EXPERIMENTAL INVESTIGATION ON THE FLEXURAL STRENGTH OF FERROGEOCRETE WITH PARTIAL REPLACEMENTS OF CEMENT BY RED MUD AND FINE AGGREGATE BY CRUSHER SAND

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Abstract : *Red mud is a waste product that is obtained in the process of extracting Aluminium from Bauxite Ore. This red mud is hazardous when dumped and causes environmental pollution. So it has been attempted to find a suitable means of effective disposal by using red mud as partial replacement for cement in ferrocement. Also, river sand is very expensive and crusher sand is more economical to be used in place of river sand. In this work the mechanical properties such as flexural strength of ferro-geocrete with cement partially replaced by red mud and fine aggregate partially replaced by crusher sand is studied. Cement mortar cubes of size 100mmx100mmx100mm were prepared with cement sand ratio of 1:2 and w/c ratio 0.41 to determine the compressive strength of cement mortar that can be used in ferro-geocrete. The optimum percentage of red mud that can be used to replace cement is determined by casting cubes with replacements of 5%, 10%, and 15% of cement by red mud. Then mortar cubes were cast with the optimum percentage of red mud and river sand partially replaced by crusher sand. Ferro-geocrete specimens are cast and tested for flexural strength with the optimum percentage of red mud and crusher sand determined from compressive strength tests. Weld mesh was used to reinforce the ferrogeocrete flexural specimens.*

***Key words**: Ferrogeocrete, partial replacement, Flexural strength, Compressive strength, Crusher sand, red mud*

1. INTRODUCTION:

During manufacture of one tonne of Ordinary Portland Cement an equal amount of carbon-dioxide is released into the atmosphere. The carbon-dioxide emissions act as a silent killer in the environment in various ways. In this scenario, there is a need of the search for cheaper substitute to OPC. The parent objective of the study was to suggest possible percentage of use of red mud along with cement which will help to reduce the cement consumption in construction industry. Red mud is a side-product of the Bayer Process, the principal means of refining bauxite to alumina. Around all over the world about 35 million tons of red mud is produced yearly. Because of the complex Physicochemical properties of red mud it is very challenging task for the designers to find out the economical utilization and safe disposal of red mud [1]. Over the years many attempts have been made to find the use of red mud but none have been proved to be economically satisfactory. Red mud is composed of a mixture of solid and metallic oxide-bearing impurities, and presents one of the aluminium industry's most important disposal problems. The red colour is caused by the oxidized iron present, which can make up to 60% of the mass of the red mud. In addition to iron, the other dominant particles include silica, unleached residual aluminium, and titanium oxide [2]. Red mud is highly basic with a pH ranging from 10 to 13 [3]. Red mud was classified as dangerous and world while generation reached over 117 million tons/year [4]. Because of storing wastes, the waste negatively affects the environment.

To solve the problem, attempts have been made to investigate the utilization of red mud as Supplementary Cementitious Material along with copper Slag as replacement for fine aggregate by finding the compressive strength of the cement mortar. Portland cement was replaced up to 30% red mud by weight of cement and fine aggregate was replaced by 10% copper slag waste by weight of fine aggregates and the compressive Strength of red mud cement mortar was determined. It was found that 10 percent of red mud and 10% of copper slag replacements was the optimum [5]. Also study was made on using red mud and rice husk ash in partial quantities with cement in mortar. It was observed that 10% replacement of red mud for cement was possible from compressive, tensile and flexural strength point of view with a little compromise in compressive strength. However, from compressive strength point of view, rice husk ash was best alternative materials for replacement of cement in mortar and can be used up to 10% to 15 %. Moreover, tensile and flexural strength had reduced to some extent even for 5% rice husk quantity [6].

Study has also been done on the possibility of utilizing the waste red mud (bauxite residue) and quarry dust in cement concrete. Red mud was used as replacement for cement in concrete and quarry dust was used as replacement for river sand. This study aims at describing such utilization and their effective usage in concrete. Experiments done to assess the compressive strength and flexural strength of the concrete cubes made of red mud and quarry dust showed that 20% replacement of cement with red mud and 40% replacement of river sand with quarry dust was the optimumdosage.[7]

In this study it was attempted to use red mud, which is a waste product obtained in the process of extracting Aluminium from Bauxite Ore, as partial replacement for cement in cement mortar. It was aimed to find the optimum dosage that can be used as replacement and to determine the mechanical properties of cement mortar with red mud. Also it was attempted to check the effectiveness of red mud mixed cement mortar on the flexural strength of ferrocement, which is a versatile construction material and that can be used in various construction applications. Ferrocement, when red mud is mixed in the cement mortar is termed as ferrogeocrete. The function of the fine aggregate is to assist in producing workability and uniformity in the mixture. The river deposits are the most common source of fine aggregate. Now-a-days the natural river sand has become scarce and very costly. Due to depletion of river sand, it was attempted to replace river sand by crusher sand partially as fine aggregate in the red mud mixed cement mortar.

