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Study of Mechanical Behavior for Tamarind Shell Powder and Coconut Coir Fiber Epoxy Composite for Aerospace Application

Dr. G. Purushotham[1], Yathin K. L[2]
[1]Professor & HOD, [2]Senior Assistant Professor
Department of AE, MITE, Moodabidri, Mangalore, Karnataka, India

ABSTRACT
Now-a-days, the natural fibres from renewable natural resources offer the potential to act as a reinforcing material for polymer composites alternative to the use of glass, carbon and other man-made fibres. Among various fibres, coir is most widely used natural fiber due to its advantages like easy availability, low density, low production cost and satisfactory mechanical properties. For a composite material, its mechanical behavior depends on many factors such as fiber content, orientation, types, length etc.

Natural fibre composites (NFC) are gaining interest in manufacturing because they address some of the environmental problems of traditional composites: use of non-renewable resources, and large impacts related to their production and disposal. Since natural fibres are not yet optimized for composite production, it is crucial to identify the most appropriate applications, and determine the optimal fibre/ matrix ratio. Results from various experiments help identify the application with the largest reduction in environmental burden and show that the fibre/matrix combination with the lowest environmental burden also has the best mechanical properties.

Attempts have been made in this research work to study the effect of fiber loading and orientation on the physical and mechanical behavior of coconut fiber and tamarind shell powder reinforced epoxy based hybrid composites which is prepared by hand-layup method with different weight proportions.

Key Words: *Tamarind shell powder, Coconut coir, Epoxy, Hybrid composites, Mechanical properties.*

1. INTRODUCTION

Composites have become an integral part of our day-to-day life and can be found everywhere, e.g. rubber tire, spacecraft, etc. Composites have been around for a long time with the classic example of bricks made from straw and mud was used by the Israelites, plywood were used by the ancient Egyptians when they realized that wood could be rearranged to achieve superior strength and resistance to thermal expansion as well as to swelling owing to the presence of moisture [1-5].

Medieval swords and armour were constructed with layers of different materials. Nature also has its own composites in the form of wood, teeth, bones, muscle tissue, etc. Natural fibres were used for reinforcing the matrix until early into the mid-20th century. However, since 1950 there was an increased demand for stronger and stiffer, yet light weight, composites in fields such as aerospace, transportation and construction [6-11]. This led to the incorporation of high performance fibres for reinforcement. This newer composites have low specific gravity, superior strength and modulus when compared to the traditionally engineering materials like metals.

Due to their strength to weight ratio and comparable or better mechanical properties composites are gaining grounds in industrial applications where metals were used [11-16].

2. Material Selection

Major headings are to be column centered in a bold font without underline. They need be numbered. "2. Headings and Footnotes" at the top of this paragraph is a major heading.

2.1 Tamarind

Tamarind fruit are indehiscent, beanlike, curved pods 3 to 20 cm (1.2 to 7.9 in) long weighing 15 to 20 g (0.5 to 0.7 oz). Fruit have a scurfy brown, woody, fragile shell with brown pulp and 8 to 10 blackish-brown, hard, shiny seeds. Fruit are about 30%shell, 30%pulp, and 40% seeds. The color of the pulp comes from the presence of several anthocyanin's, of which vitexene is the most important. There are also fruit with red pulp; these are not commonly cultivated. However, the reddish-flesh types are distinguished in some regions and are regarded as superior in quality. Fruit are eaten at the green-mature stage or when the shell pod has become brittle and the pulp brown. Tamarind is a good source of calcium, phosphorous, and iron and an excellent source of riboflavin, thiamin, and niacin; but it contains only small amounts of vitamins A and C.

Fig. 1 Tamarind fruit shell

Fig. 2 Tamarind shell powder

Table 1: Tamarind Shell Origin

Botanical name	TamarindusIndica
Origin	Tropical Africa, Indian subcontinent,
Family	Fabaceae
Production in India	2,50,000 tonnes
Varieties	PKM1, Urigam
Soil	Deep loamy and Alluvial soil

Table 2: Botanical composition of tamarind shell

SI. NO	Constituents	Amount
1	Carbohydrates (g.)	79,91
2	Fats (g.)	3,41
3	Proteins (g.)	12,74
4	Ashes (g.)	2,16
5	Moisture (g.)	9,78
6	Cellulose (g.)	31,27

2.2 Coconut fibre

Coconut fibre is extracted from the outer shell of a coconut. The common name, scientific name and plant family of coconut fibre is Coir, Cocos nucifera and Arecaceae (Palm), respectively.

