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Properties of Self Compacting Concrete Containing Silica Fume as a Sustainable Alternative: A Review

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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Review Article

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ABSTRACT

The most frequently used building material on this planet is concrete. Concrete is the supreme user of natural resources as a result of its widespread use as construction material. Cement production produces significant amount of greenhouse emissions. The protection of environment has become challenging in many developing countries, 7-8% of CO_2 is produced by the cement industry that causes huge damage to the environment. In concrete production, Silica fumes can be a partial alternative to cement. In this study, the properties of self-compacting concrete incorporating silica fumes are reviewed. Slump flow, funnel, L-box, compressive strength, split tensile strength and flexural strength are among qualities of self-compacting concrete with silica fumes that have been discussed in this study. The cement was replaced by silica fumes in the ratio of 0% to 30% in concrete, cement content can be reduced, which turns into an eco-friendly solution.

Keywords: Silica fumes; cement; concrete; strength; slump; compressive strength; self-compacting; V-Funnel.

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1. INTRODUCTION

"Nowadays, concrete is the most widely used building material in the construction industry, which is mainly due to its design versatility, availability, and cost efficiency" [1]. "Self-Compacting concrete has become a very widely used type of concrete, which is highly able to penetrate the closely spaced steel bars without any compaction procedures. Self-Compacting Concrete differs from normal concrete as it is at a higher end in workability and the issues of segregation and bleeding are encountered in these types of concrete" [2]. "Cement production, on the other hand, results in the release of greenhouse gases into the atmosphere" [3-5]. "According to studies, every ton of cement produced emits roughly half ton of carbon dioxide, which is a considerable quantity contributing in 5% of total man-made CO_2 emissions, with India accounting for nearly 7-8% of overall carbon dioxide emissions" [6,7]. "The elimination of vibration for the compaction of fresh concrete makes the use of the self – compacting concrete beneficial in terms of cost reduction and improvement of the work environment. Due to intrinsic low porosity, SCC usually has high performance properties in terms of mechanical behavior and durability" [8]. "Quartz is a hard, crystalline chemical compound consisting of one-part silicon and two-part oxygen atoms which are linked in a continuous framework of SiO2 silicon-oxygen tetrahedral. Quartz is commonly known as silica sand for producing float glass, fiber glass, automotive glass, and other types" [9].

1.1 Benefit of the Silica Contained in Concrete Mix

"Addition of silica fume to concrete improves its durability through reduction in the permeability and refined pore structure, leading to a reduction in the diffusion of harmful ions, reducing calcium hydroxide content, which results in a higher resistance to sulfate attack" [10]. "Silica fume is having greater fineness than cement and greater surface area so the consistency increases greatly, when silica fume percentage increases" [11].

2. FRESH PROPERTIES OF CONCRETE

2.1 Slump Flow

Filling ability of self-compacting concrete is measured by slump flow test. Shobana KS, et al. [12] measured the value of slump flow of concrete with silica fumes for a constant water/cement ratio of 0.50 for 0, 10, 12.5, and 15% replacement of cement by silica fumes respectively. Fig. 1 shows the slump flow value with different replacement percentages.

Dr. B. Krishna Rao et al. [13] measured "the value of slump flow of SSC with cement replacement with micro silica at 0, 4, 8, and 12% with a W/C ratio of 0.48.Their measured that slump flow of 8% replacement is 680 mm which found to be the highest".

Junaid Mansoor et al. [14] examined "the SSC with silica fume with replacement of 0, 5, 10, 15, 20, and 25% of cement and found out that slump flow of 15 % replacement is maximum".

2.2 V- Funnel Test

V-Funnel test is done to examine the flowability of self-compacting concrete. As per standards 6 to 12 sec of time is considered in SSC. R. Vasusmitha et al. [15] carried out an experiment on SSC with micro silica and quartz powder and found out the V-Funnel reading as 8 sec which is found to be satisfactory.

B. Chandana et al. [16] investigated SSC with silica fume with different replacement percentages i.e., 6%, 9%, and 12% and carried out V-Funnel test and results are within limits of SSC.

Olatokunbo M. Ofuyata et. al. [17] evaluated the fresh properties of SSC with silica at a replacement of 0, 15, 25 and 35% and found the V-Funnel reading as follows

K. Nandhini et. al. [18] examined the effect of micro and nano silica on SSC. Cement was replaced partially by weight from 5% to 15% by micro silica and 1% to 3% nano silica correspondingly. The behavior of SCC at fresh state was determined using the following laboratory investigations (slump test, V-funnel and J-ring tests).

2.3 L-Box Test

R.Chithra et. al. [19] examined the SSC with silica fumes with a replacement of cement at a percentage of 0, 5, 7.5 and 10% and quarry dust was replaced to aggregate at a percentage of 5, 10 and 15% and found out that 7.5% replacement of cement with silica fumes gives optimum results.

