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AN INVESTIGATION MECHANICAL PROPERTIES OF ARECA FIBER COMPOSITE MATERIAL

M. Rajesh and K. Balaji
Department of Mechanical Engineering, Vel Tech Rangarajan Dr. Sagunthala R&D Institute of Science and Technology, Avadi, Chennai, Tamil Nadu, India
E-Mail: rajeshmurkur9@gmail.com

ABSTRACT

In contrast with the past natural fibers derived from renewable resources have the potential to replace glass, carbon, and other man-made fibers in polymer composites as a reinforcing material. The research emphasis is on the study of areca fiber and areca trunk husk with Araldite LY556 epoxy resin with hardener HY-951 in a 10:1 ratio and polyester Iso resin with hardeners accelerator and catalyst. Where for 1 kilogram of polyester Iso resin 20 grams of accelerator and 15 grams of catalyst should be taken for the complete composition of fiber materials. Four laminated sheets are fabricated according to ASTM standards. Two different laminate sheets are fabricated in which two contain areca trunk husk in their resin and the other two do not contain in its resin. This fabrication process is done by using the hand layup process and the press molding process. The mechanical properties of laminated sheets are tested by conducting compression, tensile, impact, and hardness tests. Laminates with optimal mechanical properties are suggested for future applications.

Keywords: areca trunk husk, mechanical properties, hand layup process.

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1. INTRODUCTION

Modern society is struggling with the age-old problem of how to dispose of or put non-reversible polymers and other solid wastes to good use. In this way, harmful compounds will be produced by the methods used to decompose these wastes, which are not smart. Taking all of the foregoing into account, the only path that will take us to a solution is to reinforce polymers using natural fibers. Regular strands are eco-friendly materials that need little effort to recycle, have a thin profile, and aren't too thick. Their excellent tensile qualities make them a potential replacement for more conventional strands used in reinforcing plastics, such as glass and carbon. Inconsistency, leading to weak adhesion between regular filaments and lattice gums and, therefore, low pliable qualities, is a major drawback of using distinctive strands as reinforcement in plastics. Some ideas and methods for surface modification are established to increase the composites' malleability and fiber-network interfacial holding. It is also quite obvious that fiber loading has a significant impact on the stiffness and strength of natural fiber polymer composites. There is a limit beyond which the mechanical characteristics do not improve with increasing fiber-to-weight ratio. To predict the tensile characteristics of composites reinforced with natural fibers, mathematical models or finite element models may be a powerful tool.

Researchers and scientists are anticipating fiber sources for sustainable processing. The ultimate objective is to create an organic fiber that may be used in the textile industry and to create environmentally friendly products (sheaths), which has drawn attention on a global scale as a hazard to biodiversity. The physical, chemical, and structural characterization of the fiber obtained from Areca catechu is thus highlighted in this work. By using manual combing in addition to conventional water retting, fibers were recovered. The sample's mechanical and physicochemical characteristics were investigated. In terms of strength and rigidity, fiber demonstrated the best mechanical qualities; however, they were less extensible [1-2]. In the current study, the mechanical characteristics of composites made of natural fibers were assessed. Areca fiber is used in this instance as a new natural fiber reinforcement, while epoxy resin serves as the matrix. Chemical processing was used to improve the interfacial interaction between the matrix and the areca fibers that were isolated from the husk. Impact and hardness tests were carried out mechanically, and the results are presented. When compared to naturally occurring, untreated fibers, the mechanical characteristics of composites made of chemically treated areca fibers perform better. It is also important to note that the strength of areca fiber composites rises with an increase in the volume percentage of fiber in the composite and post-composites curing time [3]. Studies that the areca fibers mechanical characteristics are identified and contrasted with those of other natural Fiber coins that are currently available. Also, these Areca fibers underwent chemical treatment, and their impact on fiber strength is investigated. Using randomly positioned fibers in maize stalk fine fiber and phenol formaldehyde, areca fiber composite laminates were created. To evaluate the impact of the biodegradable test on the strength of PF composites, chemical changes of fibers through alkali treatment were conducted. Most of the micro vascular tubules have fractured at once, as shown in the EMS image of the fracture surface, and they exhibit brittle behaviour Areca Fibers that have been alkali-treated and have tensile strengths that are greater than a natural fiber, reaching a maximum of 123.36 MPa. Maize fiber has a 152MPa strength which is more than areca fiber. According to what is described in the section, the alkaline treatment of maize fibers favourably enhances the fiber surface [4]. In the present study, the Areca nut fruit is retted with stagnant water, flowing, or salty for five days to explore the effects of the retting procedure and pre-treatments on the fiber surface by SEM examination. It must be dried for 2 to 3 days in the shade after 5 days. Areca nuts were thoroughly dried before the fiber was hand removed and treated with an alkali and an enzyme. The fiber's composition, characteristics, and SEM (scanning electron microscope) pictures of both enzyme- and untreated fiber were studied. With the use of SEM analysis, it is demonstrated that the retting procedure and the treatments applied to the fiber alter the surface morphology. When untreated fibers were compared to untreated fibers in the burning test, the ash and color were altered [5]. Natural fiber reinforcement is a growing subject of study due to its ease of procurement, biodegradability, and mechanical qualities that are equivalent to synthetic fiber-reinforced composites. Areca's cheap cost, lightweight, and tensile strength have made it popular in composite production. Scientists have employed various natural fibers to make bio-composites, but areca leaf fibers have seldom been studied. This study examines the mechanical performance of a natural fiber reinforced epoxy composite of areca fiber with varied orientations [6]. Our primary objective is to study Areca Palm fiber reinforced polymer composites' heat conductivity. Changing the volume fraction, temperature, and fiber angles (0^0, 45^0, 90^0) explains the findings. The Areca Palm's stalk was retted to harvest its fibers. To make green composites that decompose naturally, the recovered fibers were strengthened with polymer composites in a polyester resin matrix. The direct thermal conductivity meter technique is used for experimental exploration of thermal conductivity characterisation. Findings included a temperature-dependent and volume-fraction-dependent shift in thermal conductivity [7].

