COMPARATIVE MECHANICAL ANALISYS OF FOREST BELTS STABILITY FOR DIFFERENTS SPECIES LOADED BY THE WIND FORCES

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Abstract

The aim objective of this study is to determine the values of maximum sectional efforts, tensions and displacements from the principal sections of trees, under the static and dynamic loadings. Also it was given a major importance to the determination of the percentage differences that occur between mechanical characteristic values determined from static loads given by the own weights and dynamic loads given by the meteorological phenomena wind. The study is made for differents species of trees used for the forest belts.

Key words: beam, dynamic, static, wood, design

INTRODUCTION

It is well known that in certain geographic areas of Romania, due to the global climate changes, weather phenomena are manifested with increasing violence. In the present paper the author tries to find an answer at this problems of the wind loads of the trees using the mechanically calculations.The paper tries to find analytical responses to avoid damage caused by meteorological phenomena. From the beginning it is mentioned that the mechanical study was done for a single species of trees, namely pine wood. At present, the author considers that at the level of Romania taking into account the standard map of wind loads, it is necessary to create a database of tree species to be planted according to these aspects of mechanical action. Depending on the season's features, the problem of mechanical winds loads can be treated theoretically in several ways. The beam is made of pine wood with 15% moisture and the density. The paper aims to solve two problems:

a. the case of winds loading actions taking place during the summer on the total height of the shaft h, the mechanical stress is the bending shear;

b. the static and dynamic displacement values of the axes as well as the displacements due to the dynamic forces.

For the cases studied by the author the theoretical results are presented in this paper, the study and the analysis were performed using a analytically method.

It is known that during the application of forces on the elements of wood construction, it passes low speed from undeformed position in the deformed position, so that under the influence of static loads the wooden elements are found at rest. Introducing the inertial forces by D'Alembert principle, the strucutural element of wood construction will have to be in equilibrium under the action of external forces and inertial forces.To determine the state of stresses and strains in the transversal sections of wooden beams, is admitted the hypothesis that equilibrium is realized on undeformed shapes of the beams (Soare, 2002), (Rosca, 1999). The problem starts resolving by a analogy with a static load and a dynamical load (Sandu, 2003). The main aim of this study is to determine the values of maximum sectional tensions and displacements from the principal sections of wooden beams under the static and dynamic loadings (Bia and Ille, 1983). Also a major importance will be given to determining the percentage differences that occur between mechanical characteristic values determined from static and dynamic loads (Ille, 1977), (Missir-Vlad, 2002). A dangerous problem that can occur in the application of dynamic loads is related to forced vibrations of elastic system considered (Rosca, 2002)

MATERIAL AND METHOD

Research on the present paper were performed in the installations for constructions research laboratories of the Technical University of Cluj-Napoca, Faculty of Building Services. The research and the determination of results was done between December 2017- June 2018. Study methods applied are analytical and numerical calculation methods. Analytical study was conducted considering a straight bar of constant section loaded by an linear distributed forces. Analytical study was conducted considering a straight bar of constant section loaded by an uniformly distributed forces, as well as its own weight. To be able to shape properly the system of the mechanical standpoint forces, the linear distributed force was replaced in by a concentrated load acting at 2/3 from tree height (beam).

Also at the mechanical system forces was taking into account that the material beam is considered as a homogeneous, so its own force of gravity will load at 2/3 from height of the trees. For an accurate calculation it was adopted the Timoshenko model of the beam (Blumfeld, 2005). Analytical methods was used to determine the normal stress and the displacements of the points (Fetea M. 2010). Rigorous results can be obtained by applying the numerical methods of calculation - the finite element method (Botis, 2005). Analysis and numerical study on tension and displacements that occur in the cross section of the bar points can be done to a practical beam where frequently used in construction practice.

The analysis started with analytical calculation of own weight, taking into account the density of the wood, the volume occupied by him and gravitational acceleration, followed by determining the maximum static displacement axis of the bar. Furthermore was calculated the geometrical characteristics of the transversal section of the beam represented by the axial moment of inertia, and elastic characteristic given by the Young's modulus.

The spindle is considered conical as a mathematical model.

$$V = \frac{\pi}{8} d^2 h \, ; d = 2\sqrt{\frac{3V}{\pi h}}$$

V, spindle volume; d, diameter spindle; h, total height of spindle.

