An Examination of the Flexural and Compressive Strength of Concrete Using Silica Fumes

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Abstract: **By adding additional additives, the properties of concrete, a crucial building material, can be altered. The construction of skyscrapers has increased demand for concrete with higher compressive strength. A tried-and-true way to address this need is by adding microsilica, also known as silica fume.**
Microsilica, an amorphous form of silicon dioxide, is produced as an ultrafine powder during the manufacturing of silicon and ferrosilicon alloys. Its minute parts are made up of spherical particles that are almost 100 times smaller than normal cement particles, with an average diameter of 0.15 µm. Depending on the degree of compaction, the material's bulk density can range from 130 to 600 kg/m³, and its specific gravity typically ranges from 2.2 to 2.3.
Approximately 500,000 MT of microsilica are traded annually worldwide for use in the production of polymers, fibre cement, concrete, and oil drilling. Research shows that microsilica is safe for use in construction, despite the fact that it contains trace amounts of organic residues from natural sources and heavy metal oxides. Its application can also improve resistance to exposure to sulphate and acidic water and considerably reduce thermal cracking caused by cement hydration. Microsilica particles are spherical and 100 times finer than cement particles.

Key words: **cement, advanced material, microsilica, polymorph, ultrafine, and non-hazardous**

1. OVERVIEW

One of the most significant and extensively utilised man-made building materials is concrete. Cement (usually Portland cement), fine aggregate (sand), coarse aggregate (gravel or crushed rock), and water make up this composite material. Furthermore, when necessary, admixtures may be added to provide unique properties.

Concrete is a very durable and adaptable building material that is essential to contemporary construction and architecture. It is simple to pour into moulds and forms to form various shapes, and it quickly solidifies into a sturdy, stone-like structure. It can be used for footings, bridges, roads, and foundations in addition to buildings.

The majority of traditional concrete structures, however, deteriorate quickly, particularly in adverse weather conditions. As a result, they frequently need expensive repairs before they last as long as they should. Concrete must fulfil two crucial requirements in order to be considered high-quality: performance in both the fresh and hardened states.

When concrete is still fresh, it must be uniform and cohesive. The mixture should be easy to compact without excessive effort and cohesive enough to prevent segregation. ensuring consistency in the final product. Concrete must have sufficient flexural strength and satisfactory compressive strength after hardening to withstand external stresses and environmental influences.

Since this study focuses on the effects of silica fume on concrete strength, it is imperative to develop a more thorough understanding of both silica fume and concrete strength.
Microsilica's chemical composition

2.1 Compressive Strength Improvements

Microsilica's chemical composition

Silicon Dioxide	17-25 %
Aluminum Oxide	4-8 %
Ferric Oxide	0.5-0.6 %
Calcium Oxide	61-63 %
Magnesium Oxide	0.1-4.0 %
Sulfur Trioxide	1.3-3.0 %
Sodium Oxide	0.4-1.3 %

2. ARTICLE REVIEWS

Amudhavalli & Mathew: The study investigated the impact of silica fume on the strength and durability properties of M35 grade concrete. Silica fume was used to partially replace cement in varying percentages of 0%, 5%, 10%, 15%, and 20%. The compressive strength, split tensile strength, and flexural strength were evaluated at 7 and 28 days using a thorough experimental analysis. According to the findings, adding silica fume to the concrete greatly improved its strength and durability properties.

Srivastava: The study looked at how workable concrete was when silica fume was used as an ideal substitute for cement. Although improvements were observed in certain cases, the results showed that the addition of silica fume generally reduced the workability. When silica fume was substituted at different levels, the compressive strength increased significantly by 6–57%. Comparing the tensile and flexural strength to traditional concrete, however, revealed no appreciable variations.

Dhaka & Kumar: A review of the effects of partially substituting silica fume for cement on the characteristics of concrete was written. The focus of the study is an M35-grade concrete mix in which silica fume was used in various weight percentages to partially replace cement (0%, 5%, 9%, 12%, and 15%).

Pradhan and Dutta: The study examined the effects of silica fume on conventional concrete and discovered that at 24 hours, 7 days, and 28 days, a 20% silica fume replacement of cement produced the best compressive strength. Concrete containing silica fume could be categorised as high-strength concrete due to its increased compressive strength.

Shanmugapriya and Uma: To assess the use of silica fume as a partial cement substitute in high-performance concrete, an experimental study was carried out. The concrete was designed to achieve a target mean strength of 60 MPa, in accordance with CI 211.4R-08 guidelines. The superplasticiser used was a low CONPLASTSP 430, and the water-to-cement ratio was set at 0.32.

Various mix proportions were tested using specimens such as cubes, beams, and cylinders. Evaluations of the specimens were conducted at 7, 14, and 28 days. The results demonstrated that silica fume significantly improved split tensile strength, flexural strength, and compressive strength when substituted for some of the conventional Portland cement. The optimal silica fume content was determined to be 7.5% by weight, indicating that it is suitable for high-performance construction applications.

Sharma and Seema's: study looked at how the compressive strength of M20 grade concrete was affected by partially replacing cement with silica fume. The replacement levels of 10%, 20%, and 0% were evaluated while the water-to-cement (W/C) ratio was maintained at 0.5. The results indicated that the best compressive strength was obtained when silica fume was substituted for cement by 20% over the course of all curing times, which included 24 hours, 7 days, and 28 days. The compressive strength was 32.29 MPa, and the slump value was 21 mm after 28 days.

Perumal and Sundararajan: The study examined the effects of substituting silica fume for some of the cement on the strength and durability characteristics of premium concrete. It focused on trial mixes of high-performance concrete (HPC) in the M60, M70, and M110 grades to determine the optimal level of silica fume replacement. Compared to these mixtures, there were control mixes that did not contain silica fume. The results demonstrated that when 10% of the cement was replaced with silica fume, the corresponding grades' compressive strengths at 28 days were 60 N/mm², 70 N/mm², and 110 N/mm². The study also confirmed that the durability of the concrete was significantly improved by silica fume.