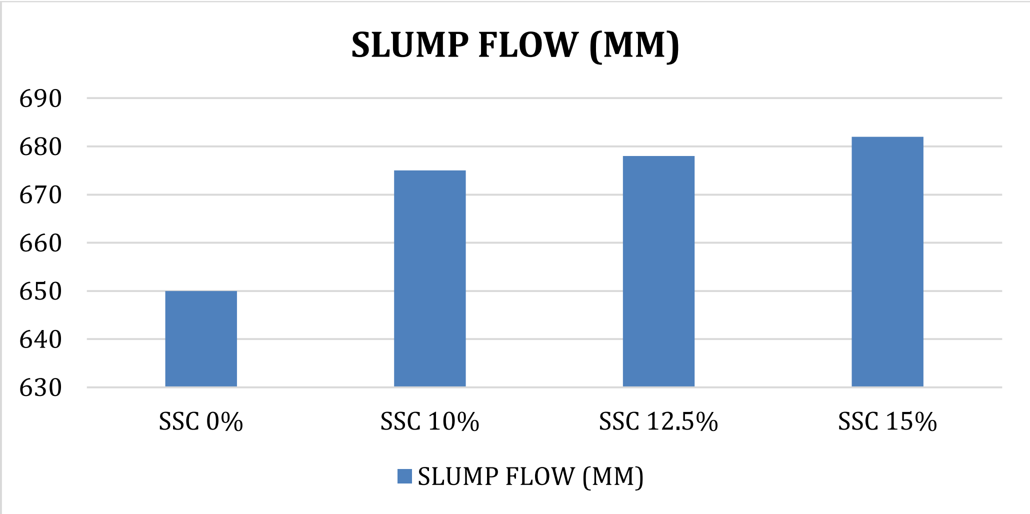

Fig. 1. Slump flow 1 [12]

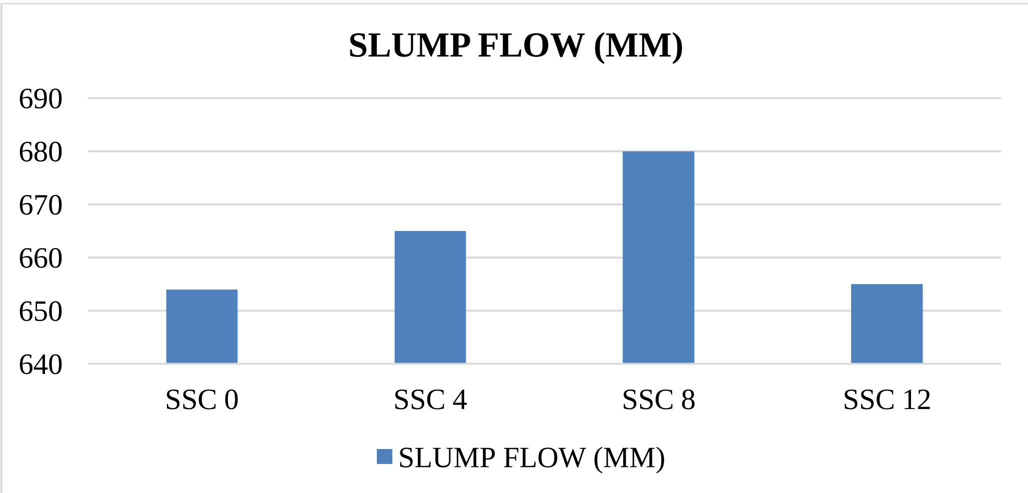

Fig. 2. Slump flow 2 [13]

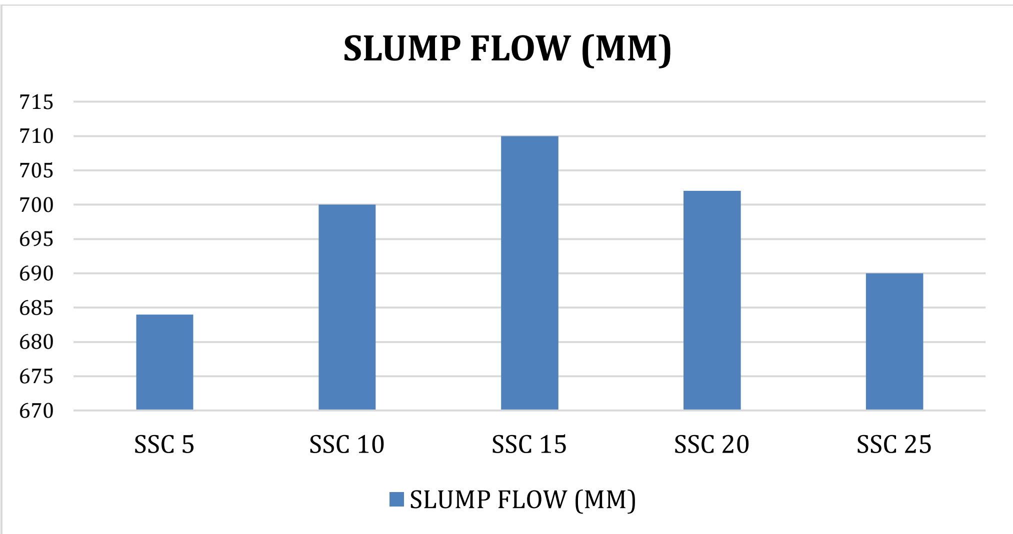

Fig. 3. Slump flow 3 [14]

