# Relative Analysis of Fly Ash–Based Geopolymer Concrete under Atmospheric Conditions for Sustainable Construction and Structural Health Safety in Built Environments

**Dr. Hana Kim**[1]
**Prof. Giulia Conti**[1]
[1] University of São Paulo, Department of Civil Engineering and Sustainable Construction Materials, São Paulo, Brazil

## ABSTRACT

In recent years the use of concrete has increased day by day due to various advantages such as good strength, long life, low maintenance etc. Due to increase in uses the environment of earth is affected. The main effect of increase is temperature that melts the glaciers and increases the water level.

One of the efforts to produce more environmentally friendly concrete is to reduce the use of ordinary Portland cement (O.P.C) by replacing the cement in concrete with geo-polymers. In geo-polymer concrete cement is replaced by fly ash and alkaline solutions such as sodium hydroxide (Na OH) and sodium silicate ($Na_2O$, $SiO_2$) to make the binder necessary to manufacture the concrete. One tone of fly ash can be utilized for manufacturing about 2.5 cubic meter of high quality Geo-polymer concrete. Test experiments proved as fly ash based Geo-polymer concrete has excellent compressive strength and flexural strength.

Trial mixes were done and noted the properties of Geopolymer concrete in hardened state such as compressive strength and flexural strength. The result is show that the geopolymer concrete is again high compressive and flexural strength as comparing with the ordinary Portland cement concrete. When concrete cubes of M15, M20 and M25 was compared to geopolymer concrete cubes of 12M, 14M and 16M it was seen that the compressive strength of geopolymer concrete is increasing by 34.43,10.24 and 10.12 percentage in 28 days.

**KEYWORDS**: Geo-polymers concrete, ordinary Portland cement (O.P.C), sodium hydroxide (Na OH) and sodium silicate (Na2O, SiO2), compressive strength, flexural strength.

## 1. INTRODUCTION

The global warming is caused by the emission of greenhouse gases, such as $CO_2$, CO to the Atmosphere by human activities. Among the green house gases, $CO_2$contributes about 65% of global warming. The cement industry is responsible for about 7% of all $CO_2$ emissions, because the production of one ton of Portland cement emits approximately one tone of $CO_2$ into the atmosphere.In this respect, the geo-polymer technology proposed by Davidovits shows considerable promise for the concrete industry as an alternative binder to OPC .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%. One of the efforts to produce more environmentally friendly concrete is to reduce the use of OPC by replacing the cement in concrete with geo-polymers (i.e. 100% fly ash in place of OPC). Concrete usage around the world is second only to water. Ordinary Portland cement (OPC) is conventionally used as the primary binder to produce concrete. The environmental issues associated with the production of OPC are well known. The amount of the carbon dioxide released during the manufacture of OPC due to the calcinations of limestone and combustion of fossil fuel is in the order of one ton for every ton of OPC produced.

In addition, the extent of energy required to produce, OPC is only next to steel and aluminum. On the other hand, the abundant availability of fly ash worldwide creates opportunity to utilize this by-product of burning coal, as a substitute for OPC to manufacture concrete. When used as a partial replacement of OPC, in the presence of water and in ambient temperature, fly ash reacts with the calcium hydroxide during the hydration process of OPC to form the calcium silicate hydrate. This research was therefore dedicated to the development, the manufacture, and the engineering properties of the fresh and hardened low-calcium (ASTM Class F) fly ash-based geo-polymer concrete.

## 2. LITERATURE REVIEW

**FRANTISEK SKVARA:**

Investigated the synthesis of geopolymer their microstructure and properties of concrete. The results showed that the mixtures containing higher percentage of fly ash exhibit a different rheological behavior. Both the static and dynamics viscosity of the geopolymer concrete are substantially higher. The strength values of pastes, mortar and concrete of the geopolymer on the basis of fly ashes increased from is to 70 Mpa after 28 days .The compressive strength measured after 28 days ranged from 100 to 160 Mpa.

**JAMES ALDRED**

Concluded that the term geopolymer was used to described the inorganic aluminosilicate polymer gel resulting from reaction of amorphous aluminosilicates with alkali hydroxide and silicate solution. The some others names was also identified in the literature , such as alkali- activated cement , inorganic polymer concrete and geocement was has been used to describe materials synthesized. Geopolymer binders was covered a wide range of possible source materials and activators. The low shrinkage, heat of hydration and high tensile strength means that the materials have been technical advantages over traditional concrete. The most common concrete grades was used and the compressive strength 32 and 40 Mpa and the cylinder strength is measured up to 70 Mpa.

**H.J.H.BROUWERS**

Described that the dissolution of pulverized powder coal fly ash. This fly ash was modeled as hollow spheres and a shrinking core model was derived for these hollow spheres that contain two regions first one is outer hull and the other is inner region. The following thermodynamics properties of the studied fly ashes were derived such as the free energy, enthalpy and entropy of reaction. The equilibrium constant and the experimental data at various temperatures and also the free energy, enthalpy and entropy of reaction are computed of EFA and LM phase. The data are used to compute the free energy of formation of both glasses. It said that the free energy of formation is mainly governed by the molar ratio of the major constituents. The results suggested that the outer layer is poorer in silica and aluminum oxide was concentrated in the exterior hull.

