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Comparative Study on Strength and Durability Properties of High Strength Self Compacting Concrete With and Without Steel Fibres

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Abstract: This paper presents an experimental program to investigate the strength and durability properties of high-strength self-compacting concrete (HSSCC) with and without steel fibers. The research work is divided into two approaches. These approaches are the development of (HSSCC) by making different trials and then studying mechanical and durability properties. Crimped-type steel fibers are used. Fly ash and Alccofine have been used as mineral admixtures to fulfil the power requirement. Chemical admixture has also been used for workability. The test results of plain and fibrous HSSC concrete indicated that steel fiber increases the tensile strength and makes concrete more durable and impermeable
Keywords: HSSCC, alccofine, tensile strength, durability.

I. INTRODUCTION

Self-consolidating concrete (SCC) has high flow ability and moderate viscosity and has no blocking by the reinforcement during flow. In addition, SCC will de-air by itself during casting. The concept of SCC was proposed first by Okamura in 1986. SCC is a highly fluid mix that had excellent deformability, and resistance to segregation, and could entirely fill and self-compact under its weight in heavily reinforced formwork for concrete (1). Self-consolidating high-performance fiber reinforced concrete (SCHPFRC) combines the self-consolidating property of self-consolidating concrete (SCC) with the strain hardening and multiple cracking characteristics of high-performance fiber-reinforced cement composites (HPFRCCs). SCHPFRC is a highly flowable, non-segregating concrete that can spread into place, fill the formwork, and encapsulate the reinforcing steel in typical concrete structures (2). ACI Committee offers the following definition of SCC: Self-consolidating concrete (SCC) is highly flowable, non-segregating concrete that can spread into place, fill the formwork, and encapsulate the reinforcement without any mechanical consolidation (3). Filling ability, resistance to segregation, and passing facility are three key aspects of workability that should be carefully controlled to ensure satisfactory performance of SCC during its wet phase and for its successful classification as SCC (4).

SCC has been described as "the most revolutionary development in concrete construction for several decades" It offers many advantages for the pre-cast pre-stressed concrete industry, and for cast-in-place construction. It is the concrete that is fully compacted without segregation and external energy and can be used as a means to create uniformity in the quality of concrete by controlling the ever-present problem of insufficient compaction by the workforce and due to the increased complexity of designs and reinforcement details in modern structural members. SCC has economic, social, and environmental benefits over conventionally vibrated concrete. It is made from the same basic constituents as conventional concrete and in addition, it also consists of a Viscosity Modifying Admixture (VMA) and high levels of super plasticizing (SP) admixtures to impart high workability. The cement/ powder content of SCC is relatively high. The ratio of fine to coarse aggregates is more in self-compacting concrete. Fine fillers such as fly ash, silica fume, slag, metakaolin, marble dust, and rice husk ash may be used in addition to cement to increase the paste content (5).

The elimination of vibrating equipment improves environment protection near construction sites where concrete is being placed, thereby reducing the exposure of workers and the surrounding area to noise and vibration. The improved construction practice and performance, reducing the manpower need for casting, increasing the speed of construction, quality of cast structures combined with the health and safety benefits, make SCC a very attractive solution for civil engineering construction (6).

Durability is, further one of the main concerns, and the purpose is to develop a concrete mix that would reduce or eliminate the need for vibration to achieve consolidation. Self-compacting concrete achieves this through its unique fresh state properties. In the plastic state, it flows under its own weight through restricted sections without segregation and bleeding, and maintains homogeneity while completely filling the formwork and passing around congested reinforcement. In the hardened state, again, it equals or excels standard concrete concerning strength and durability (7).

The special rheological properties of SCC could be achieved, through the use of chemical and mineral admixtures and mixture modifications, including Superplasticizer (SP), Viscosity Modifying Agent (VMA), Fly ash (FA), silica fume (SF), or micro-silica particles, reduced water/powder ratio (powder = cement + FA + SF), limited coarse aggregate size and content (8). Significant water reduction ability of SPs is essential to provide the necessary workability; high fluidity, however, can increase the tendency of a mix to segregate. Therefore, maintaining homogeneity is an important issue for the quality control of SCC. Polycarboxylate Ether (PCE) based superplasticizers represent a major breakthrough in concrete technology as they can reduce the water requirement by as much as 40% and impart very high workability that can be extended up to 60 minutes for good flowability (the diameter of slump flow is larger than 600mm) without the undesirable effects of postponement and segregation (9). With proper use of viscosity modifying agents, SCC could achieve higher flowability and higher slump without segregation, and also maintain better slump retention, thus making concrete more durable due to its lower water/cementitious ratio, and reducing sulphate attack and salt penetration (10).

