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Study on Strength of Geopolymer Concrete in Ambient Curing

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ABSTRACT

Geopolymer concrete technology has the potential to reduce globally the carbon emission and lead to a sustainable development and growth of the concrete industry. The influence of alkaline activators on the strength and durability properties has been studied. Sodium Hydroxide is available in plenty and Sodium hydroxides, both were added by the 1:2.5 ratio as alkaline activators along with sodium silicate at varying temperature in the preparation of geopolymer concrete. Fly ash was procured from a local thermal power station. Durability test were performed. The results indicate that the combination of the above constituents at ambient curing has a positive impact on the strength and durability properties of geopolymer concrete.
Keywords : Geopolymer, concrete, fly ash, alkaline solution, ambient curing, durability test.

I. INTRODUCTION

Geopolymer

Portland cement is the most used material in the worldwide construction industry. It has a high level of CO_2(Production 1 ton of cement generates 1 ton of CO_2) and also its use tends to become less competitive compared to alternative ecological new binders like geopolymer . Although research in this field has been published as "alkali-activated cement, or "alkaline cement" the term "geopolymer" is the generally accepted name for this technology.

Geopolymerisation involves a chemical reaction between various aluminosilicate oxides with silicates under highly alkaline conditions, yielding polymeric Si–O–Al–O bonds indicating that any Si–Al materials could become sources of geopolymerization. Geopolymer binders are used together with aggregates to produce geopolymer concrete which are ideal for building and repairing infrastructures and for precasting units, because they have very high early strength, their setting times can be controlled and they remain intact for very long time without any need for repair. The properties of geopolymer include high early strength, low shrinkage, freeze-thaw resistance, sulphate resistance and corrosion resistance. These high-alkali binders do not generate any alkaline aggregate reaction. The geopolymer binder is a low-CO_2 cementious material. It does not rely on the Calcination of limestone that generates CO_2.

II. METHODS AND MATERIAL

Experimental Investigations

2.1 Materials

The following materials have been used in the experimental study

a) Fly Ash (Class F) collected form Mettur Thermal power plant having specific gravity 2.00.
b) Fine aggregate: Sand confirming to Zone –III of IS:383-1970 having specific gravity 2.51 and fineness modulus of 2.70.
c) Coarse aggregate: Crushed granite metal confirming to IS:383-1970 having specific gravity 2.70 and fineness modulus of 5.85.
d) Water : Clean Potable water for mixing
e) Alkaline liquids: Specific gravity of
i) Sodium Hydroxide (NaOH) = 1.16
ii) Sodium Silicate (Na2SiO3) = 1.57 Tests were conducted on specimen of standard size as per IS: 516-1959 and IS: 5186-1999.

2.2 Mix Design of Geopolymer Concrete

In the design of geopolymer concrete mix, coarse and fine aggregates together were taken as 77% of entire mixture by mass. This value is similar to that used in OPC concrete in which it will be in the range of 75 to 80% of the entire mixture by mass. Fine aggregate was taken as 30% of the total aggregates. The density of geopolymer concrete is taken similar to that of OPC as 2400 kg/m3 [12]. The details of mix design and its proportions for different grades of GPC are given in Table 2.

2.3 Alkaline Solution

In geopolymerization, alkaline solution plays an important role. The most common alkaline solution used in geopolymerization is a combination of sodium hydroxide (NaOH) or potassium hydroxide (KOH) and sodium silicate (Na2SiO3) or potassium silicate (K2SiO3). In this study, a combination of sodium hydroxide and sodium silicate was choosen as the alkaline liquid. Sodium based solutions were choosen because they are cheaper than Potassium based solutions. Generally sodium hydroxide and sodium silicate are readily available in market in the form of pellets and gel (liquid).

2.4 Preparation, Casting and Curing of Geopolymer Concrete

The alkaline activator solution used in GPC mixes was a combination of sodium hydroxide solution, sodium hydroxide pellets and distilled water. The role of AAS is to dissolve the reactive portion of source materials Si and Al present in fly ash and provide a high alkaline liquid medium for condensation polymerization reaction. To prepare sodium hydroxide solution of 8 molarity (8M), 320 g of sodium hydroxide flakes was dissolved in water. The mass of NaOH solids in a solution will vary depending on the concentration of the solution expressed in terms of molar, M. The pellets of NaOH are dissolved in one liter of water for the required concentration. When sodium hydroxide and sodium silicate solutions mixed together polymerization will take place liberating large amount of heat, which indicates that the alkaline liquid must be used after 24 hours as binding agent.

