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ENHANCING MECHANICAL PROPERTIES OF POLYESTER COMPOSITE THROUGH NATURAL FIBER AND FILLER REINFORCEMENT: AN EXPERIMENTAL STUDY

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Abstract

Hibiscus Sabdariffa (Roselle) is a spinach plant found in southern Tamilnadu, India. Many food and medical uses are reported for the extracts from the leaves of the plant. The validation behind this article is to extract and characterize the cellulose fibers from the bark of Hibiscus Sabdariffa (Roselle) plant are reported for the first time in this work. Some tests are carried out in the Hibiscus Sabdariffa Fibers (Roselle) to determine the morphological and thermal properties.

•Impact Test

•Flexural Test

•Barcol Hardness Test

•Water Absorption Test

•Scanning Electron Microscopy analysis (SEM)

The findings from this study aim to contribute to the development of sustainable and environmentally friendly composite materials with potential applications in industries such as construction, automotive, and packaging. The utilization of these natural fibers not only enhances the mechanical properties of the composite but also reduces the reliance on synthetic and non-biodegradable materials, promoting a more sustainable approach to material development. The morphological study result proved that the fibers has rough surface even in raw fibers. The results revealed that the biodegradable Roselle Fibers can be used to prepare composite specimen for light weight applications. Four different types of combinations are used as composite specimens which are, Single Layer Roselle Fiber, Single layer Roselle fiber with filler, double layer roselle fiber, double layer roselle fiber with filler.

Keywords: Hibiscus Sabdariffa (Roselle), Cellulose fibers, Morphological properties, Thermal properties, Impact test, Flexural test, Barcol hardness test, Water absorption test, Scanning Electron Microscopy (SEM) analysis, Sustainable composite materials, Biodegradable fibers.

INTRODUCTION

Natural fibers have received considerable attention in the recent years Natural fibers are fibers that are made from natural materials that come from plants, animals, or minerals. Natural fibers can be extracted from the various parts such as leaf, bark, Stem, roots of the plant or tree. There are two general categories of natural fibers: animal-based or plant-based.

Any hair like raw material directly obtained from an animal or vegetable or mineral source is called as natural fiber. Human hair and chicken feather are examples of animal fibers. Palmyra, sisal, jute, banana, coir, hemp, and flax are examples of vegetable fiber. Mineral fiber includes asbestos and basalt fiber. The natural plant-based fibers are abundant and have high specific mechanical properties. Many kinds of textiles, ropes, canvas, and papers are produced by using natural vegetable fibers today. The different parts of plants such as stem, leaf, flower etc.., have been found to be viable sources of fibers.

OVERVIEWS OF NATURAL FIBER

The term of natural fibers covers a broad range of vegetable, animal, and mineral Fiber. These fibers often contribute greatly to the structural performance of the plant and when used in plastic composites, can provide significant reinforcement. In recent days growing awareness of environmental issues has led to increase in demand for goods produced from natural products, including natural fibers. They are biodegradable and hence they can easily usable and acceptable in the society.

Asian people had been using natural fibers for many years; one of the largest areas of recent growth in natural fiber plastic composites is the automotive industry, particularly in Europe, where natural fibers are advantageously used because of their low density and increasing environmental pressures. Most of the composites currently made with natural fibers are press-molded, although a wide range of processes have been investigated. Flax is the most widely used natural fiber in the European automotive industry, being one of the fastest developing countries in the world, a great deal of international attention is focused on India. It is the seventh largest country in the world production level of natural fibers in India is world's second largest producer and consumer of fibers, textiles, and manufactured products next to China the Fiber and Yarn exports in India. Hence in India more and more research works are going on to utilize natural fibers for engineering applications.

