of the work. Ferro cement is now growing demand as a building material. Ferro-cement is made from a variety of silicon and aluminum-rich components, including fly ash, rice husk ash, silica fume, metakaolin and blast furnace slag. Using ferro-cement mortar lowers pollution since less CO2 is discharged into the atmosphere. The behaviour of eco-friendly high-performance mortar (HPM), which is used to make ferrocement, will be investigated in this study. This study will examine how different percentages (0%-15%) of silica fume (SF) mortar and metakaolin (MK) mortar with natural sisal fibres (NSF) behave. It will also test-cast a cube with dimensions of 50 X 50 X 50 mm and test its compressive strength and durability. The negative impact of silica fume (SF) on workability is lessened and mechanical performance is improved when metakaolin (MK) and SF are used with cement in mortar as a partial replacement for the cement. The mortar performs best at age 28 when mixture of 5–10%SF and 10%MK is used.**

Keyword: silica fume, metakaolin, ferrocement mortar, natural sisal fibres.

I. INTRODUCTION

Natural resources like sand, gravel, crushed stone, etc. are extensively used by the construction industry as building materials. The majority (more than 70%) of the concrete matrix is made up of fine aggregate, which is its primary component. Due to the widespread usage of concrete, mortar, and plastering materials, there is an extremely high demand for natural sand on a global scale. The need for alternative supplies of fine aggregate, particularly those located close to major metropolitan areas, has been prompted by the environmental restrictions on mining riverbed sand. The price of natural sand, which is used as a fine aggregate in concrete, has fluctuated over the previous ten years, driving up construction costs. In this case, research was started on a reasonably priced and widely accessible substitute for natural sand. Sand-cement plaster is widely used in the construction industry as a decorative or protective coating on concrete and masonry walls and concrete ceilings.

A composite substance called traditional cement mortar is created by combining water, fine aggregate, and cement. The physical characteristics of mortar in its fresh condition, such as particle size distribution, specific gravity, shape, and surface roughness, have a considerable impact on its varied properties. In general, it has been discovered that aggregates' properties in the hardened state are influenced by their mineralogical composition, modulus of elasticity, toughness, and degree of alteration. The authorities have outlawed sand mining due to the negative repercussions and ecological imbalance caused by the removal of sand from riverbeds. This caused the cost of natural sand to soar. In these conditions, finding a suitable substitute for natural river sand that won't compromise the mortar's strength and durability is crucial to promoting infrastructure expansion and environmental protection.

A) Ferrocement

A building material called ferrocement is made of cement mortar and wire mesh. Due to its low dead weight, lack of trained labour, absence of necessity for a frame, etc., ferro cement is widely used in the construction sector. It was created in 1940 by Italian architect P.L.Nervi. Because the components are designed for machine adjustment and the construction site execution time is reduced, the quality of ferrocement is ensured. Low maintenance costs. Only in the past two decades has this material become widely used in the construction sector.

- A thin reinforced concrete structure with a large number of tiny diameter wire mesh evenly distributed over the entire cross-section.
- The mesh can be made of metal or any suitable material.

- It is a very versatile type of reinforced concrete.
- Instead of using concrete, Portland cement mortar is employed; the strength of the structure depends on the quality of the sand/cement mortar mix and the quantity of reinforcing materials used.

B) Natural sisal fibers (NSF)

Due to their superior mechanical qualities, wide availability, environmental friendliness, and significant processing benefits, natural fibres are becoming more and more essential in composite materials. Natural fibres are stronger, more affordable, renewable, and eco-friendly. However, the environmental circumstances in which they are generated, as well as extraction and processing methods, have an impact on the qualities of natural fibres, which results in the unpredictable nature of their mechanical properties. Such diversity must be assessed to accurately forecast fibre qualities if natural fibres are to replace synthetic fibres. The tensile behaviour of sisal and other natural fibres has already been the subject of investigations by a number of researchers. Jain et al. studied the tensile behaviour of a composite made of calibrated-length coir fibres

Fig 1 Natural sisal fibers (NSF)

C) Silica fume

Microsilica, commonly referred to as silica fume, is an amorphous (non-crystalline) form of silicon dioxide, generally known as silica. It is an ultrafine powder with an average particle diameter of 150 nm that is gathered as a waste product from the manufacturing of silicon and ferrosilicon alloy. Pozzolanic material is the primary application area for high-quality concrete. It can occasionally be mistaken for fumed silica. However, compared to silica fume, fumed silica is manufactured differently, has distinct particle characteristics, and is employed in different applications.

