Reconstruction of Industrial Buildings with Replacement of Floors with Wood-Composite

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Abstract. The article emphasizes the importance of involving unused construction objects in the economy, while preserving their historical value. A variant of the reconstruction of floors based on tree-composite beams is proposed. The design work was carried out and the optimal variant of the work was identified. The relevance of this topic is due to the fact that the problem has a global scale, in most cases they are trying to solve it by demolishing a cultural heritage object, or replacing wooden floors with reinforced concrete or metal structures. The purpose of the published work is to propose an option for the possible return of functionality to construction objects while preserving them as a cultural heritage, using new wooden bending elements with elements of composite reinforcement.

1. Introduction
St. Petersburg, one of the most beautiful cities in Russia. However, there is also not ceremonial St. Petersburg. Most of the former industrial buildings erected in the 18th-19th centuries have long been in need of major repairs or are simply abandoned. According to very superficial estimates, the area of industrial buildings requiring major repairs and complete replacement of floors is at least 2.6 million m² [1-2]. Of course, the real number of buildings in St. Petersburg requiring replacement of old wooden floors is much and much more. There are more than 15 such buildings in the Moskovsky district alone [3-4].

Figure 1. The building of the St. Petersburg Cold Factory No. 1, designed by the architect Alexander Fedorovich Golenzovsky in 1914. Figure 2. The territory of the abandoned factory "Red Triangle", nab. Obvodny Canal, built in 1860 by a Russian-American manufactory.
Their historical value does not allow these objects to be demolished, and the bearing capacity of most of the foundations and wall structures of these buildings is not able to withstand even the calculated weight of modern floors.

From the economic point of view, any unused facility is a loss of hundreds of millions of rubles from not being involved in the economy, and the cost of unused land. Unresolved financial and technological issues lead to the fact that these buildings do not find investors, stand idle, collapsing further, and by their destruction spoil the appearance of our city [5-6].

The only correct solution for these objects is the reconstruction of floors using wooden beams, however, the existing design solutions will not allow, without increasing the height of the ceiling and the load on the supporting structures, to cover large spans of industrial buildings without increasing the number of supports.

2. Statement of research tasks
The relevance of this topic is due to the fact that the problem has a global scale and concerns not only St. reinforced concrete or metal structures.

The purpose of the published work is to propose a variant of the possible return of functionality to construction objects while preserving them as a cultural heritage, using new wooden bending elements with elements of composite reinforcement.

Research objectives: development of structural and technological solutions, calculations and comparisons of wooden elements reinforced with composite materials in various ways, and the choice of the optimal solution [7-8].

It must be admitted that the issues of strengthening wooden structures were constantly of interest to engineers, the development process was always complicated by the anisotropy of wood, low strength of wood during shrinkage, chipping, stretching along the fiber, fatigue of wood under prolonged exposure to external design loads, and crushing. Over time, more and more new connections of bending elements were created: metal-wood trusses, arches, beams, which, in addition to rod elements and anchors, metal lamellar pins [9-10].

Connections, by the nature of their work, are divided by:
- stops and notches (the most reliable in terms of the nature of the work, the forces that arise in them are less than their bearing capacity, respectively, such connections do not require calculation; the pinch-groove system allows non-calibration installation, parts are much easier to replace);
- dowels and pads (compression links);
- pins-bolts, plates, pins (bending ties);
- bolts, nails, screws, clamps, and other steel ties (tensile or shear);
- adhesive seams (shear bonds are considered the most progressive connection, have sufficient solidity, with a base on synthetic adhesives, allow the creation of structures of various shapes and sizes, are resistant to water and chemical aggressive environments).

3. Problem statement
The development of composite materials as reinforcement elements, wooden structures, using the example of glued-in rods, began at the end of the Second World War. The lack of metal, its corrosiveness, contributed to the widespread introduction of fiberglass reinforcement into the industry. Wood-plastic structures are still actively used in Russia in the construction of large warehouses for storing mineral salts, ores and fertilizers, where it is not possible to use metal. Research has been carried out on high-strength fiberglass plastics of the AG-4s type, development of prestressed fiberglass reinforcement [11-12].

The advantage of composite materials: they increase the bearing capacity and deformation properties of the reinforced elements - from 10% to 60%, are lightweight, resistant to aggressive media, are absolute dielectrics and are not magnetized.
4. Theoretical part

Types and features of polymer composites, depending on the raw materials used and production methods:

- mixtures of resin and fiberglass with spiral transverse corrugation - fiberglass reinforcement ASP,
- basalt fibers and resins with longitudinal corrugation - ABP basalt-plastic reinforcement,
- thermoplastic polymers and glass fibers, with transverse corrugation - glass-reinforced polyethylene terephthalate ASPET,
- carbon fiber reinforcement made of hydrocarbon fiber — AUP.

Recently, builders have begun to pay more and more attention to the construction of LVL beams: modern LVL beams are able to take significant loads, and have much less flexibility, unlike ordinary wood, moisture-resistant, unlike metal, they are not exposed to the effects of a chemically aggressive environment.

