Characterization and Performance of Mechanical Properties of GGBS Based Geo Polymer Mortars

Bhavani chowdary T, Ranga Rao V

Abstract: From decades it has been recognized that Geopolymer will considerably replace the role of cement in the construction industry. In general, Geopolymer exhibits the property of the peak compressive strength, minimal creep and shrinkage. In this current research paper, Geopolymer mortar is prepared by using GGBS and Fly ash. The mix proportions are of (100-60)%GGBS with Fly ash by 10% replacement. The alkali activators NaOH and Na2SiO3 are used in the study for two different molarities of 4&8. The ratio to Sodium silicates to sodium hydroxide is maintained from 1.5, 2, 2.5 & 3 were used. Mortars are prepared and studied the effect of molarities of alkali activators in their setting times and strengths.

Keywords: Geo polymer, Alkali Activators, molarities, Compressive Strength

I. INTRODUCTION

Due to immense industrial growth, construction industry is thriving day by day and abruptly it will be the prime investment in the market. Accordingly, the demand for raw materials has escalated to meet up the requirement of the construction companies. Concrete as a major construction material in the worldwide and the concrete industry is the largest user of natural resources in the world. As usage of concrete is driving massive around the globe, the production of cement is estimated to be 4.5 billion tones according to the current statistical data. As it is well known that cement production will lead to the green house effect since CO2 emissions are about 5-7% of total global CO2 production. Significant increases in cement production have been observed and were anticipated to increase due to the massive increase in infrastructure and industrialization in developed and developing countries especially in India, China and South America. Scarcity of natural resources and problems involved in disposal of industrial wastes encourages us to research for better alternatives for building materials which are sustainable, eco-friendly and economical.

Fig 1 cement production

II. LITERATURE SURVEY

Due to high strength attainment in the early stage, make use of this advantage Geopolymer Concrete can successfully employed in the precast manufacturing unit, so that large production will be achieved in short duration and breakage is minimized. GPC can employ for beam column junction of RCC Structure[1]. Geopolymer is recommended in pre cast constructions since they are cured at elevated temperatures and fly ash based Geopolymer concrete are used in various engineering applications such as railway sleepers, retrofitting etc.[2]. Geopolymer gain more strength when they are subjected to high temperature curing since Geopolymerization process takes place[3]. In fly ash based Geopolymer concrete, with increase in the ratio of sodium silicate to sodium hydroxide the compressive strength is increased[4]. The concentration of sodium hydroxide is responsible to the strength attainment and curing temperature plays a vital role in strength attainment[5]. Fresh and hardened properties of Geopolymer concrete are studied, as the concentration of NaOH is increased a decline is observed in the workability[6]. The workability of Geopolymer paste has been increased by adding super plasticizers like naphthalene, melamine etc.[7]. By investing fly ash based Geopolymer and GGBS based Geopolymer , GGBS based Geopolymer achieve fair mechanical properties in outdoor conditions[8]. OPC when blended with fly ash and GGBS exhibits less compressive strength when compared to OPC+fly ash. The percentage reduction in strength is around 14-21% [9]. Fly ash based Geopolymer show signs of less water absorption and low mass loss under acidic curing (H2SO4)[10].
III. MATERIALS AND EXPERIMENTAL DATA

Fly Ash
Fly ash, renowned to be “Trampled fuel ash”, is one among the derivative of coal combustion, comprises of fine constituent part driven out from boiler by means of flues. Ash that settles at the bottom is termed to be bottom ash. In modernized power plants, fly ash is seized by precipitators and these perch at bottom of boiler, well the ash obtained is said to be coal ash. According to the source fly ash produced will have substantial quantities of SiO$_2$, Al$_2$O$_3$, CaO etc.,

Ground granulated blast furnace slag (GGBS)
It is finely divided and non-crystalline similar to pozzolans, containing ample amount of calcium to produce bogue compounds which acquire cementitious properties after interacting with alkaline fluids, such as sodium hydroxide or some other strong alkaline compound. In the current study, Ground Granulated Blast Furnace Slag (GGBS) was obtained from the Andhra Cements, Andhra Pradesh and used as the base material.