This study examines the mechanical performance of an epoxy composite reinforced with natural areca fiber in a variety of configurations. The composite with the sheath fiber orientation of 90°-90°-90° had the maximum strength, and its estimated Young's modulus was 1.798GPa. Composites with other sheath fiber orientations were constructed, and a tensile test was conducted. The composite's maximal elongation before the specimen's first failure was calculated. The composite that elongated to around 11.6% of its initial length contained sheath fibers oriented 90°, 90°, and 90°. The benefit of the composite with fibers oriented 90°, 90°, and 90° was that it could tolerate more strength when the force was simply applied in the sample's longitudinal direction [8]. This work developed biodegradable composites using areca nut frond fibers for low-strength applications. For 72 hours, the fronds are submerged in water to harvest fibers. Alkaline solution treated removed fibers. Fibers are air-dried for 24 hours. Use corn starch, water, and plasticizers to make a biodegradable resin matrix impregnated with treated short fibers in random orientation, poured into a mold, and compressed for 10 minutes the composites dried for 48 hours after extraction. The composite has 45.29N tensile strength [9]. This study examines the mechanical and physical properties of composite plates manufactured from coconut shell powder, palm kernel powder, and carboxy methylcellulose. Using hand layup, the composite plate is made with varying amounts of coconut shell, palm kernel, and carboxy methyl cellulose. ASTM Standards require tensile strength, hardness, total dissolved solids, biodegradability, and water solubility tests [10]. Fiber reinforced composites are replacing traditional materials for their strength-to-weight ratio and abundance in production for structural and engineering applications. Kenaf, hemp, flax, jute, and sisal are lightweight, recyclable, and cost-effective. The synthetic construction of two or more reinforcing matrix and suitable matrix components creates a composite, a heterogeneous material with specified qualities. This experiment uses composite specimens with one layer of jute fiber, one layer of E-Glass, and one layer of jute fiber. Another example has one layer of E-glass, one layer of jute fiber, and one layer of E-glass above it [11-12]. Admixtures strengthen concrete via physical and chemical enhancement. This article analyzes sea shells as a chemical additive and verifies concrete strength. Typical Portland cement chemical reaction temperature. A key component of marine shells is calcium carbonate (CaCo3), which helps densify and stiffen bones in all living organisms [13].

Natural fiber-reinforced composites have been the subject of steadily growing research over the past ten years due to their potential to replace synthetic fiber-reinforced plastics in various technical applications and industries at a lower cost with greater sustainability [14-15]. The development of diverse polymer matrix composites with a variety of fiber reinforcements, including carbon fiber, glass fiber, aramid, natural fibers, hybrid, etc. was stimulated by the requirement for a high strength-to-weight ratio in components that demanded great performance and efficiency. Natural fiber composites play a significant role when it comes to the use of environmentally friendly materials and the requirement to create diverse sustainably oriented engineering and industrial components [16].

