Method of Experimental Research of New Construction of Beams from Glued Wood with Combined Reinforcement

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Abstract. Structures of glued wood have significant advantages in comparison with structures made of metal or reinforced concrete (less mass, better resistance to the action of chemically aggressive environments, high fire resistance, aesthetic attractiveness, eco-friendliness). However, at the same time, scientists are looking for new ways to improve the characteristics of such wood. We also proposed a new construction of combined reinforcement of glued beams in which the steel bar reinforcement of the periodic profile was arranged in the grooves of the compressed zone, and in the stretched zone reinforcement was carried out with the external composite tape made of carbon fiber. This combination increases both rigidity and bearing capacity of the elements that we are testing from glued wood for work on transverse bending. The method of experimental research on the transverse bend of a new construction of glued beam beams with combined reinforcement was developed. The proposed method fully allows us to examine and experimentally investigate the stress-strain state under load of glued beams from combined reinforcement at different stages of their work.

1. Introduction

Structures of glued wood [1–4] have significant advantages in comparison with structures made of metal or reinforced concrete (less mass, better resistance to the action of chemically aggressive environments, high fire resistance, aesthetic attractiveness, eco-friendliness). Glued wood in comparison to solid has greater durability and does not change geometric dimensions with time or change in moisture, does not have significant shrinkage and swelling. However, at the same time, scientists are looking for new ways to improve the characteristics of such wood and improve the elements and structures based on it.

Various methods of reinforcing glued wooden structures were proposed and investigated for the improvement of the elements of wood, enhancement of bearing capacity, stiffness [5–8]. This has given a certain effect, such as the ability to reduce the overall dimensions of the cross section of the reinforced element of laminated wood and increase the spans that can be overlapped. We also proposed a new construction of combined reinforcement of glued beams in which the steel bar reinforcement of the periodic profile was arranged in the grooves of the compressed zone, and in the stretched zone reinforcement was carried out with the external composite tape made of carbon fiber Sika CarboDur S-512. This combination increases both rigidity and bearing capacity of the elements that we are testing from glued wood for work on transverse bending.
The aim of the work is to consider the research methodology of the new design of glued wooden beams with combined reinforcement, and in the future to receive and process new results of experimental tests of this type of structures.

2. Materials and Research Results

For testing several series of glued beams were manufactured with dimensions of 100 x 150 mm and a length of 3000 mm. In this case, pine boards were used in a thickness of 25 mm. The first series consisted of two unrecorded beams which were tested by a one-time short-term load to determine the bearing capacity. All elements of the second and third series were reinforced in combination and differed only in some ways of anchoring the composite tape in the stretched beam zone.

During the formation of a beam from a package of gluing boards, in the pre-made grooves of the penultimate board of the upper compressed zone two rods with a diameter of 12 mm from a steel of a periodic profile of the class A500S and with the help of epoxy EDP with a filler of quartz sand in the ratio 1 : 2 were glued. Billets from the boards were placed one by one with the layered drawing of resorcinol adhesive on the surface of two faces to the required design height. Gluing a package of boards was carried out on a special stand which ensured the correct position of the glued components under pressure. After a three-day standstill at a temperature of about 20° C and humidity of the ambient air, 65% for complete hardening of the glue began to finish the treatment of the test beams, namely the planing to the sizes of the design cross-section 100 x 150 mm. After this, an element in the stretched zone was glued with SikaDur-30 adhesive with a Sika CarboDur S-512 carbon fiber tape of 1.2 mm thick and 25 mm wide.

In the course of experimental research, priority was given to tracking the relative growth of relative deformations of wood at the height of the calculated cross-section in the zone of pure transverse bend, both in non-reinforced and in reinforced elements of glued wood. Also, the transformation of the growth of deformations of compressed and extended armature, the compatibility of their work, the establishment of a stressed-deformed state at all stages of their work for the growth of short-term external load was investigated. Determination was also made on the pillars, bends within the span and under the laminated forces of the beam.

To determine the relative deformations of wood, in the middle of the passage along the perimeter of the cross-section, the beam glued strain gauges with a base of 20 mm with a resistance of 201 ± 0.7 Ohm (figure 1a). All sensors were glued with a glue BF-2, and the surface in the places where they were placed was pre-polished with sandpaper and degreased [9]. Sensor imaging data was recorded using a strain gauge measuring system CIIT and recorded on a PC. On metal reinforcement strain gauges are glued before pasting it into pre-formed grooves in the board of the compressed beam zone. The grooves in size were larger by 1-2 mm from the diameter of the fittings. The strain gauges were placed in the middle of the span (figure 1b).

