STRENGTH PROPERTIES OF RICE ASH AND GGBS BASED GEO-POLYMER CONCRETE

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ABSTRACT

The second most consumed product in the world is Cement. It contributes nearly 7% of the global carbon dioxide emission. Geo-polymer concrete (GPC) is a special type of concrete that is manufactured using industrial waste like baggase ash, GGBS which are considered as a more eco-friendly alternative to Ordinary Portland Cement (OPC) based concrete. By using this type of industrial by-products in concrete industry as a replacement for cement we can reduce the usage of cement which results in minimizing the emission of green houses gases into the atmosphere and also savings in cost. This project mainly aims at the study of effect of Rice ash (RHA) andground granulated blast furnace slag (GGBS) on the mechanical properties of geo polymer concrete (GPC) when they were replaced for cement at different replacement levels (RHA50-GGBS50,RHA75-GGBS25, RHA100-GGBS0) using Sodium silicate (Na_2SiO_3) and sodium hydroxide (NaOH) solutions as alkaline activators. Specimens were casted and cured for different curing periods like 7, 14, 28, 56 and 112 days at ambient room temperature to determine the mechanical properties of geo-polymer concrete. Test results shows that as the percentage of GGBS in the mix is increasing, mechanical properties such as compressive strength, split tensile strength and flexural strength were increasing.

Keywords: Geopolymer concrete, GGBS, Rice ash, Sodium silicate, Sodium hydroxide, Compressive strength, Split tensile strength, Flexure strength.

INTRODUCTION:

Concrete is the most widely used construction material in the world and Ordinary Portland Cement (OPC) is the major ingredient used in concrete. The production of cement releases large amount of carbon dioxide (CO_2) to the atmosphere that significantly contributes to greenhouse gas emissions. It is estimated that one ton of CO_2 is released into the atmosphere for every ton of OPC produced[1]. In view of this, there is a need to develop sustainable alternatives to conventional cement utilizing the cementitious properties of industrial by-products such as Rice ash and ground granulated blast furnace slag[2-4]. On the other side, the abundance and availability of Rice ash and GGBS worldwide create opportunity to utilize these by-products, as partial replacement or as performance enhancer for OPC. In 1978, Davidovits developed a binder called geo-polymer to describe an alternative cementitious material which has ceramic-like properties. Geo-polymer technology is one of the new technologies attempted to reduce the use of Portland cement in concrete. Geopolymer are environmental friendly materials that do not emit green house gases during polymerization process. Geopolymer can be produced by combining a pozzolanic compound or aluminosilicate source material with highly alkaline solutions[5]. Geopolymers are made from source materials with silicon (Si) and Aluminium (Al) content and thus cement can be completely replaced by marginal materials such as Rice ash and ground granulated blast furnace slag which is rich in silica and alumina[6-7]. Rice ash and GGBS reacts with alkaline solutions to form a cementitious material which does not emit carbon dioxide into the atmosphere and enhances the mechanical properties of the geo-polymer concrete. Davidovits (1978) proposed that binders could also be produced by polymeric reaction of alkaline liquids with the silicon and the aluminum in source materials or by-product materials such as Rice ash and rice husk ash. Portland cement is still the main binder in concrete construction prompting a search for more eco-friendly materials. Furthermore, it has been reported that the durability of ordinary Portland cement concrete is under examination, as many concrete structures especially those built in corrosive environments start to deteriorate after 20 to 30 years, even though they have been designed for more than 50 years of service life.

1. EXPERIMENTAL STUDY

1.1. Experimental Program

Our objective was to determine the effect of GGBS and Fly-ash on the mechanical properties of geo polymer concrete. In this respect, GGBS and Fly-ash were used as binders, Sodium hydroxide and Sodium silicate were used as alkaline activators, Crushed granite stones of size 20 mm and 10 mm of coarse aggregate are used, river sand is used as fine aggregate.

1.2. Material Properties

1.2.1. Binders

Rice ash and GGBS were used as binders in geo polymer concrete and their physical and chemical properties of the Ground Granulated Blast Furnace Slag were tabulated below.

