

Effect of Elevated Temperature over Geopolymer Concrete

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Abstract: Geopolymer Concrete (GPC), an ecofriendly material is being used as an alternative to Ordinary Portland Cement Concrete in many areas. Research in the area of Geopolymer is acquiring strength and results predict that Geopolymer possess better engineering properties than the ordinary cement concrete under conventional conditions. Many literatures are available in the vicinity of Geopolymer concrete whereas only a few throw lime light on the residual strength of GPC after being exposed to raised temperatures. In this study, Flyash based Geopolymer Concrete were casted for different molarities and cured in two regimes separately under ambient and heat condition. These specimens were then exposed to elevated temperature of 800°C for 1 hour and their mechanical properties such as compressive strength and split tensile strength were analyzed. The tests were carried out under normal and rapid cooling conditions. The workability of the concrete were also determined using the compaction factor test. Results predict that Geopolymer Concrete possesses better residual strength at 13M and workability was found to decrease with increase in molarity of the NaOH solution.

Keywords: Elevated temperature, Flyash based Geopolymer, Heat curing and Ambient curing

I. INTRODUCTION

Concrete is the second largest substantial consumed by the people [1,2]. Ordinary concrete production consumes a large quantity of cement and fine aggregate [3,4]. Cement production involves emission of green house gases which is very harmful to the ecosystem [1,2,5-7]. It would be a better initiative if this cement is replaced with some other engineering materials [8-12]. On the other hand, there has been serious issues in disposing the flyash which is a byproduct of thermal power plant [5,8,13,14]. In order to exterminate both the problems, the excess flyash could be effectively used to replace the cement. Flyash and alkaline solution are utilized to make a concrete with no cement and is termed as Geopolymer Concrete [2,15]. Also procuring of natural river sand from the Earth is creating a lot of environmental issues in the recent years [13]. This laid the foundation for the emergence of Manufacture sand (M-sand) which is mostly obtained in the form of crushed stones. A pile of research works have focused in the area of Geopolymer and revealed that GPC possessed healthier engineering properties compared to ordinary conventional concrete [16]. There are some circumstances where concrete is subjected to high temperatures such as furnaces, nuclear exposure, reactors and also prone to fire accidents [3].

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Hence it is essential to determine the characteristics of Geopolymer Concrete under elevated temperatures to completely replace ordinary concrete at all circumstances.

The property of GPC largely lay over the type of aluminosilica source materials, molarity of alkaline activator solution used, type of curing adopted [8,17,18,23,24]. In this experimental work, flyash based Geopolymer Concrete specimens were casted and tested under ambient curing and heat curing conditions for fresh and hardened properties at elevated temperature. A blend of NaOH and Na₂SiO₃ solution was preferred as the alkali activator solution [3,8,19,20,21]. The molarity of NaOH solution was varied in the range of 8M, 10M, 13M and 16M. M-sand was preferred as the fine aggregate. The mix design was based on B.V.Rangan's proposed method, which is similar to IS method. Workability was found out using compaction factor test. Mechanical properties such as compressive strength and split tensile strength were found out after exposure to elevated temperature of 800°C. Temperature has been raised gradually from 28 to 800°C at a rate of 2°C per minute. Emphasis was given to both normal cooling and rapid cooling. Normal cooling was done by exposing the specimen in room temperature for about 5 hours after taking out from muffle furnace. For rapid cooling, the concrete specimens were either quenched in water or sprayed with water after taking out from muffle furnace. The effect of curing was also studied as the concrete specimens were cured separately under two regimes.

II. MATERIALS

In this research work, Geopolymer was manufactured using class F flyash as aluminosilica base material, concoction of sodium hydroxide and sodium silicate solution as alkali activator solution, M-sand as fine aggregate and coarse aggregate of 20mm size. The detailed material specifications are given below.

A. FLYASH

Class F flyash is a byproduct of thermal power plant. In this work, fly ash was procured from Tuticorin thermal power plant. The specific gravity of flyash was found to be 2.3

B. ALKALINE SOLUTION

A blend of NaOH and Na₂SiO₃ solution was preferred as the alkali activator solution. The concentration of sodium hydroxide solution was varied from 8M, 10M, 13M, 16M. Properties of alkaline solution are tabulated in Table 1.

Table1 Properties of Alkaline solution

S.No	Material	Specific Gravity
1.	Sodium hydroxide solution	1.47
2.	Sodium silicate solution	1.6

C. FINE AGGREGATE

M-sand is in the form of crushed granite stones. It was used as the fine aggregate. The properties of fine aggregates are tabulated in Table2.

