

# Study of Mechanical Properties of Coconut Shell Powder and Tamarind Shell Powder Reinforced with Epoxy Composites

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**Abstract.** Coconut shell is non-food part which is one of the hard agro wastes. Coconut shell is high potential material due to its high strength and modulus properties. Coconut shell powder exhibits admirable properties compared to other materials such as low cost, renewable, high specific strength to weight ratio, low density less abrasion to machine and environmental friendly. Mixing coconut shell powder with epoxy resin enhances its properties and creates a wide range of applications. Tamarind shell is also a non-food part which is an agro waste. After the tamarind fruit is extracted these shells are disposed as waste. As these shells are hard they provide better strength when used in composite materials as an additive. The components are made by mixing coconut shell powder, tamarind shell powder and epoxy resin at definite ratios and is tested for mechanical properties. The present study deals with preparation and experimentally testing the mechanical properties of Coconut Shell Powder and Tamarind shell powder reinforced epoxy resin composites. 3 different percentages of coconut shell powder and epoxy resins are made to form composite material and then results are analysed for those 3 composite materials. From the results it has been found that tamarind shell powder with coconut shell powder, increases the tensile properties by around 50%. The best result and increase in mechanical properties is obtained when the composition of the material is 50% of Coconut shell powder and 5% of Tamarind shell powder along with 45% of epoxy resin.

## 1. Introduction

In the latest years, composites fulfil optimal requirement criteria for several designers' materials. In the last 50 years, there have been major developments in the design and fabrication of light-weight, high strength materials, primarily due to the increase of polymer composite materials<sup>1</sup>. Several researchers have aimed at their work towards defining abundant combinations of biodegradable matrix/natural fillers in order to promote new classes of biodegradable composites with enhanced mechanical properties, as well as to attain products with lower cost. Among several investigated natural fibers in this area, different fillers have the significant importance<sup>[1]</sup>. The Natural Fillers (NF) reinforced materials offer several environmental advantages, such as decrease dependence on non-renewable material sources, lower pollution and green house emission. Natural lignocelluloses fillers (flax, jute, hemp, etc.) represent an environmentally friendly alternative to conventional reinforcing fibers (glass, carbon). The Advantages of natural fillers over traditional ones are their low cost, high toughness, corrosion resistance, low density, good specific strength properties and reduced tool wear<sup>2</sup>. However, there are several disadvantages in natural fillers, like low tensile strength, low melting point, not suitable for high temperature application, poor surface adhesion to hydrophobic polymers, non-



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uniform filler sizes, degradation by moisture. Therefore, chemical treatments are done so as to modify the fiber surface properties[2].

A composite is a structural material that consists of two or more constituents that are combined at a macroscopic level and are not soluble in each other. Composites have two constituents, a matrix phase and a dispersion phase. One constituent is called the reinforcing phase and the one in which it is embedded is called the matrix. In a composite, the fiber, as well as the matrix, retain their physical and chemical identities, but still provide a combination of properties that cannot be achieved with either of the constituents alone. In general, the fibers play the role of load bearer. The matrix, while keeping the fibers in the desired location and orientation, act as a load transfer agent and protects the fibers from external conditions such as chemicals, heat and moisture. Man-made fibers using glass, carbon, boron etc. are being used as reinforcing materials in the fiber reinforced plastics (FRP), which have been widely accepted as materials for structural and non-structural applications. The main reason for the interest in FRP is due to their specific modulus, high stiffness and strength to weight ratio compared to other conventional materials. However, these materials are prohibitively expensive in their use for other general purpose and applications. Nowadays-natural fibers like banana, cotton, coir, sisal jute has attracted the attention of scientists and technologists for applications in packaging, low-cost housing and other structures. It has been found that these natural fiber composites possess better electrical resistance, good thermal and acoustic insulating properties and high resistance to fracture[3,4,5].

