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FROM LOCAL WOOD MATERIALS PREPARED COMPOSITE CONSTRUCTIONS STRETCH RESISTANCE

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Abstract:

This article experimentally studies the tensile strength and deformation characteristics of prefabricated structures made of local wood materials. The aim of the study is to design environmentally friendly, inexpensive, and durable wooden structures based on local raw materials and evaluate their performance under load.

Keywords: wood structure, elongation, pavlovian, modulus of elasticity, strength, experimental study, deformation, local materials.

Introduction

Wooden structures have long been used in construction as an environmentally friendly, lightweight, and durable material [1]. In recent years, the development of energy-efficient and sustainable building concepts has allowed for the increased use of natural materials, particularly wooden structures [2]. Therefore, studying the tensile strength of local wood species, such as paulownia, pine, poplar, and walnut, is of great scientific and practical importance in our country [3-7]. For this purpose, four types of wood were selected for experimental studies:

1. Paulownia
2. Pine
3. Poplar
4. Walnut

Paulownia is a fast-growing, lightweight, and durable wood with a density of approximately 260–300 kg/m³, an elastic modulus of 8–9 MPa, and excellent tensile strength. Paulownia's fibers are straight, the surface is smooth, and the color is light brown. Its moisture resistance is moderate [3].

Currently, pine is the most widely used medium-density structural material in Uzbekistan, with a density of 500–550 kg/m³, an elastic modulus of 10–12 MPa, and a resinous structure that makes it moisture-resistant and easy to process.

Poplar is lightweight, easy to process, sensitive to moisture, has a density of 400-450 kg/m³, a modulus of elasticity of 8÷10 MPa and is mainly used in construction with low loads and temporary structures [4].

Walnut is one of the densest (650–750 kg/m³) and most durable woods. Its modulus of elasticity is 13–15 MPa. It is widely used in heavily loaded beam and frame structures, as well as in decorative and furniture elements. This wood has a dark brown color, a hard surface, and dense fibers. It is resistant to mechanical stress and has high fracture strength. Accordingly, walnut was used as a "control sample" in the experimental studies [5].

Literature Review

In recent years, the use of timber structures in civil and building engineering has attracted increasing attention due to their environmental sustainability, low weight, renewability, and favorable mechanical properties [6]. Among the various timber structural elements, bending elements such as timber beams play a crucial role in load-bearing systems. Therefore, understanding the bending behavior, deformation characteristics, and strength properties of timber beams has become an important research topic in structural engineering and mechanics [7].

Numerous studies have examined the flexural response of wooden beams using classical beam theories. Euler-Bernoulli beam theory is widely used to estimate deflection, internal forces, and stress distribution in wooden beams subjected to transverse loads [8]. According to these studies, beam deflection is primarily determined by the modulus of elasticity, cross-sectional geometry, span length, and loading conditions. Although this theory yields satisfactory results for small deformations, its applicability to wood is limited due to the anisotropic and heterogeneous nature of wood materials [9]. Despite extensive research on timber beams, several gaps remain in the existing literature. In particular, comprehensive studies combining experimental testing and numerical modeling for various timber species under identical loading conditions and boundary conditions are still limited [10].

In conclusion, the reviewed literature confirms that the flexural behavior of timber beams depends on material properties, environmental conditions, and loading duration. However, further research focused on the characteristics specific to each timber species and combined experimental and numerical analysis is necessary to improve the reliability and performance of timber structures in modern construction practice [11].

Material and Methods

For the experimental studies, wood specimens were prepared in accordance with GOST 16483.10–73. The specimen dimensions were 20×20×300 mm, the moisture content was in the range of 12±2%, and the number of specimens of each type of wood was 5 [12]. The tests were conducted on a universal testing machine, and the maximum tensile stress (σ_{max}), elastic modulus (E), elongation limit, and failure points were recorded. Based on the obtained results, load-strain curves were constructed for each wood specimen, and on this basis, the performance characteristics of the wood with respect to elongation were assessed. The test results were used as a basis for calculating the strength of wooden structures [13]. The effect of wood moisture content on strength was also studied during the study. A significant decrease in tensile strength was observed in damp wood due to a decrease in the adhesion strength between the fibers. Thus, it was determined that the natural moisture content of wood used in construction should be approximately 12–18%. In addition, the strength is also affected by the change in the direction of the fibers relative to the direction of the load: the tensile strength along the direction of the fibers gives the highest value, and in the perpendicular case it is significantly lower .

