RECYCLING OF GGBS INTO GEOPOLYMER CONCRETE AND CREATING ECO-FRIENDLY CEMENT PRODUCT

Akshay Mote1, Prof. Kuldeep Patil2
1PG Student, Department of Civil Engineering, JSPM'S ICOER, Pune 412207, India.
2 Assistant Professor, Department of Civil Engineering, JSPM'S ICOER, Pune 412207, India.

ABSTRACT
Cement industry is one of the vital contributors to the emission of greenhouse gasses. That is cement production consumes large amount of virgin materials in atmosphere, which is one of cause of global warming. Also, in India more than 100 million tons of fly ash is produced annually. Fly ash was chosen as the basic material to be activated by the Geopolymerisation process to be the concrete binder, to totally replace the use of Portland cement. For the polymerization the sodium hydroxide and potassium hydroxide were used in three combination process. The some parameter assumed as fixed with past literature review. The other parameter like temperature, curing time and testing age were analyze with different type of the activator. The activators were used like sodium hydroxide, potassium hydroxide and 50% of sodium hydroxide, 50 % of potassium hydroxide. The compressive strength test used for the optimization of temperature and curing time of geopolymer concrete. In this study solution to fly ash ratio of 0.45 with 10 Mole concentrated sodium hydroxide solution and potassium hydroxide is used and grade chosen for investigation was M30. All the specimens were cured in oven at 80^0C for 24 hours duration. All tests were conducted according to Indian standard code procedure. Test results for compressive strength, split tensile strength and flexure strength are tabulated and discussed in details and some important conclusions are made.
Keywords- *Fly Ash, GGBS, Geopolymer Concrete, Cement Product, OPC.*

1. INTRODUCTION

1.1 General

Mostly worldwide use of concrete is second the pollution due to factory smoke or other materials. Basically in civil construction concrete is an important parameter and cement is a main key factor of concrete material. One tone of cement manufacture produced one tone carbon dioxide. The carbon dioxide affects human health and surrounding environment. It is responsible for many serious problems. Now the world is focusing on eco-friendly material and products. In this project, attempts are made to replace cement by GGBS and FA which is an industrial waste material. There is also problem of disposal of this material. An expressive use of GGBS and FA in GPC material. Geopolymer concrete has excellent properties, as a researcher has already studied. The cement consumption has risen nearly more than 1.3 billion tons per annum.CO_2 is emitted during the calcination of limestone, resulting in an approximately 1 ton of CO_2 for every ton of OPC produced. So to reduce the Greenhouse gas, we need to control the emission of CO_2 Therefore its need of the time to not only introduces such materials and technologies for an alternative to the cement but also to use it more and more. Replacing 15% of cement worldwide by other cementations material will reduce CO_2 emission by 250 million tons and if it's replaced by 50 %, emission is reduced by 800 million tonnes Our Project Aim is to completely replace the cement by fly ash which is used as a binder in Geopolymer Concrete At present nearly 170 million tonnes of fly ash is being generated in India and its utilization is only 25 million tonnes. So the disposal of fly ash and GGBS is also a major issue.

1.2. Geopolymerization Starts with Oligomers:

Geopolymerization is the process of combining many small molecules known as oligomers into a covalently bonded network. The geo-chemical syntheses are carried out through oligomers which provide the actual unit structures of the three dimensional macromolecular edifice. In 2000, T.W. Swaddle and his team proved the existence of soluble isolated alumino-silicate molecules in solution in relatively high concentrations and high pH. One major improvement in their research was that their study was carried out at very low temperatures, as low as 9 °C. Indeed, it was discovered that the polymerization at room temperature of oligo-sialates was taking place on a time scale of around 100 milliseconds, i.e. 100 to 1000 times faster than the polymerization of ortho-silicate, oligo-siloxo units. At room temperature or higher, the reaction is so fast that it cannot be detected with conventional analytical equipment.

1.3 Research Significance:

In this research, an effort has made to understand the properties of geopolymer concrete and cement replaced by GGBS and Fly Ash at a different percentage. Focus is on mixing design of Geopolymer concrete and curing type and temperature. Also effects on the properties of GPC. To find out the compression and tensile strength of the concrete.

1.4 Objectives:

1. To examine the properties of GGBS and Fly Ash as the alternative material of OPC.
2. To find the economical, technical, and environmental limits of GGBS and Fly Ash over OPC.
3. To determine compressive and tensile strength of Geopolymer concrete and compare that with conventional properties of cement concrete.
4. To write a conclusion on Geopolymer concrete whether good alternative material of conventional Portland cement.

