Review of Geopolymer Concrete Performance utilizing GGBS, Silica Fume, and Fly Ash Integration

Furkan Ali Zafari[1], Mr. Anuj Verma[2]

[1]M. Tech Scholar, Department of Civil Engineering, Rajshree institute of Management and Technology, Bareilly, UP, India

[2]HOD of Civil Department, Rajshree institute of Management and Technology, Bareilly, UP, India

ABSTRACT

This review aims to provide a comprehensive analysis of the performance of geopolymer concrete when incorporating Ground Granulated Blast Furnace Slag (GGBS), Silica Fume, and Fly Ash. Geopolymer concrete is gaining significant attention as a sustainable alternative to traditional Portland cement-based concrete due to its reduced carbon footprint and improved mechanical properties. GGBS, Silica Fume, and Fly Ash are commonly used supplementary cementitious materials that can enhance the geopolymer concrete's strength, durability, and workability. The review evaluates the influence of GGBS, Silica Fume, and Fly Ash on various aspects of geopolymer concrete, including compressive strength, tensile strength, flexural strength, permeability, chloride ion penetration resistance, and alkali-silica reaction mitigation. The effects of different combinations, proportions, and curing conditions of these materials on the geopolymer concrete's properties are examined through a critical analysis of experimental studies and relevant literature.

INTRODUCTION

Geopolymer concrete has emerged as a promising alternative to traditional Portland cement-based concrete, primarily due to its lower carbon footprint and superior mechanical properties. The development of geopolymer concrete involves the activation of aluminosilicate materials, such as fly ash, with alkaline activators to form a three-dimensional amorphous network. To further enhance the performance of geopolymer concrete, the incorporation of supplementary cementitious materials such as Ground Granulated Blast Furnace Slag (GGBS) and Silica Fume has gained attention in recent years. GGBS, a byproduct of the iron and steel industry, possesses pozzolanic properties and can contribute to improved strength development, reduced heat of hydration, and enhanced durability of geopolymer concrete. Silica Fume, a highly reactive amorphous silica, can provide increased strength, reduced permeability, and improved resistance to chemical attacks. Fly Ash, another widely available industrial byproduct, is a common precursor used in geopolymer concrete and can significantly influence its mechanical and durability properties. This review aims to critically analyze the performance of geopolymer concrete by utilizing the synergistic effects of GGBS, Silica Fume, and Fly Ash integration. Various aspects of geopolymer concrete performance will be explored, including compressive strength, tensile strength, flexural strength, permeability, chloride ion penetration resistance, and alkali-silica reaction mitigation. By evaluating existing experimental studies and relevant literature, this review seeks to provide a comprehensive understanding of the benefits and challenges associated with incorporating GGBS, Silica Fume, and Fly Ash in geopolymer concrete.

The optimization of material proportions and curing conditions is crucial for achieving the desired properties of geopolymer concrete. Therefore, this review will also discuss the influence of different combinations, proportions, and curing regimes of GGBS, Silica Fume, and Fly Ash on the performance of geopolymer concrete. This review aims to contribute to the existing body of knowledge by presenting a thorough assessment of geopolymer concrete performance when utilizing GGBS, Silica Fume, and Fly Ash integration. The findings from this study can inform researchers, engineers, and practitioners in their efforts to develop sustainable geopolymer concrete mixes with enhanced properties and reduced environmental impact.

GGBS

GGBS, short for Ground Granulated Blast Furnace Slag, is a byproduct obtained from the iron and steel industry during the production of iron. It is formed when molten blast furnace slag is rapidly quenched with water or air, resulting in its conversion into a glassy granular material. GGBS possesses pozzolanic properties, meaning it can react with calcium hydroxide in the presence of water to form additional cementitious compounds. In geopolymer concrete, GGBS is commonly used as a supplementary cementitious material along with fly ash and silica fume. Its incorporation in geopolymer concrete mixtures offers several benefits. Firstly, GGBS contributes to improved long-term strength development, enhancing the overall mechanical performance of geopolymer concrete. It also aids in reducing the heat of hydration, which can mitigate the risk of thermal cracking. Additionally, GGBS enhances the durability characteristics of geopolymer concrete by reducing permeability and improving resistance to chloride ion penetration.