Advanced composite materials with anisotropic properties created a new need for new test specimens and test techniques. New test was required to evaluate reinforcing fibers, characterize matrix materials and mechanical properties. The literature review on mechanical tests that have been developed to define the mechanical properties of these engineered structural materials. According to Alok Singh et al.[1] bio composite material was tested for dimensional stability, it exhibited very low water absorption rates of less than 3 % and low thickness swelling of less than 1 %. These results have shown that plant-based fibers may be used as reinforcement in a composite system to improve the properties and performance of polymer matrix resins. Hayder Abbas Sallal [6], says that tensile strength has increased with increasing weight fraction of (coconut shell powder) filler particles and reached their maximum value at (6 % by wt). Furthermore, the increasing weight fraction revealed decreasing properties of the prepared system. Also results had shown that compression strength and impact energy increased with increasing weight fraction of (coconut shell powder) up to 6%wt. J. Olumuyiwa Agunsoye, et al.[7] says, as the percentage of coconut shell powder increases, there was a corresponding decrease in porosity. This property makes the composite suitable for the application in the interior part of a motor car where materials with good hydrophobic characteristic are required. According to Srinivas K. R. [8] et al., test for different mechanical properties were performed with different percentage of tamarind shell powder and epoxy. In this experiment better tensile strength was obtained when the composition was 80% of tamarind shell powder and 20% of epoxy. From the literature review it is found that combination of coconut shell powder and tamarind shell powder along epoxy resin composites are scanty. Hence attempt been made to study the preparation and experimentally testing the mechanical properties of Coconut Shell Powder and Tamarind shell powder reinforced epoxy resin composites.

## **2. Material Preparation and Methodology**

The coconut shell was dried in open air and grinded into powder using a pulverizing machine, the powder was sieved in accordance with BS 1377:1990 standard. The chemical analysis of the coconut shell was done with Absorption Spectrometer (AAS)-Peckinhelma 2006 model. The particle size used was 300  $\mu\text{m}$ . The pelletized polyethylene waste was sun-dried and shredded in a plastic crusher machine. The coconut shell powder and the grinded pelletized (polyethylene) were blended together using a two-roll rheomixer at 50°C and a rotor speed of 60 rpm. The percentage of the filler in the matrix was varied from 5% to 25% to produce five different compositions. Compression of the composites was carried out with a hydraulic pressing machine for 7 minutes under controlled pressure

(30 tons) at 150°C. Each of the samples was cooled to room temperature under sustained pressure before it was removed from the press.

A hydraulic hot press is used to prepare the boards. The working principle of this press is, the material from which board is to be prepared is compressed at an appropriate temperature and pressure. This set up is kept for the known duration of time. The mould is placed in hydraulic press, which is maintained at 140°C, and then a pressure of 2 MPa is applied. The set-up is maintained undisturbed about 15-20 minutes. Later, the mould is taken out and allowed to cool for half-an-hour and remove the composite board from the mould.

### 2.1 Different Types of Composite Plates

For preparation of A Composite plate, 30% of coconut shell powder and 70% of Epoxy resin are uniformly mixed and used for preparation of boards. For preparation of B Composite plate, 40% of coconut shell powder and 60% of Epoxy resin are uniformly mixed and used for preparation of boards. For preparation of C Composite plate, 50% of coconut shell powder and 50% of Epoxy resin are uniformly mixed and used for preparation of boards. For preparation of D Composite plate, 30% of coconut shell powder and 15% of Tamarind shell powder along with 55% of Epoxy resin are uniformly mixed and used for preparation of boards. For preparation of E Composite plate, 40% of coconut shell powder and 10% of Tamarind shell powder along with 50% of Epoxy resin are uniformly mixed and used for preparation of boards. For preparation of F Composite plate, 50% of coconut shell powder and 5% of Tamarind shell powder along with 45% of Epoxy resin are uniformly mixed and used for preparation of boards.

