A COMPARATIVE STUDY ON STRENGTH ASPECT OF FLY ASH BASED GEOPOLYMER CONCRETE OVER CONVENTIONAL CONCRETE

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Abstract:* Portland cement concrete industry has full-fledged Every Where in recent years. During the manufacturing of Ordinary Portland Cement (OPC), a large amount of green house is released into the atmosphere causing global warming. It also consumes large amount energy. Hence, it is necessary to find substitute to cement. Geopolymer Concrete is an innovative construction material which shall be manufactured by the source materials and the alkaline liquids. It uses an alternate material including fly ash as binding material in place of cement. Fly ash is Industrial waste material available from thermal power plants. In the present study the feasibility of industrial by-product i.e.; Fly Ash (FA) as eco-friendly and sustainable is studied. Fly ash is used to yield a geopolymer concrete. Alkaline solution used for present study is combination of sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3) with ratio 2.5. The concentration of sodium hydroxide is 8 molarity (M) solutions kept a constant to prepare alkaline liquid. A grade chosen for the investigation were M25 Standard Concrete and G25 Geopolymer Concrete. The study includes casting of Geopolymer concrete and conventional concrete specimens and tested for their compressive strength at age of 7, 14 and 28 days respectively. Hence, in this study, Cement is replaced by Fly Ash in different proportion which are 12.5% FA, 25% FA, 37.5% FA and 50% FA accordingly in Geopolymer Concrete and its feasibility study is to be carried out.

***IndexTerms* - Geo polymer Concrete, Fly Ash, Alkaline Activators, Compressive Strength.**

I. INTRODUCTION

Concrete is the most commonly used construction material, its practice by the societies across the world is second only to water. The worldwide demand for Ordinary Portland Cement (OPC) would rise further in the future. OPC production is a main contribution to carbon dioxide emissions. The global warming is caused by the total greenhouse emission to the earth atmosphere contributing greatly to the global warming. Cement is also among the most energy severe construction material after steel and aluminum. Therefore it is required to find another binder to cement. Fly ash is a byproduct of coal obtained from thermal power plant. It is also rich in silica and alumina. The copious availability of fly ash universal create opportunity to use this by product of burning coal, as substitute for OPC to manufacture concrete. In terms of reducing the global worming the geopolymer technology could reduce the CO_2 emission to the atmosphere. The word Geopolymer introduced to the world by Davidovits in year 1980s, introduced that binders could be produced by a polymeric reaction of alkaline liquids with the Silicon and the Aluminum in source materials of geological origin or by-product materials such as fly ash and GGBS, he named these binders as “Geopolymer”.

There are two main ingredients of geo polymers, namely the source materials and the alkaline liquids. The source materials for geo polymers based on alumina-silicate should be rich in silicon (Si) and aluminium (Al). These could be natural minerals such as kaolinite, clays, etc. Alternatively, by-product materials such as fly ash, silica fume, slag, rice-husk ash, red mud, etc. could be used as source materials. The alkaline liquids are from soluble alkali metals that are usually sodium or potassium based. The most common alkaline liquid used in geo polymerisation is a combination of sodium hydroxide (NaOH) or potassium hydroxide (KOH) and sodium silicate or potassium silicate.

Many research organizations are doing widespread work on waste materials concerning the viability and environmental suitability. Recent researchers aimed at the conservation in the cement and the concrete industry focused on the use of Industrial waste materials such as Bottom Ash, fly ash, etc. in Geo polymer concrete to rise the strength of Geo polymer concrete. Many researchers have made efforts to use the Industrial waste materials to reduce the disposal problems and to improve the mechanical properties of Geo polymer concrete.

II. RESEARCH OBJECTIVE

Wherever following are the main objectives of research:

1. To oversee and inspect performance of hardened Geopolymer Concrete made from industrial waste collected from Thermal Power Industry Fly Ash (Class-F).
2. To evaluate replacement of the cement by Fly Ash accordingly in range of 12.5% FA, 25% FA, 37.5% FA and 50% FA by weight of M-25 Grade of concrete in G25 Grade of Geopolymer Concrete.
3. To evaluate Mechanical property of Hardened Geopolymer Concrete by conducting Compression Strength Test.
4. To find the suitability of replacement of cement with Fly Ash for making Geopolymer Concrete.
5. To compare the cost of modified mix with control mix.

III. MAJOR FINDING FROM LITERATURE

Following are the various major findings of the reviews as follows:

1. The Literature review based on Using Industrial waste in Geopolymer concrete concluded that by using various Industrial waste material such as Fly Ash as a partial substitute of cement of design mix in Geopolymer concrete, overall cost of making of Geo polymer Concrete can reduce.