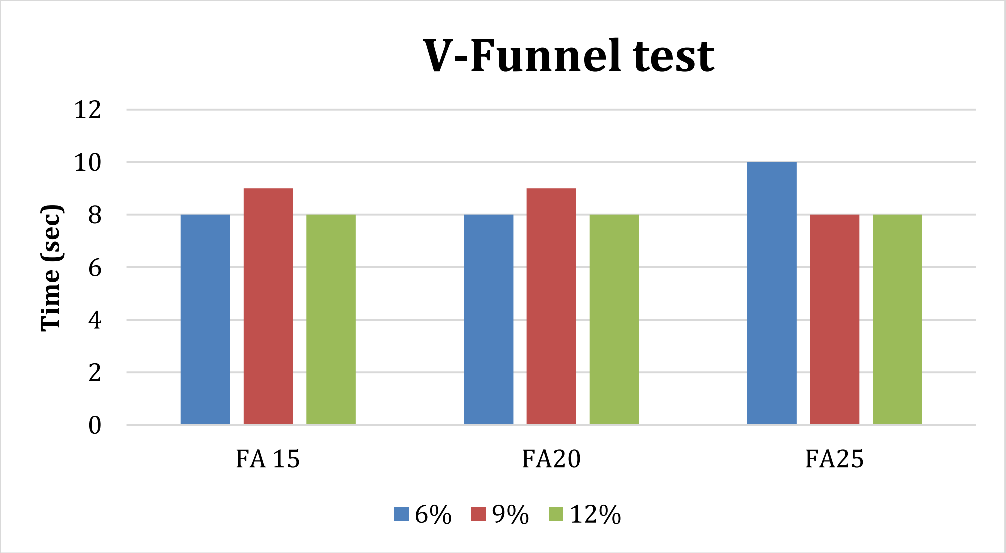

Fig. 4. V-Funnel test result 1 [16]

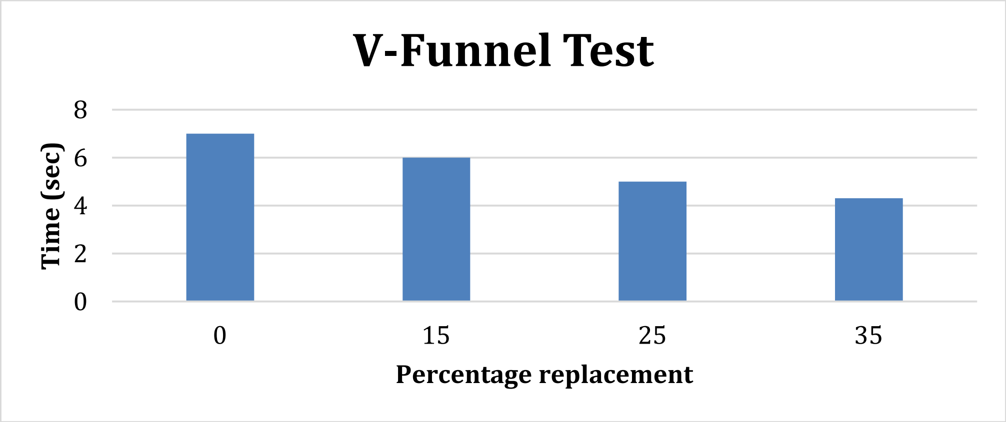

Fig. 5. V-Funnel test result 2 [17]

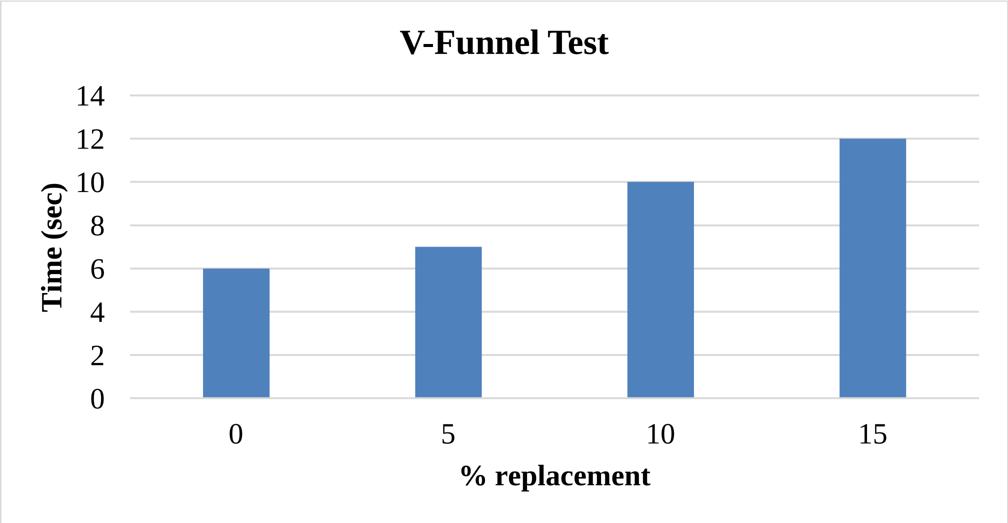

Fig. 6. V-Funnel test result 3 [18]

