# STUDY REGARDING THE WOOD BEAMS RESPONSE TO STATIC AND DYNAMIC LOADING

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***Abstract***

*The aim and objective 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. Also it was given a major importance to the determination of the percentage differences that occur between mechanical characteristic values determined from static and dynamic loads.*

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

## INTRODUCTION

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. The problem starts resolving by a analogy with a static load. 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 November 2015- July 2016. The results of the studies and analyzes carried out falls into the fundamental theoretical research. Study methods applied are analytical and numerical calculation methods. The results from the application of numerical methods were determined using LISA educational software. Numerical method used and implemented using digital educational program LISA is the finite element method (FEM). Analytical and numerical 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 uniformly distributed force was replaced in by a concentrated load acting at middle of the 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 the middle of the beam. For an accurate calculation it was adopted the Timoshenko model of the beam. Analytical and numerical methods-LISA software was used to determine the normal stress and the displacements of the points (Fetea, 2010). Analysis and numerical study on tension and displacements that occur in the cross section of the bar points was 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.

For a rigorous comparison to static and dynamic performance study considered the same type of element. The beam is made of pine wood with 15% moisture and the density In both cases, the study considered the horizontal position of the beam, being supported at the ends by two supports, namely, a simple support and a hinged support. Static and dynamic study of the beam will be made considering the appropriate median plane surface XY. For the case of static beam calculation, the external forces corresponding to the loads of others elements of the building and are taken by the beam and forward to the resistance structure. There are considered as having a uniformly distributed action that occurs on the surface of the beam with the intensity

Regarding the weight of the beam it will be determined using the relation:

$$G = \rho \cdot V \cdot g$$

Where:

$m$ , beam mass;

$V$ , total volume of the beam;

$g$ , gravitational acceleration.

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:

$E$, represent the Young's modulus and $I$, the axial moment of inertia about the X and Y axis.

For accuracy and precision is used numerical calculation with the finite element method. Finite element static calculation of structures involves the few steps (Blumenfeld, 1995). Geometric structure is modeled for static analysis using a numerical program (Lucaci et al., 2015).

Numerical modeling of the structure are presented in Figure 1 to 9. (Ciofoaia, Curtu, 1998). Research practices and numerical analysis was carried out through the following 6 work steps:Numerical modeling of research involves the followings steps (Fetea, 2010):

- in the step number 1, was entering the coordinates of basic element;
- step number 2, involves shaping the basic element;
- step number 3, requires the physico-mechanical properties attachment and cross-sectional geometry selection ( Marţian, 1999);
- in step number 4 it was dividing the principal element in the finite element;
- step number 5, requires kinematic and geometric constraints attaching to the meshed structure;
- step number 6, require to loading structure with the external forces and those from its own weight;
- step number 7, involves the determining the numerical results of the performed study.

There are many situations where forces change their values during their application so that under this action the 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). Dynamic load is given by the fall of a body on the beam, taking place in this case a dynamic application by shock the acceleration rapidly varying in time. It was considered that the beam is requested dynamically by shock at its midspan with a force $P_S$, who falls from a height $H$.Were considered the following coefficients (Ille, 1977): $k_1$, coefficient of mass reduction for the quantity of movement, $k_2$, the mass coefficient for reducing quantity of kinetic energy.

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

$$\Psi = 1 + \sqrt{1 + \frac{2H}{\Delta_{ST}} \frac{1 + k_2 \cdot \frac{F}{P_S}}{\left(1 + k_1 \cdot \frac{F}{P_S}\right)^2}}$$

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):

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

Following the same numerical algorithm by finite element method is determined the dynamic displacements, the nodal normal stresses and maximum displacement along the axis Y (Sandu, Sandu, 2003).

**RESULTS AND DISSCUSION**

The numerical results obtained after applying static and dynamic calculation using analytical and numerical methods are presented considering the stages of work in within the material and method chapter. The beam wood considered have the following dimensions: length of the beam $L = 3000[mm]$,beam width $l = 200[mm]$; beam height $h = 200[mm]$, with density $\rho = 0.55\left[\frac{Kg}{dm^3}\right]$. The uniformly distributed action is $q = 1000\left[\frac{daN}{cm^2}\right]$.

The value of its own weight of beam is:

$$G \approx 432[N] = 43{,}2[daN]$$

Total force that will operate uniformly distributed over the beam is:

$$F = G + q \cdot L = 3043{,}2[dan]$$

The axial inertia moment of the cross section determinated is

$$I = \frac{h \cdot l^3}{12} = 13333{,}3[cm^4]$$

The steps of application of the finite element method using LISA software and the results that were determined are shown in figures 1-9.

Element nodes are created mainly with plane coordinates given by its length and height (Fig. 1).

Fig. 1. The principal nodes

It was created the principal element using the 4 nodes (Fig. 2).

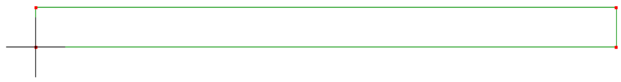

Fig. 2. The principal element

The beam finite elements created are presented in figure 3.

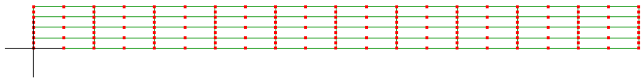

Fig. 3. The finite elements of the wood beam

It is applied the corresponding constraints (Fig. 4).

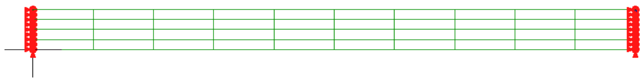

Fig. 4. Applying constraints at the ends of the beam

Total static load is applied $F = 3043.2[dan] \approx 30432[N]$ (Fig. 5).

