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Paper

PAPER

CALCULATION OF TENSION OF STRUCTURES MADE FROM LOCAL WOODEN MATERIALS UNDER DYNAMIC LOADS

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Abstract

This research article provides a theoretical and practical analysis of the behavior of beams made of paulownia, a local wood product, when elongated under dynamic loads. An example calculation is provided based on the expressions for stress and strain time under a longitudinal axial load, $F(t) = F_0 \sin(\omega t)$, as well as material parameters. This article examines solid wood beams made of local wood materials by class. It also discusses methods for calculating the elongation of beams made of local wood materials under dynamic loads. The solid wood type of beams made of local wood structures is considered depending on the type of material.

Key words: Beams made of local wood materials, paulownia, dynamic load, solid wood beam, elongation, modulus of elasticity, $\sigma(t)$ and $\varepsilon(t)$, wooden structure.

Introduction

In the context of the new Uzbekistan, the efficiency of using wooden structures in construction is rapidly increasing. Wooden structures are widely used in buildings and structures that meet modern requirements, and various wooden materials are used in the construction of new residential buildings. Therefore, studying the design of such structures, improving calculations, testing their strength based on the physical and mechanical properties of materials, and developing modern fastening methods are of great importance, and are among the key issues on the agenda.

The rapid development of the construction industry in our country requires the rational use of new and improved building structures that meet the demands of high efficiency and industrialization. The necessity and feasibility of using timber structures, which are more environmentally friendly and possess high strength properties,

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allows for an expansion of their application and increased competitiveness.

Wooden structures are considered one of the most environmentally friendly, lightweight, and renewable materials. Paulownia wood grows quickly and has excellent mechanical properties, making it suitable for lightweight construction. This research paper examines the tensile strength and durability of a paulownia beam of a given size under dynamic loads. Methods. The paulownia tree we studied is a fast-growing species. Its wood color ranges from silvery-gray to light brown, sometimes with a reddish tint. Paulownia wood is very strong, soft, and resistant to bending and twisting.

Paulownia wood absorbs water poorly, which in turn allows for savings on preservatives and varnishes. Paulownia products retain their shape and size even in harsh weather conditions and are resistant to rot. Paulownia Wood - Material Parameters

Indicator	Marking	Unity	Value
Elasticity modulus	E	GPa	9.0
Density	p	kg/m³	270
Cut surface	A	m²	0.0150
Length	L	m	2.0
Load amplitude	F_0	N	5000.0
Frequency	f	Hz	5.0

Beams are one of the fundamental elements of wooden buildings and structures. Therefore, it is important to study, design, and calculate the types, advantages, and disadvantages of beams. Beam selection is based on the building type, porch span, roof pitch, roof material, and other technical and economic factors.

Solid timber beams are less labor-intensive to manufacture, easier to fabricate, and cheaper than other beams. Their disadvantage is their limited length. Therefore, the spans of these beams are small, and they are widely used for various supports.

Solid timber beams include joists, thick planks, and round timber beams with inclined edges. Due to their solidity, they are used for spans up to 6 meters. Timber beams serve as the primary load-bearing structures for roofing sheets. In construction, timber beams are used for spans up to 3 meters. Beam structures operate primarily in bending and are designed for the first and second limit states. The beams are subject to uniformly distributed loads. $q = (g + S)\,B \cos\alpha$

where: g is the beam load and the specific weight of the beam elements, kN/m^2; S is the snow load, kN/m^2; B is the beam pitch, m; α is the angle of inclination; q is the total combined load, expressed as $q = (g + S), B \cos\alpha$.

In mechanical theory, principal stresses arising from the action of a central axial force on a tension element are widely used. These stresses are determined by the following formula. Tension (σ): $\sigma = \frac{F}{A}$, where σ is the stress, MPa (or N/mm^2), F is the axial force, N, and A is the cross-sectional area, mm^2.

The relative deformation is as follows (ε): $\varepsilon = \frac{\Delta l}{l}$.

According to the law of elasticity, $\sigma = E \cdot \varepsilon$. At the same time, absolute elongation is defined as $\Delta l = \varepsilon \cdot l = \frac{\sigma \cdot l}{E} = \frac{F \cdot l}{E \cdot A}$.

This formula fully describes the behavior of a beam in extension.

Results. Estimated values of the elastic modulus (E) for paulownia wood cited in the literature vary, typically falling in the range of 6000–10000 MPa. In this article, for calculation convenience, $E = 8000$ MPa is adopted. The tensile strength of paulownia wood under the developed conditions can range from approximately 30–50 MPa; here, a conservative value of $f_t = 40$ MPa is adopted.

For testing, a paulownia wood beam specimen with the following dimensions is manufactured: length $L = 2000$ mm, cross-section $b \times h = 100 \times 150$ mm. The beam is subjected to a constant axial force $F = 30$ kN (3000 N) along the center. The elastic modulus is taken as $E = 8000$ MPa.

The cross-sectional area of the beam is calculated as $A = b \times h = 100, \text{mm} \times 150, \text{mm} = 1500, \text{mm}^2$.

