Mechanical Analysis of Sustainable Composite Material Using Arecanut Husk Fiber and Epoxy Resin HSC8600

Roopashree C.R[1], Dr. Shivarudraiah[2], Dr. H.K Shivanand[3]

[1]Research Scholar, Department of Mechanical Engineering, University Vishvesvaraya College of Engineering (UVCE), Bangalore-560001, Karnataka, India; roopashreecr@ssit.edu.in.
[2]Professor, Department of Mechanical Engineering, University Vishvesvaraya College of Engineering (UVCE), Bangalore-560001, Karnataka, India; shivamecuvce@gmail.com.
[3]Professor, Department of Mechanical Engineering, University Vishvesvaraya College of Engineering (UVCE), Bangalore-560001, Karnataka, India; Shivanand.uvce@gmail.com.

Abstract

The areca nut is also called as betel nut. Areca catechu is the scientific name of areca nut. The areca nut plantation is seen much in the tropical Pacific (Melanesia and Micronesia), South Asia, Southeast Asia, and in some parts of east African region. In this paper, areca husk fiber is de husked manually from matured areca nut which is easily available in plantation. The methodology involves chemical retting process of areca nut husk fiber by using alkaline solution to remove foreign particles present in husk fiber. Then fine fiber and coarse fiber are separated according to its physical appearance. The linear dimension of fine fiber is observed in between 35 to 50 mm and that of coarse fiber is observed as 50 mm. The diameter of fine fiber and coarse fiber are 50 and 120 micro m respectively. The composite panels of fine fiber (50%) and coarse fiber (50%) are prepared and specimens are cut as per the ASTM standards of machine requirements and mechanical properties such as tensile test and compression test are carried out in order to find out its tension strength, compression 2 strength respectively. The tensile strength of 21.01 M Pa and a Young’s modulus of 7.11 G Pa is observed and the compression strengthof 55.80 M Pa and Young’s modulus of 14.804 G pa is obtained after the tests.

Keywords: Areca fiber, Chemical Composition, Discontinuities Composites, Mechanical behavior, Tensile test.

1. Introduction

Areca nut or betel nut is one of the major grown crops in many areas of the world. It proves various useful applications in various fields. Over the last forty years, the production of areca nut has significantly escalated across many South Asian nations where data is accessible. In India, there has been a nearly threefold increase in nut production, possibly indicates the market profitable of areca-based products since 1980s. Areca nut production in South and Southeast Asia, including Bangladesh, has significantly increased, but its utilization among the Bangladeshi population lacks detailed documentation. The Areca genus encompasses various palm species native to these regions and the Pacific islands. Areca catechu, primarily found in Sri Lanka, West Malaysia, and Melanesia, is the source of areca nut for chewing. Its fruit, produced year-round, is ovoid or oblong, green when fresh, and orange-yellow when matured. The endosperm is separated from a fibrous pericarp, round with a truncated base, and buff colored with dark wavy lines. It possesses a characteristic a stringent, slightly taste bitter and can be used in all stages of maturity, either as a whole nut or thinly sliced, in its natural state or processed into different forms. The areca nut can undergo various processing methods such as sun-drying, baking, or roasting before use, or it may be Fizzed and brewed in some regions like eastern India and Sri Lanka by enveloping with soil. These treatments alter the nut's flavor and reduce its astringency[1,2]. In Taiwan and China, the nut is typically consumed in its unripe, green stage, resembling a small olive. Across different regions, the areca nut is referred to by various names such as "supari" in Hindi, "puwak" in Sri Lanka, "gua" in Sylheti (Bangladesh), "mak" in Thailand, "pinang" in Malaysia, "daka" in Papua New Guinea, "pugua" in Guam, and "Kun-ywet" in Myanmar.

Table 1: Nutritional compositions of areca nuts

Nutritional components	Percentage
Carbohydrates	20%
Fats	15%
Phosphorus	0.13%
Calcium	0.05%
Iron	0.01%

Table 2: Phytonutrient compositions of areca nut

Phytonutrient components	Percentage
Leucocyanidins	12%
Catechins	10%
Arecoline	0.75%
Guvacoline	0.75%
Epicatechin	0.25%
Guvacine	0.29%
Arecadine	0.1%

2. Materials Used

The areca nut husk fiber as a strengthening material in composite panels provesmany advantages. This has a little economic value for areca nut plantations[2].

