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EFFECT OF CONCENTRATION OF ALKALINE LIQUID AND CURING TIME ON STRENGTH AND WATER ABSORPTION OF GEOPOLYMER CONCRETE

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ABSTRACT

In order to address environmental effects associated with Portland cement, there is need to use other binders to make concrete. An effort in this regard is the development of geopolymer concrete, synthesized from the materials of geological origin or by product materials such as fly ash, which are rich in silicon and aluminum. This paper presents results of an experimental study on the strength and absorption characteristics of geopolymer concrete.

The experiments were conducted on fly ash based geopolymer concrete by varying the concentration of NaOH and curing time. Total nine mixes were prepared with NaOH concentration as 8M, 12M, 16M and curing time as 24hrs, 48hrs, and 72hrs. Compressive strength, water absorption and tensile strength tests were conducted on each of the nine mixes. Results of the investigation indicated that there was an increase in compressive strength with increase in NaOH concentration. Strength was also increased with increase in curing time, although the increase in compressive strength after 48hrs curing time was not significant. Compressive strength up to 46 MPa was obtained with curing at 60°C. The results of water absorption test indicated that % water absorption of cubes decreased with increase in NaOH concentration and curing time. Hence, geopolymar concrete has a great potential for utilization in construction industry as it is environmental friendly and also facilitates the use of fly ash, which is a waste product from coal burning industries.

Keywords: geopolymer, fly ash, heat, curing, absorption.

1.0. INTRODUCTION

Demand for concrete as construction material is on the increase so as the production of cement. The production of cement is increasing about 3% annually[1]. Among the green house gases, CO_2 contributes about 65% of global warming. The production of one ton of cement liberates about one ton of CO_2 to atmosphere. Furthermore, it has been reported that the durability of ordinary Portland cement concrete is under examination, as many concrete structures; especially those built in corrosive environments start to deteriorate after 20 to 30 years, even though they have been designed for more than 50 years of service life.

Although the use of Portland cement is unavoidable in the foreseeable future, many efforts are being made to reduce the use of Portland cement in concrete. In this respect geopolymer concrete is very promising technique. The term geopolymer describes a family of mineral binders with chemical composition same as zeolite. Hardened geopolymer concrete has an amorphous microstructure[2] which is quite similar to that of ancient structures such as Egyptian pyramids and Roman amphitheaters.

Geopolymer is produced by a polymeric reaction of alkaline liquid with source material of geological origin or by product material such as fly ash. In terms of reducing global warming, geopolymer technology could reduce approximately 80% of CO_2 emission to the atmosphere caused by cement and aggregate industry[3]. Compared with ordinary Portland cement concrete, geopolymers show many advantages. Geopolymers show substantially superior resistance to fire[4] and acid attack[5] and much less shrinkage than OPC concrete[1]. Geopolymer concrete can obtain 70% of the final compressive strength in the first four hours of setting. The compressive strength after 14 days was found in the range of 5-51 MPa[6]. The tensile strength of geopolymer concrete falls within the range predicted for OPC based concrete. Also, the flexural strengths are generally higher than the standard model line for OPC based concrete. This favorable behavior can be attributed to the type of matrix formation in geopolymer concrete[7]. It has been reported that the stress strain relationship of fly ash based geopolymer concrete is almost similar to that of ordinary Portland cement concrete[8].

These advantages make the geopolymer concrete a strong substitute for replacing ordinary portland cement based concrete composites in construction. Therefore the present study presents the results of an investigation on strength and absorption characteristics of geopolymer concrete prepared by using fly ash as source material and NaOH + Na_2SiO_3 (both in solution form) as alkali activator.

2.0. EXPERIMENTAL PROGRAMME

The experiments were carried out using three different concentrations of NaOH solution and three different curing times. Compressive strength and water absorption tests were conducted at 7 and 28 days, while tensile strength test was conducted at 28 days using briquettes type specimens.

2.1. Materials

2.1.1. Coarse aggregate

Coarse aggregates of 10mm diameter and specific gravity of 2.64 were used.

2.1.2. Fine aggregate

Sand confirming to zone III as per IS: 383[9] was used as fine aggregate for the tests conducted. Locally available river sand having specific gravity of 2.74 was used as fine aggregate for geopolymer concrete mixes.

