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Experimental Evaluation on Durability Properties of Geopolymer Ferrocement Slab With Nano Silica

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ABSTRACT: This project aims at experimental evaluation on durability properties of geopolymer ferrocement slab with nano silica. In this experimental investigation fly ash and GGBS were used as the source material, with 25% and 75% respectively. The alkali activated solutions 25% of sodium silicate (Na_2SiO_3) and 10% of sodium hydroxide (NaOH) were used. The performance of the mix was enhanced by adding 1.5% of nano silica. The geopolymer mortar was produced at 1:2 ratio. With the above combination ferrocement slab of depth 40mm was casted. In this slab wire mesh was used as the reinforcement in which CFRP threads were wounded along its longitudinal direction as 1,2,3 and 4 no's(1W,2W,3W & 4W).Finally the durability tests were conducted on the specimen and the durability performance of the ferrocement slab was evaluated, durability tests are permeability test, acid resistance test and thermal resistance test.

KEYWORDS: Geopolymer mortar, GGBS, Nano silica, Ferrocement, Slabs, CFRP.

I. INTRODUCTION

Global warming becomes a critical issue nowadays and the released CO_2 due to cement production is considered to be responsible for approximately 7% of all greenhouse gases released worldwide. The released CO_2 amount increases with an increase in population. Therefore, the adverse effect of CO_2 releases or cement production to the environment is a significant trouble for both cement producers and human being. Novel structural materials are required to be used instead of OPC concrete to overcome this environmental issue. To date, researchers focused on the partial use of alternative cementitious materials (fly ash, silica fume, slag etc.) to improve the durability and mechanical performance of concrete. Geoplymer concrete is a concrete which does not utilize any Portland cement in its production. It is a cement less concrete. The basic concept behind using nano material which is having large area is to improve compressive strength at early ages improved hydration characteristics and reduced porosity and water absorption when compared with conventional cementitious material. Due to its ultra fine particle size, nano silica can possess a distinct pozzolanic reaction at a very early age.

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II. MATERIALS USED

2.1 Fly ash

Fly ash of class F was used in this project.Table 1 shows the properties of fly ash.

Table 1: Properties of fly ash

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

2.2 Ground Granulated Blast Furnace Slag(GGBS)

It was obtained from Dindukal steel limited, Dindukal, India. The chemical composition of GGBS given by them is depicted in table 2.

Table 2: Chemical composition of GGBS

Chemical composition	Values
CaO	45.45%
SiO_2	29.96%
Al_2O_3	12.25%
SO_3	3.62%

2.3 Nano silica

One of the silica fines with high potential as concrete additive is nano silica. Nano silica was obtained from Astrra chemicals, Chennai, India. The property given by the distributor is shown in table 3.

Table 3: Properties of Nano silica

Material properties	Values
Density	2.4 g/cm^3
pH	9.5
Viscosity	<15cps
Molar mass	59.96g/mol

2.4 Alkaline solution

The alkaline solutions used in this project were Sodium hydroxide and sodium silicate. The sodium hydroxide is purchased from chemical agencies in the form of flakes and dissolved in water to have 10 m solution. Similarly, the sodium silicate is also obtained with a mass consisting of Sio_2 = 29%; Na_2O = 15 %; H_2O = 56%. The ratio of sodium silicate and sodium hydroxide is kept to be 2.3.

2.5 Fine aggregate

The River Sand was 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.

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2.6 Super plasticizer

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

2.7 Wire mesh

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

2.8 Carbon Fiber Reinforced Polymer (CFRP)

It is a composite material which is light weight, strong polymer that contain carbon fiber it consists of a matrix as polymer resin and reinforcement as carbon fiber.

III. MIX PROPORTION

Fixing 2300 kg/m^3 as the density of mortar, this trial mix design was made. The ratio of binder to fine aggregate was fixed as 1:2 as per ACI recommendations. The binder consists of fly ash, sodium silicate, Sodium hydroxide.The mix proportions are given in table 4.

Table 4: Mix proportion

Mix	% of GGBS	Fly ash (Kg/m^3)	GGBS (Kg/m^3)
GF1	0	474.38	0
GFG1	25	355.79	118.60
GFG2	50	237.19	237.19
GFG3	75	118.60	355.79
GG1	100	0	474.38

The optimized mix was taken from the above table and it was added with nano silica as 0.5, 1, 1.5, & 2% by weight of powder (fly ash & GGBS) to get high strength mortar.

IV. TESTS CONDUCTED

4.1 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 were tested in compression testing machine of 2000 kN capacity as per IS 516 (1959).

4.2Flexural strength test of ferrocement slabs

The cast ferrocement slabs were tested on the 28th day from the day of casting. The slabs were tested by universal testing machine of 400 kN capacity. During testing the support for the slabs is given at 25mm from each end and thus 650 mm was made as effective span. Single point load is given on the slabs by placing iron rod between the loading plate and the slab. By keeping LVDT at mid span below the slabs the deflection was noted down. The load shown in the machine was noted down along with the deflection and were plotted.