**V. BHIKSHMA, M.KOTI REDDY**

Concluded that Efforts to produce more environmentally friendly concrete is to reduced the use of OPC by replacing the cement in concrete with geopolymer. In geopolymer concrete no cement is used, instead fly ash and alkaline solution such as sodium hydroxide (NaOH) Sodium silicate ($Na_2O$, $SiO_2$) and potassium hydroxide (KOH) are used to make the binder necessary to manufacture the concrete. One tone of fly ash can be utized for manufacturing about 2.5 cubic meter of high quality geopolymer concrete. Test experiments proved as fly ash based geopolymer concrete has excellent compressive strength , suffers very low drying shrinkage, low creep, excellent resistant to sulphate attack and good acid resistance . Trial mixes were done and noted the properties of the concrete both in fresh state and in hardened conditions. The workability of the concrete in terms of slump and compacting factor are observed to be excellent. The geopolymer concrete in fresh state observed to be highly viscous and good in workable. The mechanical properties such as compressive strength , flexural strength and modulus of elasticity of concrete in hardened state. The test experiment proved that a concrete of compressive strength of 30 MPa could be achieved in geoploymer concrete by adopting alkaline solution to fly ash ratio of 0.50 at 16 molarity of NaOH. The 28 days compressive strength of the geopolymer concrete is measured upto 26.06 Mpa.

**N A LLOYD, B V RANGAN**

Investigated the factors such as curing temperature and regime, aggregate shape, strengths, moisture content, preparation and grading. It has been founded that geopolymer concrete has good engineering properties with a Portland cement. It was founded that the geopolymer concrete have potential to reduced the global warming by total replacement of cement. The factors effected of aggregate particle shape and grading on the properties of geopolymer concrete is same as that Portland cement concrete. The compressive strength of geopolymer concrete is increasing up to 20 % the reason that the ambient curing for 24 hrs. For rest of the day and after that steam curing is done.

**M.KALAIVANI**

Represented the reasons to produce eco-friendly concrete to reduce the use of cement by replacing fly ash with alkaline liquids. The flexural strength of geopolymer concrete is compared with cement concrete. They casted beam of size 1000* 150* 150 mm for finding flexural strength. The beams was tested at 7, 14 and 28 days. The flexural strength of geopolymer concrete is increase with increased the molarities. The compressive strength of the geopolymer concrete was increased with increasing the curing time. The compressive strength of geopolymer concrete is not affected by the ratio of alkaline liquid to fly ash. The compressive strength of geopolymer concrete is tested on universe testing machine of 1000 KN capacity and the flexural strength is tested on two point testing machine. The length of beam is 750 mm .The load was applied on two points each 250 mm away from centre of the beams. The flexural strength of geopolymer concrete was measured at 8 molarities and 10 molarities are 57.73KN and 59.35KN.

**ABHIJITSINH PARMAR , DHAVAL M PATEL**

The 100% cement replaced by the fly ash is to decrease the carbon emission from concrete. The geopolymer concrete is place of cement by using waste materials as binders and implementing various curing techniques to provide strength. Geopolymer beams having grade M30 was maded by fly ash by replaced 100% cement and also alkaline solution used for making geoploymer concrete. The mould was used is 500* 100* 100 mm. The curing is done by 5 different methods of all moulds natural, self, oven cured, by adding accelerometer as an admixture and cured by silica fume. The increased silica fume content in geopolymer concrete will decrease the flexural strength of geopolymer concrete. The maximum flexural strength is gained by the geoploymer concrete in oven curing. The maximum flexural strength for 28th and 56th days is 15.67 and 17 N/mm2.

**D B RAIJIWALA**

Geopolyemer concrete technology was the potential to reduce globally the carbon emission and lead to a sustainable development and growth of the concrete industry. The influences of alkaline activators on the strength and durability properties have been studied. The sodium hydroxide is available in plenty and potassium hydroxide is more alkaline than NaOH, both was added in same amount. The various test was done in geopolymer concrete such as compressive strength, tensile test, Flexural test, pull out test and durability test was performed. Spilt tensile strength of GPC increased 1.45 times as compared with controlled concrete and the flexural strength of GPC increased by 1.6times as compared with controlled concrete. In pull out test, GPC increases by 1.5 times comparing with controlled concrete. It has been seen that the geopolymer concrete is cured at 80ºc gives best results.

