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Performance Evaluation of Eco friendly M30 Concrete with Recycled Steel Fiber

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Abstract-This study examines the performance of sustainable M30 concrete reinforced with Recycled Steel Fibers (RSF) obtained from waste steel scrap. RSF was added at 1%, 1.5%, 2%, 3%, and 4% by weight of cement, and the concrete was tested for compressive, split tensile, and flexural strength. Results showed that RSF improved tensile strength, flexural strength, ductility, and crack resistance through effective crack bridging and energy absorption. Optimal performance was achieved at 2–3% fiber content, balancing strength enhancement and workability, while higher fiber content reduced workability despite increased toughness. The study concludes that recycled steel fibers can effectively enhance concrete performance while promoting sustainable and resource-efficient construction practices.
Keywords- Recycled steel fibers, Sustainable construction, Mechanical properties, Flexural strength, Crack resistance, Circular economy

I. INTRODUCTION

Concrete is one of the most widely used construction materials due to its durability, versatility, and cost-effectiveness. However, cement production significantly contributes to carbon dioxide emissions and depletion of natural resources, creating a need for sustainable alternatives. The incorporation of recycled materials in concrete, particularly recycled steel fibers obtained from waste steel scrap, discarded tires, and industrial waste, offers an eco-friendly solution that enhances concrete performance while reducing environmental impact. Steel Fiber Reinforced Concrete (SFRC) improves crack resistance, ductility, toughness, and energy absorption by controlling crack propagation and bridging micro-cracks. In this study, recycled steel fibers were added to M30 grade concrete in varying proportions to evaluate their effect on compressive strength, flexural strength, and workability at 7 and 28 days of curing. The research aims to assess the mechanical performance and sustainability potential of recycled steel fiber reinforced concrete.The findings indicate that recycled steel fibers can significantly improve the mechanical properties and durability of concrete while supporting waste utilization, cost reduction, and sustainable construction practices. This eco-friendly concrete can be effectively used in industrial floors, pavements, bridge decks, and other structural applications requiring enhanced toughness and durability.

A. Objectives of the Present Study

1) To develop an eco-friendly M30 concrete mix incorporating recycled steel fibers without compromising structural performance.
2) To evaluate the improvements in mechanical properties, particularly compressive and flexural strength, compared to conventional M30 concrete.
3) To determine the optimum fiber dosage that provides maximum performance while maintaining good workability.
4) To validate recycled steel fibers as a sustainable reinforcing material that reduces waste and supports green construction practices.
5) v. To assess the cost-effectiveness and material efficiency achieved by using recycled steel fibers instead of fresh reinforcement material.

II. MATERIALS AND METHODOLOGY

The mechanical properties of FRC depend largely on the quality and compatibility of its constituent materials. All materials used were procured locally and tested as per the Bureau of Indian Standards (BIS).

1) Cement

In the present study of M30 grade cement has been used. The used cement is fresh and without any lumps during the mixing. Tests on cement are carried out in accordance with procedures described in IS: 4031- 1996 and the cement properties are listed in Table 1.1

Table 1.1 Cement Properties

Sl.No.	Properties	Results
1	fineness	5.6%
2	consistency	32%
3	Initial setting time	30minutes
4	Final setting time	600minutes
5	Specific gravity	3.16

2) Fine Aggregate

The sand was clean, hard, and free from silt and organic matter. Sieve analysis confirmed uniform grading suitable for good workability.

Table 1.2 Fine Aggregate Properties

Sl.no	Physical properties	Results
1	Water absorption	3.5%
2	Specific gravity	2.39

3) Coarse Aggregate

Crushed aggregate with a maximum size of 20 mm was used. It conformed to IS 383:2016 and IS 2386 testing procedures.

Table 1.3 Coarse Aggregate Properties

Sl.no	Physical property	Results
1	Water absorption	2.05%
2	Specific gravity	2.71

These values indicate the aggregate’s suitability for structural-grade concrete with adequate hardness and toughness.

