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Research Paper

A STUDY ON STRUCTURAL PERFORMANCE OF NANO SILICA BASED GEO POLYMER CONCRETE

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ABSTRACT

In recent years, geopolymer concrete has attracted a lot of attention since it is a sustainable and environmentally friendly material with a small carbon footprint. The geopolymer concrete's qualities, such as mechanical strength, durability, and resistance to severe conditions, are improved by the addition of inhibitors. In this study, we offer an abstract on how corrosion inhibitors affect the characteristics of geopolymer concrete. In the study, fly ash, GGBS activated with NaOH and Na2SiO3, and the corrosion inhibitors sodium chloride and sodium nitrite, were used to create geopolymer concrete. The strengths of compressive force, split tensile force, corrosion potential, and chloride penetration of geopolymer concrete were assessed. Results indicated that the characteristics of geopolymer concrete and can be a possible replacement for conventional concrete in the building sector. The addition of corrosion inhibitors to the geopolymer concrete enhances its properties, including durability, and resistance to harsh environments.

This study is based on the effect of geopolymer concrete cured at ambient conditions. Properties like Compression test strength, Split Tensile Test Strength, and durability properties like chloride penetration, and accelerated corrosion penetration are evaluated. The results showed an improvement in the durability properties of geopolymer concrete and canbe a promising alternative to traditional concrete in the construction industry.

Geopolymer concrete is produced from the geopolymerization process, in which molecules known as oligomers integrate to form geopolymer networks with covalent bonding. Its production expends less thermal energy and results in a smaller carbon footprint compared to Ordinary Portland Cement (OPC) concrete. As such, it is pertinent for this review article to provide critical insight into therecent progress in research on the durability of geopolymer concrete. One significant outcome of the review is that the admixture of geopolymer concrete could be blended with additives such as micro- silica and fibers such as polypropylene fibers, to enhance its durabilityto replace OPC concrete in the construction industry.

I. INTRODUCTION

1.1 Background

The construction industry is one of the largest consumers of natural resources and a major contributor to environmental pollution, primarily due to the extensive use of Ordinary Portland Cement (OPC). The production of cement releases a significant amount of carbon dioxide (CO_2), which contributes to global warming and climate change. In recent years, there has been a growing demand for sustainable and eco-friendly construction materials that can reduce the environmental impact associated with conventional concrete.

Geopolymer concrete has emerged as a promising alternative to traditional cement-based concrete. It is produced by activating industrial by-products such as fly ash and ground granulated blast furnace slag (GGBS) with alkaline solutions, thereby eliminating the need for cement. Geopolymer concrete offers several advantages, including high strength, low shrinkage, excellent durability, and resistance to chemical attacks. These properties make it a suitable material for modern construction applications.

1.2 Nano Silica in Geopolymer Concrete

Nano silica is a highly reactive material with extremely fine particle size and large surface area. When incorporated into geopolymer concrete, nano silica enhances the microstructure by filling voids and accelerating the geopolymerization process. It improves the bonding between particles, leading to increased strength and durability. The addition of nano silica also reduces porosity and enhances resistance to permeability, making the concrete more dense and compact.

1.3 Problem Statement

Although geopolymer concrete is considered an eco-friendly alternative, its performance can vary depending on the type of materials and mix proportions used. The incorporation of nano silica has shown potential in improving the properties of geopolymer concrete; however, its effect on structural performance needs detailed investigation. There is a need to analyze how nano silica influences strength, durability, and overall behaviour of geopolymer concrete under different conditions.

1.4 Objectives

- To study the structural performance of geopolymer concrete
- To investigate the effect of nano silica on strength properties
- To evaluate compressive and tensile strength
- To analyze the improvement in durability and microstructure
- To determine the optimum percentage of nano silica

1.5 Scope of Study

This study focuses on the experimental investigation of geopolymer concrete incorporating nano silica. The research includes evaluation of mechanical properties such as compressive strength and tensile strength. The work is limited to laboratory testing and does not include full-scale structural implementation.

