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# An Experimental Investigation on Geopolymer Concrete Blended with Alccofine Cured Under Heat and Ambient Condition

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**Abstract -** This study investigates the effects of Alccofine on the properties of geopolymer concrete cured under heat and ambient conditions. Geopolymer concrete specimens were prepared with varying proportions of Alccofine and cured at different temperatures. The results show that Alccofine improves the compressive strength, durability, and workability of geopolymer concrete. Heat curing enhances the early- age strength of geopolymer concrete, while ambient curing allows for slower strength development. The findings suggest that geopolymer concrete blended with Alccofine has potential applications in sustainable construction, particularly in projects requiring high strength and durability.Geopolymer concrete, an eco-friendly alternative to conventional Portland cement concrete, is synthesized using industrial by-products such as fly ash, activated by alkaline solutions. Alccofine, known for its ultrafine particle size and high reactivity, is introduced into the mix to enhance the mechanical and durability properties of GPC. The research evaluates the influence of different curing regimes—heat curing and ambient curing—on compressive strength, setting time, and microstructural characteristics. Results demonstrate that Alccofine significantly contributes to early strength development, particularly under heat curing, while also improving long-term performance under ambient conditions.

## 1. INTRODUCTION:

Concrete is the world's most versatile, durable and reliable construction material. Large quantities of Portland cement are required for concrete. The consumption of Ordinary Portland Cement (OPC) causes pollution to the environment due to the emission of $CO_2$. Geopolymer concrete was introduced to reduce environmental pollution that causes by production of Portland cement.

In 1978, Professor Joseph Davidovits introduced the development of mineral binders with an amorphous structure, named geopolymers. Davidovits (1988; 1994) proposed that an alkaline liquid could be used to react with the silicon (Si) and the aluminium (Al) in a source material of geological origin or in by-product materials such as fly ash and rice husk ash to produce binders. Because the chemical reaction that takes place in this case is a polymerization process, he coined the term 'Geopolymer' to represent these binders. This was a class of solid materials, produced by the reaction of an alumino silicate powder and an alkaline liquid. The initial goal for the research done on these geopolymers was to find a more fire resistant binder material due to the high amount of fires in Europe at that time. This research led to the material being used as coatings for the fire protection of cruise ships and thermal protect results in a low flexural strength. Brittleness of both concrete types is compensated by conventional steel reinforcement.

Geopolymer concrete is an innovative construction material which shall be produced by the chemical action of inorganic molecules. Otherwise geopolymer is an inorganic alumino- hydroxide polymer synthesized from predominantly silicon (Si) and aluminium (Al) materials of geological origin or byproduct materials such as fly ash. The term Geopolymer was introduced to represent the mineral polymers resulting from geochemistry. The process involves a chemical reaction under highly alkaline conditions on Si-Al minerals, yielding polymeric Si-O-Al-O bonds in amorphous form. Due to its high mechanical properties combined with substantial chemical resistance (magnesium or sulphate attack), low shrinkage and creep and environment friendly nature (very less amount of $CO_2$ production in comparison with OPC), it is a better construction material for future.

## 2. MATERIALS:

*2.1.1 Fly ash*

Fly ash ((ASTM Class F) collected from Mettur Thermal Power Station), Alccofine (Chennai) Coarse and fine aggregates used by the concrete industry are suitable to manufacture geopolymer concrete. The aggregate grading curves currently used in concrete practice are applicable in the case of geopolymer concrete.

Fly ash is a byproduct of coal combustion in power plants, consisting of fine particles that are collected from the exhaust gases. It is a pozzolanic material, meaning it reacts with calcium hydroxide to form cementitious compounds.

2.1.2 Alccofine

Alccofine is a type of supplementary cementitious material (SCM) that is used to enhance the properties of concrete. It is a finely ground, high-quality mineral admixture that is derived from slag, a byproduct of the steel industry.

2.1.3 Coarse aggregate

Coarse aggregate refers to the larger particles of aggregate used in construction, typically ranging in size

from 4.75 mm to 80 mm.

**2.1.4 Fine Aggregate**

Fine aggregate refers to the smaller particles of aggregate used in construction, typically ranging in size from 0.075 mm to 4.75 mm.

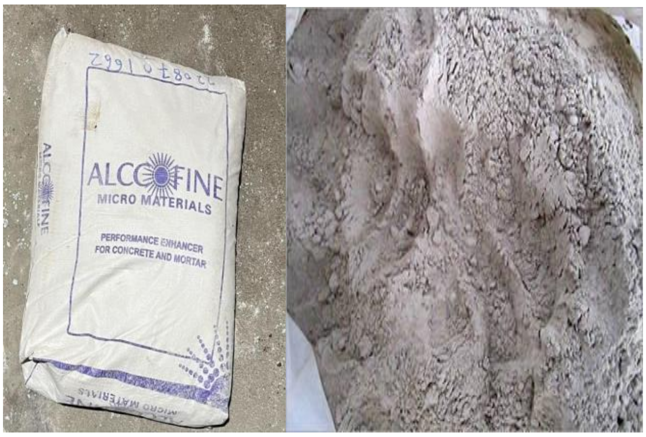
### 2.1.5 Alkaline liquid

Alkaline liquids play a crucial role in the production of Geopolymer concrete. These liquids activate the aluminosilicate materials, such as fly ash or slag, to form a binding agent.

