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Comparison of Compressive Strengths for Different Alkaline Liquid to Binder Ratio on Geopolymer Concrete under Ambient Curing

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Abstract
The geopolymer concrete is an environmental friendly material in the sense that it uses the industrial by products such as Ground Granulated Blast furnace Slag and Fly Ash, along with alkaline activated solutions. The commonly used combination of alkaline activator solution is NaOH and Na_2SiO_3. The silica byproducts form with alkaline solution a binder matrix to bind aggregate in the mixture and to produce the hardened concrete. 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 materials required for Geopolymer Concrete may be chosen by their availability, cost and other structural requirements. The mixture of Sodium hydroxide and Sodium Silicate is usually employed as alkaline activator for the Geo-polymerization. In this study alkaline to binder ratio is used 0.3 and 0.35, and mass of sodium silicate to sodium hydroxide as 2.5, total combined aggregate is considered as 70% for molarity of NaOH is 8, partially replaced fly with GGBS is 40% with an increment of 10% and under ambient curing condition. The investigations are carried out for compressive strength, flexural strength and split tensile strength.
Key Words: Geopolymer Concrete (GPC), Ground Granulated Blast Furnace Slag(GGBS), Fly ash, Sodium silicate, Sodium hydroxide, Alkaline activators (ALA),Alkaline activator to binder (ALA/B) ratio, Ambient curing.

1. Introduction:

Use of alkaline liquid could be used to react with silicon (Si) and aluminum (Al) is proposed by Davidovits (1988), these source materials are available in class F fly ash is by product of combustion of bituminous coal, silicon and aluminum because these are react with alkaline liquids are sodium silssicate and sodium hydroxide in this case is a polymerization process, he stated that term 'Geopolymer' to represent the binders. The chemical composition of Geopolymer materials is similar to zeolite, but they divulge an amorphous microstructure. During the synthesized process, silicon and aluminum atoms are combined to form the building blocks that are chemically and structurally comparable to those binding the natural rocks. Barbosa et al. (2000) reported that Metakaoline or calcined kaolin is a possible source material for the manufacture of Geopolymer. The most common alkaline liquid used in Geopolymerization is a combination of potassium hydroxide (KOH) or sodium hydroxide (NaOH) and potassium silicate or sodium silicate. Calcined source materials such as fly ash, slag, calcined kaolin show a higher final compressive strength when compared to non-calcined materials such as instance kaolin clay, mine tailings, and naturally occurring minerals. In this study, partially replacement of fly ash with GGBS upto 40% with an increment of 10%. In Geopolymerization, alkaline solution plays an important role. Fly ash is usually mixed with alkali solution to obtain alumina and silica precursors. When it comes into contact with alkali solution, dissolution of silicate species starts according to Comrie&Kriven 2003[2]. The type and concentration of alkali solution affect the dissolution of fly ash. Leaching of Al3+ and Si4+ ions are generally high with sodium hydroxide solution compared to potassium hydroxide solution, Van Jaarsveld& Van Deventer (1999) and Xu & Van Deventer (1999) [8]. Therefore, alkali concentration is a significant factor in controlling the leaching of alumina and silica from fly ash particles, subsequent Geopolymerization and mechanical properties of hardened geopolymer. The most common alkaline solution used in Geopolymerization is a combination of sodium hydroxide or potassium hydroxide and sodium silicate or potassium silicate, Hardjito&Rangan (2005)[5]. Reactions occur at a high rate when the alkaline liquid contains soluble silicate, either sodium or potassium silicate, compared to the use of only alkaline hydroxides confirming that the addition of sodium silicate solution to the sodium hydroxide solution as the alkaline liquid enhances the reaction between the source material and the solution. Due to the high cost of potassium based chemicals sodium based silicates and hydroxides are used in this research.Aliabdo et al [1] concluded that the increasing alkaline solution to fly ash ratio improves fly ash based GPC properties [3,4]. The optimum alkaline solution to fly ash ratio is 0.40. PradipNath et al [7], proven that the low-calcium fly ash was blended with GGBFS up to 15%, OPC up to 8% and calcium hydroxide (CH) up to 3% in order to accelerate setting at ambient condition.Davidovits et al. [3,4] used ground blast furnace slag to produce geopolymer binders. According to their research findings.Most of the research done in the past on strength of concrete with partial replacement of fly ash with GGBS is keeping 10 to 40 % with an increment of 10%, Hence, in this paper, it is proposed to investigate the effect on alkaline to binder ratio as 0.3,0.35, and 0.4.

