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# Analysis of geopolymer concrete and ordinary concrete with various properties

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## Abstract

The development of Geopolymer Concrete is in the response for the need of "greener concrete" in order to reduce the emission of enormous amount of $CO_2$ from cement production, it causes serious environmental problem and induces global warming. Hence, it is necessary to cater the emission of $CO_2$ by reducing the production and usage of cement. This problem can be reduced by replacing the cement with an alternative material. In India 75 million tone of fly ash per year is produced. One of the best solutions to tackle this situation is using Class F fly ash instead of cement then the cementitious property is brought by the addition of activator solutions such as NaOH and $Na_2SiO_3$. SNF is used as super plasticizer to improve the workability of fresh concrete and fine aggregate is partially replaced by M sand. Cubes and cylinders are casted and their corresponding properties are determined.

**Keywords**

*Portland cement*
*Geopolymer*
*Aggregate*
*Compressive*
*Split tensile*

## Introduction

Concrete is one of the most widely used construction materials, it is usually associated with Portland cement as the main component for making concrete. The demand for concrete as a construction material is on the increase. It is estimated that the production of cement will increase from 1.5 billion tons in 1995 to 2.2 billion tons in 2010. On the other hand, the climate change due to global warming, one of the greatest environmental issues has become a major concern during the last decade. The global warming is caused by the emission of greenhouse gases, such as $CO_2$, to the atmosphere by human activities [1]. Among the greenhouse gases, $CO_2$ contribute about 65% of global warming. The cement industry is responsible for about 6% of all $CO_2$ emissions, because the production of one tone of Portland cement emits approximately one tone of $CO_2$ into the atmosphere.

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Although the use of Portland cement is still unavailable until the foreseeable future, many efforts are being made in order to reduce the use of Portland cement in concrete [3]. These efforts include the utilization of supplementary cementing materials such as fly ash, silica fume, ground granulated blast furnace slag, rice husk ash and finding alternative binders to Portland cement. In this respect, the geo polymer technology shows considerable promise for application in concrete industry as an alternative binder to the Portland cement. In terms of reducing the global warming, the geo polymer technology could reduce the $CO_2$ emission to the atmosphere caused by cement and aggregates industries by about 80%.

## Literature review

Throughout the world, concrete is used for all types of construction. Hence, it has been properly labeled as the backbone to the infrastructure development of a nation. Currently, our country is taking major initiatives to improve and develop its infrastructure by constructing express highways, power projects and industrial structures to emerge as a major economic power [2,4]. To meet out this rapid infrastructure development a huge quantity of concrete is required. Unfortunately, India is not self-sufficient in the production of cement and availability of natural sand is also decreasing making the construction activities very costlier. Also we need high strength material as geo polymer. Some of the review examples are

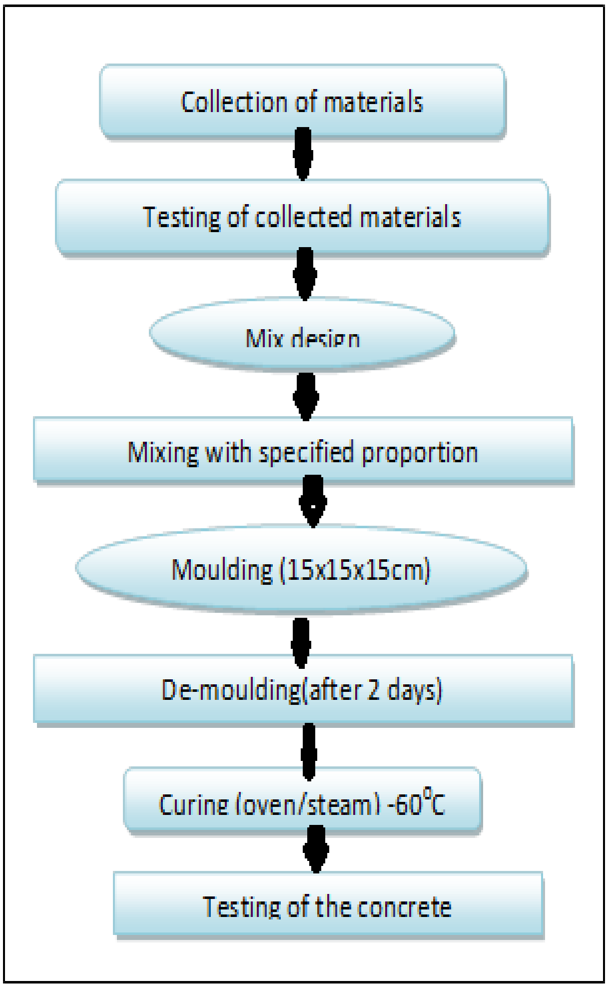
i) Knowing the density of concrete, the combined mass of alkaline liquid and fly ash can be arrived at. By assuming the ratios of alkaline liquid to fly ash as 0.4, mass of fly ash and mass of alkaline liquid was found out [5]. To obtain mass of sodium hydroxide and sodium silicate solutions, the ratio of sodium silicate solution to sodium hydroxide solution was fixed as 2.5, (2006).

