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Study on Rheological and Hardened Properties of Alccofine and Fly Ash based High Strength Self-Compacting Fibrous Concrete

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Abstract : Concrete is the most widely used development material on the planet. The type and quality of concrete being used have undergone varied transformation. Enhancing the concrete properties (fresh and hardened) is continuously one of the main necessities for construction of structures. Self-compacting concrete is one of the modern concrete which is able to achieve such type of properties at better extent. This study presents the effect of incorporating Alccofine and crimped steel fibres on the rheological and mechanical properties of HSSCC. Slump flow, V-funnel, L-box and U-box was carried out for rheological properties and compression, splitting tensile and flexure tests were carried out to know the mechanical properties. Fibres were added in the proportion of 0.5%, 1.0% and 1.5% and were compared with the controlled mix. There was significant increase in the splitting tensile strength and flexural strength of the concrete mix designed.
Keywords: Alccofine, Fly ash, Rheological and Mechanical properties, crimped steel fibres

I. INTRODUCTION

SSC is a new type of concrete that flows under its own weight and it does not require vibration, assuring complete filling of typical shapes and congested reinforcement. At the same time cohesive enough to be handled without segregation or bleeding. SCC is introduced in its fresh state by high flow ability and rheological stability. It was firstly emerged in Japan in the late 1980s. This is generally developed to overcome the gap to conventional concrete practices, where the trouble linked with the compaction by vibration is entrapped air voids and which reduce the strength as well as affects durability of concrete. SCC consists of aggregates, cement, water, filler, and chemical admixtures to take care of certain necessities, such as, passing ability, high flowability, have enough viscosity and segregation resistance. Researchers [1] have set some guidelines for the mixture proportioning of SCC, which include (i) reducing the volume ratio of aggregate to cementitious material; (ii) increasing the paste volume; (iii) controlling the maximum particle size of coarse aggregates and their total volume in the mix; and (iv) using different chemical admixtures, such as VMAs (viscosity-modifying admixtures) and superplasticizers to modify the balance between deformability and stability. Considering lower water-cement ratio and higher content of cementitious materials compared to conventional concrete, SCC should have improved durability and strength. SCC also has a brittle characteristic and these characteristic can be improved by adding fibres in to the concrete mix. Fibre-Reinforced Concrete (FRC) is defined as concrete containing dispersed randomly oriented fibres. When cracks propagate in the concrete they will reduce the service life of concrete by reducing durability of concrete and that will effect of the ability of concrete to resist weathering action and chemical attack. The properties of fibres that are usually of interest are fibre concentration, fibre orientation, fibre geometry, and distribution of fibre. The use of different type of fibre may behave in different manner with concrete.

II. RELATED WORK

Apoorva Chandak and Nitin Agrawal et al. 2016 [2] in their work on development of fibre reinforced self-compacting concrete using hybrid fibres (sisal and banana) reported that on keeping the fibre content b/w 0.3% to 0.5% . The water/cement ratio was kept at 0.4 and admixture content was 1 %.Lower slump value of SCFRC than conventional concrete was obtained. Increase in tensile and compressive strength was found with addition of fibres. SCFRC shows great resistance to the cracks than conventional concrete and with this it is feasible to produce low cost sustainable self-compacting fibre reinforced concrete.

Qi Cao et al. 2016 [3] evaluated the effect of fibre on self-compacting concrete. Workability of fresh concrete, mechanical properties and shrinkage of hardened concrete were determined. Steel fibre volume fraction used was 0.25%, 0.5% and 0.75% of the total volume of concrete; volume fraction polypropylene fibre was 0.10%. Investigation indicated that workability decreases with the increased percentage of fibres in concrete. The strength of self-compacting concrete improves with the addition of fibres.

Mounir M. Kamal et al. 2014 [4] carried out a research with the main objective of determining the optimum content of fibres (steel and polypropylene fibres) used in SCC. . These results showed that the optimal dosage of steel and polypropylene fibre was 0.75% and 1.0% of the cement content, respectively. The 28 days compressive strength was increased by 13% after using the polypropylene fibres. Usage of the steel fibres increased the 28 day compressive strength by 37% independent of the fibre content compared to the control self-compacted concrete mix without fibre addition. The impact resistance in terms of the number of drops needed to cause the fracture of test specimens was increased by 22% and 67% when polypropylene and steel fibres were used, respectively.

Sunil Suthar et al., 2013 [5] studied the effect of Alccofine and Fly ash addition on the Mechanical properties of High performance Concrete. The addition of 8% AL to different FA replacements has a high compressive strength than 10% SF. The optimum and high strength concrete can be obtained with 8% AL and 20% FA.

Pawar1 M. S., 2013 [6] studied the effect of the use of the Alccofine powder to increase the amount of the fines and hence achieve self – compatibility was also disussed in this study. It focuses on comparison of the properties of SCC with flyash and Alccofine to that of standard one with flyash. Fresh Properties and harden Properties of SCCs with 10% Alccofine are superior to SCCs with 5% and 15% of Alccofine.

