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# INFLUENCE OF DAMPING SYSTEMS ON METALLIC STRUCURE

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## ABSTRACT

*The seismic movement will be simulated with the help of an electric motor that will transmit the oscillatory movements through a bi-crank system to the two structures which are located on the supporting plate. By varying the oscillation frequency deformations of the metallic structures are obtained, resonance can be viewed deformations of structure without shock absorbers, while the structure with shock absorbers has negligible deformations.*

*it results that the largest x-axis deformations during forced vibration occur in the upper plate (0.0013061 m). The structure legs have the highest x-axis deformations in the upper area (0.0013061 m), the values decreasing to the base where the deformation is 0.00014512 m, this being the minimum deformation on the x-axis. The maximum 1.3 mm can be visualized and, therefore, those who participate in the laboratory work can appreciate what is happening with the structure with the shock absorbers during the vibrations produced by an earthquake*

**Keywords:** seismic movement, forced vibration, metallic structures, shock absorber

## 1. INTRODUCTION

Lately, there has been an increase in seismic activities that cause both material damage and human life losses. So the design and verification of strong earthquakes on metal constructions has become very important.

Due to these intensifications of seismic activities that have caused significant damage, I chose to build a laboratory stand for the Mechanical Vibration Laboratory to highlight the impact of shock absorbers in vibrations caused by an earthquake.

Seismology is a branch of geology that studies the vibrations created by both natural sources - earthquakes and volcanic eruptions, as well as artificial sources, as underground explosions. Engineering seismology aims to explain and predict strong seismic movements from a site and to study the characteristics of the seismic motion that are very important for the engineering structure response [1].

The pioneer of modern seismology research was Irish engineer Robert Mallet, who has conducted extensive field studies since the 1857 earthquake in Italy (Italy). He explained the "masses of stone and mortar dismantled" using the terms and principles of mechanics, and thus created a basic vocabulary containing terms such as: seismology, hippocene, isoseismic [1].

Although seismic habitats at different depths (from a few kilometers to more than 200 kilometers) spread rapidly on large surfaces, they reactivate the labile areas of the bark and induce various morphogenetic processes on the bark (eg landslides) accompanied by the development of new relief forms [1].

The realization of structures with proper behavior in seismic actions implies knowledge regarding the mechanism of production, propagation and management of seismic movements, as well as the determination of the structures' response to these dynamic actions [1].

Seismic engineering renders the applied part of the dynamics of structures dealing with the behavior and calculation of structures in seismic actions. It is based on the theoretical and experimental knowledge provided by seismology and has as its main objective the establishment, for different categories of structures, of the conditions that guarantee a good behavior to seismic actions. Seismic engineering includes both the principles and methods of calculating structures for vibrations caused by earthquakes, as well as design elements and constructive measures designed to provide active resistance to structures, an optimal adaptability to the seismic stresses [1].

Natural disasters are dangerous natural phenomena arising from geophysical, geological, hydrological, atmospheric, biosphere and other origins, which cause catastrophic situations, followed by disruption of human vital activity, destruction of material assets, injury, injury or death of humans [2].

Earthquakes are natural phenomena caused by the release of energy within the Earth following the fracture of the rocks subjected to tensions accumulated as a result of internal (endogenous) geological processes followed by shaking and vibration of the terrestrial surface. The surface along which the rocks "break" moving is called a blueprint. Earthquakes in Romania of tectonic origin occur along crust faults (located at depths of <60 km) or at intermediate depths (approximately 60 to 200 km deep) [3].

The place inside the earth where the earthquake is born is called a seismic outbreak or terrestrial face - epicenter. Seismic vibrations propagate from the epicenter in the form of concentric spherical waves at a speed of 6-8 km/s. The first vibrations that reach the surface of the earth are the longitudinal ones. They bring the biggest shocks for the surface vibrations and the transverse vibrations that come just a few seconds after the first vibrations. The main parameters of earthquake intensity are the power of the earth, the magnitude and the depth of the furnace [2].

