RESEARCH ARTICLE OPEN ACCESS

Experimental Investigation On Mechanical Properties Of Fiber Reinforced Geopolymer Concrete By Variation of Alkaline Activators Ratio.

Laxman Lahamge[1], Sushama Dongare[2], Supriya Gade[3], Chetan Sangale[4], Harsh Ghodekar[5]

Department of Civil Engineering, Pravara Rural Engineering College Loni.

ABSTRACT
Fly ash Geopolymer concrete (GPC) is an eco-friendly alternative to conventional concrete that uses waste materials as a cementitious material. This work contains the effect of changing the alkaline solution to fly ash ratio on the strength and workability of fiber reinforced geopolymer concrete mix, including fly ash and polypropylene fibers 1.5%. To create geopolymer concrete mixes, a ratio of alkaline solution to fly ash of 0.35 is utilized, while the ratio of sodium hydroxide to sodium silicate 1:1.5 & 1:2.5 is used. A sodium silicate mixture with two different sodium hydroxide molarities (8M and 12M). The geopolymer concrete specimens are tested for their compressive strength and flexure test at the age of 7 & 14 days. Durability is evaluated through RCPT and Bond strength is studied through Pull out test. Test results shows improvements in the properties as compared to conventional concrete.
Keywords: Geopolymer Concrete, Fly Ash, Alkaline Solution, Aggregate.

Date of Submission: 03-07-2023 Date of acceptance: 14-07-2023

I. INTRODUCTION

In the field of civil engineering constructions, concrete is one of the major components used owing to its strength and durability. Concrete is currently the most common material used in the construction industry around the globe. Ordinary Portland cement (OPC) is the primary binder for conventional concrete, which is widely used as a construction material for various types of structures. One of the new technologies that are concerned for the reduction of Portland cement in concrete is geopolymer technology.

Geopolymer concrete has been explored as an alternative sustainable concrete in recent years. Fly ash is the main source of silica (Si) in the geopolymer and hence provide good binding strength. While extensive research has been conducted on geopolymer concrete (GPC) at the material level, much less efforts have been devoted to investigate the structural performance of GPC. fly based geopolymer cement and concrete have been studied extensively, and they are well known for their properties, which are better than those of normal concrete due their lower creep, lower shrinkage, better fire and acid resistance and resistance to sulphate attack. polypropyelene fiber 1.5% is used for streghning of GPC concrete.

II. MATERIALS

2.1. Fly ash (Class F- Type):

The colour of fly ash can be tan to dark grey, depending upon the chemical and mineral constituents mean particle size ranges from less than 1 µm to 150 µm. The fly ash used in the current study was obtained from the thermal power plant.

2.2 Aggregate

Locally available river sand having specific gravity 2.64 and conforming to grading zone-II as per I.S: 383 -1970.The natural sand had a specific gravity of 2.57. Aggregate passing through 10 mm to 12mm.

Table 1: Material Required For M30 Grade GPC with 1.5 & 2.5 Activators ratio.

Fly Ash Kg/m^3	Sodium Hydroxide Kg/m^3	Sodium Silicate Kg/m^3	Fine Agg. Kg/m^3	Coarse Agg. Kg/m^3	Water Kg/m^3
470	47	117.5	737	1105.5	4.29
470	65.8	98.7	737	1105.5	4.29

Table 2: Properties of Coarse Aggregates

Sr. No.	Test	Result	IS Requirement
1.	Mean Aggregate Impact Value	10.22 %	45%
2.	Average Crushing Value	39.33%	45%
3.	Mean specific gravity	3.05	2.6-2.8
4.	Los Angeles abrasion Value	15.49%	30%

Table 3: Properties of Fine Aggregates

Sr. No	Test	Results	IS Requirement
1.	Specific gravity	2.64	2.5-3.0
2.	Moisture content	5%	20%
3.	Bulking value	4.6%	20%

2.3 Alkali activators

Two types of alkali activators were used in this study to produce geopolymer concrete. A 8M & 12M sodium hydroxide solution was prepared by dissolving sodium hydroxide pellets in distilled water. Also, a commercially available sodium silicate solution of 29.5% SiO2, 14.5% Na_2O and 55.9% H_2O (% by weight) was used in the experiment.