Table 1 Chemical and Physical Properties of Rice Ash and GGBS

Particulars	**RICE ASH**	**GGBS**
Chemical composition		
% Silica(SiO_2)	65.6	30.61
% Alumina(Al_2O_3)	28.0	16.24
% Iron Oxide(Fe_2O_3)	3.0	0.584
% Lime(CaO)	1.0	34.48
% Magnesia(MgO)	1.0	6.79
% Titanium Oxide (TiO_2)	0.5	-
% Sulphur Trioxide (SO_3)	0.2	1.85
Loss on Ignition	0.29	2.1
Physical properties		
Specific gravity	2.24	2.86
Fineness (m^2/Kg)	360	400

1.2.2. Alkaline Liquids

The alkaline liquid used was a combination of sodium silicate solution and sodium hydroxide solution. The sodium silicate solution (Na_2O= 13.7%, SiO_2=29.4%, and water=55.9% by mass) was purchased from a local supplier. The sodium hydroxide (NaOH) in flakes or pellets from with 97%-98% purity was also purchased from a local supplier. The sodium hydroxide (NaOH) solution was prepared by dissolving either the flakes or the pellets in required quantity of water. The mass of NaOH solids in a solution varied depending on the concentration of the solution expressed in terms of molarity, M. For instance, NaOH solution with a concentration of 10M consisted of 10x40 = 400 grams of NaOH solids (in flake or pellet form) per litre of the solution, where, 40 is the molecular weight of sodium hydroxide (NaOH) pellets or flakes.

1.2.3. Coarse Aggregate

Crushed granite stones of size 20 mm and 10 mm of coarse aggregate are used. The bulk specific gravity in oven dry condition and water absorption of the coarse aggregate 20 mm and 10mm as per IS code were 2.58 and 0.3% respectively. The gradation of the coarse aggregate was determined by sieve analysis as per IS code and presented in the Tables 2 and3.

Table 2 Sieve analysis of 20 mm Coarse aggregate

S.No	**Sievesize (mm)**	**Weight retained(gm)**	**Percentage weight retained**	**Cumulative percentage weight retained**	**Cumulative percent passing**	
					10 mm	**IS 383 (1970) limits**
1	10	16	0.32	0.32	99.68	85-100
2	4.75	4546	90.92	91.24	8.76	0-20
3	2.36	318	6.36	97.6	2.4	0-5

Table 3 Sieve analysis of 10 mm Coarse aggregate

S.No	eve size(mm)	Weight retained(gm)	Percentage weight retained	Cumulative percentage weight retained	Cumulative percent passing	
					10 mm	IS 383 (1970) limits
1	10	16	0.32	0.32	99.68	85-100
2	4.75	4546	90.92	91.24	8.76	0-20
3	2.36	318	6.36	97.6	2.4	0-5

1.2.4. Fine Aggregate

The sand used throughout the experimental work was obtained from the river Swarnamukhi near chandragiri in chittoor district. The bulk specific gravity in oven dry condition and water absorption of the sand as per IS code were 2.62 and 1% respectively[8]. The gradation of the sand was determined by sieve analysis as per IS code and presented in the Table 4[9].

Table 4 Sieve analysis of Fine Aggregate (Sand)

S.No	Sieve No/ size	Weight retained (gm)	Percentage weight retained	Cumulative percentage weight retained	Cumulative percent passing	
					Fine aggregate	IS 383 (1970) – Zone II requirement
1	3/8” (10mm)	0	0	0	100	100
2	No.4 (4.75mm)	12	1.2	1.2	98.8	90-100
3	No.8 (2.36mm)	35	3.5	4.7	95.3	75-100
4	No.16 (1.18mm)	135	13.5	18.2	81.8	55-90
5	No.30 (600µm)	366	36.6	54.8	45.2	35-59
6	No.50 (300µm)	290	29.0	83.8	16.2	8-30
7	No.100 (150µm)	132	13.2	97.0	3.0	0-10

1.2.5. Mixture Proportions

Based on the limited past research on GPC (Hardjito & Rangan, 2005) [10], the following proportions were selected for the constituents of the mixtures. The following scenario describes the GPC mix design of the present study: Assume that normal-density aggregates in SSD (Saturated surface Dry) condition are to be used and the unit-weight of concrete is 2400 kg/m^3. In this study, take the mass of combined aggregates as 77% of the total mass of concrete, i.e. 0.77x2400=1848 kg/m^3. The coarse and fine (combined) aggregates may be selected to match the standard grading curves used in the design of Portland cement concrete mixtures. For instance, the coarse aggregates (70%) may comprise 776 kg/m^3 (60%) of 20 mm aggregates, 518 kg/m^3 (40%) of 10 mm aggregates, and 554 kg/m^3 (30%) of fine aggregate to meet the requirements of standard grading curves. The adjusted values of coarse and fine aggregates are 774 kg/m^3 of 20 mm aggregates, 516 kg/m^3 of 10 mmaggregates and 549 kg/m^3 (30%) of fine aggregate, after considering the water absorption values of coarse and fine aggregates. The mass of geo polymer binders (Rice ash and GGBS) and the alkaline liquid = 2400 – 1848=552 kg/m^3. Take the alkaline liquid-to-Rice ash + GGBS ratio by mass as 0.35; the mass of Rice ash + GGBS = 552/ (1+0.35) = 409 kg/m^3 and the mass of alkaline liquid = 552 – 409 = 143 kg/m^3. Take the ratio of sodium silicate (Na_2Sio_3) solution-to-sodium hydroxide (NaOH) solution by mass as 2.5; the mass of sodium hydroxide (NaOH) solution = 144/ (1+2.5) = 41 kg/m^3; the mass of sodium silicate solution = 143 – 41 =102 kg/m^3. The sodium hydroxide solid (NaOH) is mixed with water to make a solution with a concentration of 8 Molar. This solution comprises 40% of NaOH solids and 60% water, by mass. For the trial mixture, water-to-geopolymer solids ratio by mass is calculated as follows: In sodium silicate solution, water = 0.559x102 = 57 kg, and solids=102 – 57 = 45 kgs. In sodium hydroxide solution, solids = 0.40x41 = 16 kg, and water = 41 – 16 = 25 kg. Therefore, total mass of water = 57+25 = 82 kg, and the mass of geopolymer solids = 409 (i.e. mass of Rice ash and GGBS) + 45 + 16 = 470 kg. Hence, the water-to-geopolymer solids ratio by mass = 82/470 = 0.17. Extra water is calculated and added on trial for adequate workability.