## 2. THE STAND. DESIGN AND EXECUTION

The purpose of this study is to observe how the dampers influence the reaction of a metallic structure during an earthquake. Thus the experiment will consist of two identical metal structures placed on a flat surface. The seismic motion will be simulated by means of an electric motor that will passes the oscillatory movements to the two structures which are located on the support plate by a whirling-crank system. The crank system consists of a 20-centimeter threaded rod. The end of the rod is caught by the plate on which the two structures are located, and the other end is caught by the engine pulley that has a rotating motion uniformly two centimeters from the motor shaft, the fastening being made by screw and nut. The support plate on which the two structures that are attached to it by cornices and screws, is of palm, and has 4 rollers to make the transl The electric motor has a power of 0.75 kW and a revolution speed of 1500 rpm, newly designed in accordance with the relevant requirements of IEC standards, namely: high efficiency, energy saving, high starting torque, low noise, low vibration, reliable operation and easy maintenance. To observe the influence of the dampers on the metal structure, the engine speed must be gradually increased. To control the engine speed, the authors used a frequency converter with maximum current of 7.5 A at 230 V. The frequency inverter control is to control the voltage and frequency of motors with controllable voltage.

The technical characteristics of the frequency converter:

- output frequency: 0.1-600 Hz,
- "auto-torque boost" function and slip compensation,
- overload: 150% of rated current (1 minute),
- voltage / frequency control,
- frequency setting: from console or potentiometer,
- 4 digital PNP / NPN inputs,
- protection functions: over-voltage, over-current, under-voltage, overload, overheating, IGBT short circuit, PTC,
- advanced PID function for process control,
- RS-485 serial interface and included EMI filter,
- optional parameter copying console and PC programming software.

Technical characteristics of the electric motor: power: 0.75 kW, speed: 1500 rpm, intensity of electric current: 5.1 A.

In the first stage of the laboratory stand, The authors decided on the material from which to construct the two structures, the plate on which they are located, the box where the engine and the converter are located and their dimensions. So, the authors used aluminum alloy as a material for the two structures and the palm of the plate and the box in which the electric motor and the converter are located. The authors also decided the dimensions of the two structures shown above, the plate they are located (800 mm in length and 750 mm in width), and the box that are equal to those of the board.

The electric motor and the converter was assembled by screws. Also on the underside of the plate I mounted four wheels also fastened by screws, through which to carry out the translation motion. The metal structure was assembled by screws and cornices. Also, the clamps between the two metal structures and pallet board were also made by screws and cornices.

Fig. 1. Engine with crank and converter box

The motor and the converter were mounted in the pallet box, the fastenings being made with screws. On the motor shaft I attached the pulleys as a crank in the mechanism, and the threaded rod (white) I attached it to the palm board by screw and cornier. Finally, the authors attached the 4 shock absorbers to a structure, the catching being done by their own mechanism.

In the fourth stage, the authors performed the first attempts, then to perform the tests at the values presented in the paper.

Fig. 2. Side view of the laboratory stand

## 3. VIBRATION ANALYSIS WITHOUT STRUCTURE DAMPING

### *3.1 Forced vibrations*

Forced (maintained) vibrations are produced by disturbing forces that exist independently of movement. In general, external loads or displacements are applied dynamically, so they are variable over time. Such excitations involve a transfer of energy from a periodically disturbing source to the system. If the transfer occurs periodically, constantly on each cycle, forced vibration is stationary, of constant amplitude. If the transfer is uneven, the vibration is transient, the amplitude varying until a stationary regime is established or until full damping.[4]

In general, when a certain disturbance is applied to a linear system with invariant parameters over time, the resulting motion is the sum of two distinct components: forced vibration, described by a function similar to the excitation function and its own vibration, dependent only on the dynamic characteristics of the system , whose function of time is usually a combination of a sinusoid and an exponential.[4]

In the case of a stationary harmonic or random disruption, the vibration itself is amortized immediately after the beginning of the movement, leaving only the forced vibration, which under certain conditions can produce resonance. If a system is actuated by a periodic external force, the frequency of which is equal to (or close to) one of the system's own frequencies, the vibration produced has relatively large amplitudes even for relatively small amplitudes of disturbing force. The system is said to be resonant. An example is the cradle pushed at certain intervals. Other examples include vibrations of toothed gears at the drive frequency, torsional vibrations of internal combustion engine shafts at cylinder ignition frequency, bearing vibrations at the frequency of the ball passing over a defect.[4]

