Areca Nut Husk Fiber Composites for Marine Use: Mechanical Characterization in Marine water

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***Abstract*— Areca nut husk fiber, an agricultural by-product, is typically treated as waste and contributes minimally to the economic value of areca nut cultivation. However, its potential use as a reinforcing material in the production of lightweight and cost-effective composites has opened new possibilities for its application. These fiber-reinforced composites offer sustainable and economical alternatives for industries such as construction, marine engineering, automotive, and aerospace. In this study, areca nut husk fibers were extracted through alkali treatment using a 6% sodium hydroxide (NaOH) solution. This process enhances the fiber's compatibility with the composite matrix by removing surface impurities and improving bonding characteristics. Composite panels were fabricated incorporating these fibers at varying weight percentages of 15%, 25%, and 30%. Both fine and coarse fibers were used to evaluate their individual impact on composite performance. The fabricated composites underwent various mechanical tests including tensile, flexural, hardness, and water absorption tests to assess their strength and durability. Additionally, their performance was analyzed under marine water exposure to determine their suitability for real-world environmental conditions. The research highlights the potential of converting agricultural waste into high-value materials while meeting the growing need for affordable, lightweight composites. Results indicated that composite panels reinforced with fine fibers consistently exhibited superior mechanical properties compared to those with coarse fibers. Nevertheless, the coarse fiber (CF) composites displayed excellent overall performance in terms of strength, stiffness, and durability. While a gradual decline in mechanical strength was observed over a 45-day period, the water absorption characteristics remained stable across all fiber types, reflecting good moisture resistance. Among all variants tested, the CF composite showed the most balanced and reliable performance, making it a strong candidate for practical applications in demanding environments.**

***Index Terms*—Areca fiber, Chemical Composition, Marine water absorption, Natural fiber composites, Marine environment performance.**

I. Introduction (Heading 1)

Areca catechu, the scientific name of areca nut, commonly known as betel nut, is the seed of the Areca palm, which thrives in humid tropical and subtropical regions. It is widely cultivated in countries such as India, Bangladesh, Indonesia, Myanmar, and Sri Lanka, with India being one of the largest producers, contributing around 50-60% of global production. In India, major growing regions include Karnataka, Kerala, Assam, Tamil Nadu, and parts of Maharashtra. Areca nut serves as an important economic crop, primarily used for chewing purposes in betel quid, a traditional cultural practice in many Asian countries. Beyond its traditional use, areca nut has applications in the pharmaceutical, cosmetic, and dye industries, as well as in agriculture as a bio-fertilizer. Recently, its husk fiber has gained attention as a potential raw material for eco-friendly and lightweight composites, opening new avenues for sustainable industrial applications.

1.1 Areca nut products

Areca nut is a versatile agricultural product that finds its application in a wide range of industries. The primary product is the areca nut itself, which is used extensively in the preparation of betel quid, supari (flavored areca nut), and gutkha. Beyond its traditional use, the nut is also processed into extracts for use in the pharmaceutical and cosmetic industries, as well as in natural dye production. Additionally, the areca nut tree's byproducts, such as its leaves, are used for making eco-friendly disposable plates and bowls.

The husk of the areca nut, which was previously treated as agricultural waste, has gained attention as a valuable resource for sustainable applications. The fibers extracted from the husk are used to produce ropes, mats, brushes, and biodegradable bags. Recent advancements in material science have demonstrated the importance of areca nut husk fibers in the production of less expensive and weight less composites. These composites, made by reinforcing areca nut husk fibers in polymer matrices, are utilized in various industries, including building, locomotive, oceanic, and aeronautical.

Figure1: Areca nut husk bi products.

1.2 Materials Required

Areca nut husk fiber: Areca nut husk fiber is a plant fiber wrenched out from the hull of the areca nut fruit (betel nut). The nature of eco-friendly and biodegradability plays a unique property. Areca nut husk fibers are natural, lightweight, and eco-friendly, making them a sustainable material. Fine fibers are smooth, silky, and light brown, while coarse fibers are rough and dark brown in color.