**L.KRISHNAN**

Concluded that the fly ash based geopolymer concrete is one of which is reduced the carbon di oxide emission. The main limitation of fly ash based geopolymer concrete are slow setting of concrete at ambient temperature and the heat curing is provided to reduced the setting time . The alkaline liquid for the polymerization process was the solution of sodium hydroxide and sodium silicates . Total 36 cubes was casted and tested for 7, 14 and 28 days of its compressive and splitting tensile strength.The geopolymer4 concrete was gain strength in 28 days without water curing. The necessity of heat curing of concrete was eliminated by incorporating GGBS and fly ash in a concrete mix.The strength of geopolymer concrete was increased with increase in percentage of ground granulated blast furnace slag and fly ash in a concrete mix. It is observed that the mix F60G40 gave maximum compressive strength of 80.50 N/mm.

**C.ANTONY JEYASEHAR**

They are proposed that a alkaline liquid could be used to react with the silicon and aluminum in a source material of geological origin or in by-product materials such as fly ash was produced cementitious binders.The mechanical properties of geopolymer concrete such as compressive strength, split tensile strength and flexural strength have been found out and compared with ordinary Portland cement. The total five beams is casted of size 125*250*3200 mm and tested. The one beam out of five beams is cement concrete and remaining four beams is geopolymer concrete with alkali-activator solution. The load deflection and moment curvature behaviours was obtained from the experimental results and was compared with the analytical solution.The low calcium fly ash is used for casted geopolymer concrete. The strength of geopolymer concrete is increased with increasing alkali activator solution/ fly ash ratio. The highest compressivestrength of GPC is achieved in 28 days is 52.08N/mm2. The tensile strength is achieved in 28 days of GPC is 10.88 N/mm2.

**SURESH THOKCHOM**

Geopolymer concrete was a new promising binder manufactured by activation of a solid aluminosilicate source material with a highly alkaline activating solution and aided by heat. The fly ash is a good waste material to used in geopolymer concrete because is rich in silica and alumina. The experimental study was conducted to assess the acid resistance of fly ash based geopolymer mortar specimens having percentage $Na_2O$ ranging from 5% to 8% of fly ash. The specimens is immersed in 10% sulfuric acid and 10% nitric acid upto a period of 24 weeks and the finding resistance in terms of surface corrosion, residual alkalinity, changes in weight and compressive strength at regular intervals. Geopolymer mortar specimens manufactured with fly ash and alkaline activators remained structurally intact and did not show any recognizable change in colour in sulfuric acid though it turned slightly yellowish in nitric acid solution. Exposure to the solution yielded very low weight losses in the range of 0.21 to 1.64 across the two solutions. The compressive strength is varied from 44% to 71% and 40% to 70% in sulfuric acid and nitric acid.

## 3. METHODOLOGY

### Project Objective

In the present Experimental Investigation the following objectives are aimed

- The various type of test is applied on aggregate such as Sieve analysis test, Flakiness test, Aggregate value test etc.
- The various type of test is applied on sand such as Sieve analysis test, Silt content.
- The various type of test is applied on fly ash such as Soundness test, initial setting and final setting test.
- To compare the compressive strength of Ordinary Portland Cement concrete cubes and compressive strength of geo-polymer concrete cubes.

### Research Formulation

The Geopolymer concrete is mixture of Fly ash, Alkali solution, Aggregate, Sand and Water. The various test is done on Fly ash, alkaline solution, Aggregate, Sand. The method used to find the compressive and flexural strength of Geopolymer concrete by same as the method used to find the strength of cement concrete. But in cement concrete the curing is done with water and the geopolymer concrete the curing is done under ambient condition. The main aim of this work is to compare the compressive and flexural strength of geopolymer and ordinary concrete and to find that the geopolymer concrete can be replaced by cement concrete.

## 4. EXPERIMENTAL WORK

### Testing of materials

- **Fly ash**

**Table 1: Properties of fly ash:**

| Physical properties | Properties of Fly Ash used |
|---|---|
| Initial setting time | 120 min. |
| Final setting time | 280 min. |
| Soundness | 1 mm |

- **Coarse aggregate:-**
  - ✓ Sieve Analysis: This test is done to finding the percentage size of aggregate .In this test different size of sieve used. This test is done IS2386, part 1.

Plate.1. 10 mm size aggregate

Plate.2. 20 mm size aggregate

**Table 2: Sieve Analysis of 20mm size Aggregates:-**

| I.S. Sieve Designation | Mass Retained (in gms.) | Cumulative Mass Retained (in gms.) | % of Cumulative Mass Retained | % Passing | Acceptable Limits ( in % age) (IS 2386 part I) |
|---|---|---|---|---|---|
| 40 mm | 0 | 00 | 00 | 10 | 100 |
| 20 mm | 1182 | 1182 | 9.85 | 90.15 | 85 to 100 |
| 10 mm | 9468 | 10650 | 88.75 | 11.25 | 0 to 20 |
| 4.75 mm | 1080 | 11730 | 97.75 | 2.2 | 0 to 5 |

