International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 08 Issue: 04 | Apr 2021 www.irjet.net p-ISSN: 2395-0072

Study on Properties of Geopolymer Concrete Made with Flyash and GGBS as Source Material

Syed Javeed[1], Syed Azam Quadri[2], Syed Wali Uddin Khan[3], Ms. Nanchari Kanchala[2]

[1, 2, 3]B.E Students, Dept. of Civil Engineering, ISL Engineering College, Hyderabad
[1]Assistant Professor, Dept. of Civil Engineering, ISL Engineering College, Hyderabad

---

Abstract –*Concrete has occupied an important place in construction industry in the past few decades and it is used widely in all types of constructions ranging from small buildings to large infrastructural dams or reservoirs. Cement is major ingredient of concrete. The cost of cement is increasing day by day due to its limited availability and large demand. At the same time the global warming is increasing day by day. Manufacturing of cement also releases carbon dioxide. In the present study an attempt been made on concrete and also an experimental investigation on the concrete using by replacing cement with FLYASH and GGBS to decrease the usage of cement as well as emission of concrete. Experimental studies were performed on plain cement concrete and replacement of cement with Fly ash is done. In this study the concrete mix were prepared by using flyash,sodium silicate, sodium hydroxide. A comparative analysis has been carried out for concrete to the Geopolymer concrete in relation to their compressive strength, split tension strength, acid resistance and water absorption. The concrete made with fly ash performed well in terms of compressive strength, split tension strength acid resistance and water absorption showed higher performance at the age of 7,14,28 days than conventional concrete. And also two different types of acid attack is done to determine the and compressive strength both on conventional concrete and geo polymeric concrete.*

***Key Words*: Fly Ash, Ground Granulated Blast Slag, Geopolymer concrete, Sodium Hydroxide, Sodium Silicate,**

1. INTRODUCTION

Worldwide cement production has grown incredibly in recent years. After fossil fuels and land-use change, it is the third biggest basis of anthropogenic emissions of CO2 (carbon dioxide). A future challenge to the construction industry is to use alternative materials to replace cement with industrial by-products. In the year 1972, "Joseph Davidovits" discovered a new class of inorganic material: geopolymer binder/resin. One of the main reasons for the development of geopolymers is to utilize industrial wastes as well as to control the emission of greenhouse gases emitted by cement production. Inorganic materials-based Geopolymer concrete are the same as conventional concrete but these inorganic materials should be rich in silica and alumina-like fly ash, silica fume, GGBFS (ground granulated blast furnace slag) with soluble solutions (sodium or potassium). The main components of Geopolymer concrete can be generally divided into two categories: alkaline liquids and the source materials. The alkaline activation on these industrial by-products will result in the configuration of Geopolymer binders [3]. A full substitution of cement in the Geopolymer concrete manufacturing with the byproduct materials reduces CO2 emissions into the atmosphere. Geopolymer concrete typically shows evidence of outstanding compressive strength, restricted durability and low flexural quality, which may confine its utilization in auxiliary constructions.

There are so many factors affecting the mechanical and durable properties of Geopolymer concrete. These are: fineness of fly ash and GGBFS, molarities of NaOH solution, and curing conditions (sunlight and oven). With an increase of molarities of NaOH solution, the mechanical properties are also increased. Generally up to 14 M NaOH solution is economic and it is suggested can improve the durability of geopolymer concrete.

