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Study on Mechanical Properties of Geopolymer Concrete Using Metakaolin and GGBS

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Metakaolin, GGBS, Cement, Sand , Aggregate.

Abstract

This research paper presents a study on the mechanical properties of geopolymer concrete produced using Metakaolin and Ground Granulated Blast Furnace Slag (GGBS) as alternative binders to conventional Portland cement. The aim is to develop sustainable, eco-friendly concrete with comparable or improved mechanical strength. The experimental investigation involves varying the proportions of Metakaolin and GGBS to analyze their influence on compressive, split tensile, and flexural strength. The study concludes that the combination of Metakaolin and GGBS significantly enhances early strength development and long-term durability while reducing CO_2 emissions.

INTRODUCTION

Concrete is the most widely used construction material in the world, yet its traditional production particularly Portland cement contributes significantly to global CO_2 emissions. As sustainability becomes a central concern in modern construction, alternative binders that reduce environmental impact while maintaining or enhancing performance have garnered growing attention. Geopolymer concrete (GPC) is one such promising alternative, offering a more sustainable and environmentally friendly solution by utilizing industrial by-products rich in aluminosilicates instead of Portland cement. This study focuses on the mechanical properties of geopolymer concrete incorporating metakaolin and Ground Granulated Blast Furnace Slag (GGBS) as the primary binders. Metakaolin, a highly reactive pozzolanic material derived from the calcination of kaolinite clay, contributes to early strength and durability. GGBS, a by-product of the steel manufacturing industry, improves long-term strength and workability due to its latent hydraulic properties. When activated by alkaline solutions, these materials form a geo polymeric binder that can achieve mechanical properties comparable to or exceeding those of conventional concrete. The primary objective of this research is to investigate the compressive, tensile, and flexural strengths of geopolymer concrete mixes using varying proportions of metakaolin and GGBS. The study also explores how the synergistic effect of these materials influences setting time, workability, and strength development.

LITERATURE REVIEW

1. Study of strength properties of geopolymer concrete using ggbs and metakaolin

Rishi Malviya, Dr. Rajeev Chandak (2025)

This study focuses on the effect of changes in the percentage variation of aluminosilicate sources in geopolymer concrete. It was observed that there was significant improvement in compressive strength with increase in the percentage of GGBS in geopolymer concrete. This can be attributed to the formation of substantial reaction products in case of higher slag percentage. All percentages were obtained for differences in GPC. This can be attributed to the presence of crystalline phases in the geopolymer matrix, which reduces the effect of the amorphous groups present inside it. In sample ID GPCG80M20, the maximum compressive strength was found to be 21.3 N/mm2 and 31.1 N/mm2 during 7 and 28 days, respectively. In sample ID GPCG80M20, the maximum flexural strength was found to be 2.07 N/mm2 and 2.31 N/mm2 during 7 and 28 days, respectively.

2. Mechanical properties of geopolymer concrete incorporating supplementary cementitious materials as binding agents.
Sandeep Thapa, Suman Debnath, Suhasini Kulkarni,Hardik Solanki,Snehansu Nath1 (2024)
From the above results it is apparent that Geopolymer concrete based on GGBS and metakaolin has got more compressive strength than conventional concrete.It is observed that the Compressive, Flexural and Split Tensile strengths of Geopolymer Concrete are increased with increase in percentage of Metakaolin quantity i.e GGBS 0%-MK 100% and decreased with increase in GGBS irrespective of curing period. The green concrete resists the attack of various chemicals and therefore, it is durable for the given mix proportion. Compressive, Flexural and split tensile strengths vary in direct relation to age for a given proportion of a mix. Proportion C1obtained the maximum in percentage reduction of 0.73 in weight for 30 days of chemical curing (Na2SO4).

3. Experimental investigation of geopolymer concrete with full replacement of cement with fly ash, metakaolin and GGBS
Sahil, Punita Thakur and Jainender Sharma(2023)
Geopolymer concrete is found out to be ecofriendly and economical at the same point. Due to the waste material used in different concentrations to give different results. Geopolymer concrete has less carbon footprint than the OPC (Ordinary Portland cement). The only drawback that is found in this experiment that with these concentration of waste material in geopolymer concrete it cannot be used in heavy construction work. The results of our experiment shows that it cannot hold large loads such as it cannot be used in bridge, multistory construction etc..

