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Experimental Evaluation on Durability Properties of Geopolymer Ferrocement Slab

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ABSTRACT: The main aim of the project is durability properties of geo polymer ferrocement slab will be evaluated. Here 75% of GGBS and 25% of fly ash will be used as source material and for alkali activation Sodium silicate and Sodium hydroxide will be added at 25% and 10% respectively. The ferro cement slab will be casted with the optimized mix by using wire mesh as the reinforcement by depth of 40mm. The CFRP threads are wound over the reinforced wire mesh as 1,2,3 & 4 Nos along its longitudinal direction. The durability studies will be done on the specimen and performance will be evaluated. In this project the durability tests were conducted like water permeability test, acid resistance test and thermal resistance tests.

I. INTRODUCTION

The overall usage of cement as OPC and PPC plays an important role in global warming and environmental pollution. The world's atmosphere is mostly enveloped with 7% of hazardous gases due to cement production. The overall global heat is also raised year by year. This can be only minimized by using alternative material on behalf of cement. In this present study, the cement mortar is totally avoided in the ferrocement slabs. Fly ash is used as basic source material of geopolymeric mortar, it shows some drawbacks when compared with cement mortar. Some of the properties which vary hugely when compared to cement mortar are cost, setting time, curing temperature and method and strength. But it resembles cement mortar to a certain degree when GGBS is used as the general source material in making geopolymer mortar. The structure of geopolymer mortar shows less property when compared to the cement mortar. On the other hand, the ferrocement slabs have good bending performance and are highly corrosive member. To augment its strength and flexural performance the carbon fiber materials are introduced into the flexural member to increase its flexural behaviour. The carbon fiber can be used both as internal and external strengthening material. This study utilized carbon fiber wound wire mesh and high strength geopolymer mortar with GGBS to make ferrocement slabs. The flexural strength of ferro cement slabs are studied with varying number of meshes (1L,2L,3L), with depth 40mm and with varying CFRP winding over the wire mesh (1w, 2w,3w,4w).

II. MATERIALS USED

2.1 Ground granulated blast furnace slag (GGBS)

It is obtained from Dindukal steel limited, Dindukal, India. The chemical composition of GGBS given by them is depicted in table 1.

Table 1. Chemical composition of GGBS

CaO	40
SiO ₂	35
Al ₂ O ₃	12
Fe ₂ O ₃	0.2
MgO	10

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2.2 Fly ash

Fly ash is obtained from Tuticorin power plant. Class F fly ash is used in this studies. Table 2 shows the properties of the fly ash

Table 2. Properties of Flyash

Property	Values
Specific Gravity	2.34
Surface area	300-500 m ² /kg
Particle size	1µm-150µm
Bulk density	540-860 kg/m ³
FinenessModulus	2.73

2.3 Fine aggregate

River Sand is obtained from Trichy river bed, India. It conforms to zone II [IS 383-1987] as per Indian codal provision. The specific gravity is 2.75 and the fineness modulus is 3.5.

2.4 Alkaline solution

The alkaline solution is formed by mixing sodium hydroxide and sodium silicate. The sodium hydroxide is purchased from chemical agencies in the form of flakes and dissolved in water to have 10m solution. Similarly, the sodium silicate is also obtained with a mass consisting of SiO₂ = 29%; Na₂O = 15 %; H₂O = 56%. The ratio of sodium silicate and sodium hydroxide is kept to be 2.3

2.5 Super plasticizer

To enhance good workability, high range water reducing naphthalene based super plasticizer from BASF Ltd is used. GLENIUM is used as the super plasticizer.

2.6 Wire mesh

Welded wire mesh of 1" x 1" size is obtained from locally available steel store. The thickness of wire mesh is found to be 5mm.

III. MIX PROPORTIONS

The mortar is prepared in 1:2 ratios. The binder consists of fly ash, sodium silicate, and sodium hydroxide. The total volume of binder is occupied by 65% of fly ash and 35% of solids in the alkaline solution. The percentage of H₂O in the alkaline solution should not be considered, lest it, leads to volumetric shrinkage.

IV. MIXING PROCEDURE

The dry materials are mixed together in a pan with alkaline solution, super plasticizer and water. The materials are thoroughly mixed and specimens of about 50mm x 50mm x 50mm are cast. The cast specimens are kept in room temperature for curing. The specimens kept in open air curing are taken for testing on the specified day. The ferrocement slabs are cast with dimensions 700mm x 300mm with varying depths. Initially, the wire mesh is cut down for the dimension mentioned. With a small cover, the weld mesh should be placed over the mortar, and again the mortar should be poured over the mesh and finishing should be done. The finished slabs should be removed from the

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mould after 5 hours from the time of casting. The finished specimens should be numbered on the next day and kept in open air until the day of testing.