III. EXPERIMENTAL PROGRAMME

A. Materials

Self-compacting concrete has the capability to consume a large amount of industrial by-products or waste as cementitious material. Mineral admixtures like silica fumes, fly ash, limestone powder and GGBFS have been used for the development of SCC. They give contribution to the properties of hardened concrete by physical and chemical processes including pozzolanic activities partly replacing cement. Alccofine is a new generation, micro fine material of particle size much finer than other hydraulic materials like cement, fly ash etc. produced in India, has unique characteristics to improve 'performance of concrete' in fresh and hardened stages.

Alccofine 1203 was used conforming to ASTM C989-99. Physical Properties of Alccofine is given in table-1. Fly ash manufactured in thermal power plant at Ropar, Punjab has been used in this project. Physical properties obtained are as shown in the table-2

Table-1: Physical Properties of Alccofine

Fineness(cm^2/gm)	Specific Gravity	Bulk Density(kg/m^3)	Particle Size Distribution (μ)		
			d10	d50	d90
>12000	2.9	700-900	1-2	4-5	8-9

Table-2: Physical properties of fly ash

Sr. No.	Property	Fly ash
1	Specific Gravity	2.2
2	Blaine's Fineness(cm^2/gm)	3260

The aggregates (coarse and fine) are obtained from Pathankot. For approval of source of supply, aggregates were tested for specific gravity, water absorption, deleterious material and organic impurities. Ordinary Portland cement (OPC-53 grade) as per IS: 12269-1987 was used for the making concrete mixtures. Crimped type steel fibres were used in the concrete of dia. 0.5mm and length 30mm of aspect ratio 60. BASF based MasterGlenium Sky 8866 is used as a superplasticiser. It is high-performance super plasticizer based on PCE (polycarboxylic ether) for concrete.

B. Development of SCC

Self-Compacting Concrete (SCC) consists of coarse aggregate phase and mortar phase. Mortar phase consists of fine aggregate and cement and supplementary cementitious material (or mineral admixtures like Alccofine, fly ash, etc.) along with water and chemical admixtures. Fresh and hardened properties of SCC mixes are greatly influenced by behaviour of mortar.

Japanese method of mix design was adopted for this study. Various trial mixes was done to achieve the desirable properties of self-compacting concrete as shown in table -3. For each mix three samples are prepared and tested at the age of 7 and 28 days moist curing. All the trial mixes were being design to get high strength. Trial mixes were prepared by incorporating different proportions of fly ash and Alccofine. The water/cement ratio was fixed to 0.2. The amount of superplasticizer varies between 1 to 1.2 %. Once the high strength was achieved, crimped steel fibres were added to the selected mix which showed high strength. The rheological and hardened properties of the final selected mix (TM6) with added crimped steel fibre was then studied in detail. The Alccofine and fly ash content in TM6 was 17% and 31% respectively. The amount of superplasticizer was 1.2% for TM6.

Table -3 Trail Mixes

Trial mixes	Cement	Fly ash	Alccofine	CA	FA	Admixture	Water
TM1	445	150	105	817	821	7	155
TM2	450	145	150	672	834	8.94	173
TM3	445	150	105	817	821	8.4	155
TM4	450	150	98	779	821	8.37	166
TM5	475	128	110	640	940	8.56	156.5
TM6	475	150	81	640	940	8.47	155

IV. RESULTS AND DISCUSSION

A. Fresh Concrete Behaviour

Rheological properties were determined: slump flow test, T50-time, L-box, U-box and V-funnel tests were executed to evaluate flowability of concrete. The cohesiveness and the absence of segregation of the mixtures were visually estimated. Slump flow test results are greater than 600 mm for all the mixes as recommended by EFNARC specifications. All tests were as per the requirement thus, showing that all the mixes containing Alccofine and steel fibre have good ability to flow.

Slump flow value is achieved were shown in table-4 below. Slump flow value decreased with increase in fibre content. Figure-1 shows the variation of slump with increase in fibre percentage.