4.3 Durability tests

4.3.1 Water permeability test

The permeability of ferrocement mortar is tested as per IS 3085-1965 method of test permeability of cement mortar and concrete. The cube specimens of size 150mm were casted with different proportions of mixtures and were cured for 28 days. After 28 days of curing the specimens were covered with the water proof material on all sides, except the top of bottom and were kept in the permeability cell. An elastic sheet of 8mm thick and 150mm x 150mm

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size with a central hole of 100mm x 100mm is fixed on the top and bottom surface of the specimen in the permeability cell. The cover plate was properly tightened. After the water reservoir is fully filled, the desired test pressure was applied. The permeability test was continued for 4 days.

4.3.2 Acid resistance test

The ASTM C267 test method WAS used for the acid resistance of concrete in this investigation. The ferrocement mortar cube specimens of different concrete mixtures of size 50 mm were casted and after 5 days of hot and air curing the specimens were allowed to immerse in acid. The weights of ferrocement mortar cube specimen were taken. The acid attack test on concrete cube was conducted by immersing the cubes in the hydrochloric acid with pH=2 for 28 days. After 28 days the specimens were taken out of acid water. Then the specimens were tested for compressive strength. The resistance of ferro cement mortar to acid attack was found by the percent loss of weight of specimen and the present loss of compressive strength on immersing ferrocement mortar cubes in acid water.

The weight loss and strength loss of the specimens as per ASTM C267 using the Equation (1) and (2)

$$\textbf{Weight loss} = \frac{w_1 - w_2}{w_1} \times 100 \quad (1)$$

Where w_1 = Weight of specimen before immersion in g

w_2 = Weight of specimen after immersion in chemical solution in g

$$\textbf{Loss in compressive strength} = \frac{f_1 - f_2}{f_1} \times 100 \quad (2)$$

Where f_1= Compressive strength of mortar cured in water in N/mm^2

f_2 = Compressive strength of mortar after immersion in chemical solution in N/mm^2

4.3.3 Thermal resistance test

4.3.3.1 Thermal effect

The cubes were kept in respective atmosphere for 28 days. Then the specimens were heated to a temperature of 200 °C in an oven. After 24 hours of heating the specimens are placed in the compression testing machine immediately and the load was applied.

4.4.3.2 Thermal shock

The cubes were kept in respective atmosphere for 28 days. The specimens were subjected to a temperature of 200 °C in an electric oven for heating. After 24 hours of heating in electric oven the specimens were dipped in water immediately. Following this the compressive test was conducted on the specimens.

V. RESULTS AND DISCUSSIONS

5.1 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 5. The strength of the specimens with nano silica were tested and the readings are shown in table 6.

Table 5: Compressive strength of geopolymer mortar

Mix No	Fly Ash (%)	GGBS (%)	Compressive Strength (N/mm^2)		
			3 days	7 days	28 days
GF1	100	0	2.46	5.79	8.50
GFG1	75	25	5.4	13.02	18.91

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GFG2	50	50	7.68	17.68	25.63
GFG3	25	75	10.92	24.89	36.61
GG1	0	100	13.70	31.51	45.72

Table 6: Compressive strength of geopolymer mortar with nano silica

Mix No	Fly Ash (%)	GGBS (%)	Nano Silica (%)	Compressive Strength (N/mm^2)		
				3 days	7 days	28 days
GFG3	25	75	0	10.92	24.89	36.61
GFG3S1	25	75	0.5	13.14	30.82	45.35
GFG3S2	25	75	1.0	17.61	40.52	58.74
GFG3S3	25	75	1.5	21.96	53.33	78.4
GFG3S4	25	75	2.0	20.80	47.90	69.42

5.2Flexural strength of ferrocement slabs

The flexural strength of the cast slabs is shown in table 7.

Table 7:Flexural strength of ferrocement slabs under various criteria's

Slab ID	Mortar Mix No	Specimen Size (mm)			Weld Mesh	No. of CFRP	Load (kN)	Deflection (mm)
		L	B	D	No. of Layer			
S1	GF1	700	300	40	1	-	1.25	9
S2	GFG3	700	300	40	1	-	2.28	9
S3	GFG3S3	700	300	40	1	-	3.67	11
S4	GFG3S3	700	300	40	2	-	5.77	12

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S5	GFG3S3	700	300	40	3	-	6.58	13
S6	GFG3S3	700	300	40	1	1	6.45	13
S7	GFG3S3	700	300	40	1	2	6.77	13
S8	GFG3S3	700	300	40	1	3	7.45	14
S9	GFG3S3	700	300	40	1	4	8.21	14

