OPTIMIZATION OF DOSE EFFECTS OF GLASS FIBER WITH POND ASH ON GEO-POLYMER CONCRETE

Amit Mishra[1*], Rakesh Pandey[2], RK Mishra[3]

[1*]Assistant Professor, Department of Civil Engineering,MATS UNIVERSITY, Arangraipur, India

[2]Associate Professor, Department of Civil Engineering, MATS UNIVERSITY, Arangraipur, India

[3]Professor, Department of Civil Engineering, Bhilai Institute of Technology, Kendri Raipur, India

[1*]amitmishrasirji106@gmail.com , [3]rkmishra4776@gmail.com

DOI:10.48047/ecb/2023.12.si4.711

Abstract

This research paper examines the endurance and mechanical characteristics of geopolymer concrete reinforced with glass fibers. (GFRGC). With better durability and a smaller carbon footprint than conventional cement-based concrete, geopolymer concrete is a potential green substitute. Glass fibers can be used to further improve the tensile qualities of geopolymer concrete, making it more ductile and crack resistant. The compressive and flexural strengths of GFRGC, as well as its resilience to fatigue and cracking, are examined in this research concerning several different parameters, including the content and length of the fibers. The findings demonstrate that adding glass fibers can greatly enhance the mechanical properties of geopolymer concrete, making it an effective substitute for traditional concrete in a variety of building applications.

Keywords: Geopolymer, Glass fiber reinforcement, Compressive strength, Crack resistance.

---

1 Introduction

Although all kinds of adhesives fall under the umbrella term "cement," the term is more specifically used to describe the binders used in construction and civil engineering projects.

Portland cement is the main type of cement described, but high-alumina and slag-containing cement are also covered. Construction Cement shares some chemical components and production processes with abrasives, refractories, and ceramic goods like brick and tile [1].

1.1 Applications of cement

The most common applications for cement are in mortar and concrete, where it is combined with aggregate, an inert substance. Cement can also be used "neat," or as a grouting medium. Cement is combined with sand or pulverized stone that must be smaller than 5 millimeters to create the mortar. (0.2 inches). Cement, sand, or another fine aggregate is blended with a coarse aggregate that typically ranges in size from 19 to 25 mm (0.75 to 1 inch). However, when concrete is poured in massive quantities, like in dams, the coarse aggregate can be as large as 150 mm. six inches. Stones, bricks, and other construction materials can be joined together to form structures using mortar to render surfaces. Concrete is used in numerous construction projects.

Earth and Portland cement mixes are used to create road bases. Many extruded products, such as bricks, tiles, shingles, pipes, beams, and railway ties, are made from Portland cement. The goods are provided factory-prefabricated and ready for assembly. Cement manufacture is quite prevalent since concrete is the most widely used construction material in the world today[1].

1.2 Geopolymer cement

The most adaptable, dependable, and durable building material in the world is concrete. Concrete is the most often utilized material after water, and a lot of Portland cement was needed. The second-largest source of carbon dioxide emissions in the atmosphere, after transportation, is regular Portland cement manufacturing. In addition, cement production required a sizable amount of electricity. Since Portland cement is presently the priciest and most resource-intensive material, a replacement must be found. Through the chemical reaction of inorganic molecules, geopolymer concrete, a novel construction material, will be produced.

Fly ash, a by-product of coal from a thermal power plant is commonly available worldwide. Large amounts of silica are present in fly ash, and when alumina and an alkaline solution were combined, an aluminosilicate polymer was produced that acted as the cement's binding agent. It is an excellent replacement for the current plain cement concrete used in buildings. Geopolymer concrete must be created without the use of any ordinary Portland cement. The components of geopolymer concrete, in addition to its durability and potential, uses [2, 3].

1.3 Difference between cement and concrete

Cement and concrete are two different materials, although they are often used interchangeably in everyday conversation. Cement is a binder material made from a mixture of limestone, clay, and other materials. It is the primary ingredient in concrete, but it can also be used on its own to bind other materials. Cement is typically a gray powder that hardens when mixed with water, forming a paste that can then be used to bind sand, gravel, or other aggregates together.

