Study of coconut fiber reinforced concrete with silica fume and fly-ash

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***Abstract*—Coconut fiber reinforced cement-based materials have found applications in residential housing construction, particularly in non-structural components such as siding and roofing materials. Among natural fibers, coconut fiber stands out as an excellent reinforcement for concrete due to its availability, low cost, and low energy consumption during production. The present work focuses on an experimental investigation of coconut fiber reinforced concrete with the addition of fly ash and silica fume. The study examines the effects of these fibers on work-ability and various strength properties, including compressive strength, flexural strength, and split tensile strength. The fiber content varies from 0% to 3% by weight of cement, with intervals of 0.5%. Specimens such as cubes measuring 150 mm X 150 mm X 150 mm for compressive strength and beams measuring 100 mm x 100 mm x 500 mm for flexural strength and similarly cylinder measuring 150 mm X 300 mm for split tensile strength. All specimens are water-cured and tested at the ages of 7 days and 28 days to assess the performance over time. The investigation reveals that the work-ability of the wet mix decreases as the fiber content increases. However, the inclusion of coconut fibers increases the ductility of concrete, which is a desirable property. Regarding the strength properties, the results show that in the case of coconut fiber reinforced concrete with fly ash and silica fume, the compressive strength increases up to a fiber content of 2.5% and then decreases with further increases in fiber content. The flexural strength increases up to a fiber content of 2% and then decreases. Similarly, the split tensile strength reaches a peak at a fiber content of 2% and subsequently decreases with higher fiber content. These findings provide insights into the mechanical behavior and performance of coconut fiber reinforced concrete with the addition of fly ash and silica fume. The results can be useful for optimizing the fiber content in such composite materials to achieve the desired strength properties for specific applications in construction.**

I. INTRODUCTION

Reinforced concrete (RC) is the most widely used type of concrete and is often used as reinforcement in barsmeshes, spirals, rods or other structures. Various fibrous materials are also used as reinforcement in concrete conventional plain concrete has drawbacks in addition to its low tensile strength, including weak impact strength, ductility, resistance to cracking, and susceptibility to chemical attacks. Fibers with different L/D ratios can have different mechanical properties and are suitable for different applications. Concrete is inherently brittle, lacking tensile strength and ductility. While conventional steel reinforcement in reinforced concrete helps address tensile stresses within its own plane, it has limited effectiveness in mitigating secondary effects like temperature and shrinkage-induced cracking in fresh concrete. This can impact on the overall performance of concrete structures.

As compared to ordinary concrete, coconut fibre reinforced concrete (CFRC) has better tensile and flexural strength, ductility, toughness, impact resistance, and fatigue resistance by introducing continuous and uniformly dispersed unidirectional fibres into the concrete matrix. CFRC finds applications in various infrastructure projects such as roads, airfield pavements, industrial floors, hydraulic structures (dams, spillways), tunnel lining, underground roof support, repairs, and restoration. Improved ductility offered by CFRC is advantageous in earthquake-resistant structures.

Concretes reinforced with natural fibres, especially those containing coconut fibres, have higher impact strength and toughness due to their improved tensile and bending strength, increased ductility, and improved fracture resistance.

AIM AND OBJECTIVES

1. Utilizing processed fibers strands with different fiber contents, compare the compressive strength, tensile strength and flexural strengths of conventional concrete to that of coconut fiber reinforced concrete (CFRC).
2. To assess the impact of fibre shape on concrete strength.
3. To learn about the work-ability and elasticity modulus of concrete, among other mechanical qualities.
4. To gain insight into its sustainability and economical.