- **Areca Nut Husk Fiber:**

Areca fiber is de husked from the outer covering of the matured areca nut. It is primarily composed of the following components:

Cellulose: Constitutes 53.2% of the fiber. Cellulose provides strength and rigidity.

Hemicellulose: Makes up 32.98% of the fiber. Hemicellulose contributes to the overallmechanical properties but also affects moisture absorption.

Lignin: Accounts for 7.2% of the fiber. Lignin provides rigidity and acts as a natural adhesive.

Pectin: Present in smaller amounts (around 7%). Pectin is a complex carbohydrate found in plant cell walls.

Properties and Applications:

Non-Toxic and Eco-Friendly: Areca fiber is safe for use and environmentally friendly.

Low Weight: Compared to synthetic fibers, it is lightweight.

Strength and Durability: The hardness and imperishability of betel fiber depend on its cellulose
Content[3,4].

Moisture Absorption*:* Higher hemicellulose content leads to increased moisture absorption, affecting fiber performance.

Composite Panel Preparation: Hand lay- uptechnique is used to make composite panel. The dehusked matured areca fiber is used to for composite panel. Matured areca nut haslower moisture absorption ability than raw areca fiber. Chemical retting process is followed toremove unwanted foreign substances and debris from the fiber surface. The fibers are treatedwith a NAOH (6%) solution. The compositions (fine fiber and coarse fiber) were used forcomposite panel preparation .Areca fiber offers an ecofriendly safe environment and flexible material for composite panels. Its eccentric structure and mechanical behavior makes inappropriate for various applications in building, aquatic structures, vehicles, and aeronauticalIndustries[3].

Figure 1: Arecanut husk, fine fiber and coarse fiber.

- **Epoxy Resin**

Epoxy resins belong to the family of thermosetting polymers. They are widely used due to their
Exceptionalproperties. These resins cure or set into a hard shape using methods like heating or cooling. The healing process is irrevocable, resulting in a polymer chain cross linked by
Molecular chemical bonds. Not similar to thermoplastics, which soften upon heating, thermosets (including epoxy resins) remain solid until they reach a temperature where degradation begins.

Key Properties of Epoxy Resins:

- **Fastening**: Epoxy resin is known for its strong sticking properties, making it ideal for binding dissimilar substances together.
- **Toughness:** Epoxy resins are high durable and can resistecological conditions such as heat, chemicals, and moisture.
- **Adjustability**: Epoxy resin is flexible for various applications, including casting, laminating, and coating.
  Advantages and Applications:
- Marine Applications: Epoxy resins protect materials from harsh marine environments, including saltwater exposure.
- Electrical Insulating Components: Their electrical resistance makes them suitable for components like circuit boards and insulators.
- Lightweight Components: Epoxy composites are lightweight and find use in aerospace and automotive industries.
- Chemical Industry: Epoxy resins are employed in chemical storage tanks and reaction chambers due to their resistance to acids, bases, solvents, and oils.
- Epoxy resins offer a versatile solution for various industries, combining strength, durability, and adhesion. Their ability to be tailored for specific applications makes them a valuable material in modern manufacturing and construction.

3. Composite Panel Fabrication

It involves various steps:

- **Collection of Dried Husk**: The matured betel nut is gathered from habitations which are easily available in plenty.
- **Soaking in Freshwater**: The dried husk is drenched in non-saline water for 24 hours. This process helps loosen the fibers.
- **Cleaning and Soil Removal**: After soaking, the water-soaked compositions are un soiled with freshwater. This step removes soil particles adhered to the fibers.
- **Alkali Treatment (Chemical Retting)**: The cleaned husk is then wetted in alkaline solution (NAOH) for two days. Alkali treatment breaks down the lignin and other components, making it easier to extract the fibers.

- **Washing and Drying**: The chemically acted husk is bathed with non-saline water to peel off any chemical debris from the fiber surface. The bathed areca fiber is dried in sunlight for 48 hours to reduce its absorbed moisture content.
- **Fiber Extraction and Storage**: Fibers are withdrawn from the sun-dried areca nut husk. These extracted fibers are packed in tight covers to prevent moisture absorption.

3.1 Microscopicallyview of Areca Fibers

Figure 2: (a).Fine fiber (b).Coarse fiber (c).Microscopic view of fine fiber (d). Microscopic view of coarse fiber.