2.1.3. Fly ash

The fly ash was tested as per IS: 1727[10]. The specific gravity of fly ash used was 2.08 and lime reactivity was found to be 1.06 MPa. Other physical and chemical properties of fly ash used in the investigation are given in the Table-1.

Table-1. Properties of fly ash used.

Properties	Description	Requirement as IS: 3812-2003	Dadri fly ash
Physical properties	Fineness- sp. Surface (m^2/kg)	> 320	437
	Comp. strength at 28 days as % of cement mortar cubes	> 80	86.8
	Lime reactivity (MPa)	> 4.0	5.0
	Drying shrinkage	< 0.15	0.05
	Soundness by autoclaving Expansion Method	< 0.8	0.04
	Retention on 45 micron sieve (%)	< 34	3-4%
	Moisture (%)	< 2.0	0.2
Chemical properties	Loss on ignition (% by wt.)	< 12	1.06
	Silica as Sio_2 (% by wt.)	> 35	67.31
	Iron Oxide as Fe_2O_3 (% by wt.)	---	4.52
	Alumina as Al_2O_3 (% by wt.)	---	30.02
	Total of SiO_2, Fe_2O_3, Al_2O_3 (% by wt.)	> 70	92.45
	Calcium Oxide CaO (% by wt.)	---	2.54
	Magnesium Oxide MgO (% by wt.)	< 5.0	0.46
	Sulfur as SO_3 (% by wt.)	< 2.75	Traces
	Alkalies (% by wt.) Sodium Oxide Na_2O, Potassium Oxide K_2O	< 1.50	0.08 1.11

2.2. Test variables

The variables taken for preparation of geopolymer concrete mixes were; 8M, 12M, 16M NaOH concentration and 24 hours, 48 hours, 72 hours curing time. For each of the NaOH concentration and a constant Na_2SiO_3 concentration (6M), the curing time has been varied by the above mentioned durations. Hence properties of total nine concrete mixes have been studied.

The ratios of fly ash: fine aggregate: 10mm aggregates were taken as 1: 1.5: 2. Alkaline liquid to fly ash ratio (by weight) was taken as 0.5 while the ratio of sodium silicate solution to sodium hydroxide solution (by weight) in alkaline liquid was 0.6.

2.3. Preparation of geopolymer concrete

2.3.1. Preparation of solution

Separate solutions of NaOH and Na_2SiO_3 of required concentrations were prepared 24 hours prior to casting. Both the solutions were mixed together at the time of casting.

2.3.2. Mixing

Weighed amount of fly ash, fine aggregate and 10mm aggregate were dry mixed in a pan mixer for 1 minute. After dry mixing, wet mixing was done for 2 minutes. 12 cubes of 5 x 5 x 5 cm^3 and 3 briquettes having minimum cross sectional area of 6.45 cm^2 were prepared for each set of variables. Compaction was done by giving 25 blows with the help of tamping rod. It was observed that freshly prepared geopolymer concrete could be handled up to 60 minutes.

2.3.3. Curing

After casting the cubes, they were kept (with moulds) in an oven at 100°C for one hour. Then the cubes were demoulded at room temperature and kept at 60°C for rest of the required curing time. After curing the cubes and briquettes were kept at room temperature until the time of testing.

2.4. Tests performed

Compressive strength, water absorption and tensile strength tests were conducted.

3.0. RESULTS AND DISCUSSIONS

3.1. Compressive strength

The compressive strength test was performed taking three cubes from each set after 7 days and 28 days. The results of tests at 7 and 28 days are plotted as Figure-1 a and b, respectively. 7 day compressive strength increased with the increase in concentration of NaOH from 8M to 16M for the same curing time. Increase in compressive strength was also observed with increase in curing time from 24 hrs to 48 hrs. However when curing time further increased from 48 hrs to 72 hrs, no significant variation in compressive strength was observed.