Fig 2 Silica fume

D) Metakaolin

The calcined anhydrous form of the clay mineral kaolinite is known as metakaolin. Minerals high in kaolinite are referred to as kaolin or kaolin, and they have historically been used to make porcelain. Metakaolin's particles are not as fine as silica fume, but they are smaller than cement's. The characteristics of the raw material are a major determinant of the metakaolin's quality and reactivity

Fig 3 Metakaolin

II. PROBLEM STATEMENT

The Plain Concrete Mortar with Normal Sisal Strands (NSF), Silica Rage, and Metakaolin was put through an exploratory evaluation to see if it was adequate and reliable in the climatic conditions of India. For the present assessment, three distinctive products from leading market producers were compared to a control mortar. It was them,

- Blend A: Plain mortor
- Blend B: mortor - silica Flume
- Blend C: mortor - metakaolin
- Blend D: mortor - silica Flume + sisal
- Blend E: mortor - metakaolin + sisal.

Table 1 Mix Proportion for Silica Fume (SF) Mortar

No of Trials	Cement (Kg/m3)	Sand (Kg/m3)	% SF	SF (Kg/m3)
1	478.8	1620	0%	0
2	466.83	1620	2.5%	11.97
3	454.86	1620	5%	23.94
4	442.89	1620	7.5%	35.91
5	430.92	1620	10%	47.88
6	406.98	1620	15%	71.82

Table 2 Mix Proportion for Metakaolin (MK) Mortar

No of Trials	Cement (Kg/m3)	Sand (Kg/m3)	% SF	SF (Kg/m3)
1	478.8	1620	0%	0
2	466.83	1620	2.5%	11.97
3	454.86	1620	5%	23.94
4	442.89	1620	7.5%	35.91
5	430.92	1620	10%	47.88
6	406.98	1620	15%	71.82

III. RESULTS AND DISCUSSION

A. Mechanical tests Results For Silica Fume (SF) Mortar

Table 3 Results for Density of Cube (N/mm2)

Compressive Strength (Mpa) Density of Mortar Cube (Silica Fume (SF) Mortar)			
SF	3 DAYS	7 DAYS	28 DAYS
SF - 0%	10.48	14.07	22.28
SF- 2.5%	10.74	14.42	22.83
SF- 5%	11.00	14.77	23.39
SF- 7.5%	11.27	15.14	23.97
SF- 10%	11.55	15.51	24.56
SF- 15%	10.98	14.74	23.34

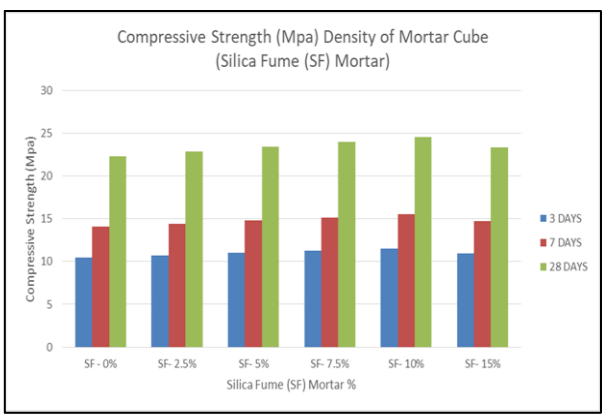

Fig 4 Results for Density of Cube (N/mm2)

The findings for cube density with 3 days, 7 days, and 28 days of curing for the substitution of silica fume (SF) mortar with 0%, 2.5%, 5%, 7.5%, 10%, and 15% are shown in the following graph. The findings demonstrate that silica fume (SF) replacement at 5% and 10% yields superior results to replacement at 15%.

B. Mechanical tests Results for Metakaolin (MK)

Table 4 Results for Density of Cube (N/mm2)

Compressive Strength (Mpa) Density of Mortar Cube Metakaolin (MK)			
MK	3 DAYS	7 DAYS	28 DAYS
MK - 0%	9.64	12.94	20.50
MK- 2.5%	9.88	13.26	21.01
MK- 5%	10.12	13.59	21.52
MK-7.5%	10.37	13.93	22.06
MK- 10%	10.63	14.27	22.60
MK- 15%	10.10	13.56	21.47

