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ANALYSIS OF THERMAL ABSORPTION FROM COMPOSITE PRODUCED WITH GREEN COCONUT RESIDUE[1]

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ABSTRACT

Coconut fiber is a very common residue in Brazil and already finds uses in different areas. This work evaluated the efficiency of this residue in the thermal insulation for later use in panels of low cost. The green fiber coconut residue was used in the production of samples for thermal and chemical analysis. By using a calorimeter, the measurements of temperatures were made and the coefficients of thermal conductivity were determined. The results showed the good performance of the material regarding its thermal absorption when compared to the data of a traditional material sold in the market.

Keywords: Coconut fiber, Thermal comfort, Thermal insulation.

ANÁLISE DE ABSORÇÃO TÉRMICA DE COMPÓSITO PRODUZIDO COM RESÍDUO DE COCO VERDE

RESUMO

A fibra de coco é um resíduo muito comum no Brasil e já encontra usos em diferentes áreas. Este trabalho avaliou a eficiência desse resíduo no isolamento térmico para uso posterior em painéis de baixo custo. O resíduo de fibra de coco verde foi utilizado na produção de amostras para análise térmica e química. Ao utilizar um calorímetro, foram feitas as medidas das temperaturas e determinaram-se os coeficientes de condutividade térmica. Os resultados mostraram o bom desempenho do material em relação à sua absorção térmica quando comparado aos dados de um material tradicional vendido no mercado.

Palavras-chave: Fibra de coco, Conforto térmico, Isolamento térmico.

INTRODUCTION

The technological development brings with it advantages but also consequent harms to the natural resources. In the search for equilibrium, new technologies that reuse materials collaborate to minimize such impacts.

This work aims to analyze the thermal properties of panels produced with coconut fiber, with the objective of providing thermal comfort in environments with high heat content by reusing a solid residue.

The increase in coconut water consumption has generated approximately 6.7 million tons of bark per year. About 15% of the product is used for consumption, that is, 85% of the material is disposed of in the environment (MACHADO; DAMM; FORNARI JUNIOR, 2009). Coconut is a material of difficult degradation, taking eight years to fully decompose when thrown to the ground, besides being a place for the reproduction of vectors and proliferation of diseases. Another aggravating factor is the production of methane in the process of coconut fiber decomposition. This gas is released into the atmosphere being one of the responsible for global warming via the greenhouse effect.

It is extremely important to find a way to increase value to the coconut waste, for economic and technological purposes, reducing negative impacts on the environment, as well as providing employment and income.

Thermal insulators are used to reduce the flow of heat between thermal systems and the surrounding environment, generating a sense of well-being and reducing costs with air conditioning.

According with Sias (2006), considers what determines whether a material will be a good conductor or thermal insulator are the bonds in its atomic or molecular structure. Materials that are bad heat conductors have the outermost electrons of their atoms tightly connected.

Borges (2009) explains that materials such as cotton, sugarcane bagasse, sisal, coconut fiber and others can be used *in natura* as thermal insulation without needing treatment, as they have low thermal conductivity, and the use of these materials in the production of a composite can be economically and ecologically viable.

MATERIALS AND METHODS

Samples

The samples used for the tests were made by mixing a natural resin with crushed coconut fiber. The choice for the crushed coconut fiber was due to the good results obtained by this material in an earlier survey associated to the constitution of an acoustic insulation panel (XAVIER et al., 2013). Table 1 and Figure 1 show, respectively, the features and the appearance of the samples chosen to the current survey:

Table 1: Identification and Constitution of samples.

Sample	Fiber(g)	Resin(g)	Thickness (mm)	Ratio Fiber / Resin
CT-15-05	15	5	5	3,00
CT-30-15	30	15	8	2,00
CT-50-25	50	25	15	2,00
CT-100-	100	30	28	3,33

Figure 1: Samples for analysis.

The data acquisition system

The system set up to do the tests was comprised of the following components, as shown in Figure 2:

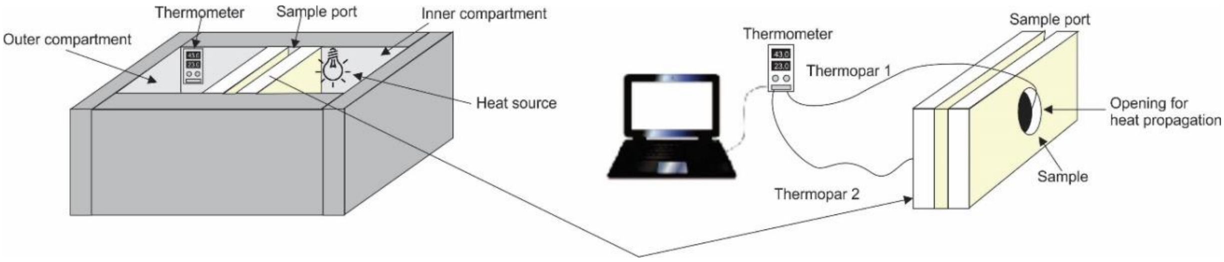

Figure 2: System for testing the thermal conductivity of the samples.

