Transforming Steel Scrap into Reinforcing Fibers: A Sustainable Approach for Concrete Enhancement

A

Major Project Report

Submitted in partial fulfilment of the requirements for the award of the degree of

BACHELOR OF TECHNOLOGY

IN

CIVIL ENGINEERING

Under the supervision

of

Mr. Chandra Pal Gautam

(Assistant Professor)

by

Somender (201635)

to

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MAY – 2024

STUDENT’S DECLARATION

We confirm that the project report titled "**Transforming Steel Scrap into Reinforcing Fibers: A Sustainable Approach for Concrete Enhancement**," submitted as part of the requirements for the **Bachelor of Technology** degree in **Civil Engineering at Jaypee University of Information Technology, Waknaghat**, is our original creation. This project was carried out under the guidance of **Mr. Chandra Pal Gautam**, and this project has not been submitted elsewhere for the fulfillment of any other degree or diploma.

We take full accountability for the content of our project report and verify its authenticity.

Signature of Student
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CERTIFICATE

This certifies that the project report titled **"Transforming Steel Scrap into Reinforcing Fibers: A Sustainable Approach for Concrete Enhancement,"** submitted to the **Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat**, for the partial fulfillment of the requirements for the degree of **Bachelor of Technology in Civil Engineering**, is an authentic record of the work carried out by **Somender (201635)** from August 2023 to May 2024. The project was conducted under the supervision of **Mr. Chandra Pal Gautam** from the **Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.**

The above statement made is correct to the best of our knowledge.

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ACKNOWLEDGEMENT

The successful completion of our project was made possible by the invaluable guidance and assistance provided by our supervisor. We are incredibly fortunate to have received such comprehensive support throughout the project's duration, and we attribute our achievements entirely to their oversight and help. We express our heartfelt gratitude for their unwavering commitment and dedication.

Furthermore, we extend our sincere appreciation to **Mr. Chandra Pal Gautam (Assistant Professor)** for his invaluable guidance and kind supervision. His mentorship played a crucial role in shaping the project's direction and ensuring its successful completion. We are truly grateful for his insights and support.

We acknowledge our profound indebtedness to our supervisor and **Mr. Chandra Pal Gautam** for their guidance, encouragement, and constant support. Their contributions have been instrumental in navigating the challenges of the project and achieving our goals. We express our sincere thanks to them for their invaluable contributions to our success.

ABSTRACT

The construction industry, as one of the largest consumers of natural resources, faces significant environmental challenges, particularly in the production of concrete, a material integral to modern infrastructure. Traditional concrete reinforcement methods, predominantly using steel rebar, contribute to considerable carbon emissions and resource depletion. In response to these issues, this report explores an innovative and sustainable approach: transforming steel scrap into reinforcing fibers for concrete enhancement. This method not only addresses the environmental impact associated with traditional reinforcement techniques but also offers substantial performance improvements in concrete.

Steel scrap, generated in large quantities from industrial processes, demolition activities, and end-of-life consumer products, often ends up either being recycled in energy-intensive processes or discarded in landfills. Utilizing this scrap for reinforcing concrete can mitigate these environmental concerns. The process involves collecting steel scrap, processing it into fine fibers, and incorporating these fibers into the concrete mix. The resultant steel fiber-reinforced concrete (SFRC) demonstrates improved tensile strength, toughness, and crack resistance compared to traditional reinforced concrete.

The materials and methods section details the process of transforming steel scrap into reinforcing fibers. This includes the collection of suitable scrap, processing techniques such as shredding and cleaning, and the integration of these fibers into concrete. The report discusses the importance of maintaining consistent quality and dimensions of the fibers to ensure uniform reinforcement. Additionally, it covers the methods used to test and evaluate the performance of SFRC, including assessments of compressive strength, tensile strength and durability.

The benefits of using steel scrap fibers are multifaceted. Environmentally, this approach promotes a circular economy by repurposing waste materials and reducing the carbon footprint associated with new steel production. Economically, it offers potential cost reductions in construction projects, particularly in large-scale applications. Performance-wise, SFRC provides superior mechanical properties, enhancing the longevity and resilience of concrete structures.

To illustrate the practical application of this technology, the report includes case studies of successful projects that have implemented steel scrap fibers in concrete. These examples provide real-world data on the performance and benefits of SFRC, showcasing its potential for broader adoption in the construction industry.

However, the report also addresses the challenges associated with this approach. Technical issues such as the variability in scrap quality and the need for efficient processing techniques are discussed. Solutions to these challenges, including advancements in processing technologies and the development of industry standards for SFRC, are proposed.

In conclusion, the transformation of steel scrap into reinforcing fibers represents a promising avenue for sustainable construction. By combining environmental benefits with enhanced concrete performance, this approach offers a viable alternative to traditional reinforcement methods. The report calls for further research and development to optimize this technology and encourages its adoption to build a more sustainable and resilient built environment.

Keywords: *Sustainable construction, Steel scrap recycling, Fiber-reinforced concrete (FRC), Concrete reinforcement, Environmental impact.*

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CHAPTER 1

INTRODUCTION

1.1 GENERAL

The construction industry is one of the largest consumers of raw materials globally, significantly contributing to environmental degradation through the extraction of natural resources and the generation of waste. Concrete, the most widely used construction material, plays a central role in this scenario. However, traditional concrete production is resource-intensive and has a considerable environmental footprint. The process of manufacturing Portland cement, a key ingredient in concrete, is particularly harmful, accounting for approximately 8% of global carbon dioxide (CO2) emissions.

In the quest for more sustainable construction practices, the industry is exploring alternative materials and methods that reduce environmental impact without compromising the performance and durability of structures. One promising approach is the incorporation of recycled materials into concrete. Among these materials, steel scrap—a byproduct of various industrial processes—emerges as a potential candidate for enhancing concrete's properties while promoting sustainability.

1.2 INTRODUCTION

The Need for Enhanced Concrete

Concrete is inherently strong in compression but weak in tension and prone to cracking under stress. To address this weakness, reinforcement is essential. Traditional reinforcement methods primarily involve the use of steel bars (rebar) and welded wire fabric. While effective, these methods are not without their drawbacks. The production of new steel for reinforcement is energy-intensive and contributes to greenhouse gas emissions. Additionally, the global construction boom is leading to increased demand for steel, putting pressure on natural resources.

Reinforcing concrete with steel fibers presents a viable alternative. Steel fibers, dispersed throughout the concrete mix, can improve tensile strength, toughness, and resistance to cracking and shrinkage. However, producing steel fibers from virgin materials is not an environmentally benign process. This is where the use of steel scrap offers a dual benefit: it provides a sustainable source of reinforcement material and contributes to waste reduction.

Steel Scrap as a Resource

Steel scrap is generated in large quantities from various sources, including industrial manufacturing processes, demolition of buildings, automotive recycling, and consumer goods disposal. Traditionally, much of this scrap is recycled back into steel production. However, there is a growing interest in finding innovative applications for steel scrap to maximize its value and reduce the environmental impact associated with recycling processes.

Transforming steel scrap into reinforcing fibers for concrete is a novel approach that leverages the inherent properties of steel while addressing sustainability concerns. This method involves collecting steel scrap, processing it into fibers, and integrating these fibers into the concrete mix. The resulting fiber-reinforced concrete (FRC) exhibits enhanced mechanical properties and durability, making it suitable for a wide range of construction applications.

Current State of Concrete Reinforcement Technologies

Traditional reinforcement techniques have been the backbone of concrete construction for decades. Steel rebar, the most common form of reinforcement, provides significant structural strength but comes with limitations such as susceptibility to corrosion and the need for labor-intensive installation. Other methods, such as using welded wire fabric, offer ease of use but are still dependent on the production of new steel.

In recent years, the industry has seen a growing interest in alternative reinforcement technologies, including the use of synthetic fibers (e.g., polypropylene, nylon), glass fibers, and natural fibers (e.g., coconut coir, sisal). Each of these materials has its advantages and disadvantages. Synthetic fibers, while effective, are derived from non-renewable petroleum resources. Glass fibers offer high strength but can be brittle and less compatible with certain concrete mixes. Natural fibers, although renewable, often suffer from variability in quality and durability.

