# EXPERIMENTAL STUDY ON BEHAVIOUR OF GEOPOLYMER TILES WITH GGBS AND M-SAND

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**Abstract -** *As construction increases, there is increase in the production of certain essential materials. Particularly, this increases the production of cement in industries that results in greater emission of $CO_2$ into atmosphere which is equal to the amount of production of cement. It causes Greenhouse effect in the atmosphere and affects the environment. Also, the waste from power plants and industries rest dumped into the environment that causes disposal problems. To overcome these problems in an efficient way a new concrete type is obtained called as Geopolymer concrete which is the mixture of source materials, fine and coarse aggregate. Here, GGBFS is mixed with certain ratios of source material along with M-sand instead of river sand as fine aggregate. Thus, the properties of Geopolymer tile is observed and determined to be higher than conventional type. The silica content in both fly-ash and GGBFS are high that enhance the strength in concrete and hence used here with mix proportions. This GPC tile completely avoids the use of cement (OPC) and hence it is called as no cement mortar tile and is highly economical and eco-friendly by nature. Thus, Geopolymer tile is observed to have excellent physical and mechanical property. With these property the precast GPC tiles is prepared and checked for adequate strength, thermal resistance and durability.*

***Key Words***: *Precast Geopolymer tiles, Fly ash, GGBFS, No cement mortar tile, Economical.*

## 1. INTRODUCTION

The present paper study embodies the performance of fly ash based Geopolymer tiles with GGBFS and M-sand. It is of more to know the following;

1. To produce eco-friendly Geopolymer tiles with replaced substitutes.
2. To evaluate the optimum mix proportion of Geopolymer concrete with fly ash replaced in various percentage by GGBS.
3. To achieve enhanced strength, thermal and durability properties in Geopolymer tiles.

### 1.3 Need

The problem of disposing waste into the environment is the major crises now-a-days. Also, River sand used as fine aggregate so far is now in demand due to over exploitation. To overcome these problems, this project is carried on to produce a precast geopolymer tiles with waste, from power plants and industries with M-sand.

### 1.4 Scope and objective

Utilization of Geopolymer concrete brings Economy in construction, Reduce pollution, Less harmful to the environment. Thus, it can be considered that Geopolymer concrete, as a replacement for Portland cement has wide scope in future.

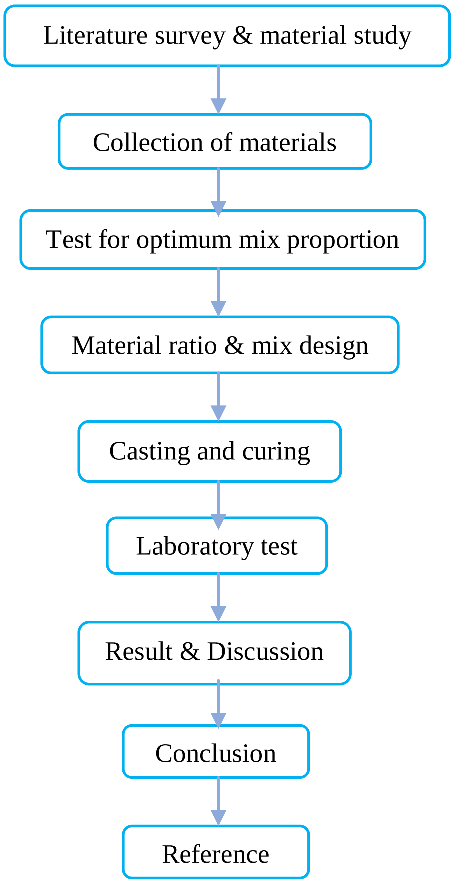
## 2. Literature summary

Various literature studies have been made to know about the characteristics and properties of Geopolymer concrete with different ratios of admixtures and binder content.