Table-4: Sump flow Test

Sr. No.	Percentage of fibre (%)	Aspect ratio	Slump Flow by Abrams Cone (mm)	
			Horizontal Slump (mm)	T50-Time (sec)
1	0	60	750	2.92
2	0.5	60	730	3.36
3	1.0	60	690	4.2
4	1.5	60	665	4.6

From the table- 4 it can be seen that the slump flow within the range of 680 to 770 and flow time ranging from 2.98 to 4.44 seconds

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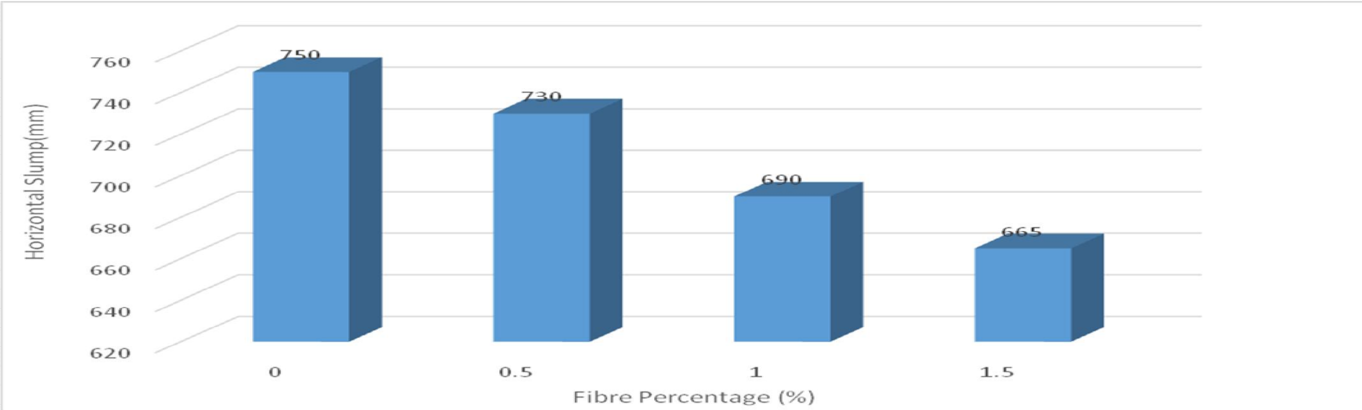

Figure-1: Slump value for different percentage of fibre

The T- 50 time of the concrete is shown in figure-2. T-50 time also increases with increase in fibre content

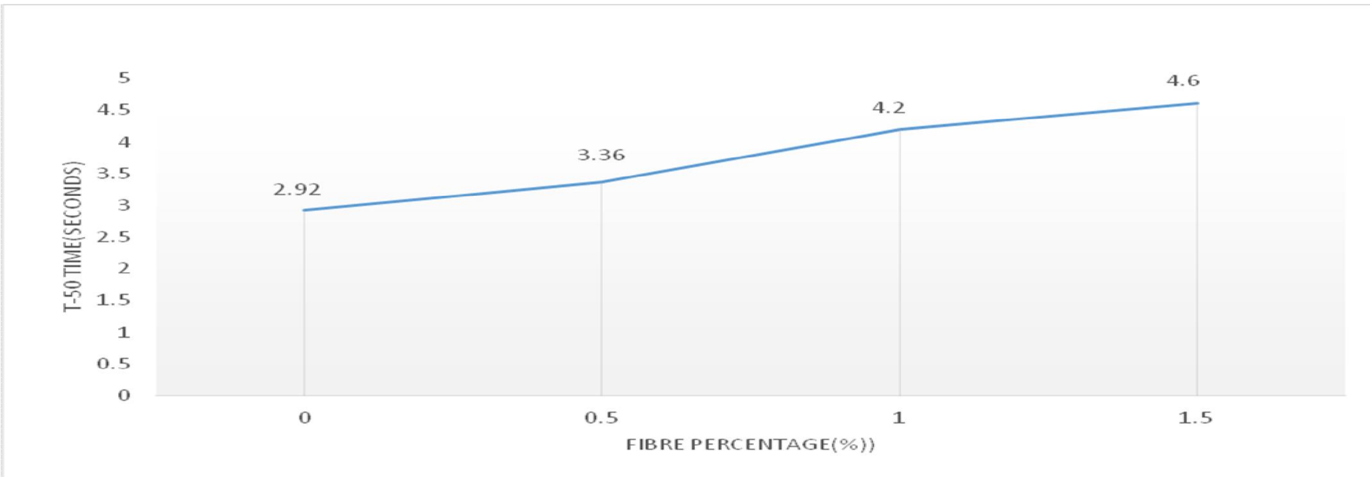

Figure-2: T-50 time for different percentage of fibre

V-funnel is used to determine the flowablitiy of concrete. Shorter the flow time greater is the flowability. The flow time observed was between 7.56 to 9.78 seconds which is in EFNARC guidelines. The $T_{5\ min.}$ time was observed between 8.10 to 11.10 seconds. Table-5 below shows the time in V-funnel test.

Table-5: V-funnel Test

Sr. No.	Percentage of fibre (%)	Aspect ratio	V-Funnel Test	
			Flow Time(sec)	$T_{5\ min.}$ (sec)
1	0	60	7.56	8.10
2	0.5	60	8.02	9.20
3	1.0	60	8.72	10.24
4	1.5	60	9.78	11.10

The figure-3 below shows the comparison of flow time and $T_{5\ min}$ with different percentage of fibre.

