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# Study on the Characteristics of Natural Fibre Composite Using Coir Fibre Composite for Car Outer Hood

**Danny Iskandar Mohd Yazli[1], Norhasikin Ismail[1]***

[1] *Faculty of Engineering Technology*
*Universiti Tun Hussein Onn Malaysia, Parit Raja, Johor, 86400, Malaysia*

*Corresponding Author: nhasikin@uthm.edu.my
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**Abstract**

The use of natural fibre composites in automotive applications has gained significant attention in recent years due to their potential to reduce the environmental impact of vehicles. Coir fibre, derived from coconut husk, has emerged as a promising natural fibre for composite materials. This research presents a comprehensive analysis of the characteristics and performance of natural fibre composites using coir fibre, specifically for the outer hood of a car. Different fibre-to-weight ratios (wt%) of coir fibre were used, 10 %, 15 % and 20 %, and mixed with epoxy resin and hardener to create the coir fibre composite. The original state of coir fibres was brown and matured coconut husks. The coir fibres were extracted by using a fibre extractor machine. Then, they underwent an alkaline treatment of 10 litres of distilled water and 180 g of NaOH for 42 hours before being rinsed with distilled water containing a few drops of acetic acid and oven-dried at 60 C for 72 hours. Lastly, it was ground using an RT-34 Vertical High-Speed Pulverizing Machine with a fibre length of 0.1 to 0.2 mm. The hand lay-up method was used on a 20 cm x 20 cm mould to create a square-shaped coir fibre composite cut into the specific ASTM for each test. The mechanical tests conducted were a tensile strength test (ASTM D638 type 4), a bending test (ASTM D790), and an impact test (ASTM D256). The results from the tensile strength test show that the highest obtained was 15.7 MPa from the 10 wt%, and the young modulus was 8.52 MPa. The bending test shows the highest, which is 20 wt%, which is 122.96 MPa. The highest result for the impact test was at 15 wt%, with impact energy for dual units of 5.87 MPa and 82.92 J/m and an energy absorption of 0.71 %. It can be concluded that the 20 wt% of coir fibre was the most optimum mixture to be used for the outer hood application.

## 1. Introduction

Despite their performance advantages, the demand for environmentally friendly alternatives has limited the use of synthetic fibres. However, engineering innovations have introduced renewable materials as practical and economical substitutes. Synthetic plastics, while superior in performance, pose environmental issues due to fossil fuel use and emissions. Natural fibre composites (NFCs) have gained interest for their potential to replace synthetic composites, especially in automotive applications, offering excellent strength-to-weight ratios, insulation, and minimal environmental impact. NFCs, derived from plants like coir fibre, present a sustainable and affordable option. With their lightweight, strong mechanical qualities and environmental friendliness, coir fibre composites are identified as potential substitutes for steel or carbon fibre composites in automotive outer hood panels. The adoption of NFCs in the automotive industry, such as using coir fibre composites for car hoods in Malaysia, could contribute to carbon emission reduction and improved fuel economy, as they can reduce the weight of automotive parts by up to 30% [1][2].

## 2. Methodology

### 2.1 Preparation of Coir Fibre

Brown coir fibre and resin were utilised in the fabrication investigation, with a preference for brown coir due to its advantages over white fibre. The experiment used ripped and matured coconuts sourced from local areas in Muar, Johor. The extraction of coir fibre followed several steps. Initially, coconuts were fed into a husking machine designed for efficient coconut husk removal, functioning as a fibre extractor. The process aimed to separate coir fibre effectively from the husk, facilitating subsequent use in the fabrication experiment.

### 2.2 Chemical Treatment of Coir Fibre

The coir undergoes alkali treatment involving immersion in a 2% sodium hydroxide (NaOH) solution for approximately 48 hours. The 2% alkaline solution was prepared using 10L of distilled water with 180g of NaOH, ensuring thorough mixing. Subsequently, the treated coir fibres were rinsed with distilled water containing a few drops of acetic acid to neutralise any remaining sodium hydroxide. The extracted fibre must be dried before further processing, utilising a well-ventilated area with sunlight or a controlled temperature. Therefore, to completely remove any moisture, the coir fibres were oven-dried at 60°C for 72 hours using the Heavy-Duty Universal Oven (Memmert, Germany).

### 2.3 Grinding Process of Coir Fibre

To achieve the required lengths of the coir fibre for the experiment, the fibre was first cut into small pieces using a knife. Then, it was fed into an RT-34 Vertical High-Speed Pulverizing Machine, a grinding machine that grinds the fibre into a more appropriate length of approximately 0.1 to 0.2 mm.

### 2.4 Composite Fabrication

Three ratios of coir fibre used were 10%, 15% and 20%. Each ratio will have three samples, and an average from those three will be taken. The fibre composition and amount of resin and hardener were weighed according to its ratios using an electronic precision balance of Mettler Toledo. Table 1 shows the total weight, fibre weight, resin, and hardener weight based on the fibre percentage used.

**Table 1** *Weight of Fibre Composite for Each Percentage*

| Sample | Fibre Ratio (wt%) | Fibre Weight (g) | Resin Ratio | Resin Weight (g) | Hardener Ratio | Hardener Weight (g) | Total weight (g) |
|---|---|---|---|---|---|---|---|
| A | 0.10 | 12 | 3 | 81 | 1 | 27 | 120 |
| B | 0.15 | 18 | 3 | 76.5 | 1 | 25.5 | 120 |
| C | 0.20 | 24 | 3 | 72 | 1 | 24 | 120 |

Preparation of the coir fibre specimen involves using the hand lay-up method. The hand lay-up method is often used in coir fibre composites due to its simplicity and cost-effectiveness. This technique allows for flexibility in design, making it easy to create products with intricate shapes. It is well-suited for small to medium production runs and requires less specialised equipment. The coir fibre composites were produced by pouring the fibre mixed with epoxy resin and hardener into the mould, where the size used is 20cm x 20cm. Before that, a layer of lubricant silicone is sprayed onto the surface of the mould to ease the removal after curing, which is 24 hours at room temperature. After curing, a hand grinder was used to cut the coir fibre composite to follow three different specific ASTMs for testing, which were ASTM D638 Type 4 for the tensile test, ASTM D790 for the bending test and ASTM D256 for the impact test.

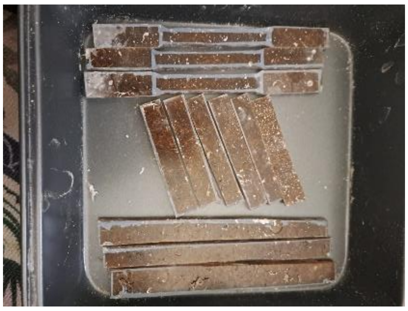

**Fig 1** *Sample of Test Specimen*

## 3. Results and Discussion

The results and discussion of testing coir fibre composites with resin and hardener can give important insights into the mechanical features and performance characteristics of the material. These findings can be used to evaluate the composite's suitability for automotive applications, specifically the outer hood, and confirm that it complies with predetermined specifications. A total of nine samples were created for each fibre ratio, which is 10 wt%, 15 wt%, and 20 wt%, with three samples used for each test. All methods of producing the samples were fully explained in the previous chapter.

### 3.1 Tensile Strength Test

From the data shown in Fig 2, the ratio of 20% of coir fibre has an optimum interaction between the coir fibre and the matrix. This means that the fibre is well spread throughout the matrix, which could have been a factor for its effective stress transfer as the stress transfer plays a crucial role in allowing the fibre to absorb and distribute the mechanical loads. It may provide less reinforcement for specimens at 10% compared to the 15% coir fibre. However, it still shows a decent balance of fibre-matrix interaction. A distribution that is not uniform may result from the coir fibre clumping together, which may lead to the stress concentration and lower its tensile strength.

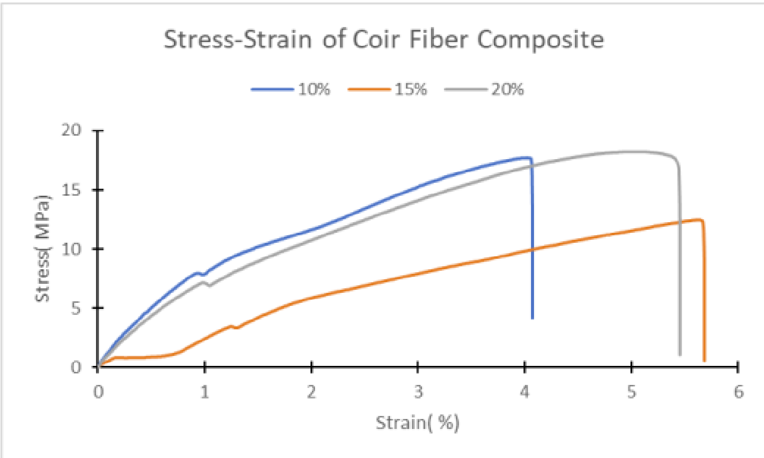


**Fig 2** *Stress-Strain Graph*

Fig 3 shows that the 20% is the strongest where it could withstand more stress; however, it has a lower tensile strength than the 10% of coir fibre. This means that the composite structure and porosity are more favourable in the 10% rather than the 20% of coir fibre. This is because increasing or having an excessive fibre content could increase its porosity and structural flaws, which has caused a negative impact on the mechanical performance of the material. As stated for the 15% coir fibre ratio, it may have the propensity to clump, which could have created weak points within the material. Compared with the 10% and 20% with more scattered and aligned coir fibres, it may have led to the 15% having an uneven distribution of stress and reduced tensile strength. Young modulus is directly proportional to tensile strength. This indicates that when the tensile strength increases, the young modulus also increases. Material with a higher young modulus is stiffer and more deformation-resistant, which means it can withstand higher loads or stress before breaking. Therefore, it shows how an ideal fibre matrix interaction could affect the material's performance and how it could bear up against higher stress.

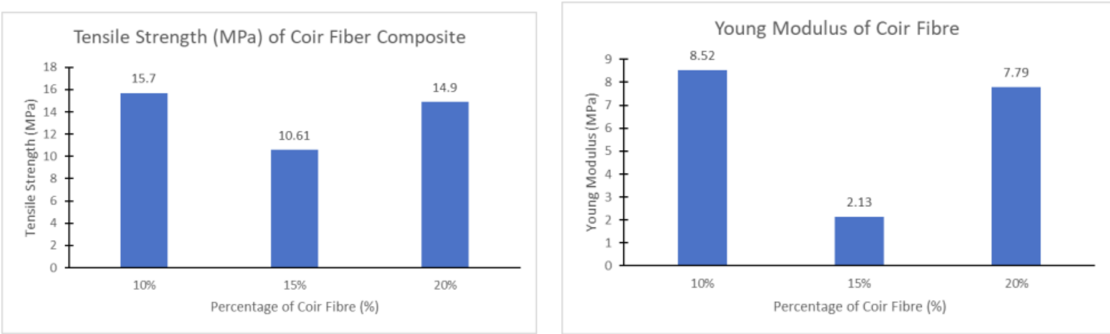


**Fig 3** *Tensile Strength and Young Modulus Graph*

This is also similar to the research done by [3], which investigated the tensile strength of coir fibre; however, it is reinforced with polyester composite. From the study, the coir fibre percentage used was 10%, 20%, 30% and 40%. It can be seen that the 10% coir fibre has the highest tensile strength compared to the other percentages. From there, it shows that the continuous addition of coir fibre does not increase the tensile strength and stiffness of the polyester matrix composite. This is also supported by research done by [4], which says the higher the wt% of coir fibre, the more increased fibre-to-fibre contact, which makes the fibre harder to disperse inside the polymer matrix, which, means it has a poor fibre-to-matrix bonding that causes a non-uniform distribution of stress transfer when load is applied. Another research to prove this theory from [5] also states in their experiment that after getting 20% coir fibre percentage, the highest in the tensile test is that the volume portion has a uniformly distributed fibre in the composite, making the composite material's property stronger. However, when the coir fibre percentage increases, it could make the mixed product brittle, making the stress poorly distributed and yielding poor tensile strength results.

## 3.2 Bending Strength Test

The results from Fig 4 show that at the 20% ratio, the highest bending strength was recorded with a value of 122.96 MPa. The result can be linked with the coir fibre reinforcing properties, which have improved the resistance of the composite towards bending forces. With a bending strength of 109.67 MPa, the 10% coir fibre composite placed itself between 15% and 20%. However, it differs from the tensile strength test as it shows that the 10% ratio is higher than the 20%. The difference indicates that different fibre contents have other effects on the mechanical properties between under tension and bending stresses. This is because while bending strength evaluates the material's resistance towards bending or flexural stresses, tensile strength measures how well a material can withstand pulling force. How well the fibre's optimum interaction between fibre and the matrix is still considered, but increasing the fibre content often increases the load-bearing capacity and structural integrity. This is one of the pros of advancing the fibre content rather than its cons, which could increase its porosity.

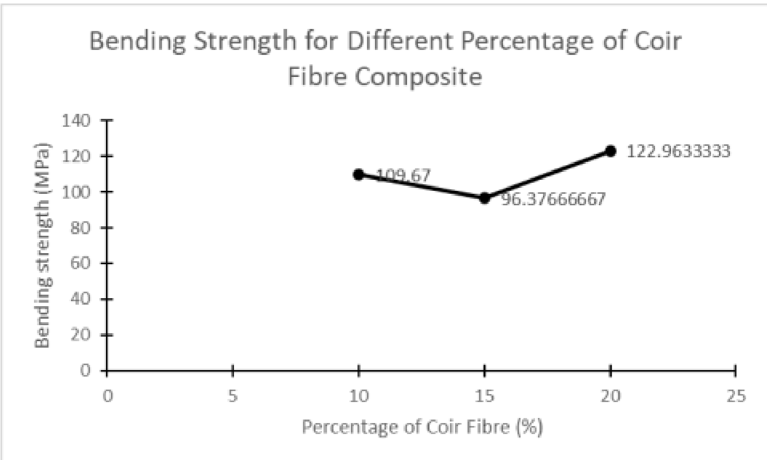


**Fig 4** *Bending Strength Graph*

This can be demonstrated when an experiment done by [6] shows that the bending test graph shows a drastic decline graph from the lowest percentage of coir fibre, which is 20% to 40% where it is due to the uneven distribution of coir fibre in the composite material that causes the interaction or interfacial bond between the fibre and the epoxy or matrix used to be weak. In other words, an excessive amount of coir fibre would make the composite unable to connect with every fibre surface, which results in poor matrix-fibre bonding.

Next, the bending strength of 10% and 20% coir fibre percentage also can be proven with the research done by [7], which states that from its experimental data obtained from the lowest percentage of coir fibre (10%) having less flexural or bending strength compared towards the highest which is 40%. This means that the portion of coir fibre in the composite is too low to achieve an ideal fibre alignment inside the matrix, which could make it have a low potential of an effective load transfer between fibre and matrix, which could have made it the possibility of the 10% having less bending strength. Moreover, the 10% and 20% for the tensile and bending tests only slightly differ.

## 3.3 Impact Strength Test

Fig 5 clearly shows the trend movement of the impact energy obtained by the ratios. From the 10% to the 20% coir fibre ratio, there was a significant improvement as the coir fibre in the composite increased, therefore starting the trend to incline from 2.81 KJ/m2 to 5.87 KJ/m2. Nevertheless, the impact energy marginally dropped when the coir fibre was at 20%, making the trend slightly decline at 5.66 KJ/m2. The increase in the impact energy may suggest that the composite's impact resistance may have improved within a specific range of fibre content. When the impact energy starts to drop at a 20% ratio, it implies that adding too much fibre may only sometimes increase the composite's impact strength. This is the same as the percentage of the energy absorption for the three ratios. When one coir fibre composite ratio has reached a limit to absorb more energy, adding more coir fibre might not increase energy absorption, which is proportionate.

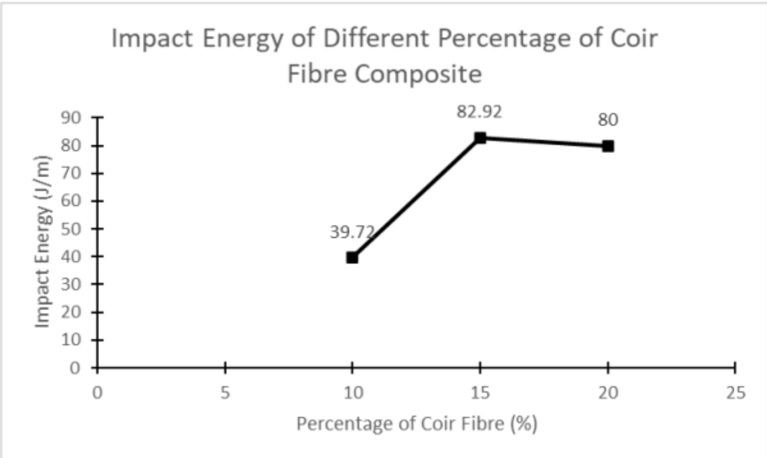


**Fig 5** *Trendline of Impact Energy*

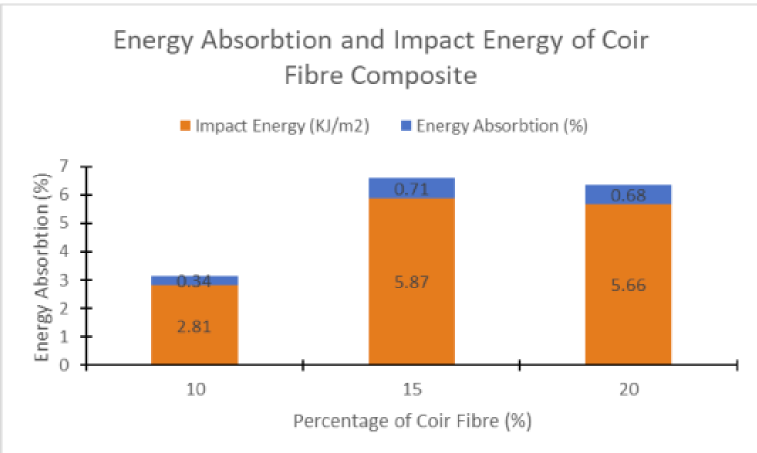


**Fig 6** *Energy Absorption and Impact Energy Bar-Chart*

With that, the slight decrease seen in Fig 5 can be defined as the low bonding interaction between the fibre and matrix, causing the force impacted towards the composite to have a non-uniform distribution of stress force. [8] Studies of the mechanical behaviour of coir fibre-reinforced polymer matrix composites also illustrate the effect of coir fibre percentage towards impact strength but with the percentages in the length of the coir fibre. The

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unit of KJm2 shows the lowest percentage, 16.0 KJ/m2, followed by 16.5 KJ/m2 and 17.5 KJ/m2, as the coir fibre length gradually increases. This determines how well the resistance towards impact increases as the fibre length increases; however, too much portion of fibre causes the readings to drop.

## 3.4 Tensile Strength Comparison

In a SolidWorks simulation, the tensile strength obtained from the yield strength was 41.36 MPa after changing from the von Mises unit of N/m2. This clearly shows that aluminium has a higher tensile strength than coir fibre, the highest obtained being 15.7 MPa. However, it is known from the engineering construction of the hood panel that the inner panel would be much stronger than the outer panel, which may have a nice, attractive look but cannot withstand an impact force on its own.

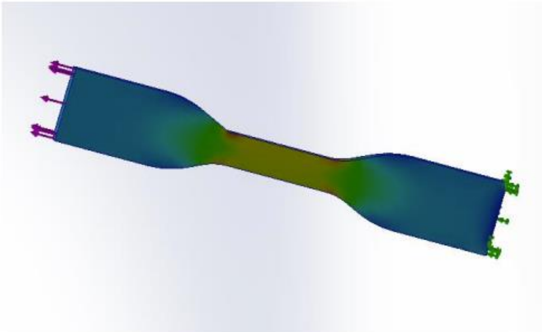

**Fig 7** *SolidWorks Simulation Specimen*

It is crucial to understand each material's material properties to design and build an excellent outer hood of a car, including its specific needs and limitations towards the application itself. Since coir fibre composites and aluminium are different materials, other factors such as manufacturing, cost, and weight could help deteriorate a good outer hood. As for manufacturing, coir fibre composite can be moulded into any shape and size compared to aluminium, which can be easily compressed using machinery. But the difference is that the coir fibre composite can be quite advantageous as it can be moulded into complex designs. Also, aluminium tends to be corrosive without an extra layer of coating protection, and coir fibre is known to have excellent corrosion resistance. Lastly, aluminium would be more costly compared to coir fibre. Therefore, for the use of the outer hood, the coir fibre composite can be considered.

# 4. Conclusion

To conclude, the research objectives have been achieved. The research analyses the possibility of coir fibre composites for automotive applications, specifically for the outer hood of a car. The study incorporates different weight percentages (10%, 15%, and 20%) of coir fibre combined with epoxy resin and hardener to create composite materials. Extracted from matured coconut husks, the coir fibres undergo a comprehensive treatment process, including alkaline treatment and mechanical processing, to optimise their properties for composite integration. In accordance with ASTM guidelines, standardised tests such as the tensile strength test, bending test, and impact test are used to assess the mechanical properties of the coir fibre composites. There are two layers of the hood application, which are the inner and outer where the outer layer of the car hood might have less strength than the inner; however, it is the first contact surface with the outside conditions. Therefore, considering the overall performance across the mechanical tests and the specific requirements for an outer car hood application, the coir fibre composite with the 20 wt% coir fibre content is the ideal mixture based on the composite index from the tests done. This composition is a good option for lightweight and eco-friendly automotive components since it balances tensile strength, bending strength, and impact resistance.


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