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# AN EXPERIMENTAL STUDY ON GEOPOLYMER CONCRETE WITH THE PARTIAL REPLACEMENT OF COARSE AGGREGATE WITH LATERITE

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**ABSTRACT**

*Geopolymer Concrete (GPCs) is a new class of concrete based on an inorganic aluminosilicate binder system and is considered to be an innovative material that is viable alternative to traditional concrete. In the construction industry mainly the production of portlad cemet causing the emission of pollutants results in environmental pollution. Geopolymer concrete can avoid these enviromental problems to some extend. Advantages of geopolymer concrete includes rapid strength gain, elimination of water curing, good mechanical and durability properties. In this experimental study an attempt is made to study the strength properties of geopolymer concrete using Ground Granulated Blast Furnace Slag (GGBS) with the partial replacement of coarse aggregate with laterite. The alkaline liquids used in this study for the geopolymerization are sodium hydroxide (NaOH) and sodium silicate ($Na_2SiO_3$)*

## I. INTRODUCTION

The term ''Geopolymer'' was first introduced to the world by Davidovits of France resulting a new field of research and technology. Geopolymer is an inorganic polymer resulting from the reaction of amorphous aluminosilicates with alkali hydroxide and silicate solutions. Synthesis of a geopolymer usually involves mixing of source materials containing aluminosilicates, such as metakaolin, fly ash, GGBS, rice husk etc with alkaline solution. For the binding of materials the silica and alumina present in the source material are induced by alkaline activators and the chemical reaction that takes place in this case is a polymerization process. The most common alkaline liquid used in the geo-polymerization is the combination of Sodium hydroxide/ Potassium hydroxide and Sodium silicate/ Potassium silicate. Alkaline solution is prepared by mixing sodium hydroxide in form of flakes with sodium silicate solution of definite proportion. The mass of NaOH flakes in a solution vary depending on the concentration of the solution expressed in terms of molar, M. The sodium hydroxide solution is mixed with sodium silicate solution to get the desired alkaline solution one day before making the geopolymer concrete. After solution is prepared the composition is weighed and mixed in concrete mixture as conventional concrete and transferred into moulds.

Aggregates are inert granular materials such as sand, gravel, or crushed stone that, along with water and portland cement, are an essential ingredient in concrete. Aggregate is mined from earth, either dug out of pits or blasted out of quarries. However, continuous quarrying activities will result in the eventual depletion of the aggregates.

The cost of concrete materials will increase if, owing to the continuous decline of the local granite aggregate production, there is increased dependence on the supply of imported material. Therefore, introduction of other materials as partial coarse aggregates in concrete making should reduce the high consumption of local granite.

Here the study is based on partial replacement of course aggregate with laterites in geopolymer concrete. The strength of the concrete is examined by the replacement of coarse aggregate with laterite, using Ground Granulated Blast Furnace Slag (GGBS).

## II. LITERATURE REVIEW

High resistance against the development of thermal cracks up to an exposure temperature of 800°C and Showed better physical and mechanical properties at elevated temperatures (Mathew M Paul and George Mathews,2014). Higher concentration of NaOH solution and ratio of sodium silicate-to-sodium hydroxide liquid ratio by mass resulted higher compressive strength of geopolymer concrete (Djwantoro Hardjito, Steenie E. Wallah, Dody M. J and B.Vijaya Rangan,2004). Geopolymer concrete can be prepared at comparable cost with that of OPC concrete and offer huge reduction in carbon dioxide emissions(Bennet Jose Mathew, M.Sudhakar and C Natarajan,2013). Higher concentration of NaOH solution results higher compressive strength(Ammar Motorwala, Vineet Shah, Ravishankar Kammula, Praveena Nannapanenl and D. B. Raijiwala,2013)

## III. EXPERIMENTAL PROGRAM

### 3.1. Materials Used

#### 3.1.1. Ground Granulated Blast Furnace Slag

Ground granulated blast furnace slag was obtained from Alcotech Micro Fines, Goa. GGBS slag comprises mainly of calcium oxide, silicon di-oxide, aluminium oxide, magnesium oxide. It has the same main chemical constituents as ordinary portland cement but in different proportions.And the addition of G.G.B.S in Geo-Polymer Concrete increases the strength of the concrete and also curing of Geo-Polymer concrete at room temperature is possible. Its properties is shown in table.1.