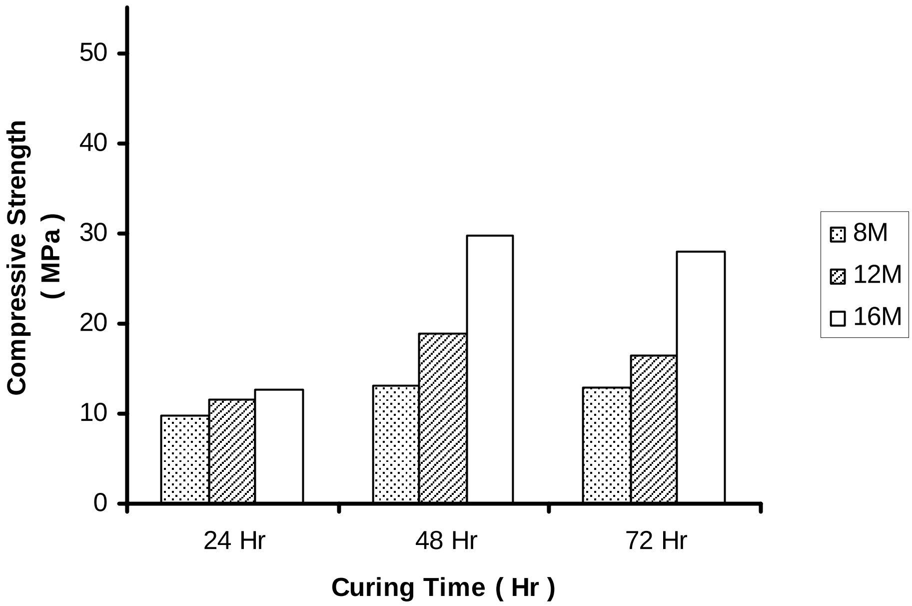

Figure-1a. Variations in 7 days compressive strength with curing time.

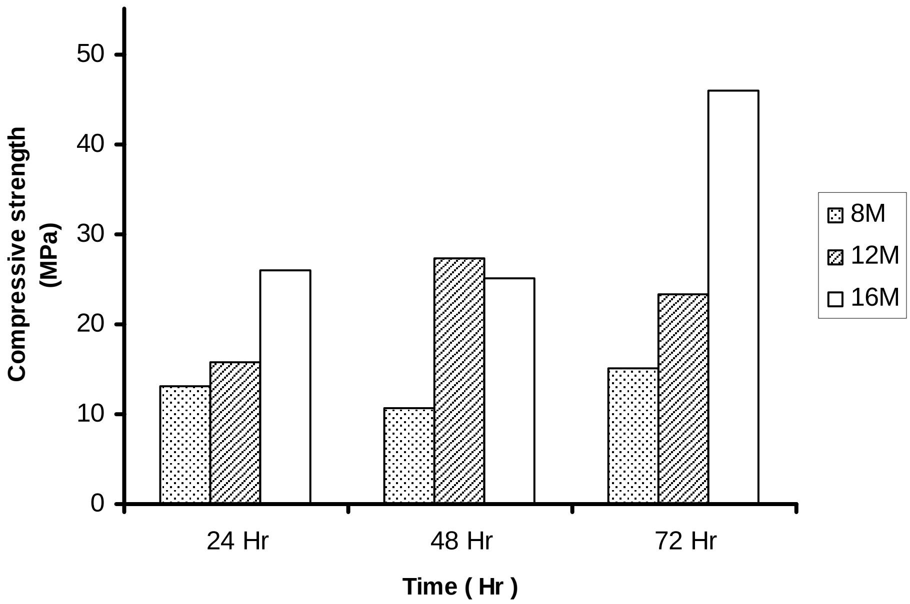

Figure-1b. Variations in 28 days compressive strength with curing time.

The effect of variation in concentration of NaOH and curing time on compressive strength testing after 28 days indicated a variation in compressive strength similar to that of compressive strength after 7 days. However, a significant increase in compressive strength was observed from 7 to 28 days. It shows that compressive strength of geopolymer concrete increases with the passage of time.

3.2. Tensile strength

Tensile strength test was performed after 28 days on standard briquette specimens. Figure-2 shows the results of tensile strength test. Increase in tensile strength was observed with increase in concentration of NaOH from 24 to 48 hours curing time. However, the strength was found to marginally decrease with increase in concentration for 72 hours curing time. Further investigations are necessary to examine this effect.

