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"A Comprehensive Study on Sisal Fiber–Reinforced Concrete with Silica Fume as a Cementitious Modifier"

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Abstract

Traditionally, sisal fibers have been used for ropes, mats, carpets, and decorative products, but in recent decades, their application in civil engineering—especially in cementitious composites—has gained substantial importance. This study provides an overview of the recent advancements in sisal fiber–reinforced concrete (SFRC). Key characteristics of sisal fibers, their interaction with the concrete matrix, and their influence on fresh properties, mechanical strength, and durability were critically examined. The results indicate that the addition of sisal fibers decreases the flowability/workability of concrete due to increased internal friction and water absorption. However, the mechanical and durability properties significantly improve when fibers are added in suitable proportions. For the compressive strength evaluation, the conventional concrete specimen is designated as CC, while the sisal fiber–reinforced specimen is labelled S-2.0. The compressive strength of SFRC (S-2.0) was found to be 38.75 N/mm², and the maximum compressive strength achieved in the modified mix was 43.75 N/mm². After 28 days of curing, the strength increased by 46.59% compared with the control concrete. Similarly, for the split tensile strength, the specimen S-2.0 showed a value of 6.67 N/mm², representing a 46.59% increase over the conventional concrete mix after 28 days. This demonstrates that sisal fibers significantly enhance the tensile performance by improving crack resistance and energy absorption capacity.

Keywords: Conventional concrete, Reinforced Concrete, Sisal Fibres Concrete, Compressive Strength, Tensile Strength and Flexural Strength

1. Introduction

Sisal Fiber Reinforced Concrete (SFRC) is an innovative composite material that incorporates natural sisal fibers into the concrete matrix to enhance its mechanical properties and durability. Sisal is a natural fiber derived from the leaves of the sisal plant, known for its high tensile strength, low cost, and biodegradability, making it an environmentally friendly alternative to synthetic fibers in concrete reinforcement. Incorporating sisal fibers into concrete improves tensile strength, toughness, and crack resistance, addressing the inherent brittleness of conventional concrete.

Silica fume powder, an ultrafine byproduct of silicon metal and ferrosilicon alloy production, is widely used as a supplementary cementitious material due to its excellent pozzolanic properties. When added to concrete, silica fume significantly enhances the density and bonding of the cement matrix, resulting in improved compressive strength and durability.

The combination of sisal fibers and silica fume powder in concrete aims to leverage the advantages of both materials: the fiber's crack-bridging capability and the pozzolanic enhancement of the cementitious matrix. Experimental investigations into the mechanical properties of SFRC with silica fume focus on optimizing the mixture proportions to maximize strength, toughness, and durability for sustainable and high-performance construction applications. This research direction aligns with the growing interest in using natural fibers and industrial byproducts to create eco-friendly, cost-effective concrete composites with superior mechanical characteristics.

The use of unconventional (or green) building materials in the construction of sustainable structures has been growing fast. Particular focus is placed on concrete blocks reinforced with vegetable fibers, which are notable for their low cost and widespread availability in many developing nations. Vegetable fibers improve the mechanical qualities of concrete, regulate the formation and spread of cracks, and typically boost the tensile strength, toughness, and ductility of the materials they are employed in. This allows for relatively high deformations without compromising the integrity of the material. These surveys indicate that when added to the cementitious matrix, cellulosic or vegetable fibers improve the mechanical, thermal, and physical performances of cement-based composites by increasing their flexural strength, toughness, and impact resistance, decreasing drying shrinkage, increasing thermal conductivity, and increasing sound absorption. Conversely, because they are renewable and far less expensive, natural fibers can increase the sustainability of cement composites. Using natural fibers in low-cost building has gained popularity in recent years. A novel and unique class of building materials known as concrete reinforced with natural fibers (NFRC) performs nearly identically to traditional concrete composites reinforced with metallic, organic, or synthetic fibers. Concrete is always vulnerable to acid damage because of its high alkalinity. Therefore, an attempt was made in this inquiry to understand how standard concrete of M30 grade specimen behaves when it is cured with acid, such as Na2Co3.The most potent compounds that have an impact on the long-term resilience of concrete structures are sulphate and chloride. The durability and qualities of M30 grade, both with and without additional cementing materials, are presented in this study.