II. LITERATURE REVIEW

The development of geopolymer concrete has gained significant attention as a sustainable alternative to conventional cement-based concrete. Researchers have extensively studied the properties of geopolymer concrete and the influence of nano materials such as nano silica on its performance.

Davidovits (1991) introduced the concept of geopolymer materials and highlighted their potential as eco-friendly binders produced from alumino-silicate sources activated by alkaline solutions. His work laid the foundation for the development of geopolymer concrete as a sustainable construction material.

Hardjito and Rangan (2005) conducted experimental studies on fly ash-based geopolymer concrete and reported that it exhibits comparable or even superior strength compared to conventional concrete. They also emphasized that curing conditions and alkaline activator concentration significantly influence the strength development.

Duxson, Fernández-Jiménez, Provis, Lukey, Palomo, and van Deventer (2007) studied the chemistry and microstructure of geopolymer materials and concluded that geopolymerization leads to the formation of a dense and durable binder. Their research highlighted the importance of raw material composition in determining mechanical properties.

Provis and van Deventer (2009) reviewed geopolymer technology and emphasized its advantages such as low carbon emissions, high durability, and resistance to chemical attack. They suggested that geopolymer concrete has great potential for future construction applications.

Jo, Kim, Tae, and Park (2007) investigated the effect of nano silica in cement-based concrete and found that nano silica significantly improves compressive strength and reduces permeability due to its filler effect and pozzolanic reactivity.

Said, Zeidan, Bassuoni, and Tian (2012) studied the influence of nano silica on concrete properties and reported that it enhances early-age strength and improves the microstructure by reducing pore size and increasing density.

Zhang and Islam (2012) examined nano silica in concrete and concluded that it accelerates hydration and improves mechanical properties, especially compressive strength and durability.

Nazari and Riahi (2011) investigated the effects of nano silica on geopolymer concrete and found that the addition of nano silica significantly increases compressive strength and reduces water absorption. The study also highlighted improvement in microstructural characteristics.

Riahi and Nazari (2012) further analyzed nano silica-based geopolymer concrete and reported that optimum dosage of nano silica enhances both strength and durability, while excessive amounts may lead to agglomeration and reduced performance.

Kong and Sanjayan (2010) studied the durability of geopolymer concrete and found that it exhibits excellent resistance to acid attack and high temperatures. The study confirmed the superior performance of geopolymer concrete compared to conventional concrete.

Deb, Sarker, and Barbhuiya (2014) investigated the mechanical and durability properties of geopolymer concrete and reported that it has high compressive strength and better resistance to chemical exposure.

Singh, Ishwarya, Gupta, and Bhattacharyya (2015) reviewed geopolymer concrete technology and emphasized its environmental benefits and suitability as a replacement for conventional concrete.

III. DATA COLLECTION

3.1 Materials Used

The materials used in this study include fly ash, ground granulated blast furnace slag (GGBS), nano silica, alkaline activators, fine aggregates, coarse aggregates, and water. Fly ash and GGBS are used as the primary source materials for geopolymerization due to their rich alumino-silicate content. These materials act as binders in place of Ordinary Portland Cement.

Nano silica is used as an additive to enhance the properties of geopolymer concrete. Due to its extremely fine particle size and high reactivity, nano silica improves the microstructure by filling voids and increasing the density of the concrete. Fine aggregates such as river sand and coarse aggregates of suitable size are used as per standard specifications. Alkaline solutions such as sodium hydroxide ($NaOH$) and sodium silicate (Na_2SiO_3) are used as activators to initiate the geopolymerization process.

3.2 Mix Proportion

The mix design for geopolymer concrete is prepared by considering the ratio of fly ash to GGBS, alkaline solution concentration, and aggregate proportions. Nano silica is added as a partial replacement in varying percentages to study its effect on the structural performance of concrete. Different mixes are prepared with varying nano silica content to determine the optimum dosage that provides maximum strength and durability.

