THERMAL PROPERTIES OF OIL AND RAFFIA PALM FIBRES

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ABSTRACT
Thermal conductivities, specific heat capacities and bulk densities were determined for some fibre samples from oil and raffia palms. Thermal diffusivities and absorptivities were evaluated for each sample. Results show that the thermal conductivity values for the different samples are within the range of the thermal conductivities of construction and heat insulating material which is between 0.023 - 2.9 Wm⁻¹K⁻¹. Raffia palm frond fibre has the greatest thermal diffusivity of 3.4 x 10⁻⁴ m²s⁻¹ while oil palm frond fibre has the least diffusivity of 1.9 x 10⁻⁸ m²s⁻¹.

A model was developed for the prediction of temperature variation with thickness of the samples. Prediction from the model show that raffia palm frond fibre will make the best choice over the other fibres for use in making insulation fibre boards. The various fibre samples could also be used for lateral and bottom insulation in the making of simple solar oven/cooler.

KEY WORDS: Thermal properties, oil and raffia palm fibres.

INTRODUCTION
Extensive theoretical and experimental studies of the thermal properties of porous materials (such as building materials and soils) have been made and many models based on different assumptions, have been developed in order to effectively predict the thermal conductivities of these systems (Mahrer, 1982; Monteith, 1990; Pratt, 1969; Ekpe et. Al, 1996 and Bouguerra et al, 1997). Porous materials are used for thermal insulation and heat exchanges. A knowledge of their thermal properties is essential to analyze the heat transfer through such materials. For example, the thermal conductivity of a sand mould must be known in order to accurately determine the solidification time and rate of casting.

The oil and raffia palms are heavily fibrous. From ancient time inhabitants of the tropical rain forest (where these palms flourish) had perfected the art of making roofing mate from the foliage of raffia palm. These mats combined with the laterite walls produce a passively cooled building design. These designs as concluded by some researchers (Ekpe et al 1994), cuts down cost in the use of mechanical and electrical devices in cooling buildings.

The essence of this work is to determine if fibres from oil and raffia palms can be used as thermal insulators. This could be achieved by determining the specific heat capacity, thermal conductivity, density and hence thermal diffusivity and absorptivity for every sample collected. From the absorptivity values, a temperature-thickness variation model shall be developed for every sample and consequently used as criterion for selecting purposes. Table 1 shows the classification of oil and raffia palms used for this research work.

<table>
<thead>
<tr>
<th>Botanical name</th>
<th>Oil Palm</th>
<th>Raffia Palm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elaeis guineensis</td>
<td>Raphia hookeri</td>
<td></td>
</tr>
<tr>
<td>Average height</td>
<td>(8 - 20)m</td>
<td>(7 - 15)m</td>
</tr>
<tr>
<td>Type of wood</td>
<td>Soft and pored</td>
<td>Soft and pored</td>
</tr>
</tbody>
</table>

THEORETICAL BACKGROUND AND CALCULATION
The three main processes of heat propagation in materials are: thermal conduction through the solid phase, radiation and convection through porous materials.
Convection can be neglected for small pore sizes while radiation transport is strongly dependent on temperature and becomes significant at high temperatures. The temperature of a porous material at any depth depends on the net amount of heat absorbed by the material (a factor of thermal conductivity), the heat energy required to bring about a given change in temperature of the material (thermal capacity) and the energy required for changes such as evaporation which occurs constantly at the surface. Temperature variations with thickness in solid materials determine whether or not the material can be used as a heat sink or source.

Temperature as a function of time and thickness can be estimated from an equation given by Ekpe et al. 1994 and Ekpe et al. 1996.

\[ T(x, t) = T_m - A_e \exp(-\alpha x) \cos[\omega(t - t_o - \alpha x / \omega)] \]

Where
- \( A_e \) = daily temperature amplitude at \( x = 0 \)°C.
- \( t \) = time of the day in hours.
- \( t_o \) = time of minimum temperature at the surface hours.
- \( \alpha \) = thermal absorptivity \( \text{m}^{-1} \).
- \( \omega \) = angular velocity \( \text{day}^{-1} \) (365 days cycle).
- \( T_m \) = calculated from the hourly surface temperature average \( T_{\text{ave}} \) (°C) as:

\[ T_m = \frac{\sum (T_{\text{ave}}/24)}{n} \]

Hence on a 24-hour period, equation (1) becomes

\[ T(x, t) = T_m - A_e \exp(-\alpha x) \cos[(2\pi/24)(t - t_o - 12\alpha x / \omega)] \]

The measurement of thermal diffusivity, \( \lambda \), allows us to obtain the thermal conductivity, \( k \), once the density, \( \rho \), and the specific heat, \( c_v \), of any material are known. We determine thermal diffusivity, \( \lambda \), by the relation (Silva et al 1998 and Suleiman, 1997).

\[ \lambda = k/(\rho c_v) \]

The thermal diffusivity (\( \lambda \)) is used in calculating the thermal absorptivity \( \alpha \) from

\[ \alpha = [\omega / 2\lambda]^{1/2} \]

