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Strength and Durability of Geo-Polymer Concrete with Mineral Admixture

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Abstract: It is important to durable of structure and reduce co2 emission through the greater use of substitute of cement. The use of supplementry cementitious materials as partial replacement for the cement in concrete will play a significant role with respect to the environmental control of greenhouse and global temperature reduction. The development of geopolymer concrete (GPC) processing of geopolymer using black rice husk ash, GGBS in combination with sodium hydroxide and sodium silicate solutions, offers a promising alternative to ordinary portland cement concrete. This study compares the different ratio of black rice husk ash to GGBS where50:50 60:40 40:60 ratios and differing the molarities of alkaline solutions which are 8m , 10m and 12m and comparing the strength of the above ratios and conducting durability characteristics of fly ash and GGBS based geopolymer concrete by conducting test procedure like compressive strength , split tensile strength test, sorpitivity test.
Keywords: Geo-polymer concrete ,Black rice husk ash (BRHA),Ground granulated blast furnace slag (GGBS).

I. INTRODUCTION

Concrete, the predominantly used construction material in the world has gained its popularity because of its multiple benefits like relatively low cost of production, ease of handling, capacity to be moulded into desired shape, achievement of desired strength ranging from low to very high, serviceability and durability In 1978, Joseph Davidovits (1999) proposed that it is possible to produce binders resulting from the polymerization reaction between alkaline liquids and source materials that are rich in silica and aluminium. He coined the term 'geo-polymer' to describe this family of mineral binders that possessa chemical composition similar to zeolites but exhibiting an amorphous microstructure. Paloma et al (1999) suggested that pozzolanic materials like blast furnace slag can be activated with the help of alkaline liquids to produce binders which could completely replace OPC in concrete production. Contrasting to OPC concrete (OPCC), the principal binders in GPC are not calcium-silicate-hydrates (C-S-H). Instead, silicate polymeric gel formed by tetrahedrally-bonded silicon and aluminium with oxygen atoms shared in between acts the binder. The two important constituents of GPC are source materials and alkaline liquids. The source materials must be rich in silicon (Si) and aluminium (Al). These could be of geological origin like metakaolin or by-product materials like fly ash, Ground Granulated Blast furnace Slag (GGBS), silica fume, rice-husk ash, etc. The alkaline liquids are based from soluble alkali metals usually being sodium or potassium. The most common alkaline liquid used is a combination of sodium or potassium hydroxide along with sodium or potassium silicate correspondingly.

II. MATERIAL AND METHODOLOGY

A. Ground Granulated Blast Furnace Slag (GGBS)

GGBS conforming to the specifications of IS 12089-1987 was used as the primary binder to produce GPC in which BRHA was replaced from 0% to 30%. GGBS was obtained from JSW cements limited, Bellari, India. The chemical composition and physical properties of GGBS were tested (as per ASTM D3682-01) in SGS Laboratories, Chennai and are given in Table 4.1.

Table 4.1 Properties of GGBS

S. No	Property Value	Value
1	Silicon-di-Oxide (SiO2)	31.25 %
2	Aluminium tri oxide (Al2O3)	14.06 %
3	Ferric Oxide (Fe2O3)	2.80 %
4	Calcium Oxide (CaO)	33.75 %
5	Magnesium Oxide (MgO)	7.03 %
6	Loss on Ignition	1.52%
7	Specific gravity	2.61
8	Blaine fineness	4550 /g

B. Black Rice Husk Ash (BRHA)

BRHA was obtained from a rice mill near Karaikudi. It was finely ground in a ball-mill for 30 minutes and passed through 75 sieve (Rashid et al, 2010) before using in GPC production. The chemical composition and physical properties of BRHA were tested (as per ASTM D3682-01) in SGS Laboratories, Chennai and are given in Table 4.2. BRHA was obtained from a rice mill near Karaikudi. It was finely ground in a ball-mill for 30 minutes and passed through 75 sieve (Rashid et al, 2010) before using in GPC production. The chemical composition and physical properties of BRHA were tested (as per ASTM D3682-01) in SGS Laboratories, Chennai and are given in Table 4.2.

