COMPARATIVE DYNAMIC ANALYSIS OF WOODEN BEAMS AND METAL BEAMS SUBJECTED TO SHOCK

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RESEARCH ARTICLE

Abstract

The dynamic action of loads on structures is a particularly complex phenomenon. The complexity of the phenomenon is also given by the behavior of the material from which the structure is made up and which, in dynamic loads, presents very different properties compared to those in the case of static loads. There are numerous situations of action of external forces on various mechanical or civil structures, when during their application they change their module, meaning, direction or even their position. As a result of this mode of action of these forces, the structure will be in motion. Therefore, the movement that is imprinted on the structure will be accompanied by the accelerations of the various points that will not be neglected. The introduction of the kinematic parameter into the balance equations will be done by applying the inertial forces. The dynamic demand of wooden or metal structures is caused by several factors, namely: the vibratory action of various tools or machines, the fall of some bodies, the action of the wind with variable intensity, the action of hitting the structures or different structural component elements by other bodies. The present work presents a comparative study regarding the behavior under dynamic loads of wood and metal structures. The study presented in the work by the author wants to present and establish the limits of practical use for which using the same structure from the geometric point of view and the external dynamic loads but different materials, the metal can be replaced with the wooden material. For the case presented in the paper, the author considered the dynamic shock stress of the structures.

Keywords: parameters, displacements, dynamic, beams.

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INTRODUCTION

The static analysis of stress and deformation problems in mechanical or civil structures considered the progressive application of external loads from a zero value of their intensity to a final maximum value. In this case, it is known that the structure will pass with reduced speed from the undeformed form to the deformed form, so that the accelerations of its points are considered to be negligible. (Simopoulos, 1999).

The current work proposes the dynamic study of the shock stress of a bar made of two different materials, namely: wooden material and metal. The shock load of the bar-type structural element is given by its sudden contact with another body. The shock stress phenomenon of straight bars is complicated due to the fact that the inertial forces are different along the bars. Due to the complexity of the phenomenon in the present work, the author has limited himself to the case of shock stress which produces only elastic deformations when the deformation process has propagated throughout the bar. As it is known, the assumptions that are the basis of the calculation for shock loads are approximate and do not give a rigorous representation of the phenomenon which is much more complex, even in the case of the behavior of the materials only in the elastic domain. If the shock is not imposed with a high speed, this being low in relation to the propagation speed of the deformation waves, the stress of the element being carried out in the elastic domain, the established analytical relations give satisfactory results. In the case of the vertical shock with a zero drop height (h=0), the dynamic coefficient is considered to be $\Psi=2$.
The study was carried out considering the following working hypotheses:
1. The deformation of the bar from the external force applied by the shock propagated throughout the bar is governed by Hooke's law (Soare 1999);
2. The body that determines the shock stress is considered to be inelastic.
In the case studied in the paper, it was considered that the force acting on the

construction element determined by the fall of a body is F=300[daN] falling from a height h=10[cm]. The structural elements taken into account are made of metal and wooden material (oak) with a length of L=2[m]. It is considered that the structural elements are simply supported on the ends. It was considered the most frequently encountered case in practice of dynamic stress with constant acceleration through transverse bending shock. In the known classical cases, there are two possibilities for the analysis of transverse or horizontal dynamic demands, namely:

- when the mass of the hit body is taken into account;
- when the mass of the hit body is not taken into account.

In the present case, the struck body was considered to be a wooden beam and a metal beam, both having identical geometric characteristics.

MATERIAL AND METHOD

In the case studied in the paper, it was considered that the force acting on the construction element is determined by the rapid action of the force acting on the beams at the maximum value of F=300 [daN] due to a mass hitting the middle section of the beams from the height being . h=10 [cm]. The structural elements taken into account are made of metal and wooden material (oak) with a length of L=2[m]. It is considered that the structural elements are simply supported on the ends. It was considered the most frequently encountered case in practice of dynamic stress with constant acceleration through transverse bending shock. In the known classical cases, there are two possibilities for the analysis of transverse or horizontal dynamic demands, namely:

- when the mass of the hit body is taken into account;
- when the mass of the hit body is not taken into account.

In the present case, the struck body was considered to be a wooden beam and a metal beam, both having identical geometric characteristics.In the present case, the mass of the hit body is taken into account as follows, for wooden and metal beams, the following geometric characteristics were considered:

- diameter D=25[cm]=0.25[m];
- the lengths of the beams are L=2[m].

