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Research paper

The Basis of the Deformation Method for Calculating of Elements from Wood under Cross-Section Bending

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Abstract

The analysis of Ukrainian and foreign norms in calculating whole and laminated wood for different types of loads has been carried out. It is revealed that the calculation of wooden constructions is carried out by methods of boundary states in an elastic stage of work. The real stages of the stress-strain state of bending elements from wood and their constructions, taking into account the plastic work of the material, are considered. Developed and brought some preconditions for calculating given full diagram of the work of the wood taking into account the descending branch. The basis of the method of calculation of elements from solid and glued wood according to the deformation model, taking into account the growth of deformations in the calculated section, is presented.

Keywords: *solid and glued wood, deformation, stress-strain state.*

1. Introduction

Introduction. At present, all calculations of constructions of solid and glued wood for different types of loads, according to the operating norms of different countries [1, 2, 3], are carried out by the method of boundary states, which are based on elastic wood work. The solution of tasks for determining the bearing capacity of wood elements in normal sections based on the concept of strength criterion. Now, in the norms [1, 2, 3], there is only one criterion in which, in a normal section of the stress across the entire cross-section, or at the most remote point of the compressed or stretched areas of wood $\sigma_d = f_d$. In fact, this criterion is power, as the moment of destruction is estimated by the power characteristic - the limiting value of the stres. An expression for a strength criterion can be represented for power influences in the general form of dependence

$$\sigma_d = f_d = const. \tag{1}$$

Significant drawbacks of criterion (1) are that external stresses for bending, noncentrally extended and compressed elements in reality give rise to stresses of varying intensity in compressed and stretched zones due to the heterogeneity of the growth of wood deformations at the simultaneous joint operation of the cross section on compression and tension [4, 5 , 6]. Also, there are different values of tensile strength of wood in compression and tension in the section with the same initial modulus of elasticity for the same load. The durability of wood on stretching is twice the compressive strength, and an approximate definition is possible only within the limits of conditional proportionality. The calculated resistance of the bending wood $f_{m,d}$ used in formula (1) is a value that is not from the direct experimental setting, but from the proposals [7] according to the imperial expression

$$R_u = R_c \frac{3\frac{R_t}{R_c} - 1}{\frac{R_t}{R_c} + 1}, \tag{2}$$

where R_u - the calculated resistance of the bending wood: R_c - estimated resistance of compression wood along the fibers; R_t - estimated resistance of wood tension along the fibers.

In 1955, Khukhryansky P. generalized all existing knowledge of the strength of wood in the work [8], starting from the structure of the cell of the wood and ending with the work of various types of stress-strain state. By that time, the compression, tensile and bend of the wooden element were well studied. Skin, torsion and three-way stressed states scientists have been neglected. In all cases, the elastic work of an element of wood was taken as the basis for calculations, and the distribution of stresses - linear for the whole period of operation up to destruction.

At the same time, attempts were made to construct a theory of strength based on tensor calculus (Ashkenazy E. [9, 10, 11], Geniev G. [12], Klymenko V. [13]). But this approach has not found practical use due to the cumbersome and complexity of analytical expressions, which requires special mathematical preparation for the calculation. Also, for the use of tensor strength criteria, the required parameters could only be obtained experimentally. The criteria describe the behavior of wood unsatisfactory when working for a complex stressed state. Ashkenazi E. herself pointed to the fact that for loads that create a trilateral tense state, its criteria need to be finalized [10]. Later Orlovich R. [14], Fursov V. [15, 16] performed experimental tests and refinement of these criteria.

The problem of fracture resistance of wood from the position of the mechanics of destruction was considered by Shatts T. in his work [17], Naychuk A. [18, 19] and Jockwer R. [20]. But in the 60 years of the previous century Drozdovsky B. and Friedman Ya. [21] it was noted that the linear mechanics of destruction, with its advantages in simplicity, does not sufficiently cover the process of destruction in order to be deprived of the basic theoretical basis. The founder of the destruction mechanics Griffiths [22] very carefully spoke about the use of his proposed approaches to complex non-homogeneous materials, in which, for the stresses close to the destructive, there is a deviation from Hooke's law.

Tuturyn S. in work [23] continued to develop a synthetic theory of material strength, adjusting it to a natural anisotropic material - wood. The author, analyzing the finding of elastic potential, made it easier to find elastic permanent wood from 36 to 9. To find the relations between stresses and deformations, as well as determination of the elastic potential for the case of tripartite symmetry of properties, to 5 elastic constants.

2. The main part

The most common for the elements of wood is its work on a bending. A large number of works are devoted to solving the problem of bending a wooden element, because from the point of view of a practicing engineer this work is most interesting. So there are two types of layers (fibers) for the work of the beam with a zone of pure bending: some of them work under stresses of compression of different intensity, while others are for stretching stresses. These layers are separated by a neutral plane (line) (Fig. 1 and Fig. 2).

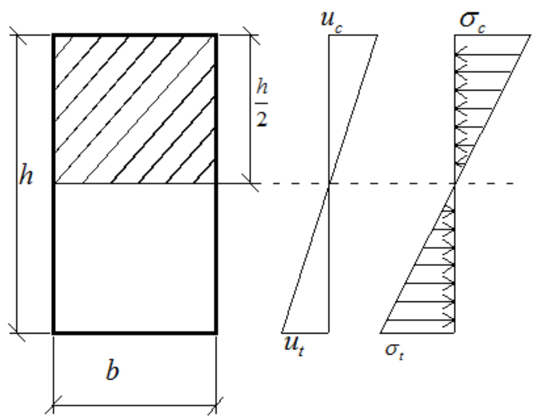

Fig.1: To calculate normal cross sections for pure straight bend: h = element height; b = the width of the element; u_c = relative deformations.