Table 2 Properties of Fine Aggregate

S.No	Property	Value
1.	Fineness modulus	2.9
2.	Specific gravity	2.6

D. COARSE AGGREGATE

Coarse aggregates were obtained from locally available quarry and were of size 20mm. The properties of coarse aggregates were tabulated in Table3.

Table3 Properties of Coarse Aggregate

S.No	Property	Value
1.	Fineness modulus	3.1
2.	Specific gravity	2.8

III. EXPERIMENTAL PROGRAM

The proportions of various ingredients of Geopolymer Concrete were selected from the B.V.Rangan's proposed mix design for M40. The cubes and cylinders were casted and cured separately under ambient condition and heat condition. Heat curing was done by placing the specimens in the hot air oven at 150°C for 6 hours. Fresh and Hardened properties of the concrete was found out after exposing the concrete specimens to elevated temperature of 800°C by keeping the specimen in the muffle furnace as shown in the Fig 1.



Fig 1. Cylinder in Muffle furnace

A. SPECIMEN DETAILS

The total number of specimens casted in this experimental investigation is specified in the Table4.

Table4 Number of specimens

Molarity	Number of specimens			
	Heat Curing		Ambient Curing	
	Normal cooling	Ambient Cooling	Normal cooling	Ambient Cooling
8	3	3	3	3
10	3	3	3	3
13	3	3	3	3
16	3	3	3	3

B. TEST AND WORKABILITY DISCUSSIONS

1. WORKABILITY

Compaction factor test was performed to determine the workability of the Geopolymer Concrete specimen for various molarities. The results of compaction factor test are tabulated in Table5.

Table5 Compaction Factor Test

S.No	Molarity (M)	Compaction Factor
1.	8M	0.92
2.	10M	0.92
3.	13M	0.9
4.	16M	0.85

From the results it was inferred that the workability of GPC decreases when there is a increase in the molarity of the sodium hydroxide solution. The variation of the workability is well depicted in the Fig2.

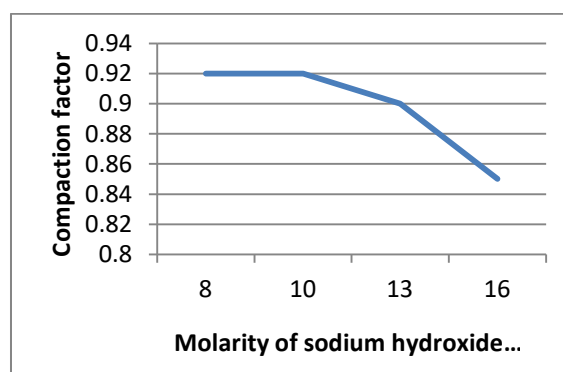


Fig2 Workability of fresh concrete

2. COMPRESSIVE STRENGTH

Compressive strength of the specimens of size 100mmX100mmX100mm was found out using CTMat room temperature initially and then after the specimens are subjected to elevated temperatures. The results are tabulated separately for ambient curing and heat curing in Table 6 and Table7 respectively.

Table6 Compressive strength under ambient curing

S.No	Molarity (M)	Compressive Strength (MPa) (Room Temperature)	Compressive Strength (MPa) (After exposure)	
			Normal Cooling	Rapid Cooling
1.	8	17.84	5.5	5.1
2.	10	20.55	6.3	5.8
3.	13	23.33	7.2	6.7
4.	16	21.68	6.8	6.5



Table7 Compressive strength under heat curing

S.No	Molarity (M)	Compressive Strength (MPa)		
		Before elevated temperature	Normal Cooling	Rapid Cooling
1.	8	32.38	14.57	12.4
2.	10	41.7	20.01	17.6
3.	13	50.80	22.86	19.5
4.	16	46.30	22.22	20.5

The characteristic strength witnessed increase with the molarity up to 13M and then starts decreasing. The variation is well depicted in the Fig 3 and Fig 4.