2. LITERATURE REVIEW

Joseph Davidovits (1994) studied of properties geopolymer cement carried out by the author. Researcher focused on excellent properties of geopolymer and its use regarding rehabilitation of retrofitting of structures after a disaster. The geopolymer is the best material for retrofitting regarding the environmental and construction usages.

Lyon E et al (1996) studied that geopolymer is noncombustible and fire resistive structural materials. Which are suitable for infrastructure where a high degree of fire resistance is needed at low to moderate cost. The main conclusion was entered that load bearing capability increases with increasing fire up to 100^0C temperature might be reached.

Balaguru. P (1997) from this paper it is being concluded that study has been done with the help of geopolymer concrete for repair and rehabilitation RCC beam. The first objective of this paper was to know whether geopolymer can be used or not for repair of the concrete structure. It has been also concluded that geopolymer concrete has the strongest bond with carbon fabrics.

Vijaya Rangan B (2004) carried out a study on durability of geopolymer concrete by considering the environmental protection. This paper described the results by conducting the test by large scale reinforced geopolymer concrete member and also give the application of geopolymer concrete in the construction industry. The test gave the results regarding excellent to resistance to sulfate attack and fire undergoes low creep was noted the based benefit of geopolymer concrete

Vijaya Rangan et al (2006) studied the behavior of fly ash based Geopolymer concrete and informed that the geopolymer concrete had an excellent compressive strength and is suitable for the structural applications. The elastic properties of the hardened concrete, as well as the behavior and strength of the reinforced structural members, were similar to those of Portland cement concrete. Therefore, the design provisions present in the current standards and codes can be used to design the reinforced fly ash-based geopolymer concrete structural members.

Sumajouw D.M.J et al (2006) Studied of the behavior of fly ash and slender reinforced columns. They studied analysis of the behavior and the strength of reinforced geopolymer concrete slender columns. The low calcium fly ash based geopolymer concrete reinforced columns had excellent potential in the precast industry.

Bhikshma et al. (2010) In this paper author investigated that flexural behavior of high strength manufacture sand concrete. The researcher observes the workability of M50 grade investigated sand concrete is supposed to be 30% less compared to ordinary concrete and compressive strength of M50 grade concrete having varying percentages that are 0%, 25%, 50%, 75%, 100%. Manufacture concrete improves the strengths by 6.89%, 10.76%, 20.68% respectively and the outcome was while comparing to ordinary concrete the load carrying and moment carrying capacity of reinforced concrete beam was 3 to 12 % higher.

Vijai et al (2010) informed that geopolymer concrete had an excellent compressive strength and it is more suitable for the structural application. The elastic as well as behavior and strength properties of reinforced structure members here similar to those of portland cement concrete. Hence the design provisions according to the current codes and standards can be used to design the reinforced fly ash-based geopolymer concrete member structure.

3. METHODOLOGY

3.1 Introduction

This section includes planning of project work and step by step all detail explanations about work which as follows.

3.2 Experiment Procedure:

Before starting the project work study of many research papers which give me basic of carrying out my experiment work. After referring various papers material finalization done and following project work was followed.

- Selection of material like Coarse aggregate, fine aggregate, Fly Ash, GGBS, Polymer and catalyst
- Laboratory test on were performed on Coarse Aggregate, Fine Aggregate, GGBS, Fly Ash, Catalyst Activator, Polymer Activator
- Mix Design was done for M30 Grade of Concrete.
- Cement is replaced in various proportions by Fly Ash and GGBS.
- Workability of concrete was checked.
- Determining the compressive strength of concrete of different mix.

- Determining compressive strength and flexural strength by steam curing.
- Flexural strength of concrete is determined by the flexural testing machine.
- Test results were compared with conventional concrete.

3.2 Material:

3.2.1 Ground Granulated Blast Furnace Slag (GGBS)

It is the by-product from the blast-furnaces used to make iron, blast furnaces are fed with a controlled mixture of iron ore, coke, and limestone, and operated at a temperature of about 1500^{0}C. when these materials are melt then there is two by-products are formed molten slag and iron. This slag is very light in weight than the cement particle and it is floated on top of the molten iron. This slag is nothing but alumina and silicates from the real iron ore, including with oxides from limestone. The manufacturing process of slag to implicate at maximum water pressure jets. The slag particle size is not greater than 5 mm. Further, this is used in process for drying and then grinding in a mill to very thin powder, which is known as GGBS.

