Comparative study on flow characteristics, strength and durability of GGBS based geopolymer concrete

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Abstract. Use of OPC causes the emission of CO₂, which is a global house gas, to reduce the usage of OPC (Ordinary Portland Cement), GPC (Geopolymer Concrete) can be used as an alternative. To study the impact of molarity in GPC and compared with conventional concrete. The grade of concrete tested are M30 and M40 by using OPC 53 grade to compare the strength and geopolymer concrete M40 by using GGBS with River sand and M-sand. In geopolymer concrete when strength compares with different molarities 8M to 16M are used in this project work. In GPC strength is directly proportional to the molarity of NaOH. The mechanical properties are conducted to find out the strength. Different molarities were conducted with ( slump test; compaction factor) workability strength of concrete. The different acid test is conducted in durability (i.e., HCl, water absorption test, MgSO₄, H₂SO₄, NaCl). Geopolymer concrete energy absorption is more when compare the normal concrete. The strength increases to increasing the molarity of concrete in GPC.

1. Introduction
GPC is eco-friendly and sustainable materials are used. Cement is used to rapidly increase the demand day by day in construction material [1]. In French professor J. Davidovits in 1970 is formed to the geopolymer inorganic molecules is characterize the range of materials [2]. It does not utilize the conventional concrete in geopolymer concrete to its product about 2.8 billion ton of greenhouse gases [3]. To increase the concrete urbanization as a constituent of binder material [4]. To cause the temperature of one ton of carbon dioxide and cement production of air emits [5].

In reducing the CO₂ with seven per cent issue of the GPC is caused by cement industries. To increase the urbanization of energy demand production of the day by day [6]. It is more role for the construction industries in the economy. The iron waste material produced to slag in industry. It is two wastes of concrete to decrease the cost and safe disposal of the construction material [7]. In construction material is good for geopolymer concrete in several years. Alkali activator of the combination of NaOH (or) caustic soda and Na₂SiO₃ (or) alkali silica of the geopolymer concrete [8].

To study the slag is based on the GPC. It is very high for the growth rate is reflect by the rate of concrete production [9]. It is a large amount of non-renewable resource of the world to utilise a concrete [10]. It reduces the carbon dioxide release from produces the Ordinary Portland Cement [11]. It is utilizing the industrial wastage by-product of the material to cause the CO₂ emission in a binding
material to cause the CO₂ emission is a binding material. The use of the geopolymer's commodity includes the processing of aluminosilicate products, such as environmentally friendly, and alternative content of ordinary portland cement [13]. The formation of geopolymer concrete shown in Fig. 1.

\[
n(\text{Si}_2\text{O}_5\cdot\text{Al}_2\text{O}_3)+2n\text{SiO}_2+4n\text{H}_2\text{O} \rightarrow n(\text{OH})_3\cdot\text{Si-O-}\text{Al}^{3+}\cdot\text{O-Si-(OH)}_3
\]

\[
(\text{Geopolymer Precursor})
\]

\[
n(\text{OH})_2\cdot\text{Si-O-}\text{Al}^{3+}\cdot\text{O-Si-(OH)}_3 \rightarrow (\text{Na}^+\cdot\text{K}^+)\cdot(\text{Si-O-}\text{Al}^{3+}\cdot\text{O-Si-})+4n\text{H}_2\text{O}
\]

\[
(\text{Geopolymer Backbone})
\]

**Figure 1.** Formation of Geopolymer Concrete [10].

2. Materials

2.1. Ground Granulated Blast Furnace Slag
It is non-metallic and consists a silicate and alumina silicate of Ca develop a molten with an iron into a slag is a ground material is a form to a rapid fine ground powder. Slag into alternate binder materials is taken alkali activator ratio proportion of 1:2.5 by mass [14]. The fineness of GGBS is 1.2, standard consistency of GGBS is 33, initial and final setting of GGBS is 24 and 170, specific gravity of slag is 2.9 are properties of GGBS.

2.2. Ordinary Portland Cement
It is mostly used in the world because of abundance to less cost produce it. OPC 53 grade is the strength of 53MPa in 28 days of setting. It is used for fast placed construction were initial strength is rapidly [15]. The fineness OPC is 1.67, standard consistency of OPC is 35, initial and final setting of OPC is 28 and 244, the specific gravity of OPC is 3.14 are properties of OPC.

2.3. Coarse Aggregate
It is used for max size 20mm and minimum size 10mm. The Coarse Aggregate is crushed Basalt rock, conforming to IS 383 as shown in the figure 1. They range are 9.5mm to 37.5mm in dia. It can be a hard, strong, durable etc. the gravel aggregate is almost the same as that of sand [15]. In this project 20mm, 12.5mm and 10mm are used.

