Investigating the Effect of Steel Fiber Reinforcement and the Combination of Steel & Sisal Fibers on the Properties of Self Compacting Concrete

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Abstract— **Self-Compacting concrete is considered as a breakthrough in the Concrete industry from several decades due to its faster construction, easier placing even in the dense reinforcement, requiring less manpower, can have better durability,& segregation resistance. The major aim of the present work is to study the fresh and hardened state properties of SCC mix with steel fiber reinforcement. Hooked end Steel fibers of 35mm length, 0.5mm diameter were added to the SCC mix. These Steel fibers were used in the volume fraction of 0, 0.5, 1, & 1.5. Sisal fibers were cut into 3.5cm length and to study the effect of combination of both the fibers. This research work consists of 2 stages. The first stage involves developing the SCC mix design of grade M35. In the second stage, fibers were added into the SCC mix and determining their fresh and hardened state properties and also compared. From this study, it can be concluded that by the inclusion of Steel fibers to the SCC mix, its strength get increases when compared to normal SCC**

Index Terms— **Self-compacting concrete, Steel fibers, Fresh & Hardened state properties, Compressive and Flexure strength**

I. INTRODUCTION

Self-compacting concrete is a highly flowable concrete which spreads into the form without the need of external vibration. Self-compacting concrete is a non-segregating concrete which is placed easily by its own weight. As a high-performance concrete, it can maintain all the common mechanical and durability properties of concrete. It has high workability, self-healing quality without undergoing segregation and bleeding. It is also known as Self consolidating concrete, Super workable concrete, and Self leveling concrete. In the present scenario SCC plays an important role in the field of modern constructions to satisfy the demands of modern architectural and indeterminate structural construction having complex geometrical configurations. SCC was first developed in Japan in 1988 to achieve more durable concrete structures by improving the quality of construction process. The benefits of SCC include speedy construction, reduction in labor and equipment wear, increased quality, strength & durability but the cost of the material is little bit more SCC provides a revolutionary development in the advanced concrete research field particularly in precast industry it has a huge impact due to its higher performance. It has a large scope in the construction of various structures particularly in the confined zones where vibrating compaction is difficult & in the construction of bridges, dams, tunnel, and shear walls.

The main characteristics of SCC are the properties in the fresh state. The mix design is based on the ability to flow by its own weight without vibration (filling ability) and to maintain homogeneity (passing ability) without segregation (segregation resistance).

The main objective of the present work is to study about the influence of Steel fiber reinforcement in different volume fractions on the fresh and hardened state properties of SCC. The methodology includes the mix design preparation of a typical M35 grade of concrete. SCC mix design is done as per IS 10262:2019. All the required quantity of materials was collected and does the check for their physical properties. Chemical admixtures like Superplasticizer for enhancing workability without modifying the water cement ratio and Viscosity modifying agent to build resistance against segregation. Fly ash of class C can be used as partial replacement of cement content. Steel fibers of 35mm length and 0.5mm diameter are used for the reinforcement & are varied for different volume fractions. Casting of the design mixes have done. Cubes and beams were tested for 7 & 28 days and the resulting values are noted and compared and study the influence of steel fiber reinforcement on the fresh and hardened state properties of SCC.

II. EXPERIMENTALPROGRAMME

A. Materials

Ordinary Portland cement (OPC) of grade 53 which is readily available in the market was used in the present work. Preliminary tests like Fineness, Standard consistency, Setting time test, & specific gravity test are conducted for OPC is confirming to IS: 8112-1989 and the results are presented in Table 1. The coarse aggregates which are in the form of crushed angular stones of 12mm down size are used in the present work. Manufacture sand conforms to grading Zone 1 of IS: 383-1970 is used with a maximum size of 4.75mm. Sieve analysis for fine aggregate and coarse aggregate is done as per the requirements of IS: 383-1970 Physical properties of aggregates like specific gravity, Fineness modulus, water absorption test is determined according to IS: 2386 (part III), and the results are tabulated in Table I, II & III. Fly ash of class C having specific gravity 2.35 is used in this experimental work. Chemical admixtures like Master glenium SKY 8650 Superplasticizer having relative density of 1.065 at 25^0 C and Viscosity modifying agent having specific gravity of 1.009 at 25^0 C & having pH-value of 9.5 @ 25^0 C is being used in this present study. Ordinary Potable water is used for mixing and curing of specimens for the entire experimental work. Steel fiber for reinforcing concrete is short, discrete lengths of steel fibers with an aspect ratio between 20 & 100, with different cross sections, that are sufficiently small which are added to the dry mixture by using general mixing procedures. Hooked end Steel fibers of 35mm length and 0.5mm diameter is utilized in the experiment. Sisal fibers are used in combination with steel fibers. Fiber content can be determined by considering

the volume of cement. Steel fibers are added to the mix by varying fractions of 0, 0.5%, 1%, & 1.5% volume of cementitious material.