Concrete, on the other hand, is a composite material made from cement, water, and aggregates like sand, gravel, or crushed stone. The aggregates give the concrete its strength and durability, while the cement acts as a binder, holding everything together. When mixed with water, the cement reacts chemically to form a hardened mass, which we know as concrete.

In summary, cement is a binder material, while concrete is a composite material made from cement, water, and aggregates. [4].

2 Literature Review

2.1 Geopolymer Cement

When regular Portland cement (OPC) is replaced with fly ash and ground granulated blast furnace slag (GGBFS), several benefits can be achieved:

1. Reduced environmental impact: Both fly ash and GGBFS are byproducts of other industrial processes, so using them as cement replacements can reduce the amount of waste that would otherwise be sent to landfills.

2. Improved durability: The use of fly ash and GGBFS in concrete can increase its durability and resistance to corrosion, reducing the need for maintenance and repair.
3. Reduced heat of hydration: OPC generates a significant amount of heat during the curing process, which can lead to cracking in the concrete. Fly ash and GGBFS have a lower heat of hydration, which can help mitigate this issue.
4. Reduced cost: The use of fly ash and GGBFS can reduce the cost of concrete production, as these materials are often less expensive than OPC.

However, it is important to note that the properties of the resulting concrete may be different from those of concrete made with OPC alone. For example, the use of fly ash can result in slower setting times and lower early strength, while the use of GGBFS can result in higher setting times and reduced early strength. Therefore, the suitability of these materials as replacements for OPC should be evaluated on a case-by-case basis [5].

2.2 Fiber-Reinforced Concrete

Fiber Reinforced Concrete (FRC) is a type of concrete that incorporates fibers to improve its mechanical properties. The fibers used in FRC can be made of various materials, including steel, glass, synthetic polymers, natural fibers, and others.

The addition of fibers to the concrete mix can provide several benefits, including:

1. Increased toughness and durability: FRC has higher toughness and durability than conventional concrete, making it more resistant to cracking, impact, and fatigue.
2. Improved resistance to shrinkage and cracking: The fibers help to distribute stresses more evenly throughout the concrete, reducing the likelihood of shrinkage and cracking.
3. Better resistance to temperature changes: FRC has a lower thermal conductivity than conventional concrete, making it more resistant to temperature changes.
4. Enhanced flexural strength and ductility: The fibers improve the flexural strength and ductility of the concrete, allowing it to bend and deform without breaking.

FRC is commonly used in applications where high strength and durability are required, such as in the construction of bridges, tunnels, and pavements. It can also be used in architectural applications where the appearance of the concrete is important, as the fibers can be made in various colors and shapes to create unique designs.[6].

2.3 Glass Fiber reinforcement

In buildings, reinforced concrete (RC) is a popular composite material. It is made of longitudinally and transversally positioned steel rods and stirrups with high tensile strength and high compressive strength concrete that work together to strengthen each other's weaknesses. Corrosion of steel reinforcement and cement sustainability are two major ongoing problems that are seriously hindering the global building industry. Sincere attempts have been made for more than 20 years to replace regular Portland cement with geopolymer cement and steel reinforcement with fiber reinforcement. They were used in a variety of ways, including as beams, slabs, columns, and mixtures of the aforementioned.Even though the study has produced many leads, no conclusive evidence regarding the ideal combinations and the structural code for widespread use has been produced. The existing literature was thoroughly reviewed and summarized in this work. The results of a study that was conducted to identify potential focal areas for additional research are listed [7].

3 Methodology

Pond ash samples were collected from the NTPC-SAIL Power Company Limited power facility in Bhilai, Chhattisgarh, India, and the Bhilai Steel facility, Chhattisgarh, India respectively, for use as aggregates with geopolymer cement. Pond ash is a waste material produced by thermal power plants that burn coal. The ash is collected in ponds and is a major environmental concern due to its disposal. However, recent studies have shown that pond ash can be used as a sustainable alternative to conventional aggregates in construction [8].