2. MATERIALS AND METHODS

Materials used in this study were chosen according to the specifications that meet the requirement of appropriate standards as well as the objective of this research.

2.1 Cement

Cement is the most important ingredient used in the mortar mix. One of the important criteria for the selection of cement is its ability to produce improved microstructure. Hence selection of proper grade and quality of cement is important for obtaining rich mix. The cement that was used was tested and the properties are given in table 1.

Table - 1 Properties of Cement

S.No	Characteristics	Values
1	Consistency	32%
2	Initial setting time	33 Min
3	Final setting time	252 Min
4	Fineness	4%
5	Specific Gravity	3.12
6	Soundness	3 mm

2.2 Red mud

The Sieve analysis test values of dry Red Mud shown in figure 1 obtained from MALCO (Madras Aluminium Company Ltd) are given in table 2.

Fig-1 Red mud

Table 2 Properties of red mud

Properties	Value
Fineness modulus	2.8
Coefficient of Curvature	0.78
Coefficient of uniformity	4.68
Specific gravity	2.9

The results of EDAX test on red mud sample is as given in Figure 2 and table 3.

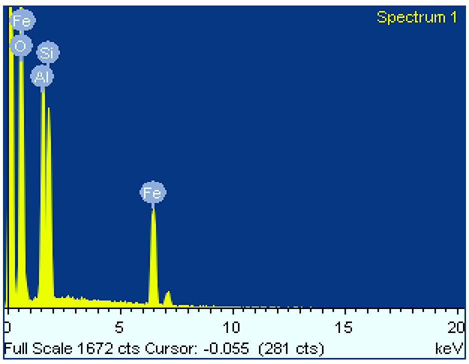

Fig-2 Spectrum Analysis of red soil by EDAX test

Table -3 Weight percentage of various elements in Red Soil

Element	App Conc	Intensity Corrn.	Weight %	Weight % Sigma	Atomic %
O	101.51	1.32	52.01	0.54	70.29
Al	15.84	0.74	14.44	0.3	11.57
Si	14.07	0.70	13.43	0.3	10.29
Fe	25.29	0.85	20.13	0.43	7.79

2.3 Fine Aggregate

Fine aggregate used for cement mortar should be properly graded to give minimum void ratio and be free from deleterious materials like clay, silt content and chloride contamination etc. Grading of fine aggregate should be such that it does not cause increase in water demand for the mortar and should give maximum voids so that the fine cementitious particles fill the voids. Hence it is desirable to use coarser variety of fine aggregate having a high fineness modulus for making workable and strong concrete. The details of tests conducted on fine aggregate is given in table 4.

Table -4 Properties of Fine aggregate

S.No	Characteristics		Values
1	Type		River Sand
2	Specific gravity		2.36
3	Bulk density	Partially	1554 kg/m^3
		Fully	1717.6 kg/m^3
4	Fineness modulus		2.7
5	Grading zone		II

2.4 Crusher Sand

Fig- 3

Crusher Sand

In quarrying activities, the rock has been crushed into various sizes; during the process the dust generated is called Crusher sand and it is formed as waste. So it becomes as a useless material and also results in air pollution. Therefore, Crusher sand can be used in construction works, which will reduce the cost of construction and the natural resources can be utiltised properly. Crusher sand has been used for different activities in the construction industry, such as building materials, road development materials, aggregates, bricks, and tiles. The properties of crusher sand is given in table 5.

Table -5 Properties of Crusher sand

Properties	Value
Specific Gravity	2.57
Fineness Modulus	2.41
Density	1.85gm/cc
Void Ratio	0.42

2.5 Wire Mesh

Many different kinds of reinforcing mesh will produce successful ferrocement structures in which the general requirement is flexibility. Shapes with tight curves need more flexible meshes. Mild steel square welded wire mesh layer of 2mm diameter and 15mm spacing of wires as shown in figure 4 was used in this experiment. Adequate cover to protect the steel from corrosion is necessary because in almost every application of Ferrocement, the durability and resistance to environmental effects depend on the thin mortar cover over the steel mesh and its ability to protect the easily corroding steel mesh.

