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Influence of Nano Silica and Flyash on High Volume Blended Concrete

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ABSTRACT: This study investigates the mechanical and dynamic properties of high-volume fly ash (HVFA) concrete modified with nano-silica, comparing its structural characteristics with conventional concrete. By partially replacing ordinary Portland cement (OPC) with fly ash, HVFA concrete reduces carbon emissions, while the addition of nano-silica enhances strength and durability. This paper presents results from compressive, tensile, and flexural tests across different curing periods, focusing on the effect of varying nano-silica percentages on HVFA concrete's performance under both static and dynamic loads.

KEYWORDS: HVFA concrete, nano-silica, compressive strength, sustainable materials, pozzolanic reactivity, strain rate, dynamic properties.

I. INTRODUCTION

The growing demand for sustainable and eco-friendly construction materials has led to significant advancements in concrete technology, particularly through the use of supplementary cementitious materials (SCMs). Among these, Nano Silica (NS) and Fly Ash (FA) have emerged as highly effective additives to enhance the properties of concrete, both in terms of durability and strength. High Volume Blended Concrete (HVBC), which incorporates a large proportion of SCMs like FA, has gained prominence due to its potential to reduce the environmental impact of traditional concrete production. The inclusion of Nano Silica, with its fine particle size and unique reactivity, further improves the microstructure of the concrete, resulting in enhanced strength, reduced permeability, and increased resistance to aggressive environmental conditions. This paper aims to explore the synergistic effects of combining Nano Silica and Fly Ash in High Volume Blended Concrete, analyzing their influence on the mechanical, durability, and environmental performance of concrete. The study will highlight the potential benefits and challenges associated with this innovative approach, contributing to the development of more sustainable and high-performance concrete materials in the construction industry.

II. LITERATURE SURVEY

Chamila Gunasekara et al. (2020) stated the compressive strength of high-volume fly ash (HVFA) concrete mixes, HVFA-65 and HVFA-80, was tested over 7 to 28 days. Results showed an increase in strength from 25.0 to 42.7 MPa for HVFA-65 and from 14.5 to 29.5 MPa for HVFA-80 over that period. When 3% nano-silica (ns) was added, the compressive strength improved further, with HVFA-65 ns reaching 47.1 MPa and HVFA-80 ns reaching 40.1 MPa by 28 days. This increase is attributed to the very fine particles of nano-silica, which act as nucleation sites that enhance the hydration process of cement, thereby boosting the strength of the HVFA composite with hydrated lime (HL).

Abhilash P. P et al. (2021) concluded that Concrete is a crucial material with significant environmental impact, mainly due to the CO₂ emissions associated with cement production. To reduce this impact, improving the durability of concrete structures is key. One approach is the incorporation of nanoparticles, particularly nano-silica (nS), which has shown superior performance compared to traditional mineral additives. Nano-silica improves concrete's mechanical properties, durability, and microstructure by enhancing hydration, reducing porosity, and increasing strength. Nano-silica works by reacting with calcium hydroxide (Ca(OH)₂) to form calcium silicate hydrate (CSH), which enhances the material's properties. The optimal dosage for maximum benefit is typically 2-3%, where it has been found to improve

compressive strength, reduce setting times, and improve pore structure. Nano-silica also enhances the early-age strength of concrete and accelerates hydration. Despite the promising benefits, challenges exist in the widespread adoption of nanomaterials due to high costs, lack of standardization, and potential health risks. However, research continues to explore the combined effects of nano-silica with other materials like micro-silica to further improve concrete properties. Ultimately, incorporating nano-silica into concrete offers an eco-efficient path towards high-performance, durable concrete with reduced CO₂ emissions.

R. Abdulwahab et al. (2021) discusses the challenges associated with the widespread use of Ordinary Portland Cement (OPC) in construction, particularly in developing countries like Nigeria, where the high cost and environmental impact of cement production pose significant issues. OPC production contributes heavily to carbon dioxide emissions and environmental degradation. To address these problems, there has been growing interest in using Supplementary Cementitious Materials (SCMs) such as fly ash, rice husk ash, silica fume, and metakaolin as partial replacements for cement. These materials help reduce both costs and environmental pollution while enhancing the durability and strength of concrete. It also highlights the role of nanoparticles in concrete, which can improve the material's mechanical properties by refining the molecular structure, enhancing hydration, and increasing strength. Nanomaterials are praised for their small size, large surface area, and potential to reduce energy consumption in cement production. Despite their benefits, challenges remain in effectively dispersing nanoparticles in the cement matrix and issues with ductility. Overall, the use of SCMs and nanomaterials represents a promising direction for sustainable and high-performance concrete technologies.