II. LITERATURE REVIEW

A. Review Stage

Kochova et. Al. [1] studied the produced coir fiber cement boards with the necessary mechanical properties for their application as insulated interior wall or ceiling panels. The first objective involved investigating and enhancing the inter-facial properties between the fibers and the cement. This was achieved by modifying the fiber surface through chemical pre-treatments. The second objective focused on studying the process and design of cement boards to optimize the manufacturing process and enhance the overall properties of the boards. Finally, the mechanical and physical properties of these boards were measured and compared to those of conventional wood wool cement boards (WWCB). Majid Ali et. al. [2] investigated the mechanical characteristics, such as energy absorption and toughness indices, of silica-fume plain concrete (S-PC) and silica-fume coconut fibre reinforced concrete (S-CFRC), with the addition of various silica-fume contents, i.e., 5%, 10%, 15%, and 20%, by cement mass. The American Concrete Pavement Association's Street Pave thickness design program is also used to assess the reduction in concrete road thickness. With 15% SF concentration, it is discovered that S-CFRC has generally superior mechanical properties than its corresponding S-PC. Furthermore, up to 12 mm less concrete road thickness is shown when CFRC has the ideal SF percentage. S-CFRC is therefore more useful for reducing the thickness of concrete roads due to its improved mechanical qualities. Sri Rama Chand Madduru et. al. [3] investigated various fiber contents were tested with either conventional concrete or pre-stressed concrete, and various strength parameters, including coconut fiber's bending, compression, and tensile strength, varied with proportions between 0.6% and 1.2% of the volume's total weight. Coconut fibre mesh testing from pre-defined dimensions was used to study the impact of fibre shape on strength characteristics. Trial and error were used to identify the ideal ratio of treated fibre yarn to raw fibrenets, as well as the maximum amount of super plasticizer that should be added to both regular cement and the coconut fibres in the mixture for basic operability. George Adeniyi et. al. [4] investigated the study of coir fibre and coir fibre reinforced polymer composites, providing an overview of the state of the art. This paper explains the preparation and creation of various matricesreinforced with coir fibres as well as the mechanical, structural, and thermal characteristics of these composites. It was noted that the most researched polymer matrix for coir fibre reinforced composites is polypropylene. Gupta et. al. [5] examined the impact of nano silica and coir fibre on the compressive strength and abrasion resistance of concrete. The study incorporated coir fibre into the concrete at varying proportions of 0.25%, 0.5%, and 0.75% relative to the weight of the fine aggregates. Additionally, 2% and 3% of nano silica were added along with 15% fly ash, which partially replaced cement in the concrete mixture. Various concrete samples were prepared, considering different percentages of nano silica and coir fiber, while maintaining water-to-binder ratios of 0.47, 0.45, and 0.42. The compressive strength and abrasion resistance of these samples were then compared to controlled specimens. The findings indicated that the optimal dosage of coir fiber was 0.25%, while for nano silica, it was 3%. These proportions yielded abrasion resistance levels approximately equal to those of conventional concrete samples. Mehran Khan et. al. [6] Investigated two forms of fly ash silica-fume concrete-fly ash silica-fume plain concrete and fly ash silica-fume coconut fiber reinforced concrete is assessed based on their mechanical properties. For additives of 0%, 0, 5, 10, and 15% fly ash, cement has a silica-fume content of 15% by mass. Coconut fibers with 50 mm length and a 2% by cement mixture composition are included in FA-SCFRC. The load-time curves, load-deflection curves, and stress-strain curves for FA-SPC and FA-SCFRChave been determined against compression as well, bending, and split-tension loadings, correspondingly. It is evident that FA-SCFRC has better qualities than the related FA-SPC. In comparison to FA-SPC, FA-SCFRC,with 10% of fly ash, has the most effective mechanical characteristics overall. Noor Faisal Abas et. al. [7] Investigated high-strength concrete was augmented with short, discrete coconut fibres to try getting over this drawback. This method is based on the idea that cracks caused by adverse conditions can be avoided by the discrete fibre localized reinforcing effect. Compressive and flexural metricswere used to gauge each structure's strength, and indicators such as carbonation depth, chloride penetration, and intrinsic permeability were used to gauge each structure's resilience. The mineralogy and micro-structure were studied using diffraction of X-rays and microscopy with scanning electrons techniques. According to the results of the tests, adding coconut fibres enhances the constructs' compressive and bending strength by as much as 13% and 9%, accordingly. Thus, it may be said that these fibres are crucial for restraint.

III. EXPERIMENTAL PROGRAM

The purpose of the study was to ascertain whether modified coconut fibre concrete might be used in actual construction projects. The M50 grade concrete mix was produced in the laboratory following the IS-10262: 2019 method, using fly ash and silica fume, with proportions designed according to the standard. Coconut fiber reinforced concrete was created by incorporating coconut fibre, fly ash and silica fume into the mixture of concrete.

