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# Mechanical Behaviors of Hybrid Composites Reinforced with Epoxy Resin

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**Abstract.** Natural fibres have emerged as a renewable and cheaper substitute to synthetic materials such as glass and carbon. A composite material can be defined as combining two or more materials that result in better properties. The constituents are reinforcement, and the other is a matrix. The main advantages of composites are high strength, stiffness combined with low density. As natural fibres are gaining more importance in recent times, many industries are focusing on these natural fibre composites, so that is why they are used as a component in composite materials. In this experiment, the analysis aims to characterize different natural fibres when combined with different ratios of the coconut coir and the bamboo. So, to fabricate the specimen, the hand lay-up method is used. The coconut coir and the bamboo composition are considered in three different variations. Then the natural fibres are subjected to resin and hardener compositions to test the suitability, tensile strength, flexural strength, and shore hardness test. We also conduct static analysis through ANSYS software.

**Keywords:** natural fibre, composite material, tensile strength, finite element analysis.

## 1 Introduction

The interest in natural fibre composite material is rapidly growing in the mechanical sector. There is a profound change in both the industrial application and the fundamental research. Natural fibres are mostly preferred because they are a renewable source, non-toxic to nature, cheap, partially recyclable, and biodegradable. Plants like flax, cotton, hemp, jute, sisal, pineapple, bamboo, banana, and silkworm are primarily used for very long years due to their properties. They are generally used as lignocelluloses fibres. The availability, renewability, low density and price, and satisfactory mechanical properties make them an attractive ecological alternative to glass, carbon, and manufactured fibres used to manufacture composites. These are environmentally friendly and used in transportation like railway coaches, aerospace, military applications, building, and construction consumer products.

Recently, car manufacturers have been interested in incorporating natural fibre composites into the interior and exterior parts. So, many companies such as Mercedes Benz, Toyota, and Daimler Chrysler have already accomplished this and are looking to expand the use of natural fibre composites. This serves to lower the vehicle's overall weight of the vehicle thus increasing fuel efficiency and increasing the sustainability of their manufacturing process. The two major factors currently limit the large-scale production of natural fibres composites. Firstly, they are the strength of natural fibre composites, which is very low compared to glass. Secondly, they limit the large-scale production of natural fibre composites in water absorption. Generally, the natural fibres absorb water from the air and direct contact with the environment.

In addition to the naturally occurring composites, many other materials are generally used. They have been in use for a very long time. The demand will be placed according to the material's performance so that no other material can satisfy them. Natural fibres are now considered the most important and have a severe alert. Due to their applications and advantages, the properties of natural fibre composites can be modified by several factors based on the fibre combinations, processing methods, and fibre volume fraction.

Currently, natural fibre composites are used for the production of passenger cars. For example, Daimler Chrysler cars are equipped with an under-floor protection using abaca fibre (natural fibre) obtained from a plant called Musa Family, which belongs to the banana family. Many natural fibre composites are used in most electronic goods such as mobile phones, tablets, and laptops for weight reduction without any trade-off strength. The properties of the natural fibre are determined by the architecture together, defined by the chemical composition and the structural features. These are highly applicable in civil aviation and in mass transportation.

Properties of different natural fibres are presented in Table 1.

Table 1 – Properties of different natural fibres

| Property | Coir | Bamboo |
|---|---|---|
| Tensile strength, MPa | 144 | 330 |
| Modulus, GPa | 31.0 | 9.80 |
| Elongation, % | 32.3 | 20.0 |
| Density, kg/m$^3$ | 670 | 450 |

The materials that make up the composites are matrix, resins, additives, and reinforcements.

The resin is the main ingredient in composites. Thermoplastics and thermosets are the main resin systems. The thermoplastics resin is solid at room temperature, melts when supplied heat, and solidifies when cooled. The most commonly used resins in composites are unsaturated polyesters and vinyl esters.