Fibers have been added to concrete to improve its performance in tension and compression, as well as toughness for several decades. Fiber-reinforced concrete (FRC) has also been reported to provide increased shear and bending resistance in structural members, and to lead to improvement in the bond of reinforcing bars under monotonic and cyclic loading (11). These advantages enticed researchers to consider and evaluate fiber reinforced concrete for seismic applications as early as the 1970s (12). An earlier study reported that the relative fiber-to-coarse aggregate volume and the fiber “balling up” phenomenon limit the maximum content of steel fibers (13). Alccofine is a slag-based supplementary cementitious material (SCM) containing high glass content with high reactivity and ultra-fineness. Sunil Suthar et al. have studied the effect of alccofine and fly ash addition as mineral admixture on mechanical properties of high strength concrete (14).

II.LITERATURE REVIEW

C. Selvamony et.al (15) involved evaluating the Effectiveness of various percentages of mineral admixtures in producing SCC. Okamura's method, based on EFNARC specifications, was adopted for mix design. Ravindra rajaiah et.al (16) investigated into the development of self-compacting concrete with reduced segregation potential. The fine particle content is increased by replacing partially the fine and coarse aggregates by low-calcium fly ash. Venkateshwara Rao et.al (17) developed standard and high strength Self Compacting Concrete (SCC) with different sizes of aggregate based on Nansu’s mix design procedure. Also, fly ash optimization is done in study with the graded coarse aggregate. Youjun Xie et.al (18) presented a preparation technology of high-strength self-compacting concrete containing ultra pulverized fly ash and super plasticizer. Erdogan Ozbay et.al (19) analyzed mix proportion parameters of high strength self compacting concrete by using the Taguchi’s experiment design methodology for optimal design. Annie peter et.al (20) had compared the structural behaviour such as load- deflection characteristics, crack-width spacing of crack, numbers of cracks; crack pattern, ultimate load carrying capacity, moment curve relation and longitudinal strain in both concrete and steel for self compacting concrete and conventionally vibrated concrete and found that the crack spacing is same in both the beams. Ganesh.N et.al (21) made an attempt to study the effect of steel fibres on the strength and behaviour of Self Compacting Concrete (SCC) flexural elements. Seshadri sekhar et.al (22) has discussed the role of mineral admixtures in developing high strength self compacting concrete of grade M100. Srinivasa Rao et.al (23) has discussed the load deflection behaviour of Reinforced glass fibre self compacting concrete beams.

Rajasekaran. D et al (24) found that to increase the stability of fresh concrete use of increased amount of fine materials is required in the mixes. Some of the cement replacement material has positive effects on self- compacting concrete; mechanical and fresh properties, amount of aggregates, binders and mixing water, as well as type and dosage of super plasticizer are the major factors influencing the properties of SCC. Sherif A. Khafaga. et. al (25) indicated that the properties of the recycled aggregates SCC have only a slight difference, in their properties from the natural aggregates. The recycled concrete aggregate as both coarse and fine aggregates can successfully be used for making of SCC. Elmoaty Mohamed Abd et.al (26) indicated that steel fibres are more effective than propylene fibres. Type of coarse aggregate has negligible effect, and steel fibre volume fraction has a more significant influence than fibre shape for reinforced concrete test panels. Surface properties of tested concrete panels have a significant effect on impact and penetration resistance. Petr Máca et.al (27) reported that it is easy to prepare UHPFRC with superior mechanical properties, high flexural and direct tensile strength and high fracture modulus with standard mixing and curing technique but this concrete is more viscous and thixotropic. HPC and UHPFRC are more sensitive to quality of component, dispersion of particles, mixing procedure, specimen preparation and curing. Brittle behaviour of HPC is improved when short steel fibres are added. In direct tensile test UHPFRC showed strain hardening and the failure mode was fibre pull out which shows increased capacity to absorb energy. Maágorzata Pająk. et.al(28) investigated on concrete reinforced with new type of fibres which are crimped along the length with additional hooks at the ends.

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The results indicate that the fracture energy did not differ apparently; some differences were noted in tensile strengths due to the change of fibre shape. The difference was only observed in the shape of the load-deflection curves obtained from the tests with a use of two fibre types. The compressive strength and flexural tensile strength at the limit of proportionality were more affected by crimped and hooked fibres than hooked ones. It shows that the new type of fibre may delay the formation of the cracks in the SFRC. Salem G. Nehme et.al (29) studied the mechanical response of the steel fibre reinforced self-compacting concrete (SFR-SCC) panels. The results revealed that the workability of SCC mixtures is reduced by increasing the steel fibre content. However, the load deflection capacity is increased by the addition of the steel fibres. S.S. Vivek et.al (30) reported that assessment of optimal ratio between chemical and mineral admixtures plays a vital role in developing SCC. It was found that, 50% GGBFS, 10% SF and 20% MK were found to the optimum values as partial substitute to cement. A. Sofi et.al (31) flexural behaviour of plain and fibre-reinforced pond ash concrete (FRC) beams under monotonic loading condition was analysed. Addition of groove type fibres increased the failure load of the beams and ensured ductile behaviour. Ductility index and flexural rigidity of the beams were also studied. The predicted crack width was compared with the measured crack width, and a good correlation was obtained. Saleema Begum R et. al (32) focused on concrete mixes having water/cement ratios of 0.25, with a packing factor of 1.12. Based on the result of the investigation it found that the use of fly ash in SCC mixes reduces the possibility of bleeding and segregation, increases the filling and passing ability of the concrete. The addition of Fly ash resulted in constant proportion of super plasticizer content for same or better workability and increased 28 days compressive strength.