*Types of Alkaline Liquids*

**Sodium Hydroxide (NaOH): A strong alkaline solution commonly used in Geopolymer concrete.**

**Sodium Silicate ($Na_2SiO_3$): A liquid solution that provides additional silica, enhancing the geopolymerization reaction.**




### 3. EXPERIMENTAL INVESTIGATION:

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This Chapter presents the details of development of the process of making low calcium Fly ash ((ASTM Class F) collected from Mettur Thermal Power Station), and Alccofine based geopolymer concrete. First, the materials, mixture proportions, manufacturing and curing of the test specimens are explained. This is then followed by the test procedures. As far as possible, the current practice used in the manufacture and testing of ordinary Portland cement (OPC) concrete was followed. The aim of this action was to ease the promotion of this "new" material to the concrete construction industry. In order to simplify the development process, the compressive strength was selected as the benchmark parameter. This is not unusual because compressive strength has an intrinsic importance in the structural design of concrete structures

**<u>The properties of materials used are listed below:</u>**

- Specific gravity of Fine aggregate (G)= 2.50
- Specific gravity of Coarse aggregate (G)= 2.71
- Bulk density of Fine aggregate= 1658.06 Kg/m$^3$
- Bulk density of Coarse aggregate=1540.12 Kg/m$^3$
- Fineness modulus of Coarse aggregate= 7.08
- Fineness modulus of Fine aggregate= 2.92 [ Zone II ]
- Specific gravity of Fly ash= 2.08

### 3.1.1 MIX DESIGN

**Mix design of Geo polymer concrete (GPC) [ By using- IS- 10262-2019 ]**

- We design M25 grade
- Nominal size of aggregate = 20mm

Target strength :-

1) $f'_{ck} = f_{ck} + 1.65(S)$

$f_{ck} = 25 + 1.65(4)$

$f'_{ck} = 31.6\ N/mm^2$

2) $f'_{ck} = f_{ck} + X$

$f'_{ck} = 25 + 5.5$

$f'_{ck} = 30.5\ N/mm^2$

Let assume Target strength will be : 31.6 N/mm$^2$

 

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**Water cement ratio :-** Maximum w/c = 0.5 from graph w/c = 0.55 So, we use w/c = 0.5
For 100mm slump = 198 litres

Fly ash content

$w/c = 0.5$

$198/c = 0.5$

$c = 396 \text{ Kg/m}^3$

Volume of Coarse aggregate = 0.62 Volume of Fine aggregate

= 1-0.62= 0.38

Final mix calculation :-

i. Volume of concrete = $1\text{m}^3$

ii. Volume of entrapped air = $0.01\text{m}^3$

iii. Volume of Fly ash = $\frac{396}{2.08} \times \frac{1}{1000}$

$= 0.19 \text{ m}^3$

iv. Volume of water = $\frac{198}{1} \times \frac{1}{1000}$

$= 0.198 \text{ m}^3$

Volume of all in aggregate = [(1-0.01)-(0.19+0.198)

$= 0.602 \text{ m}^3$

Mass of Coarse aggregate = 0.602 X 0.62 X 2.71 X 1000

$= 1011.48 \text{ Kg/m}^3$

Mass of Fine aggregate = 0.602 X 0.38 X 2.5 X 1000

$= 571.90 \text{ Kg/m}^3$

*Ratio of materials for 1m$^3$*

| Fly ash : | Fine aggregate : | Coarse aggregate : | Alkali solutions |
|---|---|---|---|
| 396 : | 571.90 : | 1011.48 : | 198 |
| 1 : | 1.44 : | 2.55 : | 0.5 |

➢ **<u>For 1 cube of dimensions 100 X 100 X 100 mm cube</u>**

0.1 X 0.1 X 0.1 = 0.001 m$^3$

For 1m$^3$ = 198 liters of water

for 0.001 m$^3$ = 0.198 liters (198 ml)

*<u>Alkali solution</u> :-*

1. Sodium hydroxide (NaOH) = 8 Molarity

2. Sodium silicate ($Na_2SiO_3$)

i. $Na_2SiO_3$ = $\frac{2}{3}$ (198

= 132 ml

ii. NaOH = $\frac{1}{3}$(198) {for 1000ml of water 320grams of NaOH used}

= 66 ml {for 66ml of water 21.12grams of NaOH}

*<u>Fly ash</u> :-*

For 1m$^3$ = 396 Kgs

for 0.001 m$^3$ = 0.396 Kgs (396 grams)

*<u>Fine aggregate</u> :-*

For 1m$^3$ = 571.9 Kgs

for 0.001m$^3$ = 0.571 Kgs (571 grams)

*Coarse aggregate* :-

For $1m^3$ = 1011.48 Kgs for $0.001m^3$ = 1.011Kgs (1011 grams)