There are two types of coconut fibres, brown fibre extracted from matured coconuts and white fibres extracted from immature coconuts. Brown fibres are thick, strong and have high abrasion resistance. White fibres are smoother and finer, but also weaker. Coconut fibres are commercial available in three forms, namely bristle (long fibres), mattress (relatively short) and decorticated (mixed fibres). These different types of fibres have different uses depending upon the requirement. In engineering, brown fibres are mostly used.

Fig. 3 Coconut Coir Fibre

Table 3: Chemical Composition of Coconut Fibre

Items	Percentages
Water Soluble	5.25%
Pectin and related compounds	3.00%
Hemi – cellulose	0.25%
Lignin	45.84%
Cellulose	43.44%
Cellulose	2.22%

2.3 Epoxy Resin- Ly 556

Softener (Araldite LY 556) having the following outstanding properties have been used as the matrix material.

- Excellent adhesion to different materials.
- High resistance to chemical and atmospheric attack.
- High dimensional stability.
- Free from internal stresses.
- Excellent mechanical and electrical properties.
- Odourless, tasteless and completely nontoxic.
- Negligible shrinkage.

2.4 Hardener- Hy 951

Epoxy hardeners are not catalysts and they react with the epoxy resins, greatly contributing to the ultimate properties of the cured epoxy resin system. Epoxy hardeners provide: Gel time; mixed viscosity; remold time of the epoxy resin system. Physical properties of the epoxy resin system such as tensile ability, compression, flexural properties, etc., are also influenced by epoxy hardeners. The performance of epoxy hardeners in the epoxy resins system depend on the chemical characteristics of the epoxy resins and the physical characteristics while applying the epoxy resins system. The chemical characteristics of the epoxy resins that influence epoxy hardeners are: viscosity; amount and kind of diluents and filers in epoxy resins. The physical characteristics of the epoxy resins system influencing the behavior of epoxy hardeners in the epoxy resins system are: temperature of the work area, temperature of the resins system (i.e. the heated resins), and moisture (dampness).

The Ly-556 and Hy-951 combination gives laminate with excellent water resistance and very low cure shrinkage; hence the laminates of this epoxy are dimensionally stable and practically free from internal stresses.

3. Problem Statement

In the beginning, airplanes were constructed using wood and fabrics. During the time of world wars, monologue based metal aircrafts were made. However, these were very heavy and not so economical. Thus during 1960s, composites came into play. Day by day, newer types of composites are being manufactured and tested to be used in airplanes so as to get better weight reductions and higher load carrying capacities. One of the new composite types being researched is bio fibres. In this research work preparation of bio-fibre composite, test its tensile, bending and impact strengths.

3.1 Composite Board Preparation

Known quantities of tamarind shell powder, coir, Araldite Ly556 epoxy resin and hardener Hy951 were mixed thoroughly. A mould made of plywood of dimension of 300×300×4 mm^3 of board; two frames of same dimensions were placed adjacently on the mould. Thoroughly mixed mixture of tamarind shell powder, coir, 5% of hardener and epoxy resin was taken and placed in the mould uniformly. A layer of osp sheet was placed both at the top and bottom of the board can be easily taken from the mould. The mould boxes containing the contents are then manually pressed and left to dry under the sun.

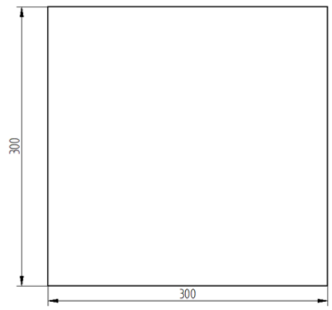


Fig. 4 Mould Box dimension

3.2 Different configurations of composite boards

For preparation of 1 composite board, 20% of tamarind shell powder, 20% of coir and 60% of epoxy resin are uniformly mixed and used for preparation of boards.

For preparation of 2 composite board, 30% of tamarind shell powder, 10% coir and 60% of epoxy resin are uniformly mixed and used for preparation of boards.

For preparation of 3 composite board, 10% of tamarind shell powder, 30% of coir and 60% of epoxy resin are uniformly mixed and used for preparation of boards.