For the conical model of the crown we have:

$$V_C = 0{,}1V \, ; d_C = 2\sqrt{\frac{3V_C}{\pi h_C}} \, , h_C = 0{,}1h \, .$$

h_C, canopy height; d_C, canopy diameter; V_C, canopy volume.

Mechanical slender coefficient

$$\lambda_M = \frac{l_B}{i} \, .$$

l_B, represent the buckling length of the spindle; i, radius of inertia of the cross-section.

The buckling length of the spindle depends on the type of loading and the bearing conditions. The spindle is considered to be shaped in the form of a straight bar clamped at the base and free to the other. It is loaded with two concentrated forces given by the action of the weight of its own spindle and the action of the weight of the crown.

For the case when the shaft is loaded with a linear distributed forces given by the wind load, having the maximum intensity at the top of the canopy, is adopted the following mechanical model (figure 1)

The total weight of the shaft (spindle and canopy) and the weight center for both of these are

$$G = G_1 + G_C \, ;$$

$$G_1 = mg = \rho V g = \rho \frac{\pi}{8} d^2 hg \quad x_1 = \frac{2h}{3}$$

$$G_C = \rho \cdot 0.1 \frac{\pi}{8} d^2 hg \, , \; x_C = \frac{2h}{30} \, , h_C = 0{,}1h$$

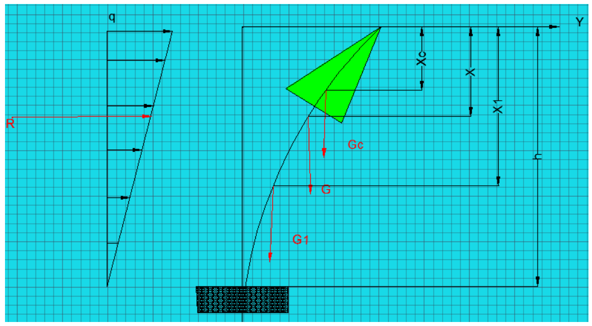

Fig. 1

The weight center of trees is given by $x_G = \dfrac{x_F G_F + x_C G_C}{G_F + G_C}$.

The wind forces is given by the relation:

$P_C^V = P_n^v \cdot C_S$

$P_C^V \left[\dfrac{KN}{m^2}\right]$ - the calculation intensity;

$P_n^v \left[\dfrac{KN}{m^2}\right]$ - the normative intensity by the wind action

$P_n^v = \beta \cdot C_n \cdot C_h^Z \cdot q$

$\beta = 2{,}1$, wind speed coefficient;

$C_n = 0{,}5$

$C_h^Z = 1{,}25$, coefficient depending on the height of the terrain Z

$q = 0.50\left[\dfrac{KN}{m^2}\right]$, dynamic pressure at 10 meters

$P_C^V = P_n^v \cdot C_S = 0{,}5 \cdot 1.4 = 1{,}115\left[\dfrac{KN}{m^2}\right]$

$C_S = 1{,}7$ - safety coefficient.

In the present paper, the problem of static displacement values of axes was treated using a different method than the classical ones (Mohr's method, initial parameters, etc.)

The maximum static displacement along the Y axis will be determined analytically using the relation (Ivan, 1997):

$$\Delta_{ST} = \frac{F \cdot L}{48EI}$$

Where:

$E = 0.1 \cdot 10^8 \left[\frac{KN}{m^2}\right]$, represent the Young's modulus and I, the axial moment of inertia about the X and Y axis. It is known that the wind forces change their values during their application so under this action the tree (beam) will be in motion (Munteanu, 1998). In this situation the accelerations of different points of the beam will not be negligible, the application process being characterized by the appearance of inertial forces (Ivan, 1997).