**Cast of test Specimens**

**3.1.2.1 Preparation of Alkaline liquid**

***In this study, NaOH solids of 40X8=320 grams have been dissolved in 1000ml of water to prepare one litre of NaOH solution with a concentration of 8 Molarity (M). where 40 is the molecular weight of NaOH pellets. The sodium silicate solution ($Na_2SiO_3$) and the sodium hydroxide solution (NaOH) were mixed together one day prior to use.***

***3.1.2.2 Manufacture of fresh concrete***

The concrete batch was mixed on a water tight, non-absorbent steel platform with a shovel using the following procedure:

i. The flyash, alccofine and fine aggregate were mixed dry until the mixture is thoroughly blended and is uniform in colour.

ii. The coarse aggregate was added and mixed with the flyash, alccofine and fine aggregate until the coarse aggregate was uniformly distributed throughout the batch.

iii. The chemical solution was added and the entire batch was mixed until the concrete appeared to be homogenous and had the desired consistency. If repeated mixing was necessary, because of the addition water in increments while adjusting the consistency, the batch is to be discarded and fresh batch is made.

***3.1.2.3 Mixing, Casting and Curing***

The fresh fly ash ((ASTM Class F) collected from Mettur Thermal Power Station), Alccofine (Chennai) was used. The aggregates were prepared in saturated surface dry condition. The liquid part of the mixture, ie. the sodium silicate solution, the sodium hydroxide solution mixed well. The solids constituents of the fly ash based geopolymer concrete, ie. the aggregates and the fly ash were dry mixed by a Pan mixer for about three minutes. The wet mixing of liquid and dry mixture of aggregates usually continued for another four minutes. The wet mixing usually is in cohesive condition.

After getting the desired consistency , fill each mould (100mm x 100 mm x 100 mm) with above mix in three layers by tamping each layer 25 times with tamping rod.

After casting, the specimens were cured at 80 $^{o}$ C in oven for 4hrs, 6hrs, 20hrs and cubes are tested at above mentioned curing ages in universal testing machine (UTM).

For every time of testing three 100mm x 100 mm x 100 mm cubes are tested.

**4. RESULTS**

Geopolymer concrete blended with Alccofine exhibits improved properties when cured under both heat and ambient conditions.

Geopolymer concrete with Alccofine can achieve target strength compressive strength, when cured at 80°C for 20Hours. Even at ambient temperature it can reach target strength for 28 Days

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Adding Alccofine enhances the workability of geopolymer concrete.

Heat curing accelerates the geopolymerization process, leading to quick gain of compressive strength.

Ambient curing is more practical for cast-in-situ applications, and geopolymer concrete with Alccofine can still achieve desirable properties.

Geopolymer concrete with Alccofine exhibits higher Compressive strength compared to conventional concrete.

**4.1** Compressive strength test on cube specimens ( 99% Fly ash, 1% Alccofine)

| S.NO | LOAD (Kgf) | WEIGHT OF CUBE (gm) | COMPRESSIVE STRENGTH (N/mm$^2$) |
|---|---|---|---|
| 4Hrs curing – Heat curing | | | |
| 1 | 7180 | 2334 | 7.180 |
| 2 | 7321 | 2353 | 7.321 |
| 3 | 7184 | 2307 | 7.184 |
| Average Compressive strength (N/mm$^2$) | | | 7.228 |
| 6Hrs curing – Heat curing | | | |
| 1 | 8791 | 2333 | 8.791 |
| 2 | 8987 | 2285 | 8.987 |
| 3 | 8952 | 2365 | 8.952 |
| Average Compressive strength (N/mm$^2$) | | | 8.910 |
| 6Hrs curing – Heat curing | | | |
| 1 | 21906 | 2304 | 21.906 |
| 2 | 22382 | 2207 | 22.382 |
| 3 | 23160 | 2318 | 23.160 |
| Average Compressive strength (N/mm$^2$) | | | 22.483 |
| 28 Days – Ambient curing | | | |
| 1 | 7586 | 2320 | 7.586 |
| 2 | 8210 | 2257 | 8.210 |
| 3 | 7922 | 2299 | 7.922 |
| Average Compressive strength (N/mm$^2$) | | | 7.906 |

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4.2 Compressive strength test on cube specimens ( 98% Fly ash, 2% Alcofine )

| S.NO | LOAD (Kgf) | WEIGHT OF CUBE (gm) | COMPRESSIVE STRENGTH (N/mm) |
|---|---|---|---|
| 4Hrs curing – Heat curing | | | |
| 1 | 10801 | 2394 | 10.801 |
| 2 | 9765 | 2472 | 9.765 |
| 3 | 11519 | 2310 | 11.519 |
| Average Compressive strength (N/mm$^2$) | | | 10.695 |
| 6Hrs curing – Heat curing | | | |
| 1 | 14347 | 2375 | 14.347 |
| 2 | 13185 | 2423 | 13.185 |
| 3 | 14430 | 2277 | 14.430 |
| Average Compressive strength (N/mm$^2$) | | | 13.987 |
| 20Hrs curing – Heat curing | | | |
| 1 | 24820 | 2432 | 24.820 |
| 2 | 25681 | 2417 | 25.681 |
| 3 | 26012 | 2426 | 26.012 |
| Average Compressive strength (N/mm$^2$) | | | 25.504 |
| 28 Days – Ambient curing | | | |
| 1 | 14048 | 2389 | 14.048 |
| 2 | 15947 | 2297 | 15.947 |
| 3 | 15717 | 2430 | 15.717 |
| Average Compressive strength (N/mm$^2$) | | | 15.237 |

