

Comparison of thermal properties of selected wood species from Africa

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Abstract: *Comparison of thermal properties of selected wood species from Africa.* The work deals with the issue of thermal properties of wood. The scope of study included mostly tropical wood from Africa: badi (*Nauclea diderrichii* De Wild.), bubinga (*Guibourtia tessmannii* (Harms) J. Leonard) and amazokue (*Guibourtia ehie* (A. Chev.) J. Léonard). The reference was European beech wood (*Fagus silvatica* L.) Thermal conductivity, temperature compensation coefficient and specific heat were studied. The results allow to conclude that the higher density of wood, material exhibits a higher thermal conductivity. Among the studied species of wood, the largest thermal conductivity and the highest values of specific heat characterized by wood amazokue.

Keywords: thermal conductivity, thermal properties of wood, tropical wood, *Nauclea diderrichii*, *Guibourtia tessmannii*, *Guibourtia ehie*

INTRODUCTION

The increasing demand for tropical wood products leads to expand trade offers, as well as knowledge of the characteristics of exotic wood such as its physical, mechanical, technological properties. Due to special aesthetical, mechanical and physical properties, tropical wood is often used for floor. It is worth noting that frequently solution to heat buildings underfloor heating system. This is a reason to perform determinations of thermal properties of wood intended to floor. In fact, European wood species are sufficiently tested and described in the literature, but exotic wood lacks any reliable information (Jankowska 2012). Therefore, the study of wood properties is required. Full characteristics is important from an ecological and an economic point of view. Knowledge of the subject will allow choose proper wood species according to the needs (depending on expected conditions of use).

According to literature data (MacLean 1941), thermal properties of wood are correlated with moisture content and specific gravity. Thermal properties of wood are also affected by a number of other basic factors such as extractive content, grain direction, structural irregularities and temperature (Yapici et al. 2011). Thermal property values such as specific heat, thermal conductivity, and emissivity vary with moisture content, temperature, and degree of thermal degradation by one order of magnitude (Ragglund et al. 1992).

In this study, determination and comparison thermal properties of selected wood species. Scope of research included testing selected wood species from Africa: opepe (*Nauclea diderrichii* De Wild.), bubinga (*Guibourtia tessmannii* (Harms) J. Leonard) and amazokue (*Guibourtia ehie* (A. Chev.) J. Léonard) – the name of wood according EN 13556:2003. The reference was a national beech wood – European beech (*Fagus silvatica* L.). The selection of wood species was preceded by analysis of exotic wood market in Poland – selected wood species are use for floor (Jankowska, Kozakiewicz, Szczęśna 2012, Kozakiewicz, Noskowiak, Pióro 2012).

MATERIAL AND METHODS

The research were conducted using samples of dimension 25 x 90 x 125 mm (last dimension along fibers). Six measurements for each wood species were performed. Measurements were conducted on longitudinal wood section. Prior to the determination of

properties, samples were conditioned in air at temperature close to 20 °C and relative humidity around 60 %.

Study of thermal properties of wood was carried out using ISOMET 2104. ISOMET 2104 device is equipped with a sensor with a diameter of 60 mm. The measurement is based on analysis of changes in the temperature of the test material at a flow of heat impulses. The heat flow is induced by a resistive heating element located in the sensor contacting with tested material. The values of tested properties were read directly from the monitor of device after each measurement.

ISOMET 2104 measures the following quantities:

- λ – thermal conductivity [$W \cdot (m \cdot K)^{-1}$],
- a – temperature compensation coefficient (conductivity temperature) [$m^2 \cdot s^{-1}$] or [$m^2 \cdot h^{-1}$],
- c – specific heat [$kJ \cdot (kg \cdot K)^{-1}$].

RESULTS

Moisture content wood of tested species was approximately 10 %. This is a typical moisture content of wood flooring materials used in enclosed areas in temperate climates in Central Europe. Results of test are shown in Table 1 and Figure 1. In practice of the technical calculations, a constant value of the specific heat of absolutely dry wood equal $1,357 \text{ kJ} \cdot (\text{kg} \cdot \text{K})^{-1}$ and therefore do not dependent upon its density (Kozakiewicz 2012). In fact, the specific heat of wood with the assumption of the same moisture content depends on its density. This is confirmed in our research. Experimentally determined specific heat of wood appear to be low and reported differences between tested wood species too pronounced, probably due to the specificity of the measuring apparatus used.

As expected, designated thermal conductivity across the fibers is strongly dependent (directly proportional) on density of wood. Different extractives content and arrangement of wood fibers (Jankowska, Kozakiewicz, Szczęśna 2012, Kozakiewicz, Noskowiak, Pióro 2012) do not appear to be significant. Tested amazokue wood (wood with the highest density) exhibits the greatest variation in thermal conductivity. The thermal conductivities across the fibers of African wood species with high density (bubinga, amazokue) is comparable to light concrete and bricks with density of about $800 \text{ kg} \cdot \text{m}^{-2}$ (Kozakiewicz 2012) and these wood species are not towards them "competitive" insulating material.

In present work, temperature compensation coefficients were determined. This parameter is important in products working in direct contact with users such as furniture and floors (whereas they should be "warm" to the touch). In this respect, tested wood species are similar to each. Temperature coefficient compensation is not of great value and varies in a small range of $0,16$ to $0,18 \cdot 10^{-9} \text{ m}^2 \cdot \text{s}^{-1}$. Influence of density of wood is less important here.

