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# THERMOPHYSICAL PROPERTIES OF COMPOSITES: NATURAL LATEX REINFORCED WITH SHEATH STRAW COCONUT

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***Abstract.*** *This paper presents physical and thermal properties of a compound that uses natural latex as a matrix and sheath straw coconut (coconut plaids) as reinforcement. Once selected, the plaids were subjected to treatment with an aqueous solution of 2 % sodium hydroxide (NaOH). This compound was prepared by the plaids percentage, in the proportions 15 %, 25 % and 35 % of the total compound volume. Give the intention to use as a thermal insulation, it is necessary to determine the thermal conductivity, thermal resistivity, specific heat and thermal diffusivity. In addition to the thermal parameters were determined densities of the materials used, as well as composites produced. Based on the results obtained it can be concluded that the composite produced from sheath straw coconut can be used as thermal insulation. With this, it gives a better destination for this material, which most often is burned or discarded improperly in the environment.*

***Keywords:*** *Composite, natural latex, sheath straw coconut, thermal insulation*

## 1. INTRODUCTION

Knowledge of the properties of a material allows us to identify your physical limitations, thermal, chemical, among others; and determine whether such properties meet or not, required in a given application.

The use of a fiber as a raw material based on properties such as elongation, temperature resistance, temperature characteristics, mechanical strength, density, low-cost and availability, among others.

According to Trotman (1975), none of the known fibers satisfies all these requirements, therefore, each fiber is only suitable for the manufacture of those products that require specific properties.

When compared to synthetic fibers, vegetable fibers offer the following advantages: Abundant source and rapid renewal, low cost, low density, high specific properties, are less abrasive when compared to the glass fibers, non-toxic and biodegradable (Bledzki and Gassan, 1999).

Moreover, present high specific strength per unit weight, are durable, and easy drying, suitable for various applications. As disadvantages, stands out: the low processing temperature, limited to approximately 200 ° C; the lack of uniformity of properties which depend on the origin of the fibers of the planting area and high moisture absorption.

The moisture absorption constitutes a serious problem, when combined with the heat. But it can be drastically reduced by chemical modification of the fibers and good adhesion in the fiber/matrix interface

The plant fibers are produced in almost every country, some fibers occur spontaneously in nature, others are grown as agricultural activity and still others are waste generated mainly by the agribusiness, such as the plaids, extracted sheath straw coconut.

According to Lopes et al (2006), in recent years there has been a growing increase in the disposal of solid waste, which, together with the problems arising from the depletion of natural raw materials, are driving the studies on the use of this waste in the form of new materials with lower environmental impact.

In this context, it was found that agribusiness coconut seal and/or dry, produces large amounts of waste which are most often burned or disposed of improperly in the environment. Thus, it was found that between residues of coconut trees, is a natural tissue, extracted from "sheath straw coconut," called "coconut plaid", also called "coconut cloth", which can be used as a reinforcing element in polymer latex matrix composite for thermal and acoustic insulation.

According Kreith (2008), the ability of a material to retard the flow of heat between two media is the main parameter that characterize as a thermal insulating material. However, for it to be classified as an insulator, it is necessary, a more detailed study of its main mechanical and thermal properties.

According Torreira (1980), to obtain a good thermal insulator, certain parameters must be considered, such as: durability of the material; compressive strength; low absorption of water vapor; resistance to combustion; low thermal conductivity; low density; low thermal diffusivity; high specific heat; low coefficient of thermal expansion; chemical and physical stability; resistance to the use of environment; ease of implementation; resistance to attack by rodents, insects and fungi; absence of odor and low cost.

However, obtaining a material with all the features described above would be virtually impossible. But it is advisable to look for a material with the highest number among the qualities already mentioned (Torreira, 1980).

For choosing a good thermal insulator, some properties are essential, such as thermal conductivity, thermal diffusivity, thermal resistivity, specific heat.

This paper presents a study of the physical properties (density, water absorption and moisture content) and thermal (conductivity, resistivity, specific heat and thermal diffusivity) of polymer composite, which uses natural latex with matrix and the coconut plaids as reinforcement. The thermal data obtained were compared with of thermal insulator commercially available.

