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Review of experimental study on sustainable concrete using recycled materials

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Abstract

Concrete is one of the most widely used construction materials; however, its production leads to significant environmental issues such as high carbon dioxide emissions from cement manufacturing and depletion of natural sand resources. This experimental study focuses on the development of sustainable concrete by incorporating eco-friendly and waste materials as partial replacements for conventional constituents. Neem leaf powder is used as a partial replacement for cement due to its pozzolanic and antibacterial properties, while styrene-butadiene-styrene (SBS) polymer waste is used as a partial replacement for fine aggregate to enhance bonding and crack resistance. The study involves laboratory-based casting, curing, and testing of concrete specimens to evaluate workability and strength characteristics. The results are expected to demonstrate reduced cement consumption, effective utilization of agricultural and polymer waste, improved durability, and overall enhancement in sustainability. This research promotes the use of low cost, environmentally friendly materials in concrete for sustainable construction practices.

Keywords: Styrene-butadiene-styrene (SBS); Polymer; Crack resistance

1. Introduction

Concrete is the most widely used construction material across the world due to its strength, durability, and versatility. However, the extensive use of concrete has raised serious environmental concerns. Cement, a primary constituent of concrete, is responsible for a significant amount of global carbon dioxide (CO_2) emissions due to energy-intensive production processes. The increasing demand for cement directly contributes to environmental pollution and climate change. At the same time, the excessive extraction of natural river sand, used as fine aggregate in concrete, has led to depletion of natural resources and severe ecological imbalance, including riverbank erosion and loss of aquatic habitats.

In recent years, the construction industry has focused on developing sustainable and eco-friendly alternatives to conventional concrete materials. The utilization of waste and by-product materials not only helps in reducing environmental pollution but also contributes to cost-effective and sustainable construction practices. Agricultural wastes and polymer-based materials are often underutilized despite their potential benefits when incorporated into construction materials.

Neem (Azadirachta indica) leaf waste is an abundant agricultural by-product in many regions. Neem leaves possess unique chemical properties and, when processed into powder form, can be explored as a partial replacement for cement. The use of neem leaf powder helps reduce cement consumption, thereby lowering CO_2 emissions and promoting the effective utilization of agricultural waste. Similarly, styrene-butadiene-styrene (SBS) polymer, widely used in industrial applications, can be utilized as a partial replacement for fine aggregate. SBS polymer has the potential to enhance durability, flexibility, and resistance to cracking in concrete while reducing dependence on natural sand resources.

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This study focuses on a laboratory-based experimental investigation of concrete incorporating partial replacement of cement with neem leaf powder and partial replacement of fine aggregate with SBS polymer. The research aims to evaluate the strength and workability characteristics of such modified concrete and assess its suitability for sustainable construction applications. By reducing cement usage and natural sand consumption, this study contributes to the development of low-cost, durable, and eco-friendly concrete, supporting the broader goal of sustainable infrastructure development.

2. Literature Review

The published studies on alternative and sustainable construction materials were examined to assess the current state of knowledge on partial replacement of cement and fine aggregate.

2.1. Experimental analysis of waste foundry sand in partial replacement of fine aggregate in concrete

The provided document is a research paper titled "Experimental analysis of waste foundry sand in partial replacement of fine aggregate in concrete," published in the International Journal of ChemTech Research in 2017. The study explores the environmental and structural benefits of reusing waste foundry sand (WFS)—a major by-product of the casting industry that typically causes land pollution—as a partial substitute for natural river sand in concrete. The researchers tested various replacement levels (0%, 5%, 10%, 15%, and 20% by weight) across different concrete mix proportions to evaluate fresh and hardened concrete properties, including workability and compressive strength at various curing intervals. Their findings indicate that incorporating WFS can increase the compressive strength of concrete while satisfying the acceptable limits established by the American Concrete Institute (ACI), offering a sustainable solution to both reduce land pollution and the high demand for natural river sand.

2.2. Replacement of Fine Aggregate by Allied Materials

This paper, titled "Replacement of Fine Aggregate by Allied Materials," was published in the International Journal of Engineering Research & Technology (IJERT) as part of the ICETCE-2021 Conference Proceedings. It investigates the experimental use of rice husk as a partial replacement for fine aggregate in an M-30 concrete mix to address the shortage of building materials and the need for sustainable waste utilization. The study replaced fine aggregate by 0%, 5%, and 10% by weight and tested the resulting concrete cubes for compressive strength at 7 and 28 days. Findings indicate that while both workability and compressive strength decrease as the percentage of rice husk increases, an optimum replacement level of 5% was identified. At this 5% replacement level, the 28-day compressive strength was 38.37 N/mm^2, exceeding the target strength for M-30 concrete, suggesting it is a viable alternative to conventional concrete.

