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Experimental Investigation Of A Geopolymer Concrete-Without Cement In Concrete And Its Durability

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Abstract –As per united nations study there is available of lime ore for manufacturing of cement is sufficient for only 150 years & for production of 1 ton of Portland cement-1 ton of carbon dioxide gas is releasing in atmosphere and its causes green house effect, so have to choose green concrete. The geopolymer concrete has shown considerable good results for construction industry as an alternative binder to Portland cement. In construction industry applications a water resistant binder with sufficient strength is desirable. In addition, the production technology necessitates an adequate processing time. Nevertheless, after the shaping procedure the material should be demould immediately to enable feasible production. Therefore, the binder should show a rather a late beginning of setting, but it should be possible to accelerate strength evolution when the material is shaped. The form of cementitious material using silicon and aluminum activated in a high alkali solution was developed. This material is usually based on fly ash as a source material and is termed geopolymer or alkali-activated fly ash cement. The mortar and concrete made from this geopolymer possess similar strength and appearance to those from ordinary Portland cement. Geopolymer exhibit many excellent properties such as high compressive strength, low creep, good acid resistance, low shrinkage, fire resistance and other mechanical properties. The work on geopolymer has been based on the normally used low calcium fly ash. Low calcium fly ash has been successfully used to manufacture geopolymer concrete when the silicon and aluminium oxides constituted about 80% by mass, with the Si-to Al ratio of about 2. It is also known that high calcium fly ash contains a reasonable amount of silica and alumina. This high calcium fly ash could also be suitable for use as base material for making geopolymer.

Key words: Without Cement concrete, fly ash, Geopolymer, Ground Granulated Blast Furnace Slag, durability.

1. INTRODUCTION

Concrete is one of the most widely used construction material. The global use of cement concrete is second only to the use of water. It is mainly related to the Portland cement as the main component for making concrete. The demand for concrete as a construction material is increasing day to day. It has been estimated that the production of cement had increased to 2.2 billion tones in 2010 which was about to 1.5 billion tons in 1995.The manufacturing of Portland cement is an energy intensive process and releases a large amount of greenhouse gas to the atmosphere. The climate change due to global warming, one of the greatest environmental issues has become major concern during the last decade. The global warming is caused by the emission of greenhouse gases, such as CO_2, to the atmosphere by human activities. CO_2 contributes to near about 67% of global warming. The cement industry is responsible for about 6% of all CO_2 emissions, because the production of one tone of Portland cement emits approximately one tone of CO_2 into the atmosphere. In future use of Portland cement is unavoidable. Efforts are being taken to reduce the use of Portland cement in production of concrete. The effort include the utilization of supplementary cementing material such as fly ash, silica fume, granulated blast furnace slag, rise-husk ash and metakaolin, and finding alternative binders to Portland cement.

2. METHODOLOGY

The materials and their properties, mixture proportions, manufacturing and curing of test specimens are described.

2.1 Materials

The materials used for making geopolymer concrete specimen are alkaline liquids, aggregates, water, and low-calcium fly ash.

2.1.1 Alkaline Liquid

Generally alkaline liquids were prepared by mixing of the sodium hydroxide solution and sodium silicate at the room temperature. When the solution mixed together the both solution start to react, it is recommended to use it in next 36 hour.

2.1.2 Sodium Silicate

The advantages of sodium silicate adhesives include their ability to expand and make contact; a controllable index adjustment across broad ranges; and the formation of a rigid layer that is a strong, permanent seal resistant to tearing, bugs (i.e., pests) and moderately resistant to heat and water. They are used for paper, wood, metal, sheet metal and other materials, except plastic.

2.1.3 Sodium Hydroxide

The sodium hydroxide used was in the flakes form with 99% purity.

Table -1: Chemical ingredients of sodium hydroxide

Chemical ingredients	Percent
Carbonate	2%
Chloride	0.01%
Sulfate	0.05%
Potassium	0.1%
Silicate	0.05%
Zinc	0.02%
Iron	0.002%

2.1.4 Aggregates

For this Project work, locally available aggregates, comprising 20 mm and 14 mm coarse aggregates, in dry surface condition were used. Locally available river sand was used as fine aggregates.

