Performance of Silica Fume as A Partial Replacement on Cement Concrete Strength

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Abstract:
With many uses, concrete is one of the most significant composite building materials. Currently, one of the biggest challenges is to produce durable, reasonably priced concrete. Different qualities of concrete may be achieved by adding a variety of extra cementitious components. Many different methods have been created these days to alter the strength and durability of concrete. The reduction of waste produced by different businesses that would be harmful to the environment is another goal of this project. High performance concrete is the preferable option for significant projects like tall skyscrapers. We may also incorporate some of the wastes produced by other industries, such as fly ash, GGBs, copper slag, silica fume, etc., to enhance the performance of concrete. Included materials may improve the property and raise the final strength and durability. Initially, we need to determine the ideal mix design from which we may adjust the parts to create the ideal mixer with the appropriate amount of concrete added silica fume. Based on the collected data, we may conclude that 15% is the suitable percentage of silica fume since the current study demonstrates a significant improvement by using the proper amount of silica fume in the analysis. The OPC strength of the concrete was demonstrated to increase for a dosage of 15% replacement and to gradually decline beyond this limit. The combination of concrete gets less workable the more silica fume is added. A few of additives are also used to enhance the performance and workability. Further admixtures were also used to enhance the consistency.

Keywords: Compressive Strength, Tensile Strength, Flexural Strength, Silica Fume.

Introduction:
It is a very big challenge we faced nowadays to minimize the waste generated by many companies is a big issue that we currently face in many different situations. Indian industry produces a large amount of waste. The environmental effect is lessened these days since concrete is made from these industrial wastes. Several types of pollutants that have a direct impact on the environment are generated throughout the cement production process. As such, less cement has to be manufactured in excess to reduce pollution. Still, additional cementitious wastes from various industrial processes are needed to reduce the environmental harm. This time, to increase the concrete's mechanical and physical properties, silica fume is added.

Increased pozzolanic silica fume from the ferrosilicon industry may help concrete resist penetration by chloride ions. These ultrafine, spherical silica vapours include 90% silica (SiO2) made up of particles as small as 0.15µm on average mean particle size. Surface area of 15,000–30,000 m^2/kg, bulk density of 130–600 kg/m^3, and specific gravity of 2.2–2.3 are characteristics of silica fume, which is produced at a high temperature of around 2000º C. Then the silica fume oxidises at a lower temperature. These waste products produce particular problems and affect the local ecology when they are thrown directly on the ground. Further weakened is the soil's inherent fertility, and the bodies of water will irritate and harm the locals.

Literature Review:

Wedding, Carette et.al (1983) the study from the authors analysed the property of silica fume and its effectiveness in the concrete to produce and to enhance the mechanical and durability of the concrete when partially replaced with cement [1].

Luthfiana, Wibowo et.al (2024) from their investigation when silica fume is added to the concrete significantly shows good results and improved the mechanical properties for a certain replacement level. For instance, a 10% replacement of cement with silica fume can improve its compressive strength by up to 55.91%. In addition of silica fume to concrete mixer helps to improve the hardened properties like strength and durability& reduce the pore pressure. [2].

Alvansaz, Arico et.al (2022) proposed the combination of silica fume with other materials like nanosilica particles or steel fibres has shown further improvement in physical and mechanical properties of concrete [3].

Luthfiana, Wibowo et.al (2024) investigated and found the use of silica fume and which also positively affects the stress-strain characteristics of concrete, providing higher maximum stress and strain capabilities, which are critical for the structural performance of the concrete under various different load conditions.

Padang, Kencanawati et.al (2020) performed the analysis and found the overall benefits of silica fume in improving concrete's performance to make it a valuable additive in the construction industry, particularly for achieving high-strength and durable concrete structures [4].

Chandramouli, Chaitanya et.al (2022) explored the synergistic effects of silica fume and fly ash, no improvements in strength parameters when these materials were used together, particularly at 10-15% replacement levels. This indicates a potential for optimizing concrete mixes for enhanced durability and strength [5].

Karthikeyan, Selvaraj et.al (2022) focused on permeation characteristics of concrete, using ultrafine ground mineral admixtures including silica fume. Their findings, suggests that finer admixtures can significantly enhance the concrete's properties, which is crucial for developing high- performance concrete with increased durability [6].

Garg et.al (2021) studies involve comparative analysis against control mixes to highlight the improvements brought by the use of silica fume and other additives [7].

