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ANALYSIS OF THERMAL INSULATION AND IMPACT RESISTANCE OF COMPOSITES PRODUCED WITH GREEN COCONUT RESIDUE

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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 as thermal insulation for later use in low cost panels. Thus, green fiber coconut residue was used in the production of samples for thermal, chemical and mechanical analyses. By using a calorimeter, temperature measurements were performed and the coefficients of thermal conductivity were determined. The Charpy method was adopted for the impact resistance assessment. 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, Sustainable engineering*

1. INTRODUCTION

Technological development brings with it advantages but also consequent harms to natural resources. Aiming for sustainability, modern technologies that reuse materials collaborate to minimize their impacts.

This work aims to analyze thermal and mechanical 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.

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

SIAS (2006, apud NAVROSKI, 2010) considers what determines whether a material will be a good conductor or thermal insulator are the bonds in its atomic or molecular structure. Bad heat conductors have the outermost electrons of their atoms tightly connected.

2. MATERIALS AND METHODS

2.1. Coefficient of thermal conductivity

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 satisfactory 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 this current survey.

Table 1: Identification and composition of the samples.

Sample code	Fiber (g)	Resin (mL)	Thickness (mm)	Fiber/Resin Ratio
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-100-30	100	30	28	3,33

Figure 1: Studied samples.

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

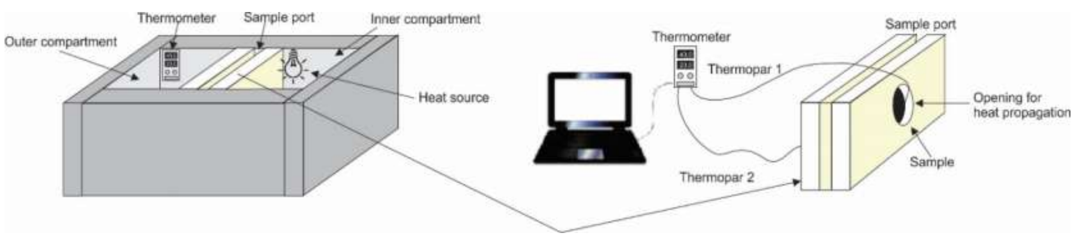

Figure 2: System used to measure the thermal conductivity of the samples.

The coefficient of thermal conductivity, k, is related to the nature of the material. The value of this coefficient is high for good conductors and low for thermal insulation, and it can be determined by the following equation:

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

Where q is the heat flow rate, 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, and A its surface area.

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

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

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.

$$h_e = 8{,}1 \frac{W}{m^2 k} \tag{3}$$

2.2. Impact test method

The Charpy method was used for the impact test using a Veb Werkstoffpruffmaschinen Leipzig device, produced in Germany, with a 19.962 kg hammer and a 790 mm rod length. The test specimens were prepared in 10 replicates according to Figure 3. The method was based on ASTM D6110 / 04 standard with an adequacy in length of specimen due to the equipment used. The specimens were developed with a resin/fiber ratio of 2.

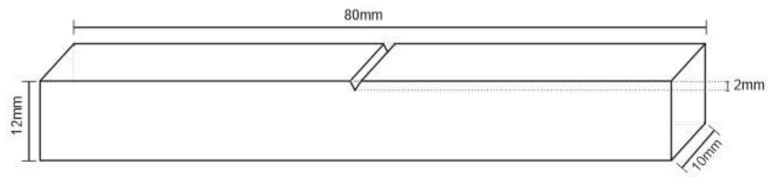

Figure 3: Dimensions of simple beam, Charpy type, impact test specimen.

3. RESULTS AND DISCUSSION

3.1. Thermal Conductivity

Table 2: 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

Table 2 shows the *k* values obtained in the experiments. The samples with a higher fiber/resin ratios obtained the lowest values for *k*, while those that had lower ratios obtained the highest values. It follows from this result that the lower the conductivity, the less resin needs to be used in relation to the fiber mass in the sample composition.

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 (Table 2) of samples CT-100-30 and CT-15-05, which present distinct thickness values.

Although the thickness is not a relevant characteristic regarding the coefficient of thermal conductivity, it is a factor that interfered in 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 values.

3.2. Impact test

After the tests, two groups of samples were separated: samples that were broken and samples that did not break. Table 3 presents the results of the test with the determination of the resistance value of each test piece. These results follow a normal distribution, according to the normality analysis shown in Figure 4 and Figure 5 for the group of broken and unbroken samples, respectively. Since the p-value is greater than the level of significance, $\alpha = 0.10$, the data follow a normal distribution.

Table 3: Impact Resistance results for the coconut fiber composite.

