EXPERIMENTAL STUDY ON BEHAVIOUR OF FLYASH BASED GEOPOLYMER CONCRETE

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ABSTRACT  

Objective: The experimental study on behavior of fly ash based geo-polymer concrete and other parameters like strength properties, concentration of alkaline solution, ratio of NaOH to Na₂SiO₃, curing time, additional water in mix. Method: In the present study sustainable materials were used such as Fly ash. Combination of Sodium Hydroxide and sodium silicate is used as activator solution to form geopolymer concrete. The activator solution is prepared 24 hours prior of casting. The mix is designed for 10 Molarity with varying ratios of 1:2, 1:2.5, 1:3. The GPC specimens are tested for compression, flexural and tension tests at the age of 3, 7, 28 days. Findings: As the activator ratio increases the compressive strength, Split tensile strength, Flexural strength is also increased. As the time curing is increased the geopolymer specimens also improved. Applications/ Improvements: Fly ash based geopolymer concrete can be used as precast products like parking tiles, pavement tiles, precast GPC beams, girders, railway sleepers, building blocks, electric power poles. They are good resistance towards fire, permeability.  

Key words: Geopolymer Concrete, Fly Ash, Sodium Silicate, Sodium Hydroxide, Curing.  

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1. INTRODUCTION  

In 1978, ¹ suggested that a binder could be generated by a polymerization process including a response between soluble fluids and mixes containing aluminium and silicon. The folios made were termed as “geopolymers”. Not at all like normal Portland/pozzolanic bonds, geopolymers don’t frame calcium-silicate-hydrates (CSHs) for matrix formative and strength, yet silica and alumina responding with an alkaline solution and creates an aluminasilicate gel that ties the
aggregates and gives the strength of concrete, source materials and antacid fluids/alkaline fluids are the tow primary constituents of geo-polymers, the strengths of which rely on the nature of the materials and the sorts of fluids.$^{1,2}$

Materials containing silicon (Si) and aluminum (Al) in indistinct structure, which originate from characteristic materials or by-item materials, could be utilized as source materials for geo-polymers. Kaolinite, clay, etc., are incorporated into the common materials bunch though fly cinder, silica smoke, granulated ground blast slag, rice-husk fiery debris, red mud etc., are by products obtained from various sources. For the production of geo-polymers, the decision of source materials depends majorly on their accessibility and expense, the sort of utilization and the particular interest of the clients.$^3$ Fly powder based geo-polymers cements give phenomenal building properties that make them suitable materials for structural applications in the world.

The sort of alkaline solution utilized has imperative part as an influence of the polymerization process. Caustic Soda (NaOH) with sodium metasilicate (Na$_2$SiO$_3$) and Caustic potash (KOH) with potassium metasilicate (K$_2$SiO$_3$) are commonly well-known soluble fluids utilized as a part of geo-polymerisation. Both Caustic potash and Caustic Soda have an in potent/power/hard base and, at room temperature, show just about indistinguishable solubility’s in water.$^4,5$ The concentrated on the impact of alkaline liquid on the Physical Properties of fly cinder type motor. They expressed that the mechanical strength of motor enhances when water-glass (Na$_2$SiO$_3$) is added to NaOH, contrasted and utilizing just NaOH, as compared to using of only NaOH. If the addition of water glass is done then, it gives an increment in the Si/Al and Na/Al ratios, bringing about expansion arrangements of N-A-S-H gel (sodium aluminosilicate gel) which shows greater strengths.$^6,7$ The compressive strength of fly cinder based geo-polymer concrete can be enhanced either by enhancing the concentration (in terms of Molarity) of sodium hydroxide solution or by increasing the mass ratios of sodium metasilicate to Caustic soda solutions.$^8$ Since neumerous reports on the dangerous effect of cement production on environment have been brought out and right now fly ash-based geo-polymer cement has been turned out to be a suitable substitution for cement concrete due to their incredible engineering properties.$^9,10$

Thus, in present study an attempt is done to distinguish and concentrate on impact of remarkable parameters which influences the properties of class F fly ash based GPC and GPC properties with different activator solution concentrations and how the strength characteristics vary with respect to change in temperature.