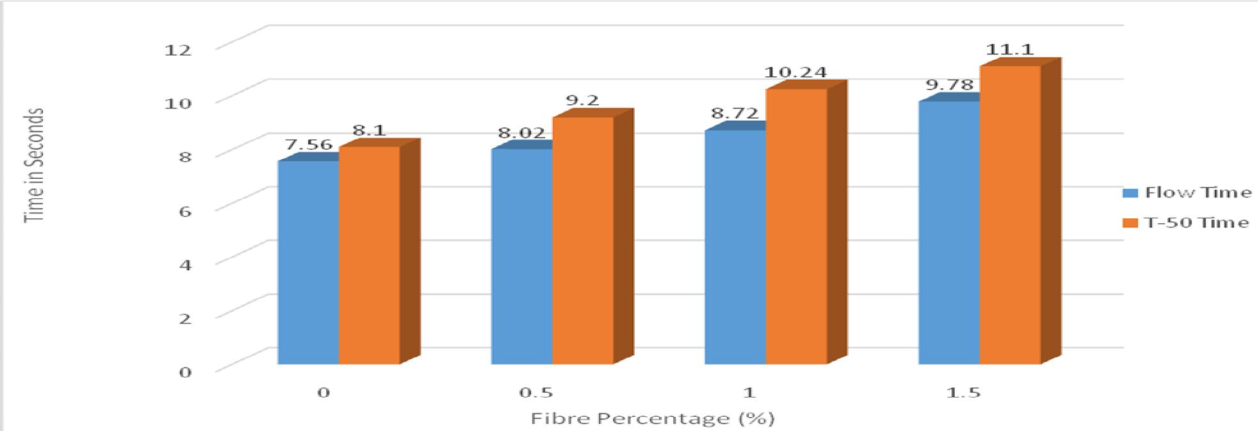

Figure-3: Comparison of Flow time and T_{min} time

Table-6: L-Box Test

Sr. No.	Percentage of fibre (%)	Aspect ratio	L-BOX TEST
			H2/H1
1	0	60	0.956
2	0.5	60	0.914
3	1.0	60	0.902
4	1.5	60	0.889

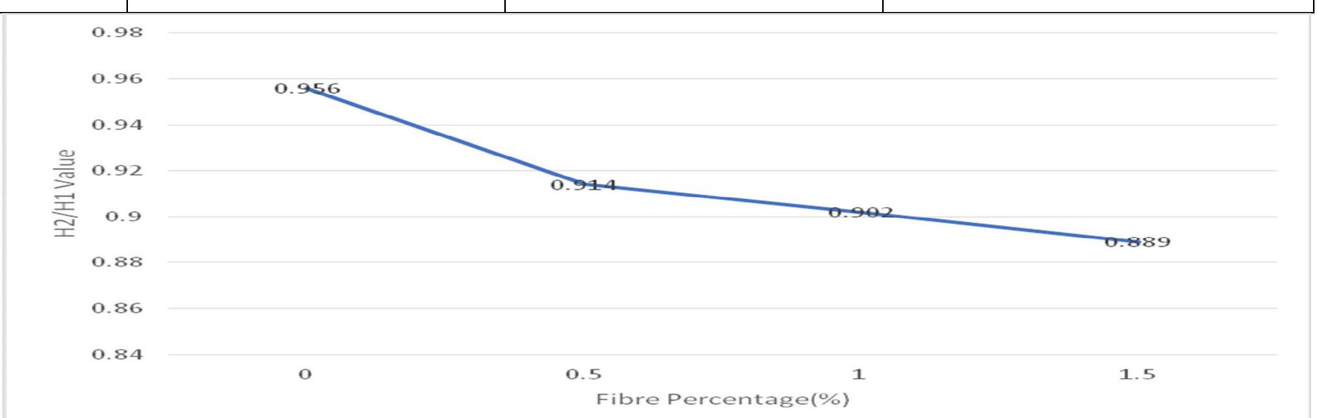

Figure-4: L-box value with different percentage of fibres

Table -7: U-BOX TEST

Sr. No	Percentage of fibre (%)	Aspect ratio	U-BOX TEST		
			H_2 (mm)	H_1 (mm)	H_2-H_1 (mm)
1	0	60	311	301	10
2	0.5	60	317	306	11
3	1.0	60	322	309	13
4	1.5	60	325	311	14

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The figure-5 below shows the value of U-Box with different percentage of fibre