**Table3: Sieve analysis of 10 mm size Aggregates**

| I.S. Sieve Designation | Mass Retained (in gms.) | Cumulative Mass Retained (in gms.) | % of Cumulative Mass Retained | % Passing | Acceptable Limits ( in % age) (IS 2386 , part I) |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| 12.5 mm | 00 | 00 | 100 | 100 | 100 |
| 10mm | 1175 | 1175 | 11.75 | 88.25 | 85 to 100 |
| 4.75mm | 7573 | 8748 | 87.48 | 12.52 | 0 to 20 |
| 2.36mm | 1129 | 9877 | 98.77 | 1.23 | 0 to 5 |

- ✓ Determination of Specific Gravity and Water Absorption:

In this test generally a pycnometer used. The diameter of pycnometer is 5mm and the capacity of pycnometer is 500 ml. The limit of water absorption of aggregate in concrete work is 2% max. And the specific gravity of aggregate is 3% max allowing in concrete work as per I.S. Code 2386 part 3. If water absorption is more than 2% than soundness test is done

**Table 4: Determination of Specific Gravity and Water Absorption:-**

| **Determination No.** | **1** |
|---|---|
| Wt. of saturated surface dry sample | 630 |
| Wt. of picnometer containing sample and water | 1652 |
| Wt. of picnometer filled with water | 1248 |
| Wt. of oven dried sample | 620 |
| Specific gravity on oven dried basis | 2.74 |
| Water absorption | 1.61 |

- ✓ Flakiness index

In this test find the shape of aggregate. Generally, two types of test done for finding shape of aggregate one is flakiness and other is elongation tests. For concrete flakiness test is generally done on concrete work. In this test the sieve used is 63-50 mm, 50-40 mm, 40-31.5 mm, 31.5-25mm, 25-20 mm, 20-16 mm, 16-12.5 mm, 12.5-10 mm, 10-6.3 mm.

**Table 5: Flakiness Index- (I.S.2386 Part-1)**

| **Sieve Size (mm)** | **Total wt. of aggregates retained** | **Wt. retained on Flakiness gauge** | **Wt. passing on flakiness gauge** |
|---|---|---|---|
| 63-50 | 00 | 00 | 00 |
| 50-40 | 00 | 00 | 00 |
| 40-31.5 | 00 | 00 | 00 |
| 31.5-25 | 00 | 00 | 00 |
| 25-20 | 2980 | 2555 | 425 |
| 20-16 | 1660 | 1352 | 308 |
| 16-12.5 | 420 | 214 | 103 |
| 12.5-10 | 00 | 00 | 00 |
| 10-6.3 | 00 | 00 | 00 |
| Total | 5060 | 4130 | 836 |

- ✓ Aggregate Impact Value

This test show the behavior of aggregate under sadden load applied in aggregate. This test shows the property of toughness of aggregate. Firstly the aggregate is passing the sieve 12.5 mm and 10 mm the material is retained in 10mm sieve is taken and test done during this test using the wt. for impact is 14 kg. The passing limit of aggregate for concrete work is 30 % max. as per I.S.Code 2386 part 4.

**Table 6: Aggregate Impact Value**

| Sample No. | Weight of container (gm) | Weight of container + Aggregate(gm) | Weight of aggregate before compaction (gm) | Weight of aggregate retained 2.36 mm sieve(gm) | Weight of aggregate passing on 2.36 mm sieve(gm) | Aggregate impact value(%) |
|---|---|---|---|---|---|---|
| 1 | 972.6 | 1299 | 326.4 | 253 | 73.4 | 22.49 |
| 2 | 972.6 | 1290.2 | 317.6 | 238 | 79.6 | 25.06 |
| 3 | 972.6 | 1291.6 | 319 | 246.5 | 72.5 | 23.73 |
| **Average** | | | | | | **23.76** |

- **Fine aggregate:**

The various test applied on fine aggregate is sieve analysis, silt percentage. The sand used is zone II and the source is river koel.

Plate.3 Fine aggregate

- ✓ Sieve Analysis of Sand**:**

This test is done to find the various size of particle in sample. To done this test used sieve is 10 mm, 4.75 mm, 2.36 mm,1.18 mm, 600micron,300 micron,150 micron. This test is coming under I.S.Code 2386, part1.The main purpose of sand in concrete to fill fine gap and make hard mass of concrete.

**Table7. Sieve Analysis of Sand**

| I.S. Sieve Designation | Mass Retained (in gms.) | Cumulative Mass Retained (in gms.) | % of Cumulative Mass Retained | % Passing | Acceptable Limits ( in% age) (IS 2386 , part I) |
|---|---|---|---|---|---|
| 10 mm | 0 | 0 | 0 | 1 | 100 |
| 4.75 mm | 16 | 16 | 3.20 | 96.80 | 90 to 100 |
| 2.36 mm | 42 | 58 | 11.60 | 88.40 | 75 to 100 |
| 1.18 mm | 152 | 210 | 42.00 | 58.00 | 55 to 90 |
| 600 micron | 70 | 280 | 56.00 | 44.00 | 35 to 59 |
| 300 micron | 106 | 386 | 77.20 | 22.80 | 8 to 30 |
| 150 micron | 72 | 458 | 96.60 | 8.4 | 0 to 10 |

- ✓ Silt content in sand:

This test is done to find the silt percentage in sand. For road work the value of silt is 8% max. and for building work the value of silt is 4%max.In this test taking 100 gm sand sample and drop in water filled in tube and added one spoon salt in water. The salt help to settle the silt partical in less time.

