The Use of Larch Wood in Composite Wood Elements on Inclined Screwed Rods

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Abstract. The article discusses the use of larch wood in wooden elements of a composite section on pliable bonds in the form of oblique metal rods (IRS compounds). The test results of samples of IRS compounds from larch wood on inclined screwed rods are presented. The upper boundary of the region of elastic work of IRS compounds from larch wood and deformation of compounds are determined. A comparative assessment of the bearing capacity and deformability of IRS compounds on screwed rods made of pine wooden elements and larch wood is performed. Based on the test results of compounds, the calculations of bending elements of a composite section with a span of 6 m were performed using the theory of composite rods by A. R. Rzhanitsyn. The effectiveness of the use of larch wood in supporting structures made of solid wood is shown.

1. Introduction

Of structural coniferous wood, pine wood is the most demanded, which has an optimal set of technological properties and strength indicators. However, the raw material resources of pine are currently substantially limited, and for building structures, the possibility of using other types of wood in accordance with the regions of growth should be considered. Such species include larch, the reserves of which in individual regions make it possible to rely on its successful application in load-bearing building structures. Having high strength and durability, larch wood, denser and harder than pine and spruce wood, is more difficult in the technology of drying, machining, gluing and mounting. The use of larch in solid wood structures based on wooden elements of a composite section with joints on pliable bonds in the form of inclined metal rods (IRS) will reduce the volume of mechanical processing and drying of wood, as well as eliminate gluing at the stage of manufacturing structures. The strength and elastic characteristics of larch wood are on average 17-20% higher than the corresponding pine parameters, which is reflected in an increase in the bearing capacity of structures and a decrease in the deformability of joints.

2. Statement of the problem

The purpose of this work is to assess the bearing capacity and deformability of ISR compounds and elements of a composite section made of larch wood compared to traditional designs of pine and spruce. Wooden elements of a composite section are made of beams or edged logs up to 9 m long with mechanical ties that are flexible in contrast to rigid adhesive joints [12-14]. The joint work of several bars forming the cross section of the composite element is ensured by ISR connections on screwed
rods without the use of glue (ISR) [1, 2, 3, 4, 5, 11], which are installed along the length of the structure in accordance with the load application scheme. Tests for a comparative assessment of the bearing capacity and deformability of NMS compounds on screwed rods for pine wood (according to [9]) and larch were performed on symmetric two-section samples (Figure 1.a). Wooden elements with a section of 35x70 mm are made of pine and larch. Inclined metal rods with a diameter of 10 mm with an enlarged thread pitch are installed in a sample of the joint at 45 degrees to the direction of the fibers and the axis of action of the shear force into the pre-drilled holes dot = 7.2 mm.

![Figure 1.](image)

**Figure 1.** The test results of the samples: a) deformation of the ISR-compounds on the screwed rods 10 mm; b - calculated deflections of wooden beams of composite section, taking into account the actual deformations of the ISR joints on the screwed rods 20 mm.

### 3. Tests of the ISR compounds

Tests of NMS compounds from larch wood, including comparison with similar samples of ISR-compounds from pine wood (according to [9]) including deformations and load corresponding to the upper boundary of the elastic region of the ISR-joints in the form of a shear force NI-II and shear stresses of the wood along the thread of an inclined rod, σ-cut I-II are presented in tables 1 and 2, in the graphs in Figure 1.

| Nsh kN | Nst = Nsh/cos45 kN | σ slice MPa | Dp, mm for 3 samples | Deformability, mm/MPa | Larch / Pine |
|-------|----------------------|-------------|---------------------|----------------------|-------------|
| 0     | 0                    | 0           | 0                   | 0.00                 | 0           | 0           |
| 3     | 1.06                 | 0.682       | 0.2                 | 0.17                 | 0.293       | 0.242       | 1.210 |
| 6     | 2.12                 | 1.365       | 0.55                | 0.38                 | 0.403       | 0.280       | 1.437 |
| 9     | 3.18                 | 2.047       | 0.91                | 0.66                 | 0.444       | 0.320       | 1.387 |
| 12    | 4.24                 | 2.730       | 1.28                | 0.97                 | 0.469       | 0.356       | 1.315 |
| 15    | 5.30                 | 3.412       | 1.67                | 1.31                 | 0.489       | 0.384       | 1.274 |
| 18    | 6.36                 | 4.095       | 2.1                 | 1.67                 | 0.513       | 0.409       | 1.255 |
| 21    | 7.43                 | 4.777       | 2.58                | 2.06                 | 0.540       | 0.431       | 1.253 |
| 24    | 8.49                 | 5.460       | 3.12                | 2.47                 | 0.571       | 0.453       | 1.262 |
| 27    | 9.55                 | 6.142       | 3.9                 | 2.96                 | 0.635       | 0.482       | 1.316 |

Table 1. Deformability of samples of ISR compounds on screwed-in rods.
Table 2. Load bearing capacity for larch and pine wood.

| № sample | NI-II , kN | σ slice I-II , MPa |
|----------|------------|--------------------|
|          | Pine       | Larch              | Pine       | Larch |
| 1        | 24,0       | 30,0               | 5,460      | 6,824 |
| 2        | 27,0       | 33,0               | 6,142      | 7,507 |
| 3        | 24,0       | 30,0               | 5,460      | 6,824 |
| Average  | 25,0       | 31,0               | 5,687      | 7,052 |
| LBC by NI-II | 19,2   | 23,85              | Ncalc = NI-II/1,3 |

Within the elastic work of ISR compounds for larch samples, the deformability is 1.31 times less, the bearing capacity according to the criterion of the upper boundary of the elastic work region is 1.24 times greater than in samples of ISR compounds from pine wood. The calculation of the wooden elements of a composite section on pliable connections is performed according to the theory of A.R.Zhanitsyna [6, 7].

