

# Experimental Investigation of Concrete Using Silica as a Partial Replacement with Cement

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**Abstract**— This study investigates the effects of using silica as a partial replacement for cement in concrete to enhance its mechanical and durability properties while promoting sustainable construction practices. Silica, particularly in the form of silica by product of silicon metal or ferrosilicon alloy production is known for its high pozzolanic activity and fine particle size, making it a promising supplementary cementitious material. Concrete mixes were prepared with varying percentages of silica fume (1%, 2%, and 3% by weight of cement) and tested for compressive strength, split tensile strength, and flexural strength at different curing ages (3, 7, and 28 days). The results demonstrated that the inclusion of silica up to an optimal replacement level significantly improved the compressive and tensile strength of the concrete. Beyond the optimum percentage, a reduction in strength was observed, possibly due to excessive fineness and water demand. Durability characteristics, including water absorption and resistance to sulfate attack, were also evaluated and found to improve with the addition of silica. Thus research concludes that partial replacement of cement with silica can enhance concrete performance and contribute to environmental sustainability by reducing cement usage.

**Keywords**—Silica, Aggregate, Cement, Fine Aggregate.

## 1. INTRODUCTION

Concrete is the most widely used construction material in the world, valued for its strength, durability, and versatility. However, the production of ordinary Portland cement (OPC), a key ingredient in concrete, contributes significantly to global carbon dioxide emissions. In response to increasing environmental concerns and the need for sustainable construction practices, researchers and engineers are exploring alternative materials that can partially replace cement without compromising the performance of concrete. Silica, particularly in the form of silica fume or micro-silica, has emerged as a promising supplementary cementitious material (SCM). It is a by product of the silicon and ferrosilicon alloy industry, characterized by its extremely fine particles and high pozzolanic activity. When added to concrete, silica reacts with calcium hydroxide produced during cement hydration, forming additional calcium silicate hydrate (C-S-H) gel, which enhances the strength and durability of the concrete matrix. This experimental investigation aims to evaluate the effects of partially replacing cement with silica on the mechanical and physical properties of concrete. The study involves varying the percentage of silica replacement and testing key properties such as compressive strength, workability, and durability. The findings are expected to provide insights into the feasibility and performance benefits of using silica as a sustainable alternative in concrete production.

## 2. LITERATURE REVIEW

**1. Pradhan and Dutta (2013)** investigated the effects of silica fume on conventional concrete. The optimum compressive strength was obtained at 20% cement replacement by silica fume at 24 hours, 7 and 28 days. Higher compressive strength resembles that the concrete incorporated with silica fume was high strength concrete.

- 2. Ajileye (2012)** Cement replacement up to 10% with silica fume leads to increase in compressive strength for M30 grade of concrete. From 15% there is a decrease in compressive strength for 3, 7, 14 and 28 days curing period. Compressive strength of M30 grade of concrete was increased from 16.15% to 29.24% and decrease from 23.98% to 20.22%
- 3. Roy & Sil (2012)** Studied the Effect of Partial Replacement of Cement by Silica Fume on Hardened Concrete. From the study it has been observed that maximum compressive strength (both cube and cylinder) is noted for 10% replacement of cement with silica fume and the values are higher (by 19.6% and 16.82% respectively) than those of the normal concrete (for cube and cylinder) whereas split tensile strength.
- 4. Shanmugapriya & Uma (2013)** carried an Experimental Investigation on Silica Fume as a partial Replacement of Cement in High Performance Concrete. The concrete used in this investigation was proportioned to target a mean strength of 60 MPa and designed as per A The water cement ratio (W/C) adopted was 0.32 and the Super Plasticizer used was CONPLAST SP 430. Specimens such as cubes, beams and cylinders were cast for various mix proportions and tested at the age of 7, 14 and 28 days CI 211.4R-08. The investigation revealed that the partial replacement of cement by silica fume will develop sufficient compressive strength, flexure strength and split tensile strength for construction purposes. The optimum dosage of silica fume found to be 7.5% (by weight), when used as partial replacement of ordinary Portland cement.
- 5. Amudhavalli & Mathew (2012)** studied the Effect of silica fume on the strength and durability characteristics of concrete. The main parameter investigated in this study is M35 grade concrete with partial replacement of cement by silica fume by 0, 5, 10, 15 and by 20%. a detailed experimental study in Compressive strength, split tensile strength, flexural strength at age of 7 and 28 day was carried out. Results Shows that Silica fume in concrete has improved the performance of concrete in strength as well as in durability aspect.
- 6. Jain & Pawade (2015)** studied the Characteristics of Silica Fume Concrete. The physical properties of high strength silica fume concretes and their sensitivity to curing procedures were evaluated and compared with reference Portland cement concretes, having either the same concrete content as the silica fume concrete or the same water to cementitious materials ratio. The experimental program comprised six levels of silica-fume contents (as partial replacement of cement by weight) at 0% (control mix), 5%, 10%, 15%, 20%, and 25%, with and without superplasticizer. It also included two mixes with 15% silica fume added to cement in normal concrete. Durability of silica- fume mortar was tested in chemical environments of sulphate compounds, ammonium nitrate, calcium chloride, and various kinds of acids.
- 7. Srivastava (2012)** worked out the workability of concrete on optimum replacement of silica fume by cement. Workability reduces with the addition of silica fume. However, in some cases improved workability was observed. With the addition and variation of replacement levels of silica fume the compressive strength significantly increased by (6- 57%). There was no change observed in the tensile and flexural strength of the concrete as compared to the conventional concrete.
- 8. Perumal & Sundararajan (2004)** observe the Effect of partial replacement of cement with silica fume on the strength and durability properties of high grade concrete. Strength and durability properties for M60, M70 and M110 grades of HPC trial mixes and to arrive at the maximum levels of replacement of cement with Silica fume, investigations were taken. The strength and durability characteristics of these mixes are compared with the mixes without SF. Compressive strengths of 60 N/mm<sup>2</sup>, 70 N/mm<sup>2</sup> and 110 N/mm<sup>2</sup> at 28 days were obtained by using 10 percent replacement of cement with SF. The results also show that the SF concretes possess superior durability properties.

