

Study on Mechanical Properties of Geo Polymer Concrete Using Different Source Material

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ABSTRACT: The demand of concrete is increasing day by day and Cement is used for satisfying the need of development of infrastructure facilities, 1 tone cement production generates 1 tone CO₂, which adversely affect the environment. In order to reduce the use of OPC and CO₂ generation, the new generation concrete has been developed such as GEOPOLYMER CONCRETE. It uses Fly ash, Ground granulated blast furnace slag (GGBFS), Rice Husk Ash and Alkaline Solution as their Binding Materials. This paper presents the laboratory tests conducted to investigate the mechanical properties of geopolymer concrete. The experiments were conducted at different curing temperature of 60°C, 70°C and ambient temperature using different source material such as Fly ash, GGBFS, and rice husk ash. Different mixes were design with Rice Husk Ash as 25 %, 50 %, and 75 % of total binder. The alkaline solution used for present study is sodium silicate and sodium hydroxide solution. The compressive strength and split tensile strength have been determined at different curing period of 3,7,28 Days .The results show that Geopolymer concrete with 100 % GGBFS gains maximum strength. Up to replacement of 25 % of RHA achieves required strength. Increase in the mechanical properties as increase in the temperature.

KEYWORDS: Geopolymer concrete, Fly Ash, GGBFS (Ground granulated blast furnace slag), RHA (Rice Husk Ash), Sodium silicate, Sodium Hydroxide.

I. INTRODUCTION

As a result of booming infrastructural development around the world, the demand for cement production is also increased. Ordinary Portland Cement (OPC) is mainly used as a cementations material for the concrete production. Nowadays, concrete industry is known to be the major consumer of natural resources, such as water, sand and aggregates, and manufacturing Portland cement also requires large amounts of each of them. As a result, the energy consumption for the cement production is high. It is estimated that the production of cement will increase from 1.5 billion tons in 1995 to 2.2 billion tons in 2010 [4]. For manufacturing each tone of the Portland cement about 1.5 tons of raw materials is needed [5]. The production of 1 tone ordinary Portland cement consumes 4GJ energy and produces about 1 tons of carbon dioxide (CO₂) to the atmosphere [6] which leads to environmental pollution. To reduce the environmental pollution and excess embodied energy utilization, the alternative solution is Geo-polymer concrete.

The term 'geo-polymer' was first coined by Davidovits in 1978 to describe a family of mineral binders with chemical composition similar to zeolites but with an amorphous microstructure [1]. Unlike ordinary Portland/pozzolanic cements, geo-polymers do not form calcium- silicate-hydrates (CSHs) gel for matrix formation and strength, but utilize the poly-condensation reaction of silica and alumina precursors to attain structural strength. Two main constituents of geo-polymers are: source materials and alkaline liquids. The source materials should be rich in silicon (Si) and aluminium (Al). These could be natural minerals such as kaolinite, clays, etc. Alternatively, by-product

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materials such as fly ash, silica fume, slag, rice-husk ash, red mud, etc could be used as source materials. The alkaline liquids are from soluble alkali metals that are usually sodium or potassium based. The most common alkaline liquid used in geo-polymerization is a combination of sodium hydroxide (NaOH) or potassium hydroxide (KOH) and sodium silicate or potassium silicate. Till now most of the research has been conducted on fly ash based geopolymer and in this study, industrial wastes such as ground granulated blast furnace slag (GGBS) and agro waste as rice husk ash (RHA) are used as a source materials to prepare geopolymer concrete.

II. MATERIALS USED

A. Fly Ash

Fly ash (FA) is a by-product of the combustion of pulverized coal in thermal power plants. It is a fine grained, powdery and glassy particulate material that is collected from the exhaust gases by electrostatic precipitators or bag filters. When pulverised coal is burnt to generate heat, the residue contains 80 per cent fly ash and 20 per cent bottom ash. The size of particles is largely dependent on the type of dust collection equipment. Diameter of fly ash particles ranges from less than 1 μm –150 μm . It is generally finer than Portland cement.



Figure 1- Fly Ash

B. Ground granulated blast furnace slag (GGBS)

Geopolymer concrete is produced by activating alumino-silicate based source material with an alkaline solution. Ground granulated blast furnace slags are used as one of the source material for geopolymer binder. GGBS was obtained from JSW cements limited, Bellari, Karnataka. It was given to Laboratory for testing. Table 1 shows the Chemical composition of GGBS.

