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DURABILITY STRENGTH OF BLENDED CONCRETE MANUFACTURED WITH SLAG AND BLACK RICE HUSK ASH

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ABSTRACT:- Black Rice Husk Ash (BRHA) is an agro-industrial waste obtained by incinerating the rice husk and has a high content of unburnt carbon. Consequently, the use of BRHA as a construction material is very limited, even though it has high silica content about 90%. But, some researchers have reported that the addition of BRHA in concrete has improved its durability property.

The objective of the present study was to develop geopolymer concrete mixtures using GGBS and BRHA. The investigation utilized GGBS as the base material for making the control geopolymer concrete. Then BRHA was used to replace GGBS in the mix in three different proportions, from 10- 30%, for the rest of the mixes used in the study. The GPC specimens were subjected to a range of test methods to ascertain their performance in different strength and durability conditions.

It was observed from the test results that the strength of GPC increased with the increase in concentration of sodium hydroxide as well as the curing temperature. Addition of BRHA beyond 10% in GPC retarded its strength development. However, the strengths were well above the target strength up to 20% replacement levels of BRHA in GPC.

INTRODUCTION

Concrete is the most predominantly used construction material in the world. The basic ingredient of concrete that is Ordinary Portland Cement (OPC) is a major contributor of global warming. The yearly global cement production of 1.6 billion tons is responsible for about 7% of the total CO2 emission into the atmosphere. The raw materials required for cement production are non-renewable and depleting at a rapid rate. At the same time, a lot of industrial and agro wastes with inherent cementations properties are produced abundantly but mostly dumped into landfills. Employing such by products as alternates for cement has multiple benefits including conservation of environment, sustainability of resources and solving the disposal problem of by-products. Extensive researches are being carried out to assess the feasibility of utilizing industrial wastes as complete replacement for OPC and generating superior binders from the same. One such successful attempt is Geopolymer concrete which entirely eliminates the use of OPC in concrete production.

In 1978, Joseph Davidovits (1999) recommended that it is conceivable to create fasteners coming about because of the polymerization response between antacid fluids and source materials that are wealthy in silica and aluminum. He instituted the term 'geo-polymer' to portray this group of mineral folios that have a compound creation like zeolites however showing an undefined microstructure. Paloma et al (1999) proposed that pozzolanic materials like impact heater slag can be enacted with the assistance of antacid fluids to deliver folios which could totally supplant OPC in concrete creation. Differentiating to OPC concrete (OPCC), the essential fasteners in GPC are not calcium-silicate-hydrates (C-S-H). Rather, an alumino-silicate polymeric gel shaped by tetrahedrally-fortified silicon and aluminum with oxygen molecules partook in the middle of acts the folio. The two vital constituents of GPC are source materials and antacid fluids. The source materials must be wealthy in silicon (Si) and aluminum (Al). These could be of geographical birthplace like metakaolin or side- effect materials like fly fiery debris, Ground Granulated Blast heater Slag (GGBS), silica smolder, rice-husk powder, and so forth. The basic fluids are based from dissolvable antacid metals for the most part being sodium or potassium. The most widely recognized soluble fluid utilized is a blend of sodium or potassium hydroxide alongside sodium or potassium silicate correspondingly. Black Rice Husk Ash (BRHA) is an agro-industrial waste generated from rice milling industry. It is obtained by burning rice husk in the incinerator. The ash obtained as a result of this combustion process has a high content of un burnt carbon. Hence the use of BRHA as a construction material is very limited, even though it has high silica content about 90%. But several researchers including Chatweera and Lertwattanaruk (2011) and Piyaphanuwat and Asavapisit (2009) reported that the addition of BRHA in concrete has improved its durability property. In Geopolymer concrete, most of the research works have been made on Fly ash based geopolymers and in this present study, industrial waste which is Ground Granulated Blast furnace Slag(GGBS) and the agro waste which is Black Rice Husk Ash(BRHA) are used as source materials for Geopolymer concrete. GGBS was kept as the base material in which BRHA was replaced at different percentages and its effect on the compressive, flexural and tensile strengths and other durability properties like sorptivity, chloride permeability and resistance to accelerated corrosion were studied

OBJECTIVES OF THE STUDY

- To create geopolymer concrete mixtures utilizing GGBS and BRHA.
- To study the impact of notable parameters on the compressive quality of the geopolymer concrete which incorporate restoring temperature and concentration of sodium hydroxide utilized for the basic arrangement.
- To study the execution of the geopolymer concrete under various toughness measure like sorptivity, chloride penetration, quickened consumption, corrosive and ocean water obstruction.
- To recognize a reasonable mix extent for the geopolymer concrete regarding level of GGBS, BRHA and furthermore on the ideal relieving temperature and concentration of sodium hydroxide utilized as the antacid arrangement.
- To look at the assembling expenses of geopolymer concrete with regular concrete.

