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RESEARCH ARTICLE

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EFFECT ON COMPRESSIVE STRENGTH OF GEOPOLYMER CONCRETE USING GROUND GRANULATED BLAST FURNACE SLAG AND BLACK RICE HUSK ASH

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ABSTRACT

Ordinary Portland Cement (OPC) is unfortunately found to be associated with some adverse effects. At the same time, a lot of industrial and agro wastes with inherent cementitious 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. One such promising alternative is 'Geopolymer Concrete' (GPC) which completely eliminates OPC in its production.

The source materials of geopolymer could be of geological origin by-product materials of Ground Granulated Blast furnace Slag (GGBS), GPC is proven to have superior strength and durability over conventional concrete. 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%. The objective of the present study was to develop geopolymer concrete mixtures using 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. Compressive strength was studied. It was observed from the test results that the strength of GPC increased in 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.

Key words: Geo polymer, Concrete, Black Rice husk ash, compressive strength, Ground Granulated Blast furnace Slag, Tensile Strength.

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. The principal ingredient of concrete is cement, generally Ordinary Portland Cement (OPC) which acts as the binder and holds the aggregates intact. But unfortunately, OPC is found to be associated with some adverse effects on environment [1]. The production of OPC is highly energy intensive and emits high amount of CO_2 into the atmosphere. At the same time, a number of industrial and agro wastes with inherent cementitious properties are produced abundantly. But they are mostly disposed into landfills. Employing such by-products as alternates for cement has various benefits including conservation of environment, sustainability of resources and solving the disposal problem of by-products. The 'geopolymer concrete' (GPC) which completely eliminates OPC in its production [2].

OBJECTIVES OF THE STUDY

- To develop geopolymer concrete mixtures using GGBS and BRHA.
- To study the influence of salient parameters on the compressive strength of the geopolymer concrete .
- To identify a suitable mix proportion for the geopolymer concrete in terms of percentage of GGBS, BRHA.

MATERIALS AND METHODOLOGY

Ground Granulated Blast Furnace Slag (GGBS) [3]

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 1.

Black Rice Husk Ash (BRHA) [7]

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 2.

Table 1 Properties of GGBS

S. No	Property	Value
1.	Silicon-di-Oxide (SiO_2)	31.25 %
2.	Aluminium tri oxide (Al_2O_3)	14.06 %
3.	Ferric Oxide (Fe_2O_3)	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 cm^2/g

Table 2 Properties of BRHA

S. No	Property	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	5673 cm^2/g

The SEM images of GGBS, unground BRHA and ground BRHA are shown in Figures 1, 2 and 3 respectively.

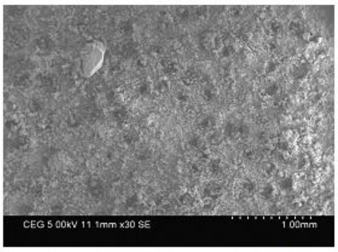

Figure 1 SEM image of GGBS

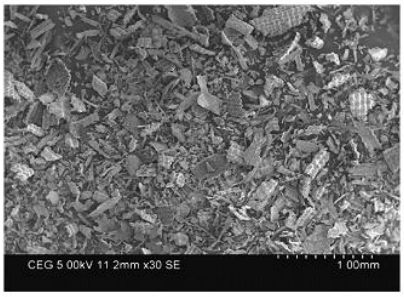

Figure 2 SEM image of unground BRHA

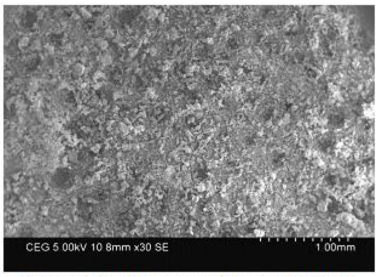

Figure 3 SEM image of ground BRHA

Aggregates

Natural river sand conforming to Zone II as per IS 383 (1987) with a fineness modulus of 3.54 and a specific gravity of 2.61 was used as fine aggregate. Crushed granite coarse aggregate conforming to IS: 383 (1987) was used. Coarse aggregate of maximum nominal size 20 mm, with a specific gravity of 2.72 and fineness modulus of 6.29 was used. The aggregates were tested as per IS 2386 (1963).