TABLE I
RESULTS ON TESTS CONDUCTED ON CEMENT

Sl. no	Characteristics		Value
1	Fineness		6%
2	Standard consistency		31%
3	Setting Time	Initial	40minutes
		Final	390minutes
4	Specific gravity		3.15

TABLE II
RESULTS ON TESTS CONDUCTED ON COARSE AGGREGATES

Sl. no	Tests	Value
1	Specific gravity	2.64
2	Fineness modulus	3.12
3	Loose density	1373.5 kg/m^3
4	Water absorption	0.5%

TABLE III
RESULTS ON TESTS CONDUCTED ON FINE AGGREGATES

Sl. no	Tests	Results
1	Specific gravity	2.63
2	Fineness modulus	2.32
3	Loose density	1463.08 kg/m^3
4	Water absorption	2.23%

B. Mixing and Curing

First phase of the investigation involves the development of SCC mix design of strength M35 grade using fly ash, chemical admixtures and to study its properties in fresh and hardened state. SCC mix design is done as per Nan su et al using fly ash as a mineral admixture. SCC mixes which gives satisfactory results are taken for further investigation.

In the Second phase of investigation Steel fibers with different volume fractions were added to the SCC mix. The mix design is as shown in table 4. After the addition of fibers the same procedure is followed to determine the fresh and hardened properties of SCC. Casting is done using the Cubes of size 150 X 150 X150 mm and Beams of Size 100 X 100 X 500 mm and kept for curing upto 28 days. Compressive strength and Flexure strength is determined for 7 and 28 days.

TABLE IV
MIX CONTENT SUMMARY OF CONVENTIONAL CONCRETE

Cement	479 kg/m3
Water	191.6kg/m3
Coarse aggregates	1073.74kg/m3
Fine aggregate	655.60kg/m3
Water cement ratio	0.40

TABLE V
SPECIFIC GRAVITY OF MATERIALS

cement	3.15
Coarse aggregate	2.64
fine aggregate	2.63
Fly ash	2.35
Superplasticizer	1.009
Viscosity Modifying agent	0.57

TABLE VI
MIX CONTENT SUMMARY OF SCC

Cement	313.644 kg/m^3
Fly Ash	187.23 kg/m^3
Fine aggregate	916.80 kg/m^3
Coarse aggregate	661.48 kg/m^3
Water content	195.33 kg/m^3
Super plasticizer	10.06 kg/m^3
VMA	0.9

C. Testing Methods

The fresh state properties of SCC like deformability and viscosity can be determined by Slump flow test. This test is used to evaluate the horizontal flow of concrete and it also indicates resistance to segregation. V-funnel & U-box test is carried out to determine the filling ability of SCC. L-box test is used to determine the passing ability of SCC mix & also to find the extent to which the concrete is subjected to blocking by reinforcement. J-ring test is used for the determination of the passing ability of SCC. Cubes and beams were casted to determine the compressive strength and flexural strength. Inclusion of fibers increases the strength of the fiber & this is being checked using electronic testing machine (UTM) by applying two-point load system. The results of load deflection curves for varying fiber content were compared and analyzed.

III. RESULTS AND DISCUSSIONS

A. *Fresh Properties of SCC:*

Concrete slump value is used to determine the workability, which indicates water-cement ratio. When the fiber content increases, there is a decrease in slump flow value. Superplasticizers also have influence on the fresh properties of SCC which is shown in Table VII. From the table it can be seen that the flow diameter increased and the T500 time decreased with increase in the amount of super plasticizer. Dosage of SP above 1.75% resulted in concrete that exhibited too much segregation and flash setting. Below 1% dosage there was no possibility of concrete flow. Hence, SP dosage of 1.25-1.5 can be considered as optimum.

