Multi-span composite beam

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Abstract. The development of wooden structures tends to create systems, types, elements and types of connection that would allow you to save wood while increasing the load-bearing capacity and best take into account its physical and mechanical features. One of the priority directions is the creation of lightweight composite bent structures based on wood. The scientific novelty of the article consists in the study of multi-span continuous composite beams, the use of which is possible both in new construction and reconstruction. Composite multi-span wood-glued beams with the proposed reinforcement scheme are an experimental design and to date, their work is poorly studied. The essence of the proposed design is to strengthen the lower zones in the spans of the beam and the upper zones of the beam at the location of the support with fiberglass on an epoxy oligomer. To perform the calculations, we set a model of a beam with three spans of 1.5 m. the Load is assumed to be evenly distributed along the entire length of the beam. A comparison of the structure to assess its rationality was carried out with an unreinforced glued beam with the same design scheme. The study found that, in contrast to wooden beams, the strength of composite beams with rational reinforcement of stretched zones increases by 24-27 %, and the deformability decreases by 8-13 %. From the point of view of the work, it is proposed to use the method of vacuum infusion, which is proven, which has a positive effect on technical and economic indicators.

1. Introduction
Throughout history, wooden structures have evolved all the time, absorbing new elements. Rational use of wood in the manufacture of new types of structures and their elements provides for the strengthening of nodes and interfaces with the use of new materials and technical solutions based on the latest achievements. A significant role in the improvement of wooden structures made the appearance and development of epoxy resins. The development of wooden structures tends to create...
systems, types, elements and types of compounds that would save wood while increasing the load-bearing capacity and best take into account its physical and mechanical features. The main feature that characterizes the progress in the field of wooden structures is the orientation to glued [1-5] and composite wooden structures [6-10]. The development and distribution of glued wooden structures is inextricably linked with the success in the production of synthetic polymeric materials, since adhesives based on them are the best for gluing wood. One of the priority directions is the creation of light composite bent structures based on wood. These include reinforced [11-14], cleaner, concrete-wood [11], other truss and beam construction [15-17]. The use of fabrics can significantly reduce the impact of various defects of wood-knots, slanting, etc., to use low-grade wood, which is usually not used, to expand the scope of composite beam structures not only in the framework of new construction, but also in the reconstruction of significant historical sites [18-21].

At the present time glued wooden structures are used mainly in the construction of gyms, swimming pools, stadiums and bridges. Taking into account the requirements of fire regulations, they are also used for industrial buildings, especially for warehouses and buildings with chemically aggressive environment, where the use of metal and reinforced concrete is associated with high costs for their anti-corrosion protection. At the same time, we should not forget about the aesthetic component, which plays an increasingly important role in the selection of future building designs [22-24].

The scientific novelty of the article lies in the study of multi-span continuous composite beams, the use of which is possible both in new construction and reconstruction [25-28]. Composite wood-glued beams are an experimental design and today their use is poorly studied. The scientific nature of the article can be traced in the study of the stress – strain state of continuous composite beams by studying the results of a numerical experiment performed in the software design complex and finding the optimal design parameters [29-37].

2. Methods
The study is based on a wooden glued multi-span beam with reinforcement of stretched zones by layers of fiberglass on an epoxy oligomer ED-20. Layers are located in places of the greatest action of the moment in the middle of spans of a beam in the lower zone and in the upper zone of a beam on supports. A three-span continuous beam with reinforcement by two layers of fiberglass was adopted as a computational scheme for the numerical experiment and further testing of the models. The cross-section of the beam for numerical simulation and further experimental study is 70x100 (h) mm.

The optimal coefficient of reinforcement of low solid-wood beams is \( \mu = 0.75...2\% \), the border of the theoretical breakage of the composite reinforcing material should be located at a distance of 0.22...0.3 L. The Actual border of the breakage of the reinforcing material is assigned taking into account the required anchorage length for the action of tensile forces across the fibers and cleavage of the adhesive seam.

![Figure 1. Type of beam under consideration (half the length)](image)

As a standard for comparison of results and an assessment of expediency of the offered design we will accept a beam of similar section, but without reinforcing.