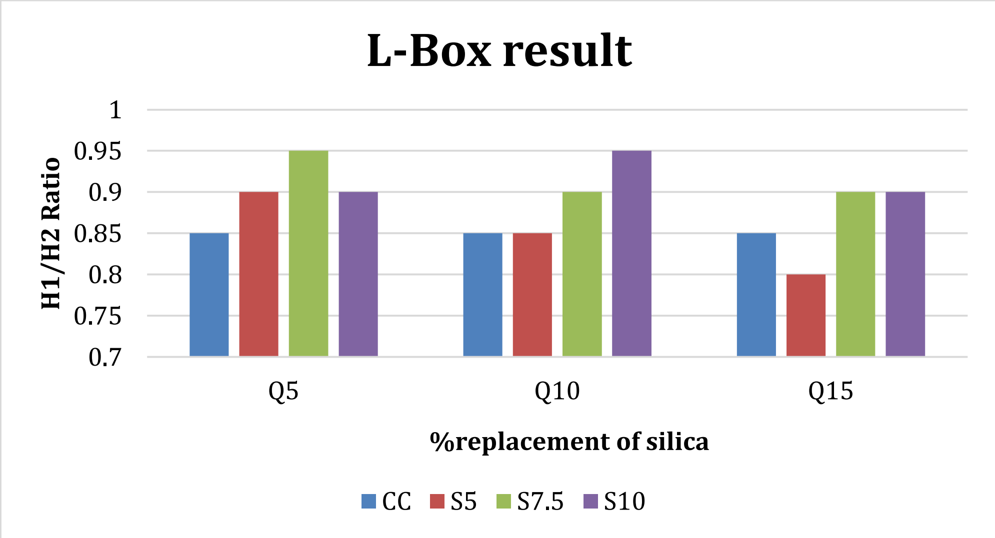

Fig. 7. L-Box test result 1 [19]

Rajesh.M. et. al. [20] studied the effect of quartz material on SSC with a replacement of cement by quartz powder at a percentage of 0, 10, 15, 20, 25, 30 and 35% and found out that flowability of SSC increases up to 25 % replacement with quartz powder.

Dr. B. Krishna Rao et. al. [13] studied the effect of micro silica with partial replacement with cement and examined the L- Box result with different replacement percentages. Study was done with replacement percentages of 0, 4, 8 and 12%.

3. HARDENED PROPERTIES OF SCC

3.1 Compressive Strength Test

Syyed Adnan Raheel Shah et al. [14] determined the compressive strength of SCC by replacing cement with silica fumes at a replacement of 0, 5, 10, 15, 20 and 25%. Compressive test was done on 7, 14 and 28 days of curing and found out increment in strength.

V. Harikrishnan et al. conducted an experimental study on self-compacting concrete by using silica fume as partial replacement of cement with percentage level of 0, 5, 10, 15 and 20%. Compressive strength test was done after 7 and 28 days and found out that at 15% replacement of cement with silica fume gives the maximum compressive strength.

Olatokunbo M. Ofuyatan et. al. [17] evaluated the hardened properties of SCC with silica fume blend with replacement levels of 0, 15, 25 and 35% with cement. Compressive strength test was done on 7, 14 and 21 days of curing.

3.2 Flexural Strength

Flexural strength which is a measurement of tensile strength of concrete is used to determine the ability of an unreinforced concrete beam or slab to counterattack the failure during bending.

R. Chithra et. al. [19] investigated the flexural strength of self-compacting concrete with silica fume and quarry dust at replacement percentage of 0, 5, 7.5 and 10%. In this study conclusion was drawn as at 7.5% replacement of cement with silica fume gives increment in flexural strength.

S.S. Janagan et. al. [21] examined the effect of silica fumes on the flexural strength of self-compacting concrete at replacement level of 0, 5, 10, 15 and 20 of cement. The study concluded that by increasing the amount of silica fumes in concrete flexural strength is also increasing. Maximum strength was found out at 20 % replacement level at both 7 days and 28 days test.

N. K. Amudhavalli et. al. [22] examined “the effect of silica fumes on the flexural strength of concrete at replacement level of 0, 5, 10, 15 and 20 of cement. The study concluded that by increasing the amount of silica fumes up to a replacement level of 15% flexural strength increases and after that it decreases in concrete. Maximum strength was found out at 15 % replacement level at both 7 days and 28 days test”.

