Effect of Alkaline Solution Ratio on GGBS added Geopolymer Concrete
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Abstract—The demand of concrete is increasing day by day and Cement is used for satisfying the need of development of infrastructure facilities, 1 tone cement production generates 1 tone CO₂, which adversely affect the environment. In order to reduce the use of OPC and CO₂ generation, the new generation concrete has been developed such as GEOPOLYMER CONCRETE. Geopolymer requires Oven Curing in the varying range of 60°C to 100°C for a period of 24 to 96 hours. The objective of the present work is to find the Optimum Alkaline Solution Ratio and to study the effect of GGBS on fly ash based Geopolymer concrete. Present work also considers the Effect of Oven Curing and Ambient temperature curing with Varying Alkaline Solution ratio. This research work focuses the development in field of GEOPOLYMER CONCRETE by replacing fly ash from 0 to 50% with GGBS and inspecting the Fresh Properties and Hardened Concrete properties at 7 days.

Key words: Alkaline Solution Ratio, Ground Granulated Blast Furnace Slag, compressive strength, Tensile Strength

I. INTRODUCTION

Concrete usage around the world is second only to water. Ordinary Portland cement (OPC) is conventionally used as the primary binder to produce concrete. The amount of the carbon dioxide released during the manufacture of OPC due to the calcinations of limestone and combustion of fossil fuel is in the order of 3.7 Gig tons (GT) of CO₂ in the year of 2013. The production of one ton of cement emits approximately one ton carbon dioxide to the atmosphere, which leads to global warming conditions.

One of the ways to produce environmentally friendly concrete is to reduce the use of Ordinary Portland Cement by replacing cement with by-product materials such as fly ash. On the other hand, the ample availability of fly ash worldwide creates opportunity to utilize this by-product of burning coal, as a substitute for OPC to manufacture concrete. Ground Granulated Blast Slag (GGBS) is a by-Product generated during manufacturing of pig iron and steel. Slag is the glass-like by-product left over after a desired metal has been separated from its raw ore.

II. MATERIALS

The Basic Materials required for Geopolymer Concrete are Fine Aggregate, Coarse Aggregate, Fly ash, Sodium Silicate (Na₂SiO₃), Sodium Hydroxide(NaOH), Ground Granulate Blast Slag(GGBS). Sodium Hydroxide is in the form of Pallets and Sodium Silicate is in Liquid Form.

A. Fly Ash

Fly ash is a waste material generated in the thermal power plants after the combustion of coal. In present work Class F Fly ash is used.

B. SLAG

SLAG is a by-product generated during manufacturing of pig iron and steel. It is of two types such as Blast furnace Slag and Steel Making Slag.

In the Present Work Ground Granulated Blast slag is used for Replacing Fly ash. Blast furnace slag is recovered by melting separation from blast furnaces that produce molten pig iron. The molten slag is cooled rapidly by jets of pressurized water, resulting in a vitreous, granulated slag. GGBS is a non-metallic Product Consisting of Silicates and Alumino silicates of Calcium, that is developed in a molten condition simultaneously with iron in a blast furnace, then water chilled rapidly to form Glassy granular particles, then ground to finer form.

Table 1: Characteristics of Fly Ash

<table>
<thead>
<tr>
<th>Constituents</th>
<th>Value (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CaO</td>
<td>30-34</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>18-25</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>0.8-3.0</td>
</tr>
<tr>
<td>MgO</td>
<td>6-10</td>
</tr>
<tr>
<td>SO₃</td>
<td>0.1-0.4</td>
</tr>
<tr>
<td>SiO₂</td>
<td>30-36</td>
</tr>
</tbody>
</table>

Table 2: Characteristics of GGBS

C. Coarse and Fine Aggregate

The naturally available river sand used as fine aggregate. The properties of sand were determined by conducting tests as per IS 2386 (Part-1) and locally available 10mm and 20mm course aggregates were used for this experimental study.

Table 3: Physical Properties of Coarse and Fine Aggregate

D. Alkaline Solution

The alkaline solution was a combination of sodium silicate solution and sodium hydroxide solution. Sodium-based solutions were chosen because they were cheaper than Potassium-based solutions. The sodium hydroxide solids were either a technical grade in flakes form (3 mm), with a specific gravity of 2.21, 98% purity, and obtained from shri
The sodium hydroxide (NaOH) solution was prepared by dissolving either the flakes or the pellets in water. The mass of NaOH solids in a solution varied depending on the concentration of the solution expressed in terms of molar, M. For instance, NaOH solution with a concentration of 8M consisted of 8x40 = 320 grams of NaOH solids (in flake or pellet form) per litre of the solution, where 40 is the molecular weight of NaOH. In this experimental work sodium hydroxide was used of 16M Solution.