Hand lay-up, which dates back the longest, is the method used to make woven composites. Following certain protocols, the samples are prepared. The surface is initially treated with release anti adhesive to stop the polymer from sticking to the mold surface [17]. A thin plastic sheet is then placed over the mould plate at the top and bottom to provide a level surface for the completed product. The woven reinforcing layers are spread down on the surface of the mold and cut into the required shapes. As a consequence, as already said, the resin was blended with other components and infused onto the surface of the reinforcement that was already assembled in the mold. Following that, the remaining mats are positioned on top of the previous polymer layer, and pressure is applied with a roller to get rid of any trapped air bubbles and additional polymer. After that, the mould is sealed and the pressure is released to create a single mat. Once room-temperature curing is complete, the woven composite is removed from the molded surface [18].

Areca fibers are extracted from the stem of the areca tree and by utilizing a NaOH solution, the proposed work compares the mechanical characteristics of naturally occurring fibres that have undergone chemical treatment and those that have not. The mechanical characteristics of the fibres from Areca trees will be assessed when laminates are manufactured utilizing the hand lay-up method [19]

Areca fruit, fronds, and stem leaves are the main sources of areca fiber. With non-reversible polymers in particular, the world nowadays is challenged with the dilemma of developing new and propelled technologies and techniques to eliminate or utilize solid wastes. The techniques used to separate the wastes aren’t cost-effective and often produce dangerous substances [20]. Given these considerations, it appears that the only solution to the problem is to reinforce polymers with natural fibers. Normal strands are less thick, readily available, reusable, and environmentally beneficial. They can be used to replace conventional strands because they have great tensile qualities. Using characteristic strands to strengthen plastics has the significant drawback of creating a weak link between regular filaments and lattice gums, which results in less flexible properties [21].

The primary objective of this research is to investigate the density, impact strength, hardness, and dielectric properties of a polypropylene areca fiber composite reinforced with random distribution and varying areca fiber loading. The findings show that polypropylene areca fiber composites improved characteristics over plain polypropylene growth with fiber loading. Using the extrusion method, this study has effectively produced polypropylene reinforced with areca fibers with various fiber loading fractions, and test samples have been generated using the injection molding method. We may conclude that composites strengthened with areca fibers are promising new materials with increased strength for use in commercial, residential, and automotive applications.

2. PREPARATION OF LAMINATED SHEETS

The composite materials used in the current investigation are the areca fiber cloth mat andareca trunk husk. A total of four laminated sheets are prepared for this research. Two different resins are used to form these laminate sheets. Two laminate sheets are prepared by using Araldite LY556 as resin and HY951 as a hardener. The other two laminate sheets are prepared using polyester Iso resin, accelerator, and catalyst as hardeners.

Laminates are prepared by using Araldite LY556 as resin and HY951 as hardener and two areca laminated sheets using Araldite LY556 with hardener HY951 are prepared. These laminates were prepared by taking the resin-hardener ratio as 10:1. One of these laminates was prepared by mixing the areca trunk husk in the resin. The second laminate does not contain the areca trunk husk.

Araldite LY556 - HY951 laminated sheet (with areca trunk husk): The current study composite materials include an areca Fiber cloth mat and an areca trunk husk. In this laminate the areca trunk husk is added to the Araldite LY556 resin - HY951 hardener composition. A hand layup process is used to prepare these laminates. To prevent the composite mat from bonding to the surface, a thin PVC transparent film sheet is utilized at the mold's apex and base. Five layers of areca fibers are placed on top of one another with the resin mixture applied between each layer. The weight of the areca cloth mat is 64 grams. Since the weight of the resin should be three times more than the weight of the mat as per standard. 192 grams of resin including 10 grams of areca trunk husk is taken to produce these laminates. Rubber wipers are utilized to avoid air bubbles on the mat's surface.

Araldite LY556 - HY951 laminated sheet (without areca trunk husk): This laminate is produced by using the same process as laminated sheets with areca trunk husk. However, this laminate sheet does not contain areca trunk husk in its resin mixture. These mats have been left for up to 24 hours in the sunlight to harden. Each mat is split into two laminates after hardening by ASTM specifications for tensile, compression, impact, and hardness testing.