2.3. Effect of banana tree leaves ash as cementations material on the durability of concrete against sulphate and acid attacks

Heliyon is an all-science, open-access journal published by Cell Press that features research from across the life, physical, social, and medical sciences. The journal emphasizes providing a platform for high-quality, impactful research and makes its content available through Science Direct to ensure broad accessibility. The specific research article in this journal explores the use of banana tree leaf ash (BLA) as a sustainable cementitious material to enhance the durability of concrete. The study finds that replacing cement with up to 10% BLA improves compressive strength and enhances resistance to acid and sulphate attacks, contributing to a more sustainable construction industry with a reduced carbon footprint.

2.4. Fabrication and characterization of Neem leaves waste material reinforced composites

This article, published in the journal Materials Today: Proceedings in 2021, investigates the fabrication and characterization of composite materials reinforced with recycled Neem leaves. The study explores the potential of using agricultural waste, specifically Neem leaves and wood chips, as a low-cost, eco-friendly alternative to traditional fillers in polymer composites to improve structural strength while reducing weight. By combining crushed Neem powder with epoxy resin and a hardener, researchers developed an Epoxy-Neem Recyclable Composite (ENRC) that exhibited enhanced thermal stability and a maximum impact toughness of 12.32 J/m. Various analytical techniques were employed to characterize the material, including Thermogravimetric Analysis (TGA) and Differential Scanning Calorimetry (DSC) for thermal properties, X-ray diffraction (XRD) which revealed a crystallinity of 58.67%, and Scanning Electron Microscopy (SEM) with Energy-dispersive X-ray spectroscopy (EDS) for elemental and morphological analysis. The findings suggest that recycled Neem materials can be effectively utilized in industrial applications, such as food packaging and textiles, providing a sustainable solution to mitigate plastic waste accumulation.

2.5. Investigation of Partial Replacement of Cement with Neem Leaf Ash in Concrete

This research paper, published in the Nigerian Journal of Engineering Science and Technology Research (Vol. 11, No. 2, 2025), investigates the partial replacement of Ordinary Portland Cement with Neem Leaf Ash (NLA) in concrete. Conducted at the Federal Polytechnic Kaura Namoda in Nigeria, the study addresses the high cost and environmental impact of cement by evaluating NLA as a sustainable pozzolanic alternative. The researchers analyzed the material's chemical properties using X-Ray Fluorescence (XRF) and Fourier-Transform Infrared Spectroscopy (FTIR), finding a high calcium content (49.58%) that supports binding properties. While the study noted that increasing NLA content leads to reduced workability and a general decline in compressive strength, it concluded that a 10% replacement is the optimum level to achieve a target strength of 15~N/mm^2 after 28 days of curing.

2.6. Review on Partial Replacement of Cement in Concrete

This paper, titled "Review on Partial Replacement of Cement in Concrete," was published as part of the UKIERI Concrete Congress – Concrete Research Driving Profit and Sustainability. The research explores sustainable construction practices by investigating how various waste materials can partially replace cement to reduce CO2 emissions and environmental degradation. The study provides a comprehensive literature review of previous investigations into the mechanical and chemical properties of concrete utilizing materials such as fly ash, ground granulated blast furnace slag (GGBFS), waste glass, and industrial sludges. Ultimately, the journal emphasizes that using locally available industrial waste can result in more economical and eco-friendly concrete without compromising the required strength and performance.

3. Conclusion

The collective findings from these studies underscore a significant shift toward sustainable construction by integrating agricultural, industrial, and polymer wastes into concrete production. The research highlights that materials such as Neem leaf ash, waste foundry sand, rice husks, and banana leaf ash can serve as viable partial replacements for cement and fine aggregates, effectively reducing the industry's carbon footprint and the depletion of natural resources like river sand. While challenges such as decreased workability or a slight reduction in compressive strength at higher replacement levels were noted, the literature consistently identifies "optimum replacement levels"—typically around 5% to 10%—where the concrete maintains or even exceeds target structural strengths. Ultimately, the integration of these eco-friendly materials, including the promising use of SBS polymers and Neem-based additives, proves that sustainable infrastructure can be achieved by balancing environmental responsibility with the necessary mechanical performance and durability.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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