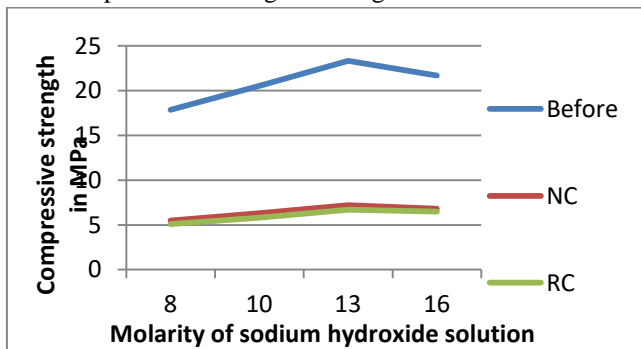


Fig 3. Variation of compressive strength under ambient curing

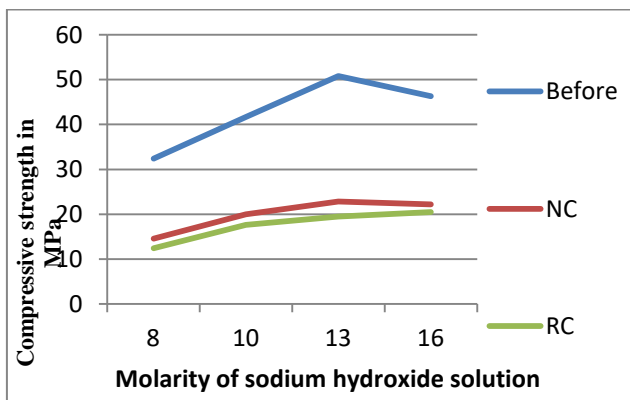


Fig 4 Variation of compressive strength under heat curing

3 SPLIT TENSILE STRENGTH

Split tensile strength of specimen 100mmX200mm was determined using Universal testing machine. The results are tabulated in the Table8 and Table9 for ambient curing and heat curing respectively.

Table8 Split tensile strength under ambient curing

S.No	Molarity(M)	Split tensile Strength (MPa) Before elevated temperature	Split Tensile Strength (MPa)	
			Normal Cooling	Rapid Cooling
1.	8	2.34	0.93	0.75
2.	10	2.47	0.95	0.75
3.	13	2.90	1.2	1
4.	16	2.8	1.0	0.8

1	8	3.72	1.79	1.55
2	10	3.95	1.85	1.6
3	13	4.25	2.1	1.8
4	16	4.1	2	1.6

Table 9 Split tensile strength under Heat curing

S.No	Molarity (M)	Split Tensile Strength (MPa) Before elevated temperature	Split tensile Strength (MPa)	
			Normal Cooling	Rapid Cooling
1.	8	2.34	0.93	0.75
2.	10	2.47	0.95	0.75
3.	13	2.90	1.2	1
4.	16	2.8	1.0	0.8

The result show that the under both the condition the split tensile strength increases up to 13M and then decreases. The variation of split tensile strength with the temperature is well depicted in the Fig 5 and Fig 6.

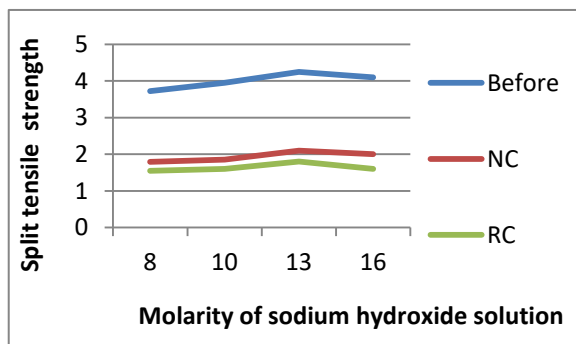


Fig 5. Variation of split tensile strength under ambient curing

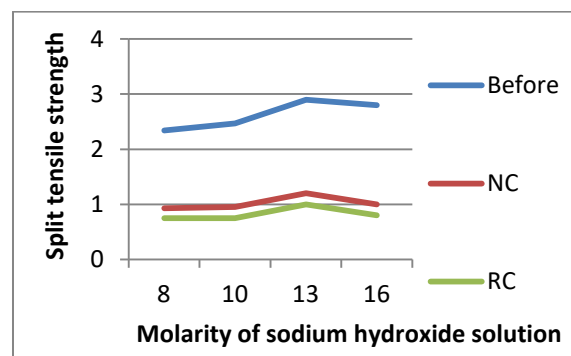


Fig6. Variation of compressive strength under heat curing

IV. CONCLUSION

Considering the above considerations, the succeeding points could be drawn as conclusions, In the case of flyash based Geopolymer Concrete specimens, oven cured specimens yielded better compressive strength and split tensile strength than the ambient cured specimens.



The workability of the Geopolymer Concrete specimens was found to decrease with the increase in the molarity. This is due to the increased concentration of sodium hydroxide solution which increased the viscosity and density of the alkaline solution.

Both compressive strength and split tensile strength of the Geopolymer Concrete specimens are found to increase till 13M of sodium hydroxide solution and then found to decrease. Till 13 M, with the increase in the concentration, the dissolution of precursor ions also increased which enhanced the engineering properties. Beyond 13 M, there was precipitation problem in the alkaline solution which decreased the mechanical properties of the concrete. Rapid cooling of concrete specimens decreased the strength since rapid cooling imparted impact shock waves in the specimen.