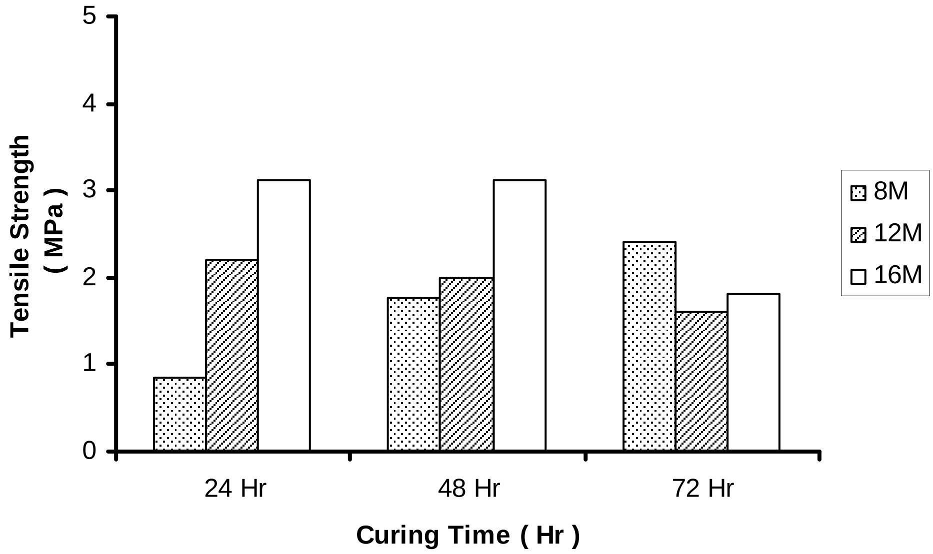

Figure-2. Variations in 28 days tensile strength with curing time.

3.3. Water absorption

Water absorption tests were performed at 7 and 28 days on 5 x 5 x 5 cm cubes. Figure-3a and b shows the results of water absorption tests at 7 days and 28 days, respectively. The decrease in water absorption was observed at 7 days with increase in NaOH concentration from 8M to 16M and also with the increase in curing time from 24 to 72 hours with exception for 16 M NaOH concentration. It was found that 28 days water absorption decreased with increase in curing time and concentration (of NaOH) with marginal increase in two cases.

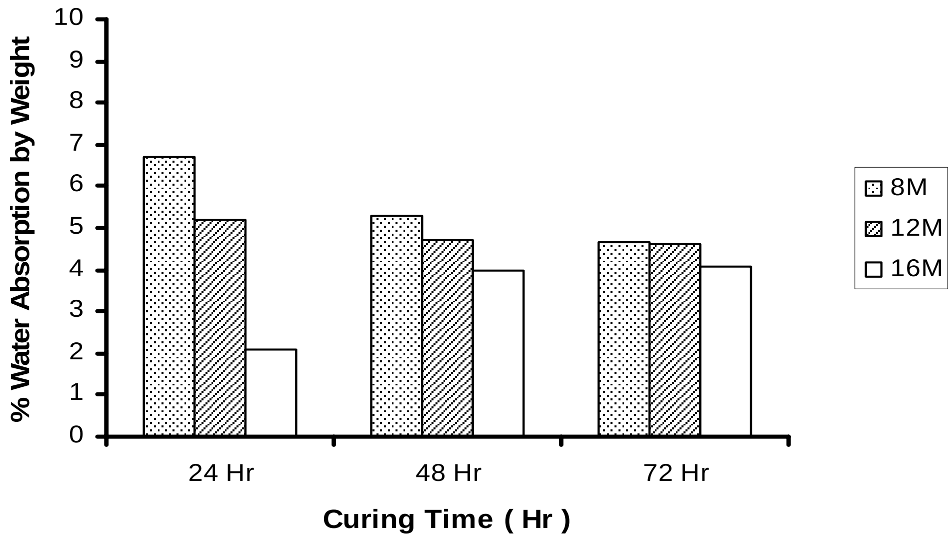

Figure-3a. Variations in 7 day % water absorption with curing time.