**Table 1** Composite plates composition

Plate Name	CS Powder in %	TS Powder in %	Epoxy resin in %
A	30	0	70
B	40	0	60
C	50	0	50
D	30	15	55
E	40	10	50
F	50	5	45

### 2.2 Tensile Test

Tensile strength of a material is the ability of the material to withstand tensile forces applied either sides of the specimen. The test is used to determine the tensile strength and young's modulus of the material.

For this test Universal Testing Machine (UTM) is used. Using this machine with suitable jigs, almost all mechanical tests are performed by this machine to determine the material properties. Figure 1 shows the typical UTM in working.

According to ASTM standards, the composite specimen was prepared for tensile testing to determine the material properties. Each test specimen of 100 mm gauge length, 15 mm wide and thickness 6mm were prepared as shown in figure 2. For this test UTM of capacity 100kN was used. 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.

The specimen prepared as per the standard is placed in the UTM with the arrangements of the jigs, as the setup is clear, a constant state of loading is applied on the either sides of the specimens which are equal and opposite in direction. The arrangement of the UTM with the specimen is shown in the figure 2.



**Figure 1** Universal Testing Machine



**Figure 2** Universal Testing Machine - Tensile test

### 2.3 Flexural Strength

Flexural strength is the ability of the material to withstand 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.

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 three-point bending test is the ease 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 3. According to ASTM standard the composite specimens were prepared for bending test. Each test specimen of 50-mm width, length 210 mm and thickness 6 mm as shown in figure 3 were prepared. The span (center to center distance between roller supports) for each specimen is 160 mm. the specimen is loaded at the center of the span through a loading cell. The test is carried until the specimen completely fails.



**Figure 3** Universal Testing Machine - Bending test

### 3. Results and Discussions

Composites are prepared with above specified composition and size and tested in UTM to get tensile and flexural strength of material. Seven composites plates are prepared with different composition of coconut shell powder, tamarind shell powder and epoxy resins. Before testing in UTM, water absorption and hardness test are conducted.

#### 3.1 Water Absorption Test

Studies had revealed that mechanical properties such as toughness and resistance will fall after exposure the specimen for moisture, or after absorption of specific quantity of water and the reason for this, is that the moisture has a role in breaking the interface between the matrix material and the reinforced material and by reducing the adhesion between the matrix material and the reinforced material, or the reinforced material may absorb greater amounts of the water, causing swelling of the matrix material and therefore separation in the matrix material will be expected and the deterioration of the interface in the composite material will happen and this leads to decreasing in transfer of stress to the filler material and thus lead to decrease in toughness and resistance will be decreased. By immersion of the specimen in water, the water absorption (change in mass) can be calculated according to equation.

$$\text{Water absorption (\%)} = \frac{m_a - m_b}{m_b} \times 100$$

Where  $m_b$  = mass of specimen before immersion (g).

$m_a$  = mass of specimen after immersion (g).

The tests were carried out for 15 days and weight of the specimens were noted on the daily basis. The specimen was cut into 40x40 mm and inserted in a beaker of water. 2 beakers were used, one filled with distilled water and other with regular tap water. Long term water immersion method was used to determine the absorption behaviour of composites. The conditioned composite sample was placed in a beaker with water at  $23 \pm 1^\circ$ . At the end of 24 hours one of the sample is removed from the water at a time, all surface water wiped off with a dry cloth and weighed immediately and then replaced in the water and this procedure was repeated at every 24 hours till 15 days and the data was recorded. The percentage increase in weight was calculated by above equation. Table 1 shows the experimental results of water absorption test. From the calculated percentage of water absorption, it is clear that the maximum percentage of water absorbed is 6.4%. Hence it creates a wide range of applications regardless of the problem of water absorption.

