Potential for Utilizing Organic Waste as a Heat-Insulating Composite

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Abstract

The ever-increasing global population growth has a direct impact on residential building demand, which often does not keep pace with construction growth. This condition leads to an increase in housing density and a decrease in construction quality, which contributes to excessive heat inside homes. Therefore, this research explores the use of organic waste, specifically reeds and young coconut fiber, as environmentally friendly thermal materials to reduce dependence on artificial energy and its negative impacts. The high cellulose content in reeds and the fiber in young coconut fiber is a combination that has the potential to create an effective heat absorber. Product composition material testing was carried out using a thermogun, and the results were analyzed using the one-way Analysis of Variance (ANOVA) method. This research aims to utilize the potential of organic waste to produce insulation that can reduce heat temperatures in buildings, with the hope of finding alternative materials that are more sustainable and environmentally friendly.

Keywords: heat, temperature, thermal material, cellulose, organic waste

1. Introduction

The increasing global population growth can affect the demand for housing construction. If the growth of housing construction is unable to keep up with the demand for housing needs, then the density of houses will increase, and the quality of houses will decrease over time [1]. Global warming, which is an increase in the average temperature of the atmosphere, sea, and land of the earth, has become a significant factor in causing extreme climate change. As a result, poor quality house construction and drastic climate change can cause uncomfortable temperature increases inside the house, forcing the owner to use air conditioners such as Air Conditioners (AC), Fans, and Air Coolers so that the occupants of the room inside will feel more comfortable and not too hot. Buildings consume 47.6% of heat energy and produce 44.6% of CO2 emissions [2]. The use of energy sources using artificial resources and environmentally unfriendly technology can cause environmental damage [3]. A critical factor in building a house is the selection of building materials that have good thermal insulation capabilities so that they can create a more energy-efficient, comfortable, and healthy environment for its occupants by optimizing the use of natural energy and reducing dependence on artificial energy [4].

The use of artificial energy, such as air conditioning, has caused climate change and has an impact on increasing CO2 emissions. The increase in CO2 emissions increases the temperature and greenhouse gas emissions, which have an impact on people becoming uncomfortable in their environment [5]. Therefore, alternative solutions are needed to minimize the hot temperature in a building, which also reduces carbon emissions due to the use of air conditioning. One effort that can be made is to use heat dampers as roof insulation [6].

Heat insulators are materials installed on the roof of a building to reduce the intensity of heat entering the room below. Thus, the occupants of the room will feel more comfortable (not too hot). In addition, this heat insulator is also more energy efficient because it can reduce the use of cooling energy, such as air conditioners or fans [7]. This roof heat insulator will be very useful, especially in tropical climates or areas with high temperatures, such as in Indonesia; with a simple way of working, the installed heat insulator will regulate the circulation of heat in the house so that heat energy outside the house cannot enter quickly. This condition ensures that the hot temperature in the room remains stable [8]. In general, heat insulators are made of synthetic or organic materials that are commonly used in the manufacture of thermal insulation, namely polyethylene, bubble pack, and glass wool. Polyethylene is more effective in reducing the sound of rainwater from the sky, while bubble packs are effective in reducing hot temperatures [9]. The production process of polyester insulation is not environmentally friendly because it is made from petroleum products that can run out in a few years. On the other hand, the process of making glass wool requires much energy to reach a temperature of 1500-1700 ° C to produce insulation [10]. Therefore, environmentally friendly heat-insulating materials are needed, and organic materials such as cogon grass and young coconut fiber can be developed.

