An Experimental Investigation of Fiber-Reinforced Concrete Incorporating Sisal Fiber: A Revolution Towards Sustainability

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Abstract

The sisal fibre concrete have preferred durability and effect qualities over the concrete. It is observed that the addition of sisal fibre in concrete changes the method of failure from brittle mode of failure to ductile mode of failure when subjected to compression, bending and impact. Owing to its high tensile property it improves rigidity of concrete when blended in ideal fibre proportion and has demonstrated satisfactory upgrade in flexural behaviour such as load-deflection, Moment curvature and crack pattern. The experimental results of sisal fibre concrete is compared with conventional concrete results.

Keywords: concrete, fibre-reinforced concrete, sisal fibre, tensile,

Introduction

Cement is that the world's most generally used artifact with an estimated annual use of about 2.86 billion a lot of cement. However, cement production is harmful to the environment to the emissions of dioxide. Approximately 0.8 a lot of CO_2 per ton produced is estimated to be released into the atmosphere. Natural Fiber cement and cementitious composites commonly used primarily for low-cost housing activities and there have also been growing interest in natural fibre composites and lots of research goes around the world. The foremost important technical features like excellent lightweight tensile properties, more strength, high impact resistance, and better post cracking behaviour so on. The need for construction services is rising as the world's population rises. Concrete is the greatest and most widely used building material because of its exceptional inherent properties, which include strong compressive capacity, excellent durability, fire resistance, and low penetrability. In addition to these benefits, there are certain drawbacks, such as reduced tensile strength, brittleness, poor fracture resistance, and decreased impact resistance. The creation of techniques to improve the properties of concrete was required due to these problems. Some of these defects, such low tensile strength, can be somewhat remedied by using conventional steel reinforcement bars and, to a lesser extent, by adding the proper quantity of certain fibres to concrete.

Natural fibres are now among the most widely used options for concrete reinforcement in terms of sustainability and biodegradability due to their non- toxicity and environmental friendliness, attributes that are particularly favourable for the manufacturing of natural fibres. Instead, they assist in lowering CO_2 emissions into the atmosphere. Bio composites are becoming more well-known as desirable materials in a variety of industries, including biomedicine, building, architecture, and the automobile industry. Natural fibres can be found all over the world, are more rigid than synthetic fibres, cost less, and are recyclable. The shells of ripe coconuts are harvested to make coir, a common natural fibre used to make hard, strong objects. Due to their many advantages, such as their widespread availability, biodegradability, light weight, low cost, and ease of manufacture, natural fibre-based bio composites have essentially supplanted synthetic polymers for a variety of purposes. Researchers have proposed a variety of natural fibre concretes for use in a range of technical applications. A recent study found that coir fibres from about 50 billion coconuts are harvested worldwide.

Materials and Methods

Methodology in concrete preparation refers to the systematic process of selecting materials, mixing, casting, curing, and testing concrete to ensure it meets the required strength, durability, and workability standards. It outlines step-by-step procedures used in concrete production for construction or research purposes. The methodology for working with concrete depends on the purpose, whether it is for construction, testing, or research. Below is a general methodology covering concrete mix design, preparation, casting, curing, and testing.

1. Cement

Cement is the binding material in concrete that reacts with water to form a paste, which hardens over time. Portland Pozzolana Cement (PPC) of 53 grade conforming to Indian Standard IS 12269-1987 is used in the experimental program. Cement is a substance that sets and hardens and can bind other material together.

2. Fine Aggregates

Fine aggregates such as sand, it is naturally occurring granular material which is composed of mineral particles and finely divided material. The composition of sand varies depending on the local rock condition and sources, but the most constituent of sand in inland continental setting and non-tropical costal region in silica dioxide in the form of quartz. The second commonly used sand is the calcium carbonate. The sand fill the voids between coarse aggregates, improving concrete's workability and reducing shrinkage.

3. Coarse Aggregates

Coarse aggregate is one of the key components of concrete, providing strength, stability, and durability. It consists of crushed stone, gravel, or other materials that are larger than 4.75mm in size that form the bulk of the concrete mix. Coarse aggregates help in reducing shrinkage and improve the load-bearing capacity and enhancing overall performance of concrete structures.

5.Water

Water is essential for the hydration reaction of cement, which binds the aggregates together. The water-cement ratio is critical, as too much water weakens the concrete, while too little makes it difficult to work with.

Selection and Preparation of Sisal Fibre

1. Fibre Extraction and Treatment

Sisal fibres are extracted from the leaves of the Agave sisalana plant through mechanical or manual processes. The extracted fibres undergo cleaning to remove impurities such as dust, lignin, and natural oils. To enhance the bonding of the fibre with the cement matrix and reduce its water absorption, various treatments are applied, including:

Alkali Treatment (Sodium Hydroxide - NaOH): Improves adhesion by increasing fibre roughness.

