EFFECT OF ALKALINE ACTIVATOR ON THE STRENGTH OF GEOPOLYMER CONCRETE

Sagar Chavan[1], Girish Joshi[2], Sandeep Hake[3]

[1] *PG student, Civil Engineering, GHRCOEM Pune, M.S., India*
[2] *Associate Professor, Civil Engineering, GHRCOEM Pune, M.S., India*
[3] *Associate Professor, Civil Engineering, GHRCOEM Ahmednagar, M.S., India*

ABSTRACT

Cement industry is one of the major contributors to the emission of greenhouse gasses. That is cement production consumes huge 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. Which acts as a binder instead of cement in concrete. The activators were used like sodium hydroxide, potassium hydroxide and 50% of sodium hydroxide, 50 % of potassium hydroxide. In this study solution to fly ash ratio of 0.35 with 13 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 60^0C, 100^0C and 140^0C for 12 and 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.

Keyword: - *Alkaline solution, Fly Ash, Curing, Temperature, Compressive strength.*

1. INTRODUCTION

India is a developing country and it is developing in various sectors. Infrastructure is one of the important part of it. For that the construction industry has grown up rapidly. As the number of construction industry increases the use of cement concrete also grown astronomically and it will continue to grow as the result of continuous urban development. It is estimated that the production of cement is increased about 1.5 billion tons in 1995 to 2.2 billion tons in 2010 and still increasing rapidly now-a-days. Ordinary Portland cement is conventionally used as the primary binder to produce concrete. By comparing the cement concrete with other construction material it have many benefits like easily available material, strength and durability, versatility, affordability, low maintenance, making process is easy etc. Though the cement concrete has such advantages it has some disadvantages also such as low tensile strength, less ductility and it creates environmental pollution. On the other side, fly ash is the waste material of coal based thermal power plant, available abundantly but have a disposal problem. As it is light in weight and easily flies with some good advantages like Environmental Benefit, High Strength, Resistant to Heat and Cold Chemical Resistance so it is better to use in construction.

2. METHODOLOGY

This details presents development of the process of making geo polymer concrete. Although geo polymer concrete can be made using various source materials, the present study used only low-calcium (ASTM Class F) dry fly ash. Also, as in the case of OPC, the aggregates occupied 75-80 % of the total mass of concrete. In order to minimize the effect of the properties of the aggregates on the properties of fly ash based geo polymer, the study used aggregates from only one source. Most of the information particularly initial mix composition and test methods given in this chapter are based on specification and guidelines for normal concrete given by IS 383-1970 (Reaffirmed 2002) and IS: 456-2000 codes.

2.1 Preparations of Specimen

2.1 Measurement of ingredients: - All fly ash, sand and coarse aggregate 20mm respectively are measured with Digital balance. The water is measured with measuring cylinder of capacity 1 liter and measuring jars of capacity 1000ml and 2000 ml.

2.2 Alkaline solution preparation;-The sodium hydroxide was prepared by dissolving sodium hydroxide flakes in water. The flakes are commercial grade with 97% purity; thus 13 molar solutions were made by dissolving 520 grams of sodium flakes in 1 liter water. The sodium hydroxide solution was prepared one day prior to concrete batching to allow the exothermically heated liquid to cool to room temperature. The sodium silicate and sodium hydroxide solution were mixed just prior to concrete batching. The same procedure were adopted for potassium hydroxide solution.

2.3 Demoulding and Curing of Test specimens:-The specimens were demoulded after 24 hours of casting and immediately stored in the oven for 1 day at required temperature. The specimens left in mould for at least 4-6 hours in order to avoid major change in the environmental condition. After demoulding the concrete specimens are allowed to become air dry in laboratory until the day of testing.

2.4 Curing Method:-In this project the oven heat curing method was used for polymerization of geopolymer concrete. As discussed in Literature reviews the oven heat curing is the best method for geopolymer concrete. The oven heat curing was used for different curing time as well as different curing temperature. For 12, 24 hrs of curing time and 60^0C, 100^0C, 140^0C temperature variation the different test was to be carried out.