Laminates are prepared by using Polyester Iso resin and Accelerator, catalyst as hardener: Two areca laminated sheets using Polyester Iso resin with hardener (accelerator, catalyst) are prepared. For 1 kilogram of polyester resin, 20 grams of accelerator and 15 grams of catalyst should be taken for the complete composition of fiber materials. One of these laminates was prepared by mixing the areca trunk husk in the resin. The second laminate does not contain the areca trunk husk.

Polyester Iso resin with hardener as the accelerator, and catalyst (with areca trunk husk): The current study's composite materials include an areca fiber cloth mat and an areca trunk husk. In this laminate, the areca trunk husk is added to the Polyester-accelerator and catalyst hardener composition. A hand layup process is used to prepare these laminates. To prevent the composite mat from bonding to the surface, a thin PVC clear film sheet is used at the top and bottom of the mold. Five layers of areca cloth fibers are placed on top of one another with the resin mixture applied between each layer. The weight of the areca cloth mat is 64 grams. Since the weight of the resin should be three times more than the weight of the mat as per standard. 192 grams of resin including 10 grams of areca trunk husk is taken to produce these laminates. Rubber wipers are utilized to avoid air bubbles on the mat's surface.

3. LAMINATES COMPOSITION

Polyester Iso resin with hardener as the accelerator, and catalyst (without areca trunk husk): This laminate is produced by using the same process as laminated sheets with areca trunk husk. However, this laminate sheet does not contain areca trunk husk in its resin mixture. These mats have been left for up to 24 hours in the sunlight to harden. Each mat is split into two laminates after hardening by ASTM specifications for tensile, compression, impact, and hardness testing.Fig-1indicates the Preparation of laminates by using Araldite LY556, Polyester, and Areca trunk husk. The laminate composition is shown in Table-1. Figures 2-5 show the Laminates S1, S2, S3 and S4.

Figure-1. Preparation of laminates by using Araldite LY556, Polyester, and Areca trunk husk.

Table-1. Laminates composition.

Laminates	Laminated Sheets Composition	Areca Mat (AM)		Areca Trunk Husk In Resins (AH)	Araldite LY556 (A.LY556)	Polyester Iso Resin (PR)
		No. of layers	In gm	In gm	In gm	In gm
S1	AM+AH+A.LY556	5	64	10	192	0
S2	AM+A.LY556	5	64	0	192	0
S3	AM+AH+PR	5	64	10	0	192
S4	AM+PR	5	64	0	0	192

Figure-2. S1.

Figure-3. S2.

Figure-4. S3.

Figure-5. S4.

4. TEST METHODS AND DISCUSSIONS

4.1 Compression Test

After the preparation of laminates, they are tested using a universal testing machine (UTM) to examine their compression and tensile properties. The impact and hardness tests are conducted using Charpy and Rockwell hardness testing machines. The results obtained from these tests are discussed below.

The force which is responsible for the deformation of the laminate refers to the compressive tests. All laminates were subjected to a compression test using a fixture that was based on the ASTM D695 standard. The compressive qualities of specimens S-1, S-2, S-3, and S-4 were tested using a UTM machine in line with the ASTM standard. The test specimen has a size of (200 x 20mm). During the test, Uni-axial stress is delivered through both ends of the specimen until it fractures. Table-2 displays these outcomes. Figure-6 describes the compression test of the specimens.

Table-2. Compression test results.

Specimens	Maximum Load (N)	Compressive Strength (Mpa)	Compressive Strain (mm/mm)	Compressive Modulus (Gpa)	Extension At Max. Compressive Load(mm)
S1	2417.96	5.34	0.00796	1240.35906	-2.29223
S2	1899.38	4.20	0.00659	1236.17141	-2.31152
S3	874.17	1.93	0.00814	346.97219	-5.21187
S4	1783.52	3.94	0.00549	1326.01151	-1.92275

According to Figure-6 the braking area is situated in the middle of the specimen. Figure-7 shows the specimen that is shattered. The stress-strain raw data used to calculate the compressive strength and compressive modulus of various specimens is represented by specimen graphs in Figure-8. The results shown in Table-2 indicate that Araldite LY556 - HY951 specimen pieces (with areca trunk husk) can withstand the maximum load, maximum compressive strength, and maximum compressive modulus than the Araldite LY556 - HY951 specimen pieces (without areca trunk husk). Specimen pieceS1 (AM+AH+A.LY556) is better than specimen pieceS2 (AM+A.LY556). The same process is done by using polyester Iso resin then the results are obtained by using Polyester Iso resin with hardener as the accelerator, and catalyst (with areca trunk husk). The specimen pieceS3 (AM+AH+PR) has less maximum load, maximum compressive strength, and maximum compressive modulus than the specimen pieceS4 (AM+PR) Polyester Iso resin with hardener as the accelerator, and catalyst (without areca trunk husk).

