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A study on flexural behaviour of glass fiber reinforced ternary blended geopolymer concrete

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ABSTRACT :

This paper investigates the flexural behavior of glass fiber-reinforced geopolymer concrete blends incorporating fly ash, GGBS, and metakaolin. The construction industry's shift towards sustainability has prompted the exploration of geopolymer concrete as an eco-friendly alternative to traditional Portland cement-based materials. By replacing cement with industrial by-products, geopolymer concrete reduces waste and CO_2 emissions associated with cement production.

The study aims to understand the synergistic effects of these materials on flexural strength and durability through experimental analysis. Glass fibers are incorporated to further enhance the concrete's mechanical properties, making it stronger and more resilient. Geopolymer concrete offers advantages such as higher compressive and flexural strengths, as well as improved resistance to chemical damage compared to conventional concrete.

This research contributes to advancing sustainable construction practices by optimizing the composition of geopolymer concrete blends. By reducing environmental impact and promoting efficient resource utilization, geopolymer concrete aligns with global efforts towards sustainable development in the construction sector.

***IndexTerms* – Fly ash, GGBS, Metakaolin, Geopolymer, Glass fiber.**

INTRODUCTION

Geopolymer concrete is a promising sustainable alternative to traditional concrete, driven by concerns over environmental impact, resource scarcity, and pollution. Unlike conventional concrete, geopolymer concrete reduces reliance on Portland cement—a significant source of CO2 emissions—and utilizes industrial by-products like fly ash, GGBS, and metakaolin, which are typically discarded. This approach not only minimizes waste but also decreases greenhouse gas emissions during production.

One of the primary environmental benefits of geopolymer concrete is its lower carbon footprint compared to traditional concrete. This is because geopolymer production generates significantly less carbon dioxide, aligning with global efforts to mitigate climate change. Additionally, geopolymer concrete exhibits superior mechanical properties such as higher strength, enhanced durability against chemical attacks, and reduced permeability to water. These attributes make it suitable for various demanding applications, including marine environments and industrial facilities.

This study specifically investigates the addition of glass fibers to geopolymer concrete blends containing fly ash, GGBS, and metakaolin. Glass fibers are known for their ability to reinforce concrete, improving its flexural strength and resistance to cracking under bending stresses. Through rigorous experimental analysis, this research aims to optimize the composition of geopolymer blends for enhanced performance and durability, thereby contributing to the advancement of sustainable construction practices.

OBJECTIVES OF THE PROJECT:

- This project aims to investigate how geopolymer concrete behaves when incorporating fly ash, GGBS, and metakaolin, while also using glass fiber as reinforcement. The focus is on understanding how these components affect the concrete's characteristics. Through this study, we seek to improve the strength and durability of geopolymer concrete for various construction applications.
- To understand the environmental and economic viability of using glass fiber- reinforced ternary blended geopolymer concrete as a sustainable alternative to traditional concrete for structural applications.

- To investigate how different proportions of glass fiber reinforcement, in conjunction with varying amounts of fly ash, ggbs, and metakaolin, influence the flexural strength of geopolymer concrete. This analysis will help identify the optimal combinations of fiber content and ternary binder materials to achieve the desired flexural properties.

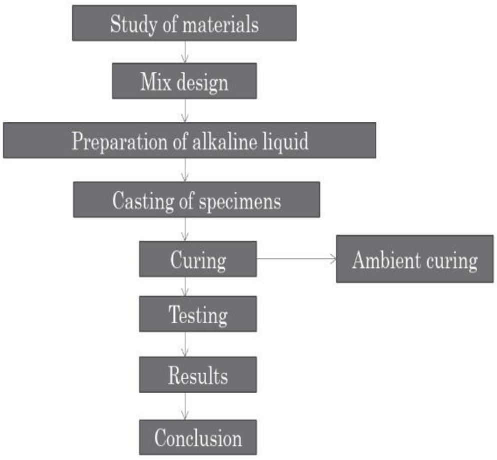
MATERIALS USED:

1. **Fly ash:** a byproduct of coal combustion, is utilized in construction for its beneficial properties in enhancing concrete. It contains silica, alumina, iron oxide, and calcium oxide, making it suitable as a supplementary cementitious material. When mixed with concrete, fly ash reacts with calcium hydroxide to form additional cementitious compounds, improving strength, durability, and workability.
2. **Ground Granulated Blast Furnace Slag (GGBS) :** It is a crucial ingredient in geopolymer concrete, replacing some of the Portland cement to enhance sustainability. It reacts with alkali solutions like sodium hydroxide and sodium silicate to form a strong binder that holds the concrete together. This reduces reliance on Portland cement, cutting carbon emissions from production. GGBS's composition rich in silicates and aluminates promotes the formation of a dense aluminosilicate gel network, improving concrete strength and durability.
3. **Metakaolin:** produced by heating kaolin clay at high temperatures, enhances concrete as a supplementary material. Its amorphous structure, rich in reactive silica and alumina, boosts concrete strength and durability by forming additional binding compounds during hydration.
4. **Glass fibers:** It improve geopolymer concrete by enhancing mechanical properties and durability. They act as reinforcement, boosting tensile and flexural strength, reducing cracking, and increasing resilience to stresses like drying shrinkage and thermal changes. Glass fibers come in short, dispersed forms for early-age issues and long fibers for post-cracking toughness.
5. **Alkaline solutions:** sodium hydroxide (NaOH) and potassium hydroxide (KOH) are essential activators in geopolymer concrete. They dissolve aluminosilicate precursors from industrial by-products such as fly ash, releasing reactive silicon and aluminum ions.

FLOW CHART:

The replacement of cement with fly ash, Ggbs and metakaolin in glass fiber reinforced concrete reduces the environmental pollution and improves the mechanical and durability properties of concrete compared to regular cement concrete.

MANUFACTURING PROCEDURE OF FRESH



CONCRETE :

- Geopolymer concrete can be manufactured by adopting the conventional techniques used in the manufacture of Portland cement concrete. In the laboratory, for 1st sample , Flyash (70%) ,Ggbs (30%) and the aggregates are mixed together for nearly 3-4 minutes. Then the alkaline solution was then added to the dry materials and the mixing continued for further about 4 minutes to manufacture the fresh concrete. Immediately after mixing, the fresh concrete was poured into molds in three layers to form cube-shaped specimens with dimensions of 100mm x 100mm x 100mm. To ensure proper compaction, each layer received 60 to 80 manual strokes using a roding bar.
- For 2nd sample, Fly ash (70%), Ggbs (30%), glass fiber (2.5%) and the aggregates are mixed together carefully. Then the alkaline solution was then added to the dry materials and the mixing continued for further about 4-5 minutes. After mixing repeat the procedure with the pouring the fresh concrete in mould and roding bar.
- For 3rd sample, Fly ash (70%), Ggbs (20%) , metakaolin (10%) and the aggregates are mixed together. Then add alkaline solution and mixed for about 5 minutes. After repeat the procedure by pouring the fresh concrete in the mould by proper compaction using a roding bar.

CURING OF GEOPOLYMER CONCRETE:

Curing geopolymer concrete involves maintaining a moist environment around the concrete for a specific period after it's made. This process helps the concrete gain strength and durability over time. Typically, this is done by covering the concrete with a damp cloth, plastic sheeting, or continuously spraying it with water to prevent moisture loss.

After casting geopolymer concrete specimens were cured immediately. For this study we have used Ambient curing. This method mimics real-world conditions and helps evaluate how the concrete performs under typical environmental factors such as temperature fluctuations and humidity levels.

- We have kept the specimens under the ambient conditions for curing at room temperature.

EXPERIMENTATION AND RESULTS

EXPERIMENTS CONDUCTED:

1. **Compressive strength test :** The compressive strength test on hardened fly ash based geopolymer concrete was performed on standard compression testing machine of 3000kN Capacity, Totally 3 number of cubical Specimens of size 100mm x 100mm x 100mm was casted and tested for the Compressive strength at the age of 21 days, The compressive strength test was performed as shown in Figure.