Ghutke, Bhandari (2014) analysed how silica fume affects concrete. The silica fume proved to be a quite effective substitute for cement. Concrete made of silica fumes gain strength very quickly. Concrete becomes less workable the more silica percentage it contains. 10% substitution of silica fume will provide the compressive strength at its maximum. A 15% substitution of cement by silica fume results in stronger concrete than ordinary concrete. From 10-15% replacement level is the ideal silica fume replacement percentage [8].

Jain & Pawade (2015) assessed and compared the physical properties of high strength silica fume concretes. The experimental work with six different percentages was conducted with and without super plasticizer. Tested the durability where silica fume mortars in chemical condition including calcium chloride, ammonium nitrate and other acids [9].

Kumar & Dhaka (2016) examine the consequences of using silica fume in place of cement to some extent on the characteristics of concrete and studied on M35 concrete with partial substitution of silica fume with different percentage variation with various different tests and shows the use of silica fume concrete with improved results [10].

Sasikumar & Tamilvanan (2016) investigated the characteristics of silica fume as a partial replacement for cement and performed analysis for M30 grade concrete with partial substitution of silica fume at different percentage replacements at 0%, 10%, 20%, 30%, 40% & 50% and found the ideal compressive strength of 7 and 28 days has been reached at the replacement levels of 25% silica fume. The split tensile strength is also stronger when cement is replaced with 25% of silica fume [11]. **Srivastava (2012)** determined how well concrete might substitute silica fume. Addition of silica fume lowers workability. The compressive strength increased by 6-57% with addition & modification of replacement quantities of silica fume but tensile and flexural strength of concrete were found unchanged from those typical mixture [12].

Materials & Methodology:

It is very important to observe the proportion of different materials which is used in the concrete, because concrete should be strong enough to carry the various different structural loads acting internally and externally. The strength of concrete is very important to observe therefore proper mix proportion and mix design is suitably done to minimize the errors. Careful selection of different materials, other supplementary materials, proportioning, mixing, transporting, placing, finishing, processing & curing is also play very important role in the entire process from initial to final stages. The materials used in the concrete shall be properly selected and laboratory tests also be performed suitably as per the standard procedure. Concrete was prepared and casted different cubes, cylinders for various tests at different percentages of silica fume added to the concrete as a partial replacement. The additional usage of these materials enhance the properties of concrete like mechanical and durability aspects compared to normal mixes in general.

Cement: The materials which is added to the concrete all are very important, but cement is most the important material because it is act as a binder which holds all the materials together to form a dense mix. A chemical substance used for the construction that sets, hardens and adhere to other materials to bind them together as a dense matrix. In general there are mainly divided into three different grades such as 33, 43 & 53 grades. These different grade cements are used for different purposes and application based on the importance of work in general.

Aggregate: - The aggregates which is used in the concrete should meet certain requirements in order to be useful, durable and also economical. The aggregates must possess the shape and size of the aggregate is also affects the workability and durability so it is very important to observe the shape, size, colour of the aggregates. The aggregates must be well graded, clean, hard and durable. Aggregates are inert granular material are an essential ingredient in concrete.

Fine aggregate: The particle size which are below 4.75 mm IS sieve are categorised as fine aggregates. Fine aggregate usually consists of natural river sand or crushed stone with most of the particles passing through 3/8-inch sieve (manufactured sand). Fine aggregates is an important material in concrete and sand is a form of silica (quartz) and it may be calcareous, siliceous or may be argillaceous according to its

International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

composition. Fine aggregates are classified in to four zone (I-IV) and tests are performed as per IS: 383-1970 and results obtained were satisfactory
Coarse aggregate: Coarse aggregates, crushed stones are available from large broken stones or hard rocks. This process formed by natural decomposition of stones. Coarse aggregates generally used in concrete are from 20mm and downsized. Depends on the type of work it may vary up to 40mm also. Usually the aggregates should be washed before it is used in the concrete to remove dirt and dust. Tests are performed in the laboratory as per the guidelines of IS: 383-1970. The Specific gravity, sieve analysis results were obtained as per the guidelines and fineness modulus was calculated as per the results obtained from sieve analysis.
Water: Suitable quality of water which is satisfactory with normal pH; any water that is potable (drinkable) will be preferred for satisfactory results without any variation. The amount of water in concrete controls many fresh and hardened properties in concrete hence the proper quantity & quality water is preferred as it is used for both mixing and curing.
Silica Fume (SF): The waste from industry has utilized to improve the properties of concrete as well as to minimize the environmental pollution therefore, silica fume is one of the most important type of supplementary cementitious material used in the concrete as a partial replacement to cement, which was used to improve the strength of the concrete and also for the durability'.