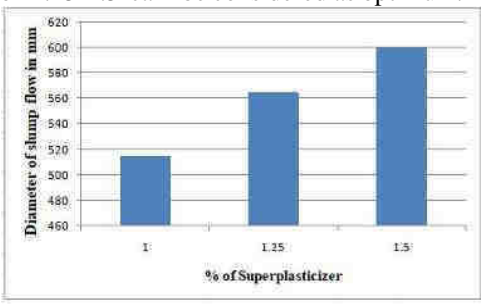

Fig 1: Variation of T500 time with SP dosage

From the above graph it can be seen that it can be seen that increasing the percentage of SP upto 1.5% increase with diameter of slump flow. Hence SP dosage of 1.25-1.5% can be considered as optimum.

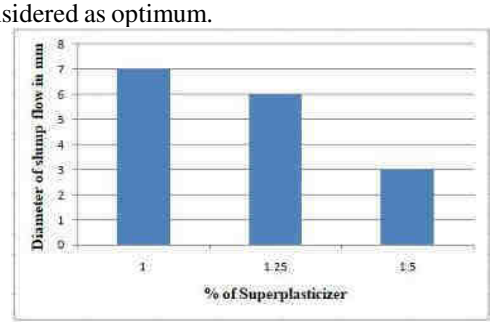

Fig 2: Variation of slump flow with SP dosage

TABLE VII
RESULTS ON SP DOSAGE ON FRESH PROPERTIES OF SCC

Testing date	**Superplasticizer in (%)**	**D1 in (mm)**	**D2 in (mm)**	**D(avg.)**	**T500 in (second)**
1/1/20	0.5	No flow occurred			
1/1/20	0.75	No flow occurred			
2/1/20	1.0	510	520	515	7
2/2/20	1.25	550	580	565	6
4/2/20	1.5	605	600	600	3
4/2/20	1.75	Segregation observed – not satisfactory			

TABLE VIII
FRESH PROPERTY TEST RESULT ON SCC WITH AND WITHOUT STEEL FIBERS WITH 1.5% SP

Characteristics	**Workability test**	**Unit**	**Measured value**				**EFNARC**
			0%	**0.5%**	**1%**	**1.5%**	
Flowability	Slump flow (dia)	mm	620	600	540	500	650-800
Viscosity	V - Funnel (time of flow)	sec	9	10.2	10.6	11	8-12
Passing ability	L – Box(H2/H1)		0.95	0.89	0.83	0.8	0.8-1
	J – Ring (dia)	mm	5	7	8	9	0-10

1. Slump flow test

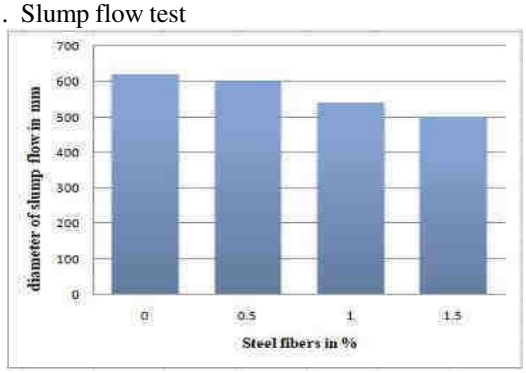

Fig 3: Slum flow variation with Steel fibers

From the above graph it can be seen that, the diameter of slump flow goes on decreasing by increasing the percentage of Steel fiber content that is from 0.5% to 1.5%. It shows that at the 1.5% steel fiber content flowability decreases to 500mm.Hence 0.5% of steel fiber can be considered as optimum.

2. V-Funnel test

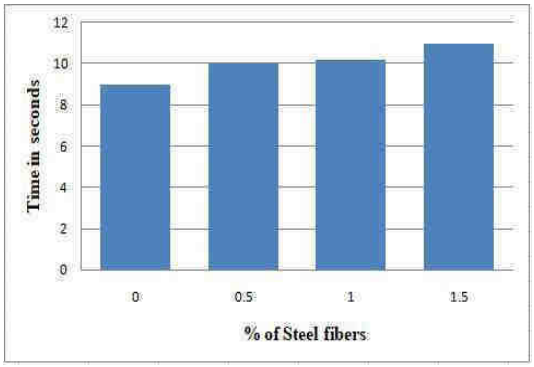

Fig 4: Variation of time flow with steel fibers

From the above graph it can be seen that, by increasing the percentage of steel fiber content from 0.5% to 1.5%, the flow time also increases and also viscosity increases with the increase of Steel fiber up to 1.5%. The maximum decrease in the flow of concrete is 85% at 1.5% of steel fiber content with respect to SCC without fiber

