

Performance of Self Compacting Concrete Containing Micro-Silica and Steel Fibre

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Abstract: Self-compacting concrete (SCC) originated in the late 1980's by Japanese in order to compensate the shortage of labour. The SCC is a special type of labour-friendly concrete that possess the ability to flow and compact by its self-weight. When properly designed, it could save time, eliminates the need for vibration, better compaction is produced compared to the conventional control mix. SCC contains more of binder content consisting of higher cement content. This cement was replaced by micro-silica at varying percentage and also steel fibres were used to improve the ductile nature. In addition to this, micro-silica have been used to improve the strength and durability of concrete. Addition of silica to a concrete mix alters the cement paste structure. Then the resulting paste contains more of the calcium-silicate hydrates and less of the weak and easily soluble calcium hydroxides. Due to its smaller particle size distribution, they disperse among and separate the cement particles. In the present study, the different mix ratio using steel fibres, micro-silica has been prepared and the fresh and hardened properties of SCC has been studied.

Key Words: Micro-silica, Steel fibre, SCC, Water absorption.

I. INTRODUCTION

The use of SCC has grown tremendously since its invention in the late 1980s in Japan. The difference between SCC and conventional control concrete is in the additional use of special admixture and the viscosity modifying agent in the former part. SCC is as a material that can flow through congested reinforcing bars without any need for compaction. The fresh state properties of SCC has been studied and followed as per EFNARC guidelines[2]. Silica particles provide a more uniform distribution and a greater volume of hydration products. The use of silica decreases thermal cracking and eventually helps to improve the durability and also reduces the shrinkage cracks caused by heat of hydration [5,6]. Addition of fibrous materials and silica particle improves the ductility and durability properties of concrete respectively. In the present study, additives such as micro- silica and steel fibre are added to SCC mix and the fresh state properties has been studied. Hardened properties of concrete have also been studied.

II. MATERIAL TESTING AND MIX DESIGN

Self-Compacting Concrete (SCC) was designed to flow under its own weight. Normal concrete was designed by using IS method and Self-Compacting Concrete was designed by using Nan Su method. The mix proportion is chosen in such a way that it satisfies the performance criteria for the concrete in both fresh and hardened state. To obtain the required workability in SCC, a higher proportion

of finer materials and the incorporation of chemical admixture are necessary. Table 1 shows the results of material testing. Micro-silica was added to improve the CSH gel formation in concrete [7]. Table 2 shows the physical properties of Micro-silica. Steel fibres are added to improve the ductility property of concrete [3,4,8] and the properties of steel fibre are shown in Table 3.

Physical property	Values
Specific gravity of cement	3.1
Specific gravity of sand	2.61
Specific gravity of coarse aggregate	2.66
Packing factor of sand	1.09
Packing factor of coarse aggregate	1.1

Table 1. Material testing results

Property	Micro-silica
SiO ₂ content	92.8%
Loss on ignition	2.6%
Moisture	0.2%
Particle size	150 nm
Surface area	22 m ² /g

Table 2. Physical Properties Of Micro-Silica

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Property	Values
Fibre type	Hooked end
Length	30 mm
Diameter	0.6 mm
Aspect ratio	50

Table 3. Physical Property Of Steel Fibre

Numerous trial mixes were carried out in order to achieve the slump flow. The strength parameters were also examined and then the final mix proportions were concluded depending upon the dosage of micro-silica, steel fibres, Super Plasticizer and VMA content. Water content, Super Plasticizer and VMA content is increased to get a workable concrete in the combination mix of micro-silica and steel fibre due to their uniform distribution within the concrete mix. Mix proportion was derived based on the EFNARC guidelines and is shown in Table 4. The mix proportion was varied for obtaining various mix with 5%, 10% and 15% micro-silica and 0.5% steel fibre as a partial replacement of cement. The optimum mix was obtained by choosing the optimum micro-silica mix showing better fresh and hardened properties of concrete.

Mix	Cement (kg/m ³)	Water (kg/m ³)	Fine aggregate (kg/m ³)	Coarse aggregate (kg/m ³)	Micro silica (kg/m ³)	Steel fibre (kg/m ³)	S.P (%)	VMA (%)
C	450	200	1000	750	---	---	1.2	0.12

Table 4. Mix Proportion For Control Concrete

III. EXPERIMENTAL INVESTIGATION

In the present study, tests were conducted on fresh and hardened concrete. Fresh SCC mixes were conducted for tests like Slump flow and J-ring. The J-ring test was conducted by placing the slump cone inside the J-ring and the concrete was filled in the slump cone without compacting. Then slump cone was removed and the concrete flow through the J-ring was measured in terms of horizontal flow spread as shown in Fig.1. The slump flow was tested basically to satisfy the flowing ability criteria and is shown in Fig.2. [2]. The J-ring flow and slump flow are related to each other by the term Passing Ability Index (PAI). Passing Ability Index is the ratio of the J-ring slump flow and slump flow whose value should be less than or equal to 1.

$$PAI = 1 - \frac{(d_{sf} - d_{jf})}{d_{sf}} = \frac{d_{jf}}{d_{sf}}$$

where

$$d_{sf} = \text{Diameter of slump flow}$$

$$d_{jf} = \text{Diameter of J - ring slump flow}$$

The acceptance range of values for different workability tests were shown in Table 5. From the successful mixes, final mix proportion after the cubes were cast and tested after 7 days and 28 days of curing were chosen. The compressive strength is carried out as per IS 516-1999 standard, conducted on concrete specimen of size 150mm x 150mm x 150mm. Cylinder of 100 mm diameter and 200 mm height was used for split tensile strength and prism of size 100mm x 100mm x 500mm was used for flexural strength and tested as per IS 516-1959.