2. **Objective of the study**

1. Examine the “Performance Evaluation of Sisal Fiber Reinforced Concrete Modified with Silica Fume Powder” such as its mechanical strengths.
2. Study the workability of fresh Sisal Fiber Reinforced Concrete (SFRC) with varying silica fume content.
3. To evaluate the compressive, split tensile, and flexural strength of SFRC incorporating silica fume at different replacement levels ,e.g., i.e. 0% of Silica fume powder and 100% of OPC, 0% of Silica fume powder and 100% of OPC, 5% of Silica fume powder and 95% of OPC, 10% of Silica fume powder and 90% of OPC, 15% of Silica fume powder and 85% of OPC, 20% of Silica fume powder and 80% of OPC, 25% of Silica fume powder and 75% of OPC, 30% of Silica fume powder and 70% of OPC, of total dosage (i.e.30%) by weight of cement.
4. To determine the optimum sisal fiber percentage 1.5% & 2.5 % that balances strength and workability.
5. To analyse the failure pattern and crack propagation in SFRC specimens.

6. Sisal fibers exhibit high moisture sensitivity, which can lead to deterioration when exposed to water or humid conditions.
7. The alkaline environment of cement can degrade sisal fibers over time, reducing their effectiveness as reinforcement.
8. The long-term durability of SFRC in various environmental conditions (acidic, saline, etc.) remains a significant concern.
9. Material tests are conduct the materials such as OPC cement with Silica fume powder, fine aggregates, coarse aggregates and fibers. Based on the materials test values cement, fine aggregate, coarse aggregate and sisal fiber using IS10262-2019 we design for M30 grade concrete.

3. Problem Statement

1. Comparing Sisal Fibers Reinforced Concrete (SFRC) to conventional concrete, it is more workable with OPC cement by partially replacement of Silica fume powder.
2. Conventional concrete Specimen Description CC Compressive strength and Sisal Fibers Reinforced Concrete (SFRC) is Maximum compressive strength Increase in strength at 7,14 & 28 days with OPC cement by partially replacement of Silica fume powder.
3. Conventional concrete Specimen Description CC Split tensile strength and Sisal Fibers Reinforced Concrete (SFRC) is Maximum Split tensile strength Increase in strength at 7 & 28 days with OPC cement by partially replacement of Silica fume powder.
4. Conventional concrete Specimen Description CC Flexural tensile strength and Sisal Fibers Reinforced Concrete (SFRC) is Maximum Flexural tensile strength Increase in strength at 28 days with OPC cement by partially replacement of Silica fume powder.
5. With varying percentage of Na2Co3 treated sisal fibers such as 1.5 %& 2.5%.
6. In this experiment 1.5 %& 2.5% of total dosage of fiber content was fixed with Supplementary materials Silica fume powder in 5%,10%,15%,20 & 25 % by Weight of Cement.

