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Short Communication

Thermal properties of *Calamus deërratus*, *Raphia hookeri* and synthetic board in building design in Southwestern Nigeria

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For a self-cooling building, alternative sources of roofing and ceiling materials in building design was investigated. The thermal property of Rattan palms (*Calamus deërratus*), Raffia palms *(Raphia hookeri)* and synthetic Nigerite asbestos sheets were determined using the Lees' disc apparatus. Results showed that Rattan palms sheet had the lower thermal conductivity (k = 0.046 Wm^{-1} K^{-1}) and a higher resistivity (r = 21.930 $W^{-1}mK$) compared with Raffia palms sheet. While both palms showed lower thermal conductivity (k = 0.046 to 0.056 $Wm^{-1}K$) and higher resistivity (r = 17.73 to 21.930 $W^{-1}mK$) than asbestos sheet (k = 0.084 $Wm^{-1}K$, r = 11.919 $W^{-1}mK$). The results indicated that Rattan palms have a higher potential for heat resistivity than many other wood based heat-insulating materials and are recommended for ceiling in modern building design.

Key words: Self-cooling building, insulators, heat, Lees' disk, Rattan, Raffia.

INTRODUCTION

In tropical region, with reference to Nigeria, materials like zinc, aluminum and asbestos are commonly used in form of sheets for roofing in modern building constructions, but these materials have a high ability to conduct heat (solar radiation) into the interior space of a building, a situation that causes discomfort in indoor space in dry season. The heat generated indoor depends solely on the rate of heat conducted through the building materials used for the construction. Besides, the heat flow through any building material is dependent on the thermal properties of the material (Akpabio et al., 2001). The need for the self-cooling building has resulted in the search for alternative sources of roofing and ceiling materials with suitable building construction properties. Rattan and Raffia palms are one of such.

Raffia palms *(Raphia hookeri* Mann and Wendl) is a solid straight monocotyledonous plant belonging to the family Palmae, and with trunk covered with an attractive unusual coils, and occasionally producing suckers. A typical full-grown *R. hookeri* of the forest zone in Southwestern Nigeria can be taller than 16 m with large green shining fronds and curved spadices branching to form numerous hanging partial inflorescences. Trunk of *R. hookeri* is a very useful source of building material and the local people in Nigeria tap wine from the living trunks (Hutchinson and Dalziel, 1963).

Rattan palms (*Calamus deërratus Mann* and Wendl) commonly called nasty palms, is a monocotyledonous plant in the Arecaceae family. Mature Rattan is similar to bamboo (*Bambusa vulgaris*) but the stems are solid rather than hollow as found in bamboo. Rattan palm is fast growing and distinct from other palms due to its slender sheathed stem (1.8 - 3.0 cm diameter) with long internodes similar to bamboo, between the leaves when matured. Rattan leaf-sheath often thickly armed with straight spines (4 - 5 cm). Leaves (1 m long) are arranged distant from each other (2.5 cm). Lower surface of the leaves have fine slender and tapering spiny vine-like hooks. Spiny vine-like hooks aid leaves to scramble through and over other plants to the tree canopy for light. Leaves rachis is armed with sharp recurve hooks ending in a slender tentacles (cirrus); long, slender spadix, tapering to a fine flagellum armed with recurve thorns, and partial inflorescences, bearing flowers branchlets

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Table 1. Thermal resistivity and conductivity of Rattan (*Calamus deërratus*), Raffia (*Raphia hookeri*) palms and Asbestos board.

Sample	Thermal resistivity [$W^{-1}mK$ (r)]	Thermal conductivity [(k) $Wm^{-1}K$]
Calamus deërratus	21.930	0.046
Raphia hookeri	17.730	0.056
Asbestos sheet (Nigerite)	11.9190	0.084

(5 cm long). Flowers are singles in male spadix, and paired in the fruiting female spadix, with a male or neuter in the same small bract (bracteole). A fruit shape is oblong-ellipsoid, pointed (1.5 cm long), with 16 – 21 vertical rows of triangular-ovate, and fringed (fimbriate) scales (Hutchinson and Dalziel, 1963).

The attributes of Rattan, lightweight, durability, flexibility and resistant to splintering makes it a very good material for building construction. Akpabio et al. (2001) studied the thermal properties of some palms fibers and established that Raffia palms fibers are good thermal insulators. There is no report on thermal properties of Rattan palms known to the authors.

The process of conduction and radiation often generate heat experience in interior spaces via the roof and walls. The radiation transport is strongly dependent on temperature and particularly significant at high temperatures. The convention can be negligible for small pore sizes (Akpabio et al., 2001). The temperature variation with thickness of a solid material determines if a material is suitable as heat insulator or conductor. The actual heat transmission by conduction depends on the bonding between molecules (Collieu and Powney, 1977).

The theory therefore is, the rate of heat flow in dry solid material is proportional to the area (*A*) of the part perpendicular to the direction of heat flow and temperature gradient at that section $\left(\frac{-d\theta}{dx}\right)$ and the properties (nature) of the material.