3. L-Box test

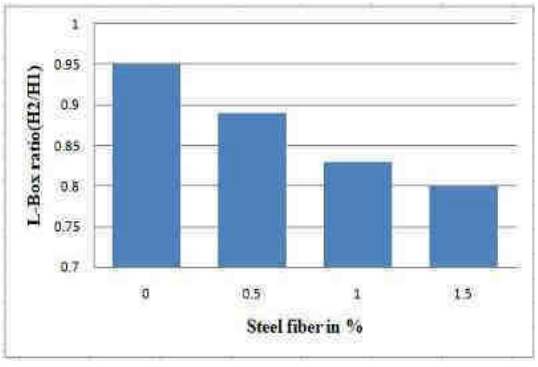

Fig 5: Variation of L-Box ratio with Steel fibers

L-Box ratio (H2/H1) decreases with the increase in the percentage of steel fiber content from 0.5% to 1.5%. The maximum decrease in the concrete flow is 31.5% at 1.5% Steel fiber content with respect to SCC without fiber. Hence

the maximum decrease in the L-Box ratio is 0.8 at 1.5% of Steel fiber

4. J - Ring test

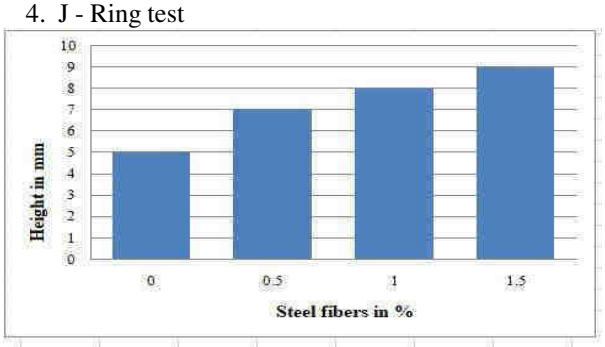

Fig 6: Variation of J-ring height with steel fibers

From the above graph, we can observe that, J-ring height increases with the increasing in the steel fiber content from 0.5% to 1.5%. The maximum difference in concrete height inside or outside J-ring bars is 8mm at 1.5% of fiber content. It can be seen that passing ability decreases through congested reinforcement with the increase in the steel fiber content upto 1.5%.

B. Compressive strength

Compressive strength of steel fiber reinforced concrete can be done by testing the specimens for 7 & 28 days, results are tabulated in table IX. It was observed that compressive strength gradually increases for 1.5% fiber content. The variation of compressive strength with the % of fiber content is shown in the fig 7. Compressive strength increases upto 3% to 6% for every % increase in the fiber content.

TABLE IX
COMPRESSIVE STRENGTH RESULTS OF STEEL FIBER REINFORCED SCC

Sl.no	Steel fiber in %	Compressive strength in N/mm^2	
		7 days	28 days
1	0	25.33	35.45
2	0.5	27.58	37.38
3	1	29.18	41.78
4	1.5	32.48	48.10

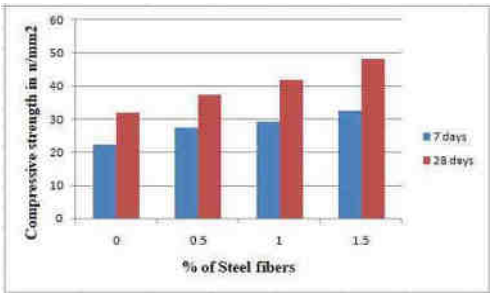

Fig 7: Variation of Compressive strength of SCC for 7 & 28days

TABLE X
COMPRESSIVE STRENGTH RESULTS OF COMBINATION OF STEEL & SISAL FIBER REINFORCED SCC

Sl.no	Combination of fiber in %	Compressive strength in N/mm^2	
		7 days	28 days
1	0%	22.33	35.13
2	0.25% steel & 0.25% sisal	26.32	36.86

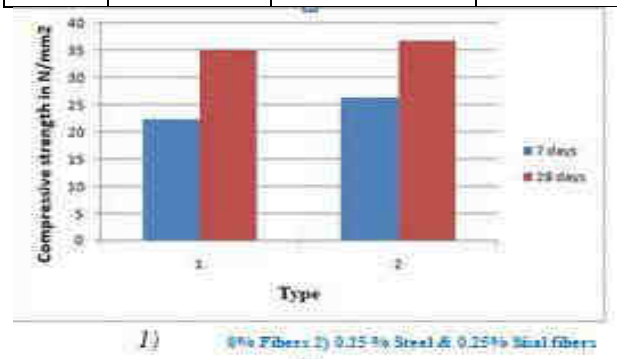

Fig 8: Variation of Compressive strength of SCC with combination of fibers for 7 & 28days

C. Flexure strength

Flexure strength of steel fiber reinforced self-compacting concrete can be done by testing the specimens for 7 & 28 days, results are tabulated in table XI. It was observed that flexure strength gradually increases for 1.5% fiber content. The variation of flexure strength with the % of fiber content is shown in the fig 10. Flexure strength increases upto 3% to 6% for every % increase in the fiber content.

