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A systematic review of corncob ash in construction: Current findings and future directions

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ABSTRACT

The increasing environmental impact of traditional cement production necessitates the exploration of sustainable alternatives in construction materials. This paper investigates corncob ash (CCA), an agro-waste by-product, as a viable substitute for cement in several construction and building material applications such as concrete, masonry, geopolymer materials, and soil stabilization. A comprehensive review of existing literature reveals that CCA enhances the mechanical properties of these materials, such as compressive strength and durability, and significantly reduces the carbon footprint associated with conventional cement production. The findings indicate that incorporating CCA improves workability and resistance to aggressive environmental conditions, positioning it as a promising material for sustainable construction. Furthermore, the paper identifies gaps in current research, particularly concerning long-term performance and standardization of testing methods. Future research directions are proposed, including optimization of processing techniques, life cycle assessments, and real-world applications, to fully leverage the potential of CCA in promoting environmentally friendly construction practices. Overall, this study underscores the critical role of CCA in advancing sustainability within the construction industry.

1. Introduction

Cement is a cornerstone of modern construction, acting as the binding agent in concrete and mortar [1]. It plays a critical role in ensuring various infrastructures' structural integrity and longevity, from residential buildings to monumental bridges [2]. However, cement production emits approximately 1.8 billion tons of CO_2 annually, accounting for about 8 % of global emissions [3]. For every ton of cement produced, around 0.8 tons of CO_2 are released, primarily through the calcination of limestone and the combustion of fossil fuels [4]. This energy-intensive process consumes about 2.5–4.0 GJ of energy per ton of cement, raising sustainability concerns due to its reliance on non-renewable energy sources [5]. The extraction of raw materials, such as limestone and clay, contributes to soil erosion and biodiversity loss. Annually, about three billion tons of limestone are mined, significantly impacting local ecosystems [6]. Additionally, cement production requires substantial water use, leading to potential over-extraction and water scarcity in some regions. The industry also emits pollutants like particulate matter (PM), nitrogen oxides (NOx), and sulfur oxides (SOx), which degrade air quality and pose health risks [7]. Waste generation is another critical issue, with cement manufacturing producing about 10–15 % of total industry waste, including kiln dust that can contaminate soil and water [8]. Moreover, the establishment of cement plants often leads to land use changes that disrupt local ecosystems and displace communities. To mitigate these impacts, strategies such as utilizing alternative fuels, implementing carbon capture and storage (CCS) technologies, recycling waste materials, and improving energy efficiency are essential. This staggering environmental footprint underscores the urgent need for sustainable alternatives in construction materials [9]. This substantial environmental footprint raises concerns about sustainability and the industry's impact on climate change [10]. As awareness of these issues grows, the need for alternatives to traditional cement has become increasingly urgent.

Various alternatives, including materials like fly ash, slag, and natural pozzolans, have been explored. These materials can partially replace cement in concrete, reducing its carbon footprint [11]. However, using industrial by-products as cement replacements poses challenges, such as variability in quality [12], potential issues with long-term durability, and regulatory hurdles. In this context, agro-waste is emerging as a promising alternative to conventional cement. Utilizing

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