CLASSIFICATIONS OF NATURAL FIBER

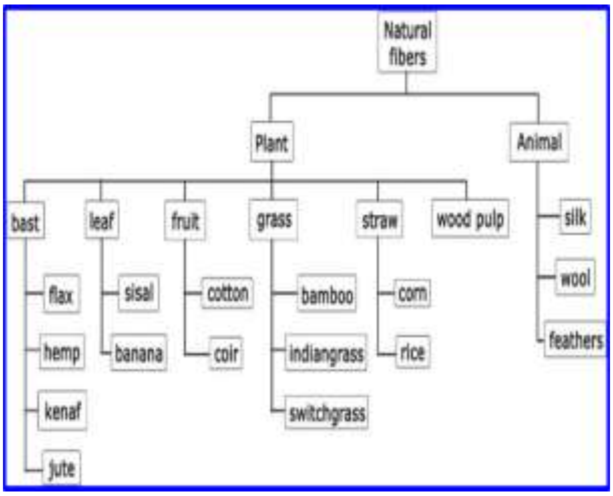

Figure 1.1 Classifications of Natural Fiber

LITERATURE SURVEY

Ravinder Kumar et al. 2024 [1] this study systematically reviews Life Cycle Assessments (LCAs) evaluating the environmental impact of bioplastics as an alternative to conventional plastics. Bioplastics show promise in mitigating environmental concerns associated with single-use and conventional plastics, owing to their potential to reduce greenhouse gas emissions and pollution. However, inconsistencies in LCA methodologies across studies hinder comparison of results. Mechanical characteristics of bioplastics, including tensile strength, Young's modulus, flexural modulus, and elongation at break, indicate superior performance compared to synthetic plastics, enhancing their sustainability and reliability. Key challenges in bioplastic adoption and production include competition with food production for feedstock, high production costs, uncertain end-of-life management, limited biodegradability, lack of standardization, and technical performance limitations. Collaboration among stakeholders is essential to drive innovation, reduce costs, improve end-of-life management, and enhance awareness and education. While bioplastics hold potential for reducing environmental impact, further research is necessary to optimize their life cycle, end-of-life management, and production processes for maximizing environmental benefits. Cristiano Fragassa et al. 2023[2] this experimental study investigates the mechanical and impact properties of flax and basalt fiber hybrids, along with their composites using vinylester resin for reinforcement. Laminates were fabricated via hand lay-up and resin infusion techniques, with accelerated curing processes employing heat and pressure in an autoclave. Tensile, flexural, and falling weight impact tests were conducted, with energies up to 40 J. Results revealed that hybrid laminates often deviated from predictions based on the rule-of-mixtures, particularly in flexural performance. However, advantages were observed, such as reduced brittleness in basalt and evidence of plastic behavior, notably in flax fiber-reinforced laminates exhibiting prolonged periods of quasi-constant load during impact tests, delaying failure despite extensive damage. These findings challenge the notion that optimal performance in basalt/flax fiber hybrid laminates necessitates basalt fibers exclusively in outer layers, suggesting potential for future utilization of more intricate stacking sequences with interleaved flax and basalt layers.

Mahesh C. Swami et al. 2022 [3] in this study the glass fiber is reinforced in Iso-polyester, Epoxy & vinyl ester resin with different percent fiber and resin combination. The composites were prepared with the hand lay-up technique followed by compression. After preparing specimens as per ASTM standard these specimens are tested on the computerized universal testing machine for flexural strength and inter-laminar shear stress (ILSS). The experimental data is used to compare and find the best percentage combination of resin and fiber for different applications of composite.

C. Sowmya et al. 2018 [4] This paper discusses the development of new hybrid composite using natural fibre as reinforcement with commercially available epoxy resin and polyester resins with the hybrid materials. Jute, hemp fiber and epoxy resin and polyester resin along with graphite filler were developed for 30°, 45° and 90° fibre orientations. The experimentation done on Hemp/Polyester, Hemp/Epoxy, 0/90° Hybrid/polyester, 0/90° Hybrid/Epoxy, 0/30° polyester, 0/30° Epoxy, 0/45° Polyester and 0/45° Epoxy. Thus fabricated materials were subjected to tensile, flexural, impact, Specific gravity, water test and hardness tests at different orientations. In addition, the effect of combination of two fibers was also investigated. The finite element analysis was carried out to compare it with experimental results. The conclusions were drawn as regards to identifying the effects of these hybrid composites on varying material properties.

Identification of New Natural Fiber Composites:

In the selection of natural fibers as reinforcements for composites, several characteristics are taken into account:

- Tensile strength and modulus
- Extensibility
- Chemical composition
- Density
- Handling difficulties
- Availability and cost
- Fineness
- Thermal stability
- Suitability for chemical treatment

With these factors in mind, a search for new natural fiber reinforcements was conducted in the southern region of India. The following novel natural fiber reinforcements were identified and are being considered for further analysis.

Environmental Aspects of Natural Fibers:

Environmental consciousness plays a pivotal role in contemporary industrial and technological development. The utilization of synthetic fibers such as glass, carbon, and nylon has posed significant environmental challenges due to their harmful impact. In response, natural fibers have emerged as a sustainable alternative, captivating researchers with their advantageous properties including cost-effectiveness, biodegradability, low density, and substantial mechanical strength compared to their synthetic counterparts. The production of natural fibers in many developing countries not only provides employment opportunities but also mitigates environmental hazards.

Natural fibers, extracted from various plant parts such as leaves, bark, stems, and roots, have been extensively studied for reinforcement in polymer matrices to achieve desired mechanical properties. The strength of natural fibers predominantly hinges on their chemical composition and bonding interface. These fibers have the potential to revolutionize the composite industry due to their eco-friendly nature. Incorporating natural fibers into automotive components contributes to environmental sustainability. The current global emphasis on environmental awareness has spurred research and academic exploration of natural fibers and their composites.

Natural fibers are instrumental in the development of high-performance, fully biodegradable 'green' composites, offering a promising solution to contemporary ecological and environmental challenges. Natural fiber-reinforced composites, characterized by their lightweight nature and renewable material sources, present cost-effective solutions across various applications.

Fiber (Roselle) Testing Requirements and Applications:

In the pursuit of identifying suitable fiber reinforcements for polymer matrices, Roselle fibers have been discovered and characterized among numerous candidates. In this study, Roselle fibers were extracted and subjected to thorough analysis of their physical and chemical properties, including:
Impact test, Flexural test, Barcol hardness test, Water absorption test and Scanning electron microscope (SEM) analysis
The chemical composition of Roselle fibers is influenced by geological and environmental factors, as well as the specific plant part from which they are extracted.

