Short-term and long-term longitudinal load tests of wooden rods

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Abstract. The purpose of the experimental studies was to verify the reliability of the method for solving the stability problem of centrally compressed rods, taking into account the creep of wood. To achieve this goal, it is necessary to have a diagram of deformations of real wood and experimental data on the behavior of rods of the same wood under continuous load. Experimental studies include short-term axial compression tests of small specimens with recording of load-deformation diagrams, as well as short-term and long-term tests of cores of different flexibility for central compression, the description of which is presented in this article. The authors of the paper obtained the values of critical stresses under longitudinal bending for wooden rods with different lengths and flexibility. These results have a high convergence with the values obtained as a result of theoretical calculations.

1. Introduction

In [1] and [2], the authors obtained analytical expressions of the long-term critical force for the longitudinal bending of a wooden rod taking creep into account. To verify the reliability of the proposed method for solving the stability problem of centrally compressed rods, taking into account the creep of wood, experimental studies were carried out.

Figure 1. Installation diagram.
To test the rods for longitudinal bending, a steel linkage was designed and manufactured. The installation diagram is shown in figure 1. The device of the installation ensures the fulfillment of the theoretical boundary conditions of the test wooden poles and allows for long-term testing with controlled load without the need for additional loading during the creep process.

Calibration of the installation was carried out using a DIN-1 electronic dynamometer. With a force measurement range of 0 ... 100 kN and a relative error limit of force measurement of 0.1 ... 0.5%. For loading weights of 2 and 4 kg were used. Thus, due to the ratio of the shoulders, a 2kg increase in the load created a compressive force on the rod of 31.35 kgf.

2. Experiment description
Sample preparation was carried out in accordance with the requirements of GOST 16483.0-89 “Wood. General requirements for physical and mechanical tests”. Timber was harvested from the plantations in the Novgorod region. A pine with a butt-log portion diameter of 34 cm was selected. A beam of 3.5 m length with a section of 200 × 200 mm was cut from the bole. For testing, samples with a section of 30 × 30 mm with lengths of 540 and 630 mm were made out of the beam. In accordance with the accepted lengths, taking into account the end hinges (25 mm), the rods had flexibility of about 65 and 76. 5 samples of each flexibility were tested for short-term compression and 5 for long-term action of a centrally applied load.

The air temperature in the laboratory during short-term and long-term tests was 21-23 °C, relative humidity was 65 ± 2%. The average humidity of the samples was 10 ± 0.5%.

The ends of the samples were fixed in knife hinges. The horizontalness and alignment of the joints were carefully verified using level and theodolite. The position of the hinges during the tests was controlled using dial gauges with a division price of 0.01 mm. For the most accurate load application along the geometrical axis of the rod, test loads were applied (up to 40% of the expected breaking load). In this case, in the middle of the sample length, the deflection value was fixed using a dial gauge. After each test load, the ends of the sample were displaced relative to the hinge knives until a position was reached at which the indicator arrow did not depart from the initial reference.

The loading of the samples was carried out by the own weight of the lever and manually using weights. The dead weight of the lever and the suspended empty cargo platform was about 30% of the breaking load. This load was smoothly transferred to the sample by lowering the lever with a screw jack.

In short-term tests, the loading rate was about 20 kg per second. The sample was being loaded for about 1.5 minutes. The destruction of the samples was brittle, in the form of an instantaneous rupture of the fibers along the sawtooth surface.

The test results of the rods under short-term loading are presented in table 1.

| Sample № | Length l, cm | Section b×h, cm² | Flexibility λ | Breaking load Ncr, kgf | Breaking stresses σcr, kgf/cm² |
|----------|--------------|-----------------|--------------|---------------------|---------------------------|
| 1        | 56.5         | 3.00×3.01=9.03  | 65           | 3127                | 346                       |
| 2        | 56.5         | 3.00×3.01=9.03  | 65           | 3065                | 339                       |
| 3        | 56.5         | 3.00×3.00=9.00  | 65           | 3284                | 365                       |
| 4        | 56.5         | 3.00×2.99=8.97  | 65           | 3347                | 373                       |
| 5        | 56.5         | 3.01×2.98=8.97  | 65           | 3378                | 377                       |
| 6        | 65.5         | 3.00×3.01=9.03  | 76           | 2698                | 299                       |
| 7        | 65.5         | 2.98×3.01=8.97  | 76           | 2510                | 280                       |
| 8        | 65.5         | 3.00×3.01=9.03  | 76           | 2698                | 299                       |
| 9        | 65.5         | 2.98×3.01=8.97  | 76           | 2573                | 287                       |
| 10       | 65.5         | 3.00×3.01=9.03  | 76           | 2729                | 302                       |
The average value of breaking stresses for rods with a flexibility of 65 is 360 kgf/cm² (coefficient of variation is 5%). The average value of breaking stresses for rods with a flexibility of 76 is 293 kgf/cm² (coefficient of variation is 3%).