2.4 Mix Proportions

In this experiment, the mix design technique is used centered on the performance of the Concrete. Normally for Concrete is containing 75% of the aggregate of the total Concrete that is coarse and fine aggregates. Same 75% of the aggregate was taken to the mass of Geopolymer Concrete for calculation of material required for designing the Geopolymer Concrete according to the history of research, the density of Geopolymer Concrete was taken 2400 kg/m^3, which is the same as ordinary portland cement.

2.5 Preparation of Geopolymer Concrete Mixes:

Preparation of geopolymer concrete is similar to that of cement concrete. Two types of coarse aggregates, sand and fly ash were mixed in dry state. Then add prepared mixture solution of sodium hydroxide and sodium silicate along with extra water based on water-to-geopolymer binder ratio and mix thoroughly for 3–4 min so as to give homogeneous mix. It was found that the fresh fly ash based geopolymer concrete was viscous, cohesive and dark in color. After making the homogeneous mix workability of fresh geopolymer concrete was measured by flow table apparatus as per IS 5512-1983 and IS 1727-1967. Concrete cubes of side 150 mm are casted in three layers. Each layer is well compacted by tamping rod of diameter 16 mm. All cubes were place on table vibrator and vibrated for 2 min for proper compaction of concrete. After compaction of concrete, the top surface was levelled by using trowel. After 24 h of casting, all cubes were demoulded and then placed in an oven for thermal curing (heating). To avoid the sudden variation in temperature, the concrete cubes were allowed to cool down up to room temperature in an oven. The compaction factor ranges from 0.78-0.95 and polypropyelene fiber 1.5% is used for streghning of GPC concrete.

III. Methodology

3.1 The various workability, strength &durability tests conducted are mentioned below:

- Workability
- Compressive Strength
- Flexural Strength
- Rapid Chloride Penetration Test (RCPT)
- Pull Out Test

Table 4: Experimental Program

Sr. No	Name Of Test	Ratio (NH:NS)	Days	Specimen	Total	Size
1.	Compressive Test	1:1.5	7	Cube	3	150x150x150 mm
		1:1.5	14	Cube	3	150x150x150 mm
		1:2.5	7	Cube	3	150x150x150 mm
		1:2.5	14	Cube	3	150x150x150 mm
2.	Flexural Strength	1:1.5	7	Beam	3	150x150x700 mm
		1:1.5	14	Beam	3	150x150x700 mm
		1:2.5	7	Beam	3	150x150x700mm
		1:2.5	14	Beam	3	150x150x700 mm
3.	Rapid Chloride Penetration Test (RCPT)	1:1.5	14	Disc	3	D=100mm,t=50mm
		1:2.5	14	Disc	3	D=100mm,t=50mm
4.	Pull Out Test	1:2.5	14	Cube	3	150x150x150 mm
Total					33	

3.2 Experimental Work

3.2.1 Workability Test

Table 5.0 Observation on Workability Test for geopolymer concrete

Sr. No	**Alkaline Activator Ratio**	**Slump in (mm)**	**Compression Factor**
1.	1:1.5	51	0.93
2.	1:2.5	42	0.89

3.2.2 Compressive Strength Test:

Concrete cubes are tested in compressive testing machine (200 Ton capacity) to determine their compressive strength of 3 specimens at the age of 7 days and 14 days of curing. Compression test on the cubes of size 150x150x150mm. cubes was performed to calculate the compressive strength of the Geopolymer concrete.

