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Effect on Mechanical Properties of Self Compacting Geopolymer Concrete by Varying Percentage of Fly Ash and GGBS

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ABSTRACT: The increasing generation of foundry waste, particularly sand and other by-products, presents significant environmental challenges. However, these materials can potentially be repurposed in the construction industry, especially in the manufacturing of paver blocks and concrete. This study explores the beneficial reuse of foundry waste in the production of paver blocks and concrete, aiming to reduce waste disposal issues and enhance sustainability in construction practices. The foundry waste was incorporated into concrete and paver block mixtures at varying replacement levels of sand and cement. The effects on the physical, mechanical, and durability properties of the resulting concrete and paver blocks were thoroughly analyzed. The study reveals that the incorporation of foundry waste led to improvements in workability, compressive strength, and durability, especially when used at moderate replacement levels. This research suggests that foundry waste, when processed and used appropriately, can serve as a sustainable alternative in concrete production, reducing the environmental impact of both the construction and foundry industries.

KEYWORDS: GGBS, Fly ash, Geopolymer.

I. INTRODUCTION

The work environment on construction and precast sites where concrete is being poured is greatly improved by eliminating the need for vibrating equipment, which reduces both noise levels and the exposure to vibration for workers. Self-compacting concrete (SCC) is an attractive choice for both precast and civil engineering projects due to its enhanced construction practices, improved performance, and health and safety benefits.

Geopolymers, a class of inorganic binders, are characterized by several key properties. The compressive strength of geopolymers is influenced by both the curing temperature and duration, with strength increasing as these factors are optimized. Unlike conventional cement, which uses limestone, geopolymers are highly resistant to corrosion in both acidic and alkaline environments, making them particularly suitable for harsh conditions.

Geopolymer materials also exhibit enhanced durability and thermal stability. Key benefits include:

- Early strength development
- Bleed-free properties
- Extended working life
- Improved resistance to high temperatures and resistance to all inorganic solvents.
- Impermeable

These qualities make geopolymers a highly reliable option for applications in demanding environments

Ground Granulated Blast Furnace Slag

Ground Granulated Blast Furnace Slag (GGBS) is a by-product of the blast furnaces used in the production of iron. These furnaces operate at a temperature of around 1,500°C and are fed with a carefully measured combination of iron





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ore, coke, and limestone. As the iron ore is transformed into iron, the remaining components combine to form slag, which floats on top of the molten iron.

This slag is regularly tapped out as a molten liquid and must be rapidly cooled using large amounts of water if it is to be used in the production of GGBS. The rapid cooling, or quenching, enhances the cementitious properties of the slag and results in granules that resemble coarse sand. The granulated slag is then dried and processed into a fine powder, known as Ground Granulated Blast Furnace Slag (GGBS), which is often used as a supplementary cementitious material in concrete production

CHEMICAL COMPOSITION OF GGBS		PHYSICAL PROPERTIES OF GGBS		
Calcium oxide	40%	Colour	Off-white	
Silica	35%	Specific Gravity	2.9	
Alumina	13%	Bulk Density	1200 kg/m3	
Magnesia	8	Fineness	>350m2/kg	



Fig 1 Bagasse and Bagasse Ash

Bagasse Ash

The sugar industry is one among the well-established industries in India which is a boon to farmers. As per the statistics of the Indian Sugar Mill Association, around 538 sugarcane factories are in operation in the country presently. In this century, most of the sugar industries in India have been developed as self-sustained ones by various means. It is one among the industries that generate electricity and export the excess to the government through the power grid.

Fly Ash

Fly ash is a residue of the burning of coal during the generation of electricity in thermal power plants and is collected from the flue gases using electrostatic precipitators (ESP). Class F fly ash is normally produced from burning anthracite or bituminous coal.

There are two types of fly ash:

- **Class F:** It is the burning of harder, older anthracite and bituminous coal that typically produces class F fly ash.
- Class C: Fly ash produced from the burning of younger lignite or sub-bituminous coal, in addition to having pozzolanic properties, also has some self-cementing properties





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II. PROBLEM STATEMENT

The production of one tonne of Portland cement results in the release of an equal amount of carbon dioxide into the atmosphere, contributing to environmental pollution. Fly ash, a by-product of coal-based thermal power plants, presents a significant disposal challenge. Improper handling of fly ash can lead to health issues, including respiratory conditions such as asthma and bronchitis. Geopolymer concrete, which combines fly ash with an alkaline solution (sodium hydroxide and sodium silicate), offers a sustainable alternative. Government regulations now mandate the full utilization of fly ash, given its environmental and health impacts. Therefore, it is essential to determine the optimal mix ratio for geopolymer concrete using Class-F low-calcium fly ash to ensure both performance and sustainability.