For gluing LVL beams, thermosetting resins, KB-3 phenol-formaldehyde adhesives and RF-12 resorcinol glue are used. The tensile strength of the seams is small and is approximately equal to the tensile strength of wood across the grain [13-14].

When operating floors on wooden beams, various kinds of deformations and defects can occur: the formation of fungus and mold, rotting of individual elements, flattening of wood, cracks in beams, excessive deflections and displacement of slabs from the plane, displacement of slabs relative to one another, chipping of elements in the stretched zone etc.

Elimination of most of these defects requires major repairs or reconstruction of floors.

As a rule, most of the work carried out is carried out with the temporary or permanent removal of the wooden element, which begins with the removal of the elements of the interbeam filling.

When reconstructing floors with partial preservation of previously existing beam supports: disassemble the interbeam filling, restore or arrange a new coating and filling.

The main research question: the joint work of basalt reinforcement, glass horn and LVL beams.

Reinforcing reinforcement is installed to increase the bearing capacity, their location is often in the lower zone of the section, the bar of which is glued in at an angle.

The weight of the composite rebar is much lighter than the weight of the metal rebar. The following is an algorithm of calculations in the PC SolidWorks Simulation (Figure 8), in relation to the investigated composite wooden beam with glued-in basalt-plastic rods, combined into an assembly model, and constraints are defined. The previously calculated loads in the form of concentrated forces in thirds of the span are applied to the model (Figure 2). Component pins are defined [15-16].

![Figure 3. Grid of elements.](image-url)
The calculation results of composite wooden beams with glued-in basalt-plastic rods in the form of stresses, displacements and deformations are shown in Figures 4, 5, 6. The ultimate deflection for the structure is: \( \frac{l_0}{250} = \frac{600}{250} = 2.4 \) cm. Design bending resistance: \( R_i = 21 \) MPa.

![Figure 4](image1.png)

**Figure 4.** Deflection of a composite wooden beam with transversely glued in rods under loads in thirds of the span of 13.671 kN.

The work of a composite wooden beam with obliquely glued basalt-plastic rods in a static linear analysis.

![Figure 5](image2.png)

**Figure 5.** Map of distribution of normal stresses at loads in thirds of the span of 13.671 kN.
Figure 6. Deflection of a composite wooden beam with obliquely glued rods under loads in thirds of the span of 13.671 kN.

5. Practical relevance
After analyzing the results obtained, the following conclusions can be drawn:

1. The discrepancy between the results does not exceed 5%, which allows us to conclude about the correct selected design model, and the possibility of using basalt plastic, in order to improve the final quality and work of joining wooden beams;

2. Working a braced polybeam shows good results in deflection, normal and shear stresses. Such a beam can be used in construction [17-18].

3. A composite beam with glued-in basalt rods across the fibers reaches the ultimate deflection at a load of 17.5 kN; a composite beam with rods glued at an angle of 45 ° to the fibers reaches the ultimate deflection at a load of 20.05 kN. Thus, the deformability of a composite beam with obliquely glued ties is reduced by 9% compared to a transverse connection [19-20].

4. A composite beam with basalt rods glued across the fibers reaches its ultimate strength at a load of 29.5 kN; a composite beam with rods glued at an angle of 45 ° to the fibers reaches its ultimate strength under a load of 35 kN. Thus, the load-bearing capacity is increased by about 4%.

6. Conclusion
Strengthening the structure, as one of the ways to increase the bearing capacity, is still frequently used today, however, previously proposed solutions included the use of only metal inserts, which increases the load on the supporting structures, increases the cross-sectional area, and reduces corrosion resistance.

The urgency of the problem lies in the development of a connection of wooden structures with a higher load-bearing capacity, but subject to aggressive effects and not increasing the cross-sectional area. Polymer composites, as a replacement for steel materials, have high strength characteristics, low density and are resistant to the influence of the external environment.

Known examples of reinforcement with polymer composites, such as fiberglass, do not take into account a number of characteristics of wood products, such as the effect of moisture on the size of wood, the work of wood on crushing. Experimental and numerical studies were carried out on the basis of creating a 3D model using the finite element method in the SolidWorks software. The studies carried out on the joints of wooden beams made of LVL beams with basalt-plastic rods glued at an angle to the fibers showed that the connection works better and is less expensive in materials than the
connection with transversely glued steel rods. The bonding is less labor intensive compared to adhesive bonding in general due to the lack of adhesive components and the work of two materials.

