

**PROPERTIES OF SELF COMPACTING CONCRETE CONTAINING SILICA FUME
AS A SUSTAINABLE ALTERNATIVE: A REVIEW**

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 CO₂ 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.

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 CO₂ 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

31 beneficial in terms of cost reduction and improvement of the work environment. Due to intrinsic
32 low porosity, SCC usually has high performance properties in terms of mechanical behavior and
33 durability” [8]. “Quartz is a hard, crystalline chemical compound consisting of one-part silicon
34 and two-part oxygen atoms which are linked in a continuous framework of SiO₂ silicon-oxygen
35 tetrahedral. Quartz is commonly known as silica sand for producing float glass, fiber glass,
36 automotive glass, and other types” [9].

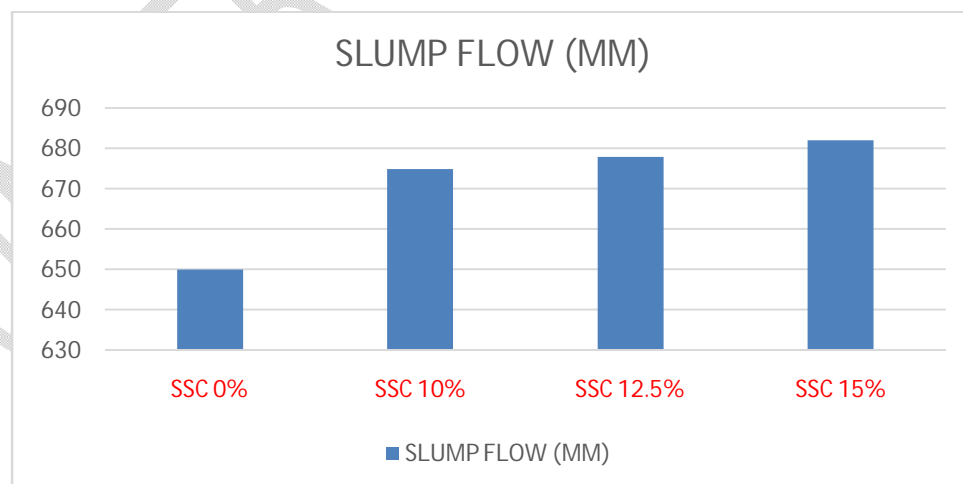
37 **1.1 Benefit of the Silica contained in concrete mix**

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

43 **2. Fresh properties of concrete**

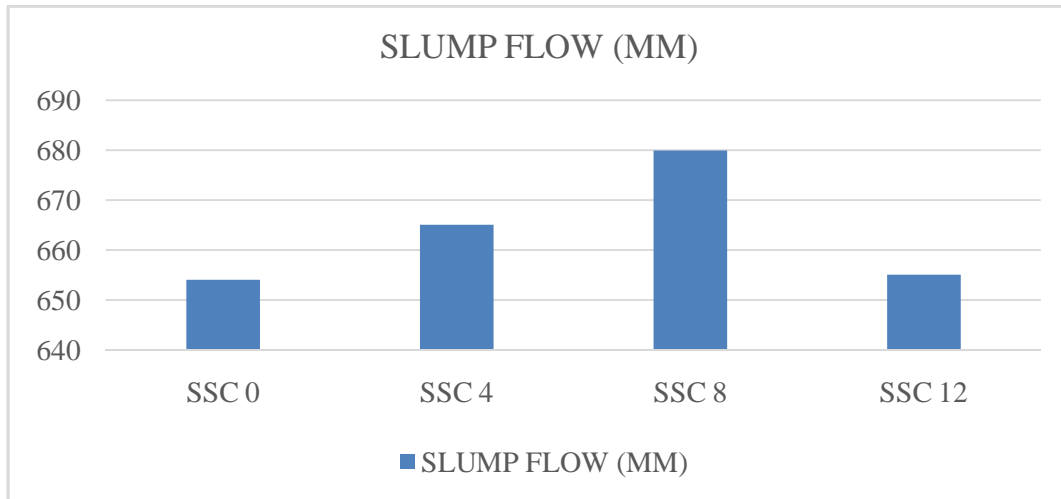
44 **2.1 Slump Flow**

45 Filling ability of self-compacting concrete is measured by slump flow test. Shobana K. S. et al.
46 [12] measured the value of slump flow of concrete with silica fumes for a constant water/cement
47 ratio of 0.50 for 0, 10, 12.5, and 15% replacement of cement by silica fumes respectively. Fig 1
48 shows the slump flow value with different replacement percentages.