The demand for concrete as a construction material is on the increase 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 CO2, to the atmosphere by human activities. Among the greenhouse gases, CO2 contributes about 65% of global warming. The cement industry is responsible for about 6% of all CO2 emissions, because the production of one ton of Portland cement emits approximately one ton of CO2 into the atmosphere.Although the use of Portland cement is still unavoidable until the foreseeable future, many efforts are being made in order to reduce the use of Portland cement in concrete. These efforts include the utilization of supplementary cementing materials such as fly ash, silica fume, granulated blast furnace slag, rice-husk ash and Metakaolin, and finding alternative binders to Portland cement. In this respect, the geopolymer 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 geopolymer technology could reduce the CO2 emission to the atmosphere caused by cement and aggregates industries by about 80%Heat-cured low-calcium fly ash-based geopolymer concrete has excellent compressive strength, suffers very little drying shrinkage and low creep, excellent resistance to sulfate attack, and good acid resistance. It can be used in many infrastructure applications. One ton of low-calcium fly ash can be utilised to produce about 2.5 cubic meters of high quality geopolymer concrete, and the bulk price of chemicals needed to manufacture this concrete is cheaper than the bulk price of one ton of Portland cement. Given the fact that fly ash is considered as a waste material, the lowcalcium fly ash-based geopolymer concrete is, therefore, cheaper than the Portland cement concrete. The special properties of geopolymer concrete can further enhance the economic benefits. Moreover, reduction of one ton of carbon dioxideThe main objective of this paper is to examine the physical properties of coarse aggregate, fine aggregate and cement. Investigate the mechanical properties of concrete by complete replacement of fly ash in concrete mix then find their mechanical properties and determine the special mechanical properties using acid attack and bond strength on conventional concrete and geo polymeric concrete Among the waste or by-product materials, fly ash and slag are the most potential source of geopolymers.

2. LITERATURE REVIEW

Ganapati Naidu. P, A.S.S.N.Prasad reported in this paper that an attempt is made to study strength properties of geopolymer concrete using low calcium fly ash replacing with slag in 5 different percentages. Higher concentrations of G.G.B.S (Slag) result in higher compressive strength of geopolymer concrete.90% of compressive strength was achieved in 14 days.

Supraja V, M. KantaRao presented a study of geopolymer concrete, the portland cement is fully replaced with GGBS and alkaline liquids (sodium hydroxide and sodium silicate) are used for the binding of materials. Different molarities of sodium hydroxide solutions i.e. 3M, 5M, 7M and 9M are considered. The strength of geopolymer increases with increase of molarity of sodium hydroxide.

SundarKumar, S.Vasugi summarized the development of low concentration alkali activator geopolymer concrete mixes and the results of tests conducted to determine the mechanical properties such has compressive.

Parthiban.K, K.Saravanarajamohan presented the influence of the various proportions of GGBS (0-100%) on Fly Ash based GPC; the effect of the amount of Alkaline Activated Solution (AAS) in the mixture of GPC on their compressive strength is studied under ambient temperature conditions.

Gokulram.H, R.Anuradha presented the results of an experimental investigation and compare on the mechanical properties of different binder composition (100% replacement of cement by ASTM class F Fly ash (FA) and ground granulated blast furnace slag (GGBS)) of Geopolymer Concrete Composites (GPCC). The study analyses of polypropylene fibre on the mechanical properties of hardened GPCC.

Palaniappan. A,S.Vasantha discussed the results of an experimental investigation and compare on the mechanical properties of different binder composition (17 TO 20 % replacement of cement by ground granulated blast furnace slag (GGBS)) of Geopolymer Concrete Composites (GPCC). The test results show that GGBS concrete shown increase in compressive strength of 13.82% as compared with conventional concrete.

Prof.Pratap,Krishnan concluded the experimental investigation FLY ASH and BLAST FURNACE SLAG are used in equal proportion (50% each).The geopolymer concrete gains about 60-70% of the total compressive strength within 7days.

Mr. Pratik B. Shinde., Mr. Swapnil A. Suryawanshi., Mr. Amit D. Chougule. investigated light weight Geopolymer concrete and got results as follow: The light weight Geopolymer concrete gain the strength within 24 hours without water curing. The strength of light weight Geopolymer concrete was increased with decreased in molarity of alkaline solution. It was observed that, with a 1M solution the sample gives good compressive strength with achievable density to make it light weight