Alkaline Liquids
Sodium Silicate
Sodium Silicate is a mixture of sodium oxide (Na$_2$O) with silica sand (SiO$_2$) along with water. Sodium silicate is otherwise termed as water glass. Table showing the proportions of the Na$_2$O, SiO$_2$ are given below.

![Figure 2 Sodium Hydroxide Pellets](image1)

Table 1 Chemical Composition of Sodium Silicate

<table>
<thead>
<tr>
<th>Oxides</th>
<th>Percentage of Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO$_2$</td>
<td>29.4</td>
</tr>
<tr>
<td>Na$_2$O</td>
<td>14.7</td>
</tr>
<tr>
<td>H$_2$O</td>
<td>55.9</td>
</tr>
</tbody>
</table>

Sodium Hydroxide
Sodium hydroxide, well-known as caustic soda (NaOH) comprises of white solid crystals available as pellets, flakes, granules. Sodium hydroxide pellets were used in current study.

![Figure 3 Geopolymerization Process](image2)

Figure 3 Geopolymerization Process

Table 2 Representation of the mix specifications

<table>
<thead>
<tr>
<th>S.No</th>
<th>SPECIFICATIONS OF THE MIXES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>NaOH Concentration</td>
</tr>
<tr>
<td>2</td>
<td>1 Na$_2$SiO$_3$/NaOH</td>
</tr>
<tr>
<td></td>
<td>4M</td>
</tr>
<tr>
<td></td>
<td>8M</td>
</tr>
<tr>
<td>3</td>
<td>GGBS to fly ash ratio</td>
</tr>
<tr>
<td></td>
<td>M1</td>
</tr>
<tr>
<td></td>
<td>M2</td>
</tr>
<tr>
<td></td>
<td>M3</td>
</tr>
<tr>
<td></td>
<td>M4</td>
</tr>
<tr>
<td></td>
<td>M5</td>
</tr>
<tr>
<td>4</td>
<td>Curing type</td>
</tr>
<tr>
<td></td>
<td>oven dried and outdoor</td>
</tr>
<tr>
<td></td>
<td>24 hours, 7 &amp; 28 days</td>
</tr>
<tr>
<td>5</td>
<td>Curing Regime</td>
</tr>
<tr>
<td></td>
<td>24 hours, 7 &amp; 28 days</td>
</tr>
</tbody>
</table>

Here the proportions of mixes are as follows
M1 (100GGBS+0FlyAsh); M2 (90 GGBS +10 FlyAsh); M3 (80 GGBS +20 FlyAsh); M4 (70 GGBS +30 FlyAsh); M5 (60 GGBS +40 FlyAsh).

Preparation of Geopolymer mortar
Density of mortar = 2200 kg/m$^3$
Ratio = 1:3:0.55

In the above mix proportion with GGBS replaced in percentage to fly ash for 10%, 20%, 30%, 40%.

Mixing and Casting:
Initially the source material and aggregates were mixed in dry condition as per the predetermined calculation and then pre mixed alkaline solution was added and mixed thoroughly with hand until uniform mix is obtained. The prepared mortar poured in mortar cubes of size 100mm x 100mm x100mm in three layers and compacted.
The casted specimen is left for a day and then demoulded, it is transferred to the oven at 110°C for 24 hours for oven curing and left to dry for 7 & 28 days in outdoor.

Testing:
Compressive strength is an essential property for all where it also depends on curing time and curing temperature. When the curing time and temperature increase, the compressive strength also increases. With curing temperature in range of 105°C to 110°C, within time in 24 h, the compressive strength of concrete can be obtained about 400 to 500 kg/cm². In addition, the compressive strength of geopolymer also mainly depends on the content of fly ash fine particles (smaller than 43 μm). The compressive strength was increase when the finest of fly ash increase. Hence the nature and the concentration of the activators were dominant factors in the reaction of alkali activation.

\[
F = \frac{P}{A} \text{ (MPa or N/mm}^2\text{)}
\]

Where, \(F\) = compressive strength
\(P\) = peak load observed on the specimen,
\(A\) = area of the specimen.
The compressive test is conducted on three specimens and average compressive strength is calculated for each mix.