Ghasan Fahim Huseien et al. (2024) explores on creating environmentally friendly, sustainable cement mortars by incorporating high volumes of fly ash (FA) and bottle glass waste nanoparticles (BGWNPs) as partial replacements for ordinary Portland cement (OPC). The primary goal is to address the challenges associated with high-FA content, such as reduced early-age strength, by enhancing the mixture with BGWNPs. The results showed that adding up to 6% BGWNPs significantly improved the mechanical properties, including bond strength, while also enhancing durability against drying shrinkage, acid attack, and abrasion. The use of FA and BGWNPs reduced environmental impacts, including carbon dioxide emissions, energy consumption, and binder costs. The study suggests that this approach offers a viable alternative for producing high-performance mortars for concrete repair applications. Additionally, the inclusion of BGWNPs improved the microstructure and pozzolanic reactions, enhancing the overall sustainability and reducing the environmental footprint of construction materials.

According to Osama Zaid et al. (2023) the effects of nano-silica (NS) on concrete's strength, durability, and microstructure, highlighting several key conclusions. The inclusion of nano-materials with large surface areas in concrete mixes requires increased water or admixtures to maintain workability (slump). The impact of nano-silica is influenced by factors such as its surface area, particle size, water-to-cement ratio, and dosage. A dosage of 3-4% nano-silica is optimal for enhancing both mechanical and durability properties, due to its filling effect, pore structure refinement, and pozzolanic behavior. However, exceeding this amount can reduce strength. Nano-silica accelerates the hydration process, especially during early hydration stages, resulting in higher compressive strength, although this effect diminishes beyond 4%. Additionally, nano-silica improves the microstructure by reducing harmful pores and permeability, strengthening the calcium-silicate-hydrate (C-S-H) gel, and enhancing the interfacial transition zone between the binder and aggregates, thus improving long-term durability. The synergistic combination of waste pozzolanic materials and nano-silica further enhances concrete's mechanical properties, hydration, and pore structure. In summary, nano-silica optimizes concrete's microstructure, improving its mechanical and durability performance through better hydration, pore refinement, and interfacial bonding.

Subhashish Dey et al. (2023) investigates the performance of blended concrete mixes incorporating fly ash, ground granulated blast furnace slag (GGBS), and nano-silica as partial cement replacements. The inclusion of these mineral admixtures (20% fly ash, 20% GGBS, and 2% nano-silica) improves workability compared to the control mix across all concrete grades. Durability tests revealed that concrete with higher grades (70 MPa) exhibited better resistance to acid and sulfate attacks, with lower acid mass loss and strength loss factors compared to lower-grade concrete (30 MPa). Concrete exposed to HCl showed a higher acid durability factor (ADF) than those exposed to H₂SO₄, indicating better performance in HCl environments. The use of blended cement with mineral admixtures also showed superior performance in tests like the Accelerated Chloride Permeability Test (ACPT) and Rapid Chloride Permeability Test (RCPT) compared to the control mix. Nano-silica, with its small particle size (1.45 μm) and high surface area (250.64 m²/g), significantly enhanced compressive strength due to its ability to fill pores and improve the microstructure. XRD

analysis confirmed that nano-silica has smaller crystallite sizes, contributing to better strength performance. Additionally, the high pore volume of nano-silica ($0.480 \text{ cm}^3/\text{g}$) compared to fly ash and GGBS further enhanced the material's strength. The study also emphasizes the importance of concrete pH for the effective passivation of reinforcement and highlights the potential for minimizing corrosion through proper control of chloride and sulfate ion content.

