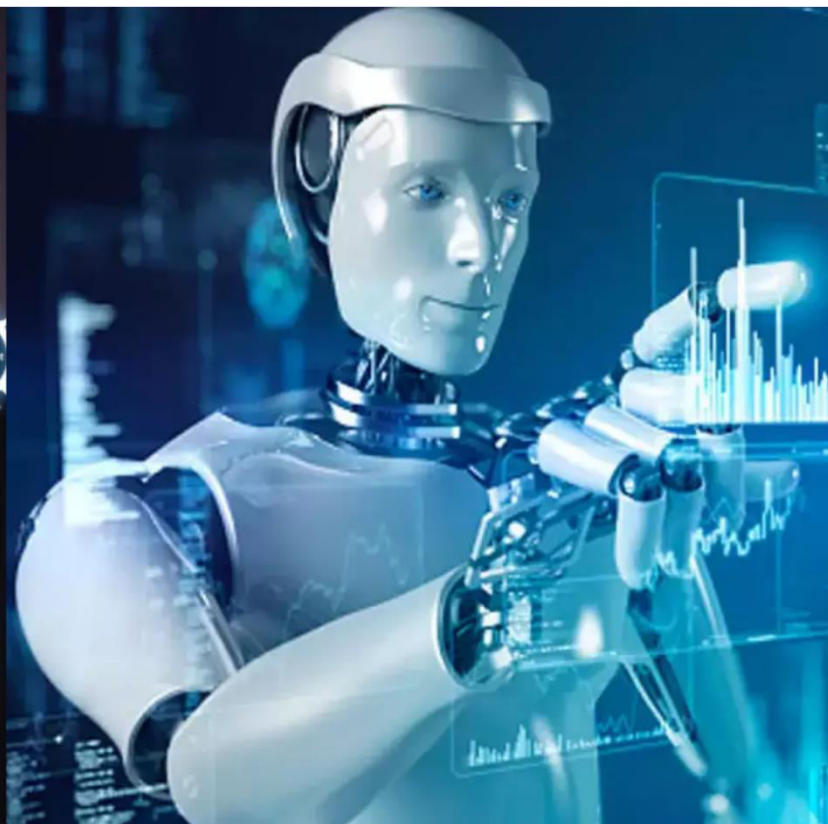




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Review of Experimental Studies on Sisal Fiber and Silica Fume Modified Concrete

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ABSTRACT: This review presents a comprehensive overview of research studies on Sisal Fiber Reinforced Concrete (SFRC) modified with Silica Fume Powder. The combination of natural fibers and pozzolanic materials has gained attention for enhancing the strength, ductility, and sustainability of concrete. The paper summarizes various experimental findings on workability, compressive, tensile, and flexural strengths, durability characteristics, and microstructural performance. It also highlights the optimum fiber content and silica fume replacement levels, concluding with research gaps and recommendations for future studies.

I. INTRODUCTION

Concrete is one of the most widely used construction materials across the world due to its versatility, strength, and economic advantages. However, the production of **Ordinary Portland Cement (OPC)** — a primary ingredient in concrete — is energy-intensive and contributes significantly to global **CO₂ emissions**, which account for nearly 8% of total greenhouse gases. The growing demand for sustainable infrastructure has therefore encouraged researchers to explore **eco-friendly and resource-efficient alternatives** in concrete production. This includes the **use of industrial by-products, natural fibers, and supplementary cementitious materials (SCMs)** to minimize environmental impact while improving mechanical performance.

1.1 Sustainable Concrete and Waste Minimization

Sustainable concrete aims to balance performance with environmental responsibility by reducing the use of virgin materials and carbon emissions during production. Waste minimization in the construction industry involves substituting traditional materials with renewable or waste-derived components. The incorporation of **pozzolanic materials**, such as silica fume, fly ash, and slag, can partially replace cement, leading to a reduction in energy consumption and CO₂ output. Similarly, the addition of **natural plant-based fibers** improves the ductility and toughness of concrete, contributing to enhanced durability and crack control.

