NANO-SILICA: CATALYST FOR ADVANCING AMBIENT CURED GROUND GRANULATED BLAST FURNACE SLAG BASED GEOPOLYMER CONCRETE CHARACTERISTICS

Project Reference No.: *48S_BE_4283*

College : Jyothy Institute of Technology, Bengaluru
Branch : Civil Engineering
Guide(S) : Dr. Sreekeshava K S
Mr. Ganesh C R
Student(S) : Ms. Akshatha R
Mr. Nithin Kumar R J
Mr. Prajwal N
Ms. Yuvasree M

Keywords:
Geopolymer concrete, Nano silica, GGBS, Fly ash, Sodium silicate, Sodium hydroxide, Ambient curing, Rebound hammer test, Compression test, Scanning Electro Microscopy (SEM), X-Ray Diffraction (XRD).

Introduction:

Concrete is a fundamental construction material, primarily composed of cement, aggregates (like sand and gravel), and water. Cement acts as a binder, hardening and adhering the aggregates together. Ordinary Portland Cement (OPC) is the most common type of cement used globally.

However, the production of OPC is energy-intensive and releases significant amounts of carbon dioxide (CO_2), a major greenhouse gas, into the atmosphere. This makes the widespread use of cement a significant contributor to climate change. Additionally, the extraction of raw materials for cement production can have detrimental environmental impacts on landscapes and ecosystems.

Geopolymer concrete emerges as a more sustainable alternative. Unlike traditional concrete that uses OPC, geopolymer concrete utilizes industrial by-products rich in alumina and silica, such as fly ash (from coal-fired power plants) or ground granulated blast furnace slag (GGBS) (from iron and steel production). These materials are activated using an alkaline solution to create a binder.

Objectives: This study investigates the potential of nano-silica as a performance enhancing additive for ambient-cured geopolymer concrete. The scope includes examining the influence of nano-silica on the microstructural, mechanical, and durability properties of geopolymer concrete, with a focus on practical applications in sustainable construction. The main scope of this present study includes the following.

1. Evaluation of fresh and hardened properties, including workability, compressive strength, and flexural strength.
2. Microstructural analysis using techniques such as SEM (Scanning Electron Microscopy) and XRD (X-ray Diffraction) to assess the interaction between nano-silica and the geopolymer matrix.
3. Durability assessments, including resistance to chemical attack, water permeability, and drying shrinkage.
4. To evaluate the impact of nano-silica on the fresh properties of geopolymer concrete.
5. To understand the microstructural changes induced by nano-silica & to establish the optimal dosage of nano-silica for maximizing benefit.
6. To assess the durability performance of nano-silica-modified geopolymer concret

Introduction/Background:

Selection of geopolymer precursors such as fly ash or slag and optimization of their mix proportions. Incorporation of varying dosages of nano-silica into geopolymer concrete.

Concrete is the primary material used in the construction of all structures. Water is used more than concrete worldwide. Portland cement is the primary ingredient used to make concrete. However, environmental pollution and global warming pose the greatest threat to humanity today. Because $CO2$ is released throughout the cement-making process, pollution is produced. When cement is being produced, $CO2$ emissions come from two distinct sources. The biggest source of CO_2 is the combustion of fossil fuels to run the rotary kiln. Another source is the chemical process in the cement kiln that turns limestone into lime. About 5% of all carbon dioxide emissions worldwide are caused by the cement industry.

Furthermore, Degradation of the environment is another effect of quarrying these basic resources. About 1.6 tons of raw ingredients are needed to make 1 ton of cement, and it takes a lot longer to manufacture the lime stone than it does for people. However, because concrete is so easy to prepare and fabricate in a variety of handy shapes, its demand is growing daily. Therefore, environmentally friendly concrete should be used to solve this issue. A cutting-edge building material, geopolymer concrete (GPC) lowers the need for regular Portland cement (OPC), protects natural resources, ensures environmental safety, addresses industrial waste disposal issues, and yields high- strength concrete.

Remedies: Reduced Carbon Footprint. By utilizing industrial wastes and eliminating the need for OPC, geopolymer concrete significantly lowers CO2 emissions associated with concrete production. Some studies suggest a reduction of up to 80% in embodied carbon compared to OPC concrete.

1. **Waste Valorization:** It provides a beneficial use for industrial by-products that would otherwise require disposal, contributing to a circular economy.
2. **Enhanced Durability:** Geopolymer concrete often exhibits superior resistance to chemical attacks, including sulfates and chlorides, as well as high temperatures, potentially leading to longer-lasting structures, especially in aggressive environments.
3. **Comparable or Superior Strength:** Geopolymer concrete can achieve comparable or even higher compressive strength than conventional concrete, often with faster curing times.

Methodology:

The step-by-step experimental process involved in comparing geopolymer concrete with conventional concrete. The methodology begins with the procurement and basic testing of materials, followed by the preparation of an alkaline solution essential for geopolymer mix design. It proceeds with testing the fresh concrete for workability, casting specimens, and curing under controlled conditions. Subsequent stages include testing hardened concrete for mechanical properties and conducting a comparative analysis between geopolymer and traditional concrete types. The process concludes with drawing meaningful conclusions based on the experimental results, making the flowchart an effective visual representation of the research workflow.

Results & Conclusions:

1. The basic material testing result such as specific gravity, sieve analysis, water absorption etc, are conducted to check the property of particular material in permissible range.
2. Micro structural analysis is conducted to evaluate the interaction between the Geo polymer concrete, the methods like SEM and XRD is used for elemental and morphological analysis.
3. For 28 days compressive strength for the equal combinations of fly ash and cement was found to be 47.55 MPa and for 28 days the compressive strength for equal combinations of GGBS and cement was found to be 62.49% by comparing these two GGBS gives better compressive strength.
4. For 90 days the compressive strength of the equal combination of fly Ash and cement was found to be 62.755 MPa similarly for GGBS and assessment was found to be 40.66 % fly ash gives better strength for 90 days. Due to the presence of Fly Ash.

Project Outcomes and Learnings:

The following outcomes are expected after completion of proposed work.

1. Stronger, more durable concrete with better mechanical properties.
2. Improved sustainability with reduced environmental impact.
3. Practical insights into the use of nano-silica for concrete applications.

Future Scope:

1. Durability test to be conducted for all the samples Acid and sulphate Attack test (HCL and MnSO4) for different mix ratios of GGBS, fly ash and Precipitated silica.
2. Further Cost analysis can be done for Geopolymer Mixes and compared with conventional geopolymer concrete.
3. To Investigate improvements in compressive, tensile and flexural strength.