49
50 Fig. 1. Slump flow 1 [12]

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



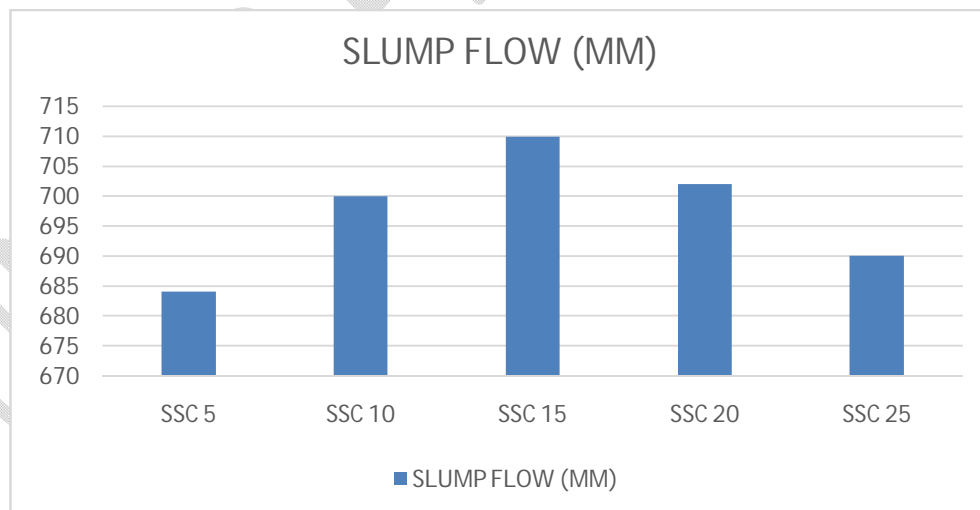
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Fig. 2. Slump flow 2 [13]

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57 Junaid Mansoor et al. [14] examined “the SSC with silica fume with replacement of 0, 5, 10, 15,
58 20, and 25% of cement and found out that slump flow of 15 % replacement is maximum”.



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Fig. 3. Slump flow 3 [14]

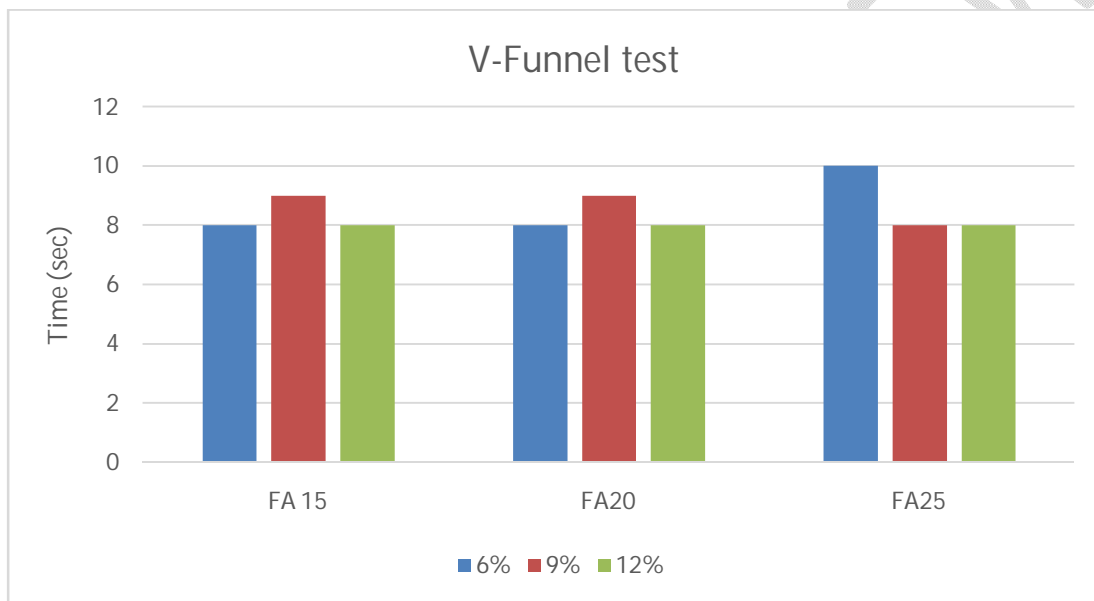
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62 2.2 V- Funnel Test