7. References
[1] Abu-Khasan M, Egorov V, Rozantseva N, Kuprava L 2018 Load carrying wood and metal structures of trusses of covering of long spanned rail depot IOP Conference Series: Materials Science and Engineering 463(4) 042075 DOI: 10.1088/1757-899X/463/4/042075
[2] Veselov V, Abu-Khasan M, Egorov V 2020 Innovative design of wooden beams in the far North IOP conference series: materials science and engineering DOI: 10.1088/1757-899X/753/2/022024
[3] Abu-Khasan M, Rozantseva N, Egorov V, Kuprava L 2020 Prefabricated Dome Structures with Walls Made of Soil Composites and Urea-Formaldehyde Foam Insulation (UFFI) as a Way to Solve Transport Infrastructure Problems in Permafrost Regions IOP conference series: materials science and engineering DOI: 10.1088/1757-899X/753/2/022022
[4] Temnev V, Abu-Khasan M, Charnik D, Kuprava L, Egorov V 2020 The mesh of shells of a bionic type to be operated in extreme habitats IOP conference series: materials science and engineering DOI: 10.1088/1757-899X/753/2/022023
[5] Egorov V, Kravchenko A, Abu-Khasan M 2020 The Application of Evolutional Algorithm Optimization of Sprengel Systems of Transport Buildings and Structures for Northern Districts IOP conference series: materials science and engineering DOI: 10.1088/1757-899X/753/2/022020
[6] Egorov V, Abu-Khasan M, Shikova V 2020 The systems of reservation of bearing structures coatings of transport buildings and constructions for northern areas IOP conference series: materials science and engineering DOI: 10.1088/1757-899X/753/2/022021
[7] Abu-Khasan M, Egorov V 2020 The Influence of Different Types of Reinforcement on the Deformation Characteristics of Clay Soil in the Conditions of Seasonal Freezing and Thawing IOP conference series: materials science and engineering DOI: 10.1088/1757-899X/753/4/042083
[8] Chernykh A K, Gorskhoeva E E, Dergachev A I, Abu-Khasan M S Use of Integrated Accounting Methods for Calculation of the Profile Volume of Embankments IOP Conference Series: Earth and Environmental Science DOI: 10.1088/1755-1315/459/6/062008
[9] Vilkov V B, Dergachev A I, Chernykh A K, Abu-Khasan M S 2020 On the Concept of Solving a Fuzzy Cooperative Game with Side Payments 2020 International Multi-Conference on Industrial Engineering and Modern Technologies FarEastCon 2020 9271558 DOI: 10.1109/FarEastCon50210.2020.9271558
[10] Egorov V, Belyy G Nonlinear properties of hybrid construction of coatings of buildings and structures E3S Web of Conferences 217 01001 DOI: 10.1051/e3sconf/202021701001
[11] Rusanova E, Abu-Khasan M, Sakharova A 2019 The control waste of communal services IOP Conference Series: 2019 Earth and Environmental Science 272(2) 022109 DOI: 10.1088/1755-1315/272/2/022109
[12] Abu-Khasan M, Solovyova V, Solovyov D 2018 High-strength Concrete with new organic mineral complex admixture 2018-MATEC Web of Conferences 193 03019 DOI: 10.1051/matecconf/201819303019
[13] Rusanova E, Abu-Khasan M, Egorov V 2020 Influence of wooden cross ties on the surrounding medium at operation of transport objects in cold regions IOP conference series: materials science and engineering DOI: 10.1088/1757-899X/753/2/022042
[14] Rusanova E, Abu-Khasan M, Egorov V 2020 The complex evaluation of geo eco-protective technologies taking into account the influence of negative temperatures IOP conference series: materials science and engineering DOI: 10.1088/1757-899X/753/2/022042
[15] Dergachev A, Dergachev S, Perepechenov A, Abu-Khasan M 2019 Fundamentals of Algorithmization of Functional and Computational Problems 2019 International Multi-Conference
on Industrial Engineering and Modern Technologies FarEastCon 2019 8933942 DOI: 10.1109/FarEastCon.2019.8933942

[16] Sakharova A S, Svatovskaya L B, Baidarashvili M M, Petriaev A V 2017 Detoxication of the heavy metal ions in water resources by means of mineral. Bearing Capacity of Roads, Railways and Airfields Proceedings of the 10th International Conference on the Bearing Capacity of Roads, Railways and Airfields, BCRRA 2017 pp 2187-2190 DOI: 10.1201/9781315100333-309

[17] Sakharova A, Svatovskaya L, Baidarashvili M, Petriaev A 2016 Sustainable Development in Transport Construction through the Use of the Geocoppotive Technologies Procedia Engineering 143 pp 1401-1408 DOI: 10.1016/j.proeng.2016.06.165

[18] Sakharova A S, Svatovskaya L B, Baidarashvilly M M, Petriaev A V 2014 Building wastes and cement clinker using in the geocoppotive technologies in transport construction Computer Methods and Recent Advances in Geomechanics - Proceedings of the 14th Int. Conference of International Association for Computer Methods and Recent Advances in Geomechanics IACMAG 2014 pp 619-622 DOI: 10.1201/b17435-106

[19] Shershneva M, Sakharova A, Kozlov I Geoecoprotective screens for road construction and operation in cold regions Lecture Notes in Civil Engineering 50 pp 347-356 DOI: 10.1007/978-981-15-0454-9_36

[20] Shershneva M, Puzanova Y, Sakharova A Geoecoprotective technologies from heavy metal ions pollution for transport construction in permafrost regions Lecture Notes in Civil Engineering 50 pp 329-338 DOI: 10.1007/978-981-15-0454-9_34