MATERIAL USED

Ground Granulated Blast Furnace Slag (GGBS) :- GGBS adjusting to the particulars of IS 12089-1987 was utilized as the essential cover to create GPC in which BRHA was supplanted from 0% to 30%. GGBS was gotten from JSW cements limited, India.

Table 1 Properties of GGBS

S. No	Property	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 cm2/g

Black Rice Husk Ash (BRHA) :- BRHA was acquired from a rice factory. It was finely ground in a ball-factory for 30 minutes and went through 75µ strainer (Rashid et al, 2010) preceding utilizing in GPC generation. The compound organization and physical properties of BRHA were tried (according to ASTM D3682-01) in Laboratories, and are given in Table 2.

Table 2 Properties of BRHA

S. No	Property	Value
1.	Silicon-di-Oxide (SiO2)	93.96 %
2.	Aluminium tri oxide (Al2O3)	0.56 %
3.	Ferric Oxide (Fe2O3)	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	5673 cm2/g

Aggregates :- Characteristic waterway sand fitting in with Zone II according to IS 383 (1987) with a fineness modulus of 3.54 and a particular gravity of 2.61 was utilized as fine aggregate. Pulverized stone coarse aggregate fitting in with IS: 383 (1987) was utilized. Coarse aggregate of most extreme ostensible size 20 mm, with a particular gravity of 2.72 and fineness modulus of 6.29 was utilized. The aggregates were tried according to IS 2386 (1963).

Alkaline Solution :- A mixture of sodium hydroxide and sodium silicate was utilized as the basic arrangement. Business grade sodium hydroxide in pellets structure

(97%-100% immaculateness) and sodium silicate arrangement having an organization of 14.7% Na_2O, 29.4% SiO_2 (all out solids = 45.4%) and 55.6% water by mass were utilized. The antacid fluid to folio ratio was fixed as 0.4 and the ratio of sodium silicate to sodium hydroxide was taken as 2.5 in the wake of directing a great deal of preliminaries with conformance to functionality and quality. The concentration of sodium hydroxide was fixed at 8 M for every one of the tests aside from the study because of sodium hydroxide on the compressive quality where three diverse NaOH concentrations were utilized.

MIX PROPORTIONS :-Since there are no standard codal arrangements accessible for the mix design of geopolymer concrete, the density of geopolymer concrete was expected as 2400 kg/m3 and different figurings were made dependent on the density of concrete according to the mix design given by Lloyd and Rangan (2010). The consolidated complete volume involved by the coarse and fine aggregates was thought to be 77%. The antacid fluid to folio ratio was taken as 0.40. As there are no standard mix design techniques accessible to appraise the objective quality of GPC what's more this being a generally new sort of concrete that is still in formative stage, least target quality was taken as 30 MPa, considering it as a normal quality concrete. GGBS was kept as the base material for making the control GPC examples (GP). At that point BRHA was utilized to supplant GGBS in the mix in three distinct extents, 10% (GPR1), 20% (GPR2) and 30% (GPR3), for the remainder of the mixes utilized in the examination.

S. No	Quantities	Proportions (kg/m3)			
		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

Tests Conducted

Compressive Strength Test:- The compressive strength of the geopolymer concrete was tested as per IS 516:1959. Cube specimens of size 150 mm were cast for each proportion and tested for their compressive strength at the ages of 3, 7 and 28 days. All the specimens were tested using Compression Testing Machine (CTM) of 2000 kN capacity 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.

Split Tensile Strength Test:-

The split tensile strength test was carried out as per IS 5816:1999. Cylindrical concrete specimens of size 150 mm diameter and 300 mm height were cast. The specimens were then tested for their splitting tensile strength using Universal Testing Machine (UTM) at the ages of 3, 7 and 28 days.

