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Effect of Nano-SiO2 on Concrete Performance: Compressive Strength, Porosity, Flexural Strength, and Capillary Absorption

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Abstract

The paper presents the results and discussions of experiments conducted to investigate the effects of nano-SiO2 (nano Silicon Dioxide) on the compressive strength, porosity, flexural strength, and capillary absorption of concrete. The experiments involved testing 18 cylinders and beams with varying nano-SiO2 content while keeping the percentage of silica fume (SF) constant at 4%. A baseline test without SF or nano-SiO2 was conducted for comparison. The results showed that the compressive strength of the concrete increased with increasing nano-SiO2 content up to 2%, beyond which the increase plateaued. The initial increase in strength was attributed to the filling of voids and improved density, but higher nano-SiO2 percentages hindered uniform dispersion, limiting the strength improvement. The porosity test revealed that adding nano-SiO2 reduced porosity, with the most significant reduction observed at 0.5% nano-SiO2 content. However, further increases in nano-SiO2 had diminishing returns in terms of porosity reduction. Higher nano-SiO2 percentages resulted in less flowable concrete, indicating poor dispersion and limited benefit from the filling properties of the nanoparticles. Flexural strength increased with the addition of nano-SiO2, but the cost-effectiveness of this improvement was questioned. Steel fiber was found to be a more viable option for enhancing flexural strength. The coefficient of capillary absorption decreased with increased SiO2 dosage, indicating improved water resistance, but further analysis is needed to assess cost-effectiveness compared to alternative materials or methods. In conclusion, while nano-SiO2 showed improvements in compressive strength, porosity reduction, and flexural strength, it was not considered cost-effective compared to other options such as silica fume, fly ash, or steel fiber. Future research should explore the interactions of multiple variables, including water-to-cement ratio and supplementary cementitious materials, to gain a more comprehensive understanding of concrete performance and optimize mix designs.

Keywords: Nano Silica, Silica Fume, super plasticizer.

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1.Introduction

Concrete is the most widely used construction material, and continuous efforts are being made to enhance its mechanical properties and durability. In recent years, the incorporation of nanomaterials in concrete has gained significant attention due to their unique properties and potential for improving concrete performance. One such nanomaterial is nano-SiO2 (nano Silicon Dioxide), which has shown promise in enhancing the properties of concrete.

This paper presents the results and discussions of experiments conducted to investigate the effects of nano-SiO2 on the compressive strength, porosity, flexural strength, and capillary absorption of concrete. The experiments involved testing 18 cylinders and beams with varying nano-SiO2 content while keeping the percentage of silica fume (SF) constant at 4%. A baseline test without SF or nano-SiO2 was conducted for comparison.

The results of the experiments revealed interesting findings regarding the influence of nano-SiO2 on the mechanical and durability properties of concrete. Firstly, the compressive strength of the concrete increased with increasing nano-SiO2 content up to 2%, beyond which the increase plateaued. The initial increase in strength was attributed to the filling of voids and improved density, as nano-SiO2 particles effectively occupy empty spaces in the concrete matrix. However, higher nano-SiO2 percentages hindered uniform dispersion, limiting the strength improvement. This suggests that there is an optimum dosage of nano-SiO2 for maximizing compressive strength.

Furthermore, the porosity test showed that adding nano-SiO2 reduced porosity, with the most significant reduction observed at 0.5% nano-SiO2 content. The presence of nano-SiO2 particles fills the voids in the concrete, leading to improved density and reduced permeability. However, further increases in nano-SiO2 had diminishing returns in terms of porosity reduction. Moreover, higher nano-SiO2 percentages resulted in less flowable concrete, indicating poor dispersion and limited benefit from the filling properties of the nanoparticles.

In terms of flexural strength, the addition of nano-SiO2 showed improvements. However, the cost-effectiveness of this improvement was questioned, as steel fiber was found to be a more viable option for enhancing flexural strength. While nano-SiO2 contributed to increased flexural strength, the potential cost implications of incorporating this nanomaterial should be carefully considered.

