EFFECT OF ALKALI ACTIVATOR SOLUTION ON THE STRENGTH OF FLY ASH-BASED GEOPOLYMER MORTAR

Mandeep Kaur[1], Jaspal Singh[1], Manpreet Kaur[1]

1. Punjab Agricultural University. Ludhiana, India

ABSTRACT. In the construction industry, geopolymer mortar, produced by the alkali activation of silica and alumina rich waste materials, becomes the sustainable alternative to the ordinary Portland cement (OPC) mortar. Numerous factors affect the compressive strength of geopolymer mortar. This paper elucidates the fluctuations in 3 days compressive strength of fly ash based geopolymer mortar with the variation in sodium silicate (Na_2SiO_3) to sodium hydroxide (NaOH) ratio and alkaline activator solution to fly ash (AAS/FA) ratio. The alkaline activator solution was comprised of Na_2SiO_3 and 14M of NaOH. Na_2SiO_3 / NaOH and AAS/FA ratio was varied in the range of 2.0-3.0 and 0.35-0.45 respectively. All the geopolymer mortar mixes were oven cured at 70°C for 24 hours followed by ambient curing until the time of testing. From the test results, combination of AAS/FA and Na_2SiO_3 / NaOH ratios of 0.40 and 2.5, respectively, reported the maximum compressive strength.

Keywords: Geopolymer mortar, Fly ash, Alkaline activator solution, Sodium silicate, Sodium hydroxide, Compressive strength

Mandeep Kaur is PG scholar, Punjab Agricultural University. Ludhiana, India. Phone number: +919041611534 & Email Id:mkmeenu86@gmail.com

Dr Jaspal Singh, is a Professor in Department of Civil Engineering at Punjab Agricultural University. Ludhiana, India. Phone number: +919463313427 & Email Id: jaspalsingh@pau.edu

Manpreet Kaur is a Assistant Professor in Department of Civil Engineering at Punjab Agricultural University. Ludhiana, India. Phone number: +919855506342 & Email Id: manpreetkharay@pau.edu

INTRODUCTION

In the present era, Ordinary Portland Cement (OPC) is widely used as a prominent building material. However, the production of Portland cement causes the emission of air pollutants and results in environmental pollution [1,2]. The cement generating plant is responsible for hazardous impacts on environment because during the production of one tonne of Portland cement, approximately equivalent amount of CO_2 is emitted into the surroundings [3]. In this concern, geopolymer mortar is emerging as a greener promising binder alternate to Portland cement [4,5]. Geopolymer binding materials are mainly composed of two components: source material and alkaline activator liquid. The source material for geopolymer mortar and concrete should be rich in silica (Si) and alumina (Al) [6].

Waste materials namely fly ash, red mud, copper slag, rice-husk ash etc. can be effectively used as source materials and sodium or potassium based alkaline solutions are commonly used as alkaline activator solutions in geopolymers [7,8]. There are numerous parameters that influence the properties of geopolymer materials. Out of these, main parameters include alumina-silicate source material, curing conditions, type and concentration of alkaline activator and the alkaline activator to source material ratio.

Fly ash is the fine particulate waste material generated during the agitation of pulverized coal in thermal power plant. In accordance of survey report, the worldwide annual production of the fly ash is about 780 million tonne whereas; utilization of this waste material is only about 17–20 %. In India, more than 220 million tonnes of fly ash is produced annually [9]. Many researchers have investigated the feasibility of using fly ash as a source material in geopolymer mortar and concrete production [10]. By applying this innovative technology, by-products such as fly ash can be transformed into useful construction materials and the carbon dioxide from Portland cement production can be reduced by as much as 90 % [11]. Fly ash based geopolymer mortar prepared with higher concentration of alkaline solution performed superior in magnesium sulphate solution than those manufactured with lower concentration of alkaline solution [12]. Various researchers found that the geopolymer materials have better mechanical properties and better durability in aggressive environments as compared to conventional cement based binding materials [13]. Also, the compressive strength of fly ash based geopolymer mortar increases as the molar concentration of sodium hydroxide solution increases [14].

The present study has been accomplished to find the effect of Na_2SiO_3/NaOH and alkaline activator solution to fly ash (AAS/FA) ratio on the 3-days compressive strength of fly ash based geopolymer mortar.