2. Various tests have been operated as per the standards on the Geopolymer Concrete. The General parameter calculated by various researchers is compressive strength.
3. Fly Ash is advantageous but its uses as tested against strength needs to be confirmed. It is emphasized on the research and development activity in construction materials using fly ash with geo polymers.
4. The Compressive Strength test results have shown that compressive strength increases with increase in molarity.
5. It can be educed that savings in cost can be got in the production of Geopolymer Concretes of higher grades as well as lower grades with only a marginal difference.
6. The study is helpful for various resource persons involved in using industrial waste material (Fly Ash) to develop sustainable construction material.

IV.DESIGN MIX MATERIALS

The following constituent materials used in the present investigation were:

1) Cement

The most common cement used is an Ordinary Portland Cement (OPC). The Ordinary Portland Cement of 53 grade conforming to IS 12269-1987 is used. Many tests were directed on cement; some of them are specific gravity, consistency tests, setting time tests, compressive strengths, etc.

Table 1 Properties of Cement (OPC 53 grade)

Sr.No.	Physical properties of cement	Result	Requirement of IS 12269-1987
1	Specific gravity	3.14	3.10-3.15
2	Standard consistency (%)	28%	30-35
3	Initial setting time (min)	154	30
4	Final setting time (min)	233	600
5	Compressive Strength (Mpa) a) 72+/-1hr. b) 168+/-2hr. c) 672+/-4hr.	 40 50 65.8	 27 37 53

2) Fine Aggregate

Those fractions from 4.75 mm to 150 micron are designated as fine aggregate. Locally available sand, free from silt and organic matters was used. The river sand is be used in combination as fine aggregate conforming to the requirements of IS 383- 1970. Table-2 gives the properties of Fine aggregate. Specific gravity, water absorption and gradation of sand (FM) test were carried out as per IS 2386 (part I and Part III) - 1963.

Table 2 Properties of Aggregates

Property	Fine Aggregate	Coarse Aggregate	
		20 mm down	10 mm down (Grit)
Fineness modulus	3.35	7.54	3.19
Specific Gravity	2.65	2.84	2.69
Water absorption (%)	1.20	1.83	1.35
Bulk Density (gm/cc)	1753	1741	1711

3) Coarse Aggregate

It is crushed granite metal with 60% passing 20 mm and retained on 12.5mm sieve and 40% passing 12.5mm and retained on 4.75mm sieve were used. The weight of coarse aggregate was 60% of the total aggregate and specific gravity of coarse aggregate was 2.84. Table-2 gives the properties of Coarse aggregate. Gradation of sand (FM), Specific gravity, water absorption and Bulk Density test were carried out as per IS 2386 (part I, II & IV) - 1963.

4) Fly Ash

Fly ash is composed of the non-combustible mineral portion of coal. Particles are glassy, spherical “ball bearings” finer than cement particles. Sizes of particle are 0.1µm-150µm. The fly ash is procured from Amrita Magnetics Pvt. Ltd., V.U. Nagar, Anand. The specific gravity is 2.20.

Figure 1 Fly Ash (Class-F)

5) Alkaline Activators

The solution of sodium hydroxide and sodium silicate are used as alkaline solutions in the present study. Commercial grade sodium hydroxide in flakes form and sodium silicate solution are used. To produce higher strength geopolymer, the optimum sodium silicate to sodium, hydroxide ratio was in range of 0.67 to 1.00. The concentration of NaOH between 10 and 20 M give small effect on the strength.

The mixture of sodium silicate solution and sodium hydroxide solution forms the alkaline liquid. In this research work the compressive strength of Geopolymer concrete is invesigated for the mixes of 8 Molarity of sodium hydroxide. The molecular weight of sodium hydroxide is 40. To prepare 13 Molarity of solution 320 gm of sodium hydroxide flakes are weighed and they can be dissolved in distilled water to form 1 litre solution has to be prepared 24 hours advance before use. Sodium hydroxide flakes are added slowly to distilled water to prepare 1liter solution.

FIGURE 2 SODIUM HYDROXIDE FLAKES AND SODIUM SILICATE

6) Water

Water is an important constituent of concrete as it actually contributes in the chemical reaction with cement. Since it helps to from the strength giving cement gel, the quantity and quality of water is required to be looked into very carefully. Water cement ratio used is 0.44 for M25.