2. Experimental Program:

2.1 Materials used inGPC:

2.11 Fly Ash:

The composition of fly ash (collected from Vijayawada Thermal Power Station): SiO_2 is 53.80%, Al_2O_3 is 21.20%, Fe_2O_3 is 17.00%, CaO is 0.92%.

2.12 Ground Granulated Blast Furnace Slag (GGBS):

GGBS is a glassy, granular material, obtained by quenching molten iron slag from a blast furnace in water or steam in the production of pig iron. The main components of GGBS are CaO (calcium oxide) is 36.3, SiO_2 (silicon oxide) is 34.83 and Al_2O_3 (aluminum oxide) is 15.6.The calcium oxide available in GGBS undergoes hydration process in concrete to form C-S-H gel which is the cementitious phase in concrete that improves the strength and setting properties of the concrete.

2.13Fine Aggregate:

River sand is used, and it is free from clay. Specific gravity is 2.64, Fineness modulus is 2.65, water absorption is zero, bulk density loose and compacted are 1628 kg/m^3 and 1690.4 kg/m^3 respectively.

2.14Coarse Aggregate:

The size of the coarse aggregate used for this study between 20 mm and 4.75 mm, with a specific gravity of 2.67, Fine modulus is 7.09, bulk density loose and compacted are 1605 kg/m^3 and 1673 kg/m^3.

2.15Super Plasticizer:

Conplast SP 430 which is manufactured by FOSROC is used with specific gravity of 1.2 at 20℃.

2.16Alkaline Activators (AAB):

The alkaline liquid used was a combination of sodium silicate solution and sodium hydroxide solution, the molarity of NaOH is 8, alkaline to binder ratio is 0.3 and 0.35.

2.17 Ambient Curing condition:

Test specimens are kept 28 for ambient curing only.

3.0 Mix Proportion:

Based on the limited past research on GPC specified by Hardjito&Rangan, 2005 [5], the following proportions were selected for the constituents of the mixtures, Assume that normal-density aggregates in SSD (Saturated surface Dry) condition are to be used and the unit-weight of concrete is 2400 kg/m^3 . In this study, the mass of combined aggregates considered as 70%,partially replaced with GGBS is taken as 10%, 20%, 30% and 40%, alkaline to binder ratio is 0.3 and 0.35, Mass of Fly Ash +GGBS is 387.69 kg/m^3 and 373.33 kg/m^3 for AAB 0.3 and 0.35 respectively. Mass of Na_2SiO_3 to NaOH are 2.5 and 3.0 i.e 33.23 kg/m^3 , 37.33 kg/m^3 and 83.08 kg/m^3 , 93.34 kg/m^3 respectively.According to N A Lioyd and B V Rangon[7] the mix proportion is prepared based.

4.0 Testing of specimens:

The concrete cube specimens are capped at both ends to ensure smooth surfaces and tested for compressive strength at the age of 28 days. The reported results are the average of three concrete samples.