2.1.5 Water

The water used for the preparation of the solutions was potable distilled water. And water was used only for the preparation of sodium hydroxide solution.

2.1.6 GGBS

The GGBS which was obtained from quenching molten iron slag from a blast furnace in water or stream, to produce a glassy, granular product that is then dried and ground into a fine powder.

2.1.7 Fly Ash

The mineralogical and chemical composition is dependent to a large extent on the composition of the coal. It having same physical properties and chemical compositions.

2.2 Mixture Proportion

The development and manufacture of geopolymer concrete had taken place at Curtin University when the present work was undertaken. Some results of that study which was already been published by several authors were referred. Based on that study, mixture proportions were formulated. For preparing the following mixture proportion IS 456 was used.

Table no. 2 Mixture Proportion for 8 Molarity of NaOH for one Specimen

Materials	Quantity
Fly ash	1.5 kg
Fine Aggregate (Sand)	2.25kg
Coarse aggregate	4.5 kg
Sodium silicate solution	450 ml
Sodium Hydroxide Solution	167 ml
Potable water	520 ml

1. Preparation of Test Specimens 2.3Preparation of Liquids

The sodium hydroxide flakes were dissolved in water to make the solution. The mass of NaOH flakes in a solution is varied according to the molarity required. NaOH solution with a concentration of 8M consists of 320 grams of NaOH flakes per liter of the solution. It was noted that mass of the NaOH solids was only a fraction of the mass of the NaOH solution, and water was the major component. When sodium hydroxide is mixed with water, solution kept for 24 hours as it produces large amount of heat. Sodium silicate is already in liquid state and hence no requirement any special procedure.

2.4 Preparation of Concrete

1. First fly ash, GGBS and the aggregates were mixed together in the pan for 5 minutes.
2. The liquid component of the mixture was then added to the dry materials and mixed it thoroughly for approximately 3 minutes to manufacture fresh geopolymer concrete.
3. The fresh concrete was cast into the moulds immediately after mixing, in three layers for square block.
4. For compaction of the specimens, each layer was given 25 strokes using tamping rod.
5. The slump value of fresh concrete was measure 60mm before the fresh concrete was cast into the moulds.
6. It was kept for 24 hours in oven at 90 degrees temperature.

2.5 Curing

Curing of concrete must begin as soon as possible after placement & finishing and must continue for a reasonable period of time as per the relevant standards, for the concrete to achieve its desired strength and durability. Uniform temperature should also be maintained throughout the concrete depth to avoid thermal shrinkage cracks. Also, protective measures to control moisture loss from the concrete surface are essential to prevent plastic shrinkage cracks.

3. Result and Discussion

3.1 Introduction

Results of this dissertation work are summarized in this chapter. Results for average strengths are calculated by change in proportion of sodium hydroxide and sodium silicate of Geopolymer Concrete. Further dissertation work concludes results average strengths for 8 molar and 16 molar with NaOH solution. Also, average strengths are calculated by considering change in temperature and change in curing period. Mainly this dissertation work consists of study of average strength for optimum percentage of GGBS. Effect of acid attack, sulfate attack and high temperature is also studied in this dissertation work.

3.2 Proportion Variation

While preparing the alkali activated solution the proportion of sodium hydroxide solution to sodium silicate solution has to be maintained. Variation in this proportion has shown variation in strength of geopolymer concrete. In experimental work those proportions were 30:70, 40:60, and 50:50.