Table 6: Compressive Strength for FR-GPC with Activators ratio 1:1.5

Specimen ID	**Ratio (NH:NS)**	**Compressive Strength (N/mm^2)**	
		No. of Days	
		7	**14**
G1	1:1.5	27.58	33.42
G2	1:1.5	26.70	32.98
G3	1:1.5	26.13	33.87
Average		26.80	33.42

Table 7: Compressive Strength for FR-GPC with Activators ratio 1:2.5

Specimen ID	Ratio (NH:NS)	Flexural Strength (N/mm^2)	
		No of Days	
		7	14
P1	1:2.5	1.471	1.956
P2	1:2.5	1.612	2.142
P3	1:2.5	1.345	2.013
Average		1.476	2.036

3.2.3 The flexural strength test

The flexural strength test was carried out as per BIS 516-1968 Methods of Tests for Strength of Concrete, to find the flexural strength of geopolymer concrete. Totally four specimens of size 200x100x60mm were subjected to flexural strength test. The test was carried out at the age of 7 & 14 days curing period for both control and geopolymer concrete specimens.

Table 8: Flexural strength for FR-GPC with activators ratio of 1:1.5

Specimen Label	Ratio (NH:NS)	Flexural Strength (N/mm^2)	
		No of Days	
		7	14
G1	1:1.5	0.848	1.162
G2	1:1.5	1.124	1.431
G3	1:1.5	0.972	1.314
Average		0.981	1.30

Table 9: Flexural strength for FR-GPC with activators ratio of 1:2.5

Specimen ID	Ratio (NH:NS)	Compressive Strength (N/mm^2)	
		No. of Days	
		7	14
P1	1:2.5	30.56	41.54
P2	1:2.5	30.72	42.33
P3	1:2.5	31.06	40.02
Average		30.78	41.29

3.2.4 Rapid chloride test:

The test set up is called Rapid Chloride Penetration Test (RCPT) assembly. This is two-compartment cell assembly. Disk specimen is assembled between the two compartments cell assembly and checked for air and watertight. The cathode compartment is filled with 3% NaCl solution and anode compartment is filled with 0.3 normality NaOH solutions. Then, the concrete specimens were subjected to RCPT by impressing a 60V from a DC power source between anode and cathode.

Table 10: Observation on Rapid Chloride Penetration Test for FR-GPC:-

Sr. No	Ratio (NH:NS)	Charge passing, coulombs	Chloride Penetration	Concrete type
1.	1:2.5	1237	Low	Low WC Ratio (<0.40) conventional pc concrete
2.	1:2.5	1316	Low	Low WC Ratio (<0.40) conventional pc concrete
3.	1:2.5	1267	Low	Low WC Ratio (<0.40) conventional pc concrete

3.2.5 Pull out Test

Pull out test measures the force required to pull out a previously cast in steel insert, with an embedded enlarged end in the concrete. In this operation, a cone of concrete is pulled out and the force required is related to the compressive strength of concrete. The failure of RC structures happens primarily due to the deterioration of the bond. Hence it is necessary to study the bond characteristics.

Bond stress is calculated as

$$\tau b = P/\pi x\ db \times lb$$

Where,

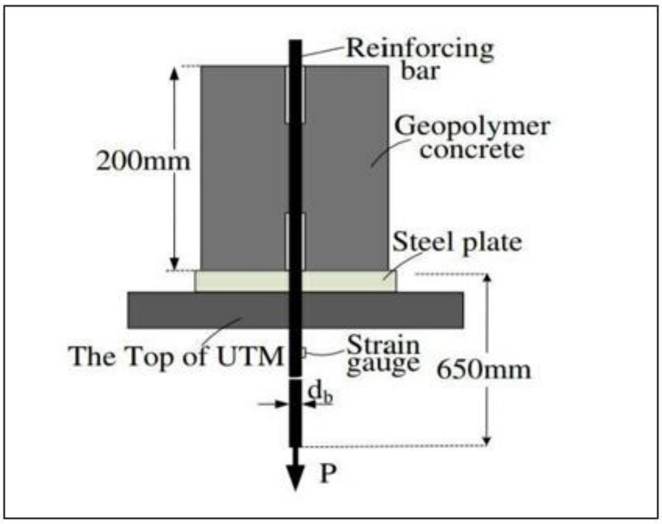
τb - bond stress (N/mm^2)