4.Methodology

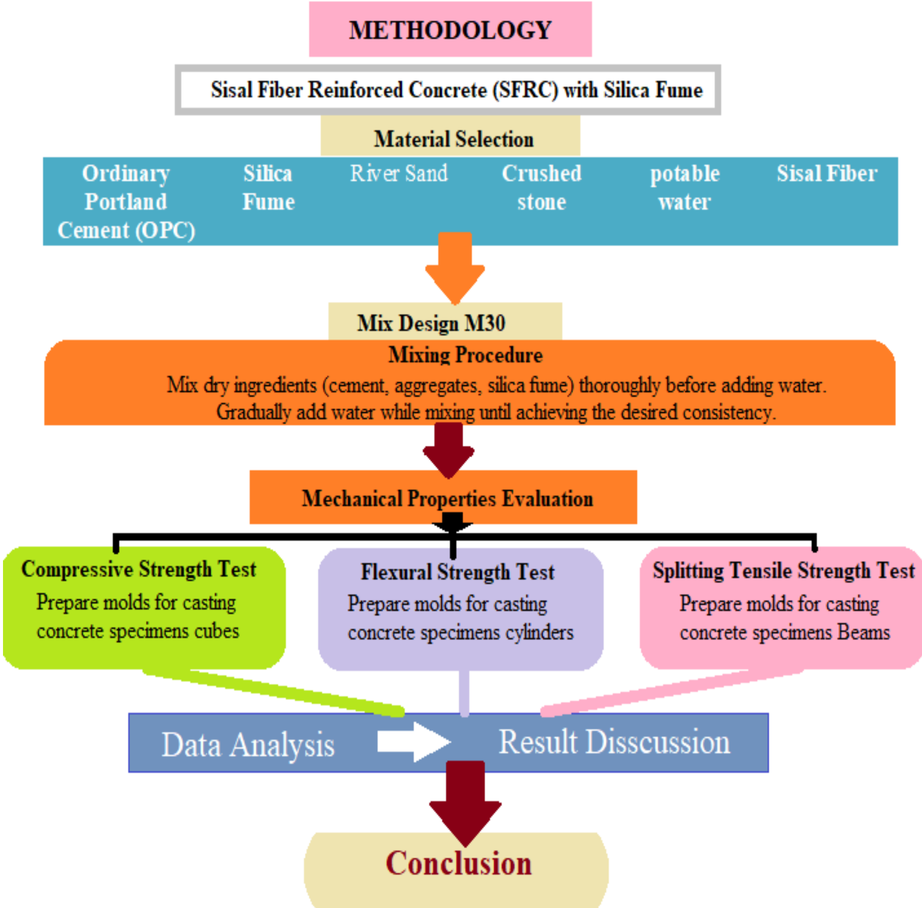

Figure 1; Methodology of Sisal Fiber Reinforced Concrete with Silica Fume

The target mean strength (f target) is calculated to account for variations in concrete strength.

Therefore,

$$F_{target} = f_{ck} + 1.65 \times S$$

$$F_{target} = 30 + 1.65 \times 5 = 38.25 \text{ N/mm2}$$

Or

$$F_{target} = f_{ck} + X$$

$$30 + 6.5 = 36.5 \text{ N/mm2}$$

The higher value is adopted, so the target strength is 38.25 N/mm2

Table no. 1 ; Mix proportion of M30 Grade of concrete			
Cement	**Water**	**Fine aggregate**	**Coarse aggregate**
359 kg	**158 lts**	**760.60 kg/m3**	**1125.73 kg/m3**
1	**0.44**	**2.12**	**3.14**

5. Results And Discussion

The combined use of **sisal fibers** and **silica fume** significantly improves the mechanical behavior of concrete. While silica fume enhances **strength, density, and durability**, sisal fibers enhance **ductility, toughness, and crack resistance**.

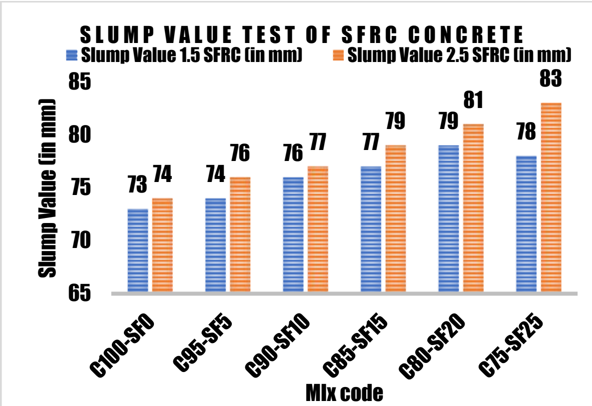

Figure 2; Slump Value Test of SFRC Concrete with 1.5 % & 2.5 % Sisel Fiber (Volume of Concrete)

