iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 11 Issue: V Month of publication: May 2023

DOI: https://doi.org/10.22214/ijraset.2023.52449

Performance Evaluation of M_{20} Grade Geopolymer Concrete using Fly Ash and GGBS with Super Plasticizer

Neeraj Kumar Verma[1], Gyanendra Kumar Sahu[2], Barun Singh[3], Khirendra Netam[4], Manisha Verma[5], Dr. Anil Kumar Suman[6]

[1, 2, 3, 4, 5]B.Tech Student, [6]Associate Professor

Dept. of Civil Engineering Shri Shankaracharya Technical Campus, Bhilai (C.G), India

Abstract: This study aimed to evaluate the strength properties of geopolymer concrete using fly ash and ground granulated blast furnace slag (GGBS) with the addition of a super plasticizer at a grade M20. The study used 70% fly ash and 30% GGBS to replace the cement content of the concrete mix, and sodium hydroxide and sodium silicate were used as Alkaline activators. The concentration of (NaOH) solution was maintained at 8 molarity and the dosage of activator ratio is 2.5 is a combination of sodium silicate and sodium hydroxide ratio. The compressive strength of the geopolymer concrete was tested at different ages (7, 14, and 28 days) to evaluate the strength properties. The results showed that the addition of fly ash and GGBS significantly improved the strength properties of the geopolymer concrete. Moreover, the optimized dosage of the super plasticizer was found to be 1% of the total weight of the mix. The study concludes that the use of fly ash and GGBS in geopolymer concrete can significantly improve its strength properties, and the addition of a super plasticizer can enhance its workability. This finding suggests that geopolymer concrete could be a viable alternative to conventional concrete in construction applications .The test result shows encouraging results of ordinary Portland cement concrete and geo polymer concrete so one can easily replace ordinary concrete with geopolymer concrete for precast applications.

Keywords: Geopolymer concrete, Fly Ash, GGBS, Alkaline Activators, Super plasticizers, Molarity.

I. INTRODUCTION

Geopolymer concrete is an alternative concrete in which an alkali activated alumina silicate material is used as the binder instead of the traditional cement binder. Thus the traditional binder based on cement or cement and other puzzolanic materials is replaced by the alkali activated inorganic binder in geopolymer concrete. Geopolymer concrete is a type of concrete that is made using industrial by-products like fly ash and slag instead of traditional cement. It plays a vital role in the context of sustainability and environmental issues.

Cement production contributes the release of carbon dioxide gas (CO_2) in a massive amount which is responsible for around 8% of world wide CO_2 emission.

In order to decrease the CO_2 emission, it is necessary to limit the production and usages of OPC. Approximately 5% of global CO_2 emissions originate from the manufacturing of Portland cement. On the other hand, industrial by-product materials such as slag has been shown to release up to 80% less greenhouse gas emissions and there are 80% to 90% less greenhouse gas emissions in the production of fly ash. Therefore, a full replacement of OPC with GGBS or fly ash would significantly reduce the CO_2 emission of concrete production

The major processes involve the reaction between an aluminosilicate source such as fly ash, metakaolin or blast furnace slag and an alkaline solution which leads to final hardening of the material by exclusion of excess water and the growth of an inorganic polymer. The chemical reaction and the rate of strength development of geopolymer concrete are influenced by several factors based on chemical compositions of the source materials, alkaline activators and curing condition

The development of geopolymer concrete without curing at elevated heat will widen its application to the areas beyond precast concrete members. Elimination of the elevated heat for curing will also reduce the cost and energy associated with the heat curing process.

.

II. LITERATURE REVEIW

Djwantoro Hardjito et al (2020) was described in its impact on the characteristics and strength of fly ash-based geopolymer concrete. Variables for test include: age, curing time, heat treatment temperature, geopolymer number of super plasticizer, rest before heat treatment and water quality of mixture.

The test variables included the time of testing. Ground-grained fuel-fired (GGBS) blasting creates the glass-dried granular product, which is then dried into fine powder by quenching the moulded slag of iron (a by-product of the manufacture of iron and steel) from a fired flame or steam oven. The base-granulate blasting oven is a strongly cemented and high CSH (calcium silicate hydrates) compound that increases the concrete's strength, toughness and appearance.

