

Behaviour of Fly Ash based Geopolymer Concrete in Fresh State

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Abstract

An attempt has been made in this study to investigate the properties of geopolymer concrete while in the fresh state. Fresh properties of geopolymer cement have been studied by varying concentration of sodium hydroxide (NaOH) having concentration 8M, 10M, and 14M. Further, the ratio of Na_2SiO_3 to NaOH was kept in the range of 1, 1.5 and 2.5. It has been found that standard consistency decreased significantly and initial and final setting times decreased as the salt concentration of the alkaline solution and of NaOH increased. The compressive strength of geopolymer cement increased with the increase in the concentration of NaOH and with the increase in the concentration of sodium hydroxide. The compressive strength was even higher than conventional concrete at the concentration of 14M.

Keywords: Activator Solution, Compressive Strength, Fly Ash, Geopolymer

1. Introduction

1.1 Background

Geopolymer technology is a latest field of research interest in engineering and concrete science and is gaining increasing attention for utilization of industrial by products such as Ground Granulated Blast Furnace Slag (GGBS) and Fly Ash (FA). These novel, amorphous and three-dimensional binder materials were named as 'geopolymers' by Davidovits in the year 1978¹. Any pozzolanic material containing alumina and silica that dissolved in the alkaline solution acts as a source of geopolymer precursor species and lends itself to geopolymerization^{2,3}. FA is one of the prime natural sources of alumina-silicates. Its relatively less impurities and stable chemical composition than that of the industrial waste precursor material like blast furnace slag etc. makes it a popular choice for geopolymer synthesis^{4,5}.

The polymerisation process involves a spontaneous reaction of silico-aluminates minerals in the source

materials with alkali metal hydroxide/silicates activators solution resulting in the formation of a 3D polymeric chain/network structure of Si-O-Al-O bonds⁶⁻⁸. The two main precursors in making geopolymer are alkaline liquids and source materials rich in silica and alumina such as kaolinite, fly ash, and others. Mostly used alkaline liquids include potassium hydroxide (KOH) and NaOH and in combination with Na_2SiO_3 . When geopolymer are blended together with aggregates, the resulting mixture can be handled and cast in the same manner as Portland cement based concrete. Because the reaction mechanism of geopolymer is poly-condensation rather than hydration, as in the case of Portland cement, it can be aided by heating the geopolymer in temperature ranging between 25-90°C⁹. The temperature range depends upon the molar concentration of activator solution and raw materials used.

1.2 Properties

Geopolymer can be utilized as a partial or total replacement for Portland cement. By comparison to Ordinary

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Portland Concrete (OPC), Geopolymer Concrete (GPC) offer high resistance to acid and sulphate attack, rapid strength gain rate, high compressive strength and undergoes little shrinkage studied by Miranda et al., in 2005¹⁰. Van Jaarsveld et al. in 2002 reported that calcium contents and origin of fly ash precursor influence the properties of geopolymer¹¹. Diaz et al. in 2010 demonstrate that the presence of calcium in fly ash in significant quantities could interface with polymerisation setting rate¹². In term of mechanical strength, geopolymer exhibits excellent gain rate, superior even to that of rapid-setting cements and their significant maximum strength can be achieved in 3-5 days depending upon curing efforts.

1.3 Objective: Overview of Present Work

The present works examine the effect of two variable-types sodium hydroxide and sodium silicates molar concentration on the initial setting time, final setting time, standard consistency and compressive strength. Further, the concentration of NaOH was kept constant and molar concentration of Na_2SiO_3 as variables and same parameters has been studied.

2. Experimental Details

2.1 Materials Used

In a typical procedure, certain amount of Fly ash obtained from the silos of power station JHARLI, Haryana, sodium hydroxide solution (NaOH) and sodium silicate solution (Na_2SiO_3) 99% pure in flakes was obtained from the Baddley chemicals (Baton Rouge, LA), Aggregates Grade I (particle size less than 2mm & greater than 1mm), Grade – II (particle size less than 1mm & greater than 0.5mm), Grade –III (particle size less than 0.5mm & greater than 0.09mm), cement (Grade 33) and normal Potable water for curing of cements. All NaOH and Na_2SiO_3 molar solutions were prepared in the laboratory and allowed to cool for 1 day before mixing.

