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Experiment Investigation to Study the Effect of Silica Fume on Physical & Chemical Properties of Concrete M-30 Grade

Kamlesh Pawar[1], Yashoda Alabade[2], Tejaswini Lahade[3], Vaishnavi Dillikar[4], Prof. Govind Chilla[5], Prof. Shubham Kadam[6]

Students, Department of Civil Engineering[1-4]

Professor, Department of Civil Engineering[5-6]

Zeal Polytechnic, Pune, India

Abstract*: This research delves into the effects of incorporating Silica Fume as a supplementary cementitious material on the physical and chemical properties of M-30 grade concrete. Silica fume was added in varying proportions 5%, 10%, and 15% to thoroughly examine its influence on several key performance indicators, including compressive strength, workability, and resistance to chemical aggression. The results reveal noteworthy enhancements in strength, durability, and resilience against chemical attacks, indicating that optimal incorporation of silica fume can significantly elevate the overall performance of concrete. These findings highlight the potential of silica fume as a valuable additive in the quest for higher-quality, longer-lasting concrete solutions. This research delves into the effects of incorporating silica fume as a supplementary cementitious material on the physical and chemical properties of M-30 grade concrete. Silica fume was added in varying proportions 5%, 10%, and 15% to thoroughly examine its influence on several key performance indicators, including compressive strength, workability, and resistance to chemical aggression. The results reveal noteworthy enhancements in strength, durability, and resilience against chemical attacks, indicating that optimal incorporation of silica fume can significantly elevate the overall performance of concrete. These findings highlight the potential of silica fume as a valuable additive in the quest for higher-quality, longer-lasting concrete solutions.*

Keywords: Silica Fume, M-30 Grade Concrete, Compressive Strength, Chemical Durability, Workability

I. INTRODUCTION

Concrete is a fundamental material in the construction industry, acting as the backbone for infrastructure development around the globe. As the demand for durable and high-performance concrete rises, researchers continually seek innovative solutions to enhance its properties. One effective solution is the incorporation of supplementary cementitious materials (SCMs), such as **silica fume**, into concrete mixes. This study aims to investigate the effects of silica fume on the physical and chemical properties of M-30 grade concrete.

Role of Silica Fume

Silica fume is a byproduct of silicon and ferrosilicon alloy production. It is an ultrafine material primarily composed of silicon dioxide (SiO_2), with about 100 times smaller particles than conventional cement particles. Its high pozzolanic activity and large surface area make it an ideal additive for concrete. When added to concrete, silica fume:

- Reacts with calcium hydroxide to produce additional calcium silicate hydrate (C-S-H), enhancing strength and durability.
- Fills voids in the concrete matrix, reducing porosity and permeability.
- Improves resistance to chemical attacks and environmental factors.

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Significance of M-30 Grade Concrete

M-30 grade concrete is a standard mix commonly used in structural applications that require moderate strength and durability. Studying the incorporation of silica fume into this grade can provide valuable insights into optimizing concrete for practical and widespread use. Concrete is a fundamental material in the construction industry, acting as the backbone for infrastructure development around the globe. As the demand for durable and high-performance concrete rises, researchers continually seek innovative solutions to enhance its properties. One effective solution is incorporating supplementary cementitious materials (SCMs), such as silica fume, into concrete mixes. This study aims to investigate the effects of silica fume on the physical and chemical properties of M-30 grade concrete.

Concrete and Its Challenges

Concrete is a versatile and widely used construction material due to its strength, durability, and cost-effectiveness. However, traditional concrete faces several challenges, including:

- Limited resistance to chemical attacks and environmental degradation.
- Variability in mechanical strength.
- Permeability issues that lead to reduced durability.

These challenges highlight the need to explore advanced materials and techniques to enhance concrete's overall performance.

II. LITERATURE REVIEWS

1. Silica fume, a byproduct of silicon metal production, enhances concrete's strength and durability. Its fine particles fill gaps, improving workability and crack resistance. By reacting with calcium hydroxide during hydration, it forms a more uniform and durable matrix. Using silica fumes also promotes eco-friendly construction by recycling industrial waste. This review highlights its benefits for both fresh and hardened concrete.

2. High-strength concrete, made by reducing porosity and microcracks, can be enhanced with industrial by-products like fly ash, slag, and silica fume. These materials replace part of cement, reducing costs and environmental impact. Concrete specimens with varying percentages of fly ash and slag (5% - 20%) were tested at 7, 28, and 56 days for compressive and tensile strength. High-strength concrete, with a compressive strength above 40 MPa, is widely used due to improved durability and performance. Utilizing industrial by-products promotes eco-friendly and economical construction.