## 2. MATERIALS AND METHODS

### 2.1 Materials

The materials used for the formulation of composites analyzed in this study were: the coconut plaids used as reinforcement and natural latex as matrix. The plaids were washed with water and dried in the sun. After drying, the plaids were selected and subjected to an alkaline treatment, which consisted of immersing the coconut plaids in NaOH solution and distilled water with a mass concentration of 2 % (NaOH) for 1 hour period.

After the alkali treatment, the plaids were washed and dried again. Then it was determined the density of the plaids and latex. Fig. 1 shows the process of cleaning and preparation of the material before manufacture of the composite.

Figure 1. Cleaning and preparing the materials used in the production of composite

The formulations of composites for the manufacture of test specimens (CP) have been defined in percentage of the total volume of the mold as described in Tab. 1. These compositions were set up to the limit of 35 % of coconut plaids. The volume of the plaids was found by determining their volumetric density.

Table 1 - Composition of proof bodies

| Proof Bodies | Description |
|---|---|
| CP-15 | 15 % of Coconut plaids and 85 % of latex |
| CP-25 | 25 % of Coconut plaids and 75 % of latex |
| CP-35 | 35 % of Coconut plaids and 85 % of latex |

### 2.2 A method of manufacturing composite

The manufacture of composite is carried out by manual lamination process (Hand Lay Up). For the preparation of the specimens was built a cast acrylic, with internal dimensions of 6 cm x 6 cm x 6 cm with upper and lower lids, fastened with screws.

The manufacture of the test specimens was performed as follows: after determining the internal volume of the mold, the percentages determined volume of each material to be used. With properly separated materials, gave up early manufacturing of the specimen, with alternating placement plaids and latex into the mold.

With the aid of a metal spatula, the plaids are pressed inside the mold, with aim of improving impregnation process and eliminate bubbles. After placing all plaids and all the latex in the mold, this was capped.

After 2 days the specimen was removed from the mold and cured giving up the shade at room temperature, ranging from 3 to 5 days. Fig. 2 shows the manufacturing process of the specimens.

Figure 2. Manufacturing process of composite test specimens under study

## 2.3 Density test

The densities of the materials used as well as composites were determined using a Digital Densimeter Gehaka the brand, model DSL 910, which uses Archimedes principle (buoyancy) and is suitable for solid and liquid. In this test 18 samples were used for composites with dimensions 7.62 cm x 2.54 cm x 1 cm, and 6 samples of each of 3 types of composites. The tests were performed according to standard ASTM D 792.

## 2.4 Water absorption test

For the measurement of the percentage of water absorption or hygroscopicity, was used coconut plaids 30 samples, 6 samples of latex and 6 samples of each of 3 types of composites. Fig. 3 shows the samples used for water absorption tests.

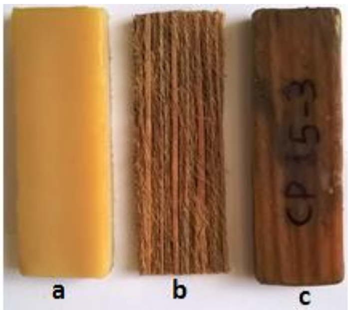


Figure 3. (a) rubber latex; (b) coconut plaid; (c) composite with 15% coconut plaids

The analyzes were performed according to ASTM D 570. After dipping in distilled water 3 measurements were made at 24, 48 and 72 hours. The mass increase of percentage was determined in accordance with Eq. (1).

$$Abs_{water} = \frac{M_M - M_D}{M_D} x100 \qquad (1)$$

Where:
$M_M$ - Moist Mass (g);
$M_D$ - Dry Mass (g);
$Abs_{water}$ - Water Absorption (%)

### 2.5 Determination of moisture content

The determination of moisture content (%) contained in coconut plaids, in natural rubber (latex) and composites, had as objective to verify the susceptibility of these materials to existing moisture absorption in ambient air.

For this we used a moisture determiner, Mars mark, ID-200 with a sensitivity (mass) 0.01 g precision (humidity) 0.1 %. Fig. 4 shows the moisture determiner used.

Figure 4. Humidity determiner Mars ID-200

In this analysis the sample material was placed into the heating unit, where it was exposed to a temperature of 110 ± 5 ° C, until constant mass. 5 samples were used coconut plaids, samples 5 natural rubber (latex), 5 samples of each composite (15 %, 25 % and 35 %). The samples were previously exposed, in a room with relative humidity in the range of 68-82 %.