1.2 Importance of Natural Fibers (Sisal Fiber)

Among various natural fibers, **sisal fiber** has gained significant attention in concrete research due to its **high tensile strength, low density, biodegradability, and renewability**. Derived from the leaves of the *Agave sisalana* plant, sisal fiber acts as a **micro-reinforcement**, enhancing post-cracking behavior and preventing brittle failure. When appropriately treated and distributed, sisal fibers improve **flexural strength, impact resistance, and energy absorption capacity** of concrete. Their availability in tropical regions and low cost make them a promising material for sustainable construction applications.

1.3 Role of Silica Fume as a Supplementary Cementitious Material

Silica fume (SF), a by-product of the silicon and ferrosilicon alloy industries, is a highly reactive pozzolanic material with an average particle size 100 times smaller than cement grains. When used as a **partial replacement for cement**, typically in the range of 5–15%, silica fume reacts with calcium hydroxide to form additional **calcium silicate hydrate (C–S–H)**, which refines the pore structure and enhances strength and durability. Its incorporation leads to reduced permeability, improved bond strength, and higher resistance to chemical attacks — making it an ideal component for high-performance and fiber-reinforced concretes.

1.4 Scope and Objectives of the Review

The primary objective of this review is to **synthesize and evaluate** the existing literature on the combined use of **sisal fiber and silica fume** in concrete. The paper focuses on understanding how these materials influence the **physical and mechanical properties** of concrete, including **workability, compressive strength, flexural behavior**, and **durability characteristics**. Additionally, it aims to identify the **optimum mix proportions, limitations**, and **future research needs** to promote the use of sisal fiber–silica fume composites in sustainable construction practices.



Figure 1: Ingredients of sisal fiber concrete with silica fume

II. LITERATURE REVIEW

Relevance to current Research

No.	Paper Title	Author Name	Key Points	Remark
1	Influence of fiber treatment methods on the mechanical properties of high strength concrete reinforced with sisal fibers	Bernard Adjei Antwi-Afari (2024)	The treated fibers were mixed with concrete with percentage fiber content of 0.5 %, 1.0 %, 1.5 % and 2 % and their compressive strength, tensile strength and flexural strength were tested.	The compressive strength was also improved by the thermal and hybrid treatment methods, however, the chemical treatment method led to a reduction in the compressive strength. With regard to the flexural strength, all the treatment methods considered led to a reduction in the flexural strength when compared to the concrete without fibers.
2	“Mechanical And Physical Characteristics Of Sisal Fiber Reinforced Concrete (SFRC): An Experimental Study”	Praveen Kumar*1, Kamlesh Kumar Choudhary*2 (July-2024)	1) Sisal is an affordable, easily obtainable, renewable natural fiber. Because of its low cost, low density, high specific strength, high modulus, little health risk, ease of accessibility in some states, and renewability, SSF is a viable reinforcement material for use in concrete. 2) Finding new applications for SSF-reinforced concrete, which is typically used to manufacture ropes, mats, carpets, and other decorative objects, has become increasingly important in recent centuries. The findings demonstrate that SSF reduced flowability while increasing strength and durability.	Conventional concrete Description of Specimen CC The specimen description for Sisal Fiber Reinforced Concrete (SFRC) is S-2.0, and its compressive strength is 38.75 N/mm ³ . The maximum compressive strength is 43.75 N/mm [^] , and after 28 days, there is a 46.59% increase in strength. Conventional concrete Description of Specimen CC The specimen description for Sisal Fiber Reinforced Concrete (SFRC) is S-2.0, and its split tensile strength is 38.75 N/mm ² . The maximum split tensile strength is 6.67 N/mm ² , and after 28 days, the strength

