iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 12 Issue: V Month of publication: May 2024

DOI: https://doi.org/10.22214/ijraset.2024.62592

Performance Evaluation of M30 Grade Concrete Using Silica Sand as Partial Replacement of Cement in Concrete

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Abstract: This study explores the improvement of concrete parcels, particularly strength and continuity, through the partial substitute of cement with silica fume (SF). The exploration addresses the environmental and health issues caused by artificial waste disposal, similar to covering ash and copper slag, by incorporating silica sand into concrete. A literature review reveals that SF significantly improves the mechanical and continuity characteristics of concrete, enabling the product of high-performance concrete suitable for these soundings. This paper investigates the strength parameters of concrete with 0 –15% SF relief in increment of 5%, comparing the results with conventional concrete. Findings indicate that the optimal compressive strength and split tens are achieved at 10% SF relief, beyond which strength decreases. This study aims to inform civil masterminds about the benefits of SF- modified concrete composites.
Keywords: Silica Sand, Cement, pozzolanic.

I. INTRODUCTION

Leaving waste materials directly in the environment causes significant ecological problems. Reusing industrial waste as admixtures in concrete production not only mitigates these issues but also has the potential to enhance concrete properties. One such by-product, silica fume, a pozzolanic material derived from the manufacture of silicon alloys, is being investigated for its benefits to concrete. Silica fume is composed of over 90% silicon dioxide with particles about 0.1-0.2 microns in diameter.

Preliminary research suggests that incorporating silica fume into concrete could increase its compressive and tensile strengths. An optimal replacement level is estimated to be around 10%, potentially increasing compressive strength by up to 19.6%, and split tensile strength by 38.58% compared to normal concrete. However, beyond 10%, additional silica fume may lead to a decrease in strength due to the brittle nature of the excess binder.

The use of silica fume in concrete is expected to not only enhance strength but also improve durability, reducing permeability and increasing resistance to aggressive environments. Further experimental studies are planned to validate these hypotheses and to explore the full potential of silica fume-modified concrete as a promising solution for sustainable construction practices, particularly for producing high-performance concrete with superior mechanical properties and durability.

II. LITERATURE REVIEW

1) Perumal and Sundararajan (2004) investigated the impact of substituting cement with silica fume on the strength and durability of high-grade concrete. They examined M60, M70, and M110 grades of high-performance concrete (HPC) and found that a 10% replacement of cement with silica fume resulted in compressive strengths of 60 N/mm², 70 N/mm², and 110 N/mm² after 28 days. The study concluded that concrete containing silica fume exhibited superior durability properties compared to standard mixes.
2) Ajileye (2012) explored the effects of cement replacement with silica fume up to 10% in M30 grade concrete. The findings indicated an increase in compressive strength for up to 10% replacement, with a subsequent decrease beyond this level. The compressive strength increased from 16.15% to 29.24%, and then decreased from 23.98% to 20.22% as the silica fume content increased beyond 10%.
3) Roy and Sil (2012) studied the partial replacement of cement with silica fume in hardened concrete. Their research showed that the maximum compressive strength occurred at 10% replacement, which was 19.6% and 16.82% higher than normal concrete for cubes and cylinders, respectively. Additionally, the split tensile strength also increased.

4) Amudhavalli and Mathew (2012) evaluated M35 grade concrete with varying levels of silica fume replacement (0%, 5%, 10%, 15%, and 20%). Their detailed experimental study showed improved compressive, split tensile, and flexural strengths at 7 and 28 days, with the best performance at a 10% replacement level.
5) Srivastava (2012) examined the workability and strength of concrete with varying silica fume content. The study found that workability generally decreased with higher silica fume content, although some cases showed improved workability. Compressive strength significantly increased (by 6-57%) with no noticeable changes in tensile and flexural strengths compared to conventional concrete.
6) Sharma and Seema (2012) investigated M20 grade concrete with partial cement replacement by silica fume at 0%, 10%, and 20%. They determined that a 20% replacement yielded the optimal compressive strength at all ages tested, with a 28-day compressive strength of 32.29 MPa and a slump value of 21 mm.
7) Pradhan and Dutta (2013) focused on conventional concrete with silica fume replacement. They found that a 20% replacement achieved the highest compressive strength at 24 hours, 7 days, and 28 days, indicating that silica fume significantly enhances the strength of concrete.
8) Shanmugapriya and Uma (2013) conducted experiments on high-performance concrete with partial cement replacement by silica fume targeting a mean strength of 60 MPa. They found that 7.5% silica fume replacement provided sufficient compressive, flexural, and split tensile strengths, making it suitable for construction purposes.
9) Ghutke and Bhandari (2014) examined the influence of silica fume on concrete strength. Their results indicated that silica fume is an effective replacement for cement, with the optimal compressive strength observed at a 10% replacement level. Beyond this, workability decreased while strength continued to increase up to a 15% replacement.

III.MATERIALS AND METHODOLOGY

A. *Materials*

To achieve the objectives of this study, an experimental program was planned to investigate the effects of silica sand on the compressive and split tensile strengths of concrete

The following materials were used:

Cement: Ordinary Portland Cement (OPC), specifically 43 grade, conforming to IS: 8112:1989, with properties listed in Table 1.