For the case of the wooden material, the following physical-mechanical characteristics were considered

- ρ =700 [Kg/mc]= oak density;
-E=11500[N/mm2]-modulul de elasticitate longitudinal;

ν=0.372 – Poisson's ratio.

For the steel material, they considered the following physical-mechanical characteristics

- ρ =7860 [Kg/mc]= oak density;
- E=210000[N/mm2]– longitudinal modulus of elasticity;

ν=0.3 – Poisson's ratio.

The weight of the wooden and metal beams acts as a uniformly distributed force with the resulting values determined in the section in the center of the beams:

- for the wooden beam;

$$G_1 = m_1 g = \rho_1 V_1 g = 686.8[N].$$

- For the steel beam:

$$G_2 = m_2 g = \rho_2 V_2 g = 7712.6[N]$$

The axial moments of inertia are given by the relation (Martian 1999):

$$I = \frac{\pi D^4}{64} = 0.000191[m^4]$$

As is known, the static displacements for the wooden and metal beams are given by the relations:

- For the wooden beam (Barsan 2003)

$$\Delta_{st1} = \frac{FL^3}{48E_1 I}$$

- For steel beam (Barsan 2003)

$$\Delta_{st2} = \frac{FL^3}{48E_2 I}$$

The notations are made:

K1 - it is called the mass reduction coefficient for the movement of the weight and the beam at the point of contact. (Bors 2005)

$$K_1 = \frac{5}{8}$$

K_2- it is called the mass reduction coefficient for the kinetic energy of the weight and the beam at the point of contact (Bors 2005) (Ille 1977)

$$K_2 = \frac{17}{35}$$

Ψ - dynamic coefficient or impact multiplier (Ille 2004), (Ille 1977)
.

$$\Psi = 1 + \sqrt{1 + \frac{2h\left(1 + K_2\frac{G}{F}\right)}{\Delta_{ST}\left(1 + K_1\frac{G}{F}\right)^2}}$$

Having the calculated dynamic coefficient, it will be possible to determine the maximum dynamic load, the maximum dynamic displacement and the maximum tension in the joists subjected to the shock.

RESULTS AND DISCUSSIONS

Using the numerical calculation program Lisa (Ghinea 2004), the 2 beams were modeled in a 2D graphic representation, namely the metal beam whose graphic representations of the values of acceleration, speed and displacements in the direction of the Y coordinate axis are represented in figures 1,2 and 3.

Regarding the modeling and presentation of deformations and kinematic parameters for the wooden beam, figures 3, 4 and 5 are presented.

For an overview of the values obtained for the kinematic parameters, table 1 shows the values corresponding to node 3 located in the middle of the opening of the metal bar with length L=2 [m].

Table 2 shows the same kinematic parameters but for the wooden bar. From the analysis carried out on the basis of the obtained data, the following relevant aspects regarding the dynamic shock behavior of the two beams emerge.

Regarding the dynamic stress, it is considered for the calculation that the acceleration of the body's weight at the contact point located at the middle of the opening is constant for the same force, being 11.4 times higher in the case of the wooden beam compared to the metal one.

Regarding the speed at the point of contact (node 3), it is found that for an interval of 3 seconds for which the determination of the kinematic parameters was initially set, it will have a much higher value in the case of the wooden beam, it is approximately 11.24 times higher than in the case of the wooden beam for each time considered and presented in tables 1 and 2.

Regarding the displacements of the points on the metal bar, they are between 0.1 [mm] and 0.9 [mm], and on the wooden bar they are between 4 [cm] and 9 [cm]. Therefore, the stiffness conditions for the dynamic action will not be met for the bar made of wooden material.

Using the relationship

$$\Psi = 1 + \sqrt{1 + \frac{2h\left(1 + K_2\frac{G}{F}\right)}{\Delta_{ST}\left(1 + K_1\frac{G}{F}\right)^2}}$$

the dynamic multiplication coefficient for the metal beam is obtained:

$$\Psi = 2.82$$

Therefore the maximum dynamic force will be (Ille 2004), (Ille 1977)

$$F_{DIN} = \Psi F = 846 [N]$$

The maximum dynamic displacement will be:

$$\Delta_{DIN} = \Psi \Delta_{ST}$$

$$\Delta_{ST\ MAX} = 0.9\ [mm]$$

$$\Delta_{DIN} = 2.538\ [mm]$$

Regarding the wooden beam, the dynamic parameters show that they do not allow the fulfillment of the resistance and rigidity conditions of the bar