Natural fiber-reinforced polymer composites are extensively utilized in diverse applications such as electrical appliances, sporting goods, and lightweight components. They find usage in automobile parts (including brake friction materials, bumpers, doors, and windshields), household appliances, textile industries, and aerospace applications. The strength of these composites is determined by a multitude of properties. By improving our understanding and utilization of natural fibers, we can advance the development of sustainable materials that meet both environmental and performance requirements.

Process of Roselle Fiber Extraction from Plants:

To extract Roselle fibers, the following steps were undertaken:

Identification and Collection: The Roselle plant was identified, and its stems were carefully collected.
Drying: The collected stems were dried under sunlight for two days to eliminate excess moisture.
Soaking: The dried stems were then submerged in water for a period ranging from 21 to 27 days.
Fiber Extraction: Following the soaking period, the stems yielded fibers, which were subsequently washed thoroughly to remove any impurities. The fibers were then air-dried for four to five days.
Cleaning and Thinning: The dried fibers underwent a cleaning process to remove any remaining debris. Additionally, they were thinned by gently pressing to eliminate short and broken fibers.
Grinding: To facilitate certain tests requiring a powdered form, the fibers were ground into a fine powder.
Testing: Various tests were conducted on the extracted Roselle fibers, including:

- Impact test
- Flexural test
- Barcol hardness test
- Water absorption test
- Scanning electron microscope (SEM) analysis

The entire extraction process, from stem collection to testing, spanned approximately 30 to 35 days. This comprehensive process ensured the extraction of high-quality Roselle fibers suitable for further analysis and application in various industries.

Process of fiber extraction images:

Figure 1. Roselle Fiber Plant

Figure 2. Dried and Rammed Finished Fiber

Figure 3. Threaded Fiber Mat

Figure 4. Polyester Resin Added Roselle Fiber Mat

Natural Fiber Reinforced Composites:

Natural plant-based fibers offer abundant resources with high specific mechanical properties. Today, various textiles, ropes, canvas, and papers are manufactured using these fibers sourced from different parts of plants such as stems, leaves, and flowers. Polymeric composites incorporating natural fibers have garnered significant attention in recent years due to their potential to replace plastics. The interest in natural fiber-reinforced composites is growing rapidly owing to specific benefits including:

- High specific strength and modulus
- Less abrasion to processing equipment
- Low cost and weight
- Good thermal properties
- Reduced tool wear
- Low density

- Renewability and biodegradability
- Enhanced energy recovery
- Moderate strength

These composites are environmentally friendly and find applications in various sectors such as automotive, railway coaches, aerospace, military, and building and construction industries.

Needs for Natural Fiber Composites:

The development of natural fiber composites has been supported by governmental policies promoting technical applications for renewable resources. It is imperative to reduce environmental impacts such as global warming associated with the consumption of petroleum and non-renewable resources. The driving forces behind natural fiber composites include cost reduction, weight reduction, and marketing strategies emphasizing the use of renewable materials. Natural fiber-reinforced polymers offer an attractive method for replacing traditional materials, addressing disposal methods for glass fiber reinforced plastics, and contributing to sustainable practices in various industries including furniture and automotive.

Applications of Natural Fiber (Roselle):

Natural fibers present attractive options for industries seeking environmentally sound products and reduced dependence on fossil fuels. Their utilization can create employment opportunities in rural and less developed regions, aligning with sustainable development goals. Natural fibers are currently used in various applications such as automotive parts, household appliances, textile industries, and aerospace applications.

Industrial Applications of Natural Fiber Composites in the Automotive Sector:

The automotive industry is increasingly turning to raw materials from renewable resources and prioritizing recyclability and biodegradability. Natural fiber-based composites offer significant potential in this regard, contributing to weight and cost reductions for automotive parts. Studies suggest that natural fiber composites can lead to a 20% cost reduction and a 30% weight reduction in automotive components. The lightweight nature of these components results in lower fuel consumption, improved recycling possibilities, reduced waste disposal, and lower greenhouse emissions. Natural fiber composites are predominantly used for interior parts such as dashboards, door panels, seat cushions, and cabin linings, with limited use in exterior applications.

Figure 5. Applicable in Car door Dashboard for Composite Fiber

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Applications in Non-Automotive Sectors:

Natural fiber composites are utilized across various industries beyond automotive, including:

- Textiles
- Medical, healthcare, and pharmaceuticals
- Home and personal care
- Food and feed additives
- Construction and furniture
- Packaging and paper
- Bioenergy and biofuels

These composites offer lower weight and relatively lower cost, making them ideal for diverse applications such as construction, pharmaceuticals, sports equipment, and musical instruments. They are employed to manufacture panels, containers, boxes, casings, and other supporting and packaging objects, providing sustainable and cost-effective solutions.