**4.3** Compressive strength test on cube specimens ( 97% Fly ash, 3% Alcofine )

| S.NO | LOAD (Kgf) | WEIGHT OF CUBE (gm) | COMPRESSIVE STRENGTH (N/mm) |
|---|---|---|---|
| 4Hrs curing – Heat curing | | | |
| 1 | 12775 | 2378 | 12.775 |
| 2 | 12744 | 2283 | 12.744 |
| 3 | 11495 | 2321 | 11.495 |
| Average Compressive strength (N/mm$^2$) | | | 12.671 |
| 6Hrs curing – Heat curing | | | |
| 1 | 16198 | 2309 | 16.198 |
| 2 | 17484 | 2413 | 17.484 |
| 3 | 16214 | 2419 | 16.214 |
| Average Compressive strength (N/mm$^2$) | | | 16.632 |
| 20Hrs curing – Heat curing | | | |
| 1 | 27145 | 2336 | 27.145 |
| 2 | 28587 | 2319 | 28.587 |
| 3 | 26170 | 2285 | 26.170 |
| Average Compressive strength (N/mm$^2$) | | | 27.480 |
| 28 Days – Ambient curing | | | |
| 1 | 21994 | 2368 | 21.994 |
| 2 | 20187 | 2399 | 20.187 |
| 3 | 20255 | 2358 | 20.255 |
| Average Compressive strength (N/mm$^2$) | | | 20.812 |

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**4.4** Compressive strength test on cube specimens ( 96% Fly ash, 4% Alccofine )

| S.NO | LOAD (Kgf) | WEIGHT OF CUBE (gm) | COMPRESSIVE STRENGTH (N/mm) |
|---|---|---|---|
| 4Hrs curing – Heat curing | | | |
| 1 | 13258 | 2363 | 13.258 |
| 2 | 16424 | 2347 | 16.424 |
| 3 | 13490 | 2321 | 13.490 |

| | | | |
|---|---|---|---|
| Average Compressive strength (N/mm$^2$) | | | 14.384 |
| 6Hrs curing – Heat curing | | | |
| 1 | 20810 | 2377 | 20.810 |
| 2 | 19742 | 2402 | 19.742 |
| 3 | 19155 | 2316 | 19.155 |
| Average Compressive strength (N/mm$^2$) | | | 19.902 |
| 20Hrs curing – Heat curing | | | |
| 1 | 29150 | 2438 | 29.150 |
| 2 | 28512 | 2419 | 28.512 |
| 3 | 30845 | 2316 | 30.845 |
| Average Compressive strength (N/mm$^2$) | | | 29.502 |
| 28 Days – Ambient curing | | | |
| 1 | 26353 | 2459 | 26.353 |
| 2 | 26718 | 2354 | 26.718 |
| 3 | 27267 | 2351 | 27.267 |
| Average Compressive strength (N/mm$^2$) | | | 26.779 |

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4.5 Compressive strength test on cube specimens ( 95% Fly ash, 5% Alcofine )

| **S.NO** | **LOAD (Kgf)** | **WEIGHT OF CUBE (gm)** | **COMPRESSIVE STRENGTH (N/mm)** |
|---|---|---|---|
| 4Hrs curing – Heat curing | | | |
| 1 | 18232 | 2416 | 18.232 |
| 2 | 17148 | 2432 | 17.148 |
| 3 | 17103 | 2383 | 17.103 |
| Average Compressive strength (N/mm$^2$) | | | 17.494 |

| | | | |
|---|---|---|---|
| 6Hrs curing – Heat curing | | | |
| 1 | 24655 | 2316 | 24.655 |
| 2 | 25199 | 2395 | 25.199 |
| 3 | 26006 | 2371 | 26.006 |
| Average Compression strength (N/mm$^2$) | 25.286 | | |
| 20Hrs curing – Heat curing | | | |
| 1 | 32398 | 2292 | 32.398 |
| 2 | 33383 | 2354 | 33.383 |
| 3 | 31218 | 2455 | 31.218 |