V. RESULTS AND DISCUSSIONS
The Geopolymer mortar is environment friendly, since the usage of fly ash which is the waste material and reduction in the greenhouse gases due to the complete cement replacement. A total of 480 cubes were cast for two different molarities of alkaline solution of 1.5, 2, 2.5 and 3, their compressive strength was obtained. The strength of the Geopolymer specimen was increased by varying molarities. The results obtained are shown below.

Graph 1 showing 4M R1.5 oven drying values
In 4 molarity ratio of sodium silicate to sodium hydroxide at 1.5, oven curing is giving better strength than ambient curing, since geopolymerisation process gives better strength gain at elevated temperatures.

Graph 3 indicates 4M R2 Ambient Curing values
Graph 4 showing 4M R2 oven drying values
In 4 molarity ratio of Na₂SiO₃ to NaOH at 2.0, oven curing exhibit better performance than ambient curing, since geopolymerisation process yields higher strength at higher temperatures.

Graph 5 showing 4M R2.5 Ambient Curing values
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Graph 6 showing 4M R3 Ambient Curing

Graph 7 showing 4M R3 oven drying

Graph 8 showing 4M 7 day Ambient Curing for all ratio’s

Graph 9 showing 4M 28 day Ambient Curing for all ratio’s

Graph 10 showing 4M 7 day oven drying for all ratio’s

From this graph 7 day oven curing regime says that the early strength is attained and 4MR2, 4M R2.5 are showing almost similar results and much strength variation is not found between them. By careful observation this we can conclude that 4MR2.5 is giving better performance.

Graph 11 showing 4M 28 day oven drying for all ratios

From this graph 28 day oven curing says that the 4MR2, 4M R2.5 are giving exact evidence that there is 12.5% strength variation between results. it is clearly evident that 4MR2.5 is outshined by attaining better results.

Graph 12 showing 8M R1.5 Ambient Curing

By observing this we can explicitly mention 4M R2.5 is performing good in 7day ambient curing regime.

Graph 13 showing 4M 7 day Ambient Curing

Graph 14 showing 4M 28 day Ambient Curing

In 28 day ambient curing regime, results show 4M R2.5 is giving better yield.
By observation this we can decide that 8M R2.5 is performing good
By observation this we can decide that 8M R2.5 is performing good

Graph 20 showing 8M 7day oven drying for all ratio’s

By observation this we can decide that 8M R2.5 is giving better performance

Graph 20 showing 8M 28day ambient drying for all ratio’s

By studying this graph we can conclude that 8M R2.5 is having good compressive strength.

VI. CONCLUSIONS:

Based on the experimental investigation the following conclusions were made for 4&8 molarity geopolymer mortar cubes.

- By observation of results it is clear that the mix M1(i.e.100GGBS-0FA) has got better strength when compared to all other mixes.
- Mix M1 & M2 are almost got the same strengths, by using naphthalene based admixture we can reduce the setting time
- Setting time is very rapid in all the mixes since their major content is GGBS, it can be eliminated by using naphthalene based admixtures.
- when comparing 4 and 8 molarities, 8 molarity yields better strength.
- In both 4&8 molarities, sodium silicate to sodium hydroxide ratio 2.5 is showing better strength.
- Maximum strength attained in the current study is 80MPa.
- A specimen which has undergone oven curing has shown higher strength when compared to the outdoor curing.
- Ultrasonic pulse velocity values for outdoor curing specimens are higher than oven curing specimens.
- The strength of specimen which is oven cured have 12%-13.5% on an average strength gain when compared to the outdoor cured specimens.
- Nearly 45-50% of the compressive strength increased with 28 days curing compared to 7 days.
- Rate of Gain of strength is faster at initial stage.
- As the fly ash content increasing the strength degrades.

REFERENCES:

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