2.5 Preparation of Reference Mix:-All ingredients of concrete were thoroughly mixed in concrete mixer. Then, required quantity of Sodium Hydroxide solution and sodium silicate solution with proper proportion was added and mixed until homogeneous mix was formed. After making the homogeneous mix, workability test by slump cone and compaction factor is determined. Then, cubes of size 150 mm X 150 mm X 150 mm were cast in three layers as per standard process.

3. MATERIALS

3.1 Fly Ash:-In the present experimental work, low calcium, Class F (American Society for Testing and Materials 2001) dry fly ash obtained from the dirk India pvt limited, Nashik.

General Information of fly ash

Presentation	:	Finely divided dry powder
Color	:	Light grey
Bulk Weight	:	Approx. 0.90 metric ton per cubic meter
Specific density	:	Approx. 2.30 metric ton per cubic meter
Size	:	90% < 45 micron
Particle shape	:	Spherical
Package	:	30 kg paper bags, 1 metric ton big-bags and bulk tankers

3.2 Alkaline Liquid

A combination of sodium silicate solution and sodium hydroxide solution was chosen as the alkaline liquid. Sodium-based solutions were chosen because they were cheaper than Potassium-based solutions. The sodium hydroxide solids were either a technical grade in flakes form (3 mm), with a specific gravity of 2.130, 97% purity.

The sodium hydroxide (NaOH) solution was prepared by dissolving either the flakes or the pellets in water. The mass of NaOH solids in a solution varied depending on the concentration of the solution expressed in terms of molar, M. For instance, NaOH solution with a concentration of 8M consisted of 8x40 = 320 grams of NaOH solids (in flake or pellet form) per litre of the solution, where 40 is the molecular weight of NaOH. The mass of NaOH solids was measured as 262 grams per kg of NaOH solution of 8M concentration. Similarly, the mass of NaOH solids per kg of the solution for other concentrations were measured as 10M: 314 grams, 12M: 361 grams, 14M: 404 grams, and 16M: 444 grams. Note that the mass of NaOH solids was only a fraction of the mass of the NaOH solution, and water is the major component. Same as the molecular weight of potassium hydroxide is 56.1 so prepare the solution as 10M 13 M and 16M for the KOH Solids. And use this KOH in the geopolymer concrete for activation purpose. The chemical composition of the sodium silicate solution was Na2O=16.37%, SiO2=34.31%, and water 49.32% by mass. The other characteristics of the sodium silicate solution were specific gravity=1.53 g/cc and viscosity at 20^{o}C=400 cp. The ratio of sodium silicate to sodium hydroxide is kept 2.5.

4. EXPERIMENTATION AND TESTS

The compressive strength tests on hardened fly ash-based Geopolymer concrete were performed on Universal Compressive testing machine. 150x150x150 mm concrete cubes were tested for every mix. A test result is the Average of at least three standard-cured strength specimens made from the same concrete sample and tested at the Same age. The specimen used was cubes, beams specimens and cylinder specimens. Dimensions of each test specimen are as under:

Cube : 150 mm x 150 mm x 150 mm
Beam : 100 mm x 100 mm x 500 mm
Cylinder : 150 mm Diameter x 300 mm Length

5. RESULT AND CONCLUSION

The tests on geopolymer concrete are carried out according to relevant standards wherever applicable. The geopolymer concrete were casted with of combination sodium hydroxide and sodium silicate and results are plotted below.