The pond ash samples were collected from five different locations in Chhattisgarh using a random sampling method [9]. The samples were then cleaned and dried before being creased into a fine powder using a mortar and pestle. The powder was then sieved through a 2.36 mm sieve to ensure a uniform particle size [10]distribution.

To prepare the geopolymer cement specimens, the pond ash powder was variegated with an alkaline activator solution consisting of sodium silicate and sodium hydroxide in a 1:1.5 ratio by weight. The mixture was stirred for 5 minutes using a mechanical mixer and poured into cylindrical molds of 50 mm diameter and 50 mm height. The specimens were then cured in an oven at 60°C for 24 hours [11-13].

After curing, the specimens were removed from the molds and tested for compressive strength using a universal testing machine. The results showed that pond ash can be used to produce geopolymer cement specimens with good compressive strength. However, the compressive strength varied depending on the location of the pond ash sample.

Using pond ash as an aggregate with geopolymer cement has the potential to reduce the environmental impact of construction and provide a sustainable alternative to conventional aggregates. Further research is needed to optimize the process and identify the best conditions for using pond ash as an aggregate with geopolymer cement. A summary of each sample is given in Table 1.

4 Experimental Setup

The limit equilibrium method-based software GEOSLOPE was used to conduct a stability study. F values for various geometric configurations were calculated using Bishop's straightforward technique. Compared to other limit equilibrium methods, this procedure yields results for the F value that are more accurate. The estimated axis-symmetrical cross-sectional geometry of the embankment is shown in Table 1 at a height of 6.0 meters and a slope angle of 28 degrees.

Table1:A portrayal of the arranged samples.

Samples No.	Samples	Element of constituents (in %)		
		Pond Ash	GGBS	Soil
1.	SAP1	10	0	90
2.	SAP2	10	5	85
3.	SAP3	10	10	80

4.	SAP4	10	15	75
5.	SAP5	15	0	85
6.	SAP6	15	5	80
7.	SAP7	15	10	75
8.	SAP8	15	15	70
9.	SAP9	20	0	80
10.	SAP10	20	5	75
11.	SAP11	20	10	70
12.	SAP12	20	15	65
13.	SAP13	25	0	75
14.	SAP14	25	5	70
15.	SAP15	25	10	65
16.	SAP16	25	15	60
17.	SAP17	0	0	100

5 Results and Discussion

5.1 Material Properties

The results of the tests showed in Tables 2 and 3, depeictMaterials' physical and chemical characteristics, that when compared to the other materials, GGBS had the highest specific gravity. Here are material properties of soil, pond ash, and ground granulated blast furnace slag (GGBS):

Soil:

- Density: variable, depending on soil type and moisture content
- Particle size: variable, depending on soil type
- Compressive strength: typically low
- Tensile strength: typically low
- Flexural strength: typically low
- Durability: typically low
- Permeability: varies widely depending on soil type and structure
- Cost: typically low

Pond ash:

- Density: 1.8-2.1 g/cm³
- Particle size: fine
- Compressive strength: typically low
- Tensile strength: typically low
- Flexural strength: typically low
- Durability: typically low
- Permeability: low
- Cost: typically low

GGBS:

- Density: 2.8-3.0 g/cm³
- Particle size: fine
- Compressive strength: typically high
- Tensile strength: typically high
- Flexural strength: typically high
- Durability: typically high
- Permeability: low
- Cost: Moderate

It is important to note that these properties are generalizations, and the specific properties of taken samples of soil, pond ash, or GGBS can vary depending on a variety of factors. Additionally, the properties of these materials may be influenced by the conditions under which they are used or processed.