4. Results

Using the Theory of A.R. Zhanitsyn and taking into account the actual deformations of the ISR compounds, we consider the work and determine the calculated deflections of the composite wooden elements with a span of 6 m from three beams with a section of each 100x150 (h) mm of larch and pine wood. Joint work of wooden bars is provided by ISR-connections on screwed rods in the amount of 6 pcs. at each half-span of the construction (Figure 1.b). To determine the shear strains of the ISR joints on the screwed rods, we take the strains $D_p$ according to Table 1 as the initial ones, obtained from tests of the samples of the ISR joints on 10 mm screws. Since screws 20 20 mm are used in real designs, we introduce the Kmf coefficient taking into account the scale factor. According to the data of [10] for ISR compounds on screwed rods, Kmf = 1.75. The calculation results are presented in table 3 and in the graph in fig. 1.b.

Table 3. Indicators of the stress-strain state for pine and larch wood element.

| Load N=2P, kN | Stress, MPa | Deformations, mm, connections with rods 20 mm for wood | Deflection L/2 f, mm for wood |
|--------------|-------------|-----------------------------------------------------|-------------------------------|
|              | bend ob     | slice                                               | Pine                         | Larch                        | Pine | Larch |
| 6            | 2,1         | 0,315                                               | 0,161                        | 0,133                        | 4,9  | 4,1   |
| 12           | 4,2         | 0,630                                               | 0,323                        | 0,267                        | 9,7  | 8,2   |
| 18           | 6,3         | 0,944                                               | 0,585                        | 0,435                        | 15,6 | 12,7  |
| 24           | 8,4         | 1,259                                               | 0,868                        | 0,611                        | 21,7 | 17,2  |
| 30           | 10,5        | 1,574                                               | 1,155                        | 0,816                        | 27,8 | 22,0  |
| 36           | 12,5        | 1,889                                               | 1,446                        | 1,037                        | 34,0 | 27,0  |
| 42           | 14,6        | 2,203                                               | 1,741                        | 1,275                        | 40,2 | 32,2  |
| 48           | 16,7        | 2,518                                               | 2,039                        | 1,531                        | 46,4 | 37,6  |
| 54           | 18,8        | 2,833                                               | 2,343                        | 1,792                        | 52,7 | 42,9  |
| 60           | 20,9        | 3,148                                               | 2,658                        | 2,065                        | 59,1 | 48,5  |
| 66           | 23,0        | 3,459                                               | 2,337                        |                              | 53,9 |
Accepting the calculated resistance of larch according to SP 64.13330.2017 “Wooden structures” we see that according to the first group of limiting states, the load-bearing capacity of wooden beams of composite cross-section from pine and larch with symmetrical loading by two concentrated forces in the third span is $2xP = 36 \text{kN}$ and $45 \text{kN}$, which corresponds to the linear design load $q = 8 \text{kN/m}$ and $10 \text{kN/m}$, respectively. Taking the limiting deflection $f_{ult} = 1/250 \ L = 24 \text{mm}$, we see that according to the second group of limiting states, the bearing capacity of composite wooden beams made of pine and larch is $2xP = 26 \text{kN}$ and $33 \text{kN}$, which corresponds to the linear normative load $q_{eq} = 5.8 \text{kN/m}$ and $7.4 \text{kN/m}$, respectively.

5. Summary

Based on the tests and calculations performed, the following conclusions are made:

5.1. Tests of samples of ISR compounds on screwed rods without the use of glue showed that the use of larch wood compared to pine wood leads to an increase in the bearing capacity of ISR compounds on screwed rods by 1.24 times and a decrease in the deformability of compounds by 1.31 times.

5.2. The load $N_{I-II}$, corresponding to the upper boundary of the elastic region of the ISR compounds on screwed rods $10 \text{mm}$, for samples from pine and larch wood averaged $N_{I-II} = 25 \text{kN}$ and $31 \text{kN}$, which corresponds to the design bearing capacity of the samples $N_p = 19.2 \text{kN}$ and $23.85 \text{kN}$ and confirms the effectiveness of the use of larch wood in load-bearing wooden structures with a cross-section with ISR joints on screwed rods.

5.3. Based on the theory of composite rods of A. R. Rzhanitsyn, taking into account the actual deformations of the NMS joints on the screwed-in rods, the calculated bearing capacity of the bent elements of the composite section $bxH = 100x (3x150) \text{mm}$ with a span of $6 \text{m}$ from larch wood was determined. The bearing capacity of beams made of larch beams in the first group of limiting states $q$ foliage $= 10 \text{kN} / \text{m}$, in the second group of limiting states $q$ foliage $n = 7.4 \text{kN} / \text{m}$, which is greater than for the constituent elements of pine wood of the same sizes in $1, 25 - 1.275$ times. The results obtained are consistent with the operating condition coefficient $m_p = 1.2$ established in SP 64.13330.2017, which takes into account wood species in the calculated resistance of the material. The difference does not exceed 6%.

5.4. The use of larch elements in the supporting structures of solid wood contributes to the development of less scarce forest resources in the respective regions and leads, compared with pine wood, to an increase in the carrying capacity of structures in the 1st and 2nd groups of limiting states by 25%.

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