

Assessment of thermal characteristics of building materials made from non-commercial wood

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Abstract. Currently, the forest industry of the Russian Federation is experiencing difficulties with the sale of hardwood pulpwood, which necessitates the search for new technical and technological solutions for its use. The paper describes the design of wooden bricks made from hardwood. Wooden brick is made by gluing lamellas, oriented in a certain way, together into wood panels, followed by gluing the panels together through a layer of veneer. The slats and veneer are made from hardwood. The bricks have a trapezoidal shape with tenons and mortices for ease of connection when installing wall structures. The authors made an assessment of the thermal characteristics of wall structures assembled from these bricks. The calculation was performed using the example of four cities in the European part of Russia, which differ noticeably in climatic conditions. The calculation showed that for all considered climatic conditions this material is suitable for the construction of walls of buildings and structures of a lower importance class with limited service life and the presence of people in them, where there are premises with dry or normal operating mode, ensuring the level of resource saving required by construction regulations without additional insulation. In more difficult climatic operating conditions, additional insulation of facades will be required to ensure the required level of resource saving.

1 Introduction

Currently, loggers are having difficulty processing hardwood pulpwood. Previously, large volumes of pulp birch wood unclaimed in Russia were sent to Scandinavian countries, but due to sanctions this is impossible today. One of the ways to use hard wood is its use in wooden house construction [1, 2], which is associated with certain difficulties, for example, low quality of raw materials and, as a consequence, low yield of products, higher labor intensity of processing compared to coniferous species [3]. This requires the search for new technical and technological solutions. Examples for this are the use of birch veneer for the creation of such a new material as corrugated veneer panel [4], the development of technologies for wooden frame house construction [5].

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Insufficient sizes of deciduous pulpwood, defects in the shape of the trunk and heterogeneity of the wood structure do not allow the use of such pulpwood as a solid beam or log [6]. However, lined products can be produced from this wood raw material [7]. For example, lamellas of small length and cross-section are first made from round pulpwood, which are then connected to each other in a certain way. An example of such a product is wooden brick (Figure 1a). It can be made from pulpwood and piece veneer (Figure 1b), a material not used in plywood production. Wooden bricks can be used in the construction of wall structures (Figure 1c).

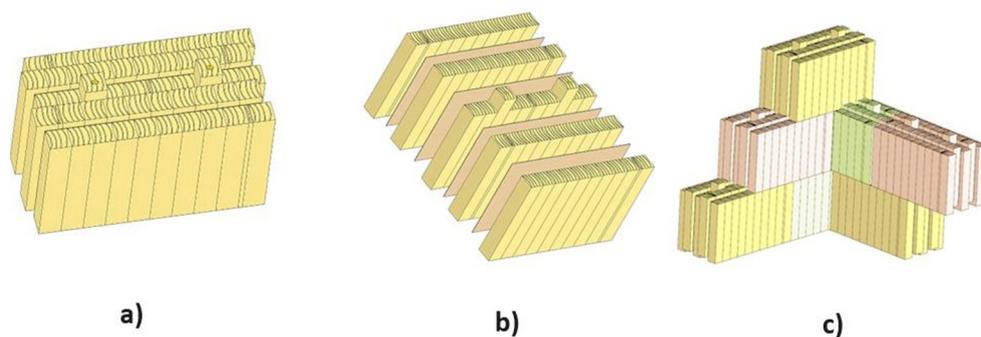


Fig. 1. Wooden brick and a fragment of a wall structure made from it (drawing made by the authors): a) wooden brick; b) wood brick construction; c) fragment of a corner of a wall structure.

2 Materials and methods

The proposed wooden brick consists of five blockboards assembled from wooden lamellas (Figure 1b). The blockboards are connected through veneer sheets with horizontal and vertical shifts, which makes it possible to form a “thermal lock” into which jute insulation can be laid. Such glued products can be used in the construction of walls of buildings and structures of a lower importance class with limited service life and the presence of people in them, for example, production facilities, cabins, warehouses and sheds, garages, greenhouses, garden houses, tourist shelters, etc. From the point of view of manufacturability and assembly into wall structures, the recommended overall dimensions of the brick are the following: length - 530 mm, width - 255 mm, height - 300 mm (excluding protruding tenon), tenon height - 20 mm.

Buildings and structures of a lower importance class with limited service life and the presence of people in them must also provide the necessary microclimate parameters and hygienic standards in the premises, and, in addition, meet resource saving requirements.