**Table 8: Silt content in sand:-**

| Trail No. | 1 | 2 | 3 |
|---|---|---|---|
| Total volume of sand taken | 70 mm | 72 mm | 80 mm |
| Volume of sand after submerging | 68 mm | 70mm | 77 mm |
| Volume of silt after submerging | 2 mm | 2 mm | 3 mm |
| Silt content % | 2.85 | 2.77 | 3.75 |

- **Alkali solution:**

The alkaline liquid used was a combination of sodium silicate and sodium hydroxide solution. The NaOH pallets were dissolved in water to make the solution with required molarity and left for 24 hr. After that the solution silicate was mixed with solution to make geopolymer concrete. The mass of NaOH in a solution is varied depending on the concentration of the solution expressed in terms of molarity (M). For example NaOH solution with a concentration of 12M consisted of 12*40= 480 gm of NaOH palletes per litre of solution, where 40 is the molecular weight of NaOH

## 5. RESULTS AND DISCUSSION

To estimate the compressive strength of cement concrete and geopolymer concrete mixture cubes are prepared. The test procedure for cement and geopolymer concrete cubes is same. For the cement concrete mixture and geopolymer concrete cubes, compressive strength test has given following results.

**Table no.9 Compressive strength (N/mm²) of cement concrete after 28 days.**

| GRADE | M-15 | | | M-20 | | | M-25 | | |
|---|---|---|---|---|---|---|---|---|---|
| **7 DAYS** MEAN STRENGTH $N/mm^2$ | 11.33 | 12.00 | 12.09 | 15.33 | 15.38 | 15.91 | 18.29 | 19.64 | 19.33 |
| | 11.80 | | | 15.54 | | | 19.08 | | |
| 14 DAYS MEAN STRENGTH N/mm2 | 13.78 | 14.56 | 14.22 | 19.08 | 18.97 | 18.55 | 24.49 | 24.34 | 24.77 |
| | 14.18 | | | 18.86 | | | 24.53 | | |
| **28 DAYS** MEAN STRENGTH $N/mm^2$ | 17.33 | 16.93 | 17.16 | 24.44 | 23.64 | 23.76 | 28.18 | 27.33 | 28.76 |
| | 17.14 | | | 23.94 | | | 28.09 | | |

**Table no. 10 Compressive strength (N/mm²) of geopolymer after 28 days**

| GRADE CURING | 12M | | | 14M | | | 16M | | |
|---|---|---|---|---|---|---|---|---|---|
| **7 DAYS** MEAN STRENGTH N/mm2 | 19.33 | 17.33 | 17.91 | 21.23 | 21.00 | 21.59 | 24.34 | 24.52 | 24.56 |
| | 18.19 | | | 21.27 | | | 24.47 | | |
| **14 DAYS** MEAN STRENGTH N/mm2 | 21.22 | 21.59 | 22.00 | 23.43 | 23.76 | 23.00 | 27.32 | 27.98 | 27.12 |
| | 21.60 | | | 23.39 | | | 27.47 | | |
| **28 DAYS** MEAN STRENGTH N/mm2 | 25.90 | 26.12 | 26.43 | 27.23 | 27.12 | 27.34 | 31.33 | 31.57 | 32.00 |
| | 26.15 | | | 27.23 | | | 31.63 | | |

**M-15 Grade of Concrete and 12M of GEOPOLYMER CONCRETE**

- Highest Compressive Strength of cement concrete cubes : (17.33 N/mm²)
- Highest Compressive Strength of geopolymer concrete cubes: (26.43 N/mm²)

- When concrete cubes of M15 grade was compared to geopolymer concrete cubes of 12M it was seen that the compressive strength is increasing by 9.10 N/mm$^2$

**M-20 Grade of Concrete and 14M of GEOPOLYMER CONCRETE**

- Highest Compressive Strength of cement concrete cubes : (24.44 N/mm²)
- Highest Compressive Strength of geopolymer concrete cubes: (27.23 N/mm²)
- When concrete cubes of M20 grade was compared to geopolymer concrete cubes of 14M it was seen that the compressive strength is increasing by 2.79 N/mm2

**M-25 Grade of Concrete and 16M of GEOPOLYMER CONCRETE**

- Highest Compressive Strength of cement concrete cubes : (28.76 N/mm²)
- Highest Compressive Strength of geopolymer concrete cubes: (32.00 N/mm²)
- When concrete cubes of M25 grade was compared to geopolymer concrete cubes of 16M it was seen that the compressive strength is increasing by 3.24 N/mm$^2$