The glycides, ethers, and amines are the main epoxies in the composites. The material properties are hardening are to be manipulated to get the good performances. The applications of epoxies are in the aeronautical industries and electrical device applications.

Application of fibre composites is represented by the following groups, which are 70 % of the total market value: automotive (23%), building and public works (21 %), aeronautics (17 %), and sports (11 %).

North America represents 40 % of the composites industry's total market value, 22 % in the Asia-Pacific region, and 3 % of the rest of the world.

## 2 Literature Review

Satyanarayana et al. [1] initiated research on the structural property studies of coir fibres. Fibres from different parts of the coconut palm tree were examined for properties such as size, density, electrical resistivity, ultimate tensile strength, initial modulus, and percentage elongation. Their research determined the stress-strain diagrams of the fracture mode, micro fibrillary angle, and cellulose and lignin contents of these fibres.

Shibata et al. [2] discovered composites reinforced with natural fibres and observed properties of biocomposites made from short abaca fibre and biodegradable polyester.

Rout et al. [3] show that the untreated coir fibres have weak interfacial bonding with the polyester matrix and the mechanical properties of the composites are poor.

Rajak et al. [4] investigated that the glass fibre or synthetic fibre reinforced polymeric composites acquire more strength. But these application areas are limited due to their very high fabrication cost. It also identifies natural fibers' four potential environmental improvements as substitution of higher volume natural fibres for some base polymer material. Lower environmental impact from natural fibre production compared to glass fibre production, lower emission while in use due to weight reduction, and energy/carbon credits from the end of life incineration.

Haneefa et al. [5] studied the tensile and flexural properties of short banana and glass hybrid fibre reinforced polystyrene composites. They observed that the elongation at break decreases with an increase in the volume fraction of fibres.

Ahmed and Vijayarangan [6] evaluated the tensile, flexural, and interlaminar shear properties of woven jute and jute-glass fabric reinforced polyester composites by arranging different stacking sequences. The above two researchers listed the systematic procedure for evaluating tensile and flexural properties in their work.

Syduzzaman et al. [7] studied that natural fibres are advantageous over glass fibre as they buckle rather than break during processing and fabrication. In addition, cellulose possesses a flattened oval cross-section that enhances stress transfer by presenting an effectively higher aspect ratio.

Mohammed et al. [8] studied the advantages mentioned above. The natural fibre composite also has disadvantages, such as poor compatibility between hydrophobic polymer matrix and hydrophilic fibres, leading to weak interfaces and poor mechanical properties.

Khanam et al. [9] investigated tensile, flexural, and compressive properties of coir-silk fibre reinforced composites, and Dong [10] reviewed studies evaluating tensile properties for glass and bamboo fibres reinforced polyester hybrid composites.

Therefore, the present project work aims to fabricate various composite laminates with epoxy resin. The fibres involved in this experimental analysis are bamboo and coir. These are subjected to different ratios (bamboo 70 % + coir 30 %, bamboo 60 % + coir 40 %, and bamboo 80 % + coir 20 %). This experimental fabrication is done by the hand lay method. ASTM D638 finds the tensile strength. Analysis done is done through ANSYS software.

The main objectives are:

– to test the strength of the specimen when different bamboo and coir are in different ratios;

– to study the tensile strength of each material separately to apply in automotive applications;

– to study the SHORE hardness property of the material when mixed with different proportions.

## 3 Research Methodology

### 3.1 Materials selection

Natural fibres are taken initially for fabrication. The epoxy is used to make the composite laminate. The fabrication process has been done to fabricate the FRP laminate. This process is done by the hand lay method.

The materials have been selected according to the fibers' usage and availability. The following are some essential points for material selection. They are:

– to develop an alternative new solution for the given applications;

– to use quantitative methods in material selection;

– to find reliable properties sources of material properties;

– to analyze the performance requirements;

– to evaluate the different solutions.

The raw materials used in this experimental process are natural fibre (coconut coir and bamboo), epoxy resin, and hardener.

