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Fabrication and Mechanical Characterization of Sisal Fiber, Banana Fiber and Bamboo Strip Reinforced Hybrid Composite

Vivek Kumar[1*] and D.K. Singh[2]

[1,2]Mechanical Engineering Department,
Madan Mohan Malaviya University of Technology, Gorakhpur, UP
E-mail: [1]khu.vivek1999@gmail.com

Abstract—*Natural fibres exceptional mechanical qualities have made them a popular choice for reinforcement in composite materials and environmental benefits in recent years. In this study, a hybrid composite material was fabricated using sisal fiber, banana fiber, and bamboo strip as reinforcements in a polyester resin matrix. The fibers were prepared, and then combined with the matrix material using Hand layup techniques. The composite was then cured under specific temperature and pressure conditions.*

Mechanical properties of the hybrid composite were characterized using impact, flexural, and tensile tests. After fabrication of the sample with different composition it shows that the tensile and flexural strength of hybrid composite get decreases when the amount of sisal fiber increases while the impact strength of the hybrid composite get increases.

Overall, the results of this study demonstrate that sisal fiber, banana fiber, and bamboo strip can be used as potential reinforcements in composite materials, providing an environmentally friendly alternative to traditional synthetic fibers. The hybrid composite material produced in this study exhibited excellent mechanical properties, which makes it suitable for a range of applications in various industries, including construction, automotive, and aerospace.

1. INTRODUCTION

Natural fibres are gaining importance in the burgeoning green economy. Natural fibres are abundant renewable resources in nature. Natural fibres are carbon neutral because they absorb the same amount of Carbon dioxide that they emit. Natural fibres like jute, banana, sisal, coir, and others are completely renewable, environmentally friendly, have a high specific strength, are nonabrasive, very cheap, and biodegradable. These properties have recently piqued the interest of natural fibre researchers. Since bananas are grown by farmers all over the world, banana fibres are widely available as agricultural waste. These wastes are biodegradable and environmentally friendly, as well as having a low cost, lightweight, low density, and high tensile strength. They can be used for a variety of purposes. During the last few decades, composites research has produced excellent engineering materials. Many composite materials have demonstrated their utility and are now ready to replace other materials. The introduced polymer resin matrix materials also performed well as a matrix.

A study to investigate the properties and potential applications of a composite material made from Aloe vera and jute, as reinforcement materials in epoxy-based composite laminates. HY951 hardener and LY556 Epoxy resin were used as the matrix and hardener, respectively. The results of the study showed that the ultimate tensile strength (UTS) and flexural strength of the Aloe vera laminate were slightly higher than that of the jute fiber.

However, the drop impact test results showed that the three samples had similar behavior. Moreover, the thermal conductivity of the aloe vera/jute hybrid laminates is almost the same as that of Aloe vera laminates. However, it is higher by 13.65% than that of the jute fiber alone.

Overall, the study suggests that Aloe vera and jute fibers can be used as potential reinforcement materials in epoxy-based composite laminates. The results indicate that Aloe vera has slightly better mechanical properties than jute fiber, while the thermal conductivity of the hybrid jute/aloe vera laminate is higher than that of jute fiber alone. These findings could have significant implications for the development of new, environmentally friendly composite materials with improved mechanical and thermal properties. [1]. 2 In a study, banana and bagasse fibers were used as reinforcement materials for composite fabrication. The chemical treatment of fiber with NaOH and NaCl solutions of 5% concentration to improve their mechanical properties. The volume fractions of the fibers used were 20% and 30%, and they were used in equal proportions for fabrication using the hand layup method..By these improved adhesion properties observed. 30% volume fraction has more harder than the 20% volume fraction. [2]. 3. Hybrid composites are indeed fabricated by the combination of two or more fiber in single matrix. The properties of the composite material can be affected by several factors, including the variation in fiber volume or weight fraction, variation in the stacking sequence of fiber layers, fiber treatment, and environmental conditions, extreme fiber layer and treatment of fiber by NaOH. [3]. 4. Hybrid composites were fabricated using combinations of banana/bamboo, pineapple/bamboo, banana/pineapple, and bamboo/ banana/ pineapple. The composites were manufactured by using the hand layup technique, with 70% resin and 30% fiber. [4].