Figure 1. **The acceleration by the Y coordinate for steel beam**

Figure 2. **The velocity by the Y coordinate for steel beam**

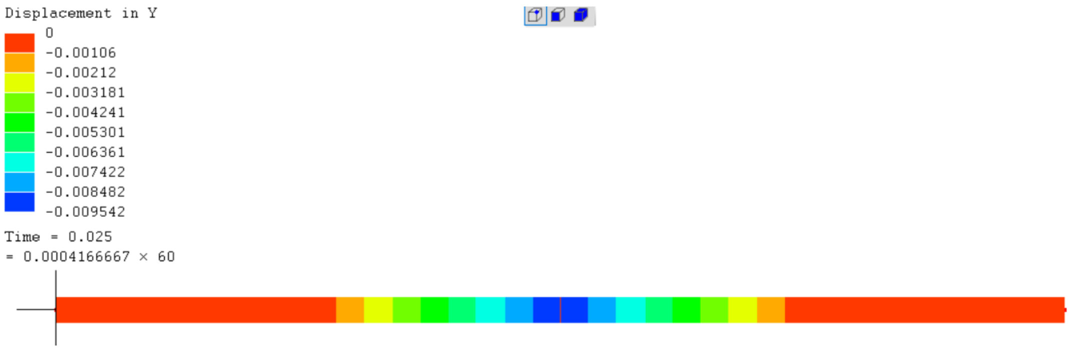

Figure 3. **The displacements in Y for steel beam**

Table 1

The kinematic parameters of the metal structure recorded in node no. 3 of the force with dynamic action

For Node 3	Time step 0 Time 0	Time step 1 Time 0.005	Time step 2 Time 0.01	Time step 3 Time 0.015	Time step 4 Time 0.02	Time step 5 Time 0.025
Acceleration	30.534	30.534	30.534	30.534	30.534	30.534
Velocity	0	0.152	0.305	0.458	0.610	0.763
Displacements	0	0.00003	0.00015	0.00034	0.00061	0.000954