Untreated Fibers:

- Color: The unprocessed husk fibers show a light brown color.
- Surface Texture: The exterior portion appeared smooth but had the presence of nativeparticles.
- Observation: The smooth surface is because of the fiber natural state, but the foreign particles could affect their bonding properties.

Treated Fibers:

- Texture: The processed fibers had a satin texture.
- External Appearance: Unlike the smooth surface of treated fibers, the unprocessed fibersshowed an undulated (wavy) surface.
- Chemical Treatment: The fluctuated surface likely resulted from the chemically alteredprocess (alkali solution treatment).
- Bonding Potential: The fluctuated surface could enhance the better binding between theepoxy and the fibers composition.

Epoxy Resin Interaction:

- Purpose: Epoxy resin serves as a soldering agent in composite panels.
- Protection: areca fibers are protected from environmental conditions (such as moisture,chemicals, and marine environments) with the addition of epoxy in appropriate ratio.
- Cost Considerations: While epoxy resin is effective, its cost can be a limiting factor.

- Composite Panels: Composites can be prepared by areca fibers with the addition of rightproportion of epoxy which are suitable for various applications, including marine,electrical, lightweight components, automobiles, and chemical industries.
- The combination of treated areca nut husk fibers and epoxy resin offers a promisingmaterial for composite panels. The undulated surface of the treated fibers may indeedenhance the bonding between the fibers and the epoxy resin.

3.2 Composite Panel Casting

A composite panel was casted with the help of mild steel mold with typical dimensions of320mm x 320mm x 4mm and a 3mm thick mould head plate. The low carbon steel pattern wascleaned with an acetone solution to eliminate any debris that had presented. A thin film of wax was then applied to the mold surface and the cap plate to make pulling thecomposite board from the mold easier[1]. A mass of around 150kg was placed evenly over thehead toremove air-voids and achieve a uniform thickness. The loaded pattern was cooled for 6 hours and then unpacked.

Figure 3: Pouring of mixed fibers.

Figure 4: load applied.

Figure 5: Failed composite board.

The composite board is prepared again by following same methodology with proper fiber epoxy
ratio and hand layup process.
For 10%Weight of percentage of fiber

Weight of areca nut husk fiber (fine fiber + coarse fiber) is100g (50+50).
Weight of epoxy resin is 410.55g
Weight of hardner is 60g.

Figure 6: Success model.

4. Experimental Results

4.1 Tear /Tension Strength

Specimens were prepared by cutting the cast areca fiber panel according to the required specifications of 320 mm x 320 mm x 4 mm^2. Three trials were done (coarse fiber(CF)+fine fiber (FF)which are cut according to ASTM D3039 standards. Three repeated trials areconducted with three samples to commemorate the constant results.

Figure 7:Tension machine and ready specimen.

Tensile tests are tabulated below:

Table 3: Tensile test results

Specimen	Tensile strength(Mpa)	Young's modulus(Gpa)	Percentage of elongation(%)
S1	21.01	7.11	0.406
S2	18.10	5.52	0.409
S3	19.20	6.30	0.611

From the above table, it is observed that Specimen S1 (21.01MPa) had a higher strength than the other two samples.

Stress V/S strain curve of a specimen S1and S2:

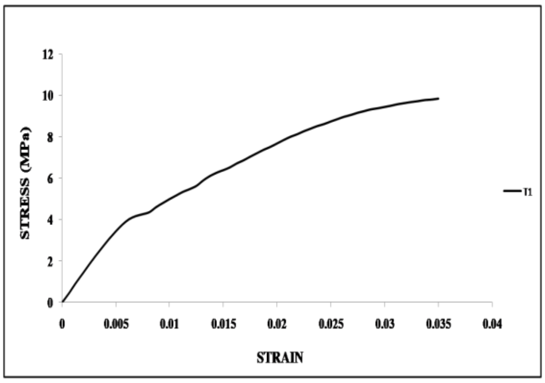

Figure 8: Stress versus strain curves for tensile test specimen S1.