MATERIALS AND METHODS

Materials

In this investigation, class F fly ash taken from Guru Nanak Dev thermal plant, Bathinda was used as source material for geopolymer mortar. The physical and chemical properties of the fly ash sample are given in Table 1. Locally available river sand, passing through 2.36mm sieve was used as fine aggregate. The alkaline activator solution was consists of sodium silicate (Na_2SiO_3) and sodium hydroxide (NaOH). These activators were supplied by local supplier. The sodium silicate was taken in liquid form with Na_2O and SiO_2 in the range of 7.5-8.5%, 25.0-28.0% respectively. Sodium hydroxide solution of 14M was used in this study. Sodium hydroxide was supplied in pellet form and 14 M sodium hydroxide solution was prepared by dissolving 560gm of NaOH pellets in water to form one litre NaOH solution.

Table 1 Physical and chemical properties of fly ash

Physical properties	**Values**
Colour	Light Grey
Class	F
Particles retained on 45 micron IS sieve in %	31
Chemical component	**Percentage (%)**
$(SiO_2) + (Al_2O_3) + (Fe_2O_3)$	94.36
Silicon dioxide (SiO_2)	52.66
Calcium Oxide (CaO)	1.64
Magnesium oxide (MgO)	0.84
Sodium oxide (Na_2O)	0.02
Loss on ignition	2.35

Preparation of Geopolymer Mortar

The fly ash-based geopolymer mortar was prepared by adopting constant fly ash to sand ratio and water to solid (W/S) ratio of 1:3 and 0.35, respectively. Here, W is total water content required for preparation of geopolymer mortar including water presents in activator solution and S is total solid content of geopolymer mortar including solids of NaOH and Na_2SiO_3 [15].

During this experimental programme, geopolymer mortar samples were casted by varying the Na_2SiO_3 to NaOH ratio as 2, 2.5, 3 and alkaline activator to fly ash ratio as 0.35, 0.40, 0.45. The casted geopolymer mortar mixes were oven cured at 70 °C for 24 hours. Table 2 elucidates the geopolymer mortar mix proportion using different AAS/FA and Na_2SiO_3 / NaOH ratios. The extra water required was calculated from water to solid (W/S) ratio [15].

Mixing and Casting of Geopolymer Mortar Mixes

Sodium hydroxide solution was prepared one day prior to casting. The calculated quantities of sodium hydroxide solution according to required molar concentration and the sodium silicate solution were mixed thoroughly in beaker to give homogeneous solution at the time of casting. Firstly, alkaline solution was added in dry fly ash and mixed for 5-7 minutes to get homogeneous mix. After that, sand was mixed with activated source material for another 2-3 minutes to ensure the homogeneity of mixture. Extra water if required as per W/ S ratio of 0.35 was added to mixture after adding required amount of sand. Figure 1depicted the prepared light grey fly ash based geopolymer mortar.

The prepared geopolymer mortar was then poured into standard size 70.6mm x 70.6mm x 70.6mm cubic moulds. After that, samples were placed on a vibrating table for 10-20 seconds to remove entrapped air. Past an hour of casting, the geopolymer mortar cubes along with moulds were placed in oven at 70°C temperature curing for 24 hours. All the cubes were allowed to cool down up to room temperature in an oven itself. After 24 hours, specimens were removed from oven and de-moulded. After that cubes were kept to ambient curing until the day of testing.

Figure 1 Fly ash based geopolymer mortar

Table 2 Mix proportion of geopolymer mortar

MIXES	AAS/FA RATIO	Na_2SiO_3/ NaOH RATIO	FLY ASH (gm)	SAND (gm)	NaOH SOLUTION	Na_2Sio_3 SOLUTION
S-1		2.0	600	1800	70	140
S-2	0.35	2.5			60	150
S-3		3.0			52	158
S-4		2.0	600	1800	80	160
S- 5	0.40	2.5			68	172
S-6		3.0			60	180
S-7		2.0	600	1800	90	180
S-8	0.45	2.5			77	193
S-9		3.0			68	202

Compressive Strength Testing

The compressive strength testing procedure of geopolymer mortar was adopted as similar to cement mortar [16]. All the specimens of standard size were tested for compressive strength under the universal testing machine (UTM). Three cubes of each mix were casted to evaluate the average compressive strength.