The data were acquired through a calorimeter produced from wood and coated with 45 mm polystyrene, containing two regions for temperature measurement and subsequent calculation of heat flux and thermal conductivity. With a thermometer installed in the region opposite the heat source, thermocouples attached to the sample surfaces and connected to a data logger system with the help of a computer, temperatures were recorded every minute for one hour. The temperature variation was obtained by means of an incandescent lamp placed in one of the regions of the calorimeter. With the temperature data collected by the system, they were recorded in spreadsheets of computer, applied the formulas mentioned above and generated the graphs for analysis.

The process of getting data

The material for analysis was placed on the sample holder that was in the middle of the calorimeter between two polystyrene bases. The polystyrene base had the goal to avoid that heat generated was transferred to the external compartment, influencing the results.

After placing the sample, the thermocouple was fixed in each of its faces. Then the thermocouple was connected to the thermometer in this one to the computer to record the data. With the system all set up, a plate of polystyrene of 45 mm was used to close the compartment that simulates the external environment. Then the heating source was switched on and it began to obtain the temperatures of the internal and external faces of the sample. The temperature values were recorded and stored through the software. This software was configured to collect temperature values every minute. To each sample there were recorded 60 measures for each sensor.

Calculation of the thermal conductivity coefficient

The coefficient of thermal conductivity *k* is related to the nature of the material. The value of this coefficient is higher for good conductors and lower for thermal insulation.

The coefficient *k* can be determined by the according to equation 1:

$$q = \frac{\mathrm{k}}{\mathrm{L}} A \left(T_{SI} - T_{SE}\right) \quad (1)$$

where q is the heat flux, L is the thickness of the sample and (T_{SI}-T_{SE}) is the temperature difference between the inner and outer surfaces of the sample.

The heat flux q can also be measured taking into account the convection process:

$$q_{ce} = h_e A\left(T_{SE} - T_{AE}\right) \quad (2)$$

where h_e is the coefficient of heat transfer by external convection, T_{SE} is the temperature on the outer surface of the sample and T_{AE} is the external temperature of a point far from that surface.

Based on these equations, it was necessary to get the internal and external temperatures of the sample surface, apart from the temperature of the air near the external surface. The convection heat transfer coefficient for air is constant for the situation and it has a value equal to equation 3.

$$h_e = 8{,}1 \frac{\mathrm{W}}{m^2\ \mathrm{K}} \quad (3)$$

Through the data collected by the software, a spreadsheet organized in a way that identified each set of data with its due tests was generated. Table 2 represents the spreadsheet model that performed the calculations of the coefficient of thermal conductivity and made it possible to generate the graphs for analysis of the results.

Table 2: Part of the Calculation Worksheet for Thermal Conductivity Coefficient.

Ext Surface (°C).	Int. Surface (°C)	Ext. Temp. (°C)	Thickness (m)	Ext. Conv. (W°C K^{-1})	Surf. Temp. Diff. (°C)	Cond. thermal	Heat Flow (W m^{-2})
33.4	40.7	26.5	0.005	55.89	7.30	0.038	55.89
33.8	41.7	26.5	0.005	59.13	7.90	0.037	59.13
34.5	43.1	26.5	0.005	64.80	8.60	0.038	64.80

The table was based on the following data:

Time: Determines the time in minutes that the temperatures were collected

Ext. Surface Temp.: External surface temperature of the sample. Collected by one of the DataLogger channels. It represents the temperature of the sample in the external environment.

Int. Surface Temp.: Temperature of the internal surface of the sample. Collected by one of the DataLogger channels. Represents the temperature of the sample in the internal environment.

Ext. Temp.: External environment temperature. It is the temperature of the region that will simulate the environment that desires thermal comfort.

Thickness: It is the measurement of the thickness of the sample under analysis.

Ext. Conv.: Value of the thermal transmission constant for convection.

Surf. Temp. Diff.: It is the calculation of the temperature difference between the surfaces of the sample in relation to the internal and external environment.

Cond. Therm: Represents the value of the coefficient of thermal conductivity calculated through equation 1.

Heat Flow: Represents the heat flux through the convection calculated through equation 2.