First, beams of 1 m, 2 m, 3 m length were made for testing from 3-year-old paulownia of the EFTE type and other types of wood, dried according to the established method [7-9]. Samples of the specified size were prepared from paulownia, poplar, pine and walnut trees, on which we conduct experimental studies, in accordance with the requirements of GOST 16483.23-73 (Fig. 4-5).

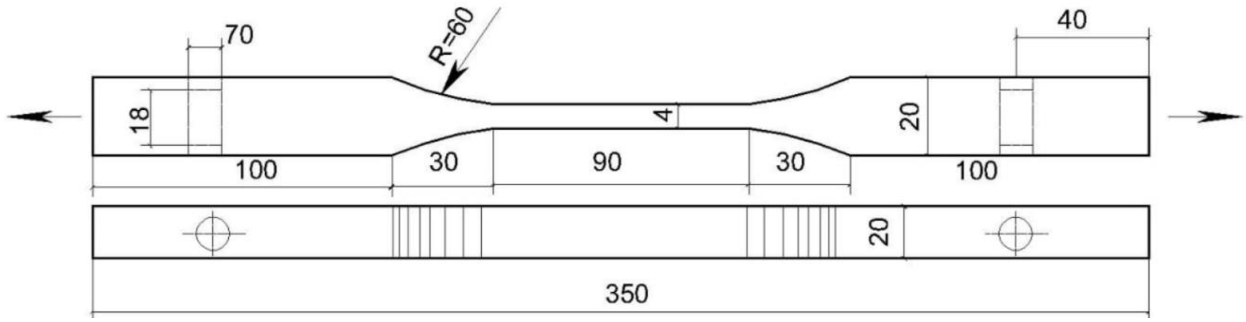

Figure 4. Test sample

Figure 5. Wood samples

After the moisture content of the samples reached the specified value, experimental tests of the samples were carried out using an F14-32 hydraulic press for tensile testing (Fig. 6).

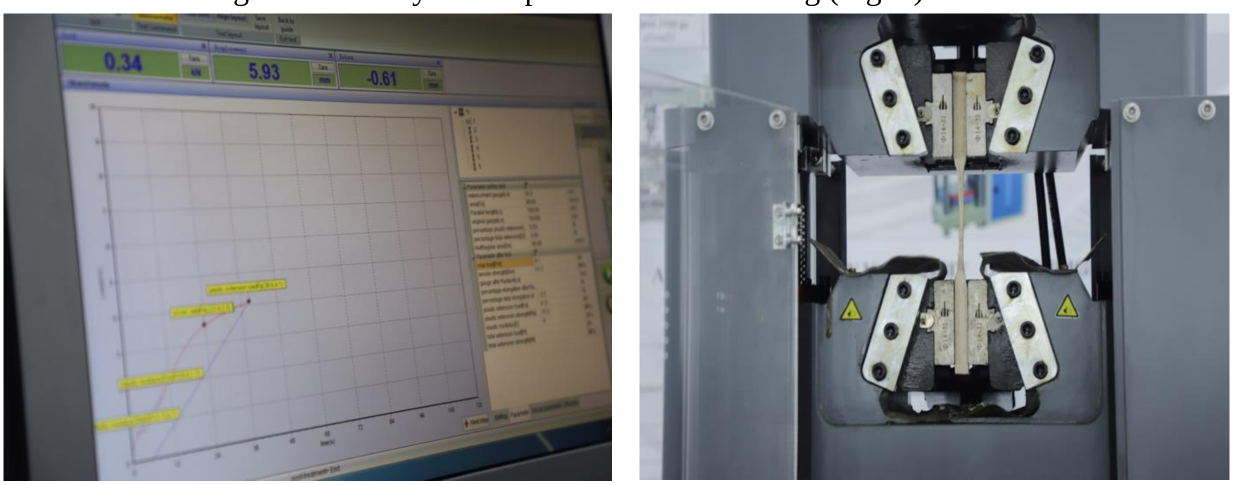

Figure 6. The process of conducting testing.

