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EXPERIMENTAL INVESTIGATION TO FIND THE OPTIMUM DOSE OF STEEL FIBERS IN CONCRETE INCORPORATING ULTRA FINE SLAG

SAURAV*, ASHOK KUMAR GUPTA

Department of civil Engineering,
Jaypee University of information Technology, Solan, H.P, India
*Corresponding Author: ersauravsupstar@gmail.com

Abstract

This paper presents a comparison between split tensile strength of normal concrete by adding 12% ultrafine slag (Alccofine) and varying percentage of steel fibers. Different materials like fly ash, silica fume, GGBS, rice husk ash has played important part in the development of high performance concrete. During recent past use of mineral admixture has gained pace. There is huge savings in terms of energy and cost when industrial by products are used as partial replacement of cement which is otherwise highly energy intensive. In this paper one of the mineral admixture ultra fine slag (alccofine) is used as a partial replacement of cement. Due to its appropriate size and shape this mineral admixture can be used comfortably even under low water cement ratio. In this paper cement is partially replaced by a fixed amount of alccofine i.e. 12% by weight of cement which has been calculated from previous literatures. Concrete cylinders with 12% alccofine and Steel fibers of varying weight were casted and tested at different ages of curing. Flexural strength was also determined using similar variations of steel fibers and alccofine. Efforts have been done to investigate the performance of concrete using ultra fine slag and steel fibers which can be termed as high strength and high performance concrete.

Keywords:Steel fibers, Aspect ratio, Split tensile strength.

1.Introduction

Many experiments have been conducted successfully using steel fibers mixed with fresh concrete. When set and hard it improves the mechanical properties of hardened concrete. Fibers used as a reinforcing material may be steel or any natural product such as pine leaves, jutes, etc. These fibers can be of any shapes

Abbreviations	
IS	Indian Standards
SFRC	Steel Fiber Reinforced Concrete

like circular, triangular or flat in cross section. In this study steel fibers are used and hence the concrete is termed as steel fiber reinforced concrete (SFRC).In many research papers it has been observed that alccofine can be used as a good cementitious material [1-2]. Partial replacement of cement with alccofine results in higher compressive and flexural strength of concrete and optimum dose of alccofine achieved is nearly close to 12% [1-2]. In this paper efforts have been done to improve the crack resistance of steel fiber reinforced concrete incorporating ultrafine slag. Along with crack resistance its toughness and tensile strength also improves. All mechanical properties such as toughness, crack resistance, etc., mostly depends on the bonding of the steel fibers and concrete and its distribution within the matrix of the fibers [3-5]. Most important parameter that plays an important role is the aspect ratio which is defined as the ratio of length to its diameter [6-9]. Shrinkage (both plastic and drying shrinkage) is inherent properties of a hardened concrete. Steel fibers are used to control cracking due to shrinkage [10]. Once control on cracking is achieved it reduces permeability and bleeding of water. Generally steel fires have marginal impact on flexural strength of concrete so they cannot replace entirely the traditional structural steel. Amount of fibers used in concrete is expressed in terms of volume fraction (V_f) which is defined as the amount of fibers added to the total volume of concrete mix. V_f generally ranges from 0.1% to 2% [11, 12]. If the modulus of elasticity of fibers is kept higher than that of cement matrix then its load carrying capacity increases. But increase in aspect ratio of the fibers reduces the flexural strength and tensile strength of hardened concrete and also creates workability problems.

Saurav and Gupta [1] conducted an experimental investigation to determine the strength relationship of concrete cube and concrete cylinder using ultrafine slag. Their results indicated that hardened properties of concrete increases after adding alccofine and optimum dose of alccofine is close to 12%. They conducted experiments on M50 grade of concrete with water cement ratio 0.40.

Shukla et al. [3] investigated the effect of alccofine as a supplementary cementing and filling material. They used a ternary blend of alccofine 10% and fly ash 30% with ordinary Portland cement. They also suggested that alccofine increases the filling and passing ability of concrete and also increases resistance to segregation.

