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Comparison of Strength Properties Between Steel Fiber Reinforced Concrete and Coir Fiber Reinforced Concrete

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***Abstract*— Concrete, which is generally weak in tension and brittle, has had attempts to enhance it by using fibers. This started with materials such as straw in mud bricks, the addition of horse hair into plaster and the inclusion of asbestos to increase strength on pottery. On the other hand, there's a continuous reinforcement that supports reinforced concrete but calls for extreme precision and skilled labor. In contrast, putting fibers in plain or reinforced concrete in discrete form seems more promising. Fiber-reinforced concrete (FRC) evolved during early sixties and showed that it could convert concrete into homogeneous isotropic materials. For FRC, randomly dispersed fibers prevent crack formation and propagation once concrete cracks hence increasing both its strength as well as ductility. The two main failure modes for FRC include bond failure between fiber and matrix or material failure respectively. In this study we compare the steel fiber performance against coir fiber at different percentages ranging from 0.5%, 1%, 1.5% and 2% by weight of cement to evaluate compressive strength and split tensile strengths at both 7 days and 28 days respectively.**

***Keywords*— Concrete, Steel fibers, Coir fibers Compressive Strength, Split Tensile strength.**

1. INTRODUCTION

It isn't difficult to make concrete. Just by hardening a composite material made from a mixture of binding materials (such as cement or lime), fine aggregates (for example, sand), coarse aggregates (for instance, crushed gravel), admixtures, and water in some fixed proportions [1] [7]. The binder used here is termed lime concrete if it's lime while cement concrete results when cement is used as the binder [1][7]. However, despite its use in modern construction for its strength and durability, concrete demonstrates weaknesses in tension and behaves brittlely [1].

The notion of enhancing properties of building materials through fiber addition has been there for ages. This started with the early techniques that included adding substances such as straw to mud bricks during their formation; using horse hair to reinforce plaster; and using asbestos to toughen pottery [2] [3]. Though continuous reinforcement improves strength and ductility as found in reinforced concrete technology so that it requires careful placement procedures personnel costs are high too [4] [5]. Alternatively discrete addition of fibers into plain or reinforced concrete provides an attractive solution [4].

In fact the recent development of fiber reinforced concretes may be traced back until about the sixties [4]. The incorporation of fibers changes concrete to a uniform and isotropic material [5]. Cracks run through the ordinary concrete randomly while the fibers dispersed in it prevent their appearance or further spread; thus, augmenting strength and durability [6][7]. In FRC failure modes are usually bond failure between fiber and matrix or material failure [7].

1.1 Steel Fibers

Over recent years steel fiber reinforced concrete has transformed from an innovative untried material to one that is widely recognized in numerous engineering applications [4]. It has been applied extensively since its versatility allows for diverse uses such as tunnel linings, slabs and airport pavements [5]. There exist different types of steel fibers including round ones which are most common having dimensions ranging between 0.25mm and 0.75 mm typically [7]. Bundles of deformed fibers rectangular in shape with thicknesses of about .25mm also find use [7] [4]

1.1.1 Properties of Concrete Improved by Steel Fibers

The incorporation of steel fibers significantly enhances several properties of concrete, including:

Flexural Strength: Up to threefold increase compared to conventional concrete [4].

Fatigue Resistance: About one and a half times greater fatigue strength [5].

Impact Resistance: Enhanced resistance to damage from heavy impacts [7].

Permeability: Reduced porosity [6].

Abrasion Resistance: Improved resistance against abrasion and spalling [7].

Shrinkage: Mitigation of shrinkage cracks [4].

Corrosion: Limited impact of corrosion on the material [5].

1.1.2 Advantages & Disadvantages

Advantages:

- Increased durability, flexural and fatigue strength, and resistance to abrasion, spalling, and impact [4] [5].
- Potential productivity improvements and cost savings [7].
- Crack-free stress accommodation throughout the concrete [6].
- Economical design alternative [7].

Disadvantages:

- Aesthetically poor appearance if slabs are damaged [4].
- Diminished cost savings in certain structural elements [5].
- Strict control of concrete wastage required to minimize fiber wastage [7].