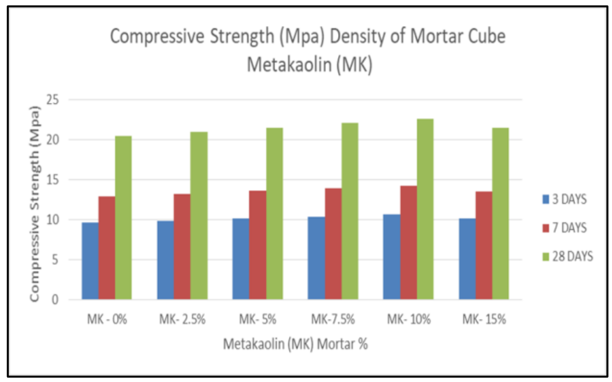

Fig 5 Results for Density of Cube (N/mm2)

The graph up top displays the density of the cube after 3 days, 7 days, and 28 days of curing when Metakaolin (MK) mortar was substituted with 0%, 2.5%, 5%, 7.5%, 10%, and 15%. The findings demonstrate that replacing Metakaolin (MK) at 10% has superior effects to replacing it at 5% and 15%. However, silica fume (SF) replacement is reduced by 2-5%.

C. Mechanical tests Results For Silica Fume (SF) Mortar with natural sisal fibers (NSF)

After reviewing the substitute When silica fume (SF) and natural sisal fibres (NSF) were added to mortar, each specimen's compressive strength was measured. The results are as follows.

Table 5 Results for Density of Cube (N/mm2)

Compressive Strength (Mpa) Density of Mortar Cube (Silica Fume (SF) Mortar) with natural sisal fibers (NSF) 0.5%			
SF +(NSF) 0.5%	3 DAYS	7 DAYS	28 DAYS
SF - 0%+(NSF) 0.5%	12.05	16.18	25.62
SF- 5%+(NSF) 0.5%	12.65	16.99	26.90
SF- 10%+(NSF) 0.5%	13.28	17.84	28.24
SF- 15%+(NSF) 0.5%	12.63	16.95	26.84

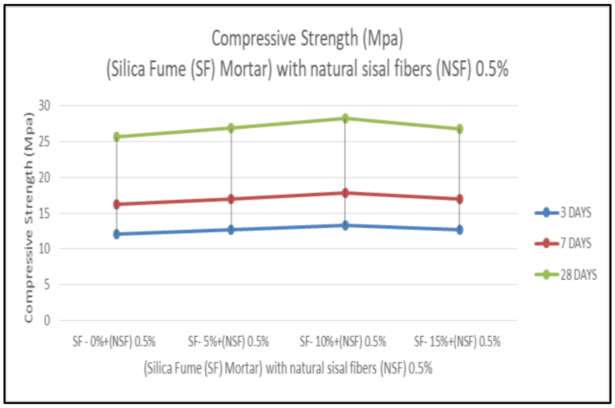

Fig 6 Results for Density of Cube (N/mm2)

The results of replacing silica fume (SF) mortar with natural sisal fibres (NSF) 0.5% after 3 days, 7 days, and 28 days of curing are shown in the graph above for the density of the cube. The findings demonstrate that adding 0.5% of natural sisal fibres (NSF) to mortar that already contains silica fume (SF) improves each replacement of mortar by 15%

D) Mechanical tests Results for Metakaolin (MK) with natural sisal fibers (NSF

The results of analyzing the compressive strength of the cube after adding 0.5% of natural sisal fibres to the mortar to replace the metakaolin (MK) are as follows

Table 6 Results for Density of Cube (N/mm2)

Compressive Strength (Mpa) Density of Mortar Cube Metakaolin (MK) + natural sisal fibers (NSF) 0.5%			
MK+(NSF) 0.5%	3 DAYS	7 DAYS	28 DAYS
MK - 0%+(NSF) 0.5%	11.182	15.010	23.780
MK- 5%+(NSF) 0.5%	11.739	15.764	24.963
MK- 10%+(NSF) 0.5%	12.331	16.553	26.216
MK- 15%+(NSF) 0.5%	11.716	15.730	24.905

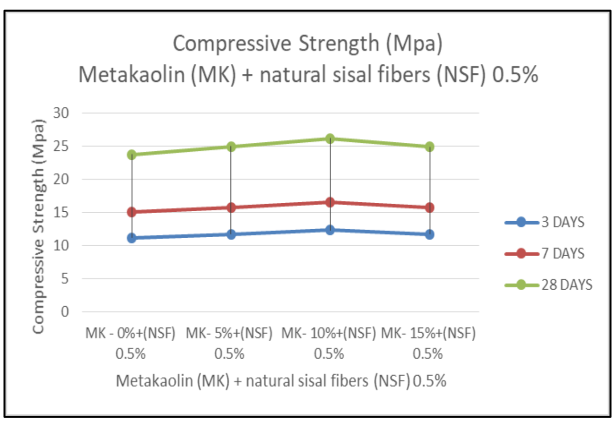

Fig 7 Results for Density of Cube (N/mm2)