Chemical composition & particle size of material affects mechanical properties of GPC [3]. Higher fineness of fly ash results in higher compressive strength. Higher $Na_2O/SiO_2$ ratio (up to 2.5) results in higher compression strength [11]. Compression strength is indirectly proportional to the water-binder ratio. Flow of GPC is directly proportional to the water-binder ratio [12]. Higher molarity of NaOH results in higher strength and lesser workability [9]. Increase in GGBS content increases workability, Range of $Na_2SiO_3$: NaOH ratio = 0.5 – 2.5. Use of (NaOH + Na2SiO3) in combination enhances the strength greater than using KOH combination, GGBFS based GPC have faster hydration rate and greater strength than conventional OPC concrete [4]. In conventional concrete, compression strength of River sand is greater than M-sand and in Geo-polymer concrete, the compression strength of M-sand is greater than River sand and this is due to binder nature [5]. With proper curing period and temperature, 96.4% strength of 28$^{th}$ day is attained in 7$^{th}$ day itself [14]. Addition of fiber and admixture in GPC tiles enhance strength and fire resisting capacity of tile [6].

## 3. METHODOLOGY

The study of the properties of Geopolymer tiles includes the layout shown below.




**Flow chart -1:** Layout of project work.

## 4. MATERIALS AND ITS PROPERTIES

**4.1 Fly ash:** Fly ash is a fine powdered byproduct of burning pulverized coal in electric generation power plants. In this project, fly ash is taken from Neyveli Lignite Corporation (NLC), India limited. Lignite mining and Thermal power generation is the main purpose of NLC. The properties of fly ash include the following; specific gravity 2.94 and class F category.

**4.2 GGBS:** Ground-granulated blast-furnace slag is obtained by quenching molten iron slag. It is a by-product of iron and steel-making from a blast furnace in water or steam, to produce a granular product that is then dried and ground into a fine powder. GGBS for this project is bought from a dealership with Jindal Steel and Power Limited, Haryana. The properties of GGBS includes specific gravity 1.92

**4.3 M-Sand:** Sources of natural river sand for use as an aggregate in construction are becoming scarce and exhausted due to environmental degradation. M-sand, for this project is purchased from manufacturing company itself in Nemur, Villupuram. By sieve analysis test, it is categorized under Zone-I and the fineness modulus is 3.35. The specific gravity is 2.5

**4.4 Alkaline activators:** Sodium silicate ($Na_2SiO_3$) in liquid gel form and Sodium Hydroxide (NaOH) in pellet form with 13M are used as alkaline activators in geopolymer mix. Generally, these activators are used to enhance the polymerization reaction and also act as binding agent in the mixture. In this project, the sodium silicate and sodium hydroxide are purchased from "Sri Moogambika Chemicals", Pondicherry.

## 5. MIX PROPORTION

| GPC | Quantity | Mix ratio |
|---|---|---|
| **Fly ash** | 243 | 0.6 |
| **GGBS** | 162 | 0.4 |
| **$Na_2SiO_3$** | 70.88 | 0.35 |
| **NaOH** | 70.88 | 0.35 |
| **Fine aggregate** | 683.13 | 1.83 |
| **Coarse aggregate** | 1268.66 | 3.37 |
| **Total water content** | 108.35 | 0.211 |
| **Extra water required** | 29.46 | 0.07 |

## 6. MIXING, CASTING AND CURING.

Firstly, the sodium hydroxide of required quantity is well mixed with water and allowed for heat of hydration. The next day, sodium silicate of required quantity is mixed up with the prepared sodium hydroxide solution. Finally, the alkaline activators are prepared and left for few hours. The other essential materials like Fly ash, GGBS, M-sand are measured as required per calculations and mixed well without any lumps using trowel. Then, the alkaline activators are poured and mixed together for mortar. Water is added additionally, if required. Thus, the geopolymer mortar is prepared. The prepared geopolymer mortar is casted in cubes of size 70.6 x 70.6 x 70.6 mm and tiles of size 200 x 200 x 12 mm. The casting of cubes and tiles are as shown below;

**Fig -1**: Mixing of materials


**Fig -2**: Casting of mortar cubes

**Fig -3**: Casting of tiles

After demolding of cubes and tiles, they are kept for curing process at ambient room temperature itself for 28 days and there is no need of water or steam curing.