![Figure 1. Placement of strain gauge sensors: (a) on the studied beam; (b) on metal reinforcement](image)

(a)

(b)
The electrical signal from the sensors from the metal armature was transmitted through the insulated wire, which was output outwards through specially provided holes in the boards. On the composite tape, strain gauges were stuck in the middle of the span, after the tape was firmly glued to the wooden beams. The layout of the strain gauge location on all elements of the studied beam is shown in figure 2.

![Figure 2. Scheme of location of strain gauges on the studied beam](image)

Before the start of the experimental test, the size of all samples was specified and recorded in the journal of conducting experimental studies. Efforts to the experimental beam-sample were applied with the help of a hydraulic jack and its level was measured with the help of a ring dynamometer. Load from the jack in the form of two symmetrical lumped forces was transferred to the design through a metal traverse. The tests were performed with a single load which was applied in steps of 10% of the anticipated destructive load in accordance with the requirements [10,11]. The shutter speed at each load level was 5-7 minutes. During this time impressions were taken from all the devices installed on the beam.

In the ends of the beams, the MIG-2 indicators were specially fixed (figure 3a). With the help of these indicators, it was possible to slip the metal armature into the grooves during the application of external load. The scheme of the experimental installation with the arrangement of all devices is shown in figure 3.
**Figure 3.** Scheme of the experimental installation when testing the beams of laminated wood with combined reinforcement on the bend: 1) jack; 2) dynamometer; 3) metal traverse; 4) the beam being studied; 5) metal substrate; 6) wooden lining; 7) strain gauges; 8) Steel fittings 2 Ø 12 mm A500C; 9) composite tape reinforcement Sika CarboDur S-512; 10) deflection meter 6-PAO; 11) indicator ICH-10; 12) MIG-2 indicator

To determine the deflection of beams the deflection meter 6-PAO were used. Two deflection meter were located above the supports, two under lumped forces, and one in the middle of the beam in the calculated cross section. The calculation scheme for testing the transverse bend of beams made of laminated wood with combined reinforcement is shown in figure 4 in the form of a freely rolled one flying beam.

**Figure 4.** Scheme for testing bending of wood beams made of laminated wood with combined reinforcement

The beams were one flying and were installed as can be seen from the calculation scheme (figure 4), on two supports one of which was fixed, and the second one was mobile. Wooden napkins were installed to prevent the wood from joining the beams on supports and under lumped forces between the metal plates and the element. The combined work of wood and composite tape reinforcement Sika CarboDur S-512 was fixed using strain gauges in the calculated cross section. Also, observations were made at all stages of the beam at the displacement of the composite tape relative to the wood of the stretched beams zone with the help of special devices at both supports. For this purpose, indicators of a clock type IR-10n with a price of 0.22 mm were used. IR-10n indicators were fixed to specially designed holders, one of which was attached to the tape, and the other to the wood in one definite cross-section of the beam (figure 5b).
Figure 5. Indicators for measuring the displacement of steel: (a) and composite; (b) fittings

The second-row beam combined reinforcements differed from the third-series beams only by way of questioning the composite tape reinforcement Sika CarboDur S-512. So in the beams of the second series of questioning was carried out by gluing the composite tape reinforcement Sika CarboDur S-512 to the wood of the stretched zone of the element. In the beams of the third series, after the hardening of the adhesive layer Sikadur-30, which glued the composite tape reinforcement Sika CarboDur S-512 to the wood, on the supporting areas the tape was anchored by sticking the SikaWrap-230 C adhesive with Sikadur-330 adhesive. The scheme of reinforcement and anchoring of the composite tape reinforcement Sika CarboDur S-512 by the canvas SikaWrap-230 C of the third series of beams is shown in figure 6.

Figure 6. Scheme for reinforcing wooden glued beams and questionnaire for composite tape reinforcement Sika CarboDur S-512 by SikaWrap-230 C
The general view of the experimental test of a beam with combined reinforcement is shown in figure 7.

Figure 7. General view of the beam with combined reinforcement under load

3. Conclusions
The method of experimental research on the transverse bend of a new construction of glued beam beams with combined reinforcement was developed, in which in the grooves of the compressed zone the steel bar reinforcement of the periodic profile was arranged, and the stretched zone was reinforced with the outer composite tape reinforcement of carbon fiber Sika CarboDur S-512.

The proposed method fully allows us to examine and experimentally investigate the stress-strain state under load of glued beams from combined reinforcement at different stages of their work.

The relative deformations of different layers of wood on the height of the calculated cross-section, metal and composite tape reinforcement Sika CarboDur S-512, deflection of beams, and also the joint work of steel and composite reinforcement with compatible wood layers were observed.

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