Table 4: Composite board composition

Sl. No.	Epoxy in %	Tamarind shell powder in %	Coir in %
1.	60	30	10
2.	60	20	20
3.	60	10	30

3.3 Fabrication

Step 1: Procurement of Raw Materials

The raw materials including the tamarind shell powder, coconut fibre, epoxy resins (Ly-556) and hardeners (Hy-951) were bought from retailers.

Fig. 5 Epoxy Resin and Hardener

Fig. 6 Coir

Fig. 7 Tamarind Shell Powder

Step 2: Making of Mould Box

A wooden mould box of dimensions 300*300 is made. The mould box is covered with a protective layer of osp sheet to help easy removal of mould after curing. A roller of wood covered with osp sheet is also made.

Fig. 7 Mould box and roller

Step 3: Preparation of Mould-Hand Lay-up Method

The fibres- coir and tamarind shell powder are first put in place in the mould. Then the resin and hardener mixer is mixed in 1:100 ratios and then is impregnated into the mould. The impregnation of resin is done by using rollers. The impregnation helps in forcing the resin inside the fibres and also for uniform spreading of resin. This method has the advantage of being simple and requiring overall tools and process cost.

Fig.9 Preparing the mixture

Step 4: Curing

The mould is then kept for curing at room temperature. Curing is the process that refers to toughening or hardening of polymer materials by cross-linking of polymer chains. The mould is kept for curing for at least 1-2 days.

Fig. 10 Curing process

Fig.11 Mould kept for curing

Step 5: Drying
After curing, the mould is kept for drying for 1 day.

Step 6: Machining- CNC drilling
The material is machined according to the ASTM standards for tensile, bending and impact testing. The process used for machining is CNC drilling where the program is done beforehand and drilling is done by placing the work piece correctly.

Fig 12 CNC drilling

Fig 13 Arranging different work pieces

4. Experimentation

Tensile test
According to ASTM standards, the composite specimens were prepared for tensile testing to determine the material property (Young's modulus). Each test specimen of 57mm gauge length, 13 mm wide and thickness 3.2 mm were prepared as shown in figure. Using this machine with suitable jaws and the initial adjustments are made. All the required dimensions of the specimen are entered into the computer along with the maximum load and displacements are assumed and entered. After the failure of the specimen, the computer shows the load displacement curve. From these obtained curves stress, strain and young's modulus were evaluated. For this universal test machine (UTM) is used. Using this machine with suitable jigs, almost all mechanical tests are performed by this machine to determine the material properties.

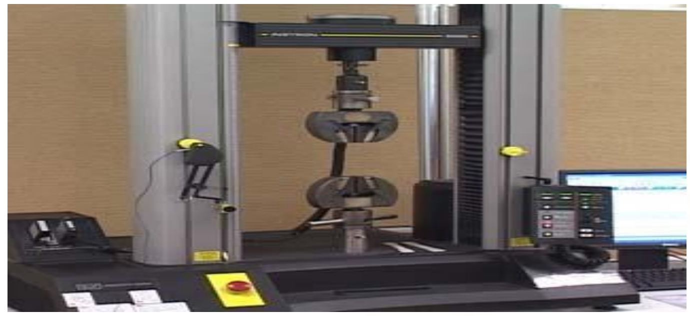
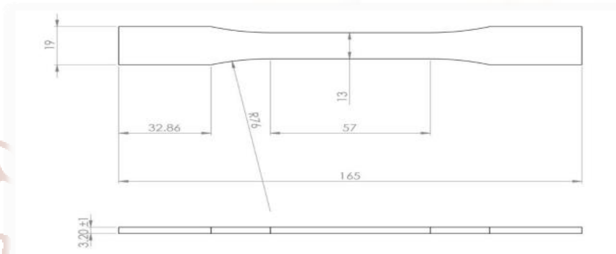


Fig 14 Instrol universal tester



All dimensions are in mm
Fig 15 Type 1 ASTM D638 Tensile specimen

Flexural Strength:
Flexural strength is the ability of the material to withstand the bending forces applied perpendicular to its longitudinal axis. The stresses induced due to the flexural load are a combination of compressive and tensile stresses. The test is used to determine the flexural strength and stiffness.