The graph above displays the density of the cube after 3 days, 7 days, and 28 days of curing when Metakaolin (MK) mortar was substituted with 0%, 5%, 10%, and 15%) of natural sisal fibres (NSF). The findings demonstrate that adding 0.5% of natural sisal fibres (NSF) to Metakaolin (MK) mortar improves each mortar replacement by 16% as compared to using only Metakaolin (MK).

IV. CONCLUSION

- Ferrocement has undergone significant development over the past three decades and is now a very sophisticated building material in terms of manufacture and design. For emergency shelters and low-cost housing in disaster-affected cities, the construction method utilising ferrocement is highly helpful in terms of cost reduction and environmental impact.
- This research studied the behavior of eco-friendly high-performance mortar (HPM) that is used for producing ferrocement.
- The Mixture of metakaolin (MK) and silica fume (SF) in mortar as a partial replacement of cement gave better effect of SF on workability, enhance the mechanical performance compared with the SF or MK.
- The use of mixture 5-10%SF and 10 %MK gives the mortar the best performance at age 28 days.
- The inclusion of natural sisal fiber in High performance mortar (HPM) slightly increases the compressive strength.

REFRENCE

[1] *S F A Rafeeqi "Performance Of Ferrocement As Flexural Strengthening In Rural Areas" October 2012*

[2] *Eethar Thanon Dawood "Flexural performance of ferrocement based on sustainable high-performance mortar" case studies in construction materials (dec 2021)*

[3] *Amjad Masood et. al. "Performance of ferrocement panels in different environments" April 2003*

[4] *Malathy Ramalingam et. al. "Flexural Performance and Microstructural Studies of Trough-Shaped Geopolymer Ferrocement Panels" MDPI August 2022*

[5] *Hamid Souzandeh "Study and Characterization of Sisal Fiber/Zein Resin Interface" Fiber Science and Apparel Design, Cornell University*

[6] *Jian-Tong Ding "Effects of metakaolin and silica fume on properties of concrete" July 2002*

[7] *Daman K.Panesar et. al. "Supplementary cementing materials" science direct 2019*

[8] *M.Glavind "Sustainability of cement, concrete and cement replacement materials in construction"*

[9] *Balaji Balshankar et. al. "Recent Ferrocement Construction Technology in Sustainable Construction" Ignited Minds Journals Apr, 2022*

[10] *Marek, C. R. "Importance of fine aggregate shape and grading on properties of concrete", ICAR 3rd annual symposium, 1995.*

[11] *Persson, A.L. "Image analysis of shape and size of fine aggregates", Engineering Geology, Vol. 50, pp. 177-186, 1998.*

[12] *Garboczi, E. J., Martys, N. S., Saleh, H. and Livingston, R. "Acquiring, Analyzing, and Using Complete Three-Dimensional Aggregate Shape Information", ICAR 9th Annual Symposium, 2001.*

[13] *Kim, H, Haas, C. T, Rauch A. F. and Browne, C. "A Prototype Laser Scanner for Characterizing Size and Shape Parameters in Aggregates", ICAR 9th Annual Symposium, 2001.*

[14] *Pedro Quiroga, N. Namshik Ahn and David Fowler, W. "Concrete Mixtures with High Microfines", ACI Materials Journal, pp. 103-108, 2006.*

[15] *Gerry Huber and Bob McGennis "How to Increase Voids in Mineral Aggregate", The Superpave Asphalt Research Programme, 2008.*

[16] *Celik Ozyildirim "High Performance Concrete for Transportation Structures", Concrete International, pp. 513-517, 1993.*

[17] *Jackson, N. M. and Brown, R. H. "Use of higher fines contents in Portland cement concrete", ICAR 4th annual symposium, 1996.*

[18] *Smith, J. O. and Slaughter, P. "Uses of by-product fines", ICAR 4th Annual Symposium, 1996.*

[19] *Babu, K.K "Performance of quarry waste as replacement of aggregate in concrete", International Seminar on Civil Engineering Practice Roorkee, pp. 926-934, 1996.*