III.EXPERIMENTAL PROGRAM

A. Material

1) *Cement:* Ordinary Portland cement (OPC 53) of specific gravity 3.15 conforming to IS: 12269-1987 was procured from Ultra-Tech Ltd. Mohali (Pb), India. Saturated surface dry crushed coarse aggregate (CA) of nominal size 10 mm of Khizrabad and river sand (Zone-II) was used as fine aggregate (FA), conforming to IS: 383-1970[34];

TABLE I

Properties of Coarse Aggregate and Fine Aggregate (IS: 383-1970)

Sr. No.	Characteristic	CA	FA	Cement
1	Colour	Grey	Light Grey	Greenish grey
2	Maximum Size(mm)	10	4.75	----
3	Specific Gravity	2.69	2.64	3.15
4	Fineness Modulus	7.69	2.95	--
5	Water Absorption (%)	0.51	0.63	---

2) *Fly ash:* Fly ash was procured from Nabha Power Ltd, Rajpura (Punjab). The physical and Chemical properties of Fly Ash are given below in table 2.

TABLE II

Physical and Chemical Properties of Fly Ash (I.S. 3812 – 1981) (35)

Sr. No.	Physical Properties*			Chemical Properties*(% By mass)				
1	Sp. gravity	2.3	1	Silica	60.03%	8	Total Sulphur	0.10
2	Fineness (Blaine) m2/Kg	461	2	Reactive Sio2	41.69%	9	Available Alkalies	0.18
3	Residue on 45 micron sieve	3.9 %	3	Iron Oxide	3.37	10	Chlorides	0.026
4	Lime reactivity	8.6 %	4	Alumina	30.08	11	Reactive Lime	1.19
5	Loss on ignition	0.32%	5	Sio2+Al2 O3+Fe2 O3	94.38			
6			6	CaO	1.5			
7			7	MgO	0.71			

3) *Alccofine:* Alccofine 1203 was procured from County Microfine products pvt. ltd. Panjim, Goa, a subsidiary of Ambuja cement ltd. The physical and Chemical Properties of Alccofine 1203 are given in the table below.

TABLE III
Physical and Chemical Properties of Alccofine 1203[33]

Sr. No.	Physical Properties*					Chemical Properties*			
1	Specific Gravity	Density (kg/m3)	D10	D50	D90	CaO	Al2O3	SiO2	Glass content
2	2.9	600-700	1-2	4-5	8-9	31-33%	23-25%	33-35%	>90%

4) *Fibres:* Crimped mild steel fibres 0.5mm diameter, 30mm long having an aspect ratio 60 are used.
5) *Admixtures:* 8866 SKY of BASF was used as admixture (High range water reducer).
6) *Water:* Normal potable water available in the laboratory tap was used for this concrete.

B. Test Specimen

High strength self compacting concrete (HSSCC) with mineral admixture was designed and developed as per EFNARC guidelines. Mixes were prepared by incorporating different proportions of fly ash and Alccofine as mineral admixture. A number of trials were conducted by testing concrete cubes of 150x150x150mm and cylinders of 100mm diameter and 200mm length. The properties of fresh concrete were investigated by conducting various tests such as Slump test to determine slump and slump flow for checking the flowability and workability of concrete, V-funnel test was conducted to determine viscosity of concrete and L-box test conducted to determine the passing ability of concrete. The properties of hardened concrete were investigated by conducting the compressive strength and split tensile strength tests. 150mm size cubes were cast for compressive strength test, 100mmx200mm cylinders were cast for split tensile strength test. The durability properties of hardened concrete were investigated by conducting water absorption, rapid chloride permeability test, and acid and alkaline resistance test. Various trial mixes were done to achieve the desirable properties of self-compacting concrete (SCC). For the designed mix, cubes and cylinders were tested after continuous moist curing. Crimped steel fibres were used in 1% and 1.5% of the volume of concrete. A total 18 trials were made and the mixes giving desired compressive strength were selected for detailed study of concrete properties. The effect of addition of fibres, mineral admixture alccofine (Slag) and fly ash on fresh and hardened properties (strength and durability) of self compacting concrete (SCC) was studied in detail to draw inferences.

