IJREAT International Journal of Research in Engineering & Advanced Technology, Volume 9, Issue 2, April- May, 2021
ISSN: 2320 – 8791 (Impact Factor: 2.317)
www.ijreat.org

A Case Study on Partial Replacement of GGBS with Fly-Ash Strengthens Geo-polymer Concrete

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Abstract

Concrete is one of the most vital materials in constructions. One of the main ingredients in concrete is Portland cement. Cement acts as a binder and high energy intensive material. Due to the excess usage of cement, pollution also increases. Cement also consumes significant amount of natural resources. Geo polymer is an alternate binder to cement. Geo polymer concrete is a green technology and eco friendly and it is more sustainable than cement concrete.

In this study, the industrial wastes like fly-ash and GGBS were introduced in Geo-polymer concrete technology. No any standard mix design procedures are available for Geo-polymer concrete like cement concrete. To obtain the quantities of constituents of GPC, the unit weight of concrete is assumed. Geo-polymer concrete was prepared as 70% of its volume with aggregates and replacing Fly ash partially with GGBS varying from 5%, 10%, 15, 20% and 25% by mass of fly ash. Workability and strength properties were studied with two different concentrations of 8M and 14M. Heat curing influences the strength gaining. The effect of heat or oven curing on GPC is studied for 3hrs, 12hrs and 24 hrs.

Key words: *Aggregates, Compressive strength, Flexural strength, Fly-ash, Geo-polymer concrete, Slump cone test, GGBS, Split tensile strength.*

I. INTRODUCTION

1.1 General

Concrete is one of the most vital materials in constructions. . Most of developing countries like India etc. are in vast usage of concrete for the infrastructure development and also increases the rate of demand for the concrete. The manufacture of Portland cement produces large volumes of carbon dioxide and other gases. Cement is highly energy-intensive material next to steel and aluminium, it also consumes significant amount of natural resources. Many researches are in progress to reduce the use of Portland cement in concrete to address the global warming issues and utilization of industrial wastes in the field of civil engineering by implementing a new building material. In this aspect, the Geo-polymer technology has a raised and it is proposed by Davidovits. He showed the considerable trust for application in concrete industry as an alternative binder to the Portland cement.

Geo-polymers may be seen as man-made rocks. They can be produced by reacting solid alumino-silicates with a highly concentrated aqueous alkali hydroxide and silicate solution. Geo-polymer concrete utilizes industrial waste materials such as fly ash from thermal power stations to provide a practical solution to waste management as well as environmental protection methods. In comparison with Portland cement, concrete is having many advantages such as: Abundant Raw material Resources, energy saving and thermal processing, simple manufacturing technique, good volume stability, reasonable strength gain in a short time, excellent durability, high fire resistance and low thermal conductivity.

1.2 Fly-ash

Fly ash is finely divided residue resulting from the combustion of powdered coal and transported by the flue gases and collected by electrostatic precipitator. The fly ash is freely available at the thermal stations. Fly ash itself has little cementitious value but in the presence of moisture it reacts chemically and forms cementitious compounds and attributes to the improvement of strength of concrete.

In India, the total production of fly ash is nearly as that of cement (75 million tons). But our utilization of fly-ash is about 5% of the production. The disposal of fly-ash has become a serious environmental problem. Therefore, the use of fly ash must be popularized for more than one reason.

1.3 GGBS

Ground granulated blast furnace slag (GGBS) is a by-product from the blast-furnaces used to make pig iron. Iron ore, coke and lime stone are fed into the furnace and resulting molten slag floats above the molten iron temperature of about 1500^0C to1600^0C. GGBS has almost as same particle size as cement, GGBS often blended with Portland cement as low cost filter, enhances concrete workability, density, durability, and resistance to alkali-silica reaction.

1.4 Need of the study

To utilize industrial wastes like Fly-ash and GGBS as the dumping of industrial wastes in open lands are creating a huge environmental pollution and hence there is a need to explore the possibility of utilization of industrial waste materials like Fly-ash, GGBS etc.

1.5 Objectives of the study

The objectives of this experimental project are

- To develop geo-polymer concrete with lower (8M) and higher (14M) concentrations of Na-OH solution.
- To study the fresh and hardened properties of geo-polymer concrete by partial replacement of FLY-ASH with GGBS by percentage of mass based on percentage.
- To study the effect of oven curing with respect to time.

II. EXPERIMENTAL PROCEDURE

2.1 Materials used

- Fly-ash
- Alkaline liquid
  1. Na-OH
  2. Na_2SiO_3
- Aggregates
  1. Fine aggregates (sand)
  2. Coarse aggregates
     a. 20mm aggregates
     b. 12mm aggregates
     c. 6mm aggregates
- Water
- GGBS

2.2 Mix design

The geo-polymer concrete has no standard mix design procedure like OPC concrete. To obtain the quantities of constituents of GPC unit weight of concrete is assumed and in this work the mix proportions were made as 70% aggregate mass present in unit mass of concrete. The table-1 shows the quantities of ingredients estimated for GPC.