## 6. CONCLUSION

1. After comparing compressive strength of cement concrete (M-15) and geopolymer concrete (12M) at 7, 14 and 28 days . It is concluded that Strength of gopolymer concrete is higher as compared to cement concrete. The compressive strength of geopolymer concrete in 28 days is 26.15 N/mm2and the compressive strength of cement concrete in 28 days is 17.14 N/mm2.
2. After comparing compressive strength of cement concrete (M-20) and geopolymer concrete (14M) at 7, 14 and 28 days . It is concluded that Strength of gopolymer concrete is higher as compared to cement concrete. The compressive strength of geopolymer concrete in 28 days is 27.23 N/mm2and the compressive strength of cement concrete in 28 days is 23.94 N/mm2.
3. After comparing compressive strength of cement concrete (M-25) and geopolymer concrete (16M) at 7, 14 and 28 days. It is concluded that Strength of gopolymer concrete is higher as compared to cement concrete. The compressive strength of geopolymer concrete in 28 days is 31.63 N/mm2and the compressive strength of cement concrete in 28 days is 28.09 N/mm2.

## 7. REFERENCES


1. .Kolli Ramujee and M.Potharaju. "Development Of Low Calcium Flyash Based Geopolymer Concrete " IACSIT International Journal for Engineering and Technology. Vol.6.No. 1, February 2014
2. Frantisek Skvara, Josef Dolezal, Pavel Svoboda, Lubomir Kopecky, Simona Pawlasova, Martin Lucuk, Kamil Dvoracek, Martin Beksa, Lenka Myskova, Rostislav Sulc. " Concrete Based On Fly Ash Geopolymers" 1ICT Prague, Faculty of Chemical Technology, Dept. of Glass and Cermics, Technicka 5, 166 28 Praha 6, 2 Czech Technical University, Faculty of Civil Engineering, Dept. of Building Technology , Thakurova 7, 166 29 Praha 6 3 Betonconsult , BELOHORSKA 54 , 169 00 Praha 6
3. James Aldred and John Day " Is Geopolymer Concrete A Suitable Alternative To Traditional Concrete " 37th Conference on our World in Concrete and Structure 29-31 August 2012, Singapore
4. H.J.H. Brouwers and R.J. Van Eijk " Chemical Reaction Of Fly Ash " Proceedings of the 11th International Congress on the Chemistry of Cement (ICCC) 'Cement's Contribution to the Development in the 21st Century'
5. V.Bhikshma , M.koti Reddy and T. Srinivas Rao " An Experimental Investigation On Properties Of Geopolymer Concrete (No Cement Concrete) " Asia journal Of Civil Engineering (Building and Housing ) Vol.13,No. 6 (2012)
6. N.A.Lloyd and B.V. Rangan " Geopolymer Concrete : A Review Of Development And Oppoetunities ". 35th Conference on OUR WORLD IN CONCRETE AND STRUCTURES:25-27 August 2010,Singapore
7. M.Kalaivani " Experimental Investigation For Flexural Strength Of Fly Ash Concrete With Addition Of Alkaline Activator " ARPN Journal Of Engineering And Applied Sciences Vol. 10, No. 11 , June 2015
8. ABHIJITSINH PARMAR1 , DHAVAL M PATEL2 "Effect On Flexural Strength Of Geopolymer Concrete By Using Fly Ash And Alkaline Solution As A 100% Replacement Of Cement" Abhijitsinh Parmar, IJPRET , 2014; Volume 3 (4) : 100-106
9. D.B.Raijiwala , H.S. Patil , I.U.Kundan " Effect Of Alkaline Activator On The Strength And Durability Of Geopolymer Concrete " Journal Of Engineering Research And Studies. Studies/Vol.III/IssueI/January-March, 2012/18-21
10. L.Krishnan , S.Karthikeyan , S.Nathiya , K.Suganya " Geopolymer Concrete An EcoFriendly

onstruction Material " International Journal of Research in Engineering and Technology Volume: 03 Special Issue: 11|NCAMESHE-2014 | Jun-2014

