Floorings of Wooden Frame Buildings with Application of CLT-Panels

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Annotation. The aim of the study is to analyze the floor structures of a wooden frame building, made with the use of glued CLT-panels and the use of perspective wood material of their unidirectional veneer – LVL-bar, which has enhanced strength characteristics compared to ordinary wood. Four options for securing floor slabs were considered. Analysis of the stress-strain state (VAT) of the CLT-panel design with lamellae of LVL-beam is performed using the MSC Nastran finite element analysis application package. The CLT panel is approximated by four-node LAMINATE type layered elements that take into account all internal force factors: membrane, shear, transverse and flexural. At each node, the element has six degrees of freedom: three translational along each of the axes ox, oy, oz and three rotational with respect to the axes ox, oy, oz. Analysis of the results of the calculations made it possible to evaluate the most effective design solutions for floor slabs of frame buildings using CLT panels.

1. Introduction
Wooden housing construction, including construction of multi-storey buildings, in recent years has received a new impetus, which is associated with the emergence of new materials, structures and technologies. In parallel, increased requirements for the performance of the material. CLT-panels are currently considered to be one of the most high-tech wood constructions for the bearing and enclosing elements of multi-storey buildings. Unlike many other wood building materials, CLT panels are not subject to shrinkage. Buildings from such panels are recognized not only as energy-saving, but also as the most ecological.

The objectives of the authors of the studies performed were the development of floor structures for wooden frame buildings using CLT panels and using LVL lamellas (Laminated Veneer Lumber of the Ultralam R brand) in them, which have significantly higher strength characteristics compared to conventional wood [1]. The considered construction of the ceiling of the building is a five-layer orthotropic CLT-plate 3000 mm wide, 6000 mm long; plate thickness - 300 mm (with a lamella thickness of 60mm). In the calculation of the plate, it was taken into account its frame bordering from LVL-bar or glue-glued elements of I-section. The accepted values of the basic physicomechanical characteristics of CLT-panels with lamellas of LVL-timber and laminated wood are given in Tables 1. and 2.

To calculate the factor of safety, taking into account the layout of the lamellae in the CLT-panel with lamellae from the LVL-beam, the average integral value $\sigma_{BP} \approx 24$ MPa was taken.

During the calculation of the stress-strain state of the CLT-panel with lamellae from the LVL-bar, the following factors were chosen as the influencing factors, $c$, the coefficient of reliability ohm for load $\gamma_f = 1.1$ [2]:

a) own weight of the panel;
b) the weight of homogeneous linoleum with a thickness of 2 mm, a density of 1600 kg / m$^3$, in the form of a distributed load on the surface of the plate;
c) the weight of the insulation thickness of 20 mm, a density of 30 kg / m$^3$, in the form of a distributed load on the surface of the plate;
d) payload 1, 5kN g / m 2, in the form of a distributed load on the surface of the plate; The total distributed load (pressure), taking into account all the influencing factors and the load safety factor, is P ≈ 2000 Pa.

Analysis of the stress-strain state (VAT) of the CLT-panel design with lamellae from an LVL-beam is performed using the application package [3] of the finite element analysis MSC Nastran. The CLT-panel is approximated by four-layer LAMINATE type layered elements that take into account all internal force factors: membrane, shear, transverse and flexural [4]. At each node, the element has six degrees of freedom: three translational along each of the axes O x, O y, O z and three rotational relative to the axes O x, O y, O z.

**Table 1.** Physicomechanical characteristics of CLT-panel with lamellas from LVL-timber.

| Limits of strength, MPa | Module of elasticity, MPa | Module of shear, MPa | Coefficient of Poisson | Density, kg / m ³ |
|-------------------------|---------------------------|---------------------|------------------------|-------------------|
| σврx                    | σврy                      | Eх                  | Eу                      | Gху               | μху               | μyx               |
| 36                      | 6                         | 12000               | 500                    | 700               | 0.018             | 0.45              |

σврx - ultimate tensile strength parallel to the direction of the fibers, 99999999
σврy - ultimate tensile strength perpendicular to the direction of the fibers.

**Table 2.** Physical-mechanical properties of the wood adhesive hydrochloric

| Limits of strength, MPa | Module of elasticity, MPa | Module of shear, MPa | Coefficient of Poisson | Density, kg / m ³ |
|-------------------------|---------------------------|---------------------|------------------------|-------------------|
| σврx                    | σврy                      | Ex                  | Ey                      | Gxy               | μxy               | μyx               |
| 16,5                    | 0.4                       | 10000               | 390                    | 720               | 0.018             | 0.45              |

The loading scheme and 4 options for fixing the floor slabs of CLT panels are presented in Figure 1.

Fastening option 1 - the design is fixed in all nodes rigidly around the perimeter. Fastening option 2 - the design is rigidly fixed in 4 corners.
Fastening option 3 - the design is rigidly fixed with a step of 1m

Fastening option 4 - the design is rigidly fixed at 4 angles and in the middle of each side

Figure 1. Loading scheme and options for fixing floor slabs from CLT - panel to it

Table 3. The results of a comparative analysis of the design of the CLT-panel with lamellas of LVL-bar and a panel of glued laminated timber with the combined effect of the panel’s own weight, weight of linoleum, insulation and distributed load.

| Estimated parameters of structural deformation | Maximum total strain (mm) | Maximum equivalent stresses $\sigma_{ekvo}$ according to Mises, MPa. | Factor of safety in layers, MPa |
|-----------------------------------------------|---------------------------|-------------------------------------------------|--------------------------------|
| CLT –Panel with LVL lamellas                  | 7.45                      | 3.7                                             | 6.5                            |
| Panel of laminated veneer lumber              | 9.0                       | 3.89                                            | 2.6                            |

2. Conclusions - research results

Comparative analysis of the results of the calculation of CLT-panel designs with lamellas from LVL-beam and a panel of glued-beam shows that for the same fastening pattern under its own weight, weight of linoleum, insulation and distributed load, the CLT-panel with LVL-lamellas has a large factor margin of safety and less deformed.

The results of the analysis of the stress-strain state of the CLT-panel design with lamellas of LVL-bar under the combined effect of the panel’s own weight, weight of linoleum, insulation and distributed load made in accordance with the requirements of [2] show:
- the maximum stresses in the construction of the CLT-panel with lamellas from LVL-bar arise in the attachment points of the structure;
- the worst from the point of view of strength and deformability is the second version of fixing the structure of the floor plate (mounting at the corners of the structure). For this option, the stresses and strains are respectively 17.79 MPa and 94.3 mm. The safety factor of 1.35.
- from the point of view of strength and deformability, the best option of fastening among the options considered is option 1 (fastening along the perimeter with a step of 0.2 m). For this variant, the deformations do not exceed 0.83 mm, and the safety factor is no less than 32. It should be noted that the fixing option 3 is also acceptable when designing floor slabs of CLT panels with lamella LVL beams.
- a comparative analysis of the results of the calculation of CLT-panel structures with lamellas of LVL-beam and a panel of glued timber shows that for the same fixing pattern under its own weight, weight of linoleum, insulation and distributed load, the CLT-panel has LVL lamellas of 2, 5 times more factor of safety and is 18% less deformed.
3. Findings
Use as a material for slabs of wooden floor slat CLT-panel multilayer laminated veneer lumber (LVL-bar) is a promising due to high strength and elastic characteristics of the material.

References
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