After testing the rods, 120 mm high prisms were cut from intact areas and tests were carried out to determine the ultimate strength. According to the results of testing 10 samples for compression along the fibers, the average value of the tensile strength was 578 kgf/cm² (coefficient of variation is 4%).

The loading of the rods during long-term tests was performed step by step. At the first loading step, which amounted to about 30% of the short-term critical load, the rods were centered according to the method described above. Each further loading step was 62.7 kgf (a weight of 4 kg on the platform), and when approaching destruction it was 31.35 kgf (a weight of 2 kg).

At each step, the position of the supports was monitored and the parameters of the stress-strain state of the wooden post were measured, which corresponds to the developed theoretical model for calculating the post.

Deflections in the middle of the sample were measured by dial gauges, with a division value of 0.01 and 0.001 mm. To measure the relative edge deformations, we used resistive strain gages with a base of 10 mm, a sensitivity of $K = 2.19$, and a resistance of $P = 99.6 + 0.1 \, \Omega$. On opposite sides, exactly in the middle of the length of the samples, two sensors were glued — one on each side. To measure the output signals of resistive strain gages, we used the multichannel universal meter-recorder TEREM-4.1 of the scientific and production enterprise Interpribor (Chelyabinsk). The readings from each of the resistive strain gages were taken and automatically recorded in the memory of the device every 4 hours.

Loading to the next stage was carried out if for seven days the deflection of the rod with an accuracy of 0.01 mm remained unchanged. The duration of testing for each sample was about two months.

Figure 2 shows the characteristic curves of the deflection growth over time of one of the samples with flexibility 76 depending on the level of stresses. For convenience, the curves are reduced to a common origin of coordinates.

![Figure 2. Growth curves of rod deflection over time as a function of stress level.](image-url)
The growth curve of the relative edge compression strains of the rod according to the readings of the resistive strain gage at the stage of destructive stresses of 239 kgf/cm² is shown in figure 3.

![Growth curve of edge relative deformations according to strain gauges.](image)

**Figure 3.** Growth curve of edge relative deformations according to strain gauges.

### 3. Conclusion

In general, the obtained curves of the development of creep deformations are in good agreement with the data of experiments on creep of wood by foreign researchers [3, 4].

The experiments showed that the exhaustion of the bearing capacity of wooden rods occurred from a loss of stability during longitudinal bending.

The results of long-term longitudinal bending test of the rods are presented in table 2.

| Sample № | Length l, cm | Section b×h, cm² | Flexibility λ | Breaking load Ncr, kgf | Breaking stresses σcr, kgf/cm² |
|-----------|--------------|------------------|--------------|---------------------|-----------------------------|
| 1         | 56.5         | 3.00×3.01=9.03   | 65           | 2249                | 249                         |
| 2         | 56.5         | 3.00×3.01=9.03   | 65           | 2093                | 232                         |
| 3         | 56.5         | 3.00×3.01=9.03   | 65           | 2312                | 256                         |
| 4         | 56.5         | 2.99×3.01=9.00   | 65           | 2218                | 246                         |
| 5         | 65.5         | 3.00×3.01=9.03   | 76           | 2156                | 239                         |
| 6         | 65.5         | 3.00×3.01=9.03   | 76           | 2218                | 218                         |
| 7         | 65.5         | 2.98×3.01=8.97   | 76           | 1999                | 223                         |
| 8         | 65.5         | 2.98×3.01=8.97   | 76           | 2061                | 230                         |

The average value of breaking stresses for rods with a flexibility of 65 is 246 kgf/cm² (coefficient of variation is 4%). The average value of breaking stresses for rods with flexibility of 76 is 227 kgf/cm² (coefficient of variation is 4%).

The theoretical and experimental results obtained by the author are presented in the form of stress-flexibility relationships in Figure 4. The results are close to the data of L.P. Drozdova, who conducted extensive experiments on the central compression of the elements of wooden structures under long-term load [5].
Figure 4. Theoretical and experimental dependences $\sigma$-$\lambda$ for short-term and long-term central compression of wooden rods.

In figure 4: 1 – theoretical curve of short-term stability; 2 – theoretical curve of long-term bearing capacity taking into account the creep of wood; • – experimental points for short-term loading; • – experimental points during prolonged loading; ○ – experimental points under prolonged loading by L.R.Drozdova.

The maximum deviation of the experimental critical stress values during prolonged loading of wooden rods from theoretical data is less than 12%. Thus, we can conclude that the method for solving the problem of stability of centrally compressed rods taking into account the creep of wood proposed by the authors in [1] and [2] is reliable.

References

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