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EXPERIMENTAL INVESTIGATION OF ALKALI-ACTIVATED SLAG AND FLYASH BASED GEOPOLYMER CONCRETE

S. Aravindan[1], Jagadish.N[2] and Peter Guspher.A[3]
[1]Department of Civil Engineering, Sathyabama University, Chennai, India
[2]M.E Structural Engineering, Sathyabama University, Chennai, India
[3]M.E Structural Engineering, Immanuel Arasar JJ College of Engineering, Tamil Nadu, India
E-Mail: s.aravindan.m.e@gmail.com

ABSTRACT

This paper investigates about the long term strength and durability properties of Alkali-Activated and Flyash based Geopolymer Concrete comparing with the conventional concrete of M40 grade. The Alkali activators are prepared by combining sodium hydroxide and sodium silicate solution in the ratio of 2.5 and molarities are 12M and 16M by varying two different curing regims namely dry curing and open air curing. Totally nine mixes were prepared with Naoh concentration of 12M and 16M was compares with two curing regims namely open air curing and dry curing . Split tensile strength, flexural strength and durability tests namely rapid chloride permeability tests (RCPT) and sorpitivity tests were conducted on 56 and 90 days. Compressive strength tests were carried out on 14, 28, 56 and 90 days. The investigation resulted that there is increase in strength characteristics with increase in concentration of sodium hydroxide solution and open air cured specimens gained more strength than dry cured specimens. However the sorptivity and rapid chloride permeability test results were not found to perform good due to cracking of surface. When compared with conventional concrete results the strength gained is more in AAS-FA based geopolymer concrete. Also the utilization in construction field is easy since it is Ecofriendly and convenient curing process.

Keywords: alkali activated slag, fly ash, compression, split tensile, flexural, sorpitivity, RCPT.

1. INTRODUCTION

In order to reduce environmental effects and pollution caused in manufacturing of cement there is a need in search for an alternative material, the newly developed geopolymer concrete helps up to replace conventional concrete. Researches are being done in current status in developing standard mix design according to Indian standards. As an alternative method to overcome economical drawbacks which decreases strength of building, there is a need to seek for alternative way which gave rise to development of geopolymer concrete.

For long term periods it is considered that buildings are durable in nature without any exterior failure occurrences. Geopolymer usage helps in utilizing in concrete and reduces cost of manufacturing the concrete in Eco-friendly methods. Attempt has been made in replacing cement completely with equal amounts of flyash and GGBS.

Many past researches have studied the behavior of geopolymer concrete at ambient temperature or elevated temperature but only few studies were made in comparing it with alkali activated and flyash based geopolymer concrete. This paper highlights the strength, and durability properties at two different curing methods in different molarities of Naoh solution.

2. LITERATURE REVIEW

High calcium flyash and ground granulated balst furnace slag are latent cementitious materials which possess cementitious properties after interacting with water and gets activated by calcium hydroxide during hydration process (jiang, 1997). According to jiang (1997), alkali activation is the term used to imply the alkali ions to stimulate puzzolonic reaction. Xie *et al* (2008) proposed two processes that control the chemical degradation. Slag is different when compared with other supplementary cementitious materials, when mixed with water; slag develops its own hydraulic reaction. Slag is not hydraulic at room temperature, so activators are in need to initiate hydration. The concentration of NaoH solution which is used to prepare alkaline solution plays a great role in strength gaining properties as the concentration increases. Investigation and discussions for mix design code for geopolymer concrete are in process to add up in IS standards. Curing of geopolymer concrete plays a vital role and it is easy curing process which is more suitable in construction field.

3. EXPERIMENTAL PROGRAM

Ground granulated blast furnace which is a waste product of thermal power plant and low calcium flyash (class F) are been used as binders. River sand according to IS: 383-1970 having specific gravity of 2.54 and fineness modulus of 2.87 was used. Crushed angular aggregate of size 12.5mm and 20mm was used as coarse aggregate of specific gravity 2.66 and 2.72 respectively. Sodium hydroxide flakes of 99% purity and sodium silicate solution was used in preparation of alkaline solution by combining in ratio of 2.5. The binders used are completely replaced in the ratio of 1:1 off the total amount of binders. Two molarities namely12M and 16M are investigated in

ARPN Journal of Engineering and Applied Sciences

this study. 1.2% of Admixture of BASF company (1125) is been used for workability.

A. Cement

Ordinary Portland cement of grade53 was used according to IS 1269-1987 was used as binding material. The physical and chemical properties of ordinary Portland cement used is listed in below table.

Table-1. Properties of ordinary Portland cement.

