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Study on Steel Fibre Reinforced Self Compacting Concrete

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***Abstract* - Self Compacting Concrete (SCC) consists of a higher amount of fine content and admixtures, thus eliminating the time for compaction and labour cost. Micro silica is a by-product of the industrial manufacture of ferrosilicon and metallic silicon that is been made in high-temperature electric arc furnace. The ferrosilicon is drawn from 2000°C furnace, thus after when it cools down, the particles are condensed and are trapped in huge cloth bags. The condensed fume is processed by removing impurities and thus micro silica is being formed. Micro silica, as a waste by-product, being used for land filling, instead it can be used as an additive to concrete. The overall weight of the concrete increases up to 15 percent, thus increasing the unit weight of concrete. In addition, nano silica and steel fibres have been used to improve the strength and durability of concrete. Addition of silica to a concrete mix alters the cement paste structure. The resulting paste contains more of the calcium-silicate hydrates and less of the easily soluble calcium hydroxides. Due to its smaller size particle distribution, they disperse among and separate the cement particles. In the present study, different mix ratio using micro silica, nano silica and steel fibres has been prepared to study the fresh and hardened properties of SCC respectively.**
***Keywords:* Micro Silica, Nano Silica, Passing Ability, SCC, Steel Fibre**

I. INTRODUCTION

The use of SCC has grown tremendously since its invention in the 1980s. SCC uses higher quantity of finer content in concrete with special admixture and viscosity modifying agent. SCC can flow through congested reinforcing bars without any need for compaction [3]. SCC provides good surface finish to the structures. The fresh state properties of SCC has been studied and followed as per EFNARC guidelines [1]. Silica particles provides a more uniform distribution and a greater volume of hydration products are thus formed [4]. Silica particles decreases thermal cracking and helps to improve the durability and also reduces the shrinkage cracks caused by heat of hydration [6]. Addition of fibrous materials and silica particles improves the ductility and durability properties of concrete respectively [2]. In the present study, additives such as microsilica, nanosilica and steel fibre are added to SCC mix and the fresh state properties has been studied. Hardened properties of concrete has also been studied.

II. MATERIAL TESTING AND MIX DESIGN

Self-Compacting Concrete (SCC) was designed to flow under its own weight. Self-Compacting Concrete was designed by using Nan Su method. Cement used in the mix is Ordinary Portland Cement 53 grade. Fineaggregate used was locally available river sand conforming to grading zone II of IS 383-1970. The maximum size of coarse aggregate was restricted to 12.5 mm to avoid blockages in SCC. The mix composition 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 I shows the results of material testing. Micro and Nano silica are added to improve the CSH gel formation and pore filling effect in concrete [5,6]. The physical properties of Micro and Nano silica has been explained in TABLE II. Steel fibres are added to improve the ductility property of concrete [7]. The type of steel fibre used here is hooked end type, of length and diameter of 30 mm and 0.6 mm respectively. Super plasticizer used is Polycarboxylate ether type, named BASF- Master Glenium 8233. VMA used here is Fosroc Auramix V200. Potable water was used for mixing and curing of concrete.

Numerous trial mixes were carried out in order to achieve the slump flow. The strength parameters were also examined. Water, Super Plasticizer and VMA content is increased to get a workable concrete for different mixes of silica particles due to their uniform distribution within the concrete mix. Various mix proportions of M40 grade are obtained based on the EFNARC guidelines and is shown in TABLE III.

TABLE I MATERIAL TESTING RESULTS

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 II PHYSICAL PROPERTIES OF MICRO-SILICA AND NANO-SILICA

Property	Microsilica	Nanosilica
SiO_2 content	92.8%	99.9%
Loss on ignition	2.6%	0.66%
Particle size	150 nm	17 nm
Surface area	22 m^2/g	160 m^2/g

