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EXPERIMENTAL INVESTIGATION OF ADDITION OF STEEL FIBERS IN SELF COMPACTING CONCRETE

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ABSTRACT

Steel fiber-reinforced self-compacting concrete (SFRSCC) is a high-strength concrete with enhanced mechanical and durability properties. Steel fibers impart tensile strength, toughness, crack control, and reduce shrinkage and permeability. The effect of various steel fiber volume (1%, 2%, and 3%) on SCC workability, compressive strength, and flexural strength is examined in the present research. Workability tests like slump flow, V-funnel, and L-box show that higher steel fiber content reduces workability due to higher viscosity. Compressive and flexural strength tests, however, indicate a significant improvement in mechanical performance. The study suggests an optimal fiber dosage that balances the enhancement in strength with appropriate workability, often requiring superplasticizers or other admixtures. The study also establishes the effect of aspect ratio and fiber volume fraction on performance. SFRSCC is recommended for application in high-structural integrity and high-durability construction such as pavements, bridges, and industrial floors. The results confirm the application of steel fiber-reinforced concrete under extreme conditions, resulting in more durable and longer-lasting structures. Steel fiber-reinforced self-compacting concrete (SFRSCC) is a new and durable material with enhanced mechanical properties. Steel fibers improve impact resistance, tensile strength, crack control, and reduce shrinkage and permeability. This study examines the effect of various steel fiber contents (1%, 2%, and 3% by volume) on the workability, compressive strength, and flexural strength of SCC. Workability tests like slump flow, V-funnel, and L-box indicate that increased steel fiber content reduces workability due to higher viscosity. Compressive strength and flexural strength tests, however, indicate significant enhancement of the mechanical performance. The research indicates an ideal dosage of fibers that enhances strength without sacrificing workability, typically requiring superplasticizers or additional admixtures. The study further demonstrates the impact of volume fraction and aspect ratio of fibers towards overall performance. SFRSCC finds application in cases of high requirements of structural integrity and durability such as industrial floor, pavement, and bridges. The results confirm the viability of using steel fiber-reinforced concrete in severe environments, thus resulting in structures that are long-lasting and more durable.

Keywords: Steel Fiber, Self-Compacting Concrete, Strength, Durability, Workability, Flextural Strength.

I. INTRODUCTION

Self-compacting concrete (SCC) is a highly flowable and non-segregating concrete that spreads into formwork and fills intricate sections without the need for mechanical vibration. Due to its superior workability and uniformity, SCC has gained widespread acceptance in the construction industry. However, like conventional concrete, SCC can be brittle and prone to cracking, which may compromise its structural integrity and durability. Importance of SCC (Self-Compacting Concrete): SCC is highly flowable and can fill complex formwork and dense reinforcement without the need for vibration. This ensures uniformity and eliminates honeycombs or voids. The ease of placement reduces the time and labor required for compaction, speeding up construction processes. SCC provides smooth and uniform surfaces, reducing the need for additional finishing work. The uniform distribution of materials and the absence of voids improve the long-term durability and resistance to environmental factors. Since SCC does not require mechanical vibration, it reduces noise on-site and minimizes health risks for workers. SCC is suitable for a wide range of applications, including precast concrete, high-rise buildings, and structures with dense reinforcement.

Importance of Steel Fiber in Concrete:

Steel Fibers enhance the tensile strength of concrete, improving its ability to resist cracking and deformation under load. Steel Fibers distribute stress more evenly across the material, reducing the propagation of micro-cracks and increasing the concrete's fracture toughness. The addition of steel Fibers improves the flexural capacity of concrete, making it more suitable for applications like industrial floors, pavements, and tunnel linings. Steel reinforced concrete exhibits higher resistance to impact, fatigue, and abrasion, extending the life of structures. While steel Fibers may increase the initial cost, they reduce long-term maintenance expenses by improving durability and reducing the likelihood of repairs. The enhanced ductility and energy absorption capacity provided by steel Fibers make structures more resistant to seismic forces.

To address these limitations, steel fibers are often introduced into SCC. Steel fibers are discrete, short steel reinforcements with high tensile strength, designed to enhance the performance of concrete by improving its mechanical properties and crack resistance. When integrated into SCC, steel fibers act as crack arrestors, enhancing the material's ductility, tensile strength, and overall toughness. The incorporation of steel fibers in SCC combines the benefits of high workability with improved mechanical performance, making it a preferred choice for applications requiring superior durability and structural reliability. This study explores the effects of steel fibers on the fresh and hardened properties of SCC, as well as their contribution to the long-term durability of the material.