V. TESTS CONDUCTED

5.1 Compressive strength test

The cube specimens cast for each proportion of size 50mm are tested under compression load at 3, 7 and 28 days. The specimens are tested in compression testing machine of 2000 KN capacity. As per IS 5161959, the compression test is conducted.

5.2 Flexural strength test on ferro cement slabs

The cast ferrocement slabs are tested on the 28th day. Testing of slabs are done on universal testing machine of 400 KN capacity. The support for the slabs should be made at 25mm from each end and thus 650 mm can be kept as effective span. Single point loading is given on the slabs by using iron rods. The deflection is noted down by keeping LVDT at mid span of slabs.

VI. RESULTS AND DISCUSSIONS

6.1. Compressive strength:

The compression strength of the mortar specimens with different percentage of GGBS are tested on 3, 7, and 28 days and the results are illustrated in table 4.

Table 4. Compressive strength of geopolymer mortar

Mix No	GGBS (%)	Compressive Strength (N/mm ²)		
		3 days	7 days	28 days
1	0	2.46	5.79	8.50
2	25	5.4	13.08	18.91
3	50	7.68	17.68	25.63
4	75	10.92	24.89	36.61
5	100	13.70	31.51	45.72

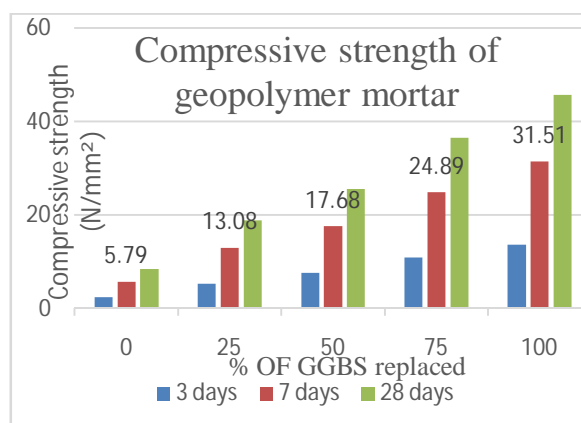


Fig.1 Compressive strength values of geopolymer mortar with different percentage of GGBS

The specimen with 100% of fly ash attains its final setting time only after 4 days. But with the addition of GGBS the setting time is found to get decrease as cement mortar. For each 20% replacement of fly ash by GGBS, the strength

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increased. The maximum strength is achieved at 100% replacement of fly ash with GGBS. Nearly 85% of strength is increased from the control specimen. Even though 100% of GGBS gained optimum, some small cracks are found over the surface of the cube specimens and it is not advisable for slabs. So the mix with 80% GGBS and 25% of fly ash is concluded as the optimized mix and the strength increases by 70% from the control specimen.

6.2 Flexural strength of ferrocement slabs:

The flexural strength of the cast slabs is noted down and shown in table 6.

Slab	D	B	L	Weld mesh No of layers (Nos)	No of CFRP layers	LOAD	Deflection (mm)
S1	40	300	700	1		3.24	11
S2	40	300	700	2		4.32	12
S3	40	300	700	3		5.26	12
S4	40	300	700	1	1w	6.45	13
S5	40	300	700	1	2w	6.77	13
S6	40	300	700	1	3w	7.45	14
S7	40	300	700	1	4w	8.21	15

Table 5 Flexural strength of ferrocement slabs

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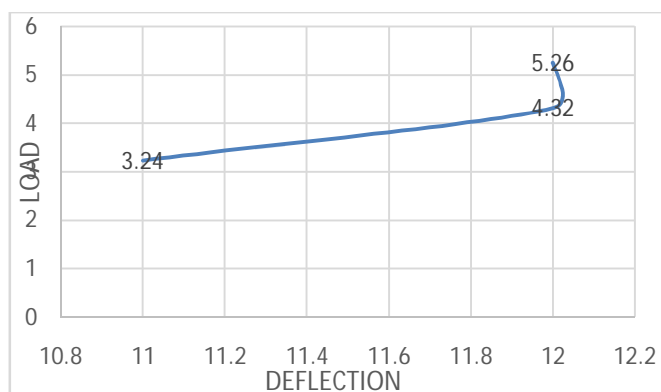


Fig 2 Flexural strength of the ferrocement slabs with varying number of mesh layers