P. Subathra et al. (2020) concluded that mortar ductility is substantially linked to this gain and loss measure. Two different fly ash with strengths from 5 MPa to 60 MPa was prepared for this. They concluded that strength losses decrease as ductility increases, even strength increases when ductility is high. This relation has a high thermal incompatibility because of the high ductility mortar. The two opposing process is thought to occur in morteries: (1) geo-polymerization and/or sintering at high temperatures, resulting in a substantial rise in temperature; (2) mortar damage due to non-uniform thermal distribution. The power gain or loss occurs depending on the dominant mechanism

Patankar S.V et al. (2018) studied effect of duration and temperature curing on compressive strength of fly ash based of geopolymer concrete and observed while finding effect of concentration of sodium hydroxide on fly ash based geopolymer concrete that the compressive strength of geopolymer concrete increases with increase in the concentration of sodium hydroxide solution for all temperatures but the rate of gain of strength at and above 60^0C is not very significant.

Zhang H.Y. et al. (2018) based on their experimental results on the bond behaviour between geopolymer concrete and rebar reported that Geopolymer concrete exhibits significant temperature induced degradation in bond strength, when exposed to temperatures above 300˚C also Bond strength of geopolymer concrete was found to decrease at the same rate as that of splitting tensile strength with temperature, but this degradation is at a higher pace than that of the compressive strength

Patankar S.V. et al. (2018) studied effect of various concentrations of sodium hydroxide solution in terms of molarity at solution to fly ash ratios of 0.30, 0.35, and 0.40 on workability in terms of flow in plastic state and effect of degree of heating on compressive strength.

They reported that the workability as well as compressive strength of geopolymer mortar increases with increase in concentration of sodium hydroxide solution in terms of molarity and they recommended, 13-molar solution of sodium hydroxide is recommended on the basis of workability and compressive strength.

Oyebisi S et al. (2018) investigated the utilization of both corncob ash and ground granulated blast furnace slag as source materials activating with both sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3) solutions in the production of geopolymer concrete and reported that the geopolymer concrete with 12 M sodium hydroxide shows a higher compressive strength when compared with the Portland cement concrete.

Comparing with the Portland cement concrete, the optimal replacement level of both ground granulated blast furnace slag and corncob ash for optimum strength is obtained at 60% and 40% respectively.

Lăzărescu A et al. (2018) investigated on the parameter affecting the mechanical property of fly ash based geopolymer concrete while keeping the alkaline liquid to fly ash mixing ratio constant, they varied the Na_2SiO_3 to NaOH solution ratio and the NaOH solution concentration, Results showed that by increasing the sodium silicate solution content in the mixtures, a significant increase in the compressive strength can be obtained.

Manimaran, E and Mohan kumar, G (2017) carried out an investigation on influence of sodium hydroxide concentration on the strength of fly ash based geopolymer concrete and reported that the strength of ambient cured specimens is always less and about 95% to 97% of the hot cured concrete irrespective of the molarity of NaOH solution. Under specified concentration of NaOH, the required strength of Geopolymer concrete can be achieved by ambient curing itself and hot curing is not at all required under laboratory condition. Hot curing may be employed in case of fabrication of precast units.

N.Manoj kumar (2016) investigated the compressive strength and micro-structural properties of a

Class C fly ash Geopolymer. They have concluded that when a mixed alkaline triggering unit with the optimum module viz, the SiO_2/Na_2O molar proportion was enabled, a high compressive strength was obtained. The CFA is activated and, because of the dissolution of alumino-silicate in the high pH alkaline solution, the sphere appears assaulted and destroyed. The use of this fly ash in geopolymer materials is a method that saves money and energy and indirectly reduces greenhouse gas emissions from cement processing. This is good for the conservation of resources and the preservation of the environment.

III. MATERIALS AND METHODOLOGY

A. Materials

1) *Fly Ash:* Fly ash is fine grey powder that is a by-product material of pulverized bituminous coal blown into a fire furnace which is produced in electricity generating thermal power station.

Specific gravity Fly Ash = 2.26.

Fineness of the Fly Ash = 360 m^2/kg.