Coir is a versatile natural fibre extracted from mesocarp tissue or husk of coconut fruit. Generally, fibre is of a golden color when cleaned after removing from coconut husk.

Coir is the fibrous husk of the coconut shell. Being tough and naturally resistant to seawater, the coir protects the fruit enough to survive months floating on ocean currents to be washed up on a sandy shore where it may sprout and grow into a tree if it has enough freshwater because of all the other nutrients it needs have been carried along with the seed. These characteristics make the fibres quite valuable for the floor and outdoor mats.

The term “bamboo fabric” widely refers to many different textiles made from the bamboo plant. Fabrics have been made from bamboo for thousands of years, but it is only in contemporary times that the process of making this hardy and fast-growing wood into fabric has been perfected.

Epoxy is the chemical name, and Araldite is the marketing name by Hindustan international (India) private limited manufacturing company.

Epoxy has the following properties: high strength, good sticky nature, toughness, water resistance, and tasteless and non-toxic.

Epoxy resin is defined as a molecule containing more than one epoxy group. This has high mechanical properties, like a large cohesive force. It has flexibility and diversity in design. It also has excellent stability without impurities. These have good strength and low absorption of moisture. These are relatively high in viscosity, so that they are usually moulded at temperatures in the region of 50–100 °C. When these get reacted with hardeners, they are set to a hard mass that does not melt or dissolve in solvents. Hardeners are typically amine anhydride-based chemistry. They are usually synthetic, most commonly derived from petrochemicals, but are partially natural.

### 3.2 Hand lay-up method

This experimental process follows the Hand lay method. This is one of the most traditional methods used in the industry. It is a straightforward process, where each ply is handled only by hand and is stacked layer by layer up to the desired thickness.

Although this method is reliable, it requires much labor, and the procedure requires more time than the advanced manufacturing methods. Brushes and rolls are used in this method to apply the resin and reduce the air bubbles. There is no heat required during the curing process, and it is usually left until cured at room temperatures.

They are prepared by respecting some steps. First, the mould surfaces are treated by releasing an anti-adhesive agent to avoid sticking polymer to the surface.

Then, a thin plastic sheet is applied at the top and bottom of the mould plate to get the smooth surfaces of the product. The layers are woven reinforcement is cut to required shapes and placed on the surface of the mould.

Thus, previously mentioned, the resin is thoroughly mixed with the hardener and poured uniformly on the mats.

It is seen that no air bubbles should roll inside the sheets. The mould is then closed and pressured on the single mat.

After it is cured at room temperature, the mould is opened, and woven composite is removed from the mould surface.

### 3.3 Experimental procedure

The experimental technique follows the hand lay method. This has a long wide plate used as a base. The resin and hardener are mixed firstly, and then the coating is applied uniformly on the entire area of the required size of the laminate. Then a layer of fiber is evenly placed over the resin, then a small amount of force is applied on it with the roller. Then again, a coating is kept on it.

This process is repeated until the required thickness is obtained. Then a coating of wax is kept to finish the product, or a Teflon sheet is kept on it with a little weight.

The laminate setting on the board is gently removed by releasing the Teflon sheet. The laminate has on the edges with the fibres are cut in to make laminate to a uniform shape. The carpentry chisel cuts fibres. The chisel also cuts the extra parts. The tensile and flexural tests specimens were cut on a CNC machine as per ASTM standards: length – 165 mm; width – 19 mm; thickness – 3 mm.

