BASIC THERMAL PROPERTIES AND GEOMETRIC CHARACTERISTICS OF WOOD AND ORIENTED STRAND BOARDS USED IN LOW-ENERGY BUILDINGS

OSNOVNE TOPLOTNE I GEOMETRIJSKE KARAKTERISTIKE DRVNIH I ORIJENTIRANIH RAVNIH PLOČA (OSB) KORIŠĆENIH U ZGRADIMA NISKE ENERGETSKE POTROŠNJE

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ABSTRACT

This paper deals with the thermal properties and densities of selected wood types and oriented strand boards used in low-energy buildings. Basic thermophysical parameters such as thermal conductivity, as well as the density of each sample, were measured in the study. The thermal conductivity of the samples was measured by the transient method, i.e. the extended dynamic plane source (EDPS) method. The EDPS method is a modification of the dynamic plane source method for low thermally conductive materials. A total of two identical disc-shaped samples of the material tested and two metal blocks of sufficient geometrical size were enrolled in the study. In the first measurement series, the thermal conductivity of the samples was measured at a constant laboratory temperature of 20 °C, and the measurement was performed 100 times for each sample. The second measurement series was focused on the density determination of the material tested. The densities of the wood and oriented strand board samples were calculated from the geometric dimensions and mass of the samples measured. The results obtained were statistically processed. Furthermore, the experimental results pertinent to the thermal conductivity of the wood types tested were within the range of 0.103 – 0.275 $W.(m.K)^{-1}$, whereas the thermal conductivity values of the oriented strand board samples ranged from 0.109 to 0.129 $W.m^{-1}.K^{-1}$. The present results are characteristic of the wood obtained from Slovak timber harvesting localities, as well as of wood products made from wood waste.

Key words: thermal conductivity, density, oak, red spruce, OSB.

REZIME

Ovaj rad se bavi termičkim svojstvima i gustinama odabranih vrsta drveta i orijentacionih ploča (OSB) koje se koriste u gradnji zgrada niske energetske potrošnje. U studiji su mereni osnovni termofizički parametri, kao što je toplotna provodljivost, kao i gustina svakog uzorka. Toplotna provodljivost uzoraka merena je prolaznim metodom, tj. metodom proširene dinamičke ravni (EDPS). EDPS metoda je modifikacija metode dinamičkog ravnog izvora za lošije termoprovodljive materijale. Studijom su obuhvaćena ukupno dva identična uzorka u obliku diska testiranog materijala i dva metalna bloka dovoljne geometrijske veličine. U prvoj seriji mjerenja, toplotna provodljivost uzoraka merena je na konstantnoj laboratorijskoj temperaturi vazduha od 20°C, a merenje je obavljeno 100 puta za svaki uzorak. Druga merna serija bila je fokusirana na određivanje gustine ispitivanog materijala. Gustine uzoraka drveta i orijentisanih ploča su izračunate iz geometrijskih dimenzija i mase uzoraka. Dobijeni rezultati su statistički obrađeni. Pored toga, rezultati eksperimenta, koji se odnose na koeficijent toplotne provodljivost testiranih vrsta drveta su bili u opsegu od 0.103 - 0.275 Wm-1K-1, dok su vrednosti koeficijenata toplotne provodljivosti orijentisanih uzoraka ploča bile u rasponu od 0.109 do 0.129 Wm-1K-1. Sadašnji rezultati su karakteristični za drvo dobijeno od slovačkih lokaliteta za seču drvne građe, kao i proizvoda od drveta koji su napravljeni od drvnog otpada.

Ključne reči: toplotna provodljivost, gustina, hrast, crvena smreka, OSB ploče.

INTRODUCTION

Information on the thermal conductivity of wood and the influence of important variables affecting this property is of special importance to building insulation, as well as the use of wood in many other fields where wood resistance to heat transfer is a major consideration. Such information is also essential for comparing the thermal insulating properties of different wood types, and also for comparing wood with other insulating materials which are used in low-energy buildings.