The trials that produced the highest strength comprised substituting 5% of the cement with silica fume and 15% of the cement with fly ash. To substitute the cement, fly ash was constantly supplied to the plain cementconcrete (PCC) at a weight to cement ratio of 15%. The percentage of coconut fibres varied from 0.5% to 3%,with 0.5% intervals. The coconut fibres' lengths of 25, 50, and 75 mm were evaluated, and their correspondingdiameters ranged from 0.20 mm to 0.26 mm. Aspect ratios of 120 and 140 were also taken into consideration.Trials were run to evaluate the M50 grade concrete mix's flexural, compressive, and split tensile strength. Thismix contained fly ash and silica fume. The results showed that the strongest fibres had lengths between 25 and50 mm. As a result, a constant proportion of fly ash and silica fume was added to the coconut fibre reinforced concrete, which had an average aspect ratio of 150. In the experimental work, coconut fibers were used as shown in photograph 1. These fibers confirm the ACI544.1R-96 standard. The fibers were sourced from India Mart in Hyderabad. The dosage of coconut fibers ranged from 0.5% to 3.0% by weight of cement, with increments of 0.5% for each dosage level. The physical properties of the fibers utilized in the experiment are presented in table 3.8, providing information on their relevant characteristics.

For the grade M50 concrete, the mix proportion was found out using the Indian standard method (IS-10262:2019).

Fig 1: *View of Coconut Fiber*

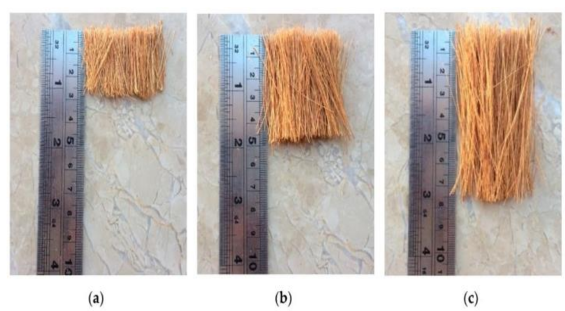


Fig 2: *Coconut Fiber*

The mix proportion for grade M50 concrete is as follows: 1 Parts Cement: 1.45 Parts Sand: 2.82 Parts Aggregate

In total, 126 specimens were cast in the laboratory for grade M50. These specimens were cast with varying coconut fiber content varies from 0% to 3% at intervals of 0.5%. Additionally, Fly-Ash and Silica Fume were incorporated as replacements for cement at a constant percentage of 15% and 5% by weight of cement, respectively.

The mix designations were labeled as M0 for the normal mix, while M1 to M3 indicated the specimens containing fibers ranging from 0.5% to 3%, known as Coconut Fiber Reinforced Concrete (CFRC) with Fly Ash and Silica Fume. Before casting the specimens, the mould and base plate were coated with a thin film ofmould oil to prevent the concrete from adhering to them. The concrete mix was compacted in the mould on a vibrating table and left on a platform 24 hours before demould. The specimens were then placed in a clean and fresh water curing tank with a temperature maintained around 27°C ± 2°C. They were cured for a period of 28 days before being tested for the respective strength properties.

In the current research, various strength characteristics of Coconut Fiber Reinforced Concrete (CFRC) were found out at the ages of 7 days and 28 days.

By using 150 mm x 150 mm x 150 mm cubic test specimens, a compression test was performed to measure the compressive strength of coconut fibre reinforced concrete, following IS-516: 1959. The test setup, failure pattern of the cube and the core of the failed cube in compression.

IV. RESULTS AND DISCUSSION

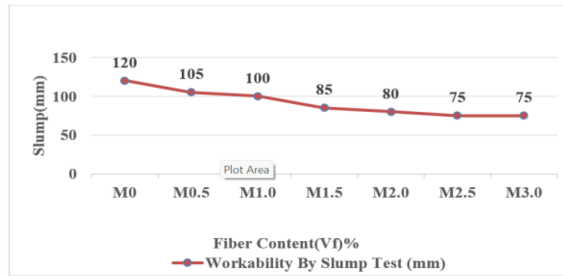
The outcomes of tests conducted on specimens of regular concrete mix and coconut fibre reinforced concretemix at ages 7 and 28 have been recorded and tabulated. Various tests including compression strength test, split tensile strength test, and flexure strength test have been conducted on hardened concrete in the laboratory. These tests have been performed according to the relevant standards and experimental test procedures. While all other tests were performed on hardened (dry) concrete after 7 and 28 days of curing, the work-ability of concrete was evaluated on fresh (wet) concrete.

