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A Study on Effect of Curing Condition & Molarity Concentration on Geo-polymer Concrete.

KEYWORDS

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ABSTRACT Geoplolymer was first introduced to the world by Joseph Davidovits in 1978, the name given to this kind of polymer is because, raw materials used in the synthesis of silicon-based polymers are mainly rock-forming minerals of geological origin; hence the name is given "geopolymer". Geopolymer used in concrete instead of cement is made of rich aluminium and silicon material with alkali activator and water.

Geopolymer is a class of aluminosilicate binding materials synthesized by thermal activation of solid aluminosilicate base materials such as fly ash, metakaolin, Ground Granulated Blast Furnace Slag etc., with an alkali metal hydroxide and silicate solution. The geopolymer was activated with sodium hydroxide, sodium silicate and heat. This paper presents the experimental investigation done on the variation of alkaline solution on mechanical properties of geopolymer concrete. The grades chosen for the investigation were M-20, M-40 and M-60; the mixes were designed for 8 & 16 molarity. The alkaline solution used for present study was the combination of sodium silicate and sodium hydroxide solution with the varying ratio of 2 & 2.50. The test specimens were 150x150x150 mm cubes and 100x200 mm cylinders heat-cured at 60°C in an oven.

INTRODUCTION

Concrete is one of the most widely used construction materials; it is usually associated with Portland cement as the main component for making concrete. The demand for concrete as a construction material is on the increase. It is estimated that the production of cement will increased from about from 1.5 billion tons in 1995 to 2.2 billion tons in 2010, and still increasing rapidly in now days.

Concrete, as a major construction material, is being used at an ever increasing rate all around the world. Almost all of this concrete is currently made using OPC, leading to a massive global cement industry with an estimated current annual production of 2.8 billion tonnes [2] and increasing by 3% annually [3]. OPC production is an extremely energy-intensive process, and therefore there has been a significant push in the past two decades to develop alternative binders, other than OPC, to make concrete. This has largely been due to the requirement to address the environmental effects associated with OPC concrete. Although the use of Portland cement is still unavoidable until the foreseeable future, many efforts are being made in order to reduce the use of Portland cement in concrete. These efforts include the utilisation of supplementary cementing materials such as fly ash, silica fume, granulated blast furnace slag, rice-husk ash and metakaolin, and finding alternative binders to Portland cement. CO_2 emission during manufacture the manufacture of portland cement clinker involves the calcination of calcium carbonate according to the reaction:

$$5CaCO_3 + 2SiO_2 \rightarrow (3CaO, SiO_2)(2CaO, SiO_2) + 5CO_2$$

The production of 1 tonne of portland clinker directly generates 0.55 tonnes of chemical-CO_2 and requires the combustion of carbon-fuel to yield an additional 0.40 tonnes of carbon dioxide. Hence, 1 tonne of Portland cement produces 0.95 tonne of carbon dioxide. On the opposite, geopolymer cements do not rely on calcium carbonate and generate much less CO_2 during manufacture, i.e. a reduction in the range of 40% to 80-90%.

Materials Used:

All materials is given approximate percentage for 1 cubic meter of Geopolymer concrete.

Fly ash: (13-16%): Low calcium dry fly ash Containing 80% silicon and aluminum constitutes.

Alkaline liquid: (7-10%): Contribution of sodium silicate solution, and sodium hydroxide solution.

Aggregates: (75-80%): Local coarse aggregates like 20 mm, 14mm, 7mm and fine aggregates in saturated surface dry condition.

Super plasticizer: (0.2-0.4%): To improve workability , high range water reducing naphthalene based or for fly ash carbon based super plasticizer is used.

Water (0.5-1%): To improve workability or to maintain the ratios which affect strength, Pure potable water having ph near to 7.

Preparation of alkaline liquids:

The alkaline solutions used in this study were sodium hydroxide in flake form (NaOH with 98 % purity) dissolved in water and sodium silicate solution (Na_2O=14.7%, SiO_2=29.4%, and water=55.9%). Both the solutions were mixed together and the alkaline liquid was prepared;

1 - Sodium hydroxide

Sodium hydroxide pellets are taken and dissolved in the water at the rate of 16 molar concentrations. It is strongly recommended that the sodium hydroxide solution must be prepared 24 hours prior to use and also if it exceeds 36 hours it terminate to semi solid liquid state. So the prepared solution should be used within this time. But different

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timings were tried like 4 hours before using and 3 hours before use of chemicals were experimented, although no difference is noted.