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

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



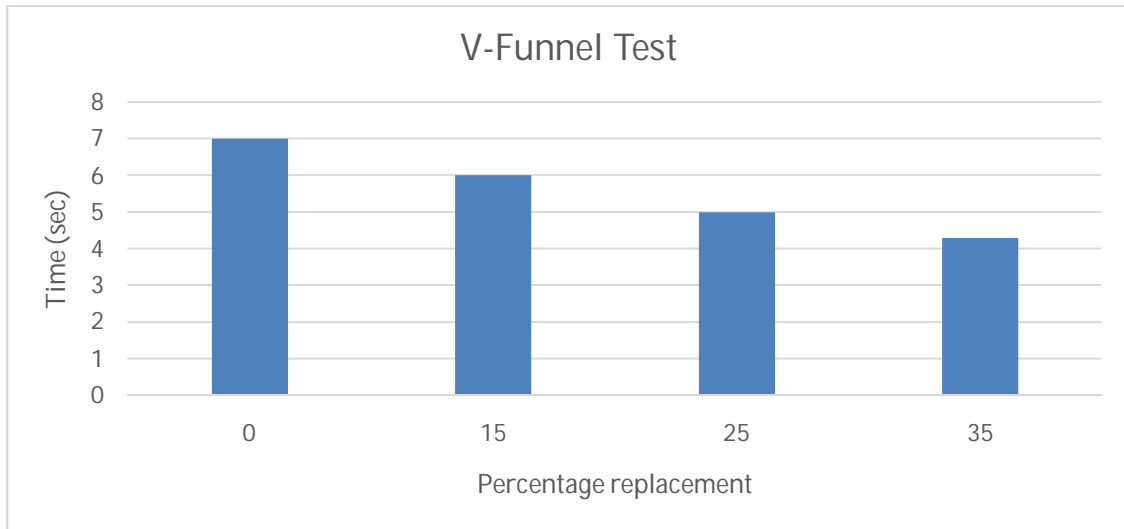
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Fig. 4. V-Funnel test result 1 [16]

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



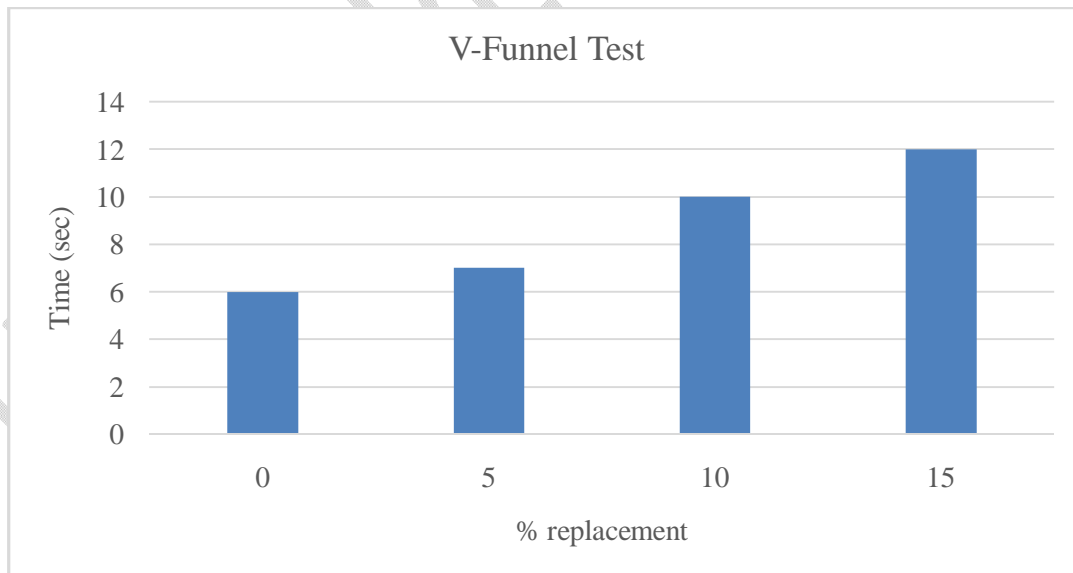
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Fig. 5. V-Funnel test result 2 [17]

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



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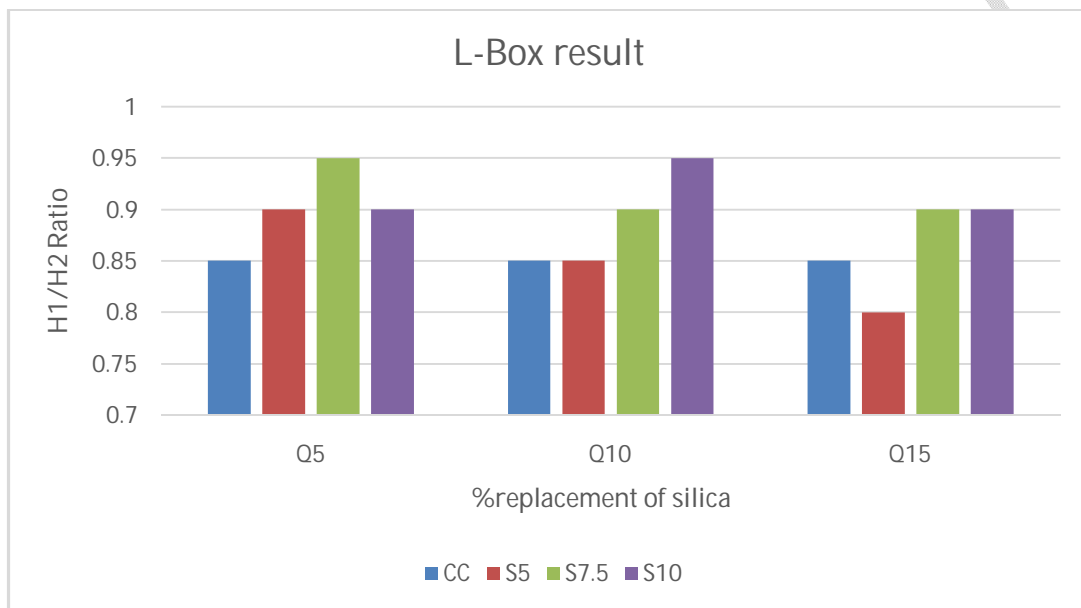
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Fig. 6. V-Funnel test result 3 [18]