The purpose of the work is to check the thermotechnical indicators of the proposed wooden bricks and assess the potential of wall structures made from them to meet the requirements for heat-insulating properties by construction regulations.

In construction, thermotechnical calculations of enclosing structures are carried out using regulatory documents Corporate Standard 50.13330.2012 “Thermal protection of buildings” and Corporate Standard 131.13330.2020 “Building climatology”.

The section “Wood and products made from it” of Appendix “T” Corporate Standard 50.13330.2012 includes calculated thermotechnical indicators only for pine, spruce and oak, but there is no data for birch and aspen. Therefore, the calculated values of thermal conductivities were used in the work. According to reference data the thermal conductivity of wood species is directly proportional to density, and the dependence is linear (Figure 2). To calculate the thermal conductivity values of birch and aspen (Table 1), we used data on

the thermotechnical indicators of pine and oak and density from the wood reference book for the center of the European part of the Russian Federation.

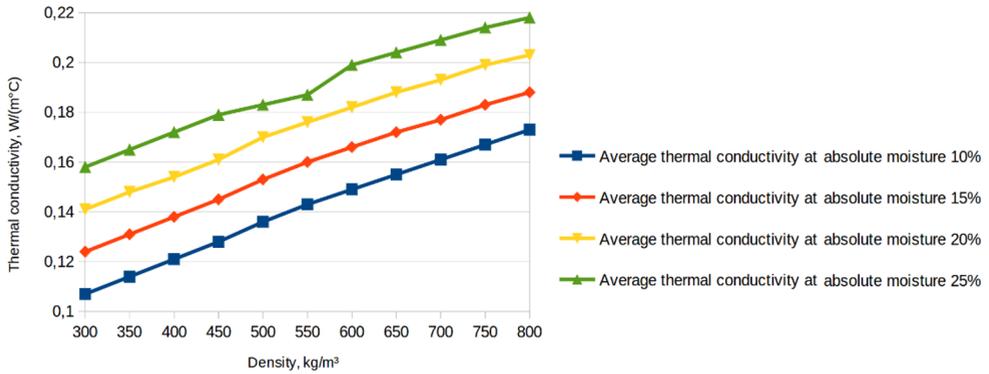


Fig. 2. Dependence of thermal conductivity on the density and moisture content of wood (drawing made by the authors).

Table 1. Thermal indicators of birch and aspen used in the calculation.

| Wood species | Density, kg/m ³ | Thermal conductivity λ_A , W/(m°C) | Thermal conductivity λ_A , W/(m°C) |
|--------------|----------------------------|--|--|
| Birch | 616 | 0.16 | 0.20 |
| Aspen | 485 | 0.13 | 0.17 |

The calculated parameters of the indoor microclimate (temperature, humidity) were set based on the requirements of regulatory documents. According to Sanitary Rules and Regulations 1.2.3685-21 “Hygienic standards and requirements for ensuring the safety and (or) harmlessness of environmental factors for humans,” the maximum permissible levels of physical factors in the workplace for category Ia work in terms of the level of energy expenditure of the body at an air temperature of 20 °C and relative air humidity 15-75%. According to all-Union State Standard 30494-2011 “Residential and public buildings. Indoor microclimate parameters”, permissible relative humidity standards for premises categories 1-5 in the service area of public and administrative buildings should be no more than 60%.

Depending on the parameters of the microclimate of the premises, they are classified according to the humidity regime as “dry”, “normal”, “humid” or “wet”. Thus, according to Corporate Standard 50.13330.2012, at the accepted temperature and relative humidity, the humidity regime of the room is “normal” at a relative humidity of up to 60% and “humid” at a relative humidity from 60% to 75%.

To assess climatic conditions, we calculated the base value of the required heat transfer resistance. The calculation was carried out using the example of four cities in the European part of Russia: Sortavala, Izhevsk, Krasnodar and Sochi, which differ markedly in climatic conditions (Corporate Standard 50.13330.2012 and Corporate Standard 131.13330.2020). Sortavala is located in the North-West of Russia, the climate is transitional from maritime to continental, and, despite the proximity of high latitudes, winters are relatively mild; according to Corporate Standard 50.13330.2012, the city is located in a humid zone. Izhevsk is located in the east of the Eastern European part of Russia, in a dry climate zone (according to Corporate Standard 50.13330.2012), despite the fact that Izhevsk is further south of Sortavala and the winter is shorter, but in terms of temperature it is more severe. Krasnodar is located in the South-West of Russia, in a dry climate zone (according to

Corporate Standard 50.13330.2012) on the border of a temperate continental climate zone with mild and short winters without stable snow cover. Sochi is one of the warmest cities in Russia; the coastal zone of the city belongs to a subtropical climate with warm winters; according to Corporate Standard 50.13330.2012, the city is located in a humid zone. The location of the selected cities is shown in Figure 3.