Table-1
quantities of various ingredients

% mass of aggregate = 70, mass of Na-OH = 68.57, mass of Na_2SiO_3 = 171.42

S.No	Combined mass of aggregate	mass of F.A + A.L	mass of F.A	% of GGBS	mass of GGBS	vol. of F.A	mass of A.L	mass of fine Aggregate	mass of coarse agg
1	1680	720	480	5	24	456	240	504	1176
2	1680	7	4	10	48	4	2	504	11

		20	80			32	40		76
3	1680	720	480	15	72	408	240	504	1176
4	1680	720	480	20	96	384	240	504	1176
5	1680	720	480	25	120	360	240	504	1176

The combined mass of aggregates are 1176kg/m^3, of these total mass 823.3kg/m^3 (70%) of 20mm aggregate, 235.2kg/m^3 (20%) of 12mm aggregate and 117.6 kg/m^3 (10%) of 6mm aggregate.

2.3 Preparation of samples

a) Mixing

Ten mixes are prepared by choosing 70% of aggregate content in total volume of GPC, with 5% interval 5%,10%,15%,20%&25% Flyash is partially replaced with GGBS for two concentrations 8M and 14M which of five mixes each. The table-2 shows the mix proportions of % variation of GGBS.

Table-2
Mix proportion of % variation of GGBS

S. No	% Replacement	Flyash	GGBS	Alkaline Liquid	NaOH solution	Na_2SiO_3 solution	Fine Aggregates	Coarse aggregates
1	5	1	0.010	0.5	0.143	0.357	1.050	2.450
2	10	1	0.023	0.5	0.143	0.357	1.050	2.450
3	15	1	0.036	0.5	0.143	0.357	1.050	2.450
4	20	1	0.052	0.5	0.143	0.357	1.050	2.450
5	25	1	0.333	0.5	0.143	0.357	1.050	2.450

b) Casting

Table-3
Number of specimens for 8M and 14M % variation of GGBS with 70% aggregate

S. No	% GGBS	Molarity	No. of specimens		
			Cubes 100mm×100m	Cylinders 100mm×200mm	Beams 500mm×100mm×100mm

			m× 100 mm		
1	5	8M	9	9	9
		14M	9	9	9
2	10	8M	9	9	9
		14M	9	9	9
3	15	8M	9	9	9
		14M	9	9	9
4	20	8M	9	9	9
		14M	9	9	9
5	25	8M	9	9	9
		14M	9	9	9

c) Curing

Here in the present study all the specimens were placed in the oven after 30 minutes without delay for curing at elevated temperature of 70°C for 3 hours, 12 hours and 24 hours. After curing at elevated temperature for four hours, the specimens were allowed to cool for an hour and then removed from the moulds. The heat curing was continued for one day. The specimens were cured further at room temperature until the day of testing.

Table-4
Curing particulars for 8M and 14M % variation of GGBS with 70% of aggregates

S. No	%GGBS	Time Of Curing (hrs)
1	5	3
		12
		24
2	10	3
		12
		24
3	15	3
		12
		24
4	20	3
		12
		24
5	25	3
		12
		24

2.4 testing

a) For studying the workability of geo polymer concrete **slump cone test** was conducted on fresh geo polymer concrete.

b) For studying the hardened properties of geo polymer concrete the following tests by conducting **compression strength, split tensile strength, flexural strength.**

III. RESULTS AND DISCUSSIONS

3.1 Slump cone test

The results obtained in slump cone test are shown in table-5.

Table-5

Workability for %GGBS with % of aggregate = 70

% GGBS	Concentration of NaOH	Slump(mm)
5	8M	60
	14M	30
10	8M	90
	14M	30
15	8M	90
	14M	40
20	8M	150
	14M	50
25	8M	160
	14M	70

By referring the above table it can be observed that slump values increases with increase in percentage of GGBS like (%5, %10, %15, %20, %25). When compared to above table 5.1.2 slump results %5 obtained lesser slump than %10, %15 obtained lower than %20, finally 25% of GGBS obtained higher slump value rather than other percentages variation.

It is also observed that slump values are decreased with the increase in concentration of alkaline solution. It is because of the fact that the amount of water in 14M solution is obviously less than that of 8M solution, which contributes to the reduction in values.

3.2 Compressive strength test

The average value of the 3 specimens was reported as the strength of the concrete of that particular category. The test results were shown in Table-6.

Table-6

Compressive strength test results

A.L/F.A = 0.5, NaS_2iO_3/NaOH = 2.5, % of aggregate =70

% GGBS	Concentration of NaOH	Compressive Strength(N/mm^2)		
		3 hrs	**12 hrs**	**24 hrs**
5%	8M	32	48.3	46.6
	14M	36.6	48.3	60
10%	8M	48.6	55.6	50.6
	14M	38.1	46.8	70
15%	8M	53.5	57.1	57.3
	14M	40	52.6	75.8
20%	8M	52	55.7	56.3
	14M	41	53.1	76.3
25%	8M	36.3	41.4	44
	14M	41.5	48	51.8

From the results for GPC with 8M it can be observed that 24 hrs cured specimen strength is achieved around 85 to 90% of strength is in 3 hrs of oven curing and 90 to 95% is achieved in 12 hrs of oven curing. The Lowest compressive strength occurred at 25% of GGBS and maximum strength occurred at 20% of GGBS with 8M solution.