The liquid component of the mixture is then added to the dry materials and the mixing continued usually for another four minutes. The addition of sodium silicate is to enhance the process of geopolymerization .For the present study, concentration of NaOH solution is taken as 8M with varying ratio of Na2SiO3 / NaOH as 2, 2.5, 3 and 3.5 for all the grades of GPC mixes. The workability of the fresh concrete was measured by means of conventional slump test.In order to improve the workability, superplasticizer Conplast SP-430 with a dosage of 1.5% by mass of the fly ash was added to the mixture. Extra water (other than the water used for the preparation of alkaline solutions) and dosage of super plasticizer was added to the mix according to the mix design details. The fly ash and alkaline activator were mixed together in the mixer until homogeneous pate was obtained. This mixing process can be handled within 5 minutes for each mixture with different ratios of alkaline solution. Heat curing of GPC is generally recommended, both curing time and curing temperature influence the compressive strength of GPC. After casting the specimens, they were kept in rest period for two days and then they were demoulded. The demoulded specimens were kept at ambient curing for 24 hours.

2.5 Wrapping Curing

The casted specimens were wrapped by the polythene paper below 3microns. Generally geopolymer has high strength in steam curing but for heavy structures it is not convenient hence wrapping is tested. By covering the specimens it will have direct contact with the atmosphere and moreover due to exothermic process the heat is reproduced inside the polythene paper and results in obtaining strength earlier.

Figure 1. Wrapping Curing

III. RESULTS AND DISCUSSION

3.1 Effect of ratio of sodium hydroxide to sodium silicate solution

The effect of ratio of sodium hydroxide to sodium silicate solution by mass on the compressive strength of concrete can be seen by comparing the results. For these grades the concentration of sodium silicate solution (in terms of molarity), the water content, the fly ash content and the condition of curing were kept constant. The ratio was varied from 2 to 3.5, in the increment of 0.5. the average maximum strength was obtained when the ratio was 2.5.

3.2 Compression strength test

Compressive strength test was carried out in concrete cubes of size 100X100X100mm using 1:1:2 mix with w/c ratio of 0.45. Specimens with ordinary Portland cement concrete (control) were removed from the mould after 24h and subjected to water curing for 1,3,7, 14 , 28and 56 days**.** Compression test was carried out on the specimens after 7 and 28 days of curing. The test should be carried out as per codal provision IS: 516-1959. The average compressive strength test results for 7 and 28 days testing are given in table 5.1. The compressive strength calculated as

fck = P/A

The results tested are below.

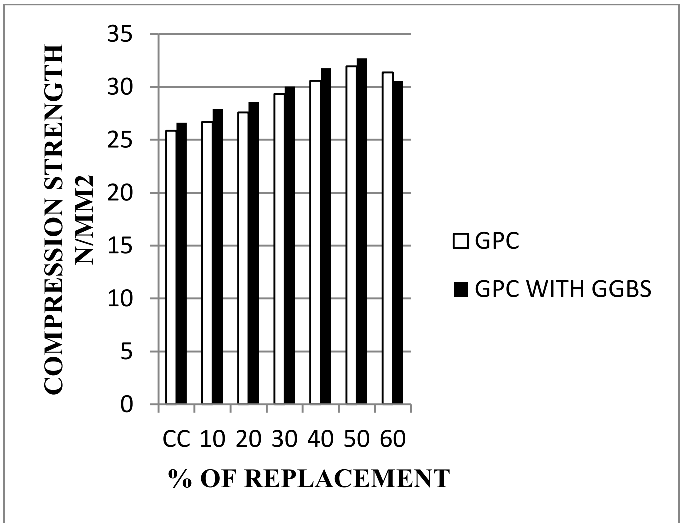

Figure 2. Average Compressive strength for all replacement IN CURING after 7days.

