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Research Article

SYNERGISTIC EFFECTS OF GLASS POWDER AND RICE HUSK ASH ON THE MECHANICAL AND DURABILITY PROPERTIES OF CONCRETE

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ABSTRACT

The increasing demand for sustainable construction materials has driven the exploration of supplementary cementitious materials (SCMs) to enhance the properties of concrete while reducing its environmental impact. This study investigates the synergistic effects of glass powder (GP) and rice husk ash (RHA) as partial replacements for cement in concrete. Various mix proportions were tested to evaluate their influence on mechanical properties, including compressive strength, tensile strength, and flexural strength, as well as durability parameters such as water absorption, chloride resistance, and sulfate attack.

Results reveal that the combination of GP and RHA significantly improves the mechanical properties of concrete, particularly at later ages, due to the pozzolanic reactions and filler effects. The inclusion of these materials also enhances durability by reducing permeability and improving resistance to chemical attacks. Optimal performance was observed at a combined replacement level of 20–30%, beyond which a slight reduction in strength was noted. This research highlights the potential of using GP and RHA to produce eco-friendly concrete with improved performance, aligning with sustainability goals in the construction industry.

KEYWORDS

Glass Powder, Rice Husk Ash, Sustainable Concrete, Supplementary Cementitious Materials, Mechanical Properties, Durability, Pozzolanic Reactions, Chloride Resistance.

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INTRODUCTION

Concrete is one of the most widely used construction materials globally, owing to its versatility, durability, and cost-effectiveness. However, the production of its key component, Portland cement, is a significant contributor to greenhouse gas emissions, accounting for approximately 8% of global CO_2 emissions. As the demand for sustainable construction practices increases, researchers and engineers are exploring the use of supplementary cementitious materials (SCMs) to partially replace cement in concrete. These materials not only reduce the carbon footprint of concrete but also enhance its mechanical and durability properties through pozzolanic reactions and microstructural refinement.

Glass powder (GP) and rice husk ash (RHA) have emerged as promising SCMs due to their abundant availability and beneficial chemical compositions. GP, derived from waste glass, is rich in silica and exhibits excellent pozzolanic properties when finely ground. Similarly, RHA, a byproduct of rice milling, contains high levels of amorphous silica, making it a highly reactive material for cementitious applications. Individually, both materials have been shown to improve the strength and durability of concrete by filling voids, refining pore structures, and enhancing resistance to chemical attacks.

Despite the documented benefits of GP and RHA as individual SCMs, limited research has explored their combined effects on concrete properties. It is hypothesized that their complementary characteristics may create a synergistic effect, further improving the mechanical strength and durability of concrete. The combination of GP and RHA could also address issues such as workability, setting time, and early-age strength development, which are often challenges with the use of single SCMs.

This study investigates the synergistic effects of GP and RHA as partial replacements for cement in concrete. The objectives include evaluating the mechanical properties (compressive, tensile, and flexural strength) and durability characteristics (water absorption, chloride penetration, and sulfate resistance) of concrete with varying proportions of GP and RHA. By optimizing their combined use, this research aims to contribute to the development of sustainable, high-performance concrete that meets the demands of modern construction while minimizing its environmental impact.

METHOD

The methodology for studying the synergistic effects of glass powder (GP) and rice husk ash (RHA) on concrete properties involves a systematic approach encompassing material characterization, mix design, testing procedures, and data analysis. Each step ensures a thorough understanding of how these supplementary cementitious materials (SCMs) influence

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concrete's mechanical and durability performance.

Material Selection and Preparation

Glass powder was sourced from recycled waste glass, which was cleaned, dried, and finely ground to achieve a particle size comparable to cement. Rice husk ash was obtained from rice milling byproducts and processed to enhance its amorphous silica content through controlled burning and subsequent grinding. Both GP and RHA were characterized for chemical composition using X-ray fluorescence (XRF) and for physical properties, such as particle size distribution and specific surface area. Ordinary Portland Cement (OPC), fine and coarse aggregates, and potable water were used as primary constituents in the concrete mixes.