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1.2 Coconut Fibers

Coconut cultivation can be found spreading across the tropical and subtropical regions between the latitudes 20° N and 20° S [8]. It can be **seen** in most Asian countries, especially Thailand, Indonesia, India, and Malaysia, as well as tropical climate countries like Hawaii and the Fiji Islands [8]. Coconuts are mainly cultivated on coastal clays and sands [8]. Coconut trees can grow up to 30 meters in height [8]. Coconut coir fiber is classified as a natural fiber, extracted from the outer shell of a coconut [9]. The common name, scientific name, and plant family of coconut fiber is Coir, Cocos nucifera, and Arecaceae (Palm), respectively [9]. There are two types of coconut fibers: brown fiber extracted from matured coconuts and white fibers extracted from immature coconuts [9]. Brown fibers are thick, strong, and have high abrasion resistance, while white fibers are smoother, finer, but also weaker [10]. Coconut fibers are commercially available in three forms: bristle (long fibers), mattress (relatively short), and decorticated (mixed fibers) [9]. These different types of fibers have different uses depending upon the requirement, with brown fibers mostly used in engineering [10].

1.2.1 Advantages & Disadvantages

Advantages:

- Reinforcing concrete with coir fibers results in durable concrete with high flexural and fatigue strength, improved abrasion, spalling, and impact resistance [9].
- The elimination of conventional reinforcement, and in some cases, the reduction in section thickness can contribute to significant productivity improvements. Coir fibers can deliver significant cost savings, together with reduced material volume, more rapid construction, and reduced labor costs [10].
- The random distribution of coir fibers in concrete ensures that crack-free stress accommodation occurs throughout the concrete. Thus, microcracks are intercepted before they develop and impair the performance of the concrete [10].
- Coir fibers are a far more economical design alternative [9].

Disadvantages:

- Damaged slabs allow both aggregate and fibers to be exposed, which will present as aesthetically poor while maintaining structural soundness [9].
- Fibers are capable of substituting reinforcement in all structural elements (including primary reinforcement); however, within each element, there will be a point where the fiber alternative's cost-saving and design economies are diminished [10].
- Strict control of concrete wastage must be monitored to keep it at a minimum. Wasted concrete means wasted fibers [9].

This study aims to compare the performance of steel fibers and coir fibers in concrete at different percentages (0.5%, 1%, 1.5%, and 2% by weight of cement) to evaluate compressive strength and split tensile strength at 7 and 28 days. The findings will provide insights into the effectiveness of these fibers in enhancing the mechanical properties of concrete.

2. MATERIALS METHODS AND MIX DESIGN

In developing concrete mixes for construction, selecting proper ingredients, evaluating their properties, and understanding the interactions among different materials are crucial for optimal performance. The ingredients used in this investigation include cement, fine aggregate, coarse aggregate, water, steel fibers, and coir fibers.

2.1 Materials

2.1.1 Cement

Cement is a fine grey powder that, when mixed with water and materials such as sand or pozzolans, forms mortar and concrete. The mixture of cement and water creates a paste that binds other materials together. In this study, ordinary Portland cement of 53 grade, conforming to IS: 12269-1987 [13], was used.

TABLE I. Experimental Values of the Cement Properties

PHYSICAL PROPORTIES OF GRADE OF CEMENT	RESULTS	REQUIREMENT AS PER IS:8112-1989
Specific gravity	3.148	3.10-3.15
Consistency	33%	30-35
Initial setting time	45 min	Minimum 300 min
Final setting time	210 min	Maximum 600 min
Fineness of cement	1.267%	Less than 10%

2.1.2 Aggregates

Aggregates are essential components of concrete, providing body, reducing shrinkage, and contributing to the economy of the mix. Proper gradation of aggregates ensures minimal voids, requiring less paste to fill these voids, which leads to increased strength, reduced shrinkage, and greater durability.

Fine Aggregate:

The fine aggregate used was river sand conforming to Zone-II as per IS: 383-1970 [14]. The sand was washed and screened to eliminate deleterious materials and oversized particles. Sieve analysis and physical property evaluation of the fine aggregate were conducted, with the following results:

TABLE II. Experimental Values of the Fine Aggregate Properties

PHYSICAL PROPERTIES	TEST RESULTS
Specific gravity	2.61
Fineness modulus	2.46
Bulking of sand	4%

Coarse Aggregate

Coarse aggregates from a local crushing unit, with a nominal size of 20 mm, were used. These aggregates conform to IS: 383-1970. The material was sieved through various sieves (20 mm, 16 mm, 12.5 mm, 10 mm, and 4.75 mm) to obtain well-graded aggregates. The physical properties and gradation of coarse aggregates were evaluated, confirming to IS: 2386 (Part 1) – 1963 [16].

