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STUDY OF CONCRETE STRENGTH AND DURABILITY IMPROVEMENTS USING SILICA FUME AND STEEL FIBERS

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ABSTRACT

The concrete industry's growing environmental concerns, coupled with the challenge of effective disposal of construction waste, have driven interest in sustainable materials like silica fume and steel fibers. This paper investigates the impact of these materials on concrete performance, focusing on strength and durability. Laboratory experiments were conducted on M30 grade concrete, incorporating Portland Pozzolana Cement (PPC) with silica fume (SF) and steel fibers in varying proportions. The study highlights that replacing 10-15% of cement with silica fume, along with steel fibers ranging from 0% to 1%, improves concrete's compressive strength and durability. The findings indicate that this combination can lead to long-lasting concrete structures.

Keywords: Concrete mix, Silica fume, Steel fibers, Compressive strength, Durability

1. INTRODUCTION

Concrete has long been a foundational material in construction due to its versatility and strength. However, concrete structures face durability challenges, primarily due to environmental degradation and the weakening of internal reinforcement systems. To counter these issues, supplementary materials like silica fume and steel fibers have been proposed to enhance both strength and durability.

Silica fume, a by-product of silicon and ferrosilicon alloy production, is a highly pozzolanic material known for its fine particle size and high silica content, which enhances the cementitious properties of concrete. Steel fibers, on the other hand, improve the structural integrity of concrete by reducing crack propagation and enhancing tensile strength. This research explores the combined effects of silica fume and steel fibers on concrete's strength and durability.

2. LITERATURE REVIEW

Extensive research has been conducted on the use of silica fume and steel fibers to enhance concrete performance. Previous studies have shown that silica fume significantly improves the compressive strength of concrete by reacting with calcium hydroxide to form additional calcium silicate hydrates, which contribute to stronger and denser concrete matrices. Steel fibers, when used in low volumes (less than 1%), improve tensile strength and crack resistance without compromising compressive strength.

- **Perumal & Sundararajan (2004)**

In their study, Perumal and Sundararajan explored the effect of partially replacing cement with silica fume on the strength and durability properties of high-performance concrete. The study focused on M60, M70, and M110 grades of concrete, with up to 10% cement replacement using silica fume. The findings showed that silica fume significantly improved compressive strength and durability, with the most favorable results occurring at 10% replacement. The authors concluded that the addition of silica fume reduces permeability and enhances the durability properties of concrete structures, especially in high-performance applications.

- **Amudhavalli & Mathew (2012)**

Amudhavalli and Mathew studied the effect of silica fume on M35 grade concrete, investigating how partial replacement of cement with silica fume influenced the strength and durability of concrete. Their research revealed that replacing cement with 10-15% silica fume resulted in improved compressive strength, flexural strength, and split tensile strength. Additionally, the study indicated that silica fume increases concrete's resistance to chloride penetration, thereby enhancing its durability in aggressive environments

- **Milind V. Mohod (2012)**

Mohod investigated the use of steel fibers in concrete and their effect on both compressive and flexural strength. His study focused on M30 grade concrete, incorporating steel fibers in varying proportions (0.25% to 1.5% by volume). The results showed a significant improvement in both compressive and flexural strength, with the optimum steel fiber content found to be 0.75%. The inclusion of steel fibers also contributed to better crack resistance and structural integrity, making it an ideal reinforcement material for high-strength applications

- **Katkhuda, Hanayneh & Shatarat (2009)**

Katkhuda et al. studied the influence of silica fume on high-strength lightweight concrete. In their experiment, they replaced cement with varying percentages of silica fume (5%, 10%, 15%, and 20%) in concrete mixes with different

water-to-cement ratios. Their findings demonstrated that silica fume significantly enhances compressive and flexural strength. The optimum replacement level of silica fume was found to be between 15% and 20%, depending on the water-to-cement ratio used. Additionally, the incorporation of silica fume was shown to improve the overall durability of lightweight concrete

3. METHODOLOGY

3.1 Materials Used

- **Cement**: Ordinary Portland Cement (OPC) conforming to IS: 8112-1989 was used in this study.
- **Fine Aggregates**: Natural river sand, confirming to zone III, was used.
- **Coarse Aggregates**: Crushed stone with a maximum size of 20 mm.
- **Silica Fume**: Supplied by Cornice India Pvt. Ltd., silica fume was used to partially replace cement at 10% and 15% levels.
- **Steel Fibers**: Steel fibers with a diameter of 0.6 mm and length of 30 mm were incorporated in varying proportions ranging from 0% to 1%.

