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Issue Article

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DEFORMATIONS AND OSCILLATIONS OF A WOODEN BEAM DURING BENDING

Abstract: *The stress and strain state of a beam made of pine under the action of a distributed load applied perpendicular to the axial line of the element was considered in the article. The modes of oscillations and relative displacements of the beam at different frequencies after removing the static load were determined.*
Key words: *beam, bending, load, oscillation.*
Language: *English*
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Introduction

The beam is one of the main building elements working on bending. The beams of various cross sections made of metals, wood and reinforced concrete are mainly used in the construction of buildings. Each material has both advantages and disadvantages, so their use is rational in certain cases.

The wooden beams have high strength, low thermal conductivity, high technological properties, good machinability and high heat capacity, which is an advantage over beams made of other materials [1-2]. Applying special protective agents to wooden structures allows you to preserve the material properties and increase the service life [3]. Determination of the physical and mechanical properties of wood for the manufacture of structural elements is carried out according to the methodology described in GOST [4-5].

Pine is an anisotropic material, that is, a material whose properties differ in directions relative to the fibers [6]. For example, the tensile strength along the fibers of pine is 20 times greater than the tensile strength across the fibers. The bending strength is 24% less than the tensile strength along the fibers.

The wooden beam is subjected to bending under the action of concentrated and distributed loads. After removing the load, elastic deformations of the material lead to damped oscillations of the beam at a certain time interval until the element returns to its original shape [7]. The calculation of the stress and strain state of the material and oscillations of the beam will determine the stability and strength of the structure as a whole.

Materials and methods

The stationary study of the loaded state of the wooden beam was performed in a two-dimensional formulation. After loading, the beam oscillations were calculated at various frequency ranges.

The beam was a closed rectangular area in the longitudinal section. The beam had the shape of a square in the cross section. The ratio of the beam height to length was assumed to be 1:7.

Pine was specified as the material of the square beam. The calculation of stresses and strains was carried out on the basis of known values of the physical and mechanical properties for the given material, specifically, density, bulk modulus, shear modulus, Young's modulus, Poisson's ratio and elasticity matrix. Taking into account the anisotropic model of a solid, a standard ordering of the material data was adopted.

The beam model was fixed on both sides. The constant distributed load perpendicular to the axial line of the element was applied to the beam surface free from fixing. The initial conditions of the problem under study are presented in the Fig. 1.

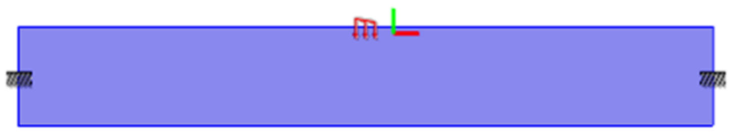

Figure 1. The initial conditions of the problem under study.

Results and discussions

The longitudinal axis of the beam bends under the action of the distributed load. There is a deflection of the beam with the greatest deviation of the longitudinal axis at a distance from the edge of the seal to ½ of the total length of the building element. Accordingly, the layers of the beam material located above the longitudinal axis will undergo compression deformation, and the layers located below the longitudinal axis will undergo tensile deformation. The calculated stress and strain state of the square section wooden beam under the action of the short-term distributed load is presented in the Fig. 2. The color scheme of the contours on the model characterizes the intensity of von Mises stress of the beam material [8].

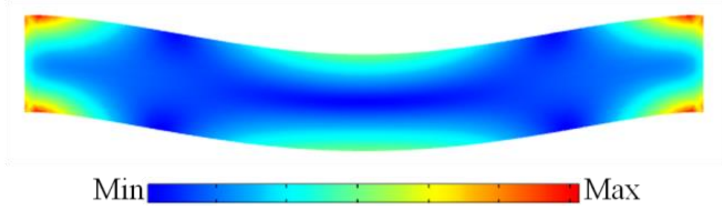

Figure 2. The von Mises stress contours on the deformed model of the wooden beam.

The inner layers of the square beam are deformed less than the surface layers. At the point of maximum deflection of the beam, the surface layers above and below the curved axial line have deformations of the same value. The minimally loaded cross section of the beam is located at a distance of ¼ of the total length of the beam from the left and right seals. Layers of the beam material in the sealing area are more deformed. The change in von Mises stress of the beam material occurs 143 times from the minimum to the maximum values.