ii) An attempt has been made to find out an optimum mix for the Geopolymer concrete. The geopolymer concrete was demoulded and then placed in a steam curing for 24 hours at a temperature of $60^0$C, and then it is allowed to cool in room temperature for 24 hours [8]. The concrete will harden at steam curing or hot air curing and the minimum curing period is 24 hours. After casting the specimens, they were kept in rest period in room temperature for 2 days.

iii) The most commonly used cement manufactured by burning of large quantities of fuel, typically coal with lime stone. Source Materials: Fly ash, Silica fume, Slag, Rice-husk ash, Red mud, etc. Alkaline Liquids: Sodium hydroxide with sodium silicate, Potassium hydroxide with potassium silicate [6]. It is used to induce the silicon and aluminum atoms in the source materials to dissolve and form a gel and the specimen is cured by steam and hot air.

iv) Portland cement have become costlier nowadays and it also not eco-friendly. So fly ash based Geopolymer concrete is becoming popular now. This paper deals with the ways of curing geopolymer concrete namely ambient curing and hot curing. For all samples the ratio of alkaline liquid to fly ash was fixed as 0.4. The density of the geopolymer concrete is 2400 kg/$m^3$ which are equivalent to conventional concrete [7]. The rest period of samples was kept as 5 days. The compressive strength test is conducted for all samples. For hot curing the temperature was maintained at 60 $^o$C for 24 h in hot air oven. The compressive strength of ambient curing and hot curing is compared.

## Process involved in manufacturing



## Casting and testing theory of concrete

### Proportioning and mixing

The quantities of (Class F) fly ash, aggregate and alkaline solution are determined by weight. Aggregates and fly ash were mixed dry in a pan mixer for 3 minutes. The alkaline solution and the super plasticiser were mixed together, and then added to the solid particles and mixed it for 3 to 5 minutes.th fresh concrete had a stiff consistency and was glossy appearance [10]. This concrete has low workability and extra water can be added if required. In assembling the mould for use, the joints between the sections of mould are thinly coated with mould oil and a similar coating of mould oil is applied between the contact surfaces of the bottom of the mould and the base plate in order to ensure that no water escapes during the filling. The interior surfaces of the assembled mould are thinly coated with mould oil to prevent adhesion of the concrete.

## Compacting

The concrete is filled into the mould in layers approximately 5 cm deep and each layer is subjected to 35 strokes with tamping rod, distributed uniformly over the cross-section of the mould. The strokes shall penetrate into the underlying layer and the bottom layer is rodded throughout its depth. Where voids are left by the tamping bar, the sides of the mould are tapped to close the voids. After the top layer has been compacted, the surface of the concrete is finished level with the top of the mould, using a trowel and covered with a glass or metal plate to prevent evaporation [9,12][]. The test specimens are stored in a place, free from vibration, in moist air of at least 90 percent relative humidity and at a temperature of 27 ± 2 °C for 24 hours ± ½ hour from the time of addition of water to the dry ingredients

### Polymerization process

Fly ash has silica and alumina naturally, by the addition of alkaline solution, the silica and aluminium atoms are induced, to dissolve to form gel. The Polymerization process may be assisted by applied heat followed by drying. The geopolymer gel binds the loose coarse and fine aggregate to form geopolymer concrete [11]. Geopolymer gel replaces the C-S-H gel in cement concrete. The geopolymer gel is formed during curing period.

## Curing

The Geopolymer concrete did not attain any strength at room temperature or by water curing. The Geopolymer concrete will harden at steam curing or hot air curing and the minimum curing period shall be 24 h. After casting the specimens, they were kept in rest period in room temperature for 2 days. The term ‘Rest Period’ was coined to indicate the time taken from the completion of casting of test specimen to the start of curing at an elevated temperature. The Geopolymer concrete was demoulded and then placed in an autoclave for steam curing for 24 h at a temperature of 60 $^0$C.The cubes were then allowed to cool in room temperature for 24 h.