The existing methods of calculation of wooden structures allow with sufficient accuracy to assess their bearing capacity and deformability for any cross-sections and at any stage of work. When loading
wooden structures with an external load, three characteristic and successive stages of the stress-strain state are clearly manifested: conditionally elastic, elastically plastic and fracture.

The stage of conditional elastic work is characterized by the value of deformations not exceeding the limit values of elastic deformations of wood and reinforcement. At unloading of the reinforced elements in this stage residual deformations are absent or so insignificant that they can be neglected. Due to the fact that even at low stresses the linear relationship between the stresses and strains of wood is somewhat violated, the first stage of the stress-strain state can only be considered as conditionally elastic. The stage of elastic-plastic work is characterized by the appearance of tangible plastic deformations in the compressed fibers of wood, and then in the compressed reinforcement. In the compressed part of the section, a plastic zone is formed, spreading with increasing load into the depth of the section. There is a redistribution of forces, as a result of which the neutral layer is shifted towards the stretched fibers. Deformations of stretched wood fibers increase to the value of the proportionality limit. When unloading the element at this stage, significant residual deformations are manifested. The stage of destruction is characterized by a significant increase in the deformability of the reinforced element with a small increase in the load. Plastic deformations get the maximum development. There is a destruction of the element, the nature of which depends on the type of reinforcement.

The paper presents a detailed analysis of the stress-strain state of structures at all stages of work using the finite element method in the Lira software package.

The calculation is performed in a linear and physically nonlinear formulation of the problem using the method of successive loads. The reinforcement is made by a unidirectional carbon tape on an epoxy matrix on a part of the span and on supports in 2 layers, the edge of the break is located at a distance of 0.3 m from the support, while the overlap of the upper and lower layers is 0.3 m.

The design scheme of the structure is adopted in the form of a pivotally supported continuous three-span beam. The spans are accepted for 1.5 m, the beam is loaded with a uniformly distributed load along the entire length. The numerical experiment is performed on the cross-section dimensions corresponding to the dimensions of the beam model, which are available for full-scale tests. Isofields of stresses and displacements based on the results of numerical calculation for half of the span of a composite beam structure are shown in Fig. 2-3.

3. Results and Discussion
As a result of modeling it is established that destruction of composite beams has plastic character, it is possible to state that destruction begins with crushing in the compressed zone then in the stretched zone stress concentrations in places of defects, such as knots are formed. Separation of fiberglass from wood and its rupture does not occur. Destruction of composite beams occurs only on normal sections. This eliminates the possibility of destruction of reinforced beams from chipping and splitting in the supporting areas, i.e. ensures the reliability of structures to the action of shear forces in the support sections, thereby increasing the reliability of the structure against collapse.

Figure 2. Normal stress isofield $\sigma_x$, MPa for glued laminated beams (half length)
Unlike wooden beams, the strength of composite beams with rational reinforcement of stretched zones increases by 24-27 %, deformability decreases by 8-13 %.

The reliability of the results is insured by the correctness of the tasks, the use of hypotheses and assumptions accepted in the construction mechanics; modern means of research using a certified tool base; methods of numerical experiments using computer programs.
4. Conclusions
The main indicators of the efficiency of bearing structures are both structural and technological indicators: cross-sectional dimensions and mounting weight, and technical and economic indicators: consumption of basic materials, factory cost, cost of structures in the case, the given costs, operational suitability, etc. The efficiency of the composite wooden structures compared to traditional no doubt: reducing the cross-section of strengthened elements (especially height) to reduce building volume and therefore the cost of building envelope and heating; reducing the width of the cross section of the elements enables the use of the abundant lumber width 130-150 mm; reducing the size and weight of the elements makes it possible to more efficiently solve the issues of storage, transportation and installation.

Based on the results obtained, it can be argued about the feasibility and effectiveness of the method of strengthening wooden beams. According to the numerical experiment carried out on the example of a three-span beam, the increase in strength when strengthening stretched zones with fiberglass on an epoxy oligomer in comparison with solid wood beams occurs by 24.27%, the decrease in deformability by 8.13%.

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