Cogon grass is a type of grass that is often found in agricultural land and vacant land. Currently, cogon grass is only used as animal feed. Cogon grass contains 97.76% water, 59.62% holocellulose, 40.22% α-cellulose, 31.29% lignin, and 18.40% pentosan. Due to its high cellulose content, cogon grass can be used as a material for making composites [11]. Composite boards consist of a mixture of two or more materials mixed by a matrix. The matrix is a fiber binder, and the fiber is a filler [12]. Indonesia is the largest coconut-producing country in the world. The amount of coconut fiber produced each year is 1,804,444 tons, but only 3% is used for the production of broom fiber, fertilizer, handicrafts, and household products. The composition of young coconut fiber is 5.43% water content, 30.34% crude fiber, 3.95% ash content, 3.54% lignin, 0.52% cellulose, and 23.70% hemicellulose [13]. Coconut fiber is a low-density material, so it is useful when produced as a composite, resulting in a lightweight composite with high specifications. In addition, coconut fiber composites are cheaper than synthetic fibers such as glass, nylon, and carbon [14]. The combination of cogon grass and young coconut fiber is good for the formation of heat insulators because of the high cellulose content of cogon grass and the high fiber content of young coconut fiber. Cellulose is helpful as a binder for materials [15], and coconut fiber is a composite board strengthener. Therefore, it is necessary to make efforts to make heat dampers using organic waste. The study was conducted by studying or analyzing in order to achieve the goal, and it can be seen that coconut fiber and cogon grass waste can be used as heat insulation, so that with this study can be used as a comparison and can find the most perfect and environmentally friendly test material.

2. Material and methods

2.1. Material

The research conducted consists of 2 types of data, namely primary data and secondary data. Primary data in this study is the composition of young coconut fiber and cogon grass stems. Secondary data in this study is a literature study that seeks relevant theoretical references to the problem cases or solutions found. Furthermore, this research was developed into the implementation of research for testing the material composition of heat-insulating products through heat tests with a thermo gun, and then the data was processed using the one-way Analysis Of Variance (ANOVA) method. One-way ANOVA, or one-way analysis of variance, is a statistical method used to test the average difference between several different groups or populations. This method is applied in experiments involving a one-factor variable with two or more levels. The goal is to determine whether there is a significant difference in the average between the groups [16].
The tools used in the process of making this heat damper include a C clamp, a 25x25x6 cm wooden mold, a machete, scissors, a cement spoon, a basin (as a container for raw materials), and PPE in the form of gloves, safety glasses, and masks. The raw materials used in the manufacture of this heat damper product include young coconut fiber waste, cogongrass stems, and Fox Glue. The manufacture of test objects for composites with variations in filler composition (young coconut fiber and cogongrass stem) and Fox Glue is as follows (Table 1). Furthermore, to make a test specimen, a wooden mold with a length of 21 cm x 22 cm x 3 cm was made.

Table 1 Composition of Raw Materials

Material	Composition A	Composition B	Composition C
Young Coconut Fiber	50%	30%	70%
Cogongrass	50%	70%	30%

Based on the data above, the comparison made is the percentage composition between young coconut fiber and cogongrass stems.

The following is the preparation of basic materials and preparation of tools for making heat-insulating products from organic waste, namely coconut fiber and cogongrass.

Figure 1. *Cogon grass*

The picture above is the cogon grass that researchers have collected. The cogon grass that was collected came from empty land overgrown with wild grass and cogon grass. The cogon grass that has been collected will later be dried again to make it drier/have a lower water content.

Figure 2. Young coconut fibre

The picture above is the remaining unused young coconut waste from coconut ice sellers. Usually, coconut ice sellers pile up a lot of unused young coconut waste and wait for the garbage collector to pick it up. This young coconut waste will then be dried first and then separated from the skin.

Figure 3. Dry coconut fibre

The image above is the result of drying young coconut waste for five days, after which the coarse fibers are separated from the coconut shell.

Figure 4. The process of chopping cogon grass using a blender

In the image above, the cogon grass is smoothed using a blender/chopper to make it easier later in the process of mixing the ingredients to make the heat insulator.

Figure 5. Coconut Fiber Chopping

Coconut fiber that has been separated from the coconut shell and skin will be ground/cut into small pieces. The aim is to make the heat-insulating adhesive higher, and the mixing process with the cogon grass that has also been ground will be more straightforward.

Figure 6. Heat Reducer Mold

The picture above is a mold for making a heat damper measuring 25x25x6 cm. made from pallet wood.