After obtaining the values from the spreadsheets, graphs were made that related the values of the coefficient of thermal conductivity with the temperature difference between the surfaces of the sample. This is because the temperature difference is the main value that represents the efficiency of the sample with respect to its thermal conductivity.

Thus, it would be very significant for the study the construction of curves relating these elements. This procedure was repeated for each sample, obtaining a set of information for later analysis and conclusion.

RESULTS AND DISCUSSION

The analysis was performed through the graphs that related the values of the coefficient of thermal conductivity *k*, and the temperature variation between the external and internal surface of the test sample.

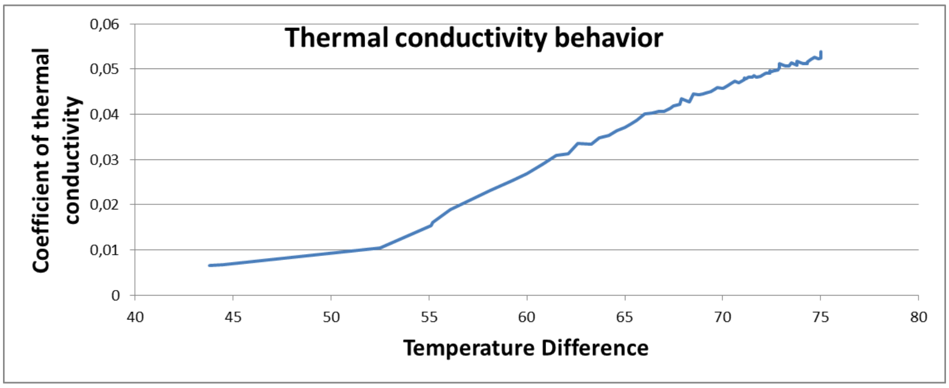

Figure1: Graph Sample 30-15.

Figure 1 refers to sample 30-15 exhibiting practically constant behavior during the increase in the temperature variation between the surfaces of the sample. The mean value was close to $k = 0{,}058 W \cdot m^{-1} \cdot K^{-1}$.

Figure 2 shows the variation of the coefficient of thermal conductivity as a function of the temperature variation of sample 50-25:

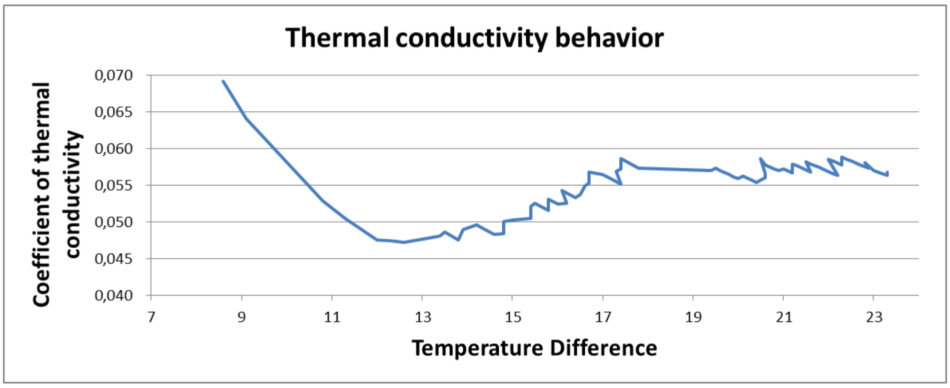

Figure 2: Graph Sample 50-25.

Figure 2 presents, as well as the first one, a behavior practically constant around a value close to $k = 0{,}054 W \cdot m^{-1} \cdot K^{-1}$.

These results are important because they point to a convergence between the values of *k* associated with the two samples that have a similar constitution and emphasizes the little influence of the thickness, as expected.

The two samples below have practically the same ratio between the mass of coconut fiber and the volume of resin used. In these cases the ratio is approximately 3: 1, that is, it was used a smaller amount of resin and larger amount of fiber to make the sample.

Figure 3 for sample 15-05 demonstrates a stability of the coefficient of thermal conductivity for increasing the temperature variation between sample surfaces. For this sample, the average value the model obtained for the coefficient was k = 0,040$W \cdot m^{-1} \cdot K^{-1}$.