5.1 Geopolymer Concrete Test Results

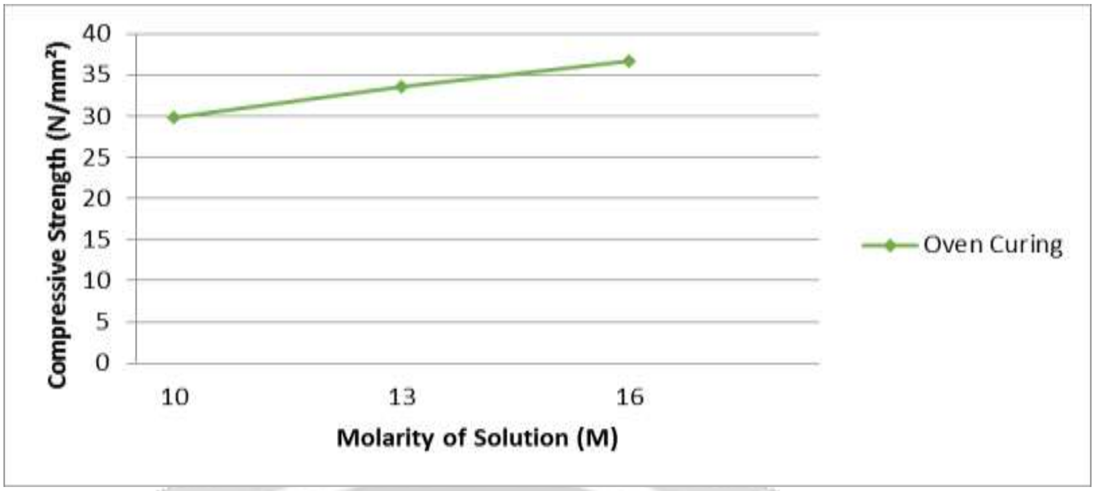
Testing of geopolymer concrete is an important role in controlling and confirming the quality of cement concrete work. Tests are made by casting cubes, beams, and cylinder from the actual concrete. The effect of compressive strength, flexural strength, split tensile strength, geopolymer concrete were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

5.2 Effect of molarity of Sodium hydroxide solution.

The molarity variation tested by using compressive strength with respect to curing temperature, curing time and testing age of concrete (days) are shown in table 5.1 and graph 5.1. 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.

Table 5.1 Effect of molarity on compressive strength of Geopolymer concrete.

Sr No.	Molarity	Sample No	Temperature (°C)	Curing Time (Hrs)	Rest Period (Days)	Load (KN)	Comp Strength (N/mm²)	Average (N/mm²)
1	10	C4	80°C	24	7	620	27.56	29.78
		C5				680	30.22	
		C6				710	31.56	
2	13	C10	80°C	24	7	730	32.44	33.63
		C11				760	33.78	
		C12				780	34.67	
3	16	C13	80°C	24	7	810	36.00	36.74
		C14				820	36.44	
		C15				850	37.78	



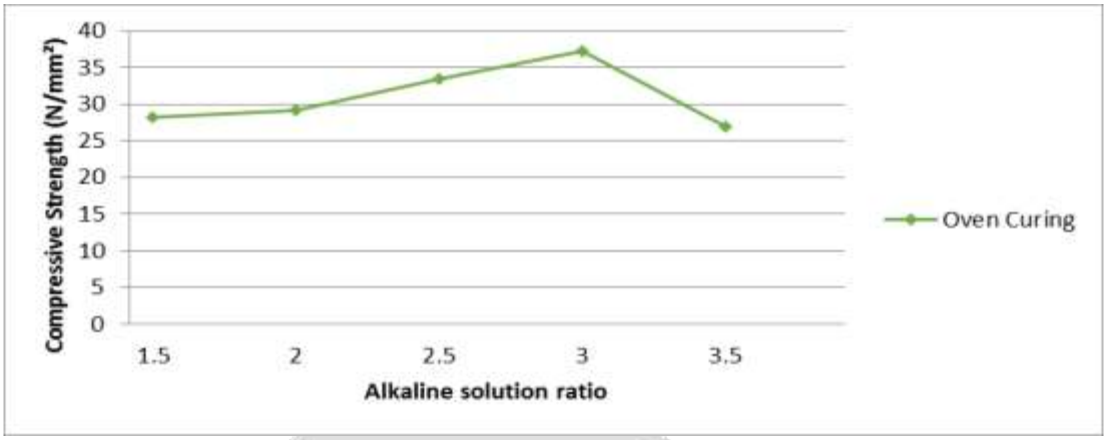
Graph 5.1: Effect of molarity on compressive strength.

5.3 Effect of sodium silicate to sodium hydroxide ratio on GPC.

The sodium silicate to sodium hydroxide ratio were optimized with compressive strength test with variation of 1.5, 2, 2.5, 3 and 3.5 ratio. The test result shown in table 5.2and graph 5.3.

Table 5.2: Effect of alkaline solution ratio on compressive strength of Geopolymer concrete.