The work-ability of fresh normal concrete mix and coconut fiber reinforced concrete mix was assessed using the slump cone test. The outcomes of the slump test have been recorded and presented in table 4.1. The resultsshow that when the amounts of fibre in the concrete increases, the slump value decreases. The reduction in slump is more pronounced for higher fiber content. Graph 4.1 for M50 displays a graph demonstrating the variance in slump with respect to fibre content (%)

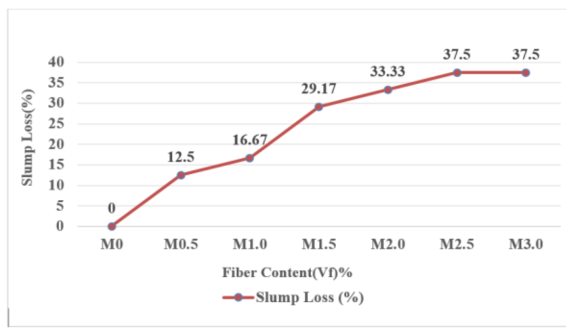
Table 4.1 presents the work-ability of concrete and the corresponding slump loss for various fiber.

Sr. No.	Mix Designation	Fiber Content (Vf)%	Work-ability By Slump Test (mm)	Slump Loss (%)
1	M0	0	120	00.00
2	M0.5	0.5	105	12.50
3	M1.0	1.0	100	16.67
4	M1.5	1.5	85	29.17
5	M2.0	2.0	80	33.33
6	M2.5	2.5	75	37.50
7	M3.0	3.0	75	37.50

***Table 4.1**: Work-ability by Slump Test*



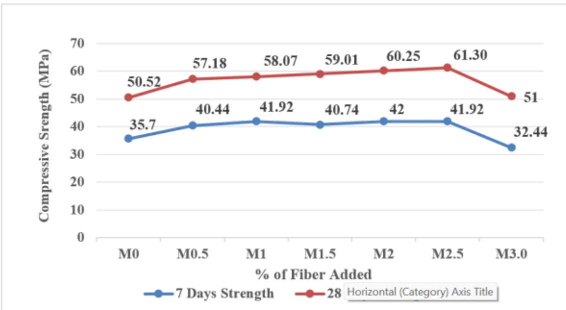
***Graph 4.1**: Variation of Slump with respect to Fiber Content (Vf) %*



***Graph 4.2**: Variation of Slump Loss with respect to Fiber Content (Vf) %*

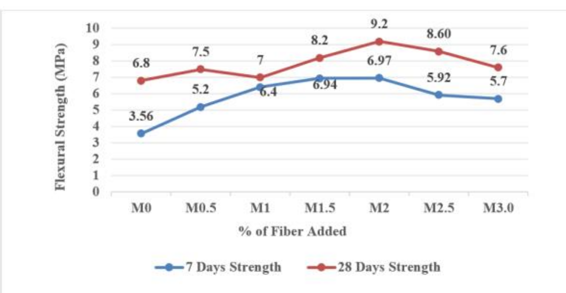
increases, the work-ability of fresh coconut fiber reinforced concrete steadily decreases. This is demonstrated by the fact thatboth M50 coconut fibre reinforced concrete mixes have slump values and slump losses that are decreasing. The partial substitution of cement by fly ash and silica fume, ratio for M50 mix designation is 0.34. It can be seen from the results presented in table 4.1 and graph 4.1 that as the percentage of concrete in concrete contents for M50 mix designation. The variation of Slump Loss with respect to fiber content (Vf)% is shown in graph for M50. The water/cement (w/c).

Graphs 4.2 illustrate the relationship between fiber content and compressive strength for 7 days and 28 days. According to graph 4.2, M50 with a 2% fiber content in CFRC achieves a maximum compressive strength of 42 MPa after 7 days. Similarly, it states that for M50 with a fiber content of 2.5% in CFRC, the maximum compressive strength achieved is 61.25 MPa at 28 days.