**Fig.1. Ground Granulated Blast Furnace Slag**

**Table 1. Properties of GGBS**

| Characteristics | Value |
|---|---|
| Fineness | 202.7 |
| Specific Gravity | 2.9 |

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**3.1.2. Alkaline Liquid**

A combination of alkaline silicate solution and alkaline hydroxide solution was chosen as the alkaline liquid. In this project chemicals are the very important constituents. Sodium Silicate and Sodium Hydroxide liquid are obtained from Diamond industries.

*a. Sodium Hydroxide*

The sodium hydroxide solids in flakes form with 99% purity, obtained from Diamond Industries. The sodium hydroxide (NaOH) solution was prepared by dissolving the flakes in water. The mass of sodium hydroxide solids in a solution varied depending on the concentration of the solution expressed in terms of molar, M. For instance, in this project sodium hydroxide solution with a concentration of 10M is taken and it consists of 10x40 = 400 grams of sodium hydroxide per liter of the solution, where 40 is the molecular weight of sodium hydroxide

*b. Sodium Silicate*

Sodium silicate solution obtained from Diamond Industries was used. The chemical composition of the sodium silicate solution was $Na_2O$ 18.69% by mass, $SiO_2$ 41.31% by mass and remaining water. The mixture of sodium silicate solution and sodium hydroxide solution forms the alkaline liquid.

**3.1.3. Superplasticizer**

Superplasticizers are water reducers which are capable of reducing water contents by about 30 percent. Addition of superplasticizer to stiff concrete mix reduces its water reducing efficiency. Depending on the solid content of the mixture, a dosage of 1 to 3 percent by weight of cement is advisable. In this present investigation, a superplasticizer namely CONPLAST SP 430 has been used and is based on Sulphonated Napthalene Polymers.

**3.1.4. Fine Aggregate**

The fine aggregate used in the project was locally supplied and conformed to grading zone I as per IS: 383:1970. It was first sieved through 4.75mm sieve to remove any particles greater than 4.75mm. Properties of the fine aggregate are tabulated below in Table.2.

**Table 2. Properties of Fine Aggregate**

| Properties | Value Obtained |
|---|---|
| Specific Gravity | 2.65 |
| Fineness Modulus | 3.28 |
| Grading Zone | Zone I |

**3.1.5. Coarse Aggregate**

Locally available granite having the maximum size of 20mm were used in this project. Laterite used in this project were collected from quarry at Chingavanam, Kottayam. Properties of Granite coarse aggregate and laterite coarse aggregate are tabulated in Table.3 and Table.4

**Table 3. Properties of Granite Coarse Aggregate**

| Properties | Value Obtained |
|---|---|
| Specific Gravity | 2.79 |
| Bulk Density | 1.32 g/cc |
| Water absorption | 0.151% |

**Table 4. Properties of Laterite Coarse Aggregate**

| Properties | Value Obtained |
|---|---|
| Specific Gravity | 2.79 |
| Bulk Density | 0.900 g/cc |
| Water absorption | 14.28% |

**Fig.2- Sieved Laterite Coarse Aggregate Fig.3- Granite Aggregate**

## 3.2. Mixing, Casting and Curing

There is no code provisions for the mix design of geopolymer concrete. The total aggregate content was varied from 60% to 75% . Based on the previous studies, the ratios were taken. The alkaline liquid to GGBS ratio is taken as 0.30, ratio of sodium silicate to sodium hydroxide is 2.5 and the molarity is 10M.

