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Use of Fly Ash and Copper Slag as Construction Material in Ferrocement to Make it More Sustainable and Ecological

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***Abstract* - Ferro cement is an unorthodox concept in civil engineering. It is only used for non-structural elements of construction and for aesthetically pleasing elements in the elevation of a structure.**

We are all aware of the catastrophe of climate change and also the factors which lead to climate change. The construction industry is one of the major contributors to the negative effects induced by climate change. When more cement and steel is used, more carbon is emitted into the atmosphere. Also, so when sand is used, it leads to soil erosion or erosion of the riverbed from where the sand is extracted.

Keeping this in mind, we are trying to to lower the use of this material without compromising on the structural stability of a structure and ferro cement it seems to be one of the solutions to do so.

1.INTRODUCTION

1.1INTRODUCTION OF TOPIC

Ever since the 20th century until now, the demand for or steel and concrete in the construction industry has been constantly increasing. Its rampant usage has led to the Emission of immense amount of greenhouse gases which have intern contributed to the climate change catastrophe that we are facing now. Until the industry finds z substitute to completely replace this traditional construction methods and components, we have a technique to curb its usage. What is called as ferro cement. The amount of steel and cement used while construction by this technique is far less than the traditional method. To instill confidence in the industry about the uses of ferro cement, more and more studies need to be conducted and more improvements need to be done.

In this study, we are going to to make ferrocement more ecologically and economically sustainable so that it can emerge as a solution for climate change and a good alternative for the industry as well.

Ferrocement is a form of thin reinforced concrete Structure in which a brittle cement-sand mortar matrix Is reinforced with closely spaced multiple layers of thin wire mesh and /or small diameter rods, uniformly Dispersed throughout the matrix of the composite. Ferrocement has taken a significant place among Components used for construction, for its Specification of durability and strength, and its small Thickness, which makes it a component suitable for Constructing many lightweight structures. From the Architectural standpoint, ferrocement is very useful, since it can be molded into different shapes for Different designs. These facts ensure a significant Future for the use of this component, and for these Reasons, a careful study of the characteristics of this Component was made, to determine its specifications from the structural engineering standpoint, to make it Easier for use. Ferrocement is a special form of Reinforced concrete and its production, performance, Strength behavior and potential utility make it Imperative that must be treated as a separate Material. Ferrocement has been widely and Successfully used for the construction of booths, Domes, silos, tanks, folded roof structures, wall Panels, barges, composite column constructions, Ferrocement shell roofs or roofing elements, large Span vaulted roofs, swimming pools construction and Housing components Ferrocement is a construction material composed with a Relatively thin and closely spaced layer of metal mesh, Covering such binding agent like Cement mortar. Because the Building techniques are simple enough to be done by unskilled Labour, ferrocement is an attractive construction method in Areas where costs of labour are low. There is no need for the Complicated formwork of reinforced cement concrete (RCC) Construction, or for the welding needed for steel construction, everything can be done by hand,

and no expensive machinery Is required. 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.

1.2 INTRODUCTION OF PROJECT

1.2.1 Scope of the project

1. Project will be done for ferrocement elements
2. Materials used to achieve economic sustainability are copper slag and fly ash
3. Laboratory test should be performed on the elements
4. Field tests will also be performed on each individual component of the ferrocement
5. Only two types of elements, i.e., ferrocement panels and cubes, will be casted and then tested

1.2.2 Problem statement

Unavailability of study on economically and ecologically sustainable ferrocement, particularly, one involving fly ash and copper slag in its mix design.

1.2.3 Objective

- To enhance the properties of ferrocement like
    1. Its compressive strength
    2. Economic viability
    3. Durability
- To use fly ash and copper slag in ferrocement
- Find an optimum mix ratio for ferrocement infused with fly ash and copper slag
- Laboratory testing of ferrocement elements to reach the above objectives
- To make this study are openly available

2.EXPERIMENTAL WORK

2.1 MATERIALS

2.1.1 Required Materials

For our study we have to caste cubes and panels of ferrocement. Also, as a measure of addressing our problem statement we have to use fly ash and Copper slag in the mix design of our casted for cement elements. Hence, we require the following material for our study.