Sr No	alkaline solution ratio	Sample No	Temperatur e	Curing Time (Hours)	Rest Period (Days)	Compressive Load (KN)	Compressive Strength (N/mm2)	Average Compressive Strength (N/mm^2)
1	1.5	OC-C43	80°C	24	7	630	28.00	28.15
		OC-C44				610	27.11	
		OC-C45				660	29.33	
2	2	OC-C46	80°C	24	7	690	30.67	29.19
		OC-C47				610	27.11	
		OC-C48				670	29.78	
3	2.5	OC-C49	80°C	24	7	750	33.33	33.48
		OC-C50				730	32.44	
		OC-C51				780	34.67	
4	3	OC-C52	80°C	24	7	810	36.00	37.19
		OC-C53				860	38.22	
		OC-C54				840	37.33	
5	3.5	OC-C55	80°C	24	7	610	27.11	26.96
		OC-C56				590	26.22	
		OC-C57				620	27.56	



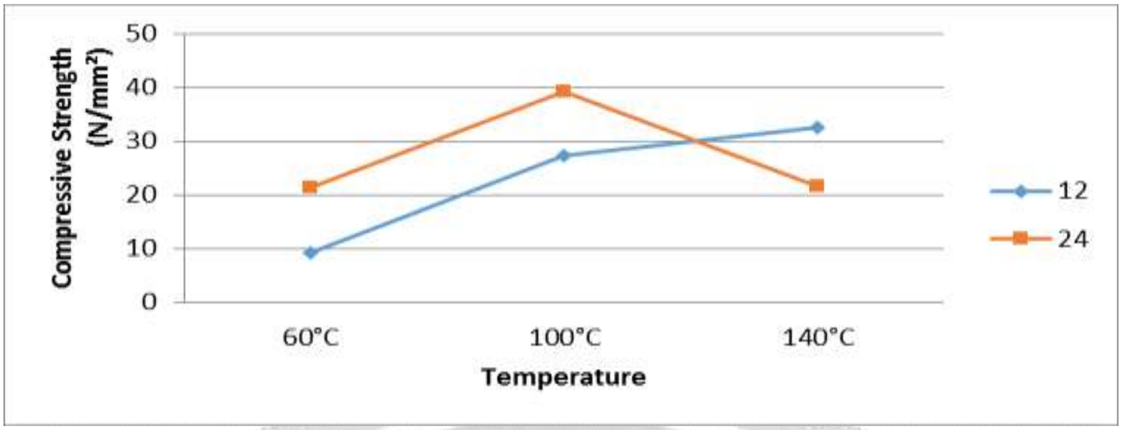
Graph 5.2: Effect of Alkaline solution ratio on compressive strength.

5.3 Compression Strength Test:

The results of compressive strength which are obtained from temperature variation of 60°C, 100°C, 140°C oven cured concrete. The sodium hydroxide of 13 M solution were prepare for this test. The table 5.3 shows the temperature effect on compressive strength of geopolymer concrete. The graphical presentation shown in Graph 5.3 Higher curing temperature resulted in larger compressive strength, but after 140^{0}C the compressive strength go on decreases.

Table 5.3: Effect of temperature on compressive strength of Geopolymer concrete.

Sr.No.	Sample No.	Temperature (°C)	Curing Time (Hrs)	Rest Period (Days)	Load (KN)	Compressive Strength (N/mm²)	Average (N/mm²)
1	OC-C4	60°C	12	7	150	6.67	9.33
	OC-C5				230	10.22	
	OC-C6				250	11.11	
	OC-C10		24		370	16.44	21.33
	OC-C11				530	23.56	
	OC-C12				540	24.00	
2	OC-C16	100°C	12	7	590	26.22	27.41
	OC-C17				620	27.56	
	OC-C18				640	28.44	
	OC-C22		24		850	37.78	39.26
	OC-C23				890	39.56	
	OC-C24				910	40.44	
3	OC-C28	140°C	12	7	750	33.33	32.44
	OC-C29				730	32.44	
	OC-C30				710	31.56	
	OC-C34		24		430	19.11	21.63
	OC-C35				510	22.67	
	OC-C36				520	23.11	



