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Comparison of thermal properties of selected wood species intended to woodwork windows production

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Abstract: *Comparison of thermal properties of selected wood species intended to woodwork windows production.* The work deals with the issue of density, moisture content and thermal properties of wood: thermal conductivity, specific heat and temperature compensation coefficient. The scope of study included mostly tropical wood (bintangor, dark red meranti, framire) and as reference Scots pine). The basic attribute of wood is its density. Thermal conductivity across the fibers is strongly dependent (directly proportional) on density of wood as well as temperature compensation coefficient, but in lower extent.

Keywords: density of wood, thermal properties of wood, tropical wood, wooden windows.

INTRODUCTION

Thermal conductivity, specific heat and thermal diffusivity are three important thermal conductive properties. 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 properties values vary with many factors [Raggland et al. 1992].

Thermal conductivity of wood and the influence of more important variables affecting this property is special interesting from the standpoint of building insulation, the use of wood in connection with refrigeration and in many other fields where the resistance of wood to heat transfer is a major consideration. The influences of temperature, density, porosity and anisotropy on thermal conduction are known [Raggland et al. 1992, Suleiman et al. 1999]. It is important to taking into account anisotropy of wood and variability of wood structure. This information is of interest for comparing the thermal insulating properties of the different species of woods and for comparing wood with other insulating materials. Due to increasing demand for tropical wood products, trade offers have been expanded. Characteristics of exotic wood such as its physical, mechanical, technological properties need to be expanded as well. Because of special aesthetical, mechanical and physical properties, tropical wood is often used for many applications. This is a reason to perform determinations of thermal properties of wood intended to many application. 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).

In this study, determination and comparison thermal properties of selected wood species from east-southern Asia and Africa was conducted. The scope of study included bintangor wood (*Calophyllum* sp.), dark red meranti (*Shorea* sp.) and framire (*Terminalia ivorensis* A. Chev.). The reference was Scots pine wood (*Pinus sylvestris* L.). The selection of wood species was preceded by analysis of exotic wood market in Poland. They are used in external and internal joinery, building elevation and especially in windows and doors frames [Jankowska, Kozakiewicz and Szczęsna 2012, Kurowska and Kozakiewicz 2010].

Dimensions stability, density, bending and shear strength, natural durability and thermal properties of wood are very important in application of this material to woodwork windows. For example the infiltration heat coefficient of windows in house with interior temperature 20°C must be lower than 2,6 W·(m^2·K)$^{-1}$ in I, II and III climatic zone (these climatic zones cover most of territory of Poland) and lower than 2,0 W·(m^2·K)$^{-1}$ in IV and V climatic zone [EN 14220:2006].

MATERIAL AND METHODS

The research were conducted using samples of dimension 25 x 90 x 125 mm (last dimension along fibers). The statement of natural durability of hardwood-destroying fungi and density tested wood samples are given in Tab. 1. 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 %.

Table 1. The comparison of natural durability of hardwood-destroying fungi and average wood density and moisture content of tested wood samples (for the whole batch of samples)

Trade name according to EN 13556:2003	Latin name	Natural durability of hardwood* according to EN 350-2:1994	Specific gravity		Moisture content	
			kg·m^{-3}		%	
			AV**	SD**	AV**	SD**
Bintangor	*Calophyllum* sp.	Class 3 moderately durable	603	3	10,1	1,2
Dark red meranti	*Shorea* sp.	Class 2 – 4 durable – poorly durable	740	3	9,5	1,5
Framire	*Terminalia ivorensis* A. Chev	Class 2 – 3 durable – moderately durable	534	15	9,4	1,4
Scots pine	*Pinus sylvestris* L.	Class 3 – 4 moderately durable – poorly durable	550	8	10,9	2,1

*sapwood is non-durable (Class 5)
** AV – average value, SD - standard deviation

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·(m·deg)$^{-1}$],
a – temperature compensation coefficient (conductivity temperature) [m^2·s^{-1}] or [m^2·h^{-1}],
c – specific heat [kJ·(kg·deg)$^{-1}$].

RESULTS

Moisture content wood of tested species was approximately 9-11 %. This is a typical moisture content of wood used in enclosed areas in temperate climates in Central Europe. Results of test are shown in Table 2 and Figure 1. In practice of the technical calculations, a constant value of the specific heat of absolutely dry wood equal 1,357 kJ·(kg·deg)$^{-1}$ 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.