C. Mix Design

TABLE IV. Different trial mix designs

Sr. No.	Cement	Fly Ash	Alccofine	Water	w/p ratio	Fine Agg	C Agg	Admixture (%)	Fibre (%)
M1	450	150	105	155	0.22	821	817	8.4(1.2)	--
M2	450	200	150	173	0.216	593	885	8 (1.2)	--
M3	475	128	110	156.5	0.22	940	640	8.56()	---
M4	475	150	81	155	0.22	940	640	8.47()	---
M5	500	140	90	161	0.22	798	732	11.17(1.53)	---
M6	500	150	85	170	0.23	790	732	10.88(1.48)	
M7	500	130	95	167	0.23	801	716	10.51(1.45)	
M8	560	130	95	182	0.23	810	686	11(1.4)	
M9	560	130	95	182	0.23	810	686	11(1.4)	
M10	560	130	95	182	0.23	810	686	11.82(1.5)	
M11	560	130	95	172	0.22	759	681	11.78(1.5)	
M12	560	130	95	188	0.239	715	681	12.5(1.59)	
M13	560	130	95	172	0.22	770	685	5.9(0.75)	
M14	560	130	95	195	0.248	696	681	12.56(1.6)	
M15	560	130	77	198	0.258	755	614	11.5(1.5)	
M16	560	130	77	191	0.249	775	614	11.9(1.55)	1.5
M17	560	130	77	191	0.249	775	614	11.9(1.55)	1.0
M18	500	180	50	156	0.21	834	645	11.17(1.53)	1.0

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IV. RESULT AND DISCUSSION

The experimental programme carried out to study various fresh and hardened properties of self-compacting concrete as per relevant standard codes. The detailed analysis and discussion of results obtained from the experimental investigation is discussed below. Ten concrete mixes giving compressive strength more than 85 MPa were selected for detailed study. First of all the concrete mixes were tested for rheological properties.

A. Rheological Properties

1) *Slump Flow:* The consistency and workability of SCC has been assessed using the slump flow test. In this study the diameter of concrete flowing out of the slump cone has been obtained by calculating average of two perpendicularly measured diameters. It was observed that increase in percentage of Alccofine makes the concrete mix more cohesive and tends to reduce the spread of concrete. Further, when fibres are added in concrete flow is further reduced and concrete having 1.5% fibres shows less spread. The slump flow ability results are given in table below.
2) *V-Funnel Test:* V-funnel was conducted to determine the filling ability (flowability) of concrete. Shorter the flow time greater is the flowability. The inverted shape cone restricts the flow and prolonged flow time may give indication of the susceptibility of mix blocking. Segregation of concrete will show a less continuous flow with increase in flow time. It has been observed that with increase in Alccofine and fibre content, flow time increases. When percentage of fibres is 1.5%, there was problem of balling of fibres which retard the passing of concrete through funnel opening.
3) *L-Box Test:* This test assesses the passing ability of self-compacting concrete through narrow spaces. L-box blocking ratio indicates the degree to which the passage of concrete through the bars is restricted. When concrete flows freely as water the blocking ratio H2/H1 is one. It has been observed that the blocking ratio decreases with increase in Alccofine and fibre content as shown in table. Further when percentage of fibres is 1.5%, there was problem of balling of fibres which retard the passing of concrete through bars. Therefore the percentage of fibres in this self-compacting concrete cannot be more than 1.5%.

The slump flow ability, V-Funnel test and L-Box test results are given in table below.

TABLE V
Results of Slump Cone, V-funnel, and L-Box Test

Sr. No.	Slump Flow values		V-Funnel Values	L-Box values
	Horizontal Slump (mm)	T50-Time (sec)	Flow Time(in sec)	H2/H1
1	754	2.94	7.56	0.956
2	746	2.90	7.6	0.954
3	742	2.92	8.1	0.960
4	753	3.0	7.8	0.952
5	751	2.98	8.0	0.95
6	750	3.06	8.1	0.95
7	748	3.09	8.5	0.945
8	723	3.2	9.0	0.91
9	704	3.9	9.5	0.91
10	678	4.8	10	0.85

B. Hardened Properties

Eighteen trials were made to find out suitable mix giving desirable strength more than 85 MPa. Mix 8, 9 and 10 were cast with crimped steel fibres 0.5mm diameter, 30mm long having aspect ratio 60. Cubes and cylinder specimen of standard sizes were cast and moist cured. The specimens were tested at the age of 7 and 28 day for compressive strength and split tensile strength.