Coarse Aggregate: Locally available, maximum size 20 mm, conforming to IS: 383-1970. Properties are summarized in Table 2.

Fine Aggregate (Natural Sand): Locally sourced natural sand, conforming to IS: 383-1970 and grading zone II. Properties are listed in Table 3.

Silica Sand: Used as a partial replacement for cement. Properties are listed in Table 4.

Water: Potable water was used for mixing and curing.

TABLE I
PROPERTIES OF OPC 43 GRADE CONCRETE

Characteristics	Values Obtained
Specific Gravity	3.15
Standard Consistency	33%
Initial Setting Time	105 minutes
Final Setting Time	430 minutes

TABLE II
PROPERTIES OF COARSE AGGREGATE

Characteristics	Value
Colour	Grey
Size	20mm
Shape	Angular
Specific gravity	2.74

TABLE III
PROPERTIES OF FINE AGGREGATE

Characteristics	Value
Specific gravity	2.34
Bulk density(kg/m^3)	1.3
Fineness modulus	2.62
Water absorptption	0.88

TABLE IV
PROPERTIES OF SILICA SAND

S.No.	Characteristics	Value
1	Specific Gravity	2.65
2	Bulk Density	1.4 kg/m^3
3	Fineness Modulus	2.80
4	Water Absorption	0.60%
5	SiO_2 Content	90-99%

B. Methodology

1) Mix Proportions and Mixing

Concrete mix was designed to achieve specific target strengths. The mix proportions were calculated to ensure workability, strength, and durability. Mixing was done by hand or using a laboratory mixer to ensure homogeneity.

2) Casting and Curing

Concrete specimens were cast in molds and compacted to remove air voids. Specimens were cured in water for 7 and 14 days to evaluate strength development over time.

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 12 Issue V May 2024- Available at www.ijraset.com

3) Testing Procedures

Compressive Strength Test:
Specimens: Cubes of 150 mm x 150 mm x 150 mm.
Testing Machine: Compression testing machine.
Procedure: Specimens were tested after 7 and 14 days of curing. Load was applied gradually until failure, and the compressive strength was calculated using the formula:
Compressive Strength=Load x Cross-sectional Area
Split Tensile Strength Test:
Specimens: Cylindrical concrete specimens.
Procedure: Specimens were tested after 7 and 28 days of curing. Load was applied along the diameter of the cylinder until failure, and the tensile strength was calculated.
Flexural Strength Test:
Specimens: Beams.
Procedure: Flexural strength was evaluated using a three-point loading test as per ASTM standards. The modulus of rupture was calculated to determine the concrete's tensile strength.

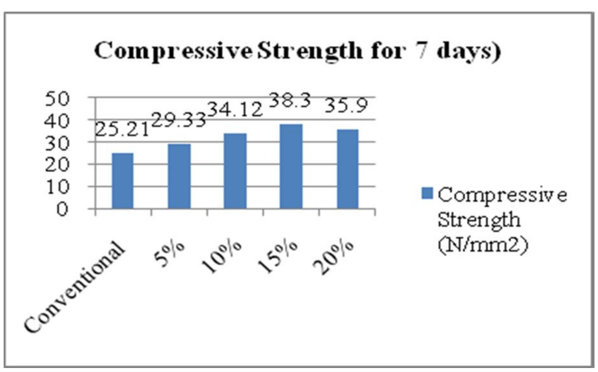
IV. RESULTS

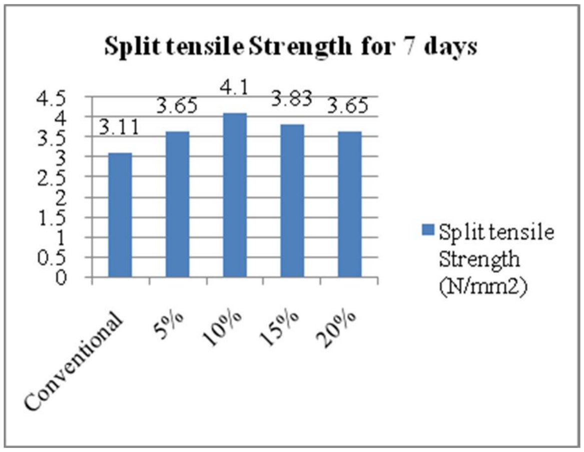
TABLE V
HARDENED CONCRETE TEST FOR 7 DAYS

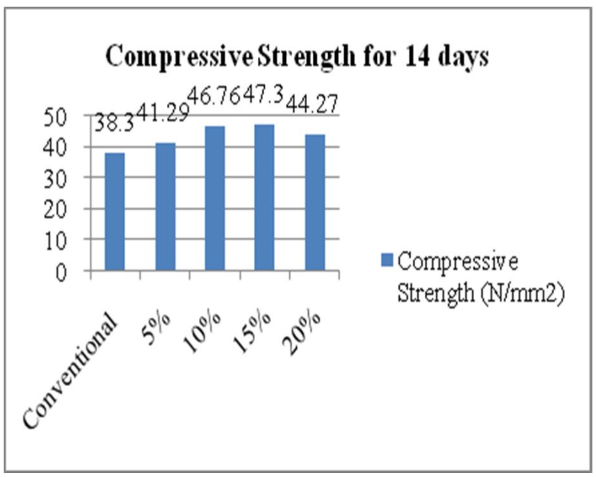
	0% of silica fume	5 % of silica fume	10 % of silica fume	15 % of silica fume	20 % of silica fume
Compressive Strength (N/mm2)	25.21	29.33	34.12	38.30	35.90
Split tensile Strength (N/mm2)	3.11	3.65	4.10	3.83	3.65

