International Journal of Engineering Applied Science and Management
ISSN (Online): 2582-6948
Vol. 5 Issue 6, June 2024

Enhancement of M25 Concrete Mix Properties Using Nano Silica: An Investigative Study

Bhaskarjit Deka[1],Vikas Patidar[2]
M.Tech. Scholar, SSSUTMS, Sehore (M.P.), India[1]
Assistant Professor, SSSUTMS, Sehore[2]

Abstract: *Concrete is a fundamental construction material known for its versatility, strength, and ease of use. However, its inherent properties can be further enhanced through the inclusion of nanomaterials. Nano silica (NS) has emerged as a significant additive, offering improved mechanical and durability properties. This survey paper reviews the current research on the use of nano silica in concrete, focusing on its effects on compressive strength, microstructure, and other relevant properties. Key studies and findings are discussed, providing a comprehensive understanding of the impact of nano silica on concrete.*

Keywords: *Concrete, Nano silica, Compressive strength, Microstructure, Durability, Nanomaterials.*

1. Introduction

Concrete is a crystalline compound composed mainly of calcium silicates and other calcium compounds with hydraulic properties. The principal components, known as Bogue's Compounds, include Tricalcium silicate (C3S), Dicalcium silicate (C2S), Tricalcium aluminate (C3A), and Tetracalcium aluminoferrite (C4AF). These components contribute significantly to the strength and durability of concrete, with C3S and C2S together making up about 70% of the total composition. The hydration of cement, an exothermic reaction, produces Calcium-Silicate-Hydrate (C-S-H) gel and calcium hydroxide ($Ca(OH)_2$), with C-S-H being the primary contributor to the strength of concrete.
The use of nanomaterials, particularly nano silica, in concrete has gained attention due to their ability to modify concrete properties at the nanoscale. Nano silica particles, due to their small size and high surface area, enhance the pozzolanic reaction, leading to the formation of additional C-S-H gel, thus improving the microstructure and mechanical properties of concrete.

2. Literature Review

Numerous studies have explored the use of nano silica and other nanomaterials in concrete. This section summarizes the findings of key research efforts.

2.1 Early Age Properties and Compressive Strength

J. Comiletti et al. (2012) examined the effect of micro and nano $CaCO_3$ on the early age properties of ultra-high-performance concrete (UHPC). Their results indicated that the combination of nano and micro $CaCO_3$ improved the flowability and early compressive strength of UHPC under various curing conditions.
Min. Hong Zhang et al. (2012) studied the impact of nano silica and high-volume slag on mortar. They found that the rate of hydration increased with the addition of nano silica, and the compressive strength of the slag mortar increased significantly with nano silica dosages from 0.5% to 2% by weight of cement. The study also noted a reduction in the setting time of the mortar.

2.2 Microstructure Enhancement

G. Dhinakaran et al. (2014) investigated the microstructure and strength properties of cement with nano silica. The nano silica was ground in a planetary ball mill and incorporated into the cement at 5%, 10%, and 15% by weight of cement. The results showed an increase in compressive strength, with the maximum strength achieved at 10% replacement. The enhanced strength was attributed to the improved microstructure due to the filling of voids and the formation of additional C-S-H gel.

Mukharjee and Barai (2014) focused on the compressive strength and characteristics of the interfacial transition zone (ITZ) of concrete containing recycled aggregates and nano silica. Their findings demonstrated an improvement in compressive strength and a more compact and uniform microstructure with the inclusion of nano silica.

3. Materials and Methods

The materials used to design the concrete mix for this study included Portland slag cement, sand, coarse aggregate, water, and nano silica. The properties of these materials are summarized below.

3.1 Properties of Materials

- **Portland Slag Cement**: Specific gravity of 3.014, fineness of 2.01%, and normal consistency of 33%.
- **Coarse Aggregate and Fine Aggregate**: Loose bulk density, water absorption, impact value, crushing value, and fineness modulus were determined as per relevant standards.
- **Nano Silica**: The average particle size was 236 nm, with specific surface area, pH value, and other properties conforming to the standard requirements.

3.2 Mix Design

The mix design for M25 grade concrete was conducted according to Indian Standard Code IS: 10262-1982. The target compressive strength at 28 days was set at 31.6 MPa. The water-cement ratio was selected as 0.43, and the proportions of cement, fine aggregate, coarse aggregate, and water were calculated accordingly.