### 2.6 Analyzed thermal properties

Thermal analysis of the composites were carried out in order to determine the thermal conductivity, thermal resistivity, the specific heat and thermal diffusivity, and compare them with the thermal insulation found in the market.

In this study we used 15 specimens with dimensions 6 cm x 6 cm 6 cm, (5 units of CP-15, 5 units of CP-25 and 5 units of CP-35).

For the determination of the properties cited above, used the KD2 Pro Thermal Properties Analyzer equipment which utilizes a double needle sensor (HS-1) 1.3 mm in diameter, with a spacing of 6 mm between them and 3 cm length capable of determining thermal conductivity (with range from 0.02 to 2 W/(m.K)), thermal resistivity (with range from 50-5000 °C.cm/W), diffusivity (with range from 0.1 to 1 $mm^2$/s) and volumetric specific heat (with range from 0,5 to 4 MJ/$m^3$.K). The sensor was inserted into the specimen for a period of 2 minutes.

Fig. 5 shows the thermal tests carried out using the KD2 Pro Thermal Properties Analyzer equipment. 16 readings were made for each of the 4 parameters mentioned in each of the 15 specimens. The measurements were made in 4 faces of each test proof bodies.

Figure 5. Thermal analysis

## 3. RESUSLTS AND DISCUSSION

### 3.1 Density test

The determination of the volumetric density of CP-15, CP-25 and CP35, showed values of 0.882 g/cm$^3$, 0.871 g/cm$^3$ and 0.856 g/cm$^3$, respectively, as shown in Tab.2. The gradual decrease in the values of the densities of composites is associated with an increased latex percentage.

Table 2. Densities of composite

| Material | Coconut plaid | Latex | CP-15 | CP-25 | CP-35 | Tire zest and latex[1] | Glass wool[2] | Asbesto[2] |
|---|---|---|---|---|---|---|---|---|
| Density (g/cm$^3$) | 1.105 | 0.980 | 0.882 | 0.871 | 0.856 | 0.922 | 0.200 | 0.47 |

[1] Ford, 2011; [2] Kreith, 2008

Knowing the density of the materials is of fundamental importance as it influences the total weight of the system.

In systems using suspended thermal insulation, such as industrial pipes, the effect of weight is felt in the final cost of the installation due to the need for better support system. So for thermal insulation, it is important that they present low volumetric density.

As comparator against insulation such as glass wool or asbestos, it was found that all composites had higher values. But compared the zest tire composites and latex, the composites under study had lower value.

### 3.2 Water absorption test

The results of water absorption tests on coconut plaids, natural rubber (latex) and the composites are shown in Tab. 3. The objective of the test is to assess the affinity of these materials to water absorption.

Table 3. Water absorption by the materials

| Material | Increased mass of the sample by water absorption (%) | | | |
|---|---|---|---|---|
| | After 24 hours | After 48 hours | After 72 hours | After 96 hours |
| Coconut plaids | 209.068 | 3.632 | 0.977 | 0.986 |
| Rubber (latex) | 3.092 | 0.714 | 0.626 | 0.608 |
| CP-15 | 1.266 | 0.323 | 0.966 | 0.103 |
| CP-25 | 1.679 | 1.183 | 1.971 | 0.311 |
| CP-35 | 1.769 | 1.517 | 1.761 | 0.240 |

It was found that the coconut plaids have high hygroscopicity, with a view to their mass after 24 hours increased by more than 209 %. But in the following days this percentage drops dramatically and stabilizes due to saturation.

After 24 hours, the latex rubber increased by 3.092 % of its mass, but the following days the increase was less than 1 %.

With respect to the composites, it was found that after 24 hours submerged in water, increases in mass percentage was less than 2 %, to stabilize the following days.

There was a small increase in the water absorption of the composites with a higher percentage of plaids (fiber).

It was also observed that the latex has a great influence on the decrease of higrospicity plaids in order that it functions as a buffer in the micro pores of the fibers.

### 3.3 Determination of moisture content

The results for the moisture content found in coconut plaids, natural rubber (latex) and composites, as well as other insulators are shown in Tab. 4.