2.2 Experimental Procedure

An experimental design was carried out for the three-concentration of the alkaline solution. Three cubes (repetition) were made for each combination. Each cube was considered as a repetition. Four response variables were selected for this study: the effects of initial set-

ting time, final setting time, standard consistency and compressive strength. The main effects of each research variables, as well as the interactions among them were evaluated. NaOH solutions of three different molar concentrations were mixed with respective sodium silicates to prepare alkaline solution. The fresh paste was cast into 70.6mm cubical moulds in two layers. After casting the specimen were placed in the oven and cured at 60°C for 24 hours. Compressive strength was measured after 24 hours curing periods, following ASTM (2011) C109.

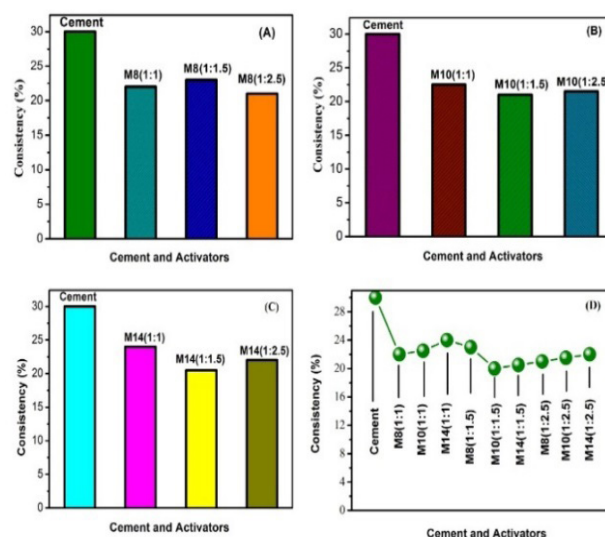


Figure 1(A). Consistency M8 and cement (B) Consistency M10 and cement (C) Consistency M14 and cement and (D) Comparison of Consistency with the molar concentration and cement.

3. Results and Discussion

Experimental measurements were expressed graphically to display the effect of different levels of each design factors on the response variables as well as the interactions among the factors with respect to their effect on the response variables.

3.1 Standard Consistency Test

The consistency is an important test of cement paste. This test gives an idea of water required for the hydration of cement. The results were obtained while testing the consistency of cement and activator are shown in Figure 1.

From the Graph, it can be concluded that the consistency of cement is highest as compared to the FA with

solutions of M8, M10 and M14. The main reason of higher consistency of cement as compared to that of FA was that the particles of FA are spherical in nature with minimum friction. FA particles contain less reactive silica as compared to the cement. Therefore, the FA consistency is less as compared to the conventional cement. Therefore, it can be inferred that standard consistency decreased when geopolymer concrete was used and the reduction indicated less water requirement of geopolymer concrete. It is further to note that minimum decrease in standard consistency of 23.33% was observed i.e. from 30% to 23%. However, the decrease for geopolymer concrete was not that significant so that a relationship between standard consistency and salt concentration of activator can be inferred.

From the above data, it can be concluded that M14 (1:2.5) has lowest setting time. This decrease in initial and final setting times may be due to increased concentration of active silica solution.

M8 (1:1) has highest setting time. Cement has lowest setting time as compared to all the activators. It can be seen from the data presented in graph that the IST & FST higher setting time of M8 solution. However, there was decrease in IST & FST as the salt concentration increased. The setting time of solution of concentration M14 had IST & FST less than the M8 and M10 activator. It is further to note that increase in IST & FST of 48 min & 1300 min was observed i.e. from cement –128 min. & 240 min. to M14 (1:2.5) –176 min. & 1540 min. IST & FST increased by 60 min. & 1350 min. i.e. from conventional cement – 128 min. & 240 min. to M14 (1:1.5) –188 min. & 1590 min. IST & FST increased by 82 min. & 1380 min. i.e. from conventional cement –128 min. & 240 min. to M14 (1:1) – 210 min. & 1620 min. Similar trend was observed in case of alkaline activators.