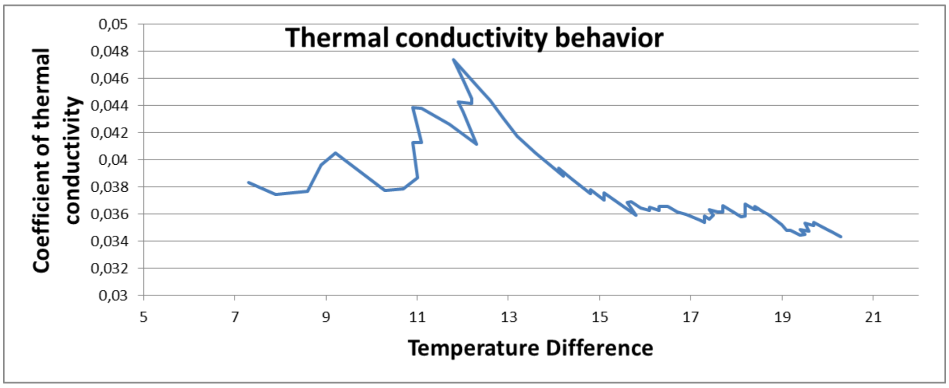

Figure 3: Graph Sample 15-05.

Figure 4 refers to sample 100-30 which, despite presenting a significant initial variation, reaches a more stable behavior after the 8°C variation. For this sample, the mean value was k = 0,041$W \cdot m^{-1} \cdot K^{-1}$.

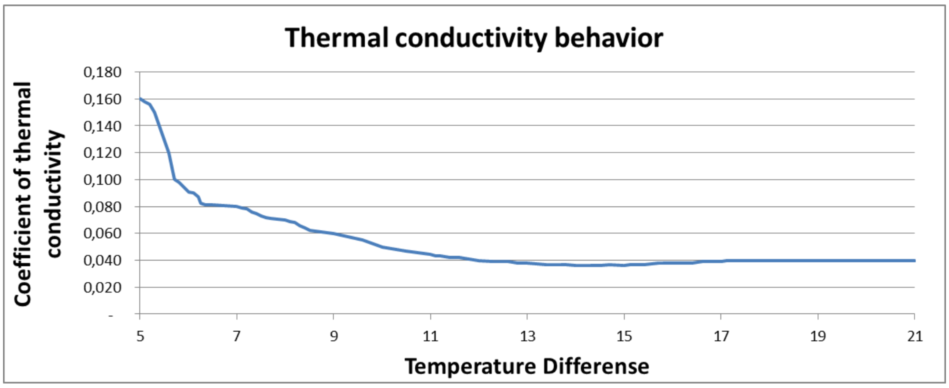

Figure 4: Graph Sample 100-30.

The difference of 10% in the ratio between fiber mass and resin volume in the constitution of the last two samples analyzed did not cause a significant difference in the value of *k* for these samples.

However, in the comparison with the first two samples (30-15 and 50-25), it is possible to relate the result obtained for the coefficient *k* with the constitution of the samples.

Table 3: Coefficient of thermal conductivity of each sample.

SAMPLE	RATIO (Fiber/Resin)	K (Coefficient)
CT-30-15	2,00	0,058
CT-50-25	2,00	0,054
CT-15-05	3,00	0,040
CT-100-30	3,33	0,041

Those that had higher ratios obtained the lowest values for the coefficient *k*, while those that had lower ratios obtained the highest values for this coefficient. It follows from this result that the lower the conductivity, the higher the resin ratio in relation to the fiber mass in the sample composition.

CONCLUSIONS

Due to the low thermal conductivity, the fiber obtained from the coconut shell can be used in the manufacture of panels that will act as thermal insulation for various applications. The samples used for this research have different proportions of coconut fiber with resin and thickness, fundamental characteristics for the determination of the coefficient of thermal conductivity.

From the experiments, data analysis and with the aid of graphs, it was possible to interpret the behavior of the samples regarding thermal absorption and to conclude that the higher fiber concentration inside the composite is responsible for lower thermal conductivity indices.

Although the resin was only used as a binder material, it is not possible to say if there was interference of this solution in the thermal conductivity index, since the proportion of the samples tested was the same.

In relation to the thickness of the samples, the coefficients of thermal conductivity did not change as a function of this variable for the interval studied. This assertion can be proved by comparing the values obtained for *K* of samples 100-30 and 15-05, which have different thickness values from each other.

Although the thickness is not a relevant characteristic regarding the coefficient of thermal conductivity, it is a factor that interfered with the heat flow in each sample. It is possible to indicate this factor, observing a larger temperature difference between the surfaces of the samples of the same fiber/resin ratio and different thickness.

Comparing figures 3 and 4, a larger differential was found between the internal and external temperatures in sample 100-30, that is, this sample absorbed a greater amount of heat due to its greater thickness.

For new research lines, it is important to perform other tests for temperatures below zero degrees, flammability index, stable temperature and maximum resin reduction without losing the binder characteristic, in order to better target the development and applications of thermal insulation panels based on the researched composite.

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