Steel fibers, particularly those derived from recycled scrap, present a balanced solution. They combine the high strength and durability of steel with the environmental benefits of recycling. Research has shown that steel fiber-reinforced concrete (SFRC) can significantly improve the mechanical properties of concrete, including its tensile strength, toughness, and resistance to cracking and shrinkage.

Environmental and Economic Benefits

The transformation of steel scrap into reinforcing fibers for concrete has both environmental and economic advantages. Environmentally, this approach reduces the demand for virgin steel production, thereby lowering associated greenhouse gas emissions and energy consumption. It also diverts steel scrap from landfills, promoting a circular economy where waste materials are repurposed into valuable products.

Economically, using steel scrap as a raw material for reinforcing fibers can lower costs. The price of steel scrap is generally lower than that of virgin steel, and the processing techniques required to convert scrap into fibers are relatively straightforward and cost-effective. This cost advantage can be particularly significant in large-scale construction projects where the quantity of reinforcement required is substantial.

Moreover, the enhanced performance of SFRC can lead to longer-lasting structures with reduced maintenance needs, offering further economic benefits over the lifecycle of the construction. These advantages make steel scrap fibers an attractive option for both developed and developing regions, where cost and sustainability are critical considerations.

Technical Challenges and Solutions

While the benefits of using steel scrap fibers in concrete are clear, there are technical challenges that need to be addressed to ensure successful implementation. These challenges include:

1. Quality and Consistency of Steel Scrap: The variability in the composition and properties of steel scrap can affect the performance of the resulting fibers. Ensuring a consistent quality of scrap is essential for reliable concrete performance.

2. Processing Techniques: Efficient and cost-effective methods for processing steel scrap into fibers need to be developed and optimized. This includes shredding, cleaning, and shaping the scrap into fibers of appropriate dimensions.

3. Integration with Concrete Mix: The dispersion of steel fibers within the concrete mix is crucial for achieving uniform reinforcement. Proper mixing techniques and the use of admixtures can help achieve this goal.

4. Regulatory Compliance: Ensuring that steel scrap fibers meet the required standards and regulations for construction materials is essential for widespread adoption. This involves rigorous testing and certification processes.

Innovations in materials science and processing technologies are helping to overcome these challenges. Advanced sorting and cleaning techniques can improve the quality and consistency of steel scrap. New mixing methods and chemical admixtures are being developed to enhance the dispersion of fibers within the concrete matrix. Additionally, ongoing research and development are focused on optimizing the mechanical properties of SFRC to meet and exceed industry standards.

1.3 SUMMARY

The transformation of steel scrap into reinforcing fibers for concrete represents a significant step towards more sustainable construction practices. By leveraging industrial waste, this approach reduces environmental impact, lowers costs, and enhances the performance of concrete structures. As the construction industry continues to seek innovative solutions to its sustainability challenges, steel scrap fibers offer a promising path forward. This report will delve into the various aspects of this technology, providing a comprehensive overview of its potential and paving the way for its broader adoption.

CHAPTER 2

LITERATURE REVIEW

2.1 GENERAL

The increasing demand for sustainable construction materials has driven significant research into innovative methods for enhancing concrete performance while minimizing environmental impact. One promising approach involves the transformation of steel scrap into reinforcing fibers for concrete. This literature review examines the current state of knowledge on this topic, focusing on the processes of converting steel scrap into usable fibers, the mechanical and durability benefits of fiber-reinforced concrete, and the environmental advantages of this recycling method. By integrating steel scrap fibers into concrete, not only can waste be reduced, but the resulting material can also exhibit improved tensile strength, crack resistance, and overall durability, contributing to more sustainable and resilient construction practices.

2.2 LITERATURE REVIEW

Prasad, et al., Incorporating steel fibers into concrete slabs enhances structural performance by improving punching shear resistance and reducing crack widths. The fibers distribute stresses more evenly, bridge cracks, and increase ductility, resulting in more durable and resilient concrete structures suitable for heavy loads and demanding conditions.

Shewalul, et al., The modulus of elasticity and peak strain of concrete show significant improvement with the increased addition of waste steel scrap. This enhancement is attributed to the steel fibers' ability to provide additional stiffness and resistance to deformation, resulting in a more robust and flexible concrete matrix capable of withstanding higher stress and strain before failure.

Negriokie, et al., Incorporating 4.5% steel cord scrap into concrete substantially diminishes its water absorption, with a notable 22.7% reduction. This modification enhances the concrete's durability and resilience against moisture ingress, crucial for structures exposed to environmental elements. The steel cord scrap acts as a barrier, limiting water penetration and thereby increasing the longevity and performance of the concrete composite.

Rasidi, et al., The study indicates that as the length of the fiber in the concrete composite increases from 2cm to 4cm, there is a noticeable escalation in the bending moment. This suggests that longer fibers contribute to greater resistance against bending forces within the concrete structure. The extended length likely enhances the fibers' ability to distribute and withstand applied loads, resulting in improved overall structural integrity and load-bearing capacity.

Akin et al. underscored the importance of steel fiber energy absorption capacity under pressure loads in preventing sudden collapse and absorbing energy under dynamic loads. They noted that while steel fiber concrete exhibits lower mechanical performance under tensile stress compared to pressure stress, the mechanical properties vary based on factors like fiber type, geometry, and volume usage rate, as well as fiber placement in concrete preparation.

Domski et al. compared the properties of hooked-end steel fibers (ESFs) and straight steel fibers (WSFs). They found ESFs to be more diverse than commonly assumed, with aspect ratio and other geometrical properties not necessarily correlating with mechanical characteristics. They suggested testing and analyzing additional ESF properties simultaneously, preferably using multivariate statistics, to establish clearer correlations.
Barroz et al. observed differences in the fiber reinforcement mechanisms between industrial steel fibers (ISFRC) and recycled steel fibers (RSFRC) in three-point notched beam bending tests. While ISFRC exhibited a deflection hardening phase, RSFRC did not, indicating less effective fiber reinforcement mechanisms in RSFRC due to fiber geometry and surface characteristics. However, RSFRC showed almost constant flexural strength, indicating potential benefits in certain applications.

Sahoo et al. reported increased displacement ductility and curvature response with the addition of steel fibers, noting maximum improvements at 1.5% fiber content. They found that higher fiber content led to increased ductility and curvature response compared to plain reinforced concrete specimens.

Mahmood et al. compared the behavior of reinforced concrete (RC) and steel fiber-reinforced concrete (R-SFRC) specimens under bending tests. While both exhibited crack localization, RC specimens showed lengthy hardening regions after forming a second plastic hinge, while R-SFRC specimens showed shorter hardening lengths followed by gentle softening. Ductility decreased with increasing moment redistribution in both RC and R-SFRC specimens.

Tadokano et al. proposed a simplified method for estimating concrete expansion using circumferential strain, noting its applicability for moderate expansions but potential overestimation for larger expansions. Gao et al. introduced a novel channel allocation scheme for body sensor networks aimed at improving packet delivery ratio (PDR) before deadlines by prioritizing paths with urgent deadlines and heavier collisions in channel allocation.

Manzoli et al. conducted three-point bending tests on fiber-reinforced concrete beams and developed numerical simulations based on experimental results. They calibrated fiber/concrete interface parameters and plan to improve the numerical model by incorporating fiber pullout tests and 3D analyses using high-performance computing in future work.

Liu et al. demonstrated promising results with a proposed method for fiber pull-out tests and structural failure tests of fiber-reinforced concrete under three-point bending. Stress analysis showed effective stress transfer from pulley force and interfacial friction to the cement matrix, with friction work significantly higher than internal work for steel fiber-reinforced concrete.

2.3 GAP IDENTIFICATION

Many studies predominantly utilize lathe steel scrap, whereas a variety of steel scraps sourced from different industries, each with distinct aspect ratios of steel scrap fibers, remain underexplored in research.

2.4 OBJECTIVE OF THE STUDY

- To analyse the impact of steel scrap obtained from different industry on the mechanical properties of concrete.
- To enhance the strength of concrete mix by addition of steel scrap as a fibre with different aspect ratio.