Flexural Strength Test:-

The flexural strength of the geopolymer concrete was carried out as per IS 516:1959. Beams of size 150 mm × 150 mm × 700 mm size were cast and then subjected to the flexural strength test using Universal Testing Machine (UTM) at the ages of 3, 7 and 28 days.

Sorptivity Test:- The sorptivity test was done in accordance with ASTM C1585-

04. 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 $s = I/t1/2$, where s is sorptivity in mm/min; t is the elapsed time in min; and I is the cumulative absorption given by $I = \Delta m/Ad$ where Äm 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 given by the slope of the best fitting line of the plot.

Rapid Chloride Permeability Test :-The Rapid Chloride Permeability Test (RCPT) was done in accordance with ASTM C1202-97. This test is the rapid measurement of the electrical conductance of the concrete with respect to its resistance against chloride ion penetration. Cylindrical specimens of size 100 mm diameter and 50 mm thick were used for this test after 28 days from the date of casting. A potential difference of 60 V was maintained across the ends of the specimen for about 6 hours. One end was mounted to a cell containing 3% sodium chloride solution and the other end was mounted to a cell containing 0.3 N sodium hydroxide solution.

Accelerated Corrosion Test:-

The accelerated corrosion test was conducted on cylindrical specimens of 100 mm diameter and 200 mm height with a 14 mm diameter steel rod embedded centrally so that equal cover was maintained on all the sides. The specimens were oven cured at 60°C for 48 hours after casting and then further cured in room temperature for 28 days. The cylindrical specimens were then placed in individual containers each containing 4% sodium chloride solution. The level of the solution was maintained at 75 mm from the bottom of the specimen throughout the test. A stainless steel plate was placed in each container which acted as the cathode whereas the steel rod embedded in concrete served as the anode and they were connected to a constant DC supply of 6V so that the setup acted as an electrochemical cell. The voltage was maintained constantly throughout the test and current passing through each specimen was measured daily. At the instance of the appearance of first crack on each specimen, the specimens were stopped off the current supply and removed from the test setup respectively. Once the test was completed for all the specimens, a graph was plotted for the current passed in mA versus time in days to determine the corrosion initiation and propagation periods.

RESULTS

Compressive strength test:- From the results, it can be seen that the compressive strength of GPC increased with increase in NaOH concentration. At 28 days, the strength increase of control specimen (GP) ranged from 10 to 18% for the corresponding rise in molarity starting from 5 M to 8 M and then to 11 M. The increase in NaOH concentration could have increased the rate of dissolution of silica and alumina ions in the alkaline solution resulting in the compressive strength gain. In the current study, at all three levels of NaOH molarity, the control GPC specimen (made fully with GGBS) exceeded the 28th day strength of both the GGBS based GPC and the conventional concrete of the literature referred above. This again shows that the performance of GPC is better than conventional concrete and this fact has been proved by various other researchers also.

