Investigating Mechanical Characteristics of Ferrocement with Partial Replacement of Fine Aggregate using Copper Slag

S.G.S.Navean[1] , Prof.M.Raffikbasha[2]
[1]*PG Student, M.E Structural ENGINEERING, Government College of Engineering, Salem*
[2]*Assistant Professor, Dept. of Civil Engineering, Government College of Engineering, Salem*

***Abstract*-Ferrocement, a versatile composite material comprising a cement-based mortar matrix reinforced with mesh or metal elements, stands out for its exceptional mechanical properties and varied applications in construction. This study delves into exploring the mechanical behavior of ferrocement, focusing specifically on partially replacing its fine aggregate with copper slag, eliminating the conventional metal mesh reinforcement. The primary objective is to assess the impact of incorporating copper slag, an industrial by-product, on the mechanical characteristics of ferrocement.**

In this research, varying percentages of copper slag (ranging from 0% to 70%) replace the fine aggregate in the ferrocement mix. The study meticulously examines the impact of this substitution on crucial mechanical properties, encompassing compression, tensile, and flexural strengths, alongside additional characteristics like elastic modulus, durability, and density. Experimental procedures involve preparing ferrocement samples with diverse copper slag replacement ratios, followed by standardized curing processes and rigorous mechanical testing adhering to recognized standards.

The findings sought aim to offer insights into the feasibility of utilizing copper slag as a partial replacement for fine aggregate in ferrocement without relying on a metal mesh for reinforcement. Beyond understanding the mechanical implications, this research aims to evaluate the potential sustainable implications of this alteration in construction practices. Ultimately, the outcomes of this study aspire to provide valuable knowledge for engineers, researchers, and construction professionals, offering innovative and environmentally friendly alternatives in the domain of construction materials.

Keywords: Ferrocement, copper slag, mechanical properties

1. INTRODUCTION

Ferrocement, a composite material composed of a cement-based mortar matrix reinforced with metal mesh, showcases remarkable versatility and strength across various applications in building construction. Its unique properties make it an optimal choice for diverse structural elements and foundation solutions. Copper slag has angular particles with rough surfaces. These characteristics contribute to improved bonding between the cement matrix and the reinforcement, enhancing the overall strength and durability of the ferrocement.When used as a partial replacement for fine aggregate in ferrocement, copper slag can enhance the compressive and flexural strength of the material. The slag's properties can also improve resistance to corrosion and abrasion, making it suitable for various construction applications, especially in environments prone to harsh conditions. Utilizing copper slag as a substitute for fine aggregate in ferrocement can offer economic advantages by reducing the reliance on natural resources and minimizing waste disposal. It contributes to sustainable construction practices by reusing a by-product that might otherwise be discarded. The use of copper slag in ferrocement may contribute to improved impermeability, reducing water penetration and increasing resistance to chloride ion ingress, which is beneficial in enhancing the material's durability, especially in marine or aggressive environments.

2. OBJECTIVES

- To investigate the mechanical properties of the cement mortar by replacing M-sand with the copper slag.

- To determine various trial mixes of cement mortar were conducted by varying the percentage of copper slag as a partial replacement of fine aggregate in cement mortar.
- The results of these tests were compared with that of the normal mortar mixture.

3. MATERIALS USED

CEMENT

OPC 53 grade cement is used.

Characteristics	Values
Specific Gravity	3.16
Consistency	29%
Initial Setting Time	45mins
Final Setting Time	610mins
Fineness	9% Residue

FINE AGGREGATE

Characteristics	Values
Specific Gravity	2.507
Fineness Modulus	2.44
Water Absorption	1.5%
Bulk Density	1632.9kg/M3
Grading Zone	Ii

WATER

The quality of water used is potable water standard which is available is the laboratory for mixing and curing which is used for reinforced concrete structures

COPPER SLAG

Characteristics	Values
Fineness Modulus	2.99
Specificgravity	3.36
Bulk Density	1.782 G/Cc
Water Absorption	0.682
Grading Of Aggregate	Zone II