Table 2. Summary of results of thermal properties of wood

Trade name of wood	thermal conductivity λ_w*		specific heat **c***		temperature compensation coefficient **a***	
	$W \cdot (m \cdot deg)^{-1}$		10^6 $kJ \cdot (kg \cdot deg)^{-1}$		10^{-9} $m^2 \cdot s^{-1}$	
	AV*	SD*	AV*	SD*	AV*	SD*
Bintangor	0,159	0,004	0,841	0,034	0,191	0,006
Dark red meranti	0,186	0,008	1,011	0,032	0,184	0,004
Framire	0,140	0,012	0,731	0,077	0,191	0,007
Scots pine	0,147	0,008	0,803	0,027	0,183	0,002

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

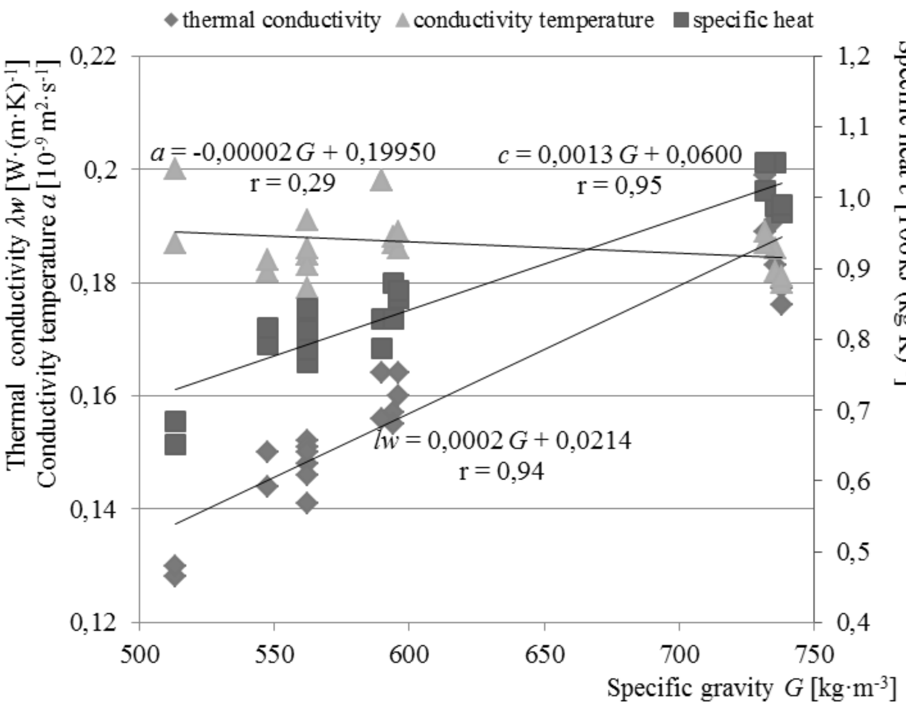

Figure 1. Dependence thermal properties of wood of specific gravity

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, Szczęsna 2012] do not appear to be significant. Tested dark red meranti wood (wood of the highest density) exhibits the greatest variation in thermal conductivity.

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 0,183 to 0,191 $\cdot 10^{-9}$ $m^2 \cdot s^{-1}$. Influence of density of wood is less important here.

The softwood used in woodwork windows production ought to has density more than 350 $kg \cdot m^{-3}$ and the hardwood more than 450 $kg \cdot m^{-3}$ considering the mechanical (strength) requirements [Kurowska, Kozakiewicz 2010]. The higher density of wood causes unfavourable growth of thermal conductivity and drop of dimensions stability [Kozakiewicz 2012], and also impedes machining [Jankowska, Kozakiewicz, Szczęsna 2012]. Probably the optimal specific gravity of wood applied to woodwork windows production ought to be in range of 450 to 750 kg·m^{-3}.

The natural durability (Table 1) is important in additional to following properties of wood. The elements of exterior windows and doors are exposed of the weather. They are working in "use class" 2 and „use class" 3.1 according to EN 335-1:2006. The species of poorly durable wood used in exposition of the weather, for example Scots pine wood with the wide sapwood, should be impregnated [EN 460:1994]. That kind of treatment is not necessary, but enjoin to tropical woods investigated in this work. It is possible that the impregnation of wood may impact on the thermal properties of wood. This problem requires more investigation.