Chennur Jithendra Reddy and Dr. S. Elavenil researchers wrote GEOPOLYMER CONCRETE WITH SELF COMPACTING: A REVIEW, it is founded that, increasing the dosage of sodium hydroxide molarity leads to decrease in fresh properties, however it increased the compressive strength. The contribution of GGBS helps the SCGC to attain high compressive strength at ambient room temperature. GGBS at ambient curing condition had more compressive strength rather than Fly ash based SCGC

Ajay Kumar Singh studied strength and durability of Fly ash and GGBS based Geopolymer concrete. The specimens were taken to be tested after 28 days of curing in sun. Then the specimens were immersed in 3% HCL, 3% H_2SO_4 and 3% HNO_3. Results showed greater resistance to acid environment and high compressive strength compared to conventional Portland cement concrete.

K.Prasanna, Arun Kumar, M.Dinesh Kumaran J R and Lakshminarayanan.B investigated Fly ash based Geopolymer concrete with GGBS. Based on results gained from experimental investigation. The Geopolymer concrete gained strength within 24 hours at ambient temperature without water curing and also the strength of Geopolymer concrete was increased with increase in percentage of GGBS in a mix. Low calcium Fly ash (ASTM Class F) was used. Low calcium Fly ash based Geopolymer concrete has excellent compressive strength and is suitable for structural applications.

Studies by **Djwantoro.Hardjito et.al** the effect on compressive strength of geo-polymer concrete prepared with fly ash was studied. The test variables included were the age of concrete, curing time, curing temperature, quantity of super plasticizer, the rest period prior to curing, and the water content of the mix. Cylinders of

100mm x 200mm were cast and after casting, samples were covered by film and left in room temperature for 30 to 60 min and then kept in oven for heat curing. 8M sodium hydroxide solution was used with 2 molar ratio of sodium silicate solution and sodium silicate to sodium hydroxide ratio was kept constant at 2.5. Water to geopolymer solids (by mass) ratios chosen for the study was 0.175, 0.2 and 0.225. The strength results obtained showed a decreasing trend with increase in the water to geopolymer solids ratio.

3. OBJECTIVES OF THE STUDY:

- To make a concrete without using cement (i.e. Geopolymer concrete).
- To study the different strength properties of geopolymer concrete with percentage replacement of GGBS.
- To evaluate the optimum mix proportion of Geopolymer concrete with fly ash replaced in various percentage by GGBS.
- To compare the cost variation of geo-polymer concrete with normal concrete

4. MATERIALS:

In these study the materials used for geo-polymer concrete is GGBS, class F fly ash coarse aggregate, fine aggregate, cement, sodium nitrate and sodium silicate were used.

4.1 Fly ash:

It is the alumino siliitcate source material used for synthesis of geopolymeric binder. There are two types of fly ash. They are but in this stud they prefer class F fly ash.

- **Class F fly ash**
- **Class C fly ash**

Class F fly ash:

This fly ash is pozzolanic in nature, and contains less than7% lime. Possessing pozzolanic
properties, the glassy silica and aluminium of class F fly ash requires a cementing agent, such as Portland cement, quick lime, or hydrated lime-mixed with water to react and produce cementitious compounds.

4.2 GGBS:

GGBS is used to fill voids between fly ash and fine aggregate sodium hydroxide and sodium silicate or sodium nitrate solution used as alkaline liquids react with fly ash and GGBS to form the polymer gel binding the aggregates to produce GPC[2].GGBS is the by-product of steel industry. Blast furnace slag is defined as the non-metallic product consisting essentially of calcium silicates and other bases. About 10% by mass of binders was replaced with GGBS. The chemical composition of fly ash and GGBS predicted by X-ray fluorescence were given.

Chemical composition of raw materials by XRF analysis

Composition	Fly ash	GGBS
Sio_2	53.71	29.96
Al_2o_3	27.20	12.25
fe_2o_3	11.71	0.52
Cao	1.90	45.45
Na_2o	0.36	0.31
k_2o	0.54	0.38
so_3	0.30	3.62
P_2O_5	0.71	0.04
Tio_2	1.62	0.46
LOI^a	0.68	2.39

Table-1 Chemical Composition of Raw Materials

4.3 Alkaline liquid:

A merging of successfully obtainable 98% without any extraneous sodium hydroxide & sodium silicate was taking as alkaline activators for the purpose of geopolymerization.