Table 3 Result for Chemical Proportion Variation of GPC

Sr. n o	Proportion	Molarity	Curing temperature (°C)	Curing period (hours)	Load (KN)	Strength (MPa)	Average
1	50: 50	8	90	72	478	21.24	21.27
		8	90	72	476	21.15	
		8	90	72	482	21.42	
2	60: 40	8	90	72	541	24.04	23.78
		8	90	72	529	23.51	
		8	90	72	535	23.77	
3	70: 30	8	90	72	408	18.13	18.00
		8	90	72	402	17.86	
		8	90	72	405	18.00	

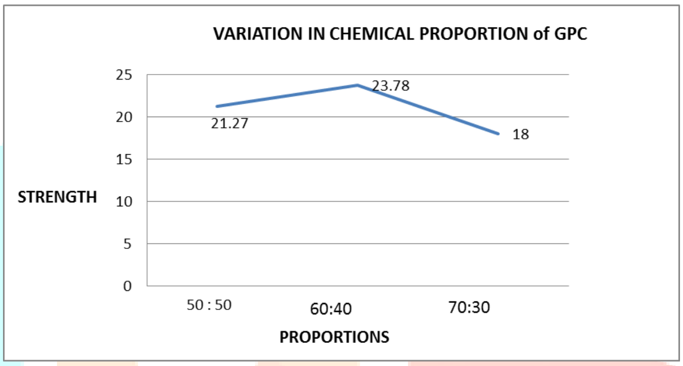

Figure 1 Variation in Chemical proportion of GPC

3.2.1 Result

It had been seen from the above figure (Fig. 4.1.1) for M 20 proportion of concrete mix, varying results were found for the varying chemical proportion between sodium hydroxide and sodium silicate. It can be seen that for proportion 60:40 gives the maximum strength compared to 50:50 and 70:30.

3.3 Molarity

Molarity of NaOH solution plays a vital role in the strength of geopolymer concrete. With a higher concentration of NaOH solution a higher compressive strength can be achieved. Tests were made for the 8 Molarity and 16 Molarity of NaOH and had provided satisfactory results.

Table 4 Results for 8 Mole and 16 Mole of GPC

Sr. no	Proportion	Molarity	Curing temperature (°C)	Curing period (hours)	Load (KN)	Strength (MPa)	Average
1	60: 40	8	90	72	535	23.78	24.05
		8	90	72	568	25.24	
		8	90	72	521	23.15	
2		16	90	72	541	24.04	25.97
		16	90	72	610	27.11	
		16	90	72	602	26.75	

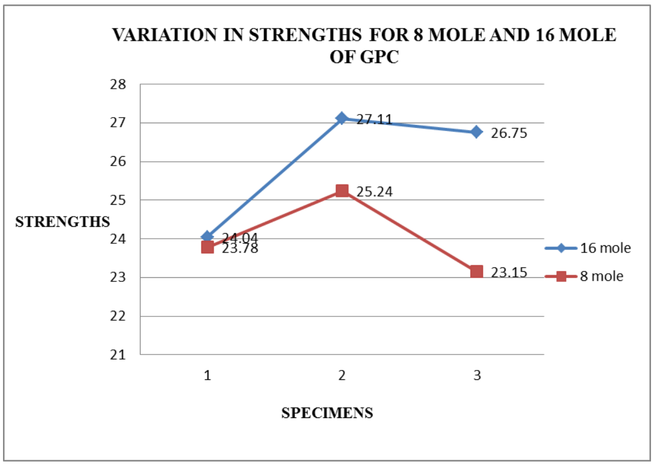

Figure2.Variation in Strength of GPC

3.3.1 Result

When molarity of NaOH is changed from 8 Mole to 16 Mole, strength of the geopolymer increased up-to 25.97. Hence to increase the strength of geopolymer slightly molarity of NaOH can be increased up-to some limit.

3.4 Curing Temperature

While taking the tests for compressive strength of the concrete, the curing temperature of the specimen was varied. This test will be able to provide the efficient temperature required for the specimen to provide desired value of strength. Temperature was varied between 60 °C to 90 °C.