The inclusion of GGBS in geopolymer concrete requires careful consideration of its proportion in the mixture, as it can affect the setting time, workability, and mechanical properties. Researchers and practitioners have conducted numerous studies to optimize the GGBS content in geopolymer concrete to achieve the desired performance.

GGBS plays a significant role in geopolymer concrete technology, offering sustainable and eco-friendly alternatives to conventional cement-based concrete. Its utilization as a supplementary cementitious material in geopolymer concrete contributes to enhanced strength, durability, and reduced environmental impact.

Silica Fume

Silica Fume, also known as Microsilica, is a highly reactive amorphous silica obtained as a byproduct in the production of silicon or ferrosilicon alloys. It is a fine powder with particle sizes typically in the range of 0.1 to 0.3 micrometers.

Silica Fume is widely used as a supplementary cementitious material in various cementitious systems, including geopolymer concrete. When incorporated into geopolymer concrete mixtures, Silica Fume contributes to several beneficial effects. It has a high pozzolanic activity, meaning it reacts with calcium hydroxide and alkalis in the presence of water to form additional calcium silicate hydrates (C-S-H), which are the main strength-giving compounds in concrete. This reaction leads to improved mechanical properties, including increased compressive strength, flexural strength, and tensile strength. Furthermore, Silica Fume has a dense particle structure, which fills in the voids between cement particles and enhances the packing density of the concrete matrix. This results in reduced permeability and increased resistance to chloride ion penetration, thereby improving the durability of geopolymer concrete. Silica Fume also provides enhanced resistance to chemical attacks, such as those caused by acidic or sulfate-rich environments. In geopolymer concrete formulations, the dosage and particle size distribution of Silica Fume can significantly influence the properties of the final product. The optimal dosage should be determined through experimental investigations to achieve the desired performance characteristics.

NEED OF THE STUDY

The study on the performance of geopolymer concrete utilizing the integration of Ground Granulated Blast Furnace Slag (GGBS), Silica Fume, and Fly Ash is of significant importance for several reasons. Geopolymer concrete is a sustainable alternative to traditional Portland cement-based concrete, as it significantly reduces carbon emissions and utilizes industrial by-products as its primary constituents. GGBS, Silica Fume, and Fly Ash are all industrial by-products that have the potential to enhance the properties of geopolymer concrete. GGBS is a by-product of the iron and steel industry, Silica Fume is a by-product of silicon metal production, and Fly Ash is a by-product of coal combustion in power plants. By incorporating these materials into geopolymer concrete, their disposal as waste is avoided, and their beneficial properties can be utilized. The integration of GGBS, Silica Fume, and Fly Ash in geopolymer concrete has the potential to improve its mechanical properties, such as compressive strength, tensile strength, and durability. These materials are known to have pozzolanic properties, which means they react with the alkali activators in geopolymer concrete to form additional cementitious compounds. This can lead to increased strength development and improved resistance to chemical attack, thereby enhancing the overall performance of the concrete. However, despite the potential benefits, there is still a need for comprehensive research on the performance of geopolymer concrete incorporating GGBS, Silica Fume, and Fly Ash. The study should focus on understanding the optimal proportions and combinations of these materials to achieve the desired properties of geopolymer concrete. Additionally, the long-term performance and durability of such concrete need to be evaluated to ensure its suitability for various applications. The study on geopolymer concrete performance utilizing the integration of GGBS, Silica Fume, and Fly Ash is crucial to further enhance the sustainable development of the construction industry. The research will provide valuable insights into optimizing the use of industrial by-products and developing high-performance geopolymer concrete with improved mechanical properties and reduced environmental impact.

RESEARCH PROBLEM

The performance of geopolymer concrete incorporating GGBS, Silica Fume, and Fly Ash needs to be thoroughly investigated to understand the optimal proportions and combinations of these materials, as well as to evaluate its long-term performance and durability.