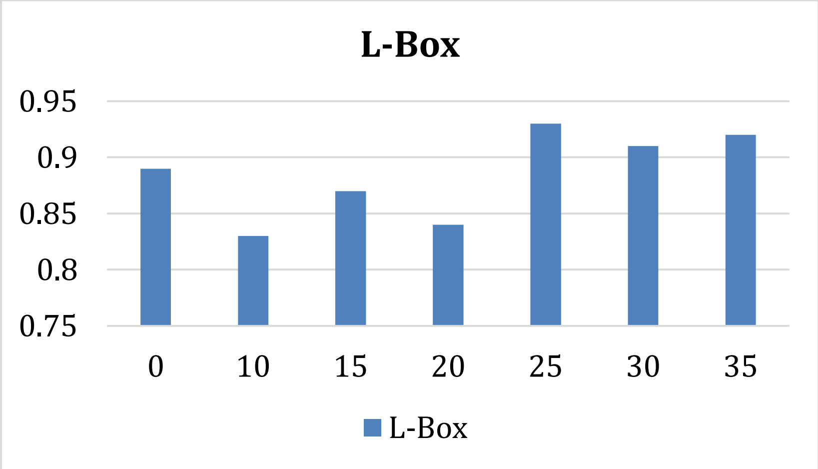

Fig. 8. L-Box test result 2 [20]

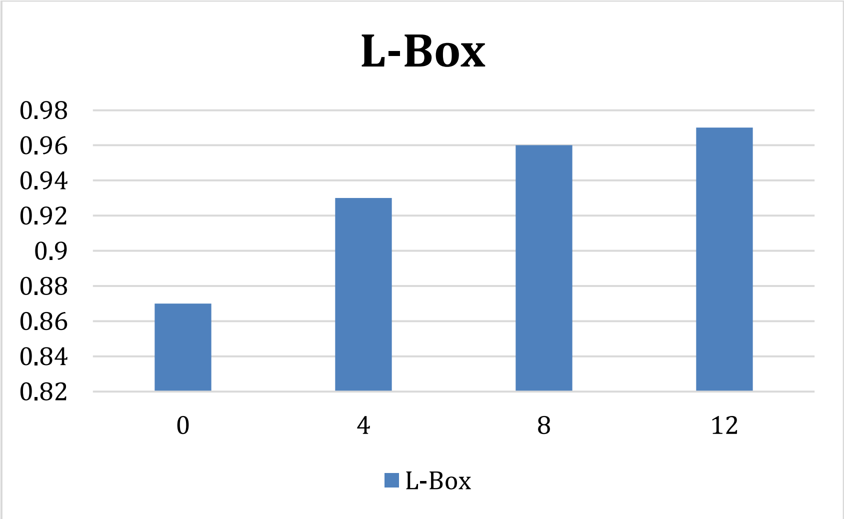

Fig. 9. L-Box test result 3 [21]

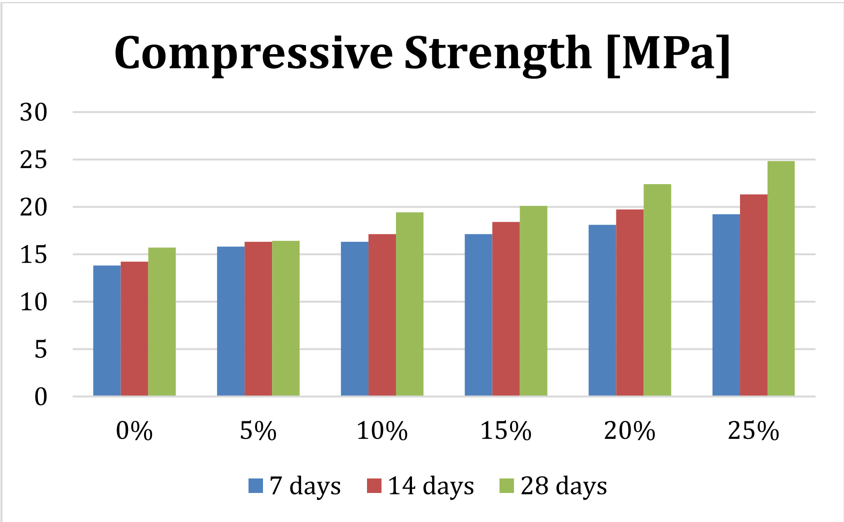

Fig. 10. Compressive strength results 1 [22]

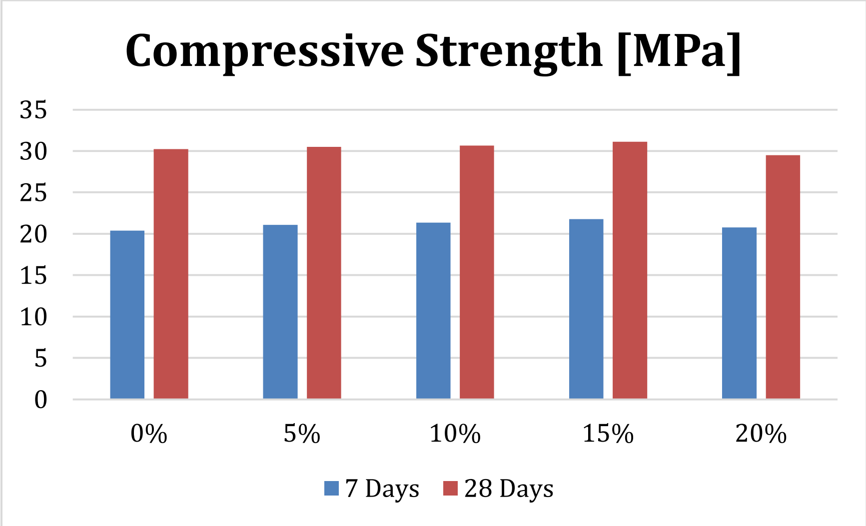

Fig. 11. Compressive strength results 2 [21]