P - Applied load (N),

db- diameter of bar (mm)

Table 11 : Observation on pull out test for FR-GPC

Specimen Label	Ratio (NH:NS)	Bond Strength (N/mm^2)
		No. of days
		14
G1	1:2.5	341.73
G2	1:2.5	328.14
G3	1:2.5	317.46
Average		329.11



IV. CONCLUSION

Based on the test experimental results, following conclusions are drawn:

1. In this experimental work on Fiber Reinforced Geopolymer concrete it is found that workability of geopolymer concrete in terms of slump with alkaline activator ratio of 1:1.5 is increases as compared to 1:2.5
2. It is observed that compressive strength of fiber reinforced geopolymer concrete increases by about 28% at 7 days and 23% 14 days for alkaline activator ratio of 1:1.5
3. It is observed that compressive strength of Geopolymer concrete increases by about 35% at 7 days and 55% 14 days for alkaline activator ratio of 1:2.5
4. It is also observed that flexural strength of Geopolymer concrete shows increasing trend with alkaline activators ratio.
5. The average bond strength of Geopolymer concrete obtained by pull out test is 341.73 N/mm$^{2.}$

REFERENCES:-

[1]. Muhammad Faheem Mohd Tahir , Mohd Mustafa Al Bakri Abdullah , Shayfull Zamree Abd Rahim , Mohd Rosli Mohd Hasan , Mohamed Saafi , Ramadhansyah Putra Jaya , Rosnita Mohamed , Potential of industrial By-Products based geopolymer for rigid concrete pavement application, https://d oi.or g/10 .10 16/j.co nbuildmat.2 022.1281 90. (AUG 22)

[2]. Aamar Danisha, Togay Ozbakkaloglu , , Mohammad Ali Mosaberpanahb, Muhammad Usama Salim , Muhammed Bayram , Jung Heum Yeon , Komael Jafar , Sustainability benefits and commercialization challenges and strategies of geopolymer concrete: A review, https://doi.org/10.1016/j.jobe.2022.105005(JULY 22)

[3]. Yazan Issa Abu Aisheh , Dawood Sulaiman Atrushi , Mahmoud H. Akeed , Shaker Qaidi , Bassam A. Tayeh , Influence of steel fibers and microsilica on the mechanical properties of ultra-high-performance geopolymer concrete (UHP-GPC), https://doi.org/10.10 16/j.cscm.2022.e01245.(June 2022)

[4]. Kaffayatullah Khan 1 , Waqas Ahmad 2 , Muhammad Nasir Amin 1 and Ayaz Ahmad 3, A Systematic Review of the Research Development on the Application of Machine Learning for Concrete, DOI:10.3390/ma15134512(JUN 2022)

[5]. A. Suresh Kumar , M. Muthukannan , K. Arunkumar , M. Sriram , R. Vigneshwar , A. Gulshan Sikkandar, Development of ecofriendly geopolymer concrete by utilizing hazardous industrial wastematerials, https://doi.org /10.1016/j.matpr.2022.06.039. (JUN 22)

[6]. S. Kavipriya, C.G. Deepanraj, M.P. Iniya, and B. Jeyanth, Geopolymer Concrete Paver Blocks: A Review, DOI:10.21741/9781644901953-32.(MAY 22)

[7]. G. Laxmi , Suresh G. Patil , Effect of fiber types, shape, aspect ratio and volume fraction on properties of geopolymer concrete – A review, Materials Today: Proceedings 65 (2022) 1086–1094, https://doi.org/10 .1016/j.matpr.2 022.04.157. (APR 22)