Results & Discussions:
Slump Cone test: The addition of silica fume in the concrete has shown some decrement in the slump value. The reduction in the slump shows requirement of more water than cement content. Fig 1 shows the results of slump flow test.

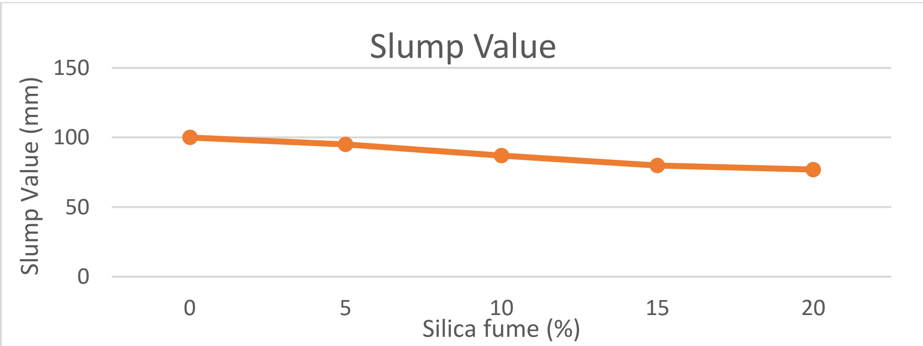


Fig. 1 Slump Flow value (mm)

In the table below shows the results of different tests was conducted on hardened concrete and results are as shown for various different percentages of silica fume (SF).

Table 1: Test results for 7 days strength

	0 % SF	5 % SF	10 % SF	15 % SF	20 % SF
Compressive Strength (N/mm^2)	25.75	29.78	34.35	39.05	36.24
Split Tensile Strength (N/mm^2)	3.23	3.78	3.88	4.26	3.75
Flexural Strength (N/mm^2)	5.01	6.23	7.55	7.87	6.28

Table 2: Test results for 14 days strength

	0 % SF	5 % SF	10 % SF	15 % SF	20 % SF
Compressive Strength (N/mm^2)	32.28	37.34	43.07	48.96	45.44
Split Tensile Strength (N/mm^2)	4.75	4.98	5.05	5.25	4.95
Flexural Strength (N/mm^2)	5.92	6.54	8.07	9.15	7.84

Table 3: Test results for 28 days strength

	0 % SF	5 % SF	10 % SF	15 % SF	20 % SF
Compressive Strength (N/mm^2)	35.36	40.89	47.17	52.92	49.76
Split Tensile Strength (N/mm^2)	4.85	5.08	5.24	5.58	5.10
Flexural Strength (N/mm^2)	6.02	6.78	8.24	9.26	8.03

