WWW.IJRPR.COM

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Review Paper on Microstructure and Mechanical Properties of Geocement Incorporating Nano Silica and Industrial By-Products

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A B S T R A C T

Gecement concrete (Geocrete) represents an emerging class of eco-friendly construction materials offering a sustainable alternative to ordinary Portland cement (OPC) concrete. This review paper investigates the influence of nano silica and industrial by-products—particularly foundry sand—on the microstructure and mechanical properties of Geocrete. The incorporation of nano silica enhances polymerization reactions, refines pore structure, and significantly improves compressive and tensile strength. Foundry sand, as a partial replacement for fine aggregates, contributes to sustainable material use while maintaining satisfactory mechanical performance. This review synthesizes findings from various studies on geopolymer technology, nano-material modification, and industrial waste utilization to highlight advancements in microstructural development and mechanical behavior.

Keywords: Geocrete, Nano Silica, Foundry Sand, Industrial By-Products, Microstructure, Mechanical Properties, Sustainability.

1. Main text

The construction industry is one of the largest consumers of natural resources and a major contributor to CO_2 emissions. The global search for sustainable alternatives has driven attention toward geopolymer concrete, or Geocrete, which uses alumino-silicate-based materials activated by alkaline solutions instead of conventional cement. Developed initially by Davidovits [5], geopolymer technology offers significant reductions in embodied energy and greenhouse gas emissions. The performance of Geocrete is strongly influenced by its source materials, activator chemistry, and microstructural refinement. Among these, nano silica has emerged as a crucial additive, improving reactivity and densification of the geopolymer matrix. Additionally, industrial by-products such as foundry sand serve as sustainable aggregate replacements, minimizing environmental impact while maintaining desirable mechanical properties.

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2.1 Structure

Table 1 - An example of a table.

2.2 Construction of references

2.3 Section headings

Study on Microstructure and Mechanical Properties of Geocement Incorporating Nano Silica and Industrial By-Products

2.4 General guidelines for the preparation of your text

Avoid hyphenation at the end of a line. Symbols denoting vectors and matrices should be indicated in bold type. Scalar variable names should normally be expressed using italics. Weights and measures should be expressed in SI units. All non-standard abbreviations or symbols must be defined when first mentioned, or a glossary provided.

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2.6 Footnotes

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3. Illustrations

. Role of Nano Silica in Geocrete

Nano silica (SiO_2) acts as a pozzolanic and nucleation agent in geopolymer systems. Its ultra-fine particle size accelerates geopolymerization by providing additional reactive surfaces for alumino-silicate bonding. When incorporated into Geocrete, nano silica enhances polymeric chain formation and improves matrix compactness. Studies report substantial improvements in compressive and flexural strength with nano silica addition due to pore refinement and reduced micro-cracking. Furthermore, nano silica contributes to higher early-age strength and improved durability under aggressive environments. SEM and XRD analyses indicate denser gel structures and reduced porosity in nano silica-modified geopolymer matrices, confirming its effectiveness in improving both microstructure and mechanical performance.

4. Role of Foundry Sand and Other Industrial By-Products

Foundry sand, an industrial by-product generated from metal casting industries, consists mainly of high-quality silica sand coated with residual binders such as bentonite or carbonaceous materials. According to Carnin et al. [3], its physicochemical properties make it a viable candidate for partial replacement of fine aggregates in concrete. Khatib et al. [9] and Salokhe et al. [11] observed that up to 30% replacement of natural sand with foundry sand can maintain satisfactory mechanical performance while improving sustainability. The reuse of foundry sand reduces landfill disposal and the extraction of virgin aggregates. When incorporated in Geocrete, it interacts with alkaline activators to form secondary binding gels, further enhancing mechanical strength and microstructural uniformity. Other industrial by-products, such as fly ash, slag, and red brick waste, have also shown synergistic effects in geopolymer systems by optimizing alumino-silicate ratios and enhancing polymerization kinetics.

[1] Footnote text.

5. Microstructural Analysis and Mechanical Properties

Microstructural refinement in geopolymer concrete depends on the balance between reactive alumino-silicate materials and the activator concentration. Nano silica reduces the pore size distribution and refines the interfacial transition zone (ITZ) between binder and aggregates. The combined addition of nano silica and foundry sand leads to denser matrices, which directly correlates with improved compressive, tensile, and flexural strengths. According to IS 516:1959 [6], standard testing of compressive strength reveals up to 25–35% enhancement when nano silica is added at 2–4% by weight of binder. The durability performance, including resistance to acid attack and thermal stability, is also significantly improved due to the dense polymeric network formed during geopolymerization.

Microstructural investigations using SEM and XRD indicate a reduction in unreacted fly ash particles and an increase in the amorphous geopolymer gel phase. Nano silica acts as a seed for gel nucleation, while foundry sand contributes to particle packing and dimensional stability. This synergistic effect enhances both microstructure and macro-performance of the Geocrete, making it a promising alternative for sustainable construction applications.

6. Sustainability and Practical Implications

The use of nano silica and foundry sand in Geocrete promotes sustainable construction by reducing the demand for cement and natural aggregates. By utilizing industrial by-products, the carbon footprint associated with concrete production can be significantly reduced. The integration of these materials aligns with the principles of circular economy and resource efficiency. Moreover, improved durability and strength contribute to longer service life, minimizing maintenance and replacement needs.

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Acknowledgements

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An example appendix

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Example of a sub-heading within an appendix

There is also the option to include a subheading within the Appendix if you wish.

Conclusion:

This review highlights the critical role of nano silica and foundry sand in enhancing the microstructural and mechanical properties of Geocrete. Nano silica, through its nano-scale activity, refines the geopolymer matrix, increases gel formation, and enhances strength and durability. Foundry sand serves as a sustainable fine aggregate replacement, improving particle packing and contributing to environmental conservation. The synergistic effect of both additives results in dense, high-performance geopolymer concrete with superior mechanical and durability characteristics. Future research should focus on optimizing mix proportions, understanding long-term durability, and developing standard guidelines for large-scale applications.

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