				increases by 46.59%.
3	“Studies on Properties of Sisal Fiber Reinforced Self Compacting Concrete”	M. Aravinda Samy1, Dr. V. Ramasamy2, S. Selvakmar (Oct 2023)	To evaluate the mechanical properties of self-compacting concrete (M30) with sisal fibers. Self-compacting concrete (SCC) mixes are produced by replacing the cement with Fly ash and with addition of sisal fiber of 0, 0.5%, 1% and 1.5% and length of fibers considered are 5mm, 10mm, and 20mm to the SCC concrete. Sulphonated naphthalene Formaldehyde condensates-based SP is used as water reducing agent. Compressive strength of SCC mix has to be determined at 7, 14 and 28 days. Flexural strength of SCC mix has to be determined at 14 and 28 days. Impact strength of SCC mix has to be determined at 28 days.	1) In the present investigation the maximum sisal fibre content can be used in SCC is 1%, where the slump flow is 17.24% less than the reference slump flow value. 2) At the sisal fibre content of 1.5%, the mix proportion of SCC for M30 grade of concrete has to be revised especially with respect to the finer portions of the mix, so that the mix will be consistent, without separation of sisal fibres from the cement matrix.
4	“Mechanical properties of recycled aggregates concrete with sisal fiber and silica fume”	Vishnu Vijayan (2022)	The government would incur colossal losses and the ecosystem will suffer greatly degrading the sustainability of concrete. Hence in this research, the objective was chosen to recycle the old Concrete waste as coarse aggregate with different grades to prepare new mixes in M30 mix design. We can solve the impact of these wastes by strengthening and reutilizing the demolished wastes by adding sisal fibres with silica fumes as admixtures to the recycled aggregate concrete to improve the mechanical properties of the RAC.	The casted cubes were tested by Compression Testing Machine. From the graph it is clear that the maximum value of compressive strength was obtained for the 28 days cured specimen which is 30.56 for the M1 mix, M2 Mix is 31.2 N/mm ² and M3 Mix is 32.30 N/mm ² . Hence maximum compressive strength is obtained at 28 days for M3 Mix. the maximum compressive strength is obtained in 1.5% of sisal fibres and 15% of silica fumes.
5	A Review on Fiber Reinforced Concrete using sisal fiber.	Iniya.M.P , Nirmalkumar.K (2021)	The utilization of sisal, a natural fiber with increased mechanical efficiency, as reinforcement in an exceeding matrix based on supported cement. The proportion of sisal fiber used in concrete ranged from 0.1% to 2% of concrete and length of fiber 50mm to 60mm fiber length in concrete with aspect ratio.	By adding short fibers, tensile strength is improved, thaw resistance is frozen, impact resistance, and concrete brittleness are reduced. In general, fiber does not enhance the concrete strength, as the replacement moment is reduced in the reinforcement of structural steel.

III. GAP OF STUDY

1. While several studies have examined the use of either sisal fibers or silica fume individually in concrete, there is still limited research on their combined effect on mechanical and durability properties of concrete.
2. There is no standard mix design guideline available for the optimum dosage of sisal fibers and silica fume, leading to inconsistent results across various research works.
3. Most existing studies focus mainly on compressive and flexural strength, with less emphasis on durability parameters such as water absorption, permeability, sulfate resistance, and long-term behavior.

4. The microstructural interaction between sisal fibers and silica fume within the cement matrix (such as bonding, pore structure, and fiber–matrix interface) is not thoroughly explored using techniques like SEM or XRD.
5. Very few studies have investigated how sisal fibers perform over extended periods—especially considering fiber degradation, moisture sensitivity, and alkali resistance within the concrete.
6. Most experimental works are restricted to small-scale specimens; there is a lack of large-scale or field-based studies applying SFRC in beams, slabs, or pavement structures.
7. Although sisal fiber is a sustainable material, comprehensive life-cycle assessment (LCA) and cost-benefit analyses of SFRC with silica fume are rarely reported.