The objectives of the study are to develop a GPC mix, to distinguish and examine the impact of parameters such as activator ratio, type of curing that impacts the properties of fly ash based GPC ,to examine the short term engineering properties of fresh and hardened fly ash based GPC, to examine the behavior of fly ash based GPC.

2. OBJECTIVE: The experimental study on behavior of fly ash based geo-polymer concrete and other parameters like strength properties, concentration of alkaline solution, ratio of NaOH to Na$_2$SiO$_3$, curing time, additional water in mix.

3. METHODOLOGY
In the present study, fly cinder of Class F (low calcium) based geo-polymer was utilized as binder, rather than OPC or other water cement paste, to deliver concrete. The fly debris based geo-polymer paste ties coarse and fine aggregates and other un-responded materials combined so as to form geo-polymer concrete, with vicinity of admixtures. Geo-polymer cement production is completed by utilizing the standard concrete techniques which are used for OPC. The silicon and aluminium
present in low calcium fly ash respond with a basic fluid that is a blend of Na$_2$SiO$_3$ and NaOH solutions to frame the geo-polymer paste that ties all aggregates and also, other materials which remained as un-responded.

3.1. MATERIALS

The fly cinder utilized for geo-polymer concrete was class F as it is acquired from thermal power generating station of Vijayawada. The fine aggregate used is locally accessible river coarsed river sand conforming Zone II and sieved with 4.75 mm sifter so as to evacuate bigger particles. The coarse aggregates utilized were locally available coarse aggregate having the maximum size of (10 -12mm) was used for this study. NaOH was acquired in the form pellets or flakes which are used for commercial purpose. The sodium silicate is used is in the form of gel which is used for preparing of activator solution.

3.2. PREPARATION OF ACTIVATOR SOLUTION

NaOH which was acquired as pellet / flakes was made to an answer utilizing faucet water. 10M caustic soada is choosen by taking past work in to account. to make sodium hydroxide solution of 10M, 400 grams of NaOH flakes should be dissolved in one liter of fresh tap water and at the time of this mixing process heat is liberated .this prepared sodium hydroxide solution should be prepared before 24 hours of casting. The desired amount sodium silicate gel is added to prepared desired sodium hydroxide solution before 20 minutes of casting and stirred well to form a good solution. Figure 1 and 2 shows the chemicals used in the present study.

![Sodium hydroxide flakes](image1)

**Figure 1** Sodium hydroxide flakes

![Sodium silicate solution](image2)

**Figure 2** Sodium silicate solution
3.3 TRAIL MIX PROPORTION

As there is no proper mix design and codal provisions, a trail mix design is opted and the geo-polymer concrete density is assumed as 2400 Kg/m$^3$ and mix is designed and the quantities are in kg/m$^3$ for ratios 1:2, 1:2.5, 1:3 are in Table 1.

Table 1 Mix proportion of GPC

<table>
<thead>
<tr>
<th>S.No</th>
<th>Materials</th>
<th>Quantities</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fly Ash</td>
<td>331.04 Kg/m$^3$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>331.04 Kg/m$^3$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>331.04 Kg/m$^3$</td>
</tr>
<tr>
<td>2</td>
<td>Metakaolin</td>
<td>82.76 Kg/m$^3$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>82.76 Kg/m$^3$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>82.76 Kg/m$^3$</td>
</tr>
<tr>
<td>3</td>
<td>Fine aggregate (Passing through 4.75 mm</td>
<td>540 Kg/m$^3$</td>
</tr>
<tr>
<td></td>
<td>sieve)</td>
<td>540 Kg/m$^3$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>540 Kg/m$^3$</td>
</tr>
<tr>
<td>4</td>
<td>10mm size coarse aggregate</td>
<td>1260 Kg/m$^3$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1260 Kg/m$^3$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1260 Kg/m$^3$</td>
</tr>
<tr>
<td>5</td>
<td>Mass of NaOH Solution</td>
<td>62.1 Kg/m$^3$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>53.2 Kg/m$^3$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>46.6 Kg/m$^3$</td>
</tr>
<tr>
<td>6</td>
<td>Mass of Na$_2$SiO$_3$ Solution</td>
<td>124.1 Kg/m$^3$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>133 Kg/m$^3$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>139.6 Kg/m$^3$</td>
</tr>
<tr>
<td>7</td>
<td>Liquid to Fly ash Ratio</td>
<td>0.45</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.45</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.45</td>
</tr>
<tr>
<td>8</td>
<td>Extra water</td>
<td>45.5 Kg/m$^3$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>45.5 Kg/m$^3$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>45.5 Kg/m$^3$</td>
</tr>
</tbody>
</table>

