International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-9 Issue-1S4, December 2019

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 threw 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 800OC 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 utilizedto 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 possessedhealthier engineering properties compared to ordinary conventional concrete[16]. There are some circumstances where concrete is subjected to high temperatures such asfurnaces, nuclear exposure, reactors and also prone to fire accidents[3].

Manuscript published on 30 December 2019.

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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 GPClargelylaysover the type of alumino silica 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 800ºC.Temperature has been raised gradually from 28o to 800ºC at a rate of 2ºC 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 alumino silica 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 Table1.

Table1Properties 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 2Properties 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^{o}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.

Table4Number 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.

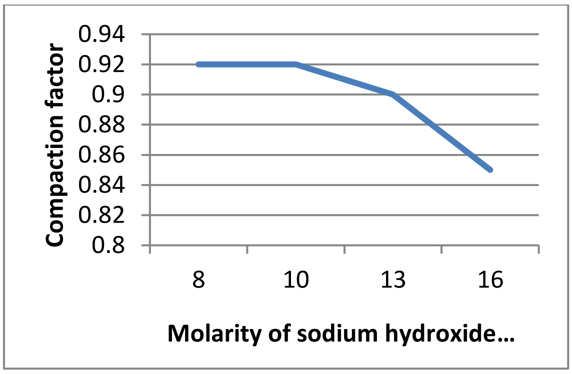

Fig2Workability of fresh concrete

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

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Blue Eyes Intelligence Engineering
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Table7Compressive strength underheat 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.

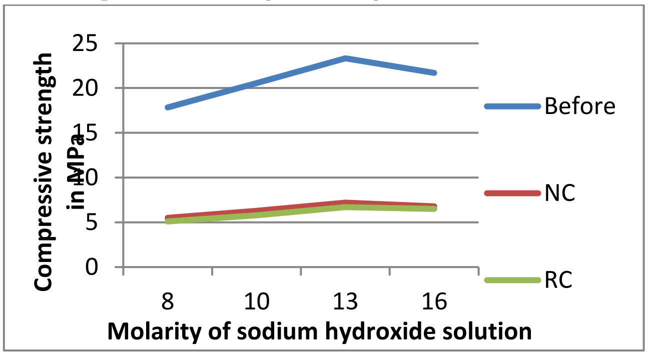

Fig 3. Variation of compressive strength under ambient curing

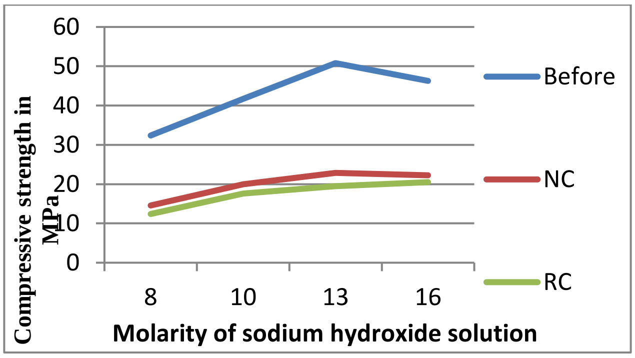

Fig 4 Variation of compressive strength under heat curing

3 SPLIT TENSILE STRENGTH

Split tensile strength of specimen 100mmX200mm was determined using Universal testing machine. The results are tabulated in the Table8 andTable9 for ambient curing and heat curing respectively.

Table8Split 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	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 9Split 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 andFig 6.

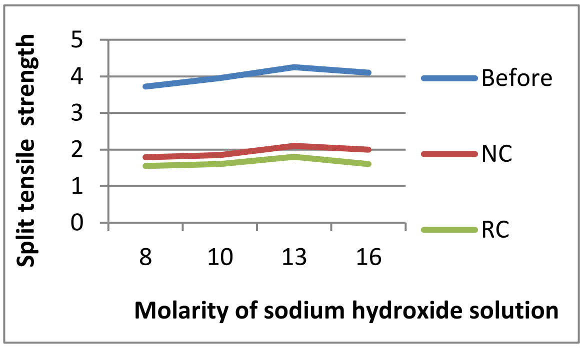

Fig 5.Variation of split tensile strength under ambient curing

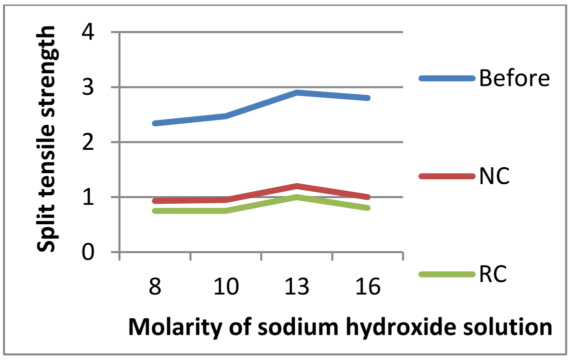

Fig6. Variation of compressive strength under heat curing

IV. CONCLUSION

Considering the above considerations, the succeedingpoints 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.

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Retrieval Number: A10251291S419/2019©BEIESP
DOI:10.35940/ijeat.A1025.1291S419
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