There are many advantages of using SCC, especially when the material cost is minimized. These include:

- Reducing the construction time and labor cost;
- Eliminating the need for vibration;
- Reducing the noise pollution;
- Improving the filling capacity of highly congested structural members;
- Facilitating constructability and ensuring good structural performance;

1.3. OBJECTIVES

- To evaluate the effect of steel fibers on the workability of SCC.
- To assess the impact of steel fibers on the compressive strength of SCC.
- To determine the influence of steel fibers on the flexural strength and toughness of SCC.
- To analyze the durability characteristics of SCC containing steel fibers.

II. METHODOLOGY

The mix design for Self-Compacting concrete (SCC) used in this study is prepared according to EFNARC 2005. Table 1 shows the mix proportions of plain SCC. Addition of steel fibers from 1 to 3% by volume of cementitious material. All the mixing, testing, casting and curing were done in laboratory. Fresh state properties of plain SCC and steel fiber self-compacting concrete (SFRSCC) are tested by L-box for passing ability, V-funnel for flow time and T500 for slump flow. Hardened properties are tested at the age of 7 days. 9 cubes (150X150X150mm) for compressive strength test, 9 cylinders (150X300mm) for splitting tensile test and 9 beams (100X100X500mm) for flexural strength test.

III. MIX DESIGN

A plain SCC was developed using EFNARC 2005 and IS 10262:2019. 53 grade ordinary Portland cement conforming to IS 12269 (1987) and fly ash as the filler conforming to IS 3812 (Part 1). Polycarboxilic ether polymer based superplasticizer was used as water reducing agent. Viscosity modifying agent (VMA) was used for controlling the flow characteristics of concrete and to enhance concrete's workability. Flat crimped steel fiber was used as it gives improved tensile strength, control shrinkage cracks and improve durability. Mix design for plain SCC along with steel fiber percentage is as follows in table 1.

Table 1. Proportion for plain SCC along with steel fiber

Quantities (Kg/m3)									
Cement	Fly ash	Fine Agg.	Coarse Agg.	Water	Admixture	VMA	Steel Fiber		
							1%	2%	3%
358.2	39.8	900	905	191.25	3.98	1.99	3.98	7.96	11.94

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IV. RESULTS AND DISCUSSION

1. Fresh Mix Properties

The properties of the new mix of the tested concretes were investigated using a series of standard tests, such as the slump flow test, T_{500} time test, L-Box passing ability test, and V-Funnel flow time test. The tests were conducted on normal concrete (NC), plain self-compacting concrete (SCC), and SCC mixtures with steel fibers at different dosages (SFSCC1 at 1%, SFSCC2 at 2%, and SFSCC3 at 3%). The findings are summarized in the table below:

Table 2. Fresh state properties

Concrete type	Slimp flow (mm)	T500(Sec)	L-Box (blocking ratio (H2/H1))	V-Funnel (Sec)
NC	110	-	-	-
SCC	638	2.89	0.94	7.67
SFCC1	620	3.76	0.91	8.01
SFSCC2	597	4.9	0.88	10.12
SFSCC3	589	5.3	0.84	12.34

