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Development of various curing effect of nominal strength Geopolymer concrete

S. Kumaravel

Dept. of Structural Engg., Annamalai University, Annamalainagar - 608 002, India.

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Abstract

Geopolymer concrete is an innovative method and is produced by complete elimination of ordinary Portland cement by-produced in fly ash. This study on different condition of curing in geopolymer concrete suitable for curing at ambient and heat-cured condition of temperature will widen its application to concrete structures. Low lime fly ash is used as the base material, which is reacted by alkaline solution and additional use of ground granulated blast furnace slag. Workability of fresh concrete and compressive strength of geopolymer concrete was investigated. The curing effect of geopolymer concrete is steam, hot air and ambient cubes specimens are tested in different days. Results are compared for various curing and strength of concrete.

Keywords: Geopolymer concrete, alkaline solution, Fly ash, GGBS, curing, compressive strength

1. Introduction

The increasing demand of environment friendly construction has been the driving force for developing sustainable and economical building materials. The critical aspects influencing the development are performance of the materials under different and special user conditions, economic aspects as well as environmental impact aspects. Cement is an energy consuming and high green house gas emitting product. On the other hand, the abundant availability of fly ash worldwide creates opportunity to utilize this by-product of burning coal, as a substitute for OPC to manufacture concrete. The development and application of high volume fly ash concrete, which enabled the replacement of OPC up to 60% by mass (Malhotra, 2002; Malhotra and Mehta, 2002). Recently, the suitability of fly ash based geopolymers mixed with silica fume, metakaolin (Wu and Sun, 2010) and ground granulated blast furnace slag (Guerrieri and Sanjayan, 2010) has been studied by several investigators. Geopolymers are gaining increased interest as binders with low CO_2-emission in comparison to Portland cement. Geopolymers also exhibit similar or superior engineering properties compared to cement (Wallah and Rangan, 2006). The term geopolymer describes a family of mineral binders with chemical composition same as zeolites. Hardened geopolymer concrete has an amorphous microstructure which is quite similar to that of ancient structures such as Egyptian pyramids and Roman amphitheaters.

2. Geopolymer Concrete

Geopolymer pioneered by Joseph Davidovits is an inorganic alumino-silicate polymer synthesized from predominantly silicon (Si) and aluminium (Al) materials of geological origin or by-product materials like fly ash, metakaolin, GGBS, rice husk ash, red mu etc. 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. The main constituents of geopolymers are the fly ash and the alkaline liquids. The alkaline liquids are formed soluble alkali metals that are sodium or potassium based. The combination of sodium hydroxide with sodium silicate is used on alkaline liquids since it is cheap when compared to potassium. The type of alkaline liquids is as significant factors affecting the mechanical and the combination of sodium silicate and sodium hydroxide also affects the highest compressive strength.

3. Preparation Of Geopolymer Concrete

3.1 Materials

Low lime fly ash (ASTM class F) collected from Mettur Thermal Power Station is used. Fine aggregate (sand) used is clean dry natural river sand is specific gravity of 2.62, bulk density of 1562 kg/m^3 and fineness modulus of 2.40, is used. Coarse aggregates of 20 mm maximum size having a fineness modulus of 6.80, bulk density of 1643 kg/m^3 and specific gravity of 2.70 are used.

3.2 Alkaline Solution

The alkaline liquid is prepared by mixing sodium silicate and sodium hydroxide solution, the sodium hydroxide with 98% purity in pellet form and sodium silicate solution is commercially available in different grades. The sodium silicate solution (Na_2SiO_3) with sodium hydroxide (NaOH) ratio by mass of 2.5 is used. Allow the mix for a minimum period of 24 hours and maximum 36 hours to the reaction of polymerization. i.e To prepare 8 molarity concentration of sodium hydroxide solution, 320 grams (molarity x molecular weight) of sodium hydroxide pellet is dissolved in water and makeup to one liter. The mass of NaOH solids was measured as 268 grams per kg of NaOH solution of 8 M concentration. The materials required for making geopolymer concrete as shown in Figure 1.