METHODOLOGY

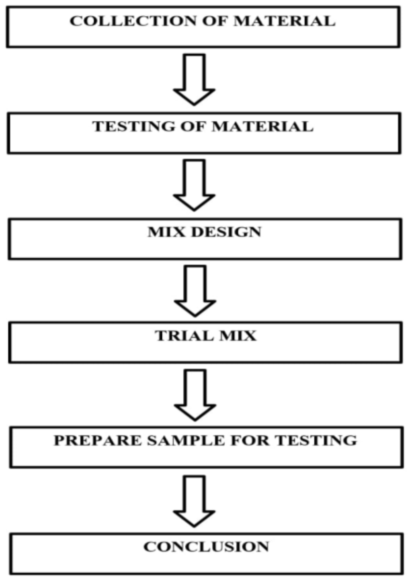

Fig 1: Flow Chart

Material Testing Procedure
1. Specific gravity

Fig 2: pycnometer

Procedure :
1. Clean and dry the pycnometer: Clean the pycnometer thoroughly and dry it in an oven at 110°C.
2. Weigh the empty pycnometer: Weigh the empty pycnometer (W1) accurately to the nearest 0.1 g.
3. Add aggregate to the pycnometer: Add about 200-400 g of aggregate sample to the pycnometer.
4. Weigh the pycnometer + aggregate: Weigh the pycnometer with aggregate (W2) accurately to the nearest 0.1 g.
5. Add water to the pycnometer: Fill the pycnometer with water, making sure to remove

any air bubbles.
6. Weigh the pycnometer + aggregate + water: Weigh the pycnometer with aggregate and water (W3) accurately to the nearest 0.1 g.
7. Weigh the pycnometer + water: Weigh the pycnometer with water only (W4) accurately to the nearest 0.1 g.

2. Sieve Analysis

Fig 3: Sieves

Procedure:
1. Prepare the sample: Take a representative sample of aggregate and dry it in an oven at 110°C.
2. Weigh the sample: Weigh the dried sample accurately to the nearest 0.1 g.
3. Select the sieves: Select a set of standard sieves with the following sizes:
   - 80 mm
   - 40 mm
   - 20 mm
   - 10 mm
   - 4.75 mm
   - 2.36 mm
   - 1.18 mm
   - 600 µm
   - 300 µm
   - 150 µm
   - 75 µm
4. Assemble the sieves: Assemble the sieves in order of decreasing size, with the largest sieve at top sieve.
6. Sieve the top.
5. Add the sample: Add the weighed sample to the the sample: Sieve the sample using a mechanical sieve shaker or by hand, making sure to cover all surfaces of the sieves.
7. Weigh the retained material: Weigh the material retained on each sieve accurately to the nearest 0.1 g.
8. Calculate the percentage retained: Calculate the percentage of material retained on each sieve.
9. Plot the results: Plot the results on a semi-log graph paper to obtain the particle size distribution curve.

3. Compressive strength test

Fig 4 Compression testing machine

1. Prepare the specimen: Prepare a cube or cylinder specimen of the material to be tested, typically 150 mm x 150 mm x 150 mm or 150 mm diameter x 300 mm height.
2. Cure the specimen: Cure the specimen in a controlled environment (typically 20°C and 100% RH) for a specified period (usually 28 days).
3. Test the specimen: Place the specimen in a compression testing machine and apply a compressive load at a controlled rate (usually 0.25 MPa/s).
4. Record the load: Record the maximum load applied to the specimen at failure.
5. Calculate the compressive strength: Calculate the compressive strength using the formula:
   - Compressive Strength (fck) = Maximum Load / Cross-sectional Area

CONCLUSION

- Geopolymer concrete based on GGBS and metakaolin has got more compressive strength than conventional concrete.
- Compressive, Flexural and Split Tensile strengths of Geopolymer Concrete are increased with increase in percentage of Metakaolin quantity i.e GGBS 0%-MK 100% and decreased with increase in GGBS irrespective of curing period.
- The green concrete resists the attack of various chemicals and therefore, it is durable for the given mix proportion.
- Compressive, Flexural and split tensile strengths vary in direct relation to age for a given proportion of a mix.
- Proportion C1 obtained the maximum in percentage reduction of 0.73 in weight for 30 days of chemical curing (Na2SO)

REFERENCE

Study of strength properties of geopolymer concrete using ggbs and metakaolin Rishi Malviya, Dr. Rajeev Chandak (2025)

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Experimental investigation of geopolymer concrete with full replacement of cement with fly ash, metakaolin and GGBS Sahil, Punita Thakur and Jainender Sharma (2023)

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