4) Water

Potable water satisfying IS 456:2000, Clause 5.4 was used for both mixing and curing operations. Water-cement ratio was maintained at 0.43 to achieve M30 target strength with optimum workability.

5) Hooked-End Steel Fiber

Steel fibers used in concrete are typically made from high or low carbon steel and feature hooked ends, which provide strong anchorage and help prevent fiber pull-out. Their length ranges from 30 mm to 60 mm, with diameters between 0.5 mm and 1.0 mm, resulting in an aspect ratio (length-to-diameter) of 50 to 100. These fibers exhibit high tensile strength, approximately 800– 1200 MPa, and a modulus of elasticity around 200 GPa, comparable to structural steel. With a density of about 7.85 g/cm³ and a melting point near 1500°C, they offer excellent fire resistance.

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III. METHODOLOGY

Fig. 1 Methodology adopted in the Present Work

IV. RESULTS AND DISCUSSION

In this chapter, the test results of concrete with and without fibers are presented and properties of concrete consisting of different fibers are discussed in this section. The properties hardened concrete such as compressive strength and f1exural strength of conventional concrete is compared with FRC.

A. Slump test

Slump was tested for Control mix and different percentages of 2%,2.5% and 3% and it is observed that slump increases with increasing percentage of coir fiber because the stiffness of the mix increases with fiber content.

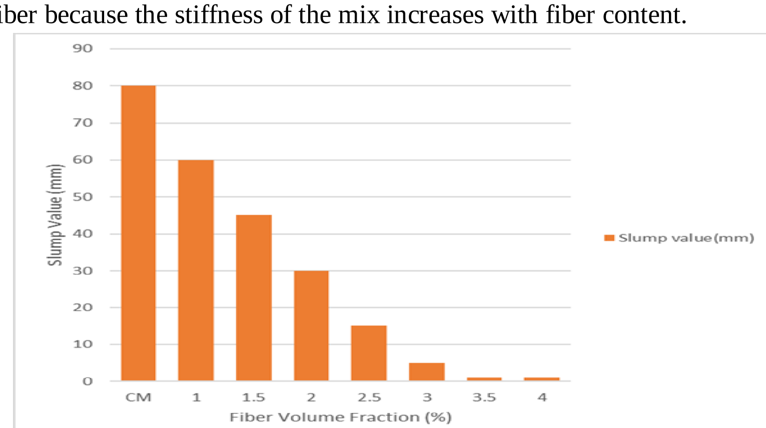

Fig 2. Effect of Fiber Volume Fraction on Slump Value

The graph illustrates the Slump Value (mm) as a function of the Fiber volume fraction (%). As the fiber volume fraction increases, the slump value decreases significantly, indicating a reduction in the workability of the concrete mix due to the increased stiffness provided by the steel fibers.

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B. Compressive Strength Test

As fiber content increases from 1% to 2%, compressive strength generally improves due to better crack control and matrix bonding. Around 2% fiber, the mix usually reaches its optimum compressive strength. Beyond 2.5%, workability decreases and compaction becomes difficult, reducing the effectiveness of the mix. At 4% fiber, excessive congestion and void formation lead to a noticeable drop in compressive strength.