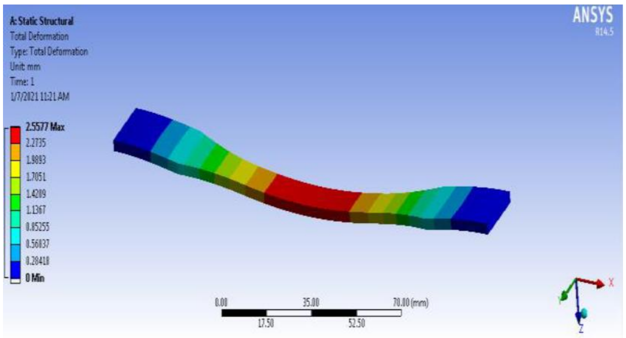
## 4 Results

The laminate setting on the board is gently removed by releasing the Teflon sheet. The laminate has on the edges with the fibres are cut in to make laminate to a uniform shape. The carpentry chisel cuts fibres. The chisel also cuts the extra parts. As per ASTM standards, the tensile and flexural tests specimens were cut on the CNC machine.

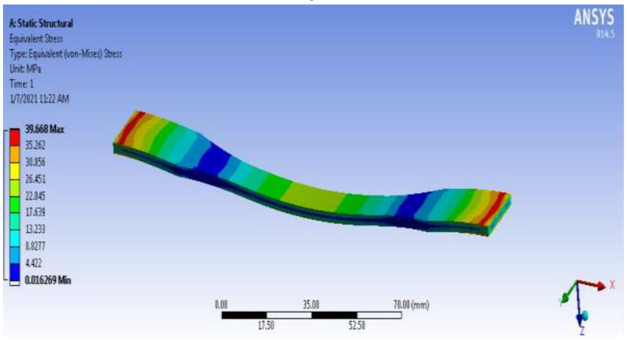
The numerical simulation results are presented in Figure 1 and summarized in Tables 2–3. The results for different material compositions are also presented in Figure 2.

Shore D Hardness is a standardized test measuring the depth of penetration of a specific indenter. Test methods used to measure shore D hardness are ASTM D2240 and ISO 868. The results are presented in Table 4.

Flexure tests are generally used to determine flexural modulus or flexural strength. A flexure test is more affordable than a tensile test, and test results are slightly different. The material is laid horizontally over two points of contact (lower support span), and then a force is applied to the top of the material through either one or two points of contact (upper loading span) until the sample fails. The maximum recorded force is the flexural strength of that particular sample. The results are also presented in Table 4.




a

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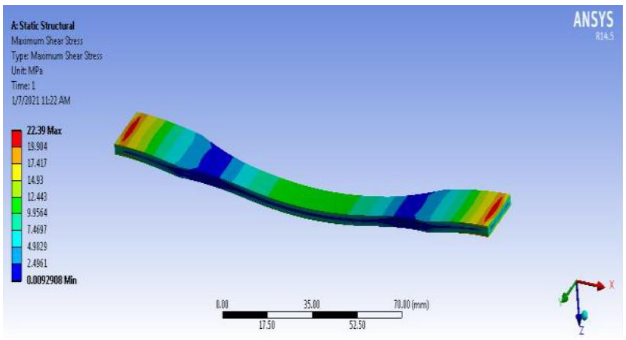


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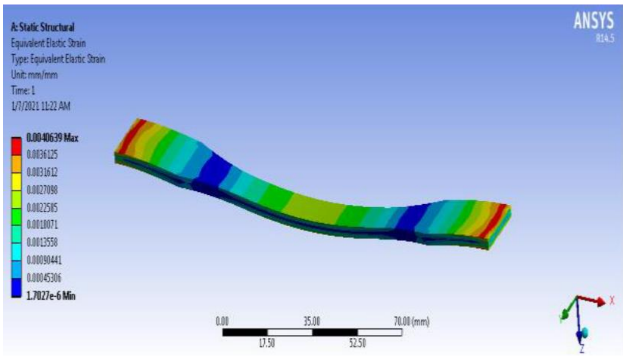
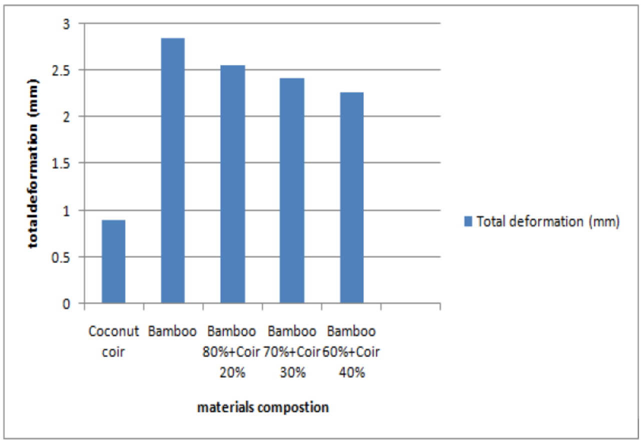



