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To cite this article: L B Aruova *et al* 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **829** 012017

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Cyclic Tests of Joints of Glued Wooden Structures

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Abstract. The use of large-span structures made of glued wood in countries with large timber reserves in Finland, Sweden, Norway, Russia, the USA and Canada has shown that this can be quite interesting and expressive from the architectural position of the building. Sports facilities, sports and sports facilities, sports facilities, sports and cultural facilities. The practice of building bridges made of glued wood in these countries shows that they have been in operation for decades without additional operating costs. Glued wood in modern conditions, when productive flame retardants are used that protect it from fire, antiseptics from possible decay expand the scope of such structures. One of the important obstacles to the limiting applications of large-span glued wooden structures is the complexity of the solution nodes. Bearing structures experience difficulties when exposed to static and cyclic loads. Cyclic loads can be caused by wind loads, production equipment, traffic, and seismic processes. Reinforcement in wood, reinforcement and reinforcement under load. Wood and metal are resistant to cyclic loads. Studies will be conducted at the border of the elements to be glued. This article presents the results of tests for the effects of static and cyclic loads on reinforcement from a 14 mm reinforcing bar of class A5 on FRF-50T along natural-sized glued wood fibers. Certain coefficients of the endurance of the compound when exposed to cyclic loads with two load asymmetry coefficients $p = 0.5$ and $p = 0.2$.

1. Introduction

Laminated wood is increasingly being used as the main load-bearing structure for public buildings, including for entertainment purposes. The use of large-span structures in Europe and Canada from glued wood has shown in practice that it can be quite interesting and expressive from the architectural position of the building. Glued wood in modern conditions, when productive flame retardants are used that protect it from fire, antiseptics from possible decay expand the field of application of such structures [1,2].



One of the important obstacles limiting the use of designs - the complexity of the solution nodes. Since the 1980s, research has been actively conducted in Europe on the development of units of wooden structures on glued and screwed steel rods of long-span structures [3]. Climate change in recent decades causes a significant variety of disasters in nature, it is the temperature changes that cause an increase in wind load in the form of tornadoes, storms, hurricanes. For example, every year the number of hurricanes along the southeastern coast of the United States increases and leads to the destruction of the first coating of private homes. Studies of the work have shown that the destruction of the roof from the effects of the hurricane occurred on the walls of panels made mainly on nails [4]. Studies of structures and their components on the effects of static loads are not sufficient, since a number of structures are experiencing dynamic loads. For example, for bridge structures made of laminated wood, the impact of dynamic loads resulting from uneven movement of load-lifting vehicles along one of the tracks is especially important [5]. Three types of joints are used in wooden structures: connections on cuttings-frontal, in a half-tree and others; mechanical connecting parts using bolts, nails, bands and brackets, metal fasteners - lining, gussets and other; adhesive joints, which allowed in the production of wood products to produce structures of considerable size, any configuration and any size.

The third type of compounds on adhesives allowed to revive wood as a constructive material in the field of construction of public buildings. The only obstacle is the complexity of solving nodes. In the design and application of large-span structures due to the impossibility of transportation and installation, large structures must be divided into elements that in the construction conditions must be connected. These compounds are subject to stringent requirements for strength, compliance, fire resistance and durability.

2. Experiment objectives

In this work, the task was to study the work of the joint on glued steel rods on the effect of static and cyclic loads. The requirements are set for the nodes: the strength of the connection should be comparable with the strength of the connected elements; nodes must meet the requirements of universality, in the manufacture of easily assembled at the construction site; nodes of structures for glue and adjacent wood (fiber) during operation perceive both static and cyclic loads.

In modern construction, when the nature of the greenhouse effect provokes significant wind loads in the form of tornadoes, storms and an increase in the pressure of the wind, taking into account the effect of cyclic loading becomes important [2].

3. Research methodology

Studies in this work were conducted on samples of the prisms of the natural sizes of laminated wood, which is along the Central axis was placed the steel rods with a diameter of 14mm class A5 along the fibers on the glue $\Phi P\Phi 50T$ [6]. (figure 1).

Static short-term pull-out tests of the samples were carried out on a Shopper tensile testing machine at a scale of 100 kN with a division price of 500 N. The load applied was approximately 1/10 of the load. The sample was suspended from the upper grip of the press using a frame. The prism was mounted by the supporting end on a steel plate of a frame 25 mm thick having a central square hole of 70x70 mm in size. A load was applied to the protruding end of the rod, the sample was centered using a ball joint with a central hole for the passage of reinforcement. When tested for static loads, samples were tested at a speed of 5 mm per minute.

A load of about 500 N was applied and alignment checked. Prism samples were tested for static and cyclic loads according to the scheme of pulling the rod out of the prism with an emphasis on the end face (figure 2).

The samples were tested for the effect of a cyclic load on pulling a rod glued into the wood using the GRM-1 universal hydraulic testing machine using a frame. The machine consists of a control panel and a pulsator.