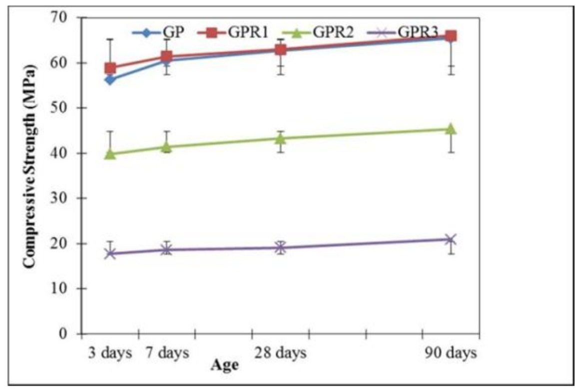

Figure 1 Compressive strength of GPC at 5 M NaOH concentration

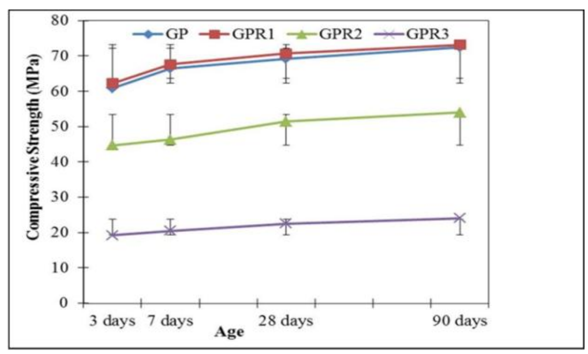

Figure 2 Compressive strength of GPC at 8 M NaOH concentration

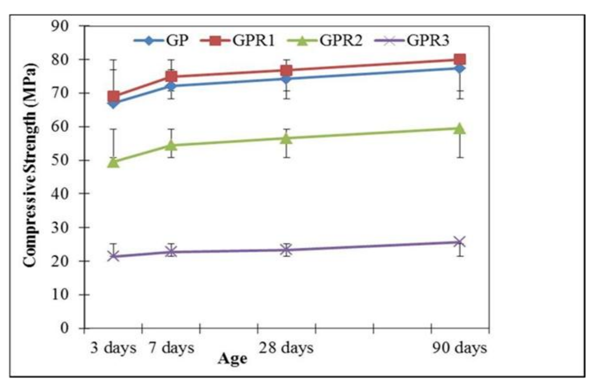

Figure 3 Compressive strength of GPC at 11 M NaOH concentration

Splitting Tensile and Flexural Strength Tests:-

When comparing the 10% BRHA replaced mix GPR1 with control mix GP, there was a slight improvement in both split tensile and flexural strengths. The heat curing of the specimens along with a suitably increased SiO2/Al2O3 ratio and higher fineness of BRHA particles might have assisted the dissolution of ions and polycondensation mechanism of the geopolymer framework.

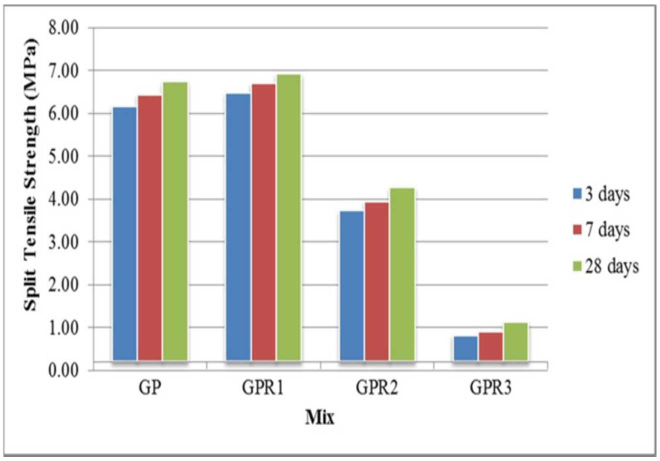

Figure 4.Splitting tensile strength of GPC

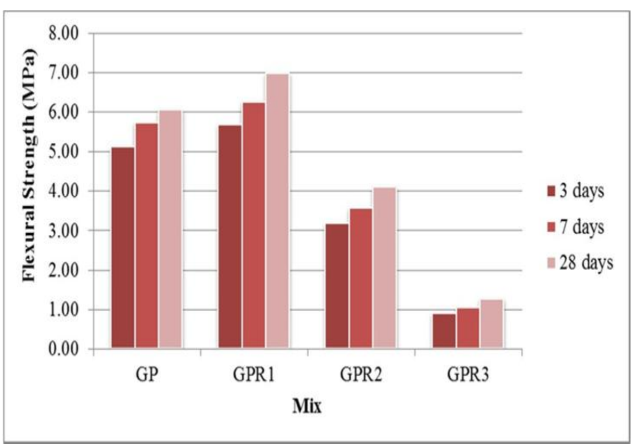

Figure 5 Flexural strength of GPC

Modulus of Elasticity Test:- The 10% BRHA replaced mix GPR1 has a higher elastic modulus than the control mix GP. The increase in E value was about 5.7% for GPR1. Both the mixes GP and GPR1 showed E values as high as 36155 MPa and 38183 MPa respectively. The possible reason for such high values of elastic modulus could be the co- existence of the secondary C-S-H phase along with the primary geopolymer phase. The other two mixes GPR1 and GPR2 show reduced elastic modulus in comparison with the control mix. The possible reason for the decrease in elastic modulus could be attributed to the reduction in strength due to inappropriate silica-alumina ratio from excessive addition of BRHA.