Faiz Uddin Ahmed Shaikh et al. (2019) explores the effects of nano-silica (NS) on the compressive strength and microstructure of cement pastes containing high volumes of blast furnace slag (BFS) and BFS-fly ash (FA) blends as partial replacements for ordinary Portland cement (OPC). The results indicate that high volume BFS pastes with 60% and 70% BFS show a slight increase or similar compressive strength compared to control cement pastes. However, when BFS content increases to 80% and 90%, compressive strength significantly decreases by 9% and 37%, respectively. In contrast, high volume BFS-FA pastes with a total BFS-FA content of 60% exhibit improved compressive strength (5-16% higher) compared to control mixes, but higher BFS-FA blends with increasing fly ash content experience a reduction in strength. The addition of 1-4% NS improves compressive strength in high volume BFS pastes, with enhancements ranging from 9-41%, especially at higher BFS contents (80%-90%). The inclusion of NS also reduces calcium hydroxide (CH) content and enhances the formation of calcium silicate hydrate (C-S-H) gels, as confirmed by thermogravimetric (TGA) and X-ray diffraction (XRD) analysis. Scanning electron microscopy (SEM) further confirms the densification of the microstructure in pastes containing NS. Additionally, combining high volumes of BFS and FA with NS can reduce the carbon footprint of cement pastes while maintaining similar compressive strength to control mixes. The study also evaluates the environmental benefits of using high volume BFS and BFS-FA blends in reducing the carbon footprint of concrete.

Doo-Yeol Yoo et al. (2024) stated that the study investigates the substitution of silica fume (SF) with nanosilica (NS) in Ultra-High-Performance Concrete (UHPC) to enhance hydration behavior and mechanical properties. Thermogravimetric analysis (TGA) shows that NS has higher reactivity than other ingredients in the mix, accelerating the hydration process. The maximum exothermic peak occurs earlier with increasing NS content, and nuclear magnetic resonance (NMR) results reveal that the silicate chain length of calcium silicate hydrate (C-S-H) improves by about 68% at a 10% NS substitution rate. The highest compressive strength of 161.5 MPa and best tensile properties in terms of tensile strength and strain energy density were achieved with 10% NS substitution, showing improvements of 2.2%, 9.3%, and 42.7%, respectively, over the control. However, at higher NS substitution rates (above 20%), compressive strength and tensile performance declined. The best pullout strength and lowest porosity were observed at 20% NS due to a densified fiber-matrix interfacial transition zone. These findings suggest that substituting SF with 10-20% NS in UHPC offers optimal performance.

Dr. P.S. Nagaraja et al. (2021) explores the impact of varying fly ash content on the mechanical properties of concrete, including compressive strength, split tensile strength, and flexural strength. The results show that as the percentage of fly ash increases, compressive strength decreases across all ages (7, 14, and 28 days). The reduction in compressive strength is most significant at 28 days, with a maximum decrease of up to 54.18% for the highest fly ash content (M5) compared to the control mix (M1). Similarly, split tensile strength also decreases with higher fly ash content, with the greatest reduction observed at 7 days for mixes M3, M4, and M5. While the decrease in tensile strength diminishes over time, it remains notable even at 28 days. The flexural strength follows a similar trend, showing a substantial reduction at early ages, particularly at 7 days, with a decrease of up to 75.66% for M4 compared to M1. This reduction in flexural strength decreases with time but remains significant at 28 days. In conclusion, while high-volume fly ash concrete exhibits lower early strength compared to normal concrete, this strength gap narrows over time, suggesting potential improvements in long-term durability. Additionally, the filler effect of micro particles in the concrete contributes to slight increases in strength in some mixes.

Roman Fediuk et al. (2021) proposes a new method for producing a nano-modifier for cement concretes from a renewable source, using a hydrothermal solution and polycondensation of orthosilicic acid, followed by ultrafiltration membrane concentration. The results show that the average diameters of amorphous SiO_2 nanoparticles in the sol range from 10 to 100 nm, with a specific surface area (SBET) of 50–500 m^2/g and a high density of silanol groups ($\sigma = 4.9 \text{ nm}^{-2}$). Concrete specimens modified with SiO_2 sol (0.5–3.0 wt%) and polycarboxylate superplasticizer (0.2–3.98 wt%) exhibited significant increases in compressive strength—up to 128% at 1 day and 40% at 28 days. Furthermore, the modified concrete demonstrated improved water impermeability due to a reduction in pore volume and an increase in pore uniformity. The pozzolanic reaction, involving the formation of crystalline calcium hydrosilicates, was studied

using X-ray diffraction, electron microscopy, and thermogravimetry. The hydrothermal SiO₂ nanoparticles exhibited a much higher chemisorption capacity for binding Ca(OH)₂ compared to silica fume, especially in the early stages of hydration. The modified cement matrices showed accelerated hydration of alite (C₃S), with a 20–30% increase in the hydration rate at 1 day and a sustained effect over 100 days. This research suggests that hydrothermal SiO₂ nanoparticles have significant potential for improving the mechanical properties and durability of cement composites, offering a promising route for future cement modification technologies.