### 3. MATERIALS

The various materials such as Cement, Fine Aggregate, Coarse Aggregate, Water, Silica used for the proposed study.

**AGGREGATES:** Aggregate used in concrete are divided into two categories:

**FINE AGGREGATES:** Aggregate which passed through 4.75mm IS Sieve and retained on 75micron(0.075mm) IS Sieve is termed as fine aggregate. Fine aggregate is added to concrete to assist workability and to bring uniformity in mixture. Usually, the natural river sand is used as fine aggregate. Ordinary river sand conforming IS 383-1970 is used in this project.

**COARSE AGGREGATES:** The coarse aggregate for the works should be river gravel or crushed stone. The aggregate which passed through 75mm sieve and retain on 4.75mm are known as coarse aggregate. It should be hard, strong, dense, durable, clean, and free from clay or loamy admixtures or quarry refuse or vegetable matter. The pieces of aggregates should be cubical, or rounded shaped and should have granular or crystalline or smooth (but not glossy) non powdery surfaces. Aggregates should be properly screened and if necessary washed clean before use. Coarse aggregates containing flat, elongated or flaky pieces or mica should be rejected. The grading of coarse aggregates should be as per specifications of IS383-1970. In this project, 20mm size of angular shaped coarse aggregate is used.

**CEMENT:** Another The Bureau of Indian Standards (BIS) has classified OPC in three different grades The classification is mainly based on the compressive strength of cement- sand mortar cubes of face area 50 cm<sup>2</sup> composed of 1 part of cement and 3 parts of standard sand by weight with a water- cement ratio arrived at by a specified procedure. The grades are (i) 33 grade (ii) 43 grade (iii) 53 grade. The grade number indicates the minimum compressive strength of cement sand mortar in N/mm<sup>2</sup> at 28 days, as tested by above mentioned procedure. In this project, 53 Grade Ordinary Portland cement is used.

**SILICA FUME:** Micro silica or silica fume is the most commonly used mineral admixture in high strength concrete. It has become the chosen favorites for high strength concrete and is a good pozzolanic material. It can be used in a big way, adding to the concrete mix dramatically enhance the workability, strength & impermeability of concrete mixes while making the concrete durable to chemical attacks, abrasion & reinforcement corrosion, increasing the compressive strength.

#### 4. PRELIMINARY INVESTIGATION

Ordinary Portland cement as per IS: 8112:1976 was tested to find the properties of cement. The specific gravity test was conducted by adopting chatelier method. Normal consistency, Initial and final setting time of cement were also conducted on Ordinary Portland Cement [3]. The main aim of this test is to find the percentage of water required to produce a cement paste of standard consistency. For finding out initial setting time, final setting time and soundness of cement, and strength parameter known as standard consistency has to be used. It is pertinent at this stage to describe the procedure of standard consistency test. The standard consistency of a cement paste is defined as that consistency which will permit a plunger 10mm diameter and 50mm length to penetrate to a depth of 5 to 7mm from the bottom of the mould. The apparatus is called Vicat apparatus. This apparatus is used to find out the percentage of water required to produce a cement paste of standard consistency. The standard consistency of a cement paste is some time called as normal consistency [4]. The following procedure is adopted to find standard consistency. Take about 500g of cement and prepare a paste with a weighing quantity of water (say 24 percent by weigh of cement) for the first trial. The paste must be prepared in a standard manner and filled to expel air. A standard plunger, 10mm diameter, 50mm long is attached and brought down to touch the surface of the paste in test block and quickly allowing it to sink in to the paste by its own weight [5]. Take the reading by noting the depth of penetration of the plunger. Conduct a second trial (say with 25 percent of water) and find out the depth of penetration of the plunger. Conduct trials with higher and higher water/cement ratios till such time the plunger penetrates for a depth of 5 to 7mm from bottom is known as percentage of water required to produce a cement paste of standard consistency.