Table 2:Materials' characteristics

Properties	Pond ash	GGBS	soil
Specific Gravity	2.00	2.75	2.67
Grain size, Sand size particle	82.34	86.80	52.28
Distribution, Silt size particle (%)	15.45	12.00	35.32
Clay size particle (%)	02.21	01.20	12.40
Liquid limit (%)	46.50	41.00	28.60
Plastic limit (%)	Non-Plastic	Non-Plastic	20.05
Classification	SW-SM	SP-SM	SC
Modified Proctor MDD, kN/m^3	12.30	18.90	18.50
Compaction test OMC,%	29.80	18.20	12.28

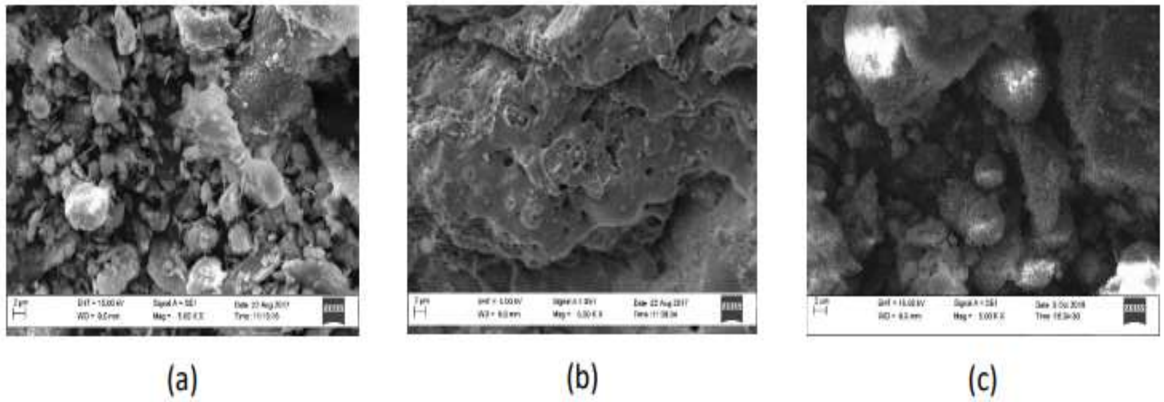

Figure1: Apparent classification of materials made of (a) soil, (b) pond ash, and (c) GGBS using an SEM picture magnified five times.

5.2 Compaction Behavior

The compaction behavior of soil, pond ash, and ground granulated blast furnace slag (GGBS) can vary depending on their respective properties.

Soil:

- The compaction behavior of soil depends on its type, moisture content, and particle size distribution.
- Generally, as the moisture content of the soil increases, its maximum dry density decreases, and its optimum moisture content increases.
- The compaction of soil is typically achieved through the use of a compaction machine, such as a vibratory roller or a plate compactor.

Pond ash:

- The compaction behavior of pond ash is typically similar to that of other fine-grained materials.
- Due to its fine particle size, pond ash can be susceptible to excessive air voids and poor compaction.
- The addition of water and compaction through the use of a compaction machine can help to improve the compaction of pond ash.

GGBS:

- The compaction behavior of GGBS is typically better than that of soil or pond ash, due to its high density and fine particle size.
- GGBS can be compacted to high densities using conventional compaction equipment, such as vibratory rollers.
- However, the addition of water can increase the workability of the GGBS mix and improve its compaction characteristics.

Overall, the compaction behavior of these materials is an important consideration in their use as construction materials, as it can affect their strength, durability, and other properties. The compaction process should be carefully monitored and controlled to ensure that the desired compaction level is achieved while minimizing the risk of over-compaction or other issues. Adapted Proctor compaction test was executed to decide the Maximum Dry Density (MDD) and Optimum Moisture Content (OMC). (Table 1) and Table 3 shows the compaction behavior.

Table 3: Chemical Characteristics of the Materials (Element Composition by Percentage Weight)

Material	**Si**	**K**	**Ca**	**Ti**	**Fe**	**Al**
Pond ash	65.13	02.94	01.24	02.88	03.14	23.91
GGBS	27.21	01.1.	51.67	00.89	0.38	18.75
Soil	57.45	04.46	00.64	02.61	09.82	25.01

5.3 Strength Behavior

The strength behavior of concrete made with soil, pond ash, and GGBS can vary depending on the proportions and properties of the materials used, as well as the curing conditions and testing procedures.