[20] *Hiroshi Uchikawa "Influence of microstructure on the physical properties of concrete prepared by substituting mineral powder for part of fine aggregate", Cement and Concrete Research, Vol. 26, No. 1, pp. 101-111, 1996.*

[21] *Pedro Quiroga, N. Namshik Ahn and David Fowler, W. "Concrete Mixtures with High Microfines", ACI Materials Journal, pp. 103-108, 2006.*

[22] *Baguant, B.K. "Use of rock dust for enhancing durability of concrete" University of Mauritius, 81 – 95. https://eprints.kfupm.edu.sa/.../1999.*

[23] *Hudson B.P. "Manufactured sand for Concrete", The Indian Concrete Journal, pp. 237-240, 1997.*

[24] *Ilangovan, R. "Studies on Strength and behaviour of concrete by using quarry dust as fine aggregate", Proceedings of All India Seminar on Materials and Machines for Construction, New Age International, pp. 99-102, 2000.*

[25] *Shukla, A.K. and Sachan, A.K. "Performance of stone dust as fine aggregate replacing sand in concrete and mortar", National Seminar on Advances in Special Concretes, Indian Concrete Institute, Bangalore, pp. 241-248, 1998.*

[26] *Ahn, N. "An Experimental Study on the Guidelines for Using Higher Contents of Aggregate Microfines in Portland Cement Concrete", PhD Dissertation, University of Texas at Austin, 2000.*

[27] *Sahu A.K., Sunil Kumar and Sachan A.K "Quarry Stone Waste as Fine aggregate for concrete", The Indian Concrete Journal, pp. 845-848, 2003.*

[28] *Topçu, B. and Uurlu, A. "Effect of the use of mineral filler on the properties of concrete", Cement and concrete research, Vol. 33, pp. 1071-1075, 2003.*

[29] *Mark James Krinke "The Effect of Admixtures in Concrete Containing Manufactured Sand", Research Project towards the degree of Bachelor of Civil Engineering, Faculty of Engineering and Surveying, University of Southern Queensland, pp. 1-71, 2004.*

[30] *Lamb, M.J. "Design guide for applications of sandstone quarry sand in South Wales", Virigis Report VR8, TRL Limited, 2005.*

[31] *Salvador Villalobos, Lange, D.A. and Roesler, J.R. "Evaluation, testing and comparison between the crushed manufactured sand and natural sand", Technical Note, Dept of Civil and Environmental Engineering, University of Illinois, pp. 1-6, 2005.*

[32] *Pedro Quiroga, N. Namshik Ahn and David Fowler, W. "Concrete Mixtures with High Microfines", ACI Materials Journal, pp. 103-108, 2006.*

[33] *Aldağ, M. C., & Eker, B. (2018). Application of Finite Element Method in Engineering: A Review. International Refereed Journal of Engineering and Sciences, 0(13), 0–0. https://doi.org/10.17366/uhmfd.2018.2.4*

[34] *Al-Kubaisy, M. A., & Zamin Jumaat, M. (2000). Flexural behaviour of reinforced concrete slabs with*

ferrocement tension zone cover. Construction and Building Materials, 14(5), 245–252. https://doi.org/10.1016/S09500618(00)00019-2

[35] *Ashraf, M., & Halhalli, V. (2013). Flexural Behaviour of SCC Ferrocement Slabs Incorporating Steel Fibers. 2(10), 557561. [4] Basunbul, I. A., Saleem, M., & Al-Sulaimani, G. J. (1991). Flexural behavior of ferrocement sandwich panels. Cement and Concrete Composites, 13(1), 21–28. https://doi.org/10.1016/0958-9465(91)90043-H*

[36] *Cheah, C. B., & Ramli, M. (2013). Composites: Part B The structural behaviour of HCWA ferrocement – reinforced concrete composite slabs. COMPOSITES PART B, 51, 68–78. https://doi.org/10.1016/j.compositesb.2013.02.042*

[37] *De Silva, S., & Abeygunawardana, N. T. (2020). Performance of Ferro-Cement Strengthened Unreinforced Masonry Walls against Reverse Cyclic Loading. Engineer: Journal of the Institution of Engineers, Sri Lanka, 52(4), 11. https://doi.org/10.4038/engineer.v52i4.7345*

[38] *Ganesan, N., Indira, P. V., & Irshad, P. (2017). Effect of ferrocement infill on the strength and behavior of RCC frames under reverse cyclic loading. Engineering Structures, 151, 273–281. https://doi.org/10.1016/j.engstruct.2017.08.031*