Table 1- Properties of GGBFS

S.No	Chemical Composition	Percentage
1	Al ₂ O ₃	14.06
2	Fe ₂ O ₃	2.80
3	CaO	33.75
4	MgO	7.03
5	K ₂ O	0.69
6	Na ₂ O	0.41
7	SiO ₂	31.25

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Figure 2- GGBFS

C. Rice husk ash (RHA)

Rice husk ash (RHA) is a by-product from the burning of rice husk. The rice husk ash is a highly siliceous material that can be used as an admixture in concrete if the rice husk is burnt in a specific manner. The available Rice husk ash is black in colour as it contains unburnt carbon. Chemical composition of black Rice husk ash is shown in Table 2.

Table 2- Properties of RHA

S.No	Chemical Composition	Percentage
1	Al ₂ O ₃	0.56
2	Fe ₂ O ₃	0.43
3	CaO	0.55
4	MgO	0.40
5	K ₂ O	0.66
6	Na ₂ O	0.06
7	SiO ₂	93.96

D. Alkaline activator solution

A combination of sodium hydroxide solution (NaOH) and sodium silicate and sodium hydroxide were used as alkaline activator solution. The sodium hydroxide solution was prepared by dissolving the sodium hydroxide solids, in the form of pellets in distilled water. In order to avoid the effect of unknown contaminants in the mixing water, the sodium hydroxide pellets were dissolved in distilled water.

In this study, the molar concentration of NaOH used is 12M. There are various molar concentration of NaOH but many of research paper shows that the maximum strength of concrete achieve in 12M, after 12M the strength is decreases, So in this investigation it is selected 12M. Since the molecular weight of Sodium Hydroxide is 40g, and in order to prepare 12M solution $12 \times 40 = 480$ gms of Sodium Hydroxide was dissolved in 1000 ml of distilled water. The sodium silicate solution contained Na₂O = 14.7%, SiO₂ = 29.4%, and 55.6% of water, by mass. The activator solution was prepared at least 2 hour prior to its use.

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Figure 3- Alkaline solution

E. Fine Aggregates

Natural river sand conforming to Zone II as per IS 383 (1987) [7], with a fineness modulus of 3.45 and a specific gravity of 2.6, was used.

F. Coarse Aggregates

Crushed granite coarse aggregate conforming to IS: 383 (1987) [7] was used. Coarse aggregate of size 20 mm and below with a specific gravity of 2.87, and fineness modulus of 8.14 was used. The aggregates were tested as per IS 2386 (1963) [8].

G. Super plasticizer

Master Glenium Sky 8784 super plasticizer made by BASF was added to the mixture to improve the workability of fresh concrete.

H. Water

Extra water is added to increase the workability of the concrete.

III. MIX PROPORTIONS

Since no code provisions are available for the mix design of geopolymer concrete, the density of geopolymer concrete was assumed to be 2400 kg/m³, and other calculations were made based on the density of concrete as per the design proposed by Lloyd and Rangan (2010) [14]. The combined total volume occupied by the coarse and fine aggregates was assumed to be 77%. The alkaline liquid to binder ratio was taken to be 0.35. The target strength of 30 MPa was fixed as for a regular strength concrete. The mix proportions are given in table 3 and table 4.

In table 3 shows control mix of Geopolymer concrete using Fly Ash. In table 4 shows that the replacement of rice husk ash to GGBFS. So that the different mixes were design with rice husk ash 25%, 50% and 75% of GGBFS. Master Glenium sky 8784 has been used to improve the workability of the mix. present study. An admixture dosage of 1.5% by mass of fly ash, GGBFS and rice husk ash arrived based on trial mixes, has been found suitable in the present study.

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Table 3- Control mix of Fly Ash

Mixture	Fly Ash (kg/m ³)	Temperature	Coarse aggregate (kg/m ³)		Fine aggregate (kg/m ³)	Sodium silicate (kg/m ³)	Sodium Hydroxide (kg/m ³)	Super plasticizer (%)	Water (%)
			20mm	10mm					
GP1 12M	408.89	Ambient	776.16	517.44	554.4	102.22	40.89	1.5%	10%
GP2 12M	408.89	60°C	776.16	517.44	554.4	102.22	40.89	1.5%	10%
GP3 12M	408.89	70°C	776.16	517.44	554.4	102.22	40.89	1.5%	10%