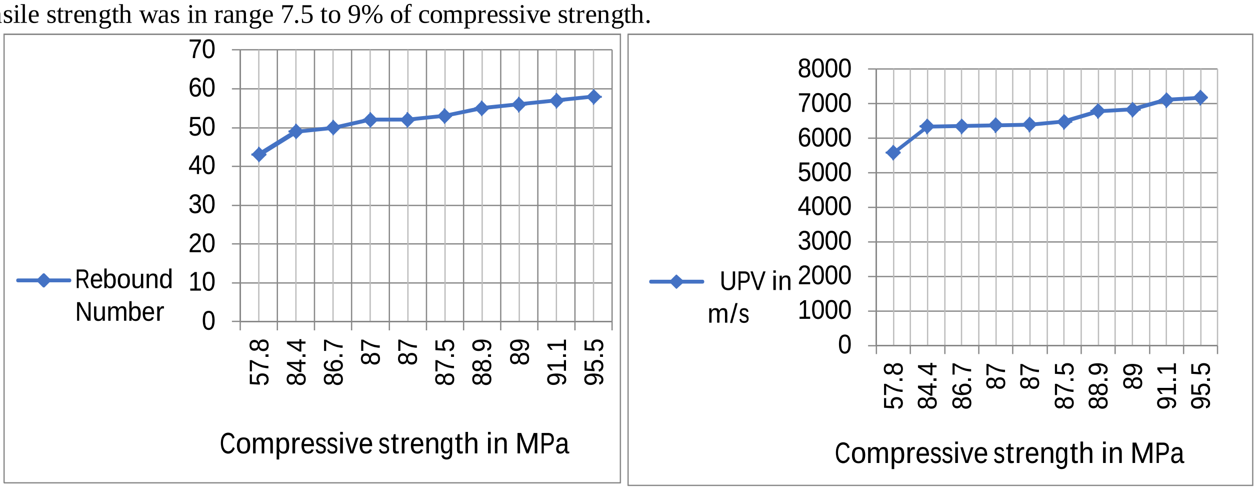
TABLE VI

Results of compressive and Split tensile strength of selected mixes

Mix No.	Compressive strength (CS)		Split tensile strength (STS)		R N	UPV
	7day	28day	7day	28day		m/s
M1	64.4	87	5.73	7.32	49	6340
M2	82	87	6.05	7.32	52	6400
M3	81	95.5	6.68	7.96	57	7180
M4	77.8	87.5	6.53	7.64	53	6480
M5	56	86.7	6.21	7.48	52	6380
M6	60	88.9	6.37	7.80	55	6790
M7	62.7	89	6.37	7.96	56	6830
M8 F	69.8	91.1	6.68	7.96	58	7110
M9 F	65.3	84.4	5.73	6.37	50	6350
M10 F	53.3	57.8	4.46	5.57	43	5580

F = With Fiber RN = Rebound Number UPV = Ultra sonic pulse velocity

SCC having 28 day compressive strength of 95.5 MPa can be achieved with available material. It was found that 28 day strength was nearly 40 to 50% more than 7 day strength. Non destructive testing (NDT) of concrete was done to find its co-relation with compressive strength. Rebound numbers (Average of 9 points) are in range of 43 to 58 and corresponding ultra sonic pulse velocity (UPV) readings are more than 5500 m/s, thereby giving that concrete is of excellent quality. Further it was found that 28 day split tensile strength was in range 7.5 to 9% of compressive strength.



(a) (b)

Fig. 1-A & B showing relation of compressive strength, rebound number and UPV

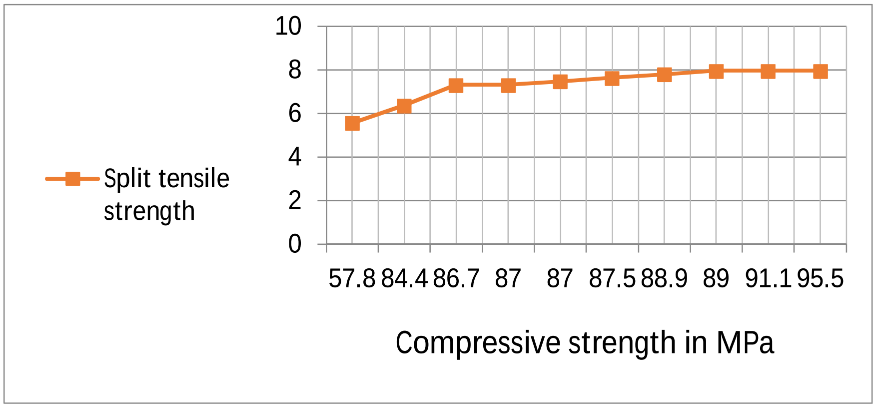


Fig. 2- showing relation of compressive strength and Split tensile strength

Table VII
Variation in compressive and split tensile strength with % variation in Alccofine

Mix No.	Alccofine (% of Total Powder)	Compressive Strength		Split Tensile Strength	
		7	28	7	28
M1	10.04	65.3	84.4	5.73	6.37
M2	11.5	77.8	87.5	6.21	7.48
M3	11.6	56	86.7	6.53	7.64
M4	12.1	62.7	89	6.37	7.96
M5	13.1	60	88.9	6.37	7.80
M6	14.9	62.7	89	5.73	7.32
M7	15.4	81	95.5	6.68	7.96
M8 F	18.75	82	87	6.05	7.32
M9F	6.8	69.8	91.1	6.68	7.96

From the table it is clear that compressive strength increases with increase in percentage of Alccofine up to 15%, and then starts decreasing. Similar trend was found in case of split tensile strength. From this it can be concluded that 15% is optimum dose of Alccofine for optimum strength.