REFERENCE

1. Farhad Aslani, "Thermal Performance Modeling of Geopolymer Concrete", J.Mater.Civ.Eng.
2. F.U.A Shaikh, "Review of mechanical properties of short Fiber reinforced Geopolymer composites", Constr. Build Mater 43(2013) 37-49.
3. Omer Arioiz "Effects of elevated temperature on properties of concrete", Fire Safety Journal 42 (2007) 516-522.
4. Hager, "Behavior of cement concrete at high temperature", Bulletin of the polish academy of sciences technical sciences vol. 61, no. 1 2013.
5. Weibo Ren, Jinyu Xu. And Erlei Bai, Ph.D, "Strength and ultrasonic characteristics of alkali activated fly -ash slag Geopolymer concrete after exposure to elevated temperatures". Journal of Materials in Civil Engineering.
6. Kong, D.L.Y., and Sanjayan, J.G (2008) " bDamage behaviour of geopolymer composites exposed to elevated temperatures", cem. concr. campos., 45, 125-135.
7. Struble, L., and Godfrey, J.(2004). " how sustainable is concrete?" Proc., Int. Workshop on Sustainable Development and concrete technology, Iowa State Unive., Ames, IA, 201-211.
8. S.Aleheyn, M.E.L. Achouri, M. Taibai, "Characterization, microstructure and properties of fly ash based Geopolymer". Journal of Materials and Environmental Sciences, ISSN:2028-2500 JMES.2017, 8(5), pp 1783-1796
9. Kirubanjiny Pasupathy, Marita Berndt, Jay Sanjayan, Pathmanathan Rajeev, and Didar Singh Cheema, "Durability performance of precast fly ash based Geopolymer concrete under atmospheric exposure conditions", J.Mater.Civ.Eng.,2018,30(3):04018007.
10. R.Roychand, S.DE Silva, D.Law and S. Setunge, "Micro and nano engineered high volume ultrafine fly ash cement composite with and without additives", International Journal of Concrete structures and materials, vol.10, no.1, pp.113-124, March 2016.
11. Davidovits J., GEOPOLYMER chemistry and application, 4th Edition,Institute Geopolymer (2015).
12. Verdolotti L., Iannace S., Lavirgna M., Lamanna R., Journal of materials science 43(3)(2008) 865.
13. .D.Hardjito, S.E. Wallah, D.M.J. Sumajouw, and B.V. Rangan, "Brief review of development of Geopolymer concrete", Invited paper, George Hoff Symposium, American Concrete Institute, Los Vegas, USA, 25 may 2005.
14. E.Arioiz, O.Arioiz and O.M. Kockar, "Mechanical and Microstructural properties of fly ash based Geopolymer ". International Journal of Chemical Engineering and Application. Vol.4. No.6. December 2013.
15. Frantisek Skvara, Lumbomir Kofecky, Jiri Nemecek, Zdenek Bittnar, "Microstructure of Geopolymer materials based on fly ash", ceramics - silikaty (4) 208-215 (2005).
16. Clarke Snell, Brett Tempest, Ph.D., A.M.ASCE, and Thomas Gentry, "Comparison of the thermal characteristics of Portland cement and Geopolymer cement concrete mixes", J.Archit. Eng.
17. Chithambar Ganesh. A & Muthukannan. M, "A Review Of Recent Developments In Geopolymer Concrete". International Journal of Engineering & Technology. 7 (4.5) (2018) 696-699.
18. Chithambar Ganesh. A & Muthukannan. M, Rajeswaran. M, Uma Shankar. T and Mari Selvam, Comparative Study On The behaviour Of Geopolymer Concrete Using M-Sand and conventional concrete exposed to elevated temperature. International Journal Of Civil Engineering And Technology (IJCIET), 9 (11) (2018), 981-989.
19. Gaurav Nagalia, Yeonho Park, Ph.D., M.ASCE, Ali Abolmaali Ph.D., M.ASCE, and Pranesh Aswath, Ph.D "Compressive strength and Microstructural properties of fly ash based Geopolymer concrete". Journal of Materials in Civil Engineering.
20. P.Duxson, A. Fernandez- Jimenez. J.L. Provis, G.C. Lukey, A. Palomo, J.S.J. Van Deventer, "Geopolymer technology: the current state of the art", J. Mater. Sci.42(9) (2007) 2917-2933.
21. F.U.A. Shaikh and V.Vimonsatit, "Compressive strength of fly ash based Geopolymer concrete at elevated temperatures". Fire and materials (2014).
22. K.Vijai, R.Kumutha and B.G Vishnuram, "Effects of types of curing on strength of geopolymer concrete", International Journal of the Physical Sciences Vol. 5(9). pp. 1419-1423, 18 August, 2010.
23. A.Palomo, M.W. Grutzeck, M.T. Blanco, " Alakali- activated fly ashes - A cement for the future". Cement and Concrete Research 1999; 29(8):pp. 1323-1329.

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