Properties of ordinary Portland Cement	
Requirements of IS:12269-1987	
Fineness	225
Initial setting time (min)	30 min
Final setting time (min)	600 min
Lime saturation factor	0.8-1.02
Alumina modulus	0.66(min)
Insoluble residue %	4(max)
Magnesia %	6(max)
Suphuric anhydride%	3(max)
Loss on ignition%	4(max)
Chloride%	0.1(max)

B. Ground granulated blast furnace (GGBS)

GGBS is a latent hydraulic material which can directly react with water, as an alternative it requires an alkali activator. The chemical properties of the GGBS and flyash is tabulated below.

Table-2. Properties of GGBS and Fly ash.

Chemical composition of alternative binders		
Component	**GGBS**	**FA**
SiO_2	33.45	49.45
Al_2O_3	13.46	29.61
Fe_2O_3	0.31	10.72
CaO	41.74	3.47
MgO	5.99	1.3
K_2O	0.29	0.54
Na_2O	0.16	0.31
Tio_2	0.84	1.76
P_2O_5	0.12	0.53
Mn_2O_3	0.40	0.17
SO_3	2.74	0.27
LOI	NA	1.45

C. Fly ash (Class F)

Fly ash used in this investigatiom is of class-F which means low calcium flyash according to IS standards. The fineness modulus of the flyash was 86.82% passing 45µ sieve. The SO_3 is less than 1% which will ensure high volume stability. The chemical properties of flyash used in this investigation is tabulated above.

D. Alkaline activators

The alkaline activator used in this study was combination of sodium hydroxide and sodium silicate solution in the ratio of 2.5. The sodium hydroxide solution was prepared by dissolving sodium hydroxide flakes in distilled water atleast prior a day to mixing. The sodium silicate solution is of composition Na_2O=13.7%, SiO_2=29.4%, and water =55.9%.

E. Fine aggregate

Locally available river sand was used as fine aggregate and sieve analysis was done as per IS a standard, IS: 383-1970 was categorized as zone-II.

Table-3. Sieve analysis of fine aggregate.

Sieve sizes	**Percentage passing**
10mm	100
4.75mm	90-100
2.36mm	75-100
1.18mm	55-90
600µ	35-59
300µ	10-30
150µ	0-10

F. Coarse aggregate

Crushed angular aggregate of size 20mm and 12.5mm are been used.

G. Super plasticizer

Super plasticizer used here is of BASF company 1125 grade admixture of 1.2 % for workability.

H. Casting details

The above mentioned materiasl were taken in proper proportions for manufacturing of alkali activated slag and flyash based geopolymer concrete. The mix proportion of AAS-FA based geopolymer concrete is tabulated below

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Table-4. Mix Proportions of Geopolymer Concrete.

Item	Quantity
Coarse aggregate 20mm	370 kg/m^3
Coarse aggregate 12.5mm	924 kg/m^3
Fine aggregate	554 kg/m^3
Ground granulated blast furnace slag	394.29 kg/m^3
Fly ash	394.29 kg/m^3
Sodium hydroxide solution	45.06 kg/m^3
Sodium silicate solution	112.65 kg/m^3
super plasticizer	6 kg/m^3

The prepared fresh concrete were checked for slump and then immediately casted into mould and left for curing.

I. Curing

After casting the test specimens are left for open air curing and dry curing conditions, for open air curing the specimens are been placed in ambient temperature until the day of testing for dry curing the specimens were dry cured in hot air oven at 100ºc for 24 hours after casting along with the moulds and then they were demoulded and left into ambient temperature condition until the day of testing.

J. Testing

The compressive strength of the specimens was tested on 14, 28, 56 and 90 days. The split tensile, flexural and sorpitivity and RCPT were tested at 56 and 90 days. Testing of hardened concrete plays a vital role in controlling and confirming the quality of concrete works.

a) Compressive strength

The below table shows the compressive strength results of 12M and 16M specimens cured at different conditions.

Table-5. Compressive Strength of Geopolymer Concrete.

Compressive Strength of Geoploymer Concrete (N/mm^2)				
Age	**Molarity of NaOH**			
	12 Molarity (12M)		**16 Molarity** (16M)	
	Open air cured	Dry cured	Open air cured	Dry cured
14 Days	53.81	54.90	55.5	51.8
28 Days	58	58.9	67.2	62.3
56 Days	77.34	60.21	64.40	56.05
90 Days	85.01	62.15	84.42	71.58

The respective compressive strength graph is been shown below:

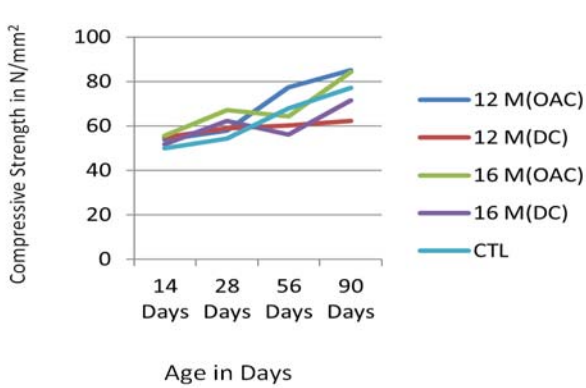

Figure-1. Compressive Strength of Geopolymer Concrete.

b) Split tensile strength

The results of split tensile strength is shown below in the graph.