Figure 6. Applicable in furniture's for composite fibers

5.1 Data Collection on Natural and Advanced Fibers:

Natural fibers encompass any hair-like raw material directly obtainable from animals, vegetables, or minerals, convertible into nonwoven fabrics like felt or paper, or, after spinning into yarns, into woven cloth. These fibers are slender, flexible, and relatively strong, offering a wide range of applications in composite material manufacturing. Fiber extraction technology yields fibers bonded to one another in strand form, often associated with the destruction of the stem or other plant parts containing fiber-bearing tissues.

Advanced composites utilize reinforcing fibers such as glass, carbon, graphite, aramid, and boron fibers. The properties of a single fiber depend on factors like shape, size, crystallite content, orientation, and cell wall thickness. Natural fibers are characterized by low energy consumption, density, abrasiveness, cost, renewability, biodegradability, easy availability, and worldwide abundance.

These fibers, typically rigid yet not brittle like synthetic fibers, demonstrate comparable specific strength and stiffness to glass fibers. They offer moderately high tensile strength and stiffness, are cost-effective, high-performing, and easily accessible. Plant fibers, categorized as eco-friendly due to their biodegradability and minimal environmental impact, are abundant in agricultural crops and tropical areas.

Sources and Types of Fibers:

Natural fibers originate from plant, animal, and mineral sources. Plant fibers, primarily composed of cellulose, are classified into primary and secondary sources. Primary sources include fibers produced as by-products of other principal products like food and fuel, while secondary plants are derived from manufacturing processes.

There are eight major types of plant fibers:

Bast fibers (e.g., jute, ramie, flax, rattan, soybean, hemp, vine, banana, and kenaf) collected from the skin and bast around plant sytems.
Leaf fibers (e.g., abaca, banana, sisal, and pineapple) collected from leaves.
Seed fibers (e.g., cotton, kapok, coir, and oil palm) obtained from seeds.
Fruit fibers (e.g., coconut, oil palm, and durian) extracted from fruits.
Stalk fibers (e.g., wheat, rice, bamboo, and corn) derived from stalks.
Grass fibers (e.g., rice, wheat, and bamboo) sourced from grasses.
Wood fibers (e.g., birch, pine, and eucalyptus) obtained from wood.
Animal fibers (e.g., wool, silk, hair, and fur) predominantly composed of protein.
These fibers serve diverse industrial applications, ranging from textiles and construction to bioenergy and biofuels, offering sustainable and versatile solutions.
To analyze and characterize Roselle fiber:
The several tests are required to understand its properties comprehensively. These tests include:
Impact Test:
Purpose: Assess the resilience and durability of Roselle fiber when subjected to sudden force or shock.
Method: Utilize impact testing equipment to measure how well the fiber withstands sudden loading without excessive deformation or failure.
Importance: Helps evaluate the fiber's suitability for applications where impact resistance is crucial, such as in automotive components or protective gear.

Figure 7. Impact Tester Equipment of Tinius Olsen

Flexural Test:
Purpose: Evaluate the behavior of Roselle fiber when subjected to bending loads.

Method: Support the fiber specimen and apply a bending force to measure its deflection and deformation until failure.
Importance: Provides insights into the fiber's modulus of elasticity, strength, and ductility, which are vital for structural applications.

Figure 8. Flexural Test Equipment of Tinius Olsen

Barcol Hardness Test:
Purpose: Determine the hardness of Roselle fiber, particularly its resistance to indentation.
Method: Use a Barcol Impressor to apply a specific force to the fiber surface and measure the depth of indentation.
Importance: Offers a quick and non-destructive way to assess the fiber's hardness, aiding in material selection and quality control processes.

Figure 9. Barcol Hardness Tester

Water Absorption Test:
Purpose: Measure the amount of water absorbed by Roselle fiber, indicating its porosity and susceptibility to moisture.
Method: Submerge the fiber specimen in water for a specified period and measure its weight before and after soaking.
Importance: Helps evaluate the fiber's durability, dimensional stability, and resistance to environmental factors like humidity and moisture.
Scanning Electron Microscope (SEM) Analysis:
Purpose: Examine the microstructure of Roselle fiber at high magnification to understand its morphology and composition.
Method: Use SEM to scan the fiber specimen with an electron beam and generate magnified images for analysis.
Importance: Provides detailed insights into the fiber's internal structure, allowing researchers to study its properties at a microscopic level and guide material development and processing.

Figure 10. Specimens Soaked in Water (3 different waters) for Water Absorption Test

By conducting these tests, researchers can gain a comprehensive understanding of Roselle fiber's characteristics, including its mechanical properties, hardness, water absorption behavior, and microstructural features. This knowledge is essential for optimizing the fiber's performance and identifying potential applications in various industries.

Principle of Scanning Electron Microscope (SEM):

The SEM operates on the principle of generating electron-hole pairs from backscattered electrons that escape the sample and are detected. This process forms the basis for producing magnified images of samples for analysis. Unlike optical microscopes, SEMs utilize a focused electron beam instead of light to examine specimens. This difference allows SEMs to achieve much higher magnifications and resolutions, enabling observation at subcellular, molecular, and atomic levels.