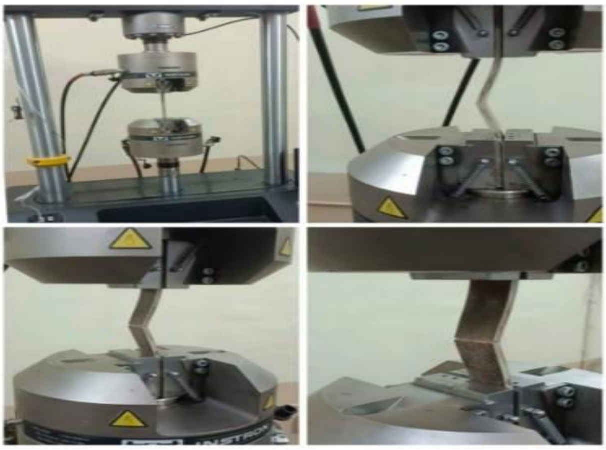

Figure-6. Compression test of the specimens.

Figure-7. Specimens after the compression test.

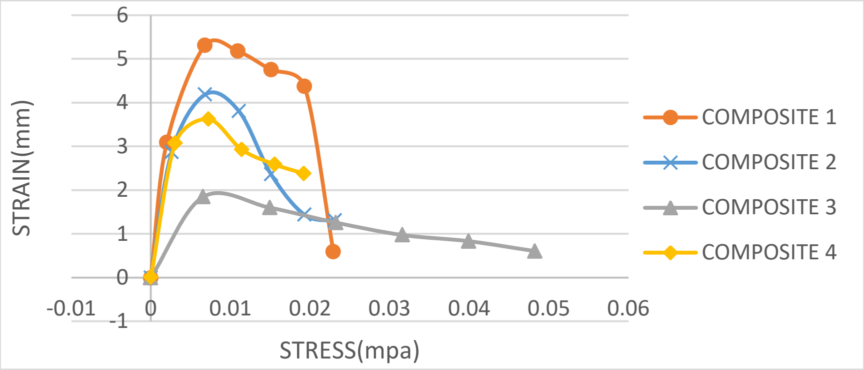

Figure-8. Stress vs strain graph for compression test.

4.2 Tensile Strength Test

As demonstrated in Figure-3, it measures the amount of force required to break a composite as well as how much stretching or elongation must occur before the specimen breaks. Tensile characteristics of specimens S-1, S-2, S-3, and S-4 were examined by the ASTM D3039 standard using a UTM machine. The size of the test sample is (200 x 25 mm). The specimen is subjected to a uni-axial load through both ends of the test until it cracks, as shown in fig. Following the result analysis, the ultimate tensile strength of the composite laminates is determined. Table-3 shows the tensile test results.

Table-3. Tensile test results.

Specimens	Maximum load (N)	Ultimate Tensile Strength (Mpa)	Tensile Strain (mm/mm)	Tensile Modulus (Gpa)	Elongation (mm)
S1	4131.65	65.58	0.01482	6238.64530	1.78
S2	1374.86	21.82	0.02440	1368.94120	2.95
S3	3231.51	51.29	0.01203	5779.02193	1.44
S4	5155.72	81.84	0.02293	4601.23326	2.76

Using stress-strain raw data, the specimen graphs in Figure-11 show we estimated the tensile strength and tensile modulus of different specimens. The tested specimens got deformed in their shape shown below in Figure-10. The results show that the Araldite LY556 - HY951 specimen piece (with areca trunk husk) can withstand the maximum load, maximum tensile strength, and maximum tensile modulus than the Araldite LY566 - HY951 specimen piece (without areca trunk husk). Specimen pieceS1 (AM+AH+A.LY556) is better than specimen pieceS2 (AM+A.LY556). The same process is done by using the polyester Iso resin then the results are obtained by using Polyester Iso resin with hardener as the accelerator, and catalyst (with areca trunk husk). The specimen pieceS3 (AM+AH+PR) has less maximum load, maximum tensile strength, and maximum tensile modulus than the thespecimenS4 (AM+PR) Polyester Iso resin with hardener as the accelerator, and catalyst (without areca trunk husk). Figure-12 indicates the Ccompression and Tensile test load graph.