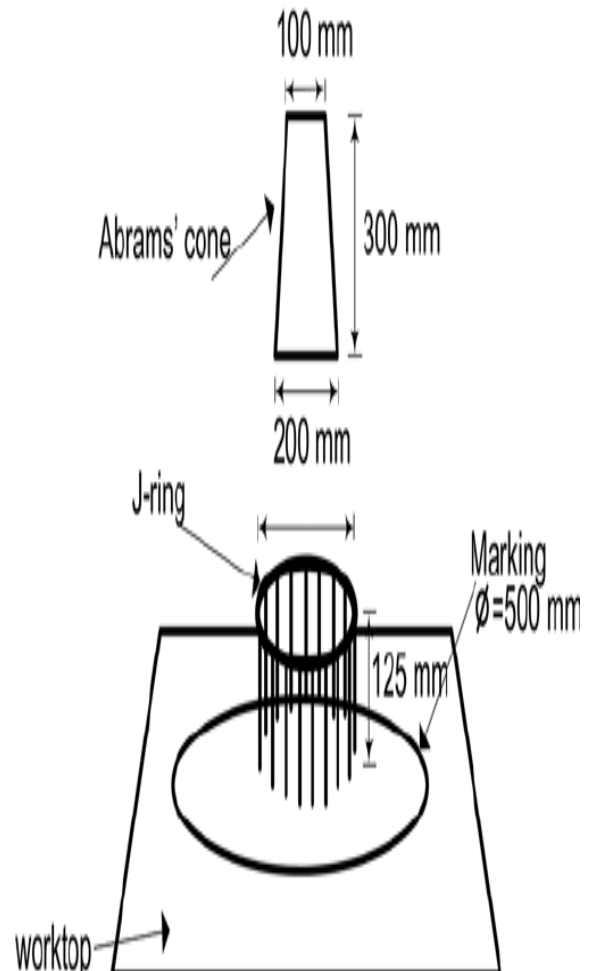


Figure 1. J-Ring Test

S.No.	Method	Unit	Typical range
1	Slump Flow	mm	650-880
2	J-Ring	mm	600-820

Table 5. Acceptance Criteria for Flow Test Results of Scc

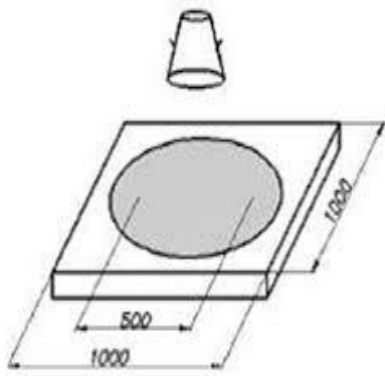


Figure 2. Slump Flow Test

IV. RESULTS AND DISCUSSION

The different types of concrete mixes were carried out in the laboratory as per the mix proportions mentioned. The fresh concrete properties were tested. The slump flow was measured and the average values of diameters at right angles were noted. The slump flow obtained for SCC control, control with 0.5% steel fibres, 10% micro-silica mix and combination mix of 10% micro-silica and 0.5% steel fibre showed slump flow of 660 mm, 658 mm, 675 mm and 657 mm respectively. From Fig.3., as the percentage of micro-silica increases, the PAI value gets increased. Linear regression was carried out and the result was better with a result of $R^2 = 0.9986$. Figure 4. and Figure 5. shows the J-Ring slump spread and Slump flow spread respectively.

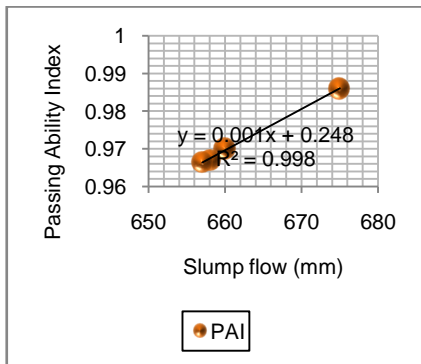


Figure 3. Variation Of Pai



Figure 4. J-Ring Slump Spread

From Fig. 6., it can be seen that the control concrete with 0.5% steel fibre and micro-silica mix with 0.5% steel fibre exhibited a higher percentage increase in compressive strength compared to control concrete, meanwhile the mix with micro-silica showed 4.48% increase in compressive strength.