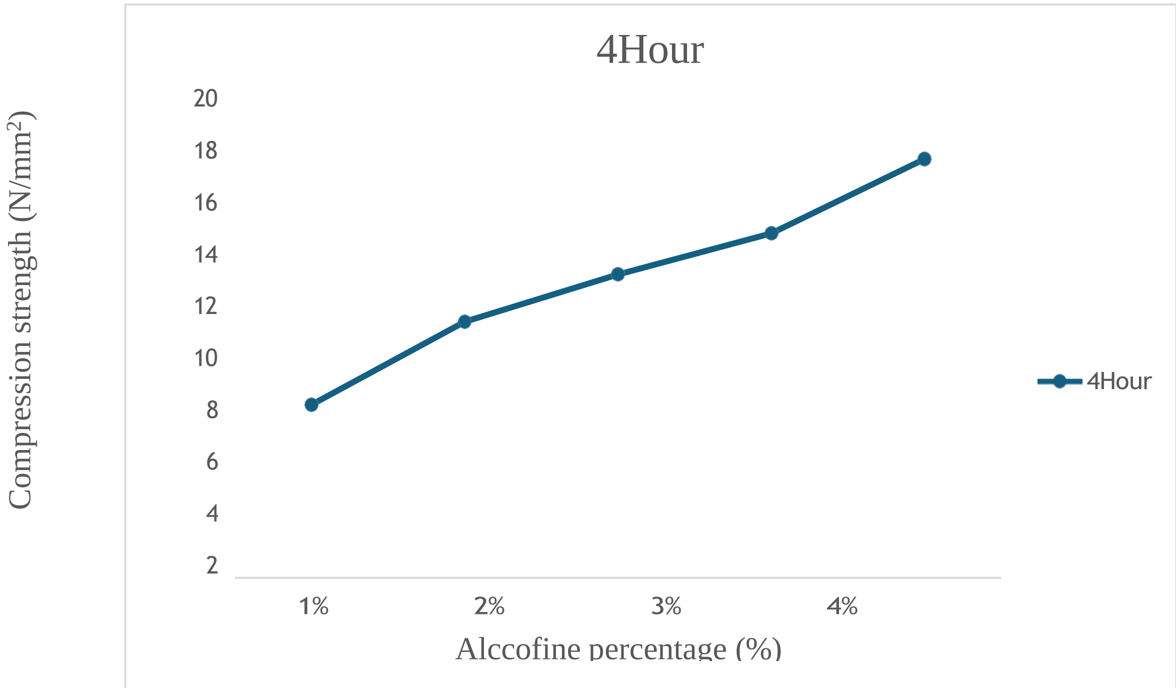
| | | | |
|---|---|---|---|
| Average Compression strength (N/mm$^2$) | | | 32.333 |
| 28 Days – Ambient curing | | | |
| 1 | 30751 | 2450 | 30.751 |
| 2 | 31139 | 2466 | 31.139 |
| 3 | 31829 | 2442 | 31.829 |
| Average Compression strength (N/mm$^2$) | | | 31.239 |

**4.6** Compressive Strength Of Conventional Concrete at 28 Days

| S.NO | LOAD (Kgf) | WEIGHT OF CUBE (gm) | COMPRESSION STRENGTH (N/mm) |
|---|---|---|---|
| 1 | 34531 | 2450 | 34.531 |
| 2 | 33363 | 2466 | 33.363 |
| 3 | 31685 | 2442 | 31.685 |
| Average Compression strength (N/mm$^2$) | | | 33.193 |