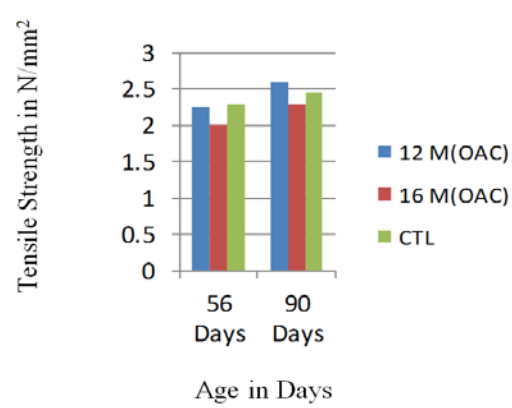

Figure-2. Split tensile strength of Geopolymer Concrete.

c) Flexural strength

Flexural strength testing were performed on a universal testing machine which was fully computerized control. The specimens are of prism beams of size 100x100x500mm. The below figure shows the flexural strength comparison of different molarities of specimens.

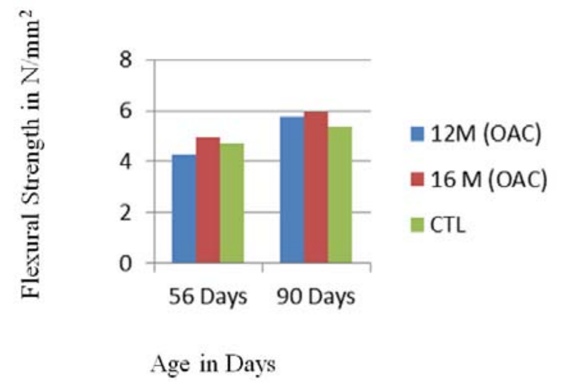

Figure-3. Flexural strength of Geopolymer Concrete.

d) Rapid Chloride Permeability Test (RCPT)

Chlorides penetrate crack-free concrete by a variety of mechanisms in which of these diffusion is predominant. The RCPT is performed by monitoring the amount of electric current that passes through a sample.

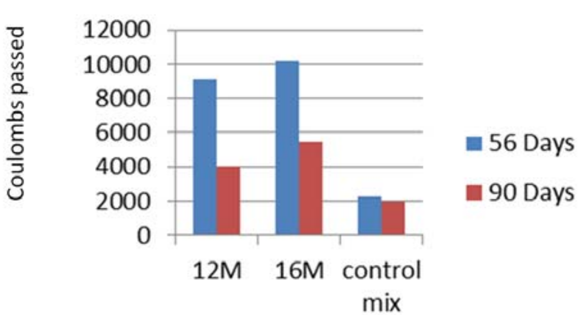

Figure-4. Results of rapid Chloride Permeability test.

e) Sorpitivity

The sorpitivity specimens were undertaken for duplicate specimens with 100mm diameter and 50mm height in accordance with ASTM C 1585-04. The sides of the specimens were coated with epoxy to allow water only through bottom surface of the specimen. The weights of specimens were measures after 1, 5, 10, 20, 30 and at every 30 minutes up to 6 hours, the initial weight also been recorded. The penetration of water is calculated by

$I=A+St^{½}$

Where I is the cumulative absorbed volume after time per unit area. The results of sorpitivity of 12M, 16M and control mix specimens are presented in the below chart.

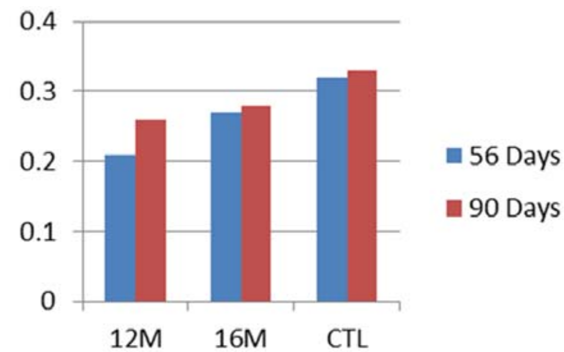

Figure-5. Results of Sorpitivity test.

4. RESULTS AND DISCUSSIONS

From the compression test, split tensile test and flexural strength tests carried out it was found that there was an increase in strength than control mix specimens. Increasing the alkali concentration was considerably higher than that of conventional concrete and similar for 28 days, and the strength attained at long term period of 56 and 90days showed a greater strength gain when compared to alkali activated slag and flyash based geopolymer concrete. There was a large reduction in durability properties both RCPT and sorpitivity of AAS-FA based geopolymer concrete than nominal mix conventional concrete. Further research should be undertaken in durability properties.

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