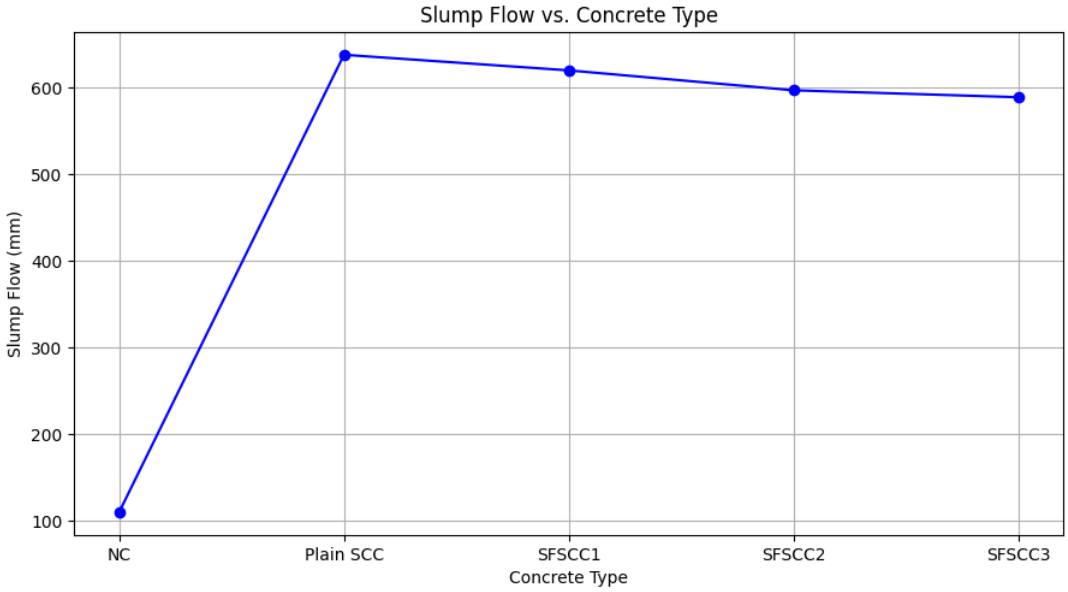

Figure 1: Slump flow vs Concrete type graph

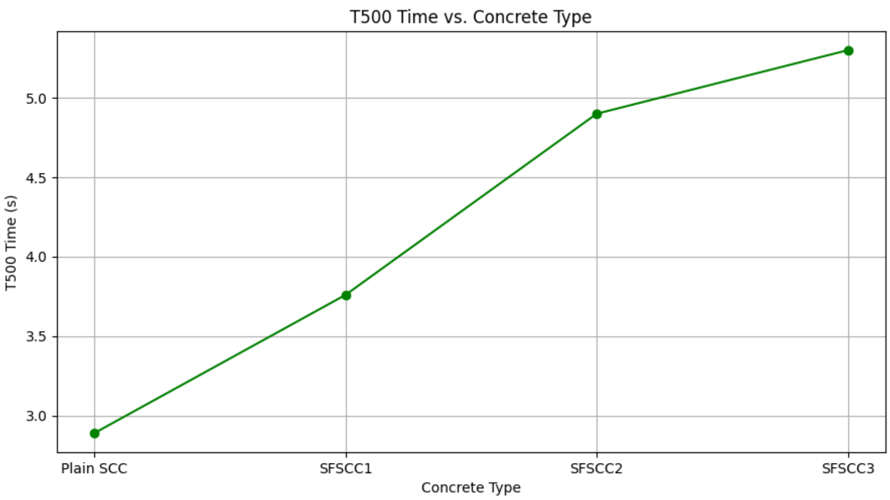

Figure 2: T500 vs Concrete type graph

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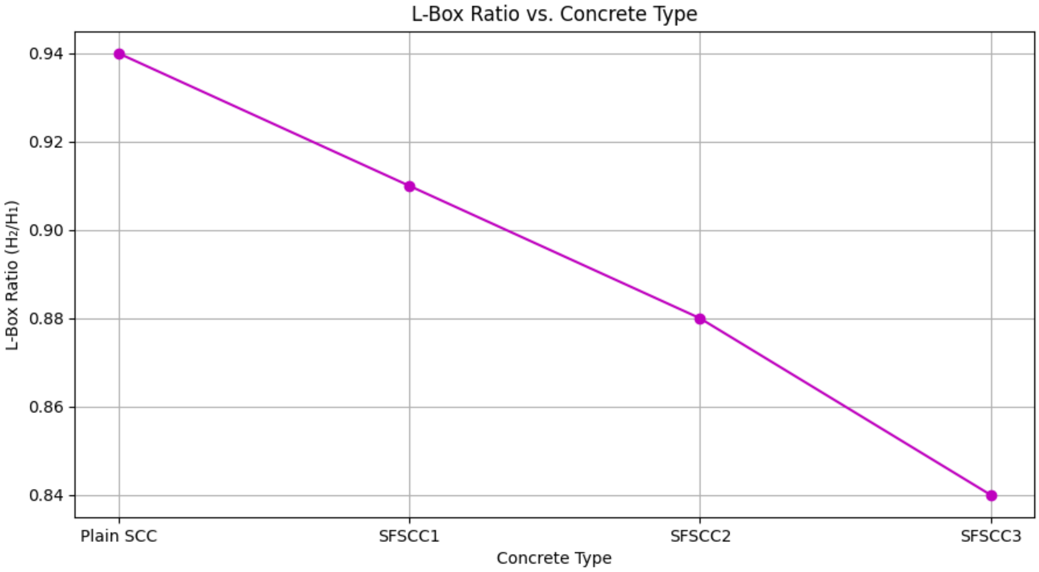