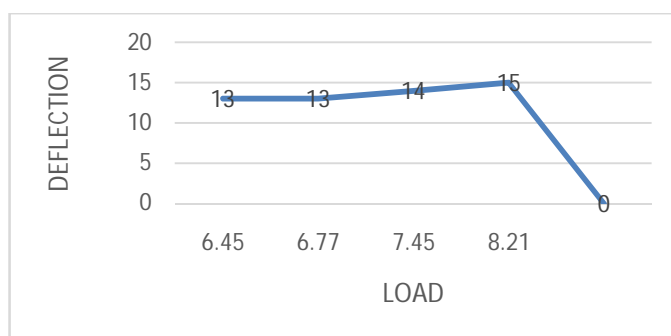


Fig 3 Flexural strength of the ferrocement slabs with varying number of CFRP windings

The flexural test on the ferrocement slabs clearly shows that the CFRP winding over the wire meshes increases the strength enormously when compared to conventional specimens. By referring fig 2, the strength increase of ferrocement slabs can be found with the increases in number of wire mesh layer. About 48% of the strength increases with three layers of welded mesh compared to single layer. Similarly, the increase in strength due to CFRP winding can be known from fig 3. Up to 3 winding of CFRP over wire mesh can be prepared, beyond that it affects the binding capacity of the mortar. For four layers of fiber winding, the strength increases by 31% compared to the slab without winding.

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VII. DURABILITY TESTS

7.1 Permeability test

The depth of penetration on specimen from the permeability test is shown in figure 1.

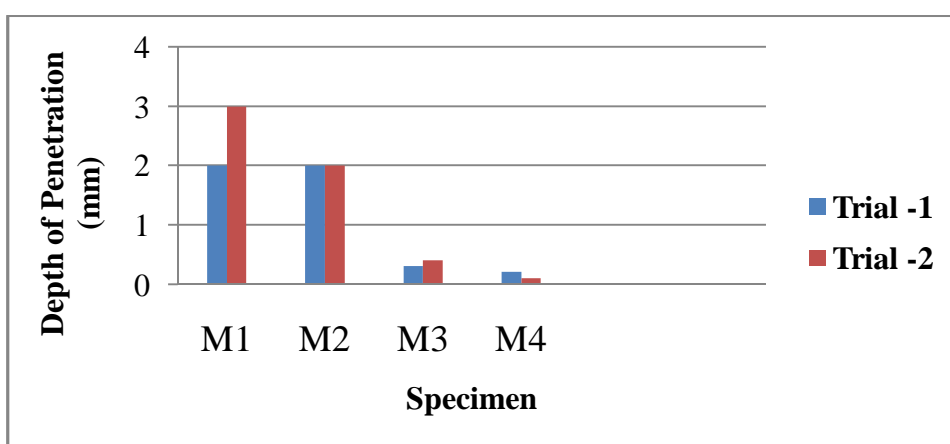


Figure 4 Penetration Depth of Permeability Test

7.2 Acid resistance test

The acid resistance test results under normal cured specimen and acid cured specimen are shown in figure 2.

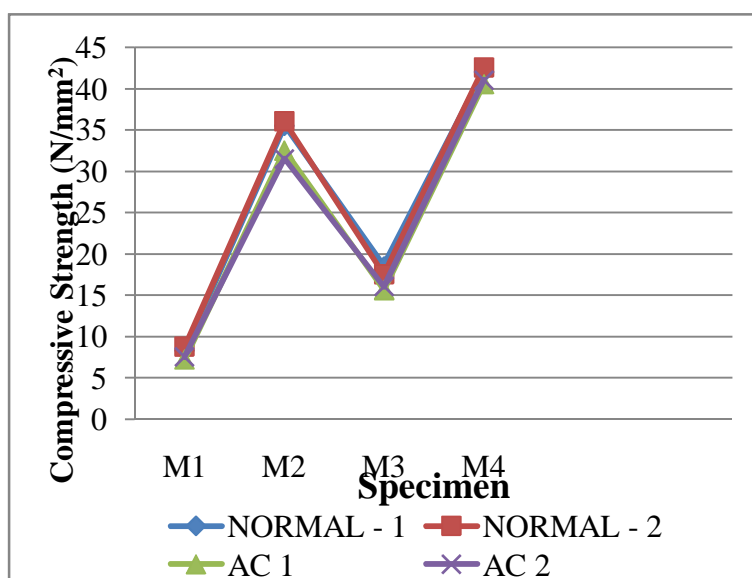


Figure 5 Comparison of Normal Cured and Acid Cured Specimens

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7.3 Thermal resistance test

7.3.1 Thermal effect

Figure 6 shows that six different composition of specimens M1 to M6 at different curing condition.