Figure-9. Tensile test of the specimens using UTM.

Figure-10. Specimens after tensile test.

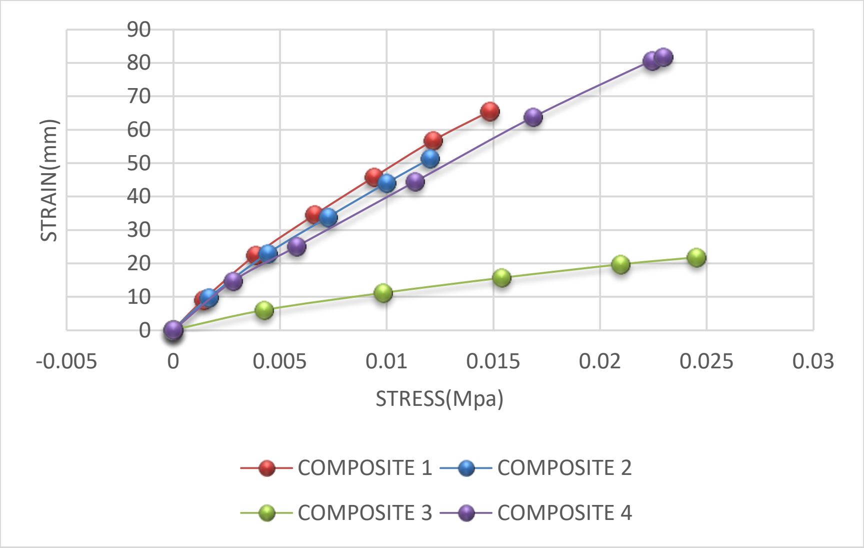

Figure-11. Stress vs strain graph for tensile test.

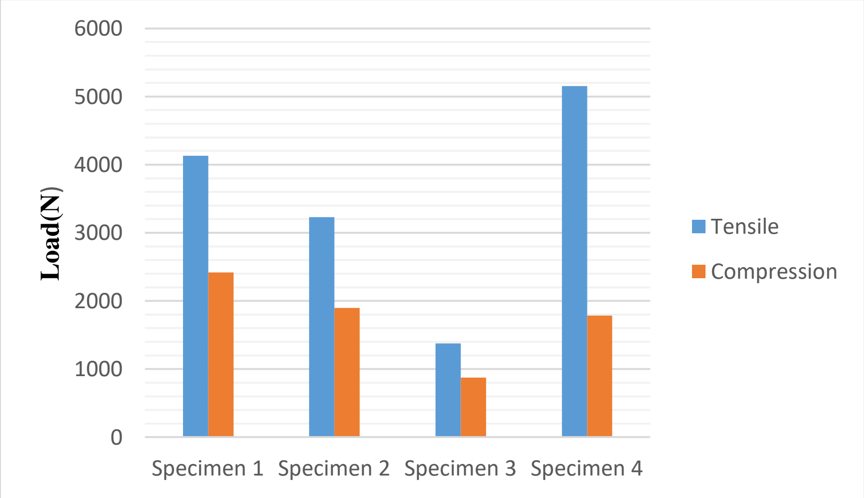

Figure-12. Load graph.

The raw data is used to plot the load graph after the laminates have undergone mechanical testing, as illustrated in Figure-4. The above load graph shows that the laminate which is prepared by using Araldite LY566 as resin and HY951 as a hardener (with areca trunk husk) has more compression and tensile load than the laminate prepared without areca trunk hunk. The laminate is prepared by using Polyester Iso resin and Accelerator, catalyst as hardener Polyester Iso resin and Accelerator, catalyst as a hardener (with areca trunk husk) has less compressive and tensile load than the laminate prepared without areca trunk hunk.

4.3 Hardness Test

According to the net increase in depth of imprint as a force is applied, the Rockwell Hardness test gauges hardness. Many times, the R, L, M, E, and K scale express hardness numbers without units. Higher numbers indicate a material's hardness. Using a hardness testing device by the ASTM D785 standard, the hardness of laminates S-1, S-2, S-3, and S-4 was assessed. The dimensions of the test sample are (30 x 30 mm). A reference sample is set on top of the Rockwell Hardness tester. Table-4 Hardness test results. The gauge is reset to zero in the wake of a light load. The principal load is imposed by pulling a lever. After 15 seconds the lift is completed. The hardness is assessed while still providing light stress after giving the specimen 15 seconds to recuperate.