3. This study examines the effect of varying silica fume (SF) percentages on M25 and M40 grade concretes, focusing on properties like compressive strength, elastic modulus, and shrinkage under sealed and unsealed conditions. Findings reveal improved hardened properties with higher SF content but also increased shrinkage with prolonged curing.

4. Silica fume, a byproduct of silicon production, enhances concrete's strength and durability by acting as a fine filler and reacting rapidly due to its high surface area. Experimental findings suggest that a 15% replacement of OPC with silica fume optimizes both sustainability and concrete performance.

1. Improvement in Compressive Strength: Research shows that silica fume enhances the compressive strength of concrete due to its pozzolanic reaction with calcium hydroxide, producing additional calcium silicate hydrate (C-S-H). This reaction strengthens the concrete matrix and reduces porosity.

2. Durability Enhancements: Silica fume contributes to improved resistance against chemical attacks (e.g., acids and sulfates) and reduces permeability, making the concrete more durable in aggressive environments.

3. Reduced Workability: Several studies report a reduction in workability with increasing silica fume content due to its ultrafine particles. Superplasticizers are often used to compensate for this effect.

4. Optimal Dosage: Researchers generally recommend an optimal silica fume content of 10–15% by weight of cement for achieving the best balance of strength, durability, and workability.

5. Environmental Benefits: Utilizing silica fume, a byproduct of the silicon industry, promotes sustainable construction practices by recycling industrial waste.

Gaps in existing research include:

• Limited studies on long-term performance (e.g., beyond 28 days of curing).

• Need for standardized guidelines for mix designs incorporating silica fume in various grades of concrete.

AUTHORS: Md Athar Kazmi, Mirza Ali Baig, Md Hesamuddin**.**

2. Workability and Consistency of Concrete with Silica Fume

Concrete containing silica fume displays improved cohesion and reduced segregation compared to conventional concrete. To achieve similar workability, the initial slump should be increased by about 50 mm for mixes with silica fume. This additive also enhances the ability to pump concrete over long distances, particularly vertically. A notable example of this was at the Burj Khalifa in Dubai, where concrete was pumped to a height of 601 meters in a single operation, showcasing the effectiveness of silica fume in high-rise construction.

Setting Time:

In contrast to other supplementary cementitious materials, such as slag and fly ash, silica fume does not have a significant impact on the setting time of the mix.

Water Demand:

Silica fume increases the water demand in concrete, which can be managed with admixtures. Higher amounts of silica fume lead to greater water demand due to its high

surface area. To maximize strength and durability, concrete with silica fume should use a high-range water-reducing admixture.

Bleeding

Concrete that incorporates silica fume exhibits a substantial reduction in bleeding. As the dosage of silica fume increases, the bleeding decreases effectively. This remarkable effect is primarily due to the high surface area of the silica fume, which absorbs a significant amount of water, leaving very little free water in the mixture for bleeding. It is crucial to recognize that because of this reduced bleeding, it is essential to take proactive measures to prevent early moisture loss from freshly placed silica-fume concrete, particularly in conditions that promote rapid surface drying.

Heat of hydration

The heat of hydration is defined as the quantity of heat released during the chemical reaction that occurs when cement interacts with water. This exothermic reaction plays a vital role in the hydration process, leading to the formation of hydration products that contribute to the strength and durability of concrete.

Sensitivity to curing

Curing is a critical process in concrete construction that ensures proper hydration of cement and optimal development of strength and durability. The sensitivity of concrete to curing refers to how its properties (such as strength, durability, and surface quality) are affected by curing conditions, including time, temperature, and moisture availability.

3. Effect on Concrete Strength

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Silica fume enhances concrete strength by creating a denser microstructure, reducing porosity, and generating additional calcium silicate hydrate (C-S-H). This improves compressive and tensile strength, especially in the early stages. However, it may reduce workability, often requiring superplasticizers. The ideal amount is 10% to 15%, resulting in durable, high-performance concrete for demanding applications. Concrete made with silica fume enhances the conventional relationship between compressive strength and the water/cement (w/c) ratio, leading to increased strength at given ratios. It can achieve over 25 N/mm² in compressive strength within 24 hours, and very high 28-day strengths can be obtained with standard ready-mixed concrete plants. In the USA and Asia, strengths of 100–130 N/mm² are used in tall buildings, with cementitious content over 400 kg/m³ and w/c ratios between 0.30 and 0.40.An example is the 79-floor East Island Centre in Hong Kong, where Grade 100 MPa self-compacting concrete reduced the concrete volume by 15%, providing sustainability benefits and allowing for additional rental space in a prime area.