CONCLUSIONS

1. Wood density is the most important property of wood and impacts on other properties of wood and usefulness of this material in woodwork windows production. The species of wood predestined to woodwork windows production ought to have specific gravity ranging from 450 to 750 kg·m^{-3}.
2. Thermal conductivity across the fibers is strongly dependent (directly proportional) on wood density. The framire has the least thermal conductivity (0,140 W·(m·deg)$^{-1}$) of all four investigated wood species.
3. Temperature compensation coefficients of all investigated species of wood (bintangor, dark red meranti, framire, Scott pine) are similar and fit in a small range of 0,183 to 0,191 ·10^{-9} m^2·s-^{1}. Temperature coefficient compensation across the fibers is less dependent on wood density.

REFERENCES:

1. EN 335-1:2006 Durability of wood and wood-based products - Definition of use classes - Part 1: General.
2. EN 350-2:1994 Durability of Wood and Wood-based Products – Natural Durability of Solid Wood: Guide to natural durability and treatability of selected wood species of importance in Europe.
3. EN 460:1994 Durability of wood and wood-based products. Natural durability of solid wood. Guide to the durability requirements for wood to be used in hazard classes.
4. EN 13556:2003 Round and sawn timber. Nomenclature of timbers used in Europe.
5. EN 14220:2006 Timber and wood-based materials in external windows, external door leaves and external doorframes - Requirements and specifications.
6. JANKOWSKA A., 2012: Wpływ sztucznego starzenia na wybrane właściwości drewna egzotycznego. Rozprawa doktorska wykonana w Szkole Głównej Gospodarstwa Wiejskiego w Warszawie, Wydział Technologii Drewna, Warszawa.
7. JANKOWSKA A., KOZAKIEWICZ P., SZCZĘSNA M., 2012: Drewno egzotyczne – rozpoznawanie, właściwości zastosowanie. Wydanie I. Wydawnictwo SGGW. Warszawa.
8. KOZAKIEWICZ P., 2012: Fizyka drewna w teorii i zadaniach. Wydanie IV zmienione. Wydawnictwo SGGW. Warszawa.
9. KUROWSKA A., KOZAKIEWICZ P., 2010: Density and shear strength as solid wood and glued laminated timber suitability criterion for window woodwork manufacturing. Annals of Warsaw University of Life Sciences – SGGW Forestry and Wood Technology No 71, 2010: 429-434.

10. MacLEAN J.D., 1941: Thermal Conductivity of wood. Heating, piping & air conditioning. Madison, USA.
11. RAGLAND K. W., AERTS D. J., BAKER A. J., 1991: Properties of wood for combustion analysis. Bioresource Technology Vol. 37(2), 161–168.
12. SULEIMAN B. M., LARFELDT J., LECKNER B., GUSTAVSSON M., 1999: Thermal conductivity and diffusivity of wood. Wood Science and Technology 33: 465-473.
13. YAPICI F., OZCIFCI A., ESEN R., KUTR S., 2011: The effect of grain angle and species on thermal conductivity of some selected wood species. Bioresources 6 (3), 2757-2762.

Streszczenie: *Porównanie właściwości cieplnych wybranych gatunków drewna stosowanych do produkcji stolarki okiennej.* W niniejszej pracy zbadano gęstość, wilgotność, współczynnik przewodnictwa cieplnego i temperatury wybranych rodzajów drewna tropikalnego: gumiak (*Calophyllum* sp.), damarzyk meranti ciemne (*Shorea sp.*) i migdałecznik idigbo (*Terminalia ivorensis* A. Chev) oraz drewna sosny zwyczajnej (*Pinus sylvestris* L.). Podstawową cechą decydującą o zastosowaniu drewna w stolarce okiennej jest jego gęstość, która uwzględniając różne czynniki między innymi właściwości cieplne, powinna zawierać się w przedziale od 450 do 750 $kg{\cdot}m^{-3}$. Przewodność cieplna drewna w poprzek włókien jest silnie uzależniona i wprost proporcjonalna do gęstości drewna. Ze zbadanych gatunków korzystnie najniższą przewodnością charakteryzowało się drewna migdałecznika idigbo. Współczynnik przewodnictwa temperatury jest w znacznie mniejszym stopniu zależny od gęstości drewna i kształtował się na podobnym poziomie we wszystkich badanych gatunkach.

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