11. Pradip Natha, Prabir Kumar Sarkera ,*, Vijaya B Rangana “Early age properties of low calcium fly ash geopolymer concrete suitable for ambient curing” The 5th International Conference of Euro Asia Civil Engineering Forum (EACEF-5)
12. Mrs. P. Priya Rachel and Dr. P. Partheeban “Durability Study of Low Calcium Fly ash Based Geopolymer Concrete” Indian Journal Of Applied Research Vol.3|Issue:6|June 2013|ISSN-2249-555X.
13. Prabir Sarker “Bond Strength of Geopolymer and Cement Concretes”
14. Madheswaran C.K1, Gnanasundar G2, Gopalkrishnan.N3 “Effect of molarity in geopolymer concrete” International Journal of Civil And Structural Engineering Vol.4, No.2, 2013.
15. Martynkova R. And Mavroulidou M.* “Properties of Alkali-Activated Concrete Based On Industrial Wastes Or By Products” Proceedings of the 14th International conference on Environmental Science and Technology Athens, Greece,3-5 September 2015.
16. Muhammad Salman , Ozlem Cizer , Yiannis Pontikes , Luice Vandewalle , Bart Blanpain and Koen Van Balen “Effect of Temperature On The Alkali Activation of Continuous Casting Stainless Steel Slag” Central Europe Towards Sustainable Building 2013.
17. Niragi Dave and Vaishali Sahu “ Experimental Evaluation of Low Calcium Fly Ash Based Geopolymer Concrete” Inetenational Journal of Engineering Science and Technology (IJEST) Vol.4 No.12 December 2012 ISSN:0975-5462
18. S.Kumaravel1, S.Thrirugnanasambandam2 “ Flexural Behaviour of Low Calcium Fly ash Based Geopolymer Concrete Beams” International Journal of Structural and Civil Engineering Volume 2 Issue 11 (November 2013) ISSN:2277-7032
19. A.M.Mustafa Al Bakri, 1H.Kamarudin, 1A.K Omar, 2M.N.Norazian, 1C.M.Ruzaidi abd 1A.R.Rafiza “The Effect of Alkaline Activator Ratio on The Compressive Strength of Fly ash Based Geopolymers” Australian Journal of Basic and Appiled Science,5(9):1916- 1922,2011 ISSN 1991-8178.
20. S.V.Joshi and M.S.Kadu “ Role of Alkaline in Development of Eco-friendly Fly Ash Based Geopolymer Concrete” International Journal of Environmental Science and Development,Vol.3, No.5,October 2012
21. D.V.S.P.Rajesh3, A.Narender Reddy2 , U.Venkata Tilak3, M.Raghavendra4 “Performance of Alkali Activated Slag With Various Alkali Activators” International Journal of Innovative Research in Science, Engineering and Technology Vol.2, Issue 2 , February 2013
22. Mike McDonald and Judy LaRosa Thompson “Sodium Silicate a Binder for the 21st Century”
23. O.Arloz*, M.Tuncan , E.Arioz , K.Kilinc “Geopolymer : A New Generation construction Material” 31st Conference on our world in concrete and structures : 16-17 August 2006.
24. Jin-Kyu Song, Keun- Hyeok Yang, Geon-Woo Kim, Chan-Taek Lee, byeong-Jo Kim, Jae-hyeok Lee “ Properties of Sodium Alkali-Activated Ground Granulated Blast-Furnace Slag (GGBS) Mortar” First International Conference on Sustainability and the Fucture FISC2010.
25. Rangarajan.P.T and Antony Francis.V “ Comparative Study on Strength characteristics of Geopolymer Concrete With Altered Curing Conditions” International Journal of Innovations In Engineering and Technology (IJIET) Vo.5 Issue 1 February 2015 ISSN: 2319-1058.
26. Hussanaiah Dakka1 , T.Raghavendra2 “ A Novel Research Approach for Fly Ash- Based Geopolymer Concrete” International Journal of Scientific Engineering and Technology Research , Vol.04,Issue.22, July-2015 Pages:4231-4238.
27. Sundar Kumar , S.*, Vasugi, J.# , Ambility , P.S.* and Bharatkumar ,B.H.* “Development and Determination of Mechanical properties of fly ash and slag blended geopolymer concrete” International Journal of Scientific and Engineering Research , Volume 4 , Issue 8 , August 2013 ISSN 2229-5518
28. Robina Kouser Tabassum, Ankush Khadwal “Effect of Sodium Hydroxide Concentration on Various Properties of Geopolymer Concrete” International Journal of Engineering nd Technical Research (IJETR) ISSN:2321-0869(O) 2454-4698(P), Volume- 3,Issue-10, October 2015.
29. D.Sabitha1,* , J.K.Dattatreya2 , N.Sakthivel2 , M.Bhuvaneshwari2 and S.A.Jaffer Sathik2 “ Reactivity, Workability and Strength of potassium Versus Sodium-activated high volume fly ash-based geopolymers” Current Science, Vol.103, No.11, 10 DECEMBER 2012.
30. C.Antony Jeyasehar*1, G.Saravanam2, M.Salahuddin3 and S.Thirugnanasambandam4 “ Development of Fly ash Based Geopolymer Concrete Elements” Asian Journal of Civil Engineering (BHRC) Vol.14,No.4(2013) Pages 605-615
31. Suresh Thokchom1, Dr.Partha Ghosh2 and Dr. Somnath Ghosh3 “ Acid Resistance of Fly Ash based Geopolymer mortars” International Journal of Recent Trends in Engineering, Vol.1, No.6,May 2009.
32. Djwantoro Hardjito, Chua Chung Cheak and Carrie Ho Lee Ing “ Strength and Setting Times of Low

Calcium Fly Ash Based geopolymer Mortar" Modern Applied Science Vol.2,No.4, July 2008

