

## **Determination of Mechanical Properties of Coir Reinforced Composites for Auto Parts Applications**

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### **Abstract**

The demand for sustainable materials in automotive applications has led to increased interest in natural fiber reinforced composites. Coir fiber, derived from coconut husk, is one such renewable and eco-friendly material showing promise in enhancing mechanical properties of composites. This article presents a comprehensive review and experimental study on the determination of mechanical properties of coir fiber reinforced composites, aiming to assess their suitability for automotive applications. As the automotive industry seeks to extend vehicles' lifespans and also minimize the impact of waste, this study on coir as a sustainable alternative to synthetic fiber can propel the automobile sector towards more environmentally conscious practices. The method of establishing the mechanical properties of coir fiber reinforced composites were discussed, along with the effects of processing parameters and fiber treatment. The application of response surface methodology after conducting of tests on 15 samples of coir fiber reinforced composites revealed the desirability of accomplishing the selected result as 94.9%, while the results showed that the optimal solutions for the input parameters are coir 45.000%, epoxy 54.543%, and coir length 45.000mm. Also, the optimal solutions for the response parameters or mechanical properties which were later validated with linear programming gave the following results: flexural strength 57.118MPa, tensile strength, 49.333MPa and impact strength 34.787KJ/M2, Young modulus 4.788 GPa, Stress 4.534, as well as 20.483 units for Strain. The findings revealed that coir fiber reinforced composites possess favorable mechanical properties, making them viable alternatives to conventional materials in automobile parts manufacturing.

**Keywords:** coir, coir fiber, composite, natural fiber composites, mechanical properties, automotive applications, sustainability

## **1. Introduction**

In recent years, the automotive industry has witnessed a significant shift towards incorporating modern composite materials, indicating a promising future for innovation and sustainability (University of Utah Engineering Research, 2011). The utilization of polymers in automotive parts has ushered in transformative improvements, spanning cost-effectiveness, resistance to corrosion, reduced weight, enhanced performance, innovative design, and heightened safety measures in vehicle manufacturing. This evolution has empowered automotive manufacturers to substitute conventional materials with polymer matrix, thereby streamlining the complexity of car assembly.

An intriguing avenue in this trajectory is the emergence of Polymer Matrix Composites (PMCs), a class of materials defined by Hariprakash et al. (2019) as the incorporation of fibers within a polymer matrix, typically with approximately 60 percent volume fraction of reinforcing fibers. These PMC possesses desirable attributes such as remarkable rigidity, strength, and corrosion resistance. However, despite these strengths, tensile strength of PMC remains a challenge when compared to metals, necessitating reinforcement for optimal performance.

Natural fibers are fibers that are neither synthetic nor man-made. They may be obtained from either plants or animals (Siakeng et al., 2019). These naturally occurring cellulosic fibers have been used for over 10,000 years. Cellulosic were utilized for textiles around 8,000 B.C. in the Middle East and China (Mittal and Chaudhary, 2018). Natural fibers are type of composite material created by nature. The fibers are essentially a matrix of hard, crystalline cellulose microfibril-reinforced amorphous lignin and hemicelluloses. Except for cotton, most plant fibers are made up of cellulose, hemicelluloses, lignin, waxes, and certain water-soluble chemicals, with cellulose, hemicelluloses, and lignin being the most abundant (Jayamani et al., 2014).

The importance of polymer matrix composites in automotive applications cannot be over-emphasized. From increased productivity to increased customer satisfaction, through improved performance, reduced corrosive parts, as well as overall safety and aesthetic design. Because of the high cost of synthetic fiber and its negative impact on the environment, the study attempts to replace synthetic fiber polymer matrix composite used in automotive applications with coir fiber reinforced polymer matrix composite due to its high lignin content (which aids in slow degradability), low density, ease of separation, availability, lower cost, and environmental friendliness.

With a growing emphasis on fuel efficiency, natural fiber composites such as coir-based composites are finding greater applications in vehicles, railway coaches, and buses for public transportation and other long-lasting uses. There is a great possibility in the fabrication of coir-based composites for a wide range of applications in building and construction such as boards and blocks as reconstituted wood, flooring tiles, etc. Extra value novel uses of natural fibers and coir-

based composites would not only improve the quality of life of coir farmers, but would also secure a worldwide market for cheaper composite substitutes.

The automotive industry is under increasing pressure to adopt sustainable practices and materials to reduce environmental impact. Natural fiber reinforced composites have emerged as promising alternatives to traditional synthetic composites due to their renewable nature, low cost, and biodegradability. Coir fiber, derived from coconut husk, is particularly attractive for its abundance, low cost, and desirable mechanical properties. This article aims to provide an overview of the mechanical properties of coir fiber reinforced composites and their potential for automotive applications.

## **2. Literature Review**

### **Coconut Retting**

Zelasko (2024), explained that retting process employs the action of bacteria and moisture on plants to dissolve or rot away much of the cellular tissues and gummy substances surrounding bast-fibre bundles, thus facilitating separation of the fibre from the stem. He pointed out that common methods are dew retting and water retting.

Ihueze, Obiafudo and Okafor (2017), explored the utilization of Biological (water) retting as a method for extracting plantain fiber, specifically for its application in the design of Oil and Gas Product Systems. The researchers employed a double retting process, initially followed by a single straight duration. The stems of the plantain were cut axially and fully immersed in containers filled with water. The retting process was conducted over a period of 14 days, with an intermediate fiber extraction performed after the first 7 days. Subsequently, the retting water was discharged, and the resulting fiber bundles were soaked in fresh water for an additional 7 days. On the 14th day, a complete fiber extraction was carried out. Throughout the retting process, the researchers also conducted pH level calibration to gain insights into the impact of microorganism-assisted decomposition.

There are two stages to retting, Physical and Biological stage. During the first or physical stage, the husk absorbs water and the plant tissues expand. Several components are dissolved in the tissue to produce solutions, including glucosides, tannins, carbohydrates, and nitrogen compounds. During the second step known as the biological stage, a variety of microorganisms multiply at the cost of the extracted chemicals, creating favorable environmental conditions, and allowing the microorganisms to breakdown the tissue binders. Because of their flexibility and color, fresh husks, used within a few days of husking nuts, are perfect for retting.

Due to the oxidation of natural phenolic compounds in the husk, coir fibers that have not been retted are generally brittle and brownish. Retting technique eliminates a significant proportion of phenolic compounds, therefore, coir fibers that have passed through the process of retting are

typically uncolored. The retting process must be closely managed since under-retting makes separation difficult and over-retting weakens the fiber.

### **Coir Fiber Extraction**

Okpala, Chinwuko and Ezeliora (2021), explained that the traditional extraction process of coir which involves retting over a long period yields the best white fiber quality which are employed for diverse usage. However, they noted that in the mechanical fiber extraction processes, the coconut husks are immersed for just five days in tanks of water after which decorticating or de-fibering machines are used to extract the fibers. To achieve the best white fiber quality, traditional extraction process was adopted for the research, although it was very tedious and also consumes a lot of time.

After soaking the husks of harvested coconuts in water for eleven months after which the husks were softened due to anaerobic fermentation, the fibers were extracted in line with the suggestions of Onukwuli, Okpala, and Okeagu (2022), as the retted husks were thoroughly washed to remove all the clinging slime, sand and dirt after which the exocarp were peeled off as shown in figure 1. Before the fibers were thoroughly washed, dried and stacked together, the husks were pounded with wooden mallets on stones to ensure the separation of the fibers.



Figure 1: Extracted coir fiber

### **Coir Fiber Cross-Section**

The cross-sectional area of the fibers must be carefully addressed when calculating the characteristics of coir fibers. Natural fibers have a lot of cross section diversity, and they also have a lot of voids, which range from 30% to 60% of the overall area (Weed, 2014). Figure 2 depicts a typical cross-sectional view of a single coir fiber. Because not all fibers are round, estimating the cross-sectional area by measuring the apparent fiber diameter is incorrect.

Furthermore, there is considerable disagreement about whether the area of the voids should be included in the cross sectional area. (Lee et al., 2021) subtracted the area of voids from jute fibers, because of the presence of a low-viscosity epoxy matrix within the voids. The incorporation of the voids in the cross-sectional area offers a strength value for the fiber on a more feasible macro scale,

so the single fiber strengths were calculated with the inclusion of voids. The cross-sectional view of a single Coir Fibers taken with SEM is shown in figure 2.

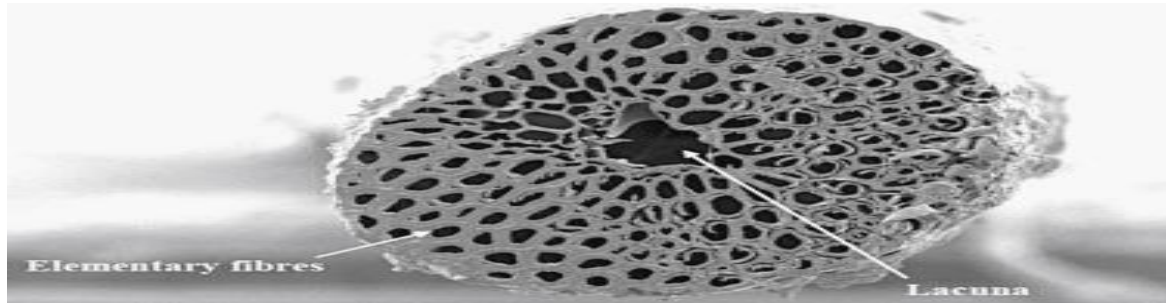


Figure 2: Cross-sectional view of single Coir Fiber taken with SEM. Source: Tran et al. (2015).

The density of the fibers is another essential characteristic determined from the cross section. Given the intrinsic diversity of fiber diameters, measuring fiber density is a difficult process. Rao et al. (2012), used a picnometric technique to determine the densities of various natural fibers, which measures the density of the fiber material itself, eliminating voids. He empirically obtained the value of 1.1 to 1.5 g/cm<sup>3</sup>, which is compatible with other academic research on coir fiber density (Annandarajah et al., 2018).

### **Coir Fiber Treatment**

Anyakora (2013), investigated the effect of ash content and fiber treatment on the tensile behavior of coir reinforced polyester composites. He utilized a hand lay-up approach to construct composite panels from untreated and saline-treated coir reinforced with a polyester matrix. Among the processing factors were surface treatment and fiber content modification, as well as ash content assessment with tensile strength characteristics. The result shows that, increasing the fiber content and surface treatment of coir composite panels can enhance their tensile strength and modulus of stiffness. Scanning Electron Microscopy (SEM) and Energy Dispersive Spectroscopy (EDS) examination indicated greater ash content; suggesting that the tensile strength of the treated coir reinforced polyester composite panels was enhanced favorably. The harmful effects of acid on fiber were, however, mitigated by the greater proportion of calcium in untreated coir.

Carvalho et al. (2010), investigated the influence of chemical modification on the performance of coconut fiber composites. Lignocellulose fibers from green coconut fruit were bleached with sodium chloride and acetic acid after being treated with an alkaline solution (NaOH 10% m/v). To obtain the specimen for the tensile test, alkali-treated bleached fibers were mixed with High Impact Strength Polystyrene (HISP) and put in an injector chamber. Specimens were tested in tensile mode, and composite fracture surfaces were examined using a scanning electron microscope and x-ray diffraction. The results revealed that adding 30% alkali-treated and bleached fibers reinforced in HISP matrix provided a significant change in mechanical characteristics when compared to pure HISP.

According to Verma and Gope (2014), the treatment of coir fiber with NaOH ensures that alkali-sensitive hydrogen bonds existing among the fibers are agitated and new hydrogen bonds form between the cellulose molecular chains, thereby increasing the surface roughness, and also eliminate the waxy substances on the fiber surface and thus improve the close contact of the fiber–matrix.

### **3. Methodology**

The study aimed to accomplish three main tasks to achieve its objectives. The first task involved creating the composite material by combining Epoxy and coir using hand lay-up methods. The next step was to conduct mechanical tests on the samples, and finally, using the optimized solution of the input variables, to determine the suitability of coir fiber reinforced composites for the manufacturing of automotive parts like car fender, driving mirror encasement, etc.

The flowchart of the study which commenced with coir preparation and ended with mechanical properties determination is illustrated in figure 3.

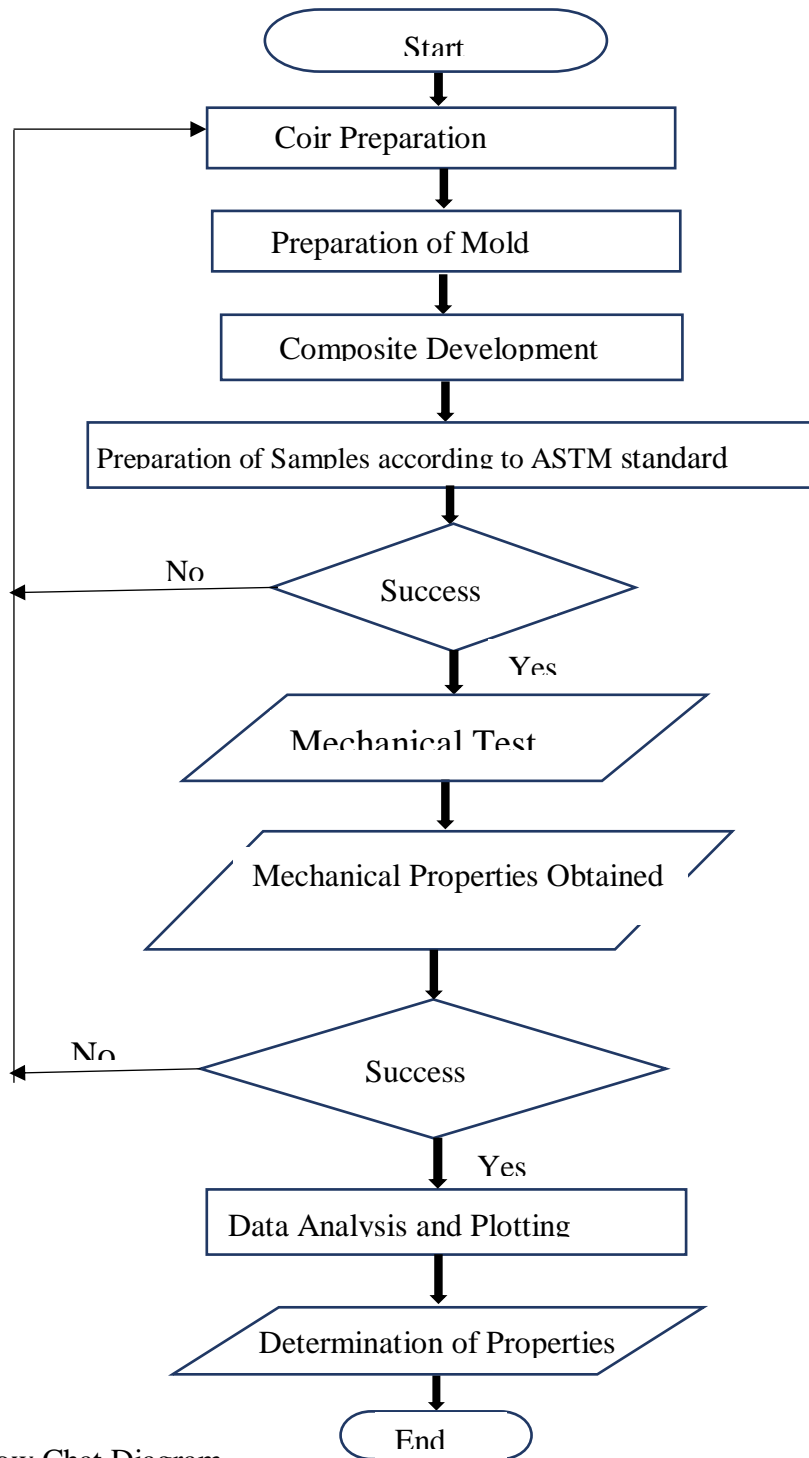


Figure 3: Flow Chat Diagram

Coconut was sourced locally from Adazi ani and Obeledu, in Anaocha Local Government Area of Anambra State - Nigeria. Initially, coir was derived from the leftover coconut fruit residues following harvests. These residues primarily consisted of coconut husks, which serve as the main material of interest and the fiber source for this research. Instead of being regarded as waste or discarded material, coconut husks are now recognized as valuable engineering materials capable of contributing to a wide range of composite end products. Once the coconut fruit has been extracted, the husks were carefully cut into the desired sizes and subsequently placed in large containers to undergo further fiber extraction processes.

Based on the recommendations of Okpala, Onukwuli and Ezeanyim (2021), Sodium Hydroxide (NaOH) was applied for the treatment of the extracted coir fiber which resulted to the formation of amorphous region through the swelling of the cell wall of the fiber, as well as remarkable changes in the packed crystalline cellulose orientation, thereby leading to enhanced reception to chemicals permeation. The fibers' weight fraction was taken for the estimation of the required fiber mass and resin mass needed to carry out the experiment.

To successfully carry out the composite design, ASTM D638, ASTM D790, and ASTM D6110 standard specification was adopted for tensile, flexural and impact tests respectively. The ratio of fiber to the weight of composite ( $W_c$ ) expressed as  $W_{fr} = \frac{(w_f)}{w_c}$  is the weight fraction of fiber. With the hand lay-up technique, fifteen different coir fiber reinforced composite samples as depicted in figure 4 were fabricated. As stated in the product data sheet, the matrix was prepared by the mixture of Epoxy LY556 with hardener HY951 in a ratio of 10:1 by weight.



Figure 4: 15 Samples before the Mechanical Testing

Analogue model TFIT-300; 300J ASTM Charpy impact testing machine, and 3383 Floor Model universal testing machine are the equipment used for the mechanical test.

### **Flexural Strength Test**

In this test, a specimen of the material is placed on two supports and subjected to tensile or compressive force at its center, which causes it to bend. The amount of force required to cause the material to bend, and the resulting deformation, are measured using 3383 Floor Model Universal Testing Machine in accordance with ASTM D790. This standard describes the test procedure for determining the Flexural Properties of Unreinforced and Reinforced Plastics and Electrical

Insulating Materials. This standard provides procedures for determining the flexural properties of plastic materials, including flexural strength and modulus. The specimens were stored in sealed plastic bags with desiccant at room temperature, then conditioned by heating at 75°C for 12 hours, and then cooled to room temperature for up to 4 hours before testing. For this specific test, the composite has a specimen dimension of 150mm x 15mm x 4mm. This dimension is important because it affects the stress distribution and deformation behavior of the material during the test with 1% strain rate. The specimen is typically carefully prepared to ensure that it meets the specifications of the test ASTM standard being used.

To conduct the flexural test, each specimen was positioned in the flexural testing machine and loaded using the three-point flexing arrangement, with fracture occurring at the middle point of the specimen as shown in Figure 5.

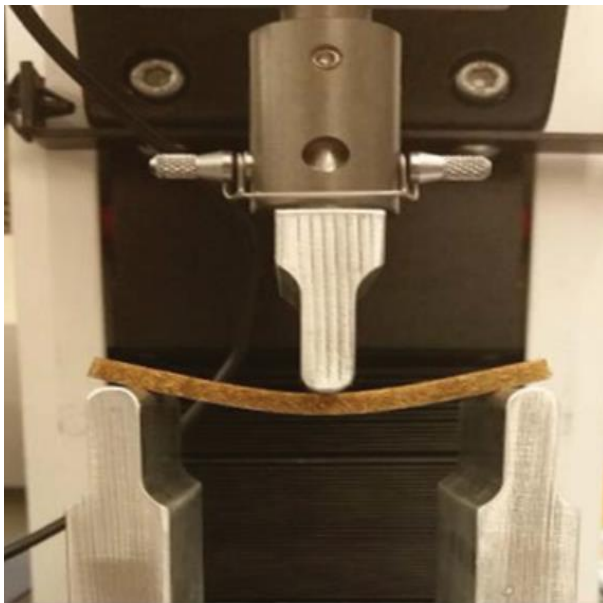


Figure 3.11: Three-point Flexural test set-up using 3383 Floor Model Universal Testing Machine

The flexural force required to fracture the specimen was recorded from the machine's scale, and the flexural strength was calculated with equation 1.

$$F_s = FL/bd^2$$

1

Where:

$F_s$  = flexural strength,  $F$  = flexural force (KN),  $L$  = length in (mm),  $b$  = breadth (mm),  $d$  = thickness (mm).

The results obtained were used to calculate the Flexural modulus ( $E_{flex}$ ), which is a measure of the material's resistance to bending, with typically three replicate tests conducted as advised by (Hodgkinson, 2000).

## Flexural Modulus

The flexural modulus from the 3-point test is specified in equation 2:

$$E_{flex} = \frac{(3pl)}{(2wdh^2)} \quad 2$$

Where: p = maximum load applied during the flexural (N), l = distance between the supports or the span of the beam (mm), w = width of the sample, measured perpendicular to the direction of the load (mm), h = height of the sample, measured parallel to the direction of the load (mm), d = maximum deflection or deformation of the sample during the test (mm).

## 4. Analysis of Results

Table 1 displays the results obtained from the conducted flexural test, which was carried out with the objective of investigating the performance and behavior of the tested materials under specific conditions. The collected data provides valuable insights into the mechanical properties and characteristics of Coir reinforced epoxy composite for automotive parts applications.

Table 1: Experimental design results of flexural strength

SAMPLE	COIR (%)	EPOXY & HARDNER (%)	COIR LENGTH (mm)	FLEXURALSTRENGTH (MPa)	AVERAGE FLEXURAL STRENGTH (MPa)
Sample 1					37.11
A1	15	85	10	36.81	
A2	15	85	10	36.02	
A3	15	85	10	38.50	
Sample 2					42.99
B1	15	85	15	43.13	
B2	15	85	15	42.50	
B3	15	85	15	43.34	
Sample 14					55.56
N1	45	55	30	54.80	
N2	45	55	30	53.75	
N3	45	55	30	58.13	
Sample 15					54.69
O1	45	55	45	52.84	
O2	45	55	45	55.97	
O3	45	55	45	55.26	

Table 2 shows the model fit summary for flexural analysis.

Table 2: Flexural Fit Summary

Source	Sequential value	p- Lack of Fit value	p- Adjusted R <sup>2</sup>	Predicted R <sup>2</sup>	
<b>Linear</b>	0.1057	0.2592	0.2542	-0.2241	
<b>2FI</b>	0.0684	0.3248	0.5584	-0.2791	
<b>Quadratic</b>	<b>0.0339</b>	<b>0.5218</b>	<b>0.8583</b>	<b>0.5491</b>	<b>Suggested</b>
<b>Cubic</b>	0.5218		0.9062		Aliased

The table shows that the model sequential probability value (p-value) for quadratic modeling is highly significant with a value of 0.0339, while the model lack of fit probability value (p-value) for quadratic modeling is highly insignificant with a value of 0.5218.

Table 3 shows the report and analytical results of the experimental runs. The runs show that the experimental trials are fit and adequate for the experimental analysis of flexural strength.

Table 3: Flexural Report and Analysis

Run Order	Actual Value	Predicted Value	Residual	Leverage	Internally Studentized Residuals	Externally Studentized Residuals	Cook's Distance	Influence on Fitted Value DFFITS
1	37.11	37.52	-0.4122	0.854	-0.510	-0.469	0.152	-1.132
2	42.99	41.98	1.01	0.841	1.195	1.264	0.754	2.905 <sup>(1)</sup>
3	45.01	45.81	-0.7982	0.487	-0.528	-0.486	0.026	-0.473
4	46.79	48.26	-1.47	0.646	-1.174	-1.234	0.252	-1.668
5	49.66	47.56	2.10	0.577	1.533	1.883	0.321	2.200
6	44.87	45.52	-0.6500	0.602	-0.488	-0.447	0.036	-0.551
7	47.44	45.81	1.63	0.487	1.079	1.102	0.110	1.073
8	48.79	48.00	0.7885	0.498	0.527	0.485	0.028	0.484
9	58.65	57.56	1.09	0.787	1.123	1.161	0.465	2.231
10	52.66	52.25	0.4111	0.859	0.519	0.477	0.165	1.179
11	45.22	47.47	-2.25	0.407	-1.385	-1.579	0.132	-1.309
12	51.21	51.43	-0.2173	0.853	-0.269	-0.242	0.042	-0.585
13	53.60	55.25	-1.65	0.691	-1.403	-1.611	0.439	-2.407
14	55.56	54.69	0.8684	0.586	0.639	0.597	0.058	0.711
15	54.69	55.14	-0.4538	0.824	-0.512	-0.470	0.122	-1.016

Figure 5 shows the predicted and the actual data variation of the flexural material composition.

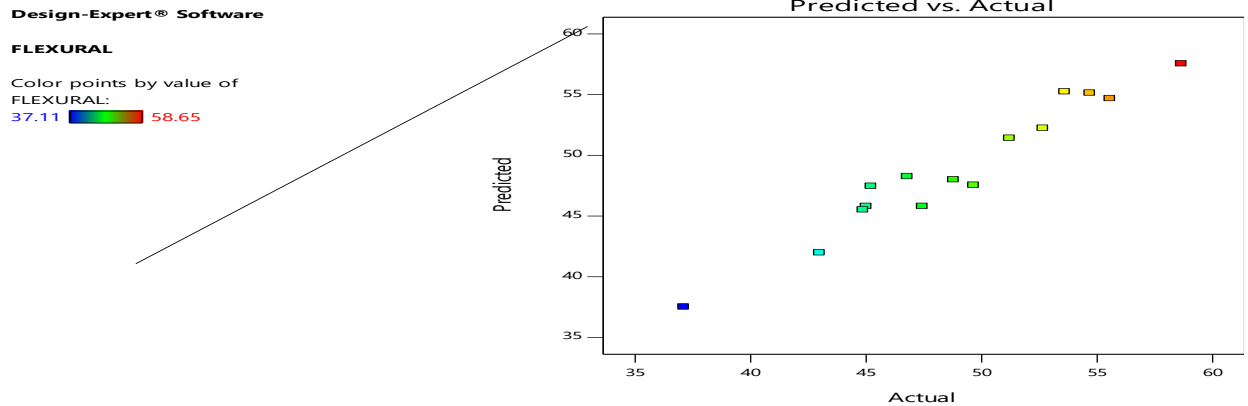


Figure 5: Flexural Plots for Predicted versus Actual Data

The variations within the predicted and the actual for the flexural experiment trials are insignificant and the residual plot of the flexural, which expressed the difference of the actual data and the predicted, is insignificantly very low. The plot also shows that the residual lack of fit is insignificant.


Figure 6 shows the three-dimensional (3-D) plot of the coir material and coir length input factors and its effect on the flexural strength response parameter.

**Design-Expert® Software**

Factor Coding: Actual

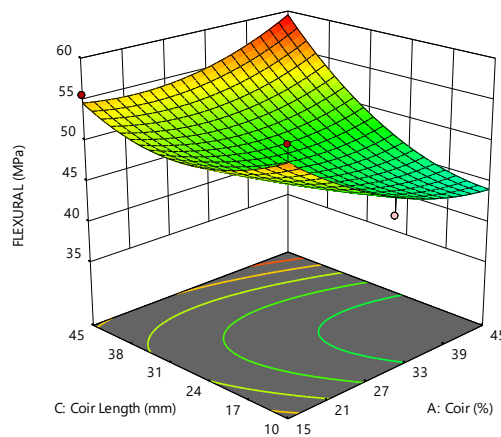
**FLEXURAL (MPa)**

- Design points above predicted value
- Design points below predicted value

37.11  58.65

X1 = A: Coir

X2 = C: Coir Length



**Right-click to export full text of legend**

Figure 6: 3-D Surface Plot of the flexural Strength, Coir and the coir length


The plot shows that the increase in coir length will slightly increase the flexural strength of the composition. However, the increase in coir material will slightly decrease flexural strength.

Figure 7 shows the three-dimensional (3-D) plot of the coir length and epoxy input factors and its effect on the flexural strength response parameter.

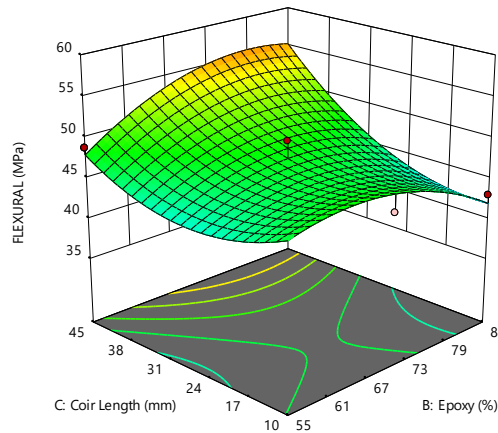
**Design-Expert® Software**

Factor Coding: Actual

**FLEXURAL (MPa)**

- Design points above predicted value
  - Design points below predicted value
- 37.11  58.65

X1 = B: Epoxy  
X2 = C: Coir Length



**Right-click to export full text of legend**

Figure 7: 3-D Surface Plot of the flexural Strength, the coir length, and Epoxy

The plot shows that the increase in epoxy slightly decreases the flexural. However, the increase in coir length input parameter slightly decreases the flexural strength composition.

**Optimization Solutions**

The application of Response Surface Methodology (RSM) to methodically optimize the parameters of the coir fiber reinforced epoxy composites for the automotive parts application which was found in the 70<sup>th</sup> trial, identified the best combination of input variables, in order to obtain the desired mechanical properties in the composite.

Table 4: Number of solutions found in the system

S/N	Coir	Epoxy	Coir Length	TENSILE	FLEXURAL	IMPACT STRENGTH	YOUNG MODULUS	STRESS	STRAIN	Desirability	
1	45.000	54.543	45.000	49.333	57.118	34.787	4.788	4.534	20.483	0.949	Selected
2	45.000	54.465	45.000	49.277	57.089	34.762	4.786	4.535	20.493	0.949	
3	45.000	59.652	45.000	49.411	57.158	34.820	4.790	4.532	20.469	0.949	
68	15.000	72.861	16.069	42.343	53.366	29.528	4.249	3.807	14.980	0.693	
69	15.000	75.001	16.885	41.440	53.108	29.154	4.235	3.849	15.263	0.691	
70	15.000	76.710	21.273	39.869	52.354	28.405	4.198	3.911	15.655	0.680	

As depicted in table 4, the optimal solution findings showed that the desirability of attaining the selected result is 0.949 or approximately 95%. The results revealed that the optimal solution for

the input parameters which are the coir, epoxy, and coir length are 45.000%, 54.543% and 45.000mm respectively. Also, the optimal solutions for the response parameters which are flexural strength, tensile strength and impact strength are 57.118MPa, 49.333MPa and 34.787KJ/M<sup>2</sup> respectively. While 4.788 GPa is for the young modulus, 4.534 is for Stress, and 20.483 units for Strain.

### Validation of Flexural Strength

The validation of the optimization solutions was achieved with the application of Linear programming tool in Tora software.

The screenshot shows the 'LINEAR PROGRAMMING OUTPUT SUMMARY' window. The title is 'LINEAR PROGRAMMING'. The final iteration number is 5, and the objective value (Max) is -58.65. The optimal solution for the variables is: x1: Coir = 0.34, x2: Epoxy = 0.22, x3: Coir Length = 0.54. The objective value contribution is 15.15. The constraints are listed with their current RHS values and slack/surplus values.

Variable	Value	Obj Coeff	Obj Val Contrib
x1: Coir	0.34	45.00	15.15
x2: Epoxy	0.22	85.00	19.10
x3: Coir Length	0.54	45.00	24.40

Constraint	RHS	Slack/Surplus
1 (<=)	37.11	7.09
2 (<=)	42.99	8.37
3 (<=)	45.01	12.08
4 (<=)	45.79	0.00
5 (<=)	49.66	8.92
6 (<=)	44.87	3.06
7 (<=)	47.44	14.51
8 (<=)	48.79	1.93
9 (<=)	58.65	0.00
10 (<=)	52.66	29.83
11 (<=)	45.22	13.97
12 (<=)	51.21	12.15
13 (<=)	53.60	0.00
14 (<=)	55.56	10.38
15 (<=)	54.69	2.78

Figure 8: Optimal Solution of Flexural Strength

Figure 8 shows the optimal solution for flexural strength by using linear programming optimization tool. The result of the optimal solution of the flexural response variable is 58.65MPa. The result of the optimal solution generated is close to that of response surface method.

The screenshot shows the '\*\*\*Sensitivity Analysis\*\*\*' window. It displays the current objective coefficients and RHS values for the variables and constraints, along with the minimum and maximum values for the objective coefficients and RHS values.

Variable	Current Obj Coeff	Min Obj Coeff	Max Obj Coeff
x1: Coir	45.00	30.00	45.00
x2: Epoxy	85.00	85.00	95.16
x3: Coir Length	45.00	37.93	45.00

Constraint	Current RHS	Min RHS	Max RHS
1 (<=)	37.11	30.02	infinity
2 (<=)	42.99	34.62	infinity
3 (<=)	45.01	32.93	infinity
4 (<=)	45.79	44.63	48.08
5 (<=)	49.66	40.74	infinity
6 (<=)	44.87	41.81	infinity
7 (<=)	47.44	32.93	infinity
8 (<=)	48.79	46.86	infinity
9 (<=)	58.65	56.96	59.30
10 (<=)	52.66	22.83	infinity
11 (<=)	45.22	31.25	infinity
12 (<=)	51.21	39.06	infinity
13 (<=)	53.60	52.17	56.45
14 (<=)	55.56	45.18	infinity
15 (<=)	54.69	51.91	infinity

Figure 9: Sensitivity Analysis of Flexural Response Parameter

Figure 9 shows the sensitivity analysis of the flexural response parameter. The sensitivity analysis shows the impact of the input factors and the objective values of the input factors to the optimal solution of the flexural response parameter. It also reveals the minimum and maximum objective coefficients of the input factors.

## **5. Conclusion**

The research showed that coir fiber reinforced composites offer a viable solution for enhancing sustainability and reducing environmental impact in the automotive industry, they also show great potential for various automotive applications, including interior trims, door panels, seat backs, and parcel shelves. Their lightweight nature, coupled with favorable mechanical properties and sustainability coupled with renewable sourcing, make them attractive alternatives to conventional materials such as glass fiber reinforced composites or plastics derived from petroleum.

The application of response surface methodology after conducting of tests on the 15 coir fiber reinforced composites revealed the desirability of accomplishing the selected result as 94.9%, while the results showed that the optimal solutions for the input parameters are coir 45.000%, epoxy 54.543%, and coir length 45.000mm. Also, the optimal solutions for the response parameters or mechanical properties which were later validated with linear programming gave the following results: flexural strength 57.118MPa, tensile strength, 49.333MPa and impact strength 34.787KJ/M<sup>2</sup>, Young modulus 4.788 GPa, Stress 4.534, as well as 20.483 units for Strain.

The results showed that coir has proven to be one of the most suitable filler materials for automotive part composites, which will enable the automotive manufacturing industry to reach new levels of achievement and production of cars that are economical, environmentally friendly, and ecologically sustainable, without compromising customers' satisfaction. Affordability, is a crucial factor in automobile production as it encompasses the expenses associated with the entire life cycle of a car, including manufacturing, operating, and maintenance costs. Carbon fiber, widely used in automotive parts, fails to meet affordability requirements due to the high costs and time consumption associated with its rigorous composite preparation, ranging from thermal pyrolysis to the transformation of raw carbon material into carbon fiber. In contrast, utilizing coir as an alternative to synthetic fiber can significantly reduce production costs and maintenance expenses in automotive parts.

However, despite the promising mechanical properties and sustainability of coir fiber reinforced composites, further research is needed to address challenges such as moisture absorption, durability, and recyclability. Future studies should focus on optimizing processing techniques, developing advanced fiber treatments, and exploring hybridization with other natural or synthetic fibers to tailor mechanical properties for specific automotive applications.

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