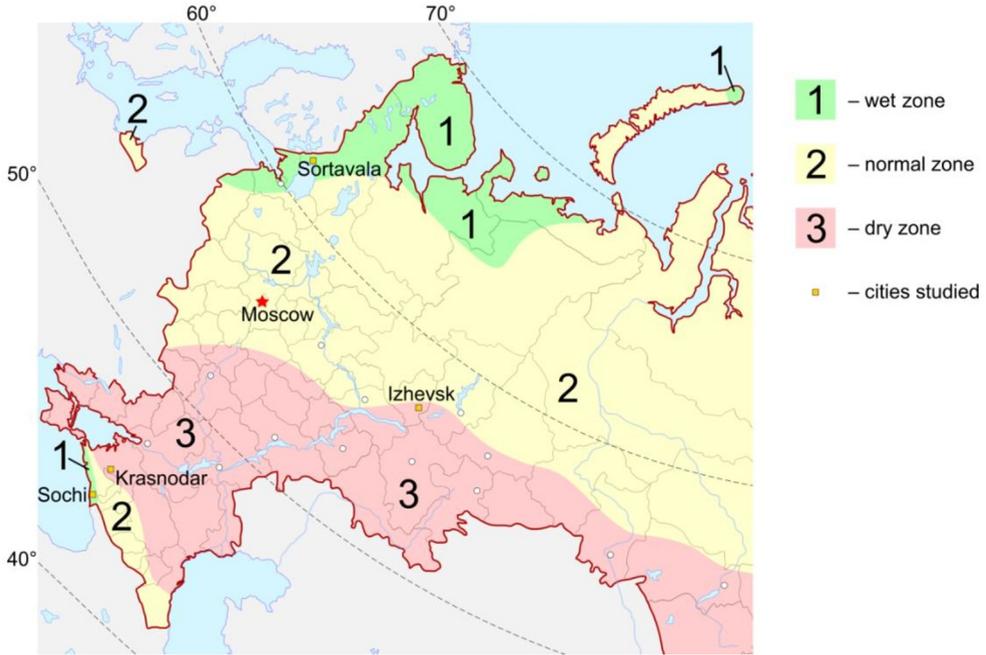


Fig. 3. Map of the location of selected cities (drawing by the authors).

3 Results

The results of calculating the required heat transfer resistance of enclosing structures are given in Table 2.

Table 2. Characteristics of heat transfer of enclosing structures.