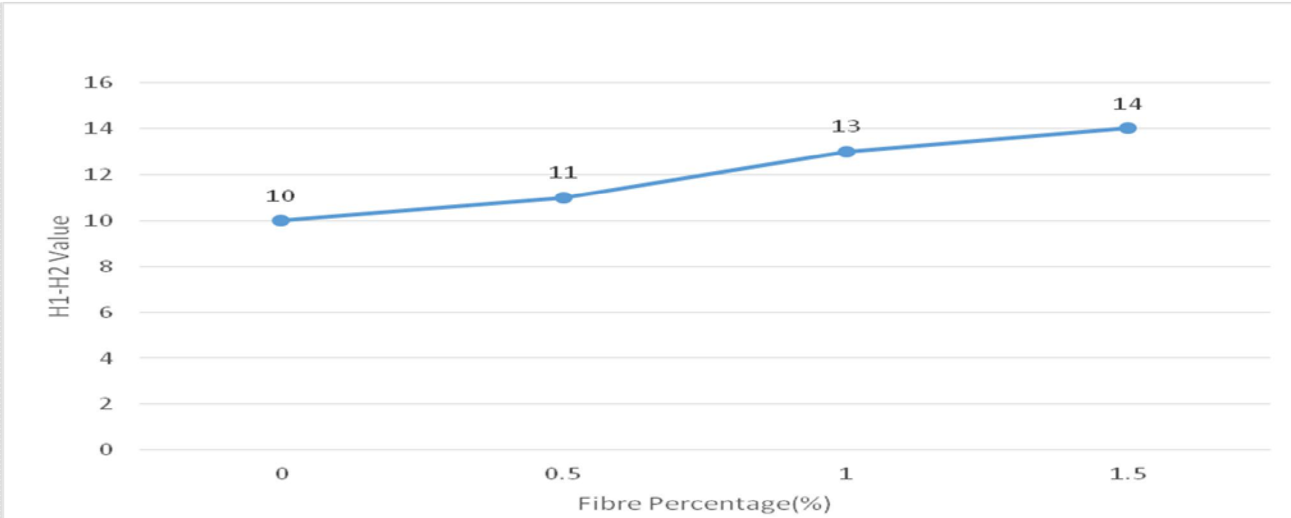

Figure-5: U-box value with different percentage of fibre

B. Effect on Compressive Strength

For compressive strength concrete cubic samples (150×150×150 mm) were casted and cured for 28 days. The results of compressive strength are shown in table-8 below.

Table-8: Results of the Compressive strength

Sr. No.	Fibre Percentage (%)	Compressive Strength(N/mm^2)			
		7 (Days)		28 (Days)	
1.	0%	86.1		109.2	
		84.5	85.3	107.5	108.4
		85.2		108.6	
2.	0.5%	88.2		109.4	
		85.2	86.6	110.7	110.8
		86.4		112.5	
3.	1.0%	84.2		115.2	
		88.4	87.4	114.1	113.7
		89.7		111.6	
4.	1.5%	98.4		114.4	
		100.6	98.6	112.6	114.4
		97.1		116.4	

From Table-8 it s observed that the SCC developed has compressive strengths at the end of 7 days ranging from 85.3 to 98.6MPa and at the end of 28 days compressive strengths ranging from 108.4 to 114.4 MPa with different percentage of fibre.