3. RESULTS AND DISCUSSIONS

The results of compressive strength of GPC given in Figure 4.1 and Table 4.1 explains the increase in compressive strength of 42%of GGBS, combined aggregate 70%, alkaline liquid to binder ratio is 0.3 and mass of Na_2SiO_3 to NaOH is 2.5, 3.0, 3.5

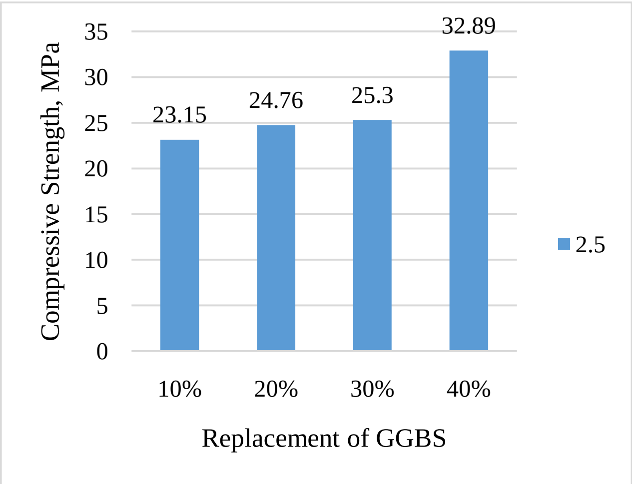

Figure 4.1 Compressive Strength for alkaline liquid to binder ratio is 0.3 and mass of Na_2SiO_3 to NaOH ratio = 2.5.

Table 4.1 Compressive Strength for alkaline liquid to binder ratio is 0.3 and mass of Na_2SiO_3 to NaOH ratio = 2.5

S.No	% of GGBS	Compressive Strengths for various alkaline liquid ratio	Percentage increase in Compressive Strengths for various alkaline liquid ratio
		2.5	2.5
1	10%	23.15	-
2	20%	24.76	07
3	30%	25.30	09
4	40%	32.89	42

Figure 4.2 and Table 4.2 explains the increase in compressive strength of 32% for 40 % of GGBS, combined aggregate 70%, alkaline liquid to binder ratio is 0.35 and mass of Na_2SiO_3 to NaOH is 2.5

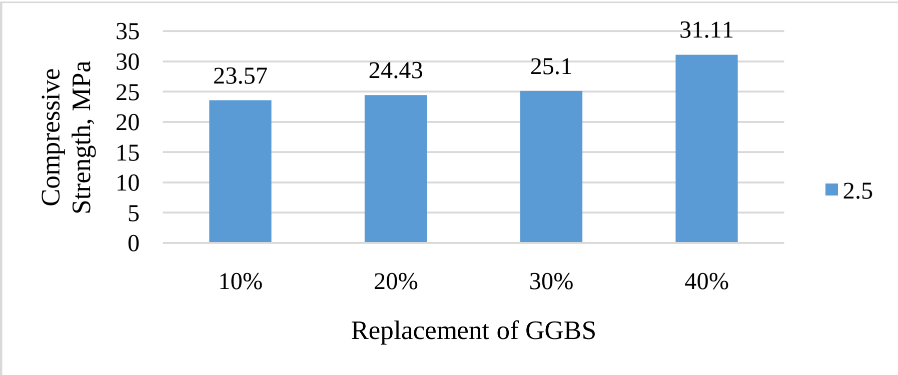

Figure 4.2 Compressive Strength for alkaline liquid to binder ratio is 0.35 and mass of Na_2SiO_3 to NaOH ratio = 2.5

Table 4.2 Compressive Strength for alkaline liquid to binder ratio is 0.35 and mass of Na_2SiO_3 to NaOH ratio = 2.5

S.No	% of GGBS	Compressive Strengths for various alkaline liquid ratio	Percentage increase in Compressive Strengths for various alkaline liquid ratio
		2.5	2.5
1	10%	23.57	-
2	20%	24.43	04
3	30%	25.10	06
4	40%	31.11	32

4. CONCLUSIONS

The compressive strength is higher for alkaline liquid to binder ratio is 0.3 compared with alkaline liquid to binder ratio is 0.35.

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