2.5 SUMMARY

In the quest for sustainable construction materials, the innovative study "Transforming Steel Scrap into Reinforcing Fibers: A Sustainable Approach for Concrete Enhancement" explores a groundbreaking method to enhance concrete using recycled steel scrap. This approach not only addresses the pressing issue of steel waste management but also significantly improves the structural integrity and durability of concrete. By converting steel scrap into reinforcing fibers, the study presents a dual-benefit solution that promotes environmental sustainability and advances the performance standards of modern construction practices.

CHAPTER 3

METHODOLOGY OF THE STUDY

3.1 GENERAL

The methodology for incorporating steel scrap in concrete involves collecting and preparing the scrap by cutting it into specified sizes. The cleaned scrap is then mixed with aggregates and cement in designated proportions. This composite is thoroughly blended to ensure even distribution of the steel within the mixture. The concrete is then poured into molds, cured under controlled conditions, and tested for strength and durability to evaluate performance enhancements.

3.2 MATERIAL AVAILABILITY

The experiment utilized materials procured from distinct sources. Portland Pozzolana Cement (PPC), Coarse Aggregate, and Fine Aggregate were acquired from a local supplier in Solan, while Steel Scrap, crucial for the study, were collected from various steel industries situated in Gobindgarh, as shown in Fig. 3.1.

(a) (b)

(c) (d)

Fig. 3.1 (a) Portland Pozzolana Cement (PPC) (b) Coarse Aggregates (c) Steel Scrap fibers (d) Fine Aggregates

3.3 METHODOLOGY OF THE STUDY

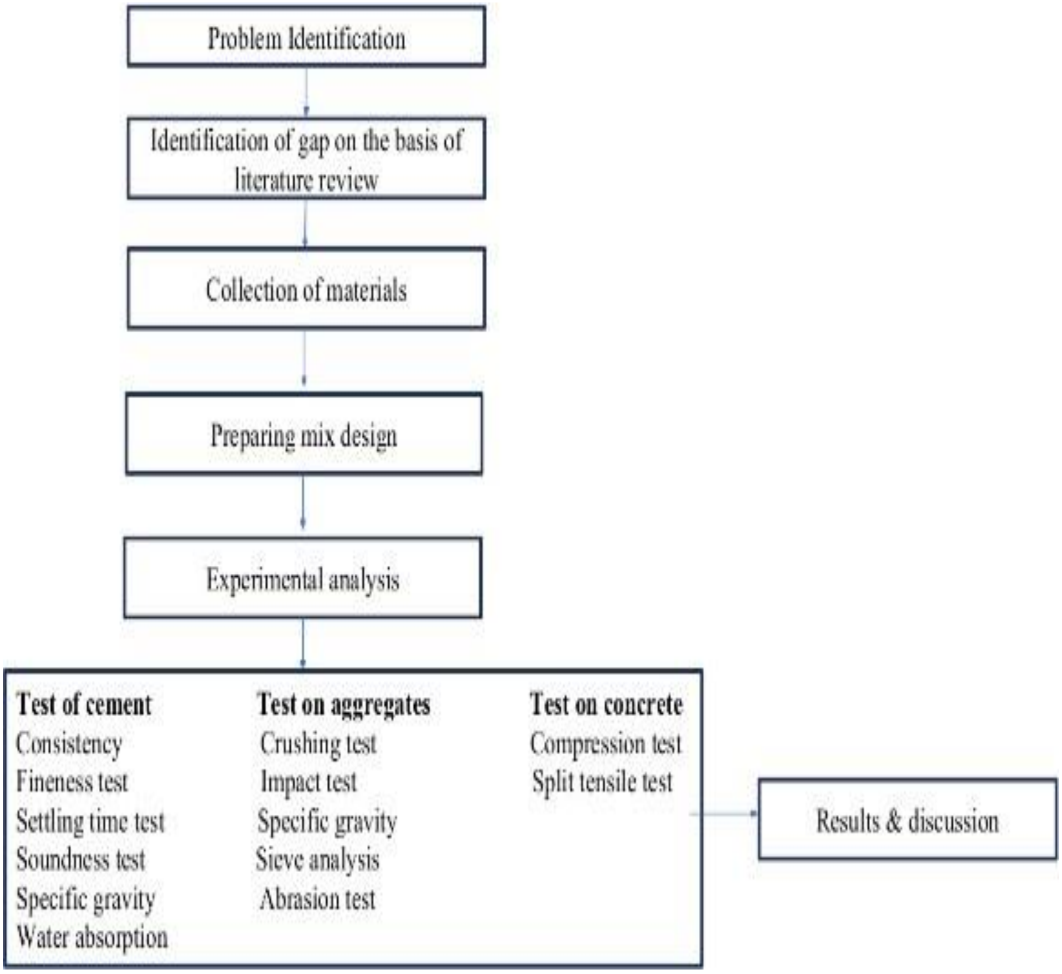


Fig 3.2 Methodology of the Study

3.4 MATERIAL’S CHARACTERISTICS

3.5 Fiber

Steel scrap is collected from scrap dump area in Mandi Gobindgarh and then it is converted into steel scrap fiber with different aspect ratios. (Average aspect ratio is 22.13)

3.6 3.4.1 Cement

Portland Pozzolana Cement (PPC) is a hydraulic cement produced by finely grinding a blend of Portland cement clinker and pozzolanic materials such as fly ash, volcanic ash, calcined clay, or silica fumes. This blend results in a cement that offers enhanced workability, durability, and strength. In India, the requirements, physical properties, chemical composition, and performance standards for PPC are detailed in IS 1489 (Part 1): 1991.

i. Fineness Test

The fineness of cement relates to the particle size, with the stipulation that it should not exceed 90 microns when sieved. This test follows the guidelines of IS 4031 Part-I, with sample collection adhering to IS 3535. The apparatus required includes a pressure gauge, valve, pipework, and spray nozzle. The sieve for the fineness test consists of a single-piece brass frame with a stainless-steel No. 325 wire cloth.

ii. Setting Time Test

According to IS 12269, the initial setting time of cement should be at least 30 minutes, and the final setting time should not exceed 600 minutes. The required apparatus includes Vicat’s apparatus, a balance, measuring cylinder, stopwatch, glass plate, enamel tray, and a trowel.

iii. Consistency Test

The consistency test determines the amount of water needed to achieve a standard consistency in a cement paste. Following IS 4031-4 (1988), the normal consistency of cement is approximately 31%, as shown in Table 3.3. The apparatus for this test includes a Vicat apparatus, balance, trowel, and stopwatch.

3.4.2 Aggregates

i. Coarse Aggregates

Coarse aggregates are crucial for concrete and construction materials, consisting of granular materials with particle sizes greater than 4.75 millimeters, typically ranging from 9.5 mm to 37.5 mm. These are usually made from crushed stone, gravel, or a combination of both. The quality standards for coarse and fine aggregates in concrete are defined in IS 383:2016, which specifies the necessary attributes such as grading, strength, and durability.

ii. Fine Aggregates

Fine aggregates are smaller-sized granular materials used in construction, typically ranging from 0.075 millimeters to 4.75 millimeters. They consist of sand, crushed stone dust, or natural silica sand particles. The specifications and quality requirements for fine aggregates are also detailed in IS 383:2016.

3.4.2.1 Tests on Coarse Aggregates

i. Crushing Test

The aggregate crushing value indicates the material's strength and its ability to withstand compressive loads. This value is essential for road and pavement construction and is determined according to IS code 2386 Part 4. Table 3.4 shows the crushing value of coarse aggregates to be approximately 26.6%. The test apparatus includes a tamping rod, balance, sieves, cylindrical measure, and steel measure.

ii. Impact Test

The impact test evaluates an aggregate's resilience to sudden loads and the energy absorbed during fracture, indicating its brittleness or ductility. The procedure follows IS code 2386 Part 4, with the impact value for coarse aggregates around 16.93% as shown in Table 3.5. The required apparatus includes a cylindrical measure, tamping rod, impact testing machine, and sieves with 12.5 mm, 10 mm, and 2.36 mm apertures.

iii. Abrasion Test

The abrasion test assesses aggregate hardness, specifically the percentage of wear when rubbed against steel balls in the Los Angeles machine. Following IS code 2386 Part 4, the abrasion test value for coarse aggregates is approximately 29.14% as indicated in Table 3.6. The apparatus includes a Los Angeles machine, drying oven, tray, and balance.

iv. Specific Gravity and Water Absorption

Specific gravity, indicative of aggregate porosity and strength, is measured as per IS code 2386 Part 3. The specific gravity and water absorption values for coarse aggregates are approximately 2.71 and 0.326%, respectively, as shown in Table 3.7. The apparatus includes a balance, box wire bucket, and drying oven.