2) *Aggregate*

Coarse and fine aggregates used by the concrete industry are suitable to manufacture geopolymer concrete. The properties of aggregates used are listed below:

- Specific gravity of Fine Aggregate = 2.68
- Specific gravity of Coarse Aggregate = 2.67
- Fineness modulus = 2.77
- Fine Aggregate is confirmed to zone-II (IS: 383 – 1970)
- Fineness Modulus = 2.21 (coarse aggregate of size ranging from 12.5 to 5mm)


Fig. 1 Fly Ash


Fig. 2 Coarse Aggregate


Fig. 3 Fine Aggregate

3) *Alkaline Liquid*

The alkaline liquid is prepared by mixing sodium silicate and sodium hydroxide solutions together at least 24 hours prior to use for thorough mixing and reaction. The sodium silicate solution is commercially available in different grades. The sodium silicate solution with sodium hydroxide ratio by mass of 2.5 is used. The sodium hydroxide with 97-98% purity in pellet form is commercially available. The solids dissolved in water to make a solution with the required concentration. The concentrations of sodium hydroxide solution are kept as 8 Mole. The mass of NaOH solids in a solution varies depending on the concentration of the solution.

4) *GGBS*

Ground-grained fuel-fired (GGBS) blasting creates the glass dried granular product, which is then dried into fine powder by quenching the moulded slag of iron (a by-product of the manufacture of iron and steel) from a flame-fired flame or steam oven .The base-granulate blasting oven is a highly cemented and high CSH (calcium silicate hydrates) compound that enhances the concrete's strength, durability and appearance. The GGBS used for this study was received from ACC Jamul, Durg (C.G).

5) *Admixture*

Sulphonated naphthalene formaldehyde is a high-range water reducing admixture for concrete. It is also called naphthalene super plasticizer or SNF super plasticizer. It has the advantages of high water reduction rate, neither retardation nor air entrainment, and strong adaptability. So sulphonated naphthalene can greatly improve the workability of concrete and reduce the water consumption for mixing, and can significantly increase the strength of concrete. The Admixture used for this study was purchased from India mart.