So far, current estimates bending elements of wood are based on such theses-dogmas:

- wood works as an absolutely elastic material;
- modulus of elasticity equal in stretched and compressed zones;
- the rectilinear dependence of stress distribution on the height of the bending element is taken;
- the position of the neutral plane is unchanged;
- introduced the concept of strength of wood on the bend.

These offers do not correspond to real work of wood. Often in structures a load of bearing capacity is more than doubled. The goals of the cost-effectiveness of the adopted section not only do not set up the current norms, and even do not mention it.

According to studies [23, 24, 25, 26] in the compressed belt, the growth of strain loads increases, both at the expense of the elastic, and due to plastic components. In addition, the tensile strength exceeds by more than twice the tensile strength under compression. For the equality of deformations in compressed and stretched fibers, the beam of stress in these layers is different. The neutral plane between compressed and stretched zones at the initial stages of loading begins to gradually move toward the stretched zone [25], and behind the oblique bend - even with a turn to one of the sides. And the main factor in calculating the elements of wood on a net bend are diagrams of "strain-strain", which are used from the data obtained from experimental tests of samples of pure wood.

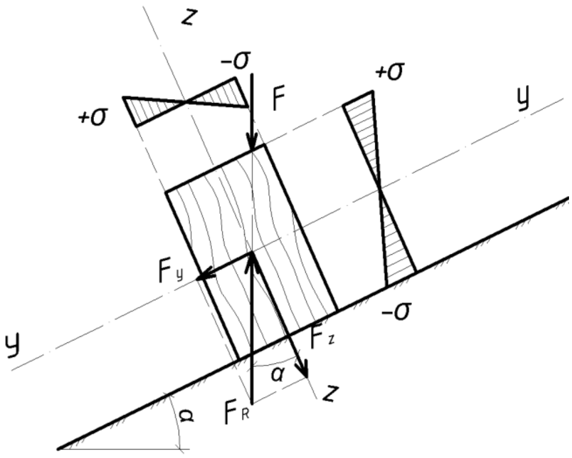

Fig. 2: To calculate normal sections on a clear oblique bend: F = external load; y-y, z-z = main axes of the cross-section of the element; F_y and F_z = components of the reference reaction F_R ; α = angle of the element to the main axis y-y; $-\sigma$ = compressive stresses; $+\sigma$ = tensile stress.

The small-sized sample of pure wood does not give us complete information about the behavior of both the microstructure of wood and macrostructure. In such samples there is an excessive amount of trace elements (cellulose molecules) and a small amount of macroelements of wood (fibers, annual rings, late and early wood). To some extent, the transfer of such data to real constructs is false. Because the work of such structures, because of their size, as well as the influence of vices and scale factor significantly differs from the work of pure wood [20, 23, 24]. However, all modern theory is based on such data, which leads to a distorted understanding of the basics of perception of material load. In addition, the construction of diagrams of "stress-strain", as a rule, ended with a point of perception of maximum effort. How it behaves wood outside this point has not yet been investigated, although it is known that the residual strength is an essential part. Such studies are needed to predict the residual lifetime of timber structures and to prevent the progressive destruction of structures for the effects of different types of loads [27]. Therefore, it is more appropriate to use for calculations the diagrams obtained on large samples of whole and glued wood. Only by changing the method of loading, for example, new results were obtained that could reveal the essence of the work of wood under the influence of loads. In addition, there are now diagrams of "strain-displacement (press plates)" (Fig. 3), which are obtained in modern presses with a strict mode of application of loading [23, 28]. And these diagrams also have a certain disadvantage, because here, when the press plates are moved at the initial stage to the deformation diagram, the local stiffening of the ends of the sample is affected by inaccuracies in the manufacturing, defects in the treatment of the face surfaces and damage in these parts of the micro and macrostructure of the wood (edge effects).

Therefore, in order to eliminate this disadvantage, it is necessary to determine the relative deformations of wood [29] (Fig. 4), rather than moving the traverses of the press [23, 28] for the hard loading mode.

In all the calculation methods considered, the plastic work of the material and the presence of a downward branch for the deformation of wood to compression are not taken into account, which is a certain important reserve in the design work. Of course, it is

not expedient to use the work of the wood throughout the length of the downward branch and for significant deformations, but a limited part of the reserve should be used.
Avoiding the disadvantages that made it impossible to solve such problems can be by adopting a curvilinear diagram of stresses in the wood of the compressed zone, which corresponds to a greater extent to the actual work of cross-sections. It should also be noted that the triangular stresses in compressed and stretched zones accepted in the norms allow us to consider the stress-deformed state of the cross-section only in the limiting state and does not make it possible to follow its changes at different stages of the load of the element.