Tab. 1 Summary of results of density and thermal properties of wood

Name of wood	λ_w^*		c^*		a^*		Specific gravity	
	$W \cdot (m \cdot K)^{-1}$		$10^6 \text{ kJ} \cdot (\text{kg} \cdot \text{K})^{-1}$		$10^{-9} \text{ m}^2 \cdot \text{s}^{-1}$		$\text{kg} \cdot \text{m}^{-3}$	
	AV*	SD*	AV*	SD*	AV*	SD*	AV*	SD*
beech	0,164	0,004	0,913	0,043	0,180	0,007	629	5
opepe	0,183	0,005	1,070	0,039	0,171	0,005	726	1
bubinga	0,218	0,006	1,330	0,044	0,164	0,007	848	9
amazokue	0,241	0,015	1,365	0,058	0,175	0,005	946	3

* λ_w - , c - , a - , AV – average value, SD - standard deviation

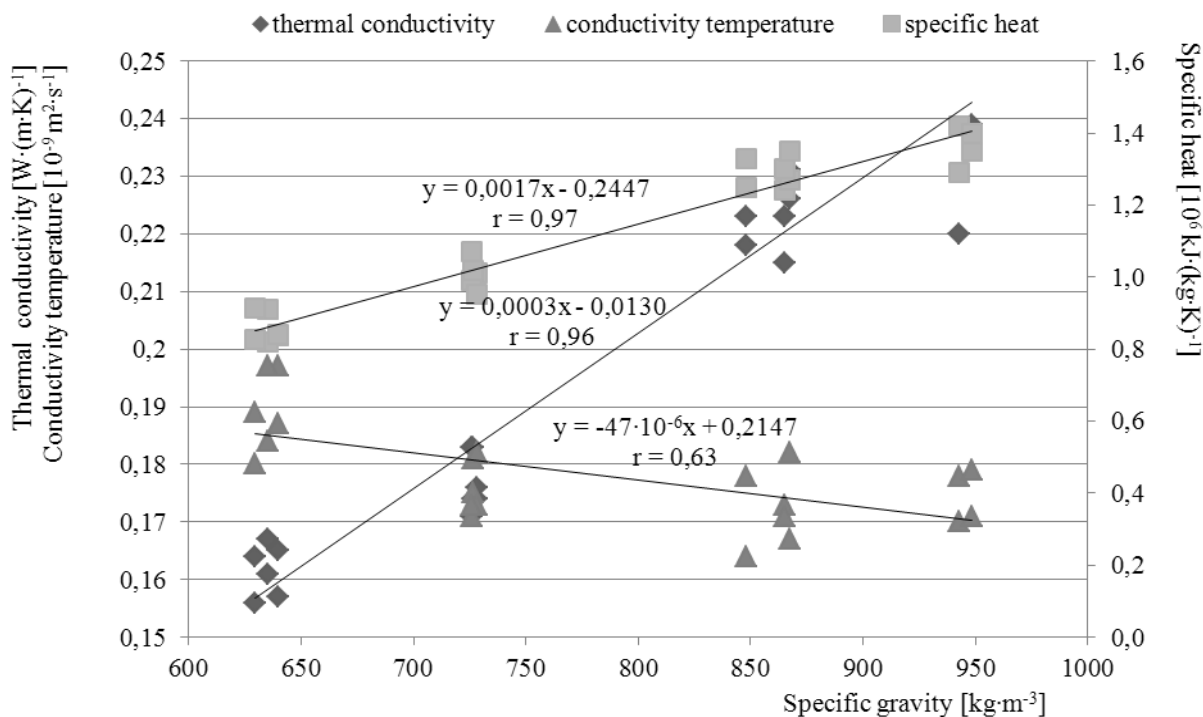


Fig. 1 Dependence thermal properties of wood of specific gravity

CONCLUSIONS

1. The African wood species (badi *Nauclea diderrichii* De Wild., bubinga *Guibourtia tessmannii* (Harms) J. Leonard, amazokue *Guibourtia ehie* (A. Chev.) J. Léonard) of high density are characterized by high coefficient of thermal conductivity across the fibers, higher than European beech wood (*Fagus silvatica* L.).
2. The highest mean value of thermal conductivity across the fibers equal $0,241 \text{ W} \cdot (\text{m} \cdot \text{K})^{-1}$ was observed in amazokue wood (*Guibourtia ehie* (A. Chev.) J. Léonard) - twice as higher as in European beech wood (*Fagus silvatica* L.).
3. Specific heat and temperature compensation coefficient tested African wood species (opepe, bubinga, amazokue) and beech wood with air dried moisture content are the qualities of much less dependent on their density (compared to thermal conductivity).

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Streszczenie: *Porównanie cieplnych właściwości wybranych gatunków drewna z Afryki.* W niniejszej pracy poruszono zagadnienie cieplnych właściwości drewna. Zakresem badań objęto głównie drewno tropikalne z Afryki: badi (*Nauclea diderrichii* De Wild.), bubinga (*Guibourtia tessmannii* (Harms) J. Léonard) i amazokue (*Guibourtia ehie* (A. Chev.) J. Léonard). Odniesienie stanowiło krajowe drewno bukowe (*Fagus* sp.). Oznaczono współczynnik przewodzenia ciepła, współczynnik wyrównania temperatury oraz ciepło właściwe drewna badanych gatunków. Wyniki badań pozwalają stwierdzić, że im wyższa gęstość drewna, tym materiał wykazuje lepszą przewodność cieplną. Spośród badanych gatunków drewna, największym przewodnictwem cieplnym charakteryzowało się drewno amazokue.

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