Ensuring the Strength of Round Logs with a Longitudinal Hole Walling Wooden Houses

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Abstract. In the article the questions devoted to the study of strength and thermal insulation properties of round logs. To prevent shrinkage and surface cracks is proposed to be dried logs through the through longitudinal hole. The proposed method of determining geometric parameters of longitudinal openings for the drying of logs, provided that the strength of the logs for a given it loads in the design of the exterior walls of the typical wooden house. Study on stress-strain state round logs in the outer walls of a wooden frame with a longitudinal hole diameters. Determined that most dangerous when the loads are voltage along the contour of the holes. The dependences obtained for the appointment of the diameter and position of holes of the load acting on the beam showed that the holes can be different depending on the position in the log height of the structure. Justified based on the thermal resistance from geometric parameters of round logs.

1. Introduction
The development of the forest complex of the Russian Federation involves the development of capacities for deep mechanical tion, chemical and power processing drives us. One of the priorities is Panamas staff development of wooden housing construction and the necessary materials and wood products to ensure Russian citizens affordable and comfortable housing [1]. One of the conditions of its implementation is the creation of high-performance construction materials [2]. Therefore the subject of research aimed at improving technology, materials for wooden housing construction is relevant and meaningful.

Wood is the most environmentally friendly building material, providing comfortable living conditions [3]. Wooden housing construction is the most promising direction of housing due to low prices, fast of construction and high quality of these houses and universality of technologies [4]. The production of houses made of logs the most promising because provided high-valuable output – up to 80%.

For the production of round logs used-out wood of the raised humidity that the operation of the house leads to the appearance of cracks and shrinkage of the framework [5]. Therefore, the aim of the research is the determination of the geometric parameters of round logs to prevent shrinkage and the formation of surface cracks during operation.

Drying can be done in several ways [6, 7]. Atmospheric drying or drying in the open air under a canopy on simplicity and accessibility. But this process is very slow – from several months to several
years. One of the ways to increase the speed drying logs without cracking is the fulfillment of the longitudinal technological holes [8, 9]. At the same time, the use of such holes associated with a reduced carrier capable-STI logs. Scientific novelty has developed the method of calculating parameters of round logs with a longitudinal hole technology. Theoretically grounded dependence, allowing to determine the location and diameter of the hole for the tre Buena the strength of the beam in the process of its operation.

The practical significance of the research is to justify the required strength and thermal resistance of enclosing structures made of logs and logs.

2. Materials and methods studies

The studied material was the wood of pine, spruce and aspen. Applied numerical methods solid mechanics and basic tenets of the theory of thermal conductivity of wood.

3. The results of the study

The research methodology worked out by calculation of round pine logs of diameter $D=220$ mm, used in the construction of the exterior walls of the typical wooden house. Studied the stress state of one of the logs 1 during the interaction with two adjacent logs 2 and 3 (Figure 1). The calculation was done for one meter of wall. It is supposed that the logs are in conditions of plane strain [10-12] In each of the logs made a technological hole for drying from the inside. The material of the logs were presented as orthotropic. Contact interaction between the logs were considered with one-sided ties 4, perpendicular to the contacting surfaces. The friction force was not considered. Asked external vertical connection 5 in the form of a hinged-rod supports.

Plane strain condition was described by using the developed refined triangular finite elements. 4 was submitted on the basis of truss finite elements. In the process of calculation was monitored to deformation in these finite elements were negative.

In the calculations we considered the influence of the diameter and offset of the hole from the center of the log on its stress-strain state. Taken into account three of the diameter $d$ of the hole 50, 66 and 80 mm. For diameter $d = 50$ mm were analyzed also the location of the center of the hole at 15 and 25 mm above the center of the log.

The construction of the specified finite element to study the stress-strain state round logs. Proposed in [13-15] the limit scheme of the finite element method allows to significantly expand the possibility of constructing efficient finite element models of increased accuracy. A feature of this approach is the rejection of the description of the displacements over the entire area of the end element. Approximation of the displacements is carried out on separate stretches on the border and inside the
item’s area, which significantly expands the possibility of creating a simple but effective finite element spatial discretizations [16].

Consider a triangular finite element that describes the plane strain condition (Figure 2). In accordance with the scheme of Allman [17] we introduce, in addition to the corner nodes I, II, III, auxiliary nodes 1, 2, 3, located at the midpoints of the sides of the triangle. In knots I, II, III we define two displacements (\(U_i\) and \(V_i\)) in the directions of the axes of the Cartesian coordinate system \(Ox\) and \(Oy\).

Connect each of the nodes 1, 2, 3 one additional move \(\delta\), perpendicular side of the triangle, which is a node. Total displacements of points 1, 2, 3 will be presented in the form of amounts of displacements expressed through the values of \(U_i, V_i\), and displacement \(\delta\). Initially consider the components of the amounts of displacements for these points is due only to the displacement \(U_i, V_i\).