Mohammad Kooshafar et al. (2020) discussed how the agglomeration state (morphology) of nanosilica affects the properties of cement composites, specifically comparing nanosilica gel, nanosilica sol, and silica fume. The results show that nanosilica gel, despite having large agglomerates, outperforms both monodispersed nanosilica sol and silica fume, particularly at early ages, in improving compressive strength, shrinkage, water sorptivity, and other properties. The agglomerated particles in the gel provide better nucleation sites for cement hydration, enhancing early strength development. Over time, concrete with nanosilica gel also showed better durability, with lower chloride penetration and water sorptivity than those with nanosilica sol. This suggests that the morphology of nanosilica plays a critical role in its effectiveness, with the agglomerated gel providing superior performance compared to the monodispersed sol, which did not offer the same benefits. The study also highlights that the simple, cost-effective production of nanosilica gel makes it a viable alternative to more complex nanosilica forms for enhancing concrete properties.

Chamila Gunasekara et al. (2021) investigated the long-term mechanical performance of High-Volume Fly Ash (HVFA) concrete with 65% and 80% cement replacement, incorporating hydrated lime (up to 18%) and nano silica (3%). The results show significant strength development over time, with HVFA-65 concrete achieving compressive strengths from 32 MPa at 7 days to 73 MPa at 450 days, while HVFA-80 concrete showed an increase from 22 MPa to 71 MPa in the same period. The study also reports improvements in flexural strength, splitting tensile strength, and elastic modulus for both mixes. HVFA-65 exhibited higher concentrations of Portlandite and a denser microstructure, indicating better pozzolanic reactions and interfacial bond strength compared to HVFA-80. Microstructural analysis confirmed the formation of a denser gel matrix and stronger bond in the interfacial transition zone (ITZ) of HVFA-65. Statistical regression models were developed to predict the long-term mechanical properties of HVFA concrete and compared to existing design equations from Australian Standards and ACI codes, highlighting the need for updated design guidelines for HVFA concrete. The study fills a gap in the literature by providing long-term data for HVFA concrete mixes with cement replacement levels above 60%, particularly in terms of their mechanical properties and performance.

E.R. Teixeira et al. (2022) explores the use of biomass fly ash (BFA) as a cement replacement and alkalinity reserve in high-volume fly ash concrete (HVFAC), aiming to improve the sustainability and performance of HVFAC. BFA, derived from biomass combustion (e.g., eucalyptus and pine bark), is evaluated for its impact on compressive strength, water absorption, carbonation resistance, and chloride penetration in concrete. The research finds that incorporating small amounts of BFA enhances the properties of HVFAC compared to high-volume coal fly ash concrete, offering benefits for durability and sustainability. Given the decreasing availability of coal fly ash (CFA) due to the closure of coal-fired power plants and the shift towards low-carbon energy sources, BFA presents a promising alternative to replace CFA in HVFAC. Additionally, the study highlights BFA's potential to address HVFAC's carbonation issues due to its alkalinity, providing a more sustainable and functional material for concrete production. Laboratory tests on various concrete mixtures containing both CFA and BFA show that BFA can significantly improve HVFAC's performance, particularly in terms of sustainability and functional quality.

D. Vivek et al. (2021) discussed the effects of nano silica (NS) and fly ash (FA) on the properties of high-performance concrete (HPC). The study uses three different HPC mixes with a binder content of 550 kg/m³ and a water-to-binder ratio of 0.33. NS was added in varying percentages (1%, 2%, 3%, and 4%) by weight of the cementitious materials. The findings indicate that nano silica significantly improves concrete properties by filling pores, accelerating hydration, and enhancing the formation of C-S-H gel, which in turn increases the density of the material. The addition of up to 3% NS accelerates hydration and increases resistance to water permeability, reducing the likelihood of corrosion. The study also highlights that NS improves the workability and consistency of both fresh and hardened concrete, leading to better microstructural characteristics, reduced permeability, and overall increased durability. These results suggest that NS is an effective additive for improving the mechanical and durability properties of high-performance concrete, particularly by enhancing early-stage strength and long-term performance.