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84 **2.3 L-Box Test**

85 R.Chithra et. al. [19] examined the SSC with silica fumes with a replacement of cement at a
86 percentage of 0, 5, 7.5 and 10% and quarry dust was replaced to aggregate at a percentage of 5,
87 10 and 15% and found out that 7.5% replacement of cement with silica fumes gives optimum
88 results.



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

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

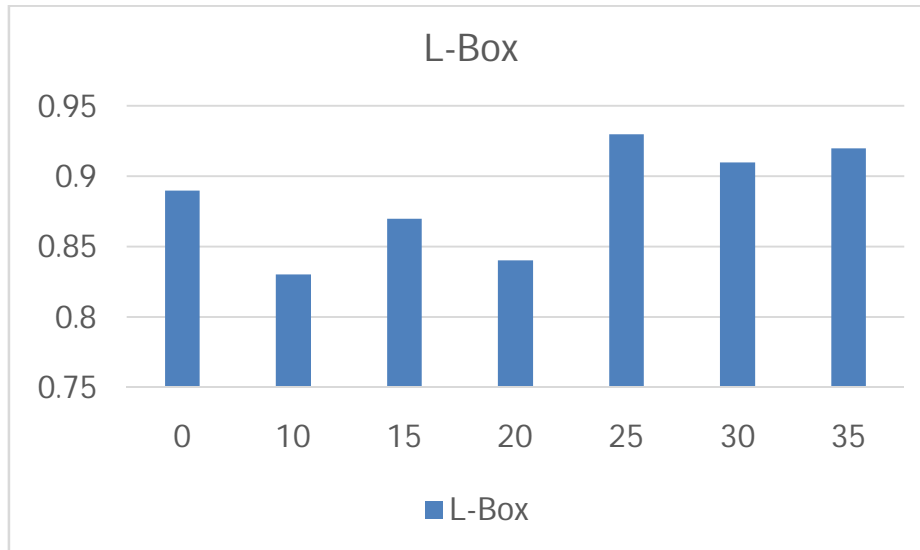


Fig. 8. L-Box test result 2 [20]

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98 Dr. B. Krishna Rao et. al. [21] studied the effect of micro silica with partial replacement with
 99 cement and examined the L- Box result with different replacement percentages. Study was done
 100 with replacement percentages of 0, 4, 8 and 12%.

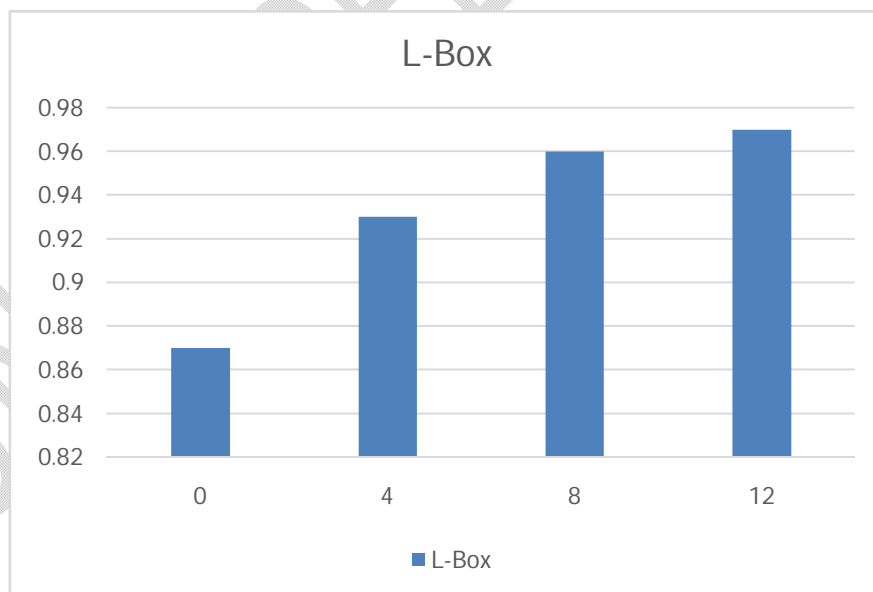


Fig. 9. L-Box test result 3 [21]