In accordance with the limit scheme of the finite element method linear deformation from these displacements for point 1 in the directions \(\Theta\) define:

\[
\varepsilon_{II}^0 = \frac{U_H - U_I}{l_{II}}, \quad \varepsilon_{I2}^0 = \frac{V_H - V_I}{l_{I2}}, \quad \varepsilon_{I3}^0 = \frac{-V_I \cos \beta - u_I \sin \beta - u_I \cos \alpha - v_I \sin \alpha}{l_{I3}},
\]

where \(u_i, v_i\) (i=1, 2, 3) - move the points 1, 2, 3 in the directions of the axes Ox and Oy calculated using the expression:

\[
u_i = \frac{U_i + U_{II}}{2}; \quad v_i = \frac{V_i + V_{II}}{2}; \quad u_I = \frac{U_I + U_{II}}{2}; \quad v_I = \frac{V_I + V_{II}}{2}; \quad u_{II} = \frac{U_{II} + U_{III}}{2}; \quad v_{II} = \frac{V_{II} + V_{III}}{2}; \quad u_1 = \frac{U_1 + U_{II}}{2}; \quad v_1 = \frac{V_1 + V_{II}}{2}; \quad u_2 = \frac{U_2 + U_{III}}{2}; \quad v_2 = \frac{V_2 + V_{III}}{2}; \quad u_3 = \frac{U_3 + U_{III}}{2}; \quad v_3 = \frac{V_3 + V_{III}}{2};
\]

\(\angle\) - the angles shown in fig. 2; \(l_{I2}, l_{I3}, l_{II}\) - the lengths of segments I-II, 1-2 1-3.

Substituting according to (2) in equality (1), we get:

\[
\varepsilon_{I2}^0 = \frac{\cos \alpha \left( \frac{U_{II} - U_I}{l_{I2}} \right) - \sin \alpha \left( \frac{V_{II} - V_I}{l_{I2}} \right)}{2l_{I2}}, \quad \varepsilon_{I3}^0 = \frac{\sin \beta \left( \frac{U_{III} - U_{II}}{l_{I3}} \right) - \cos \beta \left( \frac{V_{III} - V_{II}}{l_{I3}} \right)}{2l_{I3}}.
\]

Similarly, we arrive to the formula for finding the deformation at point 2 in the directions \(\Theta\) and at point 3 in the directions \(\Theta\).

For point 1 additional linear deformation in directions \(\Theta\) will be determined by dependencies:

\[
\varepsilon_{12}^0 = \left( \delta_2 \sin \gamma + \delta_1 \sin \alpha \right) \frac{1}{l_{I2}}, \quad \varepsilon_{13}^0 = \left( \delta_3 \sin \gamma + \delta_1 \sin \beta \right) \frac{1}{l_{I3}}.
\]

Given the expression of Allman [9] in equations (4), we write...
where $\Theta_1$, $\Theta_1$, $\Theta_2$ – the angles in the angular points of the triangle.

Similar expressions can be obtained for points 2 and 3. Matrix deformations $\mathbf{B}$ for the point $i$ ($i = 1, 2, 3$) is determined by the equality

$$
\mathbf{B} = \mathbf{D} \mathbf{T} \mathbf{V}_{K}\mathbf{b}
$$

where $\mathbf{D}$ – the elasticity matrix of plane strain for orthotropic material.

Features of stress state is analyzed under basic total force $Q = 8, 8$ kN/m. In Figure 3 and 4 show graphs of the maximum permissible values of the vertical linear load on the beam is obtained from the calculated resistances for pine, spruce and aspen [19, 20] the deformations across the grain [21].

**Figure 3.** Dependence of the permissible load on the diameter of the hole: 1–spruce; 2–pine; 3–aspen

**Figure 4.** Dependence of permissible power from offset ink and makes th of the hole: 1 - spruce; 2–pine; 3–aspen
diameter of round logs [22, 23]. For walling from round logs of pine, spruce and aspen with a diameter of from 0.18 to 0.28 m were obtained according to determine the diameter of round logs of different species (Figure 5).

Figure 5. Dependence to determine the diameter of round logs from the thermal resistance for different breeds different breeds: 1 – pine, and aspen; 2 – fir; 3 – pine, aspen with hole; 4 – fir with a hole.

4. Conclusion.
1. The technique of determining geometric parameters of longitudinal openings for the drying of logs, provided that the strength of the logs for a given it load in the design of the exterior walls of the typical wooden house.
2. Study on stress-strain state round logs in the outer walls of wooden log cabins with a Central longitudinal holes with diameters of 50, 66, 80 mm and holes with a diameter of 50 mm offset from the center of the logs up to a distance of 15 and 25 mm.
3. Found that the most dangerous for the considered loadings are the stresses along the contour of the holes.
4. The dependences obtained for the appointment of the diameter and position of holes of the load acting on the beam. At the same time in one and the same wall of the log building, the execution of the hole may be different depending on the position in the log height of the structure.
5. Justified based on the thermal resistance from geometric parameters of round logs for assigning log diameter, and holes.

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