Parametric Study of Geopolymer Concrete with Fly ash and Bottom ash activated with Potassium Activators

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ABSTRACT: Ordinary Portland cement is widely used cementitious material but is not eco-friendly. On the other hand industrial waste like Fly ash and Bottom ash needs to be effectively used as they are produced in large volume. In the present study, a concrete is produced by fully replacing Portland cement with Fly ash and Bottom ash. Theses source materials need to be activated by alkaline solutions. The alkaline liquids used in this study are the solutions of Potassium Hydroxide and Potassium Silicate. Ambient curing technique was adopted which allows it to be used in practical purpose. Parametric study was carried out to evaluate effect of different parameters on compressive strength of geopolymer concrete. After achieving required compressive strength, it was also checked for split tensile strength and flexure strength and result were slightly lower compared to Ordinary Portland cement of same grade of concrete.

1 INTRODUCTION

It is well known fact, that the production of Ordinary Portland cement (OPC) not only consumes significant amount of natural resources and energy but also releases substantial quality of carbon dioxide(CO_2) to the atmosphere. The amount of the carbon dioxide released during the manufacturing of OPC is due to the calcination of limestone and combustion of fossil fuel and is in the order of one ton of CO_2 for every ton of OPC produced(Malhotra 2000). Thus, it is essential to find alternatives to make environment friendly concrete. Bottom ash and Fly ash are by-products of the combustion of pulverized coal in power plants. Fly ash is discharged in the precipitators and is obtained from the top of power plant while bottom ash is coarser product and is generally discharged in the pond when washing off the residual ash is done. Presently only 50 % of Fly ash is used while rest is dumped as landfill, while use of bottom ash is very limited as it has large amount of unburnt coal particles and is dumped as landfill (Xie and Ozbakkaloglu 2015). Generally, bottom ash has a large particle size and a high porous surface, resulting in higher water requirement and lower compressive strength. In Geopolymer concrete, cement is totally replaced by any source material which is rich in silica (Si) and the alumina (Al) and is made to react with binders which may be potassium or sodium based. These source materials and binders react to form a chain like polymers known as geopolymer and bind the materials. (Davidovits 1991). Geopolymerisation generally requires temperature for binding reaction.

2 RESEARCH SIGNIFICANCE

Lot of studies has been carried out using on geopolymer concrete with fly ash as source material and it is found to have excellent mechanical and durability properties like acid resistance, heat resistance, sulfate attack and abrasion resistance (Hardjito et al. 2004, Kovalchuk et al. 2007). However, use of bottom ash is restricted in alkali activated concrete due to its particle size. Also alkali activated concrete gives very good compressive strength at early age when temperature is applied. However, studies applying ambient curing are limited in nature. Therefore, attempt was to study the parameters affecting mix design using ambient curing and using Potassium Hydroxide (KOH) and Potassium Silicate (K_2SiO_3) as activators.

3 MATERIALS AND PREPARATION

3.1 **Materials**

Low calcium, class F fly ash and bottom ash both obtained from Thermal power plant, Gandhinagar were used in this study. Table 1, shows chemical composition of fly ash and bottom ash. Locally available 10 mm and 20 mm crushed aggregates have been used as coarse aggregates while locally available river sand was used as fine aggregate for concrete casting. Tests on both aggregates were conducted as per IS: 2386 and IS: 383 respectively and corrections for moisture content and water absorption were carried out. Alkaline activators used were combination of KOH andK_2SiO_3. KOH which was procured from local market in flakes form and K_2SiO_3 used was in thick & sticky solution form with ratio of SiO_2 / K_2O of 2.02 and specific gravity of 1.39.