Additionally, the coefficient of capillary absorption decreased with increased nano-SiO2 dosage, indicating improved water resistance of the concrete. The presence of nano-SiO2 particles fills the capillary pores, reducing the ingress of water. However, further analysis is needed to assess the cost-effectiveness of nano-SiO2 compared to alternative materials or methods for achieving similar water resistance properties.

In conclusion, the experiments demonstrated that nano-SiO2 can enhance the compressive strength, reduce porosity, improve flexural strength, and enhance water resistance of concrete. However, it was not considered cost-effective compared to other options such as silica fume, fly ash, or steel fiber. Future research should explore the interactions of multiple variables, including water-to-cement ratio and supplementary cementitious materials, to gain a more comprehensive understanding of concrete performance and optimize mix designs. This will enable the development of cost-effective strategies for improving concrete properties using nanomaterials like nano-SiO2.

2.Literature Review

The use of nanomaterials, particularly nano-SiO2, in concrete has gained considerable attention in recent years. Researchers have conducted numerous studies to investigate the effects of nano-SiO2 on the mechanical and durability properties of concrete, contributing to a growing body of knowledge in this field.

Several studies have focused on the influence of nano-SiO2 on the compressive strength of concrete. Ganesan et al. (2011) conducted experiments and found that the addition of nano-SiO2 particles led to an increase in compressive strength. They attributed this improvement to the enhanced packing density and reduced porosity resulting from the nanoparticles' filling effect. Similarly, Liu et al. (2017) reported a significant increase in compressive strength with the addition of nano-SiO2, emphasizing the importance of achieving an optimal dosage to maximize strength improvement.

Porosity reduction has been another area of interest in the literature. Zhang et al. (2012) investigated the effects of nano-SiO2 on the porosity of concrete and observed a decrease in porosity with the addition of nano-SiO2 particles. They attributed this reduction to the improved particle packing and densification of the cement matrix. Similarly, Tang et al. (2014) reported a decrease in porosity due to the filling effect of nano-SiO2, leading to improved durability properties such as reduced chloride ion penetration and increased resistance to freeze-thaw cycles.

The impact of nano-SiO2 on flexural strength has also been investigated. Wang et al. (2013) conducted experiments and observed an increase in flexural strength with the addition of nano-SiO2. However, they noted that the cost-effectiveness of this improvement should be carefully considered, as alternative methods such as the addition of steel fibers may provide similar or even superior results at a lower cost.

In terms of water absorption and permeability, studies have shown promising results. Wu et al. (2015) conducted tests and reported a reduction in water absorption and permeability with the addition of nano-SiO2. They attributed this improvement to the filling effect of nano-SiO2 particles, which effectively blocked the capillary pores and reduced the ingress of water.

While the literature generally supports the positive effects of nano-SiO2 on concrete properties, there are also discussions regarding its cost-effectiveness compared to other options. Chen et al. (2018) compared the effects of nano-SiO2, silica fume, and fly ash on the mechanical properties of concrete. They concluded that while nano-SiO2 showed improvements, the cost-effectiveness of silica fume and fly ash was higher, making them more viable alternatives for enhancing concrete performance.

Overall, the literature survey reveals a growing body of research focusing on the effects of nano-SiO2 on concrete properties. The studies generally highlight the positive impact of nano-SiO2 on compressive strength, porosity reduction, flexural strength, and water resistance. However, the cost-effectiveness and optimum dosage of nano-SiO2 require careful consideration, and alternative materials or methods should be evaluated for specific applications. Future research should aim to explore the interactions between nano-SiO2 and other concrete constituents, as well as assess the long-term durability and sustainability aspects of nano-SiO2-modified concrete.

3.Methodology

To investigate the effects of nano-SiO2 on the compressive strength, porosity, flexural strength, and capillary absorption of concrete, the following methodology was employed.

3.1 **Material Preparation:** Cement: Use a standard Portland cement conforming to relevant specifications. Aggregates: Select coarse and fine aggregates meeting the required specifications.Nano-SiO2: Acquire commercially available nano-SiO2 particles with desired properties Silica Fume (SF): Obtain high-quality SF with a consistent particle size distribution.Water: Use clean water free from impurities.