5. A composite material was fabricated using banana and sisal fibers and an epoxy resin. The chemical treatment of fiber is conducted with 5% NaOH solution, and the resin and hardener were mixed in appropriate volumes. The composite was prepared using the hand layup technique, with 30g of epoxy and hardener used for each sample. The study found that when the banana fibers were in excess compared to the sisal fibers, the composite material had higher tensile strength values but lower bending strength values. Additionally, an excessive amount of hardener was found to lead to brittleness in the composite material. Interestingly, the study found that a composite made with 80% sisal and 20% banana fiber had higher strength values than a composite made with an equal proportion of both fibers (50% sisal and 50% banana). This suggests that the specific ratio of fibers used in the composite can have a significant impact on its mechanical properties. Banana fiber is known for its smooth surface finish, and combining it with sisal fiber could lead to a composite material with both good strength and a desirable surface finish.[5]. 6. Sisal and banana fibre are use for composite with alkali treatment by 15% $Ca(OH)_2$. Here compression molding method are use for fabrication. Three sample are made, S/B/S (untreated),B/S/B (treated),S/B/S (treated) with 40% volume of Epoxy matrix. Tensile and impact test show good result for S/B/S(treated) and flexural test show good result for S/B/S(untreated).[6] 7. In the study you mentioned, three different composites were fabricated using jute fiber, banana fiber, and a hybrid combination of jute and banana fibers. The jute composite had 20% jute fiber, the banana composite had 10% banana fiber, and the hybrid composite had 15% jute and 15% banana fiber. All composites were treated with 3% potassium permanganate to improve their wettability, and polyester resin was used along with 3% cobalt naphthenate for curing and 5% methyl ethyl ketone peroxide. The composites were manufactured using the hand lay-up technique and applying compression jute fiber was made into the length of 4 cm of length and Banana fiber is made into 5 cm long fiber. 30% Volume fraction hybrid composite shows higher increase in mechanical properties than the non hybrid composite. While potassium Permanganate treatment increases tensile and flexural strength but not show any improvement in impact test.[7] 8. In this study, kenaf fiber was used as a reinforcement material for composite fabrication using the vacuum-assisted resin transfer molding (VARTM) process with cold pressing. The process involved infusing unsaturated polyester resin into the preforms under a vacuum pressure of 1.3-1.6 kPa. The resulting composite was analyzed using dynamic mechanical analysis (DMA), which revealed that the moduli of the VARTM composite were doubled in the temperature range of -50 °C to 200 °C compared to the un-reinforced polyester matrix. This indicates that the kenaf fiber reinforcement greatly improved the stiffness and strength of the composite over a wide temperature range.[8].

Based upon literature survey, it can be seen that most of the researcher's have used Sisal/Banana or Sisal/Bamboo for fabrication the composite. Scarce literature is available on the combination of Sisal, Banana, and Bamboo together as all these three fibers have good mechanical properties and they can be stack together in single composite with better properties.

2. MATERIALS AND METHODS

Materials

In hybrid composite material we are using banana, bamboo and sisal fibers as reinforcement and epoxy(resin) as a base(matrix) material having low viscosity. We are using bamboo cross link mat, sisal and banana fibres and find effect on mechanical property of composite material on different composition.

- Sisal, Banana and Bamboo.
- Epoxy resin and hardener
- Silica gel
- Acetone
- NaOH
- SISAL FIBRE:- Sisal fiber is procure from fiber region, Chennai(India) Sisal fiber is a natural fiber that is derived from the leaves of the sisal plant, which belongs to the Agavaceae family. Sisal fiber has also gained attention as a potential reinforcement material for use in composite materials due to its desirable mechanical properties. It shown in fig.1

Figure 1: Sisal fiber

BANANA FIBRE:

Banana fibre is procure from fiber region, Chennai(India). Mature banana pseudo-stem was taken from the farm. It shown in Figure 2

Figure 2: Banana Fibre

BAMBOO STRIP:

Bamboo Strip is procure from the local market of Gorakhpur(India). It shown in Figure 3.

