The Stress Strain State of Composite Multi-Span Beams

M S Sergeev¹, A S Gribanov¹, S I Roschina¹
¹The Department of Building Constructions, Institute of Architecture of Construction and Energy, Vladimir State University named after Alexander Grigorievich and Nikolai Grigorievich Stoletovs, Gorky Street 87, Vladimir, 600000, Russian Federation

E-mail: sergeevmichael@inbox.ru

Abstract. The article presents a new design of a wooden beam. The essence of the proposed design is the rational reinforcement of multi-span glued beams. Reinforcement is performed in places of stretching of wood fibers according to the diagram of moments. A comparison of the design to assess its rationality was made with an unreinforced glued beam with the same design scheme. The numerical experiment showed the relevance of such amplification. So at the same given load there is a significant reduction of normal and tangential stresses in the cross section of the structure under study, which ultimately leads to a reduction in the cross sections of the whole beam and its better ergonomics. From the point of view of work production the technology on pasting of cores in a beam body can be considered well approved positively affecting technical and economic indicators.

1. Introduction
Wood is one of the first structural materials used by man since ancient times. The development of wooden structures tends to create systems, types, elements and types of connections that would allow to save wood while increasing the bearing capacity and take into account its physical and mechanical characteristics. The main feature that characterizes the progress in the field of wooden structures is the orientation to glued [2] and composite wooden structures [3]. 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 [1, 5-7], cleanere, concrete-wood [3], other truss and beam construction. The use of reinforcement can significantly reduce the impact of various defects both of mechanical and natural character, which expands the scope of composite beam structures not only in the new construction, but also in the reconstruction or overhaul of existing buildings and structures.

2. Relevance
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.
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. 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.

3. Problem statement
The study is based on a laminated wooden multi-span beam with rational reinforcement. The rational reinforcement refers to the installation of reinforcement whips in the places of the greatest action of the moment, which contributes to the distribution of stress strain.

A three-span continuous beam with reinforcement by individual reinforcement bars in spans and supports was adopted as a design scheme for numerical experiment and further testing of models. Diagram of the beam is shown in Figure 1.

![Diagram of the beam](image.png)

Figure 1. The scheme is under consideration of the beam (half length).

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.

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

The stage of conditionally elastic work is characterized by the value of deformations that do not exceed the limit values of elastic deformations of wood and reinforcement. When unloading reinforced elements at this stage, there are no residual deformations or they are so insignificant that they can be neglected. Due to the fact that even at low stresses the linear relationship between stresses and deformations 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 significant plastic deformations in the compressed fibers of wood, and then in the compressed reinforcement. 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 deformation of wood and reinforcement get the maximum level. There is a destruction of the element, the nature of which depends on the type of reinforcement. Elements with double reinforcement are mainly destroyed by the rupture of stretched wood fibers, and with a single – from the destruction of the compressed non-reinforced zone.
A detailed analysis of the stress-strain state (SSS) of structures at all stages of operation using the finite element method in the Lira software package is performed.

5. Results
During the experiment it was found that the destruction of beams with rational reinforcement occurs only in 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 the structures on the action of shear forces in the supporting sections, thereby increasing the reliability of the structure against collapse. Unlike non-reinforced beams, the strength of beams with rational reinforcement increases by 17 – 20 %, the deformability decreases by 7 – 10 %.

![Figure 2. Normal stress distribution plot for glued laminated beams (half length).](image)

![Figure 3. Normal stress distribution plot for reinforced beam (half length).](image)

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.

6. Summary
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 effectiveness of reinforced wooden structures in comparison with conventional glued is not in doubt: reducing the cross section of reinforced elements (especially height) can reduce the volume of the building and therefore the cost of building enclosing structures and heating; reducing the width of the cross section of the elements makes it possible to use timber with a non-deficit width of 130-150 mm; reducing the size and weight of the elements makes it possible to more effectively solve the issues of storage, transportation and installation of structures.

The results obtained demonstrate the feasibility and effectiveness of the method of strengthening the wooden beams. According to the numerical experiment, the strength ofrationally reinforced three-span beams is increased by 17...20% compared to solid-wood beams, and the deformability is reduced by 7...10%.

References
[1] Roshchina S, Lisyatnikov M and Koscheev A 2018 J. MATEC Web of conf. 251 03020
[2] Yoshihara H 2009 J. Constr. and build. mat. 23 3537–45
[3] Augeard E, Michel L and Ferrier E 2018 J. Constr. and build. mat. 191 812–25
[4] Roshchina S, Lukin M, Lukina A, Sergeyev M and Lisyatnikov M 2015 J. of app. engin. res. 24 45307-12
[5] Raftery G and Whelan C 2014 J. Constr. and build. mat. 52 209–20
[6] Grunwald C, Kaufmann M, Alter B, Valle T and Tannert T 2018 J. Comp. struct. 202 47–59
[7] Fossetti M, Minaft G and Papia M 2015 *J. Constr. and build. mat.* **95** 54–64
[8] Roschina S I, Lukin M V, Lisyatnikov M S, Sergeyev M S 2017 Reconstruction of coating by a single-stage adjustment of a lind-fitting factory in the city of vyazniki *Izvestiya Vysshikh Uchebnykh Zavedenii Seriya Teknologiya Tekstil'noi Promyshlennosti* **370**(4) pp 226-230
[9] Roschina S I, Ryazanov M A, Shishov I I, Repin V A 2017 Theoretical and experimental determination of probibes of ribbed plates in the composition of assembly-monolithic coating of industrial building *Construction and reconstruction* **5**(73) pp 50-57
[10] Jasienko J and Nowak T 2014 *J. Constr. and build. mat.* **63** 81–8
[11] Nadir Y, Nagarajan P, Ameen M and Arif M 2016 *J. Constr. and build. mat.* **112** 547–55
[12] Corradi M, Thuc P, Poologanathan K and Osofero A 2018 *J. Comp. struct.* **206** 610–20
[13] Roshchina S, Lukin M, Lukina A and Lisyatnikov M 2015 *Forest Engin. J.* **3**(19) 183–90
[14] Presekin V and Rastorguev G 2010 Fundamentals of the finite element method in mechanics of deformable bodies (Novosibirsk: NgTU) 238 p
[15] Iliin V, Karpov A and Maslennikov A 1990 Numerical Methods for Solving the Problems of Building Mechanics ed V P Iliin (Moscow: Hight school) 349 p