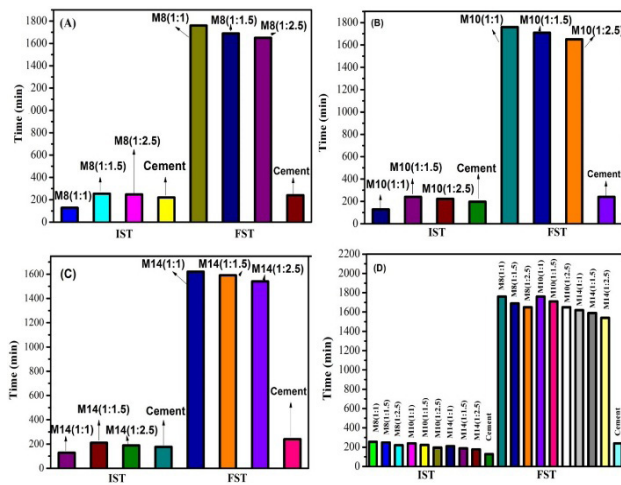


Figure 2(A). IST and FST of M8 and cement (B) IST and FST of M10 and cement (C) IST and FST of M14 and cement and (D) Comparison of IST and FST of with the molar concentration and cement.

3.2 Initial (IST) and Final Setting Times (FST)

The conventional cement concrete and fly ash based geopolymer concrete were tested for the initial and final setting time and the results obtained are shown in Figure 2.

It can be seen from the data presented graph that the initial and final setting times increased significantly in case of geopolymer cement when compared with OPC cement. It can further be seen from the graphs that the initial and final setting time decreased as the concentration of the sodium hydroxide increased from M8 to M14.

3.3 Compressive Strength

The compressive strength has been found by using compression testing machine. Three cubes of 70.6mm size were cast for each solution. These cubes were tested after 28 days in dry saturated surface condition. The result obtained has been shown in Figure 3. The compressive strength of all activators and cement has been compared.

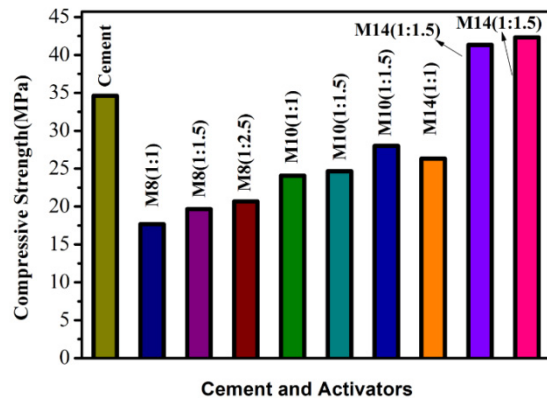


Figure 3. Compressive Strength Curve for the variable molar concentrations.

It can be seen from the data presented in the graph below that the compressive strength decreased initially for the cubes which were cast with M8 solution. However, there was increase in compressive strength as the salt

concentration increased. Compressive strength was less by 48.95% for the cubes cast with M8(1:1) as compared to cubes cast with conventional cement. M8(1:2.5) Cubes with activator M8(1:1.5) had less compressive strength by 43.17% as compared with conventional concrete. Cubes with activator M8(1:1.5) had less compressive strength by 40.18% as compared with conventional concrete. A similar trend of decrease in compressive strength was observed with activator M10. The compressive strength continued to decrease even with M14(1:1) where the compressive strength was less by 23.92% as compared to conventional cement. However, compressive strength increased at higher concentration of M14(1:1.5) and M14(1:2.5) as activators. The compressive strength was higher by 16.26% as compared to conventional cement. It was further higher by 18.24% for activator M14(1:2.5).

The increase in compressive strength at M14(1:1.5) showed that there was optimum concentration of sodium silicate solution which makes inert silica reactive in fly ash and therefore the compressive strength after this concentration was higher in conventional concrete.

4. Conclusion

Based upon the above study following conclusions can be concluded:

- The consistency of cement is highest as compared to the fly ash with solutions of M8, M10 and M14. Therefore, the water requirement of geopolymer cement is less than OPC cement.
- The initial and final setting times were highest for the cubes cast with M8. This showed that the geopolymer cement can be placed comfortably when compared with OPC cement.
- Compressive strength obtained for geopolymer cement was comparable with OPC cement and significantly higher for the cubes cast using M14. The compressive strength increased with the salt concentration of Na_2SiO_3 .

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