- Copper slag
- Fly ash
- Cement
- River sand
- Portable water
- Iron mesh of any kind

2.1.2 Material properties

Copper slag: Copper slag is a by-product obtained during the matte smelting and refining of copper. To produce every ton of copper, approximately 2.2-3.0 tons of copper slag is generated as by-product material and is used as replacement for sand in the construction industry. The blasting media manufactured from copper slag brings less harm to people and environment than sand. The product meets the most rigid health and ecological standards. Copper slag is used as a building material, formed into blocks.

Properties of copper slag

Sr. No.	Property	Value
1	Bulk Density	1.7-1.9 g/cc
2	Specific gravity	3.68
3	Hardness (Moh scale)	6-7 pH
4	pH in a aqueous solution	6.6-7.2

Fly ash : Class F fly ash is designated in ASTM C 618 and originates from anthracite and bituminous coals. It consists mainly of alumina and silica and has a higher LOI than Class C fly ash.

Sr. No.	Property	ASTM C618 requirements
1	$SiO_2 + Al_2O_3 + Fe_2O_3$, min	70
2	SO_3, max	5
3	Moisture content, max	3
4	Loss on ignition, max	6

Fly ash was obtained from Thermal power plant at Deep Nagar (Tal. Bhusawal)

Cement : Ordinary Portland cement of grade 53 is used for this study. The cement should be fresh, of uniform consistency, and Free of lumps and foreign matter. It should be stored under dry Conditions for a short duration as possible .

Fine aggregate : The importance of good, clean, well graded

Sand cannot be over emphasized if one is to make the high

Grade impervious mortar required.

River sand sieved through 2.36 mm sieve , sprinkled with water and then dried to Remove silt content , is used for casting.

Before straining and removal of slit.

Before straining and removal of slit.

Water : Water which was potable, clean, and free from harmful Salts or foreign materials was used so that concrete attains maximum Strength . pH of water used UA's between 6.5 to 7.

Iron mesh: The objective of providing wire mesh as reinforcement is to impart Tensile strength to concrete and resist against cracking. It also supports in Holding the ferrocement concrete together in wet state.

Also, one of the virtue of using mesh in ferrocement is that less amount of steel Is being used, thus reducing carbon footprint. We have used an Iron expanded type of mesh which was 2mm thick.

2.2 MATERIAL AMOUNT AND PROPORTION

2.2.1 Total amount of material required

Sr. No.	Material	Amount
1	Cement (OPC 53 Grade)	75kg
2	Sand, i.e., Fine aggregate (River sand)	135kg
3	Fly ash (Class F)	22.5kg
4	Copper slag	22.5kg

2.2.2 Mix proportion

Panel and cube no.	Cement	Sand	Fly ash	Copper slag
0	15	30	0	0
1	15	27	1.5	1.5
2	15	24	3	3
3	15	21	4.5	4.5
4	15	18	6	6
5	15	15	7.5	7.5

2.3 CASTING PROCESS

The ferrocement slab panels and mortar cubes are casted by using Normal potable water with the partial replacement of Fine aggregate with fly ash as 5%, 10%, 15%, 20% and 25%; Copper slag as 5%, 10%, 15%, 20% and 25% Respectively.

- For cubes, iron moulds of dimension 150mm*150mm*150mm are used. Total 6 cubes are casted according to the mix proportion given in the above table. Compaction of concrete in the cube is done with the help of an iron rod.
- For Panels, moulds of size 750mm*200mm*40mm are used. Total 6 panels are casted according to the mix proportion given in the table. Concrete is placed in the mould with a trowel and compacted with an iron rod. Surface of the panel is smoothened with the help of a screed. The moulds used are made of plywood, some moulds have been custom made on the site using available material. A plastic sheet has been kept at the bottom of the mould so that concrete doesn't stick to the mould surface and also to achieve a smooth texture. The expanded iron mesh of size 750mm*200mm*2mm is placed after 19mm of concrete is placed in the mould, and after mesh placement, more concrete is placed until thickness of panel becomes 40mm.

