INVESTIGATION ON FLEXURAL BEHAVIOR OF FERROCEMENT SLAB WITH GGBS & NANO SILICA

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Abstract: *The flexural behavior of ferrocement slabs using GGBS & Nano Silica based geopolymer mortar are investigated experimentally. The geopolymer mortar for ferrocement slab is prepared as 1:2. The binder composed of 65% fly ash, 25% sodium silicate and 10% sodium hydroxide. The percentage of fly ash is altered by using GGBS as 20%, 40%, 60%, 80% & 100% by its weight. Even though the optimum strength obtained with 100% fly ash by GGBS, 80% of GGBS addition is taken due to the early formation of cracks at 100% of GGBS addition. The performance of the selected mix is further improved by adding Nano Silica as 0.5%, 1%, 1.5% & 2% by weight of binder. With the 1.5% of Nano Silica and 80% of GGBS, the geopolymer mortar acquired over 250% increase in strength.*

Key words: *Geopolymer mortar, GGBS, Nano-silica, Ferrocement, Slabs*

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 [1].The overall global heat is also raised year by year [2]. 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 ferro cement slabs. The cement mortar is replaced by geopolymer mortar. The technology introduced by Davidovids [3] is used to have the geopolymer mortar. Even though fly ash is used as basic source material of geopolymeric mortar [4], it shows some drawbacks when compared with cement mortar [6]. 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 [7]. The structure of geopolymer mortar shows less property when compared to the cement mortar [8].

To enhance higher particle compaction in the internal structure of geopolymer mortar, Nano silica is added with it up to 2% of the binder's weight in this study. In geopolymer concrete, the addition of Nano silica increases its strength and decreases its voids within the concrete [9]. The same idea is tried in the mortar to have good strength and less porosity in geopolymer mortar. The GGBS is replaced on behalf of fly ash and the Nano silica is added to the optimized one up to 2%.On the other hand, the ferro cement slabs have good bending performance and are highly corrosive member [10]. Basically, with the increase in number of wire meshes and by increasing the depth, the strength of ferro cement slabs increases [11] [12]. But this can be avoided by using high strength mortar and high wire mesh in Ferrocement slabs. To augment its strength and flexural performance the carbon fiber materials are introduced into the flexural member to increase its flexural behaviour [13].The carbon fiber can be used both as internal and external strenthening material [14]. This study utilized carbon fiber wound wire mesh and high strength geopolymer mortar with GGBS and Nanosilica to make ferrocement slabs. The flexural strength of ferro cement slabs are studied with a layer of mesh and with varying depths (30mm,40mm,50mm)

II.MATERIALS USED

2.1 Ground granulated blast funace slag (GBBS)

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

The response is characterized by, L the delay time and T the time constant (see Table 1).

Table I. Chemical composition of GGBS

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

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 II. 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
Fineness Modulus	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 Coarse Aggregate

The crushed granite aggregates available locally at quarry is obtained. The size of coarse aggregate ranges from 10mm to 20mm. The specific gravity is 2.83 and fineness modulus is 7.80. It is conformed as per IS383-1987 and is tested according to IS 2386-1963.

2.5 Nano Silica

Nano silica is obtained from Astrra chemicals, Chennai, India. The material is very fine and it easily blows away by air. The property of Nano silica as given by the distributor is delineated in Table 3.

Table III. Properties of Nano Silica

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

2.6 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 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.

2.7 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.

2.8 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 H_2O in the alkaline solution should not be considered, lest it, leads to volumetric shrinkage. The mix proportions are given in table 4.

Table IV Mix proportions of geopolymer mortar

Mix	% of GGBS	Fly ash (Kg/m^3)	GGBS (kg/m^3)	Fine aggregate (Kg/m^3)	S.H	S.S	Super plasticizer %	Water (l/m^3)
1	0	455	-	1400	75	170	2	4
2	20	364	91	1400	75	170	2	4
3	40	273	182	1400	75	170	2	4
4	60	182	273	1400	75	170	2	4
5	80	91	364	1400	75	170	2	4
6	100	-	455	1400	75	170	2	4

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

IV. MIXING PROCEDURE

The dry materials are mixed together in a pan with alkaline solution, superplasticizer 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 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 516 (1959), the compression test is conducted.

5.2 Flexural strength test on ferro cement slabs

The cast ferro cement slabs are tested on the 28^{th} 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. The load shown in the machine is noted down along with the deflection and is plotted.

Fig.I. Ferro cement slabs during and after casting

VI. RESULTS AND DISCUSSIONS

6.1. Compressive strength:

The Compression strength test for the mortar specimens with different percentage of GGBS are tested on 3, 7, and 28 days of curing and the results obtained are illustrated in table 5.