Table 5 GPC Mix Proportions

Materials			**Mass (kg/m³)**	
		RHA50-GGBS50	**RHA75-GGBS25**	**RHA100-GGBS0**
Coarse aggregate	20 mm	774	774	774
	10 mm	516	516	516
Fine aggregate	Sand	549	549	549
Riceash		204.5	306.75	409
GGBS		204.5	102.25	0
Sodium silicate solution		102	102	102
Sodium hydroxide solution		41 (10M)	41 (10M)	41 (10M)
Extra water		55	65	75
Alkaline solution/ (BA+GGBS)(by weight)		0.35	0.35	0.35
Water/ geopolymer solids(by weight)		0.29	0.29	0.29

2. RESULTS AND DISCUSSIONS

2.1. Compressive Strength

Table 6. Shows the compressive strength of GPC mixes with different proportions of Riceash and GGBS (RHA50-GGBS50; RHA25-GGBS75; RHA0-GGBS100) at different curing periods.

Table 6 Compressive strength of GPC

Mechanicalproperty	**Age (in days)**	**Mix type**		
		RHA50-GGBS50	**RHA75-GGBS25**	**RHA100-GGBS0**
Compressive strength, f'_c (MPa)	7	40	21.3	10.1
	14	46.5	30.5	18.2
	28	53.5	35.4	24.5
	56	63	49	38
	112	65	52	41

It was observed that there was a significant decrease in compressive strength with the increase in percentage of Riceash from 50% to 100% in all curing periods as shown in Fig. 1. It can be concluded that the increase in Riceash replacement level has significant decrease strength in geopolymers but still exhibits good normal strength. The GPC with 100% Riceash sample exhibited compressive strength values of 10.1 MPa, 18.2 MPa, 24.5 MPa, 38 MPa and 41 MPa after 7, 14, 28, 56 and 112 days of curing respectively at ambient room temperature.

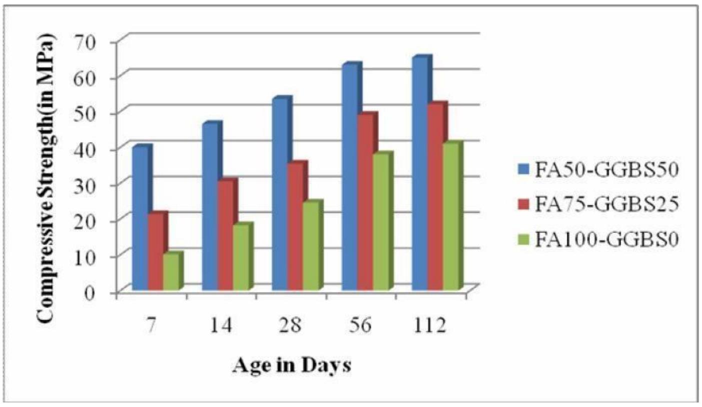

Figure 1 Flexural strength of mixes

2.2. Split Tensile Strength

Table 7. Shows the split tensile strength of GPC mixes with different proportions of Rice husk ash and GGBS (RHA50-GGBS50; RHA25-GGBS75; RHA0-GGBS100) at different curing periods.