Some photographs of the casting process-

- Cutting of expended iron mesh to fit the mould size.

- Mixing of concrete by using exact amount of material.

(Flask is used to measure water and a weigh scale is used to measure The exact weights of cement, sand , copper Slag and fly ash to be Mixed for a particular panel and cube mould.)

- Concrete being placed in the mould with a trowel.

- Placing of the iron mesh such that cover from above and below is 19mm.

- Completely casted Ferrocement panel of Dimension 750*200*40mm

- One of the group member and group leader Viraj Deshpande present on site while casting.

2.4 CURING

All the casted elements, ie, 6 cubes and 6 panels were removed form their respective casting moulds after 24 hours and kept in a curing tank at a temperature of 25 +/- 2°C for 28 days.

The panels and cubes were laid for curing after the specimens were marked legibly with a permanent marker for identification.

We have used an Iron expanded type of mesh which was 2mm thick.

2.5 TESTING

2.5.1 Testing of Ferrocement panels

• Test of flexural strength of ferrocement panels

The ferrocement panels are tested for their flexural strength by undergoing a flexural strength 3 point load test in a universal testing machine (UTM). The test is conducted according to IS 516:1959.

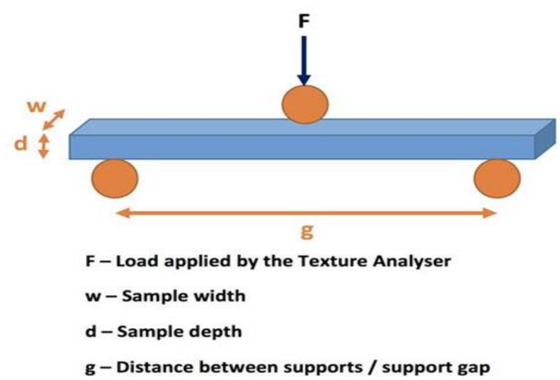
$$\sigma = \frac{3FL}{2bd^2}$$

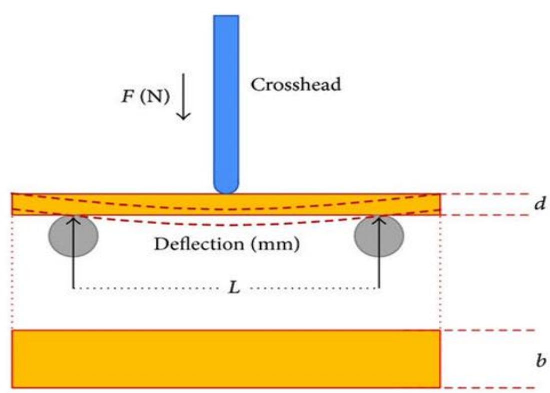
F is the load (force) at the fracture point (N)