It was adopted the notation Ψ for the dynamic coefficient. Dynamic coefficient is determined using the relation (Catarig and Kopenetz, 2001):

$$\Psi = 1 + \sqrt{1 + \frac{2h}{\Delta_{ST}}}$$

Normal dynamic tension along the Y axis is determined using the relation (Ille 1977): $\sigma_{Yd\max} = \sigma_{yst\max} \cdot \Psi$

Maximum displacement along the Y axis is determined analytically using the relation (Ille 1977):

$$\Delta_D = \Psi \cdot \Delta_{st}$$

RESULTS AND DISCUSSION

Using the wind forces given by the relation:

$$P_C^V = P_n^v \cdot C_S,$$

was determined the intensity of the wind distributed load at the total

height $h = 16{,}5$ [m]. $q_F = P_C^V = P_n^v \cdot C_S = 0{,}5 \cdot 1.4 = 1{,}115 \left[\frac{KN}{m^2}\right]$

For total height of tree $h = 16{,}5[m]$ and for a wind force of about

$$R_F = \frac{q_F h}{2} = 9{,}528 \text{ [KN]}$$

that acts at 2/3 of the terrain surface.

The sectional stresses maximum bending moments were determined at the basis of the tree.

$$|M|_{\max} = 104{,}8[KNm]$$

Using, the condition of normal stress resistance

$$\sigma_{\max} = \frac{M_{\max}}{W_z^{nec}} \leq \sigma_{adm}$$

$$W_z^{nec} \geq \frac{M_{\max}}{\sigma_{adm}}$$

$$W_z^{nec} = \frac{\pi \cdot D_{nec}^3}{32}$$

$$\frac{\pi \cdot D_{nec}^3}{32} \geq \frac{M_{\max}}{\sigma_{adm}}$$

$$D_{nec} \geq \sqrt[3]{\frac{32 \cdot M_{\max}}{\pi \cdot \sigma_{adm}}} = 434{,}5[\mathrm{mm}]$$

We choose the effective diameter

$$D_{ef} = 435[mm] = 43{,}5[cm]$$

This diameter corresponds to a tree with approximate age of 60 years and slenderness factor of 0.87.

Verification of the clamped dangerous section is done using the relation

$$\sigma_{\max} = \frac{M_{\max}}{W_z^{ef}} \leq \sigma_{adm}$$

$$W_z^{ef} = \frac{\pi \cdot D_{ef}^3}{32}.$$

For the species considered the normal allowable tension for the bending solicitation is

$$\sigma_{adm} = 130\left[\frac{N}{mm^2}\right]$$

Twe determinated the maximum normal stress having the value

$$\sigma_{\max} = 129{,}7\left[\frac{daN}{cm^2}\right].$$

In the present paper, the problem of static displacement values of axes was treated using a different method than the classical ones (Mohr's method, initial parameters, etc.)

The maximum static displacement along the Y axis given by the wind loads (Posea N 1991), (Posea N 1976)

$$\Delta_{ST} = \frac{F \cdot L}{48EI} = 0{,}180[m] \cong 18[cm]$$

$$\Psi = 1 + \sqrt{1 + \frac{2h}{\Delta_{ST}}} = 1{,}68$$

$$\Delta_D = \Psi \cdot \Delta_{st} = 30.24[cm]$$

$$\sigma_{d\,\max} = \sigma_{st\,\max} \cdot \Psi = 218{,}4\left[\frac{daN}{cm^2}\right]$$

CONCLUSIONS

The results obtained from this analitycal study have a particular importance, being able to draw the following 6 principal conclusions:

- by a mechanically correct modeling of the forces acting on the tree, can be determinated the value of effective diameter give it from the action of the wind loads such to avoid breakage.
- regarding the static displacements they represent 59,52% of the dynamic displacements, so that should be given importance to the dynamic solicitations of wood beams.
- the maximum values of displacements are registered in the top of the tree;
- maximum normal tension is $\sigma_{\max} = 129{,}7\left[\frac{daN}{cm^2}\right]$ in the clamped circular section and is very close to the normal calculation stress $\sigma_{adm} = 130\left[\frac{daN}{cm^2}\right]$;
- for the presented case it is observed that for the wind intensity considered the tree in the most requested section does not break both the dynamic action and the static action;
- based on standardized values of wind intensities in geographic areas, this study permit the correct species type determination that can be used without the risk of breaking.

The comparative study presented in this paper demonstrates the usefulness of the results obtained by analyzing the constructive elements of the beam in terms of both dynamic and static, to be able to avoid the dangerous phenomena. This type of study can be adapted for any trees species used in forest belts

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