Table 4- Mix Proportion of Geo-polymer concrete

Mix	Temperature	% Replacem ^t of RHA	GGBFS (kg/m ³)	RHA (kg/m ³)	Coarse aggregate (kg/m ³)		Fine aggregate (kg/m ³)	Sodium silicate (kg/m ³)	Sodium Hydroxide (kg/m ³)	S _p (%)	Water (%)
					20mm	10mm					
GP4 12M	Ambient	0	408.89	-	776.16	517.44	554.4	102.22	40.89	1.5%	17%
		25	306.66	102.22	776.16	517.44	554.4	102.22	40.89	1.5%	20%
		50	204.45	204.45	776.16	517.44	554.4	102.22	40.89	1.5%	24%
		75	102.22	306.66	776.16	517.44	554.4	102.22	40.89	1.5%	28%
GP5 12M	60°C	0	408.89	-	776.16	517.44	554.4	102.22	40.89	1.5%	17%
		25	306.66	102.22	776.16	517.44	554.4	102.22	40.89	1.5%	20%
		50	204.45	204.45	776.16	517.44	554.4	102.22	40.89	1.5%	24%
		75	102.22	306.66	776.16	517.44	554.4	102.22	40.89	1.5%	28%
GP6 12M	70°C	0	408.89	-	776.16	517.44	554.4	102.22	40.89	1.5%	17%
		25	306.66	102.22	776.16	517.44	554.4	102.22	40.89	1.5%	20%
		50	204.45	204.45	776.16	517.44	554.4	102.22	40.89	1.5%	24%
		75	102.22	306.66	776.16	517.44	554.4	102.22	40.89	1.5%	28%

IV. PREPARATION OF TEST SPECIMENS

The materials for the mixes were weighed and first mixed in dry condition for 3-4 minutes. Then the alkaline solution, which is a combination of sodium hydroxide and sodium silicate, and the super-plasticizer, were added to the dry mix. Extra water in the quantity of about 10 % by weight of the Fly Ash and 17% by weight of GGBFS was added to improve the workability. The mixing was continued for about 6-8 minutes. After casting, the moulds were placed in the oven where they were dried at 60°C and 70°C for 24 hours and ambient room temperature. Then the specimens were taken out and removed from their moulds. Then the specimens were taken out and allowed to cure at room temperature until the day of testing.

V. TESTS CONDUCTED

A. Compressive strength (MPa) test

The compressive strength of the geopolymer concrete was tested as per IS 516:1959 [9]. Cube specimens 150 mm in size 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 the Compression Testing Machine (CTM) 2000 kN in capacity under a uniform rate of loading of 140 kg/cm²/min until failure, and the ultimate load at failure was registered to enable calculation of compressive strength.

B. Split tensile strength (MPa) test

The split tensile strength test was carried out as per IS 5816:1999 [15]. Cylindrical concrete specimens 150 mm in diameter and 300 mm in height were cast. The specimens were then tested to determine the splitting tensile strength using a Universal Testing Machine (UTM) at the ages of 3, 7 and 28 days.

VI. RESULTS AND DISCUSSION

A. Compressive strength (MPa)

The compressive strength test results obtained for geopolymer concrete at 3, 7 and 28 days are shown in Table 5.

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Table 5- Compressive strength of Geopolymer concrete

Material	molarity	Temperature	Compressive strength		
			3 Days	7 Days	28 Days
Fly Ash	12M	Ambient	24.5	30.90	35.562
Fly Ash	12M	60°C	30.3	36.17	42.166
Fly Ash	12M	70°C	33.9	39.18	45.296

The Comparison of strength for Geopolymer concrete at 3,7, and 28 days and different temperature various like ambient room temperature ,60°C and 70°C as shown in figure 4.

As shown in figure 4 that Compressive strength values of Geopolymer concrete using Fly ash. In Graph it is shows that when temperature increase compressive strength of Geopolymer concrete increase.

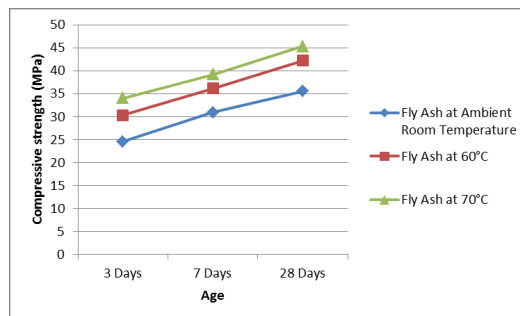


Figure 4- Compressive strength values of Geopolymer concrete

Table 6-Compressive strength at ambient temperature

% replacement of RHA	molarity	7 Days	28 Days	Compressive strength
0	12M	37.764	43.175	56.666
25	12M	29.453	33.276	37.807
50	12M	17.178	21.783	25.896
75	12M	13.234	17.453	21.453