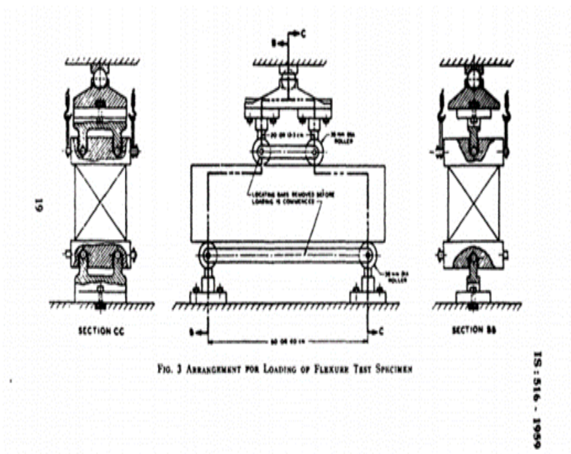
L is the length of the support span

B is width

D is thickness





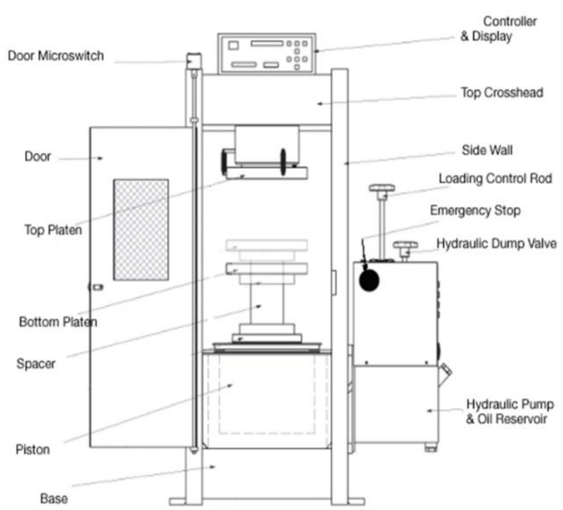


2.5.2 Testing of cubes

- Testing of compression strength of concrete used on ferrocement

The cubes are tested for their compressive strength by undergoing compressive strength test in a compression testing machine (CTM). The test is conducted according to IS 456:2000.

Compressive strength is given by Force at which cube cracks divided by cross sectional area .



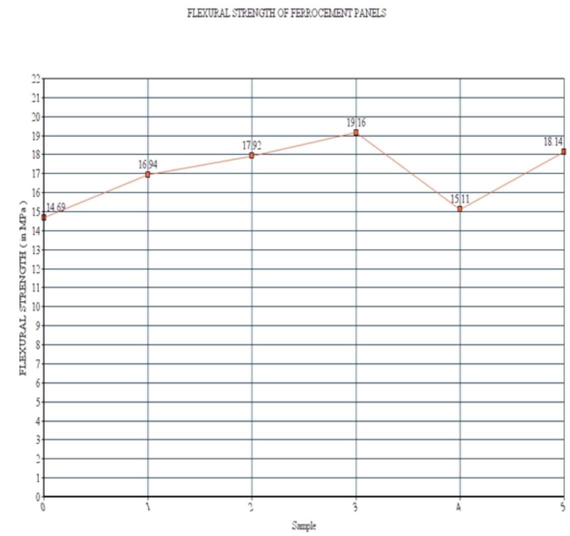
VIDEOS OF TESTS CONDUCTED ON ALL SAMPLES CAN BE VIEWED BY CLICKING ON THE LINK BELOW.

https://drive.google.com/folderview?id=1ef3Ny1c1t8HuNTt80MTK8zuwhXhD_CUi

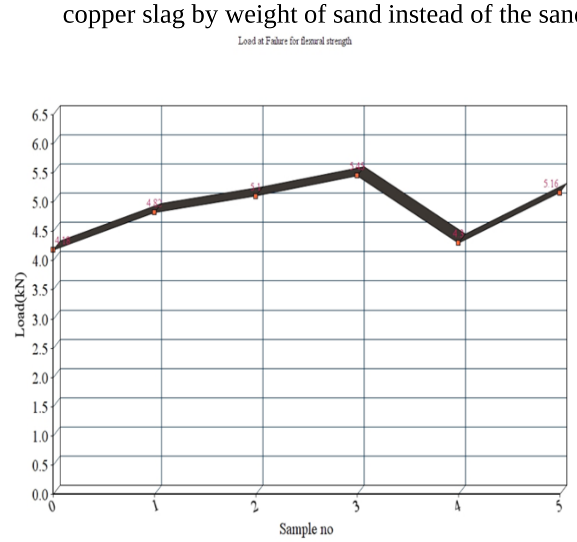
3 RESULT AND DISCUSSION

Sample no.	Flexural strength	Compressive strength
0	14.69	27.4
1	16.94	26.08
2	17.92	18.56
3	19.16	33.61
4	15.11	37
5	18.14	3.08