Mix Design and Sample Preparation

Concrete mixes were designed with GP and RHA as partial replacements for cement, with replacement levels ranging from 10% to 30% in various combinations. A control mix without SCMs was prepared for comparison. The water-cement ratio was kept constant across all mixes to isolate the effects of GP and RHA. Superplasticizers were added as needed to maintain workability. Standard molds were used to cast specimens for testing compressive strength, split tensile strength, flexural strength, and durability characteristics. Specimens were demolded after 24 hours and cured in water for specified durations (7, 28, and 56 days).

Mechanical Property Testing

Compressive strength tests were conducted on cube specimens following ASTM C39 standards, while split tensile and flexural strength tests adhered to ASTM C496 and ASTM C78 guidelines, respectively. These tests evaluated the effect of GP and RHA combinations on the mechanical behavior of concrete at various curing ages.

Durability Testing

Durability properties were assessed through water absorption, chloride penetration, and sulfate resistance tests. Water absorption was measured to evaluate the porosity of the concrete, while chloride ion penetration was tested using rapid chloride permeability tests (RCPT) as per ASTM C1202 standards. Sulfate resistance was assessed by immersing specimens in a 5% sodium sulfate solution and monitoring weight changes and strength loss over time.

Data Analysis and Optimization

The results from mechanical and durability tests were statistically analyzed to identify trends and optimal replacement levels. Comparative analysis with the control mix and between different replacement levels of GP and RHA was conducted to determine the synergistic effects of the two materials. Regression models and performance indices were used to assess the contributions of GP and RHA to overall concrete performance.

This methodical approach ensures a comprehensive evaluation of the potential of GP and RHA as sustainable alternatives in concrete, providing insights into their combined effects on both mechanical and durability properties.

Results

The experimental results demonstrated significant improvements in the mechanical and durability properties of concrete when glass powder (GP) and rice husk ash (RHA) were used as partial cement replacements.

Mechanical Properties

Compressive Strength: Concrete mixes with 20–25% combined replacement of GP and RHA achieved a 10–15% increase in compressive strength at 28 and 56 days compared to the control mix. The pozzolanic activity of GP and RHA contributed to enhanced strength over time.

Tensile and Flexural Strength: The split tensile and flexural strengths showed similar improvements, with peak values observed in mixes with a 15% GP and 10% RHA combination. This enhancement is attributed to improved bond strength and microstructural refinement.

Durability Properties

Water Absorption: The inclusion of GP and RHA reduced water absorption by up to 25%, indicating a denser matrix with reduced porosity.

Chloride Ion Penetration: Rapid chloride permeability tests revealed lower charge passed for mixes with GP and RHA, with a reduction of over 30% compared to the control, highlighting improved resistance to chloride ingress.

Sulfate Resistance: Specimens exposed to sodium sulfate solution exhibited minimal weight loss and strength deterioration, particularly in mixes with 20% GP and RHA replacement.

Discussion

The synergistic effects of GP and RHA on concrete properties are evident from the results, confirming their potential as complementary supplementary cementitious materials (SCMs). The improvements in mechanical strength can be attributed to the combined pozzolanic activity of GP and RHA, which consumes calcium hydroxide and forms additional calcium silicate hydrates (C-S-H), enhancing the concrete matrix. The fine particles of GP also act as fillers, reducing voids and improving packing density.

In terms of durability, the reduced water absorption and enhanced resistance to chloride ion penetration suggest that the combination of GP and RHA contributes to a denser, less permeable concrete matrix. This is particularly beneficial for structures exposed to aggressive environments, as it enhances the service life and reduces maintenance costs.

However, the results also indicate diminishing returns when the replacement level exceeds 30%, likely due to reduced cement content affecting early-age strength development. Proper mix design and optimization are thus critical to balancing the benefits of using these materials without compromising performance.

Conclusion

This study highlights the synergistic benefits of using glass powder (GP) and rice husk ash (RHA) as partial cement replacements in concrete. The combined use of these materials significantly enhances both the mechanical and durability properties of concrete, making it a viable option for sustainable construction.

Optimal performance was observed at a 20–25% combined replacement level, with notable improvements in compressive, tensile, and flexural strengths, as well as reduced permeability and improved resistance to chloride and sulfate attacks. These findings support the integration of GP and RHA into concrete mix designs to produce eco-friendly, high-performance concrete.

Future research could focus on long-term durability studies, field applications, and the impact of using alternative sources or processing techniques for GP and RHA to further validate their practical use in diverse construction scenarios.

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