The strength behavior of concrete made with these materials can vary depending on a variety of factors, including the specific proportions and mix design, curing conditions, and testing procedures. Additionally, the strength behavior of concrete may also be influenced by other factors such as environmental conditions, loading rates, and exposure to chemicals or other substances.

5.3.1 UCS Characteristics

The unconfined compressive strength (UCS) test is a common method used to measure the strength of soil-cement mixtures, including those made with pond ash and GGBS. The results of the UCS tests provide insight into the effect of GGBS on the strength behavior of the pond ash-soil blend over time as shown in Table 4.

It is vital to note that the effect of GGBS on the UCS values of the pond ash-soil blend may vary depending on the specific proportions and mix design, as well as the testing and curing conditions.

Table 4: UCS value of soil blended with varied pond ash proportions at varying curing times.

Samples	Pond Ash (%)	UCS Value (MPa) at various curing periods			
		Immediate	7 days	14 days	28 days
SAP3	10	0.55	0.57	0.60	0.61
SAP7	15	0.50	0.52	0.54	0.57
SAP11	20	0.48	0.50	0.52	0.54
SAP15	25	0.28	0.30	0.32	0.35
SAP17	0	0.57	0.60	0.63	0.65

5.3.2 Bearing ratio characteristics

The bearing ratio of pond ash based geopolymer concrete refers to its ability to support loads without experiencing excessive deformation or failure. The bearing ratio characteristics of pond ash based geopolymer concrete are influenced by several factors, including the mix proportions, curing conditions, and the properties of the source material.

Experiment have shown that the bearing ratio of pond ash based geopolymer concrete is typically lower than that of conventional Portland cement concrete. However, the use of additives such as fibers and nano-materials can improve the bearing ratio of geopolymer concrete. Additionally, the use of higher concentrations of alkaline activators in the mix design can also improve the bearing ratio of the concrete.

Overall, the bearing ratio characteristics of pond ash based geopolymer concrete can be optimized through careful mix design and selection of appropriate curing conditions. It is important to note that the performance of geopolymer concrete can vary depending on the specific mix design and application, and further understand the factors that influence its bearing ratio characteristics as shown in Table 5. After 28 days of curing, the soil's bearing ratio value increased from 4.30% (SAP17) to 27.55% (SAP10) with the addition of 15% pond ash and 15% GGBS.

Table 5: Bearing ratio value of soil blended with various pond ash % at varied curative times.

Samples	Pond Ash (%)	Bearing ratio value (%) at various curative periods			
		4 days	7 days	14 days	28 days
SAP3	10	5.60	5.80	6.00	6.20

SAP7	15	5.00	5.30	5.40	5.60
SAP11	20	4.90	5.10	5.20	5.40
SAP15	25	4.60	4.90	5.00	5.10
SAP17	0	4.10	4.20	4.30	4.40

It is significant to note that the properties of soil can diverge widely reliant on factors such as the type of soil, its moisture content, and its composition. Pond ash and GGBS are industrial byproducts that are typically used as partial replacements for cement in concrete production. As such, their properties are more consistent and predictable than those of soil. As seen in Tables 2 to 5, for all slope heights and slope angles, SAP6 had 10% pond ash variegated with soiland 15% GGBS, withutmost F value. The cohesion number of the SAP6 sample, which is a measure of enhanced shear strength parameters, gives the embankment more stability.With more pond ash added, the native soil's F value dropped due to a decline in cohesion value.