3.4.2.2 Tests on Fine Aggregates

i. Particle Size Distribution

Sieve analysis assesses the gradation of fine aggregates, governed by IS 2386 (Part 1):2015. This test involves passing aggregates through a series of sieves and computing the fineness modulus based on the cumulative percentages retained on each sieve.

3.4.3 Tests on Concrete

i. Compression Test

Compression testing evaluates concrete's response to compressive forces, determining properties like compressive strength, yield strength, ultimate strength, elastic limit, and elastic modulus. This test is conducted according to IS code 516:1959, which provides detailed procedures for testing concrete cubes, cylinders, and other specimens.

ii. Split Tensile Test

The split tensile test indirectly measures concrete's tensile strength. A cylindrical specimen is placed horizontally and subjected to radial force, causing vertical cracking along its diameter. This test follows IS 5816:1999, detailing the procedure, apparatus, and calculations required to determine the split tensile strength of concrete.

Fig 3.4 Split Tensile Testing Machine

3.7 SUMMARY

The study aims to utilize industrial steel waste, Portland Pozzolana Cement (PPC) and coarse and fine aggregates were obtained locally, while steel scrap was sourced from Gobindnagar Mandi. Cement properties were evaluated through fineness, setting time, and consistency tests. Aggregate tests included crushing, impact, abrasion, specific gravity, and water absorption tests. Concrete tests encompassed compression, split tensile, and flexural tests, following respective IS codes. Overall, the research explores the feasibility of incorporating waste materials into construction, emphasizing sustainability and resource optimization.

CHAPTER 4
RESULTS ANALYSIS

4.1 GENERAL

In this chapter, we will look at the methods utilized to incorporate Steel scrap fiber into concrete. We will compare and contrast the features and advantages adding percentages of steel scrap fiber in concrete mixes with different aspect ratio with respect to normal M30 concrete. of mix. The objective of this assessment is to check that whether the transformed steel scrap fiber from steel scrap with different aspect ratio helps in the enhancement of mechanical properties of normal concrete or not.

MIX DESIGN OF M30 GRADE CONCRETE

STANDARD AND SPECIFICATIONS

In this mix design and during testing, we had taken the references of different codes and standards such as IRC: 44-2017, IS: 456-2000, IS: 10262-2019, IRC: SP:62-2014

MATERIAL USED

Cement – opc
Fine Aggregates – Less than 4.75mm of Zone II
Coarse Aggregates – Less than 20mm
Steel Scrap Transformed into fibers with aspect ratio 22.13.

DESIGN MIX PROPORTION

The design mix proportion for M30-Grade Concrete:

MIX DESIGN

We take the water-cement ratio = 0.45

Table 4.1 Water-cement ratio for different grades of concrete (IRC 44: 2017)

Minimum Grade of Concrete	**Maximum Water-cement ratio**
M20	0.55
M25	0.5
M30	0.45
M35	0.4
M40	0.4

SELECTION OF WATER CONTENT

The maximum water content in an aggregate of 20 mm is 186 kg (for a slump of 25 to 50 m **able 4.2**

Water content for the nominal maximum size of coarse aggregates

Nominal maximum size of aggregates (mm)	**Maximum water content (Kg)**
10	208
20	186
40	165

We were targeting a 75 mm slump, so we had to increase the water content. To get a 25mm rise in slump, we had to increase the water content by 3%, and so on.

Water content estimate: 186 + (3/100) x 186 = 192 kg

EXPERIMENTAL INVESTIGATION

The experimental investigation of concrete involves testing various mixtures and to optimize strength, durability, and sustainability. Factors such as aggregate type, water-cement ratio, and curing methods are analyzed to enhance concrete performance. Testing methods include compression tests, slump tests, and durability assessments. Results inform industry standards and contribute to advancements in concrete technology for more resilient and efficient infrastructure.

4.1.1 PHYSICAL PROPERTIES OF CONCRETE

4.3.1.1 RESULTS OF TEST PERFORMED ON CEMENT

The cement test results revealed different findings which were made in the present studies as shown in Table 4.7 to 4.9. Key findings include compressive strength, setting time, and consistency. These results inform concrete mix designs, ensuring durability and performance in various applications.

i. Fineness Test

A minimum 3 samples were tested to find out the fineness of the cement which was formed to be varying from 5.58% to 7.2%. Average value of fineness of cement was 6.47% as shown in Table 4.7.

Table 4.7 Fineness Value of Cement

Sr. No.	Samples	W1 (Weight of cement sample in g)	W2 (Weight of cement retained on 90 µm sieve in g)	Fineness of cement (W2/W1)×100
1	S1	100	5.58	5.58%
2	S2	100	6.63	6.63%
3	S3	100	7.2	7.2%
	Avg. Fineness Value		6.47%	

ii. Settling Time Test

A sample was tested to find out the setting time of the cement which was found to be about the initial setting time of cement was 36 min and the final setting time of cement was 248 min as shown in Table 4.8.

Table 4.8 Setting Time of Cement

Sr. No.	Consistency Test	Weight of cement (g)	Water to be added in cement (ml)	Initial Setting Time of Cement (min)	Final setting Time of Cement (min)
1	31	400	102	36	248

iii. Consistency Test

A minimum 3 samples were tested to find out the Normal Consistency of the cement which was found to be about the average consistency value was 31% as shown in Table 4.9.

Table 4.9 Normal Consistency of Cement

Sr. No.	Samples	Weight of cement (g)	% of water to be added in cement sample	Weight of water to be added in sample (ml)	Penetration value (%)
1	S1	400	27	108	30
2	S2	400	30	120	32
3	S3	400	33	132	31
	Avg. Consistency of cement		31%		

4.3.1.2 RESULTS OF TEST PERFORMED ON COARSE AGGREGATES

The test results on coarse aggregates for the concrete project indicate satisfactory performance. Aggregate crushing strength surpasses minimum requirements, promising durability and load-bearing capacity. Absorption and moisture content fall within acceptable limits, preventing excessive water ingress and maintaining consistency in concrete mixtures. Aggregate shape and texture are conducive to optimal concrete cohesion and workability.

i. Crushing Test

A minimum 3 samples were tested to find out the Crushing Test of Coarse Aggregates which was found to be about the average Crushing Value was 27.5% as shown in Table 4.10.

Table 4.10 Crushing Test

Sr. No.	Total weight of aggregates W1 (g)	Weight of aggregates passing 2.36mm (g) (W2)	Weight of aggregates retained on 2.36mm W3(g)	Aggregate Crushing value (%) [W2×100]/[W1]
1	2700	692	2008	26.6%
2	2700	729	1971	27%
3	2700	782	1918	28.9%
Avg. Crushing Value			27.5%	

ii. Impact Test

A minimum 3 samples were tested to find out the Impact Test of Coarse Aggregates which was found to be about the average Impact Value was 16.96% as shown in Table 4.11.

Table 4.11 Impact Test

Sr. No.	Weight of dry sample taken (g)	Weight of aggregates passing 2.36mm sieve (g)	Aggregate impact value (%)
1	400	70.6	17.46
2	400	64.86	16.18
3	400	60.54	17.23
Avg. Impact Test		16.96%	

iii. Abrasion Test

A minimum 3samples were tested to find out the Abrasion Test of Coarse Aggregates which was found to be about the average Abrasion Value was 30% as shown in Table 4.12.