Table 4.2 Properties of BRHA

S. No	Property Value	Value
1	Silicon-di-Oxide (SiO_2)	93.96 %
2	Aluminium tri oxide (Al_2O_3)	0.56 %
3	Ferric Oxide (Fe_2O_3)	0.43 %
4	Calcium Oxide (CaO)	0.55 %
5	Magnesium Oxide (MgO)	0.40 %
6	Loss on Ignition	9.79%
7	Specific gravity	2.14
8	Blaine fineness	56732/g

III. MIX PROPORTIONS

Since there are no standard codal provisions available for the mix design of geopolymer concrete, the density of geopolymer concrete was assumed as 2400 kg/m3 and other calculations were made based on the density of concrete as per the mix design given by Lloyd & Rangan (2010). The combined total volume occupied by the coarse and fine aggregates was assumed to be 77%. The alkaline liquid to binder ratio was taken as 0.40. As there are no standard mix design procedures available to estimate the target strength of GPC and besides this being a relatively new type of concrete that is still in developmental stage, minimum target strength was taken as 30 MPa, considering it as a regular strength concrete. GGBS was kept as the base material for making the control GPC specimens (GP). Then BRHA was used to replace GGBS in the mix in three different proportions, 10% (GPR1), 20% (GPR2) and 30% (GPR3), for the rest of the mixes used in the investigation.
The mix proportions of GPC are given Table 4.3.

Table 4.3 Mix proportions of GPC

S. No	Quantities	Proportions (kg/m3) GP			
		GP	GPR1	GPR2	GPR3
1	GGBS	394	355	315	276
2	BRHA	0	39	79	118
3	Coarse aggregate	1201	1201	1201	1201
4	Fine aggregate	647	647	647	647
5	Sodium hydroxide	45	45	45	45
6	Sodium silicate	113	113	113	113
7	Super-plasticizer	8	8	8	8
8	Water	59	59	59	59

IV. TESTS CONDUCTED

A. *Compressive Strength Test*

The compressive strength of GPC was tested as per IS 516:1959. The permissible error was not to be greater than ± 2% of the maximum load. Several studies discuss the influence of salient parameters on the compressive strength of GPC. Hardjito and Rangan (2005) listed out 12 parameters that influence the strength of GPC. Among them, the curing temperature and concentration of NaOH particularly have a lot of impact on the compressive strength of GPC. Palomo et al (1999) concluded that the curing temperature is a reaction accelerator in geopolymers. Nazari et al (2011) deduced that the concentration of alkaline solution has a main effect on the strength of GPC.Accordingly, two parameters viz., the influence of curing temperature and the influence concentration of sodium hydroxide on the compressive strength of GPC were studied separately. The influence of sodium hydroxide concentration was studied for three different molarity of NaOH viz., 5 M, 8 M and 11 M. For this study, all the specimens were heat cured at 60°C. Also, the influence of curing temperature on the compressive strength of GPC was studied for three different curing conditions viz., ambient, 60°C and 90°C. For this study, the concentration of NaOH was fixed as 8 M for all the specimens. Cube specimens of size 150 mm were cast for each proportion and tested for their compressive strength at the ages of 3, 7, 28 and 90 days. All the specimens were tested using Compression Testing Machine (CTM) under a uniform rate of loading of 140 kg/cm2/min until failure and the ultimate load at failure was taken to calculate the compressive strength. Tests were carried out on triplet specimens and the average compressive strength values were recorded.

Figure 4.1 Test setup of compressive strength

B. *Split Tensile Strength Test*

The split tensile strength test was carried out as per IS 5816:1999. The apparatus test precision was the same as IS 516:1959. Cylindrical concrete specimens of size 150 mm diameter and 300 mm height were cast and tested for their splitting tensile strength using a CTM at the ages of 3, 7 and 28 days. Figure 4.2 shows the test setup.

Figure 4.2 Test setup of split tensile strength

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C. Sorptivity Test

The sorptivity test was done in accordance with ASTM C 1585-04. The allowable coefficient variation was to be 6% in preliminary measurements of the absorption. Sorptivity is the measure of the capillary force exerted by the concrete pore structure which causes the fluids to be drawn inside the body of the concrete. Concrete slices of 100 mm diameter and 50 mm thickness were used for the test. The sides of the specimen were waxed and sealed with a plastic sheet and then the initial mass of the specimen was taken. The specimen was then kept in a tray with 2 to 5 mm of the depth being immersed in water. The mass of the specimen was then measured at 1 minute, 5 minutes, 10 minutes, 20 minutes, 30 minutes, 1 hour, 2 hours, 3 hours, 4 hours, 5 hours and 6 hours after taking out and bloating off the excess surface water. Sorptivity value was calculated using the formula,

$$\mathbf{s = I/t^{0.5}}$$

s is the sorptivity in mm/min, t is the elapsed time in minutes and I is the cumulative absorption which is given by,

$$I = \Delta m/Ad$$

Δm is the increase in mass, A is the surface area of specimen through which water penetrates and d is the density of the medium, i.e. water.

The cumulative absorption values were plotted against the square root of time and sorptivity was obtained from the slope of the best fitting line of the plot. The sorptivity test done on the GPC samples is shown in Figure 4.3.