Silane Coupling Agents: Enhance durability and bonding with the cement matrix.

Boiling and Drying: Reduces lignin content and increases compatibility with cement.

2. Fibre Cutting and Proportioning

The fibres are cut into appropriate lengths, typically ranging from 10 mm to 50 mm, to ensure proper dispersion within the concrete mix. The recommended fibre content is between 0.5% to 2% by volume of concrete, ensuring an optimal balance between mechanical enhancement and workability.

Concrete Mix Design with Sisal Fibre

1. Materials Used

A standard concrete mix with sisal fibre consists of the following materials:

Cement: Pozzolonic Portland Cement (PPC).

Fine Aggregates: Sand for improved workability.

Coarse Aggregates: Gravel or crushed stone for strength.

Water: Water-cement ratio between 0.4 to 0.6 for hydration.

Sisal Fibres: Added as reinforcement to improve tensile properties.

RESULTS AND DISCUSSIONS

The experimental investigation on fibre-reinforced concrete incorporating sisal fibre highlights its potential as a sustainable alternative to conventional concrete. Based on the findings, the following conclusions can be drawn:

1. **Strength Performance:** Sisal fibre-reinforced concrete exhibited improved tensile and flexural strength compared to conventional concrete. The addition of sisal fibres enhances crack resistance, making it suitable for applications requiring higher ductility. However, compressive strength showed slight variations depending on fibre content and distribution.

2. **Durability Aspects:** The inclusion of sisal fibres contributed to better impact resistance and toughness, reducing the likelihood of sudden failure. However, proper fibre treatment and mix design optimization are necessary to mitigate potential water absorption issues, which may affect long-term durability.

3. **Workability Considerations:** Sisal fibre addition slightly reduced the workability of concrete due to fibre entanglement and water absorption tendencies. Proper mix proportioning and the use of admixtures can help maintain the required consistency. **Economic Feasibility:** Sisal fibres are an affordable and locally available material in many regions, making fibre-reinforced concrete a cost-effective and sustainable alternative to conventional concrete in specific applications, especially in developing countries.

CONCLUSION

Sisal fibre-reinforced concrete presents a promising step towards sustainable construction by improving mechanical properties, enhancing durability, and reducing environmental impact. While it may not entirely replace conventional concrete in all structural applications, it serves as an excellent reinforcement material for non-structural and semi- structural elements, particularly where sustainability and ductility are key concerns.

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Figure 1. Sisal Plant (Agave Sisalana)

Figure 2 Fine Aggregate

Figure 3 Coarse Aggregates

Figure 4. Extracted Fibre Plant

Figure 5. Concrete Materials

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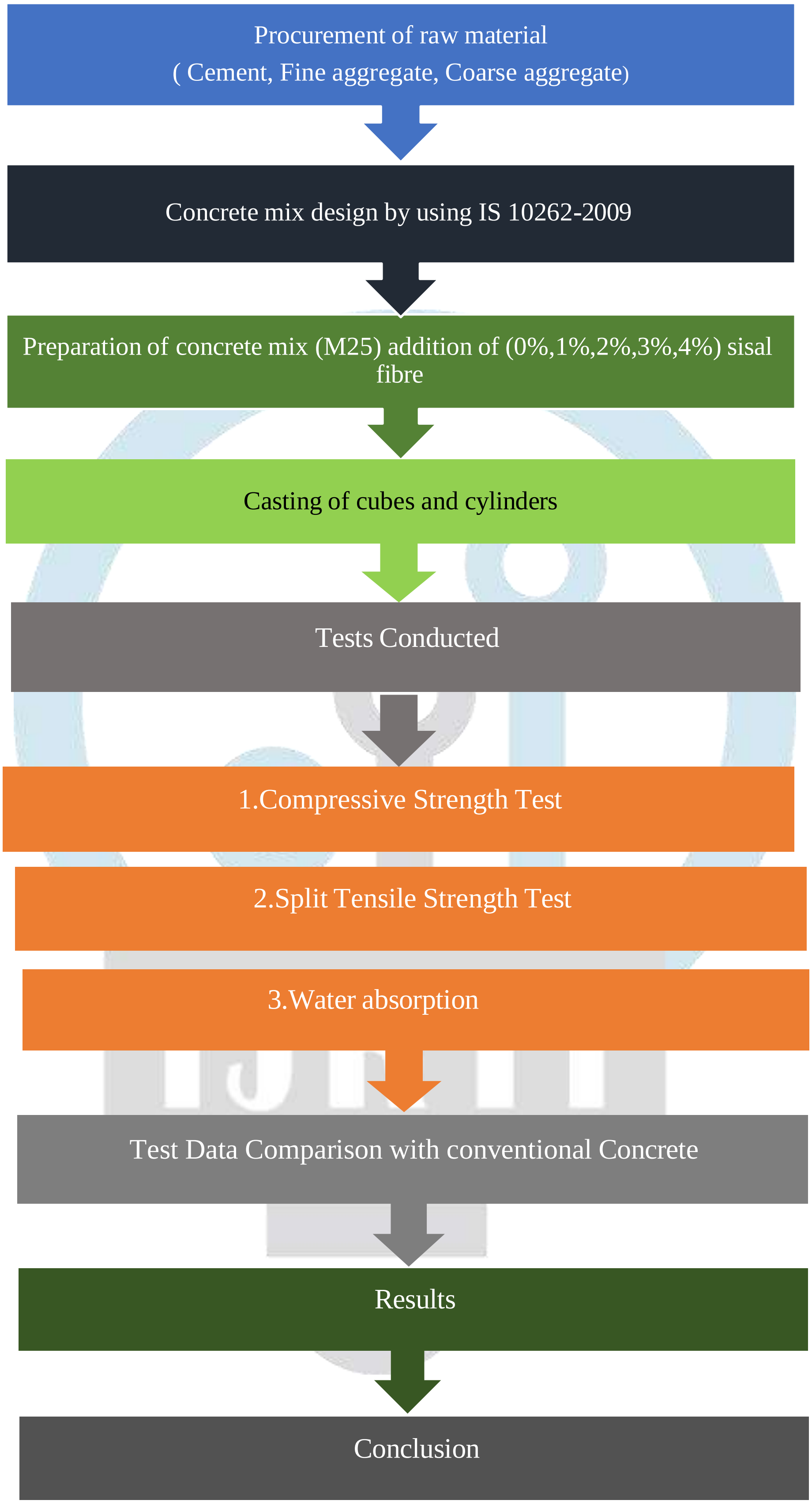
Flow Chart of Methodology