Inserting values of the respective absorptivity into equation (3) yields the temperature-thickness variation models at any given time of the day, \( t \) for each sample. For oil palm bunch fibre:

\[ T(x, t) = T_m - A_e \exp(-25x) \cos[0.262(t - 195.5)] \]

For oil palm trunk fibre:

\[ T(x, t) = T_m - A_e \exp(-30x) \cos[0.262(t - 118.0)] \]

For raffia palm bunch fibre:

\[ T(x, t) = T_m - A_e \exp(-23x) \cos[0.262(t - 88.2)] \]

For raffia (Woven):

\[ T(x, t) = T_m - A_e \exp(-30x) \cos[0.262(t - 115.4)] \]

For oil palm trunk fibre:

\[ T(x, t) = T_m - A_e \exp(-25x) \cos[0.262(t - 95.5)] \]

MATERIALS AND EXPERIMENTAL METHOD

Materials

Five samples of oil (Edulis guineensis) and raffia palms were collected for this research work. The five samples were oil palm bunch fibre, oil palm trunk fibre, raffia palm trunk fibre, Raffia (woven) and oil palm trunk fibre. Each fibre sample was collected fresh from the respective plants. They were subsequently dried of moisture and shaped into cylindrical discs with thickness varying between 4.58mm and 10.03mm. Dry fibre samples were used to eliminate the problem of moisture redistribution under the influence of a temperature gradient when fresh fibre samples are used.

Experimental method

For each of the five fibre samples, the thermal conductivities were determined using the steady state method (modified Lee’s disc apparatus) (Ekpe et al 1994). At steady state, the heat conducted across the fibre sample is equal to the rate at which it is emitted from the exposed surface. The specific heat capacities were determined for each fibre sample using the cooling correction method, which takes into account heat, loses due to radiation.

Bulk densities were also measured for each fibre sample using the weighing and displacement methods (Ekpe et al 1996). The thermal diffusivity and absorptivity were calculated for each sample using equations (4) and (5) respectively.

RESULTS AND DISCUSSION

Table 2 shows the experimental results for the thermal conductivity \( k \), specific heat capacity \( C_v \), density \( \rho \), thermal diffusivity \( \lambda \) and thermal absorptivity \( \alpha \) for the different fibre samples.

The highest thermal conductivity 0.1190 Wm\(^{-1}\)K was obtained for oil palm bunch fibre while \( \alpha \)
Table 2: Thermal Properties of Oil and Raffia palm Fibre

<table>
<thead>
<tr>
<th>Fibre Samples</th>
<th>$K$ (Wm$^{-1}$K$^{-1}$)</th>
<th>$\rho$ (kgm$^{-3}$)</th>
<th>$\lambda$ (m$^2$s$^{-1}$)</th>
<th>$\alpha$ (m$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil palm</td>
<td>0.1190</td>
<td>4.50</td>
<td>0.90</td>
<td>2.90</td>
</tr>
<tr>
<td>Bunch fibre</td>
<td>0.0586</td>
<td>8.20</td>
<td>0.38</td>
<td>1.90</td>
</tr>
<tr>
<td>Oil palm</td>
<td>0.0737</td>
<td>5.07</td>
<td>0.42</td>
<td>3.40</td>
</tr>
<tr>
<td>Raffia palm</td>
<td>0.0699</td>
<td>7.00</td>
<td>0.48</td>
<td>2.00</td>
</tr>
<tr>
<td>Plywood (Woven)</td>
<td>0.0711</td>
<td>9.09</td>
<td>0.26</td>
<td>3.00</td>
</tr>
</tbody>
</table>

From Table 2, we have seen that oil and raffia palm can be used for lateral and bottom insulation in a solar oven/cooker. When we compare the values of our thermal conductivity with those given by Nandwani (1988) (Table 3).

Table 3: Various Materials used for lateral and bottom insulation in a solar oven (Nandwani 1988)

<table>
<thead>
<tr>
<th>Material</th>
<th>Thickness (m)</th>
<th>Conductivity (Wm$^{-1}$K$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminium paper</td>
<td>0.001</td>
<td>0.0465</td>
</tr>
<tr>
<td>Plywood</td>
<td>0.004</td>
<td>0.0519</td>
</tr>
<tr>
<td>Pine Fibre</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asbestos sheet</td>
<td>0.004</td>
<td>0.3190</td>
</tr>
<tr>
<td>Glass Wool</td>
<td>0.041</td>
<td>0.0372</td>
</tr>
</tbody>
</table>

CONCLUSION

From the results obtained in this research, oil and raffia palm fibres have thermal properties, which compare favourably with those of good thermal insulators. One obvious application of this work is in the solar oven/cooker where these materials can help to lower the heat losses.

However, the hourly variation of the temperature-thickness model for the same thickness of the different samples, the prediction shows that raffia palm frond fibre with the least thermal absorptivity value will record the least temperature. Hence, raffia palm frond fibre will make the best choice over the other fibres in the making of insulation fibre boards.
Finally, we hereby recommend our research findings to the construction industry for adoption and modification in the making of ceiling boards, which will further assist in the construction of low-cost housing.

REFERENCES