d

Figure 1 – The numerical simulation results: a – total deformations; b – von Mises equivalent stress; c – shear stress; d – strain

Table 2 – The numerical simulation results

| Material | Total deformation, mm | Equivalent stress, MPa | Shear stress, MPa | Strain, $10^{-3}$ |
|---|---|---|---|---|
| Coir | 0.90 | 44.8 | 25.4 | 1.45 |
| Bamboo | 2.84 | 44.1 | 24.9 | 4.51 |
| Bamboo 80 % + + Coir 20 % | 2.56 | 39.7 | 22.4 | 4.06 |
| Bamboo 70 % + + Coir 30 % | 2.42 | 37.5 | 21.1 | 3.84 |
| Bamboo 60 % + + Coir 40 % | 2.27 | 35.3 | 19.9 | 3.61 |

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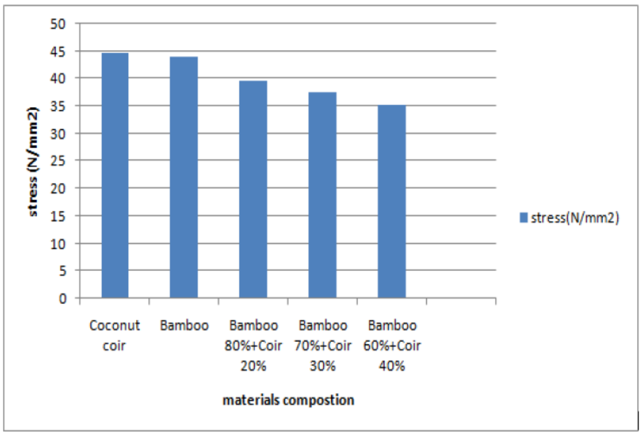


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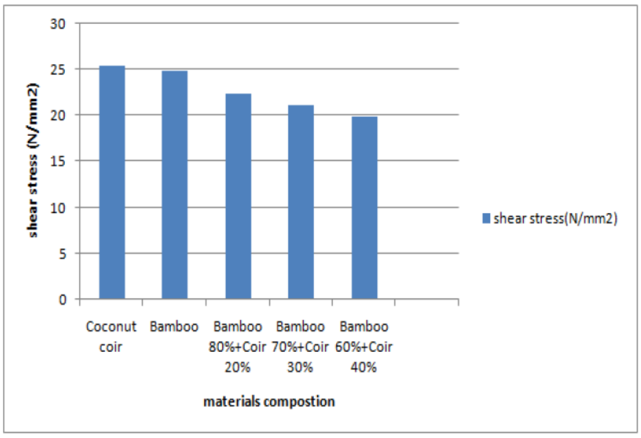
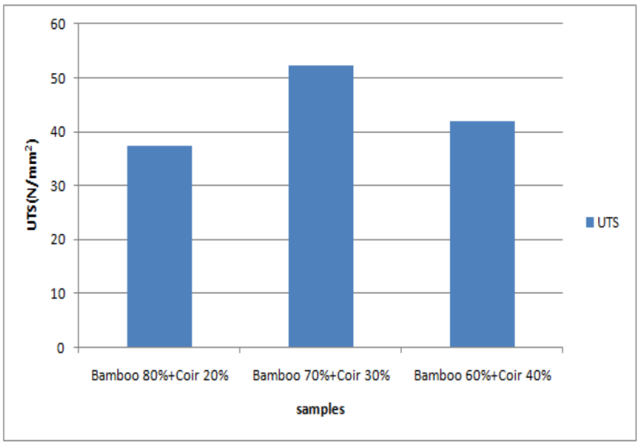