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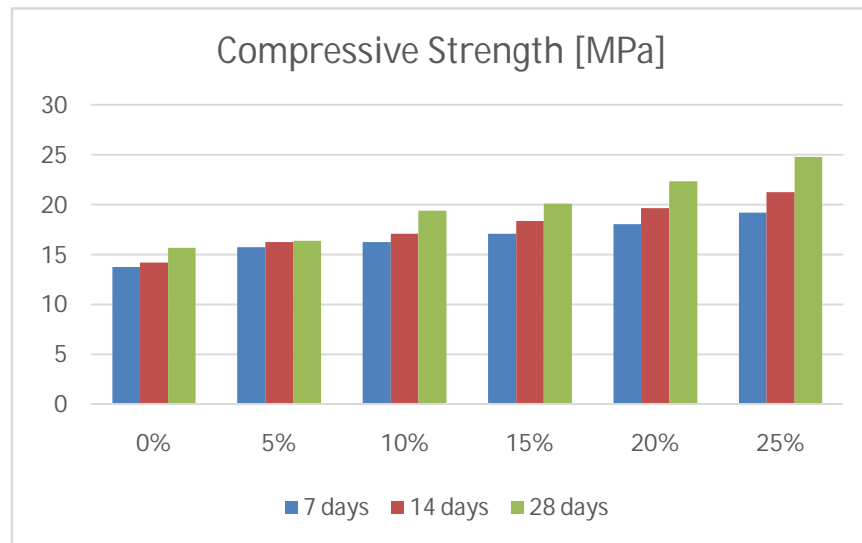
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104 **3. Hardened properties of SCC**

105 **3.1 Compressive strength test**

106 Syyed Adnan Raheel Shah et. al. [22] determined the compressive strength of SCC by replacing
107 cement with silica fumes at a replacement of 0, 5, 10, 15, 20 and 25%. Compressive test was
108 done on 7, 14 and 28 days of curing and found out increment in strength.



109

110 Fig. 10. Compressive strength results 1 [22]

111

112 V. Harikrishnan et. al. [23] conducted an experimental study on self-compacting concrete by
113 using silica fume as partial replacement of cement with percentage level of 0, 5, 10, 15 and 20%.
114 Compressive strength test was done after 7 and 28 days and found out that at 15% replacement
115 of cement with silica fume gives the maximum compressive strength.

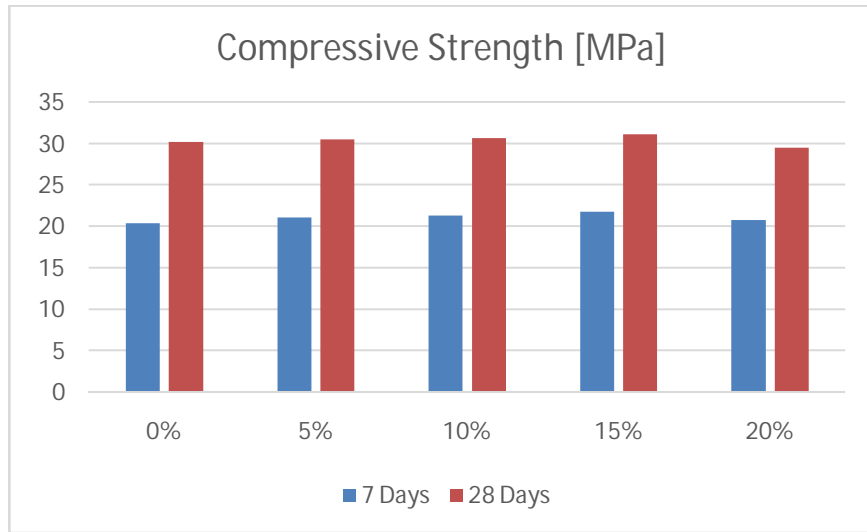


Fig. 11. Compressive strength results 2 [23]

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119 Olatokunbo M. Ofuyatan et. al. [24] evaluated the hardened properties of SCC with silica fume
 120 blend with replacement levels of 0, 15, 25 and 35% with cement. Compressive strength test was
 121 done on 7, 14 and 21 days of curing.