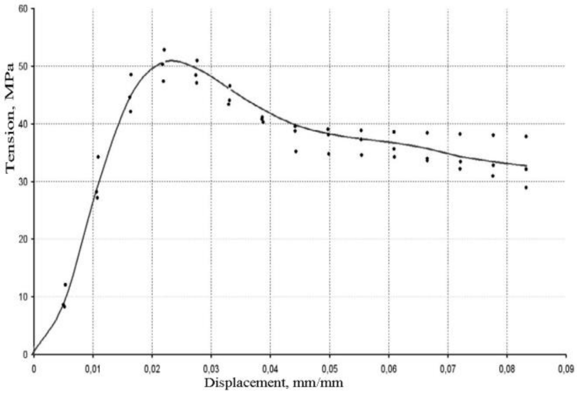

Fig. 3: Diagram of "displacement of a plate - load" when testing wood on compression along fibers on a mechanical press.

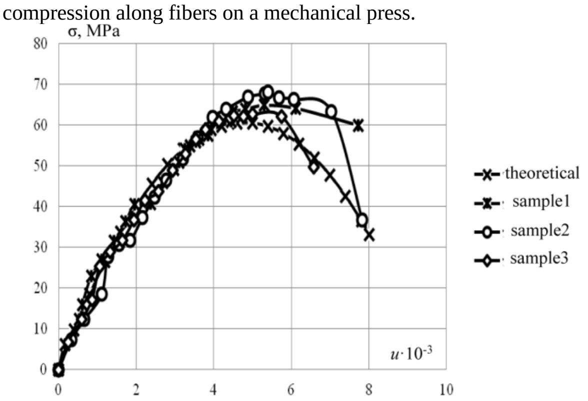

Fig. 4: Diagram "stress-deformation" for compression of wood along fibers.

Avoiding the disadvantages that made it impossible to solve such problems can be by adopting a curvilinear diagram of stresses in the wood of the compressed zone, which corresponds to a greater extent to the actual work of cross-sections. It should also be noted that the triangular stresses in compressed and stretched zones accepted in the norms allow us to consider the stress-deformed state of the cross-section only in the limiting state and does not make it possible to follow its changes at different stages of the load of the element.
Reliability of the experimental data on the deformation diagrams of the wood under the action of the deformation gradient and the analytical apparatus, the establishment of the coefficients of the second degree polynomials, as well as the transformation of the physical state of the material into the physical state of the element, make it possible to develop a calculation method for determining the stress-deformed state of the elements of wood when working on the bend.
Considering the change in the stress-strain state of the normal sections of the beam from the wood in the zone of clean bend, it is evident that for each of the stages are characterized by their characteristics.
Stage I. A small load on the element causes small stresses in compressed and stretched zones, the dependence between stresses and deformations can be taken directly linearly, deformations in the wood of compressed and extended zones can be considered elastic, the diagrams of stresses are in the form close to the triangle.
Stage II. Further increase of the load leads to the development of plastic deformations in the wood of the compressed zone, the diagram of stresses in this zone is distorted, and the boundary stress reaches the temporary resistance of the strength of the wood to compression. Deformations of the wood of the stretched zone are mostly elastic, the stresses in the wood grow, but the stress diagram retains the shape close to the triangular.
Stage III. For further increase of loads there is a crumbling of fibers and the folds of crumbling in the wood of the compressed zone are formed, some of the layers of wood are transferred to the subcritical zone of wood work, the stresses are redistributed along the height of the beam, the compressive forces are perceived by the area of the wood under the fold and the area of the wood on which the fold formed, there is a sharp increase in the deformation of the compressed zone. The stresses in the stretched wood zone are greatly increased, plastic deformation develops, and the stress diagram becomes curvilinear. Neutral line shifts, increasing the compressed wood area.
Stage IV. A further increase in the load leads to intensive development of the fold of the tongue, increases the deflection of the beam, increases the height of the compressed zone and even more distorted the circuit of stresses of the compressed zone, as a result of which the boundary tension in the wood of the stretched zone reaches a temporary resistance to tension. The destruction is due to the rupture of the most intense outer layers of wood and has a fragile character.
The basis of the calculation method is the following:
a) calculated is a section normal to the longitudinal axis of the element, in which a fold is formed in the compressed zone;
b) in the height of the calculated cross section for the mean deformations a hypothesis about the linear distribution of deformations is true;
c) the relationship between stresses and deformations of stretched wood is taken as a linear dependence;
d) the relationship between stresses and deformations of compressed wood is taken as a transformed diagram, depicted in Fig. 3 and is described by a polynomial of the second degree [29];
e) wood elements are considered in which force factors must be applied in such a way as to avoid torsion;
f) as the estimated values of wood resistance in a wooden element are taken.
According to the criterion of loss of bearing capacity, the cross section is taken:
a) the destruction of stretched wood for reaching the most stretched layer of limiting deformation values;
b) the extreme criterion is the loss of balance between internal and external efforts.
The calculation is performed according to the deformation model taking into account the growth of deformations in the calculated section.
The distribution of stresses and deformations in the normal section of the beam is shown in Fig. 4 and Fig. 5.
The stresses in the normal section of the beam were calculated using functions

$$f_1(u)=\sigma_{c,d}=k_1\cdot u_{c,d}+k_2\cdot u_{c,d}^2=E_c\frac{1}{\rho}x+k_2(\frac{1}{\rho})^2x^2 \ ; \qquad (3)$$

$$f_2(u)=\sigma_{t,d}=E\cdot u_{t,d}=E_t\frac{1}{\rho}x \ , \qquad (4)$$

where E - the elasticity of the wood during tension; $u_{t,d}$ - relative deformations for tension of wood; $u_{c,d}$ - relative deformations for compression of wood; k_1,k_2 - coefficients of the polynomial; $f_1(u)$ - stress-stretched zone; $f_2(u)$ - stresses of the compressed zone; x – the distance from the neutral line to an arbitrary point in the compression and stretched zones; E_c, E_t – elastic modulus of wood for compression and tension, respectively; $\frac{1}{\rho}$ - Cutting the bending element.