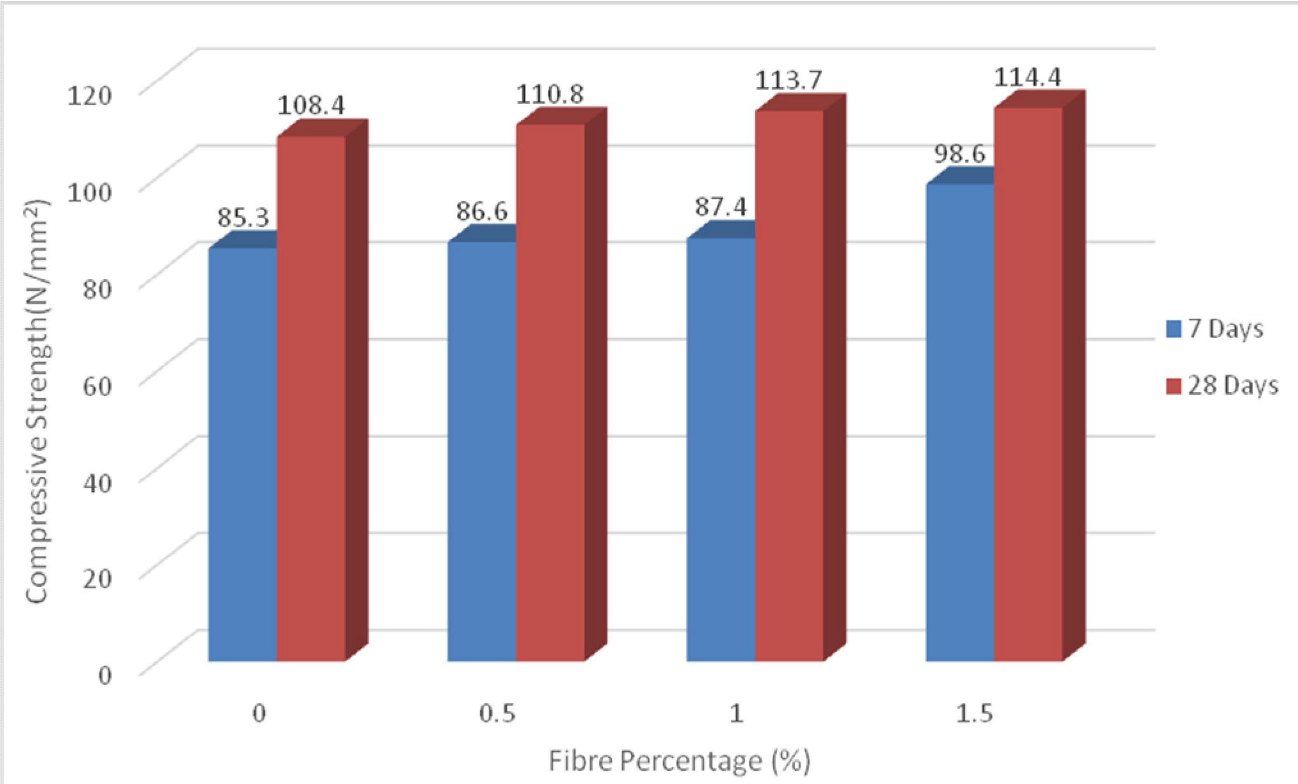

Figure-6: Comparison of 7th and 28th day compressive strength with different percentage of fibre

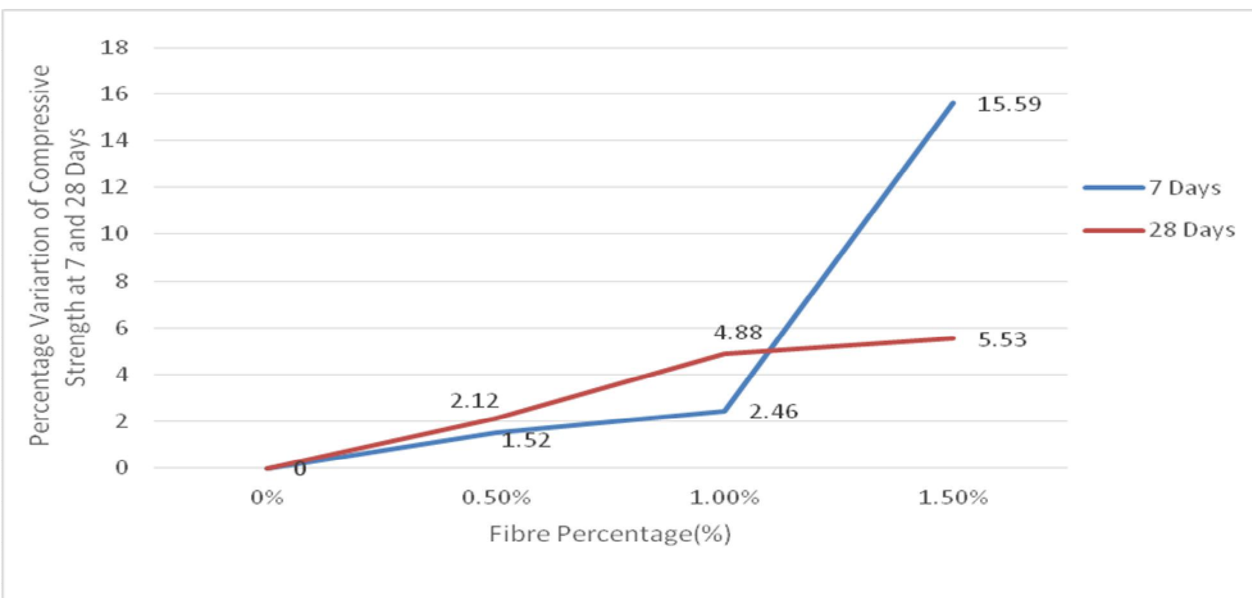

Figure-6: Percentage increase in compressive strength with increase in fibre content

From figure-6 the percentage increment in the compressive strength at 0.5%, 1.0% and 1.5% fibre content at 7days were 1.52%, 2.46% and 15.59%; and at 28days percentage increment were 2.12%, 4.88% and 5.53% for same percentages of fibre content. Thus, addition of fibre in the designed SCC has positive effect on the compressive strength of concrete.

C. Effect on Split Tensile Strength

The values of the split tensile test in listed in the table-9 shown below.