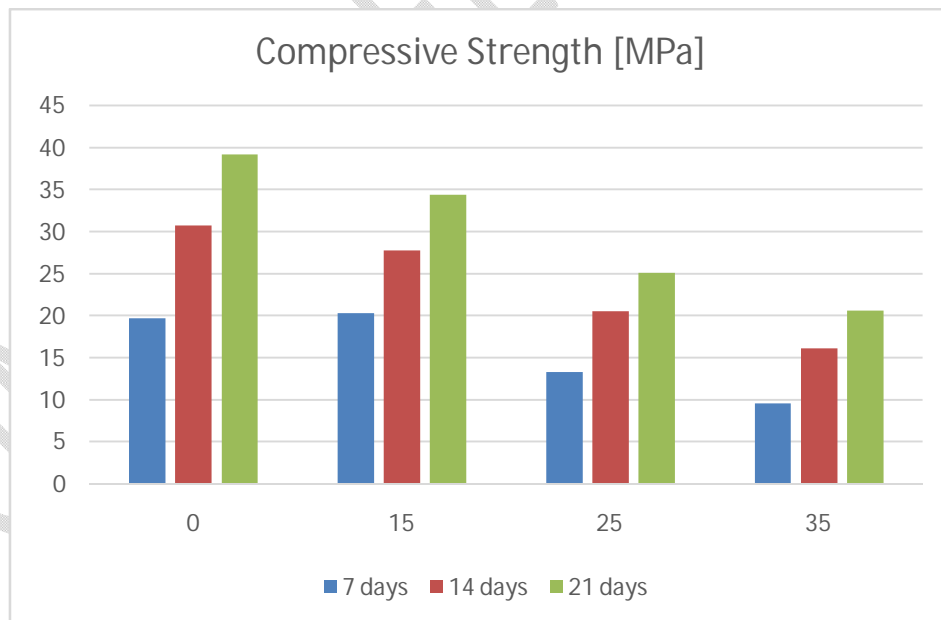


Fig. 12. Compressive strength results 3 [24]

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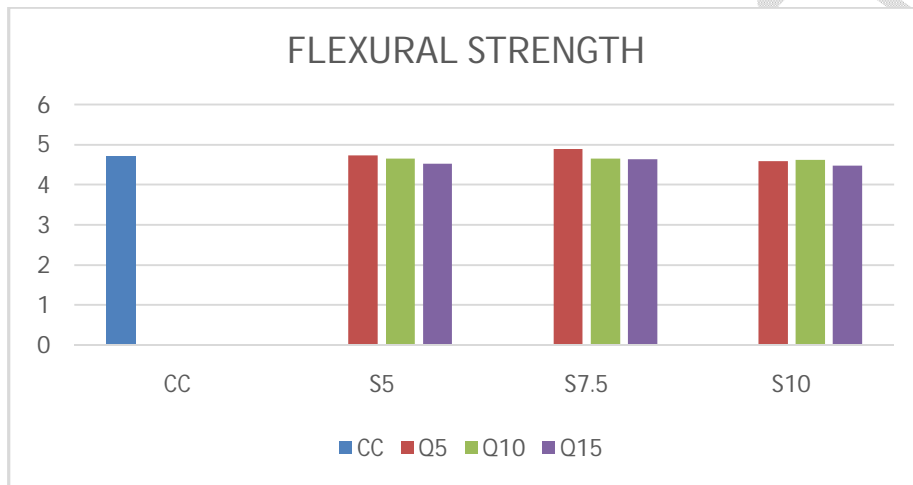
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125 **3.2. Flexural strength**

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

128 R. Chithra et. al. [25] investigated the flexural strength of self-compacting concrete with silica
129 fume and quarry dust at replacement percentage of 0, 5, 7.5 and 10%. In this study conclusion
130 was drawn as at 7.5% replacement of cement with silica fume gives increment in flexural
131 strength



132
133 Fig. 13. Flexural strength test results 1[25]

134
135 S.S. Janagan et. al. [26] examined the effect of silica fumes on the flexural strength of self-
136 compacting concrete at replacement level of 0, 5, 10, 15 and 20 of cement. The study concluded
137 that by increasing the amount of silica fumes in concrete flexural strength is also increasing.
138 Maximum strength was found out at 20 % replacement level at both 7 days and 28 days test.

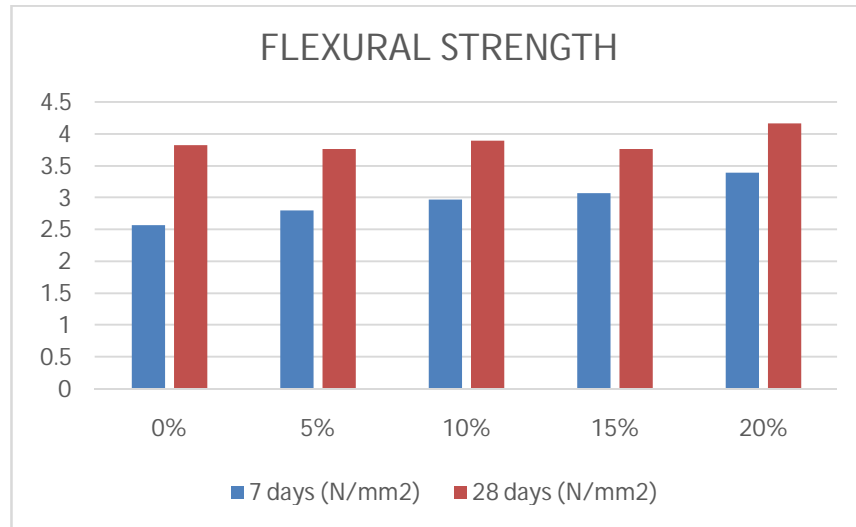


Fig. 14. Flexural strength test results 2 [26]

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143 N. K. Amudhavalli et. al. [27] examined “the effect of silica fumes on the flexural strength of
 144 concrete at replacement level of 0, 5, 10, 15 and 20 of cement. The study concluded that by
 145 increasing the amount of silica fumes up to a replacement level of 15% flexural strength
 146 increases and after that it decreases in concrete. Maximum strength was found out at 15 %
 147 replacement level at both 7 days and 28 days test”.

