Study on strength of geopolymer mortar by varying the molarity of alkaline solution

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Abstract— *This paper represents the effect on the strength of Class F fly ash based geopolymer mortar. Geopolymer mortar was produced by using unprocessed fly ash, activated with sodium silicate and sodium hydroxide solution. Test was carried out on 70.6mm × 70.6mm × 70.6 mm cube geopolymer mortar specimens. Alkaline Solution to fly ash ratio was 0.35, 0.4, 0.45 & 0.5 and molarity of 10 and 12 were used. The specimens were cured at temperature 80°C for 24 hours. In this research, the influences of parameter on the strength fly ash-based geopolymer mortar were studied. The ultimate compressive strength was obtained for various alkaline solutions to fly ash ratio of mortar specimens.*

Keywords— Class F fly ash; geopolymer mortar; alkaline Solution; molarity; heat curing

I. Introduction

Davidovits (1988; 1994) proposed that an alkaline liquid could be used to react with the silicon (Si) and the aluminum (Al) in a source material of geological origin or in by-product materials such as fly ash and rice husk ash to produce binders. Because the chemical reaction that takes place in this case is a polymerization process, he coined the term 'Geopolymer' to represent these binders. Geopolymer are members of the family of inorganic polymers. 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 (Davidovits, 1994). There are two main constituents of geopolymer, namely the source materials and the alkaline liquids. The source materials for geopolymer based on alumina-silicate should be rich in silicon (Si) and aluminum (Al). These could be natural minerals such as kaolinite, clays, etc. Alternatively, by-product materials such as fly ash, silica fume, slag, rice-husk ash, red mud, etc could be used as source materials. The choice of the source materials for making geopolymer depends on factors such as availability, cost, type of application, and specific demand of the end users. The alkaline liquids are from soluble alkali metals that are usually Sodium or Potassium based. The most common alkaline liquid used in geopolymerisation is a combination of sodium hydroxide (NaOH) or potassium hydroxide (KOH) and sodium silicate or potassium silicate.

II. Material use

A. Fly ash

Fly ash consists of finely divided ashes produced by pulverized coal in power stations. During the hydration process, fly ash chemically reacts with the calcium hydroxide forming calcium silicate hydroxide and calcium aluminates, reduces the risk of leaching calcium hydroxide and concrete's permeability. Fly ash also improves the permeability of concrete by lowering the water-to-cement ratio, which reduces the volume of capillary pores remaining in the mass. The fly ash was obtained from Thermal Power Station, Tamilnadu, India. The reaction of fly ash with an aqueous solution containing sodium Hydroxide and Sodium Silicate in their mass ratio, result in a material with three dimensional polymeric chain and ring structure consisting of Si-O-Al-O bonds. The specific gravity, fineness modulus, specific surface area and density of fly ash are 2.82, 1.375, 310 m^2/kg and 1.4 kg/m^3 respectively.

A. *Fine aggregate*

Fine Aggregate (sand) used is clean dry river sand. Zone 2 sand is used in this experiment. Particles passing through 1.18mm sieve were used as fine aggregate.

B. *Alkaline Solution*

Generally the sodium hydroxides are available in solid State in the form of pellets and flakes (NaOH With 98% purity).Sodium Silicate, usually known as “water glass" or “liquid glass”, is well-known due to wide commercial and industrial applications. In order to avoid the effect of unknown contaminants in the mixing water sodium hydroxide pellets were dissolved in distilled water. The activator solution was prepared at least one day prior to its use.

D. Super plasticizer

As a super plasticizer it substantially improved the workability without increasing the amount of water and hence reducing the risk of segregation. Conplast SP430 has been used where a high degree of workability and its retention are likely or when high ambient temperatures cause rapid slump loss. It facilitates production of high quality concrete. The conplast SP430 which was readily available super plasticizer.