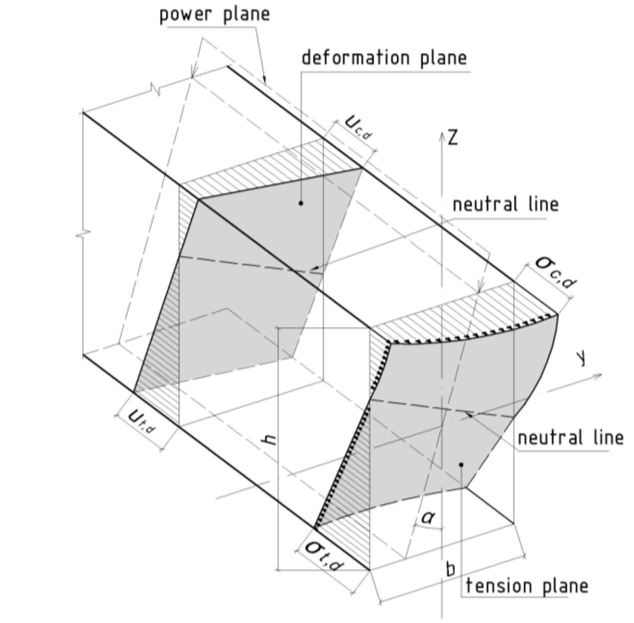

Fig. 5: Stress-deformed state of a wood element in the zone of oblique clear bend: b = width of the element; h = element height; $u_{c,d}$ = relative deformations of compression; $u_{t,d}$ = relative deformations of wood compression; $\sigma_{c,d}$ = compressive stresses; $\sigma_{t,d}$ = tensile stress; y-y, z-z = main axes of the cross-section of the element; α = angle of the element to the main axis y-y.

Consider cross-section of wood bending element Fig. 6 and Fig. 7.

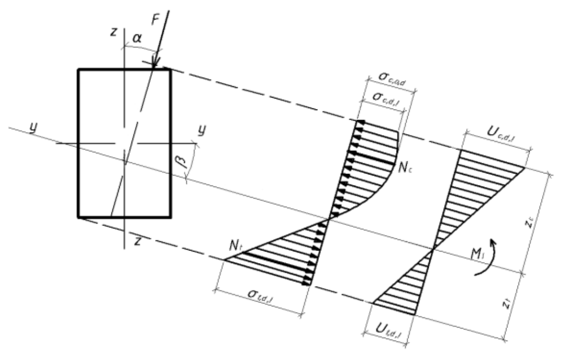

Fig. 6: Distribution of the greatest stresses and deformations in the normal section of the beam for work on a clean oblique bend: $u_{c,d,1}$ = relative deformations of compression in the extreme fiber of wood; $u_{t,d,1}$ = relative deformations of compression in the extreme fiber of wood; $\sigma_{c,d,1}$ = compressive stresses in the extreme fiber of wood; $\sigma_{t,d,1}$ = stress tension in the extreme fiber of wood; y-y, z-z = main axes of the cross-section of the element; α = the angle of inclination of the external load F on the element relative to the main axis z-z; z_t z_t = height of the stretched cross-sectional area; z_c = height of the compressed zone of the cross-section; M_1 = bending moment from the action of external load.

The equilibrium equation for the section shown in Fig. 3 has the form

$$\sum M_{н.л.} = 0; M = M_c + M_t; \tag{5}$$

$$\sum N = 0; N_c = N_t, \tag{6}$$

where M, M_c, M_t - bending moments from external loading, efforts in a compressed and stretched zone, respectively; N_t, N_c - equivalent to internal efforts in the stretched and compressed areas, respectively.

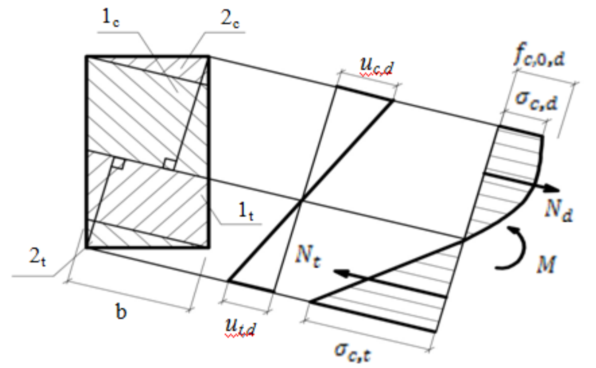

Fig. 7: To calculate the normal cross-section along the oblique bend: 1_t, 2_t - compressed zones; : $u_{c,d}$ = relative deformations of compression in the extreme fiber of wood; $u_{t,d}$ = relative deformations of compression in the extreme fiber of wood; $\sigma_{c,d}$ = compressive stresses in the extreme fiber of wood; $\sigma_{t,d}$ = stress tension in the extreme fiber of wood; M = bending moment from the action of external load; N_d = equilibrium compression force in an element undergoing a transverse bend; N_t = the surplus tensile force in the element undergoing a transverse bend; $f_{c,0,d}$ = compressible boundary calculating stresses of wood.