Table 1: physical and chemical properties of GGBS

Sr.No.	Particulars	GGBS (In %)	As per IS : 12089-1987 (Reaffirmed 2008)	
1	Calcium Oxide (Cao)	37.34	-----	
2	Aluminum Oxide ($Al_2O_{3)}$	14.42	-----	
3	Iron Oxide ($Fe_2O_{3)}$	1.11	-----	
4	Silicate Oxide (SiO_{30}	37.73	-----	
5	Magnesium Oxide (MgO)	8.71	Max. 17.0%	
6	Manganese Oxide (MnO)	0.02	Max. 5.5%	
7	Sulphate Sulphur	0.39	Max. 2.0%	
8	Loss of Ignition	1.41	----	
9	Insoluble Residue	1.59	Max. 5%	
10	Glass Content	92	Min. 85%	
A	Chemical Moduli: 1. $\frac{CaO+MgO+1/3Al2O3}{SiO2+2/3Al2O3}$	1.07	≥ 1.0	Major Oxide should be Satisfy at least one
B	2. $\frac{CaO+MgO+Al2O3}{SiO2}$	1.60	≥ 1.0	

3.2.2 Fly Ash (FA)

In this research, Class - F low calcium fly ash produced from the thermal power plant, MIDC, Satara, MH is used. As per IS 456-2000 Cement is replaced by 35 % of fly ash by weight of cementations material. The specific gravity of fly ash is 2.24.

3.3 Mix Design of Geopolymer Concrete

Design of Geopolymer Concrete is based on as per IS 10262:2009, IS 456:2000 and Previous Research Paper is as follows.

Mix Design for Grade M 30:

Characteristics Strength required at 28 days = 30 Mpa
Fly ash grade = Pozzolana 63
Max size of Aggregate = 20 mm
Degree of quality control = Good
Type of exposure = sever.

Procedure of Mix Design

Step 1:

Target mean strength, fck = fck + t x S
Where, t = a statistical value depending on expected proportion of low result t = 1.65 &
S = Standard deviation from Table 3.6
For M40 grade concrete & good quality control, S = 5
Target mean strength = 30 + (1.65 x 5) = 38.25 Mpa

Step 2:

To decide water /cement ratio, this will give 38.25 Mpa
Select water /cement ratio (w/c) = 0.45; this is lesser than 0.5 prescribed in

I.S 456-2000[20] for sever condition for reinforced concrete (Table 3.7).

Step 3:

Selection of water content: from Table 3.9

For 20 mm size of aggregate use maximum water content 186 lit.

For 100 mm slump = 186 + (6/100) ×186 = 197

Step 4:

Calculation of cement content:

Cement content: 197/0.45 = 437.78 kg/m^3

Replaced cement by Fly Ash (75 %) and GGBS (25%)

Fly Ash = 328.5 kg/m^3 and GGBS 109.5 kg/m^3

437.785 kg/m^3 > 320 kg/m^3

Step 5:

Volume of C.A. and F.A.:

Table 3.10, Volume of C.A. corresponding to 20 mm size of aggregate and F.A. zone II for W/C ratio = 0.45

Therefore, Volume of C.A. = 0.6 and Volume of F.A. = 0.4.

Step 6:

Mix calculation:

i. Volume of concrete = 1 m^3

ii. Volume of fly ash = (Mass of fly ash/ Specific gravity of fly ash) × (1/1000)
 = (328.5 /2.3) × (1/1000) = 0.1428 m^3

iii. Volume of GGBS = (Mass of GGBS/ Specific gravity of GGBS) × (1/1000)
 = (109.5 / 2.85) x (1/1000) = 0.03842 m^3

iv. Volume of water = (water/ Specific gravity of water) × (1/1000)
 = (197/ 1) × (1/1000) = 0.197 m^3

v. Volume of all aggregate = i- (ii + iii + iv)
 = 1- (0.1428+0.03842+0.197)
 = 0.62177 m^3

vi. Mass of C.A. = v × volume of C.A. × Specific gravity of C.A. × 1000
 = 0.62177 x 0.6 x 2.67 x1000
 = 996.0898 kg.

vii. Mass of F.A. = v × volume of F.A. × Specific gravity of F.A. × 1000
 = 0.62177 x 0.4 x 2.57 x 1000
 = 639.179 kg.