Table-4. Hardness test results.

S. No	Specimens	Hardness number
1	S1	56.30
2	S2	53.30
3	S3	54.07
4	S4	56.33

As shown in Table-4 the specimen piece which is prepared by using Araldite LY566 as resin and HY951 as a hardener (with areca trunk husk) has more Hardness bearing strength than the specimen piece prepared without areca trunk hunk. The specimen piece which is prepared by using Polyester Iso resin and Accelerator, catalyst as hardener Polyester Iso resin and Accelerator, catalyst as a hardener (with areca trunk husk) has less hardness bearing strength than the specimen piece without areca trunk hunk. Figure-13 shows the specimens after the hardness test. Figure-14 indicates the Hardness Test using the Rockwell Machine and the Hardness test bar graph in Figure-15.

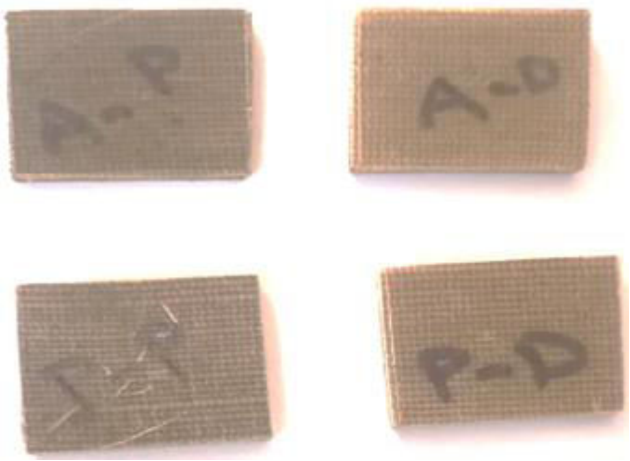

Figure-13. Specimens after hardness test.

Figure-14. Hardness test using rockwell machine.

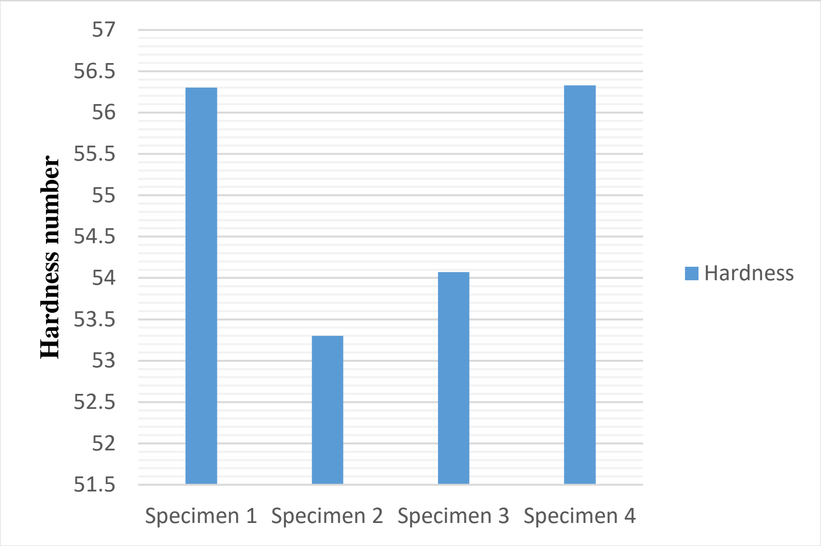

Figure-15. Hardness test bar graph.

4.4 Impact Test

A pendulum hammer is discharged from a standard height to strike a beam specimen (either notched or unnotched) with a specific amount of kinetic energy during Charpy and Izod impact tests. The Charpy test is used for the specimens. The rectangular specimen with a notch cut out of one side fits into the Charpy impact tester. The notch permits the fracture to start at a predefined place.

Using impact testing equipment by ASTM A370 standard, the impact characteristics of the specimens S-1, S-2, S-3, and S4 were examined. Test sample dimensions are (55 x 13 mm). Impact testing is a method for calculating the energy that a material absorbs during fracture. The effectiveness of a certain material is assessed using this method. The impact resistance of the composite laminates is calculated after the result analysis.