Table 4. Humidity contained in the materials

| Material | Coconut plaids | Latex | CP-15 | CP-25 | CP-35 | Tire zest and latex[1] | Glass wool[2] | Polyurethane[2] |
|---|---|---|---|---|---|---|---|---|
| Humidity (%) | 10.72 | 0.22 | 2.66 | 3.78 | 3.84 | 3.08 | 0.124 | 3.258 |

[1] Ford, 2011; [2] Kreith, 2008

It is known that moisture contained in the material is a negative factor for the thermal insulation therefore causes an increase in its thermal conductivity.

In this analysis, it was found that the higher the percentage of coconut plaids, the higher is present in the sample moisture content.

It was also observed that the latex exerts great influence on moisture decrease in the composite; mainly provide some waterproofing the surface of the fibers, preventing the moisture from entering freely.

Despite the coconut plaids has presented high moisture content; the composites with plaids 15% and 85% latex, returned a much smaller percentage of polyurethane and composite tire / latex scrapes.

For the composite with 25 % and 35 % plaids, it appears that the moisture percentages found, are greater than the glass wool, but are very close to the polyurethane.

Thus, from the point of view of moisture absorption, it can be concluded that the composite plaids / latex is suitable for use as insulation, since the low moisture content contained in the composites studied.

### 3.4 Determination of thermal conductivity

For the thermal conductivity of the composites with 15 %, 25 % and 35 % coconut plaids, were found values of 0.188 W/m.K; 0.155 W/m.K and 0.150 W/m. K, respectively. The gradual decreases in the composite conductivity values are associated with an increased coconut plaids percentage in the composites formulation. Fig. 6 shows the results obtained.

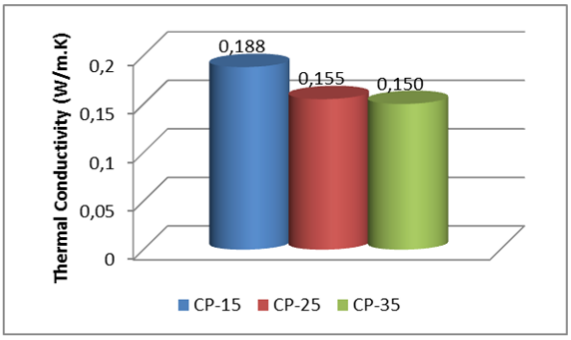


Figura 6. Thermal conductivity

The average values of thermal conductivities of the composites oscillate around 0.164 W/m.K i.e., close to the value of asbestos (0.173 W/m.K). Even if the values do not approach those of other diffused insulating commercially, as glass wool (0.039 W/m.K), rock wool (0.036 W/mK), porcelain (1.04 W/m.K), polyurethane (0.033 W/m.K ), polystyrene (0.036 W/m.K), (Kreith, 2008); can, it is concluded that the composites under study, have thermal conductivity values which classify as a good thermal insulation.

### 3.5 Determination of thermal resistivity

For the thermal resistivity of the composites with 15 %, 25 % and 35 % of coconut plaids, were found values 543.926 ºC.cm/W; 661.700 ºC.cm/W and 679.608 ºC.cm/W, respectively. These values are compatible with the thermal conductivity, since the higher the resistivity of the material, the lower its conductivity. Fig. 7 shows the results of thermal resistivity obtained.

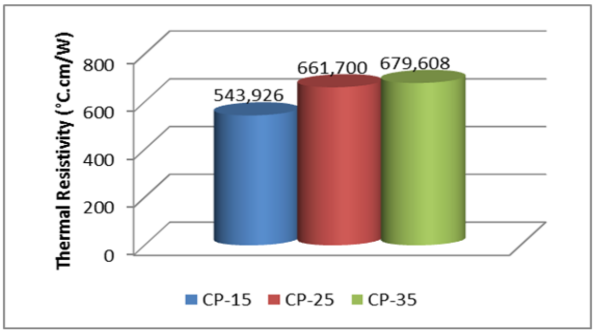


Figure 7. Thermal resistivity

### 3.6 Determination of the specific heat

For the specific heat the following values were obtained: composite with 15 % of the coconut plaids: 1.852 MJ/m$^3$.K (2099 J/kg.K); composite with 25 % of the coconut plaids: 1.457 MJ / m$^3$.K (1672 J/kg.K); composite with 35 % of the coconut plaids: 1.393 MJ/m$^3$.K (1627 J/kg.K); thus, it is observed that the higher the latex percentage, the greater is the specific heat found. Fig. 8 shows the results for the specific heat of the composite.