2 - Molarity calculations

The solids must be dissolved in water to make a solution with the required concentration. The concentration of Sodium hydroxide solution can vary in different Molar. The mass of NaOH solids in a solution varies depending on the concentration of the solution. For instance, NaOH solution with a concentration of 16 Molar consists of 16 x 40 = 640 grams of NaOH solids per litre of the water, were 40 is the molecular weight of NaOH. Note that the mass of water is the major component in both the alkaline solutions. The mass of NaOH solids was measured as 444 grams per kg of NaOH solution with a concentration of 16 M. Similarly, the mass of NaOH solids per kg of the solution for other concentrations was measured as 8 Molar: 262 grams, 10 Molar: 314 grams, 12 Molar: 361 grams, and 14 Molar: 404 grams [4].

Manufacture of Test Specimens:

Here ACI classified class F low calcium contained flyash is used as the rich source of the aluminium and silicates, whereas NaOH and Na2SiO3 are used as the alkali activator and alkali solution respectively, with some amount of potable water.

First of all the NaOH and water is mixed according to molar concentration, then it is mixed properly, then Na2SiO3 is mixed with NaOH solution, both are mixed properly at time of mixing and before use. Then for casting first of all surface dry coarse aggregates are taken and air dry fine aggregates are taken. Also the fly ash is taken from nearby thermal plant Wanakbori.

First of all the dry CA is added in the mixer machine, then FA and fly ash are added and dry mixed for a time period of 1.5 - 2 min, then the chemical solution is added carefully in mix. Then the mix is mixed for 1.5 to 2 minutes but in no case more than 2.5 - 3 minutes otherwise it causes lumps in concrete. The concrete is then poured in moulds in 3 layers with 30-35 tamping of tamping rod for compaction followed by putting on a vibrator table for a period of 45 seconds. These are demoulded the next day and kept in the overn at 60°C for a varying time period from 6, 12, 24, 48, 72, 96, 120 and 144 hours and then used for testing.

Figure Fresh Geo-polymer Concrete

Figure 2 Mixing materials in mixer machine

GPC Strength-Influencing Parameters

1.Water to Geopolymer Solids Ratio (W:GPS)

The W and GPS components are the total of water (from sodium silicate, sodium hydroxide and any extra water) and geopolymer solids (from fly ash, sodium hydroxide solids and sodium silicate solids) respectively. Testing has shown that the compressive strength of GPC increases as the W:GPS ratio by mass decreases [2, 5, 6], while the workability expectedly decreases. This is universally agreed upon by GPC researchers.

2. Alkaline Liquid to Fly Ash Ratio (AL:FA)

This ratio, second to the W:GPS, forms the second important ratio in the mix design of GPC. There is an interconnectivity between the ratios of W:GPS and AL:FA, therefore generally as AL:FA increases compressive strength increases. In some studies, AL:FA has been kept constant [7].

3. Ratio of SS to NaOH Solution (Na2SiO3:NaOH)

The Na2SiO3:NaOH solutions ratio, which then also affects the W:GPS and AL:FA ratios, is important as it contributes to the properties of the alkaline liquid which is the activator in the binder-producing reaction in any GPC. It is unanimously agreed upon that as this ratio increases so too does the compressive strength [3,2,7]. This ratio has been bracketed as NaOH is costlier than Na2SiO3, and research of very high ratios (above 2.5) has not been carried out.

4. Molar Concentration of Sodium Hydroxide

A second parameter that affects the quality/content of the alkaline liquid is the molar concentration of NaOH. Experimental results from previous research have all shown that a higher concentration in the NaOH solution results in higher compressive strength [3, 5]. Effects of a concentration greater than 16M have not been investigated yet.

