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Effect Of Concentration Of Alkaline Liquid On Strength Of Geopolymer Concrete

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ABSTRACT
Geopolymer Concrete (GPCs) is a new class of concrete based on an inorganic alumino-silicate binder system compared to the hydrated calcium silicate binder system of concrete. It possesses the advantages of rapid strength gain, elimination of water curing, good mechanical and durability properties and is eco-friendly and sustainable alternative to Ordinary Portland cement (OPC) based concrete. In the construction industry mainly the production of Portland cement causes the emission of air pollutants which results in environmental pollution. Geopolymer concrete are non Portland cement based binders with alkaline activation of industrial wastes such as fly ash and GGBS (Ground Granulated Blast furnace Slag), Sand and Coarse aggregates. This paper presents the details of the studies carried out on development of strength for various grades of geopolymer concrete with varying molarity. The alkaline liquids used in this study for the geopolymerization are sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3). Different molarities of sodium hydroxide solution (3M, 5M and 7M) are taken to prepare different mixtures. The test specimens were 150 x 150 x 150 mm cubes, 150 x 300mm cylinders prepared and ambient temperature curing conditions. The geopolymer concrete specimens are tested for their compressive strength at the age of 7 and 28 days.
Keywords: Ground Granulated Blast furnace Slag, Fly Ash, Alkaline Liquids, Sand, Coarse aggregate, Compressive Strength, Split Tensile Strength.

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I. INTRODUCTION

The production of Portland cement worldwide is increasing 9% annually. Portland cement (PC) production is under critical review due to high amount of carbon dioxide gas released to the atmosphere and Portland cement is also one among the most energy-intensive construction material. The current contribution of green house gas emission from Portland cement production is about 1.5 billion tons annually or about 7% of the total greenhouse gas emissions to the earth's atmosphere. Geopolymer concrete is a 'new' material that does not need the presence of Portland cement as a binder. Instead, the source of materials such as fly ash (FA) and ground granulated blast furnace slag (GGBS) that are rich in silicon (Si) and aluminium (Al), are activated by alkaline liquids to produce the geopolymeric binder.

The major problem, the world is facing today is the environmental pollution. It has severe effect on the ecosystem. There are many reasons which cause pollution. In our construction industry, cement is the main ingredient/material for the concrete production. But the production of cement means the production

of pollution because of the emission of CO2 during its production. There are two different sources of CO2 during cement production. Combustion of fossil fuels to operate the rotary kiln is the largest source and other one is the chemical process of calcining limestone into lime in the cement kiln also produces CO2. Hendriks et al., carried out emission reduction of green house gases from the cement industry. Ernest Worerell and Lynn Price et al., have reported that CO2 emission from the global cement industry. In India about 2,069,738 thousands of metric tons of CO2 is emitted in the year 2010. And also, the cement is manufactured by using the raw materials such as lime stone, clay and other minerals. Quarrying of these raw materials is also causes environmental degradation. To produce 1 tonne of cement, about 1.6 tonnes of raw materials are required and the time taken to form the lime stone is much longer than the rate at which humans use it.

On the other side the demand of concrete is increasing day by day for its ease of preparing and fabricating in all sorts of convenient shapes. So to overcome this problem, the concrete to be used should be environmental friendly. To produce environmental friendly concrete, it is necessary to replace the cement with the industrial by products such as fly ash, GGBS, metakaulin etc. In this respect, the new technology geo-polymer concrete is a promising technique. A huge amount of FA is generated in thermal power plants, causing several disposal-related problems, the total utilization of FA is only about 50%. India produces 130 million tonne of FA annually which is expected to reach 175 million tonne by 2012 (Ernest Worerell and Lynn Price and Nurudan et al., (2010). Disposal of FA is a growing problem as only 15% of FA is currently used for high value addition applications like concrete and building blocks, the remaining being used for land filling. The FA increases the strength in case of hardened concrete. Another alternative but promising utility of FA in construction industry that has emerged in recent years is in Geopolymer concrete. Geopolymer technology can be appropriate process technology utilize all classes and grades of FA and therefore there is a great potential for reducing stockpiles of waste FA materials. The present study considers FA utilization in production of geopolymer concrete since it can accommodate a major portion of the ash produced. GGBS is a by-product from the blast-furnaces used to make iron. The molten slag is rapidly chilled by quenching in water to form the sand like granulated material. GGBS is a glassy granular, non metallic material consisting essentially of silicates and aluminates of calcium and other bases.

