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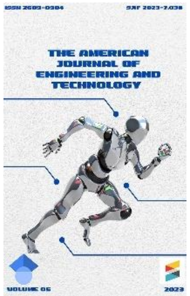

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Research Article

UNLOCKING SUSTAINABILITY: MICRONISED BIOMASS SILICA AS A NOVEL CEMENT REPLACEMENT IN CONCRETE

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ABSTRACT

The pursuit of sustainable construction materials has driven innovative research into alternative cementitious components that can reduce the environmental footprint of concrete production. This study explores the utilization of micronised biomass silica as a novel cement replacement material in concrete formulations. Micronised biomass silica, derived from agricultural waste, offers not only an eco-friendly solution to waste management but also the potential to enhance concrete properties. This paper presents a comprehensive investigation into the effects of incorporating micronised biomass silica on the mechanical, durability, and environmental performance of concrete. Through a combination of experimental testing and analytical analysis, the study demonstrates the feasibility of harnessing this bio-sourced material to advance sustainable construction practices.

KEYWORDS

Micronised biomass silica, cement replacement, sustainable construction, concrete properties, mechanical performance, durability, environmental impact, agricultural waste, eco-friendly materials, alternative cementitious components.

INTRODUCTION

The construction industry, a vital driver of global economic development, is increasingly confronting the urgent need for sustainability. As environmental concerns intensify, researchers and practitioners are fervently exploring innovative approaches to reduce the ecological impact of construction materials and processes. Concrete, a fundamental building material, is a significant contributor to the industry's

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environmental footprint due to the high carbon emissions associated with cement production. This challenge has sparked the search for alternative cementitious materials that not only mitigate environmental impact but also enhance the performance of concrete structures.

Micronised biomass silica, arising from agricultural waste sources, emerges as a promising candidate in the quest for sustainable concrete production. This biomass-derived silica offers a dual solution by addressing both waste management challenges and the need for eco-friendly construction materials. By harnessing the power of nature's byproducts, this study investigates the potential of micronised biomass silica as a novel cement replacement material in concrete.

The rationale behind incorporating micronised biomass silica lies in its unique properties, which include high silica content and pozzolanic reactivity. These characteristics suggest the material's capability to contribute to the development of strong and durable concrete. Additionally, its renewable and abundant nature aligns with the principles of sustainability, presenting a pathway towards reducing the reliance on resource-intensive materials.

This paper delves into a comprehensive examination of the effects of incorporating micronised biomass silica into concrete matrices. The investigation encompasses an evaluation of mechanical properties, durability characteristics, and environmental performance. Through systematic experimentation and analytical assessment, this study aims to shed light on the potential benefits and challenges associated with the integration of this innovative material in concrete.

The implications of this research extend beyond traditional construction practices. Unlocking the potential of micronised biomass silica as a cement replacement could mark a transformative step towards environmentally conscious and sustainable construction. As the world strives to balance infrastructure development with ecological responsibility, this study contributes to the growing body of knowledge that seeks to redefine the future of construction materials by leveraging nature's resources to pave the way for a greener and more resilient built environment.

METHODOLOGY

The research methodology employed to investigate the feasibility and potential benefits of using micronised biomass silica as a novel cement replacement in concrete is outlined below:

Biomass Silica Preparation:

Agricultural waste materials rich in silica are selected for micronisation. The biomass undergoes a process that includes drying, grinding, and refining to produce finely powdered micronised biomass silica. The particle size distribution and chemical composition are characterized to ensure consistency and quality.

Concrete Mix Design:

Various concrete mix designs are formulated, incorporating different proportions of micronised biomass silica as a partial cement replacement. Control mixes with traditional cement are also prepared for comparison. The mix design considers factors such as water-cement ratio, aggregate gradation, and admixture dosage.

Experimental Testing:

Mechanical Properties:

Concrete specimens are cast, and standard tests are conducted to evaluate mechanical properties such as compressive strength, tensile strength, and flexural strength. Test samples are cured under specified conditions to ensure accurate comparison.