## Testing

Surface water and grit shall be wiped off the specimens and any projecting fins removed from the surfaces which are to be in contact with the packing strips. Central lines shall be drawn on the two opposite faces of the specimens the mass and dimensions of the specimens shall be noted before testing. The test specimen shall be placed in the centring jig with packing strip and/or loading pieces carefully positioning along the top and bottom of the plane of loading of the specimen. In the case of cubic specimens, the load shall be applied on the moulded faces in such a way that the fracture plane will cross the trowelled surface. For cylindrical specimens, it shall be ensured that the upper platen is parallel with the lower plate. The load shall be applied without shock and increased continuously at a nominal rate within the range 1.2 N/(mm2/min) to 2.4 N/(mm2/min). The maximum load applied shall then be recorded. The appearance of concrete and any unusual features in the type of failure shall also be noted.

**Mix design:** quantities per m$^3$ of fresh concrete:

- Cement: 350 kg
- Water: 190 l(litter)
- Air : 1%
- Bulk sp. Gravity of aggregates =2.65
- Specific gravity of cement = 3.15

Absolute volume of air = 0.010 $m^3$

Absolute volume of water = $\frac{Ww}{1000} = \frac{190}{1000}$ 0.190 $m^3$

Absolute volume of cement = $\frac{Wc}{1000(3.15)} = \frac{350}{1000(3.15)}$

$= \frac{0.111}{0.311}$ $m^3$

Absolute volume of aggregates = 1.000 -0.311 = 0.689 $m^3$

Weight of aggregates = 0.689 (2.65 x 1000) = 1825.85 kg

For convenience of calculation it can be written in the form of the following table

| | Weight (kg) | Absolute volume ($m^3$) |
|---|---|---|
| Air | **-** | **0.010** |
| Water | 190 | 0.190 |
| Cement | 350 | 0.111 |
| **Total** | **540** | **0.311** |
| Aggregates | 1826 | 0.689 |
| **Total** | **2366** | **1. 000** |

The above total weight of the concrete is the unit weight in kg per $m^3$ of the fresh concrete. If the proportion of the fine to coarse aggregate by weight is **1: 2**, then the quantities of aggregates will be

Fine Aggregate (sand) $\frac{1826*1}{3} = 609kg$

Coarse Aggregate $\frac{1826*2}{3} = 1217kg$

The mix quantities and proportions by weight will be

| | Kgs | Parts |
|---|---|---|
| Water | 190 | 0.543 |
| Cement | 350 | 1 |
| Sand | 609 | 1.74 |
| C.A. | 1217 | 3.48 |

**Test on materials**

1. Specific Gravity of Fine Aggregate:

$$= \frac{\textit{dry weight of aggregate}}{\textbf{weight of water} - \textbf{weight of pore water}}$$

The specific gravity of fine aggregate = 2.5

2. Specific gravity of coarse aggregate:

$$= \frac{\textit{dry weight of aggregate}}{\textbf{weight of water} - \textbf{weight of pore water}}$$

The specific gravity of coarse aggregate = 2.8

## Tests on fresh concrete:

**Slump test**

To determine the workability of fresh concrete by Slump test as per IS:
1199 – 1959**.** The Slump observed for given sample = 130mm

**Table 1** Slump value

| S.No | Alkaline liquid /fly ash ratio | Value of Slump(mm) | Nature of collapse |
|---|---|---|---|
| 1 | 0.30 | 105 | Shear |
| 2 | 0.35 | 130 | True slump |

**Flow table test**

To determine the workability of fresh concrete byflow table test as per IS: 1199 – 1959. The flow percent of concrete is 28.67%.

**Table 2** Flow table value

| S.No. | Alkaline liquid to fly ash ratio | Spread diameter in 10cm | Flow % |
|---|---|---|---|
| 1. | 0.30 | 12.2 | 22 |
| 2. | 0.35 | 13.3 | 28.67 |
| 3. | 0.4 | 13 | 30.67 |

**Test result on hardened concrete**

**Compressive Strength**

Formula used: Compressive Strength = Load Applied / Area of the specimen

**Table 3** Compressive strength at 7 days for geopolymer concrete

| Cube. No | Duration (days) | Weight of the Cube (kg) | Load @ failure (kN) | Compressive Strength ($N/mm^2$) |
|---|---|---|---|---|
| 1 | 7 | 8.28 | 218 | 9.69 |
| 2 | 7 | 7.95 | 250 | 11.11 |
| 3 | 7 | 8.06 | 236 | 10.49 |
| 4 | 7 | 8.10 | 350 | 15.56 |
| 5 | 7 | 7.84 | 315 | 14.0 |
| 6 | 7 | 8.15 | 320 | 14.22 |

As like above table we can calculate the Compressive strength at 7 days for Geopolymer concrete (20% of M sand) and Geopolymer concrete (40% of M sand). Then we can calculate the Compressive strength at 14 days and 28 days for Geopolymer concrete (20% of M sand) and Geopolymer concrete (40% of M sand).