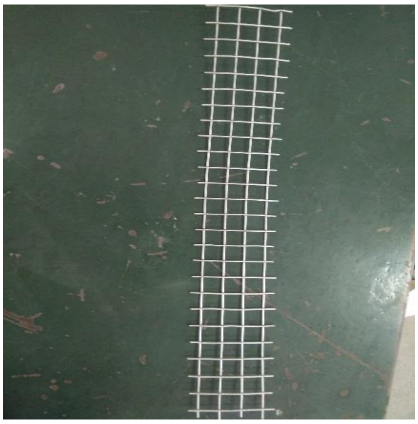

Fig-4 Welded Wire Mesh

3. CASTING OF SPECIMEN

Specimens such as mortar cubes and slabs were cast to check the compressive strength of cement mortar and flexural strength of ferrocement slabs that are used for the construction of ferrocement structures.

3.1 Compressive Strength of Cement Mortar

The test program consists primarily to determine the compressive strength of cement mortar cube when subjected to compression. Steel moulds of size 100mm×100×mm×100mm were used to cast the specimen. Cement mortar was made with 1:2 cement sand ratio and a water cement ratio of 0.41. Also specimens were cast with cement mortar with 5%, 10% and 15% replacement of cement by red mud to test their compressive strength. Crusher sand was used to replace river sand by 25% and 50% in the cement mortar with 5% and 10% replacement of cement by red mud. The specimens cast were left in the moulds for 24 hours. After that the specimens were demoulded they were immediately placed under water in a curing tank. The specimens were allowed to cure under water.

3.2 Flexural Strength of Ferrogeocrete

Specimens were cast in cement mortar with one layer of weld mesh embedded within. The cement sand ratio was kept as 1:2 and water cement ratio was 0.41. Steel moulds of size 500mm×100×mm×20mm were greased before casting the specimen to ease the demoulding process. The mould was made in such a way that two edges were connected with a bolt so that the specimen could be easily demoulded after 24 hours.

4. TESTING

The cement mortar cubes were taken out of the curing tank at the age of 3 days, 7 days and 28 days and tested for their compressive strength on compressive strength testing machine as shown in figure 5.

Fig - 5 Testing of Cement Mortar Cube

The ferrogeocrete slabs were tested for flexural strength at the age of 7 days and 28 days on a Universal Testing Machine as shown in figure 6. The specimen was placed in such a manner that the load was applied at one third distance from either supports of the slabs. The specimen was aligned centrally on the base plate of the specimen. The movable platform was rotated gently by hand so that it touched the top surface of the metal rod placed over the cylinders. The loading was continued till the failure of the specimen occurred and the failure load was noted.

Fig - 6 Flexural strength test on ferrogeocrete slab

5. TEST RESULTS

5.1 Compressive Strength of cement mortar with partial replacement of cement by red mud

The compressive strength results of specimen with 5%, 10% and 15% replacement of cement by red mud are given in table 6. From figure 7 it is found that

the optimum percentage of red mud to be used in cement mortar is 5%.

Table -6 Compressive strength of cement mortar with Partial replacement of cement by red mud

S. No	Description	3rd day N/mm²	7th day N/mm²	28th day N/mm²
1.	Control Specimen	19.7 21.54 25.24	25.3 31.44 33.87	33.354 38.259 34.335
	Mean	22.16	30.2	35.388
2.	Cement replaced with 5% of red mud	28.44 36.297 33.292	37.278 33.354 31.392	39.24 35.316 37.278
	Mean	32.045	34.008	37.278
3.	Cement replaced with 10% of red mud	19.62 22.53 23.54	33.354 16.67 27.468	30.411 36.297 28.449
	Mean	21.909	25.833	31.760
4.	Cement replaced with 15% of red mud	16.677 16.677 19.62	17.658 18.639 20.601	18.639 21.582
	Mean	17.658	18.966	20.115

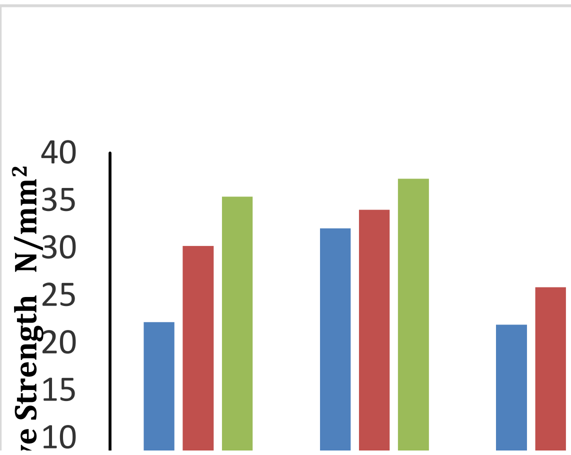

Fig-7 Compressive strength of cement mortar with partial replacements of cement by red mud

5.2 Compressive Strength of cement mortar with partial replacements of cement by red mud and fine aggregate by crusher sand

The Compressive strength results of specimen with cement replaced by 5% and 10% of red mud and fine aggregate replaced by 25% and 50% of crusher sand are given in table 7 and figure 8.