5.3 Durability tests

5.3.1 Permeability test

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

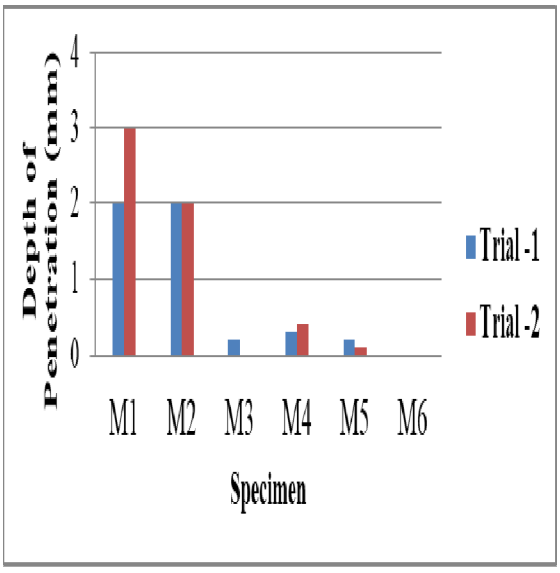

Figure 1: Penetration depth of permeability Test

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5.3.2 Acid resistance test

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

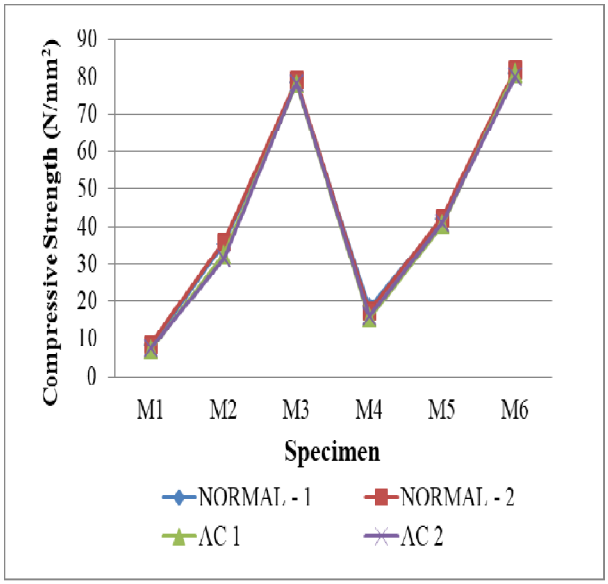

Figure 2:Comparison of normal cured and acid cured specimens

5.3.3 Thermal resistance test

5.3.3.1 Thermal effect

Figure 3 shows that six different composition of specimens M1 to M6 at different curing condition.

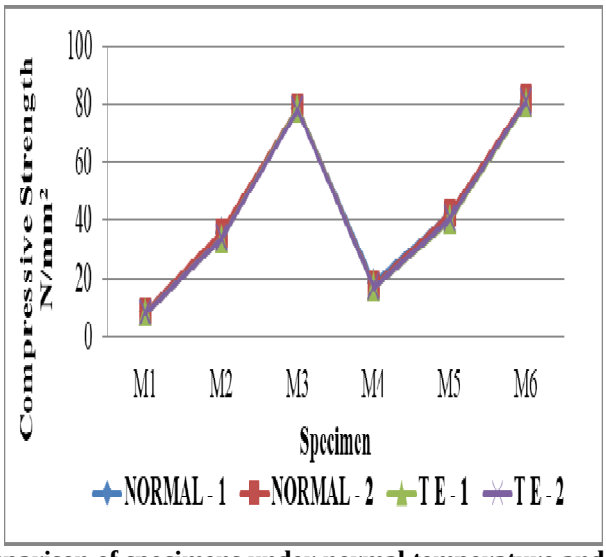

Figure 3: Comparison of specimens under normal temperature and thermal effect

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5.3.3.Thermal shock

Figure 4 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.

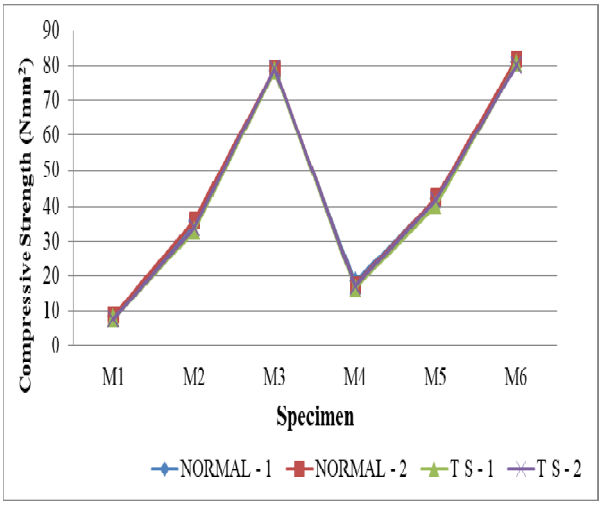

Figure 4: Comparison of specimens under normal temperature and thermal shock

VI. CONCLUSIONS

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 was 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 were found over the surface of the cube specimens which is not advisable for slabs.
- By adding the nano silica mix, the pores of mortar specimen were found to get arrested. The strength wasincreased by 114% from the optimized mix with 1.5% of nano silica.
- 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 load 124% more than the slab without winding.
- In penetration test, the specimen cast with mix combination of GFG3S3 cured at 60°C showed nil depth of penetration and negligible penetration at normal temperature curing. For acid resistance study, the compressive stress values of acid cured specimens were less compared with the normal cured specimens butstress 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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