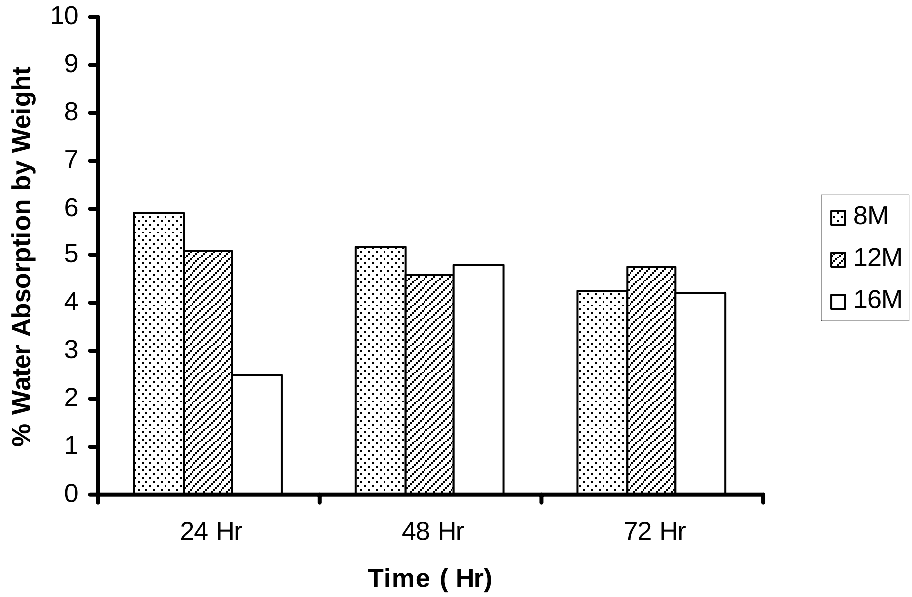

Figure-3b. Variations in 28 day % water absorption with curing time.

4.0. CONCLUSIONS

Following conclusions were drawn from the study on geopolymer concrete:

- Geopolymer concrete is more environmental friendly and has the potential to replace ordinary cement concrete in many applications such as precast units.
- Compressive strength increases with increase in concentration of NaOH from 8M to 16M. Increase in compressive strength was also observed with increase in curing time. However when curing time was increased from 48 hrs to 72 hrs, there was not much variation in compressive strength.
- The test results show that the compressive strength increases with increase in air curing time from 7 days to 28 days.
- Tensile strength increased with increase in concentration of NaOH except for 72 hours curing time. This effect of longer curing period needs to be further investigated.
- Water absorption decreased with increase in concentration and curing time. However, in two cases very small increase was observed.

REFERENCES

1. Rangan, B. V., Hardjto, D. 2005. Development and properties of low calcium fly ash based geopolymer concrete. Research report GC-1, Faculty of Engineering, Curtins University of Technology, Perth, Australia.
2. Bakharev, T. 2005. Geopolymeric materials prepared using Class Fly ash and elevated temperature curing. Cement and Concrete Research. 35: 1224-1232.
3. Rangan, B.V., Wallah, S.E. 2006. Low-calcium fly ash based geopolymer concrete: long term properties. Research report GC-2, Faculty of Engineering, Curtin University of Technology, Perth, Australia.
4. Cheng, T. W. and J. P. Chiu. 2003. Fire-resistant Geopolymer Produced by Granulated Blast Furnace Slag. Minerals Engineering.
5. Bakharev, T. 2005. Durability of geopolymer materials in sodium and magnesium sulfate solutions. Cement and Concrete Research. 35: 1233-1246.
6. Van Jaarsveld, J. G. S., Van Deventer, J. S. J., Lorenzen, L. Factors affecting the immobilization of metals in Geopolymerized fly ash. Metallurgical and Material Transactions. B 29B (1): 283-291.
7. Sofi, D., Van Deventer, J.S.J., Mendis, P.A., Lukey, G.C. 2006. Engineering properties of inorganic polymer concretes (IPCs). Cement and Concrete Research.
8. Hardjito, D. and Rangan, B.V. 2006. Development and properties of low calcium fly ash based geopolymer concrete. Research report GC-1, Faculty of Engineering, Curtin University of Technology, Perth, Australia.
9. IS: 383-1970. Specifications for coarse and fine aggregates from natural sources for concrete. 2nd revision.
10. IS: 1727-1967. Method of tests for pozzolanic materials. 1st revision.
11. IS: 516-1959. Methods of tests for strength of concrete. Incorporating amendments No. 1 and 2.