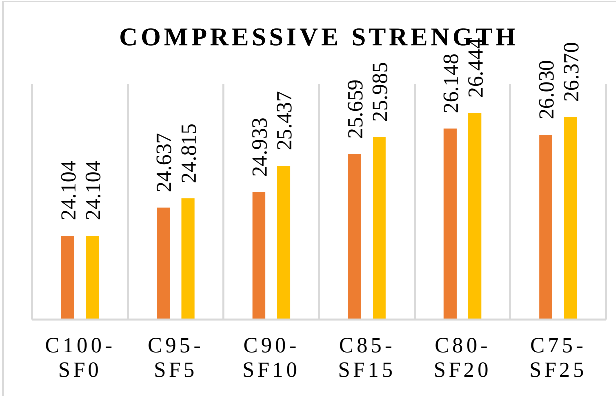

Figure 3; Compressive Strength of 1.5% & 2.5% Sisal Fiber in SFRC Concrete at 7 days

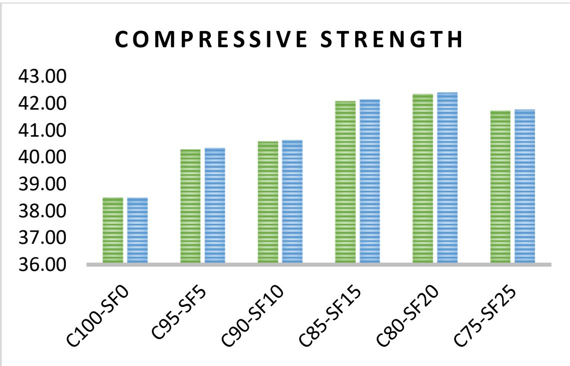

Figure 4; Compressive Strength of 1.5% & 2.5% Sisal Fiber in SFRC Concrete at 28 days

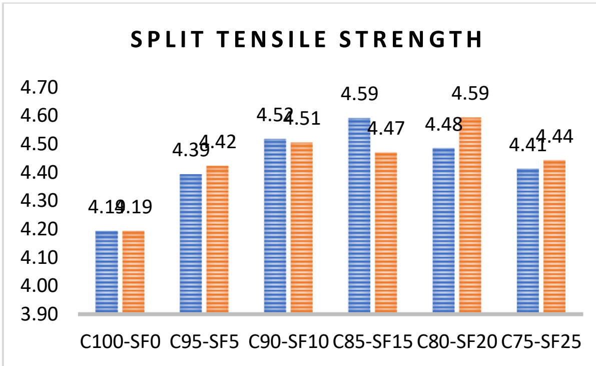

Figure 5; Split tensile strength with 1.5% & 2.5% Sisal Fiber in SFRC Concrete at 28 days

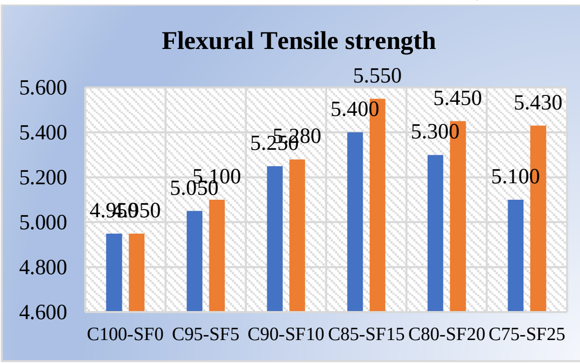

Figure 6; Flexural strength with 1.5% & 2.5% Sisal Fiber in SFRC Concrete at 28 days

Figure 7; Compressive strength test by Er. Ankit Gupta Under Supervisor Prof. Kamlesh Kumar Choudhary

6. Conclusion

In conclusion, experimental studies on the mechanical and physical characteristics of Sisal Fibers Reinforced Concrete (SFRC) with Silica fume Powder.

1. Comparing Sisal Fibers Reinforced Concrete (SFRC) to conventional concrete with Silica fume Powder as a partial replacement of OPC cement, it is more workable.