On the basis of deformations in accordance with Fig. 7, the stress in the normal cross section is described by two functions 3 and 4 in three different sections: the first section is the stretch area from the bottom of the element to the neutral line; the second section - from the neutral line to the maximum stress in the compressed zone; the third section - from the maximum stress in the compressed zone to the top of the element. The coefficients k_1, k_2 are calculated by the formulas

$$k_1 = \frac{2 \cdot f_{c,o,d}}{u_{c,fin,d}}; \tag{7}$$

$$k_2 = -\frac{f_{c,o,d}}{u^2_{c,fin,d}}, \tag{8}$$

where $f_{c,o,d}$ - the estimated value of compression along the fibers; $u_{c,fin,d}$ - complete for compression strain along the wood fibers.

The tensile force in the normal section of the bending element is determined as the sum of the forces occurring in the stretched zone of the cross section, which consists of two sections: the first in the form of a parallelogram; the second in the form of a triangle

$$N_t = N_{t1} + N_{t2}, \tag{9}$$

where N_{t1} - the tensile force in the element that perceives the first section of the cross section that is determined

$$N_{t1} = \int_0^{x_1} f_2(u)\,\mathrm{dA} = \int_0^{x_1} E_t \frac{1}{\rho} x_t b dx = E_t \frac{1}{\rho} b \frac{x_{1t}^{\ 2}}{2}. \tag{10}$$

Stretching force in an element that perceives the second triangular cross section

$$N_{t2} = \int_{x_1}^{x_2} f_2(u)\mathrm{dA} = \int_{x_1}^{x_2} f_2(u)\cdot f(b)dx =$$
$$\int_{x_1}^{x_2} (E_t \frac{1}{\rho} a_1 x_t^2 + E_t \frac{1}{\rho} a_2 x_t)dx = \tag{11}$$
$$= E_t \frac{1}{\rho} a_1 \frac{x_{2t}^3}{3} + E_t \frac{1}{\rho} a_2 \frac{x_{2t}^2}{2} - E_t \frac{1}{\rho} a_1 \frac{x_{1t}^3}{3} - E_t \frac{1}{\rho} a_2 \frac{x_{1t}^2}{2}$$

Substituting the formulas 10 and 11 for 9 we get

$$N_t = E_t \frac{1}{\rho} b x_{1t} + E_t \frac{1}{\rho} a_1 \frac{x_{2t}^3}{3} + E_t \frac{1}{\rho} a_2 \frac{x_{2t}^2}{2} - E_t \frac{1}{\rho} a_1 \frac{x_{1t}^3}{3} -$$
$$- E_t \frac{1}{\rho} a_2 \frac{x_{1t}^2}{2}. \tag{12}$$

The compressive force in the normal section of the bending element is determined as the sum of the forces occurring in the compressed zone of the cross section, which consists of two sections: the first in the form of a parallelogram; the second in the form of a triangle

$$N_c = N_{c1} + N_{c2}\ , \tag{13}$$

where N_{c1} - the compression forces in the element that undergoes a transverse bend and perceives the first section of the cross-section

$$N_{c1} = \int_0^{x_1} f_1(u)\mathrm{dA} = b\int_0^{x_1} (E_c \frac{1}{\rho} x + k_2 (\frac{1}{\rho})^2 x^2)dx =$$
$$= b(E_c \frac{1}{\rho} \frac{x_{1c}^2}{2} + k_2 (\frac{1}{\rho})^2 \frac{x_{1c}^3}{3}), \tag{14}$$

where $dA = b\cdot dx$.

The force of compression N_{c2} in an element that perceives the second triangular section of the cross-section

$$N_{c2} = \int_{x_1}^{x_2} f_1(u)\mathrm{dA} = \int_{x_1}^{x_2} (E_c \frac{1}{\rho} x_c + k_2 (\frac{1}{\rho})^2 x_c^2)\cdot(a_1 x_c + a_2)dx =$$
$$= \int_{x_1}^{x_2} (E_c \frac{1}{\rho} a_1 x_c^2 + E_c \frac{1}{\rho} x_c a_2 + k_2 (\frac{1}{\rho})^2 a_1 x_c^3 + k_2 (\frac{1}{\rho})^2 a_2 x_c^2)dx =$$
$$= E_c \frac{1}{\rho} a_1 \frac{x_{2c}^3}{3} + E_c \frac{1}{\rho} a_2 \frac{x_{2c}^2}{2} + k_2 (\frac{1}{\rho})^2 a_1 \frac{x_{2c}^4}{4} + k_2 (\frac{1}{\rho})^2 a_2 \frac{x_{2c}^3}{3} - \tag{15}$$
$$- E_c \frac{1}{\rho} a_1 \frac{x_{1c}^3}{3} - E_c \frac{1}{\rho} a_2 \frac{x_{1c}^2}{2} - k_2 (\frac{1}{\rho})^2 a_1 \frac{x_{1c}^4}{4} - k_2 (\frac{1}{\rho})^2 a_2 \frac{x_{1c}^3}{3};$$

where $dA = f(b)\cdot dx$; $f(b) = a_1 x_c + a_2$; $a_1 = \frac{b}{x_{1c} - x_{2c}}$; $a_2 = -\frac{x_{2c}\cdot b}{x_{1c} - x_{2c}}$; $b -$ section width of beam.

