'Utilization of Silica Fume as a Partial Replacement of Cement in Concrete'

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ABSTRACT - *Concrete is widely used in construction, but cement production causes significant environmental pollution and carbon emissions. Silica fume, an industrial by-product rich in silica, is used as a partial replacement (5–15%) of cement. It reacts with concrete to form additional C-S-H gel, which enhances the strength, durability, and overall performance of concrete while reducing its permeability. The use of silica fume also improves resistance to chemical attacks such as sulphates and chlorides, thereby increasing the service life of structures. Furthermore, it enhances the bond between cement paste and aggregates, leading to better mechanical properties. This material also helps in producing high-performance and eco-friendly concrete by reducing cement consumption and utilizing industrial waste effectively, contributing to sustainable construction practices.*

1. INTRODUCTION

1.1 WHAT IS SILICS FUME ?

Silica fume is an extremely fine powder material obtained as a by-product during the manufacture of silicon metal or ferrosilicon alloys in electric arc furnaces. It is mainly composed of very fine particles of silicon dioxide (SiO_2). Because of its very small particle size, it is widely used in cement concrete as a partial replacement for cement.

1.2. OBJECTIVE OF STUDY

[1] Improve durability

[2] Reduce permeability (water entry)

[3] Improve bonding between materials

[4] Use industrial waste effectively

[5] Reduce cement use (economical)

[6] Increase strength (compressive & tensile)

1.3. Scope of Study

[1] To study the properties of silica fume.

[2] To evaluate its suitability as a partial replacement for cement.

[3] To analyze the effect on workability of concrete.

[4] To determine compressive strength with different percentages of silica fume.

1.4. Methodology

[5] Collect materials like cement, aggregates, water, and silica fume.
[6] Replace a small percentage of cement with silica fume.
[7] Prepare and mix the concrete properly.
[8] Cast the concrete in molds.
[9] Cure the specimens for required days.

2. LITERSTURE RIEVIEW

2.1 Introduction

Previous studies indicate that the use of silica fume as a partial replacement for cement significantly improves the strength and durability of concrete. It enhances compressive, tensile, and flexural strength due to its high pozzolanic activity and fine particle size. However, an increase in silica fume content may reduce the workability of concrete. Most research suggests that the optimum replacement level lies between 8% and 12%, which provides the best performance. Additionally, silica fume reduces permeability, increases resistance to chemical attack, and contributes to the development of high-performance and sustainable concrete.

2.2. Review and studies of various Authors

2.2.1. Study by Sudhansu Tak et al. (2023)

Sudhansu Tak and co-authors investigated the effect of silica fume as a partial replacement of cement in concrete with replacement levels of 0%, 5%, 8%, 11%, and 15%. Their results showed that compressive strength increased with the addition of silica fume up to 11% replacement, after which the strength started decreasing. They also observed improvement in split tensile and flexural strength, while workability decreased with higher silica fume content.

2.2.2. Study by Md. Rejoan Chowdhury (2025)

Chowdhury studied silica fume in recycled aggregate concrete (RAC) with replacement levels of 0%, 4%, 8%, 12%, and 16%. The research concluded that silica fume improved both early and later age mechanical properties of concrete. The optimum replacement level was found to be around

12%, which gave the highest compressive and tensile strength.

2.2.3. Study by B. Pranav Naik et al.

Pranav Naik and co-researchers studied M25 grade concrete with silica fume replacement levels between 8% and 12%. Their findings indicated that silica fume improves compressive strength and flexural strength due to its pozzolanic reaction and ability to refine pores in concrete. The best performance was observed at about 10% silica fume replacement.

2.2.4. Study by Herliati Rahman and Puput Dwi Rahayu

Rahman and Rahayu investigated the use of silica fume in self-compacting concrete (SCC) with replacement levels of 0%, 5%, 10%, and 15%. Their research found that silica fume improved compressive strength and enhanced the compactness of concrete due to the finer particles filling voids in the mix.

2.2.5. Review by Abhinav Shyam et al. (2017)

Abhinav Shyam and co-authors conducted a literature review on silica fume in concrete and concluded that silica fume significantly improves strength, durability, and resistance to aggressive environments. They also highlighted its role in producing high-performance concrete and reducing industrial waste disposal problems.

2.2.6. Kumar & Dhaka (2016)

write a Review paper on partial replacement of cement with silica fume and its effects on concrete properties.The main parameter investigated in this study M-35 concrete mix with partial replacement by silica fume with varying 0, 5, 9, 12 and 15% by weight of cement The paper presents a detailed experimental study on compressive strength, flexural strength and split tensile strength for 7 days and 28 days respectively. The results of experimental investigation indicate that the use of silica fume in concrete has increased the strength and durability

3. DETAIL OF WORKING AND PROCESSES

In this project, silica fume was used as a partial replacement of cement to study its effect on the strength of concrete.

3.1. Selection and Collection of Materials

The first step is to collect the required materials such as cement, fine aggregate (sand), coarse aggregate, water, and silica fume. The materials should be clean and free from impurities.

FIG.NO. 3.1. COLLECTION OF MATERIALS

3.2. Mix Proportion and Replacement

A suitable concrete mix design is prepared according to the required grade of concrete. In this process, a small percentage of cement is replaced by silica fume. The replacement usually done in different percentages such as 8%, 12%, and 16% of the total weight of cement. This helps in studying the effect of silica fume on the strength and durability of concrete. We taken the mix proportion as M20 grade whose ratio is (1:1.5:3).