## 7. EXPERIMENTAL INVESTIGATION

**7.1 Dry Density Test:** Dry density is the density of the specimen in dry state and it is defined as the ratio of dry weight of the specimen after subjecting it to curing to the volume of the cured specimen. This test is carried with cube of size 70.6 mm x 70.6 mm x 70.6 mm and tile of size 200 mm x 200 mm x 12 mm. The dry density of the cubes and tiles is calculated using below formula;

$$\text{Density } (\rho) = W/V$$

**7.2 Cube Compression Strength Test:** Compressive strength is the ratio of the maximum load that a specimen can resist to the area of cross section of the specimen at which the loading is applied. The compressive strength of the geopolymer mortar cube of size 70.6 mm x 70.6 mm x 70.6 mm is tested. It is calculated using the formula; Compressive Strength (fc) = P/A

**7.3 Bending Strength Test:** The bending strength test is carried with tile of size 200 mm x 200 mm x 12 mm. In this test a specimen with round, rectangular or flat cross-section is placed on two parallel supporting pins. The loading force is applied in the middle by means loading pin at the center called center point loading or 3 – point loading. Bending strength is the ability of the tile to withstand the applied load without breaking. As a result of the loading, the specimen bends, causing formation of in its convex side and compression stress in the concave side. The bending resistance of the casted tile is determined by the formula mentioned below;

$$\text{Bending Resistance } (\sigma) = 3FL/2bh^2$$

**7.4 High Temperature Resistance Test:** To carry this experiment, we need a cube specimen of 70.6 mm x 70.6 mm x 70.6 mm. the cubes are heated at 100-900$^0$C with an interval of 100$^0$C for 1 hour in muffle furnace. Then the specimen is allowed to cool inside the furnace itself and finally it is observed for cracks and its compression strength.

**7.5 Thermal Shock Resistance Test:** Thermal shock resistance test is carried with the help of hot air oven at 145$^0$C and the specimen needed is a tile of size 200 mm x 200 mm x 12 mm. The specimen is heated for 20 minutes and immediately transferred to water. After 5 minutes the specimen is heated again for 145$^0$C for 20 minutes and this process is repeated for 10 times. At the end of test, the specimen is observed for cracks and breaks along edges and corners.

**7.6 Water Absorption Test:** For water absorption test, a tile of size 200 mm x 200 mm x 12 mm is required. The tiles are initially heated at 110$^0$C in hot air oven for 24 hours. Then the dry weight of the specimen is determined ($W_d$). Next, the specimens are immersed in water for 24 hours. The specimens are then dried and weighed ($W_s$). With these values, the percentage of water absorption is determined with the below mentioned formula;

$$\text{Percentage of Water Absorption } (\%) = [(W_s - W_d) / W_d] \times 100$$

**7.7 Apparent Porosity Test:** Apparent porosity test is similar to that of water absorption test but the specimen used here is cube of size 70.6 mm x 70.6 mm x 70.6 mm. The cubes are initially heated at 110$^0$C in hot air oven for 24 hours. Then, the mass of dry specimen is determined ($M_d$). Next, the specimens are immersed in water for 24 hours. The specimens are then dried and weighed ($W_w$). With these values, the mass of suspended specimen in water ($W_s$) is also determined. Finally, the percentage of apparent porosity is determined with the below mentioned formula;

$$\text{Percentage of apparent porosity } (\%) = [(M_w - M_d) / V] \times 100$$

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## 8. RESULT AND DISCUSSION

### 8.1 Dry Density Test:

This test is carried with cube of size 70.6 mm x 70.6 mm x 70.6 mm and tile of size 200 mm x 200 mm x 12 mm. The dry density of the cubes and tiles is calculated using below formula.

Density (ρ) = W/V

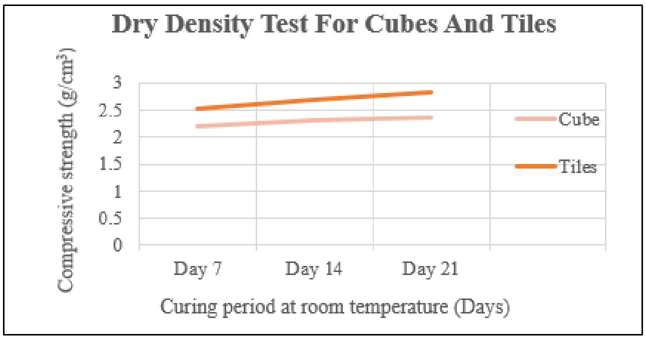


**Fig -4:** Dry density test

### 8.2 Cube Compression Strength Test:

The compressive strength of the geopolymer mortar cube of size 70.6 mm x 70.6 mm x 70.6 mm. The test results are shown below.