Substituting formulas 14 and 15 in 13 we get

$$N_c = b(E_c \frac{1}{\rho} \frac{x_{1c}^2}{2} + k_2 (\frac{1}{\rho})^2 \frac{x_{1c}^3}{3}) + E_c \frac{1}{\rho} a_1 \frac{x_{2c}^3}{3} + E_c \frac{1}{\rho} a_2 \frac{x_{2c}^2}{2} +$$
$$+ k_2 (\frac{1}{\rho})^2 a_1 \frac{x_{2c}^4}{4} + + k_2 (\frac{1}{\rho})^2 a_2 \frac{x_{2c}^3}{3} - E_c \frac{1}{\rho} a_1 \frac{x_{1c}^3}{3} - E_c \frac{1}{\rho} a_2 \frac{x_{1c}^2}{2} - \tag{16}$$
$$- k_2 (\frac{1}{\rho})^2 a_1 \frac{x_{1c}^4}{4} - k_2 (\frac{1}{\rho})^2 a_2 \frac{x_{1c}^3}{3};$$

The bending moment from the neutral line for a stretched zone in the normal section is

$$M_t = M_{t1} + M_{t2} \tag{17}$$

where M_{t1}, M_{t2} - moments that perceive areas of the stretched zone of the element

$$M_{t1} = \int_0^{x_1} f_2(u)\mathrm{dA} = \int_0^{x_1} f_2(u) b x_t dx =$$
$$= \int_0^{x_1} E_t \frac{1}{\rho} x_t^2 b dx = E_t \frac{1}{\rho} b \frac{x_{1t}^3}{3} \tag{18}$$

$$M_{t2} = \int_{x_1}^{x_2} f_2(u) x_t \mathrm{dA} = \int_{x_1}^{x_2} f_2(u) x_t \cdot f(b)dx = \int_{x_1}^{x_2} E_t \frac{1}{\rho} x_t^2 \cdot (a_1 x_t + a_2)dx =$$
$$= \int_{x_1}^{x_2} (E_t \frac{1}{\rho} a_1 x_t^3 + E_t \frac{1}{\rho} a_2 x_t^2)dx = \tag{19}$$
$$= E \frac{1}{\rho} a_1 \frac{x_{2t}^4}{4} + E_t \frac{1}{\rho} a_2 \frac{x_{2t}^3}{3} - E_t \frac{1}{\rho} a_1 \frac{x_{1t}^4}{4} - E_t \frac{1}{\rho} a_2 \frac{x_{1t}^3}{3}$$

Substituting the formulas 18 and 19 at 16, we will establish the value of the bending moment that will accept the stretched zone

$$M_t = E_t \frac{1}{\rho} b \frac{x_{1t}^3}{3} + E_t \frac{1}{\rho} a_1 \frac{x_{2t}^4}{4} + E_t \frac{1}{\rho} a_2 \frac{x_{2t}^3}{3} -$$
$$- E_t \frac{1}{\rho} a_1 \frac{x_{1t}^4}{4} - E_t \frac{1}{\rho} a_2 \frac{x_{1t}^3}{3}. \tag{20}$$

The bending moment from the neutral line for the compressed zone in the normal section is equal to

$$M_c = M_{c1} + M_{c2}, \tag{21}$$

where M_{c1}, M_{c2} - moments of the compressed zone of the element at different sections of the section, which are equal

$$M_{c1} = \int_0^{x_1} f_1(u) x_c \mathrm{dA} = \int_0^{x_1} f_1(u) x_c b dx = b(E_c \frac{1}{\rho} \frac{x_{1c}^3}{3} + k_2 (\frac{1}{\rho})^2 \frac{x_{1c}^4}{4}), \tag{22}$$

$$M_{c2} = \int_{x_1}^{x_2} f_1(u) x_c \mathrm{dA} = \int_{x_1}^{x_2} f_1(u) x_c \cdot f(b)dx = \int_{x_1}^{x_2} (E_c \frac{1}{\rho} a_1 x_c^3 +$$
$$+ E_c \frac{1}{\rho} x_c^2 a_2 + k_2 (\frac{1}{\rho})^2 a_1 x_c^4 + k_2 (\frac{1}{\rho})^2 a_2 x_c^3)dx = E_c \frac{1}{\rho} a_1 \frac{x_{2c}^4}{4} +$$
$$E_c \frac{1}{\rho} a_2 \frac{x_{2c}^3}{3} + k_2 (\frac{1}{\rho})^2 a_1 \frac{x_{2c}^5}{5} + k_2 (\frac{1}{\rho})^2 a_2 \frac{x_{2c}^4}{4} - E_c \frac{1}{\rho} a_1 \frac{x_{1c}^4}{4} - \tag{23}$$
$$- E_c \frac{1}{\rho} a_2 \frac{x_{1c}^3}{3} - k_2 (\frac{1}{\rho})^2 a_1 \frac{x_{1c}^5}{5} - k_2 (\frac{1}{\rho})^2 a_2 \frac{x_{1c}^4}{4}.$$