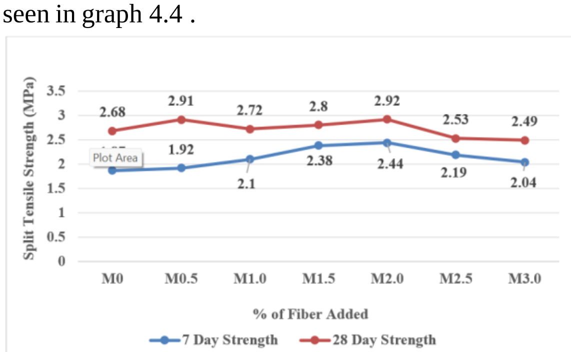
Graph 4.2: Graph represents variation of Compressive Strength at varyingpercentage of fiber.

Graph 4.3 displays the results for flexural load (P), Bending strength (fcr), and the percentage increase in Bending strength over the conventional mix for Coconut Fiber Reinforced Concrete (CFRC) at 28 days, calculated by using flexural formula 4.3 visually represents these results.



Graph 4.3: Graph represents variation of Flexural Strength at varying percentage of fiber.

The split tensile strength test of coconut fibre reinforced concrete is conducted by using split tensile strength equation. The results of this test are presented in graph 4.4, the depiction in pictorial form can be seen in graph 4.4 .



Graph 4.4: Graph represents variation of Split Tensile Strength at varyingPercentage Fiber.

The results of modulus of Elasticity (E) obtained from equation of modulus of elasticity from IS-456:2000 for Coconut Fiber Reinforced Concrete (CFRC) are shown in table 4.8.

Table 4.2: Modulus of Elasticity (E) of Coconut Fiber Reinforced Concrete 28 days

Sr. No.	Mix Designation	Fiber Content (Vf) %	Modulus of Elasticity (E) GPa Using equation IS: 456-2000
			M50
1	M0	0.0	35.53
2	M0.5	0.5	37.81
3	M1	1.0	38.10
4	M1.5	1.5	38.41
5	M2	2.0	38.81
6	**M2.5**	**2.5**	**39.15**
7	M3	3.0	35.71

The results presented in table 4.8 indicate that the modulus of elasticity of the specimens initially increases by up to 2.5% with the addition of fibre content compared to the normal mix. However, beyond this point, themodulus of elasticity decreases as the fibre content increases.

Table 4.3 provides the optimum fiber content for Coconut Fiber Reinforced Concrete, which correspondsto the fiber content that yields the highest strength. It is determined by various concrete strengths.

Table 4.3: Optimum fiber content for maximum strength

Strength MPa	Grade	Coconut Fiber Reinforced Concrete with Fly-Ash& Silica Fume		
		Coconut Fiber Content	Max. Value of Strength 28days, MPa	Strength of Normal Concrete for 28 days, MPa
Compressive Strength	M50	**2.5%**	**61.30**	**50.52**
Flexural Strength	M50	**2%**	**9.2**	**6.8**
Split Tensile Strength	M50	**2%**	**2.92**	**2.68**

V. CONCLUSION

1. Compressive strength of coconut fibre reinforced concrete is 21.36% higher than conventional concrete with fly ash and silica fume in M50, reaching a peak of 61.30 MPa after 28 days with a 2.5%coconut fibre content.
2. The highest achievable flexural strength for M50 is 6.97 MPa after 7 days and 2% coconut fibre content. The flexural strength of coconut fiber reinforced concrete is 113.5% higher than the concretereinforced with fly ash and silica fume in M50.
3. The maximum flexural strength for M50 at 28 days and 2% coconut fibre content was 9.2 MPa. For every additional 2% of coconut fibre, the flexural strength

of coconut fibre reinforced concrete increases by 35.29% when compared to regular concrete with fly ash and silica fume in M50.

4. The highest split tensile strength for M50 was 2.92 MPa after 28 days and 2% coconut fiber content.At 28 days of cure, it was discovered that the split tensile strength was somewhat higher than that of normal concrete with Fly-Ash and silica fume in M50.

5. For concrete of the M50 grade, the ideal fiber content for all strengths was found to be between 2% and 3% of coconut fibre.

6. The width of cracks is found to be less in Coconut Fiber Reinforced Concrete than in plain cement concrete beam.

7. Incorporating coconut fibre into plain concrete has been shown to significantly increase several strengths. However, it has been discovered that the amount of fibre inclusion affects the maximum increase in concrete strength. The best amount of fibre to add for a given strength increase varies depending on the strength.

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