Table 5 Results for Strength Due to Change in Temperature

Sr. no	Curing Tempera ture (°C)	Curing period (hours)	Load (KN)	Strength (MPa)	Average
1	60	72	478	21.24	21.28
	60	72	462	20.53	
	60	72	297	22.08	
2	70	72	515	22.88	23.32
	70	72	533	23.68	
	70	72	527	23.42	
3	80	72	538	23.91	23.53
	80	72	516	22.93	
	80	72	535	23.77	
4	90	72	521	23.15	24.05
	90	72	535	23.77	
	90	72	568	25.24	

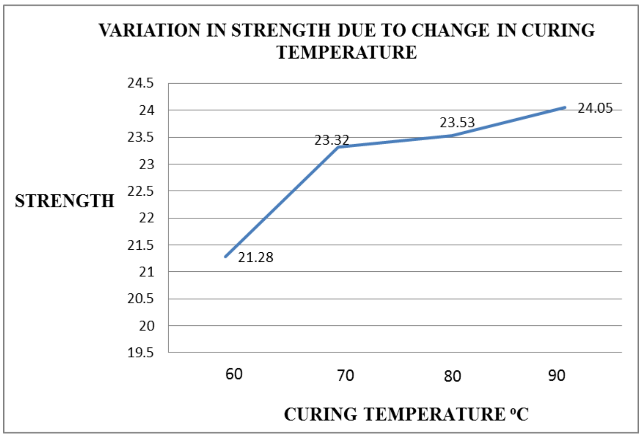

Figure 3 Variation in Strength due to change in curing Temperature of GPC

3.4.1 Result

Initially when temperature was 60 °C strength was near 20MPa but as the temperature increased to 70 °C it was increased up-to 23.

Same increment was found for 80 °C and 90 °C. At 90 °C strength reaches up to 24.05MPa.

3.5 Curing Period

Curing period of the test specimen has shown considerable effect on strength of the geopolymer concrete. As curing period increases, the strength of the concrete increases. Tests were made for various curing periods, such as 4, 24, 48, 72 and 144 hours.

Table 6 Results for Strength Due to Change in Curing Period

Sr. no	Curing Temper ature (°C)	Curing Period (hours)	Load (KN)	Strength (MPa)	Average
1	90	04	472.0	20.97	21.02
	90	04	476.2	21.16	
	90	04	470.9	20.92	
2	90	24	482	21.42	21.41
	90	24	476	21.15	
	90	24	488	21.68	
3	90	72	535	23.77	24.06
	90	72	525	23.33	
	90	72	564	25.07	
4	90	144	588	26.13	24.44
	90	144	538	23.91	
	90	144	524	23.28	

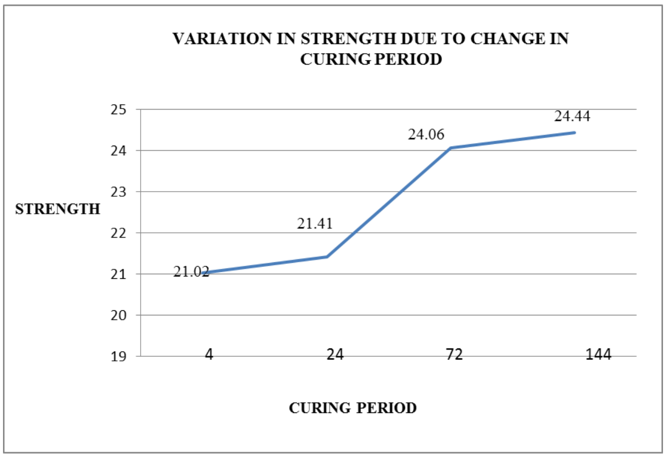

Figure 4 Variation in Strength Due to Change in Curing Period of GPC

3.5.1 Result

Increase in curing period shown good increase in strength. When specimens were cured for 4 hours average strength of 21MPa was obtained. Further curing period increased to 24 hours, 72 hours, and 144 hours and respective increase in strength was 21.41 MPa, 24.06MPa and 24.44MPa.

3.6 Replacement of Fly ash with GGBS

The fly ash in mixture proportion is partially replaced with GGBS, to determine its effect on strength. With following percentage (Fly ash: GGBS)-60:40, 50:50,40:60.This experimental has shown considerable results for this practice.