The conventional method used in the making of normal concrete is adopted to prepare geopolymer concrete. Mix sodium hydroxide solution and sodium silicate solution together at least one day prior to adding the liquid to the dry materials. First, the fine aggregate, coarse aggregate and GGBS are mixed in dry condition for 3-4 minutes and then the alkaline solution which is a combination of Sodium hydroxide solution and Sodium silicate solution with super-plasticizer is added to the dry mix. The mixing is done about 6-8 minutes for proper bonding of all the materials(Fig.4). Compaction of fresh concrete in the cube moulds was achieved by vibrating on a vibration table for ten seconds. After casting, the specimens were left undisturbed for 24 hours. The sizes of the cubes used are of size 150mmX150mmX150mm, cylinders of diameter of 150mm x height 300mm and beams of 100mm x 100mm x 500mm were cast to study compressive, split and flexural strengths. Then the GGBS based geo-polymer concrete specimens are placed at ambient temperature for curing(Fig.5).

In this experimental program, GGBS based geopolymer concrete replaced with laterite coarse aggregate of 0%, 50% and 100% percentages were prepared to obtain an optimum proportion of aggregate content and the total aggregate content was varied from 60% to 75% of the volume of geopolymer concrete.

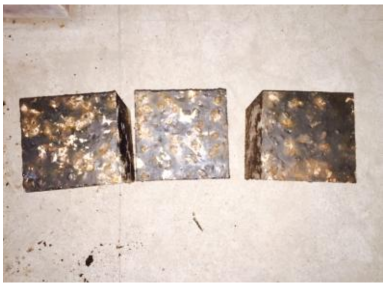

Fig.4-Curing of Cubes

### 3.3 Compressive Strength

In this research the values of compressive strength for different replacement of laterite (coarse)aggreagte of total aggregate content of 60%, 65%,70% and 75% at the end of different curing period (3days and 7 days ). 150 mm × 150 mm × 150 mm cubes were casted for carrying out compression strength test

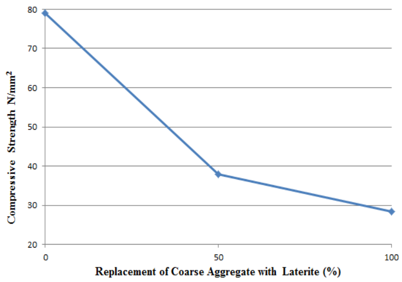


**Fig.5-Variation of Compressive Strength with the replacement of coarse aggregate with Laterite**

From the above test results it can be concluded that for 60% total aggregate content gives maximum compressive strength. As binder content increases, compressive strength increases so mix with 60% total aggregate content has more binder content compared to other total aggregate content percentages. In that for 50% and 100% replacement of laterite coarse aggregate have enough strength and can be used in constructional works.

### 3.4 Split Tensile Strength

In this investigation, the tensile strength of GGBS based geopolymer concrete mixtures were determined at the age of 7$^{th}$ day at 50% and 100% replacement of coarse aggregate aggregates with laterite. 150 mm diameter and 300 mm height cylinders were casted for carrying out split tensile strength test. The variation of split tensile strength was shown in Table 6.

**Table.5- Split Tensile Strength Results**

| S.No | Percentage of laterite Coarse Aggregate Content (%) | 7 Day N/mm$^2$ |
|---|---|---|
| 1 | 50 | 3.39 |
| 2 | 100 | 1.69 |

**Fig.6- Split Tensile Strength Testing**

It was found that split tensile strength of GGBS based geopolymer concrete depends on the replacement of coarse aggregate with laterite. Based on the split tensile test results it shows that 50% of replacement of coarse aggregate gives enough tensile strength so that it can be used in small scale constructional works

### 3.5 Flextural Strength Test

In this investigation, the flextural strength of GGBS based geopolymer concrete mixtures were determined at the age of 7th day at 50% and 100% replacement of coarse aggregate aggregates with laterite. 100 mm × 100 mm × 500 mm beams were casted for carrying out flextural strength test. Flextural strength resuls shown in Table 6.