Substituting formula 21 and 22 at 20 we get

$$M_c = b(E_c \frac{1}{\rho} \frac{x_{1c}^3}{3} + k_2 (\frac{1}{\rho})^2 \frac{x_{1c}^4}{4}) + E_c \frac{1}{\rho} a_1 \frac{x_{2c}^4}{4} + E_c \frac{1}{\rho} a_2 \frac{x_{2c}^3}{3} +$$
$$+ k_2 (\frac{1}{\rho})^2 a_1 \frac{x_{2c}^5}{5} + k_2 (\frac{1}{\rho})^2 a_2 \frac{x_{2c}^4}{4} - E_c \frac{1}{\rho} a_1 \frac{x_{1c}^4}{4} - E_c \frac{1}{\rho} a_2 \frac{x_{1c}^3}{3} - \tag{24}$$
$$- k_2 (\frac{1}{\rho})^2 a_1 \frac{x_{1c}^5}{5} - k_2 (\frac{1}{\rho})^2 a_2 \frac{x_{1c}^4}{4}.$$

To determine the bending moment by the formula 5, which can accept a beam of solid or laminated wood, the value of relative deformations in which the equilibrium equilibrium condition is performed is to be substituted in formulas 12 and 20.

For the work of the element of wood on a straight transverse bend, conditions 9, 13, 17 and 21 will form

$$N_t = N_{t1};\quad (25)$$

$$N_c = N_{c1};\quad (26)$$

$$M_t = M_{t1};\quad (27)$$

$$M_c = M_{c1}.\quad (28)$$

3. Conclusions

1. The current rules for calculating wooden beams which are in the conditions of a straight or skew transverse bend do not take into account the actual work of such elements, in particular the formation of the fold in a compressed zone of clean bend, and give a significant margin of safety.
2. A method for calculating wooden beams from solid and glued wood using a strain model that takes into account the distribution of stresses in height in compressed and stretched zones of the calculated section and provides the formation of the fold in the compressed zone of the element in the zone of pure bending.