Compressive Strength (fc) = P/A

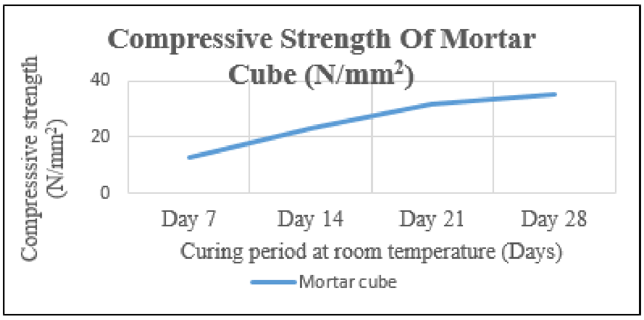


**Fig -5**: Compressive strength test

### 8.3 Bending Strength Test:

The bending resistance of the casted tile is determined by the formula mentioned below;

Bending Resistance (σ) = 3FL/2bh²

**Fig -6**: Flexural strength test

### 8.4 Thermal Shock Resistance Test:

the specimen needed is a tile of size 200 mm x 200 mm x 12 mm. The resulted test images are shown below.

**Fig -7**: Thermal shock resistance test

### 8.5 Water Absorption Test:

Percentage of Water Absorption (%) = $[(W_s-W_d)/W_d] \times 100$. The values obtained from the test carried is mentioned here;

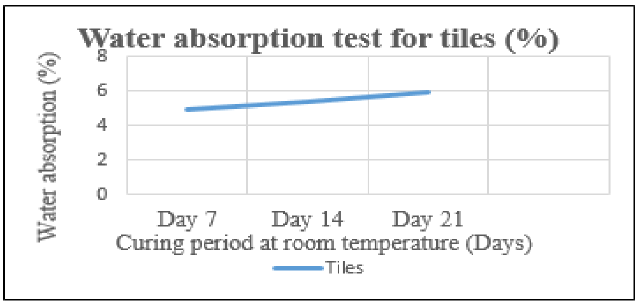


**Fig -8**: Percentage of water absorption test

### 8.6 Apparent Porosity Test:

Percentage of apparent porosity (%) = $[(M_w - M_d)/ M_d] \times 100$.

The values obtained from the test carried is mentioned here;

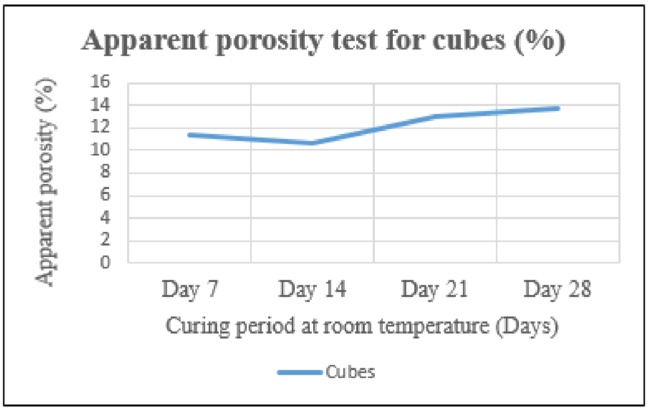


**Fig -9**: Percentage of apparent porosity test

## 9. CONCLUSIONS

Results for the conventional mortar cubes were also tested for 3 different mix ratios of fly ash and GGBS such as 50:50, 60:40, 70:30 for $7^{th}$, $14^{th}$, $21^{st}$ and $28^{th}$ days. Accordingly, the ratio 60:40 shows greater strength for the mortar cube and so the whole project is carried with fly ash: GGBS ratio as 60:40. Thus, the tiles and cubes are casted with this mix ratio. From the results,

- ✓ The compression strength for mortar cube is maximum at the $28^{th}$ day test.
- ✓ Similarly, the flexural strength test for tiles are also determined to be greater at the 21-day test.

Thus, geopolymer tiles with GGBS and M-sand shows good results on comparing with the conventional tile.

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