Table 4.12 Abrasion Test

Sr. No.	Weight of Aggregates (W1) (g)	Weight of Aggregate retain on 1.70mm sieve (W2) in g	% Abrasion Value {(W1-W2)/W1} ×100
1	5000	3543	29.14%
2	5000	3267	34.66%
3	5000	3689	26.22%
Avg. Abrasion Value		30%	

iv. Specific Gravity and Water Absorption

A sample was tested to find out the Specific Gravity and Water Absorption of Coarse Aggregates as shown in Table 4.13.

Table 4.13 Specific Gravity and Water Absorption of coarse aggregates

Weight of saturated aggregates in water with bucket (W1)	1664 g
Weight of Bucket suspended in water (W2)	690 g
Weight of saturated dry aggregates in air (W3)	1540 g
Weight of aggregates (W4)	1535 g

4.3.1.3 RESULTS OF TEST PERFORMED ON FINE AGGREGATES

The test results on fine aggregates for the concrete project indicate optimal characteristics. Aggregate grading meets specifications, ensuring proper particle distribution. Aggregate fineness modulus falls within the desired range, indicating suitable particle sizes for cohesive concrete mixtures. Specific gravity and absorption values adhere to standards, indicating good quality aggregates. Overall, the test results affirm the suitability of the fine aggregates for the intended concrete application, meeting quality and performance requirements.

i. Fineness Modulus of Fine Aggregates

Table 4.14 shows the fineness modulus value of fine aggregates about 45.23% and Fig. 4.1 shows the graphical Particle Size Distribution of Fine Aggregates

Table 4.14 Fineness modulus of fine aggregates

Sr. No.	IS Sieve (mm)	Weight Retained on Sieve (W)	% Weight retaines A=(W/1000) ×100	Cumulative Retained %age (B)	Passing %age (100-B)
1	10	0	0	0	100
2	4.75	65	6.5	6.5	93.5
3	2.36	110	11	17.5	82.5
4	1.18	140	14	31.5	68.5
5	0.6	96	9.6	41.1	58.9
6	0.3	263	26.3	67.4	32.6
7	0.15	246	24.6	92	8.0
8	0.075	39	3.9	95.9	4.1
9	Pan	41	4.1	99.9	0.01
	Total	1000		452.3	

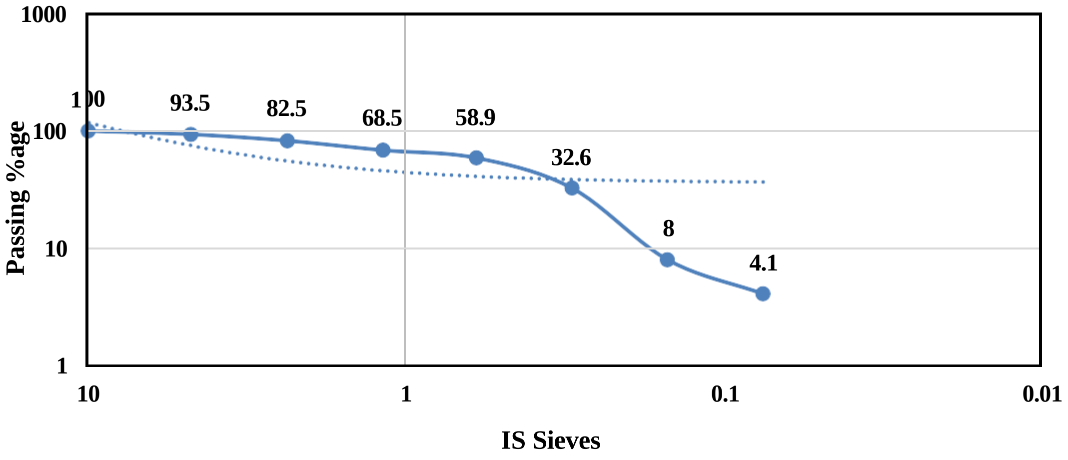


Fig 4.1 Particle Size Distribution

4.1.1.1 RESULTS OF TEST PERFORMED ON FINE AGGREGATES

The test results on fine aggregates for the concrete project indicate optimal characteristics. Aggregate grading meets specifications, ensuring proper particle distribution. Aggregate fineness modulus falls within the desired range, indicating suitable particle sizes for cohesive concrete mixtures. Specific gravity and absorption values adhere to standards, indicating good quality aggregates. Additionally, the presence of impurities or deleterious materials is negligible, ensuring the durability and strength of the concrete. Overall, the test results affirm the suitability of the fine aggregates for the intended concrete application, meeting quality and performance requirements.

4.1.2 COMPRESSIVE STRENGTH OF CONCRETE

The compressive test was conducted using a Compression Testing Machine (CTM) on concrete blocks formulated with the M30-grade concrete mix. These blocks represented the standard "normal concrete" without any fiber incorporation, serving as the benchmark for evaluating and comparing the strength characteristics of other concrete mixes. Table 4.15 in the experimental findings provides a detailed overview of the compressive strength of normal concrete at different curing intervals: 7, 14, and 28 days. Notably, at the end of the 28-day curing period, the recorded compressive strength for normal concrete was 30.33 MPa. This value serves as a fundamental benchmark for assessing the strength improvements achieved by various fiber-reinforced concrete mixes. formulations in subsequent tests and analyses.

Table 4.15 Compressive Strength of a Normal Concrete

Sr. No.	MIX ID	Days	Weight (Kg)	Strength (MPa)
1	NC	7	7.54	19.26
2	NC	14	7.98	25.7
3	NC	28	8.2	30.33

In Fig. 4.2, the 28-day compressive strength of normal concrete is visually depicted at 30.33 MPa.

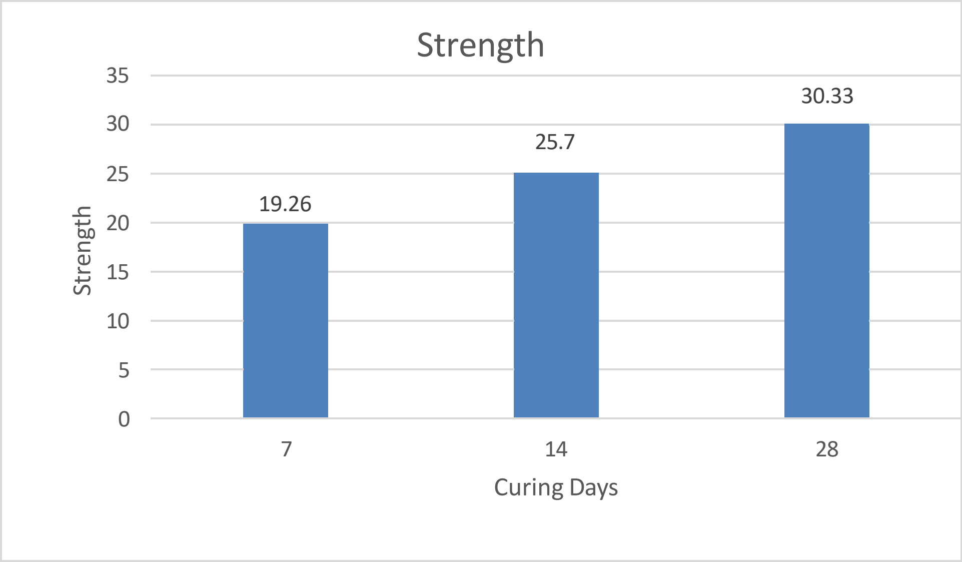


Fig 4.2 Mean Compressive Strength of Normal Concrete

The concrete blocks were prepared by integrating steel scrap fiber as a reinforcing element in the concrete mix, possessing an aspect ratio of 22.13.