Table 7 Result for Strengths of GGBS

Sr. no	Proportion	Molarity	Curing temperature (°C)	Curing period (hours)	Load (KN)	Strength (MPa)	Average
1	60 : 40	8	90	72	722	32.08	32.06
		8	90	72	715	31.77	
		8	90	72	728	32.35	
2	50 : 50	8	90	72	920	40.88	40.21
		8	90	72	880	39.11	
		8	90	72	915	40.66	
3	40 : 60	8	90	72	1080	48	48.48
		8	90	72	1100	48.88	
		8	90	72	1093	48.57	

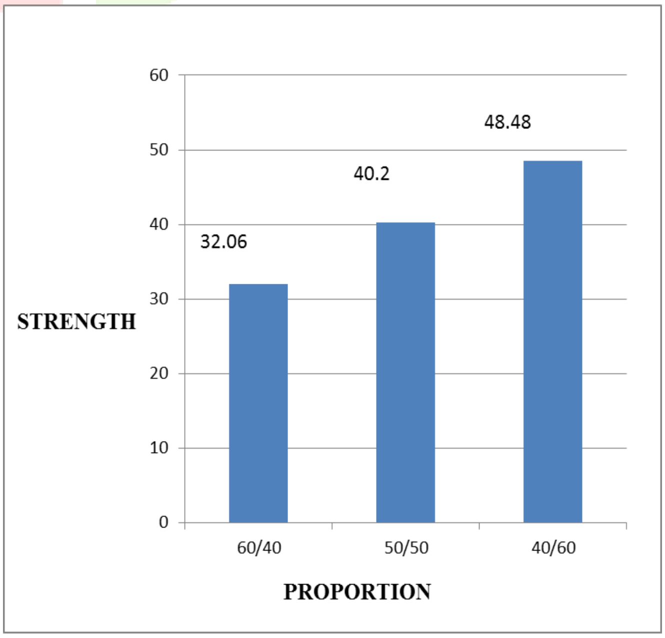

Figure 5 Variation in Strength for Different Proportions of Flyash:GGBS

3.6.1 Result

It had been seen from the above figure (Fig.) for G20 proportion of Geopolymer concrete mix, varying results were found for the varying proportion between fly ash and GGBS. It can be seen that for proportion 40:60 gives the maximum strength compared to 50:50 and 60:40.

3.7 Sodium Sulfate Attack

The Geopolymer concrete cubes where prepared .The nine Specimens were casted and cured for 24 hours. The solution was made with the proportion of 95% of water and 5% of sodium sulfate powder. The Testing period for this test is 1,2 and 4 months. The initial weight of Specimens where taken before immersing to sodium sulfate solution .after 1,2 and 4 month duration respectively the final weight of Specimens where taken and change in strength is fined.

Table 8 Test Results For Sodium Sulfate Attack

Sr. No	Weight (Kg)		Duration (Months)	Strength (MPa)	Average strength (MPa)	Decrease in strength (MPa)
	Initial	Final				
1	8.683	8.509	1	34.125	34.748	3.812
2	8.582	8.382	1	35.536		2.401
3	8.452	8.432	1	34.584		3.535
4	8.636	8.541	2	29.733	28.384	8.204
5	8.629	8.488	2	28.542		9.935
6	8.563	8.431	2	26.879		11.058
7	8.659	8.263	4	21.088	20.118	16.849
8	8.595	8.135	4	18.933		19.544
9	8.152	7.968	4	20.333		17.604

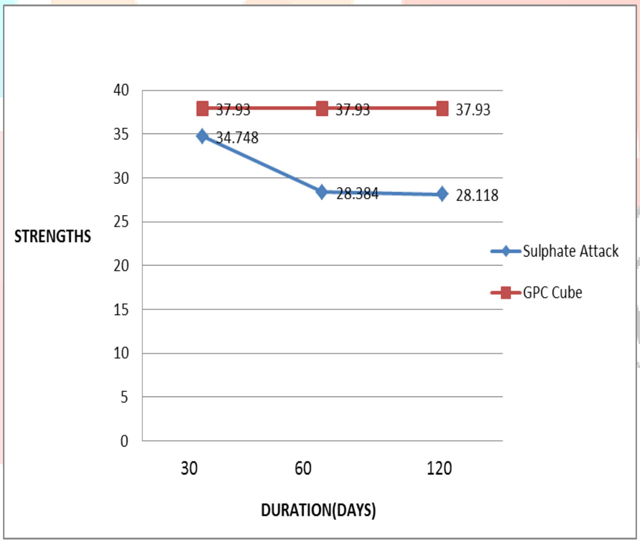

Figure 6 Variations in Strength for Sodium Sulfate Attack

3.7.1 Result

It has been seen from the above figure results for Geopolymer Concrete under sulfate attack. It can be seen that initially percentage decrease in strength of GPC is less under sulfate attack. Above graph shows varying strengths of GPC under sulfate attack.