Figure 3: L-Box vs Concrete type graph

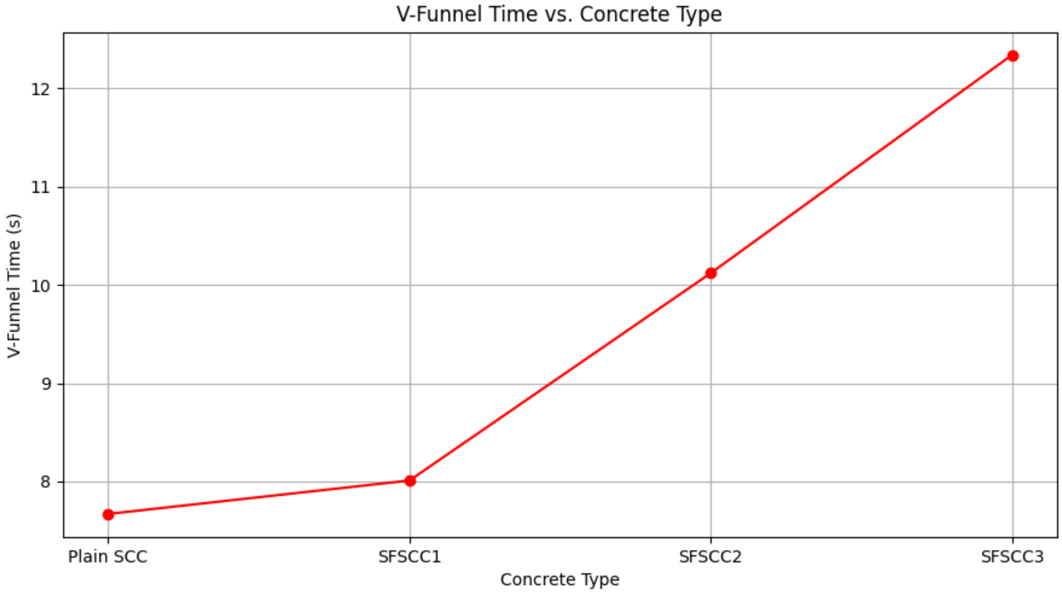

Figure 4: V-funnel vs Concrete type graph

The plain SCC mix had a slump flow of 638 mm, whereas the steel fibers resulted in a gradual decrease in flow diameter, with SFSCC3 having a slump flow of 589 mm. The T_{500} time was greater from 2.89 s in plain SCC to 5.30 s in the mix with the highest fiber content, which reflects greater viscosity. Similarly, the L-Box ratio was decreased from 0.94 to 0.84 and the V-Funnel time was greater from 7.67 s to 12.34 s, which reflects lower passing ability and decreased filling capacity due to the fibers. These results indicate that while steel fibers enhance some of the mechanical properties, they also decrease workability due to greater internal friction and potential fiber clumping.

2. Hardened Properties

On the 7th curing day, hardened properties were assessed through compressive strength, splitting tensile strength, and flexural strength tests. The outcome of each of the tests for every property is presented in the table below.

Table 3. Hardened properties at concrete age of 7 days

Concrete type	Compressive strength (Mpa)	Splitting tensile strength (Mpa)	Flexural strength (Mpa)
NC	16.45	2.39	1.8
SCC	17.94	2.41	2.21
SFSCC1	17.35	2.48	3.31
SFSCC2	16.26	2.52	6.36
SFSCC3	16.10	2.62	9.94

2.1 Compressive Strength

Plain self-compacting concrete (SCC) showed a moderate increase in compressive strength, with 17.94 MPa compared to normal concrete (NC), which was 16.45 MPa. But the addition of steel fibers provided only marginal improvement or even a reduction in compressive strength. The mix labeled as SFSCC1 was 17.35 MPa in compressive strength, while the mixes with higher fiber content, i.e., SFSCC2 and SFSCC3, were in the range of 16 MPa. This indicates that compressive strength is mostly governed by the paste-aggregate matrix and not by the reinforcing fibers, which affect the tensile properties mostly.