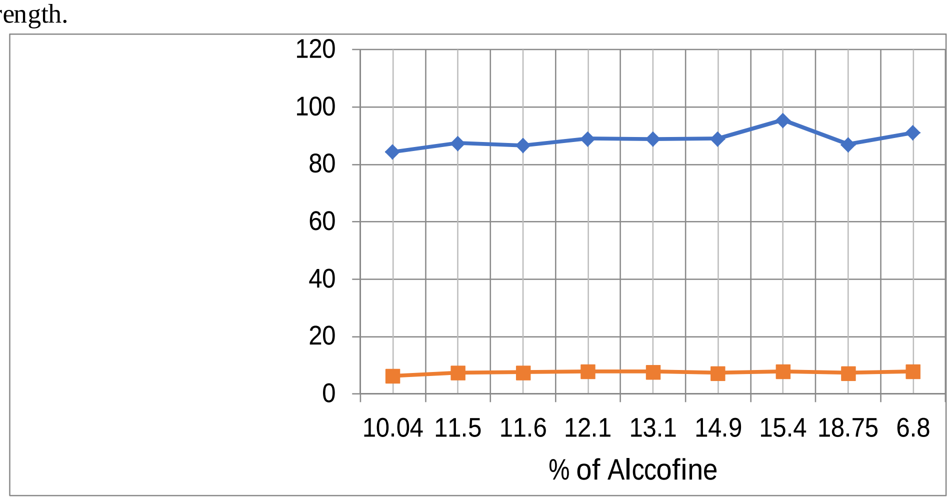


Fig. 3- Variation in compressive and split tensile strength with % variation in Alccofine

TABLE VIII
Variation in compressive strength and split tensile strength with percentage variation in Fly Ash.

Mix No.	Fly ash (% of Total Powder)	Compressive Strength		Split Tensile Strength	
		7	28	7	28
M1	16.60	62.7	89	6.37	7.96
M2	16.95	65.3	84.4	5.73	6.37
M3	17.90	60	88.9	6.37	7.80
M4	17.95	81	95.5	6.68	7.96
M5	20.40	56	86.7	6.53	7.64
M6	21.30	77.8	87.5	6.21	7.48
M7	21.40	62.7	89	5.73	7.32
M8 F	24.70	69.8	91.1	6.68	7.96
M9 F	25.00	82	87	6.05	7.32

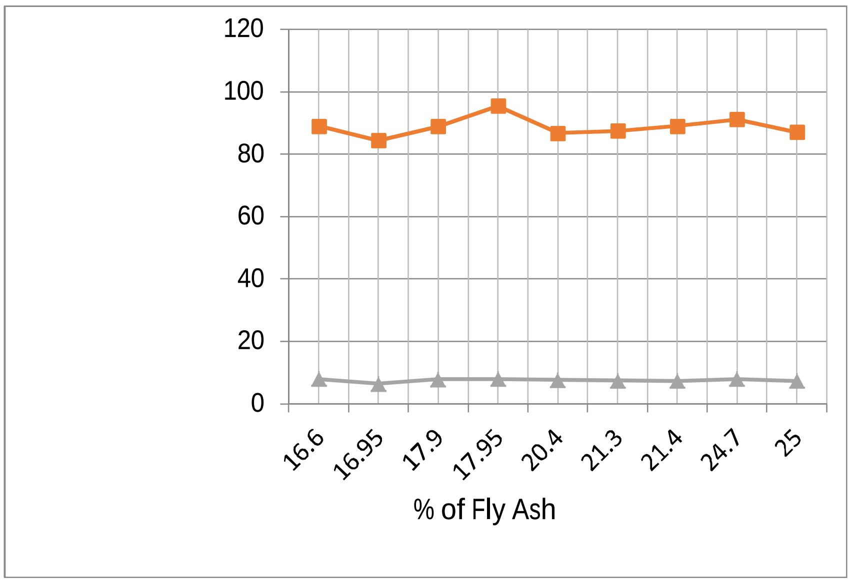


Fig. 4- Variation in compressive strength and split tensile strength with percentage variation in Fly Ash.

From the table it is clear that with increase in percentage of fly ash the compressive strength increase up to 25% and then start decreasing. At 17.95% fly ash the maximum compressive strength of 95.5 MPa was achieved and at 24.7% fly ash and 1% steel fibres, again compressive strength of 91.1 MPa was achieved. Reduction in compressive strength was due to concrete space was used by fibres. However, in case of split tensile strength increased strength of 7.96 MPa was achieved with fibres and 7.8 MPa was achieved without fibres. Increase in tensile strength was due to reinforcing effect of the fibres which prevent propagation of cracks.

C. Durability Properties

1) *Acid Resistance:* SCC mixes giving highest compressive strength (M3 and M8) were selected for durability studies. Cubes were immersed in 5% solution of Sulphuric acid (H2SO4) and Sodium hydroxide (NaOH) and after taking out from the solution their compressive strength and corresponding weight with respect to control specimen were noted, the results are shown in subsequent tables.

