American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-7, Issue-4, pp-09-12
www.ajer.org
Research Paper Open Access

Influence of Alkali Concentration on Strength Characteristic of GGBS Based Geopolymer Mortar

A.M.N.Kashyap[1], P.Varalakshmi[2] , T.Chandrasekhar Rao[3] S.Suryanarayana Raju[4], N.V.Ramana Rao[5]

[1]Assistant Professor, Department of Civil Engineering, GIET Engineering College, Rajahmundry,A.P.,INDIA
[2]UG Student, Department of Civil Engineering, GIET Engineering College,Rajahmundry,A.P.,INDIA
[3]Professor, Department of Civil Engineering, Bapatla Engineering College,Bapatla, A.P.,INDIA
[4]Professor & Principal,GIET Engineering College,Rajahmundry. A.P INDIA
[5]Director & Professor ,National Institute of Technology,Warangal,T.S., INDIA
Corresponding author: A.M.N.Kashyap

ABSTRACT : *The use of alternative non-cementing materials as cement replacement material can overcome the environmental issues, especially the global warming problem caused by the emission of greenhouse gases due to the manufacturing of cement in huge amounts. It was estimated that the amount of Carbon dioxide emitted during the process of cement production was equivalent to 1 ton for each 1 ton of cement. However, the major problem of the non-cementing material like Ground Granulated Blast Furnace Slag, a waste byproduct of steel industry is to activate with the help of alkali-activators so as to proceed for polymeric chain reactions. The most commonly used alkali-activators are the combination of sodium hydroxide (NaOH) and sodium silicate at fixed concentration. The present study is an attempt to study the effect of variation of concentration of sodium hydroxide on setting and strength characteristic of GGBS based geopolymer mortar with molarity variations of 4M,6M,8M,10M,12M and 14M, the compressive strength test was performed after 1,3,7,14 & 28 days of ambient curing . The results revealed that the highest compressive strength was achieved by geopolymer mortar at an optimum molar concentration of 12M. It exhibits a higher strength to that normal mortar at 28 days. However, the use of NaOH molarity more than 12M tends to decrease the strength of non-cement geopolymer mortar specimens.*

KEYWORDS - alkali-activators,GGBS,Geopolymer,Molarity,non-cementing materials

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Date of Submission: 23-03-2018 Date of acceptance: 07-04-2018

I. INTRODUCTION

Cement-based concrete is the most extensively used construction material. Concrete is conventionally manufactured by using Ordinary Portland Cement as the primary binder, fine aggregate, coarse aggregates and water. The ratio of Ordinary Portland Cement in conventional concrete is approximately 10% to 15% by the total mass of concrete [1,2]. However, the extensive use of Ordinary Portland Cement in concrete has an severe effects regarding the environmental pollution. According to Davidovits [3], the production of 1 ton of OPC also released about 0.7-1 ton CO_2. The contribution of cement production alone is approximately 6% anthropogenic CO_2 gas emissions which cause the greenhouse gases emissions and leads to the occurrence of global warming problems. The extensive use of cement also tends to reduce the natural resources like lime stone which are the major ingredients to manufacture the cement.

Ground Granulated Blast Furnace Slag, a waste by-product obtained from the steel plant, has been commonly used as an additive or cement replacement material due to the pozzolanic characteristic to improve mechanical and durability properties of concretes [4-6]. Recent researches also show that GGBS can be used as fully cement replacement materials with the addition of alkaline activator. This non-cement GGBS based concrete material is known as geopolymer [3, 4, 8, 9]. According to Davidovits [7], the mechanism of geopolymer reaction involves the polycondensation reaction of alumino-silicate-oxide with alkali polysialates resulting polymeric Si-O-Al bonds and forms a geopolymer matrix. This hydration product is more polymer than C-S-H gel on conventional concrete [3].

The strength properties of geopolymer are influenced by the molarity of alkaline activator, particularly in the molarity of sodium hydroxide (NaOH). Increasing the NaOH molarity will significantly increase the strength development of geopolymer specimen. According to Ryu et al. , it attributes to the activation of the reaction of the internal silicate (Si) and aluminate (Al) components caused by the increased breakage of the glassy chain of fly ash precursor, in which it is provoked by the high alkalinity resulting from the increase of the molarity of NaOH. This study revealed the effect of sodium hydroxide molarity on strength development of non-cement GGBS based geopolymer mortar. The strength properties were identified by the compressive strength test at the age of 1,3, 7,14 and 28 days in accordance with ASTM standard.

II. EXPERIMENTAL INVESTIGATION

Ground Granulated Blast Furnace Slag (GGBS) is obtained from Vizag Steel Plant, was used as primary material to develop geopolymer mortar specimens. It has a high Calcium Oxide and Silicon content which accelerates the pozzolanic action. A ratio of sodium silicate to Sodium hydroxide adopted was 2.5.