Epoxy Resin: Epoxy resin, a type of polymer, is used in this experiment due to its excellent adhesive properties, high strength, quick drying, and low contraction after curing, good material strength, electrical strength, chemical inactivity, and insolubility in liquid. Specifically, epoxy resin L-12 was combined with epoxy hardener K-6 to enhance composite material's performance.

Hardener: K-6 hardner was used. A hardener is used in fiber composite panel preparation to facilitate the curing process of the resin, ensuring the composite achieves its desired strength and durability. It acts as a curing agent, chemically reacting with the resin to form a rigid, solid matrix that binds the fibers together. This enhances the composite's mechanical behavior, while also minimizing reduction and improving its overall performance.

1.3 Research Methodology

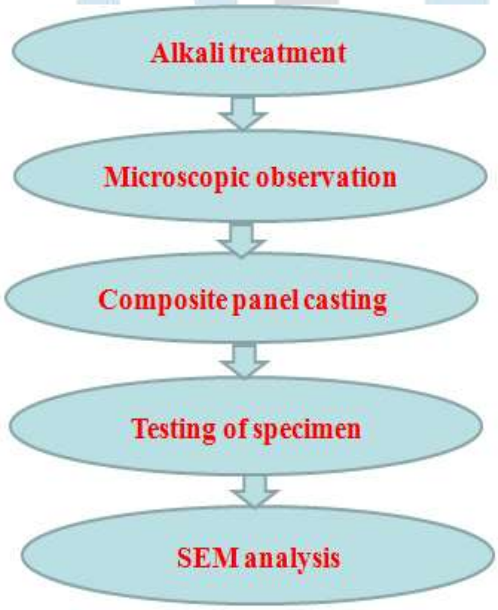

Figure 2: Research methodology for areca nut husk composite panel.

Step 1: Alkaline treatment of areca nut husk fiber

Dried areca nut husk was soaked for one day in fresh water to unstuck the fibers. The soaked husk was then cleaned with debris free water to remove any soil particles attached to the fibers. Subsequently, the debris free husk was immersed in a 6% Noah alkali solution at room temperature (26 ± 2 °C) for 24 hours to carry out the chemical treatment process. The washed husk was sun-dried for two days to reduce its moisture content. Finally, the fibers were separated from husk and stored in air free container to prevent hygroscopicity.

Figure 3: Chemical retting .

Step 2: Fiber Extraction

Fibers are extracted manually from areca nut husk and separated based on their texture and color. Fine fibers, which are smooth, silky, and light brown in color, are distinguished from coarse fibers, which are rough and dark brown in color. Length of fine fibre varies between 30-50 mm and coarse fibre varies between 50-70 mm.

Figure 4: Fine fiber.

Figure 5: Coarse fiber.

Step 3: Hand lay-up method to obtain composite panel

Panel was prepared using a mild steel mold with dimensions of 320 mm × 320 mm × 5 mm and a 3 mm thickness covering plate. Initially, the panel mould was washed with an acetone solution to remove foreign particles. Subsequently, a thin layer of wax enforced to both the mold surface and the flange plate to facilitate easy removal of the composite panel. To eliminate air cavities and ensure comparable thickness, a uniform load of approximately 150 kg was placed over the flange plate. The mold was then dried for 6 hours before load removal.

II. IMMERSION OF SPECIMENS IN SALINE WATER

The specimens of fine fiber composite panels and coarse fiber panels were tested under environmental conditions, including exposure to saline water. Tensile and flexural tests were conducted on both specimens, with each trial repeated three times to ensure accuracy, and the average values were calculated. The specimens were immersed in saline water for the time interval of 15,30,45,60 and 90 days. At each interval of time three specimens were taken and tested for tensile and flexural testing and the readings are noted down.

Figure 6: Immersion of fine fiber and coarse fiber in a saline water.

Figure 7: Immersed composite fiber specimens.