Table - 7 Compressive strength of cement mortar with cement and fine aggregate partially replaced by red mud and crusher sand.

Description	3rd day N/mm²	7th day N/mm²	28th day N/mm²
Control Specimen	19.7 21.54 25.24	25.3 31.44 33.87	33.354 38.259 34.335
Mean	22.16	30.2	35.388
Cement replaced with 5% of red mud and fine aggregate replaced with 25% of crusher sand	27.468 32.373 28.449	43.164 44.145 43.164	45.126 46.107 45.126
Mean	29.43	43.65	45.617
Cement replaced with 10% of red mud and fine aggregate replaced with 25% of crusher sand	22.563 27.468 20.601	35.316 34.335 37.278	40.221 38.259 41.202
Mean	23.544	35.643	39.895
Cement replaced with 5% of red mud and fine aggregate replaced with 50% of crusher sand	25.506 29.430 23.544	38.359 42.183 38.259	40.221 40.221 39.24
Mean	26.02	39.561	39.89
Cement replaced with 10% of red mud and fine aggregate replaced with 50% of crusher sand	23.544 28.449 23.544	39.240 33.354 40.221	44.145 42.183 38.259
Mean	25.12	37.610	41.529

From the test results it is observed that partial replacements of cement and fine aggregate by 5% red mud and 25% crusher sand respectively gives the optimum compressive strength for the cement mortar. However replacement by 10% red mud and 50% crusher sand also gives more strength than the control mix.

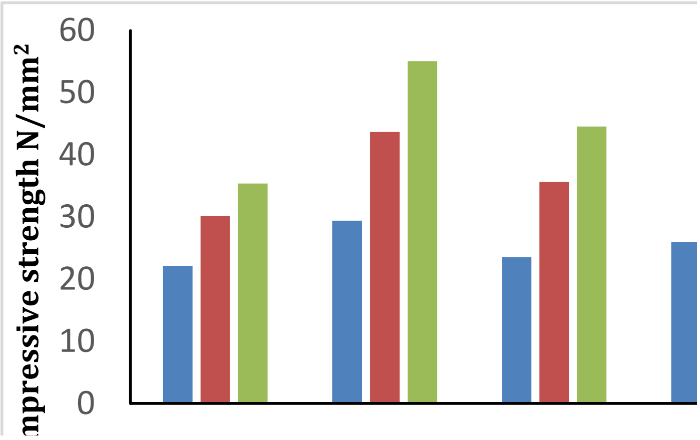

Fig-8 Compressive strength of cement mortar with cement and fine aggregate partially replaced by red mud and crusher sand

5.3 Flexural Strength of ferrogeocrete with partial replacement of cement by red mud

The flexural strength of ferrogeocrete with 5%, 10% and 15% replacements of cement by red mud were found and the results are as given in table 8 and figure 9.

Table - 8 Flexural strength of ferrogeocrete slab with Partial replacement of cement by red mud

S.No.	Description	7 days strength N/mm²	28 days strength N/mm²
1.	Control Specimen	6.62 5.52	12.12 11.04
	Mean	6.07	11.58
2.	Cement partially replaced by 5% of red mud	7.72 7.06	13.24 15.45
	Mean	7.39	14.345
3.	Cement partially replaced by 10% of red mud	5.52 6.18	9.93 7.72
	Mean	5.85	8.825
4.	Cement partially replaced by 15% of redmud	4.41 3.3	7.72 6.64
	Mean	3.855	7.18

The flexural strength test results show that 5% replacement of cement by red mud gives the optimum flexural strength of ferrogeocrete.