Neves et al. [4] investigated the influence of matrix strength, fiber content and diameter on the compressive behaviour of steel fiber. They conducted experiments on M35 and M60 grade of concrete. Volume fraction (V_f) in the concrete was varied up to 1.5%.Their results indicated that the addition of fibers to concrete enhances its toughness and strain at peak stress.

Balendra et al. [13] conducted series of experiments to investigate the effectiveness of fiber inclusion in the improvement of mechanical performance of concrete with regard to concrete type and specimen size. The experimental findings indicated that the low volume of fiber has little effect on compressive strength but improves remarkably splitting tensile strength, flexural strength and toughness

Foremost objective of the present investigation is to find the change in split tensile strength of SFRC incorporating alccofine. Flexural testing of beams with varying percentages of steel fibers and alccofine were also performed. Amount of alccofine used as a partial replacement of cement to get the maximum strength was determined as per different previous literature surveys. In this work 12% by weight of cement was replaced by alccofine. All tests were performed on M60 grade of concrete with water-cement ratio 0.30.

2. Experimental Work

2.1. Material

Ordinary Portland cement confirming to IS 343: 1970 [14] of 43 Grade from single source (ACC cement) was used in this research work. Different tests were performed as per IS: 8112-1989 [15] to get the properties of cement. These properties are listed tabulated in Table 1. Coarse aggregate with maximum size of 20 mm having specific gravity 2.62 and fineness modulus 6.7 was used in this investigation. Locally available river sand (fine aggregates) having specific gravity 2.62 and fineness modulus 2.5 was also used. Alccofine 1203 is used as cementitious material in this work. Amount of alccofine to be used as partial replacement of cement was determined from previous literature survey which comes out to be 12% by weight of cement. Apart from all these basic raw materials steel fibers were also used. Steel fibers having diameter 1 mm were cut to a fixed length of 50 mm. All other properties of steel fibers are tabulated in Table 2.

Table 1.Physical properties of cement.

Property	Result
Specific gravity	3.17
Normal consistency (*P*):	31%
Setting times	
Initial setting times	57 mins
Final setting times	245 mins
Fineness of cement (By 90 micron sieve)	5% retained
Soundness of cement	2 mm
Compressive Strength	
7 Days	28 MPa
28 Days	46 MPa

Table 2. Properties of steel fibers.

Length	50 mm
Diameter	1 mm
Appearance	Clear and Bright
Tensile strength	800-2500 MPa
Shape	Rectangular
Size	0.8 mm × 0.35 mm
Aspect ratio	43.75

2.2. Mix proportion

Based on the recommendation of IS10262: 1982 [16], the mix proportion of M60 Grade concrete was designed. Table 3 shows the quantities of different materials to be used for M60 concrete. Then 12% by weight of cement was replaced by alccofine. The concrete was cast in cylindrical moulds of size 100 mm × 200 mm as conforming to IS: 5816:1999 [17] and also concrete beams were cast in mould size 500 mm × 100 mm × 100 mm as per IS: 10086:1982 [18]. Using electronic weight balance, different percentage of steel fibers in terms of weight was measured as shown in Fig. 1. Figure 2 shows concrete with varying percentage of steel fibers are casted in cylindrical moulds. Water cement ratio was kept as low as 0.3 to maximize the strength. All tests were performed in moderate exposure conditions. Figure 3 shows concrete beams with varying percentage of steel fibers.

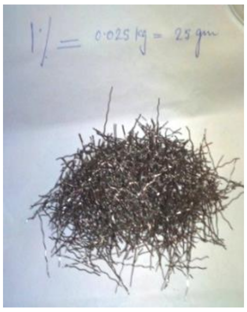
Table 3. Mix Proportion for M60 grade mixture.

Grade	Cement (kg/m^3)	Water (kg/m^3)	Fine aggregate (kg/m^3)	Coarse aggregate(kg/m^3)	Alccofine (12%) (kg/m^3)
M60	418	142.5	644	1127	57

2.3. Procedure for steel fibers and preparation of test specimens

To ensure homogenous mixing each of the small fibers were dispersed and distributed randomly in the concrete during mixing. At first dry ingredients i.e. cement, aggregates and alccofine were mixed in tilting drum type mixture for 60 seconds and then steel fibers were added. The water is added in the end and mixing is continued for 5 minutes to get a homogenous mix.