TABLE XI
FLEXURE STRENGTH RESULTS OF STEEL FIBER REINFORCED SCC

Sl.no	**Steel fiber in %**	**Flexure strength in N/mm^2**	
		7 days	**28 days**
1	0	4.13	5.45
2	0.5	4.52	5.64
3	1	4.76	5.93
4	1.5	5.37	6.34

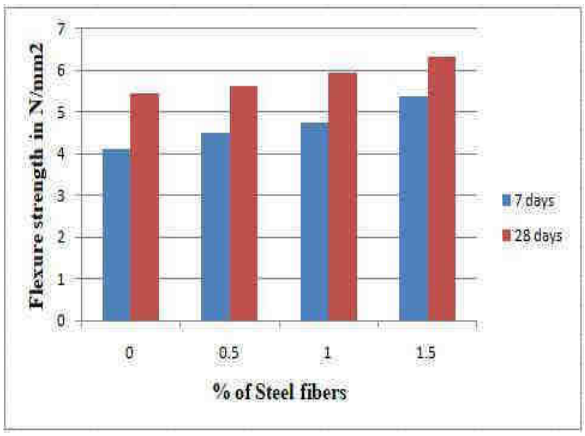

Fig 10: Variation of flexural strength of SCC for 7 & 28day

TABLE XII
FLEXURE STRENGTH RESULTS OF SCC WITH COMBINATION OF STEEL AND SISAL FIBERS

Sl.no	Combination of fiber in %	Flexure strength in N/mm^2	
		7 days	28 days
1	0%	4.13	5.45
2	0.25% steel & 0.25% sisal	4.32	5.57

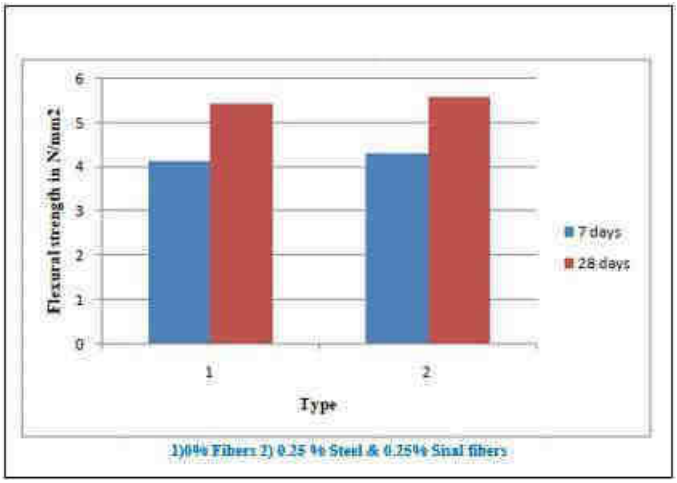

Fig 11: Variation of flexure strength of SCC with combination of fibers for 7 & 28days

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CONCLUSIONS

Conclusions obtained from the present study are following:

- Addition of fibers to the SCC mix leads to decrease in the slump value and it was noticed that for 0% fiber content the slump value was 620mm and it will reduce to 500mm.
- Acceptable flow characteristics were achieved for SCC with SP dosage between 1% and 1.5%. There will be no flow occurred for low SP dosage while higher dosage leads to segregation and quick set of the mix.
- By increasing SP dosage upto 1.5%, concrete flow increases and workability also increases.
- Slump flow test, T500 test, L-box test, V-funnel test, V-box test are conducted. From the test results we can observe that, by increasing the percentage of Steel fibers upto 1.5%, there will be decrease in the passing ability and filling ability of Self compacting concrete.
- On comparison of results of self-compacting concrete with and without Steel fibers, we can found that Concrete mix with inclusion of steel fibers have higher strength.
- We found that the Compressive strength, Flexure strength gradually increases upto 1.5% Steel fiber.
- For M35 mix design, after addition of 1.5% Steel fibers the Compressive strength, Flexural strength increased by 15.44% & 16.33% respectively

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