* E-mail address: smk_au@yahoo.com
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3.3 Mixing of Concrete

The minimum strength of concrete to be used for construction is M 20 grade as per I.S: 456- 2000. Hence the nominal mix required for M 20 grade 1:1.5:3.0 is tried in this study. The same ratio of mix is tried in the geopolymer concrete also. The constituents of geopolymer concrete of 8 M sodium hydroxide for M 20 grade concrete are given in Table 1.

Table 1. Constituents of Geopolymer Concrete

Description	Quantity (kg/m^3)		
	GPC-1	**GPC-2**	**GPC-3**
Fly ash	436	414.20	392.40
GGBS	-	21.80	43.60
NaOH solid	17.94	17.94	17.94
Water	38.12	38.12	38.12
Na_2SiO_3 solution	140.14	140.14	140.14
Fine aggregate	654	654	654
Coarse aggregate	1308	1308	1308

In the laboratory, the fly ash and fine aggregates are first mixed together dry in 50 liters capacity pan mixer for about three minutes. The course aggregates are prepared in saturated-surface-dry (SSD) condition. The alkaline solution mixture added to the dry materials and the mixing continued usually for another four minutes. The fresh concrete could be handled up to 120 minutes without any sign of setting and without any degradation.

Fig. 1. Materials for GPC

Fig. 2. Slump

The workability of fresh concrete is measured by means of the conventional slump test. The slump measured is 110 mm for GPC-1, 140 mm for GPC-2 and 170 mm for GPC-3, fresh geopolymer concrete is usually cohesive (Figure 4). The setting time test is carried out in a controlled temperature of 35^{o}C. In this condition, fly ash based geopolymer generally takes a long time to set due to slow rate. Both initial and final setting time decreased with the increase of slag content. The cube of size 100 mm and cylinder of size 100 mm diameter and 200 mm height. It is observed that a geopolymer concrete stick hard to the mould so oiling the moulds is very important to release each cube specimen, while cast in three layers by compacting manually. Each layer received 25 strokes of compaction by standard compaction rod for concrete.

3.4 Curing

The specimens after casting they are kept for one day in rest period at room temperature. The term 'Rest Period' is coined to reacting polymerization the time taken from the completion of casting of test specimen to the start of curing at an elevated temperature. After casting, the specimens are covered using vacuum bagging film in steam curing to generate the steam at a specified temperature of 60^{o}C (Figure 5). The specimens are applied in hot oven curing at 60^{o}C (Figure 6). The specimens are natural place of snow and sunlight for ambient condition at 30^{o}C - 40^{o}C (Figure 7).

Fig. 3. Steam Curing

Fig. 4. Hat air Curing

Fig. 5 Ambient Curing

4. Results and Discussion

4.1 Density of Geopolymer Concrete

Variations of density of geopolymer concrete 3, 6 and 12 days. Density of geopolymer concrete - 2350 kg/m^3 and cement concrete is approximately 2400 kg/m^3. As the age of concrete decreases, there is a slight decrease in density as shown in Figure 8. Variation of density is not much significant with respect to age of concrete and ambient curing.

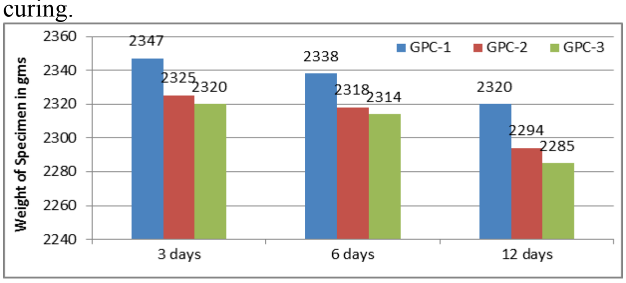
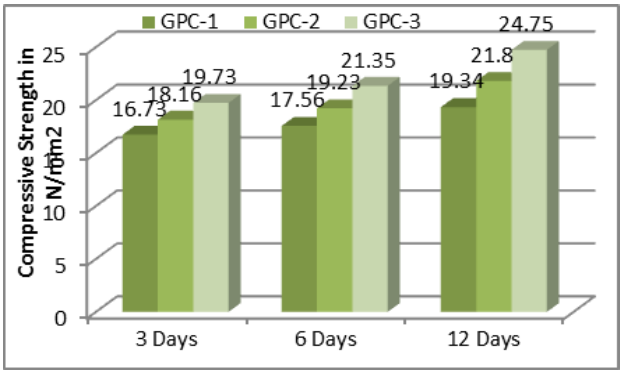