4.4 Aggregates:

Locally available river sand & grained granites were taken as fine aggregate and coarse aggregate. The sieve analysis test had been carried out for the fine aggregate. In a similar way water absorption test specific gravity test, bulk density test, fineness modulus test were carried out for various sized 6mm, 12mm, 20mm coarse aggregates.

4.5 High range water reducing admixture:

In some investigates high range water reducer such as Conplast SP 430 getting from chemical industries to enhance the workability of concrete.

4.6 Mix design of Geopolymer Concrete

The primary difference between geopolymer concrete and Portland cement concrete is the binder. To form geopolymer paste alkaline activator solution used to react with silicon and aluminium oxides which are present in fly ash and GGBS. This alkaline activator solution helps to bind coarse aggregate and fine aggregate to form geopolymer mix. The fine and coarse aggregate occupy nearly 75% to 80% mass of geopolymer concrete. The fine aggregate was taken as 30% of total aggregate. The density of geopolymer concrete is taken 2400 kg/m3.The workability and strength of concrete are influenced by properties of materials that make geopolymer concrete. Fly ash is replaced by GGBS in the range of 25%, 50% and 75%. The ratio of sodium silicate to sodium hydroxide is 2.5 and is kept constant throughout this study. The ratio of alkaline activator to the fly ash is 0.40 kept constant.

4.7 Preparation of Alkali Solution

he preparation of solution is done by dissolving sodium hydroxide in water. The concentration of sodium hydroxide changes with molarity. The quantity of sodium hydroxide solution with a concentration of 11M is calculated. The mass of NaOH solids in solution varied depending on the concentration of the solution expressed in terms of molar, M. The NaOH solution with concentration of 11M consisted of 11*40 = 440gm of NaOH solids per liter of the solution, where 40 is the molecular weight of NaOH. The mass of NaOH solids was measured as 306gm per kg of NaOH solution of 11M concentration. The sodium hydroxide is added to the water and stirred about fifteen minutes to get cool down. Then the sodium silicate is added to solution. This solution is used after 24 hours of its preparation.

Mix Designation	Flyash Kg/m³	GGBS Kg/m³	Fine Agg Kg/m³	Coarse Agg Kg/m³	NaOH Kg/m³	Na_2SiO_3 Kg/m³
MIX-1	CC (100% OPC) 394 Kg/m³		554.4	1293.6	WATER 197 Kg/m³	
MIX-2	394.28	0	554.4	1293.6	45.06	112.65
MIX-3	295.71	98.57	554.4	1293.6	45.06	112.65
MIX-4	197.14	197.14	554.4	1293.6	45.06	112.65
MIX-5	98.57	295.71	554.4	1293.6	45.06	112.65

Table-2: Properties of Mix Designs

4.8 Mixing

The alkaline activator solution is prepared before 24 hours of casting. Initially, all dry materials were mixed properly for three minutes. Alkaline activator solution is added slowly to the mixture. Mixing is done for 5 minutes to get uniform mix.

Fig.No-1: Mixing of Concrete

4.9 Casting

Properly mixed geopolymer concrete is poured immediately into the moulds. Concrete is placed in three layers and tamping is done for each layer by giving more than 25 blows, in order to get fully compacted geopolymer concrete specimens. Then the top surface is well finished. The sizes of the moulds used are cube (150mmx150mmx150mm), cylinder (150mm dia and 300mm height).

4.10 Curing

After 24 hours moulds were demoulded and were kept in room temperature for curing. The average temperature recorded during the period of curing was 38ºC. The curing is done for 7 days and 28 days.