Three-Point Bending
The 3-point bending test provides values for the modulus of elasticity in bending, flexural stress, flexural strain and the flexural stress-strain response of the material. The main advantage of a 3-point bending test is the case of the specimen preparation and testing. However, this method has also some disadvantages: the results of the testing method are sensitive to specimen and loading geometry and strain rate. The arrangement for three point bending test with bending fixtures is as shown in figure 16.

Fig 16 Bending test setup

Three-Point Bending Test Procedure

According to ASTM standard the composite specimens were prepared for bending test. Each test specimen of 12.7mm width, length 125mm and thickness 3.2mm as shown in figure 16 were prepared. The specimen is loaded at the centre of the span through a loading cell. The test is carried until the specimen completely fails.

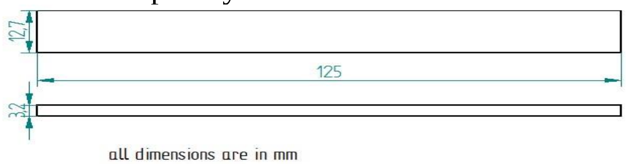


Fig 17 ASTM D790 Bending specimen Impact testing

Impact test are used in studying the toughness of material. A materials toughness is a factor of its ability to absorb energy during plastic deformation. Brittle materials have low toughness as a result of the small amount of plastic deformation that they can endure. The impact value of a material can also change with the temperature. Generally, at lower temperatures, the impact energy of material is decreased. The size of the specimen may also affect the value of the charpy impact test because it may allow a different number of imperfections in the material, which can act as stress riser and lower the impact energy.

Charpy impact testing

Impact testing is an ASTM standard method of determining impact resistance of materials. An arm held at a specific height (constant potential energy) is released. The arm hits the sample. The specimen either breaks or the weight rest on the specimen. From the energy absorbed by the sample, its impact energy is determined. A notched sample is generally used to determine impact energy and notch sensitivity. The standard specimen for ASTM D256 is 64 x 10 x 3.2 mm with V-notch of depth 1mm at center of the specimen.

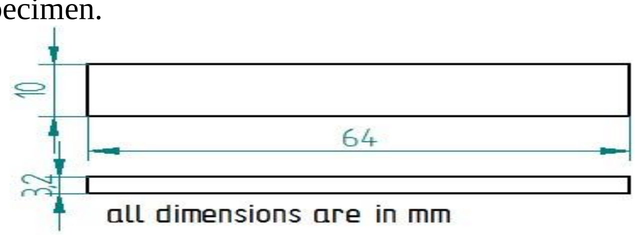


Fig 18 ASTM D256 Impact test specimen

4. Results and Discussion:

Tensile Strength:

Stress-Strain curves for 60% Matrix, 30% Tamarind powder and 10% Coir.

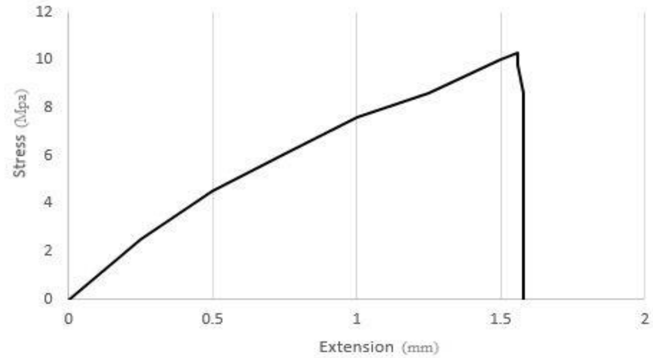


Fig 19 Stress-strain curve for composite board 1

We have performed tensile test on composite, we found maximum load at 0.503kN for the deflection of 1.53mm, and stress at maximum load is 10.30MPa.Young's Modulus is found out to be 3013.23 Mpa.

Stress-Strain curves for 60% Matrix, 20% Tamarind Powder and 20% Coir.