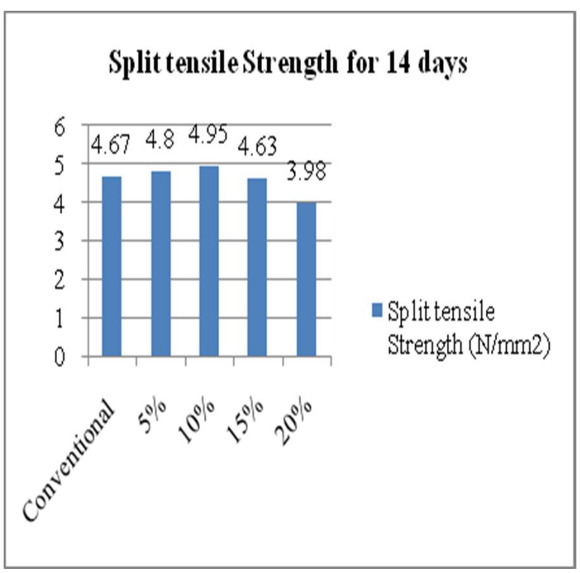
TABLE VI
Hardened Concrete Test for 14 days

	0 % of silica fume	5 % of silica fume	10 % of silica fume	15 % of silica fume	20 % of silica fume
Compressive Strength (N/mm2)	38.30	41.29	46.76	47.30	44.27
Split tensile Strength (N/mm2)	4.67	4.80	4.95	4.63	3.98




Split tensile Strength for 7 days
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
3.11
3.65
4.1
3.83
3.65
Conventional
5%
10%
15%
20%
Split tensile Strength (N/mm2)


Compressive Strength for 14 days
50
40
30
20
10
0
38.3
41.29
46.76
47.3
44.27
Conventional
5%
10%
15%
20%
Compressive Strength (N/mm2)


Split tensile Strength for 14 days
6
5
4
3
2
1
0
4.67
4.8
4.95
4.63
3.98
Conventional
5%
10%
15%
20%
Split tensile Strength (N/mm2)

V. CONCLUSIONS

The strength and durability characteristics of concrete mixtures have been investigated by replacing 5%, 10%, and 15% of cement with silica fume. Based on this study, the following conclusions are drawn:

A. *Compressive Strength*

5% Silica Fume: There is an increase in compressive strength at 7 days compared to the control mix. At 14 and 28 days, the strength increases significantly.

10% Silica Fume: There is a substantial increase in compressive strength at 7, 14, and 28 days. The compressive strength increases with the percentage of silica fume up to 10% and then decreases.

Optimal Replacement: The highest compressive strength is achieved at 10% replacement for all curing periods (7, 14, and 28 days).

B. *Split Tensile Strength*

5% Silica Fume: There is an increase in split tensile strength at 7 days compared to the control mix. At 14 and 28 days, the strength increases significantly.

10% Silica Fume: There is a substantial increase in split tensile strength at 7, 14, and 28 days. The tensile strength increases with the percentage of silica fume up to 10% and then decreases.

Optimal Replacement: The highest split tensile strength is achieved at 10% replacement for all curing periods (7, 14, and 28 days).

C. *Durability and Applications*

Durability: Silica fume concrete is more compact and durable, making it suitable for environments prone to chemical attack, frost action, etc.

Cost Efficiency: Replacing 10% of cement with silica fume achieves the characteristic strength of M30 grade concrete using an M20 grade mix, resulting in at least 4% cost reduction.

High Early Strength: With proper quality control, high early strength can be achieved, which is beneficial for structural constructions like high-rise buildings, bridges, chimneys, machine foundations, and runways. This results in quicker construction stages and cost efficiency, benefiting contractors and owners.

By leveraging silica fume in concrete mixtures, particularly at the 10% replacement level, significant improvements in both strength and durability can be realized, making it a viable option for various high-performance construction applications.

VI. ACKNOWLEDGMENT

I would like to express my profound gratitude to Mr.Shrikant Mishra, HOD of the civil department, and Dr P.B Deshmukh Director of Shri Shankaracharya Technical University for their contributions to the completion of my project titled "Performance evaluation of M30 grade concrete using Silica sand as Partial Replacement of Cement in Concrete”

I would like to express my special thanks to our mentor Dr.ANIL SUMAN for his time and efforts he provided throughout the year. Your useful advice and suggestions were really helpful to me during the project’s completion. In this aspect, I am eternally grateful to you

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ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
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