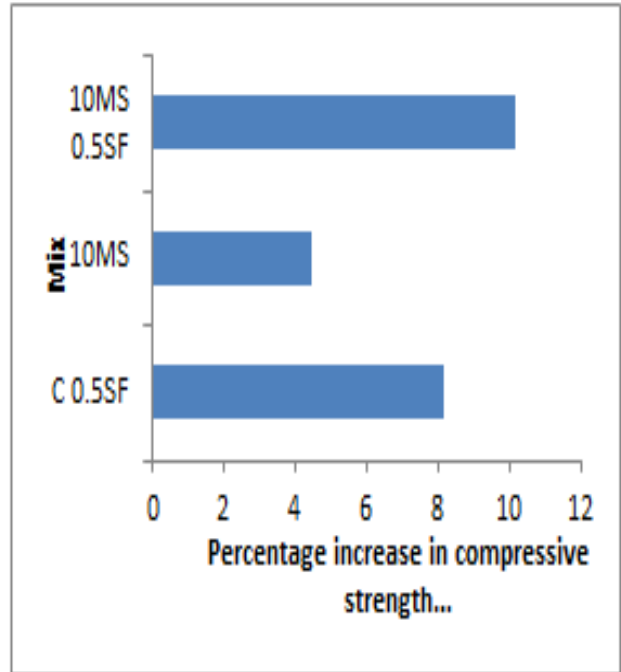


Figure 6. Percentage Variation Of Compressive Strength

From Fig.7. and Fig.8., it can be noted that as the steel fibres are added to the concrete, there is a considerable increase in both Split tensile strength and Flexural strength. Meanwhile, when micro-silica is added to concrete, both Split tensile strength and Flexural strength increases by 22.9% and 24.5% respectively compared to control concrete.



Figure 5. Slump Flow Spread

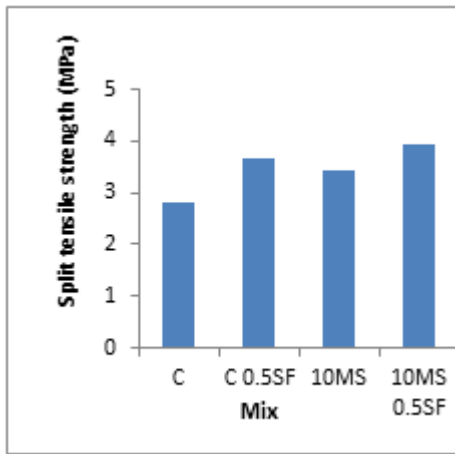


Figure 7. Variation Of 28 Days Split Tensile Strength

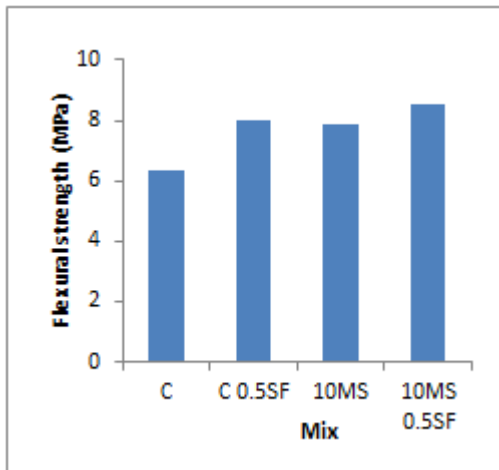


Figure 8. Variation Of 28 Days Flexural Strength

From Fig.9., it was noted that there is a reduction in absorption of water by the specimen containing micro-silica. This is due to the pore filling effect of micro-silica, leading to the formation of less porous structure. The percentage of water absorption is more for mix containing steel fibre due to the irregular positioning of steel fibres in concrete.

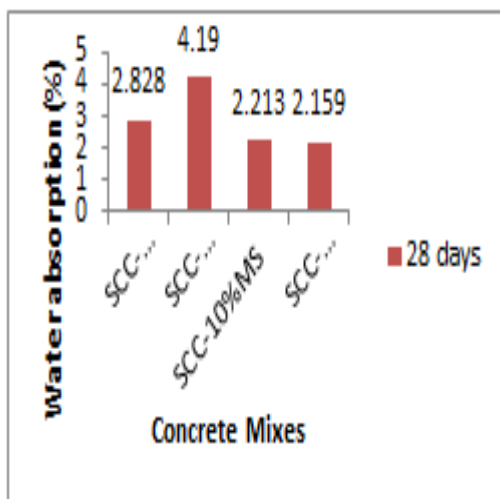


Figure 9. Variation Of Water Absorption Capacity

V. CONCLUSION

When the percentage of micro-silica gets increased, the workability of concrete gets reduced. The risk of segregation and bleeding was reduced by adding a higher percentage of

silica particles along with the appropriate dosage particles. Workability of concrete gets reduced when micro silica was added to concrete in addition to steel fibre. The mechanical properties of concrete increases with the addition of micro-silica and steel fibre. Due to more CSH gel formation in micro-silica, the absorption of water in the concrete specimen gets reduced, whereas the addition of steel fibres increases the pore size of concrete and leads to more water absorption

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