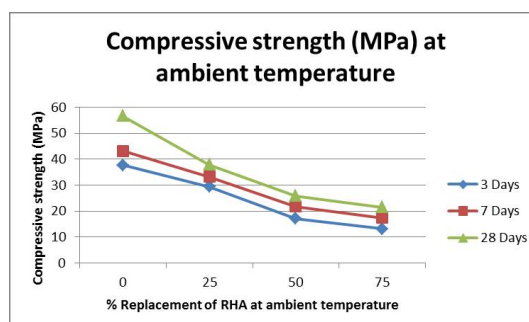


Figure 5- Compressive strength at ambient temperature

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As shown in figure 5 that % replacement of RHA at ambient temperature. It is observed that when increase % replacement of RHA, The compressive strength of Geopolymer concrete decrease.

Table 7- Compressive strength at 60°C

% replacement of RHA	Molarity	Compressive strength		
		3 Days	7 Days	28 Days
0	12M	44.342	54.962	71.333
25	12M	31.276	35.276	40.667
50	12M	19.178	24.783	29.896
75	12M	15.234	20.453	23.453

As shown in figure 7 that Compressive strength values of Geopolymer concrete of replacement of RHA with GGBFS In Graph it is shows that when Replacement of RHA increase the compressive strength of Geopolymer concrete decrease.

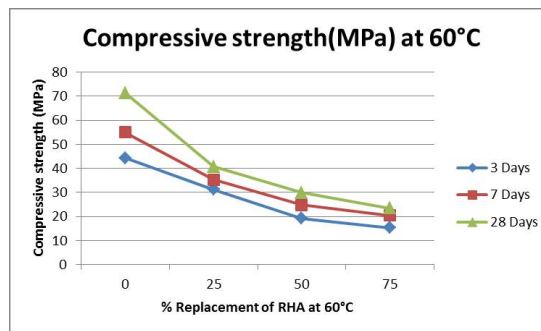


Figure 6- Compressive strength at 60°C

Table 8- Compressive strength at 70°C

% replacement of RHA	molarity	Compressive strength		
		3 Days	7 Days	28 Days
0	12M	46.356	57.956	73.452
25	12M	33.562	38.276	43.634
50	12M	21.165	25.784	31.895
75	12M	17.235	22.456	25.412

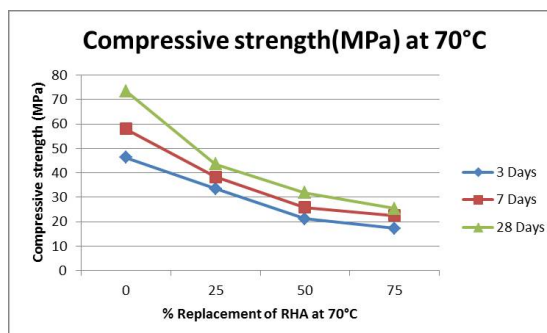


Figure 7- Compressive strength at 70°C

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Figure 5,6,7 shows that the % replacement of RHA at different temperature like ambient room temperature, 60°C and 70°C. It is observed that when % replacement of RHA increase there are decrease in compressive strength of Geopolymer concrete. It is also observed that when temperature increase there are increase in compressive strength of Geopolymer concrete.

B. Split Tensile strength(MPa)

The split tensile strength test was carried out as per IS 5816:1999 [15]. Cylindrical concrete specimens 150 mm in diameter and 300 mm in height were cast. The specimens were then tested to determine the splitting tensile strength using a Universal Testing Machine (UTM) at the ages of 3, 7 and 28 days.

Table 9- Split tensile strength of Geopolymer concrete

Material	molarity	Temperature	Split Tensile strength		
			3 Day	7 Day	28 Day
Fly Ash	12M	Ambient	1.9	2.1	2.23
Fly Ash	12M	60°C	2.34	2.6	2.8
Fly Ash	12M	70°C	2.4	2.7	2.93

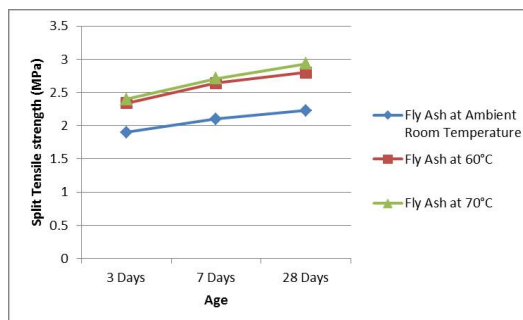


Figure 8- Split tensile strength value of Geopolymer concrete

As shown in figure 8 that Split tensile strength values of Geopolymer concrete using Fly ash. In Graph it is shows that when temperature increase split tensile strength of Geopolymer concrete increase.