TABLE III MIX PROPORTIONS

Mix (kg/m^3)	C	C 0.5S	C 0.75S	C 1.0S	10M	10M 0.5S	2N	2N 0.5S
Cement	450	450	450	450	405	405	441	441
MS	-	-	-	-	45	45	-	-
NS	-	-	-	-	-	-	9	9
SF	-	2.25	3.375	4.5	-	2.25	-	2.25
Water	200	200	200	200	200	210	200	210
FA	1000	1000	1000	1000	1000	1000	1000	1000
CA	750	750	750	750	750	750	750	750
SP (%)	1.2	1.2	1.2	1.2	1.8	2.0	1.8	2.0
VMA (%)	0.12	0.12	0.12	0.12	0.18	0.2	0.18	0.2

III. EXPERIMENTAL INVESTIGATION

In the present work, several tests were conducted on fresh and hardened concrete. Fresh SCC mixes were conducted for tests like Slump flow, J-ring, V-funnel, L-box, T_{50cm} and Orimet flow. The slump flow was tested basically to satisfy the flowing ability criteria [1]. 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 valued in terms of height difference and horizontal flow spread. V Funnel is used to evaluate the segregation resistance of freshly mixed concrete by the observation of the flowing speed measured by the time taken for a sample to flow through the funnel.

In the L-box test, the height difference at both the ends was measured and the proportion was worked out. T_{50} test is a measure of the concrete's viscosity and is measured as the amount of time taken by concrete in the slump flow test to reach a diameter of 20 inches (or 50 centimeters). The Orimet test was conducted by investigating the time taken for concrete to flow through the orifice at the bottom of the apparatus. The acceptable range of values for different workability tests were shown in Table 5. Cubes of size 150×150mm, cylinders of 100×200 mm and prism of size 100×100×500 mm were used for compressive, split tensile and flexural strength testing at 7 and 28 days.

IV. RESULTS AND DISCUSSION

From TABLE IV, it can be noted that, as the percentage of steel fibre increases, the slump flow value gets reduced, since the fibres create a block in flow of concrete. A minimum slump of 650 mm has to be accomplished so as to satisfy the flowability property.

TABLE IV VARIATION OF SLUMP FLOW

Mix	Slump flow (mm)
C	660
C 0.5S	658
C 0.75S	655
C 1.0S	640

From Fig.1, it can be seen that as the steel fibre content increases, the flow through Orimet and V-Funnel orifices do not satisfy the flowabilty criteria. The flow of concrete through Orimet and V-Funnel should be within 0 to 5 s and 6 to 12 s. As the fibre content increases, the time taken for the concrete to reach the 50 cm diameter spread increases. The range for T_{50cm} test should lie between 2 to 5 s. From these tests, it can be assured that steel fibre content determines the flow of concrete.

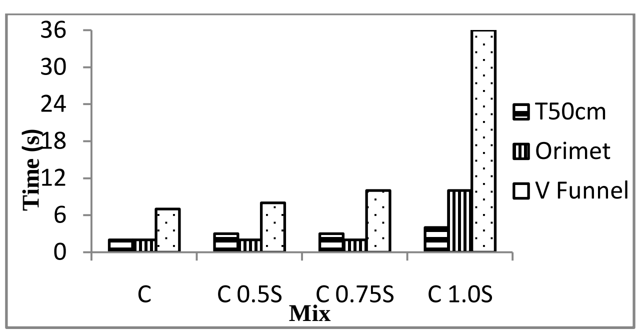

Fig. 1 Variation of time of flow of concrete through T_{50cm}, Orimet and V-Funnel

The Orimet spread and J-Ring spread values are shown in Fig.2, the spread value decreases as the fibre content increases. J-ring slump flow difference should be within 0 to 30 mm from the slump flow values. The difference do not satisfy for 1% steel fibre content. Due to the free flow of concrete from a height, the Orimet spread value is higher.

