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A COMPLEX ANALYSIS OF STRESS-STRAIN STATE OF RIBBED WOODEN STRUCTURES WITH ANISOTROPIC SHEATHINGS

K.P. Pyatikrestovsky[1*], V.I. Travush[2]

[1]JSC "NITS "STROITELSTVO" TSNIISK named after V.A. Kucherenko, Russia

[2]"Gorproekt", Russia

*e-mail: stroymex@list.ru

Abstract. The article analyzes constructions with a frame from straight or curved rods creating orthogonal net, the cells of which are filled with slab materials vulnerable to shear. For computer calculation the method of deformation integral module and the strength criteria for elements in complex stress state are used. Calculation preconditions and basic correlations are provided.

1. Introduction

The nowadays situation in the construction area of wooden structures is characterized by new technology developments in manufacturing of adhesive long-length elements of large cross section. This allows designing of large-span structure coatings and residential buildings up to 30 floors [1]. They are characterized by the internal forces redistribution with non-linear deformations, particularly occurred under long-term or short out-of-design loads. It is necessary to take into account plastic deformation creep and work of slab elements in complex stress state.

At TSNIISK named after V.A. Kucherenko experimental and theoretical studies of structures with short-term, long and out-of-design loads (taking into account the deformation of structural elements in ultimate state) are carried out [2, 3].

2. Method of integral assessments. Application features

While calculating non-linear and non-equilibrium deformable statically indeterminate wooden structural systems the method of integral estimation of non-linear and non-equilibrium deformation of timber can be used.

The deformation diagram of compressed and compressed-bent elements of timber may be approximated by a number of equations, for example, taking a parabolic dependence by F.I. Gerstner

$$\sigma = E_0\varepsilon - \frac{E_0^2}{4\sigma_{\text{ПП}}}\varepsilon^2 . \quad (1)$$

In the equation of timber mechanical state the long-term deformation of timber under $\sigma < \sigma_{\text{long}}$ and step change of stress will be:

$$\varepsilon(t) = \varepsilon(t_0)(1+b(t-t_0)^{0,21}) + \sum_{i=1}^{k} \frac{\Delta\sigma_i}{E_0 - \frac{E_0^2}{4\sigma_{\text{ПП}}}\varepsilon_{i-1}^a}(1+b(t-t_i)^{0,21}) , \quad (2)$$

$$\varepsilon_{i-1}^a = \varepsilon(t_0) + \sum_{i=1}^{k} \frac{\Delta\sigma_i}{E_0 - \frac{E_0^2}{4\sigma_{\text{ПП}}}(\varepsilon_{i-2}^a + \Delta\varepsilon_{i-1}^a)} , \quad (3)$$

ε_{i-1}^a - total value of instant (short-term) increments of relative deformations.

3. Long-term module of deformations

To express the integral module of deformations on the base (2) the long-term module of deformation is used:

$$E_{\text{ДЛ}}\left(t_0,t\right)=\left[\frac{\varepsilon(t_0)\left(1+\text{в}(t\text{-}t_0)^{0.21}\right)}{\sigma(t)}+\sum_{i=1}^{k}\frac{\Delta\varepsilon_i}{\sigma(t)}\left(1+b(t\text{-}t_i)^{0.21}\right)\right]^{-1}. \tag{4}$$

4. Integral module of deformations is presented as [4]

$$E_{\text{ин}}(x,t)=\Phi\left(\varepsilon_{\phi}^{A},\text{в},a\right)E_{\text{ДЛ}}^{\phi}\left(\varepsilon_{\phi},t,t_0\right), \tag{5}$$

where

$$\Phi\left(\varepsilon_{\phi}^{A},\text{в},a\right)=\frac{1}{1-\frac{E_0}{4\sigma_{\text{ПП}}}\varepsilon_{\phi}^{A}}\cdot\frac{1+\left(\frac{\text{в}}{a}\right)^3-100\varepsilon_{\phi}^{A}\left(1-\left(\frac{\text{в}}{a}\right)^4\right)}{1+\left(\frac{\text{в}}{a}\right)^3-50\varepsilon_{\phi}^{A}\left(1-\left(\frac{\text{в}}{a}\right)^4\right)}. \tag{6}$$

In (5) the function $E_{\text{ДЛ}}^{\phi}$ is taken depending on the stress change mode in compressed fiber, and the function $\Phi\left(\varepsilon_{\phi}^{A},\text{в},a\right)$ reflects the nonlinearity of deformation of compressed-bent element, the level of stress. Parameters *a*, *b* - the distances of the upper and lower edges from the neutral axis.

5. Mechanical (physical) models of anisotropic material for determination of its long-term and dynamic strength.

The Fig. 1 shows a mechanical model of anisotropic material, which can provide analytical and quantitative determination of its long-term and dynamic strength with a single physical concept in a wide range of time of external loads' effect - from many days and months to tenths and hundredths of a second [5].

