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Effect of Molarity on Compressive Strength of Geopolymer Mortar

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Abstract

Geopolymer mortar is an ecofriendly promising binder alternate to Portland cement. Geopolymer mortar results from the reaction of fly ash and alkaline solution. The alkaline solution comprises of sodium hydroxide and sodium silicate. Tests have been carried out on 70mm × 70mm × 70 mm cubes of geopolymer mortar specimen. The ratio of alkaline liquid to fly ash is taken as 0.5 and curing temperature is maintained at 85°C for 48 hours in hot air oven. The compressive strength of each sample has been obtained and validated by NDT results. It is found that as the molarity increases the compressive strength of cubes increases. This paper presents the results based on experimental study of molarity on compressive strength of geopolymer mortar.

Keywords: Compressive strength, geopolymer mortar, molarity, NDT (Non Destructive Testing).

1. Introduction

Geopolymer mortar is a cementitious material, better alternate to cement, as it possesses the advantages of rapid strength gain, elimination of water curing, good mechanical and durability properties and also the manufacturing of Portland cement emits large amount of CO_2 into the atmosphere. The production of one ton of Portland cement liberates about 1 ton of carbon dioxide to the atmosphere [1]. Geopolymer mortar is a binder material, produced from an alumino-silicate activated in a high alkali solution, developed by Joseph Davidovits in 1978. Geopolymer mortar consequences

from the reaction of fly ash and alkaline solution. The alkaline solution used for the study is the combination of sodium hydroxide and sodium silicate. The experiment has been conducted to study the effect of molarity on compressive strength of geopolymer mortar. Molarity is the concentration of sodium hydroxide in alkaline solution. The increase in molar concentration results in increase in the compressive strength.

2. Geopolymers

The chemical composition of the geopolymer material is similar to natural zeolitic materials, but the microstructure is amorphous. The polymerization process involves a substantially fast chemical reaction under alkaline condition on Si-Al minerals that result in a three dimensional polymeric chain and ring structure consisting of Si-O-Al-O bonds, as follows:

$$Mn\ [-(SiO_2)\ z–AlO_2]\ n.\ wH_2O \quad (1)$$

where, M = the alkaline element, indicates the presence of a bond, n is the degree of polycondensation or polymerization, z is1,2,3 or higher up to 32 [2-3]. The strength of geopolymer depends on the nature of source materials. Geopolymers made from calcined source materials, such as metakaolin (calcined kaolin), fly-ash, slag etc., yield higher compressive strength when compared to those synthesized from non-calcined materials, such as kaolin clay. A combination of sodium or potassium silicate and sodium or potassium hydroxide has been widely used as the alkaline activator. Since heat is a reaction accelerator, curing of a fresh geopolymer is carried out mostly at an elevated temperature.

3. Materials and Experimental Program

3.1 Materials

Low calcium fly ash ASTM class F (conforming to IS 3812-1987) specifications collected from Paras (District- Akola, Maharashtra) Thermal power station is used for casting the specimens. Table no.1 shows the chemical composition of fly ash. Fine Aggregate (sand) used is clean dry river sand. The alkaline liquid used for geopolymerisation is a combination of sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3). Sodium hydroxide is available commercially in flakes or pellets form and sodium silicate in solution form.

Table.1: Composition of Fly Ash (mass %).

SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	K_2O	Na_2O	SO_3	P_2O_5	LOI*
56.01%	29.8%	3.58%	1.75%	2.36%	0.30%	0.73%	0.61%	Nil	0.44%	0.40%

*LOI- Loss on ignition

3.2 Mix proportions

The alkaline liquid is prepared at least one day prior to cast. Firstly, the NaOH solution is prepared for the required molarity and then it is mixed with Na_2SiO_3 in 1:1

proportion. The samples were prepared for 8M, 10M, 12M and 14M. (where, M–molarity). For e.g. 8M means, concentration of NaOH in one litre of water is 8 × 40 = 320gm (where 40 is the molecular weight of NaOH). Mix proportions for various samples are illustrated in Table no.2.

Table 2: Mix proportions of materials used in experiment.

Specimen	Molarity	Water binder ratio	Activator-Fly Ash ratio	Sand–Fly Ash ratio
Sample 1	8	0.30	0.50	1.0
Sample 2	10	0.30	0.50	1.0
Sample 3	12	0.30	0.50	1.0
Sample 4	14	0.30	0.50	1.0

3.3 Casting and curing

The fly ash and the alkaline solution are first mixed together in specified proportion for 5 minutes. Sand is then added and mixed for another 5 minutes. The mortar samples have been casted in steel moulds of size 70mmX70mmX70mm. The mortar is then filled in mould in two layers and hand compacted using cylindrical plunger. After casting, geopolymer mortar samples are left to room temperature for one hour under atmospheric pressure and uncontrolled humidity conditions and are cured in an oven at 85°C for 48 hours. At the end of curing period the oven is turned off and the materials is allowed to cool down inside the oven to room temperature. The samples are then removed from the mould and they are left to air curing (drying) at room temperature before being used in tests.

4. Tests and Results

4.1 Non Destructive Testing (As per IS 13311 Part I- 1992)

The Ultra Sonic Pulse Velocity test is conducted for NDT on the specimen. The NDT results are presented in Table no. 3 and it shows that the velocity increases as a result of increase in concentration of sodium hydroxide in alkaline solution. The results shown in Table no.3 can be validated with the compressive strength results in Table no.4.

Table 3: Ultra sonic pulse velocity after 48 hours of hot curing at 85°C.

Samples	8M	10M	12M	14M
Ultra sonic pulse velocity (km/s)	2.48	2.58	2.64	2.85

4.2 Destructive testing

Table 4: Compressive strength of geopolymer mortar at 48hr.

Samples	**8M**	**10M**	**12M**	**14M**
Compressive strength (N/mm^2)	14.34	19.67	22.00	24.67

5. Conclusions

Geopolymer mortar which is manufactured by the polymeric reaction of fly ash and alkali activated solution is used for this experiment. The study of influence of molarity on compressive strength of geopolymer mortar have revealed as listed below-

- It has been observed that as the molarity increases, compressive strength increases.
- Molarity also affects the velocity. The velocity increases with increase in molar concentration.
- The compressive strength and velocity are dependent, i.e. as the compressive strength increases the velocity also increases or as the velocity increases the compressive strength increases.

The Geopolymer binder may be treated as future environment friendly alternative to Portland cement in certain industrial applications.

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