Some works are devoted to the study of the beam oscillations [9-10]. In these works, cracks and possible destruction of the cantilever beams under the conditions of frequency oscillations were evaluated.

The oscillation modes of the wooden beam after removing the distributed load are shown in the Fig. 3. Oscillations were determined at frequencies in the range from 489 to 3524.5 Hz. At a frequency of 489 Hz, the oscillation mode is represented by the beam deflection in the opposite direction of the action of the distributed load. At a frequency of 1248.7 Hz, oscillation is represented as a wave with the formation of two deflections in different directions. There are no oscillations at a frequency of 1772.7 Hz, the material is shifted to the left side of the beam. At a frequency of 2242.1 Hz, oscillation is represented as a wave with the formation of three deflections in different directions. There are no oscillations at a frequency of 3524.5 Hz, the material is shifted from the middle to the left and right sides of the beam. It is also noted that for wave oscillations and displacement of the material to the left and right sides of the beam, zones of minimal displacement of layers are formed between deflections and narrowing of the transverse (longitudinal) section of the beam, respectively. The maximum displacement of layers practically does not change in the value in all cases of the beam oscillations. The most dangerous are oscillations at a frequency of 2242.1 Hz. For the short beams with higher stiffness, oscillations will occur at low frequencies.

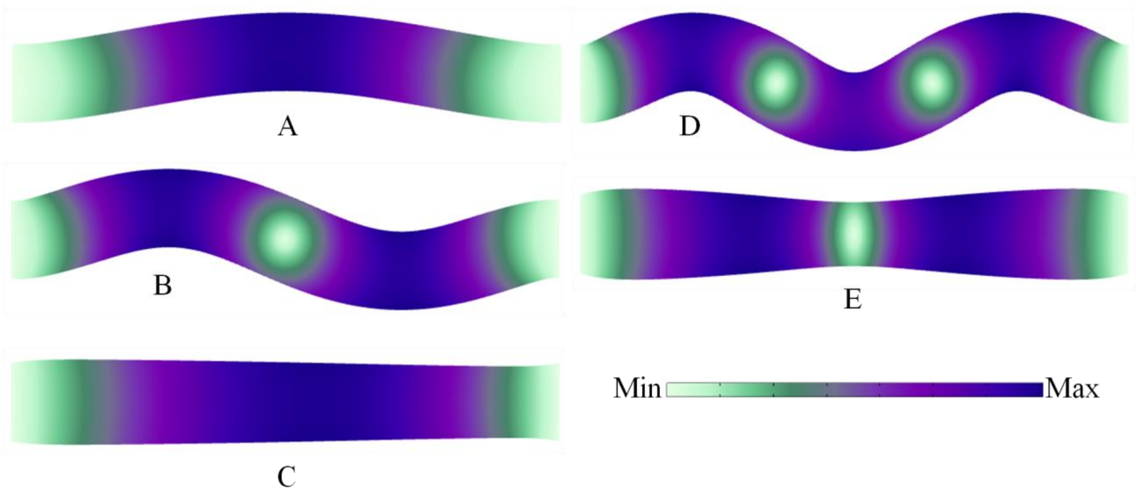

Figure 3. The beam oscillation modes at different frequencies: A – 489 Hz, B – 1248.7 Hz, C – 1772.7 Hz, D – 2242.1 Hz, E – 3524.5 Hz.

Conclusion

The computer calculation of loading of the model of the square wooden beam confirms the nature of deformation of the solid body subject to bending: the absence of stresses on the curved axial line and an increase in the value of stresses to the surface layers. The volumes of the beam material are predicted, which can lead to the rupture of both compressed and stretched fibers under the considered fixing scheme.

Wave oscillations defined at high frequencies are especially dangerous. However, in the practical conditions, the beam oscillation modes are mainly at low frequencies, so high frequencies are neglected. Thus, the real mode of oscillations (at a frequency of 489 Hz) is the beam deflection in the opposite direction of the load action.

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