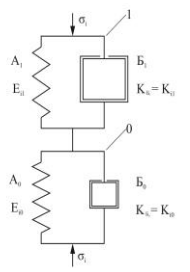

Fig. 1. The mechanical model of anisotropic material.

The model consists of two elements connected in series: element 0 and element 1, each of which represents generally the model of Kelvin-Voigt - parallel-connected elements A_o and $Б_o$, A_1 and $Б_1$, characterized by different values of their strength and deformation parameters.

Element 0 is proposed for analytical description of the development process of short-term deformations of material; element 1 - to describe the development of its long-term deformations connected with the manifestation of the creep phenomenon.

The effective working time of the element B_1 is commensurately with large time periods corresponding to the calculation of material long-term strength, taking into account the total accumulation of generalized deformations of the elements 0 and 1 within specified time $t_д$.

6. Long-term strength criteria of anisotropic material

While applied to series-connected elements O (A_0) и 1 (A_1, $Б_1$) of the generalized long-term external force effect $\sigma_i\rightarrow(\sigma_x, \sigma_y, \tau_{xy})$, total generalized deformation elements 0 and 1 –

$$\varepsilon_i = \varepsilon_{i0} + \varepsilon_{i1};$$
$$\left(\varepsilon_x = \varepsilon_{x0} + \varepsilon_{x1},\ \varepsilon_y = \varepsilon_{y0} + \varepsilon_{y1},\ \varepsilon_{xy} = \varepsilon_{xy0} + \varepsilon_{xy1}\right) \quad (7)$$

Independent ultimate strengths of material in the main axes of anisotropy (under separation, bearing and shear) are determined when values of the total deformations ε_i achieve corresponding limits – $Э_{i0} \rightarrow (Э_{x0}, Э_{y0}, Э_{xy0})$, equal to ultimate deformations of the element A_o at short-term effect of external load –

$$Э_{i0}=\frac{R_i}{E_{i0}}: \quad (8)$$

The element deformations 1 – ε_{i1} are determined upon the following obvious dependencies

$$\sigma_i=\sigma_{iA1}+\sigma_{iБ1};\ \sigma_{iA1} = E_{i1}\varepsilon_{i1};\ \ \sigma_{iБ1} = K_{i1}\frac{d\varepsilon_{i1}}{dt}, \quad (9)$$

where E_{i1} – generalized elasticity modules of element A_1, K_{i1} – viscous resistance modules of element $Б_1$. Based on (8)

Thus, in accordance with (6):

$$\varepsilon_i = \frac{\sigma_i}{E_{i0}}\left[1+\delta_i(1-e^{-\omega_{i1}t})\right] = \frac{\sigma_i}{E_{i0}}\Psi_i(t), \quad (10)$$

where $\delta_i = E_{i0} / E_{i1}$, $\omega_{i1} = E_{i0} / K_{i1}$.

Based on (7) and (9) long-term ultimate strengths of anisotropic material along the main axes of anisotropy $\bar{R}_i = \bar{R}_i\ (\bar{t}_д)$ —

$$\bar{R}_i = \sigma_i = \frac{E_{i0}\varepsilon_i}{\Psi_i(t_д)} = \frac{E_{i0}Э_{i0}}{\Psi_i(t_д)} = \frac{R_i}{\Psi_i(t_д)}, \quad (11)$$

where

$$\Psi_i(t_д) = 1+\delta_i\left(1-e^{-\omega_{i1}t_д}\right) > 1, \quad (12)$$

and $t=t_д$ – specified time limit of long-term external loads' effect.

The final equation for the long-term strength criteria of anisotropic material in parametric dependence on $t_д$ is:

for the case of separation –

$$\left[\frac{R_{px}}{\Psi_{px}(t_д)} - \sigma_x\right]\left[\frac{R_{py}}{\Psi_{py}(t_д)} - \sigma_y\right] - \tau_{xy}^2 = 0, \quad (13)$$

for the case of bearing –

$$\left[\frac{R_{cx}}{\Psi_{cx}(t_д)} + \sigma_x\right]\left[\frac{R_{cy}}{\Psi_{cy}(t_д)} + \sigma_y\right] - \tau_{xy}^2 = 0, \quad (14)$$

for the case of shear –

$$(\sigma_x - \sigma_y)^2 - 4\left[\frac{C_x}{\Psi_{xy}(t_д)} + \tau_{xy}\right]\left[\frac{C_y}{\Psi_{xy}(t_д)} - \tau_{xy}\right] = 0. \quad (15)$$

Numerical values δ_i and ω_{i1} are determined on the basis of experimental data. Calculations and examinations of structures assure the prospects of improving the reliability of structures and the possibility of material saving.

References

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