[8]. Abdulaziz S. Alsaif, And Abdulrahman S. Albidah, Compressive and flexural characteristics of geopolymer rubberized concrete reinforced with recycled tires steel fibers, Materials Today: Proceedings 65 (2022) 1230–1236, https://doi.org/10.1016/j.matpr.2022.04.182. (APR 2022)

[9]. Aslıhan Nida Derinpinar , Mehmet Burhan Karakoç , Ahmet Ozcan, Performance of glass powder substituted slag based geopolymer concretes under high temperature, Construction and Building Materials 331 (2022) 127318, https://doi.org/10.1016/j.conbuildmat.2022.12 7318. (APR 22)

[10]. Hamdi Abdulrahman , Rahimah Muhamad , Phillip Visintin , Ahmad Azim Shukri, Mechanical properties and bond stress-slip behaviour of fly ash geopolymer concrete, https://doi.org/10.1016/j.conbuildmat.2022.12 6909 (APR 22)

[11]. Navdeep Singh, Md Marghoobul Haque , Akshit Gupta, Reviewing mechanical performance of geopolymer concrete containing coal bottom ash, https://doi.org/10.1016/j.matpr.2022.04.408. (apl 22)

[12]. H. V. Moulya , A. Chandrashekhar, Experimental Investigation of Effect of Recycled Coarse Aggregate Properties on the Mechanical and Durability Characteristics of Geopolymer Concrete, https://doi.or g/10.1016/j.matpr. 2022.03.403. (apr 2 022)

[13]. Utsab Katwal , Tariq Aziz , Zhong Tao , Brian Uy , Daniel Rahme , Tests of circular geopolymer concrete-filled steel columns under ambient and fire conditions,

https://doi.org/ 10.1016/j.jcsr.2022.107393. (JUNE22)

[14]. Utsab Katwal , Tariq Aziz , Zhong Tao , Brian Uy , Daniel Rahme , Tests of circular geopolymer concrete-filled steel columns under ambient and fire conditions,https://doi.org10.1016/j.jcsr.2022. 1073.JUN 22) 15. Harit Upadhyay, Mahesh Mungule ,Kannan K. R. Iyer, Issues and challenges for development of geopolymer concrete, Materials Today: Proceedings 65 (2022) 1567–1574, https://doi.org/10.1016/j.matpr.2022.04.520.(2022).

[15]. Ramamohana Reddy Bellum, Investigation on the accelerated pavement test track (APTT) in the development of road network using geopolymer concrete, https://doi.org/10.1016/ j.clema.2022 .100074 (MAR 22)

[16]. Md Sarfaraz Ali , A.K. Sachan, A review on the durability and applicability of Geopolymer concrete from the recent research studies, https://doi.org/10.1016/j.matpr.2021.10.302. (2022)

[17]. Omer Faruk Kuranlı , Mucteba Uysal , Mele Tidjani Abbas b, Turgay Cosgun b, Anıl Nis , Yurdakul Aygormez , Orhan Canpolat , Mukhallad M. Al-mashhadani , Evaluation of slag/fly ash based geopolymer concrete with steel, polypropylene and polyamide fibers, https://doi.org/10.1016/j.conbuildmat.2022.1 26747. (mar 22)

[18]. N. Anil Kumar Reddy , Kolli Ramujee, Comparative study on mechanical properties of fly ash & GGBFS based geopolymer concrete and OPC concrete using nano-alumina, https://doi.org/10.1016/j.matpr.2022.01.260.(ja n 22)

[19]. Tanu H.M. , Sujatha Unnikrishnan, Utilization of industrial and agricultural waste materials for the development of geopolymer concrete- A review, https://doi.org/10.1016/j.matpr.2022.04 .192. (2022)

[20]. Swagato Das , Purnachandra Saha , Swatee Prajna Jena , Pratyush Panda, Geopolymer

[28]. Subhash V.Patankar,Yuwarj M.Ghugal and SanjaMix Design Of Fly Ash Based Geopolymer Cocrete.https://doi.org/ 10.1016/ j.conbuildmat.2021.124449.(Dec.2014)