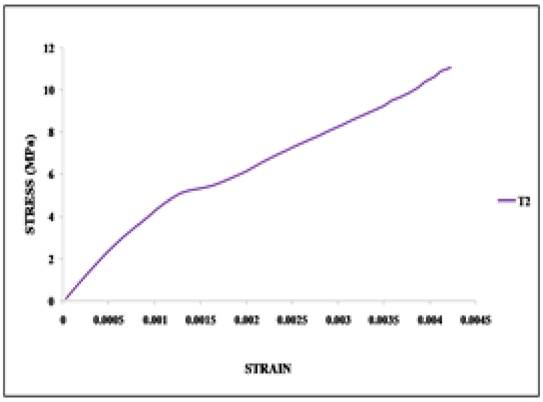

Figure 9: Stress versus strain curves for tensile test specimen S2.

5. Compression Test

Specimen dimensions of areca fiber composite are 76.2mm in all sides and the thickness is15mm[7]. The compression test is performed in universal testing machine (UTM) as per ASTMD69.

Figure 10: Compression strength testing.

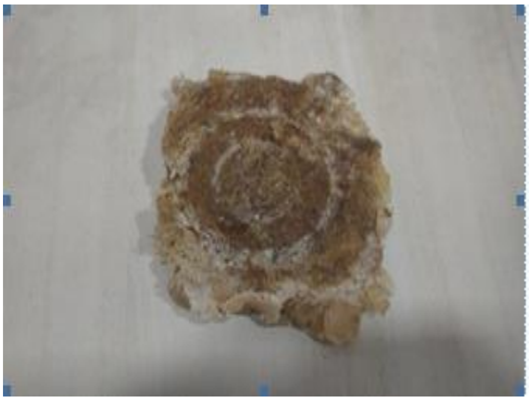

Figure 11: Tested specimen.

Readings are tabulated below:

Table 4: Compression test results

Material properties	C1	C2	C3
Compression strength	55.15	55.68	55.80
Young's modulus	14.804	2.37	5.819

From above trials it is concluded that the Specimen C3 (55.80 MPa) have more compared to other two samples. The 'stress versus strain' curves for the compression tests specimens are shown below,

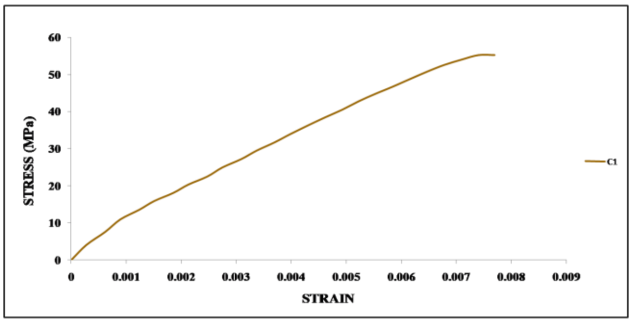

Figure 12: Stress versus strain curves for compression test specimen 1 (C1).

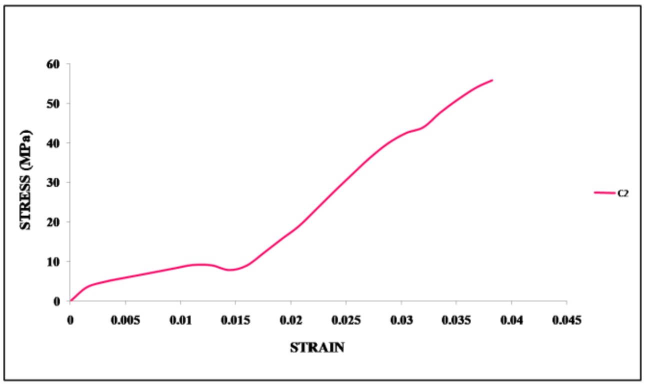

Figure 13: Stress versus strain curves for compression test specimen 2 (C2).

6. Conclusion

It is observed that surface hardening improves good binding between the fiber and the matrixwith reduction of hygroscopicityand sensitiveness. It also provides a significant goodfastening. The chemical retting processincreases the fiber surface tension by enhancing fiber fixing and by eliminating unwanted debris. The structuralapplications of areca fiber composite are used for developing the load-bearing/supportingstructures like doors, windows, and lintels and in the construction of indoor elements, doorpanels, and temporary structures. The tensile strength of 21.01MPa and a Young's modulus of 7.11GPa is observed. The compression strength of 55.80Mpa and Young's modulus of 14.80 Gpa is observed. It can be concluded that always the chemically processed arecafiber gives more strength to that of unprocessed areca fiber.

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