3.3 Split tensile strength test

The test is carried out by placing cylindrical specimens (100mm diameter and 200 mm height) horizontally between the loading surfaces of a compression testing machine and the load applied until failure of the cylinder, along the vertical diameter. The test should be carried out as per codal provision IS: 516-1959. The average split tensile strength test result for 7 days and 28 days testing's are given in table 5.2. The split tensile strength test diagram is given in fig. 5.3.

Calculation of Tensile strength of specimen

Tensile strength of specimen was calculated by the following formula,

Tensile stress = 2P/πDL N/mm2

Where, P is applied load,

D is the diameter and length of cylinder,

L is the length of cylinder

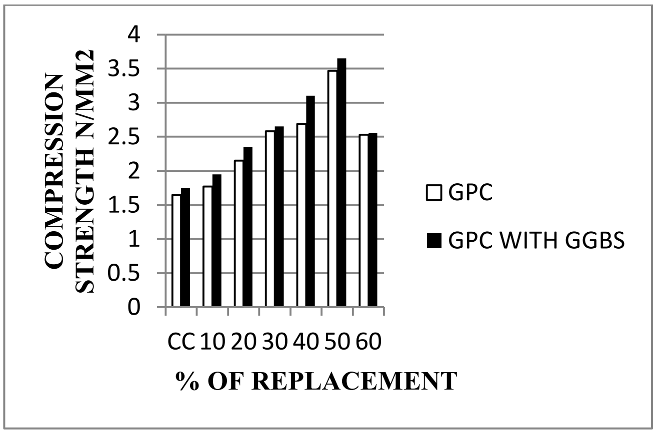

Figure 3. Average Split Tensile strength for all replacement IN CURING after 7days

3.4 Flexural strength test

The steel moulds of size 100 x 100 x 500 mm were used for casting the beam specimens. The simply supported beams were loaded at 1/3rd points keeping the span as 400 mm and were tested on a Universal Testing Machine of 400 kN capacity. The average flexural strength test result for 7 days and 28 days testing are given in table 5.3. The flexural strength test diagram is given in fig. 5.5. Flexural strengths based on the ultimate load and the flexural strength is calculated using the formula.

Flexural strength = Pl/bd^2 N/mm2

Where, P is applied load, b&d are the cross sectional dimensions l is c/c distance between the supports

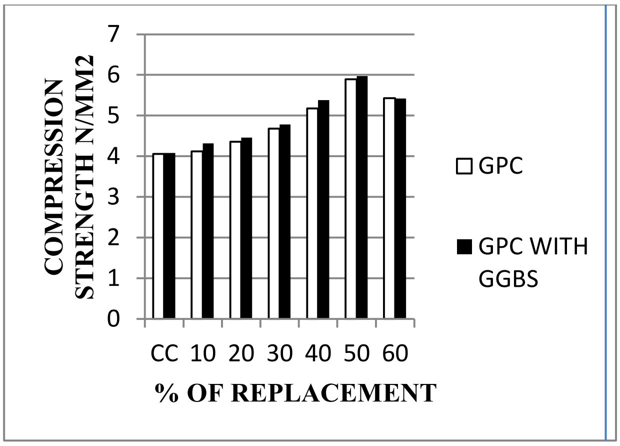

Figure 4. Average Flexural strength for all replacement IN CURING after 7days

IV. CONCLUSION

Based on the experimental investigations done the following conclusions can be drawn:

1. For any grade of GPC, as ratio of alkaline solution increases, the workability of mix goes on increasing.
2. The study showed that the strength of geopolymer concrete can be improved by decreasing the water/binding and aggregate/binding ratios. It was observed that water influences the geopolymerization process and the hardening of concrete. Inclusion of increased binder content enhances the geoplymerization and affects the final strength.
3. The optimum dosage for alkaline solution, which is used a geopolymer binder can be considered as 2.5, because for this ratio, the GPC specimens of any grade produced maximum strength results with compression and tension.
4. The fly ash can be used to produce geopolymeric binder phase which can bind the aggregate systems consisting of sand and coarse aggregate to form geopolymer concrete (GPC). Therefore these concretes can be considered as eco-friendly materials.

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