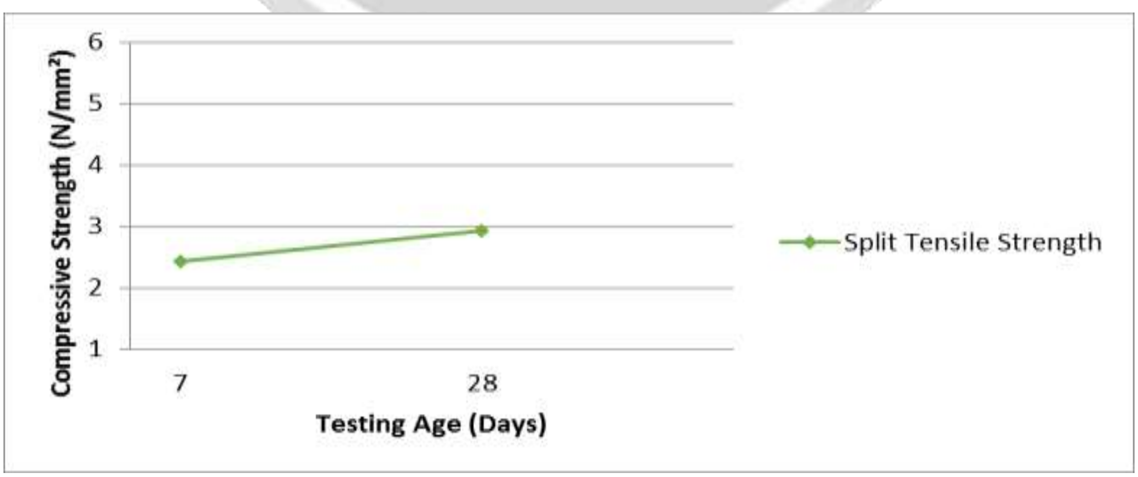
Graph 5.3: Effect of temperature on compressive strength.

5.4 Split tensile strength.

The sodium hydroxide of 13 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 100°C of oven cured concrete. The test result obtained at 7 and 28 days of testing age. The test result shown in table 5.4 and graph 5.4

Table 5.4 Optimized temperature effect on split tensile strength of Geopolymer concrete.

Sr.No.	Sample No.	Temperature (°C)	Curing Time (Hrs)	Rest Period (Days)	Load (KN)	Split Tensile Strength (N/mm^2)	Average (N/mm^2)
1	OCCy1	100°C	24	7	165	2.34	2.43
	OCCy2				170	2.41	
	OCCy3				180	2.55	
2	OCCy4	100°C	24	28	210	2.97	2.93
	OCCy5				200	2.83	
	OCCy6				210	2.97	



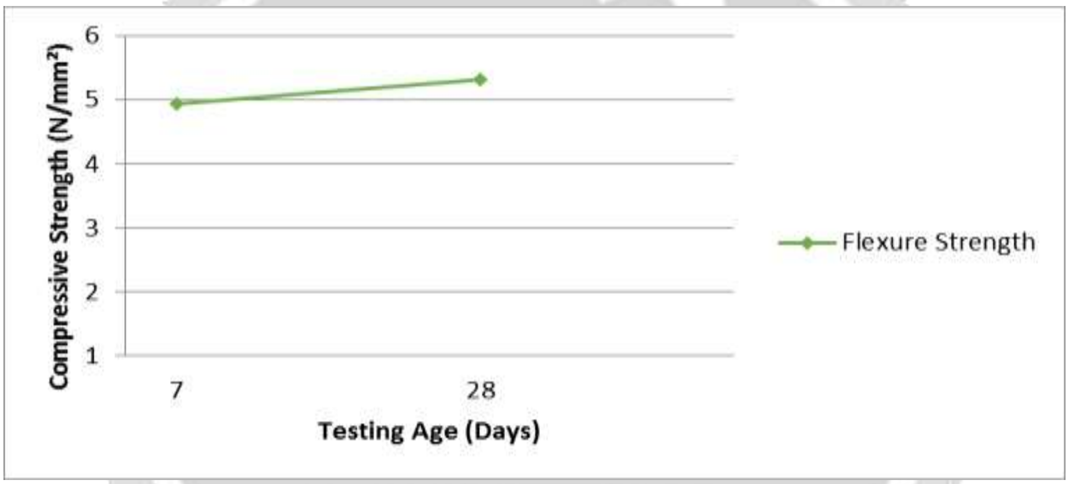
Graph 5.4: Split tensile strength of GPC.