4. Effect on Concrete Durability

Concrete Durability

Concrete durability is the ability to withstand wear, weathering, chemical attacks, and environmental conditions while maintaining its properties.

Several factors influence its durability:

Factors Affecting Durability

1. Water-Cement Ratio: A high ratio weakens the concrete and increases porosity, making it prone to damage.

2. Chemical Exposure:

- Sulfate Attacks: Cause spalling and loss of strength.
- Chloride Penetration: Leads to corrosion of steel reinforcement.

3. Environmental Conditions:

- Freeze-Thaw Cycles: Can cause cracking.
- High Temperatures: May lead to shrinkage cracking.

4. Construction Practices: Poor compaction or curing reduces resistance to damage.

5. Admixtures: Using materials like fly ash or slag can enhance durability.

6. Reinforcement Corrosion: Moisture and oxygen can corrode embedded steel, causing expansion and cracking.

7. Carbonation: A reaction with CO2 that weakens concrete over time.

Improving Durability

- Use high-quality materials with a low water-cement ratio.
- Ensure proper compaction, curing, and placement.
- Apply protective coatings to reduce exposure to harmful substances.
- Use supplementary cementitious materials (SCMs).
- Design concrete mixes for specific environmental conditions.

5. Effect on Concrete's Physical Properties

Concrete's physical properties are vital for its performance and functionality. Several factors influence these properties, directly affecting strength, workability, and durability.

Key Properties of Concrete

Compressive Strength:

Compressive strength is crucial and is affected by the water-cement ratio, curing conditions, and material quality. High porosity and poor curing can significantly reduce this strength.

Workability:

Workability refers to how easily concrete can be mixed and placed. Admixtures like superplasticizers can enhance workability without sacrificing strength, but excessive workability may lead to aggregate segregation.

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Density:

Concrete density is determined by the materials used. Denser concrete offers better durability and strength, while lightweight aggregates may lower density but compromise strength if not designed properly.

Porosity and Permeability

High porosity leads to increased water absorption and lowered durability, while permeability allows harmful agents to penetrate, risking corrosion. Using low water-cement ratios and supplementary materials can help minimize these issues.

Shrinkage and Creep:

Shrinkage can cause cracking during curing due to water evaporation. Creep refers to deformation under sustained loads. High-strength materials and proper curing can reduce these effects.

Durability:

Durability is influenced by strength, porosity, and density, with factors like abrasion resistance and freeze-thaw resilience playing key roles.

Thermal Properties:

Concrete's low thermal conductivity provides insulation, but it can crack due to thermal expansion and contraction. Special admixtures or fibers can enhance thermal performance.

Environmental Benefits: Utilizing silica fume, a byproduct of the

III. METHODOLOGY

Preparation of Samples:

Mix concrete with varying silica fume content using a mechanical mixer.

Cast specimens for compressive, tensile, and other tests.

Testing:

Conduct fresh concrete tests immediately after mixing.

Cure hardened concrete specimens in water at 27 ± 2°C.

Data Collection:

Record test results for different replacement levels.

Analysis:

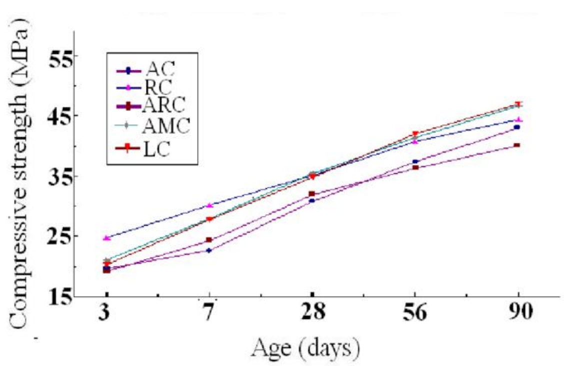
Plot strength vs. silica fume percentage curves.

Compare durability indices and microstructural characteristics.

Compare without silica M30 grade concrete cube with silica M30grade concrete cube.

1. Experimental Investigation

Concrete mix design involves selecting and proportioning materials to achieve specific characteristics in fresh and hardened concrete. Generally, mixes are tailored for workability, strength, and durability.