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TABLE IX
Percentage reduction of compressive strength and weight of cubes in H2SO4 solution

SCC Specimen	Reduction in Compressive Strength & weight at the age of (in days)						
	Without fibres			With fibres			
	28 Days	56 days	90 days		28 Days	56 days	90 days
Control Specimen M3	95.5	96.7	98.2	M8	91.7	93.4	94.3
After Immersed in H2SO4 solution	93.9	94.2	93.7		90.2	91.2	90.1
% reduction in comp. strength	1.67	2.59	4.58		1.63	2.36	4.45
% Reduction in Weight	1.22	1.75	2.87		1.07	1.42	2.21

It was observed that the top surface of concrete was eroded due to ingress of acidic water in the pores of concrete which leads to decrease in strengths and weight of concrete. It was found that percentage reduction in compressive strength and weight was less in concrete with fibres as compared to concrete without fibres.

Photo 1- Cube showing effect of acid after immersion in H2SO4 solution

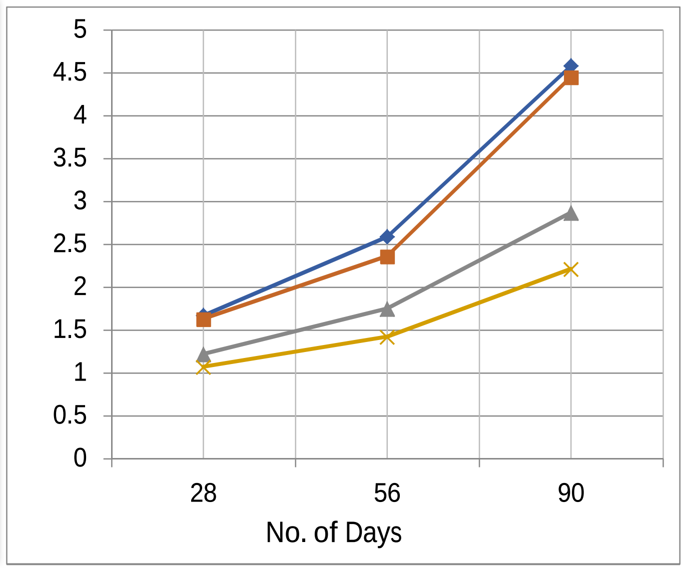

Figure 5 Percentage reduction in compressive strength and weight of cubes in H2SO4 solution

2) *Alkaline resistance:* It was observed that NAOH has a little effect on the concrete sample because concrete itself is alkaline in nature. The concrete was nearly impervious so there was no ingress of chemical inside the concrete. Further it was observed that percentage reduction in compressive strength and weight of concrete was less in concrete with fibbers as compared to concrete without fibres.

TABLE X
Percentage Reduction Strength and Weight in NaOH solution

SCC Specimen	Reduction in Compressive Strength & weight at the age of(in days)						
	Without fibres			With fibres			
	28	56	90		28	56	90
Control Specimen M3	95.5	96.7	98.2	M8	91.7	93.4	94.3
After immersion in NaOH solution	94.7	95.1	96.3		91.1	92.2	92.7
% reduction in compressive strength	0.84	1.65	1.93		0.65	1.28	1.69
Percentage reduction weight	0.29	0.54	1.02		0.20	0.42	0.90

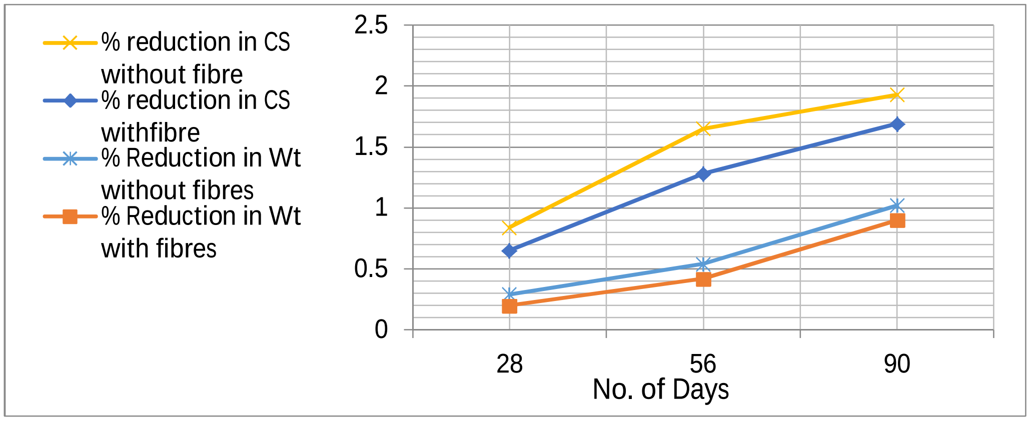

Fig. 6- showing percentage reduction in strength and weight in NaOH solution

Photo 2- Showing effect of alkaline NaOH solution concrete cube

3) *Rapid chloride permeability test:* Rapid chloride permeability test (RCPT) indicates chloride permeability inside concrete which is an indicator of corrosion of steel. The results show that charge passed in control concrete has shown very low values. Permeability of concrete decreased with the addition of Alccofine and fly ash in the concrete mix. From the results, it is clear that chloride ion permeability was almost negligible. Hence the concrete is having very low permeability.