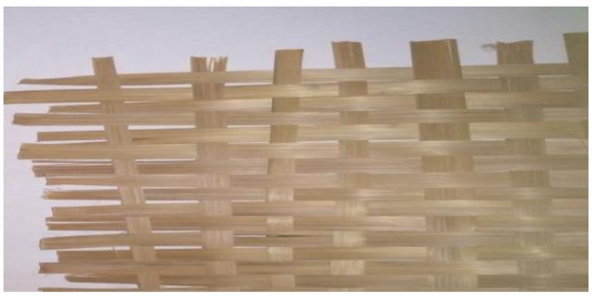

Figure 3: Bamboo strip

Epoxy and Hardener resin LY 556 and the hardener HY 951 were used. During composite construction, the Epoxy. When combined, they provide great chemical and moisture resistance as well as outstanding electrical insulating qualities. As shown in figure1.4

Figure 4: Epoxy and Hardener

Silicon Oil:

Silicon oil is used in interface between polymer sheet and composite as lubrication for easy removal of composite after fabrication. It’s chemical name is poly(dimethyl siloxane). As shown in fig 1.5.

Acetone:

Acetone is chemical solvent that is used to remove epoxy from beaker, brush. Its density is 0.7 gm/cc .

Figure 5: Acetone

Sodium Hydroxide:

Another name of sodium hydroxide is caustic soda having chemical formula NaOH. It comes in flakes, pellets, granules, and solution forms. It is employe d in the current investigation. As shown in fig3.7.It comes in flakes, pellets, granules, and solution forms. It is employe d in the current investigation. Chemical Treatment of Fibers Fibers contain more accessible hydroxyl group which leads to improper bonding between matrix and reinforcement. In order to improved bonding with matrix and fibers is treated with alkali treatment with NaOH. Other impurities like lignin and wax present on surface are also removed and aspect ratio increased. Here 5%NaOH solution use for treatment. Fiber are dip in solution for 24 hours and washed with distilled water 3-4 times.

FABRICATION METHOD:

Hand layup is a process used in the manufacturing of composite materials, such as fiberglass, carbon fiber, or Kevlar. In this process, the composite material is laid up by hand onto a mold or tool surface, and then cured to produce a solid composite part.The hand layup process involves the following steps:

Preparing the mold: The mold or tool surface is first cleaned and prepared to ensure that it is free from any contaminants or debris.

Cutting the composite material: The composite can be cut into the desired shape and size using various cutting methods such as sawing etc.

Applying the resin: A layer of resin is applied to the mold or tool surface using a brush or roller.

Laying up the composite material: The composite material is then placed onto the resin-coated mold surface, and pressed down to ensure good contact.

Adding additional layers: Additional layers of composite material and resin are added until the desired thickness and strength is achieved.

Curing: The composite material is allowed to cure or harden, usually at room temperature or with the application of heat.

Demolding: The cured composite part is removed from the mold or tool surface, and any excess material is trimmed off.

Hand layup is a common manufacturing process used in the production of a wide range of composite products, including boat hulls, aircraft parts, wind turbine blades, and sports equipment. While it is a relatively simple process, it requires skilled workers who are able to lay up the composite material in a consistent and precise manner.

FABRICATION PROCESS

After alkali treatment of sisal and banana fiber is chopped into length of 5cm and bamboo strip made into the mat format. In fabrication Hand Layup method is used. Now epoxy and hardener are mixed in10:1 and stirred for 10-15 minutes for homogeneous mixer with help of glass rod. Now fix the PVC sheet on acrylic sheet with cello tape. Apply thin coat of separator(Silicon Oil) on sheets. Now apply the first coat of Epoxy & Hardener mixture on the PVC sheet fixed to acrylic sheet with the help of brush. Coating should be to the size of Bamboo mat used. (size of bamboo mat 300mm*300mm layer).Now add the resin mixture on the first layer of bamboo mat & use roller for uniform spreading of mixture. Now the mixture of sisal and banana fiber which chopper are mixed with epoxy and hardener mixture and put on the bamboo mat and used roller. Now bamboo mat put on it and apply epoxy and hardener mixture on the top of mat with help of roller and put PVC sheet on it which is coated with silicon oil. Now these sample kept under the hydraulic press for 24 hours.