Operating Principle:

In the SEM, the specimen stage is typically grounded to prevent charging, which could distort imaging. The primary electron beam is accelerated down the microscope column by a voltage differential in the electron gun. This column is maintained under vacuum during operation. Electromagnetic lenses focus the electron beam onto the sample surface, where it scans in a raster pattern controlled by x-axis and y-axis scanning coils.

Imaging Process:

Various detectors monitor the signals emitted from each spot on the sample as the electron beam interacts with it. These signals are processed electronically to modulate the intensity of spots on a cathode ray tube, synchronized with the electron beam's raster scan. The resulting image on the cathode ray tube resembles a television display, with bright areas indicating strong response signals and dark areas indicating weak response signals.

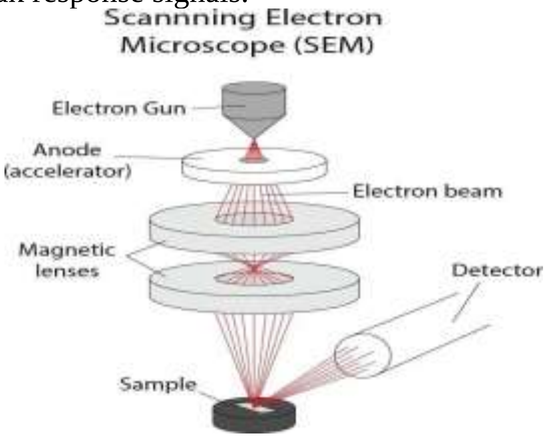

Figure 11. 3D Image of Scanning Electron Microscope Working

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By providing a more detailed explanation of the SEM principle and operating process, readers can better understand how this instrument functions and its significance in microanalysis and materials science research.

RESULTS AND DISCUSSIONS:

Impact Test Results:

Display impact test results for different Roselle fiber specimens, including single-layer and double-layer configurations with and without filler materials.
Use figures and tables to illustrate the impact strength values for each specimen type.
Provide detailed descriptions of the experimental setup and methodology used to obtain the impact test results.

Figure 12. Impact Test Results for Single Layer Roselle Fiber

Figure 13. Impact Test Results for Single Layer Roselle Fiber with Filler.

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Figure 14. Impact Test Results for Double Layer Roselle Fiber

Figure 15. Impact Test Results for Double Layer Roselle Fiber with Filler

Table:
Ensure that the table is properly formatted and labeled.
Clearly specify the composite specimen and corresponding impact strength values.

Table 1. Impact Test Results for Different Combinations

S.NO	Composite Specimen	Impact Strength (KJ/M^2)
1	Single Layer Roselle Fiber	+8.10322
2	Single Layer Roselle Fiber with Filler	+9.57132
3	Double Layer Roselle Fiber	+147.477
4	Double Layer Roselle Fiber with Filler	+112.472

Improvements in Impact Test Results:
Provide a brief interpretation or discussion of the impact test results, highlighting any trends, differences, or notable findings observed.

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Compare the impact strength values of different composite specimens to analyze the effects of adding filler material or increasing the number of layers.
Discuss the implications of the results in terms of the suitability of Roselle fiber composites for specific applications, considering factors such as strength, durability, and impact resistance.
By implementing these improvements, your impact test results and discussions will be more effectively communicated and provide valuable insights into the performance of Roselle fiber composites.

Flexural Test Results:
Present flexural test results to evaluate the bending behavior of Roselle fiber specimens.
Include data on modulus of elasticity, yield strength, ultimate strength, and ductility, if available.
Use visual aids such as graphs or tables to depict the flexural properties of the specimens.

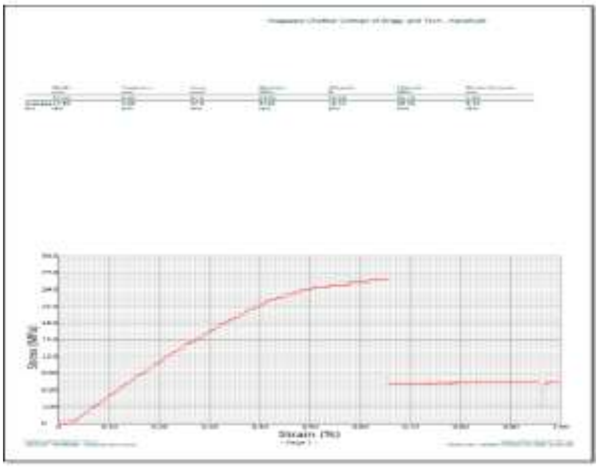

Figure 16: Flexural Test Results for Single Layer Roselle Fiber

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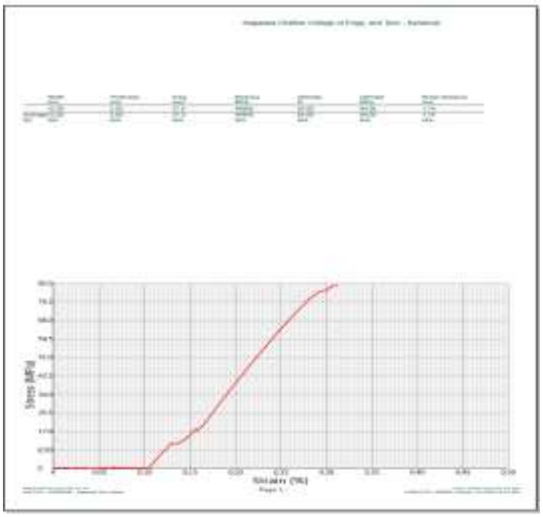