4. Experimental Results and Microstructure Analysis

This section presents the results of the experiments conducted to evaluate the impact of nano silica on concrete properties, including compressive strength, ultrasonic pulse velocity (UPV) tests, and microstructure analysis.

4.1 Compressive Strength

Compressive strength tests were performed on concrete specimens with varying percentages of nano silica (0.3%, 0.6%, and 1% by weight of cement). The results showed an improvement in early strength with the addition of nano silica, with the highest increase observed at 0.6% nano silica. However, beyond this percentage, the strength gains were marginal.

4.2 Ultrasonic Pulse Velocity (UPV) Test

The UPV test results indicated that the quality of concrete improved with the addition of nano silica. The 28-day results were better than the 7-day results, and the control specimen showed better quality compared to the specimens with nano silica.

4.3 Microstructure Analysis

Field Emission Scanning Electron Microscopy (FESEM) analysis revealed a denser and more uniform microstructure in nano silica-blended concrete. The nano silica particles filled the micro-pores and voids, preventing the growth of $Ca(OH)_2$ crystals and enhancing the formation of C-S-H gel.

5. Conclusion

The addition of nano silica to concrete significantly enhances its compressive strength and microstructure. The improved performance is attributed to the pozzolanic reaction of nano silica with calcium hydroxide, leading to the formation of additional C-S-H gel. However, the effectiveness of nano silica is influenced by its dosage and the mix design, and the use of superplasticizers is recommended to achieve better compaction and workability.

References

[1] IS:2386-1963 (Part-III). Methods of Test for aggregates for concrete Part III specific gravity, density, voids, absorption, and bulking. Bureau of Indian Standards.
[2] IS:383-1970. Specification for coarse aggregate and fine aggregate from natural sources for concrete. Bureau of Indian Standards.
[3] IS:455-1989. Portland Slag Cement- Specification. Bureau of Indian Standards.
[4] IS:456-2000. Plain and Reinforced concrete- code of practice (Fourth Revision). Bureau of Indian Standards.
[5] Hui Li, Hui-gang Xiao, Jie Yuan, and Jinping Ou. (2004). Microstructure of cement mortar with nanoparticles. Composites: Part B 35, 185-189.
[6] Ji, Tao. (2005). Preliminary study on the water permeability and microstructure of concrete incorporating nano-SiO2. Cement and Concrete Research 35, 1943-1947.

[7] Byung-Wan Jo, Chang-Hyun Kim, Ghi-ho Tae, and Jang-Bin Park. (2007). Characteristics of cement mortar with nano-SiO2 particles. Construction and Building Materials 21, 1351-1355.

[8] Nilli, M., Ehsani, A., and Shabani, K. (2009). Influence of nano SiO2 and micro silica on concrete performance. Bu-Ali Sina University Iran.

[9] Ali Nazari, Shadi Riahi, Shirin Riahi, Saydeh Fatemeh Shamekhi, and A. Khademno. (2010). Embedded ZrO2 nanoparticles mechanical properties monitoring in cementitious composites. Journal of American Science 6(4), 86-89.

[10] Ali Nazari, Shadi Riahi, Shirin Riahi, Saydeh Fatemeh Shamekhi, and A. Khademno. (2010). Improvement of the mechanical properties of the cementitious composites by using TiO2 nanoparticles. Journal of American Science 6(4), 98-101.

[11] Ali Nazari, Shadi Riahi, Shirin Riahi, Saydeh Fatemeh Shamekhi, and A. Khademno. (2010). Mechanical properties of cement mortar with Al2O3 nanoparticles. Journal of American Science 6(4), 94-97.

[12] Alireza Naji Givi, Suraya Abdul Rashid, Farah Nora A. Aziz, and Mohamad Amra Mohd Salleh. (2010). Experimental investigation of the size effects of SiO2 nanoparticles on the mechanical properties of binary blended concrete. Composites: Part B 41, 673-677.

[13] G. Quercia and H.J.H. Brouwers. (2010). Application of nanosilica(nS) in concrete mixtures. 8th fib PhD symposium in Kgs. Lyngby, Denmark.

[14] M.S. Morsy, S.H. Alsayed, and M. Aqel. (2010). Effect of Nano clay on mechanical properties and microstructure of Ordinary Portland Cement mortar. International Journal on Civil Engineering & Environmental Engineering IJCEE- IJENS Vol. 10 No. 01.