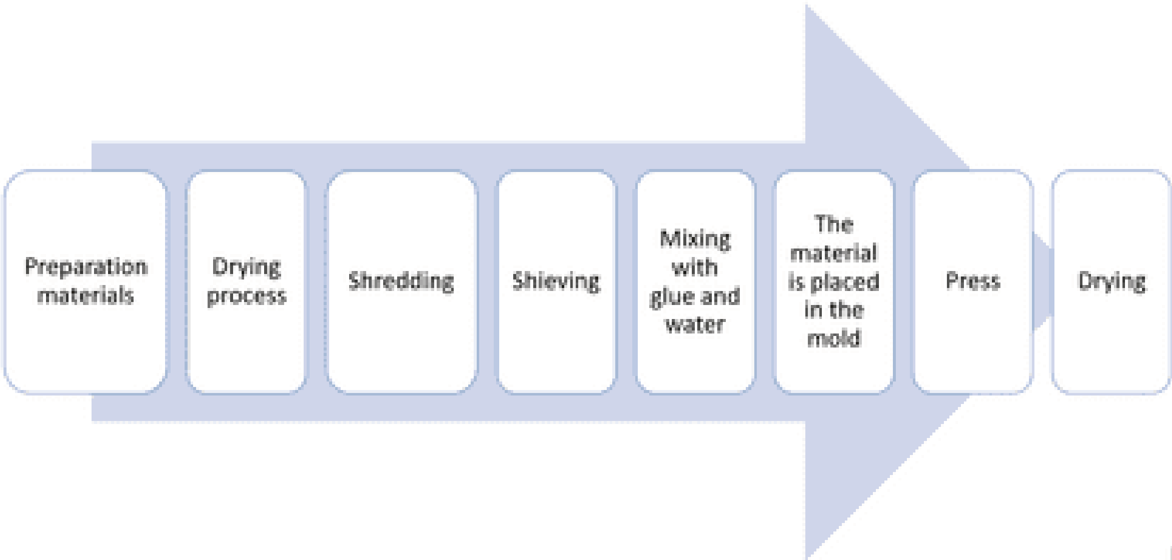
Figurre 7. *Clamp C*

Clamp C in the image above functions as a press tool to tighten during the heat damper manufacturing process.

2. Methods

2.1. Preparation of tools and materials

After preparing the materials and tools, the next step is to make a heat insulation specimen as shown in Figure 8 in the process flow diagram. Raw materials such as coconut fiber and cogon grass need to be weighed to determine the composition of the heat-insulating prototype to be made.



Figute 8 Flowchart process product development

Figure 9. Raw materials preparing

After weighing to determine the weight of the composition in the heat-insulating prototype, the cogon grass and coconut fiber were first separated into two different containers. The cogon grass and coconut fiber can be mixed evenly before the next step is carried out. This process aims to blend the cogon grass and coconut fiber into one unit so that, later, all the essential materials can play an important role in reducing heat. In addition, the process of making glue dough with a ratio of 80% Fox glue and 20% water for the adhesive is used in making a heat-insulating prototype. The glue mixture that is made must be even in its mixing so that it can become a suitable adhesive. Mixing glue and water is helpful in facilitating the process of uniting coconut fiber and cogon grass. If the glue mixture is smooth, the next step is to mix the essential ingredients little by little. The ingredients that have been mixed with the glue mixture can be put into a mold that has previously been given a plastic base so that it does not stick to the mold, which can make it difficult to remove. Once the filling of the material into the mold is complete/according to the composition, it can be immediately closed with the mold cover. After the mold is closed correctly, the next step is the pressing process with Clamp C for 30 minutes.

The hand lay-up method is the most straightforward and most open composite material manufacturing process. This process involves the use of fibers as reinforcement and thermal glue as a binder [17]. The following are the steps taken in the hand lay-up method:

Use of Fiber: Coconut fiber and cogon grass are used as reinforcing fibers in this process. Coconut fibers, which are initially in the form of coarse fibers, are cut into small pieces using scissors, and cogon grass is also cut into small pieces using a blender.

Use of Fox Glue: Fox glue is used as an adhesive to bind the fibers. The glue is usually in liquid form and is applied to the fibers by pouring it into the fibers in the mold.

Use of Mold: The mold is used to give shape to the composite being made. In this study, a closed mold was used. The mold size is 25x25x6 cm.