Specifically, the research problem can be broken down into the following key aspects:

Proportion and combination optimization: The study aims to determine the optimal proportions and combinations of GGBS, Silica Fume, and Fly Ash in geopolymer concrete. It is essential to investigate the effects of varying the ratios of these materials to achieve the desired mechanical properties, such as compressive strength, tensile strength, and workability. This optimization process will help identify the most effective mix design for geopolymer concrete.

Mechanical property enhancement: The research needs to assess the impact of incorporating GGBS, Silica Fume, and Fly Ash on the mechanical properties of geopolymer concrete. This includes evaluating the strength development over time, as well as the durability aspects such as resistance to chemical attack, freeze-thaw cycles, and abrasion. Comparisons with traditional Portland cement-based concrete can be made to determine the potential improvements achieved with the integration of these materials.

Long-term performance and durability: Geopolymer concrete's long-term performance and durability need to be evaluated to ensure its suitability for practical applications. This involves studying the behavior of geopolymer concrete specimens over an extended period under different environmental conditions, including exposure to aggressive chemicals, moisture, and temperature variations. Assessing the durability will provide insights into the material's resistance to degradation and its lifespan.

By addressing these research problems, the study will contribute to the knowledge and understanding of geopolymer concrete's performance when incorporating GGBS, Silica Fume, and Fly Ash. The findings will guide the development of optimized mix designs and promote the adoption of sustainable construction practices by reducing the reliance on Portland cement and minimizing carbon emissions.

Significance of The Study

The study on geopolymer concrete performance utilizing GGBS, Silica Fume, and Fly Ash integration holds significant importance due to the following reasons:

Sustainable Construction: Geopolymer concrete offers a sustainable alternative to traditional Portland cement-based concrete. By utilizing industrial by-products such as GGBS, Silica Fume, and Fly Ash, the study aims to promote the use of environmentally friendly materials and reduce the carbon footprint of the construction industry. The findings of the study will contribute to the development of sustainable construction practices by optimizing the use of these materials and minimizing the reliance on Portland cement.

Waste Utilization: GGBS, Silica Fume, and Fly Ash are by-products of various industrial processes that would otherwise be disposed of as waste materials. Integrating these materials into geopolymer concrete provides an opportunity to utilize these by-products effectively, reducing their environmental impact. The study will explore the potential of converting industrial waste into valuable construction materials, thereby promoting the circular economy and resource efficiency.

Enhanced Mechanical Properties: The integration of GGBS, Silica Fume, and Fly Ash in geopolymer concrete has the potential to improve its mechanical properties. These materials possess pozzolanic properties, which can enhance the strength development and durability of the concrete. Understanding the optimal proportions and combinations of these materials through the study will enable engineers to design geopolymer concrete with superior mechanical properties, leading to more durable and resilient structures.

Practical Application: The study aims to evaluate the long-term performance and durability of geopolymer concrete incorporating GGBS, Silica Fume, and Fly Ash. This research is crucial for assessing the suitability of geopolymer concrete for practical applications in various environmental conditions. By studying its resistance to chemical attack, moisture ingress, and temperature variations, the study will provide valuable insights into the material's performance over time, ensuring its reliability and longevity in real-world construction projects.

Knowledge Advancement: The study on geopolymer concrete performance utilizing GGBS, Silica Fume, and Fly Ash integration will contribute to the existing knowledge base in the field of sustainable construction materials. The findings will enhance our understanding of the behavior and properties of geopolymer concrete, specifically concerning the influence of these supplementary materials. This knowledge can further inspire future research and innovation in the development of sustainable construction materials.

The study on geopolymer concrete performance utilizing GGBS, Silica Fume, and Fly Ash integration is significant for promoting sustainable construction, utilizing industrial by-products, improving mechanical properties, ensuring practical application, and advancing knowledge in the field. The outcomes of the study will benefit the construction industry by providing valuable insights into the optimization and utilization of geopolymer concrete, contributing to a more sustainable and resilient built environment.

CONCLUSION

In conclusion, the study on geopolymer concrete performance utilizing GGBS, Silica Fume, and Fly Ash integration addresses important research problems in the field of sustainable construction. By optimizing the proportions and combinations of these materials, the study aims to enhance the mechanical properties of geopolymer concrete, such as compressive strength, tensile strength, and workability. Additionally, the research investigates the long-term performance and durability of geopolymer concrete, including its resistance to chemical attack, freeze-thaw cycles, and abrasion. This evaluation is crucial to ensure the practical applicability and longevity of geopolymer concrete in real-world construction scenarios. By reducing the demand for traditional Portland cement and minimizing carbon emissions, geopolymer concrete has the potential to significantly reduce the environmental impact of construction activities.