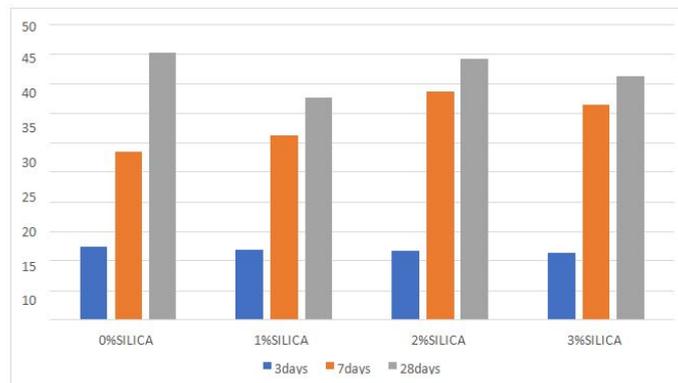
## 5. EXPERIMENTAL WORK

### 5.1 Compression Test

Compression Test Compression test is the most common test conducted on hardened concrete, partly because most of the desirable characteristic properties of concrete are quantitatively related to its compressive strength. The Compression test is carried out on specimens cubical or Cylindrical in shape. Prism also sometimes used, but it is not common in our country. Sometimes the compressive strength of concrete is determined using parts of the beam tested in flexure. The end parts of the beam are left intact after failure in flexural and, because the beam is usually of square cross section, thin part of the beam could be used to find out the compressive strength. The cube specimen sizes are 150mmx 150 mm x 150 mm.

Concrete cubes (150x150x150mm) of M40 grade concrete have been casted, the conventional cubes and the cubes with replacement of cement by 1%, 2%, 3% Silica fume have been tested. The results have been given below.

Percent tage of Silica	Compressive Strength (N/mm <sup>2</sup> )		
	3Days	7 Days	28 Days
0%	12.52N/mm <sup>2</sup>	28.44N/mm <sup>2</sup>	45.23N/mm <sup>2</sup>
1%	11.9N/mm <sup>2</sup>	31..23N/mm <sup>2</sup>	37.54N/mm <sup>2</sup>
2%	11.7N/mm <sup>2</sup>	38.66N/mm <sup>2</sup>	44.13N/mm <sup>2</sup>
3%	11.4N/mm <sup>2</sup>	36.44N/mm <sup>2</sup>	41.27N/mm <sup>2</sup>



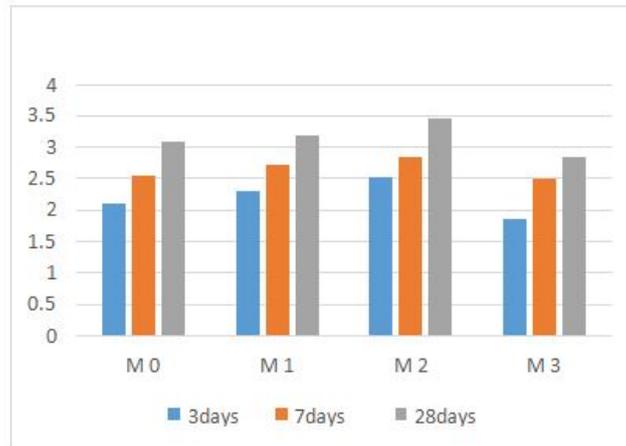
**Fig.1 Comparison of Compressive Strength of Concrete**

### 5.2 Split tensile strength Test

Concrete cylinders (dia-150mm, height-300mm) of M40 grade concrete have been casted, the conventional cylinders and the cylinders with replacement of cement by 1%, 2%, 3%.

Percent tage of Silica	Split Tensile Strength (N/mm <sup>2</sup> )		
	3Days	7 Days	28 Days
0%	2 N/mm <sup>2</sup>	2.8 N/mm <sup>2</sup>	4 N/mm <sup>2</sup>

1%	2.1N/mm <sup>2</sup>	2.95 N/mm <sup>2</sup>	4.05 N/mm <sup>2</sup>
2%	2.27N/mm <sup>2</sup>	3.08N/mm <sup>2</sup>	4.12N/mm <sup>2</sup>
3%	2.34N/mm <sup>2</sup>	3.24N/mm <sup>2</sup>	4.37N/mm <sup>2</sup>



**Fig.2 Comparison of Split Tensile Strength of Concrete**

## 6. CONCLUSIONS

The effect of Silica fume in the compressive strength and split tensile strength was determined and the following observations are made during this experiment

1. The compressive strength increases upto 15% replacement of cement by Silica fume at 3%.
2. The split tensile strength also increases upto 20% replacement of cement by Silica at 2%.
3. The compressive strength and tensile strength increases due to good packing nature of Silica fume.

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