3.2 **Preparation of Alkaline Solution and concrete**

Alkaline solution includes the particular molar of KOH which was diluted in the water mixed with the K_2SiO_3. The amount of K_2SiO_3 was decided based on the KOH to K_2SiO_3 ratio. Solution for the geopolymer concrete was prepared one day before by dissolving the KOH flakes in the tap water available in the laboratory. The mass of KOH depends on its molarity used in mixture.Since geopolymer concrete does not have code for mixture design, density method was used to design the concrete ingredient. Method suggested by Hardjito et al. (2004) was used to design the mix assuming density of concrete as 2400 kg/m^3. Variation on parameters was done as discussed in parametric study to evaluate the effect of each parameter on compressive strength. First both coarse aggregate and fine aggregate were mixed in pan mixture for four to five minutes. After this, addition of source material in form of fly ash and bottom ash was done and dry mixing was further carried out for 3 -4 minutes. Alkaline solution and extra water was added to the mix and further mixing was done to obtain a homogenous concrete. Subsequently the concrete was poured in the moulds and compacted by means of vibration table. Concrete was removed from the moulds after rest period of two days and then cured at ambient curing.

Table 1: Chemical Composition of Materials

Sr No.	Properties	Unit	Fly Ash	Bottom Ash
1	Colour	-	Light Grey	Grey
2	SiO_2	%	61.44	60.48
3	Al_2O_3	%	31.80	32.16
4	CaO	%	1.20	1.04

4 PARAMETRIC STUDY

Control concrete of M 25 grade with OPC cement was cast and Table 2, gives mixture design constituents based on IS:10262. Initially variation was done in proportion of fly ash and bottom ash. It was found that increase in bottom ash lead to decrease in compressive strength as bottom as is more porous in nature. To utilize bottom ash most effectively as it was not utilized in construction, optimum dosage of fly ash and bottom as was obtained. It was found that equal proportion of bottom ash and fly ash gave compressive strength for M 25 mix design. For parametric study, trial mixes were carried out by varying molarity, different ratio of alkaline liquid and ratio of alkaline to cementitious material as shown in Table 3.

Table 2: Mix proportion for OPC Concrete

Material	Unit	Content
Cement	kg/m^3	334
Water	kg/m^3	167
Coarse Aggregate	kg/m^3	1146
Fine Aggregate	kg/m^3	883

Table 3: Trial Mixes for Geopolymer Concrete

Mix	Fly Ash (%)	Bottom Ash (%)	Molarity	K_2SiO_3/KOH	Alkaline to cementi-tious material ratio
Mix-1	50	50	12	1	0.5
Mix-2	50	50	10	1	0.5
Mix-3	50	50	8	1	0.5
Mix-4	50	50	12	1.5	0.5
Mix-5	50	50	12	1	0.55
Mix-6	50	50	12	1.5	0.55

5 RESULTS AND DISCUSSIONS

5.1 Effect of Different Molarity of KOH Solution

The compressive strength results of Mix 1, Mix 2 and Mix 3 are shown in Figure 1. The Molarity of KOH was varied from 12 M to 8 M. It was observed that, with decrease in molarity the compressive strength of geopolymer concrete at 7, 14 and 28 days also decreased. This was due to less alkaline solution available to react with source material leading to decrease in strength.

