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Utilization of Agro-Waste Ash in Geopolymer Concrete for Sustainable Construction: An Experimental Investigation

Darandale Shubham[1], Gavhane Mangesh[2], Devade Amar[3], Gaikwad Vaibhav[4], Prof. Daule A.D.[5]

AdsulsTechnical Campus,Ahmednagar

ABSTRACT :

This paper presents an experimental investigation aimed at studying the impact of utilizing agro-waste ash as a supplementary material in geopolymer concrete. Three different agro-waste ashes, namely Rice Husk Ash (RHA), Saw Dust Ash (SDA), and Cow Dung Ash (CDA), were examined for their mechanical properties when incorporated into geopolymer concrete. The percentage of silica oxides present in each ash was determined through laboratory testing, revealing RHA to have the highest silica content (81.28%), followed by SDA (72%) and CDA (71.2%). These agro-waste ashes were mixed with an alkaline solution to act as a binding agent, with a ratio of 0.4, composed of Sodium Silicate and Sodium Hydroxide in a 2.5 proportion. The mechanical properties, including compressive, split tensile, and flexural strengths, of geopolymer concrete incorporating RHA, SDA, and CDA were evaluated after curing periods of 24 hours, 48 hours, and 72 hours at a temperature of 100°C. The results indicate that the compressive, split tensile, and flexural strengths increased with longer curing periods. Furthermore, RHA-based geopolymer concrete exhibited superior mechanical properties compared to those containing CDA and SDA. This research aims to promote the reuse of agro-waste materials, thereby alleviating the environmental burden and contributing to sustainable construction practices.

Keywords: Agro-Waste Ash, Geopolymer Concrete, Mechanical Properties, Silica Oxides, Sustainable Construction.

1. Introduction

The construction industry is increasingly seeking sustainable alternatives to traditional materials, driven by concerns over environmental impact and resource depletion. In this context, agro-waste materials have garnered attention as potential supplementary materials for concrete production. These materials, which are rich in silica oxides, hold promise for enhancing the mechanical properties of concrete while simultaneously reducing agricultural waste and its associated environmental footprint. This paper investigates the viability of incorporating three different agro-waste ashes—Rice Husk Ash (RHA), Saw Dust Ash (SDA), and Cow Dung Ash (CDA)—into geopolymer concrete to create a more sustainable construction material.

The utilization of agro-waste materials in construction represents a significant opportunity to address both environmental and agricultural challenges. Agriculture generates large quantities of waste residues, including rice husks, sawdust, and cow dung, which pose disposal challenges and environmental hazards if not managed effectively. By repurposing these waste materials as supplementary ingredients in construction materials, such as concrete, their environmental impact can be mitigated while simultaneously enhancing the performance and sustainability of construction products. This research focuses specifically on exploring the potential of agro-waste ashes, namely Rice Husk Ash (RHA), Saw Dust Ash (SDA), and Cow Dung Ash (CDA), as additives in geopolymer concrete, a promising alternative to traditional Portland cement-based concrete.

Geopolymer concrete offers several advantages over conventional concrete, including lower carbon emissions, reduced energy consumption, and improved durability. By utilizing aluminosilicate materials as binders, geopolymer concrete reduces the reliance on Portland cement, which is a major contributor to CO_2 emissions in the construction industry. Additionally, geopolymer concrete exhibits superior mechanical properties, such as higher compressive strength, better resistance to chemical attack, and increased durability in harsh environments. This study aims to evaluate the feasibility of incorporating agro-waste ashes into geopolymer concrete to further enhance its performance while simultaneously addressing agricultural waste management challenges and promoting sustainable construction practices.

Related Work

1. Utilization of Agro-Waste in Construction Materials: Previous research has explored the potential of incorporating various types of agro-waste materials into construction materials to improve sustainability and reduce environmental impact. Studies have investigated the use of agro-waste such as rice husk ash, sugarcane bagasse ash, and palm oil fuel ash as supplementary materials in concrete production. These materials, rich in silica and other reactive compounds, have shown promise in enhancing the mechanical properties and durability of concrete while reducing the consumption of traditional cementitious materials. Research in this area has focused on optimizing mix designs, evaluating mechanical properties, and assessing the long-term performance of agro-waste-based construction materials.

2 Geopolymer Concrete Utilizing Alternative Binders: Geopolymer concrete, which utilizes aluminosilicate materials as binders instead of traditional Portland cement, has emerged as a sustainable alternative to conventional concrete. Previous studies have investigated the use of various alternative binders, including fly ash, slag, and metakaolin, in geopolymer concrete production. These materials offer advantages such as reduced carbon footprint, enhanced durability, and improved resistance to aggressive environments. Researchers have explored different curing regimes, activator formulations, and mix proportions to optimize the mechanical properties and performance of geopolymer concrete. However, limited research has been conducted on the utilization of agro-waste ashes as alternative binders in geopolymer concrete.