Some of the samples were tested on a specially manufactured installation with an eccentric type pulsator. The pulsator consisted of a welded frame 1, fixed to the foundation with anchor bolts. A lever 2 is pivotally mounted on the frame.

The power element is an eccentric type vibrator, which is pivotally mounted on the lever 4 to the lever 2. The vibrator consists of a housing 5 and two gears 6 engaged with eccentrics 7. A flexible shaft from a direct current electric motor is connected to one of the gears, the rotation frequency of which can be adjusted. A cycle counter is connected to it. To create a static load, weights are hung on the vibrator 8, the load is transferred to the sample 11 through the lever 2 and the U-shaped rod 9. A sample installed in the frame 12 is fastened to the U-shaped rod using the collet. The frame is rigidly attached to the power floor face (figure 3).

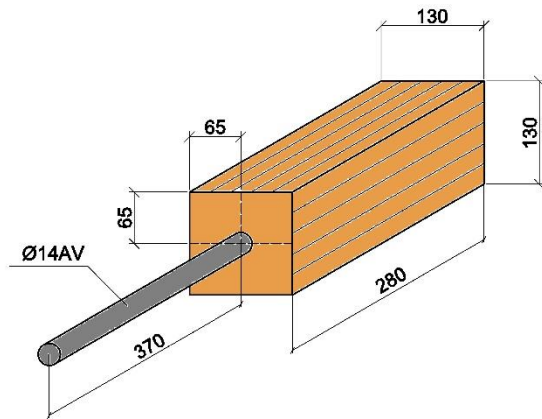


Figure 1. Samples of the prism.

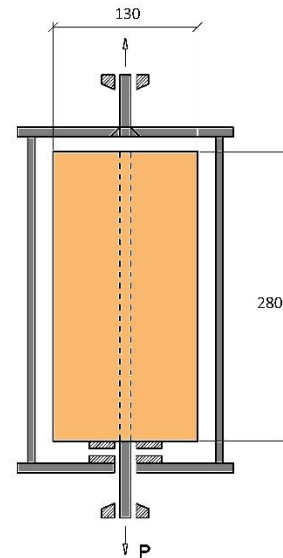


Figure 2. The scheme of testing samples of prisms to pull out the rod according to the scheme with an emphasis on the end.

4. Obtained result

The results of static tests for pulling out a steel reinforcing bar glued wooden prismatic sizes are presented in table 1.

Table 1. Test results.

Breaking load P, [H]	Average value P, [H]	Maximum tangential stress τ_i , [MPa]	Static characteristics			
			τ_i , [MPa]	S_i , [MPa]	γ_i , [%]	P, [%]
93000	92200	7,56	7,496	4,97	5,4	2,4
95000		7,72				
98000		7,97				
85000		6,91				
90000		7,32				

The nature of the destruction of all samples on wood adjacent to the connection. Together with the core, a piece of wood breaks out of the boundary layer, i.e., destruction occurs as a result of chipping. Cyclic testing of samples for pulling was performed in the range of Pmax and Pmin. Where Pmax was taken in fractions of a short-term load.

The frequency of application of the pulsating load was taken 240-300 cycles per minute. The number of cycles during destruction was recorded by a mechanical counter. When the sample was destroyed, the pulsator was automatically turned off.

Tests for cyclic loads were carried out at two cycle asymmetry coefficients $\rho = 0.5$ and $\rho = 0.2$. Only 29 samples were tested: at $\rho = 0.5$ - 20 pieces and $\rho = 0.2$ - 9 pieces.

The maximum stresses at $\rho = 0.5$ were taken 52; 39; 32.5; 26 and 23 kN, which corresponded to the level of load application: 0.81; 0.61; 0.51; 0.41 and, 32 of the short-term strength of the connection equal to 640 MPa.

At $\rho = 0.2$, tests were performed at voltages of 51.0; 32.5; 26.0 and 11.9kN, which corresponds to the level of 0.8; 0.51; 0.41 and 0.28 of σ_{cr} .

From each level, 4 to 5 samples were tested with the exception of the lower level, where an increase in the number of test samples did not make sense, since at the previous level the samples were destroyed by fatigue of the reinforcing bar or failure was not observed at a value of 2 2 106 cycles. (see table 2 and 3).

Table 2. Results of tests of samples on endurance at $\rho=0.5$.

Mark sample	Loading level (σ/σ_{kp})	Nature of destruction	The number of cycles to failure		Average value (lgN)
			N	lgN	
АЦ-1	0.81	on the glue and surrounding wood (fiber)	3000	3,48	3,73
АЦ-2			18000	4,25	
АЦ-3			1500	3,18	
АЦ-4			12000	4,08	
АЦ-5			45000	3,65	
БЦ -1	0.61	on the rod	18300	4,26	4,84
БЦ -2			15000	4,18	
БЦ -3		by glue	44500	5,65	
БЦ -4			18000	5,26	
ВЦ-1	0.51	by glue	747000	5,87	5,88
ВЦ-2		on the rod	813200	5,91	
ВЦ-3			577500	5,76	
ВЦ-4			522000	5,72	
ВЦ-5			1135000	6,05	
ДЦ-1	0.41	on the rod	1372000	6,14	6,14
ДЦ-2			1407000	6,15	
ДЦ-3			823500	5,92	
ДЦ-4			2031200	>6,3	
ГЦ-1	0.32	without destruction	2565500	>6,3	6,3
ГЦ-2			2026200	>6,3	

Table 3. Results of tests of samples on endurance at $\rho=0.5$.