[Note: 1. Replace cement by fly ash by 75% and GGBS 25%
2. Replace water by alkaline solution such as sodium silicate and sodium hydroxide by 100%.]

4. RESULT AND DISCUSSION

4.1 General

The tests on geopolymer concrete are carried out according to relevant standards wherever applicable. Various tables presented in this section show the results obtained from the test on geopolymer concrete. The geopolymer concrete were casted with three type of combination sodium hydroxide and sodium silicate, potassium hydroxide and potassium silicate and 50 % of sodium silicate and 50% of potassium silicate with same quantity of respective silicate.

4.1.1 Slump Flow Test

Slump Flow test is carried out according procedure of IS 516 - 1959 Guidelines and test results obtained from M30 grades of Geopolymer concrete, results are presented in table

Table2: Slump flow test for geopolymer concrete.

Sr. No.	Mix of concrete	Solution/ fly ash ratio	Slump Flow for Geopolymer concrete (mm)
01.	M30	0.45	125

The Slump flow is carried out as per IS 516 - 1959 and test readings are present in above table 4.1. It can be seen that the workability of Geopolymer concrete is more than that of Normal concrete.

4.2 Geopolymer Concrete Test Results

Testing of geopolymer concrete is an important role in controlling and confirming the quality of cement concrete work. Tests are made by casting cubes, beams, and cylinder from the actual concrete. The effect of compressive strength, flexural strength, split tensile strength, geopolymer concrete were studied.

4.2.1 Effect of molarity of Sodium hydroxide solution and Sodium Silicate.

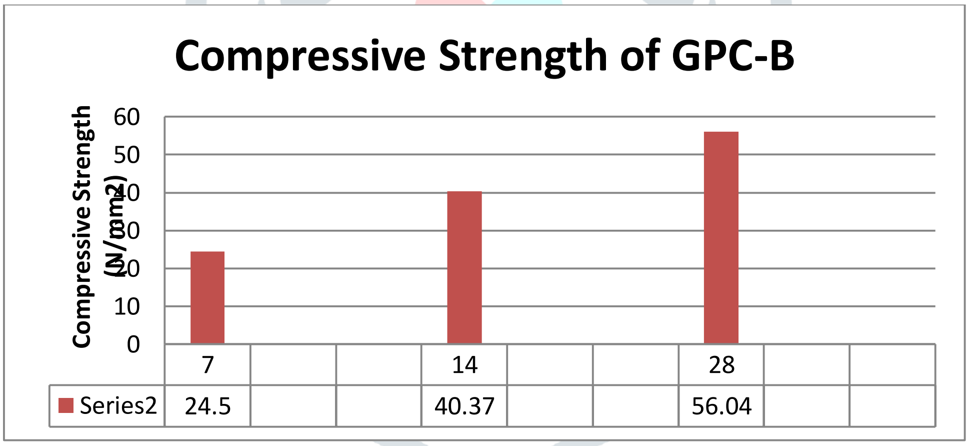
The molarity variation tested by using compressive strength with respect to curing temperature, curing time and testing age of concrete (days).

Compressive Strength of GPC.

Compressive test was carried out as per I.S. 516-1959, for that test 150 x 150 x 150 mm cube were used. For compressive test, used compression testing machine of capacity 3000 KN.

Table3: Effect of constant molarity and temperature on compressive strength of GPC.

Sr No.	Molarity	Sample No	Temperature (°C)	Curing Time (Hrs)	Rest Period (Days)	Load (KN)	Comp Strength (N/mm²)	Average (N/mm²)
1	10	A1	80°C	24	7	630	26.5	24.5
		A2				610	27.11	
		A3				660	29.33	
2	10	A4	80°C	24	14	890	39.55	40.37
		A5				920	40.889	
		A6				915	40.67	
3	10	A7	80°C	24	28	1260	56	56.04
		A8				630	26.5	
		A9				610	27.11	



Graph 1: Effect of constant molarity on compressive strength.