C80-SF20	Slump Value with SFRC 1.5 %	79 mm
C75-SF25	Slump Value with SFRC 2.5 %	83 mm

2. Comparing compressive strength of Sisal Fibers Reinforced Concrete (SFRC) to conventional concrete with Silica fume Powder as a partial replacement of OPC cement, it is more strength.

Mix designation	Age of Curing	Average Strength with SFRC 1.5 %	Average Strength with SFRC 2.5 %
C80-SF20	7 Days	26.148 N/ mm^2 with 8.499%	26.444 N/ mm^2 with 9.728 %
C80-SF20	28 Days	42.35 N/ mm^2 with 10.04 %	40.29 N/ mm^2 with 10.184%

3. Comparing Split tensile strength of Sisal Fibers Reinforced Concrete (SFRC) to conventional concrete with Silica fume Powder as a partial replacement of OPC cement, it is more strength.

Mix designation	Age of Curing	Sisal Fibers Reinforced Concrete (SFRC) %	Split tensile strength
C85-SF15	28 Days	Average Strength with SFRC 1.5 %	4.59 N/ mm^2 with 9.59 %
C80-SF20	28 Days	Average Strength with SFRC 2.5 %	4.59 N/ mm^2 with 9.63%

4. Comparing Flexural strength of Sisal Fibers Reinforced Concrete (SFRC) to conventional concrete with Silica fume Powder as a partial replacement of OPC cement, it is more strength.

Mix designation	Age of Curing	Sisal Fibers Reinforced Concrete (SFRC) %	Split tensile strength
C85-SF15	28 Days	Average Strength with SFRC 1.5 %	4.59 N/ mm^2 with 9.59 %
C80-SF20	28 Days	Average Strength with SFRC 2.5 %	4.59 N/ mm^2 with 9.63%

Declaration of Conflicting Interests

The authors declare no potential conflicts of interest with respect to the research, authorship and publication of this article.