The heat conductivity of wood is dependent on a number of factors with varying degrees of importance. The following variables greatly affect the rate of heat flow in wood: density of the wood, moisture content of the wood, direction of heat flow with respect to the grain, as well as the kind, quantity and distribution of chemical substances in the wood *(Ružiak et al.,*

2017). The thermal conductivity of wood in the radial direction is about 5 % to 10 % greater than the tangential direction, whereas the conductivity in the longitude direction is about 2.25-2.75 times the conductivity across the grain *(Francz et al, 1968, Forest Products Laboratory, 1999).* Eurocode 5 provides informative values for thermal properties *(Eurocode 5, 2001).*

The experimental results of the thermophysical parameters and density of wood and OSB samples used for the construction of low-energy buildings in Slovakia are presented in this paper.

MATERIAL AND METHOD

Measurements were performed on two different types of wood samples (oak and red spruce) and two OSB samples with different thickness (10 mm and 15 mm). As OSB is an anisotropic material with a relatively complex structure and a random arrangement of individual building fragments, the OSB

sample properties were measured in one direction only. The thermal conductivity of the samples tested was examined by the transient method, i.e. the extended dynamic plane source (EDPS) method. All the wood samples were measured 100 times at a laboratory temperature of 20 °C, and the results were statistically processed subsequently.

A total of two identical disc-shaped samples of the material tested and two metal blocks of sufficient geometrical size were analysed using the EDPS method. The thermal source was located between two identical samples with the thickness L. At the time $t = 0$, the thermal source starts acting with the constant thermal power q on the unit area, and thus the relation of temperature to time can be expressed by the following equation (1):

$$\Delta T(x,t) = \frac{qL}{\lambda\sqrt{\pi}}\sqrt{\frac{t}{\Theta}}\left[1 + 2\sqrt{\pi}\sum_{n=1}^{\infty}\beta^n ierfc\left(n\sqrt{\frac{\Theta}{t}}\right)\right] \quad (1)$$

where:

$$\beta = \frac{\dfrac{\lambda}{\sqrt{a}} - \dfrac{\lambda_M}{\sqrt{a_M}}}{\dfrac{\lambda}{\sqrt{a}} + \dfrac{\lambda_M}{\sqrt{a_M}}} \; ; \qquad \Theta = \frac{L^2}{a} \quad (2, 3)$$

and Θ is the characteristic time, a is the thermal diffusivity of the sample measured, a_M is the thermal conductivity of metal blocks, β is the parameter which describes the heat sink imperfection, $ierfc$ is the error function integral *(Liang, 1995)* for the short time $t < 0.3\,\Theta$. Equation 1 has the following simplified form:

$$\Delta T(x,t) = \frac{q\sqrt{a}}{\lambda\sqrt{\pi}}\sqrt{t} \quad (4)$$

Equation 4 is identical to the equation for a one-dimensional heat flow in the infinite homogenous medium. The principle of this method resides in the fitting of the theoretical temperature Function 1 over the experimental points. In case of the best fit, the thermal conductivity λ will be determined. The method of fitting based on the least-squares procedure was described in detail *(Malinarič, 2004a; Malinarič, 2007b)*.

The examined samples of wood types and OSB indicated different densities. The density of the samples was calculated from the mass of the sample and its dimensional characteristics according to Equation 5, where the total weight of the simple is m and the total bulk of the sample is V.

$$\rho_S = \frac{m}{V} \quad (5)$$

The experimental results are summarised in Tables 1, 2, 3 and 4.

RESULTS AND DISCUSSION

The results of the thermal conductivity measurements are summarised in Table 1, whereas Table 2 displays the measurement results of the oak and red spruce wood samples. A total of three samples were made from every wood type, which enabled conducting the experiments in three different directions:

radial, tangential and axial direction. Moreover, different values of thermal conductivity were obtained for each direction tested. The maximal value was obtained for the thermal conductivity of red spruce wood in the axial direction. The minimal values of the thermal parameter were obtained in the tangential direction for the oak wood sample 0.112 W.(m.K)$^{-1}$ and for the red spruce wood sample 0.103 W.(m.K)$^{-1}$. The results of the thermal conductivity measurements are shown in Table 3.