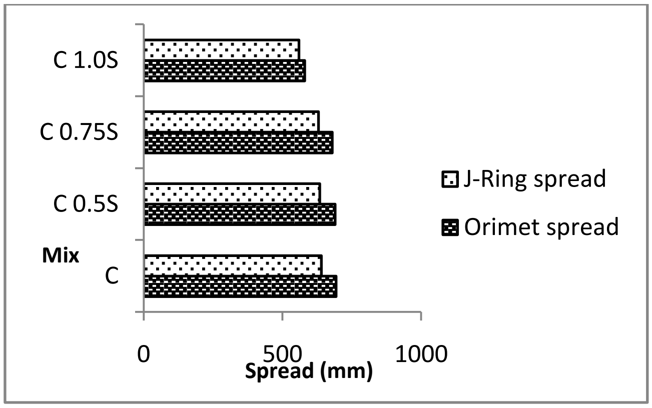

Fig. 2 Varaition of Orimet and J-Ring spread values

TABLE V shows the variation of J-Ring height difference which should lie between 0 to 10 mm. Fig.3 represents the variation of L-Box ratio. The L-Box ratio should lie within 0.8 to 1 to satisfy the flowability criteria of SCC.

TABLE V VARIATION OF J-RING HEIGHT DIFFERENCE

Mix	J-Ring height difference (mm)
C	5
C 0.5S	7
C 0.75S	8
C 1.0S	25

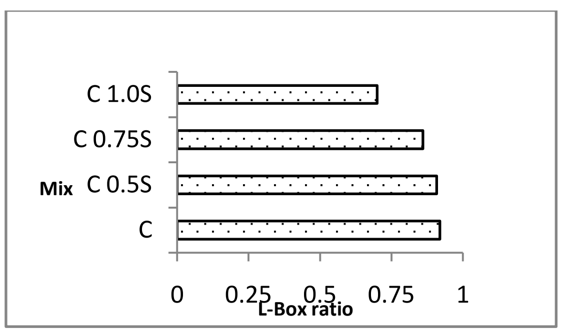

Fig. 3 Variation of L-Box ratio

TABLE VI shows the compressive strength after 28 days of curing. As the percentage of steel fibre increases the strength gets reduced.

TABLE VI COMPRESSIVE STRENGTH RESULTS

Mix	Compressive strength (MPa)
C	49
C 0.5S	53
C 0.75S	45
C 1.0S	44

Fig.4 represents the variation of split tensile strength. It can be noted that mix with 0.5%, 0.75% and 1% steel fibres had an increase of 30.71%, 13.57% and 7.85% from the control mix. The mix with steel fibres have higher split tensile strength than control mix.

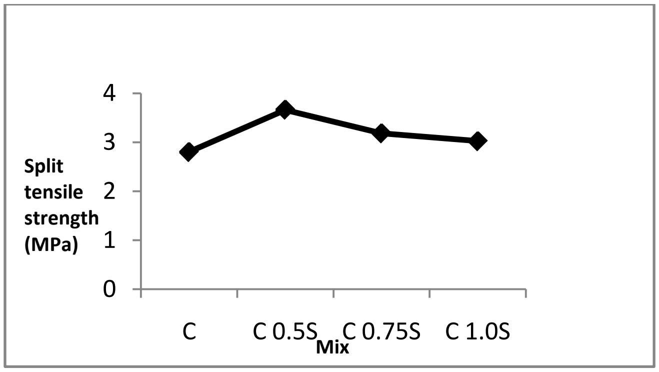

Fig. 4 Variation of Split Tensile Strength

Fig.5 represents the percentage increase of flexural strength compared to control mix. It can be noted that as the percentage of steel fibre increases, the flexural strength increases.

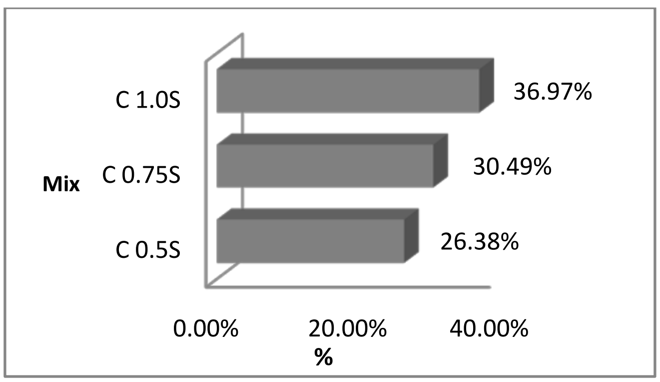

Fig. 5 Percentage Increase of Flexural Strength

Fig.6 represents the variation of V-Funnel, Orimet, T_{50cm} and L-Box values for all the mix ratios. It is observed that control concrete with 1% steel fibre do not satisfy most of the flowability property whereas the addition of steel fibre with micro and nano silica satisfied these properties. Fig.7 shows the variation of J-Ring height difference, on which, only control mix with 1% steel fibre do not satisfy the range.