Table 4.16 Compressive Strength of 1%SSF

Sr. No.	**MIX ID**	**Days**	**Weight (Kg)**	**Strength (MPa)**
1	SSF1%	7	7.74	24.43
2	SSF1%	14	7.82	27.32
3	SSF1%	28	7.96	35.5

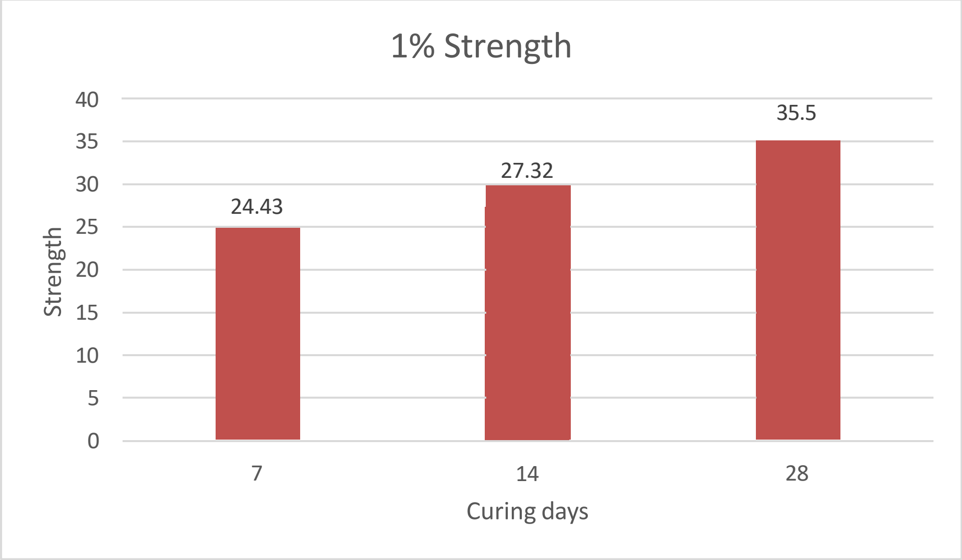
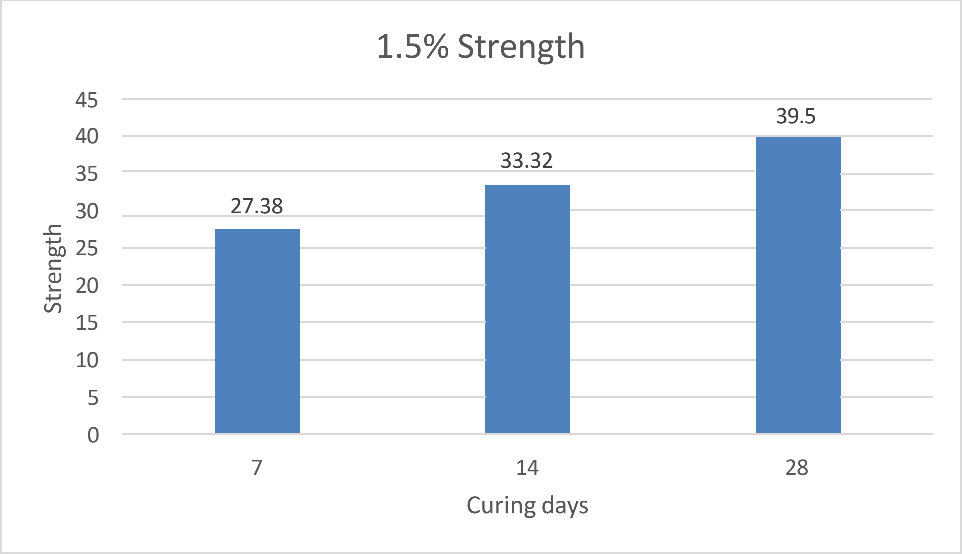


Fig 4.4 Mean Compressive Strength of 1%SSF

The compressive strength of cube increases up to 7.84% when 1% of SSF is added in normal concrete mix(m30). The steel scrap fiber is added in the concrete mix when aggregates and cement is mixed with water and then poured into cube molds of dimension (15*15*15) cm. then the cubes are placed on shaking table to remove extra air from the voids. These prepared molds are then set aside for setting time and then are cured in water for 28 days and tested under CTM for strength comparison from normal concrete.

Table 4.17 Compressive Strength of 1.5%SSF

Sr. No.	MIX ID	Days	Weight (Kg)	Strength (MPa)
1	1.5%SSF	7	7.74	27.38
2	1.5%SSF	14	7.92	33.92
3	1.5%SSF	28	8	39.95



The compressive strength of cube increase up to 13.13% when 1.5% of steel scrap fiber is added in the concrete mix, hence there is a continuous increase in compressive strength when more amount of steel scrap fiber is added in the concrete mix with respect to the weight of concrete. This technique shows a positive effect in the increment of compressive strength of concrete when fiber is added directly during preparation of normal concrete mix.

Table 4.18 Compressive Strength of 2%SSF

Sr. No.	MIX ID	Days	Weight (Kg)	Strength (MPa)
1	2%SSF	7	8.1	32.43
2	2%SSF	14	7.9	36.32
3	2%SSF	28	8.05	46.5

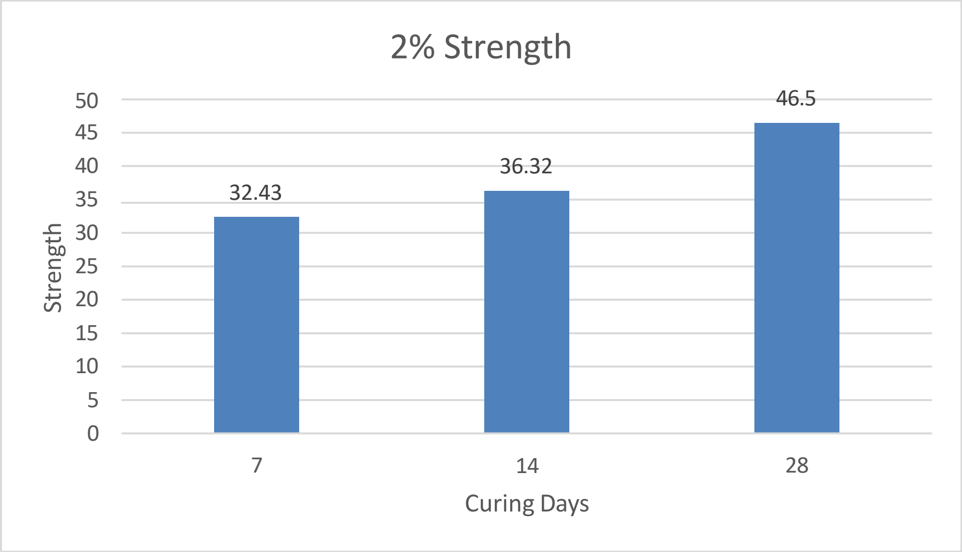


Fig 4.8 Mean Compressive Strength of 2%SSF

The compressive strength of concrete increases up to 21.04 % when 2% of steel scrap fiber is added in concrete mix and shows a further increase in compressive strength of concrete mix in comparison of previous ratio of steel scrap fibers, hence this method of converting steel scrap into fiber leads to positive effect in increasing compressive strength of concrete when fiber is added in concrete during mixing with different aspect ratio (Aspect ratio of fiber is approximately 22.13).

4.1.3 SPLIT TENSILE TESTING RESULTS

In concrete cylinder, the Split Tensile Test is performed under CTM. According to IS 5816: 1999, the strength of the specimen is calculated by this formula:

$$f_{Ct} = \frac{2P}{\pi l d} \qquad \textit{Equation (3).}$$

Where, f_{ct} is the splitting tensile strength of tensile, P is the maximum load applied on the specimen, d is the diameter of the specimen, l is the length of the specimen.

We had casted normal concrete specimens of cylinder of 150mm of height and 100 mm of diameter.

(a)

Fig. 4.17 (a) Cylinder during casting

.