Tension (σ) is determined as $\sigma = \frac{F}{A} = \frac{3000, \text{N}}{1500, \text{mm}^2} = 2, \text{N/mm}^2 = 2, \text{MPa}$.

Relative deformation (ε) is calculated from $\sigma = E{\cdot}\varepsilon$, hence $\varepsilon = \frac{\sigma}{E} = \frac{2, \text{MPa}}{8000, \text{MPa}} = 0.00025$.

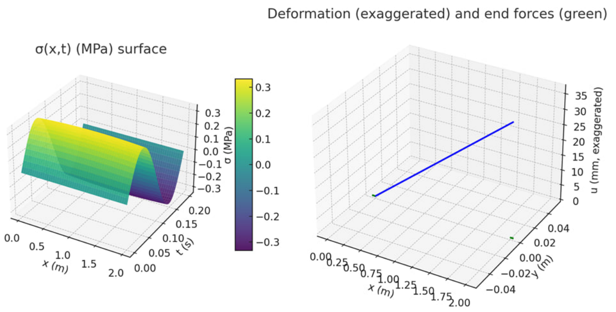
Absolute elongation (Δl) is obtained as $\Delta l = \varepsilon \cdot l = 0.00025 \times 2000, \text{mm} = 0.5, \text{mm}$.

Thus, a beam made of paulownia wood will experience a tensile stress of 2 MPa under the action of a force of 30 kN, and its elongation will be approximately 0.5 mm.

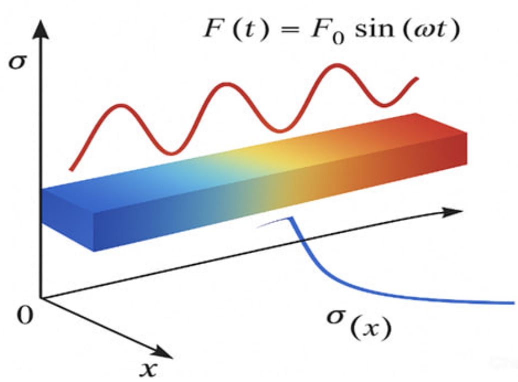
According to the safety check, if the maximum stress limit of the material is taken as $f_t = 40$ MPa and the safety coefficient $\gamma = 2$ is assumed, the allowable stress is $\sigma_{ruh} = \frac{f_t}{\gamma} = \frac{40}{2} = 20$, MPa. Since the calculated stress $\sigma = 2$ MPa is less than σ_{ruh}, the structure is considered safe in this case.

In construction practice, moisture content, fiber defects, the condition of connecting elements, and other factors are taken into account. In addition, under dynamic and impulse loads, a dynamic amplification factor may arise due to the stress-dependent behavior of the material. This factor typically lies in the range of 1.0–1.05, and the yield stress of the material increases under impulse loading.

The following 3D graph depicts the normal stress $\sigma(x,t)$ of the paulownia beam under dynamic load and the corresponding deformation at a selected time *t*.



This graph shows a 3D graphical mathematical model of a paulownia beam with line directions.



Conclusions

The calculation results presented in this study are based on the mechanical characteristics of paulownia wood and the specified loading conditions. In most cases, the modulus of elasticity and mechanical properties of wood vary significantly under the influence of moisture content. At moisture levels of 12–20%, the modulus of elasticity and strength are relatively low, whereas a moisture content of 8–12% is considered optimal for structural applications. In addition, the orientation of wood fibers and the presence of defects such as knots (particularly longitudinal knots) may lead to crack initiation and the formation of localized stress concentrations.

Therefore, the following practical aspects should be considered during the design and application of paulownia beams:

Material drying and moisture control: Prior to the use of paulownia beams in frame and roofing structures, it is recommended to condition the material to a specified moisture content, typically within the range of 10–12

Connections and fasteners: Stress concentrations are likely to occur at connection zones in timber structures; therefore, special attention should be paid to the design and detailing of joints and fasteners.

Structural application: Paulownia beams may be effectively used in frames and roofing systems subjected to light to medium loading conditions.

Safety and reinforcement: In critical structural cases, the use of reinforcement techniques and an increased safety factor is recommended, such as strip reinforcement or composite strengthening methods.

Dynamic loading conditions: When timber elements are frequently exposed to dynamic or impulse loads (e.g., vibrations or impacts), experimental investigations are required to accurately determine the dynamic characteristics of the material.

In summary, this article investigates the stress–strain behavior of paulownia wood beams subjected to axial tension using theoretical formulations and established calculation methodologies. Based on the example considered, a beam with the given cross-sectional dimensions under an axial load of 30 kN exhibits a tensile stress of approximately $\sigma \approx 2$ MPa and an elongation of approximately $\Delta l \approx 0.5$ mm. These values are substantially lower than the accepted strength limits of paulownia wood and are consistent with observations reported in construction practice.

The specific results obtained from the calculations and experimental evaluations conducted in this study form the basis for practical recommendations and well-founded conclusions, which can be effectively applied in the design and analysis of timber structures in modern construction.

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