II. OBJECTIVE OF WORK

The principal objective of the research were

1. To study the effect of alkaline concentration on strength of geo polymer concrete. The molarity of alkaline activator solutions considered is 3M, 5M and 7M.
2. To study the basic properties of GPC and OPC:

a. Compressive strength
b. Flexural strength
c. Split tensile strength
d. Mechanical properties

Development of Geopolymer Concrete Composites

III. MATERIALS USED

Following materials are generally used to produce GPCs:

i. Ordinary Portland cement (OPC)
ii. Fly ash
iii. GGBS
iv. Fine aggregates
v. Coarse aggregates
vi. Catalytic liquid system (CLS)
vii. Metakaolin

Ordinary Portland cement (OPC)

OPC conforming to IS 12269(1987) (with specific gravity of 3.15), fine aggregates, coarse aggregates and potable water were used for the control OPCC test specimens. The physical properties of the cement used are shown in the Table 1

Table 1 Properties of Cement, Fly Ash and GGBS

S. No	Descriptions	OPC	Fly ash	GGBS
	Physical Properties			
1	Fineness (Sq.m/kg)	306	419	400
2	Normal Consistency (%)	31	-	-
3	Setting Time (minutes)			
	a) Initial	55	-	-
	b) Final	100	-	-
4	Specific gravity	3.15	2.20	2.90

Fly ash and Ground Granulated Blast Furnace Slag (GGBS)

FA conforming to grade 1 of IS 3812 and Ground granulated blast furnace slag) confirming to IS 12089 were used. River sand available in Chennai was used as fine aggregates. The GPCC was obtained by mixing calculated quantities of FA and GGBS, fine aggregates, coarse aggregates with Alkaline Activator Solution (AAS). FA obtained from Ennore Thermal Power Station and GGBS (Ground Granulated Blast Furnace Slag) obtained from Quality polytech, Mangalore conforming to IS 12089 were used. The physical properties of FA and GGBS are presented in Table 2

Table 2 Chemical Analysis of Fly Ash and GGBS

Parameters	% by mass	
	Fly Ash	GGBS
LOI	0.76	
SiO_2	62.1	43.4
Al_2O_3	27.44	12.5
Fe_2O_3	4.57	1.3
CaO	0.83	40.3
MgO	0.55	1.5
Na2O	0.04	0.9
Mn_2O_3	0.04	-
K_2O	0.6	1.17

Sand

River sand available in Chennai was used as fine aggregates. They were tested as per IS 2386 standards.

Coarse Aggregate

In this investigation locally available blue granite crushed stone aggregates of maximum size 12.5mm and down size were used and characterization tests were carried out as per IS 2386.

Metakaolin:

Metakaolin (MK) is produced by heat-treating kaolin, one of the most abundant natural minerals. Kaolin is a fine, white clay that has traditionally been used in the manufacture of porcelain and as a coating for paper.MK is an SCM that conforms to ASTM C 618, Class N pozzolan specifications.MK is unique in that it is not the by-product of an industrial process nor is it entirely natural. The chemical properties are presented in Table 3

Table 3 Chemical composition of Metakaolin

Compound	Percentage
SiO_2	52-54
Al_2O_3	44-46
Fe_2O_3	0.60-1.2
TiO_2	0.65
CaO	0.09
MgO	0.03
Na_2O	0.10

Catalytic Liquid System (CLS)

The term CLS is used to represent the alkaline activator solution (AAS) in GPC concrete. The CLS is a combination of sodium silicate solution, sodium hydroxide solution and distilled water. The role of AAS is to activate the source materials Si and Al present in fly ash and GGBS. The sodium hydroxide was taken in the form of pellets. The sodium hydroxide (NaOH) solution was prepared by dissolving the pellets in distilled water.

Therefore, it was decided prepare the AAS separately and mix them at the time of casting. Since lot of heat is generated when sodium hydroxide pellets react with water, the sodium hydroxide solution was prepared a day earlier to casting. It should be noted here that water is the medium for dissolution and polymerization of Al and Si precursors to take place appropriately and is essential to achieve the desired degree of workability of the GPC concrete mix. . However, excess water can result in formation of pore network, which could be the source of low strength and low durability.

Mix Design

The mix design was done by using ACI-211.1(part-1) code. It is commonly based upon the trial and error method. The specimens are casted and tested at the end of 7th and 28th day with varying values.

Mix Design of Geopolymer Concrete
(Material Ratio: 1:1.31:2.16)

Table 4 Mix Ratio

Mix Id.	Mix Proportion (Binder: Sand: CA) By mass	Liquid / Binder solid (by mass)	Super Plasticizer (% of binder by mass and type)	Binder Composition (% by mass)
GPCA-1	1:1.31:2.16	0.65	-	75%GGBS&25%FLY ASH
GPCA-2	1:1.31:2.16	0.65	-	75%GGBS&25%FLY ASH
GPCA-3	1:1.31:2.16	0.65	-	75%GGBS&25%FLY ASH
GPC B	1:1.31:2.16	0.65	-	75%GGBS & 25% METAKAOLIN
OPC	1:2.46:2.8	0.45	-	100% OPC

Effect of Molarity of Alkaline Activator Solution for Geopolymer

The chemical ratio used in the study is 1:2:7, where 1 indicates sodium hydroxide, 2 is the amount of sodium silicate and 7 is the water to be used in the alkaline solution. Based on the molarity of the solution to be used in the study the amount of sodium hydroxide and sodium silicate is varied in the same ration.