Use of Cement Spoon: The cement spoon is used to bind the Fox Glue to the fibers and remove air trapped between the layers. This step is repeated until the desired thickness is achieved. Testing: how to test the composite that has been made by placing the composite board at a distance of 20 cm from the heat gun on one side that will be heated, and the other side is measured using a thermal gun to determine the heat absorption capacity of the composite board (as in Figure 1). From the testing of the three specimens, it can be determined which specimen can insulate heat the most.

Figure 9. Heat absorber manufacturing process

2.2. Statistical testing

The results obtained during the data collection of the three products with different composition percentages will then be compared using the one-way ANOVA method. The one-way ANOVA method used with the hypothesis:

H0= The composition between coconut fiber and cogon grass does not affect the effectiveness of heat reduction

H1= The composition between coconut fiber and cogon grass affects the effectiveness of heat reduction

With the equation formulation:

Reject H0 (accept H1) if the P-Value <Significance level α

Reject H1 (accept H0) if the P-Value > Significance level α

α= Significance level (α = 0.05)

Rejecting H0 indicates a significant difference between the average groups of variables tested so that the conclusions drawn are based on the H1 hypothesis.

To facilitate understanding, a research flow diagram was created for this study, which is shown in the figure below.

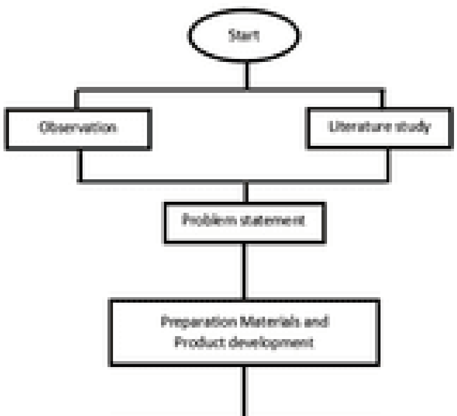


Figure 10 Research Flowchart

3. Result and discussion

Table 3. One-way ANOVA for temperature testing

3.1. Statistical test

The data obtained for this heat damper test is by conducting direct testing. The data obtained from the three specimens are shown in Table 1

Table 2. Temperature test Results of the Three Specimens

No	Time (sec)	Specimen A (^oC)	Specimen B (^oC)	Specimen C (^oC)
1	30	30	30	30
2	60	37,6	41,7	38,5
3	90	67,5	42,7	40,9
4	120	83	43,3	42,4
5	150	96,3	45,2	46,5
6	180	101,4	50	54,6
7	210	103,2	52,7	83,5
8	240	119,9	57,1	95,6
9	270	122	64,7	104,9
10	300	123,2	76,7	114,6

Table 2 provides information related to the results of the heat-absorbing composite test of the three specimens. Furthermore, the table also provides information that the test was carried out with a duration of every 30 seconds on each specimen. In specimen A, it can be seen that the maximum temperature that can be damped is 123.2 oC for 300 seconds. Furthermore, specimen B shows that the damping ability is at a temperature of 76.7 oC, while in specimen C, the damping ability is at a temperature of 114.6 ^oC. In addition, of the three specimens tested, it shows that specimen B gives the best test results in damping heat.

Moreover, statistical testing was carried out to determine the temperature differences in each specimen.

The results obtained during the data collection of the three products with different composition percentages will then be compared using the one-way ANOVA method. The one-way ANOVA method used with the hypothesis:

H0= The composition between coconut fiber and cogongrass does not affect the effectiveness of heat reduction
H1= The composition between coconut fiber and cogongrass affects the effectiveness of heat reduction

With the equation formulation:
Reject H0 (accept H1) if the P-Value <Significance level α
Reject H1 (accept H0) if the P-Value > Significance level α

α= Significance level (α = 0.05)
Rejecting H0 indicates a significant difference between the averages of the tested variable groups therefore the conclusion drawn is based on the H1 hypothesis.