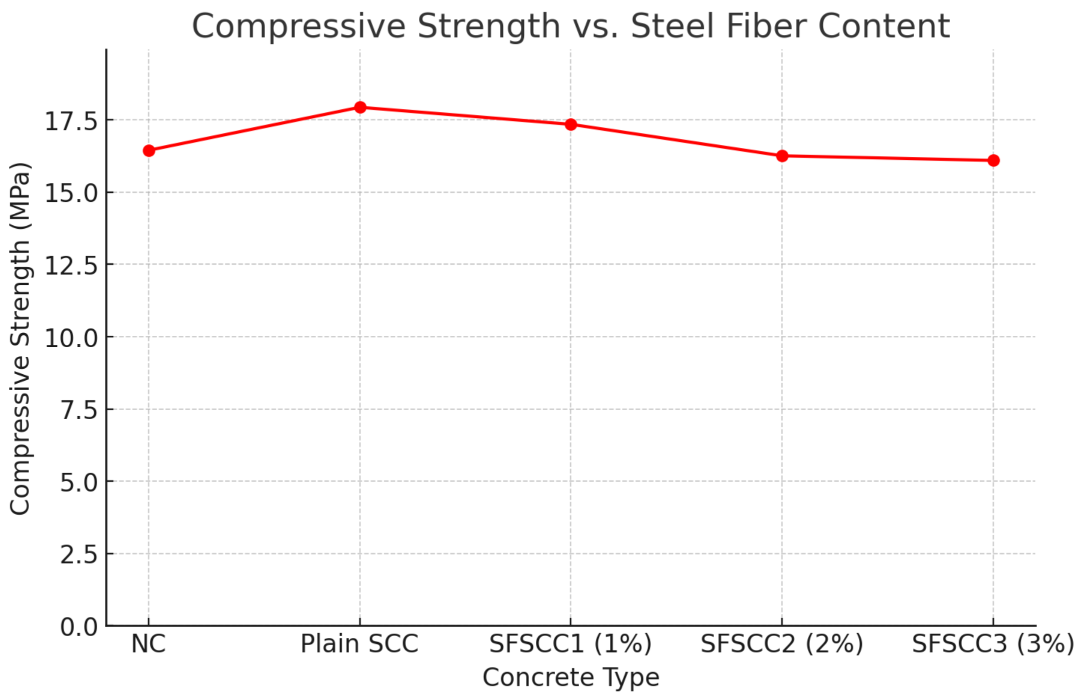

Figure 5: Compressive strength vs Concrete type graph

2.2 Tensile Strength Splitting

Tensile strength at splitting also exhibited a consistent, though minimal, increase with the increase in fiber content. The plain SCC had a tensile strength of 2.41 MPa, which improved to 2.62 MPa for SFSCC3. This is primarily due to the fiber bridging effect, which opposes the extension of the crack and enables more effective transfer of stress over the crack surfaces.