(a) 0.5% steel fibers of total volumefraction of concrete



(b) 1% steel fibers of total volume fraction of concrete

(c) 1.5% steel fibers of total volume fraction of concrete

(d) 2.0% steel fibers of total volume fraction of concrete

Fig. 1. Different proportion of steel fibers.

Concrete mixed with steel fibers was prepared under moderate exposure condition and quality control was good. It was poured into cylindrical & rectangular moulds as shown in Figs. 2 and 3 and was hand compacted by tamping rod to ensure homogenous distribution of steel fibers to minimize air entrapped which would otherwise affect the compressive strength. After 24 hours the concrete was demoulded and the specimens were kept for curing at room temperature until taken out for testing. Specimens were tested at different ages i.e. 7 days, 14 days and 28 days for split tensile test and for flexural strength. The load is applied at a constant rate thus ensuring progressive increase in stress as failure approached. For the cylinders the top surface of the cylinder was kept in contact with the platen of the existing machine. For evolution of performance of concrete using ultra fine slag (alccofine) with varying steel fiber content different specimens were created. Table 4 shows nomenclature used for different specimens. Cylindrical specimens with varying percentage of steel fibers are designated by SC0, SC5, SC1, SC15 and SC20 and beam specimens are designated as CB0, CB5, CB1, CB15 and CB20.

Table 4. Different nomenclature of specimen used.

Cylinder designation	Beam designation	% of alccofine (by weight)	% of steel fibers (by volume)
SC0	CB0	12%	0%
SC5	CB5	12%	0.5%
SC1	CB1	12%	1.0%
SC15	CB15	12%	1.5%
SC20	CB20	12%	2.0%

Fig. 2. Concrete cylinders with varying % of steel fibers.

Fig. 3. Concrete beams with varying % of steel fibers.

3.Test Results and Discussion

3.1. Split tensile strength of SFRC

When compared with controlled concrete, split tensile strength is maximum at 1.5% steel fibers with 12% alccofine common to all mixes. Different values of tensile tests performed on different cylindrical concrete with varying percentages of steel fibers are tabulated in Table 5.For each combination of steel fibers, three cylinders were casted and tested at 7 ,14 and 28 days of curing and average strength was determined. It is seen that the split tensile strength with 12% alccofine and varying % of steel fibers initially there is very less gain of strength but after 28 days there is significant gain of tensile strength. From Fig. 4, it can be observed that tensile strength of concrete cylinders in SC15 has shown 38% of increase in tensile strength when compared with controlled concrete SC0.

Table 5. Split tensile test on concrete cylinders at different ages with different % of steel fibers.

Mix	Tensile strength MPa			Average Tensile strength MPa		
	7 days	14 days	28 days	7 days	14 days	28 days
SC0	1.2	3.4	5.9	1.2	3.5	5.9
	1.1	3.6	6.1			
	1.4	3.6	5.7			
SC5	1.2	3.5	6.1	1.2	3.6	6.1
	1.2	3.6	6.1			
	1.3	3.6	6.0			
SC10	1.3	3.9	6.7	1.3	3.9	6.7
	1.3	4.0	6.6			
	1.3	3.9	6.9			
SC15	2.6	4.5	7.9	2.4	4.4	8.2
	2.3	4.3	8.2			
	2.2	4.4	8.4			
SC20	2.3	3.9	7.5	2.2	3.8	7.6
	2.3	3.5	7.5			
	2.0	4.0	7.8			