Tensile Test

Specimens of dimensions of 280 mm × 25 mm × 5 mm for tensile testing were prepared by cutting the areca nut husk fiber panel. The experiment results were obtained on specimens made from a combination of coarse fiber (CF) and fine fiber (FF) following ASTM D3039 standards using a tensile testing machine. Three trials were done on each sample to ensure consistency, and average readings were recorded for analysis. Tensile test was carried out for 15 days intervals and results are noted down.

Figure 8: Tensile tested specimens.

Table 1: Tensile test results for coarse fiber and fine fiber composites.

Time period (days)	Tensile strength (MPa) FF	Tensile strength (MPa) CF
15	55.1	51.5
30	52.3	45.9
45	44.7	40.4
60	41.3	38.6
75	40.5	36.1
90	39.4	34.6

Graphs are plotted for the results obtained.

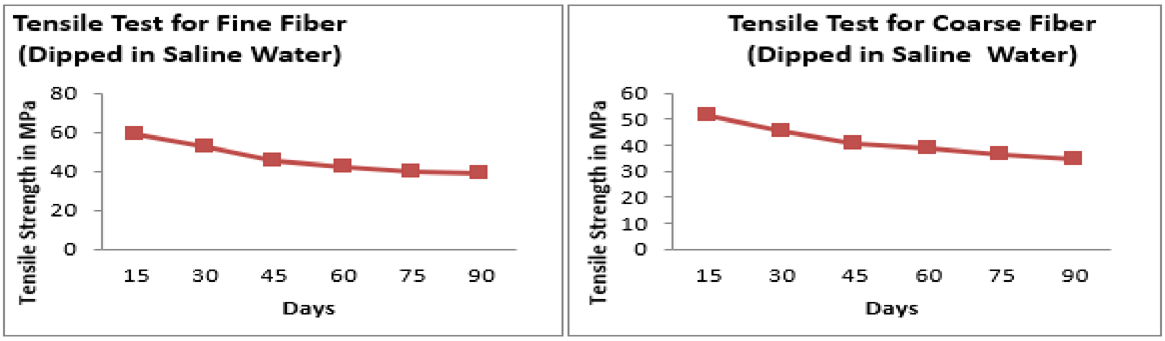

Figure 9: Tensile test for fine fiber and coarse fiber.

Flexural Test:

Tests are conducted to analyze the flexural properties of composites containing areca nut husk fiber, following ASTM D790 standards. The composite panel was cut into specimens with dimensions of 150 mm in length, 25 mm in width, and 4 mm in thickness. Three-point bending tests were performed with an effective span length of 100 mm and a mid-span deflection rate of 0.5 mm per minute. Flexural tests were conducted on composites made with fine fiber (FF) and coarse fiber (CF). Three specimens of each composite type were tested to ensure consistency, and the results were recorded for analysis.

Table 2: Flexural test results.

Time period (days)	Flexural Strength MPa (FF)	Flexural strength MPa (CF)
15	115	112
30	110.5	108.2
45	92.2	90.6
60	88.9	87.2
75	86.8	86.1
90	85.8	84.7

Graphs are plotted for the results obtained.

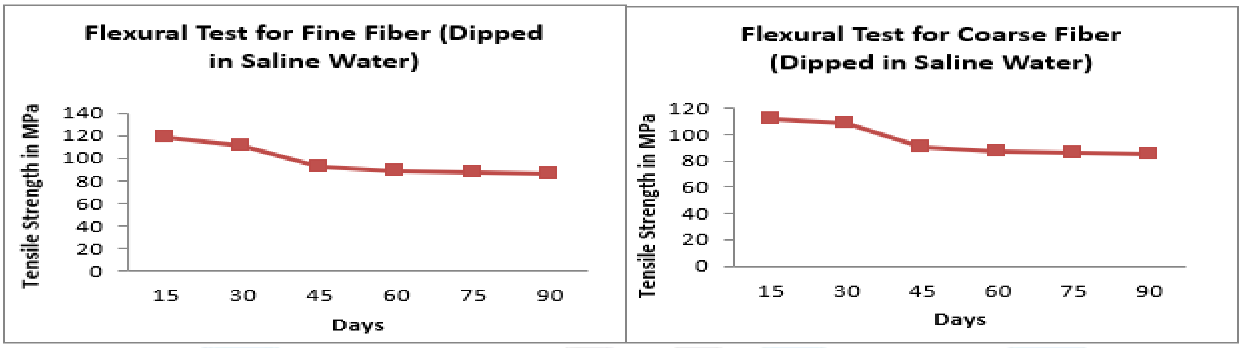

Figure 10: Flexural tests for different intervals of time.