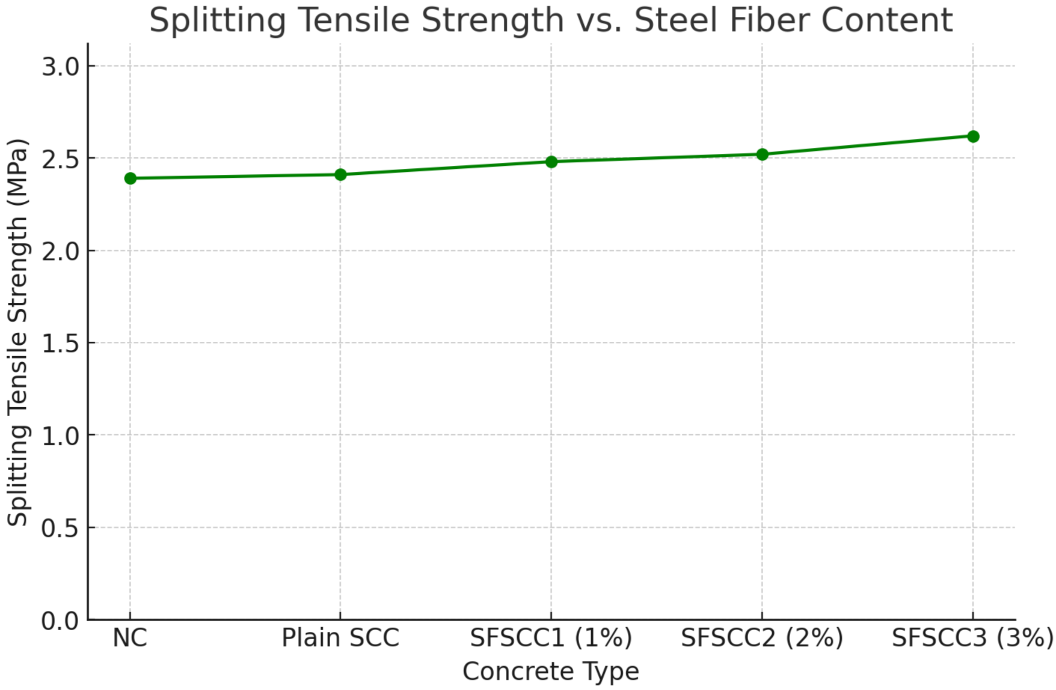

Figure 6: Splitting tensile strength vs Concrete type graph

2.3 Flexural Strength

Flexural strength was the property most significantly enhanced by the addition of steel fibers. The plain SCC had a flexural strength of 2.21 MPa, but the value improved incrementally with the content of fibers up to 9.94 MPa in SFSCC3. Such a significant improvement is a strong indication of the aptness of steel fibers to improve the ductility and post-cracking behavior of SCC. The fibers bridge the cracks that develop under flexural loading, resulting in the more ductile mode of failure and higher enegy-absorbing capacity.

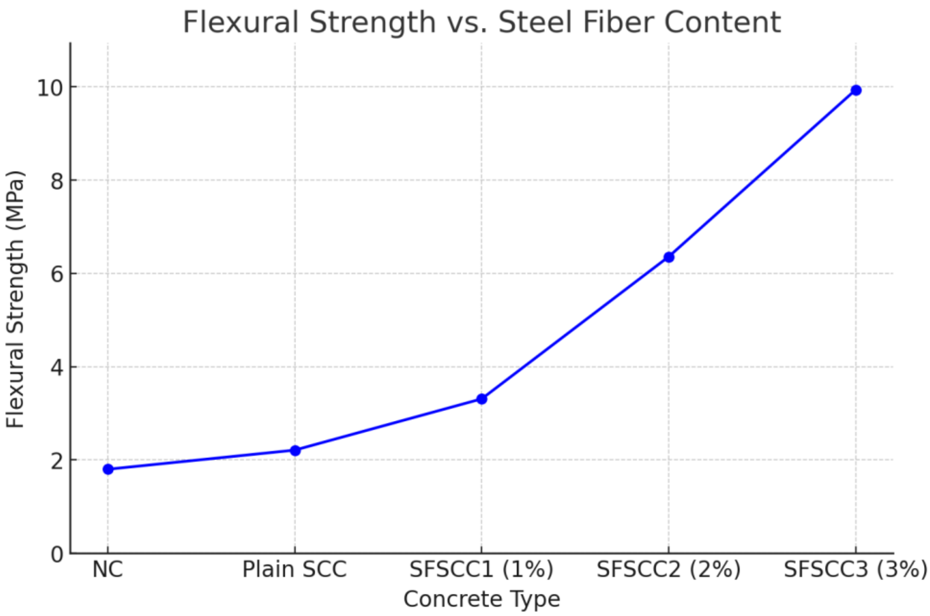

Figure 7: Flexural strength vs Concrete type graph

V. CONCLUSION

Experimental observations show that introduction of steel fibers in SCC negatively impacts fresh mix workability—quantified in terms of lower slump flow, higher T_{500} and V-Funnel times, and lower L-Box ratios—but appreciably improves some hardened properties, especially splitting tensile and flexural strengths.

The compressive strength, on the other hand, is almost insensitive to the addition of fibers, indicating that it is almost controlled by the hydration reaction and paste–aggregate bond mechanism, rather than fiber reinforcement. The improvement in tensile and flexural behaviors is due to the effective fiber bridging mechanism, which reduces the rate of crack initiation and propagation, resulting in improved ductility and toughness. The results show that good workability and mechanical performance can be obtained with effective mix design and fiber dosage selection, making steel fiber–reinforced SCC a promising material for high-performance structural applications where durability and ductility are important.

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