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Table-9: Results of Split Tensile Test

Sr. No.	Fibre Percentage (%)	Tensile Strength(N/mm^2)			
		7 Days		28 Days	
1.	0%	6.4	6.6	6.9	6.8
		6.8		6.7	
		6.6		7.0	
2.	0.5%	8.2	8.6	9.4	9.4
		8.7		9.6	
		8.9		9.2	
3.	1.0%	9.6	9.8	9.8	10.2
		9.8		10.2	
		10.2		10.6	
4.	1.5%	10.2	10.3	11.8	11.6
		10.4		11.4	
		10.4		11.6	

From Table-9 it s observed that the SCC developed has split tensile strengths at the end of 7 days ranges from 6.6 to 10.3MPa and at the end of 28 days split tensile strengths ranges from 6.8 to 11.6 MPa with different percentage of fibre.

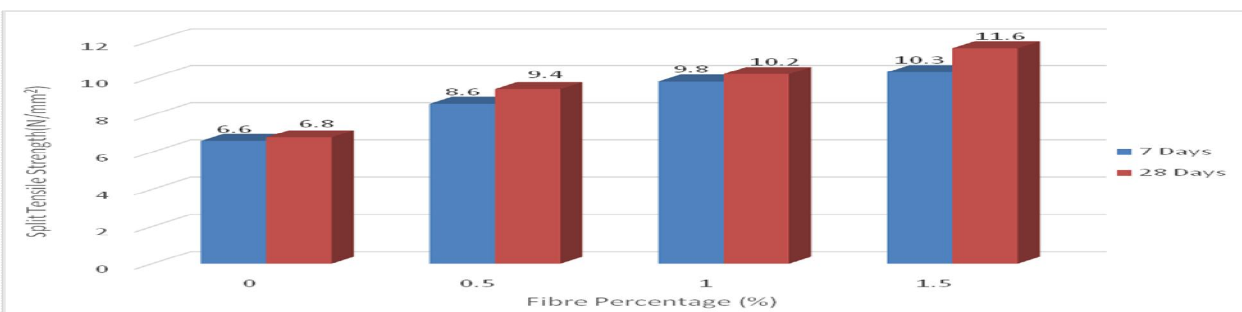

Figure-7: Comparison of 7th and 28th day split tensile strength with different percentage of fibre

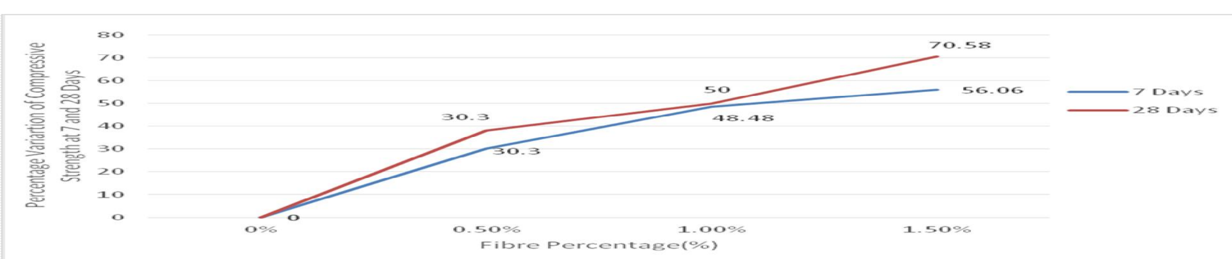

Figure-8: Percentage increase in split tensile strength with increase in fibre content

From figure-8 the percentage increment in the flexural strength at 0.5%, 1.0% and 1.5% fibre content at 7days were 30.3%, 48.48% and 56.06%; and at 28days percentage increment were 38.2%, 50% and 70.58% for same percentages of fibre content. Thus, addition of fibre in the designed SCC has positive effect on the splitting tensile strength of concrete.

D. Effect on Flexure Strength

The values of the flexural test in listed in the table-10 shown below

Table -10: Results of flexural strength

Sr. No.	Fibre Percentage (%)	Flexural Strength(N/mm^2)			
		7 (Days)		28 (Days)	
1.	0%	6.6	6.9	7.2	7.2
		7.2		7.0	
		6.9		7.4	
2.	0.5%	8.6	8.9	9.8	9.8
		8.9		10.2	
		9.4		9.6	
3.	1.0%	10.2	10.5	11.4	11.4
		10.6		11.2	
		10.8		11.8	
4.	1.5%	11.2	11.7	12.8	12.8
		11.8		12.4	
		12.2		13.2	

From Table-10 it s observed that the SCC developed flexural strengths at the end of 7 days ranges from 6.9 to 11.7MPa and at the end of 28 days flexural strengths ranges from 7.2 to 12.8 MPa with different percentage of fibre.