The graph shows that water absorption in fiber composites is affected when immersed in saline water. Water absorption increases continuously until 45 days, after which it decreases. The longer the immersion time, the lower the water absorption.

Hardness Test

Testing the hardness of areca nut husk fiber composites can help evaluate their mechanical properties and suitability for various applications. Hardness testing was conducted as per the ASTM D2240 (Shore Hardness) standards.¼ inch indenter pin was used with load 160 kgs. Hardness is found to be 50-75 shore D.

Common hardness testing methods include:

Table 3: Hardness test results.

Type of fiber composition	Specimen	Hardness (Shore D)
Fine Fiber	S1	60
	S2	56
	S3	50
	S4	52
	S5	53
Coarse Fiber	S1	48
	S2	45
	S3	41
	S4	37
	S5	32

It is observed that the hardness is more in fine fiber than coarse fiber.

Water Absorption Test

The water absorption test for composites is conducted to determine how much water a composite material absorbs over time. This property is crucial for understanding the composite's suitability for applications where moisture resistance is critical.

Calculation of Water Absorption: water absorption percentage is calculated using the formula:

Water Absorption (%) =Dry Weight-Wet Weight/Dry Weight×100.

Weight of composite is measured using measuring scale before it is immersed in saline water and noted and the weight f composites is weighed after immersion in saline water and noted down before its hardness test.

Table 4: Weight of FF and CF after immersion.

Time period(days)	Weight of specimen FF after immersion(gms)	Weight of specimen CF after immersion(gms)
15	4.70	5.6
30	5.85	6.2
45	6.2	6.7
60	6.4	6.9
75	6.5	7.0
90	6.8	7.5

Weight of coarse fiber composite specimen is observed to be more compared to that of fine fiber composite specimen.

Table 5: Water absorption percentage of FF and CF.

Time period(days)	Water absorption percentage for FF	Water absorption percentage for CF
15	4.77	5.6
30	5.8	6.99
45	6.9	8.9
60	7.3	9.1
75	7.4	9.4
90	7.8	9.5

It is absorbed from the table that the water absorption percentage in coarse fiber is more than fine fiber because of the pores and deboning of coarse fibers in composites.

III. CONCLUSION

Fiber composites, particularly those incorporating areca nut husk fibers, exhibit notable mechanical properties such as tensile strength, flexural strength, hardness and water absorption test when subjected to saline water immersion for varying durations. The fine fiber composites tend to outperform the coarse fiber composites in all tests. The superior performance of fine fibers is attributed to their improved surface area, better bonding with the matrix, and enhanced load transfer capabilities. Saline water exposure, however, can affect the mechanical integrity due to fiber swelling and matrix degradation, which are more pronounced in coarse fiber composites due to their lower interfacial adhesion. Hardness testing is an essential evaluation to understand the resistance of both fine and coarse fiber composites to localized deformation. Fine fiber composites generally exhibit higher hardness values compared to their coarse counterparts. This can be linked to the even distribution of fine fibers within the matrix, resulting in a more packed and similar structure. Coarse fibers, on the other hand, may introduce voids or irregularities that can weaken the overall hardness of the composite.

Water absorption studies reveal critical insights into the hydrophilic nature of fine and coarse fibers within the composite. To determine water absorption, specimens are weighed before and after immersion in water for a set duration. Fine fiber composites typically absorb less water compared to coarse fiber composites due to their reduced pore size and better encapsulation within the matrix. This lower water absorption contributes to the enhanced dimensional stability and durability of fine fiber composites, making them more suitable for applications in moist or saline environments.

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