Aditya Kumar Tiwary et al. (2023) stated that the study explores the impact of nano-silica (NS) and ground granulated blast furnace slag (GGBFS) as partial replacements for cement in concrete, with a focus on their behavior under elevated temperatures (27°C to 1000°C). The main goal was to assess how these additives influence the mechanical and durability properties of concrete when exposed to fire conditions, following the ISO 834 standardized fire curve. Concrete samples were subjected to two cooling methods: water cooling (WC) and air cooling (AC). The results showed that concrete containing up to 5% NS and 25% GGBFS performed better than the control concrete when exposed to elevated temperatures. The optimal mixture was 4% NS and 20% GGBFS, which significantly improved the concrete's resistance to heat up to 400°C. However, beyond 400°C, particularly at 1000°C, there was a marked degradation in the mechanical and durability properties. Microstructural analysis using SEM/EDS and XRD revealed that the addition of NS and GGBFS enhanced the concrete's microstructure, contributing to better post-fire strength recovery. Additionally, the study proposed empirical relationships to predict the residual properties of concrete exposed to high temperatures, which aligned well with the experimental data. The cooling method also played a crucial role in post-fire recovery, with water cooling generally yielding better results in terms of strength and durability restoration. Overall, the study concluded that while NS and GGBFS improve concrete's fire resistance up to around 400°C, their effectiveness diminishes at higher temperatures, emphasizing the need for careful selection of these additives when designing concrete for fire-prone environments.

Naraindas Bheel et al. (2024) investigated the use of ground granulated blast furnace slag (GGBFS) as a supplementary cementitious material (SCM) and nano-silica (NS) as a nanomaterial to enhance the properties of high-strength concrete. The research evaluates mechanical, durability, and sustainability aspects, while also developing a prediction model using response surface methodology (RSM). Key findings include a reduction in workability with the addition of GGBFS and NS, with the lowest slump observed for the highest proportions (GGBFS 20%, NS 4%). The maximum 90-day compressive strength (CS) of 93.61 MPa was achieved with GGBFS 10% and NS 3%, but higher additions of these materials negatively impacted strength, tensile strength (STS), flexural strength (FS), and modulus of elasticity (MOE). Water absorption (WA) decreased, with the lowest value of 1.71% for GGBFS 10% and NS 3%. Sustainability benefits were evident, as increasing GGBFS and NS reduced embodied carbon, with the GGBFS10NS3 mixture showing a 9% reduction in embodied carbon compared to normal high-strength concrete. The study also found improvements in eco-strength efficiency. RSM analysis indicated high predictive accuracy, with R-squared values above 0.9 for all models, suggesting that the input variables effectively explain variations in the output properties. The optimization results further highlighted the potential for producing cost-effective, sustainable high-strength concrete with minimal environmental impact, with experimental validation showing less than 5% prediction error. Overall, the study demonstrates that GGBFS and NS can be effectively used to enhance concrete properties while promoting sustainability.

Khaled A. Metwally et al. (2021) explores the effects of nano-magnesium oxide (N-MgO) and ultrafine micro-magnesium oxide (UM-MgO) on the early performance of high-volume fly ash (FA)-blended cement mortar (CM). The N-MgO, synthesized through thermal treatment of hydromagnesite at 550°C, demonstrated superior efficiency in accelerating the hydration of FA-blended cement, compared to UM-MgO, which was treated at 1100°C. The addition of 1–5 wt% N-MgO significantly enhanced the 3-day compressive strength of the FA-blended mortar, with improvements ranging from 26% to 103%, whereas UM-MgO had a more modest effect. The smaller particle size, lower crystallinity, and higher reactivity of N-MgO contributed to its ability to promote the pozzolanic activity of FA, improving early hydration and strength development. The study also highlights the environmental benefits of using N-MgO, including cost minimization, energy savings, and a reduction in the carbon footprint of cement production. Overall, the findings suggest that N-MgO is a promising additive for improving the early mechanical properties of FA-blended cement, offering a more sustainable and cost-effective solution for construction applications.