3.1 RESULT OF FLEXURAL STRENGTH TEST

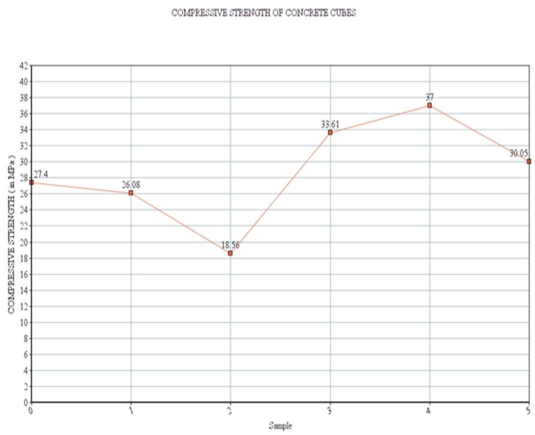


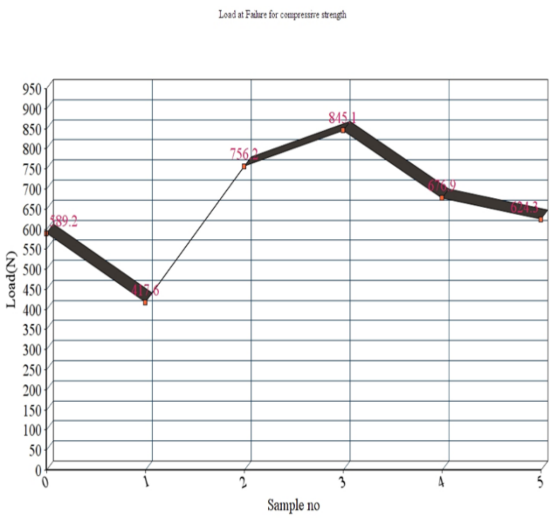
- It is evident that for sample no 3, flexural strength is the highest.
- For sample no 3, we had taken 15% of fly ash and copper slag by weight of sand instead of the sand



- For sample 3, 15 kg cement, 21 kg sand, 4.5 kg each of fly ash and copper slag is used in the mix design.

3.2 RESULT OF COMPRESSIVE STRENGTH TEST





- It is evident that sample no 4 has the highest compressive strength
- We had taken 20% of fly ash and copper slag each by weight of sand instead of sand
- For sample 4, 15 kg cement, 18 kg sand and 6-6 mag of fly ash and copper slag were used in the mix design.

3.3 DISCUSSION

We have observed that, up to a certain point, the infusion of fly ash and copper slag improves the overall strength of the concrete, that is, both its compressive and flexural strength. Although, we have observed one irregularity both in the panel and in the cube. For the panels, sample number 5 has shown irregularity of showing more flexural strength than sample 4. For the cubes, samples have not shown a particular upward or downward trend in strength value. It has decreased for first 3 samples, increased for the next two and again decreased for the last sample.

However, it is very clear that sample 3 has shown the highest flexural strength and sample 4, the highest compressive strength.

Hence, the optimum amount of infusion of fly ash and copper slag by weight of fine aggregate instead of fine aggregate should be somewhere in between 15 to 20%.

4 COST-BENEFIT ANALYSIS

Considering that we have to build a ferrocement structure or precasted ferrocement elements, we should use the method given in this study and the optimum mix ratio which we have found out for the following reasons-

- Except for the transportation cost, the cost of fly ash and copper slag is very low. (For this study, we have used fly ash at 0.25Rs/kg and copper slag at 3Rs/kg) . So, the difference in cost of normal ferrocement and infused ferrocement is not very prominent.
- The strength of concrete, as we can see in the results, has increased after adding copper slag and fly ash. Thus, increase strength can be achieved at a lower cost.
- The by product of power generation through coal, ie, flyash and the byproduct of copper extraction through its ore, ie, copper slag, which food has been wasted and thus increased the carbon footprint on earth are being used for construction purposes.
- The amount of fine aggregate required will be less, thus, the demand of soil excavation from river beds will be less, which will inturn limit erosion of soil and river bed and also the need the sand to be processed for construction purposes.

5 CONCLUSION

Thus, it is proved that by using flyash and copper slag in the mix design of ferrocement by the amount of 15-20% each (by weight of fine aggregate used) , higher flexural strength and compressive strength is achieved. Also, it reduces the overall carbon footprint of the earth by making use of byproducts of other products and helps reducing the use of fine aggregate, thus reducing its demand and inturn reducing the erosion of river beds from which the sand is extracted.

The objectives of this study have been achieved.

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