### 4.7 Comparison Graphs of Compressive Strength

**Graph 1 :-** Variation of Compression strength with different percentage of Alccofine in 4Hours of oven curing



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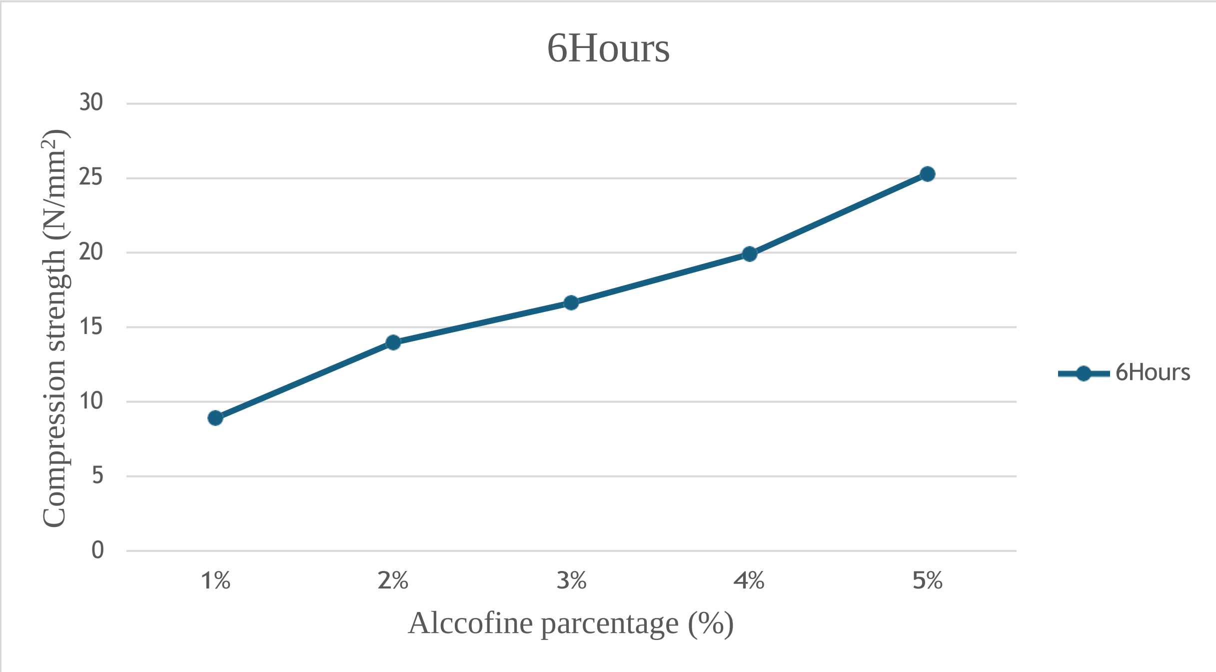
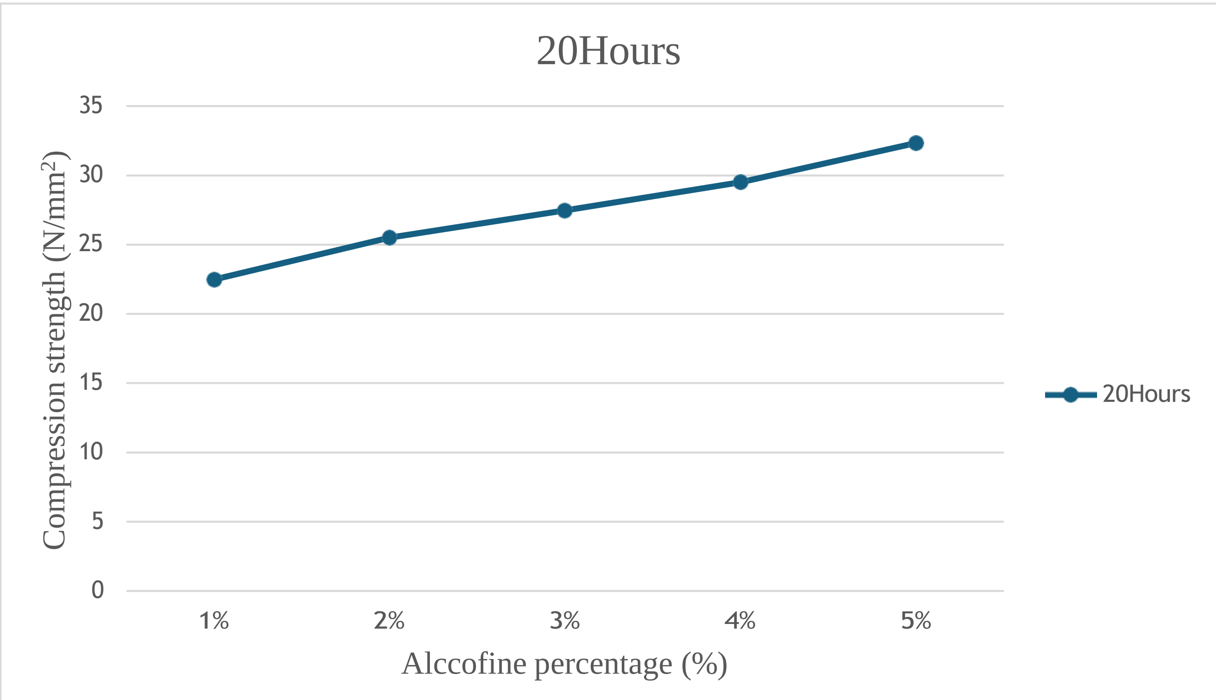
**Graph 2** :- Variation of Compression strength with different percentage of Alccofine in 6Hours of oven curing