Sample number	Impact Resistance (kj/m^2)	
	Broken Sample	Unbroken Sample
1	9.16	70.00
2	11.44	23.42
3	6.35	8.82
4	4.90	13.92
5	7.77	19.31
6	12.05	13.47
7	7.78	22.38
8	8.54	8.42
9	7.76	7.58
10	8.75	15.46

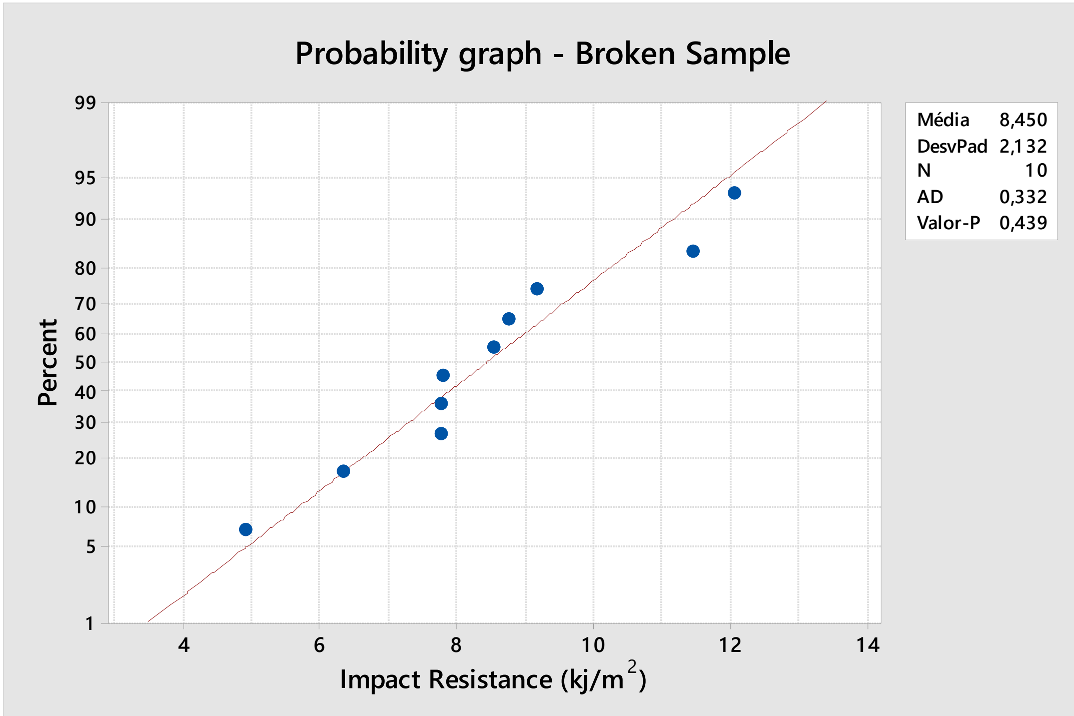

Figure 4: Normality test for the coconut fiber composite for broken samples.