Fig 2: Compressive Strength (N/mm^2) for 7, 14 & 28 days

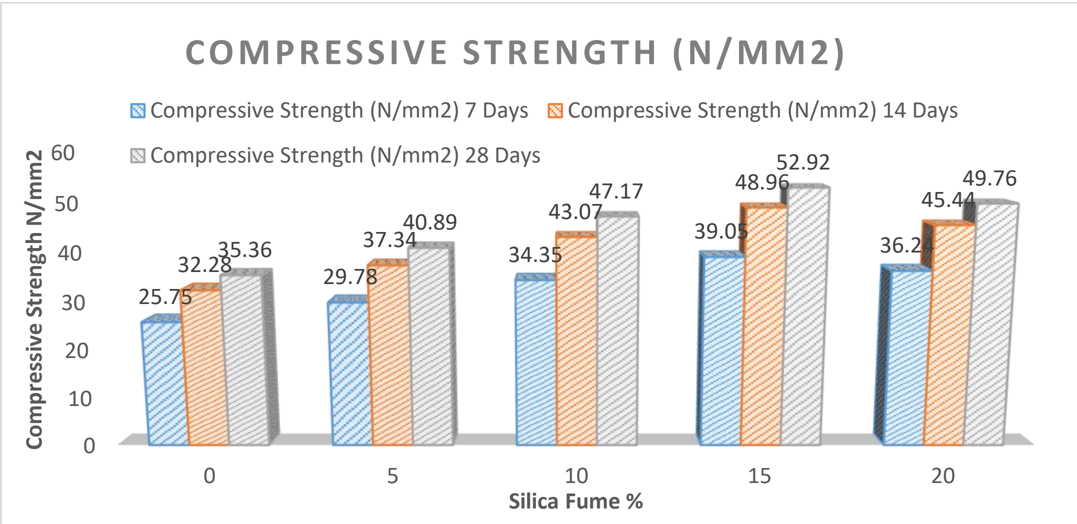


Fig 3: Split Tensile Strength (N/mm^2) for 7, 14 & 28 days

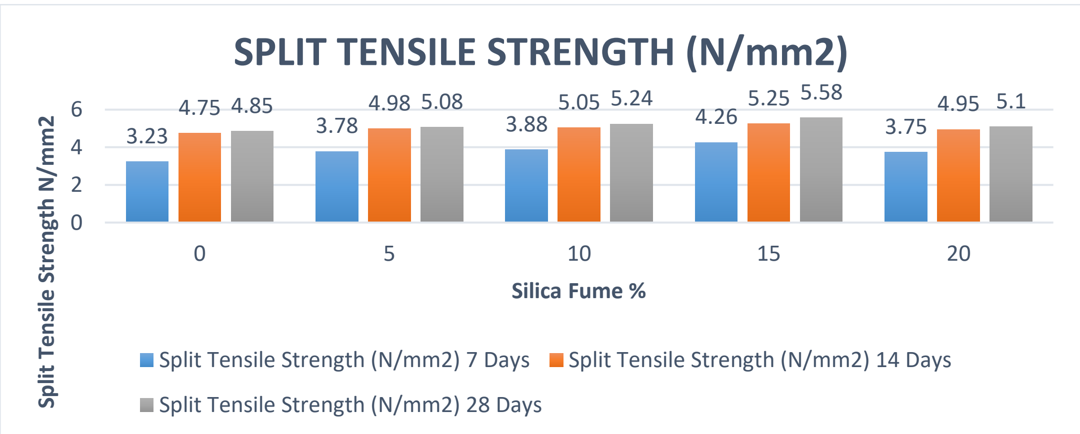
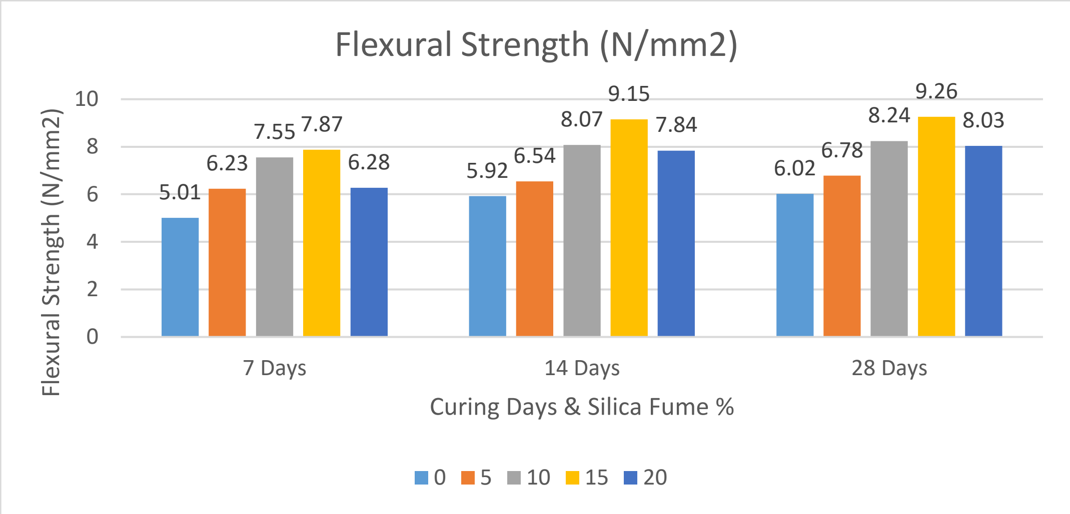


Fig. 4: Flexural Strength (N/mm^2) for 7, 14 & 28 days



Conclusions:

1. The concrete with 15% of silica fume showed excellent increase according to the findings.
2. The results demonstrate that silica fume with 15% replacement improves Compressive, Tensile and Flexural strength and it is optimum for 7, 14 and 28 days of testing.
3. External admixtures are essential for achieving the right workability and improving the performance of concrete both in fresh and hardened states by reducing the water content.
4. Incorporating silica fume into concrete has enhanced its quality, leading to increased strength, also shows less segregation and less bleeding while the concrete mix is still in fresh state.

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