Mark sample	Loading level (σ/σ_{kp})	Nature of destruction	The number of cycles to failure		Average value (lgN)
			N	lgN	
КЦ-1	0,8	on the glue and surrounding wood (fiber)	2500	3,4	3,43
КЦ-2			3000	3,47	
ЛЦ-1		by glue	327145	5,51	5,25
ЛЦ-2			75601	4,88	
ЛЦ-3		on the rod	234173	5,37	

MIИ -1	0,61	by glue	368500	5,57	5,6
MIИ -2			421000	5,62	
HIИ -1		without destruction	$2 \cdot 10^6$	>6,3	>6,3
HIИ -2			$2 \cdot 10^6$	>6,3	

According to the results of testing the samples, it was found that the samples were destroyed either by glue or by a metal rod. The table shows that at low levels of cyclic load application, destruction is observed mainly along the reinforcing bar. This is due to the fact that high-strength metal has a low endurance limit. The destruction of the metal rod in the samples occurred at the places of exit from the press grip. At high levels of application of the load of destruction on the contact layer of adhesive-wood, as with a static load.

Based on the calculations for these asymmetry coefficients, endurance coefficients for $\rho = 0.5 - 0.42$ for $\rho = 0.2 - 0.31$. By the method of Zhurkova S.I. [7] predicted durability under the action of cyclic loads for joints reinforcing glued in wood on glue FRF-50T. The relationship between the stress level σ / σ_{cr} and the number of cycles to failure N in the semi-log coordinates for two asymmetry coefficients is shown in figure 4.

For the asymmetry coefficient $\rho = 0.5$ by the least square method, the dependence is obtained:

$$\sigma / \sigma_{cr} = 1.4 - 0.155 \lg N \text{ with the correlation coefficient of the equation } \tau = 0.91$$

For $\rho = 0.2$, the dependence $\sigma / \sigma_{cr} = 1.39 - 0.172 \log N$ was obtained for the correlation coefficient of the equation $\tau = 0.84$. Deviations of experimental values from theoretical do not exceed 5%.

5. Conclusion

On the basis of the performed experimental studies on the effect of static and cyclic loads on the connections of the elements of wooden structures on the glued fibers of reinforcing bars with FGF-50T glue, the following conclusions are made: the endurance coefficients of the compound under the influence of cyclic loads at two asymmetry coefficients $\rho = 0.5$ and $\rho = 0.2$ are 0.42 and 0.31, respectively.

The investigated compounds of glued wooden structures are used at facilities in Kazakhstan, where there is a significant wind load. This tennis court SK “Daulet” in Nur-Sultan, sports club “Elkonys” in the recreation area Bayanaul and others.

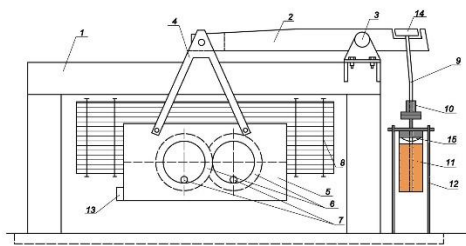


Figure 3. Eccentric type pulsator circuit: 1- pulsator frame; 2- lever; 3 hinge; 4 suspension; 5- vibrator housing; 6-gears; 7- eccentrics; 8-loads; 9-U-shaped traction; 10 collet; 11 sample; 12-frame; 13- limit switch; 14-force meter; 15- hinge.

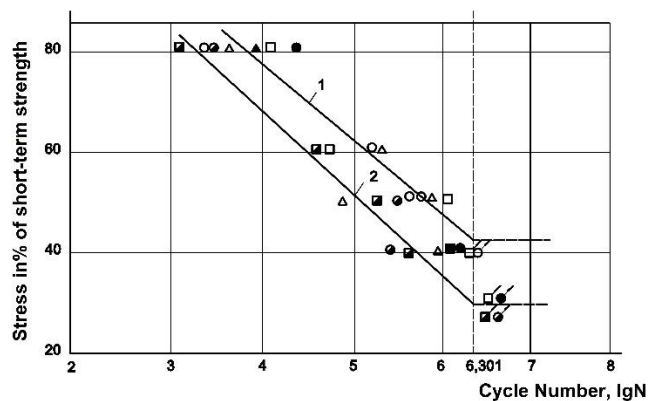


Figure 4. Curves of endurance with $\rho = 0.5$ and $\rho = 0.2$ connection of the reinforcement with wood glue on a modified FGF-50T (●▲ experimental points; - - - direct correlation equation)

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