RESULT AND DISCUSSION

The results of 3-days compressive strength of fly ash based geopolymer mortar for different alkaline activator to fly ash (AAS/FA) ratios and Na_2SiO_3 / NaOH ratios are shown in Figure 2. The test results revealed that as the AAS/FA ratio and Na2SiO3/NaOH ratio increases, 3-days compressive strength also increases. In this experimental study, the optimum compressive strength (33.71N/mm^2) was obtained at Na2SiO3/NaOH and AAS/FA ratio of 2.5 and 0.40 respectively. The improvement in compressive strength by increasing Na2SiO3/NaOH ratio from 2.0 to 2.5 is due to enhancement in the dissolution of silica and alumina of source material. Moreover, as the Na_2SiO_3/NaOH ratio increases to 3.0, compressive strength decreases for all AAS/FA ratios. The excess of sodium content can forms sodium carbonate by atmospheric carbonation that may disrupt the polymerization process [17]. Besides this, as the AAS/FA ratio increases from 0.35 to 0.40 compressive strength increases but further increase in AAS/FA ratio results in decrease of compressive strength. This may be due to excess of alkaline activator that produces relatively more OH^-, which hinders the geopolymerization process and therefore leading to low compressive strength of geopolymer.

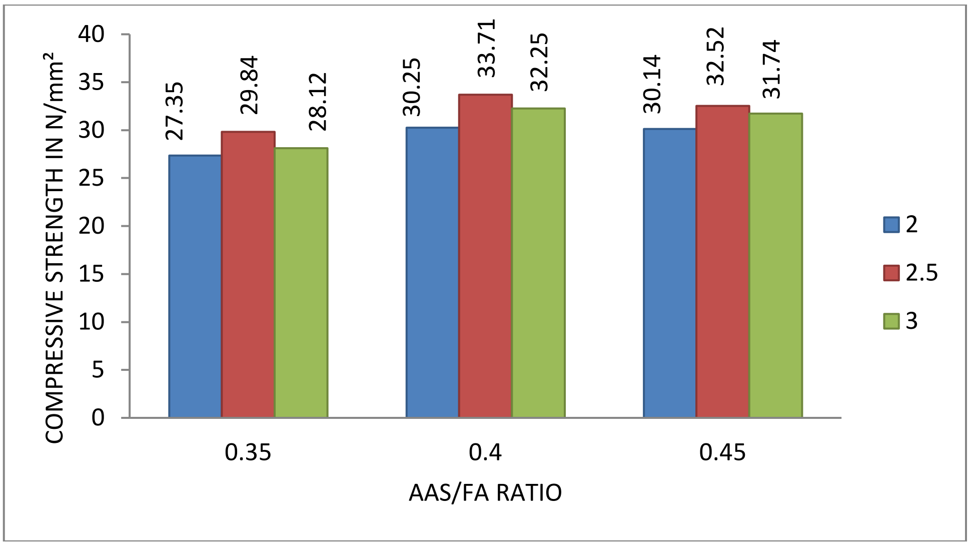

Figure2 3-days compressive strength of fly ash-based geopolymer mortar

CONCLUSION

In this experimental study, the fluctuations in the compressive strength of fly ash based geopolymer mortar were investigated due to variations in Na_2SiO_3 / NaOH and alkaline activator to fly ash (AAS/FA) ratio.

The 3-days compressive strength of fly ash-based geopolymer mortar increases with the increase in Na_2SiO_3 / NaOH and AAS/FA ratios from 2.0-2.5 and 0.35-0.40, respectively. It was observed that, at Na_2SiO_3/NaOH ratio of 3:1, compressive strength decreases. This may be attributed to disruption in polymerisation reaction due to increase in silica content. Similarly, due to increase in AAS/FA ratio to 0.45, compressive strength decreases. From the test results, it has been noticed that the optimum compressive strength of 33.71 N/mm^2 was obtained for the combination of AAS/FA and Na_2SiO_3 / NaOH ratios as 0.40 and 2.5 respectively.

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