1.1 Comparison of Test results with IS Standards

Table 1: Comparison of cement test results with IS standards

1	Cement	Test Results	IS Standards	IS Code
a	Specific Gravity of Cement	3.15	3.15	IS 1489-1-1991
b	Standard Consistancy of Cement	31%	27%-33%	IS 1489-1-1991
c	Initial and final setting time of cement	Initial=30min Final = 10 hrs	Initial=30 min Final=600 min	IS 1489-1-1991

Table 2: Comparison of Fine aggregates test results with IS standards

2	Fine Aggregate	Test Results	IS Standards	IS Code
a	Sieve Analysis of FA	3.8	3.2-3.6	IS 383
b	Specific Gravity of FA	2.68	2.60-2.75	IS 383
c	Water Absorption	0.94 %	1% - 2%	IS 383

Table 3: Comparison of Coarse aggregates test results with IS standards

3	Cement	Test Results	IS Standards	IS Code
a	Sieve Analysis of FA	1.98	2.60-2.75	IS 383
b	Specific Gravity of FA	2.65	2.60-2.75	IS 383
c	Water Absorption	0.55%	1%-2%	IS 383

Table 4: Comparison of Sisal Fibre test results with IS standard

4	Sisal Fibre	Test Results	IS Standards	IS Code
a	Density	1008 kg/m3	1400 kg/m3	IS 667-1981
b	Tensile Strength	530	400Mpa-800Mpa	IS 667-1981
c	Elongation	3%-7%	2%-7%	IS 667-1981

Table 5: Comparison of Compressive Strength of cubes test results with IS standard

5	Compressive Strength of cubes	Test Results	IS Standards	IS Code
a	Conventional Concrete at 7 days	17.1 Mpa	16-17 Mpa	IS 456-2000
b	Conventional Concrete at 28 days	28.3 Mpa	25 Mpa	IS 456-2000
c	Concrete + Sisal Fibre at 7 days	14.2-21.9 Mpa	At 0.5% 25 Mpa At higher fibre content (1%,2%,3%,4%) strength may vary.	IS 456-2000
d	Concrete + Sisal Fibre at 28 days	24.4-33.4	At 0.5% 25 Mpa At higher fibre content (1%,2%,3%,4%) strength may vary.	IS 456-2000

Table 6: Comparison of Tensile Strength of cubes test results with IS standard.

6	Compressive Strength of cubes	Test Results	IS Standards	IS Code
a	Conventional Concrete at 7 days	1.7 Mpa	1.8-2.2 Mpa	IS 5816-1999
b	Conventional Concrete at 28 days	2.5 Mpa	2.5-3.0 Mpa	IS 5816-1999
c	Concrete + Sisal Fibre at 7 days	2.8 Mpa	3.5 Mpa	IS 5816-1999
d	Concrete + Sisal Fibre at 28 days	3.9 Mpa	4.0 Mpa	IS 5816-1999