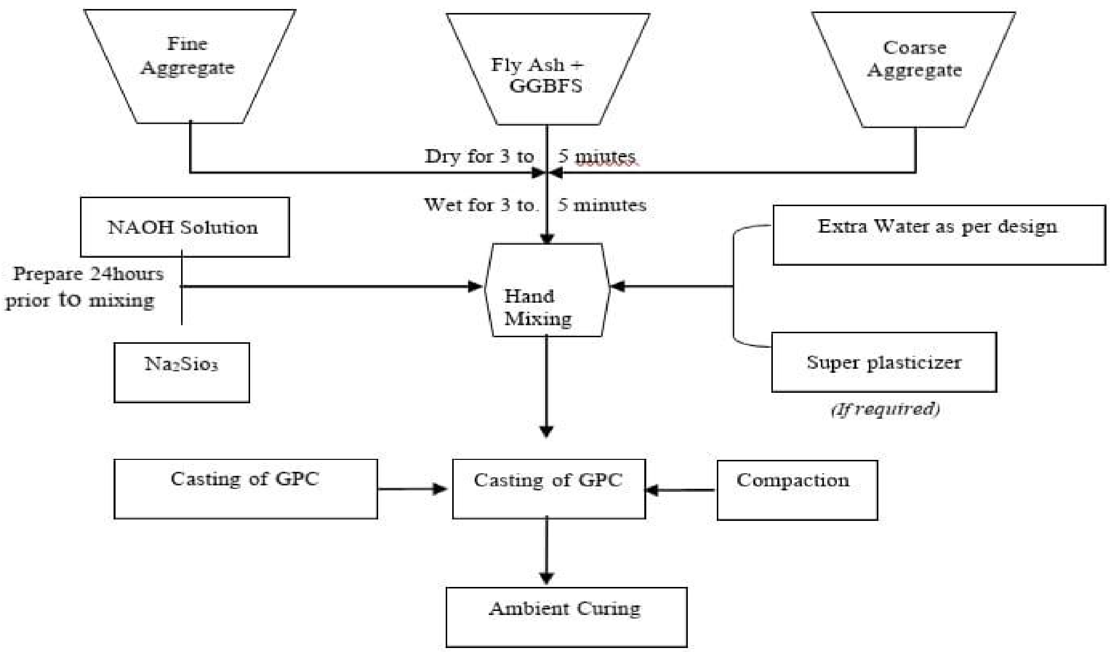

Fig. 4 Alkaline Liquid


Fig. 5 GGBS


Fig. 6 Super Plasticizer

B. Methodology

1) Flow Chart of Mixing and Casting of Geo Polymer Concrete



2) Geopolymer Concrete Mix Design as Per IS10262-2019

Geo polymer concrete (GPC) represents a rather recent development in concrete materials technology and its GGBS based concrete, possessing the most desirable properties during fresh as well as hardened concrete stages. GPC is superior to conventional cement concrete (CCC) as the ingredients of GPC contribute most optimally and efficiently to the various properties. To produce GPC mix it is essential that it requires careful selection and proportioning of the ingredients which are almost the same as that CCC. There is no standard code or specified IS code for Geo polymer concrete mix design and therefore we have used **IS10262-2019** for mix design**.**

Cementitious Material (70% Fly Ash + 30% GGBS) - 436 kg / m^3
Na_2SiO_3 / NaOH - 2.5
(Na_2SiO_3 + NaOH) / Cementitious Material - 0.45
NaOH solid - 17.94 kg / m^3
Water (added with NaOH solid) - 38.12 kg / m^3
Na_2Sio_3 solution - 140.14 kg / m^3
Coarse aggregate - 1308 kg / m^3
Fine aggregate - 654 kg / m^3
Molarity - 8 Mole

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 11 Issue V May 2023- Available at www.ijraset.com

3) Preparation of Specimen

The concrete batch is mixed on a water tight, non-absorbent steel platform with a shovel, trowel and similar suitable implement, using the following procedure.

- The fly ash and fine aggregate is mixed dry until the mixture is thoroughly blended and is uniform in colour
- The coarse aggregate is added and mixed with the fly ash and fine aggregate until the coarse aggregate is uniformly distributed throughout the batch.
- The chemical solution is added and the entire batch is mixed until the concrete appears to be homogenous and has the desired consistency. If repeated mixing is necessary, because of the addition water in increments while adjusting the consistency, the batch is to be discarded and fresh batch is made.

a) Mixing and Casting

The fresh fly ash classified as low calcium was used. The aggregates were prepared in saturated surface dry condition, and were kept in plastic buckets. Thorough mixing was carried out. The aggregates and the fly ash were dry mixed by hand mixing for about three minutes. The liquid part of the mixture, sodium silicate solution and sodium hydroxide solution mixed twenty four hours earlier for thorough mixing and reaction. The wet mixing of liquid and dry mixture of aggregates usually continued for another four minutes.

b) Curing

Heat-curing of low-calcium fly ash-based geopolymer concrete is generally recommended. Heat-curing substantially assists the chemical reaction that occurs in the geopolymer paste.

Longer curing time improves the polymerization process resulting in higher compressive strength. The rate of increase in strength was rapid up to 24 hours of curing time; beyond 24 hours, the gain in strength is only moderate. Therefore, heat-curing time need not be more than 24 hours in practical applications.

4) Compressive Strength Test

Compressive strength test measuring the maximum amount of compressive load a material can bear before fracturing. The test piece was compressed between the platens of a compression-testing machine by a gradually applied load.

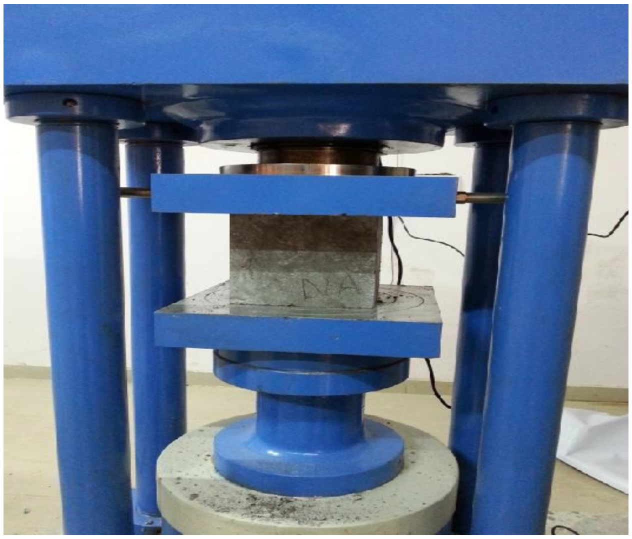


Fig. 7 Compressive Strength Test

The cube specimens are 150 mm X 150 mm X 150 mm. Geopolymer concrete specimens are tested at 7 days, 14 days and 28 days for compressive strength and are healed with direct sunlight The concrete cubes were tested according to **IS 516-1959** standards for their compressive strength in the compression testing unit.