References

[1] Derevyannyye konstruktsii, *SNiP ÍÍ-25-80*, Stroyizdat, (1982), 65.
[2] Design of timber structures. *Eurocode 5*.Part 1.1. General rules and rules for buildings (1995), 124.
[3] Konstruktsiyi budynkiv i sporud, Derev″yani konstruktsiyi, Osnovni polozhennya, *DBN* V.2.6-161:2010, Ukrarkhbudinform, (2011), 102.
[4] Lennov V.G.(1958), Eksperimental'noye issledovaniye drevesiny na szhatiye i rastyazheniye vdol' volokon s uchetom dlitel'nogo deystviya zagruzki, *Izvestiya vuzov*. Stroitel'stvo i arkhitektura, 2,147-157.
[5] Bykov V.V.(1967), Eksperimental'nyye issledovaniya prochnosti i deformativnosti drevesiny sibirskoy listvennitsy pri szhatii i rastyazhenii vdol' volokon s uchetom dlitel'nogo deystviya nagruzki, Izvestiya vuzov. *Stroitel'stvo i arkhitektura*, 8, 3-8.
[6] Klymenko V.Z., Konstruktsiyi z dereva i plastmas, *Vyshcha shkola* (2000), 304.
[7] Kochenov V.M. Nesushchaya sposobnost' elementov i soyedineniy derevyannykh konstruktsíy, *Gosudarstvennoye izdatel'stvo* (1953), 320.
[8] Khukhryanskiy P.N. Prochnost' drevesiny, *Goslesbumizdat* (1955), 152.
[9] Ashkenazi Ye.K., Boksberg I.P., Rubinshteyn G.M. Anizotropiya mekhanicheskikh svoystv drevesiny, *Goslesbumizdat* (1958), 140.
[10] Ashkenazi Ye.K., Anizotropiya drevesiny i drevesnykh materialov, *Lesnaya promyshlennost'* (1978), 222.
[11] Ashkenazi Ye.K., Ganov E.V. Anizotropiya konstruktsionnykh materialov, *Mashinostroyeniye* (1980), 247.
[12] Geniyev G.A. O kriterii prochnosti drevesiny pri ploskom napryazhennom sostoyanii, *Stroitel'naya mekhanika i raschet sooruzheniy* (1981), 3, 15–20.
[13] Klimenko V.Z. Metodicheskiye rekomendatsii po raschetu stroitel'nykh konstruktsiy iz kleyenoy drevesiny s uchetom slozhnogo napryazhennogo sostoyaniya materiala, *KISI*(1998), 50.
[14] Orlovich R.B., Yezepov G.G., Naychuk A.YA. K otsenke nekotorykh kriteriyev prochnosti anizotropnykh tel pri ploskom napryazhennom sostoyanii, Stroitel'naya mekhanika i stroitel'nyye konstruktsii, Tekhnika, tekhnologiya, organiza-tsiya i ekonomika stroitel'stva, *Vysheyshaya shkola* (1984), 10, 124-127.
[15] Fursov V.V., Abdurakhimov R.F., Cherednik D.L. Issledovaniye ob"yemnoy deformatsii drevesiny pri razlichnykh usloviyakh zagruzheniya, *Naukoviy vísnik budívnitstva*, KHGDUBA (1998), 2, 35–39.
[16] Fursov V.V., Kovlev N.N., Vasil'yev A.YU. Slozhnoye naryazhennoye sostoyaniye pri smeshannom zagruzhenii ortogonal'nykh uzlov kleyenykh derevyannykh konstruktsiy, Sovremennyye metallicheskiye i derevyannyye konstruktsii, *Mezhdunarodniy simpozium*, Brest (2009), 330–335.
[17] Schatz T. Zur bruchmechanischen Modellirung des Kurzzeit-Bruchverchaltens von Holz in Rissoffnungmodus 1. − Stuttgart, (1994), 156.
[18] Naychuk A.YA., Orlovich R.B. Otsenka prochnosti drevesiny metodami mekhaniki razrusheniya, *Sovershenstvovaniya stroitel'nikh konstruktsiy iz dereva i plastmass*, SPbISI (1992), 43-48.
[19] Naychuk A.YA. K voprosu o nesushchey sposobnosti derevyannykh kleyenykh balok so skvoznymi treshchinami, *Promyshlennoye i grazhdanskoye stroitel'stvo* (2004), 6, 38–40.
[20] Jockwer R., Streiger R., Flangi A. State-of-the-art review of approaches for the design of timber beams with notches *Journal of Structural Engineering* (United States) (2014).
DOI: 10.1061/(ASCE)ST.1943-541X.0000838
[21] Drozdovskiy B.A., Fridman YA.B. Predisloviye k russkomu izdaniyu, *Prikladnyye voprosy mekhaniki razrusheniya*, Mir (1968), 552.
[22] Griffith A. A. Trans. Phil. Roy. Soc., 221A, (1920), 163.
[23] Tuturin S.V. Mekhanicheskaya prochnost' drevesiny, *Dissertatsiya doktora tekhnicheskikh nauk*, MGU (2005), 318.
[24] Blanco C., Cabrero J.M., Martin-Meizoso A., K.G.Gebremedhin K.G. Design oriented failure model for wood accounting for different tensile and compressive behavior, *Mechanics of Materials*, 83 (2015), 103-109. https://doi.org/10.1016/j.mechmat.2015.01.001.
[25] Gomon S., Pavluk A. Study on working peculiarities of glue laminated beams under conditions of slanting bending, Underwater technologies, 7 (2017), 42-48. https://doi.org/10.26884/j.uwtech.at.2017.07.042.
[26] Gomon S. S., Polishchuk N. V. Sposob opredeleniya uprugoplasticheskikh kharakteristik tsel'noy i kleyenoy drevesiny na obraztsakh konstruktsionnykh razmerov pri szhatii, Science and Education a New Dimension, *Natural and Technical Sciences*, VI(21), Issue: 179 (2018), 17-21. https://doi.org/10.31174/SEND-NT2018-179VI21.
[27] Gomon S.S. Peredumovy do zapobihannya prohre-suyuchomu ruynuvannyu konstruktsiy z derevyny pry diyi riznykh vydiv navantazhen, *Resursoekonomni materialy, konstruktsiyi, budivli ta sporudy*, 29, NUVHP (2015), 108-116.
[28] Kopanitsa D.G., Loskutova D.V, Savchenko V.I., Plyaskin A.S. Opredeleniye koeffitsiyenta posteli dlya rascheta uzlovogo soyedineniya ele-mentov iz drevesiny na MZP, *Vesnik TGASU*, (2011), 2, 79-88.
[29] Gomon S.S., Gomon S.S., Sasovskyy T.A. Diahramy mekhanichnoho stanu derevyny sosny za odnorazovoho korotkochasnoho deformuvannya do povnoyi vtraty mitsnosti materialu, *Resursoekonomni materialy, konstruktsiyi, budivli ta sporudy*, 23, NUVHP (2012), 161-166.
[30] Kochkarev, D., & Galinska, T. (2017). Calculation methodology of reinforced concrete elements based on calculated resistance of reinforced concrete. Paper presented at the *MATEC Web of Conferences, 116* https://doi.org/10.1051/matecconf/201711602020
[31] Dmytrenko, T., Dmytrenko, A., & Derkach, T. (2018). The «Wooden structures» discipline educational and methodological complex development on the basis of informational intelligent system. *International Journal of Engineering and Technology(UAE)*, *7*(3), 92-96. https://doi.org/10.14419/ijet.v7i3.2.14381
[32] Piskunov, V. G., Goryk, A. V., & Cherednikov, V. N. (2000). Modeling of transverse shears of piecewise homogeneous composite bars using an iterative process with account of tangential loads. 1. construction of a model.Mechanics of Composite Materials, 36(4), 287-296. doi:10.1007/BF02262807
[33] Leshchenko M. V., Semko V. O. Thermal characteristics of the external walling made of cold-formed steel studs and polystyrene concrete. *Magazine of Civil Engineering*. № 8, (2015), pp. 44–55. https://doi.org/10.5862/MCE.60.6
[34] Semko O., Yurin O., Avramenko Yu., Skliarenko S. Thermophysical aspects of cold roof spaces. *MATEC Web of Conferences*. Vol. 116, (2017), p. 02030. https://doi.org/10.1051/matecconf/201711602030
[35] Yurin O., Galinska T. Study of heat shielding qualities of brick wall angle with additional insulation located on the outside fences. *MATEC Web of Conferences*. Vol. 116, (2017), p. 02039. https://doi.org/10.1051/matecconf/201711602039