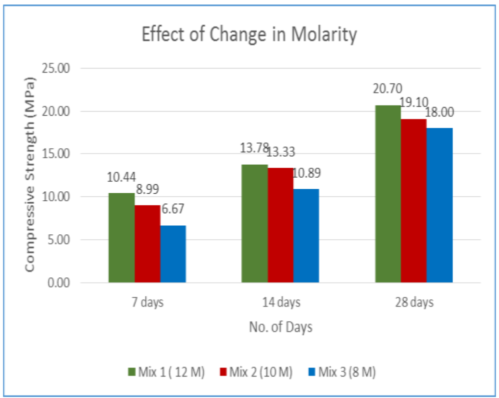


Figure 1: Effect of different Molarity

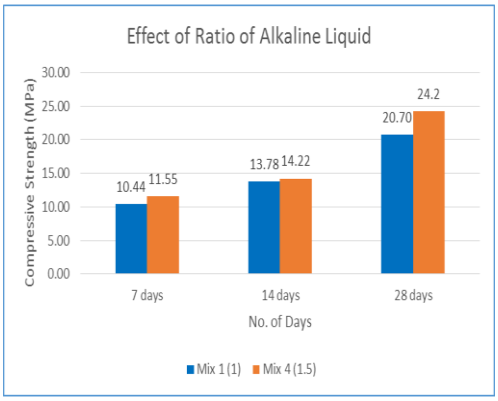


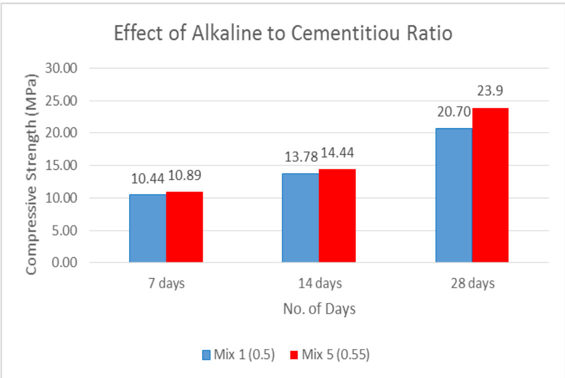
Figure 2: Effect of change in Alkaline Liquid Ratio

5.2 Effect of Different ratio of Alkaline Liquid (K_2SiO_3/KOH)

Figure 2, shows comparison of compressive strength with different ratio of alkaline liquids at 7, 14 and 28 days. As the alkaline liquid ratio increased from 1 to 1.5, increase in compressive strength was observed as higher amount of K_2SiO_3 liquid was available for reaction with source material, which increased the compressive strength.

5.3 Effect of Different ratio of Alkaline to Cementitious Material

Increase in ratio of alkaline liquid to cementitious material from 0.5 to 0.55 in Mix 1 and Mix 5, increases compressive strength at 7, 14 and 28 days as shown in Figure 3. Increase in compressive strength was due to more amount of K_2SiO_3 which increases viscosity in the material helping to bind material better and increasing the strength.



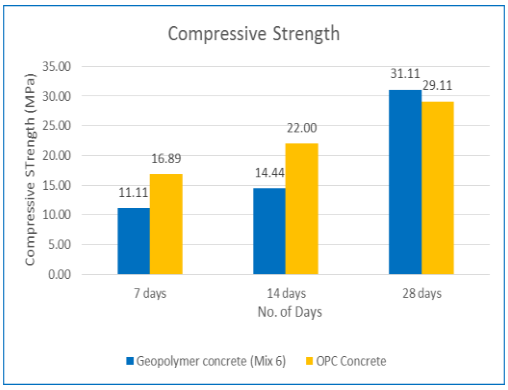


Figure 3: Effect of Alkaline to Cementitious Material **Figure 4: Comparison of OPC & Geopolymer concrete**

6 MECHANICAL PROPERTIES

Variation was done in dosage of super plasticizer and amount of extra water added for workability purpose and Mix 6 was arrived which achieved target strength. Figure 6, shows compressive strength at various ages for OPC concrete and geopolymer concrete at various ages. At 28 days the split tensile strength of geopolymer concrete was 2.78 MPa while OPC concrete was 2.84 MPa. While flexure strength of geopolymer concrete was 3.4 MPa and that of OPC was 3.8 MPa. Thus both strength were higher for OPC concrete compared to geopolymer concrete, though the difference was small.

7. CONCLUSION

It can be concluded that bottom ash and fly ash combination can be used to prepare medium strength alkali activated concrete. It can also be found that increase in molarity increases the strength. Similarly increases in ratio alkaline to cementitious material and ratio of alkaline activator also increases the compressive strength. Due to ambient curing, strength was achieved gradually and increased from 7 days to 28 days. While split tensile strength and flexural strength of geopolymer concrete was 2.11% and 10.5% less than OPC concrete. Thus though, slight lower strength was obtained at compared to OPC in flexure and split tensile strength, compressive strength was approximate same. This implies that for medium strength concrete ambient cured geopolymer concrete with equal proportion of fly ash and bottom ash be used as strength criteria is satisfied and it is very sustainable. Ambient curing technique makes it application more easy and can be readily applied in field without any specific requirements.

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