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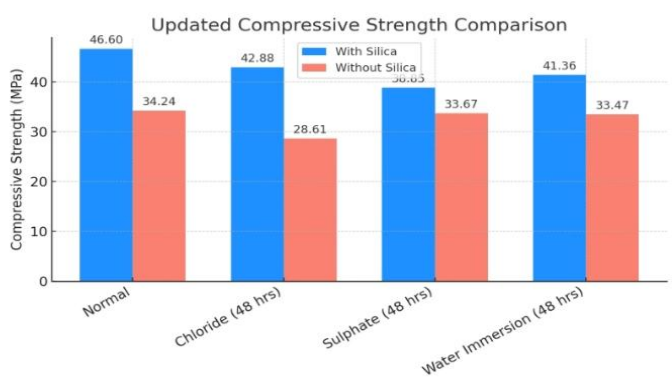
Key factors influencing the design include:
- Structural requirements
- Environmental exposure
- Job site conditions, such as methods of production and placement
- Properties of available raw materials

The mix proportioning for concrete **of M 30 Grade with a W/C ratio of 0.42**

Selection of water content
From Table 2 **(IS 10262:2009)**
Maximum water content for 20mm aggregate = 186 liters (for 25 to 50mm slump range)
Estimated water content for 200 mm slump = 186+18/100*186 = 219 lit.
The mix proportion (for M30) grade of concrete is
Cement : F.A : C.A
1 : 2.76 : 1.28
The casted cubes were tested for their
Physical and chemicals Test's:
1. Normal compressive strength,
2. Compressive Strength after Chloride Penetration for 48 hrs.,
3. Compressive strength after Sulphate Penetration for 48 hrs.
4. Compressive strength after Immersion in water for 48 hrs.

for 7, 14 & 28 days and the results are tabulated as follows.
As per Indian standard code (IS-516).

Sr. No.	Test Parameter	Result		Test method
		With Silica M30 Cube	Without Silica M-30 Cube	
1.	**Compressive strength**, MPa	46.6	34.24	**IS 516**
2.	Compressive Strength after **Chloride Penetration** for 48 hrs., MPa	42.88	28.61	IS **IS 516**
3.	Compressive strength after **Sulphate penetration** for 48 hrs., MPa	38.85	33.67	**IS 516**
4.	Compressive strength after **Immersion In water** for 48 hrs., MPa (water absorption)	41.36	33.47	**IS 516**
5.	SLUME CONE TEST	130mm	130mm	



IV. CONCLUSION

The experimental investigation on M30 grade concrete demonstrated that incorporating silica fume significantly enhances its physical and chemical properties. Compressive strength improved in all conditions, with the most notable gain observed under chloride penetration, indicating increased durability. Water immersion tests also showed better strength retention in silica-modified concrete, highlighting improved resistance to moisture-induced deterioration. However, sulphate exposure presented a unique case where the strength was slightly lower than that of the non-silica mix, suggesting the need for further study. Overall, silica fume improves the performance of concrete, making it a viable additive for durable and high-strength structures.

V. ACKNOWLEDGMENT

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[1]. Vikas Srivastava1 , Alvin Harison2 , P. K. Mehta3 , Atul4 , Rakesh Kumar5 Assistant Professor, Civil Engg. Department, SHIATS (Formerly AAI-DU), Allahabad - 2110071, 2 Professor, Civil Engg. Department, MNNIT, Allahabad – 2110043.

[2]. Shubham Kadam #1, Mrs. P.V. Numbulwar (Guide) *2 # Sinhgad Institute of Technology & Science Narhe, Pune, India.

[3]. S. Jagan and T.R. Neelakantan Department of Civil Engineering, Kalas Lingam Academy of Research and Education, Anand Nagar, Krishnan Koil 626 126, India Received: April 28, 2020 • Accepted: July 15, 2020

[4]. V. Preetha1*, Sathyapriyadharshini2, Sarguna2, Senthamilselvan2 1Assistant Professor, Department of civil Engineering Bannari Amman Institute of technology, Sathya Mangalam, Erode, Tamil Nadu India. 2UG Student, Department of civil EngineeringBannari Amman Institute of technology, Sathya Mangalam, Erode, Tamil Nadu India. *Corresponding author E-Mail ID: preethav@bitsathy.ac.in, Doi: https://doi.org/10.34256/irjmtcon21