Ruijun Wang et al. (2022) provides a comprehensive review of high-volume fly ash concrete (HVFAC), where fly ash (FA) replaces more than 40% of Portland cement (PC). It examines nearly 180 studies on the microstructural, fresh, mechanical, and durability properties of HVFAC, comparing it with low-volume FA concrete (LVFAC) and 100% PC concrete. HVFAC generally shows lower early-age mechanical properties but higher strength at later ages. It also demonstrates improved workability, reduced drying shrinkage, and enhanced resistance to sulfate attacks and chloride penetration. The review identifies three key mechanisms to improve the early-age strength of HVFAC: promoting the pozzolanic reaction of FA, adding high-pozzolanic activity additives, and using alkali activation. Moreover, the economic and environmental benefits of HVFAC, such as reduced CO₂ emissions and cost savings, are highlighted. Despite these advantages, gaps in research remain, particularly regarding the long-term durability of HVFAC in various

environmental conditions, which requires further exploration to optimize its use in construction. The paper concludes with a call for future studies focusing on enhancing the long-term performance and durability of HVFAC, as well as improving its industrial adoption for more sustainable concrete production.

Wensu Chen et al. (2021) investigated the dynamic and quasi-static properties of high-volume fly ash (HVFA) concrete, where fly ash (FA) replaces 40% and 60% of Portland cement (PC), and the effect of adding 2% nano silica (NS) on these properties. The study focuses on the performance of HVFA concrete under dynamic conditions, using a split Hopkinson pressure bar (SHPB) to conduct tests at strain rates up to 149.49 s⁻¹. The results reveal that adding NS improves both the quasi-static and dynamic properties of HVFA concrete, particularly enhancing compressive strength, modulus of elasticity, and energy absorption capacity. However, increasing the FA content leads to lower strength and energy absorption, with the damage level becoming more severe as FA content rises. The dynamic increase factors (DIF) for compressive strength were quantified and compared to empirical formulae recommended by the Euro-International Committee for Concrete (CEB). The study also provides empirical formulae for DIF of compressive strength, modulus of elasticity, and energy absorption capacity of HVFA concretes, with and without NS, as a function of strain rate. The addition of NS led to better dynamic performance, with the modified HVFA concrete exhibiting higher compressive strength and energy absorption capacity than plain concrete (PC). This demonstrates the potential of NS-modified HVFA concrete as a sustainable alternative to traditional concrete for dynamic load applications.

V. Sairam et al. (2020) explores the durability of Composite Fiber Reinforced High-Performance Concrete (CFRHPC) incorporating ultra-fine fly ash (UFFA) and nanosilica, with 15% of the cement replaced by UFFA and nanosilica added in fractions of 0%, 1.5%, 3.0%, and 4.5%. Steel and polypropylene fibers were included at 1% and 0.25% by volume, respectively. The research focused on sorptivity, rapid chloride permeability (RCPT), and the effects of aggressive environments (HCl, H₂SO₄, MgSO₄) on compressive strength and weight loss. Results showed that the addition of nanosilica and UFFA significantly reduced chloride permeability, with decreases ranging from 53.83% to 71.45% at 28 days and 55.88% to 74.27% at 56 days. Durability tests in aggressive solutions demonstrated reduced compressive strength and weight loss, with the optimal combination being 15% UFFA and 3% nanosilica, offering improved resistance to chloride and sulfate attacks. The inclusion of fibers (steel and polypropylene) further enhanced the concrete's durability. The study highlights that incorporating nanosilica and UFFA improves the microstructure by reducing porosity and permeability, thus enhancing durability. This combination, along with fibers, can lead to longer-lasting concrete structures, especially in aggressive environments, and contributes to advancing the understanding of multi-admixture systems for durable concrete. These findings could help shape future concrete mix design codes, emphasizing the role of nanomaterials and fibers in improving concrete performance and extending its service life.