This work was aimed at comparing thermal properties of Rattan and Raffia palms and in turn with that of synthetic asbestos and to make recommendation on the best material for modern building constructions.

MATERIALS AND METHODS

Collection and preparation of samples

Fresh Rattan and Raffia palms used were harvested from the green reserve forest located at "The Biome" of Olabisi Onabanjo University Ago-Iwoye (Lat 6°55´ 55´´N, long 3°52´ 58´´E elevation of 30 m). The asbestos sample was collected from works and services of the university. The Rattan and Raffia palms samples were sliced into equal uniform thickness (x = 3.0 mm). Both palms samples together with asbestos sheet were oven dried to constant weight. The dried Rattan and Raffia palms samples were weaved into a small mat. Both palms together with the asbestos sheet were trimmed into a circular size of brass disc of a Lees' disk with diameters of (y = 110 mm) (Nelkon, and Ogborn, 1985).

Methods

The thermal conductivities of the palms and the asbestos were determined for each sample using the Lees' disc apparatus (Ekpe, and Akpabio, 1994; Nelkon, and Ogborn, 1985). Each sample in turn was inserted between the brass hollow cylinder, and brass slab of Lees' apparatus, and the brass base was fitted to steam chest. Steam was passed into the apparatus and temperatures T_1°C and T_2°C were recorded at a steady state. The brass hollow cylinder and the samples were removed and the brass slab was heated directly on the heating chamber until its temperature was 5°C higher than that recorded in the steady state. The heating chamber was removed to allow the brass slab cooled down and the temperature readings were taken at interval of 30 s until the temperature fell to 5°C below the steady state temperatures.

Calculations

The cooling-curve was plotted and the gradient was determined from the temperature data obtained. Thermal conductivity was determined using Nelkon and Ogborn (1985) equations.

$$\mathrm{H} = \frac{\mathrm{KA}(\theta_1 - \theta_2)}{x} = mc\frac{d\theta}{dt} \quad (1)$$

Thus,

$$K = \frac{mcx}{A(\theta_1 - \theta_2)}\frac{d\theta}{dt} \quad (2)$$

Where H is the rate of heat flows; m is the mass of the brass slab; c is the specific heat capacity of the brass slab; x is the thickness of each sample; A is the cross-sectional area of the sample; $(\theta_1 - \theta_2)$ is the difference in the steady state temperature; $\frac{d\theta}{dt}$ is the gradient from the cooling curve; K is the thermal conductivity.

RESULTS AND DISCUSSION

The results of thermal properties of the three kinds of ceiling materials were shown in Table 1. Rattan sheet (*Calamus deërratus*) exhibited the least thermal conductivity and the most thermal resistivity among the other materials tested. The fact that the rural people of

Table 2. Thermal resistivity and conductivity of wood-based heat insulating materials (Agarwal, 1967; Akpabio et al., 2001; Ekpe and Akpabio, 1994; Etuk et al., 2005).

Material	Thermal conductivity (*k*) W^{-1}*mk*	Thermal resistivity [(r) W^{-1}mK]
Asbestos board	0.319	3.135
Brick building	0.600	1.666
Pine fiberboard	0.052	19.230
Pine wood	0.138	7.246
Oak wood	0.160	6.250
Coco nucifera	0.121	8.264

Nigeria use Rattan and Raffia palms for making chairs, tables, hats, and mats for use, particularly in the hotter part of the country, corroborate the structural suitability and durability of these materials. The high resistivity of heat found in the Rattan and Raffia palms when compared to the asbestos makes it cheaper and portable materials in the design of a self-cooling building.

The results in this work (Table 2) were compared with the data values published by previous investigators for other wood-based materials used for heat insulation (Agarwal, 1967; Akpabio et al., 2001; Etuk et al., 2005; Twidell and Weir, 1990). The range of thermal conductivity (k) values (0.04 - 0.08 $Wm^{-1}K^{-1}$) determined in this work were far lower than the range of values (0.05 - 0.32 $Wm^{-1}K^{-1}$) published for other commonly used materials for heat resistance (Etuk et al., 2005). However, Raffia and pinewood had similar conductivity (k) values.

Of the three materials tested in this work, only the asbestos resistivity (r) value was within the range of values (0.74 - 16.13 W^{-1} mK), while the Rattan and Raffia values were well above the published range for commonly wood-based insulating materials used for buildings (Agarwal, 1967; Akpabio et al., 2001). Therefore, Rattan palms plantation for domestic building material as well as for exportation should be encouraged. If implemented, it will serve as an alternative to timber resources, thereby improving the economic situation of individuals and ameliorate the rate of deforestation due to lumbering of timber for building materials.

Conclusion

From the fore-going experimental results, the Rattan palms of all the three materials tested had the lowest thermal conductivity resulting in high thermal resistivity that favours it as an interior building insulating material for naturally cooled building design in tropical countries.

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