Table 1. Results of the thermal conductivity measurements of oak wood samples at a laboratory temperature of 20 °C

Thermal conductivity of oak wood samples		
Sample	Arithmetic average W.(m.K)$^{-1}$	Relative probable error %
Radial direction	0.133	± 1.51
Tangential direction	0.112	± 0.98
Axial direction	0.262	± 2.04

Table 2. Results of the thermal conductivity measurements of red spruce wood samples at a laboratory temperature of 20 °C

Thermal conductivity of red spruce wood samples		
Sample	Arithmetic average W.(m.K)$^{-1}$	Relative probable error %
Radial direction	0.108	± 2.12
Tangential direction	0.103	± 1.07
Axial direction	0.275	± 0.84

Table 3. Results of the thermal conductivity measurements of OSB 10 mm and OSB 15 mm samples at a laboratory temperature of 20 °C

Thermal conductivity of OSB samples		
Sample	Arithmetic average W.(m.K)$^{-1}$	Relative probable error %
Thickness 10 mm	0.109	± 1.51
Thickness 15 mm	0.129	± 0.95

The results obtained in the density measurement of the oak wood and red spruce samples (Table 4) indicate the influence of the structural and dimensional characteristics on the density of the material. On balance, the lowest values of density were obtained for the wood samples in the radial direction, whereas the highest were recorded in the axial direction. The density values of the oak wood samples were in the range of 435.7 – 459.5 kg m^{-3}, whereas the OSB samples were in the range of 411.8 – 418.2 kg m^{-3}. The relative probable errors ranged from 0.72 % to 1.16 %. As the density values of oak wood were higher than the density values of spruce wood, it is evident that oak has a denser structure than spruce in every measured direction, which is congruent with the results on similar wood samples reported by *Ružiak et al. (2017)*. The density values of the OSB samples were as follows: 580.5 kg.m^{-3} ± 0.65 % for a thickness of 10 mm and 605.4 kg.m^{-3} ± 0.74 % for a thickness of 15 mm. Overall, the density of OSB depends on the structure, material components, compressing methods and additives used. The density of OSB made by Slovak producers ranges from 380 to 512 kg.m^{-3}, thus the samples examined were within this density range.

Table 4. Results of the density measurements of wood and OSB samples

Sample	Arithmetic average kg.m^{-3}	Relative probable error %
Densities of oak wood samples		
Radial direction	435.7	± 0.72 %
Tangential direction	448.2	± 0.99 %
Axial direction	459.5	± 1.03 %
Densities of red spruce wood samples		
Radial direction	411.8	± 0.85 %
Tangential direction	415.9	± 1.01 %
Axial direction	418.2	± 1.16 %
Densities of OSB samples		
Thickness 10 mm	580.5	± 0.65 %
Thickness 15 mm	605.4	± 0.74 %

CONCLUSION

Measurements of physical parameters can be used for the evaluation of their quality (*Kubík and Zeman, 2014; Hlaváčová, 2002*). Physical properties are very important parameters which can determine the quality of bio-based materials *(Božiková et al., 2015)*. In the present study, the thermal and geometrical properties of selected wood and OSB samples were examined. Based on the thermal conductivity and density values of the samples, determined in the three different wood directions, the influence of composition and structure on the bio-based materials behaviour is clearly evident.

The thermal conductivity of wood is relatively low due to wood porosity. Based on the thermal conductivity and density results obtained, it can be concluded that the thermal conductivity of wood declines with an increase in the density of wood. Relative to the grain direction, the magnitude of thermal conductivity of wood is about twofold greater in the grain direction than in the direction perpendicular to the grain. Accordingly, the thermal conductivity of oak in the direction of the grain is 0.262 W.(m.K)$^{-1}$, whereas perpendicular to the grain is in the range from 0.112 to 0.133 W.(m.K)$^{-1}$.

On balance, it was found that wood and wood-based materials are very suitable for constructing low-energy buildings owing to their thermal and insulating properties.

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