V. DESIGN MIX METHODOLOGY

1. Mix Design for M25 Cement Concrete (As Per IS: 10262-1982) and G25 grade sustainable Geopolymer Concrete (Rangan method)

A mix M25 Cement Concrete was designed as per IS 10262:2009 and the same was used to prepare the test samples. The Geopolymer Concrete mix design used in the study was based on Rangan method for G25 grade of concrete. Table 3 Material requirement for 1m^3 Standard concrete and Geopolymer Concrete.

Table 3 Material requirement for 1m^3 Standard concrete and Geopolymer Concrete.

Materials	Unit	Various Mixes				
		A1	B1 (12.5% FA)	B2 (25% FA)	B3 (37.5% FA)	B4 (50% FA)
Cement	kg	436	381.5	327	272.5	218
Fine Aggregate	kg	690.79	690.79	690.79	690.79	690.79
Coarse Aggregate	kg	1127.36	1127.36	1127.36	1127.36	1127.36
Fly Ash	kg	-	54.5	109	163.5	218
NaOH	kg	-	50	50	50	50

Na_2SiO_3	kg	-	90	90	90	90
Water	Liter	191.6	191.6	191.6	191.6	191.6

VI. EXPERIMENTAL INVESTIGATION

This chapter proves the detailed experimental programme of this investigation. The Compressive Strength method available for testing hardened Geopolymer Concrete mix is studied in detail.

1. Preparation of Cement Concrete Cubes

The coarse aggregate, fine aggregates, cement and water is used to make conventional cement concrete. The Tamping rod is used for compacting during casting. The concrete cubes of size 150 x 150 mm x150 mm and are placed in water for curing for 7, 14 and 28 days.

2. Preparation of Geopolymer Concrete Cubes

The Cement, fly ash, fine aggregates, and coarse aggregates were mixed in a mixer machine and then the alkaline solution was added to prepare the geopolymer concrete. The mixing time to dry mix is 3-4 minutes. The wet mixing is required for 6-8 minutes for proper bonding of all materials. The Tamping rod is used for compacting during casting. The Geopolymer Concrete cubes of size150 x 150 mm x150 mm and are placed in water for curing for 7, 14 and 28 days.

3. Compressive Strength Test (IS 516:1959)

The compression test is used to define the hardness of cubical specimens of standard and geopolymer concrete. The strength of a concrete specimen is depends upon cement, aggregate, bond, w/c ratio, curing temperature, and age and size of specimen. Mix design is the major factor controlling the strength of concrete.

Cube of size 150 x 150 x 150 mm (as per IS: 10086-1982) should be cast. The specimen should be given adequate time for hardening (approx 24 h) and then it should be cured for adequate time based on the type of concrete. After curing, it should be loaded in the compression testing machine and tested for maximum load. Compressive strength should be calculated by dividing maximum load by the cross-sectional area. The load applied to opposite side of the cubes as cast. The maximum load was applied to the specimen until the failure recorded.

Compressive strength = Ultimate load / Contact area of the cube.

Figure 3 Compressive Strength Testing of Geopolymer Concrete

VII. EXPERIMENTAL RESULTS

In this study, Compressive strength of Fly ash hardened geopolymer concrete was investigated.

1. Tests on Hardened Concrete

The results of hardened concrete tests were conducted on Geopolymer Concrete at 7, 14 and 28 days water curing for compressive strength.

2. Compressive Strength Test

Following table 4 shows summery of compressive strength results of M25 standard Concrete and G25 Geopolymer Concrete with inclusion of Fly Ash in Different Proportions.

Table 4 Comparative Experimental Results of Compressive Strength Test for M25 and G25 concrete Mixes

Concrete Mix (M 25 and G25 Grade)	**Average Compressive Strength (N/mm^2)**		
	7 DAYS	**14 DAYS**	**28 DAYS**
Standard Concrete Mix M25			
A1-M25	25.02	28.50	32.02
Fly Ash based Geopolymer Concrete Mix G25			

B1-G25	26	29.33	33.16
B2-G25	26.69	29.43	33.76
B3-G25	27.13	30.70	34.5
B4-G25	28.56	31.55	34.66

Following figure 4 shows the compressive strength of M25 and G25 concrete mixes: Standard Concrete and Geopolymer Concrete with inclusion of Fly Ash in Different Proportions at 7, 14, 28 days