3.3 Preparation of Specimens

The concrete specimens are prepared by first mixing the dry materials such as fly ash, GGBS, aggregates, and nano silica thoroughly. The alkaline solution is then added to the dry mix and mixed uniformly to obtain a homogenous concrete mixture. The fresh concrete is placed in moulds of standard dimensions for compressive strength and tensile strength tests. Proper compaction is carried out to remove air voids and ensure uniformity.

After casting, the specimens are allowed to set and are then cured under appropriate conditions. Depending on the mix design, curing may be done at ambient temperature or elevated temperature to enhance geopolymerization.

3.4 Testing Procedures

The prepared specimens are tested to evaluate the mechanical properties of geopolymer concrete. Compressive strength tests are conducted using a compression testing machine at different curing periods such as 7 days and 28 days. Split tensile strength tests are also performed to assess the tensile behaviour of the concrete.

In addition to strength tests, observations related to workability and consistency of the fresh concrete are recorded. The test results are used to analyze the influence of nano silica on the structural performance of geopolymer concrete.

3.5 Methodology

The methodology adopted in this study involves a systematic approach starting from material selection to experimental analysis. Initially, suitable materials are selected and characterized. Mix proportions are then designed, and concrete specimens are prepared with varying percentages of nano silica. The specimens are tested under controlled conditions, and the results are recorded and analyzed.

The experimental data obtained is compared with conventional geopolymer concrete to evaluate the improvement in properties due to the addition of nano silica. Based on the analysis, conclusions are drawn regarding the effectiveness of nano silica in enhancing the structural performance of geopolymer concrete.

IV. RESULTS

The preliminary test results that we have performed are

S. No	Test Performed	Obtained values
1	Aggregate impact value test	24%
2	The specific gravity of fine aggregate	2.56
3	The specific gravity of coarse aggregate	2.65
4	Water absorption	0.4%

Table 1: Preliminary Experimental results

Mix Designation	Slump value (mm)	Slump type
M_0	27	True slump
M_1	38	True Slump
M_2	29	True Slump
M_3	40	True Slump

Table 2: Slump valve of different Mixes

Mix Designation	7 days(Mpa)	28 days(Mpa)
M0	20	37.5
M_1	28.5	41.5
M_2	29	42
M_3	32	40.5

Table 3. Compressive strength value

V. CONCLUSIONS

The present study on the structural performance of nano silica-based geopolymer concrete demonstrates that the use of advanced nano materials significantly enhances the properties of geopolymer concrete. The experimental investigation confirms that geopolymer concrete can serve as an effective and sustainable alternative to conventional cement-based concrete, reducing environmental impact and carbon emissions.

The results indicate that the incorporation of nano silica improves the compressive strength and tensile strength of geopolymer concrete due to its high reactivity and ability to refine the microstructure. The fine particles of nano silica fill the voids between larger particles, resulting in a denser and more compact concrete matrix. This leads to improved bonding and reduced porosity, which enhances the overall strength and durability of the material.

It is observed that there exists an optimum percentage of nano silica at which the concrete exhibits maximum performance. Beyond this optimum level, the strength may decrease due to particle agglomeration and reduced workability. Therefore, careful selection of nano silica dosage is essential to achieve the desired results.

The study also highlights that geopolymer concrete exhibits good workability and superior resistance to environmental effects compared to conventional concrete. The use of industrial by-products such as fly ash and GGBS further contributes to sustainable construction practices by reducing waste and conserving natural resources.

Overall, the findings confirm that nano silica-based geopolymer concrete is a promising material for modern construction applications. With proper mix design and material optimization, it can provide high strength, improved durability, and environmental benefits. The study contributes to the development of advanced concrete technologies and supports the adoption of sustainable materials in the construction industry.

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International Journal of Engineering Research and Science & Technology

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