**Table.6.- Flextural Strength Results**

| S.No | Percentage of laterite Coarse Aggregate Content (%) | 7 Day $N/mm^2$ |
|---|---|---|
| 1 | 50 | 5 |
| 2 | 100 | 2 |

**Fig.7- Flextural Strength Teasting**

Based on the flextural strength results it shows that 50% of replacement of coarse aggregate with laterite gives enough flextural strength so that it can be used in small scale constructional works.

### 3.6. Water Absorption Test

Water absorption test describes an immersion method that is used to determine the percentage of water absorbed by concrete. Testing was carried out on air-cured, cube (150 × 150 × 150 mm) specimens of 28th day.

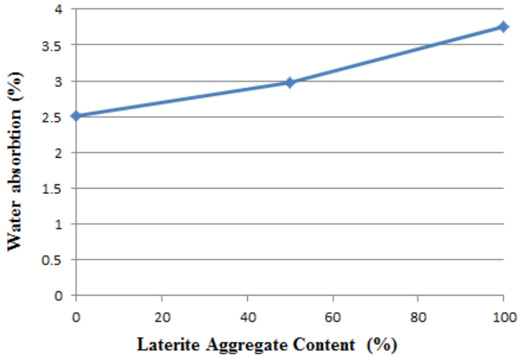


**Fig.8 -Graph Showing Relationship Between Water Absorption and Laterite Aggregates Content (%)**

The results of the water absorption test of the control and laterite concretes are shown in Fig.9. The water absorbed by the concrete increases with increasing percentage of laterite aggregates. This occurs mainly owing to the specific gravity of the laterite aggregates, which is lower than that of their granite aggregate. The lower specific gravity results in, as evidenced by the higher water absorption. However, the highest water absorption of the concrete mix produced using laterite aggregates of 100% replacement is 3.75. The absorbtion of the test sample should not be greater than 6% as per IS:15658:2006.

### 3.7 Test Based on Oven curing and Curing at Ambient Temperature

Compressive strength for 50% replacement of Coarse aggregate with laterite of total aggregate content 60% at the end of different oven curing periods (3 days and 7 days ) at 60°C.

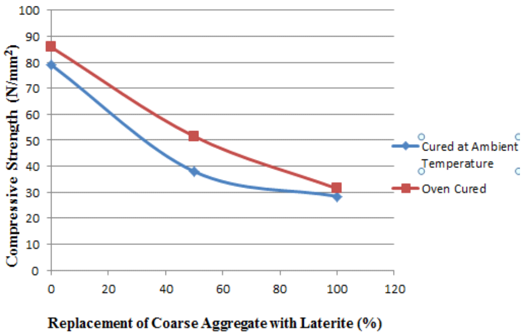


**Fig.9.-Graph showing Variation in the compressive strength at 7 days between specimens of oven cured and cured at ambient temperature**

Fig.10 shows that for oven cured specimen gives more strength than specimen cured at ambient temperature but curing at ambient temperature is convenient for practical conditions and also it gives enough strength.

## IV. CONCLUSION

These are the conclusions derived from the experimental study**:**

- Based on the compressive strength test results**,** 60% total aggregate content gives maximum compressive strength. As binder content increases, compressive strength increases so mix with 60% total aggregate content has more binder content compared to other total aggregate content percentages
- Based on the test results it can be concluded that laterite aggregates have slightly lower strength than granite aggregates, the use of a suitable portion ie 50% replacement of coarse aggregate with laterite in geopolymer concrete does not affect the durability of concrete as it relates to water absorption and can be used in small scale precast units
- Compared to curing at ambient temperature and oven curing , oven cured specimens gives the higher compressive strength but curing at ambient temperature is convenient for practical condition and have enough strength.

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