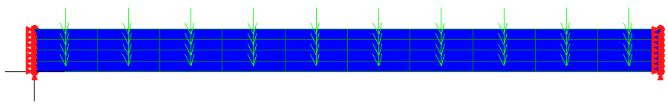

Fig. 5. The static load applied to the beam

The cross section displacement points by axis Y (Fig. 6).

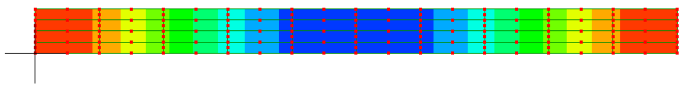

Fig. 6. Displacements by Y axis

The deformed beam and the general picture of displacement along the Y axis (Fig. 7).

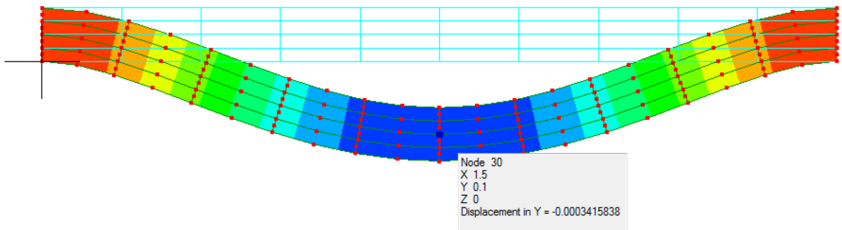


Fig. 7. The deformed beam and general displacements

Normal stresses and their distribution along the Y axis (Fig. 8).

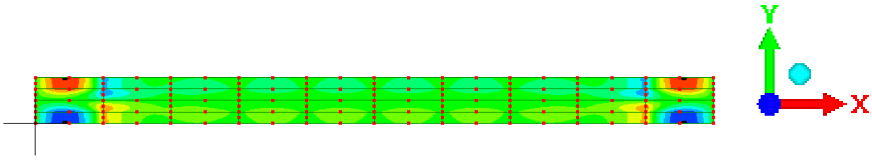


Fig. 8. Stresses distribution by Y axis

The deformed beam and the general picture of stress points along the Y axis (Fig. 9).

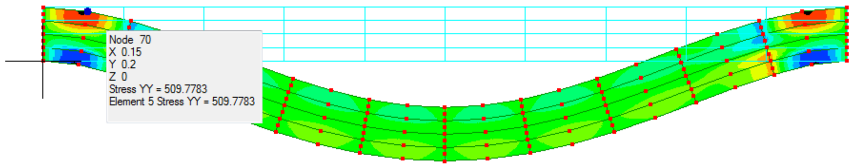


Fig. 9. Deformed beam obtained by stress analysis by Y axis

Dynamic load is given by the fall of a body on the beam, taking place in this case a dynamic application by shock the acceleration rapidly varying in time. It was considered that the beam is requested dynamically by shock at its midspan with a force $P_S = 2000[daN]$, falls from a height $H = 10[cm]$.

Were considered the following coefficients (Posea, 1991; Ille, 1977):

$k_1$, coefficient of mass reduction for the quantity of movement;

$k_2$, the mass coefficient for reducing quantity of kinetic energy;

Coefficient values are known (Ille, 1977; Posea, 1976):

$$k_1 = \frac{5}{8}, k_2 = \frac{17}{35}$$

We adopt the notation $\Psi$ for the dynamic coefficient. Dynamic coefficient is determined using the relation (Catarig, Kopenetz, 2001):

$$\Psi = 1 + = 69{,}6$$

By applying analytical and numerical methods of calculation are obtained the stress values and displacements in the sections of the considered beam (Muntenu, 1998; Lucaci et al., 2014). Following the numerical method we obtained the following values of the static displacements of cross-section by Y-axis (Botis, 2005; Sandu, Sandu, 2003). Displacements were obtained in centimeters (Fig. 10). By applying the same numerical method we obtained the following values of the static normal stress along Y axis (Botis, 2005). Normal stresses along the Y axis were obtained in $\left[\frac{daN}{cm^2}\right]$ (Fig. 11).

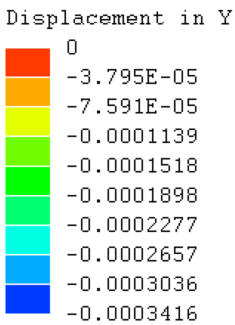


Fig. 10. Displacement values by Y axis.

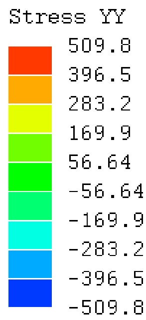


Fig. 11. Stress values by Y axis

The maximum displacement in dynamic regime occurs in the middle of the beam and has the value: $\Delta_D = 0{,}023[cm] = 0.23[mm]$

Considering the maximum normal static stress (Ille, 1977). that are registered in node 70 of the beam and having the value $\sigma_{yst\max} = 5{,}098\left[\frac{daN}{mm^2}\right]$,is obtained the maximum dynamic stress (Goia, 2000; Soare, 1999; Ille, 1977):

$$\sigma_{Yd\max} = 351{,}76\left[\frac{daN}{mm^2}\right]$$

The results determined on the beam of wooden material, can be considered as an example for future calculations.

**CONCLUSIONS**

The results obtained from calculations have a particular importance, being able to draw the following 5 principal conclusions:

- regarding the static displacements they represent 1.47% 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 middle beam cross sections;
- regarding the maximum normal stress by the Y axis for the beams loaded static, it represents 1.44% of the maximum dynamic stress;
- the calculation of wood structural elements of the building must focus intensely for the dynamic loads that occur in phenomenon;
- the calculation to determine the efforts will be made necessarily for the case of dynamic beam solicitation.

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.

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