2. **Flexural strength test :** Flexural strength tests are conducted on geopolymer concrete to assess its ability to withstand bending forces, which are common in construction applications like beams, slabs, and pavements. These tests help engineers understand how well geopolymer concrete performs structurally, guiding decisions about its suitability for different projects. By comparing its flexural strength to that of traditional concrete, we can determine any potential advantages, such as increased durability and reduced environmental impact. Overall, these tests play a crucial role in evaluating geopolymer concrete as a sustainable and reliable construction material.

Apparatus :

1. Beam molds: These come in two sizes depending on the size of the aggregate used. For aggregate less than 38 mm, use a mold sized 15 x 15 x 70 cm. For smaller aggregate (less than 19 mm), opt for a mold sized 10 x 10 x 50 cm.

2. Tamping bar: This tool is 40 cm long, weighs 2 kg, and has a tamping section measuring 25 mm x 25 mm. It's used to compact the concrete mixture evenly in the molds.

3. Flexural test machine: The testing machine's bed features two steel rollers, each 38 mm in diameter, to support the specimen. These rollers are positioned so that they're 60 cm apart for 15.0 cm specimens or 40 cm apart for 10.0 cm specimens.

Procedure :

1. Fill the mold with concrete in three uniform layers.

2. Tamp each layer evenly across the entire surface and depth using the tamping bar, performing 35 tamps for each layer.

3. Clean the bearing surfaces of the supporting and loading rollers from any loose material.

4. Use circular steel rollers for supporting and loading the specimen, ensuring proper spacing and alignment.

5. Test the specimen immediately after removing it from water while it's still wet.

6. Ensure the specimen is centered correctly in the testing machine with its longitudinal axis perpendicular to the rollers.

7. Apply the load at the specified rate according to the specimen size.

RESULTS AND DISCUSSION

GENERAL

In this chapter, the experimental results are discussed and presented in the form of tables and graphs. Compression test is the most common test conducted on hardened concrete, partly it is an easy test to perform, and partly because most of the desirable characteristic properties of concrete are qualitatively related to its compressive strength.

COMPRESSIVE STRENGTH TEST:

The Compressive strength test conducted on different geopolymer concrete for various ratio of fly ash, Ggbs , metakaolin and glass fiber content concentration of alkaline solution and ambient curing conditions were found after 7days and 21 days of casting of cubes. The results are tabulated in tables. The results shows that the Compressive strength of concrete ranges from 14Mpa to 20Mp

Type of concrete	Concentration of alkaline solution	Compressive strength of concrete	
		7 days	21 days
Fly ash + GGBS	12M	4.5N/mm^2	14.3N/mm^2
Fly ash + GGBS + Glass fiber	12M	6.5N/mm^2	19.5N/mm^2
Fly ash + GGBS + Metakaolin	12M	5.8N/mm^2	16.6N/mm^2

FLEXURAL STRENGTH TEST:

The flexural strength test conducted on different geopolymer concrete for various ratio of fly ash, Ggbs , metakaolin and glass fiber content concentration of alkaline solution and ambient curing conditions were found after 7days of casting of beam. The formula used for finding flexural strength of concrete is,

BEAM NO	SPAN LENGTH (mm)	Depth, width (mm)	Flexural load (N)	Flexural strength (N/mm²)
1	500	100	9000	4.5
2	500	100	9750	4.8
3	500	100	9500	4.75

CONCLUSION

- Glass fiber reinforced enhances flexural strength significantly.
- Incorporating glass fibers into geopolymer concrete blended with fly ash, GGBS, and metakaolin significantly enhances its resistance to flexural cracking, thereby improving its overall durability and service life, especially in harsh environments.
- The maximum compressive strength achieved by the cubes is 19.5N/mm2.
- Geopolymer concrete cured in the ambient conditions gains compressive strength with age.
- The maximum flexural strength achieved by the beam is 4.8N/mm2.

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