Experimental studies on pervious geopolymer concrete

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Abstract. The aim of the investigation is to assess the features of the utilization of a geopolymer binder for producing permeable geopolymer concrete. Materials used for producing pervious geopolymer concrete are fly ash, ground granulated blast furnace slag with the proportion of 60:40, sodium silicate solution, sodium hydroxide and coarse aggregate. The strength, functional characteristics and its relationship of the geopolymer pervious concrete were investigated. Compressive strength of geopolymer permeable concrete has enhanced along with the rise in density of Pervious geo polymer concrete. Permeability and voids exhibit a decreasing pattern with the increase in molarity and alkali binder ratio. Based on the strength attainment in the previous geopolymer concrete, it has used as a sub - base and base course of a flexible pavement layers.

1. Introduction

Geopolymer concrete has the potential to reduce carbon emission globally and lead to a sustainable development to form an important contributor towards environmentally sustainable construction and building products industry [1]. “Pervious concrete” as PC describes different category of concrete that has high porosity and used for uniform run application that permits water from precipitation and different sources to enter through it, by minimising the overflow from the location and permitting water to recharge. Pervious concrete has attracted greater interest in concrete enterprise in pursuit of environmental safety and sustainability. Due to a porosity of 15–30% and a permeability of 0.14 –1. 24 cm/s, PC can infiltrate stormwater and decrease the quantity of stormwater runoff. It has structurally weaker than the traditional concrete. The Compressive strength of normal concrete ranges between 17 to 40 MPa, but for pervious concrete the attainment is from 2.8 to 28 MPa [2]. Geopolymer concrete can diminish carbon emission all around and bring about a maintainable improvement to shape, a basic supporter toward naturally feasible creation and developing product endeavours [3]. Past exploration has been directed to diminish the reliance on conventional Portland cement (OPC) as a significant material development because of its effect on the earth [4,5]. Because of the high vitality prerequisites in the creation of OPC, it is assessed that each ton of OPC brings about a huge amount of CO₂ discharges [6]. In the midst of greenhouse gases, CO₂ give rise to huge amount of impact on Earth-wide temperature. Furthermore, concrete creation and coming about outflows are relied upon to increment by 100% from the current level by 2020[7]. Geopolymer concrete is an increasingly supportable option to OPC concrete because of utilization of safe waste materials and decreased creation of CO₂. Furthermore, geopolymer concrete exhibits better execution relative than OPC [8]. Geopolymer is synthesized from substances of geological beginning. Geopolymer concrete proposed more eco- friendly replacement to Portland cement [9].

The characteristics of “pervious geopolymer concrete - PGC” have assessed, use of binder as high calcium fly ash gives satisfactory mechanical properties for fabricating geopolymer pervious concrete [10]. It has developed pervious geo polymer concrete using recycled aggregate. They concluded that recycled aggregates have given acceptable results for producing pervious geopolymer concrete using
same binder [11]. It has revealed geo polymer concrete exhibit high compressive strength, low shrinkage, acid resistance, fire resistance and low thermal conductivity characteristics [6]. PC will be employed in the development of park floors, areas with light-weight traffic, walkways, tennis courts, floors of green buildings etc. Its porous nature of structure has the potentials utilization as thermal insulating, acoustic absorption, and water purification materials. The geo polymeric materials reveal better mechanical properties than Ordinary Portland cement products [12]. Attainment of strength for geopolymer concrete utilizing low calcium fly ash have not shown large variations by rising the binder content from 450 to 550 kg/m$^3$ [13]. Various curing conditions too influence on the strength of geopolymer concrete [14]. Attempts have also been made use of GGBS as binder and fly ash as aggregate on mechanical characteristics of geopolymer concrete [15-16]. Cement industry produces about a ton of carbon di-oxide while manufacturing one ton of OPC, which contributes major effect on climate change. This can be reduced by incorporating potential binder waste materials like Fly ash, GGBS, silica fume, Rice husk ash etc. In this aspect geopolymer concrete has the potential to reduce the carbon di-oxide emission [17]. Consequently, In the frame work of the present investigation is to use geopolymer binder for producing PGC. The mechanical characteristics viz density, compressive strength and functional properties namely permeability, porosity and abrasion resistance of pervious geo polymer concrete was studied and formulate the interrelationship between the strength, permeability and voids of PGC and its potential applications.

2. Experimental program

2.1. Materials and characteristics

Materials used for making PBG were fly ash and granulated blast furnace slag as geo polymeric binder materials, Gravel as coarse aggregate, maximum size of the aggregate as 9 mm, sodium hydroxide flakes and sodium silicate solution. Sodium hydroxide is used to activate sodium silicate. The characteristics of fly ash and GGBFS are given in Table 1, coarse aggregate is given in Table 2, Figure 1 represents the materials.

| Table 1. Characteristics of Fly ash and GGBFS. |
|-----------------------------------------------|
| Characteristics | Fly ash | GGBFS |
|-----------------|---------|-------|
| Consistency | 40 % | 36 % |
| Initial Setting Time | 38 min | 55 min |
| Specific Gravity | 2.45 | 2.78 |
| Soundness | 0 | 0 |

| Table 2. Characteristics of Aggregate. |
|----------------------------------------|
| Characteristics | Value |
|-----------------|-------|
| Crushing Value | 15% |
| Impact Value | 17% |
| Specific Gravity | 2.70 |
| Water Absorption | 0.1% |
2.2. Preparation of alkaline liquid
Alkaline liquid is produced by blending of the sodium hydroxide solution and sodium silicate at room temperature. At the point when the solution combined the both begin to respond polymerisation happens, it releases huge part of warmth because it is prescribed not to disturb for around 24 hours. It is fit to be used as binding agent.