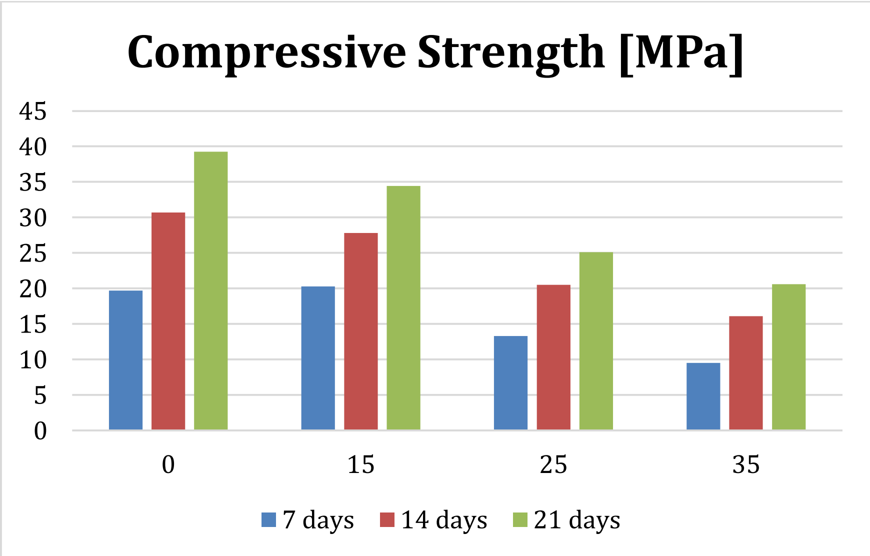

Fig. 12. Compressive strength results 3 [17]

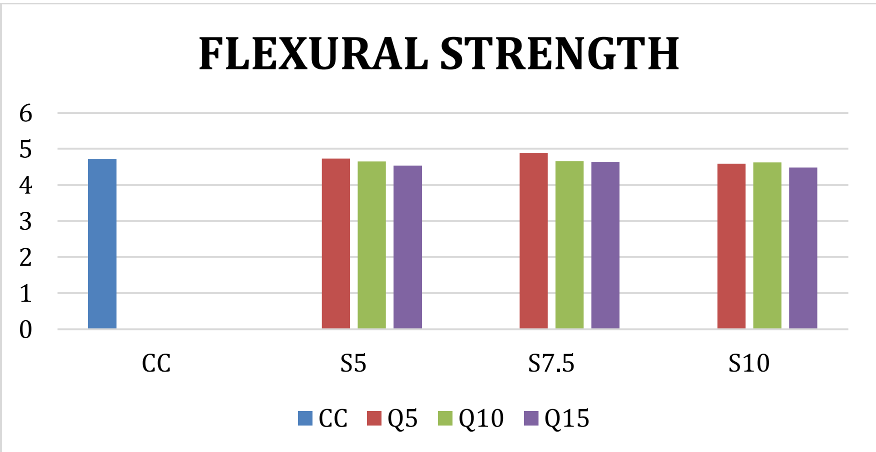

Fig. 13. Flexural strength test results 1 [19]

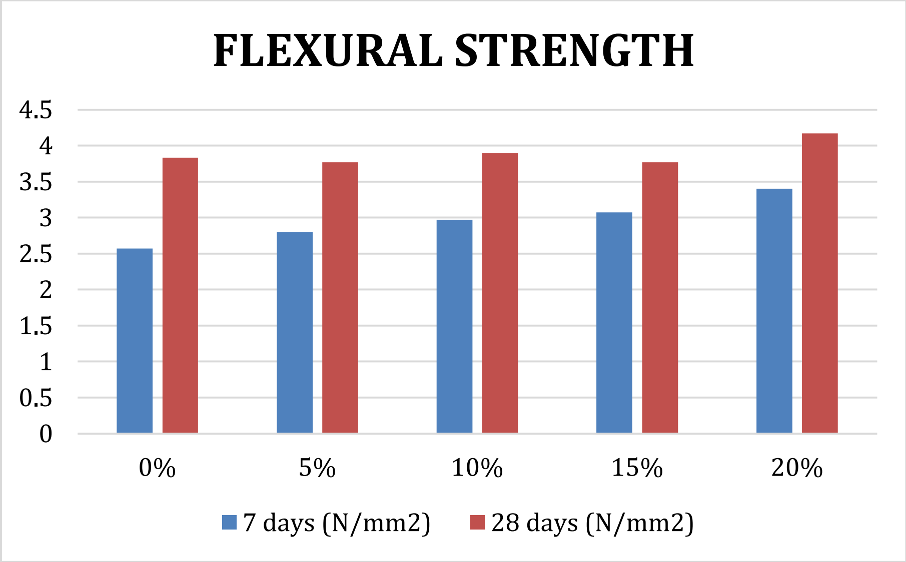

Fig. 14. Flexural strength test results 2 [23]