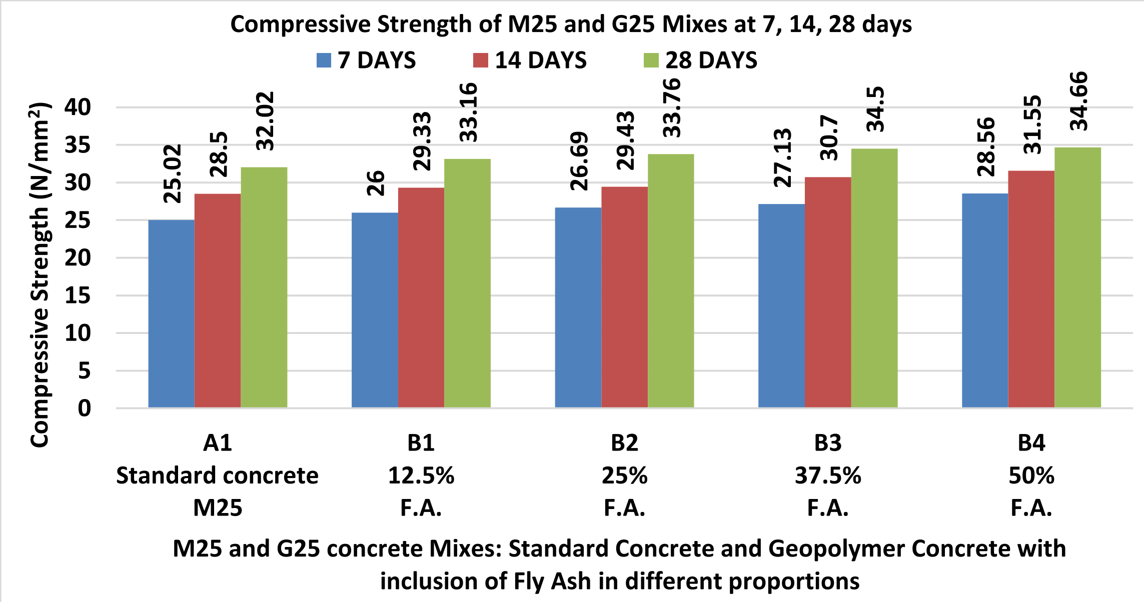

Figure 4 Results for Compressive Strength of M25 and G25 Grade concrete Mixes

VIII. RATE ANALYSIS

Following tables shows the rate analysis as per different quantity of items as per current market rates for various concrete mixes.

Table 5 Total Cost of M25 Grade Standard Concrete for 1 m^3 (Mix A1)

Materials	Cost Rs.	Quantity	Unit	Total Amount of CC
Cement	5.2	436	kg	2267
Fine Aggregates	0.6	690.79	kg	414
Coarse aggregates	0.65	1127.36	kg	733
Fly Ash	0.45	430	kg	-
NaOH	16	50	kg	-
Na_2SiO_3	18	90	kg	-
Water	0	191.6	Liter	-
Total cost (Rs./m^3)				**3414**

Table 6 Total Cost of G25 Grade Geopolymer Concrete Mixes for 1 m^3 with Inclusion of Fly Ash in Different Proportions (Mixes B1, B2, B3, and B4)

Description	Cost (Rs.)	B1 (12.5%F.A.)			B2 (25%F.A.)		
		Quantity	Unit	Cost of Material (Rs.)	Quantity	Unit	Cost of Material (Rs.)
Cement	5.2	381.5	kg	1983.8	327	kg	1700.4
Fine Aggregate	0.6	690.79	kg	414.47	690.79	kg	414.47
Coarse aggregate	0.65	1127.36	kg	732.78	1127.36	kg	732.78
Fly Ash	0.45	54.5	kg	24.52	109	kg	49.05
NaOH	16	50	kg	800	50	kg	800
Na_2SiO_3	18	90	kg	1620	90	kg	1620
Water	0	191.6	Liter	0	191.6	Liter	0

Total cost (Rs./m³)			5576		5317

Description	Cost (Rs.)	B3 (37.5%F.A.)			B4 (50%F.A.)		
		Quantity	Unit	Cost of Material (Rs.)	Quantity	Unit	Cost of Material (Rs.)
Cement	5.2	272.5	kg	1417	218	kg	1133.6
Fine Aggregate	0.6	690.79	kg	414.47	690.79	kg	414.47
Coarse aggregate	0.65	1127.36	kg	732.78	1127.36	kg	732.78
Fly Ash	0.45	163.5	kg	73.58	218	kg	98.1
NaOH	16	50	kg	800	50	kg	800
Na_2SiO_3	18	90	kg	1620	90	kg	1620
Water	0	191.6	Liter	0	191.6	Liter	0
Total cost (Rs./m³)				**5058**			**4799**

Following figure 5 shows the rates for M25 and G25 mixes standard concrete and Geopolymer Concrete with inclusion of Fly Ash in different proportion for 1 m³ concrete.