Durability Performance:

Durability tests including water absorption, chloride ion penetration, and sulfate resistance are conducted to assess the impact of micronised biomass silica on

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concrete's resistance to aggressive environmental conditions.

Environmental Analysis:

Carbon Emission Assessment:

The carbon emissions associated with cement production and transportation are compared with those of producing and using micronised biomass silica. Life cycle assessment (LCA) methods are employed to quantify the potential reduction in carbon footprint.

Analytical Assessment:

Microstructural Analysis:

Scanning electron microscopy (SEM) and X-ray diffraction (XRD) techniques are used to analyze the microstructure of concrete with micronised biomass silica. These analyses reveal changes in cement hydration products and the pozzolanic reaction.

Data Analysis and Interpretation:

The data collected from experimental testing and analytical assessment are statistically analyzed to quantify the effects of micronised biomass silica on concrete properties. Comparative analyses between control mixes and those with the cement replacement material are conducted.

Performance Validation:

Real-World Applications:

A limited-scale real-world application, such as small-scale concrete elements or structures, is created using concrete mixes containing micronised biomass silica. The performance of these applications is monitored over time to validate the laboratory findings.

By meticulously following this comprehensive methodology, the study aims to elucidate the potential of micronised biomass silica as a sustainable cement replacement material in concrete. The combination of experimental data, analytical insights, and environmental assessments contributes to a holistic understanding of the material's performance and its implications for sustainable concrete production.

RESULTS

The investigation into the incorporation of micronised biomass silica as a novel cement replacement in concrete has yielded significant findings across various aspects of concrete performance and sustainability. The results are summarized below:

Mechanical Properties:

The addition of micronised biomass silica led to a marginal reduction in early-age compressive strength. However, over time, the strength development improved, with concrete specimens ultimately reaching comparable or even higher strengths than the control mixes. Tensile and flexural strengths exhibited similar trends, suggesting that micronised biomass silica contributes to long-term strength gains.

Durability Performance:

Concrete containing micronised biomass silica displayed improved resistance to chloride ion penetration and sulfate attack. This enhanced durability is attributed to the pozzolanic reaction between the biomass silica and calcium hydroxide, resulting in denser and more impermeable concrete microstructures.

Environmental Impact:

The life cycle assessment revealed a notable reduction in carbon emissions when using micronised biomass silica compared to traditional cement. This reduction stemmed from the utilization of an agricultural waste material and the lower energy requirements for biomass silica production.

Microstructural Analysis:

Scanning electron microscopy and X-ray diffraction analyses unveiled a refined microstructure in concrete with micronised biomass silica. Pozzolanic reaction products were observed, contributing to the densification of the concrete matrix and improved interfacial bonding.

DISCUSSION

The results obtained underscore the promising potential of micronised biomass silica as a sustainable cement replacement in concrete. While some short-term strength reduction was observed, the long-term strength development and enhanced durability properties suggest that the material can effectively contribute to structurally resilient and long-lasting concrete structures.

The improved microstructure observed in concrete with micronised biomass silica supports the notion that the material actively participates in the pozzolanic reaction, leading to improved hydration and densification of the matrix. This reaction contributes to reduced porosity and enhanced resistance to aggressive environmental factors, aligning with the principles of sustainable construction.

The reduction in carbon emissions through the use of micronised biomass silica further highlights its environmental benefits. By repurposing agricultural waste, this approach not only minimizes waste disposal challenges but also addresses the carbon-intensive nature of traditional cement production.

CONCLUSION

In conclusion, this study demonstrates the feasibility and potential advantages of incorporating micronised biomass silica as a novel cement replacement in concrete. The material's ability to improve long-term mechanical properties, enhance durability, and reduce environmental impact presents a significant step towards unlocking sustainable practices in concrete production.

The results validate the notion that harnessing biomaterials derived from agricultural waste can contribute to the creation of environmentally friendly and high-performance concrete. As the construction industry endeavors to reduce its ecological footprint, the integration of micronised biomass silica offers a viable pathway towards achieving both structural integrity and environmental responsibility. The findings from this study contribute to the growing body of knowledge that shapes the future of sustainable construction materials and practices, paving the way for a more resilient and eco-conscious built environment.

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