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References

1. Bernard Adjei Antwi-Afari (2024) "Influence of fiber treatment methods on the mechanical properties of high strength concrete reinforced with sisal fibers" https://doi.org/10.1016/j.heliyon.2024.e29760 Received 13 January 2024; Received in revised form 11 April 2024; Accepted 15 April 2024 Available online 17 April 2024 2405-8440/© 2024 The Authors. Published by Elsevier Ltd. (http://creativecommons.org/licenses/by-nc/4.0/)
2. Praveen Kumar*1, Kamlesh Kumar Choudhary*2 (July-2024) "Mechanical And Physical Characteristics Of Sisal Fiber Reinforced Concrete (SFRC): An Experimental Study" e-ISSN: 2582-5208 International Research Journal of Modernization in Engineering Technology and Science (Peer-Reviewed, Open Access, Fully Refereed International Journal) Volume: 06/Issue:07/ July-2024 Impact Factor 7.868www.irjmets.com DOI: (https://www.doi.org/10.56726/IRJMETS60676)
3. Praveen Kumar a, Kamlesh Kumar Choudhary b(June 2023) "A Review Study on Sisal Fiber Reinforced Concrete" International Journal of Research Publication and Reviews, Vol 4, no 6, pp 1573-1576 June 2023 International Journal of Research Publication and Reviews Journal homepage: www.ijrpr.com ISSN 2582-7421.
4. M. Aravinda Samy1, Dr. V. Ramasamy2, S. Selvakmar (Oct 2023) "Studies on Properties of Sisal Fiber Reinforced Self Compacting Concrete" International Journal for Research in Applied Science & Engineering Technology (IJRASET) ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538 Volume 11 Issue X Oct 2023.
5. Atul, Mr. Sunil Kumar (August-2022) "Analysis of Mechanical Properties of Concrete with Replacement of Cement from Sisal" e-ISSN: 2582-5208 International Research Journal of Modernization in Engineering Technology and Science (Peer-Reviewed, Open Access, Fully Refereed International Journal Volume:04/Issue:08/August-2022 Impact Factor- 6.752
6. Iniya M.P , Nirmal kumar .K (2021) A Review on Fiber Reinforced Concrete using sisal fiber IVC RAISE 2020 IOP Conf. Series: Materials Science and Engineering 1055 (2021) 012027 IOP Publishing doi:10.1088/1757-899X/1055/1/012027Chalamcharla Venu Gopal (2017) "Partial Replacement of Cement with GGBS in Concrete" International Journal of Advance Research, Ideas and Innovations in Technology
7. Sen t, paul a (2015) confining concrete with sisal and jute frp as alternatives for cfrp and gfrp. Int j sustain built environ 4(2):248–264
8. Ferreira sr, silva fa, lima pr, toledo filho rd (2015) effect of fiber treatments on the sisal fiber properties and fiber–matrix bond in cement based systems. Constr build mater 101(1):730–740
9. de jesus nagahama k, gadéa adsm, lima prl (2015) finite strip modeling of cementitious laminates reinforced with sisal fibers. Cem concr compos 63:8–16
10. Wei j, meyer c (2014) improving degradation resistance of sisal fiber in concrete through fiber surface treatment. Appl surf sci 289:511–523
11. Sen t, jagannatha reddy hn (2014) flexural strengthening of rc beams using natural sisal and artificial carbon and glass fabric reinforced composite system. Sust cities soc 10:195–206
12. Abhishek sharma, tara sen, joyanta pal "flexural characteristics of rc beams retrofitted using frp and cement matrix composite", isor journal of mechanical and civil engineering (isor-jmce), 2016, e- issn: 2278 -1684, p-issn 2320-344x
13. Anand daftardar, jigisha vashi, shirish vichare, "deflection in rcc beam covered with sisal cordage", advance in engineering and scientific research ,2016 2(1).1-7
14. Arslan qayyum khan, qudeer hussain, winyu rattanapitikon and amorn pimanmas. "flexural strengthening of rc beams with sisal fiber composites and sisal fiber rods", research gate,2016, issn 1662-9752 volume 860, p144-147.
15. Athiappan. K, vijaychandrakanth. S, "experimental study on flexural behaviour of sisal fiber in reinforced concrete beams", international journal of research in engineering & technology, 2014, volume 3, issue 5, issn 2278-0181.
16. Nagarajan.l, s.pavithra, "use of natural fibers for structural engineering", international journal of science and research , 2016,volume 5,issue 7, issn 2319-7064.
17. Preetam prem raj.d, "shear and flexural strengthening in rc beams using frp", international journal of science, technology & management 2015, volume 4, issue 5, issn 2394-1537
18. Shetty M.S. "Concrete Technology" Chand S. and Co. Ltd.,India (2004).
19. IS:456-2000, "Plain and Reinforced Concrete - Code of Practice "Bureau of Indian Standards.
20. IS:456-2000, "Plain and Reinforced Concrete - Code of Practice "Bureau of Indian Standards.
21. IS: 2386-1963 (Part I to Part III), "Indian Standards Method of Test for Aggregate for Concrete", Bureau of Indian

Standards, New Delhi, India

22. IS: 383-1970, "Indian Standard Specification for coarse and fine aggregates from Natural Source for Concrete", Bureau of Indian Standards, New Delhi, India.
23. IS: 8112-1989, "Specifications for 43-Grade Portland Cement", Bureau of Indian Standards, New Delhi, India.
24. IS: 10262-1982," Guidelines for Concrete Mix Design",Bureau of Indian Standards, New Delhi, India
25. IS: 516-1959, "Indian Standard Code of Practice-Methods of Test for Strength of Concrete", Bureau of Indian Standards, New Delhi, India.
26. IS: 5816-1999, "Method of Test Splitting Tensile Strength of Concrete", Bureau of Indian Standards, New Delhi, India.
27. IS: 9103-1999, "Specification for Concrete Admixtures" Bureau of Indian Standards, New Delhi