III. PRELIMINARY TEST ON MATERIALS

A. *Testing of Fly ash*

1. *Fineness Test of Fly ash*

Correctly 100grms of cement was weighed and taken in a standard IS sieve (325 microns).The lumps were broken down and the material was sieved continuously for 15 minutes using sieve shaker. The residue left on the sieve was weighed. Percentage of residue left on sieve = (weight retained/weight taken) x 100

Result: Percentage of residue left on sieve = 0.29%

2. *Specific Gravity Test of Fly ash*

The equipment was dried thoroughly and weighed as W_1 g. The 50 gm of the fly ash was taken and weighed W_2 g. 50gm of the fly ash and Oil is filled in the mark and weighed W_3 g. The instrument was completely filled with a clean cloth . Then the equipment was completely filled with Oil and it was weighed as W_4 g.

Result: Specific Gravity of Fly Ash (G) = 2.02

B. *Testing of Fine Aggregate*

1. *Sieve analysis of fine aggregate*

The sample was brought to air – dried condition before weighing and sieving was achieved after drying at room temperature. The air – dry sample was weighed

Fineness modulus =2.8

Zone conformation = Zone-II

2. *Specific Gravity Test of Fine Aggregate*

The pycnometer was dried thoroughly and weighed as W_1 gram. 200 gram of fine aggregate was taken in the pycnometer and weighed as W_2 gram. The pycnometer was filled with water up to the top. Then it was shacked well and stirred thoroughly with the glass rod to remove the entrapped air. After the air has been removed the pycnometer was completely filled with water up to the mark. The outside of pycnometer was dried with a clean cloth and it was weighed as W_3 grams. The pycnometer was cleaned thoroughly. The pycnometer was completely filled with water up to the top. Then outside of the pycnometer was dried with a clean cloth and it was weighed as W_4 grams.

Result: Specific Gravity of Fine Aggregate (G) = 2.62

IV. MIX DESIGN

This experimental study on strength of geopolymer mortar by varying molarity and alkaline solution to fly ash ratio by trial and error method.

Proportion for mix:

- Sodium Hydroxide Concentration = 10M & 12M
- Sodium Hydroxide to Sodium Silicate Ratio = 1:1
- Alkaline Activator to Fly ash Ratio = 0.35, 0.4, 0.45 & 0.5
- Superplasticizer = 1% weight of fly ash
- Curing Type = Oven Curing
- Curing Period = 24 hours @ 80^{o}C

Sodium hydroxide solution prepared by,

Reference from **“Perry’s handbook for Chemical engineers”**

The geopolymer mortar used in this study is composed of low calcium fly ash and alkaline solution composed NaOH and sodium silicate combination. NaOH is mixed with soluble in water at a concentration of 10M & 12M and in the ratio of Alkaline Activator and Fly ash is 0.35, 0.4, 0.45 and 0.5. It kept for at least 24 hours prior to casting. All the geopolymer mortar was made with sand -to- fly ash ratio by equal proportion. The hydroxide to silicate ratio is kept constant as 1:1. The fly ash and fine aggregates were dry mixed together in mixer machine for 5 min, followed by the addition of activator solution containing hydroxide and silicate to the mixture, and mixed for another 10 min. The mixing was carried out in a room temperature of approximately 25-30^{o}c.

Then Geopolymer mortar is poured into the mould. For each specimen mortar cubes of size 70.7 mm × 70.7 mm × 70.7 mm cast to test the characteristic strength of the mortar mix. The mould could be easily separated from cast elements after its initial setting .The contact surface of the mould to the mortar were greased before casting the specimens to ease the demoulding process. The geopolymer mortar was cured above heated 80^{o}C for 24 hours, used in heat chamber.