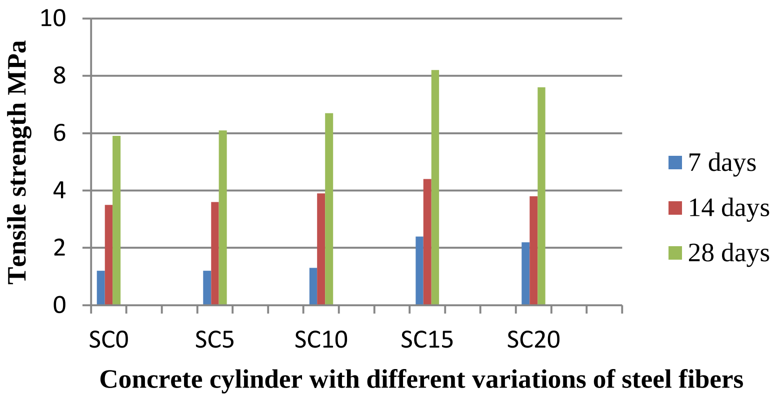


Fig. 4.Concrete comparison of tensile strength of concrete cylinders with different variations of steel fibers.

3.2. Flexural strength of beams

For flexural testing confirming to IS 9399:1959 [19], beams of size 500 mm × 100 mm × 100 mm as shown in Fig 2 were casted with 12% alccofine as partial replacement of cement and with varying % of steel fibers . These beams were cured for 7, 14 and 28 days until taken out for testing. Beams were tested under two point of loading as per BIS 516: 1959 [20]. Different values obtained after testing are tabulated in Table 6. Comparison of flexural strength is also shown in Fig. 5 which shows maximum gain of flexural strength of 29% is achieved in SB15 when compared with controlled concrete SB0.

Table 6. Flexure strength of concrete beams at different ages with different % of steel fibers.

Mix	Flexural strength MPa			Average flexural strength MPa		
	7 days	14 days	28 days	7 days	14 days	28 days
SB0	1.38	3.23	8.10	1.39	3.29	8.06
	1.45	3.36	7.88			
	1.34	3.30	8.20			
SB5	1.42	3.48	8.48	1.40	3.40	8.43
	1.39	3.33	8.39			
	1.40	3.39	8.42			
SB10	1.47	3.44	8.77	1.44	3.44	8.73
	1.44	3.43	8.72			
	1.41	3.44	8.71			
SB15	1.66	3.88	10.43	1.63	3.81	10.45
	1.64	3.78	10.48			
	1.60	3.77	10.44			
SB20	1.62	3.57	8.57	1.55	3.52	8.50
	1.49	3.52	8.43			
	1.55	3.48	8.49			

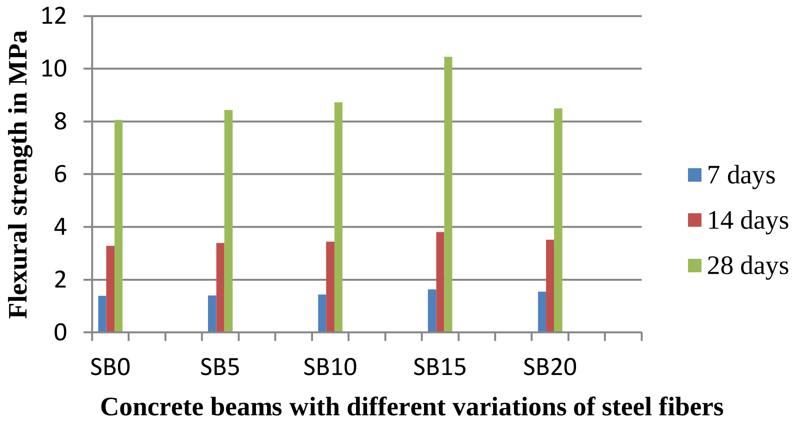


Fig. 5. Comparison of flexural strength of concrete beams with different variations of steel fibers.

4. Conclusions

Different tests performed to check the performance of steel fibers incorporating alccofine is concluded below.

- Although there is very marginal change initially i.e. at 7 days of curing in tensile and flexural strength of concrete but strength increases thereafter and at 28 days it shows significant change in their respective strengths. Strength is supposed to increase even after 28 days.
- Increase in tensile strength is due to the arrest of cracks in the matrix. Increase in flexure strength or compressive strength is not related with the fibers because of the non availability of displacement control machine.
- Maximum tensile strength is achieved when steel fibers are 1.5% by volume and then strength decreases. All tests needs to be tested even after 28 days to get more accurate results.

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