Table V. Compressive strength of geopolymer mortar

Mix	% of GGBS	Compressive strength		
		3 days	7 days	28 days
1	0	3.65	6.34	8.54
2	20	5.32	8.34	10.45
3	40	6.89	9.15	12.76
4	60	7.83	9.89	13.38
5	80	8.62	10.52	14.53
6	100	9.34	11.35	15.75

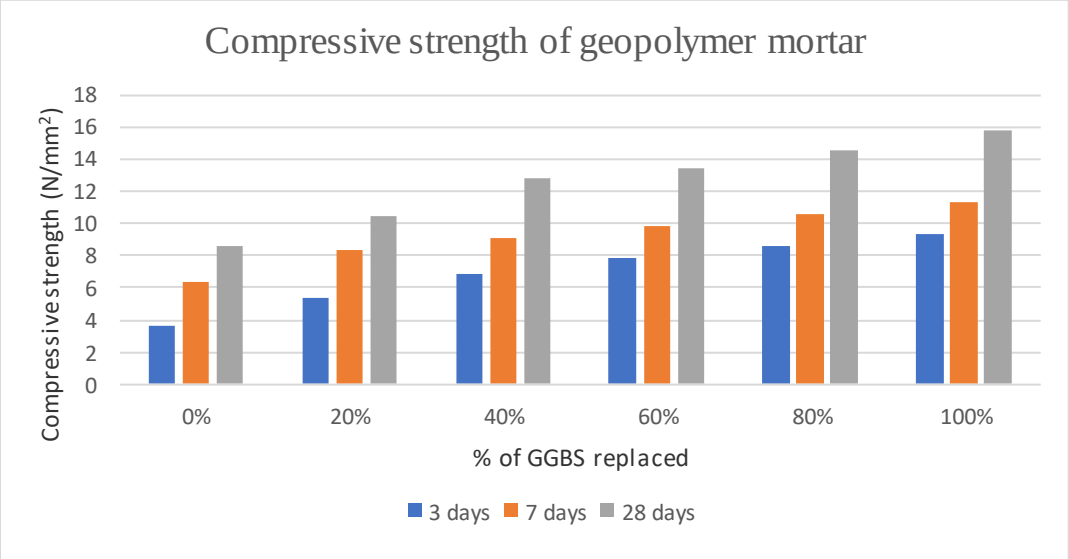

Fig.II Compressive strength values of geopolymer mortar with different percentage of GGBS

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 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 20% of fly ash is concluded as the optimized mix and the strength increases by 70% from the control specimen.

The nano silica is added with the optimized specimen of about 0.5, 1, 1.5 and 2% by weight of powder content. The weight of powder can be derived from the sum of weight of GGBS and fly ash. The strength of the specimens with Nano silica are tested and the readings are shown in table 6.

Table VI. Compression strength of geopolymer mortar with nano silica

Mix No	% of GGBS	% of fly ash	% of Nano silica	Compressive strength		
				3 days	7 days	28 days
1	80	20	0	5.63	11.35	29.24
2	80	20	0.5	6.85	13.87	31.45
3	80	20	1	7.62	15.34	33.45
4	80	20	1.5	8.23	16.45	35.67
5	80	20	2	9.17	18.34	30.67

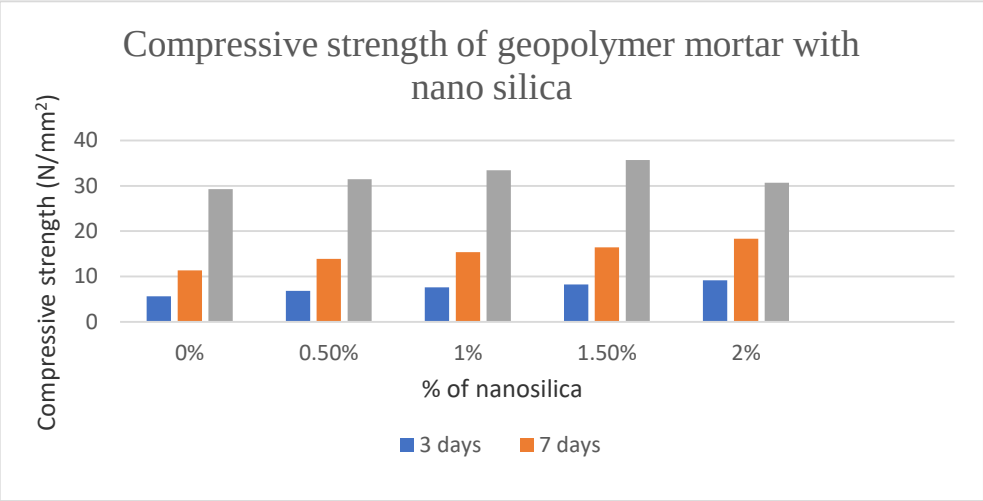

Fig. III. Compressive strength value of geopolymer mortar with different percentage of Nano silica.

The addition of Nano Silica increases the workability with addition of extra water (approx. 1lt/m^3/0.5% of Nano Silica).

The pores of mortar specimen are found to get arrested with the addition of Nano silica. With every inclusion of 0.5% Nano silica, the strength got increased. But after 1.5% inclusion of Nano Silica, the strength is found to get decreased. The strength of slab with 1.5% of Nano silica is increased by 22% from the optimized mix.

