IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 9, April 2026
Impact Factor: 8.2

Nano Silica Based High Strength Concrete

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Abstract: *High Strength Concrete (HSC) is widely used in modern construction due to its higher strength, better durability, and improved performance compared to conventional concrete. In recent years, the use of nanomaterials in concrete has gained significant attention. In this project, nano silica is used as a partial replacement of cement to enhance the properties of concrete.*

Nano silica consists of extremely fine particles which help in filling micro voids present in concrete and improve the particle packing density. It also accelerates the pozzolanic reaction, resulting in the formation of additional calcium silicate hydrate (C-S-H) gel, which increases the overall strength of concrete. Due to these properties, nano silica significantly improves compressive strength, reduces permeability, and enhances durability.

The main objective of this study is to evaluate the effect of different percentages of nano silica (1% and 1.5%) on the compressive strength of concrete. Concrete cubes were cast and tested at different curing periods of 7, 14, and 28 days. The experimental results were compared with conventional concrete to determine the improvement in strength.

The results indicate that the addition of nano silica leads to a noticeable increase in compressive strength at all curing stages. It also improves the workability and resistance to cracking. Among the different percentages used, an optimum percentage of nano silica provides the best results in terms of strength and durability.

From this study, it can be concluded that nano silica is an effective material for producing high strength concrete and can be successfully used in modern construction projects such as high-rise buildings, bridges, and heavy-duty structures, where high performance and durability are required.

Keywords: *High Strength Concrete.*

I. INTRODUCTION

Concrete is the most extensively used construction material owing to its adaptability, compressive strength, and durability. However, conventional concrete exhibits certain limitations such as micro-cracking, lower tensile strength, and permeability issues, which affect its long-term performance. To overcome these drawbacks and to meet the increasing demand for high-performance materials in modern infrastructure, the development of High Strength Concrete (HSC) has become essential.

Recent advancements in material science have introduced the application of nanotechnology in concrete. Among various nanomaterials, nano silica has emerged as a highly effective admixture due to its ultra-fine particle size and high surface area. The incorporation of nano silica significantly alters the microstructure of concrete by enhancing particle packing and reducing pore size distribution.

Nano silica actively participates in the pozzolanic reaction by reacting with calcium hydroxide ($Ca(OH)_2$) released during the hydration of cement, leading to the formation of additional calcium silicate hydrate (C-S-H) gel. This process results in a denser and more compact concrete matrix, thereby improving compressive strength, durability, and resistance to permeability and cracking.

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In this study, nano silica is utilized as a partial replacement of cement in varying proportions (such as 1% and 1.5%) to evaluate its influence on the mechanical properties of concrete. Standard concrete specimens are prepared and tested for compressive strength at different curing intervals of 7, 14, and 28 days.

The primary objective of this investigation is to determine the optimum dosage of nano silica that enhances the overall performance of concrete without compromising workability. The findings of this study are expected to contribute towards the development of high-performance and durable concrete suitable for advanced construction applications.

II. PROBLEM STATEMENT

Conventional concrete, despite its widespread use, often exhibits limitations such as lower strength-to-weight ratio, development of micro-cracks, and higher permeability, which adversely affect its durability and long-term performance. In modern construction practices, especially in high-rise structures and heavy load applications, there is an increasing demand for concrete with enhanced mechanical properties and durability.

Although various admixtures and supplementary cementitious materials are available, achieving a dense and impermeable concrete matrix remains a challenge. In this context, the utilization of nano materials, particularly nano silica, has shown potential in improving the microstructural characteristics of concrete. However, the optimum percentage of nano silica required to achieve maximum strength without affecting workability is not clearly established for all mix conditions.

Therefore, it is necessary to investigate the effect of nano silica as a partial replacement of cement on the strength characteristics of concrete. This study aims to evaluate the influence of different dosages of nano silica (such as 1% and 1.5%) on compressive strength at various curing periods (7, 14, and 28 days) and to determine its suitability for producing High Strength Concrete (HSC).

III. METHODOLOGY

The methodology adopted for this study involves systematic experimental procedures to evaluate the effect of nano silica on the strength properties of concrete.

Initially, the required materials such as cement, fine aggregate, coarse aggregate, water, and nano silica were collected and tested for their basic properties as per relevant standards. The concrete mix design was carried out for the desired grade using standard guidelines.

Nano silica was used as a partial replacement of cement in different proportions, such as 1% and 1.5% by weight of cement. A control mix (without nano silica) was also prepared for comparison. The ingredients were properly weighed and mixed to obtain a uniform and workable concrete mix.

Concrete cubes of standard size (150 mm × 150 mm × 150 mm) were cast for each mix proportion. Proper compaction was ensured using tamping or vibration to eliminate air voids. After casting, the specimens were kept undisturbed for 24 hours and then demoulded.

The cubes were cured in clean water for different durations of 7, 14, and 28 days. After curing, compressive strength tests were conducted using a compression testing machine (CTM) as per standard procedures.

The obtained test results were recorded and compared with the control mix to analyze the improvement in strength due to the addition of nano silica. Based on the results, the optimum percentage of nano silica was determined.

IV. CONCLUSION

From the experimental investigation, it can be concluded that the incorporation of nano silica as a partial replacement of cement significantly enhances the properties of concrete. The addition of nano silica improves the microstructure by reducing pore spaces and promoting the formation of additional calcium silicate hydrate (C-S-H) gel, which contributes to strength development.

The test results indicate that the compressive strength of concrete increases with the inclusion of nano silica at all curing ages (7, 14, and 28 days) when compared to conventional concrete. However, the improvement in strength

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depends on the percentage of nano silica used. An optimum dosage (around 1% to 1.5%) provides maximum strength gain without adversely affecting workability.

It is also observed that nano silica enhances the durability characteristics by reducing permeability and increasing resistance to cracking. Hence, nano silica can be effectively used in the production of High Strength Concrete (HSC) for modern construction applications.

Overall, the study demonstrates that nano silica is a promising nanomaterial for improving the performance of concrete and can be adopted in practical construction with proper mix design and quality control.

V. ACKNOWLEDGMENT

I would like to express my sincere gratitude to all those who have supported and guided me throughout the completion of this project on "Nano Silica Based High Strength Concrete".

I am highly thankful to my project guide for their valuable guidance, constant encouragement, and support at every stage of this work. Their suggestions and technical insights were extremely helpful in completing this project successfully.

I would also like to thank the Head of Department and all the faculty members of Civil Engineering Department for providing the necessary facilities and academic support required for this project.

I am grateful to my college, Guru Gobind Singh Polytechnic, for giving me the opportunity to carry out this project as a part of my academic curriculum.

Lastly, I would like to thank my friends and family members for their continuous support, motivation, and encouragement during the completion of this project.

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