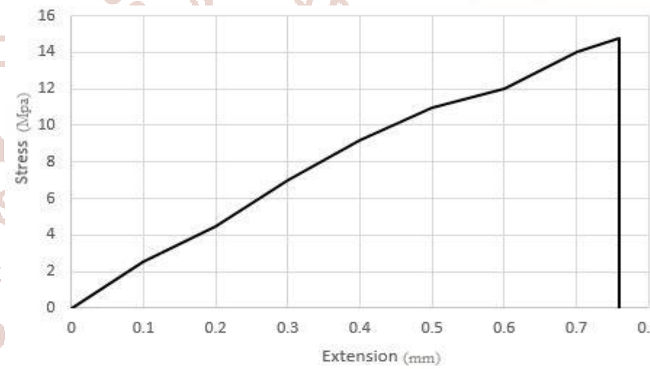


Fig 20 Stress-strain curve for composite board 2

We have performed tensile test on composite, we found maximum load at 0.669kN for the deflection of .76mm, and stress at maximum load is 14.76MPa. Young's Modulus is 3202.56 Mpa.

Stress-Strain curves for 60% Matrix, 10% Tamarind Powder and 30% Coir

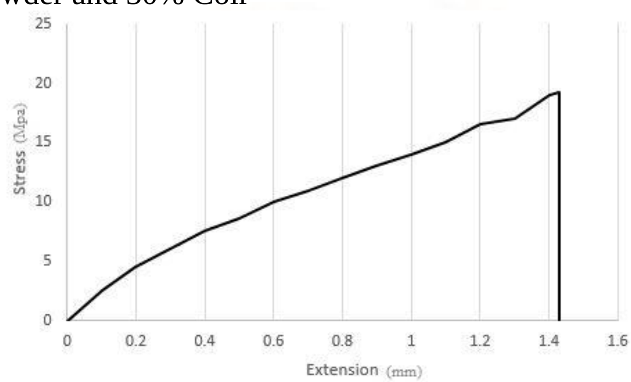


Fig 21 Stress-strain curve for composite board 3

We have performed tensile test on composite, we found maximum load at 0.903kN for the deflection of 1.42mm, and stress at maximum load is 19.25MPa. Young's Modulus is 3475.64 Mpa.

Bending test results:

Stress-Strain curves for Bending for 60% Matrix, 30% Tamarind powder and 10% Coir.

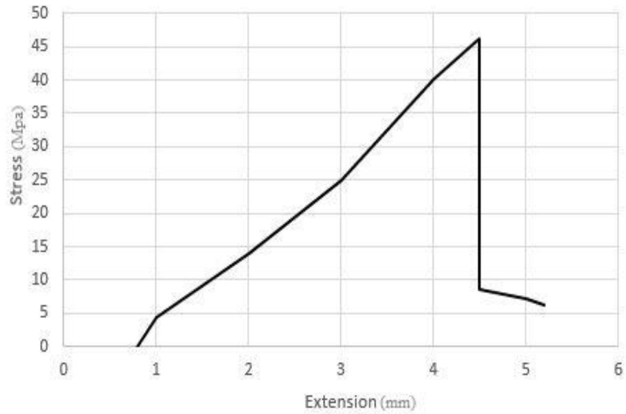


Fig 22 Stress- strain curve for bending composite board 1

We have performed bending test on composite board 2, we found maximum load at 68.15N for the deflection of 4.5mm, and bending stress at maximum load is 46.26MPa. Young's Modulus is 3671.21 Mpa.

Stress-Strain curves for Bending for 60% Matrix, 20% Tamarind Powder and 20% Coir

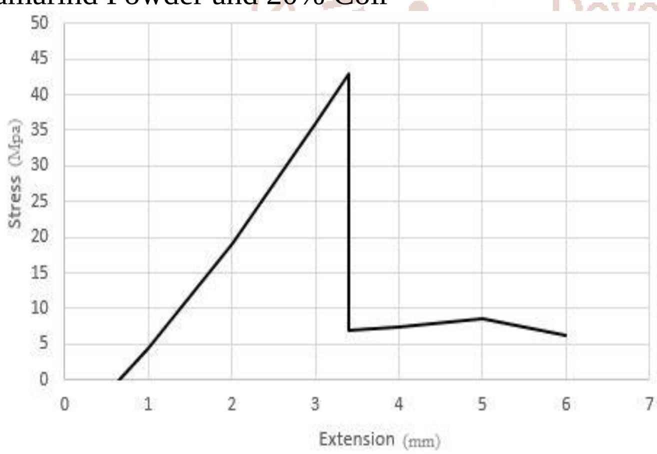


Fig 23 Stress- strain curve for bending composite board 2

We have performed bending test on composite board 1, we found maximum load at 59.38N for the deflection of 3.4mm, and bending stress at maximum load is 42.86MPa. Young's Modulus is 3909.83 Mpa.