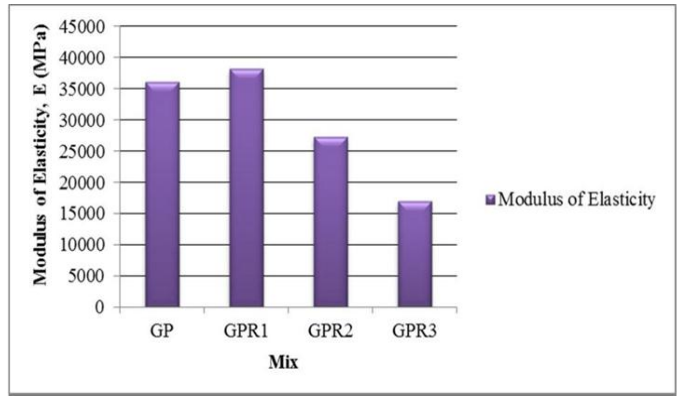

Figure 6 Elastic modulus of GPC

Rapid Chloride Penetration Test (RCPT):- BRHA replacement at a suitable level reduces the chloride ion penetration of geopolymer concrete which is characterized by the micro filler effect of the fine BRHA particles. However, BRHA being silica rich, its excessive addition leads to an inappropriate silica-alumina ratio. This affects the dissolution mechanism of Si and Al ions and the subsequent rate of polycondensation thus leading to incomplete aluminosilicate geopolymer matrix. As a result of this, the structural compactability of the resulting geopolymer might not be dense which was what was believed to have caused the higher ion transport through the concrete. At 30% BRHA replacement, the structural compactability of GPC was clearly deteriorated which was evident from the fact that it attained very low compressive strength under all the parameters considered.

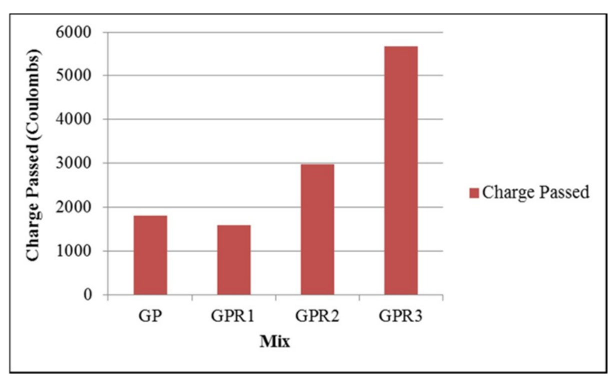

Figure 7 Charge passed through GPC

Accelerated Corrosion Test (ACT):-

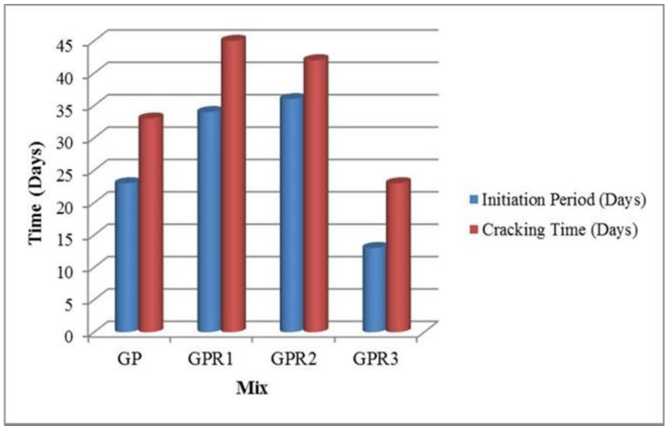

Figure 8 Corrosion initiation period and cracking time of GPC

CONCLUSIONS

- The experimental results show that it is possible to produce geopolymer concrete possessing substantial strength and durability using GGBS and BRHA.
- Increase in NaOH concentration increased the compressive strength.
- 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.
- While comparing oven curing at a temperature of 60°C and ambient curing, the strength increase at 28 days was 45% for GPR1 and nearly three times for GPR2 specimens.
- Increase in curing temperature to 90°C had only a moderate increase in the compressive strength. Hence oven curing at 60°C could be preferred for the GPC when BRHA is added.
- 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.
- Seemingly a very good correlation exists between the compressive strength and charge passed for GPC in RCPT. At lower strengths there is a higher ion transport through the concrete but it gets reduced as the strength of GPC increases.
- Addition of BRHA beyond 20% is not beneficial in geopolymer concrete. The 30% BRHA replaced specimens neither achieved significant strength nor proved to be durable.
- From the cost perspective, there is a definite saving of cost in the production of GPC over conventional concrete. While comparing, as the grade of the conventional concrete increases the cost saving also increases for the corresponding GPC mix.
- The reflection of cost savings can be more significant if the volume of production of concrete is massive.

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