TABLE III. Experimental Values of the Coarse Aggregate Properties

PHYSICAL PROPERTIES	TEST RESULTS
Specific gravity	2.71
Fineness modulus	7.06
Water absorption	5.26

2.1.3 Water

The water used for mixing concrete was potable, with a pH value between 6 and 8. It was free from organic matter and solid contents within permissible limits as per IS: 456-2000 [15] and conformed to IS: 3025-1964 [19].

2.1.4 Additional Materials

Steel fibers were used to enhance the tensile strength and ductility of concrete. The properties of the steel fibers used are:

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TABLE IV. Dimensional Values of the Steel Fibers

PROPERTIES OF STEEL FIBERS	VALUE
Lengths (mm)	30
Shape	Circular
Size/diameter (mm)	0.5
Aspect ratio (L/D)	60

Coir fibers, derived from coconut husks, were also used due to their availability and sustainable nature. The properties of the coir fibers used are

TABLE V. Dimensional Values of the Coir Fibers

PROPERTIES OF COIR FIBERS	VALUES
Lengths (mm)	50-110
Size/diameter (mm)	0.1 - 0.406
Specific gravity	0.66

The high-grade (53) cement ensures early strength gain, making it suitable for high-strength concrete applications. Its specific gravity and consistency are crucial for mix design, influencing the water-cement ratio and workability. Proper washing and screening of river sand enhance the quality of fine aggregates, reducing the presence of deleterious materials, which can negatively affect concrete properties. The fineness modulus indicates the particle size distribution, crucial for mix proportioning. The well-graded coarse aggregates contribute to the strength and durability of the concrete. Their specific gravity and water absorption rate are vital for accurate mix design calculations, affecting the concrete's density and water content. The quality of water used in concrete production is essential to prevent chemical reactions that could weaken the concrete. Potable water ensures that impurities are minimized, maintaining the integrity of the mix. The inclusion of steel and coir fibers aims to enhance the mechanical properties of the concrete. Steel fibers improve tensile strength and crack resistance, while coir fibers, being a sustainable material, offer environmental benefits and additional toughness.

These materials and their properties play a significant role in the performance and durability of the concrete mix, ensuring it meets the desired standards and specifications for construction applications.

2.2 Mix Design

Mix Design is the process of a selecting suitable ingredients of the concrete and determining their relative quantities for producing concrete of certain minimum properties of the strength, durability and consistency etc., as economically as possible.

The steps involved in the design of concrete mix as per IS: 10262-2009[17] is a follow,

TABLE VI. The Results of the pre-mix-design tests

Stipulations for proportioning	
Grade designation	M20
Type of cement	OPC 53 grade confirming to IS 12269:1987 [13]
Maximum nominal size of aggregate	20 mm
Exposure condition	mild (for reinforced concrete)
Degree of supervision	Good
Minimum cement content	300 Kg/m^3
Type of aggregate	Crushed angular aggregate
Maximum cement content	450 Kg/m^3
Workability	100 mm
Test data for Materials	
Specific gravity of cement	3.148
Specific gravity of Coarse aggregate	2.71
Specific gravity of Fine aggregate	2.61
Sieve analysis of Coarse aggregate	conforming to table 2 of IS 383
Sieve analysis of Fine aggregate	Conforming to grading zone 3 of table 4 of IS 383

From the detailed design calculation, we obtained the mix proportion ratio as follows.

TABLE VII. MIX Proportion Ratio

GRADE DESIGNATION	M20
CEMENT	1
FINE AGGREGATES	1.62
COARSE AGGREGATES	2.99
W/C RATIO	0.5

3. PREPARATION AND CASTING OF SPECIMENS

The specimens of different sizes with M20 mix as mentioned in table was used with various combinations of steel fibers and coir fibers with cement The mix combinations incorporate varying percentages of either steel or coir fibers into the concrete mix, maintaining consistent amounts of cement, fine aggregates, coarse aggregates, and water. The fiber content ranges from 0% to 2%, with the fiber weight proportionally increasing to enhance the concrete's tensile strength and durability.