6.2 Flexural strength of ferrocement slabs:

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

Table VII. Flexural strength of Ferrocement slabs under various criteria's

Slab ID	% of GGBS	% of Fly ash	% of Nano Silica	Depth (mm)	Width (mm)	Length (mm)	Effective Length (mm)	No of layers (Nos)	Load (kN)	Deflection (mm)
S_1	0	100	0	30	300	700	650	1	0.95	9
S_2	80	20	0	30	300	700	650	1	2.46	10
S_3	80	20	1.5	30	300	700	650	1	3.45	11
S_4	80	20	1.5	40	300	700	650	1	3.67	11
S_5	80	20	1.5	50	300	700	650	1	4.24	12

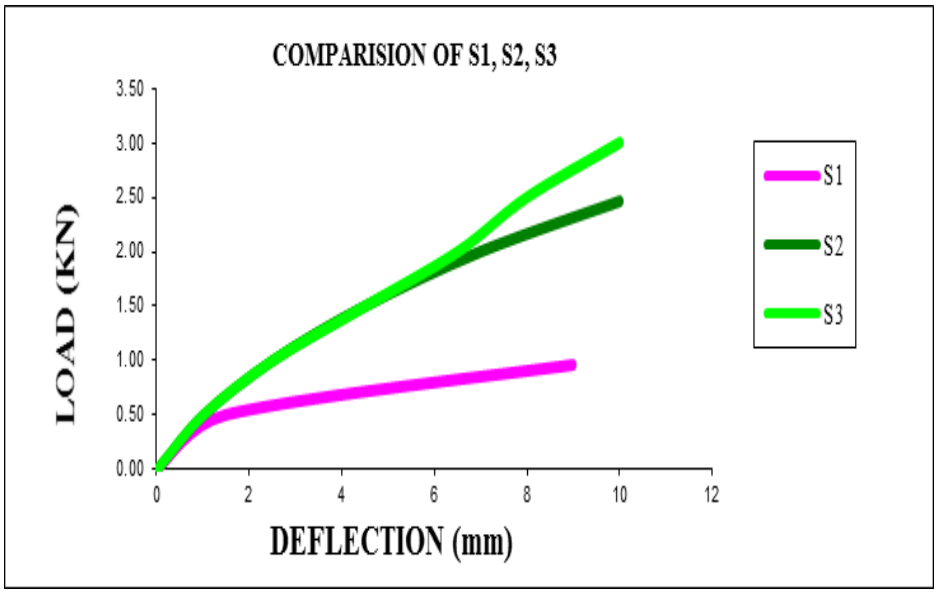

Fig IV. Flexural strength of the ferrocement slabs with varying mortar

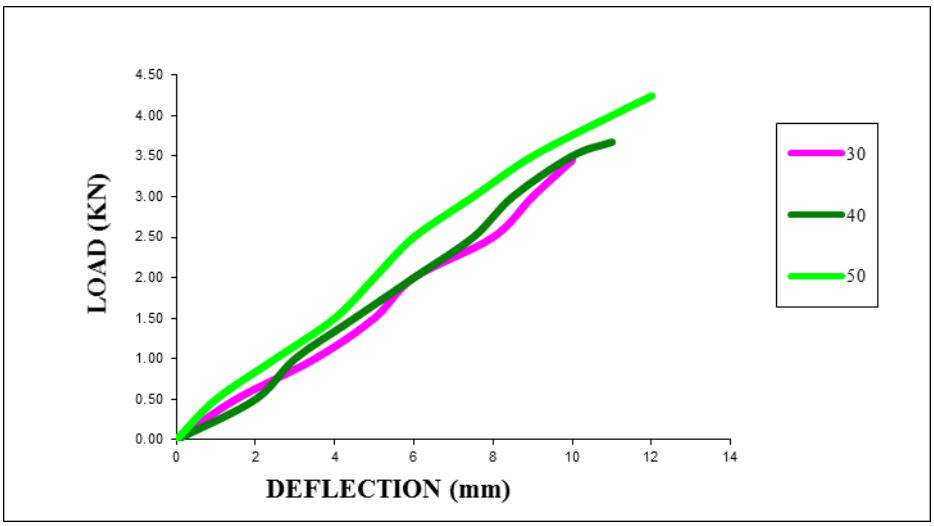

Fig V. Flexural strength of the ferrocement slabs with varying depth

Figure 4 shows that the slabs with 80% of GGBS, 20% of fly ash and 1.5% Nano Silica obtained 263% increase in strength. Fig 5 clearly shows that the strength of ferro cement slabs increases with the depth. For 50mm depth, the strength increases by 23% when compared to 30mm of depth.

VII. CONCLUSION

The following conclusions can be made from this study

- 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 similar to cement mortar.
- The mix with 80% GGBS and 20% of fly ash is concluded as the optimized mix and the strength is 70% increase 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 pores of mortar specimen are found to get arrested with the addition of Nano silica. The strength is increased by 22% from the optimized mix with 1.5% of Nano Silica.

VIII. REFERENCES

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