Figure 17. Flexural Test Results for Single Layer Roselle Fiber with Filler

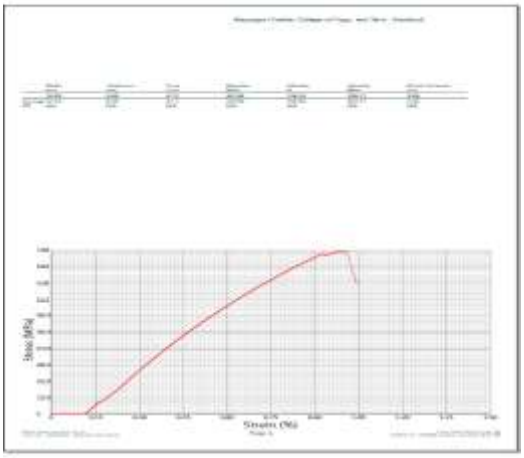

Figure 18. Flexural Test Results for Double Layer Roselle Fiber

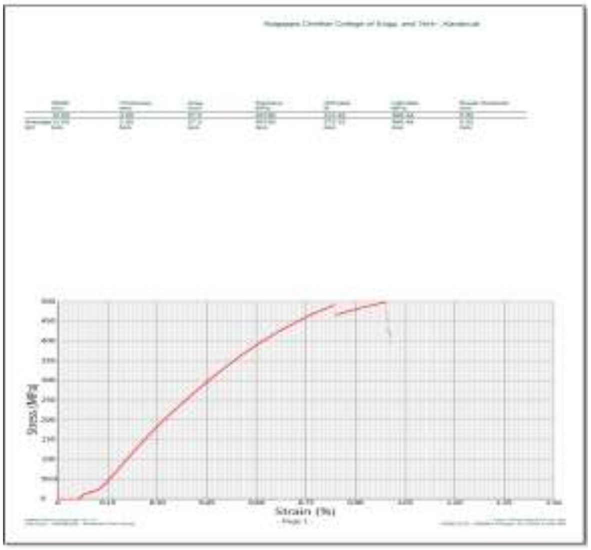

Figure 19. Flexural Test Results for Double Layer Roselle Fiber with Filler

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Table 2. Flexural Test Results for Different Specimens

S.NO.	Composite Specimen	Flexural Strength (MPa)	Flexural Modulus (MPa)	Ultimate Stress (N)	Break Distance (mm)
1	Single Layer Roselle Fiber	25.78	6120	19.33	5.32
2	Single Layer Roselle Fiber with Filler	84.00	45800	63.00	1.74
3	Double Layer Roselle Fiber	159.11	23100	119.33	5.62
4	Double Layer Roselle Fiber with Filler	372.33	93100	496.44	5.52

Discussion From the results presented in the table:

Single Layer Roselle Fiber: This specimen exhibited a flexural strength of 25.78 MPa, with a higher flexural modulus of 6120 MPa. The ultimate stress was measured at 19.33 N, with a break distance of 5.32 mm.
Single Layer Roselle Fiber with Filler: Incorporating filler material significantly increased the flexural strength to 84.00 MPa. However, the flexural modulus decreased slightly to 45800 MPa. The ultimate stress and break distance were 63.00 N and 1.74 mm, respectively, indicating reduced ductility compared to the unfilled specimen.
Double Layer Roselle Fiber: The double-layer configuration resulted in a notable improvement in flexural strength, reaching 159.11 MPa. The flexural modulus remained high at 23100 MPa, with an ultimate stress of 119.33 N and a break distance of 5.62 mm.
Double Layer Roselle Fiber with Filler: This composite specimen demonstrated the highest flexural strength of 372.33 MPa, accompanied by a flexural modulus of 93100 MPa. The ultimate stress reached 496.44 N, with a break distance of 5.52 mm.

Barcol Hardness Test Results:
Show Barcol hardness test results to assess the hardness of Roselle fiber and its composites.
Compare hardness values between different specimen types and configurations.
Discuss the implications of hardness values on the mechanical properties of the materials.