IV. MATERIALS PROPETIES

Experimental Works of Ordinary Portland Cement (OPC)

This is a type of Ordinary Portland Cement (OPC) that is commonly used in general construction projects. 43 Grade Cement is called so because it refers to the minimum compressive strength that the cement can achieve after 28 days of curing, which is 53 megapascals (MPa). The cement's specific gravity is 3.15, and the setting time is 30 minutes **at first**.

Table 1; Test Results of Physical Properties of Cement

Properties	IS Code	Values Obtained	Standard Value
Specific Gravity	IS 4031 (Part 11) - 1988	3.15	-
Fineness	IS 4031 (Part 1) - 1988	5%	<10
Normal Consistency	IS 4031 (Part 4) - 1988	30%	
Compressive Strength	IS 4031 (Part 6) - 1988	42.4 Mpa (7 days)	>37 Mpa
Initial Setting Time	IS 4031 (Part 5) -1988	160 minutes	>30
Final Setting Time	IS 4031 (Part 5) -1988	230 minutes	<600

Narmada River Sand as a Fine aggregate

Natural Narmada River Sand refers to the sand naturally found along the banks and bed of the Narmada River, which flows mainly through Madhya Pradesh, Maharashtra, and Gujarat in India. It is one of the most preferred natural river sands for construction and concrete production due to its purity, grain shape, and consistent quality.

Table 2; Physical Properties of Narmada River Sand (Fine aggregate)

S. No.	Characteristics	Result
1	Aggregate type	River Sand
2	Specific gravity	2.57
3	Fineness modulus	2.60

Coarse Aggregates

Table 3; Test Results of Physical Properties of Cement

S. No.	Characteristics	Result
1	Aggregate type	Crushed Stone
2	Specific gravity	2.80
3	Fineness modulus of 20 mm coarse aggregate	3.29

Silica Fume Powder

Silica fume is available as a fine, light-to-dark gray powder, in both loose and densified forms for easier handling and mixing. Sometimes it is converted into a slurry with water for uniformity during storage and transportation.

Its production has become more important due to environmental regulations, as capturing silica fume prevents the emission of fine particulates from industrial processes.

Silica fume powder is a valuable material for achieving stronger, longer-lasting, and more durable cementitious products in demanding engineering applications.

Table no. 4 ; Physical properties of Silica Fume Powder

Microscopic investigation	extremely fine and spherical, with a size around 0.1 to 0.2 microns,
Burning temperature	range of 1600°C to 1700°C
Grinding time	around 5 to 120 minutes
Fineness	over 95%
Specific gravity	2.2

V. CONCLUSION

1. The review of existing literature on Sisal Fiber Reinforced Concrete (SFRC) modified with Silica Fume Powder reveals that the combined use of natural fibers and pozzolanic materials offers significant potential for developing sustainable and high-performance concrete composites.
2. The addition of sisal fiber enhances the tensile, flexural, and impact strength of concrete by improving post-cracking ductility and energy absorption, whereas silica fume refines the microstructure, increases compressive strength, and reduces permeability through its pozzolanic reaction and pore-filling effect.
3. Most studies indicate that incorporating 0.5–2% sisal fiber and 5–15% silica fume achieves optimum improvements in both mechanical and durability characteristics. However, higher fiber contents may reduce workability due to poor dispersion, while excessive silica fume can increase water demand. Proper mix design, fiber treatment, and the use of superplasticizers are therefore essential to maintain desired workability and strength balance.
4. From a sustainability perspective, utilizing agricultural residues like sisal fibers and industrial by-products such as silica fume contributes to waste reduction, lower carbon emissions, and resource conservation. These materials provide a cost-effective and environmentally responsible alternative to fully cement-based concrete, aligning with global goals for green construction and circular economy practices.
5. Despite the proven benefits, gaps remain regarding long-term durability, microstructural behavior, and standardization of mix proportions. Future research should focus on hybrid fiber combinations, nano-additives, and life-cycle cost analyses to fully harness the advantages of sisal fiber–silica fume composites in structural applications.

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