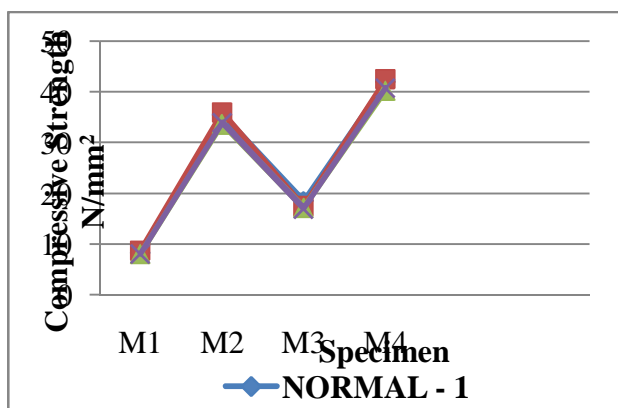


Figure 6. Comparison of specimens under normal temperature and thermal effect

7.3.2 Thermal shock

Figure 7 shows compressive strength results of thermal shock for the specimen subjected to open air curing and hot curing. Initially, the stress carrying capacity was very low and it was improved on further testing over the optimized mix. Compared to fly ash mix, stress at normal temperature optimized mix was increased by 803% at open air curing and 367% for hot curing condition.

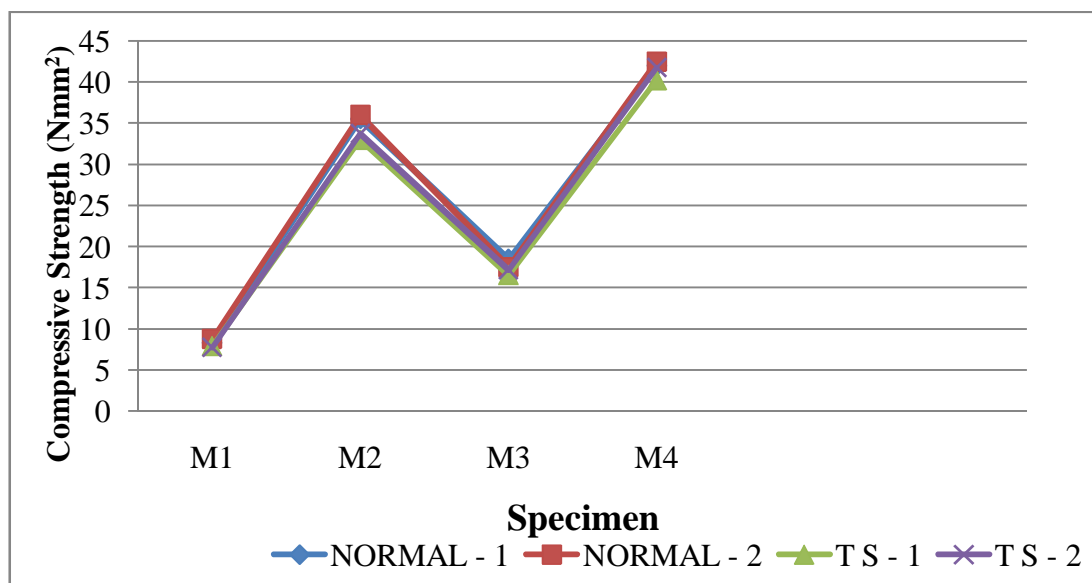


Figure 7. Comparison of specimens under normal temperature and thermal shock

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VIII. CONCLUSION

The conclusions drawn from this study are explained below:

- Specimens with 100% of fly ash attained its final setting time only after 4 days. But with the addition of GGBS, the setting time was found to get decrease similar to cement mortar.
- The mix with 75% GGBS and 25% of fly ash is concluded as the optimized mix and the strength was increased to 331% from the control specimen even though 100% of GGBS gained optimum. At 100% of GGBS, some small cracks are found over the surface of the cube specimens which is not advisable for slabs.
- The ferrocement slabs with three layers of welded mesh withstand more load when compared to single layer which was 79% higher.
- Up to 3 winding of CFRP over wire mesh can be prepared, beyond that it affects the binding capacity of the mortar. The slab with four layers of fiber winding carried 124% more than the slab without winding.
- For acid resistance study, the compressive stress values of acid cured specimens were less compared with the normal cured specimens but stress reduction was very less amount as well as weight when compared to normal specimen. The increase in stress for hot cured specimen subjected to thermal shock increased the stress carrying capacity for the optimized mix specimen by 387% for Trial 1 and 365% for Trial 2. Compared to open air curing hot curing specimen produced good stress carrying capacity.

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