Molarity is defined as the molecular weight of NaOH in 1litre of water. In this experimental study the molarity of NaOH is varied as 3M, 5M and 7M. The molarity calculations are as follows:

Molecular weight of Sodium Hydroxide = 40 gms

Molarity = Molecular weight in 1litre of water. Required molarity weight in sodium hydroxide

Table 5 Molarity Calculation

Molarity	Na_2SiO_3(gm)	NaOH(gm)	Distilled Water
3M	1680	840	7
5M	2800	1400	7
7M	3420	1960	7

IV. RESULTS AND DISCUSSION

Compressive Strength Test

Table shows the Compressive strength of the cube specimens at 7 days, 28 days age of concrete. It shows the variations in Compressive strength increment with molarity of NaOH (3M, 5M, 7M) for the specimens which were cured by ambient temperature curing. Higher concentration of sodium hydroxide solution yielded higher compressive strength. The test results of 7th and 28th day for 75% ggbs+25% flyash (GPCA) and 75% ggbs+25% metakaolin (GPCB) and Ordinary Portland Cement (OPC) are tabulated below.

Table 6 Compression Test Results

S.No	Molarity	GPCA 7th DAY (MPa)	GPCA 28th DAY (MPa)	GPCB 7th DAY (MPa)	GPCB 28th DAY (MPa)
1.	3M	36	45	-	-
2.	5M	39	52	17	20
3.	7M	48	57	-	-
4.	OPC	19	45	19	45

Flexural Strength of Gpc and Opc Concrete

Flexural Strength Test

Deflection is a term that is used to describe the degree to which a structural element is displaced under a load. The deflection of a member under a load is directly related to the slope of the deflected shape of the member under that load. The beams of size 100mm x 100mm x 500mm were tested as per IS 516-1959. The load was applied through two similar rollers mounted at one third points of the supporting span. The load was applied without shock until the failure occurs. The maximum load at failure was tabulated.

Table 7 Flexural Strength results

S.No.	Specimen	Flexural strength (N/mm^2)
1.	GPCA	14
2.	OPC	3.2

Split Tensile Test

Concrete cylinders of size 150mm diameter and 300mm long were cast. The CTM machine of 200 T capacities was used to measure the Split Tensile test. The rate of Loading is 2.35 kg/cm^2/sec. The test was carried out at 28 days of curing.

Table 8 Split Tensile Strength

S.No	Specimen	Strength (N/mm^2)
1.	GPCA	5
2.	GPCB	2
3.	OPC	4

V. SUMMARY AND CONCLUSIONS

With the generic information available on geopolymers, a rigorous trial-and-error method was adopted to develop a process of manufacturing fly ash-based geopolymer concrete following the technology currently used to manufacture Ordinary Portland Cement concrete. After some failures in the beginning, the trail-and-error method yielded successful results with regard to manufacture of low-calcium (ASTM Class F) flyash based geopolymer concrete.

Based on the analysis of results on various specimens of 3M, 5M and 7M solutions it can be seen that higher concentration of Sodium hydroxide (NaOH) yields higher strength of geopolymer concrete. Sodium hydroxide alkaline solution with 7M concentration gives the highest compressive strength. The split tensile of GPC is also more than OPC. The flexural strength of geopolymer concrete is greater than OPC. The use of metakaolin with GGBS can be used for making bricks as the strength is not as much as replacing cement with GGBS. The use of CS as a replacement for sand is environmentally helpful due to the reduction in the waste produced from the copper manufacturing process. It also contributes to conservation of natural FA.

The compressive strength of the geopolymer concrete is higher value obtained was 67MPa (50%). It is observed that upto 50% replacement, CS can be effectively used as replacement for sand. The cost of geopolymer concrete is 20% cheaper than conventional concrete. Apart from eco-friendly material geopolymer is observed to be more economical. So, geopolymer concrete can be used for structural applications.

REFERENCES

[1]. D.V. Reddy*, J-B Edouard, K. Sobhan and S.S. Rajpathak , (2006) "Durability of reinforced fly ash-based geopolymer concrete in the marine environment"- Florida Atlantic University, USA, http://www.cege.fau.edu/

[2]. Joseph Davidovits (3rd edition, july 2011) "Geopolymer Chemistry and Applications (3rd edition)" -Institut Géopolymère, www.geopolymer.org. France. Web: www.geopolymer.org

[3]. Abdul Aleem.M.I and Arumairaj.P.D "Geopolymer Concrete- a Review" , International journal of Engineering Sciences & Emerging Technologies, VOLUME 1, Issue 2, pp: 118-122,Feb 2012.

[4]. Abdul Aleem.M.I and Arumairaj.P.D "Optimum Mix for the Geopolmer" Indian Journal of Science & Technology, Volume 5, No.3, March2012.

[5]. Prof. Wallah S.E and Prof. Rangan B.V, (2006), "Low Calcium Fly ash based Geopolymer Concrete: Long Term Properties". Research Report GC-2, Curtin University of Technology, Perth, Australia.

[6]. Prof.R.Malathy, (2009), "Fresh And Hardened Properties Of Geopolymer Concrete And Mortar", Kongu Engineering College, Perundurai, India.

Dr. Vikas Singh "Implementation of Cognition in Big Data Using Bayesian Statistics." International Journal of Computational Engineering Research (IJCER), vol. 08, no. 03, 2018, pp. 01-05.