**Graph 3** :- Variation of Compression strength with different percentage of Alccofine in 20Hours of oven curing



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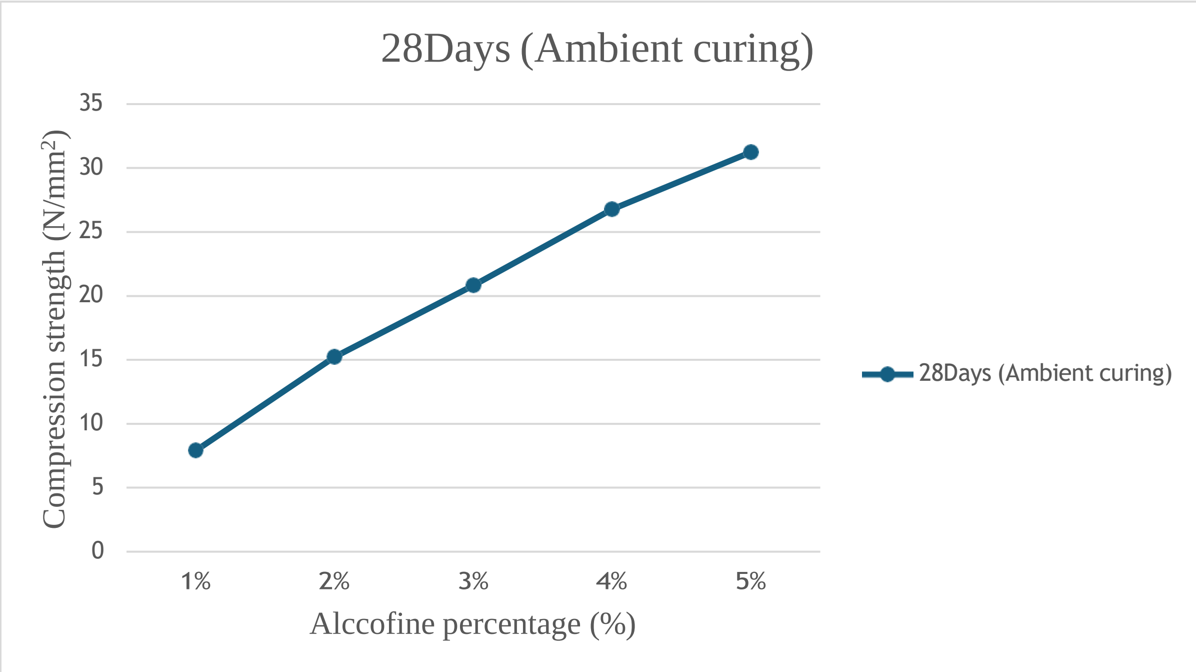
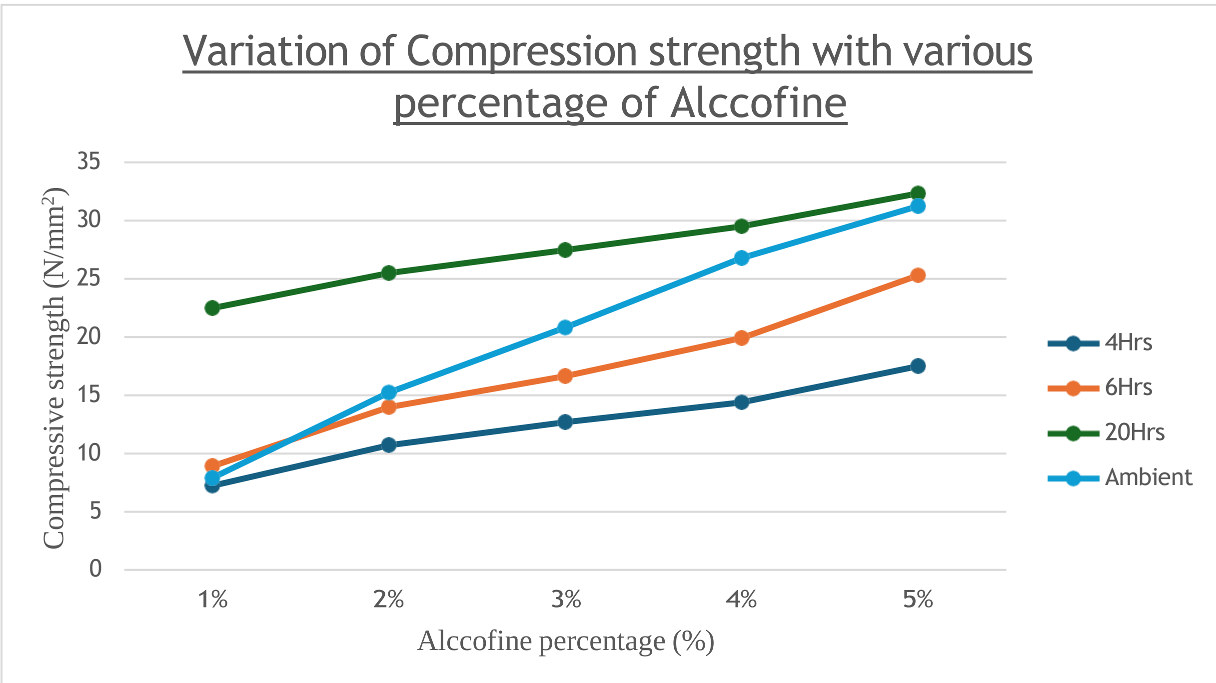
**Graph 4 :-** Variation of Compression strength with different percentage of Alccofine in 28Days of Ambient curing