MIX-1	CC (100% OPC)
MIX-2	100% FA
MIX-3	75%FA + 25% GGBS
MIX-4	50%FA + 50% GGBS
MIX-5	25%FA + 75% GGBS

Table-3 Diff types of Mixes

Fig.No-2: Casted Specimens

5. RESULTS AND DISCUSSIONS

5.1 Compressive strength

The compressive strength of a material is that value of uni-axial compressive stress reached when the material fails completely. The cubes are then tested between the loading surfaces of the compressive testing machine of capacity 2000KN in such a way that the smooth surface directly receives the load and it is applies until the failure of the load. The compressive strength is determined by the ratio of failure load to the cross sectional area of the specimen.

$$f_c = \frac{failure\ load}{cross\ sectioal\ area}$$

Mix Designations	Compressive Strength	
	7days`	28 days
MIX-1	18.6	36.4

MIX-2	**7**	**10**
MIX-3	**18**	**33**
MIX-4	**22**	**35**
MIX-5	**25**	**40**

Table-4: Compressive Strength values

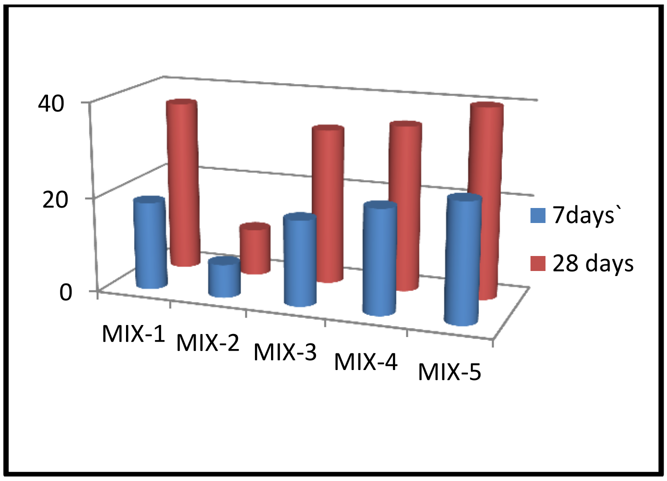
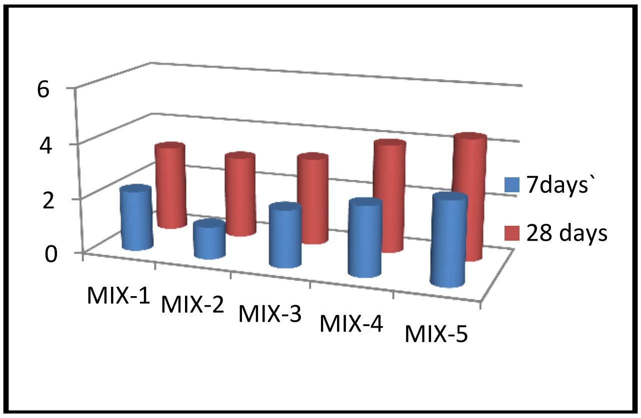


Fig.No-2: Compressive strength Graph drawn for 7 and 28 days

Split Tensile Strength:

Mix Designations	Split Tensile Strength	
	7days`	**28 days**
MIX-1	**2.19**	**3.15**
MIX-2	**1.17**	**3**
MIX-3	**2.08**	**3.20**
MIX-4	**2.52**	**3.95**
MIX-5	**2.99**	**4.40**

Table-5: Split Tensile Strength values



Fig, No-3: Split Tensile graph drawn for 7 and 28 days curing

5. SUMMARY AND CONCLUSIONS

Geopolymer concrete one of the eco-friendly alternatives to ordinary Portland cement concrete because it utilizes less raw material. For this reason, geopolymer concrete is a strong material that provides sustainable development for infrastructural needs.

The present research paper explains the mechanical characteristics of fly ash and GGBFS-synthesized geopolymer concrete with NaOH and Na2SiO3 as alkaline activators. The conclusions obtained from the study are:

The GPC specimens were cast with inorganic materials (fly ash and GGBFS) and cured at a constant room temperature for one day then further cured at sunlight for 7 and 28 days. In these conditions, the compressive strength of GPC was higher at 75% GGBS replacement of flyash at 28 days of sunlight curing, that is 40 MPa (for mix M5).