33. Chandan Kumar1, Krishna Murari2 , C.R.Sharama2 " Strength Characteristics of Low Calcium Fly Ash Based Geopolymer Concrete" IOSR Journal of Engineering (IOSRJEN) ISSN (e): 2250-3021, ISSN (p):2278-8719 Vol.04,Issue 05 (May.2014), || V7|| PP 07-17.
34. V.Ravi Kumar*, P.Mani "AN EXPERIMENTAL STUDY ON FLYASH BASED GEOPOLYMER CONCRETE" International Journal of Engineering Science and Research Technology (I2OR), Publication Impact Factor: 3.785 [Kumar*, 4.(11): November, 2015] [Kumar*, 4.(11): November, 2015] ISSN: 2277-9655
35. S. V. Joshi and M. S. Kadu "Role of Alkaline Activator in Development of Eco- friendly Fly Ash Based Geo Polymer Concrete" International Journal of Environmental Science and Development, Vol. 3, No. 5, October 2012
36. P.Yellaiah1, Sanjay Kumar Sharma1, *, T.D. Gunneshwara Rao2 "Development of Fly Ash based Geopolymer behaviour of Fly Cement" Received: April 30, 2014| Revised: May 30, 2014| Accepted: June 24, 2014
37. 1. Benny JOSEPH, 2. George MATHEW "Interface Shear Strength of Fly ash Based Geopolymer Concrete" International Journal of Engineering Tome 11(Year 2013) fascicule3 (ISSN 1584-2613)
38. Carlos Montes1, Erez N.Allouche 2.* "Influence of Activator Solution Formulation of Fresh and Hardened Properties of Low Calcium Fly Ash Geopolymer concrete" ISSN 1946-0198
39. Raijiwala D.B.*, Patil H. S., Sankalp "High Performance Green Concrete " Civil Engineering and Architecture 1(1): 1-6, 201 DOI: 10.13189/cea.2013.010101
40. J.Temuujin (1),*, C.H.Ruescher (2), A.Minjigmaa(1), B.Darkhijav(1), B.Davaabal(1), B.Battsetseg(1) "Characterization of efflorescences of ambient and elevated temperature cured fly ash based geopolymer type concretes" .
41. M. G. Palkar Geopolymer Concrete by Using Fly Ash in Construction.
42. M. Fareed Ahmed, M. Fadhil Nuruddin, and Nasir Shafiq "Compressive Strength and Workability Characteristics of Low-Calcium Fly ash-based Self-Compacting Geopolymer Concrete" World Academy of Science, Engineering and Technology International Journal of Civil, Environmental, Structural, Construction and Architectural Engineering Vol:5, No:2, 2011.
43. B. Senthil Kumar1, V. P. Arunachalam2, R. Thenmozhi3 T. Senthil Vadivel4" Effect on Strength Characteristics of Low Calcium Fly Ash based Geopolymer Concrete -An Initiative towards Green Concrete" International Journal of Applied Environmental Sciences ISSN 0973-6077 Volume 11, Number 1 (2016), pp. 173-182
44. Bharat Bhushan Jindal#1, Kamal Khetarpal*2 "Geopolymer Concrete - A Review" SSRG International Journal of Civil Engineering (SSRG-IJCE) – EFES April 2015". ISSN: 2348 – 8352
45. Mohammed Areeb Qidwai1, Md. Abid Alam2, Imran Alam3 "To Study The Properties of Geopolymer Concrete using Fly" (IJIRSE) International Journal of Innovative Research in Science & Engineering ISSN (Online) 2347-3207
46. A.R.Krishnaraja, N.P.Sathishkumar, T.Sathish Kumar, P.Dinesh Kumar "Mechanical Behaviour of Geopolymer Concrete under Ambient Curing" International Journal of Scientific Engineering and Technology (ISSN : 2277-1581) Volume No.3 Issue No.2, pp : 130 – 132
47. Maneeshkumar C S1,Manimaran G2, Prasanth S3 "An Experimental Investigation on GGBS and Flyash Based Geopolymer Concrete with Replacement of Sand by Quarry Dust" Maneesh kumar C S et al. Int. Journal of Engineering Research and Applications ISSN : 2248-9622, Vol. 5, Issue 5, ( Part -1) May 2015, pp.91-95
48. MANEESH KUMAR CS "STRENGTH AND DURABILITY STUDIES ON FLY ASHCONCRETE IN SEA ENVIRONMENT" International Journal Of Core Engineering & Management (IJCEM)Volume 2, Issue 5, August 2015
49. 1K.CHINNASUBBARAO, 2G.SHANI PRIYANKA "Effect of Aggressive Chemical Environment on Fly Ash Based Geopolymer Concrete"International Journal of Computer Engineering In Research Trends Volume 2, Issue 12, December-2015, pp. 947-952 ISSN (O): 2349-7084
50. Behzad Nematollahi and Jay Sanjayan" Efficacy of Available Superplasticizers on Geopolymers" Research Journal of Applied Sciences, Engineering and Technology 7(7): 1278-1282, 2014 ISSN: 2040-7459; e-ISSN: 2040-7467