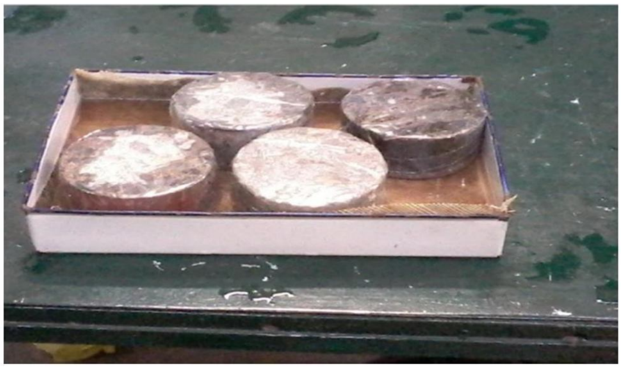
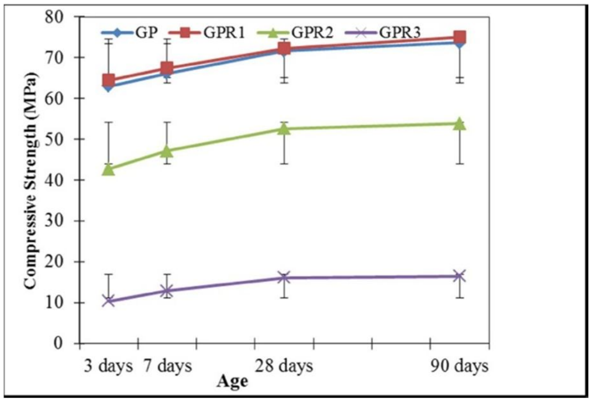


Figure 4.5 Sorptivity test on GPC

V. RESULT AND DISCUSSION

Over five hundred specimens were cast and tested to examine the strength and durability of GPC made with GGBS and BRHA. Tests were conducted on GPC with three different levels of BRHA replacement 10%, 20% and 30%. The results show the variation in compressive strength of GPC with respect to the influence of curing temperature and NaOH concentration at 3, 7, 28 and 90 days of testing. Further the flexural strength, splitting tensile strength and elastic modulus of the GPC specimens were also tested. In terms of durability, parameters including sorptivity, , corrosion resistance of GPC were assessed. Charts have been drawn to depict the variations in the aforesaid strength and durability parameters of GPC specimens at different proportions of BRHA replacement. The test results are discussed below.



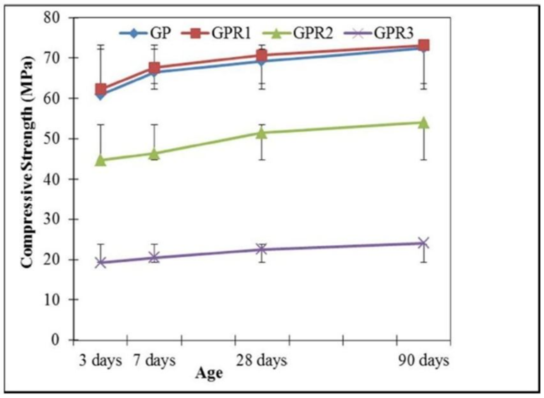


Figure Compressive strength of GPC cured at ambient temperature

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VI. DURABILITY TESTS

A. Sorptivity Test

The absorption values plotted against square roots of time are shown in Figure

The slope of the absorption curve for each mix gives the corresponding sorptivity value and the sorptivity values are given in Table 5.4. The variation of sorptivity for the GPC mixes is shown in Figure 5.10.

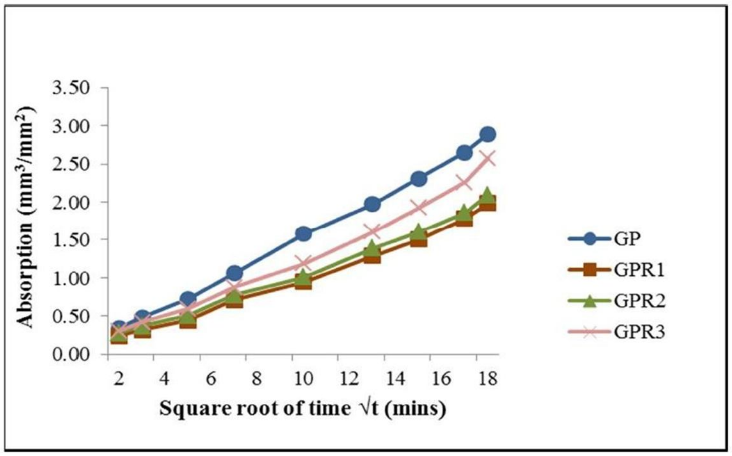

Table 5.4 Sorptivity values of GPC

S.No.	Mix	Sorptivity (mm/min1/2)
1	GP	0.1571
2	GPR1	0.1062
3	GPR2	0.1096
4	GPR3	0.1353

VII. CONCLUSION

The following conclusions can be drawn from this limited experimental investigation.