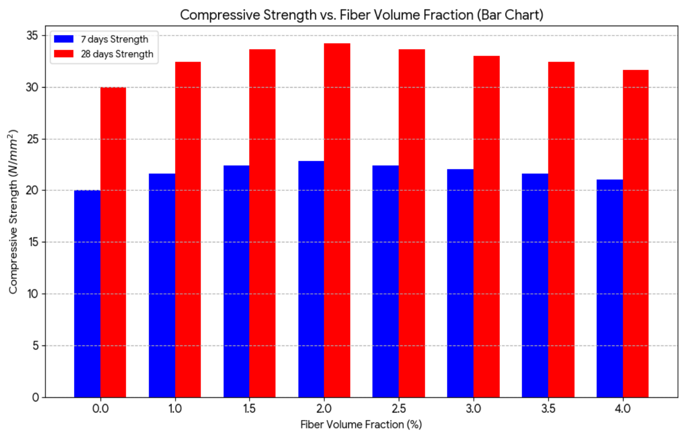

Fig 3. Effect of Fiber Volume Fraction on Compressive strength

Fibers significantly increase the internal friction and stiffness of the mixture, thereby reducing its workability. Compressive strength, conversely, initially increases (peaking at 2.0%) because the fibers act as effective micro-reinforcement, bridging cracks and enhancing load resistance. However, strength then slightly decreases beyond the optimum point because excessive fiber content severely compromises workability, leading to poor compaction, voids, and a non- homogeneous mixture, which ultimately overrides the reinforcing benefit.

C. Flexural strength Test

Flexural strength increases from 1% to 2% fiber content as fibers effectively bridge cracks and improve tensile resistance. At 2%, the mix reaches its maximum flexural performance. Beyond 2.5%, fiber congestion reduces workability and causes a gradual decline in flexural strength. Even at higher percentages like 3% and 4%, FRC still performs better in flexure than conventional concrete.

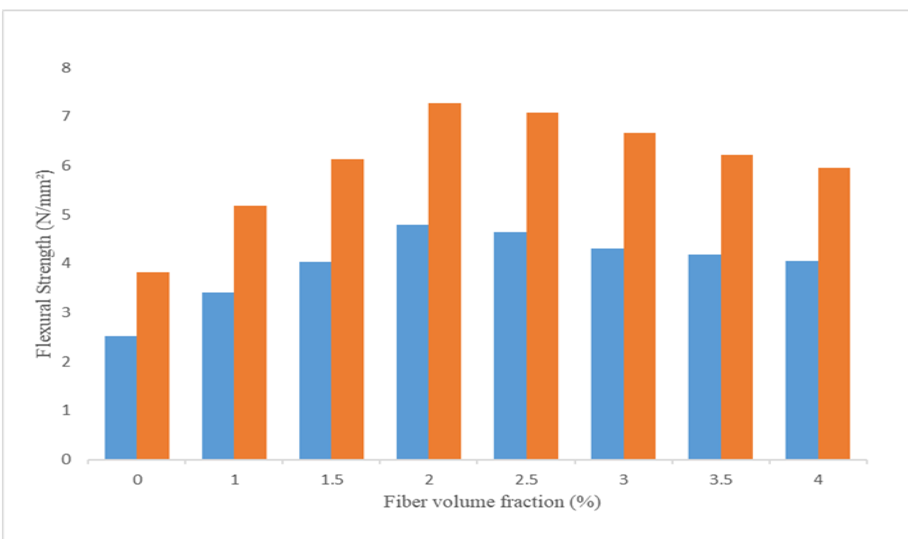

Fig 4. Effect of Fiber Volume Fraction on Flexural strength

The bar chart compares flexural strength for concrete with and without steel fibers at various fiber percentages. Fiber-reinforced concrete (orange bars) consistently shows higher flexural strength than the control mix (blue bars). Strength increases for both mixes up to around 2% fiber content, where the maximum value is observed. Beyond 2%, the flexural strength gradually decreases but remains higher for the fiber-reinforced mix

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V. CONCLUSION

1) Eco-friendly M30 concrete was successfully developed using recycled steel fibers (RSF) obtained from waste steel materials.
2) The inclusion of RSF improved the compressive, tensile, and flexural strength of concrete compared to conventional concrete.
3) Recycled steel fibers enhanced crack resistance, toughness, and energy absorption capacity by controlling crack propagation.
4) Optimum performance was observed at 2–3% fiber content, which provided a good balance between strength and workability.
5) Higher percentages of RSF increased toughness and ductility, although workability of concrete was reduced.
6) The study proved that recycled steel fibers can be effectively used as a sustainable and economical reinforcement material in concrete.

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