c

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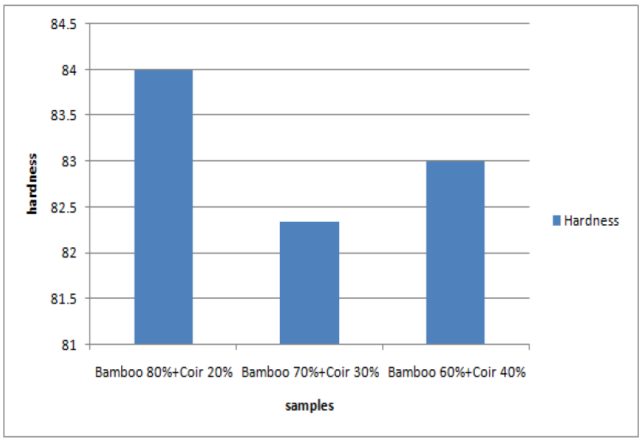
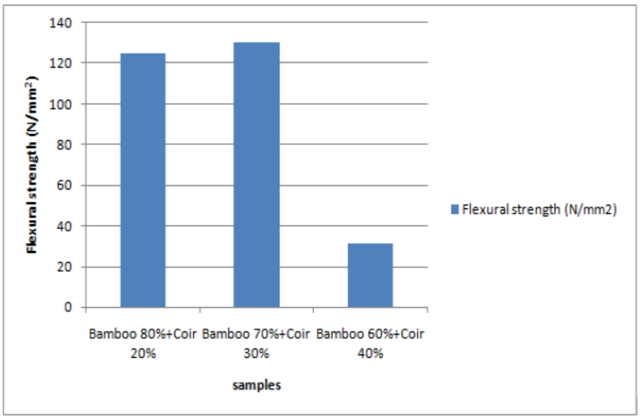



e




f

Figure 2 – Material composition vs total deformation (a), von Mises equivalent stress (b), shear stress (c), tensile stress (d), hardness (e), and flextural stress (f)

Table 3 – Experimental results on tensile stress

| Sample | UTS, MPa | Elongation, % |
|---|---|---|
| Bamboo 80 % + Coir 20 % | 37.4 | 1.44 |
| Bamboo 70 % + Coir 30 % | 52.6 | 0.60 |
| Bamboo 60 % + Coir 40 % | 42.1 | 0.84 |

Table 4 – Shore D hardness test and elongation results

| Sample | Hardness | Elongation, % |
|---|---|---|
| Bamboo 80 % + Coir 20 % | 84 | 125 |
| Bamboo 70 % + Coir 30 % | 82 | 131 |
| Bamboo 60 % + Coir 40 % | 83 | 31 |

## 5 Conclusions

The present project work aims to fabricate various composite laminates with epoxy resin. The fibers involved in this experimental analysis are bamboo and coir. These are subjected to different coir ratios (bamboo 70 % + coir 30 %, bamboo 60 % + coir 40 %, and bamboo 80 % + coir 20 %. This experimental fabrication is done by the hand-lay method. ASTM D638 finds the tensile strength. Analysis done is done through ANSYS software.

The laminates are fabricated by hand lay-up method effectively. The experimental study reveals enhanced mechanical properties like hardness, flexural strength and tensile strength.

The hardness improved by adding reinforcements to the base alloy. The addition of epoxy resin particles improved the hardness, and the improved wear properties resulted from the addition of hardener and epoxy resin. Further, the mechanical properties are enriched by heat treatment. Hardness and tensile strength were improved by the composition of (bamboo 70 % + coir 30 %, compared to other samples.

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