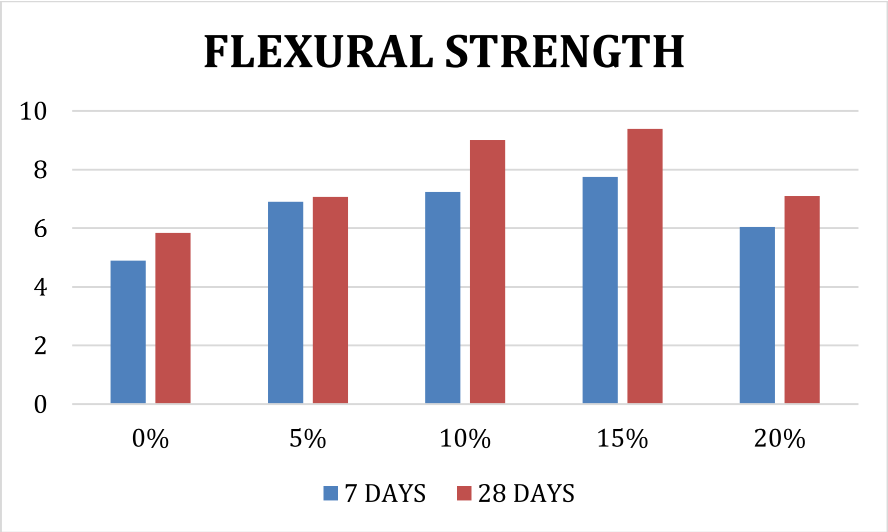

Fig. 15. Flexural strength test results 3 [22]

3.3 Tensile Strength

Largest load sustained by a material without shattering while it is strong, divided by original cross section area of the material, is referred to as tensile strength.

M. Gnanaprakash et al. deliberated "the split tensile strength of the silica fumes as partial replacement of the cement. They substituted silica fumes powder for cement in a ratio of 0% to 20%. At 20% cement replacement with silica fumes powder, greatest split tensile strength was recorded at both 7 days and 28 days". Fig. 16 depicts the findings of their research.

Reddy and Babu [23] tested "the tensile strength of the concrete comprising with silica fumes. It was replaced cement with powdered silica fumes having proportions of 0%, 5%, 10%, 15% and 20%. At 10% cement replacement with silica fumes, the greatest split tensile strength was recorded for 7 days and 28 days".

Syyed Adnan Raheel Shah et al. [14] examined "the effect of switching the cement by silica fumes. It was discovered that there was an upsurge in the percentage of silica fumes at a limit of 25% with cement. Also, the split tensile strength was increased in concrete containing replacement of 20%".

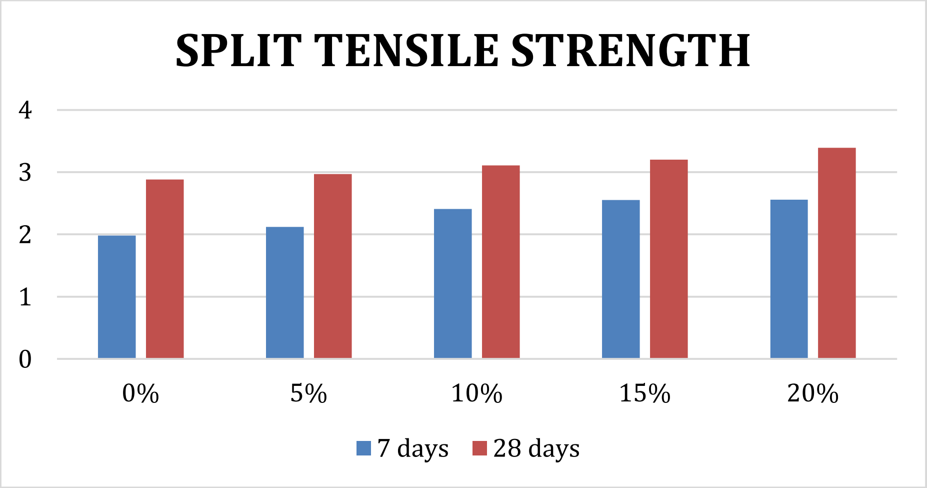

Fig. 16. Split tensile strength test results 1 [21]