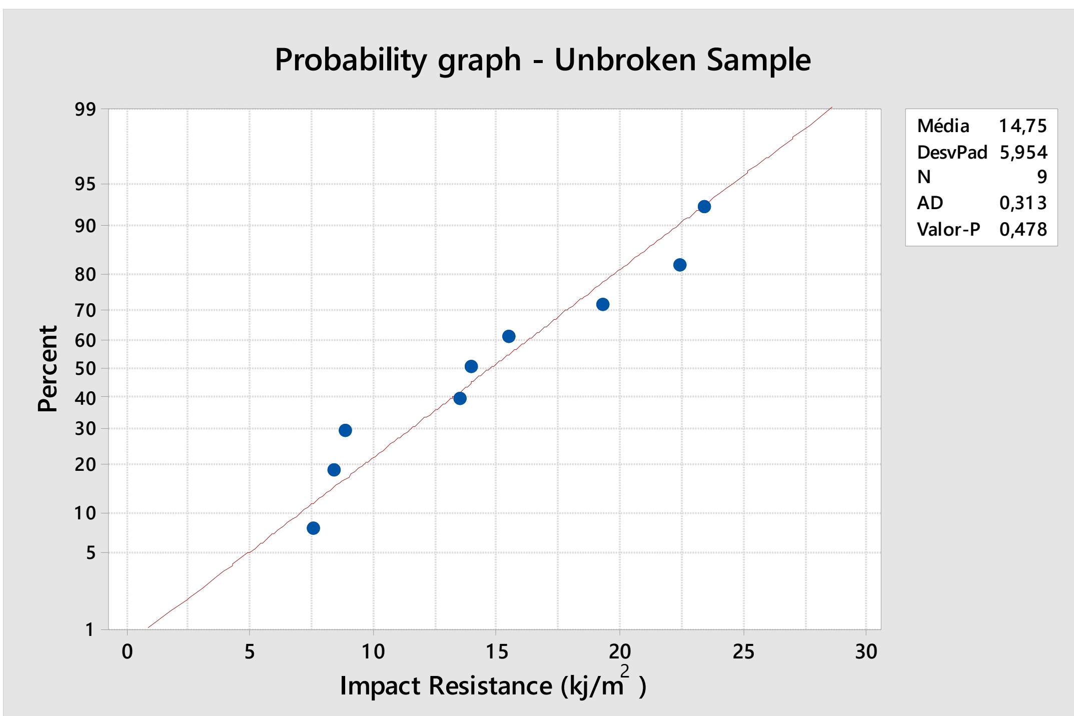

Figure 5: Normality test for the coconut fiber composite for unbroken samples.

Figures 6A and 7A show all samples broken and unbroken respectively after the test, whereas Figures 6B and 7B depict an enlargement of Figures 6A and 7A. In a visual analysis it was observed that the specimens that did not rupture have fibers of greater length in the fracture region. According to Kuruvilla (1999) in the analysis of polyester composite with sisal fiber, it was found that the increase in thefiber length causes an increase in the impact resistance. Test specimens from 5 to 10 that had not ruptured had higher resistance values. This could be confirmed with a t-test for 2 samples, which gives a p-value of 0.022. This means the hypothesis that the mean values for these 2 samples are equal is not statistically confirmed.

A B

Figure 6: Specimens after Charpy experiments with rupture.

A B

Figure 7: Specimens after Charpy experiments without rupture.

Figure 8 shows a boxplot for broken and unbroken samples. For broken samples, the mean value is 8.45 kJ/m^2, the median is 8.15 kJ/m^2 and the standard deviation is 2.13 kJ/m^2. Thus, the result for the impact energy for this sample of the compound can be expressed as (8.45 ± 2.13) kJ/m^2. For unbroken samples, the mean value is 14.75 kJ/m^2, the median is 13.92 kJ/m^2 and the standard deviation is 5.95 kJ/m^2. Thus, the result for the impact energy for this sample of the compound can be expressed as (14.75 ± 5.95) kJ/m^2.

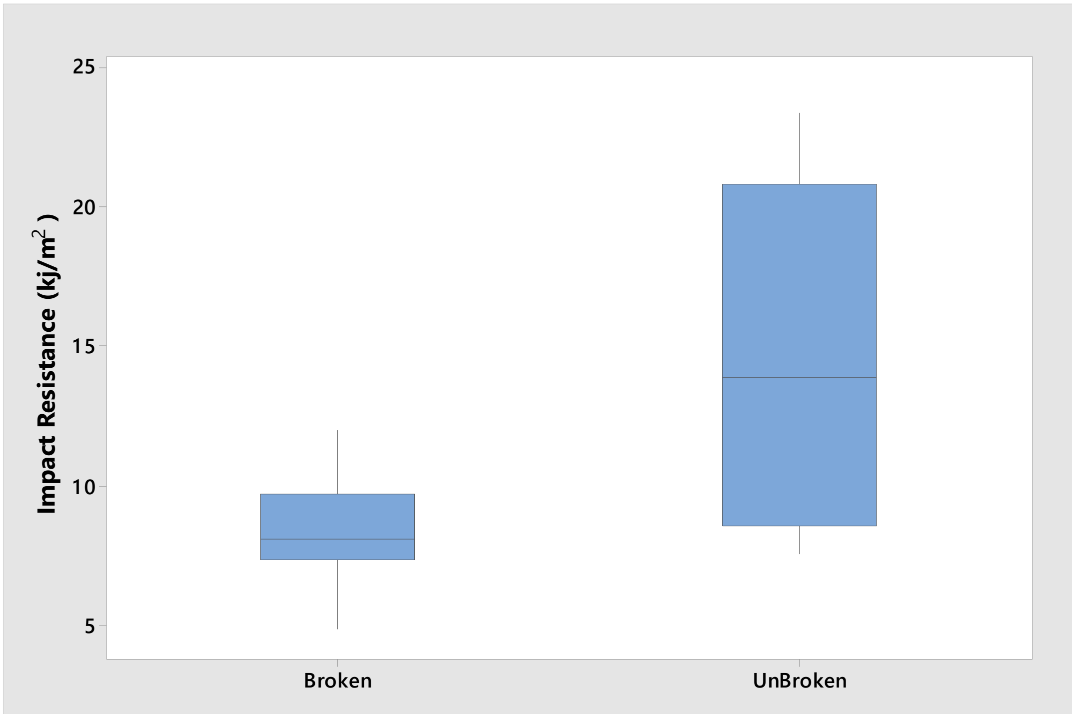

Figure 8: Boxplot for impact resistance between broken and unbroken samples.