3. TESTING

3.1 Mechanical Testing:

Mechanical testing is an important aspect of material characterization, and three common tests used to assess the mechanical properties of materials are tensile testing, flexural testing, and impact testing. Tensile testing is used to determine the strength and ductility of a material by applying a steadily increasing force until it breaks or fractures. Flexural testing is used to determine the strength and stiffness of a material under bending loads, while impact testing is used to assess a material's ability to absorb energy and resist fracture or deformation when exposed to sudden shocks or impacts.

For the testing of mechanical properties in this study, ASTM standards were followed. Tensile testing was conducted according to ASTM D638 with a feed rate of 5mm/min, and flexural testing was conducted according to ASTM D790 at a feed rate of 2mm/min. Both tests were conducted using an Instorn-1195 universal testing machine with a maximum load capacity of 100KN. Impact testing was conducted using a Zwick impact testing machine, and the sample was prepared according to ASTM D256. These tests were conducted to determine the optimal combination of materials for achieving the best mechanical strength and fire-wearing capacity.

4. RESULTS AND DISCUSSION:

Table 1: Composition of samples

Sample	Composition by wt%
Sample 1	Sisal fiber=7%, Banana fiber=7%, Bamboo strip=17%.
Sample 2	Sisal fiber=9%, Banana fiber=7%, Bamboo strip=17%.
Sample 3	Sisal fiber=11%, Banana fiber=7%, Bamboo strip=17%.

4.1 Tensile test: From the table 2 and Figure 6 it shows that when sisal fiber get increased the tensile strength of composite get decreased.

Table 2: Tensile strength of composite

S. No	Sample	Tensile Strength(MPa)
1.	Sample 1	39.616
2.	Sample 2	28.763
3.	Sample 3	20.965

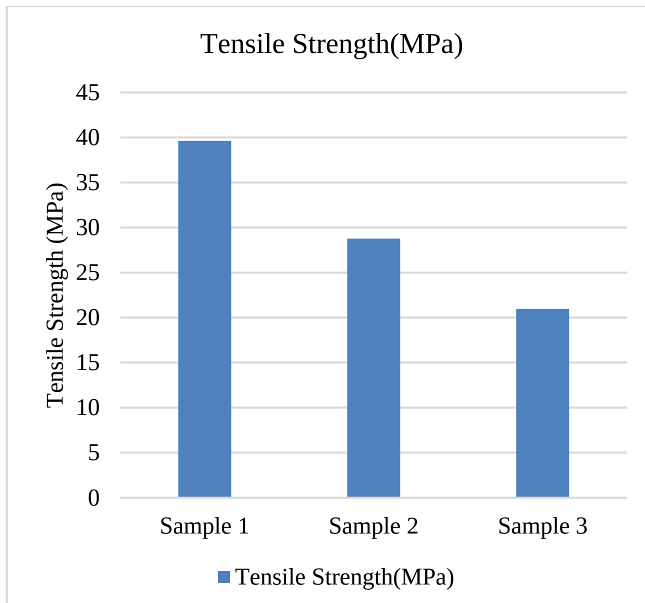

Figure 6: Tensile strength of composite

4.2 Flexural test: From the table 3 and Figure 7 it shows that when sisal fiber get increased the Flexural strength of composite get decreased.

Table 3: Flexural strength of composite

S.No	Sample	Flexural Strength(MPa)
1	Sample 1	69.933
2	Sample 2	62.259
3	Sample 3	47.707