4. MIX PROPORTION

Mix ratio=1:2

1 part -cement

2parts -M-sand & M-sand is partially replaced with copper slag 0%-60%

W/C=0.41

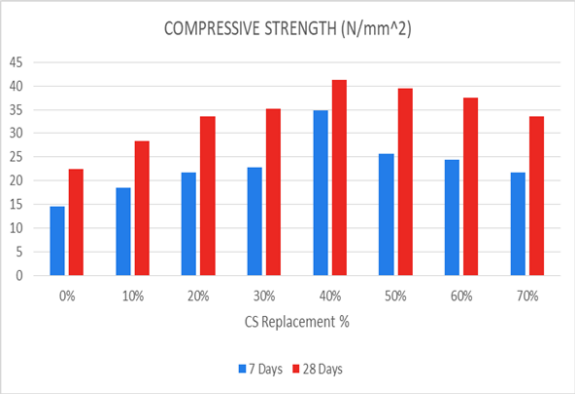
5. EXPERIMENTAL INVESTIGATION

COMPRESSION STRENGTH TEST:

The Cube of size 100 mm is cast. Fine aggregate is partially replaced with Copper slag (0-70%).The Copper slag cement mortar is cast to determine the compressive Strength values.The cube was tested in the Compression testing machine after 7 & 28 days. The casted Cube is tested in a compression testing machine for the compressive strength of cement mortar after 7days and 28 days. The average compressive strength value is tabulated.

COMPRESSIVE STRENGTH (N/mm^2)		
Copper Slag	7 Days	28 Days
1:2 0% CS	14.62	22.5
1:2 10% CS	18.48	28.44
1:2 20% CS	21.75	33.5
1:2 30% CS	22.82	35.11
1:2 40% CS	**34.78**	**41.2**
1:2 50% CS	25.71	39.56
1:2 60% CS	24.35	37.47
1:2 70% CS	21.66	33.5

TABLE 1: COMPRESSION STRENGTH TEST RESULTS



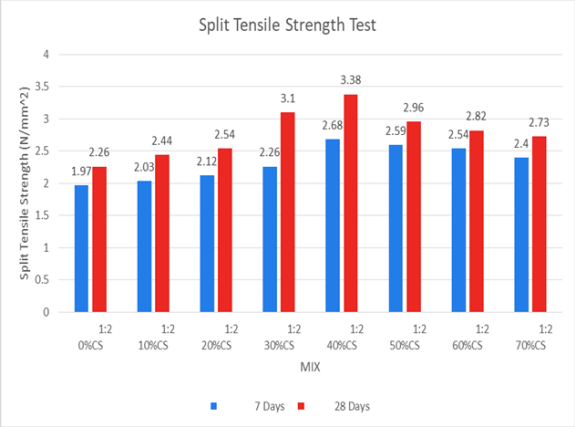
GRAPH 1: COMPRESSION STRENGTH TEST GRAPH

SPLIT TENSILE TEST

Cylindrical specimens are cast, cured, and then subjected to a splitting force applied diametrically. The tensile strength is calculated based on the maximum load applied. Tensile strength is crucial for applications where the Copper Slag Cement Mortar may be subjected to tensile stresses, such as in thin sections or areas prone to cracking. Evaluates the tensile strength of the Copper Slag Cement Mortar, which is important for assessing its durability and resistance to cracking.

TABLE 2: SPLIT TENSILE STRENGTH TEST RESULTS

SPLIT TENSILE STRENGTH (N/mm^2)		
Copper Slag	7 Days	28 Days
1:2 0% CS	1.97	2.26
1:2 10% CS	2.03	2.44
1:2 20% CS	2.12	2.54
1:2 30% CS	2.26	3.10
1:2 40% CS	2.40	**3.38**
1:2 50% CS	**2.68**	3.10
1:2 60% CS	2.59	2.96
1:2 70% CS	2.54	2.82