Figures 9 and 10 present the Grubbs test for identifying outliers. Especially for the group of uninterrupted samples, an outlier identified with a value of 70 kj/m^2 appeared, which can be discarded.

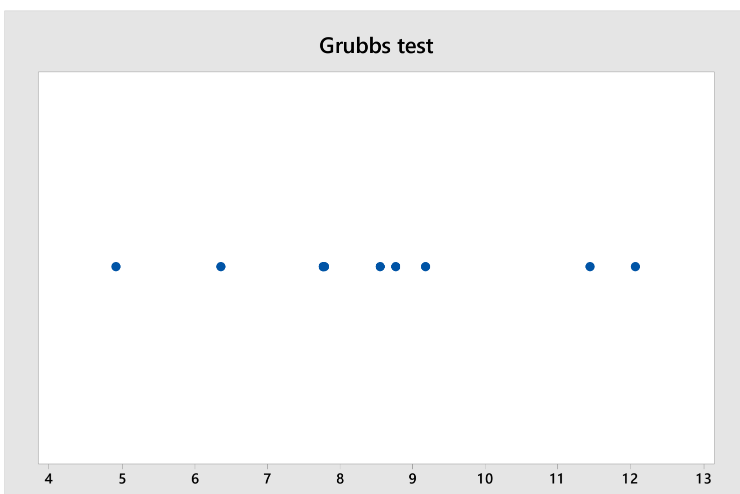

Figure 9: Grubbs test for outlier on broken samples

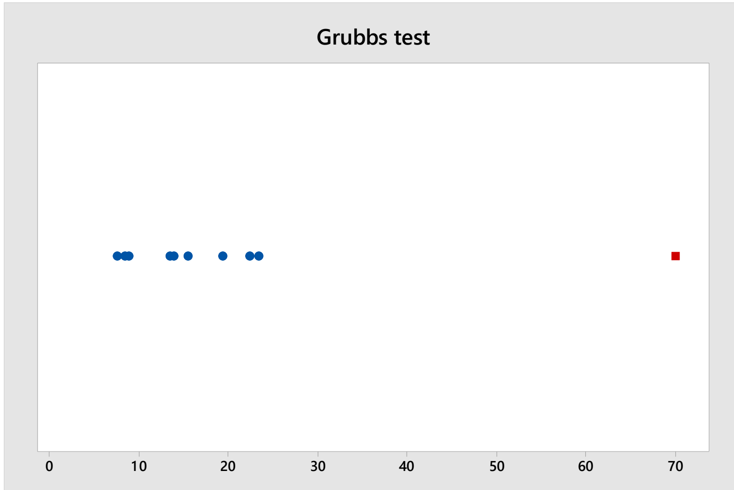

Figure 10: Grubbs test for outlier on unbroken samples

Table 4 presents some species of trees and their impact resistance values presented in the document "Wood: sustainable use in civil construction" coordinated by the Institute of Technological Research, Green and Environmental Secretariat of the city of São Paulo and the Union of Civil Construction Industries of the state of São Paulo. According to this, the composite has an impact resistance similar to that of Pinus Eliote, Louro Vermelho, Jacareuba, Itauba, Camabará and Pinho do Paraná.

Table 4: Impact Resistance for various wood species (IPT, SVMA, SINDUSCON).

Wood species	Impact Resistance (kJ/m^2)
Angelin Pedra	22.6
Angelin vermelho	48.7
Bacuri	38.7
Camabará	20.1
Cedrinho	21.5
Cupiuba	29.5
Eucaliptu Citriodora	45.3
Fava orelha de	39.5
Garapa	40.0
Itauba	17.1
Jacareuba	17.6
Louro vermelho	15.7
Pau roxo	68.2
Peroba rosa	23.3
Pinho do paraná	14.7
Pinus Eliote	14.5

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 different thicknesses, fundamental characteristics for the determination of the coefficient of thermal conductivity.

For new research lines, it is important to perform other tests for temperatures below zero degree, 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 studied composite.

Based on the values found in the impact test comparing with the results presented by the study "Madeira: sustainable use in construction", the importance of these data can be observed and suggest possible applications for the material.

4. CONCLUSIONS

The samples with a higher fiber/resin ratios obtained the lowest values for *k,* while those that had lower ratios obtained the highest values. The result for the impact energy for broken samples can be expressed as (8.45 ± 2.13) kj/m^2. For non-broken samples, the impact energy was (14.75 ± 5.95) kj/m^2.

5. REFERENCES

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6. RESPONSIBILITY NOTICE

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