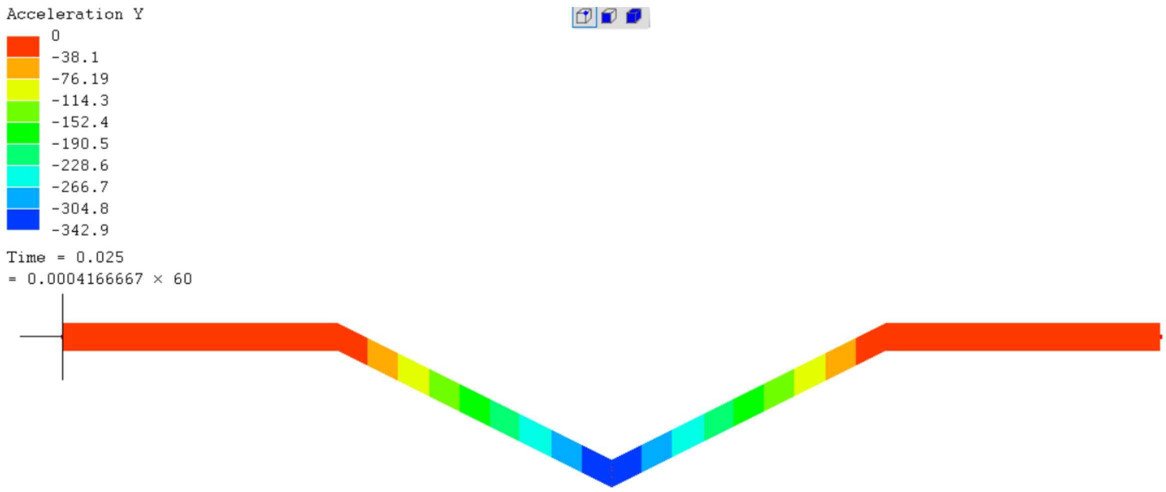

Figure 1. **The acceleration by the Y coordinate for wood beam**

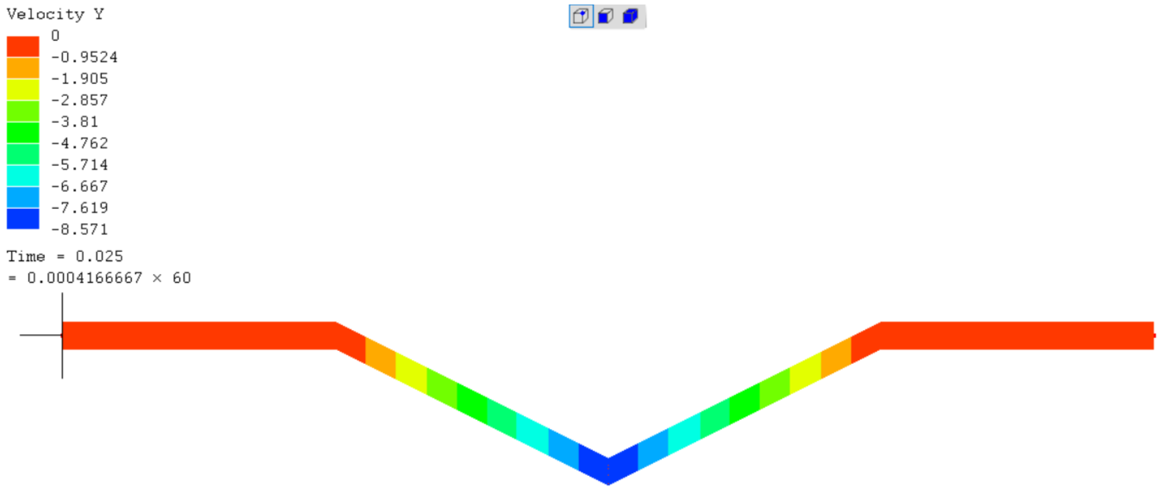

Figure 2. **The velocity by the Y coordinate for wood beam**

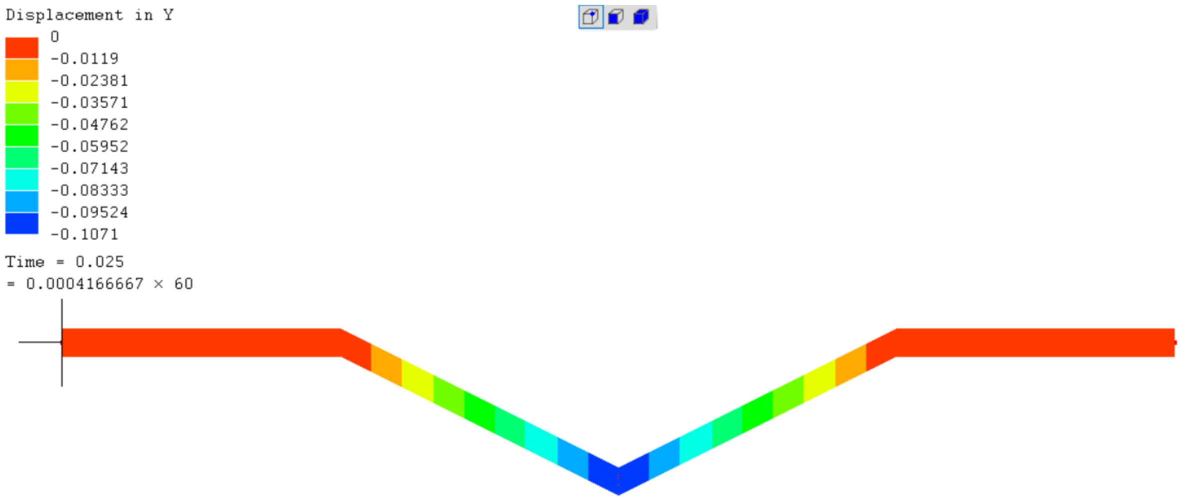

Figure 2. **The displacements in Y for wood beam**

Table 2

The kinematic parameters of the wooden structure recorded in node no. 3 of the force with dynamic action

For Node 3	Time step 0 Time 0	Time step 1 Time 0.005	Time step 2 Time 0.01	Time step 3 Time 0.015	Time step 4 Time 0.02	Time step 5 Time 0.025
Acceleration	342.85	342.85	342.85	342.85	342.85	342.85
Velocity	0	1.714	3.428	5.142	6.857	8.571
Displacements	0	0.000428	0.00171	0.00385	0.00685	0.00914

CONCLUSIONS

As a first conclusion that emerges from the dynamic analysis performed on the two types of bars is the fact that the use of wooden beams for the case of dynamic shock actions is only recommended in the case of an extremely short time of their manifestation and for force intensities what they are depending on the location where the respective structure will be used. Therefore, from the performed calculations, it is found that with the static reduction of the forces, we can be sure of the correct functioning of the structure. When applying the determined dynamic multiplication coefficient, it was found that only the metallic bar still fulfills the conditions of operation in dynamic mode. For a correct and safe use of the wooden bar, the dimensions of the transverse sections must be changed in the sense of oversizing it, which leads to an additional consumption of material.

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