TABLE VII. Mix Proportions for the M20 Concrete Specimens

S. NO.	MIX COMBINATION	FIBER PERCENTAGE (%)	CEMENT (Kg/m^3)	FINE AGGREGATES (Kg/m^3)	COARSE AGGREGATES (Kg/m^3)	FIBERS (Kg/m^3)
1.	**SF_0 (or) CF_0**	0	394	637	1176	0
2.	**$SF_{0.5}$ (or) $CF_{0.5}$**	0.5	394	637	1176	1.97
3.	**SF_1 (or) CF_1**	1	394	637	1176	3.94
4.	**$SF_{1.5}$ (or) $CF_{1.5}$**	1.5	394	637	1176	5.91
5.	**SF_2 (or) CF_2**	2	394	637	1176	7.88

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3.1 Casting of Specimens

3.1.1 Cylinders

- The dimensions of the cylindrical specimen are of Height 300mmand diameter 150mm.
- For each trail 6 cylinder specimens were casted for calculating 7 days and 28 days strengths.

3.1.2 Cubes

- The dimensions of specimen for cube are of 150mm x 150mm x 150mm.
- For each trail 6 cube specimens were casted for calculating 7 days and 28 days strength.

4. RESULTS AND DISCUSSION

4.1 WORKABILITY OF CONCRETE:

The workability of concrete is observed by the Slump Cone method. The range of slump was selected as 100 mm.

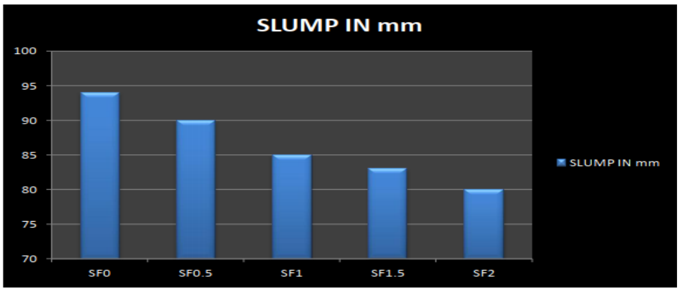

Fig.1 Slump obtained for steel fibers of M20 concrete

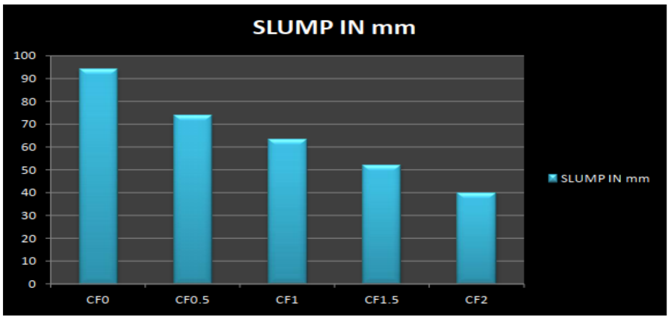

Fig.2. Slump obtained for coir fibers for M20 concrete

The results indicate that increasing the fiber content reduces the workability of the concrete mix, as shown by the decreasing slump values. This effect is more pronounced in coir fibers compared to steel fibers. The reduction in slump can be attributed to the increased surface area of fibers which absorbs more water and restricts the movement of the concrete mix. This observation aligns with findings by [10] and [4], who reported similar trends in reduced workability with higher fiber content in their studies.

4.2 COMPRESSIVE STRENGTH RESULTS

The test results are presented here for the compressive strength of 7 days and 28 days of testing. The water cured specimens are eliminated from moisture content by surface drying before testing in Compression Testing Machine.