2.4. Fine Aggregate
The marine environment is sand from the land. To form silica from granular. It is generally consisting of crushed stone to its particles of passing through the 9.5mm sieve and retaining on 75 microns IS sieve 650. Various properties of gravel, normal, and manufacture sand presented in Table 1 and 2.

2.5. Super Plasticizer
It reduces the water and additive to increase the strength of concrete. It absorbs a particle to form sheets to prevent the hydration. It is both the development of workability specific gravity of super plasticiser is 1.06.
2.6. Sodium Hydroxide and Alkali-Silica

NaOH solution a possible in pellets is a form to 95% to 97% purity in the market. NaOH solution should be made and complicated. It is also known as a refracting. It is possible for the gel form to markets. In the ratio of Na₂SiO₃ is twenty-four hours before casting and mix the NaOH and Na₂SiO₃ solution. Properties shown in table 1 to 3

| Table 1. Physical properties of Gravel. |
|----------------------------------------|
|                                      | 20mm | 12.5mm |
| Specific Gravity                      | 2.72  | 2.8    |
| Water Absorption                      | 0.36% | 0.49%  |
| Impact Test                           | 27.3% | 12%    |
| Bulk Density                          | 1662(kg/m³) | 1666(kg/m³) |
| Flakiness                             | 8.89% | 15.3%  |
| Elongation                            | 10.1% | 16.2%  |

| Table 2. Physical properties of Normal Sand and Manufacture Sand. |
|---------------------------------------------------------------|
| Fineness Modulus | 2.7 | 2.8 |
| Specific Gravity | 2.64 | 2.70 |
| Bulk Density | 1625(Kg/m³) | 1633(Kg/m³) |
| Bulking of Sand | 23% | 19.26% |
| Silt Content | 0.25% | 5.5% |
| Zone | II | II |

| Table 3. Mix proportion of Geopolymer Concrete and Normal Concrete. |
|---------------------------------------------------------------|
| Geopolymer concrete | OPC |
| GGBS | 414 | M30 | 359 |
| Fine – River sand | 330 | Cement (OPC 53 Grade) | 368.5 | 420 |
| Grained M-sand | 330 | Fine | 368.5 | 382.5 |
| Gravels 20 mm | 681.6 | M-sand | 382.5 |
| 12.5 mm | 227.2 | Coarse | 20 mm | 561.5 | 840.81 |
| 10 mm | 227.2 | Aggregate | 280.75 | 280.75 |
| NaOH | 53 | | 10 mm | 280.75 | 280.75 |
| Na₂SiO₃ | 133 | Water | 158 lit/m³ | 151 lit/m³ |
| Water | 10% | Super plasticizer | 1.34 kg/m³ | 1.89 kg/m³ |

3. Mix Proportions

3.1. Alkaline Liquid

NaOH (caustic soda) and Na₂SiO₃ (alkali-silica) are taken to volume mass range are 0.5 to 2.6. Na₂SiO₃ (sodium silicate) is cheapest than the NaOH (sodium hydroxide) and its ratio is 1:2.5. The NaOH solution is taken 8M to 16M and the mixture of gravel and fine aggregates is 74 to 81% mass. The characteristic strength of Mix proportions is 30Mpa.
3.2. Prepare of Geo-polymer Concrete
In caustic soda, solids mass 38.5% are measured. The NaOH solution should be diffused after 24 hours of preparation with a temperature of 700 to 800°C the obtained can be used at only room temperature. The prepare solution is to be mix with the solution of Na$_2$SiO$_3$ to acquire get an alkaline solution. GGBS, fine & coarse aggregates, are mix in drum mixer with 3 to 5 min to obtain a geopolymer concrete solid constituents mix. Now, the NaOH solution to add the along with some water add in the dry mix with 5 minutes mix. The mix proportions for geopolymer concrete and OPC shown in Table 3 and figure 2.

![Figure 2. Preparation of geopolymer concrete.](image)

3.3. Workability Test on Slump Test and Compaction Factor
This ready-mix concrete before to the place to last positions inner a formed work is always conducted to the supervisor on site is determining the workability. The concrete process, they should the construction place to work. To find a green concrete become waterless or place of concrete must interrupt, to remain concrete it should conduct to the pour of congest reinforce cross-section taking on the re-test in a particular area. Compaction factor test is a laboratory-based workability test for concrete. The weight ratio of partially compacted concrete is the compaction factor. The results of the slump test and compaction test for GPC and OPC shown in Figure 3 and Figure 4, respectively.