1) The experimental results show that it is possible to produce geopolymer concrete possessing substantial strength and durability using GGBS and BRHA.
2) Increase in NaOH concentration increased the compressive strength.
3) The strength increase ranged between 10 to 18% for the corresponding rise in molarity starting from 5 M to 8 M and then to 11 M.
4) Addition of BRHA beyond 10% had a retarding effect on the compressive strength. Although up to 20% replacement, the target compressive strength was surpassed and strength as high as 51 MPa was reached at 28 days.
5) The strength gain was substantial till 7 days and became moderate till 28th day.
6) Oven curing resulted in higher compressive strength than ambient curing. However, ambient curing gave strength up to 53 MPa for 100% GGBS and up to 40 MPa for 10% BRHA replacement.

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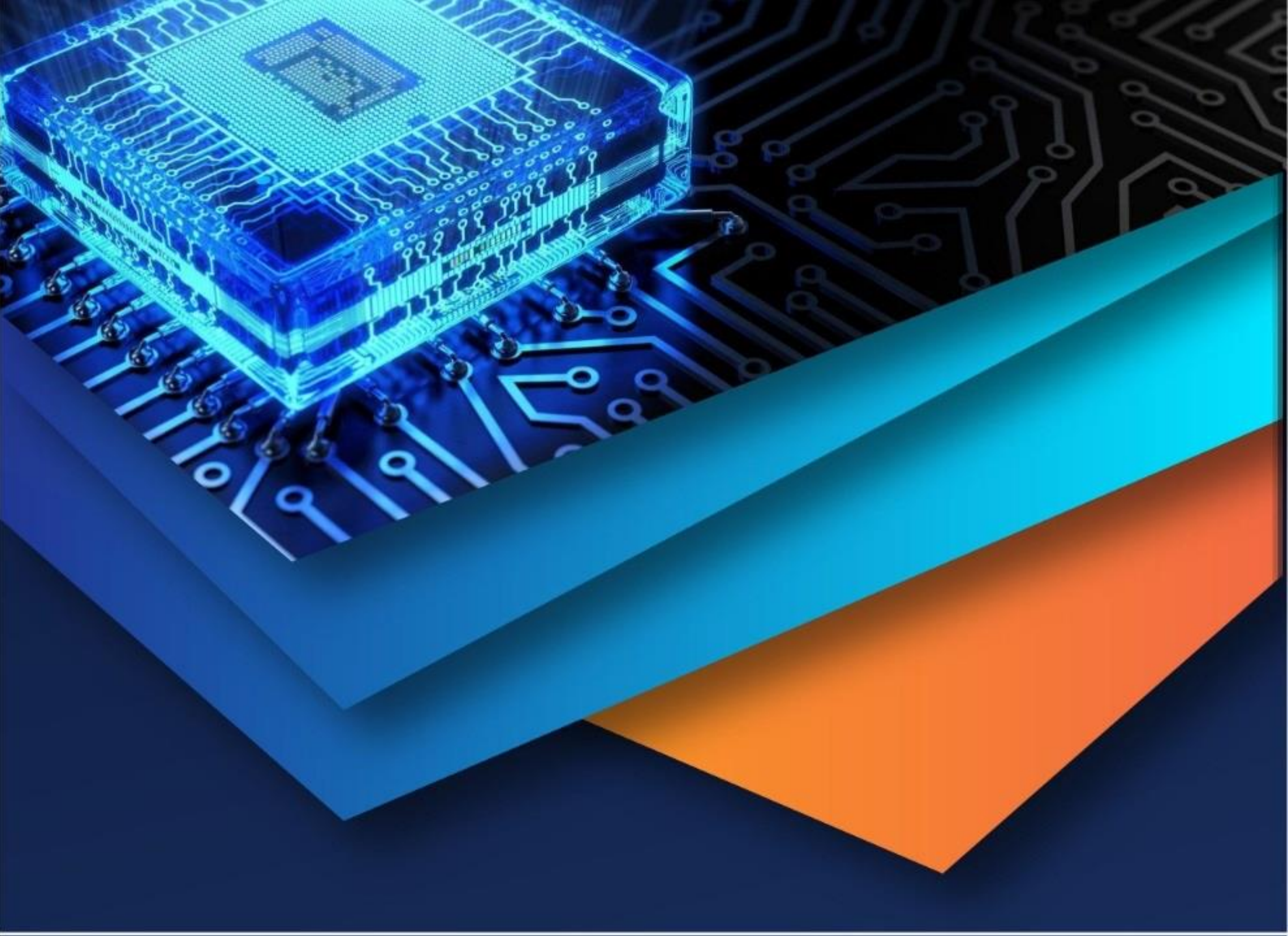

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