MIX PROPORTIONS [4]

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/m^3 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 3.

Table 3 Mix proportions of GPC

S. No	Quantities	Proportions (kg/m^3)			
		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

PREPARATION OF TEST SPECIMENS[5]

The materials for the mixes were weighed and first mixed in dry condition for 3-4 minutes. Then the alkaline liquid which is a combination of sodium hydroxide and sodium silicate solutions along with super-plasticizer were added to the dry mix. Then some extra water about 15% by weight of the binder was added to improve the workability. The mixing was continued for about 6-8 minutes. After the mixing, the concrete was placed in steel moulds by giving proper compaction. Precautions were taken to ensure uniform mixing of the ingredients.

Compressive Strength Test[6]

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. 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/cm^2/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. The test setup is shown in Figure 4.

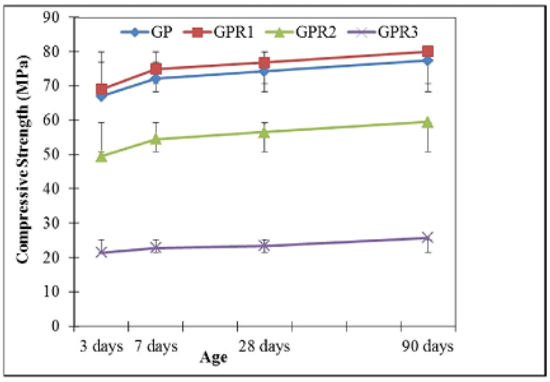

Figure 4 Compressive strength of GPC

Figure 5 Test setup of compressive strength

RESULTS AND DISCUSSION

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 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.

Compressive strength test

The compressive strength of GPC was studied for three different levels of BRHA replacement 10%, 20% and 30%. While observing the rate of strength gain with respect to age, the GPC achieved majority of its strength well within its first week from the time of casting. Both the control and BRHA added GPC specimens showed a similar trend of strength gain against age. For instance, For GPR at 3rd day it was only 67.1 MPa but increase in GPR by 10% it was observed that increased by 69.1Mpa.There was further increase in percentage by 20 it strength when tested at 3 days 49.5MPa by 30% increased only 21.4MPa strength reached by 3 days of curing. Similarly For GPR at 7th day it was only 72.1 MPa but increase in GPR by 10% it was observed that increased by 75.1Mpa.There was further increase in percentage by 20 it strength when tested at 7th day 54.5MPa by 30% increased only 22.8MPa strength reached by 7th day of curing. Similarly For GPR at 28th day it was only 74.3 MPa but increase in GPR by 10% it was observed that increased by 76.8Mpa.There was further increase in percentage by 20 it strength when tested at 28th days of curing is 56.6Mpa by 30% increased only 23.4MPa strength reached by 28th days of curing. Similarly For GPR at 90th days it was only 77.4 MPa but increase in GPR by 10% it was observed that increased by 80.0Mpa.There was further increase in percentage by 20 it strength when tested at 28th day 59.5 by 30% increased only 25.7MPa strength reached by 90th days of curing. For GPR1 the strength increase was 8.5%, 4.6% and 4.3% at the respective time intervals. Similar trend was seen with the other mixes also. As observed by Hardjito and Rangan (2005), the chemical reaction of the heat-cured geopolymer concrete is a substantially fast polymerization process that takes place within hours and that is the main reason for the compressive strength not being influenced by age. This behaviour is apparently in contrast to the behaviour of OPC concrete, where the hydration process would continue to occur over time. From the results, it can be seen that the compressive strength of GPC increased with control specimen (GP) ranged from 10 to 18.

CONCLUSIONS

The experimental results show that it is possible to produce geopolymer concrete possessing substantial strength and durability using GGBS and BRHA. The strength increase ranged between 10 to 18% BRHA replacement 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 56.6 MPa was reached at 28 days. The strength gain was substantial till 7 days and became moderate till 28th day. As evident from the 90th day compressive strength results, the strength gain beyond 28 days was only marginal for GPC. 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.

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