Determination of thermal properties of wood of Pinus sibirica Du Tour

AGNIESZKA JANKOWSKA, ALEKSANDRA WÓJCIK, IZABELLA JENCZYK-TOŁOCZKO
Faculty of Wood Technology, Warsaw University of Life Sciences - SGGW

Abstract: Determination of thermal properties of the wood of Pinus sibirica Du Tour. This paper raises the issues of thermal properties of Siberian pine wood (Pinus sibirica Du Tour.). Due to increasing interest in wooden construction, full knowledge about thermal properties of wood is needed. Thermal conductivity, temperature compensation coefficient and specific heat were studied. Thermal properties of Siberian pine were compared with other building materials (Scots pine Pinus sylvestris L., brick, concrete). Results show a very good insulating properties of tested wood. Thermal properties of Siberian pine wood and Scots pine (of similar density and moisture content) are comparable.

Keywords: thermal conductivity, thermal properties of wood, Pinus sibirica Du Tour., Siberian pine

INTRODUCTION

The interest in wood construction, both ecological and functional, is growing. According to estimations, based on the approximate number of companies building houses in the wooden frame technology existing on the Polish market (over 400 companies) and the assumption that each of these companies builds about 8-10 homes per year, it can be assumed that annually about 4000 homes in the wooden frame technology in Poland are made (Nitka 2010). Central Statistical Office reports that in 2012, 69243 new residential buildings were completed in the private construction (Budownictwo… 2013). By comparison of these values, it can be assumed that in Poland the demand for wooden frame construction is less than 6%.

Features pointing out the advantage of wood as construction material are associated with a good wood insulation. In terms of thermal insulation wood presents itself much more favourable over other building materials like brick and concrete. This allows for reduction of walls thickness. The requirements contained in Journal of Laws No. 75, item. 690 and further amendments (Dz. U. Nr 75, poz. 690 z późn. zm.), dated 15 June 2002 on the technical conditions to be met by buildings and their location, precisely determine the dimensions of the building components. This is due to the need to provide a specific thermal insulation. According to the mentioned regulations, homogeneous walls of pine or spruce logs under conditions of average moisture content, with a coefficient of thermal conductivity $\lambda_w$, defined across the grain amounting $0.16 \text{ W} \cdot (\text{m} \cdot \text{K})^{-1}$, to meet the required insulation, thickness must be min 30 cm, and by the 2010 amendments to the Journal of Laws No. 75, item 690, minimum thickness should be less than 30 cm.

Domestic raw material base is complemented with exotic wood, derived from foreign climates and showing differences in the structure and properties (Jankowska 2012). Therefore there is a doubt whether the existing legislation are current/valid for exotic wood, which is used to construction of wooden buildings. As known from the literature (MacLean 1941), thermal properties of wood are closely related to the 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).

The aim of this work was thermal properties comparison of two species of wood: Scots pine Pinus sylvestris L. and Siberian pine Pinus sibirica Du Tour. Both of them are used as a material for wooden construction.
RESEARCH METHODOLOGY

Thermal properties of Siberian pine *Pinus sibirica* Du Tur (names according to EN 13556:2003) wood were tested. Wood was brought from the Siberian part of Russia in the District of Krasnoyarsk, precisely Sayanogorsk in Republic of Khakassia (Sayan Mountains). The study was conducted on samples of dimensions 60x60x60 mm. Due to the anisotropic structure of wood, each anatomical sections (tangential, radial and transverse) were analysed. Six measurements for each wood samples were performed.

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

Examination of thermal properties was performed with ISOMET 2104 device, which is equipped with a surface sensor with a diameter of 60 mm. Measurement with the use of this device is based on an analysis of the temperature changes of the tested material at a flow rate of heat pulses. The heat flow is stimulated by a resistive heating element disposed in the sensor contacting with the tested material. The values of tested properties were read after each measurement directly from the display device.

The device measures the following quantities:

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

The thermal conductivity U counted from the formula: $U = 1/R$, where: $R = 1/\lambda$. Measuring time was standard, 10-15 minutes.

The scope of research also included density determination of the tested wood. Wood density was determined by stereometric method according to the PN-D-04101:1977, concerning the determination of the wood density.