From the results for GPC with 14M it can be observed that 24 hrs cured specimen strength is achieved around 60 to 65 % of strength was achieved in 3 hrs of oven curing. 70 to 75% achieved in 12 hrs of oven curing. The Lowest compressive strength occurred at 25% of GGBS and maximum strength occurred at 20% of GGBS with 14M solution.

It can also be observed that when concentration of NaOH increases the strength also increases upto 20% enhanced the compressive strength of geopolymer concrete. How-ever further increase of % GGBS caused decrease in compressive strength.

3.3 Split tensile strength test

The average value of the 3 specimens was reported as the strength of the concrete of that particular category. The test results were shown in Table-7.

Table-7
Split tensile strength test results
A.L/F.A = 0.5, NaS_2iO_3/NaOH = 2.5, % of aggregate = 70

% of GGBS	Concentration of NaOH	Split Tensile Strength(N/mm^2)		
		3 hrs	**12 hrs**	**24 hrs**
5%	8M	3.50	3.87	4.08
	14M	3.66	4.13	4.29
10%	8M	4.66	4.19	3.87
	14M	4.93	5.14	4.29
15%	8M	5.03	3.55	3.71
	14M	4.56	4.13	4.45
20%	8M	4.39	4.61	5.25
	14M	4.93	5.25	6.04
25%	8M	3.28	4.02	4.61
	14M	3.76	4.29	5.30

From the results for GPC with 8M it can be observed that 24 hrs cured specimen strength 90 to 95% of strength is achieved in 3 hrs of oven curing. 90 to 93% is achieved in 12 hrs of oven curing. The Lowest split strength occurred at 25% of GGBS and maximum strength occurred at 20 % of GGBS with 8M solution.

From the results for GPC with 14M it can be observed that24 hrs cured specimen strength 90 to 92% of strength was achieved in 3 hrs of oven curing. 90 to 95% of strength is achieved in 12 hrs of oven curing. The Lowest split strength occurred at 25% of GGBS and maximum strength occurred at 20 % of GGBS with 14M solution.

It can also be observed that when concentration of NaOH increases the strength also increases upto 20% enhanced the split strength of geopolymer concrete. How-ever further increase of % GGBS caused decrease in split strength.

3.4 Flexural strength test

The flexural test strength results are shown in table-8.

Table-8
Flexural Strength Test Results
A.L/F.A = 0.5 % of aggregates = 70 NaS_2iO_3 /NaOH = 2.5

% of GGBS	Concentration of NaOH	Flexural Strength(N/mm^2)		
		3 hrs	**12 hrs**	**24 hrs**
5%	8M	7.3	8.6	8.9
	14M	7.9	9.1	9.3
10%	8M	7.5	8.9	9.1
	14M	8.4	9.7	9.9
15%	8M	7.7	8.2	7.9
	14M	8.7	9.4	8.3
20%	8M	11.9	12.3	13.3
	14M	8.4	9.9	9.7
25%	8M	7.9	8.7	8.4
	14M	8.8	9	9.3

From the above table-8,

From the results for GPC with 8M it can be observed that 24 hrs cured specimen strength 85 to 90% of strength is achieved in 3 hrs of oven curing. 90 to 95 % of strength is achieved in 12 hrs of oven curing. The Lowest flexural strength occurred at 25% of GGBS, and maximum strength occurred at 20% of GGBS with 8M solution.

From the results for GPC with14M it can be observed that24 hrs cured specimen strength around 90 to 91 % of strength is achieved in 3 hrs of oven curing. 90 to 95% of strength is achieved in 12 hrs of oven curing. The Lowest flexural strength occurred at 25% of GGBS and maximum strength occurred at 20% of GGBS with 14M solution.

It can also be observed that when concentration of NaOH increases the strength also increases upto 20% enhanced the flexural strength of geopolymer concrete. How-ever further increase of % GGBS caused decrease in flexural strength.

IV. CONCLUSIONS

- From all the compressive strength test results maximum strength of concrete achieved is 76Mpa with for GPC mix with aggregate content 70%, concentration of 14M and partial replacement of Fly-ash with GGBS at 20%.
- For all the ages of curing higher the concentration of NaOH gives the better results than the lower the concentration of NaOH.
- The compressive strength of the concrete increases with the replacement of GGBS upto 20%. For further increase of GGBS decreases the result of compressive strength.
- The split tensile strength of concrete increases with the replacement of GGBS upto 20%, on further increase of GGBS decreases the result of split tensile strength.
- The flexural strength of concrete increases with the replacement of GGBS upto 20%, for further increase of GGBS decreases the result of flexural strength.
- Finally the geopolymer concrete is of more eco friendly and it is suitable for many applications.

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