6 Conclusion

The investigation's results led to the following conclusions:

- Based on the multiple tests conducted to evaluate the performance of pond ash and glass fiber based geopolymer concrete, the following conclusions and recommendations can be made:
- The use of pond ash as a partial replacement of conventional aggregates in geopolymer concrete can significantly reduce the carbon footprint and environmental impact of concrete production.
- The addition of glass fibers to geopolymer concrete can improve its mechanical properties such as compressive and flexural strength.
- The molarity of NaOH and the ratio of sodium silicate to sodium hydroxide have a significant effect on the mechanical properties of glass fiber reinforced geopolymer concrete. Increasing the molarity of NaOH and the ratio of sodium silicate to sodium hydroxide can increase the compressive and flexural strength of the concrete.
- The durability properties of pond ash and glass fiber based geopolymer concrete such as water absorption, chloride ion permeability, freeze-thaw resistance, acid and alkali resistance, and fire resistance are comparable to those of conventional concrete.
- To optimize the performance of pond ash and glass fiber based geopolymer concrete, it is recommended to conduct further research on the effect of different factors such as curing temperature, curing time, and the addition of other types of fibers on the properties of the concrete.
- Overall, pond ash and glass fiber based geopolymer concrete can be a sustainable and viable alternative to conventional concrete, with comparable mechanical and durability properties.
- It was found that the right proportion of native soil, 10% pond ash, and 15% GGBS (SAP6) produced an embankment with the right amount of stability and F value.

Reference

1. King JF, Taggart RK, Smith RC, Hower JC, Hsu-Kim H. Aqueous acid and alkaline extraction of rare earth elements from coal combustion ash. International journal of coal geology. 2018 Jul 1;195:75-83.

2. Amran YM, Alyousef R, Alabduljabbar H, El-Zeadani M. Clean production and properties of geopolymer concrete; A review. Journal of Cleaner Production. 2020 Apr 1;251:119679.
3. Shehata N, Mohamed OA, Sayed ET, Abdelkareem MA, Olabi AG. Geopolymer concrete as green building materials: Recent applications, sustainable development and circular economy potentials. Science of the Total Environment. 2022 Apr 30:155577.
4. Bharadwaj Ravi K. Towards the Development of Performance-Based Concrete Mixtures Made with Modern Cementitious Materials Using Thermodynamic Modeling.
5. Badrawi HA, Makahleh HY, Haweileh RA. Compressive Strength and Durability of Geopolymer Concrete. In2022 Advances in Science and Engineering Technology International Conferences (ASET) 2022 Feb 21 (pp. 1-6). IEEE.
6. Anna S, Khegai T, Khegai A. Modeling and Investigation of the Effect of Physical Nonlinearity of Steel Fiber-Reinforced Concrete on the Crack Height. In2021 3rd International Conference on Control Systems, Mathematical Modeling, Automation and Energy Efficiency (SUMMA) 2021 Nov 10 (pp. 725-729). IEEE.
7. Ahmed HQ, Jaf DK, Yaseen SA. Flexural capacity and behaviour of geopolymer concrete beams reinforced with glass fibre-reinforced polymer bars. International Journal of Concrete Structures and Materials. 2020 Dec;14(1):14.
8. ASTM D854-14, “Standard Test Methods for Specific Gravity of Soil Solids by Water Pycnometer,” in ASTM International, West Conshohocken, PA, 2014.
9. IS: 2720 (part 5), “Methods of test for soils: Determination of liquid limit and plastic limit,” in Indian Standards, 1985, pp. 1–16.
10. ASTM D1557, “Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort,” in ASTM International, West Conshohocken, PA, 2012, pp. 1–14.
11. ASTM D2166M - 16, “Standard Test Method for Unconfined Compressive Strength of Cohesive Soil,” in ASTM International, 2016.
12. ASTM D1883, “Standard Test Method for California Bearing Ratio (CBR) of LaboratoryCompacted Soils,” 2016.
13. ASTM D2850, “Standard Test Method for Unconsolidated-Undrained Triaxial Compression Test on Cohesive Soils,” in ASTM International, West Conshohocken, PA, 2015.
14. L. Yadu and R. K. Tripathi, “Effects of granulated blast furnace slag in the engineering behaviour of stabilized soft soil,” Procedia Eng., vol. 51, pp. 125–131, 2013