RESULTS AND DISCUSSION

The density of air-dry Siberian pine was found 380 kg·m$^{-3}$. The average values of thermal properties of tested wood are given in tab 1. The average values are supplemented with standard deviation values. At the time of the study wood moisture content was about 10%.

Tab. 1 Thermal properties of *Pinus sibirica* Du Tur

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Wood section</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\lambda_w$ [W·(m·K)$^{-1}$]</td>
<td>tangential</td>
</tr>
<tr>
<td>0.131 ±0.005</td>
<td>0.124 ±0.004</td>
</tr>
<tr>
<td>$a$ [$10^{-9}$ m$^2$·s$^{-1}$]</td>
<td>0.188 ±0.007</td>
</tr>
</tbody>
</table>

± standard deviation

The measured heat conductivity coefficient $\lambda_w$ along the wood fibers in Siberian pine (*Pinus sibirica* Du Tur,) averaged of 0.160 W·(m·K)$^{-1}$, the average across the fibers was 0.127 W·(m·K)$^{-1}$ and averaged value of specific heat was 1,635·10$^6$ kJ·(kg·K)$^{-1}$. In the literature, the average thermal conductance along the fibers for Scots pine (*Pinus sylvestris* L.) wood with moisture content of 10% is $\lambda_w = 0.140$ W·(m·K)$^{-1}$ (Niemz 1993). For comparison, after conversion to thermal conductivity U ($U = 1/R$, $R = 1/\lambda$) for specific materials popular in construction, for Siberian pine wood average value of $\lambda_w = 0.127$ W·(m·K)$^{-1}$ was assumed for the tangential and radial cross-section (across the fibres differences in the values are not
significant and differences in value of thermal conductivity coefficient and value of conductivity of temperature are probably caused by anisotropic wood structure.

Therefore comparing the construction materials we obtain (calculated on the basis of Kozakiewicz 2012):
- 18 cm of Siberian pine logs (420 kg·m⁻³) U=0.67 W·(m²·K)⁻¹
- 18 cm of Scots pine logs (427 kg·m⁻³) U=0.78 W·(m²·K)⁻¹
- 40 cm of brick (800 kg·m⁻³) U=0.70 W·(m²·K)⁻¹
- 24 cm of concrete (500 kg·m⁻³) U=0.77 W·(m²·K)⁻¹
- 24 cm of concrete (500 kg·m⁻³) + 12 cm of Styrofoam U=0.21 W·(m²·K)⁻¹

CONCLUSIONS

The above calculations and data indicate a very good insulating properties of tested wood, comparable, for example, with about more than half a thicker wall of bricks. Even 24 cm of the concrete wall gives much worse result for the thermal conductivity. It becomes competitive only after application of 12 cm of Styrofoam insulation.

After analyzing literature data, it can be assumed that results obtained for Siberian pine and Scots pine (of similar density and moisture content) are comparable.

REFERENCES:
2. Dz. U. Nr 75, poz. 690 z późn. zm. z dnia 15 czerwca 2002 r. w sprawie warunków technicznych, jakim powinny odpowiadać budynki i ich usytuowanie.
Streszczenie: Badanie cieplnych właściwości drewna Pinus sibirica Du Tour. W pracy poruszone zagadnienia cieplnych właściwości drewna limby syberyjskiej (Pinus sibirica Du Tour.). Zainteresowanie materiałem limby syberyjskiej wiąże się z rosnącym udziałem tego drewna w konstrukcjach budynków. Określono współczynnik przewodzenia ciepła, współczynnik wyrównania temperatury i ciepło właściwe drewna. Porównano cieplne właściwości sosny syberyjskiej z innymi materiałami budowlanymi (krajowe drewno sosny zwyczajnej Pinus silvestris L., cegła, beton). Właściwości cieplne drewna limby syberyjskiej i sosny zwyczajnej (o podobnej gęstości i wilgotności) są porównywalne.

Corresponding authors:

Agnieszka Jankowska, Aleksandra Wójcik, Izabella Jenczyk-Tołloczko
Faculty of Wood Technology,
Warsaw University of Life Sciences – SGGW,
Ul. Nowoursynowska 159,
02-776 Warsaw,
Poland
e-mail: agnieszka_jankowska@sggw.pl
e-mail: aleksandra_wojcik@sggw.pl
e-mail: izabella_jenczyk_tolloczko@sggw.pl