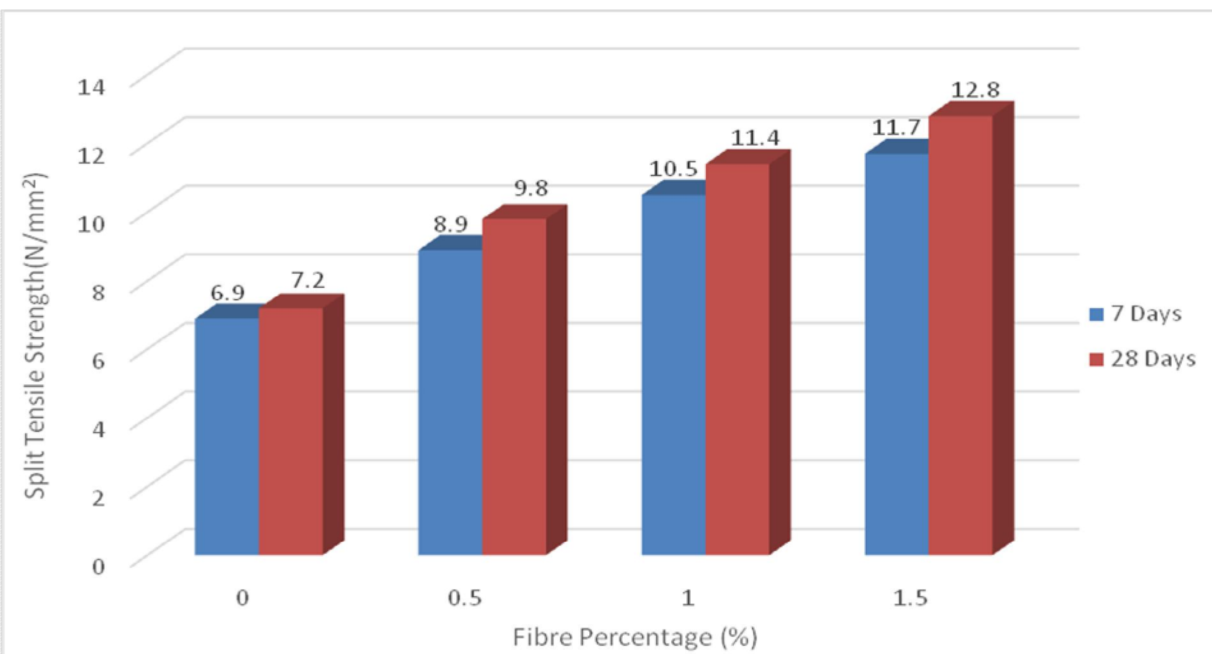

Figure-9: Flexural strength of SCC at 7 and 28 days with different percentage of fibre

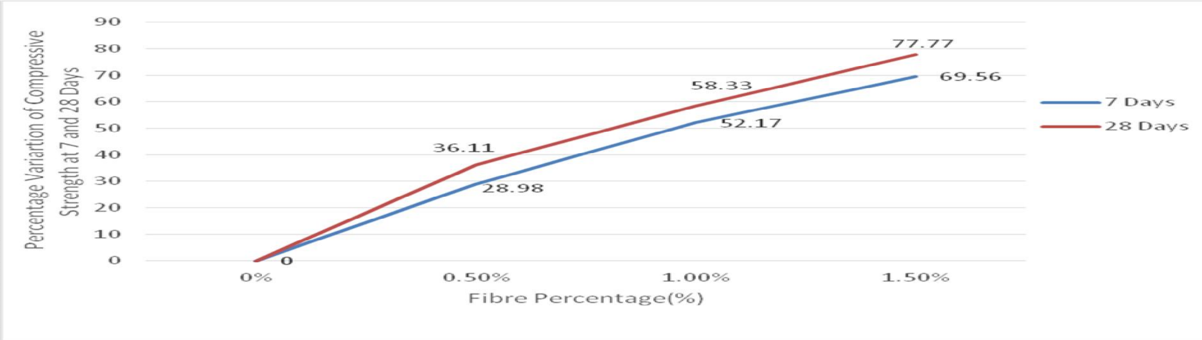

Figure-10: Percentage increase in flexural strength with increase in fibre content

From figure-10 the percentage increment in the flexural strength at 0.5%, 1.0% and 1.5% fibre content at 7days were 28.98%, 52.33% and 69.56%; and at 28days percentage increment were 36.11%,58.33% and 77.77% for same percentages of fibre content. Thus, addition of fibre in the SCC has positive effect on the flexural strength of concrete.

V. CONCLUSIONS

From the results and analysis of this experimental work, carried out, the following conclusions were arrived:

A. The study shows that it is possible to design High strength self-compacting fibrous concrete incorporating fly ash and Alccofine with various proportions of steel fibres such as 0%, 0.5%, 1.0%, and 1.5%.
B. The result obtained from all the concrete mixtures satisfy the requirements suggested by EFNARC. All the mixtures have good flow ability and acquire self-compaction characteristics.
C. It was observed that the fibres improve resistance to segregation and bleeding.
D. It can be concluded that the Alccofine and fly ash when used as a supplementary cementitious material with crimped steel fibres result in significant increase in Split tensile strength and Flexural strength.

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