[29]. Leong Sing Wong, Durability Performance of Geopolymer Concrete: A Review, Polymers

concrete: Sustainable green concrete for reduced greenhouse gas emission – A review, https://doi.org/ 10.1016/j.matpr.2021.11.588. (DEC 21)

[21]. Hasan M. Albegmprli , Zahraa K.A. Al-Qazzaz , Saeed K. Rejeb , Strength performance of alkali activated structural lightweight geopolymer concrete exposed to acid, https://doi.org/10.1016/j.ceramint. 2021.11.240. (NOV 21)

[22]. Purwanto , Januarti Jaya Ekaputri , Nuroji , Bobby Rio Indriyantho a, Aylie Han , Buntara Sthenly Gan , Shear-bond behavior of self-compacting geopolymer concrete to conventional concrete, https://doi.org/10.1016/j.conbuildmat.2021.1 2 6167.(dec21)

[23]. S. Yavana Rani , Mohammed Saleh Nusari , Jamaludin bin Non , Sandeep Poddar , Amiya Bhaumik, Durability of geopolymer concrete with addition of poly propylene fibre, https://doi.org/10.1016/j.matpr.2021.10.164. (nov 21)

[24]. Han Fang, Phillip Visintin, Structural performance of geopolymer-concrete-filled steel tube members subjected to compression and bending, https://doi.org/10.1016/j.jcsr.2021.107026. (oct 21)

[25]. Peem Nuaklong , Papassara Worawatnalunart , Pitcha Jongvivatsakul , Sawekchai Tangaramvong , Thanyawat Pothisiri , Suched Likitlersuang, Pre- and post-fire mechanical performances of high calcium fly ash geopolymer concrete containing granite waste, https://doi.org/10.1016/j.jobe.2021.103265 (sep 21).

[26]. Abhay V. Nakum , N.K. Arora, The impact of alkaline solution to fly ash ratio with different molarities of sodium hydroxide on self-compacted geopolymer concrete, https://doi.org /10.1016/j.matpr.2022.04.688. (apl 21).

[27]. Aziz Hasan Mahmood , Stephen J. Foster , Arnaud Castel , Effects of mixing duration on engineering properties of geopolymer concrete, https://doi.org/10.1016/j.conbuildmat.2021.1 2 4449. (aug 21)

2022, 14, 868. https://doi.org/10.3390/ polym14050868

[30]. Seethalakshmi,sakthieswaran,Mechanical properties of geopolymer concrete using fly ash ,GGBS and basalt fiber.(jun 2015) https:/ /doi.org/ 10.1016/j.matpr.2022.04.192.

[31]. M. I. Abdul Aleem , P. D. Arumairaj, GEO-POLYMER CONCRETE- A REVIEW, DOI:10.7323/ijeset/v1_i2_14.(2012).
[32]. The Nature of Coconut Fibre Fly Ash-Based Mechanical Geopolymer(2019). https://doi.org/10.1016/j.m atpr.202 2.04.192.
[33]. The Nature of Coconut Fibre Fly Ash-Based Mechanical Geopolymer(2019) https://doi.org/10.1016/j.conbui ldmat.2021.124449.
[34]. Fly Ash based Geopolymer Concrete.http://www.ijert. org ISSN: 22780181IJER TV9IS090472.
[35]. The impact of alkaline solution to fly ash ratio with different molarities of sodium hydroxide on self-compacted geopolymer concrete. https://doi.org/10.1016/j.matpr.2022.04.688. (2022)
[36]. Durability of geopolymer concrete with addition of polypropylene fibre S Yavana Rani, Mohammed Saleh Nusari", Jamaludin bin Non, Sandeep Poddar, Amiya Bhaumik sy, Bengaluru Karanataka, India Laversity College, Petaling Jaya, Selangor D. E, Malaya.(2022)