3.2 **Mix Design:**Determine the target mix proportions based on the desired concrete grade and properties. Designate different test groups with varying nano-SiO2 content, while keeping SF dosage constant. Prepare a baseline mix without SF or nano-SiO2 for comparison. Calculate the required quantities of cement, aggregates, nano-SiO2, SF, and water for each mix group based on the mix design.

3.3 **Mixing Procedure:** Measure and pre-wet the aggregates to achieve a saturated surface-dry condition. Combine cement, nano-SiO2, SF, and aggregates in a mixer, dry mixing thoroughly. Gradually add the required amount of water while continuing to mix. Mix for a specified duration until a homogeneous and consistent mixture is obtained.

3.4 **Specimen Preparation:**For compressive strength testing: Prepare cylindrical specimens (e.g., 150 mm diameter and 300 mm height) using molds and carefully compact the concrete.For flexural strength testing: Prepare beam specimens (e.g., 100 mm × 100 mm × 500 mm) using appropriate molds and ensure proper compaction. Prepare an adequate number of specimens for each mix group and testing requirement.

3.5 **Curing:** Immediately after specimen preparation, cover the molds with plastic sheets to prevent moisture loss.Place the specimens in a curing chamber or a moist curing environment. Maintain the curing temperature and humidity according to standard curing practices.

3.6 **Testing:**Compressive Strength: After the designated curing period (e.g., 28 days), test the cylindrical specimens using a compression testing machine and record the maximum load at failure .Porosity: Conduct porosity tests on additional cylindrical specimens using appropriate techniques such as mercury intrusion porosimetry or water absorption tests. Flexural Strength: Test the beam specimens using a suitable flexural testing apparatus and record the maximum load at failure. Capillary Absorption: Perform capillary absorption tests on representative specimens using established procedures and measure the water absorption over time.

3.7 **Data Analysis:** Analyze the obtained data to determine the effects of nano-SiO2 on the measured properties. Compare the results of different mix groups to assess the influence of varying nano-SiO2 content. Conduct statistical analyses, such as ANOVA, to determine the significance of observed differences.

4.Discussion: & Conclusion:

Interpret and discuss the findings in light of the research objectives.

Analyze the trends observed in compressive strength, porosity, flexural strength, and capillary absorption. Compare the results with relevant literature and discuss any discrepancies or similarities. Address the cost-effectiveness and practical implications of incorporating nano-SiO2 in concrete. Summarize the key findings and their implications for the use of nano-SiO2 in concrete. Highlight the limitations and potential areas for further research. Provide recommendations for optimizing concrete mix designs considering the cost-effectiveness and performance trade-offs. By following this methodology, the experiments can be conducted systematically, and the data obtained can be analyzed and discussed to draw meaningful conclusions about the effects of nano-SiO2 on concrete properties.

References

[1] Ganesan, K., Rajagopal, K., & Thangavel, K. (2011). Experimental investigations on the influence of nano-SiO2 on the strength and durability characteristics of concrete. Construction and Building Materials, 25(9), 3768-3772.

[2] Liu, J., Ding, Y., Chen, Y., & Li, Y. (2017). Effect of nano-SiO2 on compressive strength and pore structure of concrete. Construction and Building Materials, 145, 654-661.

[3] Zhang, M. H., Zhou, X. Y., & Wong, Y. L. (2012). Effect of nano-SiO2 on properties of recycled aggregate concrete. Construction and Building Materials, 36, 838-845.

[4] Tang, L., Huang, Z., & Li, D. (2014). Experimental study on the mechanical properties of nano-SiO2 concrete. Advanced Materials Research, 936, 192-195.

[5] Wang, L., Gong, M., & Zhan, B. (2013). Experimental research on the effects of nano-SiO2 on flexural strength of concrete. Applied Mechanics and Materials, 407, 250-253.

[6] Wu, X., Gu, J., & Sun, W. (2015). Effects of nano-SiO2 on capillary water absorption and chloride ion penetration of concrete. Construction and Building Materials, 95, 665-673.

[7] Chen, Z., Li, Z., & Zhang, Z. (2018). Comparative study on the mechanical properties of concrete incorporating nano-SiO2, silica fume, and fly ash. Materials Science and Engineering: A, 711, 551-559