3.2 Experimental Procedure

The concrete mix design was based on IS: 10262-2009, targeting an M30 grade concrete. Silica fume was introduced as a partial cement replacement at 10% and 15%, and steel fibers were added in six varying percentages (0%, 0.2%, 0.4%, 0.6%, 0.8%, 1.0%). The mix was then tested for workability using the slump cone test and for compressive strength at 7 and 28 days.

4. EXPERIMENTAL RESULTS

4.1 Workability

The slump cone test results indicate that the inclusion of silica fume slightly reduced workability, as finer particles increased the water demand. However, the addition of steel fibers had a more significant impact, with higher fiber content reducing slump values from 100 mm for the control mix to as low as 50 mm at a 1% fiber content.

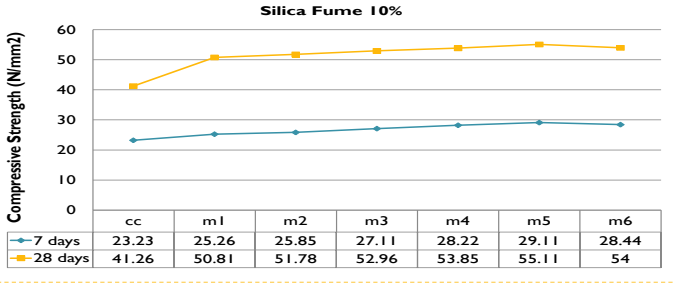
WORKABILITY

Composition	Mix designation	M30 Slump cone (mm)
Control Concrete	CC	120
Silica Fume 10% , 0% SF	M1	100
Silica Fume 10% ,0.2 % SF	M2	90
Silica Fume 10% , 0.4% SF	M3	85
Silica Fume 10% , 0.6% SF	M4	75
Silica Fume 10% , 0.8% SF	M5	65
Silica Fume 10% , 1.0% SF	M6	50
Silica Fume 15% , 0% SF	N1	70
Silica Fume 15% ,0.2 % SF	N2	65
Silica Fume 15% , 0.4% SF	N3	60
Silica Fume 15% , 0.6% SF	N4	50
Silica Fume 15% , 0.8% SF	N5	45
Silica Fume 15% , 1.0% SF	N6	40

4.2 Compressive Strength

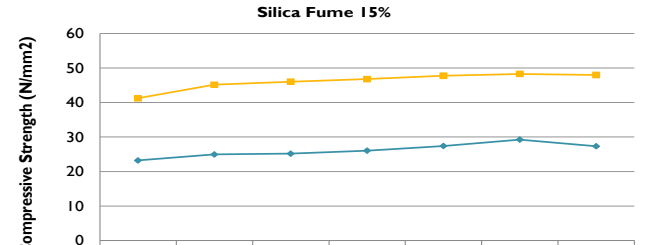
At 7 days, concrete mixes with 10% silica fume and 0.4% steel fiber showed a compressive strength of 33.8 MPa, while the mix with 15% silica fume and 0.6% steel fiber exhibited a strength of 35.1 MPa. At 28 days, the highest strength was observed in the mix containing 15% silica fume and 1.0% steel fiber, which reached 42.9 MPa, compared to 38.2 MPa for the control mix.

Compressive Strength (Silica Fume 10%)



	cc	m1	m2	m3	m4	m5	m6
7 days	23.23	25.26	25.85	27.11	28.22	29.11	28.44
28 days	41.26	50.81	51.78	52.96	53.85	55.11	54

Compressive Strength (Silica Fume 15%)



	cc	n1	n2	n3	n4	n5	n6
7 days	23.23	24.96	25.19	26.07	27.41	29.26	27.33
28 days	41.26	45.19	46.07	46.81	47.78	48.3	48

5. CONCLUSION

The results of this study demonstrate that the combined use of silica fume and steel fibers enhances both the compressive strength and durability of concrete. A 10-15% replacement of cement with silica fume improves the concrete matrix by reducing permeability, while steel fibers improve crack resistance and overall structural integrity. The optimal combination of 15% silica fume and 0.6-1.0% steel fibers provides the best results in terms of both strength and durability, making it a viable option for high-performance concrete applications.

6. FUTURE SCOPE

Further research could explore the long-term durability of silica fume and steel fiber-reinforced concrete in aggressive environments, such as those exposed to chemical or marine conditions.

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