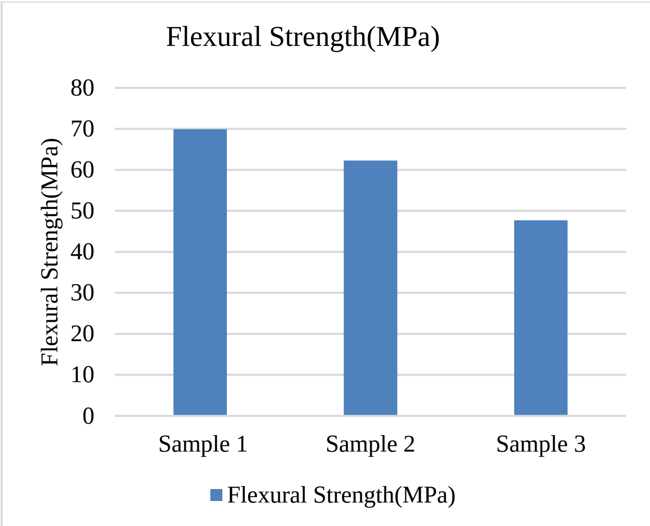

Figure 7: Flexural strength of composite

4.3 Impact Strength: From the table 4 and Figure 8 it shows that when sisal fiber get increased the impact strength of composite get increased.

Table 4: Impact strength strength of composite

S.No	Sample	Impact Strength(KJ/m^2)
1	Sample 1	101.7372
2	Sample 2	124.5539
3	Sample 3	128.3414

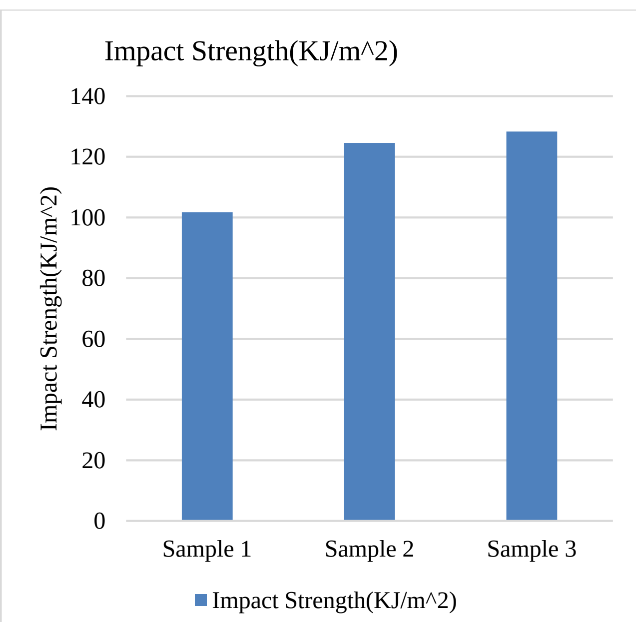

Figure 8: Impact strength of composite

5. CONCLUSION

The fabrication and mechanical characterization of bamboo strip, sisal fiber and banana fiber reinforced hybrid composite materials have shown promising results.Using natural fibers in composites offers many benefits, including low cost, lightweight, and good mechanical properties.

In this study, the composite materials were fabricated using a hand layup technique, where the fibers were arranged in a random orientation and embedded in an epoxy resin matrix. There are three mechanical properties for composite materials were tested such as tensile, flexural and impact strength.

The results showed that the study focused on the mechanical properties of hybrid composite materials made from banana fiber, bamboo strips, and sisal fiber. The results of the study indicate that the hybrid composite materials showed higher mechanical properties compared to single fiber-reinforced composites.

Overall, the hybrid composite materials showed potential for use in different type of applications, such as automotive, aerospace, and construction industries. The use of natural fibers in composites also offers environmental benefits as they are renewable, biodegradable, and can be recycled.

Further studies can be conducted to optimize the fabrication process, investigate the effects of different fiber orientations, and explore the potential of these hybrid composites in specific applications.

6. FUTURE SCOPE

The fabrication and mechanical characterization of sisal fiber, banana fiber, and bamboo strip reinforced hybrid composite materials open up several future research directions. Some of these directions include:

fibers can be aligned in different directions to optimize the mechanical properties for specific applications.

Exploration of different fiber types: Other natural fibers such as jute, hemp, and flax can be used in combination with sisal, banana, and bamboo fibers to create new hybrid composite materials with improved properties.

Study of the durability and aging effects: The long-term durability and aging effects of the hybrid composite materials can be investigated to determine their suitability for outdoor and harsh environments.

In summary, the fabrication and mechanical characterization of sisal fiber, banana fiber, and bamboo strip reinforced hybrid composite materials provide a foundation for further research to optimize the properties of these composites for various applications.

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