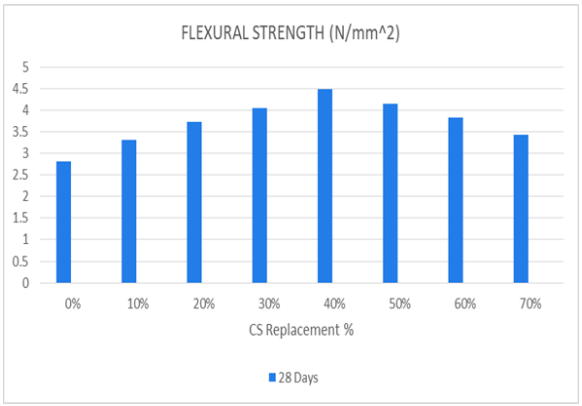
GRAPH 2: SPLIT TENSILE STRENGTH TEST GRAPH

FLEXURAL STRENGTH TEST

This test is essential for structural elements like slabs, beams, and panels where flexural strength is a critical parameter. It helps ensure the material can withstand bending loads without failure. Beam specimens are cast, cured, and then subjected to a load applied at the center of the beam. The flexural strength is calculated based on the maximum load applied and the dimensions of the beam.

TABLE 3: FLEXURAL STRENGTH TEST RESULTS

FLEXURAL STRENGTH (N/mm^2)	
Copper Slag	28 Days
1:2 0%CS	2.81
1:2 10%CS	3.32
1:2 20%CS	3.73
1:2 30%CS	4.05
1:2 40%CS	4.49
1:2 50%CS	4.14
1:2 60%CS	3.82
1:2 70%CS	3.43



GRAPH 3: FLEXURAL STRENGTH TEST GRAPH

MODULUS OF ELASTICITY OF FERROCEMENT

The Cylinder of 150 X 300 is cast and cured for 28 days, and then the cylinder is tested in a Computerized Universal testing machine. The Compressometer is fixed to the specimen, and the Gauge length is found.The Load range is selected in the UTM, and the initial correction is done in the dil. The Machine was started, and the load was applied evenly to the specimen. The compressometer reading is noted for every increase of load. Using this observation, strain and strain values are found. From the Stress and Strain values, the modulus of elasticity is found out to be 23715.17 N/mm^2.

TABLE 4 - MODULUS OF ELASTICITY OF FERROCEMNT

Stress N/mm^2	Strain	Modulus of elasticity of cement mortar N/mm^2	Average Modulus of Elasticity of cement mortar N/mm^2
10.25383	0.00043	23846.11	23714.9
10.27646	0.00043	23898.74	
10.2991	0.00043	23951.39	

6. RESULTS AND DISCUSSIONS

1. For cement mortars, all mixtures with different copper slag proportions yielded higher compressive strength than the strength of the control mixture. There was more than 83% improvement in the compressive strength of mortars with 40% copper slag substitution in comparison with the control mixture.
2. For cement mortars, all mixtures with different copper slag proportions yielded higher Split Tensile strength than the strength of the control

mixture. There was more than 49.5% improvement in the Split tensile strength of mortars with 40% copper slag substitution in comparison with the control mixture.

3. For cement mortars, all mixtures with different copper slag proportions yielded higher Flexural strength than the strength of the control mixture. There was more than 59.78% improvement in the Flexural strength of mortars with 40% copper slag substitution in comparison with the control mix.
4. The modulus of elasticity of Ferrocement is found out to be 23715.17 N/mm^2.
5. The surface water absorption of Cement mortar was reduced with up to 40% copper slag replacement for M-sand. The volume of permeable voids decreased with the replacement of up to 40% copper slag.

7. CONCLUSION

a. The replacement of fine aggregate with copper slag in ferrocement revealed that a 40% replacement level offers a significant enhancement in various mechanical characteristics.
b. This replacement level consistently demonstrated superior or comparable strength properties while maintaining optimal workability and potential cost-effectiveness.
c. The findings suggest that the 40% replacement contributes to a well-balanced solution, optimizing the mechanical performance of ferrocement.

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