Table 2 below lists the mechanical properties of timber.

Table 2. Mechanical properties of wood

№	Of wood types	Moisture content of wood %	Strength limit kg/sm^2		
			In compression in the direction of the fibers	Stretching in the direction of the fibers	Static bending
1	Pine	12	485	1035	860
		30	212	792	495
2	Walnut	12	645	1254	1115
		30	253	964	617
3	Paulownia	12	590	1450	1230
		30	325	1095	743
4	Poplar	12	425	910	690
		30	192	684	403

Results and Discussion

Tests were conducted on the 1st wooden sample, which is subjected to experimental tests for elongation in the specified dimensions from local wood products in accordance with the requirements of GOST16483.23-73. The first sample was installed in a press for testing. The start was given to begin the test work. According to the results, the wooden sample made of paulownia in sample 1 was stretched with a maximum force of 4.1 kN. The tensile strength of the experimentally tested wooden sample is calculated using the following formula.

$$—_{w} = \frac{P_{max}}{a\_\_b}$$

The quantities in this formula are:

$—_{w}$ − strength limit, Па $\quad$ P_{max}- maximum load, N

a, б - cross-sectional dimensions of the working part of the sample, мм.

$$—_{w} = \frac{P_{max}}{a\_\_b} = \frac{4.1}{2\_\_0,04} = 51,25 \text{ MPa}$$

Its tensile strength was 51.25 MPa.

Also, according to the results, the 2nd wood sample made from paulownia tree was stretched with a maximum force of 4.5 kN..

$$—_{w} = \frac{P_{max}}{a\_\_b} = \frac{4.5}{2\_\_0,04} = 56,25 \text{ MPa}$$

Its tensile strength was 56.2 MPa.

3- wooden sample was stretched with a maximum force of 5.2 kN.

$$—_{w} = \frac{P_{max}}{a\_\_b} = \frac{5.2}{2\_\_0,04} = 65.0 \text{ MPa}$$

Its tensile strength was 65.0 MPa.

The tensile strength of sample 4 showed a result of 55.0 MPa.

The tensile strength of the wood samples selected for the experimental tests when subjected to tensile tests is shown in the diagram in Figure 7 below.