III. SUMMARY OF REVIEW

From the review of these studies, they highlights the significant benefits of incorporating nano-silica (NS), fly ash (FA), ground granulated blast furnace slag (GGBFS), and other supplementary cementitious materials (SCMs) into concrete, with a focus on improving mechanical performance, durability, and sustainability. Research indicates that nano-silica enhances compressive strength, accelerates hydration, and refines the microstructure of concrete, particularly in high-volume fly ash (HVFA) mixes. The combination of NS and SCMs also reduces CO₂ emissions and energy consumption, offering a more sustainable approach to concrete production. Moreover, these materials improve concrete's durability by enhancing resistance to acid, sulfate attacks, and chloride permeability. Microstructural analysis shows that nano-silica densifies the concrete matrix, contributing to better strength and long-term durability. However, challenges such as high costs, dispersion issues, and a lack of standardization remain, necessitating further research to optimize mix designs and dosage levels for widespread adoption. Overall, the studies demonstrate that NS and SCMs can significantly improve concrete properties, but careful optimization is required for cost-effective implementation.

REFERENCES

1. Gunasekara, C., Sandanayake, M., Zhou, Z., Law, D. W., & Setunge, S. (2020). Effect of nano-silica addition into high volume fly ash-hydrated lime blended concrete. *Construction and Building Materials*, 253, 119205. <https://doi.org/10.1016/j.conbuildmat.2020.119205>
2. Abhilash, P. P., Nayak, D. K., Sangoju, B., Kumar, R., & Kumar, V. (2021). Effect of nano-silica in concrete: A review. *Construction and Building Materials*, 278, 122347. <https://doi.org/10.1016/j.conbuildmat.2021.122347>

3. Raheem, A. A., Abdulwahab, R., & Kareem, M. A. (2021). Incorporation of metakaolin and nanosilica in blended cement mortar and concrete: A review. *Journal of Cleaner Production*, 290, 125852. <https://doi.org/10.1016/j.jclepro.2020.125852>
4. Huseien, G. F., Tang, W., Yu, Y., Wong, L. S., Mirza, J., Dong, K., & Gu, X. (2024). Evaluation of high-volume fly-ash cementitious binders incorporating nanosilica as eco-friendly sustainable concrete repair materials. *Construction and Building Materials*, 447, 138022. <https://doi.org/10.1016/j.conbuildmat.2023.138022>
5. Althoey, F., Zaid, O., Martínez-García, R., Alsharari, F., Ahmed, M., & Arbili, M. M. (2023). Impact of nanosilica on the hydration, strength, durability, and microstructural properties of concrete: A state-of-the-art review. *Case Studies in Construction Materials*, 18, e01997. <https://doi.org/10.1016/j.cscm.2022.e01997>
6. Kumar, V. V. P., & Dey, S. (2023). Study on strength and durability characteristics of nano-silica based blended concrete. *Hybrid Advances*, 2, 100011. <https://doi.org/10.1016/j.hybad.2023.100011>
7. Shaikh, F. U. A., & Hosan, A. (2019). Effect of nano silica on compressive strength and microstructures of high volume blast furnace slag and high volume blast furnace slag-fly ash blended pastes. *Sustainable Materials and Technologies*, 20, e00111. <https://doi.org/10.1016/j.susmat.2019.e00111>
8. Oh, T., Chun, B., Lee, S. K., Kim, G. W., Bantia, N., & Yoo, D.-Y. (2024). Effect of high-volume substituted nanosilica on the hydration and mechanical properties of Ultra-High-Performance Concrete (UHPC). *Cement and Concrete Research*, 175, 107379. <https://doi.org/10.1016/j.cemconres.2023.107379>
9. Potapov, V., Efimenko, Y., Fediuk, R., & Gorev, D. (2021). Effect of hydrothermal nanosilica on the performances of cement concrete. *Construction and Building Materials*, 269, 121307. <https://doi.org/10.1016/j.conbuildmat.2020.121307>
10. Kooshafar, M., & Madani, H. (2020). An investigation on the influence of nano silica morphology on the characteristics of cement composites. *Journal of Building Engineering*, 30, 101293. <https://doi.org/10.1016/j.jobe.2020.101293>
11. Herath, C., Gunasekara, C., Law, D. W., & Setunge, S. (2021). Long term mechanical performance of nano-engineered high volume fly ash concrete. *Journal of Building Engineering*, 43, 103168. <https://doi.org/10.1016/j.jobe.2021.103168>
12. Teixeira, E. R., Camões, A., & Branco, F. G. (2022). Synergetic effect of biomass fly ash on improvement of high-volume coal fly ash concrete properties. *Construction and Building Materials*, 314, 125680. <https://doi.org/10.1016/j.conbuildmat.2021.125680>
13. Vivek, D., Elango, K. S., Saravanakumar, R., Rafek, B. M., Ragavendra, P., Kaviarasan, S., & Raguram, E. (2021). Effect of nano-silica in high-performance concrete. *Materials Today Proceedings*, 37(2), 1226–1229. <https://doi.org/10.1016/j.matpr.2020.08.081>
14. Singh, H., Tiwary, A. K., & Singh, S. (2023). Experimental investigation on the performance of ground granulated blast furnace slag and nano-silica blended concrete exposed to elevated temperature. *Construction and Building Materials*, 394, 132088. <https://doi.org/10.1016/j.conbuildmat.2023.132088>
15. Bheel, N., Waqar, A., Radu, D., Benjeddou, O., Alwetaishi, M., & Almujiabah, H. R. (2024). A comprehensive study on the impact of nano-silica and ground granulated blast furnace slag on high-strength concrete characteristics: RSM modeling and optimization. *Structures*, 62, 106160. <https://doi.org/10.1016/j.istruc.2023.106160>
16. Abdel-Gawwad, H. A., Metwally, K. A., Tawfik, T. A., Mohammed, M. S., Hassan, H. S., & El-Kattan, I. M. (2021). Evaluating the performance of high-volume fly ash-blended-cement mortar individually containing nano- and ultrafine micro-magnesia. *Journal of Building Engineering*, 36, 102129. <https://doi.org/10.1016/j.jobe.2020.102129>
17. Li, Y., Wu, B., & Wang, R. (2022). Critical review and gap analysis on the use of high-volume fly ash as a substitute constituent in concrete. *Construction and Building Materials*, 341, 127889. <https://doi.org/10.1016/j.conbuildmat.2022.127889>
18. Chen, W., Shaikh, F., Li, Z., Ran, W., & Hao, H. (2021). Dynamic compressive properties of high-volume fly ash (HVFA) concrete with nano silica. *Construction and Building Materials*, 301, 124352. <https://doi.org/10.1016/j.conbuildmat.2021.124352>
19. Sujay, H. M., Nair, N. A., Sudarsana Rao, H., & Sairam, V. (2020). Experimental study on durability characteristics of composite fiber-reinforced high-performance concrete incorporating nanosilica and ultrafine fly ash. *Construction and Building Materials*, 262, 120738. <https://doi.org/10.1016/j.conbuildmat.2020.120738>
20. Reddy, A. N., & Meena, T. (2020). Compressive performance enhancement of blended concrete using Alccofine. In *Emerging Technologies for Agriculture and Environment: ITsFEW 2018* (pp. 27-37). Springer Singapore.