Table 4.24 Split Tensile Strength of NC

Sr. No.	Mix ID	Days	Weight (Kg)	Strength (MPa)
1	NC	7	4.65	1.32
2	NC	14	5.03	1.73
3	NC	28	5.33	2.9

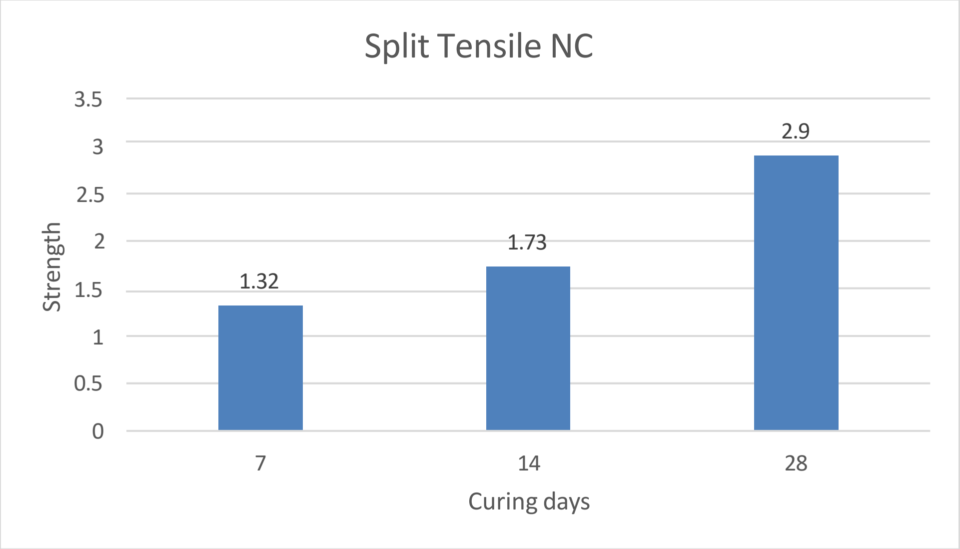


Fig. 4.18 Mean Result of Split Tensile Strength of NC

The split tensile strength of normal m30 concrete is 2.9 MPa achieved after 28 days of curing. Further different ratios of steel scrap fiber is added in concrete mix to check the after results of the split tensile strength of steel scrap fiber concrete.

Table 4.25 Split Tensile Strength of FCMS

Sr. No.	Mix ID	Days	Weight (Kg)	Strength (MPa)
1	7	1%SSF	4.67	1.52
2	14	1%SSF	5.021	2.35
3	28	1%SSF	5.43	3.32

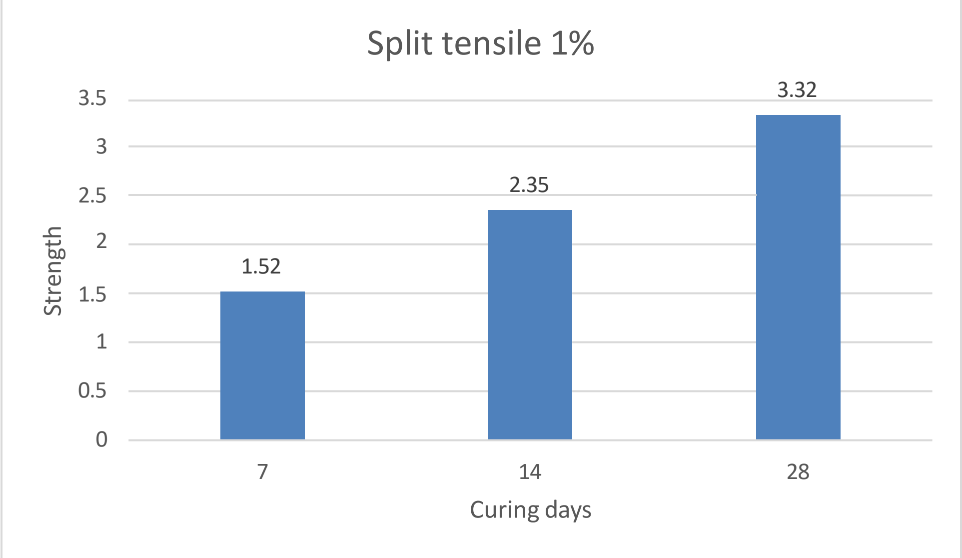


Fig. 4.20 Mean Result of Split Tensile Strength of 1%SSF.

The split tensile strength of concrete mix increases up to 6.7 % when 1% of steel scrap fiber is added in concrete mix. In this method, cylindrical molds are casted where 1% of steel scrap fiber is added in concrete during mixing and then set aside for setting period and then cured for 28-day days and then tested for split tensile strength. This method shows positive effect in the increment of split tensile strength of concrete mix .

Table 4.26 Split Tensile Strength of 1.5%SSFC

Sr. No.	Mix ID	Days	Weight (Kg)	Strength (MPa)
1	1.5%SSF	7	5.2	2.15
2	1.5%SSF	14	4.86	2.79
3	1.5%SSF	28	4.93	3.62

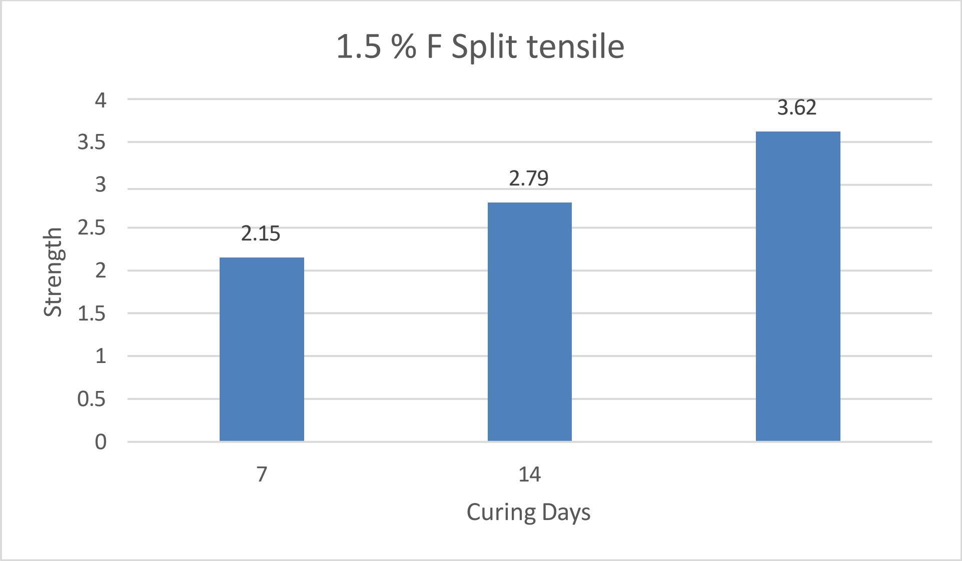


Fig. 4.21 Mean Result of Split Tensile Strength of 1.5%SSF

The split tensile of concrete increses upto11.04% when 1.5% of scrap steel fiber is added in concrete mix.The further increase in the amount of steel scrap fiber in concrete mix with respect to the weight of the concrete increases the split tensile strength of concrete. With increase in the percentage of steel scrap fiber the split tensile strength also increses.

Table 4.27 Split Tensile Strength of 2%SSF

Sr. No.	Mix ID	Days	Weight (Kg)	Strength (MPa)
1	2%SSF	7	4.84	2.47
2	2%SSF	14	5.23	2.98
3	2%SSF	28	5.16	3.92

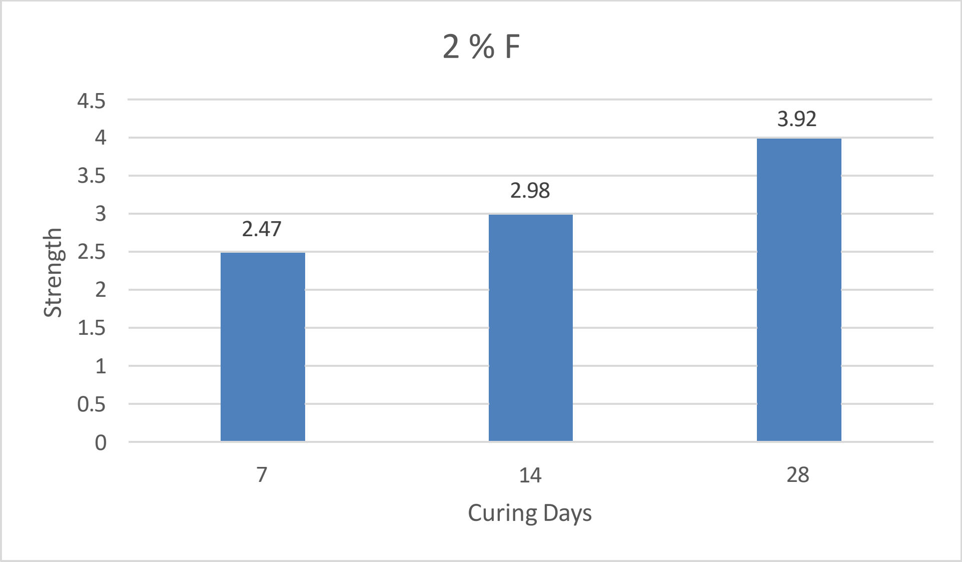


Fig. 4.22 Mean Result of Split Tensile Strength of DFCMS

The split tensile force increases up to 14.95% when 2% of steel scrap fiber is added in concrete mix. Hence this method shows positive effect in the increment of split tensile strength of the concrete mix when transformed steel scrap fiber from steel scrap is added in concrete mix with respect to the weight of the concrete with different aspect ratio fiber is added in different percentages