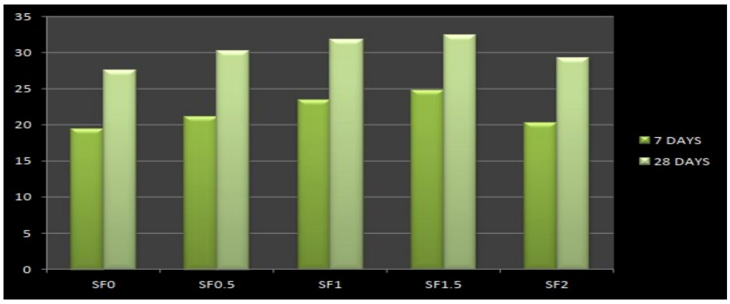

Fig.3. Compressive strengths for steel fibers for M20 concrete

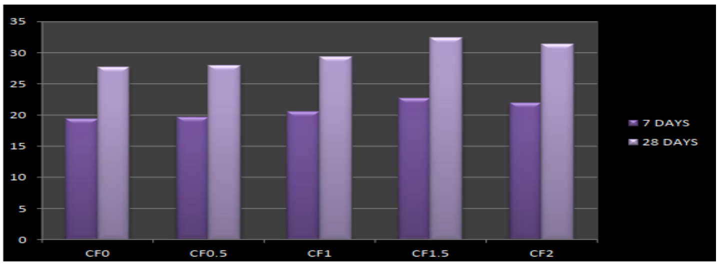

Fig.4. Compressive strength for coir fibers for M20 concrete

The compressive strength of concrete is enhanced by the addition of both steel and coir fibers. Steel fibers show a higher improvement in compressive strength compared to coir fibers, especially at lower fiber contents. The strength gains for steel fibers peak at 1.5% fiber content, while for coir fibers, significant improvements are observed up to 2%.

[4] reported that steel fibers could increase the compressive strength by up to 20%, which is consistent with our findings where a maximum increase of about 17.3% was observed at 1.5% fiber content. [10] found that coir fibers enhanced compressive strength by around 10-15% at 2% fiber content, which aligns with the 13.6% increase observed in our study.

4.3 SPLIT TENSILE STRENGTH

Split tensile strength test plays very important role. Here we tested the specimen of sizes 300mm height and 150 mm diameter cylindrical specimens. Split tensile strength is tested by keeping cylindrical specimens in the compressive testing machine and the loading is applied radically until the failure of the specimen occurs. the casted specimens are tested for 7 days and 28 days of curing.

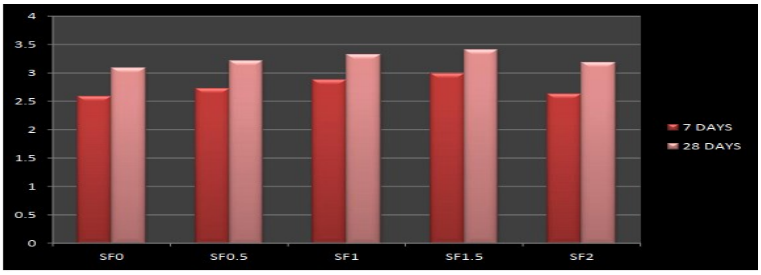

Fig.5. Split tensile strength for steel fibers.

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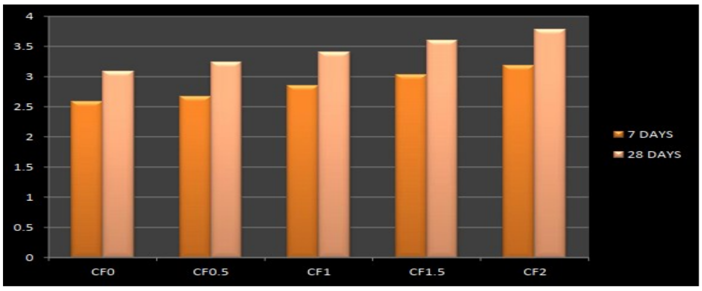

Fig.6.Split tensile strength for coir fibers

Both steel and coir fibers improve the split tensile strength of concrete. However, coir fibers demonstrate a more pronounced effect at higher percentages compared to steel fibers. At 1.5% and 2% fiber content, coir fibers provide higher split tensile strength than steel fibers.

[7] noted that steel fibers could enhance split tensile strength by up to 50%, consistent with our observed 29% increase at 1.5% fiber content. [10] reported a 20-30% increase in tensile strength for coir fibers, aligning with our findings of a 22.6% increase at 1.5% fiber content.