SUMMARY

Groups	Count	Sum	Average	Variance
Specimen A	10	884,1	88,41	1137,76
Specimen B	10	504,1	50,41	175,01
Specimen C	10	651,5	65,15	977,75

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	7340,98	2	3670,49	4,81	0,02	3,35
Within Groups	20614,76	27	763,51			
Total	27955,75	29				

Based on the results of the one-way ANOVA analysis in Table 4, the P-value is 0.02. It was, furthermore, comparing the P-value with the significance level (α = 0.05). Based on equation (1), because the P-value (0.02) <α (0.05), the H0 hypothesis is rejected. This result shows that there is a significant difference between the average treatments. In other words, the fiber volume fraction significantly affects the heat-insulating strength.

3.2. Thermal Conductivity Calculation

Thermal conductivity is an intensive quantity of a material that shows the ability of a material to conduct heat. By using the thermal conductivity formula below, we can calculate and find out the thermal conductivity value of the heat-absorbing specimen made.

$$K = \frac{Q \cdot L}{A \cdot \Delta T}$$

Calculation of thermal conductivity of specimens at composition A :

$A_{specimen} = 0.21 \times 0.22$
$A_{specimen} = 4.62 \times 10^{-2} m^3$
$L_{specimen} = 0.03$ m
$\Delta T_{specimen} = 278$ K
$Q_{heat\ gun} = 2000$ W
$K = \frac{Q \cdot L}{A \cdot \Delta T}$

$K = \frac{2000 \times 0.03}{4.62 \times 10^{-2} \times 278}$
$K = 4.67159\ W/mK$

Calculation of thermal conductivity of specimens at composition B:

$A_{specimen} = 0.21 \times 0.22$
$A_{specimen} = 4.62 \times 10^{-2} m^3$
$L_{specimen} = 0.03$ m
$\Delta T_{specimen} = 324.5$ K
$Q_{heat\ gun} = 2000$ W

$$K = \frac{Q \cdot L}{A \cdot \Delta T}$$

$$K = \frac{2000 \times 0.03}{4.62 \times 10^{-2} \times 324.5}$$
$$K = 4.00216\ W/mK$$

Calculation of thermal conductivity of specimens at composition C:

$A_{specimen} = 0.21 \times 0.22$
$A_{specimen} = 4.62 \times 10^{-2} m^3$
$L_{specimen} = 0.03$ m
$\Delta T_{specimen} = 286{,}6$ K
$Q_{heat\ gun} = 2000$ W

$$K = \frac{Q \cdot L}{A \cdot \Delta T}$$

$$K = \frac{2000 \times 0.03}{4.62 \times 10^{-2} \times 286.6}$$
$$K = 4.53141\ W/mK$$

Based on the ASTM C177 standard as a criterion for the conductivity of an item, with a thermal conductivity range of less than 16 W/mK. Thus, it can be said that the mixture of cogon grass stems and coconut fibers in this heat insulator has quite good thermal conductivity. From the three specimens whose thermal conductivity has been calculated, it can be concluded that specimen B has the lowest thermal conductivity value. So, specimen B is the most effective heat insulator among the other specimens.

4. Conclusion

The results of the one-way ANOVA analysis in Table 4, the P-value is 0.02. It is, furthermore, comparing the P-value with the significance level ($\alpha = 0.05$). Based on equation (1), because the P-value (0.02) $<\alpha$ (0.05), the H0 hypothesis is rejected. This research shows that there is a significant difference between the average treatments. In other words, the fiber volume fraction significantly affects the heat-insulating strength.

It is based on the ASTM C177 standard as a criterion for the conductivity of an item with a thermal conductivity range of less than 16 W/m K. So, it can be said that the mixture of cogon grass stems and coconut fibers in this heat insulator has quite good thermal conductivity. From the three specimens whose thermal conductivity has been calculated, it can be concluded that specimen B has the lowest thermal conductivity value, namely K = 4.00216 W/mK. So, specimen B is the most effective heat insulator among the other specimens.

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Credit authorship contribution statement

Dr. Dino Rimantho, ST., MT., IPM: Supervisor
Azami Rabani: Materials Preparation and Making Prototypes, Writing
Roger Indrawan: Prototype Testing and Collecting Data, Writing
Nanda Eka Sabrina: Analyzing Data and Creating Reports, Writing

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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