Results:

The results revealed that the workable flow of geopolymer concrete was in the range of 85 to 145 mm and was dependent on the ratio by mass of sodium silicate and sodium hydroxide solution. The freshly prepared geopolymer mixes were cohesive and their workability increased with the increase in the ratio of alkaline solution. The strength of geopolymer concrete can be improved by decreasing the water/binding and aggregate/binding ratios. The curing period improves the polymerization process resulting in higher compressive strength. The geopolymer concrete do not have any Portland cement, they can be considered as less energy interactive. It utilizes the industrial wastes such as fly ash for producing the binding system in concrete. The optimum dosage for alkaline solution can be considered as 2.5, because for this ratio the GPC specimens

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of any grade produced maximum strength in compression and tension. [1]

Figure 3 Compression Failure of Specimen

When performing compression test on specimen it fails with noise of cracking and sometimes fails with little blast, which ultimately shows that it is a very brittle material and its internal binding in concrete is good. Figure 3 Compression Failure of Specimen

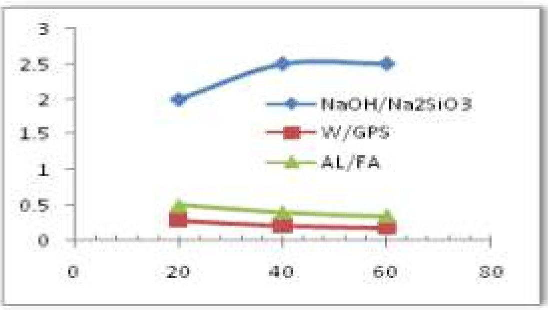

Figure 4 Main 3 ratios of GPC & its relation to strength of geopolymer concrete in normal curing conditions.

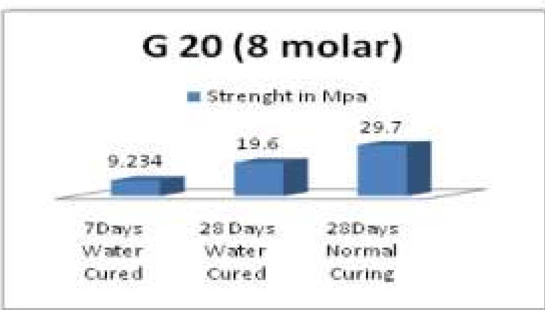

Figure 5 Strength of G20 in different curing conditions.

Here, G20 (8 molars) is giving not much good results under water curing.

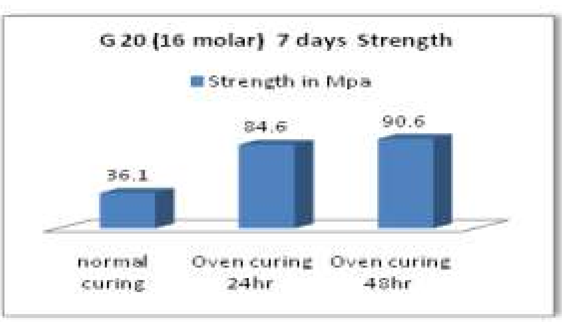

Figure 6 Strength of G20 (16 molar) in different curing conditions

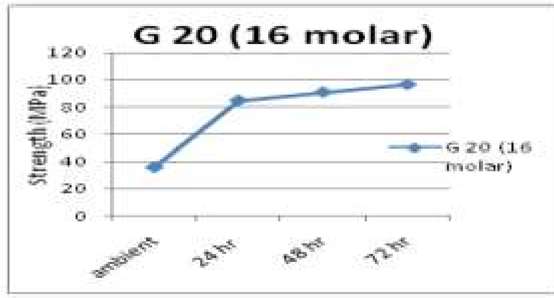

Figure 7 Showing Oven Curing on Geo-polymer Concrete for G20 (16 molars)

Here we can observe that higher the molar concentration higher is strength .

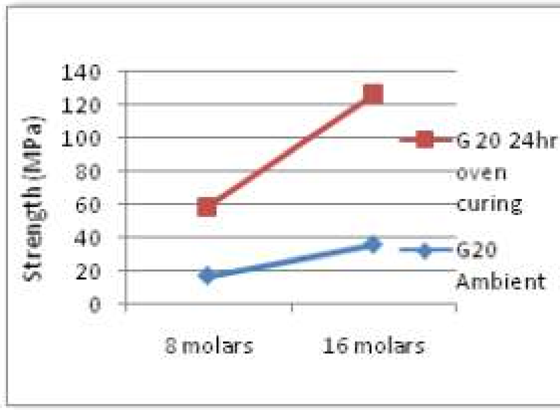

Figure 8 Showing Oven Curing on Geo-polymer Concrete of G 20 (16 molar)