4.5 COMPARISON

The main aim of this project is to compare strength properties of both steel fiber and coir fibers here there are both compared in compression strength and spilt tensile strength with and graphs

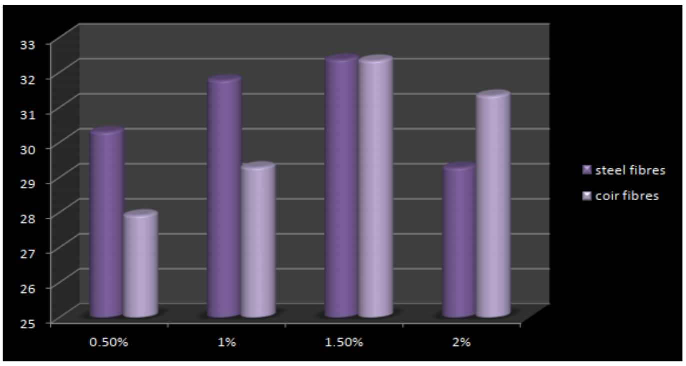

Fig.7. Comparison between coir and steel fiber reinforced concrete in compressive strength

Steel Fibers: Peak compressive strength is observed at 1.5% fiber content. Beyond this, the strength decreases slightly, likely due to fiber agglomeration and reduced workability.

Coir Fibers: Coir fibers show a steady increase in compressive strength up to 1.5% content, with a slight decrease at 2%, but overall performance remains comparable to steel fibers**.**

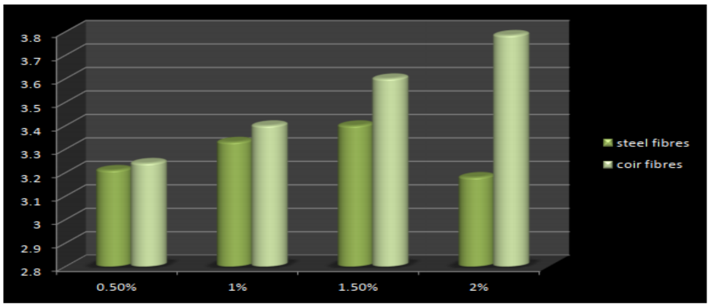

Fig.8. Comparison between coir and steel fiber reinforced concrete in split tensile strength

Steel Fibers: The split tensile strength increases with fiber content up to 1.5%, after which it slightly decreases.

Coir Fibers: Coir fibers exhibit a consistent increase in split tensile strength even at 2% fiber content, surpassing the performance of steel fibers at higher contents.

By systematically comparing the strength properties using both tables and graphs, this method provides a clear and comprehensive understanding of the performance characteristics of Steel Fiber Reinforced Concrete and Coir Fiber Reinforced Concrete, aiding in making informed decisions for practical applications.

5. CONCLUSION

The study on the effects of incorporating steel and coir fibers into concrete mixes provides valuable insights into the performance characteristics of fiber-reinforced concrete. It is observed that the slump values, which indicate the workability of the concrete, decrease with the increasing addition of both steel and coir fibers. However, the reduction in slump is more pronounced with coir fibers, suggesting that coir fibers have a greater impact on the mix's workability compared to steel fibers.

Regarding compressive strength, the results indicate that adding steel fibers to the concrete mix increases its compressive strength up to an optimal percentage of 1.5%. Beyond this point, at 2%, the compressive strength declines. Similarly, coir fibers also enhance compressive strength up to 1.5%, after which a decrease is observed at 2%. When comparing the two, steel fiber concrete demonstrates higher compressive strength than coir fiber concrete at the respective percentages of 0.5%, 1%, and 1.5%.

In terms of split tensile strength, the concrete with steel fibers shows an increase in strength up to 1.5%, with a decline at 2%. On the other hand, coir fiber concrete exhibits a continuous increase in split tensile strength up to 2%. This indicates that coir fibers are particularly effective in improving the tensile properties of concrete. Consequently, coir fiber concrete consistently shows higher split tensile strength than steel fiber concrete across all tested percentages, making coir fibers preferable for applications requiring enhanced tensile strength.

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In summary, both steel and coir fibers enhance the mechanical properties of concrete, with each type of fiber offering distinct advantages. Steel fiber concrete achieves superior compressive strength at lower fiber percentages, which is beneficial for applications where compressive strength is paramount. Conversely, coir fiber concrete excels in tensile strength,

making it ideal for applications where resistance to tensile stresses is critical. Therefore, the choice between steel and coir fibers should be guided by the specific performance requirements of the intended application.

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