Table 1 Mix Proportion of Geo-polymer Concrete for M30

Fly Ash & GGBS	NaOH	Na2SiO3	F.A	C.A
1	0.130	0.320	1.48	2.41



Fig 2 Compression Strength Test

III. RESULTS AND ANALYSIS



Fig 3 Split tensile strength test

Compression Strength Test

FIG 4 Flexural strength test



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Discussion:

- It was observed that the compressive strength of self-compacting geopolymer concrete increases with an increase in the percentage of GGBS, up to a value of 50%.
- The compressive strength of geopolymer concrete reaches its maximum at a 13M concentration.
- The optimal combination of Fly Ash and GGBS content for geopolymer concrete has been determined



Split tensile strength test



Discussion:

- As shown in Graph 4.2, At 28 days, Split Tensile strength ranges from 5.31 to 5.75 N/mm2.
- From the above results, it can be concluded that an increase in the percentage of GGBS and fly ash at the same proportion improves the split tensile strength of self-compacting geopolymer concrete.



Flexural strength test

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Discussion:

- As shown in graph 4.3 The flexural strength of self-compacting geopolymer concrete increases with the percentage of GGBS.
- The highest flexural strength is achieved when the percentage of GGBS and fly ash content in the concrete are the same.
- The maximum flexural strength of bamboo-reinforced geopolymer concrete at 28 days is 13.46 N/mm².

IV. CONCLUSION

Based on the experimental work reported in this study, the following conclusions are drawn:

- Fly ash and GGBS can serve as alternatives to conventional Portland cement. When activated with an alkaline solution, these materials function effectively as binders.
- Compressive strength increases with age across all proportions, indicating that the reactivity of the materials continues to be effective, even when influenced by environmental conditions.
- Compressive strength improved as the fly ash to solution ratio decreased from 0.6 to 0.45, but began to decline when the ratio dropped further to 0.35. Thus, 0.35 is considered the optimal ratio for achieving higher strengths.
- The reduction in water content promotes the formation of geopolymerization, which requires higher concentrations of sodium hydroxide and sodium silicate. Consequently, increasing the NaOH concentration leads to a rise in compressive strength. For medium-strength geopolymer concrete, a concentration of 13M is recommended.
- The materials should be able to mix with a relatively low-alkali activating solution and cure in a reasonable time under ambient conditions.
- Fly ash-based geopolymer concrete demonstrated excellent performance, achieving a high compressive strength of 97 MPa by the seventh day of curing.
- As the ratio of alkaline solution to geopolymer concrete increases, both the strength and other mechanical properties of the concrete improve.
- After curing the cubes at 80°C for 24 hours, they were allowed to rest in the presence of sunlight. Extending the resting period resulted in increased strength of the geopolymer concrete.
- To reduce the cost of the alkaline solutions required for geopolymer concrete, steps can be taken to source sodium hydroxide and sodium silicate from waste materials generated by chemical industries.
- The slump value of geopolymer concrete decreases as the fly ash to solution ratio increases.
- The disposal of fly ash, an environmental concern, is effectively addressed by the widespread use of ASTM Class F Indian fly ash in heat-cured geopolymer concrete.
- Fly ash, once regarded as a waste material, is now a valuable component in the production of geopolymer concrete.
- The incorporation of silicates and potassium hydroxides contributes to the production of high-strength geopolymer concrete.
- Among the seven trial mixes conducted, experiment number 7 yielded the most favorable results, suggesting its applicability for future studies.
- The addition of alkaline materials such as NaOH or Na2SiO3 influences the flowability of concrete mixtures.
- Rapid hardening of concrete occurs when large amounts of lime are combined with an alkaline solution and fly ash.
- Although various ratios of alkaline solution and other materials are used, water remains essential for ensuring the proper flowability of the concrete..





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