21. Reddy, A. N., & Meena, T. (2021). Acid resilience of ternary nanosilica concrete with fly ash and Alccofine additives. *Pores*, 26, 27.
22. Reddy, A. N., & Rajesh. (2014). Green concrete properties using alternative binders. *International Journal of Engineering Sciences & Research Technology*, 3(8).
23. Reddy, A. N., & Meena, T. (2019). Nano silica impact on the mechanical characteristics of blended concrete. *Journal of Computational and Theoretical Nanoscience*, 16(5-6), 2006-2011.
24. Reddy, A. N., & Meena, T. (2019). Performance analysis of colloidal nano-silica on blended concrete with fly ash and Alccofine. *Revista Romana de Materiale*, 49(2), 217-224.
25. Reddy, A. N., & Tilak, U. V. (2015). Durability and shrinkage properties of alkali-activated slag concrete. *International Journal of Innovative Research in Science, Engineering, and Technology*, 4(11), 11483-11492.
26. Tilak, U. V., & Reddy, A. N. (2015). Effects of weathered aggregate on young's modulus in railway concrete sleepers. *SSRG International Journal of Civil Engineering*, 2(11), 24-29.
27. Reddy, A. N., & Meena, T. (2017). Overview of Alccofine-enhanced concrete performance. *International Journal of Pharmacy Technology*, 9(1).
28. Reddy, A. N., & Meena, T. (2019). Optimum admixture dosage for enhanced concrete properties. *International Journal of Recent Technology and Engineering*, 7(2), 1062-1065.



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