**Graph-5 :-** Variation of Compression strength with various percentage of Alccofine



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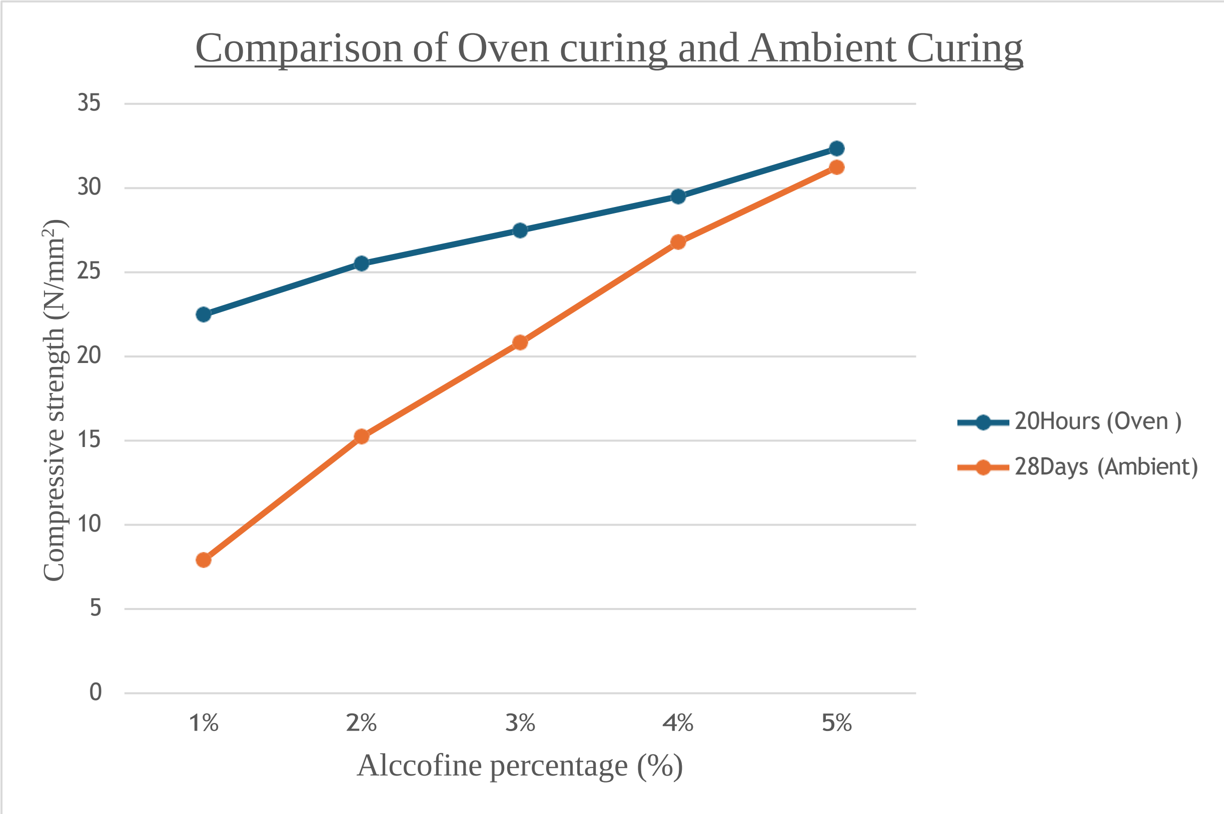
**Graph-6 :-** Comparison of Oven curing and Ambient Curing with different percentage of Alccofine




- Compressive strength of Geopolymer Concrete at 5% of Alccofine for 20Hours of Oven curing = 32.33 N/mm$^2$
- Compressive strength of Geopolymer Concrete at 5% of Alccofine for 28Days of Ambient curing = 31.24
- Compressive strength of Conventional Concrete at 28Days = 33.19 N/mm

## *5. DISCUSSIONS*

- It is observed that as percentage of replacement of Fly Ash with Alccofine increases, compressive strength also increases for ambient curing , 4 hours, 6 hours and 20 hours of heat curing.
- It is observed that target strength of Geopolymer Concrete was reached at 5% of replacement of Fly Ash with Alccofine at 20 hours of heat curing.
- It is observed that ambient cured samples out performed than 4 hours and 6 hours of heat curing.
- It is observed that target strength of Geopolymer Concrete reached at 5% of replacement of Fly Ash with Alccofine at 20 hours of heat curing is almost equal to compressive strength of Conventional Concrete.
- Geopolymer concrete with Alccofine can achieve target strength compressive strength, when cured at 80°C for 20Hours. Even at ambient temperature it can reach target strength for 28 Days
- Adding Alccofine enhances the workability of geopolymer concrete.
- Heat curing accelerates the geopolymerization process, leading to quick gain of compressive strength.
- Geopolymer concrete with Alccofine exhibits higher Compressive strength compared to conventional concrete.
- Geopolymer concrete with Alccofine offers a sustainable alternative to traditional concrete, reducing greenhouse gas emissions and promoting eco- friendly construction practices.
- The improved properties of geopolymer concrete with Alccofine make it suitable for various applications, including high-strength concrete.

## 6. CONCLUSIONS

- By increasing the alcoffine percentage the compressive strength will increase.
- The required target strength reached at 5% replacement of alccofine in heat curing.
- GPC attains the strength quickly with in a short time by heat curing.
- Even in the ambient curing for 28 days with the 5% replacement of alccofine, the GPC attains the required target strength.
- Geopolymer concrete attains more strength as compared to the conventional cement concrete.
- Geopolymer concrete can be manufactured with low calcium fly ash with different molarities of NaOH. The steam cured geopolymer concrete beams with 8 Molarity NaOH solutions attain higher strength.
- Adequate curing temperature ($60^0$C – $80^0$C) and adequate curing time (minimum 20 hrs) can give better results.
- The reason for the improvement in compressive strength of geopolymer concrete is the chemical reaction due to the speedy polymerization process and aging of the alkaline liquid.

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