| City | Premises* | Estimated average room temperature $t_v, ^\circ\text{C}$ | Average outside air temperature (<8) $t_{o15}, ^\circ\text{C}$ | Duration of the heating period (<8) Z_{o15} , days | Degree-days of the heating period GSOP, $^\circ\text{C}\cdot\text{days}$ | Coefficient a | Coefficient b | Basic value of the required resistance $R_{0, tr}, \text{M}^2\cdot^\circ\text{C}/\text{W}$ | Coefficient m_p^{**} | Standardized resistance value, $R_{0, nom}, \text{M}^2\cdot^\circ\text{C}/\text{W}$ |
|-----------|-----------|--|--|--|--|-----------------|-----------------|--|------------------------|---|
| | | | | | | | | | | |
| Sortavala | SKH | 20 | -2.4 | 231 | 5174.4 | 0.0002 | 1 | 2.035 | 1 | 2.035 |
| | | 20 | -2.4 | 231 | 5174.4 | 0.0002 | 1 | 2.035 | 0.63 | 1.282 |
| | VL | 20 | -2.4 | 231 | 5174.4 | 0.0003 | 1.2 | 2.752 | 1 | 2.752 |
| | | 20 | -2.4 | 231 | 5174.4 | 0.0003 | 1.2 | 2.752 | 0.63 | 1.734 |
| Izhevsk | SKH | 20 | -5.6 | 219 | 5606.4 | 0.0002 | 1 | 2.121 | 1 | 2.121 |
| | | 20 | -5.6 | 219 | 5606.4 | 0.0002 | 1 | 2.12128 | 0.63 | 1.336 |
| | VL | 20 | -5.6 | 219 | 5606.4 | 0.0003 | 1.2 | 2.882 | 1 | 2.882 |
| | | 20 | -5.6 | 219 | 5606.4 | 0.0003 | 1.2 | 2.882 | 0.63 | 1.816 |
| Krasnodar | SKH | 20 | 2.7 | 146 | 2525.8 | 0.0002 | 1 | 1.505 | 1 | 1.505 |
| | | 20 | 2.7 | 146 | 2525.8 | 0.0002 | 1 | 1.505 | 0.63 | 0.948 |
| | VL | 20 | 2.7 | 146 | 2525.8 | 0.0003 | 1.2 | 1.958 | 1 | 1.958 |
| | | 20 | 2.7 | 146 | 2525.8 | 0.0003 | 1.2 | 1.958 | 0.63 | 1.233 |
| Sochi | SKH | 20 | 6.6 | 93 | 1246.2 | 0.0002 | 1 | 1.249 | 1 | 1.249 |
| | | 20 | 6.6 | 93 | 1246.2 | 0.0002 | 1 | 1.249 | 0.63 | 0.787 |
| | VL | 20 | 6.6 | 93 | 1246.2 | 0.0003 | 1.2 | 1.574 | 1 | 1.574 |
| | | 20 | 6.6 | 93 | 1246.2 | 0.0003 | 1.2 | 1.574 | 0.63 | 0.992 |

Note:

* SKH - Production premises with dry and normal modes;

VL - Administrative and domestic, industrial and other buildings and premises with damp or wet conditions;

**a decrease in the value of the coefficient m_p from 1 to 0.63 is allowed only if the requirements of clause 10.1 of Corporate Standard 50.13330.2012 are met

The operating conditions of the enclosing structures were selected in accordance with Appendix "B" of Corporate Standard 50.13330.2012: Krasnodar and Izhevsk are in a dry zone in terms of climate humidity, which corresponds to category "A" of the operating conditions of the premises; in other cases, the calculation was carried out in accordance

with category “B” of the operating conditions of the premises. The calculation results are shown in Table 3.

Table 3. Heat transfer resistance assessment.

| Wood species and operating conditions | Thermal conductivity coefficient λ , W/(m°C) | Heat transfer coefficient of the internal surface of enclosing structures α_{int} , B/(m ² °C) | Heat transfer coefficient of the outer surface of the enclosing structure for cold period conditions α_{ext} , W/(m ² °C) | Material thickness δ , m | Conditional heat transfer resistance R0condition R_{0}^{isl} , m ² °C/W | Safety factor for taking into account the heterogeneity of a wall made of wooden products | Heat transfer resistance R_0 , m ² °C/W |
|---------------------------------------|--|--|---|---------------------------------|--|---|--|
| Birch, conditions "A" | 0.16 | 8.7 | 23 | 0.254 | 1.746 | 1.075 | 1.624 |
| Birch, conditions "B" | 0.2 | 8.7 | 23 | 0.254 | 1.428 | 1.075 | 1.329 |
| Aspen, conditions "A" | 0.13 | 8.7 | 23 | 0.254 | 2.112 | 1.075 | 1.965 |
| Aspen, conditions "B" | 0.17 | 8.7 | 23 | 0.254 | 1.653 | 1.075 | 1.537 |

4 Conclusion

The calculations show that wall structures made from the proposed products do not fully meet modern resource-saving requirements and they cannot be used for all operating conditions without additional insulation of the facade. For example, for the conditions of the city of Sortavala, products without additional insulation can only be used for industrial premises with dry and normal conditions. For the conditions of Izhevsk, aspen products can be used both for industrial premises with dry and normal conditions, and with humid and wet conditions. For the conditions of Krasnodar, aspen products without additional insulation fully meet the resource-saving requirements for industrial premises with dry and normal conditions. For the conditions of the city of Sochi, birch products can be used without additional insulation for industrial premises with dry and normal conditions. For more difficult climatic conditions and more critical premises, according to the calculations carried out, products with additional insulation of the facade should be used, which will allow the walls of buildings made from such products to fully meet the requirements of resource saving.

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