The strength development of mixture having 25% of replacement of fly ash is slow as compared to that of 75% of replacement. This material undergoes the processes of polymerization and hydration, depending on its mixture proportions. Adding GGBS to the fly ash for making Geopolymer concrete results in higher early strength and cubes demoulded by next day. The rate of strength development is faster during early days for mixtures having 75% replacement of fly ash through GGBS, but after 28 days, the strength gain is at lower rate. However, for the mixture proportion having 25% of replacement of fly ash with GGBS, the rate of strength development is slow and steady and continues after 28 days. Mixture of 25% fly ash and 75% GGBS shows highest values of split tensile strength

ACKNOWLEDGEMENT

We are thankful to **Dr. Mohammed Masood,** Principal, ISLEC, for his encouragement throughout the project. We would also like to express our heartfelt thanks to **Ms. K. Nanchari,** Head of Civil Engineering Department, ISLEC for her help and unending cooperation with us during completion of this work.

REFERENCES

[1]. Bakharev, T., Sanjayan, J. G., & Cheng, J. B. (2003). Resistance of alkali-activated slag concrete to acid attack. Cement and Concrete Research, 33, 1607-1611.]
[2]. Bakharev, T. (2005a). Durability of geopolymer materials in sodium and magnesium sulfate solutions. Cement And Concrete Research, 35(6), 1233-1246.
[3]. Bakharev, T. (2005b). Geopolymeric materials prepared using Class F fly ash and elevated temperature curing. Cement And Concrete Research, 35(6), 12241232.
[4]. Bakharev, T. (2005c). Resistance of geopolymer

materials to acid attack. Cement And Concrete Research, 35(4), 658-670.
[5]. Balaguru, P., Kurtz, S., & Rudolph, J. (1997). Geopolymer for Repair and Rehabilitation of Reinforced Concrete Beams. The Geopolymer Institute. Retrieved 3 April, 2002, from the World Wide Web: www.geopolymer.org
[6]. Cheng, T. W., & Chiu, J. P. (2003). Fire-resistant geopolymer produced by granulated blast furnace slag. Minerals Engineering, 16(3), 205-210.
[7]. Comrie, D. C., Paterson, J. H., & Ritchey, D. J. (1988). Geopolymer Technologies inToxic Waste Management. Paper presented at the Geopolymer ’88, First European Conference on Soft Mineralurgy, Compiegne, France.
[8]. Davidovits, J. (1984). Synthetic Mineral Polymer Compound of TheSilicoaluminates Family and Preparation Process, United States Patent - 4,472,199 (pp. 1-12). USA.
[9]. Davidovits, J. (1988a). Soft Mineralurgy and Geopolymers. Paper presented at theGeopolymer ’88, First European Conference on Soft Mineralurgy, Compiegne, France.
[10]. Davidovits, J. (1988b). Geopolymer Chemistry and Properties. Paper presented at the Geopolymer ’88, First European Conference on Soft Mineralurgy, Compiegne, France.
[11]. Davidovits, J. (1988c). Geopolymers of the First Generation: SILIFACE-Process.Paper presented at the Geopolymer ’88, First European Conference on Soft Mineralurgy, Compiegne, France.
[12]. D vidovits, J. (1988d). Geopolymeric Reactions in Archaeological Cements and in Modern Blended Cements. Paper presented at the Geopolymer ’88, First European Conference on Soft Mineralurgy, Compiegne, France.

BIOGRAPHIES

Ms. Nanchari Kanchala,
Assistant Professor, Department of Civil Engineering, ISLEC, Hyderabad, India

Syed Javeed,
Student, Department of Civil Engineering, ISLEC, Hyderabad, India

Syed Azam Quadri,
Student, Department of Civil Engineering, ISLEC, Hyderabad, India

Syed Wali Uddin Khan,
Student, Department of Civil Engineering, ISLEC, Hyderabad, India