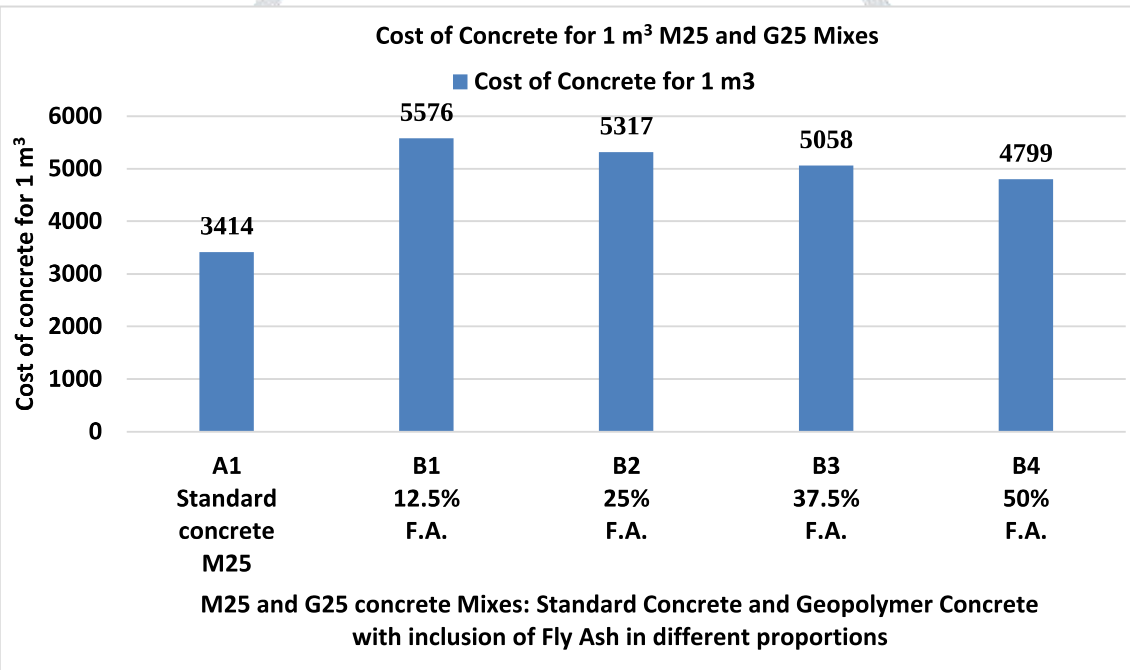

Figure 5 Cost of Concrete for 1 m³ M25 and G25 Grade Mixes: Standard Concrete and Geopolymer Concrete with Fly Ash in Different Proportions

IX. CONCLUSION

Based on experimental investigations concerning Compressive Strength and Rate Analysis for Standard Concrete and Geopolymer Concrete with inclusion of industrial waste in different proportions mixes made by Replacement of Fly Ash in different proportions, the following conclusions are drawn out for different parameters:

1. The Geopolymer Concrete achieved the required strength just in 7 days with respect to compressive strength.
2. Geopolymer Concrete mixes made content up to 50% replacement of Fly Ash gives more compressive strength of 7, 14 and 28 days compare to Conventional Concrete Mix.
3. All Geopolymer Concrete mixes which are made with replacement of Fly Ash in different proportion gives acceptable compressive strength results. So that all Geopolymer Concrete mixes have excellent compressive strength and are suitable for structural applications.
4. In B batch of Geopolymer Concrete mixes with addition Fly Ash, B4 mix made with 50% replacement of Fly Ash shows 34.66 N/mm² compressive strength and Conventional Concrete A mix shows 32.02 N/mm² both after 28 days.
5. The compressive strength obtained by conventional concrete at the age of 28 days has been already achieved by Geopolymer concrete in 7 days itself.
6. Compressive strength of Geopolymer Concrete was increasing by replacement of Fly Ash in different proportion for Geopolymer Concrete mixes as compared to Conventional Concrete.
7. Geopolymer Concrete mixes G25 with inclusion of Fly Ash in different proportion have higher rates for 1 m³ concrete with compared to standard A1 (M25) concrete mix.
8. Rates of Geopolymer Concrete decreases with increases in Fly Ash content in the Geopolymer Concrete compared to Standard Concrete.
9. Based on the cost calculations, it can be concluded that savings in cost can be attained in the production of Geopolymer Concretes of lower grades with only a marginal difference.

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