Sodium silicate solution obtained from Shri sadguru chemical pvt. ltd., Rajkot, Gujarat, India was used. The chemical composition of the sodium silicate solution was Na₂O=15.87%, SiO₂=31.73%, and water 52.4% by mass. The other characteristics of the sodium silicate solution were specific gravity=1.62 g/cc and viscosity at 20°C=400 cp.

### III. PROPOSED DESIGN MIX

In the beginning, Numbers of parameters of numerous trial mixtures of Geopolymer concrete were studied by manufacturing and test specimens in the form of 150mm X 150mm X 150mm cubes.

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Unit</th>
<th>Mixture 1</th>
<th>Mixture 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fly ash</td>
<td>Kg/m³</td>
<td>368</td>
<td>368</td>
</tr>
<tr>
<td>Fine aggregate</td>
<td>Kg/m³</td>
<td>554.4</td>
<td>554.4</td>
</tr>
<tr>
<td>Coarse aggregate</td>
<td>Kg/m³</td>
<td>443.52</td>
<td>443.52</td>
</tr>
<tr>
<td>10mm</td>
<td>Kg/m³</td>
<td>850.08</td>
<td>850.08</td>
</tr>
<tr>
<td>20mm</td>
<td>Kg/m³</td>
<td>61.33</td>
<td>46.0</td>
</tr>
<tr>
<td>NaOH solution</td>
<td>Kg/m³</td>
<td>122.66</td>
<td>138.0</td>
</tr>
<tr>
<td>Na₂SiO₃ solution</td>
<td>Kg/m³</td>
<td>29.44</td>
<td>29.44</td>
</tr>
</tbody>
</table>

Table 4: Proposed Geopolymer Concrete Mix

In order to know the effect of Na₂SiO₃/NaOH Ratio we Consider 1.50, 2.0, 2.50, 3.0, 3.50 as Alkaline Solution Ratio and GGBS Percentage is Increased from 0% to 50% to replace the Fly ash content. The Cubes are provided with Oven Curing of 80°C for 24 hours and ambient temperature is at 25°C-35°C.

### IV. EXPERIMENTAL METHODOLOGY

For the given mixture proportion casted concrete cubes of 150x150x150 mm and Cylinder of 150mm Diameter and 300mm Height provided with oven curing temperature and ambient temperature. In table sodium silicate to sodium hydroxide ratio was 2 and 3.0. Along with that 1.50, 2.50, 3.50 are also taken into consideration for finding the Optimum Ratio. Casting of cubes is done by taking parameters like sodium hydroxide Molarity (16M), curing temperature (80°C) and ambient Curing (Room temperature), curing time(24hr) and rest period 7 days) after hot oven curing.

For each alkaline Solution ratio Fly ash is replaced by GGBS from 10% to 50% and Cubes are provided with 24 hour ambient and Oven Curing.

**A. Compressive Strength Test**

Compressive of Strength is the most important for its Strength determination. Compressive strength test is performed using by cube where size of cube specimen is 150 x150 x 150 mm and this test was performed on a 2000 kN capacity compression testing machine. The Test is performed at 7 Days.

For Compressive Strength Total 36 Cubes were casted for Each ratio and 6 Cubes were casted for each replacement of Fly ash With GGBS, 3 Cubes were cured at ambient temperature and 3 at 80°C Oven Curing. The average compressive strength values of three samples are presented in this paper.
B. Tensile Strength Test

For Tensile Strength Total 36 Cylinders of 150 mm Diameter and 300mm Height were casted. For Each ratio and 6 Cylinders were casted for each replacement of Fly ash With GGBS. 3 Cylinders were cured at ambient temperature and 3 at 80°C Oven Curing.

V. DISCUSSION

Based on experimental work, it is observed that Geopolymer Concrete made with Fly ash and Alkaline Solution Provides, a new era In the Construction Industry. With the Variation of Alkaline Solution ratio there is gradual change in the Strength. For Compressive Strength from 1.50 to 2.50 the Strength gradually increases but after that up to 3.50 it goes decreases. For Tensile Strength, ratio of 2.0 shows the highest result and after that the Strength value decreases. The amount of addition of GGBS also plays an important role for the Strength generation.

VI. CONCLUSION

Based upon experimental work it can be concluded that alkaline Solution ratio has significant the effect on GGBS
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By the Experimental Work, the Optimum Na₂SiO₃/NaOH ratio for the Compressive Strength is 2.50 and for the ratio of 2.50, increases in the Compressive Strength up to 60% than the ambient cured specimens. Oven Cured Specimens Shows Higher Compressive Strength up to 59Mpa and Ambient Cured Specimens Shows up to 41 Mpa. For Tensile Strength the Optimum ratio is 2.0. There is Gradual increase in the Strength from 10% to 50% replacement of Fly ash by GGBS.

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REFERENCES