5.5 Flexure strength on GPC

The flexure test conducted as per IS code standards. The flexure test result shown in table 5.5 and graph 5.5. The flexure test conducted only on optimized oven temperature with fixed curing time and 7, 28 days of testing age.

Table 5.5 Optimized temperature effect on flexure strength of Geopolymer concrete.

Sr.No.	Sample No.	Temperature (°C)	Curing Time (Hrs)	Rest Period (Days)	Flexural Load (KN)	Average Flexural Load (KN)	Fcr (Mpa)
1	OCB1	100°C	24	7	9.3	9.87	4.93
	OCB2				10.10		
	OCB3				10.20		
2	OCB4	100°C	24	28	10.40	10.63	5.32
	OCB5				10.60		
	OCB6				10.90		



Graph 5.5: Flexure strength of GPC.

6. CONCLUSIONS:

Following conclusions are drawn after casting and testing the fly ash based geopolymer concrete for workability and compressive strength:

1. For Geopolymer concrete the curing time and temperature variation play important role for polymerization.
2. The 24 hours of curing time shows the significant result.
3. The potassium hydroxide to sodium hydroxide ratio 1 shows the significant properties of geopolymer concrete.
4. The rate of gain of strength is slow at 60^0C but high in 100^0C and reduce at 140^0C.
5. The compressive strength beyond 140^0C is not significant for 24 hours of curing.
6. The sodium hydroxide is cheaper than the potassium hydroxide shows near about same mechanical properties of geopolymer concrete.
7. Longer curing time improved the polymerization process resulting in higher compressive strength of Geopolymer concrete for optimized temperature.
8. Geopolymer concrete is more environmental friendly.
9. It has the potential to replace cement from concrete in many applications such as pre-cast units.

6. REFERENCES

[1] D. Hardjito, S. E.Wallah, D. M. J. Sumajouw, and B. V. Rangan,"On the development of fly ash-based geopolymer concrete,"ACI Materials Journal, vol.101, no. 6, pp. 467–472, 2004.

[2] S. V. Patankar, S. S. Jamkar, and Y. M. Ghugal, "Effect of sodium hydroxide on flow and strength of fly ash based geopolymer mortar," Journal of structural Engineering, vol. 39,no. 1, pp. 7–12,2012.

[3] A.T.Sayyad, and S. V. Patankar , "Effect of steel fibre s and low calcium fly ash on mechanical and elastic properties of geopolymer concrete composites," Indian journal of material science,vol.2013, artical ID 357563.

[4] R. Anuradha, V. Sreevidya, R. Venkatasubramani, and B. V.Rangan, "Modified guidelines for geopolymer concrete mix design using Indian standards," Asian journal of Civil Engineering, vol. 13, pp. 353–364, 2012.

[5] Susan, Bernal; Ruby, De Gutierrez; Silvio Delvasto; Rodriguez, "Performance of geopolymeric concrete reinforced with steel fibres," IIBCC 10th Int. Inorganic bonded fibre composite conference, November 15-18, 2006, Sao Paulo-Brazil.

[6] K. Vijai, R. Kumutha, and B. G. Vishnuram, "Effect of inclusion of steel fibre s on the properties of geopolymer concrete composites," Asian Journal of Civil Engineering, vol. 13, no. 3, pp. 377– 385, 2012.

[7] N.A.Lloyd, and B.V.Rangan, "Geopolymer concrete: A review of development and opportunities," 35th conference on our world in concrete and structure, 25 –27 August 2010, Singapore.

[8] D.Hardjito, and B.V.Rangan, "Development of fly ash-based geopolymer concrete: progress and research needs," 2nd Asian concrete federation conferences – Bali, Indonesia, November 20-21, 2006.

[9] Nguyen Van Chanh, Bui Trung, Dang Van Tuan, "Recent research geopolymer concrete," 3rd ACF International conference-ACF/VCA 2008.

[10] Shankar H. Sanni, and Khadiranaikar. R.B., "Performance of geopolymer concrete under severe environmental conditions," International journal of civil and structural engineering, vol. 3, No. 2, 2012.