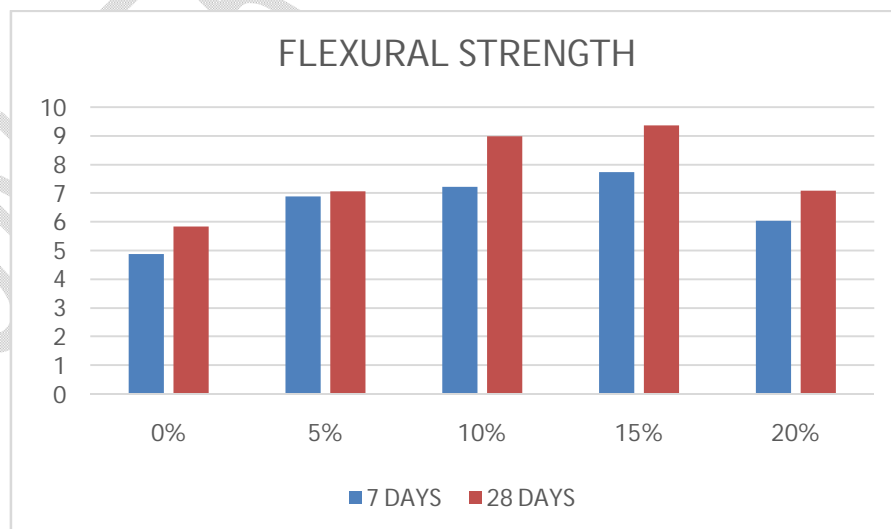


Fig. 15. Flexural strength test results 3 [27]

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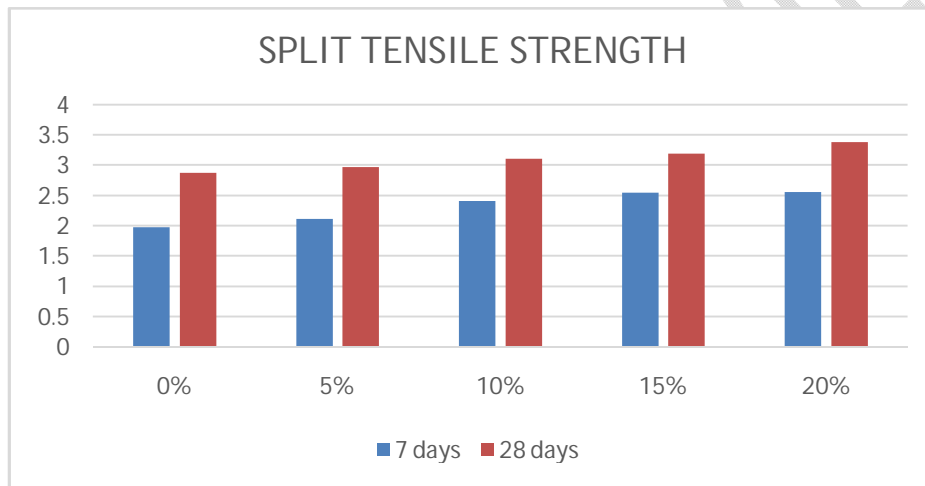
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151 **3.2. Tensile strength**

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

154 M. Gnanaprakash et al. [28] deliberated “the split tensile strength of the silica fumes as partial
155 replacement of the cement. They substituted silica fumes powder for cement in a ratio of 0% to
156 20%. At 20% cement replacement with silica fumes powder, greatest split tensile strength was
157 recorded at both 7 days and 28 days”. Fig.16 depicts the findings of their research.

