Experimental Study on the Compressive Strength and Permeable Properties of GGBS Based Geopolymer Pervious Concrete

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Abstract. This paper deals with the experimental investigation on the mechanical, thermal and moisture properties of Ground Granular Blast Furnace Slag (GGBS) based Geopolymer Pervious Concrete (GGPC) with different size of aggregates. The concentration of NaOH is maintained as 12 M throughout the study. Fine aggregate is completely eliminated in the mix proportion to maintain the pervious nature. Coarse aggregate size is varied in three sizes such as 6mm, 12mm, and 20mm to study the effect of aggregate on the properties of GGPC. The ratio between sodium silicate and sodium hydroxide is maintained as 2.5 throughout the study, and the liquid to solid ratio is maintained as 0.45. The results from the experiments revealed that the compressive strength is higher for the aggregate size 12 mm at the end of 28 days compared to other mixes. The Co-efficient of Permeability (k) is increased with respect to the increase in the aggregate size from 6 to 20 mm.

1. Introduction
In cement manufacturing process, emission of CO2 into the atmosphere is a major concern [1,2]. To avoid the usage of alternate materials instead of cement is on the rise. One such material is GGBS. GGBS is produced as a byproduct from the iron manufacturing process as a slag which is utilized as partial replacement in cement concrete[3,4]. Due to the growth in the infrastructure facilities concreting has been done in most cities which has led to the decline in the ground water table. It has to lead to the development of pervious concrete which allows the water to penetrate through it.[5-7]. Permeable property mainly depends on the ratio of water to binder, the aggregate size as well as the cementitious content[8-11]. Aggregate size plays a major role in the pervious nature, voids content and surface contact[12].In this study the mechanical and permeable properties of GGBS based geopolymer concrete with different size of aggregate were evaluated.

2. Materials
2.1 Ground Granulated Blast Furnace Slag
Ground Granulated Blast furnace Slag (GGBS) is the by-product obtained in the production of pig iron in blast furnace. Figure 1 shows the image of GGBS in back scattered imaging mode. Figure 1a shows the FTIR graph of the GGBS.
2.2 Coarse aggregate

The properties of aggregate used in this study is tabulated in Table 1

| S.No | Properties                          | 6 mm size | 12 mm size | 20 mm size |
|------|------------------------------------|-----------|------------|------------|
| 1    | Specific gravity                   | 2.7       | 2.8        | 2.8        |
| 2    | Density of coarse aggregates       | 1350 kg/m³ | 1360 kg/m³ | 1490 kg/m³ |
| 3    | Impact value                       | 24.15%    | 17.23%     | 11.45%     |

2.3 Alkali Solution

480gmof NaOH pellets is added with one liter of water to make the concentration of NaOH to 12 M.

3 Experimental Programme

3.1 Mixing Fraction, Mixing and Casting:

The weight of GGBS is fixed at 450 kg/m³ throughout the study. Sodium silicate to sodium hydroxide ratio is fixed as 2.5 based on the previous work on geopolymer concrete [12,13] and the liquid to solid ratio was fixed as 0.45. The solution has been prepared 24 hours before casting of specimen. Mixing was done in pan mixing machine with GGBS and Coarse aggregates and finally alkali solution was added and mixed till uniform mixing is achieved. The specimen is then kept at ambient curing till the age of testing.

3.2 Compressive Strength

The compressive strength test was carried out on 150x 150 x 150 mm size cube specimen at the mature of 7, 14 and 28 days.

3.3 Permeability

Falling head permeability test was used to find out the coefficient of permeability(k) value of various GGPC. Permeability Test was conducted as per ASTM C 1688. The co-efficient of permeability of the geopolymer pervious concrete sample was evaluated from the expression given below:

\[
k = \frac{2.303 a L}{A t \log \left(\frac{h_1}{h_2}\right)}
\]

Where,
- Coefficient of permeability [k] (mm/hr)
- Cross sectional area of the standpipe [a] (mm²)
- Length of the specimen[L] (mm)
- Cross sectional area of the specimen[A] (mm²)
- Time for water level to reach from [h₁] to [h₂] [sec.]
- Initial water level [h₁] (mm)
Final water level \( h_2 \) (mm)
Cross Section Area Specimen \( A \) is 78.53 cm²
Stand pipe \( a \) is 78.53 cm²
Length of the specimen \( L \) is 20 cm

4. Results and Discussion

4.1 Compressive Strength Test

Table 2 and Figure 2 shows the results of GGPC mixtures with three different aggregate sizes of 6mm, 12mm and 20mm respectively. The compressive strength of GGBS based Geopolymer pervious concrete was found to be in the range of 4.49 to 7.59 MPa at 28 days. The Strength of the GGPC was found to be highest with 12mm aggregate than 6mm and 20mm aggregate. This is because when there is increase in the size of the aggregate, the voids will be more which will result in the decrease in the strength\[14\]. But on the other hand there is also reduction in strength of 6mm aggregate concrete than 12 mm aggregate concrete. This could be due to the fact the aggregates size of 6mm was thinner than 12 mm which could easily break under load.

| Specimen ID | Compressive Strength, N/mm² |
|-------------|-----------------------------|
|             | 7 days | 14 days | 28 days |
| GGPC6       | 1.473  | 3.54    | 4.49    |
| GGPC12      | 2.04   | 6.86    | 7.59    |
| GGPC20      | 5.05   | 5.09    | 6.01    |

Figure 2. Effect of aggregate size on the compressive strength of GGPC mixtures at different ages.

4.2 Effect of aggregate size on the permeability

The permeability of GGPC mixtures with different aggregate sizes are tabulated in Table 3. Figure 3 clearly shows the effect of aggregate sizes on the permeability of GGPC mixtures [14]. From the results, as expected the permeability increases with respect to the increase in the aggregate size. 20mm aggregate showed a higher level of permeability than the other two mixtures.

| Specimen ID | Initial water level \( h_1 \) (cm) | Final water level \( h_2 \) (cm) | Time water level reach from \( h_1 \) to \( h_2 \) (t) Sec | The Co-efficient of Permeability (k) |
|-------------|-----------------------------------|---------------------------------|-----------------------------------------------|-----------------------------------|
| GGPC6       | 130                               | 100                             | 4.55                                          | 1.15                              |
| GGPC12      | 130                               | 100                             | 2.7                                           | 1.94                              |
| GGPC20      | 130                               | 100                             | 2.2                                           | 2.37                              |
5. Conclusion:
Based on the experimental results, the following conclusions has been arrived at
• Compressive strength is dependent on the aggregate size
• 12mm aggregate size shows better compressive strength than 6mm and 20mm aggregate
• Permeability increases with respect to the increase in aggregate size
• 20mm aggregate GGPC mixture showed higher permeability than other mixtures.

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