![Figure 3. Results of Slump Test on GPC and OPC.](image)
3.4. Self-Compacting Concrete

The fresh concrete property of self-compact concrete had the same guidelines in EFNARC. In a present investigation on the different fresh concrete, the test is provided on the slump flow, T50, L-Box, U-Box and V-Funnel have given some limitation in European code.

3.4.1. Slump Flow Test: In slump test are used in deforming the absence of obstacle then it is performed into a lab as per condition BS EN 12350-8:2010 are provided with a limitation of slump flow is measuring the flow diameter, it is greater than slump flow to mix under the weight and test slump flow $SF = \frac{d_1 + d_2}{2}$. The slump flow test results for GPC and OPC has shown in Figure 5.

3.4.2. T50 Slump Test: The slump flow test is measured at the time the concrete flow is taken. It is measured in 0.50m diameter to reach the concrete is spread into a cone lift the top is known as $T_{50}$. It varies between the two to ten sec of the self-compact. The $T_{50}$ slump test results for GPC and OPC has shown in Figure 6.
3.4.3. **V-Funnel**: In slump test is used in deform the absence of obstacle then it is performed into a lab as per condition BS EN 206-9:2010 are provided a limitation of V-Funnel are measuring the flow diameter. The fresh concrete is filled in 12000ml of the concrete to time take the flow is measured. The inverted cone shape limits flow. Long flow times may indicate that the mixture is susceptible to blocking. The separation of concrete after five minutes would display a decreased continuous flux with an increase in flow time. i.e., \( t_{50} < 2 \). The slump test results using V-funnel apparatus for GPC and OPC shown in Figure 7.

![Figure 7. Results of Slump test using V-funnel on GPC and OPC.](image)

3.4.4. **L-BOX**: In slump test are used in deform the absence of obstacle then it is performed into a lab as per condition BS EN 12350-10:2010 are provided with a limitation of L-Box are measured. L-Box is filling with the concrete at vertical section is lift at the block ratio is determining at the end of the horizontal section is stop flowing into the concrete it should be 0.8. i.e., \( SF = \frac{H_2}{H_1} \). The slump test results using the L-box apparatus for GPC and OPC has shown in Figure 8.

![Figure 8. Results of Slump test using L-box on GPC and OPC.](image)

3.4.5. **U-Box**: The concrete flowable to pass through the self-compact test. It is open with a slide gate is fitted with a 2 section of the concrete with 0.13m diameter to centre space 0.50m and clear space is 0.35m bars. In the left side is filled with twenty litres of concrete then the gate is the life of the concrete flow through the top of the section. i.e., \( SF = H_1 - H_2 \). The slump test results using the U-box apparatus for GPC and OPC has shown in Figure 9.

![Figure 9. Slump test using U-box.](image)
3.5. Durability Test
Durability can resist the weather action, chemical attack and abrasion of concrete as a maximum effect of concrete. In an experimental study on geopolymer concrete and convention, concrete compare to the water absorption; HCl; NaCl; H2SO4; MgSO4 are compressive strength due to attack as shown in tables.

3.5.1. Water Absorption: The durability of concrete affects the moisture to penetrate as a porous material to allow the water and through the migration. For water absorption specimen size is0.15mx0.15mx0.15m was cast and immerse water curing for 28, 56 and 90days. In geopolymer concrete cast cubes with different molarities to compare the normal concrete. Water absorption test results are shown in figure 10 and experimental work are shown in figure 14.

\[
\text{Water absorption} = \frac{M_1 - M_2}{M_2} \times 100
\]

\[M_1 = \text{before curing wt. of sample}
\]
\[M_2 = \text{after curing wt. of sample}
\]

![Figure 10. Results of Water Absorption Test on GPC and OPC.](image)

3.5.2. Acid (HCl): The mixture of concrete has cube specimen size is0.15mx0.15mx0.15m casting and five per cent of acid added is taken water after 28,56 and 90 days of curing. The sample is removing for the curing tube to allow the dry for 24hours. Acid (HCl) test results are shown in figure 11 and experimental work are shown in figure 14.

\[
\text{Resistance of concrete} = \frac{M_1 - M_2}{M_2} \times 100
\]

\[M_1 = \text{per cent loss of wt. of sample}
\]
\[M_2 = \text{per cent loss of compressive strength}
\]

![Figure 11. Results of Acid (HCl) on GPC and OPC.](image)

3.5.3. Chloride (NaCl): The mixture of concrete has cube specimen size is0.15mx0.15mx0.15m casting and five per cent of chloride (or)salt is added to take into the water after 28,56 and 90 days of
curing. In specimens are removing the cured tube to allow the dry for 24 hours. Chloride results are shown in figure 12 and experimental work are shown in figure 14.