Table 3. Barcol Hardness Test Results for Different Specimens

Composite Specimens	Barcol Hardness Number
Single Layer Roselle Fiber	46
Single Layer Roselle Fiber with Filler	29
Double Layer Roselle Fiber	28
Double Layer Roselle Fiber with Filler	32

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OMEGA INSPECTION & ANALYTICAL LABORATORY

T.S. No. 57,58 & 55, 56, GUINDY INDUSTRIAL ESTATE, GUINDY, CHENNAI - 600 032. TN. INDIA

Test Report

TR No.: OIAL/23-24/03/10001 — Page 1 of 1

TOCR No:23-6274 , Dt:20-Mar-2024	Report Date: 20-Mar-2024
Customer : SETHU INSTITUTE OF TECHNOLOGY, Pulloor, Kariapatti-626115, Virudhunagar District, TamilNadu, INDIA.	Test Started On: 20-Mar-2024
	Test Completed On: 20-Mar-2024
	Sample Drawn By: CUSTOMER

Customer Ref. : Letter, Dt. 19.03.2024
Nature of Test : Barcol Hardness Test
Test References : ASTM D 2583
Sample Details : NATURAL FIBRE COMPOSITE MATERIAL

Test Results

NAME : Mr.M.S.LOKESH, Department of Mechanical Engineering (R.TEMP : 27°C)

SAMPLE ID	BARCOL HARDNESS
DLRF	24, 26, 24, 28, 24
SLRF	46, 42, 44, 40, 42
DLRF WF	32, 30, 31, 28, 30
SLRF WF	26, 29, 28, 26, 27

CONCLUDED

P.DINESH
CHEMIST
Tested / Verified By

DY. QUALITY MANAGER
Authorised Signatory

Figure 20. Barcol Hardness Test Results

Discussion the results presented in the table:

Single Layer Roselle Fiber: This specimen exhibited the highest Barcol hardness number of 46, indicating relatively high hardness compared to other specimens.

Single Layer Roselle Fiber with Filler: Incorporating filler material resulted in a lower Barcol hardness number of 29, suggesting a reduction in hardness compared to the unfilled single-layer specimen.

Double Layer Roselle Fiber: The double-layer configuration showed a further decrease in hardness, with a Barcol hardness number of 28.

Double Layer Roselle Fiber with Filler: Interestingly, the addition of filler material to the double-layer configuration slightly increased the Barcol hardness number to 32.

Water Absorption Test Results:

Present water absorption test results to evaluate the moisture uptake of Roselle fiber specimens.

Include data on initial dry weight, saturated weight, and percentage of water absorption.

Interpret the significance of water absorption behavior in terms of material durability and environmental resistance.

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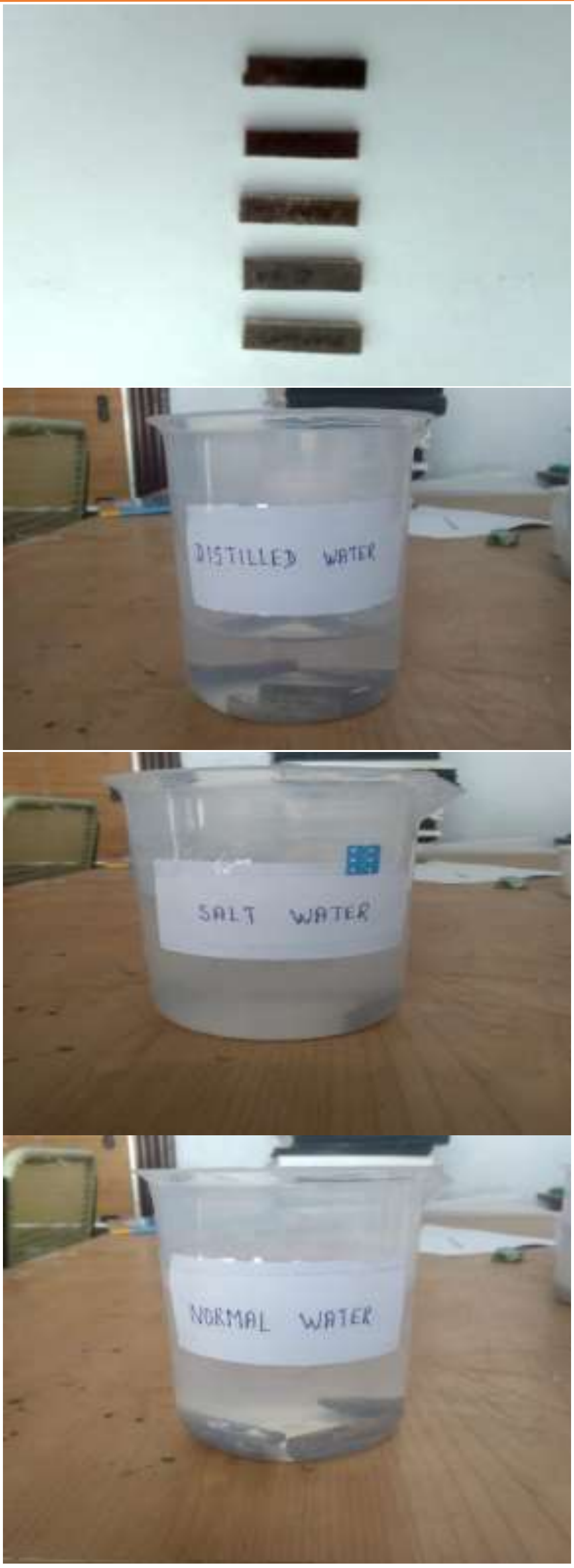

Figure 21. Specimens Soaked in Three Different Types of Water

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Table 4. Water Absorption Test Results in Salt Water:

S.NO	Composite Specimen	Initial Weight (g)	Final Weight (g)	% of Reduction
1	Single Layer Roselle Fiber	2.06	2.09	1.456
2	Single Layer Roselle Fiber with Filler	2.70	2.73	1.111
3	Double Layer Roselle Fiber	2.55	2.601	2.352
4	Double Layer Roselle Fiber with Filler	2.85	2.88	1.052

Observations:

Double Layer Roselle Fiber with Filler exhibits the lowest water absorption rate at 1.052%, followed by Single Layer Roselle Fiber with Filler at 1.111%. Double Layer Roselle Fiber composite has the highest water absorption rate at 2.352%.