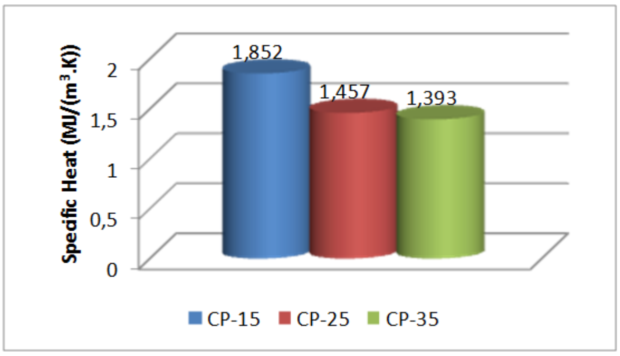


Figure 8. Specific heat

Making a comparison, as can be seen in Tab. 5 with specific heat values traditional thermal insulation as asbestos, cork, rock wool and glass wool, whose values are compatible with those of the composites analyzed. It can be stated with respect to energy storage capacity with a small variation in temperature, which composite is capable of being used as a thermal insulator.

Table 5. Specific heat of the composites and some insulators found in the market

| Material | CP-15 | CP-25 | CP-35 | Asbesto(1) | Cork(1) | Rock wool(1) | Glass wool(1) |
|---|---|---|---|---|---|---|---|
| Specific heat (J/kg.K) | 2099 | 1672 | 1627 | 815 | 1880 | 836 | 669 |

(1) Kreith, 2008

### 3.7 Determination of thermal diffusivity

For diffusivity values were obtained as follows: Composite of 15 % of coconut plaids: 0.103 mm$^2$/s; composite with 25 % of the coconut plaids: 0.108 mm$^2$/s; composite with 35 % of coconut plaids: 0.110 mm$^2$/s; respectively.

The values found are consistent with the thermal insulating material such as commercially found: Cork 0.00055 m$^2$/h (0.152 mm$^2$/s), rock wool 0.0009 m$^2$/h (0.250 mm$^2$/s) and glass wool 0.00011 m$^2$/h (0.030 mm$^2$/s). (Kreith, 2008).

These low values express well, the low heat transfer capability and high energy storage capacity on the part of the composite, enabling them to be used as thermal insulating materials. Fig. 9 shows the results of thermal diffusivity obtained.

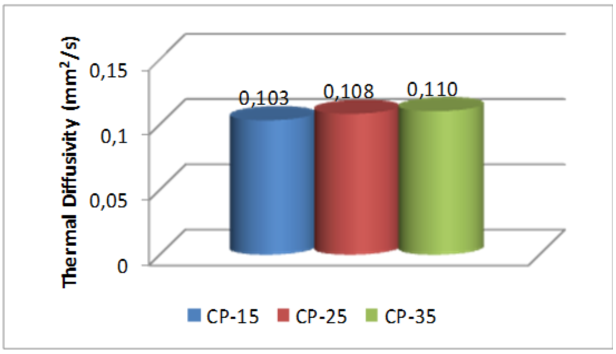


Figure 9. Thermal Diffusivity

## 4. CONCLUSIONS

According to the results obtained in this study it can be said that the coconut plaid can be utilized as a reinforcing material in the formulation of composites. And with that, give yourself a better destination for this material, which most often is burned or disposed of improperly in the environment.

According to the thermal parameters analyzed, it can be stated that the composite (plaids/latex) may be used as thermal insulation, since the values found in these parameters are compatible with the thermal insulating found on the market.

It follows then that the use of the coconut plaids as reinforcement in obtaining composite (plaid/latex), constitutes is thermal insulation of innovative character, showing to be efficient in heat retention, collaborating with environmental issues through use of biodegradable materials.

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## 6. RESPONSIBILITY NOTICE

The authors: Filho, J. R. S., Rocha, M. F., Mendes, J. U. L., are the only responsible for the printed material included in this paper.