2.3. Mix design
Polymeric binder of FA and GGBFS with the composition of 60:40, Granite as coarse aggregate with the maximum size of 9mm. Polymeric binder content of 250 Kg/m³, aggregate to binder ratio as 6.9, a constant NS/NH proportion as 1 and the alkaline liquid/binder (AL/B) ratio of 0.4,0.45 and 0.5 with the molarity of 10, 15 and 20 were used for preparing the mixes of making pervious geopolymer concrete. Totally nine mixes were used. The FA and the GGBS were initially mixed then coarse aggregate were added and blended for 2 to 3 min then alkaline liquid is poured and blended thoroughly around 5 min, geopolymer concrete mixtures were transferred to mould of cylinder of 100 diameter ,200 mm height and 100 mm cube for casting the specimen and left it for air curing, after 24 hours samples were removed from mould and kept it in the room temperature until testing.

3. Results and discussion
3.1. Density
Densities of PGC for various alkaline liquid/binder (40, 45 and 50) for different molar concentration are shown in Fig. 2. As the AL/B content increases, the density also increases continuously, but very gently for 10 molar concentrations. There is a continuous improvement in density with increase in molar concentration from 10 to 15M, but the same trend is followed for 20M with decreasing percentage. Density of PGC varies from 1832 to 1918 Kg/m³.

![Figure 2. Density of PGC for different alkaline liquid/binder and molarity.](image)

3.2. Compressive strength
Crushing strength of PGC for several alkaline liquid/binder (40, 45 and 50) for different molarity were presented in Figure. 3. The crushing strength of PGC is increases upon rise in addition of alkaline
It ranges from 11.65 to 13.43 MPa. Average raise in compressive strength is marginal to slightly marginal with the increase in AL/B content for molarity 10. Similar, trend is followed for molar concentrations 15 and 20. Based on the strength attainments in the previous geopolymer concrete, it satisfied the requirements of flexible pavement layers such as sub-base and base course according to Indian codes.

### Figure 3.
Compressive strength of PGC for different alkaline liquid/binder and molarity.

3.3. **Permeability**

Permeability is determined by falling head method according to the procedure given in ACI522R-10 [2]. Permeability of PGC for various alkaline liquid/binder (35, 40 and 45) for different molar concentrations is shown in Fig. 4. Permeability of geo polymer pervious concrete decreases with increase in AL/B content, it follows similar trend for various molar concentrations 10 to 20 with the increment of 5M. The co-efficient of permeability of PGC varies between 0.654 and 1.742 cm/s.

![Permeability of pervious geopolymer concrete for various alkaline liquid/binder and molarity.](image)

### Figure 4.
Permeability of pervious geopolymer concrete for various alkaline liquid/binder and molarity.

Abrasion Resistance of PGC for various alkaline liquid/binder (35, 40 and 45) for different molar concentrations is illustrated in Fig. 5. The abrasive value of PGC has enhanced with elevated amount of addition of alkaline liquid / binder content. Average increase in the percentage is marginal to slightly marginal with the increase in AL/B content for molarity 10. Similar, trend is followed for molar concentrations 15 and 20. It ranges from 27 % to 40%.

![Abrasion Resistance of PGC for various alkaline liquid/binder and molarity.](image)
Figure 5. Abrasion resistance of pervious geopolymer concrete for various alkaline liquid/binder and molarity.

3.4. Compressive strength and voids relationship
The regression correlation for the permeability and compressive strength is represented in Figure 6. In view of compressive strength falling pattern occurs with respect to increment in voids present in the mixture. The represented relationship is linear and given as $y = -0.4483x + 21.657; R^2 = 0.9032$. Where x- voids (%) and y- Compressive strength (MPa).

Figure 6. Relation between the voids and the compressive strength of geopolymer pervious concrete.

3.5. Voids and permeability
Permeability and voids of PBC decreases with increase in AL/B content, it follows similar trend for various molar concentrations 10 to 20 with the increment of 5M. The permeability of geo polymer pervious concrete varies from 0.654 to 1.742 cm/s. The void content follows the similar trend of permeability of geopolymer pervious concrete. The voids present in pervious geo polymer concrete differ between 18.95% - 22.87%. The correlation between void and permeability is linear as illustrated in Figure 7 and given as $y = 0.2793x - 4.5207; R^2 = 0.918$. Where x – void in % and y- Permeability (cm/s).
Figure 7. Relation between the voids and permeability of geopolymer pervious concrete.

4. Conclusions
This investigation assesses the characteristics of pervious geopolymer concrete produced from utilisation of waste materials as geo polymeric binder. Compressive strength of geopolymer pervious concrete varies between 11.65 to 13.43 MPa. Compressive strength enhanced by the use of increment in AL/B for the mixes of same molar concentration. Permeability exhibit a converse pattern while contrast with compressive strength of pervious geopolymer concrete. Permeability of pervious geopolymer concrete varies between 0.654 to 1.742 cm/s. The abrasion shows a similar trend to compressive strength and it ranges from 27% to 40 %. The voids of pervious geopolymer concrete decreases with increase in AL/B content. Based on the strength attainments in the previous geopolymer concrete, it satisfied the requirements of flexible pavement layers such as sub - base and base course according to Indian codes.

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