Table 5. Water Absorption Test Results in Normal Water:

S.No.	Composite Specimen	Initial Weight (g)	Final Weight (g)	% of Reduction
1	Single Layer Roselle Fiber	2.20	2.28	3.636
2	Single Layer Roselle Fiber with Filler	2.85	2.95	3.508
3	Double Layer Roselle Fiber	2.15	2.28	6.046
4	Double Layer Roselle Fiber with Filler	3.21	3.35	4.361

Observations:

Single Layer Roselle Fiber with Filler exhibits the lowest water absorption rate at 3.5089%, followed by Single Layer Roselle Fiber at 3.636%. Double Layer Roselle Fiber composite has the highest water absorption rate at 6.046%.

Table 6. Water Absorption Test Results in Distilled Water:

S. No.	Composite Specimen	Initial Weight (g)	Final Weight (g)	% of Reduction
1	Single Layer Roselle Fiber	1.95	2.01	3.076
2	Single Layer Roselle Fiber with Filler	3.00	3.11	3.666
3	Double Layer Roselle Fiber	2.57	2.68	4.280
4	Double Layer Roselle Fiber with Filler	3.01	3.06	1.661

Observations:
Double Layer Roselle Fiber with Filler exhibits the lowest water absorption rate at 1.661%, followed by Single Layer Roselle Fiber at 3.076%. Double Layer Roselle Fiber composite has the highest water absorption rate at 4.280%.

Scanning Electron Microscope (SEM) Analysis Results:
Describe SEM analysis findings regarding the microstructure and morphology of Roselle fiber specimens.
Present SEM images or diagrams to illustrate key features observed in the micrographs.
Discuss any insights gained from SEM analysis regarding fiber composition, orientation, or defects.

CONCLUSION

The utilization of natural fiber polymer composite Roselle fiber with four different combinations - SINGLE LAYER ROSELLE FIBER, SINGLE LAYER ROSELLE FIBER WITH FILLER, DOUBLE LAYER ROSELLE FIBER, and DOUBLE LAYER ROSELLE FIBER WITH FILLER - represents a promising and sustainable approach in material science and engineering. These natural fibers offer a range of advantageous properties, including high strength, low cost, and eco-friendliness, making them attractive reinforcements for polymer matrices.

Impact Test: The results showed that the DOUBLE LAYER ROSELLE FIBER combination exhibited the highest Impact Strength among other combinations, with a strength of +147.477 K/J M2.

Flexural Test: The results demonstrated that the DOUBLE LAYER ROSELLE FIBER WITH FILLER composite specimen displayed the highest flexural strength, measuring at 372.33 MPa, compared with other specimens. DOUBLE LAYER ROSELLE FIBER followed closely with a flexural strength of 159.11 MPa.

Barcol Hardness Test: The test results indicated that the SINGLE LAYER ROSELLE FIBER combination had the highest hardness value of 46 on the scale of 100 among the other composite fibers. It was followed by DOUBLE LAYER ROSELLE FIBER WITH FILLER composite, which had a hardness value of 32 on the scale of 100.

Water Absorption Tests:

Salt Water Absorption: DOUBLE LAYER ROSELLE FIBER WITH FILLER exhibited the lowest water absorbency at 1.052%, followed by SINGLE LAYER ROSELLE FIBER WITH FILLER at 1.111%. DOUBLE LAYER ROSELLE FIBER composite had the highest water absorption rate at 2.352%.

Normal Water Absorption: SINGLE LAYER ROSELLE FIBER WITH FILLER showed the lowest water absorbency at 3.5089%, followed by SINGLE LAYER ROSELLE FIBER at 3.636%. DOUBLE LAYER ROSELLE FIBER exhibited the highest water absorption rate at 6.046%.

Distilled Water Absorption: DOUBLE LAYER ROSELLE FIBER WITH FILLER displayed the lowest water absorbency at 1.661%, followed by SINGLE LAYER ROSELLE FIBER at 3.076%. DOUBLE LAYER ROSELLE FIBER exhibited the highest water absorption rate at 4.280%.

These findings highlight the potential of Roselle fiber composites in various applications, including automotive components, construction materials, and consumer goods, where properties such as impact resistance, flexural strength, and water resistance are crucial. Further optimization and refinement of composite formulations could lead to even more enhanced material properties, paving the way for sustainable and environmentally friendly solutions in the field of materials science and engineering.

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