Jain and Pawade: The study's primary objective was to investigate the physical properties and response to various curing reactions of silica fume concrete. High-strength concretes containing silica fume were compared to reference Portland cement concretes in the study. In the silica fume concretes, these reference mixes matched the cement content or the cementitious materials to water ratio. The comparison aimed to evaluate the impact of silica fume on the physical properties and curing sensitivity of high-strength concrete.

Six levels of silica fume content were used in the experimental programme to partially replace cement by weight: 0% (control mix), 5%, 10%, 15%, 20%, and 25%, both with and without the addition of a superplasticizer. A 15% silica fume addition to the cement was also tested in two batches of regular concrete. Samples of silica fume mortar were subjected to a variety of chemical environments, such as calcium chloride, ammonium nitrate, sulphate

compounds, and different acids, in order to assess durability.

Ajileye: The study found that adding silica fume in place of cement enhanced the M30 grade concrete's compressive strength by up to 10%. However, when the replacement level surpassed 15%, a decrease in compressive strength was noted for all curing times (3, 7, 14, and 28 days). Compressive strength initially increased from 16.15% to 29.24%, but after reaching the ideal level, it started to decline from 23.98% to 20.22%.

Using silica fume in place of some of the cement altered the properties of hardened concrete, according to Roy and Sil's study. The maximum compressive strength of the cube and cylinder specimens was discovered to be attained at a replacement level of 10%. During compared to regular concrete, the compressive strength of cubes and cylinders increased by 19.6% and 16.82%, respectively, at this ideal dosage. Further confirming the positive effect of silica fume on concrete's mechanical performance, the study also assessed the split tensile strength.

Chennaivanan and Sasikumar: The characteristics of silica fume as a partial cement substitute in M30 grade concrete were assessed experimentally. Silica fume was substituted for cement at different percentages: 0%, 25%, 30%, 40%, and 50%. The findings indicated that when the silica fume content increased from 0% to 25%, normal consistency increased by about 40%. The 25% replacement level produced the best compressive strength at 7 and 28 days. The best dosage for increasing the strength of concrete was found to be 25% silica fume replacement, which also produced the highest split tensile strength.

Srivastava: The study looked at how workable concrete was when silica fume was used as an ideal substitute for cement. Although silica fume generally decreased workability, there were some cases where it improved. When silica fume replacement levels varied, the concrete's compressive strength increased by a significant 6–57%. Comparing the tensile and flexural strength to traditional concrete, however, revealed no appreciable variations.

Ghutke and Bhandari: The study looked at how silica fume affected concrete and discovered that it was a good substitute for cement, giving concrete a high rate of strength gain. However, the concrete becomes less workable as the silica fume percentage rises. A 10% substitution of silica fume for cement produced the best compressive strength, while a 15% substitution produced a stronger concrete than traditional concrete. It was discovered that a replacement percentage of 10% to 15% was optimal for silica fume.

Borsaikia Arun: With an emphasis on workability, compressive strength, and permeability across a range of mixture proportions, the study examined the impact of silica fume on distinct concrete properties. It improves the workability of fresh concrete by up to 20% when cement is substituted, according to the experimental results. Microsilica was added, and compressive strength increased as well. According to Ultrasonic Pulse Velocity (UPV) tests, UPV marginally increased during the early compression phases. UPV started to drop as the compressive load increased, though, and this decline became noticeable when the load reached roughly 75–80% of the ultimate strength. Additionally, the study discovered that adding up to 20% microsilica considerably decreased the permeability of concrete by 35% to 50%.

Amarkhail: The study looked at how silica fume affected the characteristics of high-strength concrete and discovered that it was possible to substitute silica fume for up to 10% of cement without losing the concrete's workability. A 10% silica fume replacement produced the highest compressive strength, and a 15% replacement came in second, with only a minor strength difference. However, concrete containing 15% silica fume exhibited the highest flexural strength. Therefore, 10% and 15% silica fume replacement levels were identified as optimal for significantly enhancing compressive and flexural strength, respectively.

3. FUTURE SCOPE

To gain a more comprehensive understanding of the mechanical properties of microsilica concrete, further investigations are highly recommended. Expanding on the current research will help validate existing findings and explore additional aspects of its performance.

Investigation of Additional Mechanical Properties:

Additional laboratory tests should be carried out to investigate additional mechanical properties of microsilica concrete beyond those that have been previously studied. Understanding the high-grade concrete mixes that incorporate microsilica should also be the main goal of research.

Improving Mechanical Efficiency through Fibre Combinations:

Promising gains in mechanical properties have been observed when microsilica is added to concrete. Future studies could examine how various fibre types in the concrete mix work together to further increase its efficiency. Research on fiber-reinforced microsilica concrete may shed light on its durability and structural behavior.

Future research can help create more resilient and effective microsilica concrete formulations for a range of construction applications by tackling these issues.

4. CONCLUSION

The strength characteristics of concrete, such as its compressive strength, flexural strength, and split tensile strength, are significantly improved when past research on the partial substitution of silica fume for cement is reviewed. These tests were carried out to evaluate the effect of silica fume on the performance of concrete using different grades.

The ideal range for silica fume replacement, according to the literature, is usually between 2.5% and 15%. Improvements in the mechanical characteristics of concrete, including its tensile, flexural, and compressive strengths, have been regularly noted within this range. Additionally, prior research shows that silica fume-infused concrete has exceptional durability properties, making it a material that shows promise for improving the long-term performance of concrete structures.

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