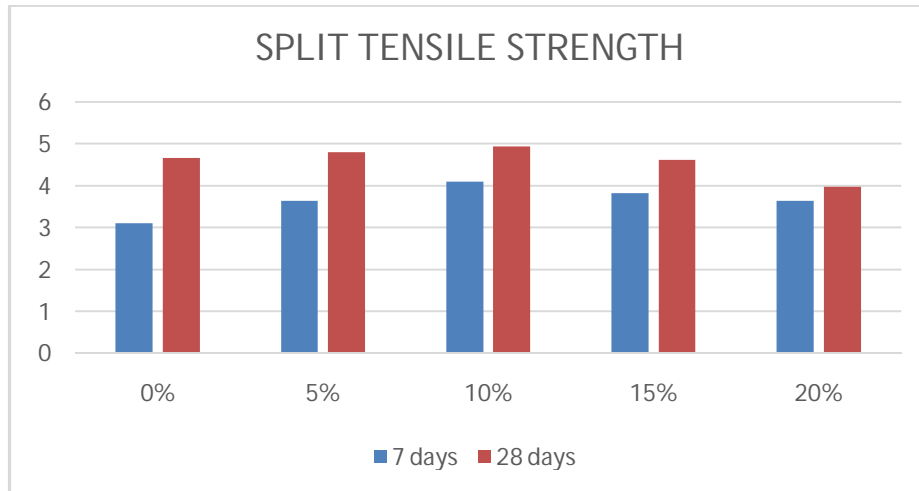


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159 Fig.16. Split tensile strength test results 1 [28]

160

161 Jeena Mathew et al. [29] tested “the tensile strength of the concrete comprising with silica fumes.
162 It was replaced cement with powdered silica fumes having proportions of 0%, 5%, 10%, 15%
163 and 20%. At 10% cement replacement with silica fumes, the greatest split tensile strength was
164 recorded for 7 days and 28 days”.



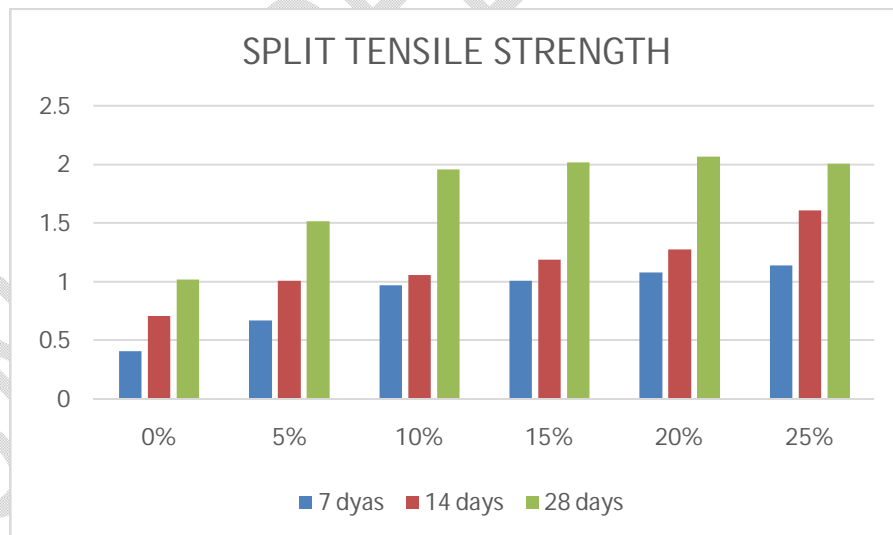
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Fig.17. Split tensile strength test results 2 [29]

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168 Syyed Adnan Raheel Shah et al. [30] examined “the effect of switching the cement by silica
 169 fumes. It was discovered that there was an upsurge in the percentage of silica fumes at a limit of
 170 25% with cement. Also, the split tensile strength was increased in concrete containing
 171 replacement of 20%”.



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Fig.18. Split tensile strength test results 3 [30]

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1765. Conclusion

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

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

- 184
- 185 ● Based on a number of study articles, results subjected to various silica fumes percentages
186 in self-compacting concrete, it can be concluded that the optimum utilization of silica
187 fumes for better fresh properties of SCC shall be 15% and for hardened concrete
188 properties it is 20% by the mass of cement in concrete.
- 189 ● The fresh properties of self-compacting concrete like slump flow with silica fumes had
190 different results, according to most of the researcher's ideal slump flow is found at 15%
191 to 20% of replacement cement with silica fumes.
- 192 ● The fresh properties of self-compacting concrete like V-funnel with silica fumes had
193 different results, according to most of the researcher's ideal mix is found at 15% of
194 replacement cement with silica fumes.
- 195 ● The fresh properties of self-compacting concrete like L box test with silica fumes had
196 different results, according to most of the researcher's ideal result is found at 15% of
197 replacement cement with silica fumes.
- 198 ● From the above study, researchers concluded that there was an increment in compressive
199 strength with the increase in silica fumes quantity up to 20%, after that, as the percentage
200 of silica fumes in self-compacting concrete increased the change in compressive strength
201 was neglectable.
- 202 ● The various studies showed that there was an enhancement in flexural strength just like
203 compressive strength up to 20% of silica fumes content, after that limit it also got reduced
204 as silica fumes content enhanced in concrete.

- 205 • As the proportions of silica fumes increased to a certain limit, the split tensile strength
206 increased. Optimum replacement of cement was around 20 percent by silica fumes after
207 that strength decreased.

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

212

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