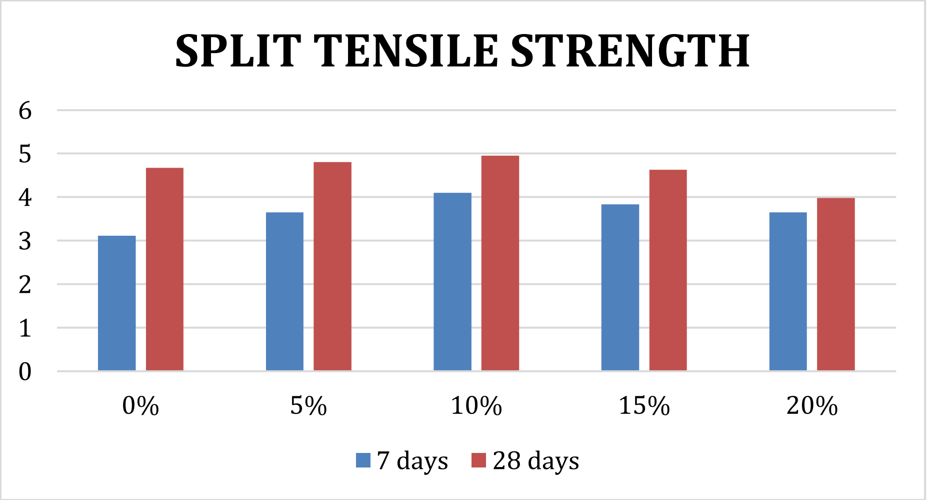

Fig. 17. Split tensile strength test results 2 [23]

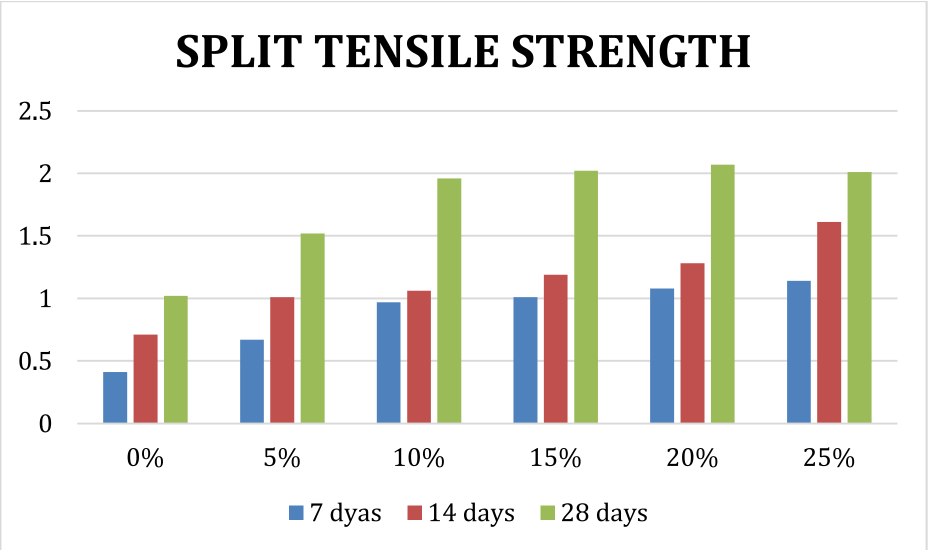

Fig. 18. Split tensile strength test results 3 [14]

4. CONCLUSION

Construction activities must now take into account sustainability. Several investigations on various materials to replace cement in self-compacting concrete have been undertaken in the past. The impact of silica fumes on concrete qualities like freshness, mechanical strength, and durability is discussed in this study. A review of silica fumes and its impact on self-compacting concrete as a cement substitute has been attempted.

The following conclusions can be derived by the research work doen on using silica fumes as a partial substitute for cement in self-compacting concrete production:

- Based on a number of study articles, results subjected to various silica fumes percentages in self-compacting concrete, it can be concluded that the optimum utilization of silica fumes for better fresh properties of SCC shall be 15% and for hardened concrete properties it is 20% by the mass of cement in concrete.
- The fresh properties of self-compacting concrete like slump flow with silica fumes had different results, according to most of the researcher's ideal slump flow is found at 15% to 20% of replacement cement with silica fumes.
- The fresh properties of self-compacting concrete like V-funnel with silica fumes had different results, according to most of the researcher's ideal mix is found at 15% of replacement cement with silica fumes.
- The fresh properties of self-compacting concrete like L box test with silica fumes had different results, according to most of the researcher's ideal result is found at 15% of replacement cement with silica fumes.
- From the above study, researchers concluded that there was an increment in compressive strength with the increase in silica fumes quantity up to 20%, after that, as the percentage of silica fumes in self-compacting concrete increased the change in compressive strength was neglectable.
- The various studies showed that there was an enhancement in flexural strength just like compressive strength up to 20% of silica fumes content, after that limit it also got reduced as silica fumes content enhanced in concrete.
- As the proportions of silica fumes increased to a certain limit, the split tensile strength increased. Optimum replacement of cement was around 20 percent by silica fumes after that strength decreased.

Self-compacting Concrete with silica fumes as a substitute is a sustainable construction material that decreases pollution as well as disposal-related issues which is harmful to the environment. The optimum substitution level of cement with limestone was found to be 15-20%. Concrete mechanical as well as fresh properties were amended by utilizing silica fumes.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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