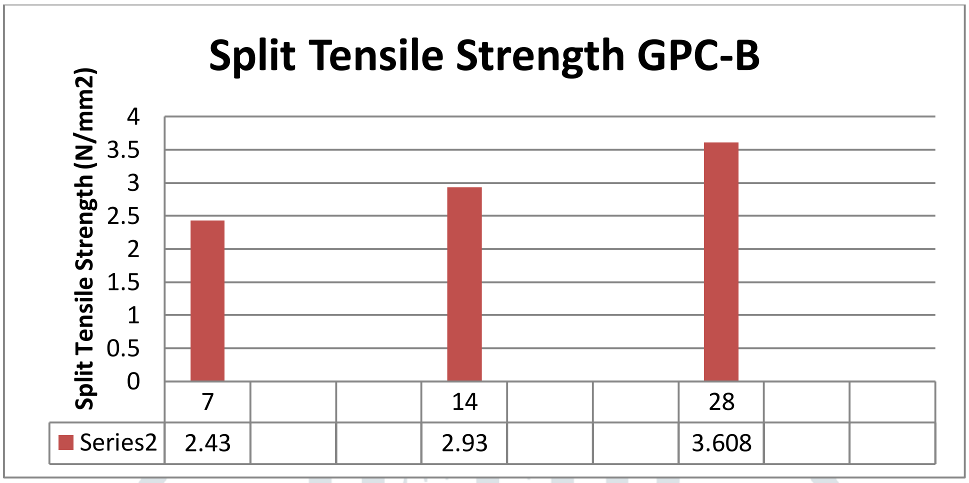
4.2.2 Split tensile strength.

The sodium hydroxide of 10 M solution were prepare and sodium silicate used as per standards. The tensile strength test were carried as per confirming IS 5816-1999. The tensile strength carried on optimized temperature of 80°C of oven cured concrete. The test result obtained at 7, 14 and 28 days of testing age. The test result shown in table.

Table4: Constant temperature effect on split tensile strength of Geopolymer concrete.

Sr.No.	Sample No.	Molarity	Curing Time (Hrs)	Rest Period (Days)	Load (KN)	Split Tensile Strength (N/mm²)	Average (N/mm²)
1	B19	10	24	7	165	2.34	2.43
	B20				170	2.41	
	B21				180	2.55	
2	B22	10	24	14	210	2.97	2.93

	B23				200	2.83	
	24				210	2.97	
3	B25	10	24	28	255.7	3.61	3.608
	B26				250	3.536	
	B27				260	3.678	



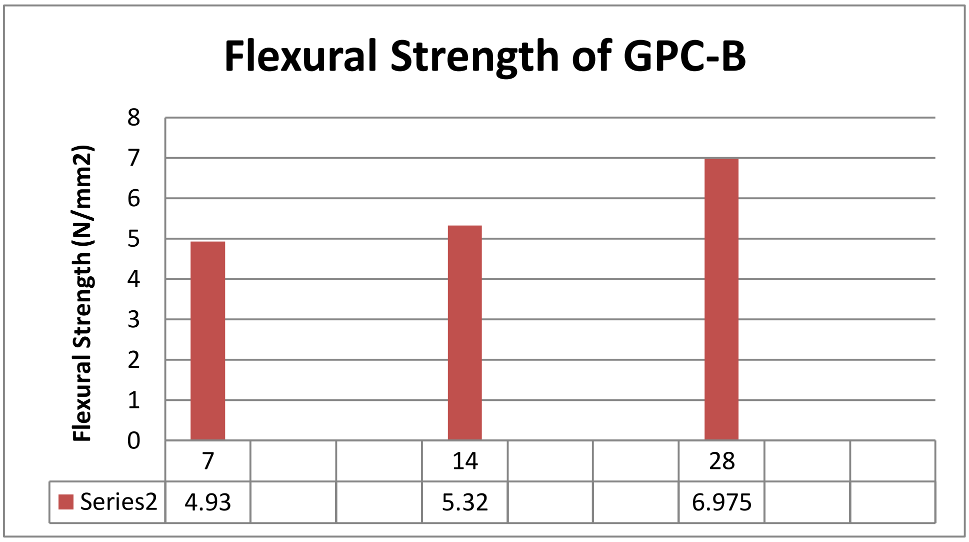
Graph 2: Effect of constant molarity on Split Tensile strength.

4.2.5 Flexure strength on GPC

The flexure test conducted as per IS code standards. The flexure test result shown in table. The flexure test conducted only on optimized oven temperature with fixed curing time and 7,14 and 28 days of testing age.

Table5: Constant temperature effect on Flexural strength of Geopolymer concrete.