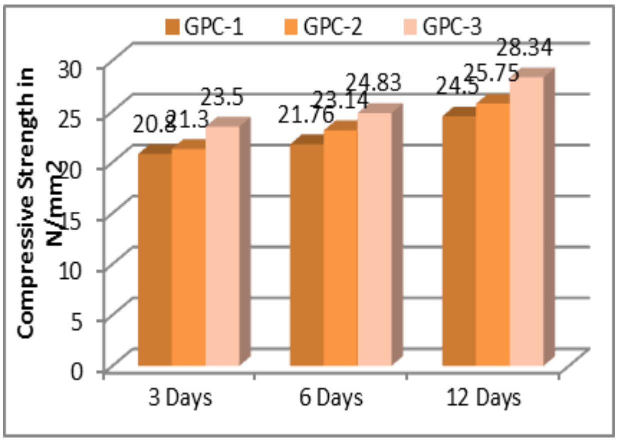
Fig. 6. Density of Geopolymer concrete in different days

4.2 Compressive Strength

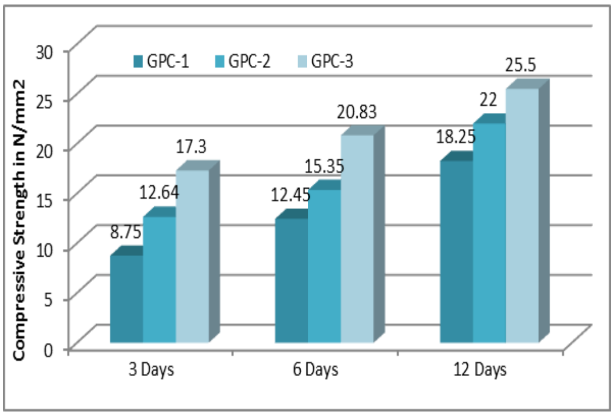
The geopolymer concrete cubes are kept in room temperature for 3, 6 and 12 days tested, keeping smooth surface of the cube in contact with loading. The compressive strength machine of 1000 kN capacity is used to apply the axial force of compression. The test result is shown in Figure 12.



a) Steam Curing



b) Hot air Curing



c) Ambient Curing

Fig. 7. Geopolymer concrete varrioues curing compressive strength test results

The compressive strength after 3, 6 and 12 days of curing is presented in Figure 9. Compressive strength of hot cured specimens is more than that of ambient cured specimens both for 12 days. These results obtained in geopolymer concrete are suited for structural applications with a minimum concrete strength of 20 MPa.

5. Conclusions

The compressive strength of hot cured concrete is much higher than that of ambient cured concrete. In ambient curing, the compressive strength increases as the age of concrete increases from 3 days to 12 days. The average density of fly ash based geopolymer concrete is similar to that of OPC concrete. Geopolymer concrete is more environmental friendly and has the potential to replace ordinary Portland cement concrete in many applications such as precast units. The results establish that slag as a part of fly ash binder is effective to accelerate setting time of geopolymer concrete in ambient condition. The geopolymer concrete possesses good compressive strength and well-suited to manufacture precast concrete products. Low calcium fly ash-based geopolymer concrete has excellent compressive strength and is suitable for structural applications.

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