Table-5. Impact test results.

S. No	Specimens	Impact strength (J)
1	S1	80
2	S2	54
3	S3	58
4	S4	70

As shown in Table-5 the specimens which are prepared by using Araldite LY566 as resin and HY951 as a hardener (with areca trunk husk) have more impact strength than the specimen piece prepared without areca trunk hunk. The specimen piece which is prepared by using Polyester Iso resin and Accelerator, catalyst as hardener Polyester Iso resin and Accelerator, catalyst as a hardener (with areca trunk husk) has less impact strength than the specimen piece prepared without areca trunk hunk. Figure-16 and Figure-17 indicate the specimens are seen both before and after the impact test. The impact test bar graph is shown in Figure-18.

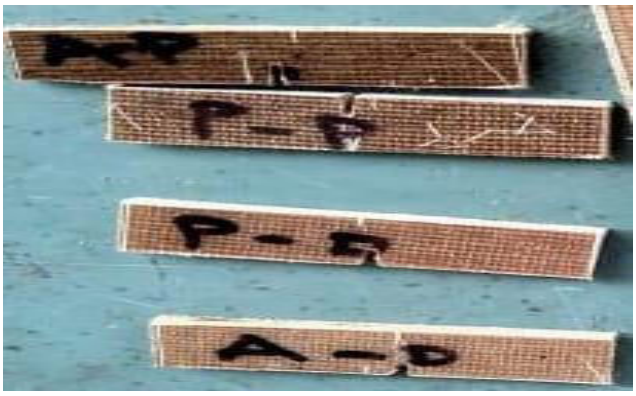

Figure-16. Specimens before impact test.

Figure-17. Specimens after impact test.

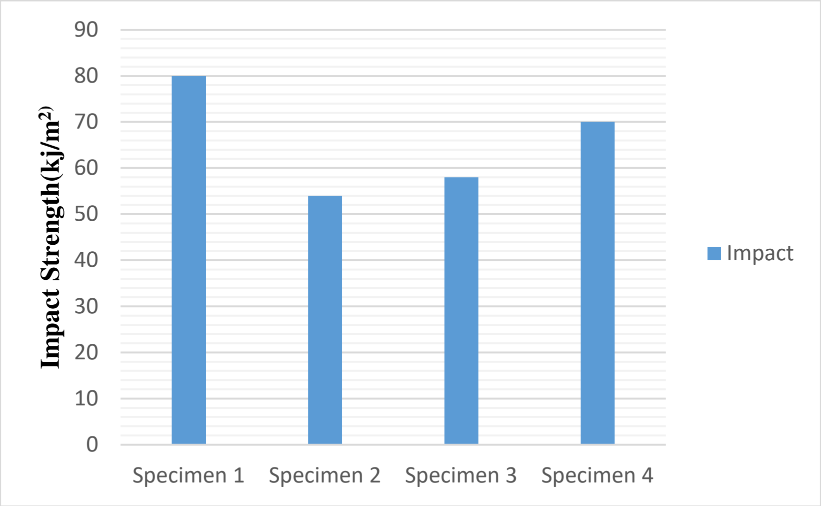

Figure-18. Impact test bar graph.

5. CONCLUSIONS

In this investigation, the results of these experimental studies on the mechanical behaviour of composites two laminates are prepared by using Araldite LY556 as resin and HY951 as a hardener, and the two Laminates are prepared by using Polyester Iso resin and Accelerator, catalyst as a hardener with areca trunk husk and resins is applied. The laminates are prepared by using a hand lay-up process. The natural fiber areca composites are tested for their compression strength, flexural, hardness, and Impact test was conducted as per the ASTM D standards (ASTM-D695) mechanical properties gathered from the laminated.

- While comparing the laminates prepared by Araldite LY556 - HY951 laminated sheet (with areca trunk husk) it is investigated that it has more compression, tensile, hardness, and impact strength than the laminate prepared without areca husk.
- In the same way, the Laminates are prepared by using Polyester Iso resin and Accelerator, catalyst as a hardener (without areca trunk husk) has more compression, tensile, hardness, and impact strength and Impact than the laminate prepared with areca husk.
- From the above investigation, the laminates prepared by using Araldite LY556 (with areca trunk husk) and laminates prepared by using Polyester Iso resin (without areca trunk husk) are suggested. It is observed that after doing tests on compression, tensile. Hardness and impact tests with better mechanical properties are obtained.

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