IV. COMPRESSIVE STRENGTH OF GEOPOLYMER MORTAR

Compressive strength is an essential property for all where it also depends on curing time and curing temperature. When the curing time and temperature increase, the compressive strength also increases. With curing temperature in range of 60ºC to 90ºC, within time in 24 to 72 h, the compressive strength of concrete can be obtained about 400 to 500 kg/cm^2. In addition, the compressive strength of geopolymer also mainly depended on the content of fly ash fine particles (smaller than 43 µm).The compressive strength was increase when the finest of fly ash increase. Hence the nature and the concentration of the activators were dominant factors in the reaction of alkali activation. The highest compressive strength was obtained using a solution of sodium silicate as an activator (n = 1.5; 10% Na2O). Sodium silicate is the most suitable as alkaline activator because it contains dissolved and partially polymerized silicon which reacts easily, incorporates into the reaction products and significantly contributes to improving the mortar characteristics,

$$F_c = p/A \text{ N/mm}^2 \text{ (or) MPa}$$

Where, Fc=compressive strength

P=maximum load taken by the specimen,

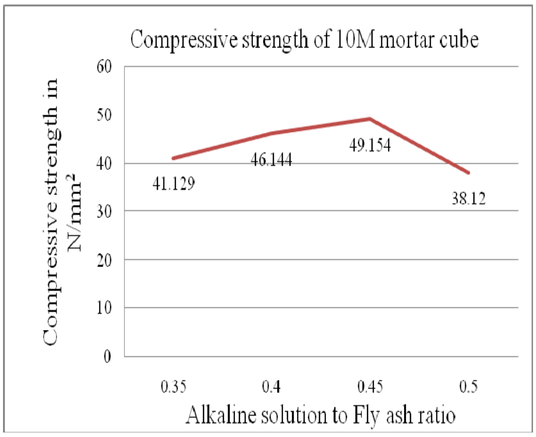
A=surface area of specimen

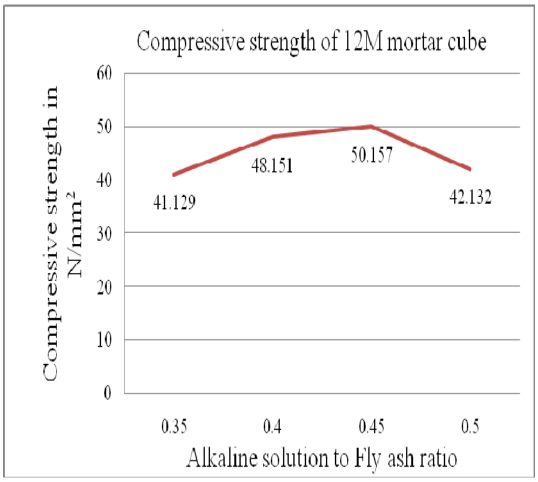
The compression test is conducted on three specimens and average compressive strength is calculated for each mix.

C. Result and discussion

The geopolymer mortar is environment friendly, since the usage of fly ash which is the waste material and reduction in the greenhouse gases due to the complete cement replacement. The strength of the geopolymer specimen was increased by varying molarity. The results are tabulated below.

MOLARITY	ALKALINE ACTIVATOR/ FLY ASH RATIO	DENSITY Kg/m^3	LOAD KN	COMPRESSIVE STRENGTH N/mm^2
10	0.35	2074.5	205	**41.129**
	0.4	2034.7	230	**46.144**
	0.45	2017.6	245	**49.154**
	0.5	1975.0	190	**38.120**
12	0.35	2077.3	205	**41.129**
	0.4	2040.4	240	**48.151**
	0.45	2017.6	250	**50.157**
	0.5	1977.9	210	**42.132**





D. Conclusion

From the experimental results reported in this paper, the following conclusions are drawn;

a) The mortar produces ultimate compressive strength of heat curing in 24 hrs.
b) The activated alkali solution to fly ash ratio 0.45 gives a gradual compressive strength on different molarity.
c) Higher concentration of activated alkali solution results in achieving the optimum compressive strength.
d) Heat curing plays a vital role to reduce the time and increase the strength.
e) The percentage increase in compressive strength of the specimen with increase in molarity decreases.

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