Table 10- Split tensile strength at ambient temperature

% replacement of RHA	molarity	Split tensile strength		
		3 Days	7 Days	28 Days
0	12M	5.3	5.56	5.87
25	12M	3.1	3.46	3.83
50	12M	0.91	1.13	1.31
75	12M	0.73	0.89	1.1

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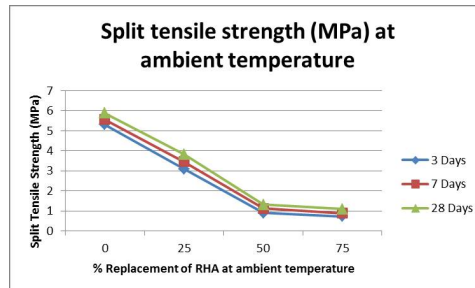


Figure 9- Split tensile strength at ambient temperature

As shown in figure 9 that % replacement of RHA at ambient temperature. It is observed that when increase % replacement of RHA, The split tensile strength of Geopolymer concrete decrease.

Table 11- Split tensile strength at 60°C

% replacement of RHA	molarity		Compressive strength	
	3 Days	7 Days	28 Days	28 Days
0	12M	5.9	6.12	6.42
25	12M	3.92	4.21	4.54
50	12M	1.41	1.73	1.97
75	12M	0.91	1.24	1.57

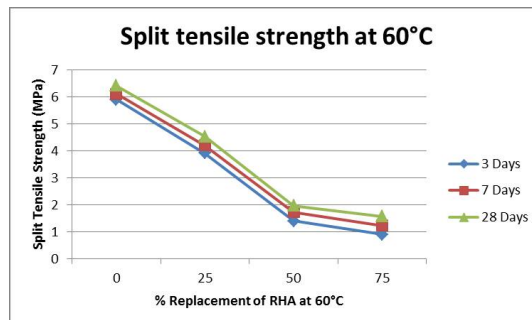


Figure 10- Split tensile strength at 60°C

Table 12- Split tensile strength at 70°C

% replacement of RHA	molarity		Split tensile strength	
	3 Days	7 Days	28 Days	28 Days
0	12M	6.1	6.38	6.72
25	12M	4.1	4.43	4.71
50	12M	1.56	1.85	2.11
75	12M	0.97	1.31	1.65

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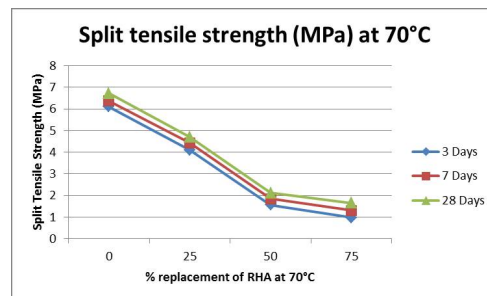


Figure 11-Split tensile strength at 70°C

Figure 9,10,11 shows that the % replacement of RHA at different temperature like ambient room temperature, 60°C and 70°C. It is observed that when % replacement of RHA increase there are decrease in split tensile strength of Geopolymer concrete. It is also observed that when temperature increase there are increase in split tensile strength of Geopolymer concrete.

VII. CONCLUSION

The experimental results show that it is possible to produce geopolymer concrete of substantial strength and durability using GGBS and RHA. The following conclusions can also be derived from the present study:

- The addition of RHA beyond 25 % had a retarding effect on the compressive strength. At up to 25 % replacement, the target strength was surpassed and compressive strength as high as 41 MPa was reached at 28 days. The split tensile strength is trend similar to that of the compressive strength with respect to the RHA proportion.
- The addition of RHA beyond 25 % is not beneficial for geopolymer concrete. The 50 % RHA replaced specimens neither achieved significant strength
- It is also observed that when temperature increase both compressive and tensile strength of Geopolymer concrete increase.
- The GGBS based geopolymer concrete gives higher strength.
- The Geo-polymer concrete was a good workable mix. High early strength was obtained in the Geo-polymer concrete mix.

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