Table 7 Split tensile strength of GPC

Iechanical property	**Age (in days)**	**Mix type**		
		RHA50-GGBS50	**RHA75-GGBS25**	**RHA100-GGBS0**
Split tensile strength, f_{ct}(MPa)	28	3.25	3.04	2.82
	56	3.38	3.16	2.98
	112	3.52	3.33	3.12

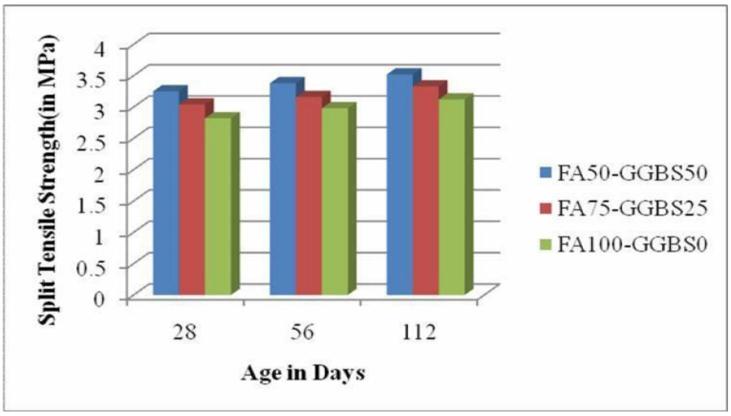

Figure 2 Split tensile strength of mixes

It was observed that there was a significant decrease in splitting tensile strength with the increase in percentage of Riceash from 50% to 100% in all curing periods as shown in Fig. 2. It can be concluded that the increase in Riceash replacement level weakens the microstructure of GPC thus leads to detriment of splitting tensile strength of GPC but the decrement is less.

The GPC with 100% Riceash sample exhibited splitting tensile strength values of 2.82 MPa, 2.98 MPa and 3.12 MPa after 28, 56 and 112 days of curing respectively at ambient room temperature.

2.3. Flexural Strength

Table 8. Shows the flexural strength of GPC mixes with different proportions of Riceash and GGBS (RHA50-GGBS50; RHA25-GGBS75; RHA0-GGBS100) at different curing periods.

Table 8 Flexural strength of GPC

Mechanical property	Age (days)	Mix type		
		RHA50-GGBS50	RHA25-GGBS75	RHA0-GGBS100
Flexural strength, f_{cr} (MPa)	28	5.35	5.06	4.98
	56	5.92	5.36	5.14
	112	6.42	5.96	5.44

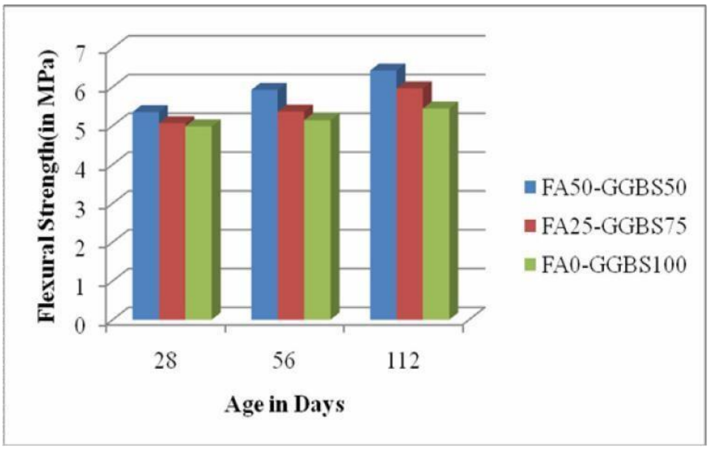

Figure 3 Flexural strength of mixes

It was observed that there was a significant decrease in flexural strength with the increase in percentage of Rice ash from 50% to 100% in all curing periods as shown in Fig. 3. It can be concluded that the decrease in GGBS replacement level reduce the Silica content of GPC thus lessens the flexural strength of GPC but maintains its strength. The GPC with 100% Rice ash sample exhibited Flexural strength values of 4.98 MPa, 5.14 MPa and 5.44 MPa after 28, 56 and 112 days of curing respectively at ambient room temperature.

From the results it is revealed that GGBS and RHA blended GPC mixes attained enhanced mechanical properties at ambient room temperature curing itself without the need of heat curing as in the case of only RHA based GPC mixes Siddique (2007).

3. CONCLUSIONS

Based on the test results, the following conclusions are drawn:

- GGBS blended RHA based GPC mixes attained enhanced mechanical properties at ambient room temperature curing itself without the need of heat curing as in the case of only RHA based GPC mixes.
- Riceash based GPC mixes have attained comparable values of mechanical properties at ambient room temperature curing at all ages to normal Strength.
- Keeping in view of savings in natural resources, sustainability, environment, production cost, maintenance cost and all other GPC properties, it can be recommended as an innovative construction material at low cost for the use of constructions.
- Though 100% Riceash exhibited decrease in strength, it maintains the strength. The cost is also low compared to the 50% GGBS& 50% Riceash

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