3.4 MIXING AND CURING

3.4.1 MIXING

The blending system of GPC is like that of mixing procedure of normal concrete only. The Figure 3. shows the mixing procedure of GPC. The arranged GPC was filled in the moulds (cubes, beams, cylinders) and was well compacted by tamping rod and upper surface is all around wrapped up and leveled. Cube moulds of size 150 mm x 150mm x 150mm, beams of size 500mm x 100mm x 100mm, cylinders of size 150mm x 300mm after the completion of casting the specimens were left for 24 hours.

Figure 3 Mixing of GPC

3.4.2 CURING

In general there are two types of curing methods temperature and ambient curing. In this study ambient curing was opted for curing. The type of curing plays an important role and its impact on
the strength parameters of the specimens. The Figure 4 shows the demoulded specimens. The polymerization process take place during first three days from casting after that there will be less polymerization occurring inside the specimens. Long time curing enhances process of polymerization and results increase of compressive strength of specimens.

Figure 4 Demoulded specimens

3.5 TESTING
The casted specimens were tested as per IS (519:1959) and the strengths were calculated for 3, 7 and 28 days. The Figure 5 shows the testing of geopolymer specimens after demoulding.

Figure 5 Testing of Specimens

4. RESULTS AND DISCUSSIONS
The various strength tests that are to be done listed as below.

- Compressive Test
- Split Tensile Test
- Flexural Test
4.1. Compressive Test:
The compressive test on cubes were conducted as per IS Specifications (IS: 516–1959). The below Figure 6 is the graphical representation of compressive strength. As the activator ratio increases there is increment in compressive strength of the specimens with respect to age of the specimens.

![Compressive strength graph]

**Figure 6** Compressive test conducted at the age of 3, 7, 28 days for different Activator ratios

4.2. Split Tensile Test
The split tensile test on test specimens is done on the compression testing machine as per IS (5816:1999). Figure 7 shows graphical representation of split tensile strength.

As the activator ratio increases there is increment in Split tensile strength of the specimens with respect to age of the specimens.

![Split tensile strength graph]

**Figure 7** Split tensile strength at the age of 3, 7, 28 days for different Activator ratios
4.2. Flexural Test:
The results of flexural Test of concrete at the ages of 3, 7, 28 days are presented in Figure 8. As the activator ratio increases there is increment in Flexural strength of the specimens with respect to age of the specimens and hence the flexural strength at the age of 28 days, 7 days is observed as same

![Figure 8](image)

**Figure 8** Flexural strength at the age of 3, 7, 28 days for different Activator ratios

5. CONCLUSIONS
1. The compressive strength, Split tensile strength, Flexural strength of fly ash based GPC specimens increased with the increase in Activator ratio i.e., 1:2, 1:2.5 and 1:3.
2. As there is increase in curing time strength of all GPC specimens improved.
3. The percentage increment in compressive strength with the control specimen for ratios 1:2, 1:2.5, 1:3 is 13.46%, 7.06%, for 7 days 8.88%, 9.74% and 4.08%, 25.29% for 28 days.
4. The percentage increment in split-tensile strength with the control specimen for ratios 1:2, 1:2.5, 1:3 is 33.1%, 3.22%, for 7 days 24.33%, 7.03% and 3.25%, 9.09% for 28 days.
5. The percentage increment in flexural strength with the control specimen for ratios 1:2, 1:2.5, 1:3 is 0%, 1%, for 7 days 22.5%, 59.18% and 39.52%, 11.58% for 28 days.

REFERENCES
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