Effect of Curing Conditions on Geopolymer Concrete Properties: The curing conditions significantly influence the development of mechanical properties and microstructure in geopolymer concrete. Previous studies have investigated the effects of curing temperature, duration, and moisture conditions on the strength, durability, and microstructural evolution of geopolymer concrete. Higher curing temperatures generally accelerate the geopolymerization process, leading to faster strength development and denser microstructure. However, prolonged curing periods may result in excessive shrinkage and cracking if not properly controlled. Researchers have explored various curing regimes, including ambient curing, steam curing, and autoclave curing, to optimize the mechanical properties and durability of geopolymer concrete under different environmental conditions.

Sustainability Assessment of Agro-Waste-Based Construction Materials: Sustainability assessments play a crucial role in evaluating the environmental, social, and economic impacts of agro-waste-based construction materials. Previous studies have employed life cycle assessment (LCA), carbon footprint analysis, and cost-benefit analysis to quantify the environmental benefits, resource savings, and economic viability of utilizing agro-waste materials in construction. These assessments consider factors such as raw material extraction, manufacturing processes, transportation, use phase, and end-of-life disposal to provide a comprehensive evaluation of the sustainability performance of agro-waste-based construction materials. Researchers have highlighted the potential of these materials to contribute to greenhouse gas emissions reduction, energy conservation, waste minimization, and rural development, thereby promoting sustainable construction practices.

2. Methodology

The experimental study involved determining the silica oxide content of RHA, SDA, and CDA through laboratory testing, following IS1727 and IS3813-1 test methods. The ashes were then mixed with an alkaline solution composed of Sodium Silicate and Sodium Hydroxide in a specified ratio to form the geopolymer binder. Geopolymer concrete specimens were cast using varying proportions of RHA, SDA, and CDA, and subjected to curing at 100°C for 24 hours, 48 hours, and 72 hours. The mechanical properties, including compressive strength, split tensile strength, and flexural strength, were evaluated using standard testing procedures.

The primary materials used in this study include Rice Husk Ash (RHA), Saw Dust Ash (SDA), and Cow Dung Ash (CDA), obtained from local agricultural sources. These agro-waste ashes were collected, processed, and characterized to determine their chemical composition, particularly the percentage of silica oxides. Laboratory testing, following standardized procedures such as IS1727 and IS3813-1, was conducted to quantify the silica content in each ash sample. Additionally, an alkaline solution was prepared as the activating agent for geopolymerization, consisting of Sodium Silicate and Sodium Hydroxide in specific proportions. The proportions of RHA, SDA, and CDA in the geopolymer concrete mixes were varied to assess their influence on the mechanical properties.

Mix Design and Specimen Preparation: Geopolymer concrete mixes were designed using a fixed ratio of alkaline solution to agro-waste ash, with different proportions of RHA, SDA, and CDA. The mix proportions were optimized based on preliminary tests to achieve desirable workability and mechanical properties. Standard concrete ingredients such as fine aggregate, coarse aggregate, and water were used in combination with the agro-waste ashes and alkaline solution. The mixtures were thoroughly blended using a mechanical mixer to ensure homogeneity.

Specimens were cast in accordance with relevant standards, such as ASTM C192 for cylindrical specimens and ASTM C78 for prismatic specimens, to evaluate compressive and flexural strengths, respectively. Molded specimens were compacted using vibration to minimize voids and ensure uniform distribution of materials. After casting, the specimens were covered with plastic sheeting to prevent moisture loss and placed in a curing chamber set at a constant temperature of 100°C for predetermined curing durations (24 hours, 48 hours, and 72 hours).

Testing Procedures: Following the curing period, the hardened geopolymer concrete specimens were subjected to mechanical testing to evaluate their compressive, split tensile, and flexural strengths. Compressive strength tests were conducted on cylindrical specimens using a compression testing machine in accordance with ASTM C39. Split tensile strength tests were performed on cylindrical specimens, while flexural strength tests were carried out on prismatic specimens using appropriate testing apparatus and procedures specified in relevant standards. The tests were repeated for each curing duration to assess the effect of curing time on the mechanical properties of geopolymer concrete incorporating RHA, SDA, and CDA.

4. Experimental Results

The results of the experimental investigation revealed that the incorporation of RHA, SDA, and CDA into geopolymer concrete led to improvements in mechanical properties compared to conventional concrete mixes. However, RHA-based geopolymer concrete exhibited the highest compressive, split tensile, and flexural strengths among the tested specimens. This superior performance can be attributed to the higher silica oxide content of RHA, which facilitates the formation of a denser and more durable concrete matrix. Additionally, the curing period significantly influenced the mechanical properties, with longer curing durations resulting in higher strengths for all specimens.

5. Conclusion

The findings of this study demonstrate the potential of utilizing agro-waste ashes, particularly RHA, as supplementary materials in geopolymer concrete for sustainable construction applications. By repurposing agricultural by-products rich in silica oxides, this approach not only enhances the mechanical properties of concrete but also contributes to reducing agricultural waste and mitigating environmental impact. Further research is warranted to explore optimization strategies and assess the long-term performance of agro-waste-based geopolymer concrete in real-world applications.

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