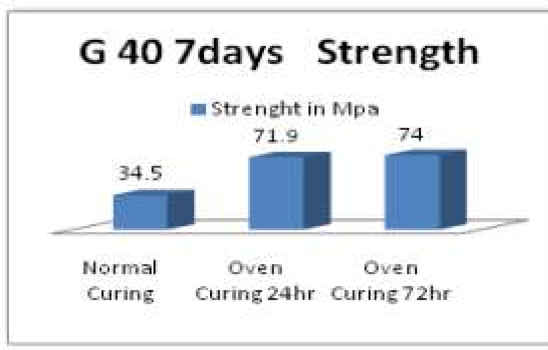

Figure 9 Strength of G40 in different curing conditions

Here, G40 (16 molar) is giving very high strength results because of high molarity concentration.

Figure 10 Strength of G40 in different curing conditions

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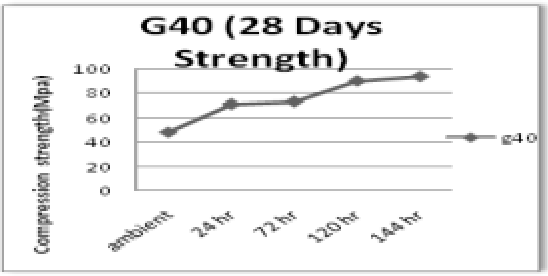

Figure 11 Showing Oven Curing on Geo-polymer Concrete for G40

Flexural strength of 100 X 100 X 500 mm beams at 28 days, which is giving much more Flexural strength than Conventional Concrete of same grade of concrete. The table is representing 16 molar concentrations for different grades and effect of different curing time on them. It is observed that high molarity concentration gives high early strength.

Curing	G20	G40	G60
Ambient	36.1	34.5	32
6 hr oven curing	40.6	52.3	45
24 hr oven curing	84.6	71.9	64.3

7 days strength comparison for 16 molars

Figure 12 Flexural strength test

Figure 13 Beam Failure in Flexural Test

Flexural Strength of beams 100 X 100 X 500 mm (16 molar)

Mix	G 20	G 40	G 60
Days	28	28	28
Strength (MPa)	5.6	6.75	7.1
Curing	Ambient	Ambient	Ambient

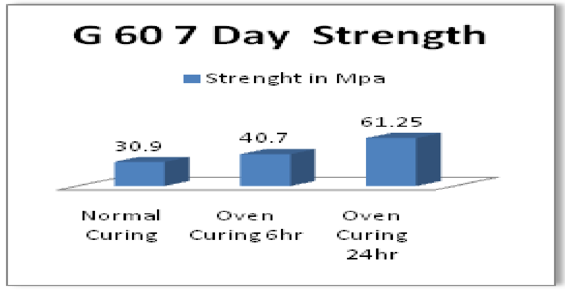

Figure 14 Strength of G60 in different curing conditions

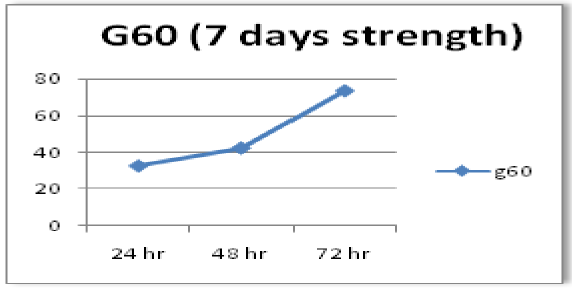

Figure 14 Oven Curing on Geo-polymer Concrete

CONCLUSIONS:

- Reduction in CO2 emissions in the range of 40% to 80-90%. The better performance of geopolymeric materials than Portland cement is attributed to lower calcium content of source material, since geopolymer concrete does not rely on lime. Based on the results of this research, a mix design process for low calcium fly ash-based geopolymer concrete is proposed.
- Low calcium fly ash based geopolymer concrete has excellent compressive strength.
- Flash sets and early stiffening of freshly mixed GPC can occur at certain times , which have the potential to cause significant problems for practical use of this product.
- The average compressive strength of heat cured specimens was higher than that of ambient curing specimens.
- By increase in concentration of NaOH, increases the compressive strength of the concrete.
- Geopolymer concrete's properties are depending on Alkline liquids to Flysh ratio , water to geopolymer solids ratio & sodium hydroxide to sodium silicate ratio.
- Curing in low temperature or in water is not advisable; it does not help to gain early strength.

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