CHAPTER 5

DISCUSSION AND CONCLUSION

5.1 GENERAL

This study investigates the transformative potential of steel scrap fibers (SSF) in enhancing the mechanical properties of concrete. Through systematic evaluation of compressive and split tensile strengths, the research sheds light on the efficacy of SSF as a sustainable reinforcement technique, offering promising implications for improved concrete performance and environmental stewardship.

5.2 DISCUSSION

The experimental findings presented in the study demonstrate the significant enhancement in the mechanical properties of concrete through the incorporation of steel scrap fibers (SSF). The research methodically evaluated the compressive and split tensile strengths of concrete mixes with varying percentages of SSF, providing valuable insights into the effectiveness of this reinforcement technique.

Firstly, the compressive strength tests conducted on concrete blocks formulated with M30-grade concrete mix revealed a notable increase in strength with the addition of SSF. The standard "normal concrete" without any fiber incorporation served as a benchmark, recording a compressive strength of 30.33 MPa at the end of the 28-day curing period. Subsequent tests on concrete mixes containing 1%, 1.5%, and 2% SSF showcased consistent improvements in compressive strength. Specifically, the compressive strength increased by 7.84%, 13.13%, and 21.04% for 1%, 1.5%, and 2% SSF respectively, compared to normal concrete.

The observed enhancements in compressive strength underscore the effectiveness of SSF as a reinforcing element in concrete. The addition of SSF introduces a network of fibers within the concrete matrix, which effectively redistributes and disperses applied loads, thereby resisting compressive forces more efficiently. This phenomenon is particularly evident in the increasing trend of compressive strength as the percentage of SSF is elevated. The aspect ratio of approximately 22.13 for the SSF plays a crucial role in enhancing the mechanical properties of the concrete, ensuring effective reinforcement throughout the matrix.

Moreover, the split tensile strength tests further corroborate the positive impact of SSF on the mechanical performance of concrete. The split tensile strength of concrete mixes containing 1%, 1.5%, and 2% SSF exhibited consistent improvements compared to normal concrete. The split tensile strength increased by 6.7%, 11.04%, and 14.95% respectively for 1%, 1.5%, and 2% SSF, highlighting the progressive enhancement in tensile resistance with increasing SSF content.

The observed increase in split tensile strength can be attributed to the bridging effect of SSF across cracks, which effectively restrains crack propagation and improves the tensile capacity of the concrete. Additionally, the aspect ratio of the fibers influences their effectiveness in bridging cracks and enhancing tensile strength, further emphasizing the importance of proper fiber geometry in reinforcement applications.

Overall, the experimental results suggest that the incorporation of SSF in concrete mixes offers a viable and effective method for enhancing both compressive and split tensile strengths. The continuous improvement in mechanical properties with increasing SSF content indicates the potential for tailored reinforcement strategies based on specific performance requirements. Furthermore, the utilization of steel scrap as a source of fibers presents an environmentally sustainable approach, offering a dual benefit of waste utilization and performance enhancement in concrete construction.

In conclusion, the study provides valuable insights into the optimization of concrete properties through the integration of SSF. The demonstrated improvements in compressive and split tensile strengths underscore the potential of SSF as a cost-effective and sustainable reinforcement solution for various concrete applications. Further research could explore additional parameters such as durability, impact resistance, and flexural strength to comprehensively evaluate the performance of SSF-reinforced concrete in real-world scenarios.

5.3 CONCLUSION

In conclusion, the findings of this study underscore the considerable potential of steel scrap fibers (SSF) in enhancing the mechanical properties of concrete. Through systematic evaluation of compressive and split tensile strengths, it becomes evident that the incorporation of SSF leads to significant improvements in both aspects, highlighting its effectiveness as a reinforcement technique.

The compressive strength tests conducted on concrete blocks formulated with M30-grade concrete mix served as a baseline for evaluating the impact of SSF. Normal concrete, without any fiber incorporation, exhibited a compressive strength of 30.33 MPa after the 28-day curing period. Subsequent tests on concrete mixes containing 1%, 1.5%, and 2% SSF revealed consistent enhancements in compressive strength. Notably, the compressive strength increased by 7.84%, 13.13%, and 21.04% for 1%, 1.5%, and 2% SSF respectively, compared to normal concrete. This progressive improvement in compressive strength highlights the effectiveness of SSF in reinforcing the concrete matrix and enhancing its load-bearing capacity.

Furthermore, the split tensile strength tests provided valuable insights into the tensile resistance of SSF-reinforced concrete. Concrete mixes containing varying percentages of SSF consistently exhibited improvements in split tensile strength compared to normal concrete. The observed increases of 6.7%, 11.04%, and 14.95% for 1%, 1.5%, and 2% SSF respectively demonstrate the ability of SSF to mitigate crack propagation and enhance the tensile capacity of concrete. The bridging effect of SSF across cracks plays a crucial role in improving the overall tensile behavior of the concrete matrix, highlighting the importance of proper fiber geometry in reinforcement applications.

The observed enhancements in both compressive and split tensile strengths can be attributed to the effective redistribution and dispersal of applied loads by the network of SSF within the concrete matrix. The aspect ratio of approximately 22.13 for the SSF further contributes to their effectiveness in reinforcing the concrete, ensuring uniform distribution of fibers throughout the matrix and optimizing mechanical performance.

Moreover, the utilization of steel scrap as a source of fibers presents significant environmental benefits, aligning with sustainability goals in construction. By repurposing steel scrap into reinforcing fibers, this approach offers a dual advantage of waste utilization and performance enhancement in concrete construction. This sustainable aspect adds further value to the adoption of SSF in concrete reinforcement strategies.

5.4 FUTURE SCOPE

Looking into the future, the transformation of steel scrap into reinforcing fibers for concrete presents a promising avenue for sustainable infrastructure development. Continued research and innovation in this field hold the potential to revolutionize construction practices, offering environmentally friendly solutions while mitigating the carbon footprint associated with traditional concrete production. As technology advances, there is scope for refining the process of converting steel scrap into high-performance fibers, optimizing their properties to enhance the strength, durability, and resilience of concrete structures. Furthermore, exploring novel methods for incorporating these fibers into concrete matrices could lead to the development of next-generation construction materials with superior mechanical properties and reduced environmental impact. Collaborative efforts between academia, industry, and policymakers will be crucial in driving forward these advancements, fostering a sustainable approach to infrastructure development that meets the needs of future generations while preserving our planet's resources.

5.5 SUMMARY

In summary, the integration of steel scrap fibers in concrete mixes offers a viable and effective method for enhancing both compressive and split tensile strengths. The continuous improvement in mechanical properties with increasing SSF content indicates the potential for tailored reinforcement strategies based on specific performance requirements. Future research endeavors could explore additional parameters such as durability, impact resistance, and flexural strength to comprehensively evaluate the performance of SSF-reinforced concrete in real-world applications. Overall, the findings of this study contribute to the ongoing efforts in optimizing concrete properties and advancing sustainable construction practices through innovative reinforcement techniques like SSF integration.

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