Sr.No.	Sample No.	Molarity	Temperature (°C)	Curing Time (Hrs)	Rest Period (Days)	Flexural Load (KN)	Average Flexural Load (KN)	Average (N/mm²)
1	B10	10	80°C	24	7	9.3	4.65	4.93
	B11					10.1	5.05	
	B12					10.2	5.1	
2	B13	10	80°C	24	14	10.4	5.2	5.32
	B14					10.6	5.3	
	B15					10.9	5.45	
3	B16	10	80°C	24	28	15	7.5	6.975
	B17					13	6.5	
	B18					13.85	6.925	



Graph 3: Effect of constant molarity on Flexural strength.

4.2.1 Effect of molarity of Potassium hydroxide solution and Potassium Silicate.

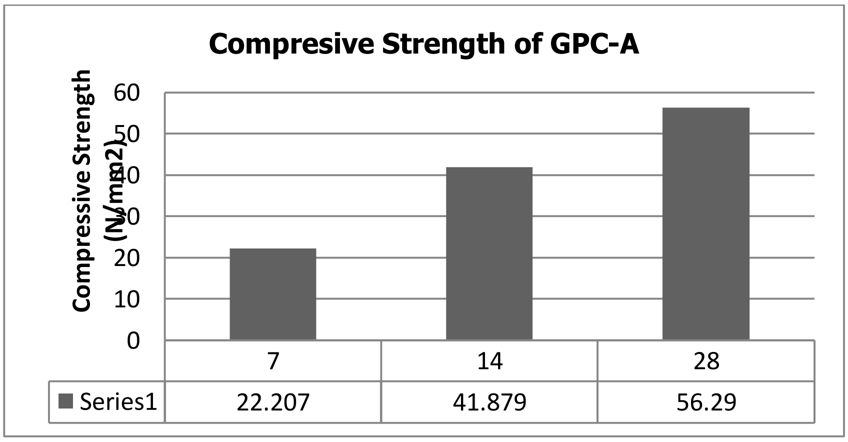
The molarity variation tested by using compressive strength with respect to curing temperature, curing time and testing age of concrete (days).

4.2.7 Compressive Strength of GPC.

The table 4.8 shows the temperature effect on compressive strength of geopolymer concrete as well graph shown. The results of compressive strength which are obtained from temperature variation of 80°C oven cured concrete. Compressive test was carried out as per I.S. 516-1959, for that test 150 x 150 x 150 mm cube were used. The potassium hydroxide solution having concentration of 10M were used.

Table6: Constant temperature and KOH Solution effect on Compressive strength of GPC

Sr.No.	Sample No.	Molarity	Temperature (°C)	Curing Time (Hrs)	Rest Period (Days)	Load (KN)	Compressive Strength (N/mm^2)	Average (N/mm^2)
1	A1	10	80°C	24	7	451	20.04	22.207
	A2					497	22.088	
	A3					550.6	24.47	
2	A4	10	80°C	24	14	844	37.51	38.84
	A5					883	39.24	
	A6					895	39.77	
3	A7	10	80°C	24	28	1250	55.55	55.52
	A8					1253	55.69	
	A9					1245	55.33	



Graph 4: Constant molarity and Temperature on Compressive strength.

CONCLUSION

For Geopolymer concrete the curing time and temperature variation play important role for polymerization. The 24 hours of curing time shows the significant result. The potassium hydroxide to sodium hydroxide ratio 1 shows the significant properties of geopolymer concrete. The rate of gain of strength is slow at 60^0C but high in 100^0C and reduces at 140^0C. The compressive strength beyond 140^0C is not significant for 24 hours of curing. The sodium hydroxide is cheaper than the potassium hydroxide shows near about same mechanical properties of geopolymer concrete. Longer curing time improved the polymerization process resulting in higher compressive strength of Geopolymer concrete for optimized temperature. Geopolymer concrete is more environmental friendly. It has the potential to replace cement from concrete in many applications such as pre-cast units. The future scope of this project is GGBS and Fly Ash is waste generate having disposal problem and it is generated from domestic use and industrial use. Study on the addition of various concentrated of molarity on Geopolymer concrete and their effect on enhancement of strengths. Achieving ultra-high strength of geopolymer concrete by addition of GGBS, Fly Ash , Catalyst activator and polymer activator. Investigate on the effect of varying curing period and curing type on strength properties of geopolymer concrete. GGBS and Fly Ash used instead of cement resulting economy up to a certain limit. The effect of temperature on the concrete developed can be studied hence environment eco-friendly concrete product.

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