Stress-Strain curves for Bending for 60% Matrix, 10% Tamarind Powder and 30% Coir

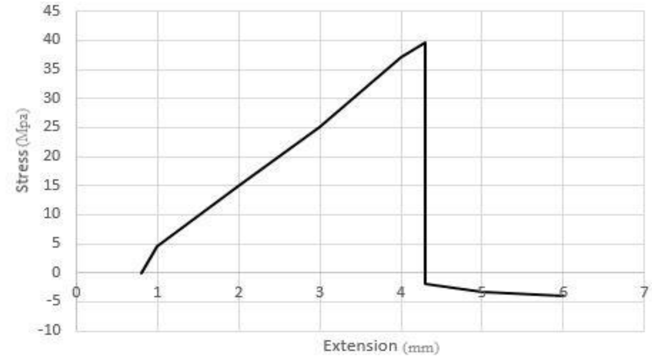


Fig 24 Stress- strain curve for bending composite board 3

We have performed bending test on composite board 3, we found maximum load at 47.76N for the deflection of 4.3mm, and bending stress at maximum load is 39.63MPa.

Young's Modulus is 3626.32 Mpa.

Impact test results:

Impact strength, I = k/t (J/m)

Where I is the impact strength of the specimen

K is the energy absorbed by the specimen for failure in joules

t is the thickness of the specimen in mm

Table 5: Impact strength of various composite plates

Botanical name	Tamarindus Indica
Origin	Tropical Africa, Indian subcontinent,
Family	Fabaceae
Production in India	2,50,000 tonnes
Varieties	PKM1, Urigam
Soil	Deep loamy and Alluvial soil

Composite plate	Impact results in J/m
1) 60% E, 30% T, 10% C	5.972
2) 60% E, 20% T, 20% C	5.46
3) 60% E, 10% T, 30% C	4.803

On performing impact tests on various composite boards of varying composition we found that the composite board 2 of composition 60% of epoxy, 30% of tamarind shell powder and 10% coir fibres has the highest impact strength of 5.972J/m.

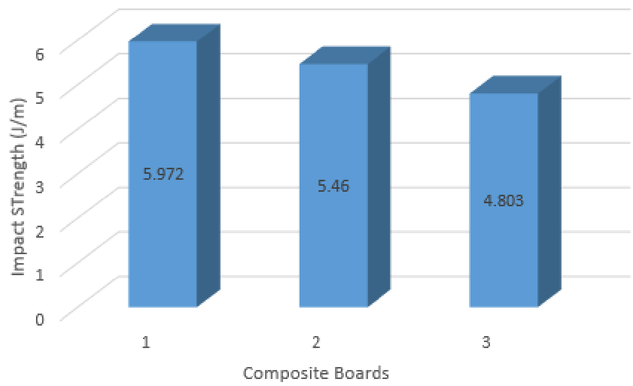


Fig 25 Comparison of Impact Strength of Composite Boards

5. Conclusions

By comparing the tensile, bending and impact for our composite plate we obtain the following:
In tensile test, the composite board 3 of composition 60% of epoxy resin, 10% tamarind shell powder and 30% coconut fibre has 44.29% more load carrying capability compared to board 1 with composition 60% epoxy, 30% tamarind shell powder and 10% coir fibres. It has 25.91% more load carrying capability compared to board 2 with 60% epoxy, 20% tamarind shell and 20% coir fibres. Hence board 3 has better tensile properties.

In bending test, the composite board 1 of composition 30% of tamarind shell particle 10% coconut fibre and 60% of epoxy resin has 12.86% more load carrying capability compared to board 1 with 60% epoxy, 30% tamarind shell powder and 10% coir fibre. It has 29.92% more load carrying capability compared to board 3 with composition 60% epoxy, 10% tamarind shell and 30% coir fibres. Hence board 1 has better bending properties.

In impact test, the composite plates 1 has a of composition 30% of tamarind shell particle, 10% coconut fibre and 60% of epoxy resin has given a result of approximately 8.5% more load carrying capability compared to board 2 with 60% epoxy, 20% tamarind shell and 20% coir fibres. Board 1 has 19.57% more load carrying capability compared to board 3 with composition 60% epoxy, 10% tamarind shell and 30% coir fibres..

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