TABLE XI
RESULTS OF RCPT TEST

S.No	SCC Specimen	RCPT(charge passed in coulombs) test at age of			Inference
		28 Days	56 Days	90 Days	
1.	M3	371	374	376	Very low
2.		380	384	386	Very low
3.		385	392	393	Very low
4.		393	395	396	Very low
Average		382.3	386.3	387.8	Very low

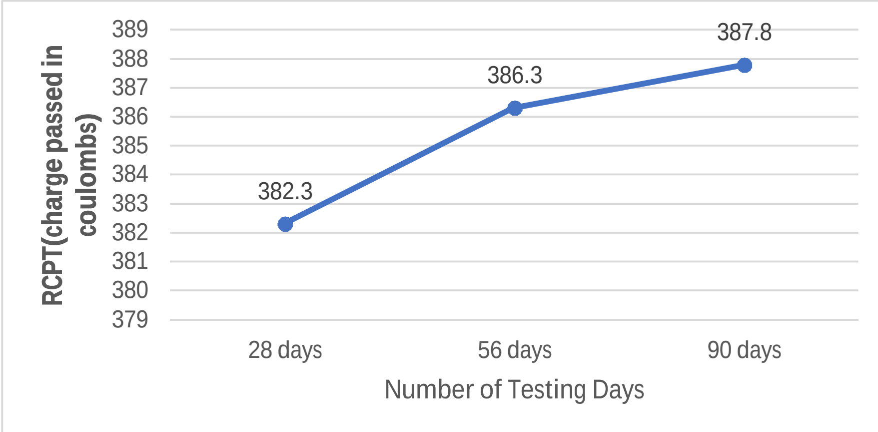

Fig. 7: showing relation between charge passed with number of days

4) *Water Absorption:* Water absorption test has been conducted on the samples. Water absorption of HSSCC samples were found to be very low which show very less porosity of the concrete made with Alccofine and fly ash. This may be due to the better pore filling ability and optimized particle size distribution of Alccofine that resulted in dense matrix of concrete.

TABLE XII
RESULTS OF WATER ABSORPTION TEST

S No.	SCC Specimen	%age water absorption at age of		
		28 Days	56 Days	90 Days
1.	M3	0.262	0.281	0.320
2.		0.290	0.295	0.341
3.		0.348	0.354	0.384
4.		0.370	0.390	0.395
Average		0.318	0.33	0.36

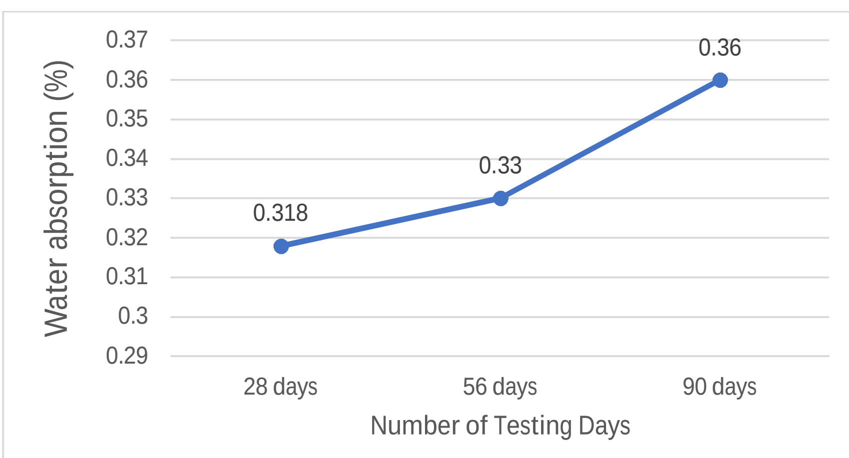

Fig. 8 showing relation between water absorption with number of days

V. CONCLUSION

The conclusions of the study are as follows:

1) It is possible to design and develop High Strength Self Compacting concrete with and without steel fibres using Alccofine and Fly Ash as mineral admixture.
2) With addition of Alccofine and Fly Ash, the strength of concrete increases up to certain percentage and then starts decreasing.
3) The 28 day compressive strength was nearly 40 to 50% more than 7 day strength and split tensile strength was in range 7.5 to 9% of compressive strength.
4) With the addition of fibres, the compressive strength was found to decrease slightly and tensile strength was increased. This may be due to reinforcing effect of steel fibres.
5) Non destructive testing (NDT) results of concrete were found in good co-relation with actual test results.
6) The results of acid and alkaline resistance test indicate that loss in strength and weight of concrete specimen was more in case of concrete without fibres as compared to fibrous concrete. The acid solution has more severe effect.
7) Both RCPT and water absorption test indicate that the concrete has dense matrix and hence very low permeability

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