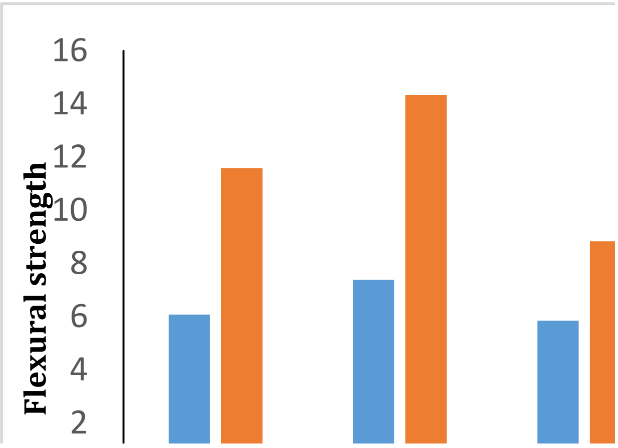

Fig-9 Flexural strength of cement partially replaced by red mud

5.4 Flexural Strength of ferrogeocrete with partial replacements of cement by red mud and fine aggregate by Crusher Sand

The test results of the flexural strength of ferrogeocrete slabs with cement partially replaced by 5% and 10% of red mud and fine aggregate partially replaced by 25% and 50% of crusher sand are given in table 9 and figure 10.

Table - 9 Flexural strength of ferrogeocrete slab with Partial replacements of cement and fine aggregate by red mud and crusher sand

S.No	Description	7th Day N/mm^2	28th Day N/mm^2
1.	Cement partially replaced by 5% of red mud & fine aggregate partially replaced by 25% of crusher sand	8.83 9.93	16.55 14.34
	Mean	9.38	15.445
2.	Cement partially replaced by 10% of red mud & fine aggregate partially replaced by 25% of crusher sand	7.72 6.62	13.24 12.81
	Mean	7.17	13.025
3.	Cement partially replaced by 5% of red mud & fine aggregate partially replaced by 50% of crusher sand	9.12 5.52	12.14 11.04
	Mean	7.32	11.59
4.	Cement partially replaced by 10% of red mud & fine aggregate partially replaced by 50% of crusher sand	6.18 5.07	10.83 9.92
	Mean	5.625	10.375

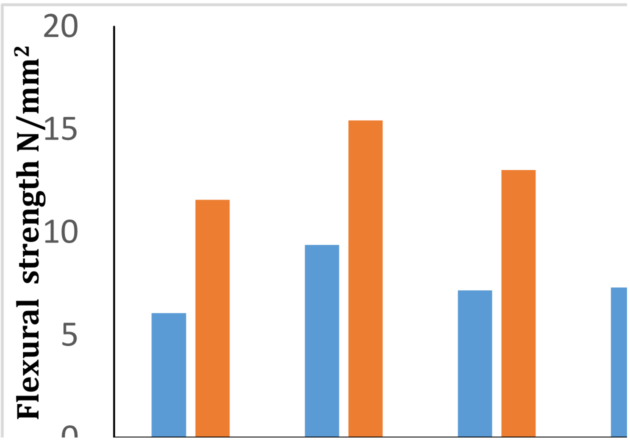

Fig-10 Flexural strength of cement partially replaced by red mud and fine aggregate partially replaced by Crusher sand

The test results show that 5% replacement of cement by red mud and 25% replacement of fine aggregate by crusher sand gives the optimum flexural strength for ferrogeocrete.

6. CONCLUSION

The following points are concluded from the experimental study:

1. In the present experimental study, effort has been put to check the feasibility of using red mud in cement mortar and also the use of red mud and crusher sand in combination.
2. From the compressive strength test on cement mortar of ratio 1:2 and water cement ratio 0.41, it is observed that the optimum percentage replacement of cement by red mud is 5%.
3. The percentage increase in 7 days and 28 days compressive strength of cement mortar in which cement was replaced by 5% of red mud was observed to be 12.61% and 5.64% greater than the control specimens respectively.
4. The optimum percentage replacements of cement and sand by red mud and crusher sand respectively when used in combination in cement mortar was found to be 5% of red mud and 25% of crusher sand from the compressive strength test.
5. On comparing the 7^{th} and 28^{th} day compressive strength of control specimen with mortar cubes in which cement is replaced by 5% of red mud and fine aggregate replaced by 25% of crusher sand is observed to be 44.54% and 28.61% greater than the control specimen respectively.
6. The flexural strength test on ferrogeocrete with stainless steel weld mesh shows that the optimum percentage replacement of cement by red mud is 5%.
7. The flexural strength test on ferrogeocrete with combined replacement of cement and sand by red mud and crusher sand respectively shows that 5% of red mud can be used to replace cement and 25% of crusher sand can be used to replace river sand.
8. On comparing the 7^{th} and 28^{th} day flexural strength of control specimen with ferrogeocrete slab in which cement is replaced by 5% of red mud is observed to be 21.75% and 23.88% greater than the control specimen respectively.
9. On comparing the 7^{th} and 28^{th} day flexural strength of control specimen with ferrogeocrete slab in which cement is replaced by 5% of red mud and fine aggregate replaced by 25% of crusher sand is observed to be 54.53% and 33.38% greater than the control specimen respectively.

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