3.8 Sulfuric Acid Attack

The Geopolymer concrete cubes where prepared .The nine Specimens were casted and cured for 24 hours. The solution was made with the proportion of 90% of water and 10% of sulfuric acid. The solution was made so as to maintain Ph value 1. The Testing period for this test is 1,2 and 4 months. The initial weight of Specimens where taken before immersing to Sulfuric acid solution .after 1,2 and 4 month duration respectively the final weight of Specimens where taken and change in strength is fined.

Table 9 Test Results for Sulfuric Acid Attack

Sr No	Weight (Kg)		Duration (Months)	Strength (MPa)	Average strength (MPa)	Decrease in strength (MPa)
	Initial	Final				
1	8.582	8.445	1	30.044		7.893
2	8.563	8.226	1	27.866		10.071
3	8.633	8.237	1	26.977	27.296	10.96
4	8.591	8.260	2	20.755		17.182
5	8.745	8.480	2	25.022		12.915
6	8.765	8.158	2	23.822	23.199	14.115
7	8.749	7.982	4	13.777		24.16
8	8.577	8.134	4	14.488		23.449
9	9.482	8.216	4	14.266	14.177	23.671

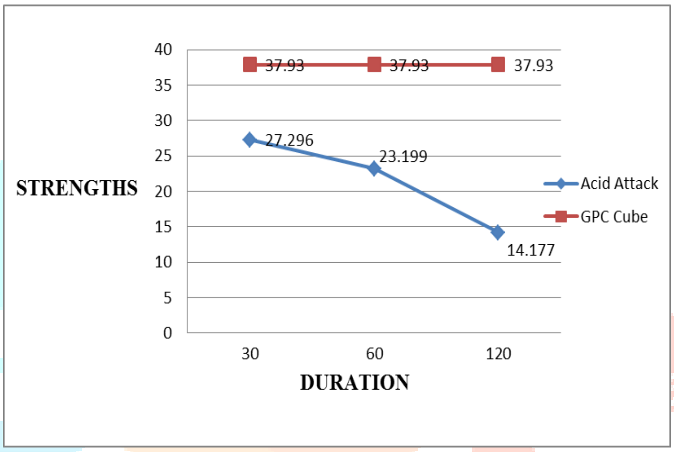

Figure 7 Variations in Strength for Sulfuric Acid Attack

3.8.1 Result

It has been seen from the above figure results for Geopolymer Concrete under acid attack. It can be seen that initially percentage decrease in strength of GPC is less under acid attack. Above graph shows varying strengths of GPC under acid attack.

4. CONCLUSIONS

Conclusions for dissertation work are as follows

1. Concluding remarks for Geopolymer concrete are as follows
   a) Proportion of sodium hydroxide to sodium silicate, 60:40 gives the maximum compressive strength compared to 50:50 and 70:30.
   b) When molarity of NaOH is changed from 8 Mole to 16 Mole, strength of the Geopolymer increased up-to 7.98%.
   c) As the curing temperature increases, compressive strength of Geopolymer concrete increases. But after the 90 ˚C there is no effective result regarding the compressive strength of concrete.
   d) Minimum required curing period is 4 hours, sufficient strength of concrete is gained during 72 hours.
   e) GPC gives better compressive strength as compared to conventional concrete at mix proportion of M20.
   f) GPC can effectively withstand sulfate attack with a very low loss in its compressive strength.
   g) GPC can be used in the structures which are subjected to light fire resistance temperature.
2. The proportion of GGBS to Fly ash, 60: 40 gives the maximum strength compared to 50:50 and 40:60.

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