## Split tensile strength

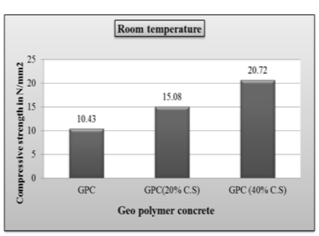
The measured splitting tensile strength fct, of the specimen shall be calculated to the nearest 0.05 N/mm2 as:

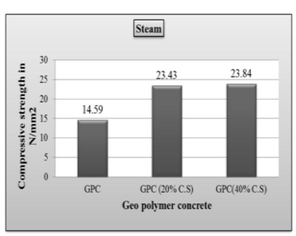
$$f_{ct} = (2 * P) / (\pi * l * d)$$

Where, P = Maximum load applied in N, l = Length of the specimen in mm, d = Cross sectional dimension of the specimen in mm

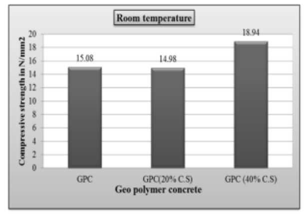
## Comparision of results

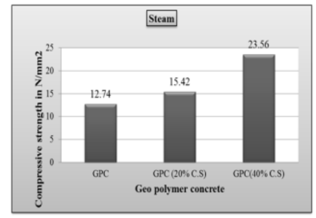
### Compressive Strength at 7 Days



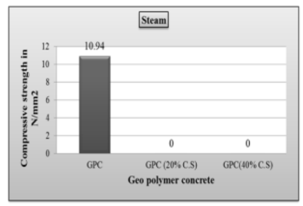



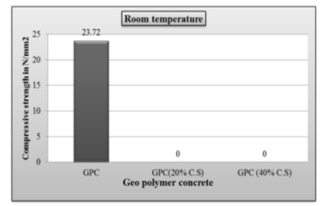

### Compressive Strength at 14 Days



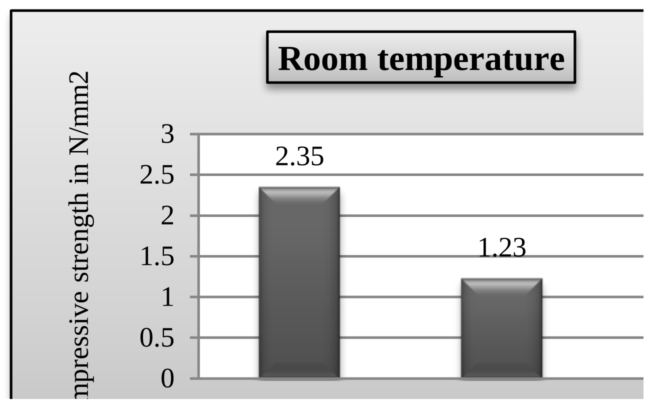




### Compressive Strength at 28 Days




### Split Tensile Strength at 28 Days



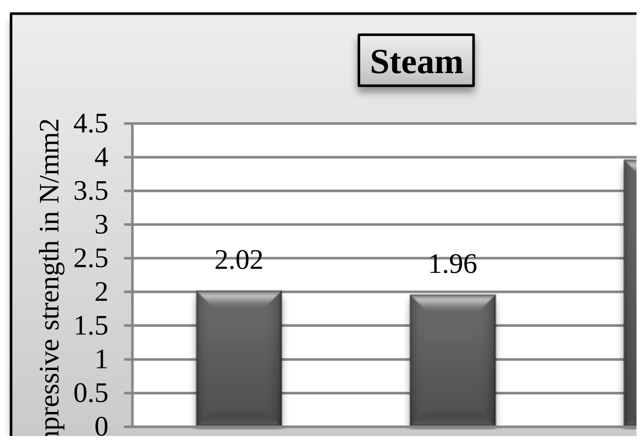



**Table 4** Comparision of ordinary cement concrete and geopolymer concrete

| Item | Ordinary cement concrete | Geo polymer concrete | Geo polymer concrete with M sand |
|---|---|---|---|
| Emission of Carbon di oxide($CO_2$) | More | Less | Less |
| Cost | More | Less | Less |
| Admixture | Unnecessary | Necessary | Necessary |
| Weight | More | Less | Less |
| Workability | More | Less | Less |

## Conclusions

The geo polymer concrete has achieved its strength by curing at room temperature as when compared to steam curing. But for the same mix when the concrete is prepared by partially replacing the sand with M sand for 20% and 40%, it attains the strength from steam curing. GPC have low workability but it posse's high strength. One of the main advantages known from this project is in normal GPC, it does not require any type of curing after taken from 24 h oven. This concrete is an Eco friendly concrete and also the cost for preparing the concrete is less.

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