Resistance of concrete = \( M_1 - M_2 / M_2 \times 100 \)

\( M_1 = \) per cent loss of wt. of sample
\( M_2 = \) percent loss of strength

3.5.4. Sulphuric Acid (H\(_2\)SO\(_4\)):

The mixture of concrete has cube specimen size is 0.15mx0.15mx0.15m casting and 5% of Sulphuric acid is added to take into the water after 28, 56 and 90 days of curing. In specimens are removing the cured tube to allow the dry for 24 hours. Sulphuric Acid test results are shown in figure 13 and experimental work are shown in figure 14.

Resistance of concrete = \( M_1 - M_2 / M_2 \times 100 \)

\( M_1 = \) per cent loss of wt. of sample
\( M_2 = \) percent loss of strength

3.5.5. Magnesium Sulfate (MgSO\(_4\)):

The mixture of concrete has cube specimen size is 0.15mx0.15mx0.15m casting and five per cent of magnesium sulfate is added to take into the water after 28, 56 and 90 days of curing. The specimens are removing for the cured tube to allow the dry for 24 hours. Magnesium sulfate test results are shown in figure 15 and experimental work are shown in figure 14.

Resistance of concrete = \( M_1 - M_2 / M_2 \times 100 \)

\( M_1 = \) per cent loss of wt. of sample
\( M_2 = \) percent loss of strength
Figure 14. Curing and Specimens of Water absorption, HCl, NaCl, H$_2$SO$_4$, MgSO$_4$.

Figure 15. Results of Magnesium Sulfate (MgSO$_4$) on GPC and OPC.

4. Strength Characteristics

4.1. Compression Test

The concrete of strength is finding only one alternate method. The cube size of moulds 0.15X0.15X0.15m was cast with same molarity (i.e., 8M, 10M, 12M, 14M, 16M) and normal concrete. After 1440 mins the specimens are demould and subjected to ambient curing. After 3, 7, 14, 28, 56, 90 day the specimens are ambient curing are taken and testing the machine as shown in figure 18 and Compressive strength test results are shown in figure 16.

Figure 16. Results of Compressive Strength Test on GPC and OPC.

4.2. Split Tensile Test

It is finding a concrete strength to subject into the cylinder of a lateral compressive force. The size of 0.15m diameter and 0.30m large cylinder were cast with same molarity (i.e., 8M, 10M, 12M, 14M, 16M) and normal concrete. After 1440 mins the cylinder specimens is demoulding and subjected to ambient curing. After 3, 7, 14, 28, 56, 90 day the specimens are ambient curing is taken and allow the
waterless and test machine to place the specimen horizontal as shown in figure 18 and split tensile test results are shown in figure 17.

![Split Tensile Test Results](image1)

**Figure 17.** Results of Split Tensile Test on GPC and OPC.

### 4.3. Flexural Strength

It is finding a concrete strength to subject into the prism beam of a lateral compressive force. The size of 0.15x0.15x0.70 were cast with same molarity (i.e., 8M, 10M, 12M, 14M, 16M) and normal concrete. After 1440 mins the beam specimens is demoulding and subjected to ambient curing. After 3,7,14,28,56,90day the specimens are ambient curing is taken and allow the waterless and test machine to place the specimen horizontal as shown in figure 18 and flexural strength test results are shown in figure 19.

![Flexural Strength Test Results](image2)

**Figure 18.** Testing of Specimen on Strength Characteristics.

**Figure 19.** Results of Flexural Strength Test on GPC and OPC.

### 5. Conclusion

Experimental study on geopolymer concrete and normal concrete to concluded that:

1. It was observed that the slump of 8M is higher than the 16M i.e., is 0.29% decrease and
2. Durability test is conducted to find the concrete strength the structure is a long life or not it is identified.
3. In this paper, have the same various acid test are conducted. In geopolymer concrete specimen immerse in chloride; sulphate; acid; magnesium sulfate and water absorption were observed to compare the normal concrete. The specimen was testing for 28,56,90 days.
4. Mechanical properties are shows an increasing trend concerning the age of concrete.
5. The strength increases with the increase in the molarity of the concrete.
6. The strength of geopolymer concrete is showing good results than conventional concrete.

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