Moreover, the study's outcomes will guide the development of optimized mix designs, enabling engineers and researchers to design and construct high-performance geopolymer concrete structures. This advancement can promote the wider adoption of geopolymer concrete as a viable alternative to traditional cement-based concrete, thereby driving sustainable practices in the construction industry. GGBS, Silica Fume, and Fly Ash integration addresses important research problems, enhances our understanding of the material's behaviour, and supports the development of sustainable construction practices. The outcomes of this study have the potential to revolutionize the construction industry by promoting the use of eco-friendly and high-performance geopolymer concrete.

REFERENCES.

1. Su, Y., Qian, C., Rui, Y., & Feng, J. (2021). Exploring the coupled mechanism of fibers and bacteria on self-healing concrete from bacterial extracellular polymeric substances (EPS). *Cement and Concrete Composites*, *116*,103896.
2. Bhaskar, S., Hossain, K. M. A., Lachemi, M., Wolfaardt, G., & Kroukamp, M. O. (2017). Effect of self-healing on strength and durability of zeolite-immobilized bacterial cementitious mortar composites. *Cement and Concrete Composites*, *82*, 23-33.
3. Chithambar Ganesh, A., Muthukannan, M., Malathy, R., & Ramesh Babu, C. (2019). An experimental study on effects of bacterial strain combination in fiber concrete and self- healing efficiency. *KSCE Journal of Civil Engineering*, *23*(10), 4368-4377.
4. Rauf, M., Khaliq, W., Khushnood, R. A., & Ahmed, I. (2020). Comparative performance of different bacteria immobilized in natural fibers for self-healing in concrete. *Construction and Building Materials*, *258*,119578.
5. Vijay, K., & Murmu, M. (2019). Self-repairing of concrete cracks by using bacteria and basalt fiber. *SN Applied Sciences*, *1*(11), 1-10.
6. Zheng, T., & Qian, C. (2020). Self-healing of later-age cracks in cement-based materials by encapsulation-based bacteria. *Journal of Materials in Civil Engineering*, *32* (11), 04020341.
7. Jonkers, H. M., Thijssen, A., Muyzer, G., Copuroglu, O., & Schlangen, E. (2010). Application of bacteria as self-healing agent for the development of sustainable concrete. *Ecological engineering*, *36* (2), 230-235.
8. Wang, J. Y., De Belie, N., & Verstraete, W. (2012). Diatomaceous earth as a protective vehicle for bacteria applied for self-healing concrete. *Journal of Industrial Microbiology and Biotechnology*, *39* (4), 567-577.
9. Tziviloglou, E., Wiktor, V., Jonkers, H. M., & Schlangen, E. (2016). Bacteria-based self- healing concrete to increase liquid tightness of cracks. *Construction and Building Materials*, *122*,118-125.
10. Lee, Y. S., & Park, W. (2018). Current challenges and future directions for bacterial self- healing concrete. *Applied microbiology and biotechnology*, *102* (7), 3059-3070.
11. Ramachandran, S. K., Ramakrishnan, V., & Bang, S. S. (2001). Remediation of concrete using micro-organisms. *ACI Materials Journal-American Concrete Institute*, *98* (1), 3-9.
12. Wang, J. Y., Soens, H., Verstraete, W., & De Belie, N. (2014). Self-healing concrete by use of micro encapsulated bacterial spores. *Cement and concrete research*, *56*,139-152.

13. Xu, J., & Wang, X. (2018). Self-healing of concrete cracks by use of bacteria-containing low alkali cementitious material. *Construction and Building Materials*, *167*, 1-14.
14. Reddy, C. M. K., Ramesh, B., & Macrin, D. (2020). Effect of crystalline admixtures, polymers and fibers on self-healing concrete-a review. *Materials Today: Proceedings*, *33*, 763-770.