Compressive Strength = Breaking load / Area of Cross section of Specimen

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 11 Issue V May 2023- Available at www.ijraset.com

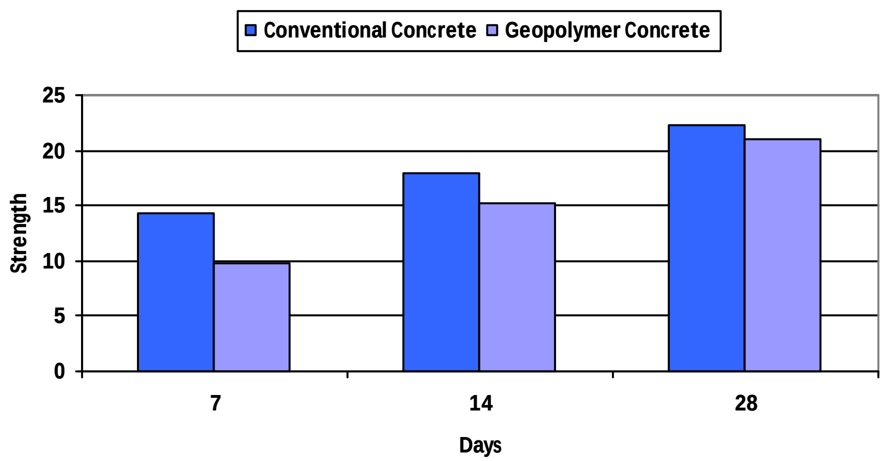
IV. RESULT AND DISSCUSION

The results discussed below mainly consist of comparison between Geopolymer M20 grade concrete with conventional concrete. The test results of harden concrete are discuss below. The table consists test results of comparative study of concrete with 7, 14 and 28 days Compressive Strength. Compressive strength is the most common property used to describe a concrete. Since other properties of concrete often correlate well with the compressive strength, it is used as an indicator of the other mechanical properties. These are the mean values of the results obtained from three identical specimens.

A. Hardened Geopolymer Concrete

Compression Strength (N/mm^2)						
Mix	7 Days	Avg	14 Days	Avg	28 Days	Avg
Conventional Concrete	13.96		15.29		19.73	
	14.20	14.24	18.80	17.97	22.88	22.34
	14.56		19.84		24.24	
Geopolymer Concrete	9.51		14.00		20	
	10.41	9.85	16.89	15.29	22.47	21.10
	9.64		15.0		20.85	

Graph: 1: Compressive Strength comparative chart:



V. CONCLUSION

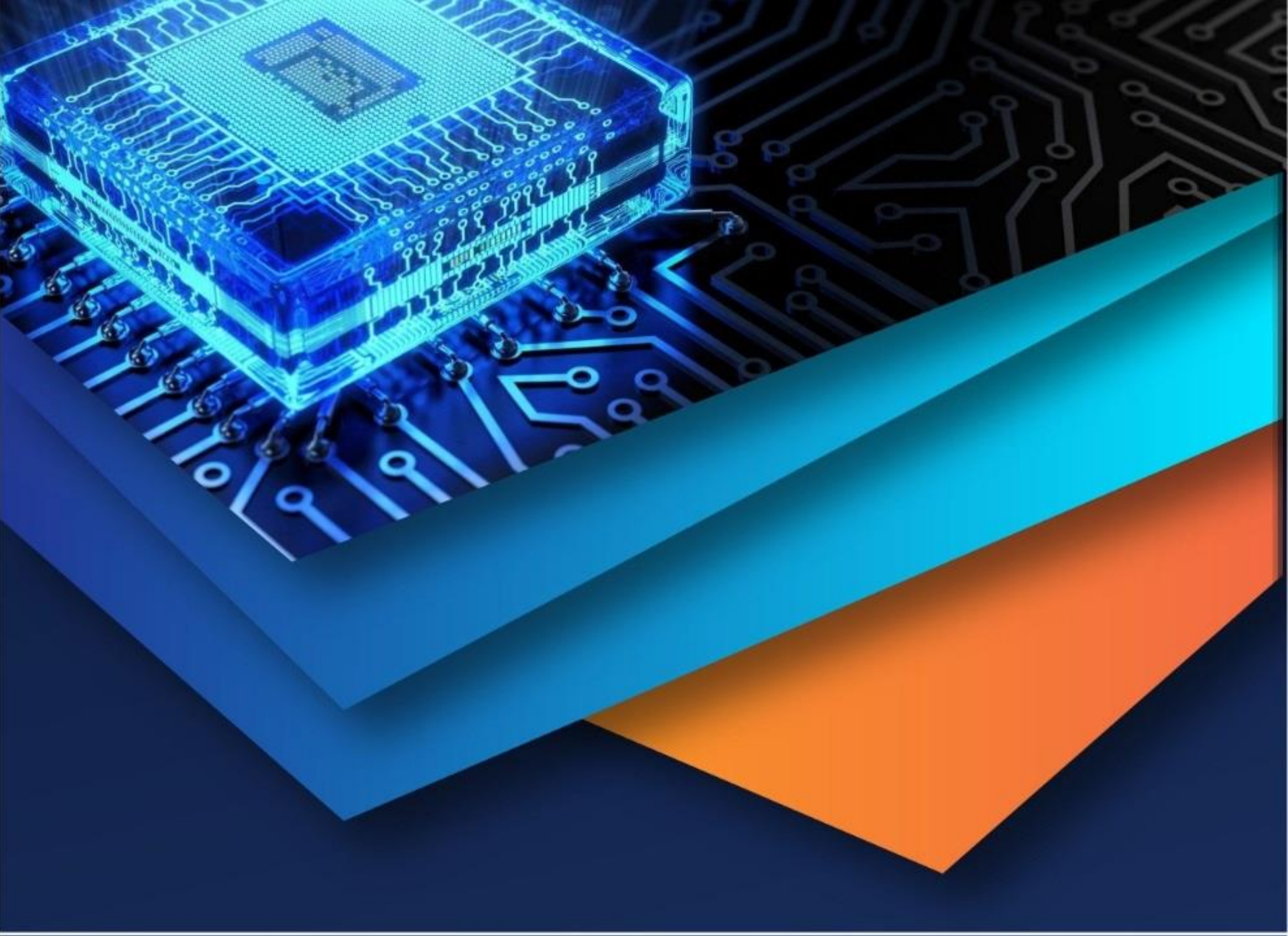
The following conclusions were drawn from the study:

1) It is observed that, the rate of gain of Comp. strength of geopolymer concrete is more than the conventional concrete made up of ordinary Portland cement.
2) It is also observed that, the maximum Comp. strength of geopolymer concrete is nearly equal to conventional concrete made up of ordinary Portland cement.
3) Compressive strength of geopolymer concrete increases with increase in molarity of sodium hydroxide (NaOH) solution.
4) Water absorption property is lesser than the nominal concrete
5) Curing at elevated and ambient temperature will form fly ash-GGBS based concrete of comparable strengths.
6) As the curing temperature in the range of 60°C to 90°C increases, the compressive strength of geopolymer concrete is increases.
7) Bottom ash –GGBS based geopolymer concrete gives very low strength probably due to large particle size.

8) Geopolymer concrete can be prepared at comparable cost with OPC based concrete provided transportation system for raw materials is well established.
9) The embodied energy of fly ash- GGBS based geopolymer concrete is 40% less than that of OPC based concrete.
10) If not handled properly, Sodium hydroxide can be very harmful to health if mishandled. It has been rated with a classification of 3 in terms of danger to health (0 being the least hazardous, and 4 being the most).
11) Sodium hydroxide is also very corrosive to areas such as the eyes, skin, and nose.
12) One application of geopolymer concrete is in the construction and repair of highways, roads, and airport runways.
13) Because of its high resistance to acids and toxic waste, geopolymer concrete can be applied in various highly acidic and toxic environments.