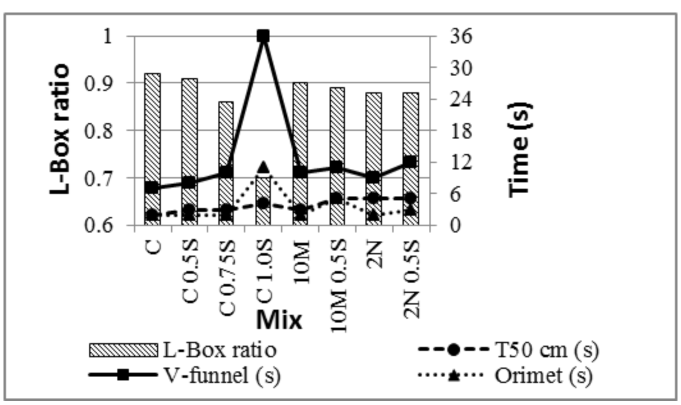

Fig. 6 Flow Properties of SCC

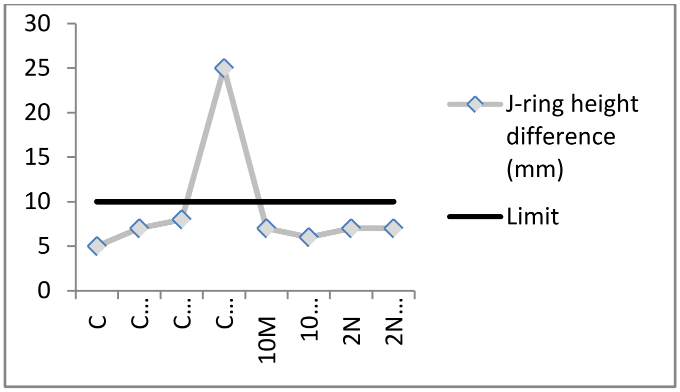

Fig. 7 J-Ring Height Difference Variation

Variation in Orimet, Slump and J-Ring flow is shown in Fig.8. Compared to all mix ratio, control mix with 1% steel fibre showed more deviation which lies below the accepted range.

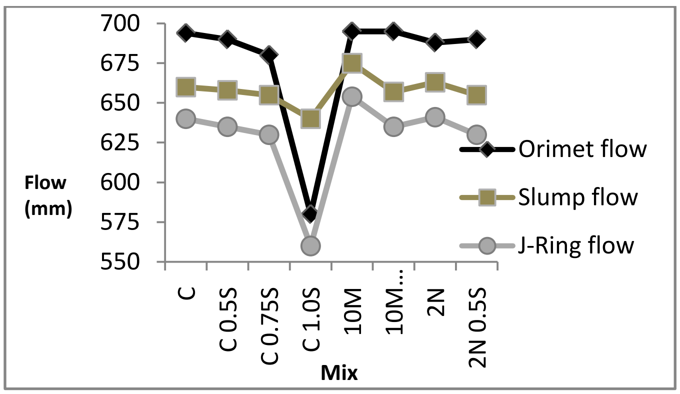

Fig. 8 Representation of Orimet, Slump and J-Ring flow

V. CONCLUSION

When the percentage of steel fibre increases, the workability and compressive strength of concrete gets reduced. Addition of silica particles had a better workability results compared to control concrete with steel fibre. The compressive strength and split tensile strength of concrete decreases when the percentage of steel fibre gets increased. Increase in percentage of steel fibre increases the flexural strength of concrete. Compared to control concrete, the mix with steel fibre. Due to the addition of steel fibres, the cylinder and prism continued to take more load until the specimen splitted into two, which proves the ductile behavior of steel fibre. SCC can be adopted in the areas of congested reinforcement and complicated structures, hence SCC is preferred over conventional concrete due to the ease flowing of concrete.

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