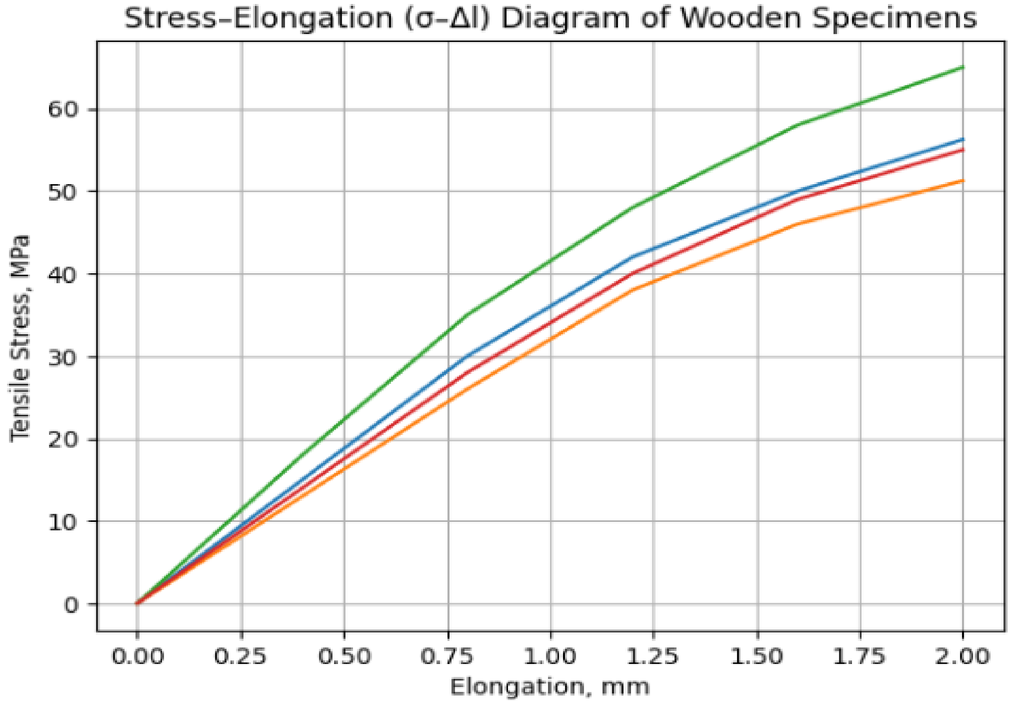

Figure 7. Curved line diagram during experimental testing of wooden samples for elongation

According to the studies conducted, the tensile strength of a sample made of paulownia wood was 0.81% of the tensile strength of wood made of pine wood. The tensile strength of wood made of poplar wood was 0.64% of the tensile strength of wood made of pine wood. The tensile strength of wood made of pine wood was 0.83% of the tensile strength of wood made of pine wood [14].

Table 3. The results of the experimental test samples for elongation

Marking of samples	Cross-sectional size, mm		Cross-sectional area, sm^2	Maximum load, P_{max},N	Strength limit, MPa	Explanation
	а	б				
1-намуна	20	4	0.08	4.1	51.25	
2-намуна	20	4	0.08	4.5	56.25	
3-намуна	20	4	0.08	5.2	65.0	
4-намуна	20	4	0.08	4.4	55.0	

Tensile elements of wooden structures are considered Category 1 elements, therefore, it is advisable to use high-quality wood materials with minimal defects in their manufacture. In this case, a strong wooden structure that can withstand central tension will be selected [15].

Conclusion

Paulownia, pine, poplar and walnut wood, which are widely distributed in Uzbekistan, can be effectively used in accordance with their physical and mechanical properties, depending on the respective loading conditions. It was found that the resistance to elongation of the studied wood species depends on its density, fiber direction, annual rings and moisture content. In particular, paulownia wood, despite being lightweight, has proven itself as a highly elastic material. Due to its high resistance to elongation, it can be used as lightweight beams and frame elements.

Pine wood proved to be a material with medium density but high strength during the experiment. Its modulus of elasticity was around 10–12 MPa, and its tensile strength was 70–80 MPa. These results indicate that pine can be used as a reliable material in medium-load beam and frame structures.

As a light and inexpensive material, Pavlovnia wood can be effectively used for low-load beam elements, while pine and poplar wood can be effectively used in medium-load wooden frame constructions. Walnut wood is recommended for high load elements.

Paulownia timber beams can be used as effective frames and roofs for structures with light to medium loads. In critical cases, it is recommended to use technologies that increase the safety factor and reinforcement (e.g., strip or composite reinforcement). If timber is frequently subjected to dynamic loads (vibrations, impacts), experimental testing is necessary to determine the dynamic behavior.

In conclusion, this article examined the stress-strain state of paulownia beams using theoretical formulas, and calculated experimental test results using the established methodology. The results obtained for a sample showed that a beam of a given cross-section under an axial load of 30 kN had a stress of $\sigma \approx 2$ MPa and an elongation of ≈ 0.5 mm. These values are significantly lower than the accepted strength limits of the material and, in some cases, can even coincide, as observed in construction practice. The specific results obtained from experimental tests and calculations conducted as part of these tests were summarized with specific practical recommendations and necessary conclusions that can be widely used in the design of timber structures in construction.

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