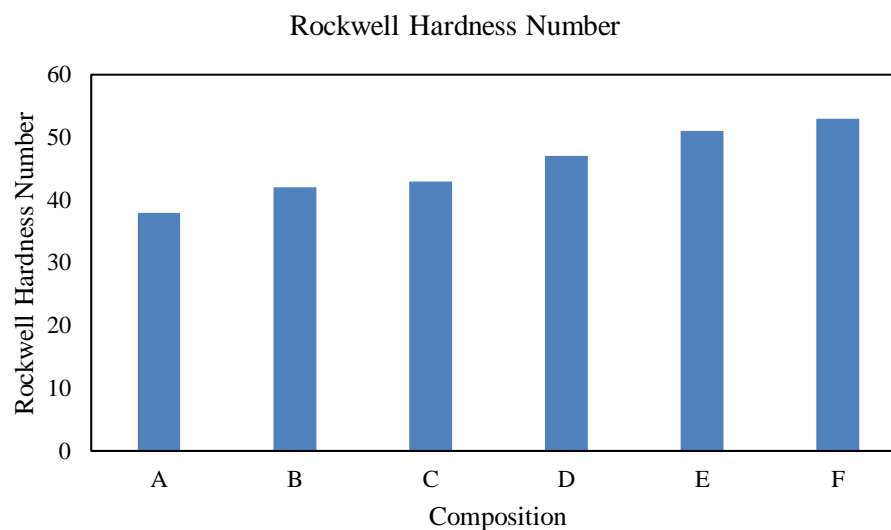


**Table 2** Water absorption test results

Specimen	Water absorption (%)	
	Tap Water	Distilled Water
Component A	5.40	2.80
Component B	6.40	3.17
Component C	2.02	4.19
Component D	5.23	4.71
Component E	5.14	4.11
Component F	4.48	5.00

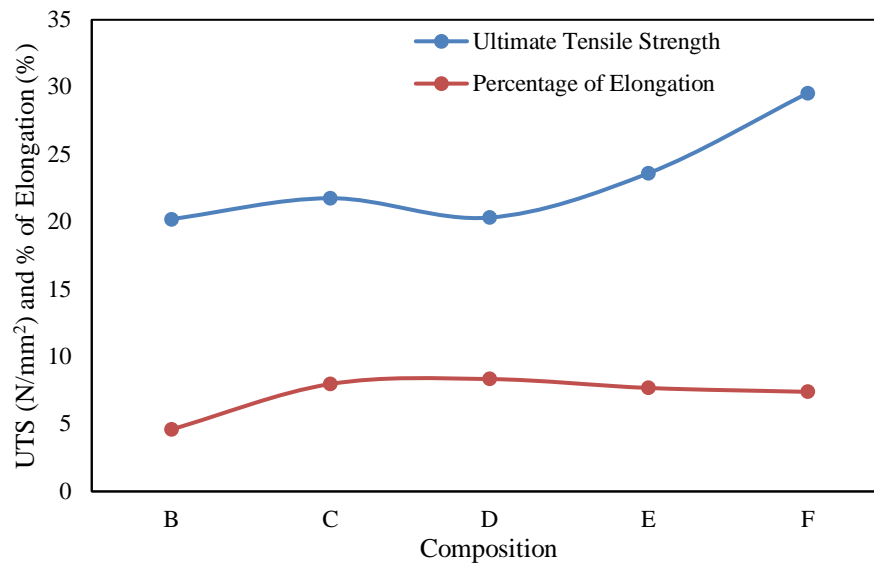
### 3.2 Hardness Test

A standard specimen is placed on the surface of the Rockwell Hardness tester. A minor load is applied and the gauge is set to zero. The major load is applied by tripping a lever. After 15 seconds the major load is removed. The specimen is allowed to recover for 15 seconds and then the hardness is read off the dial with the minor load still applied. The standard specimen for ASTM D785 has dimensions of 20mm by 20mm. Figure 4 shows the variation of Rockwell hardness number for different composition of composite material. From the above result it can be concluded that by the addition of required amount of tamarind shell powder the surface hardness can be increased. Hence by experimenting with addition of suitable percentage of tamarind shell powder we can obtain a better result.

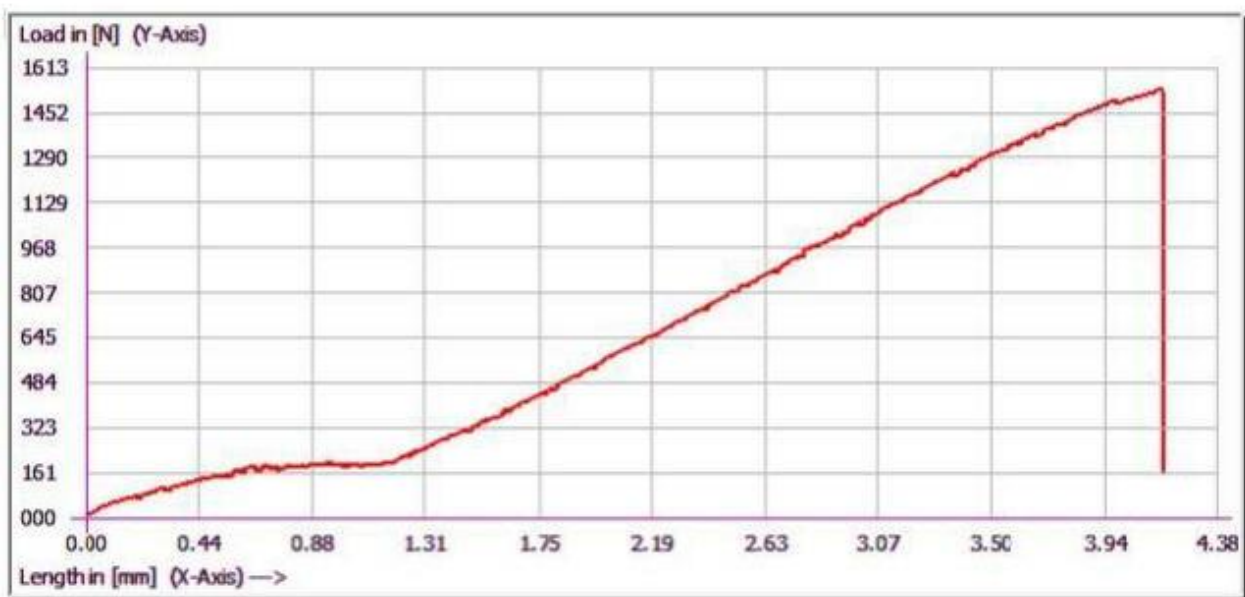
**Figure 4** Variation of Rockwell Hardness Number w.r.t. Composition

### 3.3 Tensile test

Different composites are tested under UTM for tensile test and results are obtained. Load vs deflection curve are obtained from UTM and then tensile strength is calculated. From the experimental data it is clear that by the suitable addition of tamarind shell powder with coconut shell powder, increases the tensile properties by around 50%. The best result and increase in mechanical properties is obtained when the composition of the material is 50% of Coconut shell powder and 5% of Tamarind shell powder along with 45% of epoxy resin. Figure 5 shows the effect of ultimate tensile strength for different composite plates. In the future there is scope for further researches in order to increase tensile as well as flexural test at a higher rate. With a proper mixing ratio and by varying the grain size a composite with better properties can be prepared. Figure 6 shows the sample data of load-deflection curve for F composite plate.



**Figure 5** Variation of Ultimate Tensile Strength w.r.t. Composition

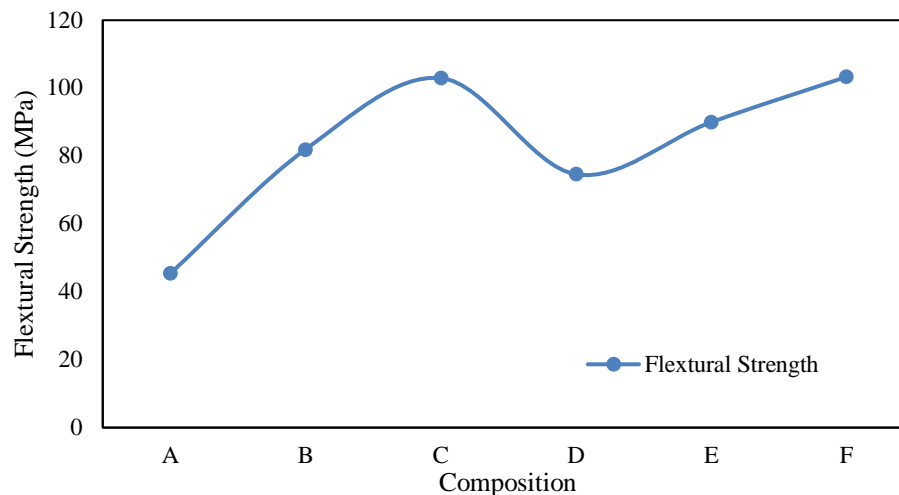


**Figure 6** Load-Deflection curve for F composite plate

### 3.4 Bending Test

Figure 7 shows the effect of flexural strength for a different composite plates. From the results it can be seen that as the percentage of coconut shell powder percentage increases in composites flexural strength also increase. This is because better hardness for the coconut shell powder. Also from the result it can be seen that 5% of tamarind shell powder will have highest flexural strength compared to all other composites. This is because tamarind shell powder will improve the grain distribution in the composites hence it will have higher strength when compared to all other composites. Flexural test shows significant increase in its properties. But overall improvement in the mechanical properties can be clearly observed.

The best result and increase in mechanical properties is obtained when the composition of the materials is 50% of Coconut shell powder and 5% of Tamarind shell powder along with 45% of epoxy resin.



**Figure 7** Variation of Flexural Strength w.r.t. Composition

#### 4. Conclusion

The use of Natural fiber polymer composites filled with natural-organic fillers, in alternate of mineral inorganic fillers. The utilization of coconut shell powder in various applications has opened up new avenues for both academicians as well as industries to design a sustainable module for future use of coconut shell fibers. Coconut shell fibers have been extensively used in composite industries for socioeconomic empowerment of peoples. The fabrication of coconut shell fibers based composites using different matrixes has developed cost effective and eco-friendly biocomposites which directly affecting the market values of coconut shell. To design such composites thorough investigation of fundamental, mechanical, and physical properties of coconut shell fibers is necessary.

An addition of tamarind shell powder has opened up a new way for enhancement of the properties of composite materials. The percentage of additive may be altered and tested. In our test result there is no significant change in flexural property when tamarind shell powder was used as an additive with coconut shell powder. But when tensile test is performed with addition of tamarind shell powder with coconut shell powder it shows a tremendous increase in its load carrying capacity. The result obtained shows about 50% increase in the strength of composite material upon adding tamarind shell powder.

Thus, this analysis has made an attempt to gather information for both basic properties of coconut shell fiber based composites as well as their economic utilization. Current research on coconut shell fiber based composite using both basic as well as applied science either in terms of modification, mechano-physical, thermal and other properties. But, the ultimate goal of utilizing the coconut shell to its full extent is far behind than its projected milestone. The sustainable future of coconut shell based composite industry would help in utilizing the coconut shell in a way other than usual traditional mode. The effective characterization of coconut shell fiber as well as coconut fiber based composites should be more advance in terms of analysis and testing. In this review, we have tried to gather the information about the analysis and testing methods used. However, researcher already done lots of work on coconut shell based composites, but it still required to do more research and innovation in this area to overcome potential challenges ahead. These things will make life easy for both urban as well as rural people who are more depended on synthetic based composites.



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