2.1. Mix design and proportion

The details of GGBS based geopolymer (GGPM) mortars mix proportion were developed from previous research. A sodium silicate to NaOH (SS/SH) ratio of 2.5 was applied in accordance with previous research . The quantity of water in GGPM mortars was calculated as the total sum of water in sodium silicate and NaOH solutions, while the quantity of solid was determined from the mass of the solid content in activator solution and GGBS raw material. A normal curing temperature at room temperature used for GGPM mortars. Mortar Cube Specimens of sizes 7.06 cm x7.06 cm x 7.06 cm were casted for molarity variations of4Molar(M),6M,8M,10M, 12M and 14M and the compressive strength test was performed after 1,3,7,14 & 28 days of ambient curing

2.1. Testing mortar specimens

The strength characteristics of GGBS based geopolymer mortars in 7.06 cm x7.06 cm x 7.06 cm cube specimens were carried out by compressive strength test using Universal Testing Machine (UTM) in accordance with ASTM C109 [12]. Three mortar geopolymer cubes were tested at the age of 1,3, 7,14 and 28 days after casting.

III. RESULTS AND DISCUSSIONS

3.1. Strength development of GGPM mortars

Table 1 and Figure 1 give the strength development reported for the GGPM mortar specimens for all mixes curing at ambient condition,where the amount of GGBS used is constant i.e., 100% and only molarity of NaOH alone changes.

Table 1. Compressive strength of GGPC mortars cured at ambient condtion

Mix Designation	Morality of NaOH	Compressive Strength (MPa) after different test ages in ambient curing condition					
		1 day	3 days	7 days	14 days	21days	28 days
GGPM – I	4	25	30	45	50	52	55
GGPM – II	6	26	32	52	56	58	64
GGPM –III	8	32	36	55	59	60	71
GGPM –IV	10	40	50	56	63	70	74
GGPM – V	12	41	51	59	66	76	78
GGPM - VI	14	32	44	55	59	64	66

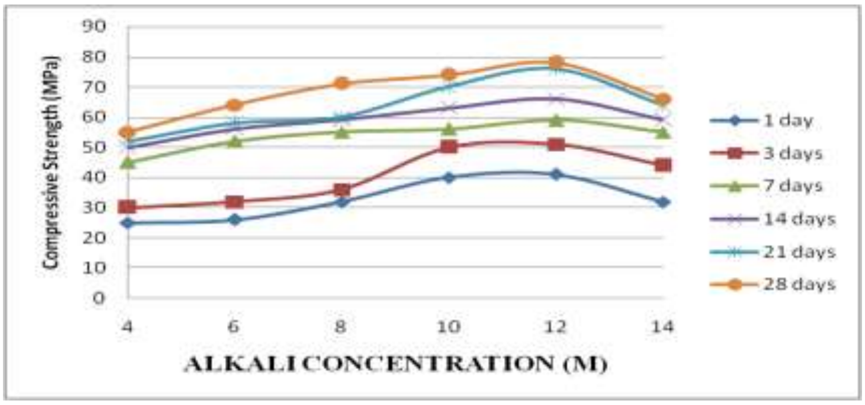

Fig. 1 showing variations in compressive strength of geopolymer mortar with various alkali concentration

From the above graph, it can be concluded that with the increase in alkali concentration, the compressive strength of geo polymer mortar specimens was increased. All the specimens exhibit a high compressive strength at alkali concentration of 12 Molar. Further increase in concentration of alkali content decreased the strength of geopolymer mortar matrix.

Table 2. Strength development ratio of GGPM mortars from 1 to 28 days age

Mix Designation	Morality of NaOH		Compressive Strength (MPa) ratio				
		1 -28 days	3-28 days	7-28 days	14-28 days	21-28 days	28 days
GGPM 100	4	0.45	0.54	0.81	0.90	0.94	1
GGPM 100	6	0.40	0.50	0.81	0.87	0.90	1
GGPM 100	8	0.45	0.50	0.77	0.83	0.84	1
GGPM 100	10	0.54	0.67	0.75	0.85	0.94	1
GGPM 100	12	0.52	0.65	0.75	0.84	0.97	1
GGPM 100	14	0.48	0.66	0.83	0.89	0.96	1

Table 2 shows the strength development ratio of GGPM mortar specimens throughout 28 days age. Ratio of strength development was determined based on the final strength at 28 days. The standard ratio of strength development of OPC (normal) mortar is 0.56 and 0.70 at 3 and 7 days, respectively as in accordance with ASTM Standard. According to ASTM C1074 , the maturity ratio of concrete strength development to the final strength at 28 days is 0.54,0.50,0.50,0.67,0.65 and 0.66 respectively for various alkali concentrations at the 3 days and for 7 days the ratios are 0.81,0.81,0.77,0.75,0.75 and 0.83 respectively for various alkali concentrations. In contrary, all GGPM mortars demonstrates an apparent strength development ratio in accordance with ASTM standard.

IV. CONCLUSION

The effect of NaOH molarity on strength development of Ground Granulated Blast Furnace Slag geopolymer mortars (GGPM) were studied experimentally from 1 to 28 days age. The primary conclusions may be drawn based on this study are:

(1) Molarity of NaOH significantly affected the compressive strength development of GGBS based geopolymer mortar specimens.
(2) The optimum compressive strength was achieved by GGPM 100 mortar with the molarity of 12 Molar throughout 28 days age.
(3) Increasing molarity above 12 Molar did not significantly affect the strength development of GGBS based geopolymer mortar but tend to decrease the mortar strength at higher value.

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A.M.N.Kashyap "Influence of Alkali Concentration on Strength Characteristic Of Ggbs Based Geopolymer Mortar"American Journal of Engineering Research (AJER), vol. 7, no. 4, 2018, pp.09-12.