REFERENCES

[1] Davidovits J. Geopolymer chemistry and application. 2nd edition. France: Institute Geopolymer Saint-Quentin; 2008
[2] Davidovits J. High alkali cements for 21st century concretes, concrete technology, past, present, and future. P.K. Mehta Ed. American Concrete Institute; 1994, p. 383–397.
[3] Yip CK, Lukey GC, Provis JL, van Deventer JSJ. Effect of calcium silicate sources on geo polymerization. Cem Concr Res 2008; 38: 554-64.
[4] Nath P, Sarker PK. Geopolymer Concrete for ambient Curing Condition. Proceedings of Australasian Structural Engineering Conference. Perth, Australia; 2012.
[5] Chang EH. Shear and Bond Behavior of Reinforced Fly Ash-based Geopolymer Concrete Beams. PhD Thesis. Perth, Australia: Faculty of Engineering, Curtin University; 2009.
[6] Ramlochan T, Zacarias P, Thoas MDA, Hooton RD. The effect of pozzolana and slag on the expansion of mortars cured at elevated temperature: Part I: Expansive behavior. Cem Concr Res 2003; 33 (6):807-814.
[7] Palomo A, Grutzeck MW, Blanco MT. Alkali-activated fly ashes a cement for the future Cem Concr Res 1999;29:1323-1329
[8] Bakharev T. Durability of geopolymer materials in sodium and magnesium sulphate solutions. Cem Concr Res 2005; 35:1233– 1246.
[9] Deb PS, Nath P, Sarker PK. Strength and Permeation Properties of Slag Blended Fly Ash Based Geopolymer Concrete. Adv Mater Res 2013; 651:168-173.
[10] A. Paulmakesh, Material characteristics of geopolymer concrete incorporated with fly-ash & GGBS, Int. Res. J. Eng. Technol. (IRJET), Volume: 07 Issue: 03 | Mar 2020.
[11] D.S. Vijayan, C. Nivetha, P. Dinesh Kumar, B. Saravanan, V. Gogulnath, ‘‘Green composite form of eco – friendly concrete by adding PVA fiber”, J. Green Eng.(JGE), Volume-10, Issue-6, June 2020.
[12] G. Jayarajan, S. Arivalagan, Geopolymer concrete by using fly ash, GGBS, quarry dust and 10mm aggregate, Int. J. Recent Technol. Eng. (IJRTE) ISSN: 2277-3878, Volume-8, Issue-6, March 2020.
[13] M. Kalpana, D.S. Vijayan, S.R. Benin, Performance study about ductility behavior in electronic waste concrete, Mater. Today Proc.
[14] M. Kalpana, C. Vaidevi, D.S. Vijayan et al., Benefits of metakaolin over micro silica in developing high performance concrete, Mater. Today Proc.
[15] D.S. Vijayan, C. Nivetha, P. Dinesh Kumar, B. Saravanan, V. Gogulnath, ‘‘Green composite form of eco – friendly concrete by adding PVA fiber”, J. Green Eng.(JGE), Volume-10, Issue-6, June 2020.
[16] D.N. Kumar Abrasion Resistance of Polypropylene Fiber Reinforced Geopolymer Concrete. J. Emerg. Technol. Innov. Res. Issue 11 vol: 4 Nov 17.
[17] Geopolymer institute, 2010. What is geopolymer? Introduction institute geopolymer institute, Saint-Quentin, France. Accessed on January 29, 2010, at http://www.geopolymer.org/science/introduction.
[18] Parth, sanumori. (2017). Study on the Behavior of Fly Ash Based Geopolymer Concrete with 20molar NaOH Activator. Project Report. Pace Institute of Technology and Sciences, Vallur
[19] Ryu, G. S., Lee, Y. B., Koh, K. T., & Chung, Y. S. (2013). The mechanical properties of fly ash-based geopolymer concrete with alkaline activators. Construction and Building Materials,47,409–418 https://doi.org/10.1016/j.conbuildmat.2013.05.069
[20] McLellan, B. C., Williams, R. P., Lay, J., Riessen, A. V., & Corder, G. D. (2011). Costs and carbon emissions for geopolymer pastes in comparison to ordinary Portland cement. Journal of Cleaner Production,19(9–10),1080–1090.
[21] Hardjito, D., & Rangan, B. V. (2005). Development and properties of low-calcium fly ash-based geopolymer concrete (Research Report GC1). Curtin University of Technology



10.22214/IJRASET

INDEX COPERNICUS
45.98

IMPACT FACTOR:
7.129

TOGETHER WE REACH THE GOAL

IMPACT FACTOR:
7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY