A Preliminary Evaluation on the Development of Sandwich Panels for House Walls Using Basic Materials of Coconut Fiber as the Outer Skin Layer and Multiplex as the Core

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A preliminary evaluation on the development of sandwich panels for house walls using basic materials of coconut fiber as the outer skin layer and multiplex as the core.

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Abstract: *Coconut fiber has numerous advantages in the industrial domain, particularly in the production of automobile dashboards, and other materials utilized in civil engineering. The purpose of this work is to create sandwich panels for basic home walls using natural fiber composites. In these panels, coconut fiber serves as the outer layer, while multiplex functions as the core material. This study employs experimental approaches and analyzes laboratory test results. With a 40% volume fraction and fiber lengths between 10 mm and 20 mm, the panels demonstrated an average flexural strength of 46.38 MPa, showcasing the impact of these parameters on the panel's strength. Moreover, at the same 40% volume percentage, the panels showed an impact strength of 4.4 joules, indicating their resilience under sudden impacts. According to the measurements, the sandwich panels had a weight of 84.672 grams of coconut fiber, 2.9808 grams of catalyst, and 146.0592 grams of polyester resin.*

Keywords: Volume Fraction; Flexural Strength; Impact Strength; Sandwich Wall Panels; Coconut Fiber

1. INTRODUCTION

The main applications of coconut fiber include constructing garden exteriors, manufacturing ropes, and producing domestic furniture and equipment. The tremendous improvements in technology have led to increasing adoption of coconut fiber in civil engineering and automotive industries. It is widely used as a key ingredient in the production of roof tiles and ceilings, and also as an additive in the making of composite wall panels, vehicle dashboards, and motorbike seats. Moreover, it is also utilized as an additional material for fabricating ship components such as walls. Coconut fiber is employed in civil engineering as a substance or supplement to fabricate an innovative composite material [1]. Composite refers to the process of merging multiple materials to form a novel material that possesses unique mechanical properties and characteristics that are different from the original components [2].

This study will especially focus on developing construction materials designed for the production of sandwich panels utilized in the construction of simple residential buildings. The panels will be manufactured using natural fiber composites, with coconut fiber as the outside layer (skin) and multiplex as the interior layer or core. The primary aims of this study are to analyze the results of bending strength tests and the most influential impact strength tests for sandwich panels made from coconut fiber in its natural composite form. Additionally, the study aims to investigate the appropriate volume fractions of coconut fiber, polyester resin, and catalysts for the production of sandwich panels used in house walls.

2. MATERIALS AND METHODS

2.1. Sandwich Panels

Sandwich panels are a form of material made from either materials or composite materials, designed to create a panel that is lightweight and moderately rigid. Ricky (2018) provides a definition of a sandwich panel as a composite material of two outside sheets (referred to as skin) that are joined together by adhesive and attached to the inner layer (known as the core). To provide high rigidity and resistance to tensile and compressive forces caused by loading, the exterior sheet, or skin, is usually made of a strong and durable material. On the other hand, the core generally exhibits a low modulus of elasticity and has a relatively low weight [2].

2.2. Sandwich Panels as House Walls

Building a house requires careful consideration of various things, including the walls. When building a house, it is crucial to consider the composition of the walls in order to ensure that they are affordable, visually pleasing, and structurally sound. When building walls for a residential home, it is important to consider the following factors:

- The materials of the house must protect its inhabitants from a variety of weather conditions, including chilly weather, wind, and heat from the sun.
- The material that is selected must be capable of eliminating interference that originates from outside the residence.
- The material used to construct the walls must effectively serve as a barrier or divider between rooms.
- The materials employed must possess exceptional aesthetic value.

2.3. Composite

A composite is the result of the combination of two or more distinct materials to form a single, new material. A fiber, which functions as an infill and reinforcement in composites, and a matrix, which functions as a fiber-binding material, are the two elements that typically comprise the composite material. The primary component or material in composite materials is fiber, as the characteristics of the composite material, including rigidity, strength, and other mechanical properties, can be determined by the use of fiber. In the interim, the composite binder that is most frequently employed is a polymer that is simple to manipulate [2].

2.4. Filler Material
The characteristics and properties of composite materials are significantly influenced by the constituent material. This is because the mechanical and physical characteristics of the composite material under consideration are determined by a comparison of the matrix composition and infill material. In general, the structure of fiber cells from plants is similar in that they consist of three primary constituent components: cellulose, hemicellulose, lignin, and other constituent materials [3].

2.5. Coconut Fiber
The coconut fruit (Cocos nucifera) is commonly found on palm trees in tropical regions. Indonesia, with its tropical climate, is a major global producer of coconuts. The coconut fruit is composed of coconut fiber, which makes up about 35% of its total weight. With an average annual coconut yield of 5.6 million tons, this means around 1.7 million tons of coconut fiber is produced. Coconut fiber has excellent absorbent properties and contains a significant amount of cellulose content [4].

2.6. Polyester Resin
Unsaturated Polyester Resin (UPR) is formed through the polymerization of dicarboxylic acid with glycol, resulting in a thermoset polymer. UPR, or unsaturated polyester resin, possesses favorable mechanical and chemical attributes, including chemical resistance, and is available at a reasonably affordable cost. Another benefit is the capacity to produce UPR unsaturated polyester resin using liquid fiber material [5].

2.7. Catalyst
In the production of sandwich panels using a polyester resin matrix, the use of a catalyst is necessary to expedite the curing process. The catalyst typically employed is MEKPO, which stands for Methyl Ethyl Ketone Peroxide. The curing process, which involves the hardening of a substance, is mostly determined by the quantity of catalyst employed. The duration of hardening (curing) will reduce according to the increase in the percentage of catalyst. It is crucial to acknowledge that excessive addition of catalyst might result in the composite becoming fragile, as the mixing process of the catalyst and polyester resin can generate a high-temperature reaction of up to 60 °C. Subsequently, the elevated reaction temperature will cause the polyester resin to solidify, leading to the formation of a composite material with the utmost rigidity. It is advised to add or utilize a catalyst in a proportion of 1% to 2% relative to the weight of the resin [6].

2.8. Testing the Strength of Bending
Flexural strength, or bending strength, is the ability of an item to resist bending under external loads without undergoing noticeable deformation. The purpose of this test is to assess the specimen's ability to withstand the application of a load at the bending point and its resistance to material flexibility. Fig. 1 illustrates the dimension and form of the flexural strength test sample.

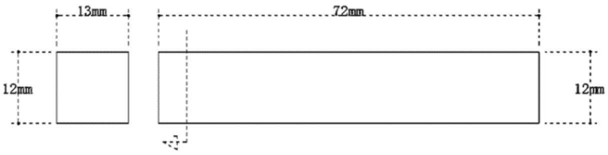

Fig. 1. The dimension and form of the flexural strength test sample

2.9. Testing the Strength of Impact
The Charpy standard and the Izod standard are the two predominant test standards utilized in impact strength testing. The Charpy standard is the predominant testing standard utilized in the United States. The Carpy standard and Izod standard impact strength test specimens have identical dimensions and shape, as depicted in Fig. 2.

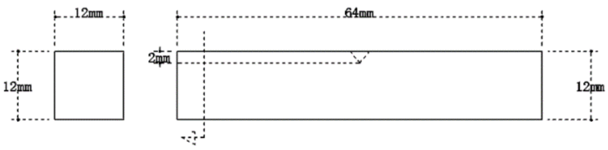

Fig. 2. The dimensions and shape of the Carpy standard and Izod standard impact strength test specimens

2.10. Research Methods
This study utilizes an experimental approach, including preset modifications in both the length of the fiber and the volume proportion of coconut fiber. Next, we proceed with the evidence by generating test objects or specimens specifically designed for flexural and impact strength tests, using the testing parameters set by ASTM (American Standard Testing and Material) for sandwich testing. This study will utilize treatments involving alterations in length and volume fraction.

1. Cutting coconut fiber with two length variations, namely 10 mm – 20 mm variation and 30 mm – 40 mm length variation.
2. Making test specimens or test objects with varying coconut fiber volume fractions with percentages of 30%, 40%, 50%.
3. Flexural strength testing uses the ASTM D 790 standard "Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Material" [7] using Zwick Roell Z100 UTM machine.
4. Impact strength testing using ASTM standard D 256 "Impact Tester For Plastics, Composites, Light Alloys and Components" [8] using the Charpy impact testing tool.

3. RESULTS AND DISCUSSION
The flexural strength and impact strength of sandwich panel test specimens for house walls were evaluated. The specimens were treated with different volume fractions of coconut fiber (30%, 40%, or 50%) and varying fiber lengths (10 mm–20 mm and 30 mm–40 mm). The data processing concludes with the presentation of the final results in the form of tables and graphs.

3.1. Flexural Strength Test Results
The flexural strength test was conducted using a Zwick Roell Z100 Universal Testing Machine (UTM) instrument. The research conducted using this tool yields immediate and tangible findings in the form of graphs and numerical values for elastic modulus, flexural

strength, and maximum strain necessary for test data. Tables 1 to 7 display the test results for this sandwich panel.

Table 1. Flexural strength test data
(Vf=30%, Fiber Length 10-20 mm)

Specimen	Modulus of Elasticity (MPa)	Flexural Strength (MPa)
1	606	30.5
2	1100	41.8
3	1180	42.8
Average	962	38.36

Table 2. Flexural strength test data
(Vf=40%, Fiber Length 10-20 mm)

Specimen	Modulus of Elasticity (MPa)	Flexural Strength (MPa)
1	391	9.88
2	654	19.9
3	498	19.6
Average	514.33	46.38

Table 1. Flexural strength test data
(Vf=50%, Fiber Length 10-20 mm)

Specimen	Modulus of Elasticity (MPa)	Flexural Strength (MPa)
1	966	30.5
2	627	18.7
3	605	27.2
Average	732.66	25.46

Table 4. Flexural strength test data
(Vf=30%, Fiber Length 30-40 mm)

Specimen	Modulus of Elasticity (MPa)	Flexural Strength (MPa)
1	1070	34.0
2	527	23.3
3	1070	27.8
Average	889	28.36

Table 5. Flexural strength test data
(Vf=40%, Fiber Length 30-40 mm)

Specimen	Modulus of Elasticity (MPa)	Flexural Strength (MPa)
1	144	13.1
2	278	14.7
3	37.1	13.2
Average	153.03	13.66

Table 6. Flexural strength test data
(Vf=50%, Fiber Length 30-40 mm)

Specimen	Modulus of Elasticity (MPa)	Flexural Strength (MPa)
1	1.20	18.0
2	416	19.3
3	460	20.4
Average	292.4	19.23

The flexural strength tests yielded the highest results in test specimen 3, which had a volume fraction variation of 30% and a coconut fiber length ranging from 10 mm to 20 mm. Specifically, the flexural strength value was measured at 42.8 MPa, with a maximum strain value (rmax) of 5%, as shown in Table 1.
The mean value of the flexural strength test results is displayed in Table 7.

Table 7. Average value in flexural strength testing

Volume Fraction (%)	Fiber Length (mm)	Modulus of Elasticity (MPa)	Flexural Strength (MPa)
30		962	38.36
40	10 – 20	514.33	46.38
50		732.66	25.46
30		889	28.36
40	30 - 40	153.03	13.66
50		292.4	19.23

Subsequently, the test results will be presented graphically, depicting the impact of different volume fractions and lengths of coconut fibers on the modulus of elasticity and flexural strength. These graphical representations can be found in Fig. 3 to Fig. 4.

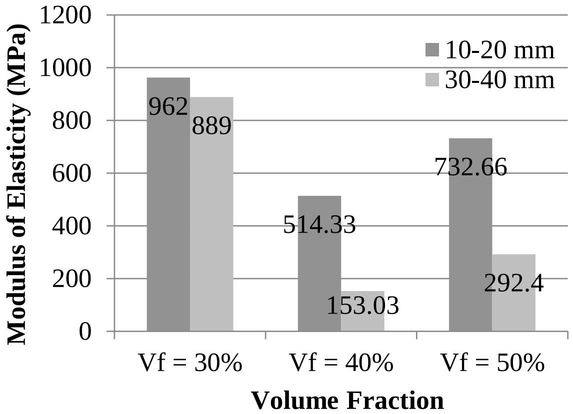

Fig. 3. Average value of elasticity modulus (MPa) based on fiber length.

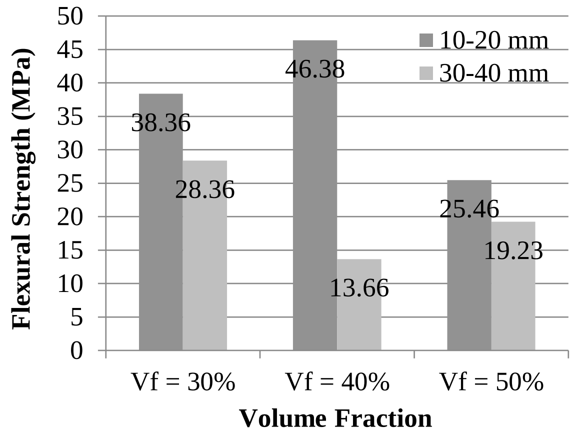

Fig. 4. Average value of flexural strength (MPa) based on fiber length.

The conducted research yielded the following results for flexural strength testing:

- The flexural strength test was conducted with variations in fiber length ranging from 10 mm to 20 mm. The lowest average flexural strength value was

observed at a volume fraction variation of 50%, with a flexural strength value of 25.46 MPa. At a volume fraction variation of 40%, the highest average strength value is observed, with a flexural strength of 46.38 MPa.
- The test findings indicate that the volume fraction variation of 40% yields the smallest average value of test results for fiber lengths ranging from 30 mm to 40 mm. The flexural strength value associated with this variation is 13.66 MPa. At a volume fraction variation of 30%, the highest average strength value is observed, with a flexural strength of 28.36 MPa.
- The test results and analysis indicate that the treatment with a volume fraction of 40% and fiber length ranging from 10 mm to 20 mm yielded the highest flexural strength, with an average value of 46.38 MPa. In comparison, the treatment with a volume fraction of 30% and fiber length ranging from 30 mm to 40 mm had a significantly lower average flexural strength of only 28.36 MPa. Therefore, the most typical flexural strength value was observed in the treatment with a volume fraction of 40% and a fiber length ranging from 10 mm to 20 mm.

In addition, while producing sandwich panels, it is advisable to use a volume percentage of 40% and fiber lengths ranging from 10 mm to 20 mm. The recommended quantities are 84.672 grams of coconut fiber, 2.9808 grams of catalyst, and 146.0592 grams of polyester resin.

3.2. Impact Strength Test Results

The Charpy impact testing tool was utilized to conduct this impact strength test. The data acquired using this instrument is presented as angle measurements following the impact of the pendulum on the test item. Refer to Tables 8–9 for the angle measurements obtained from the impact strength test.

Table 2. Angle readings and average values of impact strength testing fiber length variations 10 mm – 20 mm

Volume Fraction (%)	Fiber Length 10-20 mm Specimen 1 (Joule)	Specimen 2 (Joule)	Specimen 3 (Joule)	Average (Joule)
30	3,4	3.9	3.5	3.6
40	4.4	4.4	4.4	4.4
50	3.1	4.7	4.5	4.1

Table 3. Angle readings and average values of impact strength testing fiber length variations 30 mm – 40 mm

Volume Fraction (%)	Fiber Length 30-40 mm Specimen 1 (Joule)	Specimen 2 (Joule)	Specimen 3 (Joule)	Average (Joule)
30	3.9	2.9	3.5	3,4
40	3.15	4.45	4.3	3.9
50	2.95	2.95	3.9	3,2

Subsequently, the pendulum's impact on the specimen will be analyzed from a reading perspective, and the resulting description can be seen in Fig. 5. This image will be based on factors such as the volume fraction, changes in coconut fiber length, and the average value.

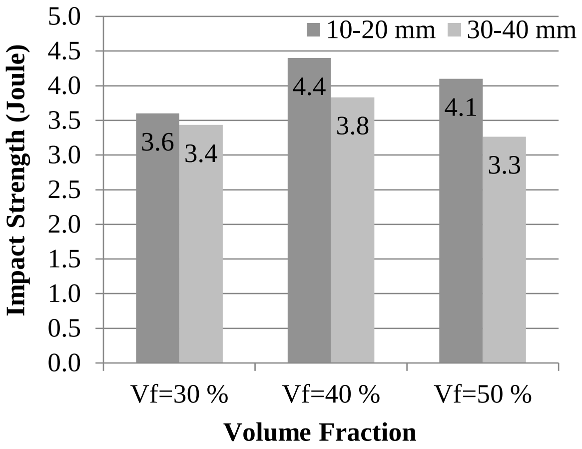

Fig. 5. Average comparison fiber length variation angle reading results.

The conducted research has yielded the following results regarding impact strength testing:

- The impact strength test revealed that the lowest average value of the test results was observed when the fiber length varied between 10 mm and 20 mm. This occurred at a volume fraction fluctuation of 30%, with an impact strength value of 3.6 joules. At a volume fraction variation of 40%, the highest impact strength value is observed, with an average value of 4.4 joules.
- The smallest average test value is observed for fiber lengths ranging from 30 mm to 40 mm. This occurs at a volume fraction variation of 50%, with an impact strength value of 3.3 joules. The highest strength value is seen when the volume fraction varies by 40%, with an average impact strength of 3.8 joules.
- The analysis of the test results indicates that the treatment with a volume fraction of 40% and fiber length ranging from 10 mm to 20 mm yielded the highest impact strength, with an average value of 4.4 joules. In comparison, the treatment with a volume fraction of 40% and fiber length ranging from 30 mm to 40 mm only achieved a flexural strength value of 3.8 joules. The most typical flexural strength value was observed in the treatment with a volume fraction of 40% and a fiber length ranging from 10 mm to 20 mm.
- In addition, while producing sandwich panels, it is advisable to use a volume percentage of 40% and fiber lengths ranging from 10 mm to 20 mm. The recommended quantities are 84.672 grams of coconut fiber, 2.9808 grams of catalyst, and 146.0592 grams of polyester resin.

5. CONCLUSION

This conclusion provides the solution for doing research on sandwich panels composed of coconut fiber for the walls of basic houses, utilizing data acquired from the conducted experiments. Conclusions can be derived from the data processing that has been conducted as follows:

- The study investigated sandwich panels with coconut fiber as filler and multiplex as the core. The flexural strength of these panels was found to be 46.38 MPa on average, with a volume fraction of 40%, a fiber length ranging from 10 to 20 mm, and an impact strength value of 4.4 joules. The volume portion is 40% and the fiber length ranges from 10 mm to 20 mm.

- Based on the two conducted tests, it can be inferred that the optimal combination for producing sandwich panels for house walls includes a 40% variation in volume fraction and a fiber length ranging from 10 mm to 20 mm. This combination involves the appropriate use of coconut fiber, polyester resin, and catalysts. The weight of the coconut fiber is 84.672 grams, the weight of the catalyst is 2.9808 grams, and the weight of the polyester resin is 146.0592 grams.
- The conclusion should address the previously mentioned issues and provide a clear assessment of the achieved outcomes, including their benefits and drawbacks. Additionally, it should suggest potential future advancements. While it is possible to present the conclusion in paragraph form, it is more effective to convey it using numbered points or bullet points.

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