Effect of Slag on Fresh and Mechanical Properties of Rha-Slag Based Geopolymer Paste

Ahmed Khan[1], Faizan Khan[2], S. Vijaya Shekara Goud[3], W. Hemanth Kumar[4]
[1234]U.G Students, Department of Civil Engineering
Ballari Institute of Technology and Management, Ballari, Karnataka, India

How to Cite this Article:
Kumar, W. H., Goud, S. V. S., Khan, F. & Khan, A. (2026). Effect of Slag on Fresh and Mechanical Properties of Rha-Slag Based Geopolymer Paste. International Journal of Creative and Open Research in Engineering and Management, <i>02</i>(05).
https://doi.org/10.55041/ijcope.v2i5.286

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ABSTRACT

The rapid growth of the construction industry has led to increased consumption of Ordinary Portland Cement (OPC), which contributes significantly to global carbon dioxide emissions. Geopolymer technology has emerged as a sustainable alternative binder utilizing industrial and agricultural waste materials. Rice Husk Ash (RHA), an agricultural by-product rich in silica, has potential as a geopolymer precursor; however, its low calcium content limits early strength development. This study investigates the influence of Ground Granulated Blast Furnace Slag (GGBS) on the fresh and mechanical properties of RHA-based geopolymer paste. Geopolymer paste specimens were prepared by partially replacing RHA with slag at different proportions. Sodium hydroxide and sodium silicate solutions were used as alkaline activators, and specimens were cured under ambient conditions. Fresh properties such as workability and setting time were evaluated, while compressive strength tests were conducted to determine mechanical performance. Experimental results indicate that the incorporation of slag significantly improves workability, reduces setting time, and enhances compressive strength. The improved performance is attributed to the formation of N-A-S-H and C-A-S-H gel structures that produce a denser geopolymer matrix. The study demonstrates that RHA–slag geopolymer paste can serve as a sustainable and low-carbon alternative to conventional cement-based materials.

Keywords Geopolymer, Rice Husk Ash (RHA), Sustainable Construction, Compressive Strength, Alkaline Activation.

I. INTRODUCTION

Concrete is the most widely used construction material due to its strength, durability, and versatility. Ordinary Portland Cement (OPC) acts as the primary binding material in conventional concrete. However, the manufacturing process of OPC releases significant quantities of carbon dioxide and consumes large amounts of natural resources. The cement industry contributes nearly 7–8% of global CO_2 emissions, creating a need for environmentally sustainable alternatives. Geopolymer technology has emerged as an effective solution for reducing the environmental impact of cement production. Geopolymers are inorganic binders formed through the alkali activation of aluminosilicate materials such as fly ash, slag, and rice husk ash. These materials react with alkaline solutions to form a hardened binder with comparable mechanical properties to traditional cement. Rice Husk Ash (RHA), an agricultural waste generated during rice processing, contains a high percentage of reactive silica. Although RHA is suitable for geopolymer applications, its low calcium content results in slower strength development. Ground Granulated Blast Furnace Slag (GGBS), an industrial by-product of steel manufacturing, is rich in calcium and can improve the mechanical performance of geopolymer systems. The objective of this study is to evaluate the influence of slag addition on the fresh and mechanical properties of RHA-based geopolymer paste and to determine an optimal mixture suitable for sustainable construction applications.

II. LITERATURE REVIEW

Recent research has focused on geopolymer binders as sustainable alternatives to conventional cement. Geopolymers are produced by activating aluminosilicate materials using alkaline solutions, forming a three-dimensional polymeric network with high strength and durability.

Several studies have investigated the use of Rice Husk Ash as a geopolymer precursor due to its high silica content and pozzolanic properties. However, researchers reported that RHA-based geopolymer systems often exhibit reduced workability and lower early-age strength due to limited calcium and alumina content.

Researchers have explored blending RHA with calcium-rich materials such as slag to improve geopolymer performance. The addition of Ground Granulated Blast Furnace Slag enhances early strength development due to the formation of calcium-aluminosilicate-hydrate (C-A-S-H) gel along with sodium-aluminosilicate-hydrate (N-A-S-H) gel.

Based on the literature review, it is evident that optimizing the proportion of slag in RHA-based geopolymer systems is essential to achieve improved performance and practical applicability in construction.

III. METHODOLOGY

The experimental investigation involved the preparation of geopolymer paste using Rice Husk Ash and Ground Granulated Blast Furnace Slag as precursor materials.

Materials Used

The primary materials used in this study include:

• Rice Husk Ash (RHA)
• Ground Granulated Blast Furnace Slag (GGBS)
• Sodium Hydroxide (NaOH)
• Sodium Silicate (Na_2SiO_3)
• Distilled Water

RHA was used as the primary silica source, while slag was incorporated to provide calcium and improve strength development.

Mix Proportions

Different mixtures were prepared by partially replacing RHA with slag at varying percentages.

Mix ID	**RHA (%)**	
R8S2	**80**	**20**
R7S3	**70**	**30**
R6S4	**60**	**40**
R5S5	**50**	**50**

Preparation Procedure

The required quantities of RHA and GGBS were dry mixed thoroughly. The alkaline activator solution was prepared by combining sodium hydroxide and sodium silicate solutions and allowing the mixture to cool for 24 hours. The activator was then added to the dry mix to produce a homogeneous geopolymer paste.

Casting and Curing

The prepared geopolymer paste was poured into standard cube molds and compacted to remove air voids. After 24 hours, specimens were demolded and cured under ambient conditions.

Testing Methods

The following tests were conducted:
• Flow test to evaluate workability
• Setting time test
• Compressive strength test at different curing ages

IV. RESULTS AND ANALYSIS

The experimental results demonstrate that slag content significantly influences the fresh and mechanical properties of RHA-based geopolymer paste.

Fresh Properties

The addition of slag improved the workability of the geopolymer paste due to improved particle packing and reaction kinetics. Setting time decreased with increasing RHA content because silica in RHA accelerates geopolymerization reactions. However, at higher RHA contents, rapid stiffening was observed, which could affect handling and placement.

Mechanical Properties

Compressive strength increased with higher slag replacement levels. The mixture containing equal proportions of RHA and slag exhibited the highest compressive strength. Strength development was observed at 3, 7, and 28 days of ambient curing. The results indicate that strength increases significantly during early curing stages, particularly for slag-rich mixtures. The improved mechanical performance is attributed to the formation of a dense geopolymer matrix consisting of N-A-S-H and C-A-S-H gel structures.

V. CONCLUSION

This study evaluated the effect of slag incorporation on the fresh and mechanical properties of RHA-based geopolymer paste. The experimental results indicate that the addition of slag significantly improves workability, reduces setting time, and enhances compressive strength. The presence of calcium in slag accelerates geopolymerization and promotes the formation of a dense microstructure, resulting in improved mechanical performance. Among the mixtures studied, the geopolymer paste containing balanced proportions of RHA and slag demonstrated superior strength characteristics.

The findings confirm that RHA–slag geopolymer systems can serve as a sustainable alternative to conventional cement-based materials. Future research may focus on durability studies, large-scale applications, and optimization of curing conditions.

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