3.3. Mix Proportion: M20 concrete with ratio 1 : 1.5 : 3 is used; cement is partially replaced with silica fume at 8%, 12%, and 16%.

3.4. Water–Cement Ratio: A water–cement ratio of about 0.5 was used to obtain proper workability of concrete.

3.5. Mixing of Concrete

After batching, all materials are mixed to get a uniform concrete. First, dry materials (cement, silica fume, fine and coarse aggregates) are mixed properly. Then water is added gradually and mixed until a homogeneous and workable concrete is obtained.

FIG.No. 3.5. MIXING OF CONCRETE

3.6. Casting of Specimens

After proper mixing, the concrete is poured into standard cube molds of size 150 mm × 150 mm × 150 mm. The molds are filled in layers and each layer is compacted using a tamping rod or vibration to remove air voids. The top surface is leveled and finished smoothly.

FIG.NO. 3.6. CASTING OF SPECIMENS

3.7. Curing of Concrete

After casting, the molds are kept undisturbed for about 24 hours at room temperature. After that, the specimens are removed from the molds and placed in clean water for curing. Curing is usually done for 7 days and 28 days to allow proper hydration and strength development.

FIG.NO. 3.7. CURING OF CONCRETE

3.8. Testing of Concrete

After curing, the concrete cubes are tested for compressive strength using a Compression Testing Machine (CTM). Load is applied gradually until the cube fails. The maximum load carried by the specimen is recorded and the compressive strength is calculated.

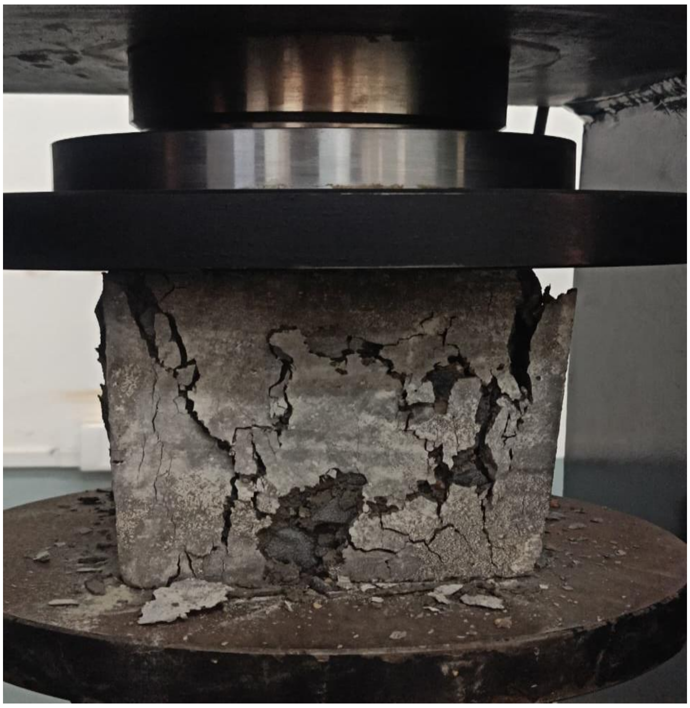

FIG.NO. 3.8. TESTING OF CONCRETE

3.9. Results After Testing

After curing the concrete cubes for 7 days and 28 days, the compressive strength test was conducted using a Compression Testing Machine (CTM). The results obtained for different percentages of silica fume replacement are summarized below.

3.9.1. Compressive Strength Test Results

Silica fume (%)	7 Days strength (MPa)	14 Days strength (MPa)	28 Days strength (MPa)
0%	18 MPa	22 MPa	26 MPa
8%	20 MPa	25 MPa	29 MPa
12%	22 MPa	27 MPa	32 MPa
16%	21 MPa	26 MPa	30 MPa

3.9.2. Result

From the experiment, it is concluded that partial replacement of cement with silica fume improves the strength and durability of concrete, and 12% replacement gives the optimum result.

4. RESULT AND APPLICATION

4.1. Result

The compressive strength test results show that adding silica fume as a partial replacement of cement increases the strength of concrete compared to normal concrete. The maximum strength is obtained at about 10–12% replacement, after which it slightly decreases but still remains higher than conventional concrete. Silica fume improves the density of concrete by filling pores and enhancing the bond between cement paste and aggregates.

4.2. Application

[1] Used in high-strength concrete structures

[2] Used in bridges, dams, and marine structures

[3] Used in high-rise buildings Used in industrial floors and pavements

[4] Used in water-retaining structures (reduces permeability)

[5] Used in repair and rehabilitation works

5. CONCLUSION AND FUTURE SCOPE

5.1. CONCLUSION:

Silica fume improves the strength and durability of concrete. Maximum compressive strength is achieved at about 12% replacement. It fills voids and enhances bonding, making concrete denser and stronger. Hence, it is an effective partial replacement for cement and reduces cement usage.

5.2. Future Scope

Silica fume can be widely used for high-strength and durable concrete. Further studies can explore different percentages and combinations with materials like fly ash or slag, along with long-term durability and environmental benefits.

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7. BIOGRAPHIES