The resonance arises at the frequencies at which the sum of the two recoverable "reactive" energies - potential and kinetic - is null, and the energy transmitted to the system is equal to the energy dissipated by friction. The phenomenon occurs when the excitation frequency spectrum covers a range that includes the system's own frequencies. At resonance, a constant amplitude force produces a maximum response, or a minimum force is required to maintain a constant amplitude response.[4]

Resonance means large amplitudes of motion at certain points or parts of the vibration system, accompanied by considerable stresses and tensions or considerable relative movements that can lead to breakage through fatigue, improper operation, wear, shocks, and noise. [4]

A resonance is defined by a frequency, a level of dynamic response, and a frequency response curve width. The occurrence of dangerous vibration modes in the vicinity of resonances can be done by:

- Changing exciting frequencies;
- changing the mass or stiffness of the vibratory system to vary its own frequencies;
- increasing or adding depreciation;
- Attaching a dynamic vibration absorber.[4]

### *3.2 The force of vibrations without damping*

From the analysis of own vibrations, it results that at a disruptive frequency of 11.198 Hz the resonance of the system appears and therefore the deformations are maximum (tending towards infinite in the absence of damping).

For a disturbing 12 Hz frequency, the system works close to the resonance and the amplitudes of the movement are large and therefore can be observed with the naked eye by the students. The system operating relatively short time does not risk destroying the structure.

For the reasons outlined above, the authors choose a 12 Hz frequency for the forced vibration study.

The computation of forced vibrations without damping was also performed in the Ansys program. For the calculation of forced vibrations without damping, the same discretization was used as in the case of free vibrations. Following the calculations with the Ansys program, diagrams for variation of the deformations on the 3 axes of the system Cartesian.

From Figure 3, it follows that the greatest deformations on the x-axis during forced vibration occur in the upper plate (27.67800 mm). The structure legs have the highest x-axis deformations in the upper zone (27.67800mm), the values decreasing towards where the deformation is 3.075300 mm, this is the minimum deformation on the x axis. The maximum dimension of 27.6 mm can be visualized and therefore those who participate in the laboratory can appreciate what happens with the structure without shock absorbers during the vibrations produced by an earthquake.

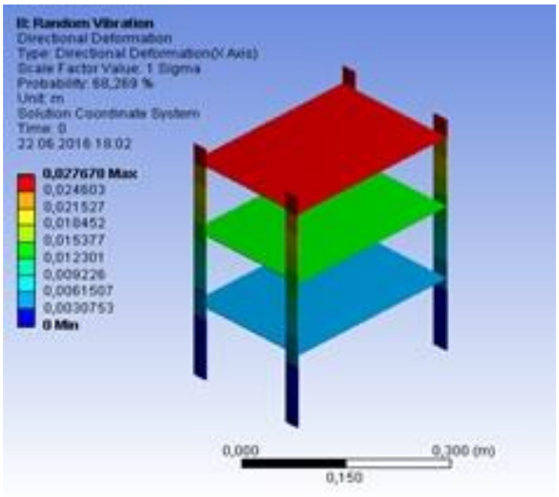

Fig. 3. Deformations on the x axis

From Figure 5, it follows that the greatest deformations on the y axis during forced vibration occur on the widths of the plate plates (1.7219 mm). The smallest y-axis deformations during forced vibration occur in the lower part of the supporting legs and in the middle area of each level plate (0.19133 mm). The y-axis deformations are negligible with respect to those on the x-axis.

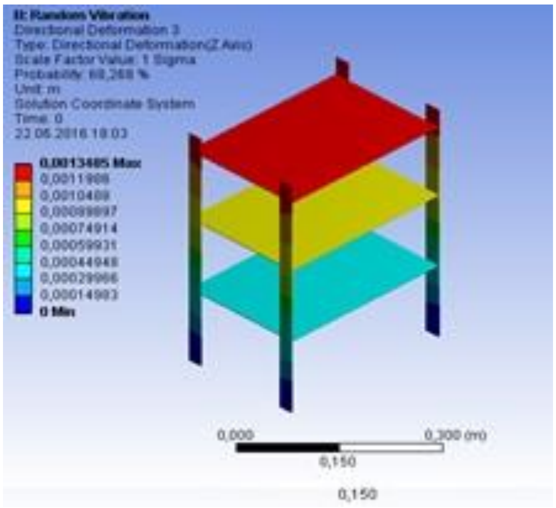

Fig. 4. Deformations on the z-axis

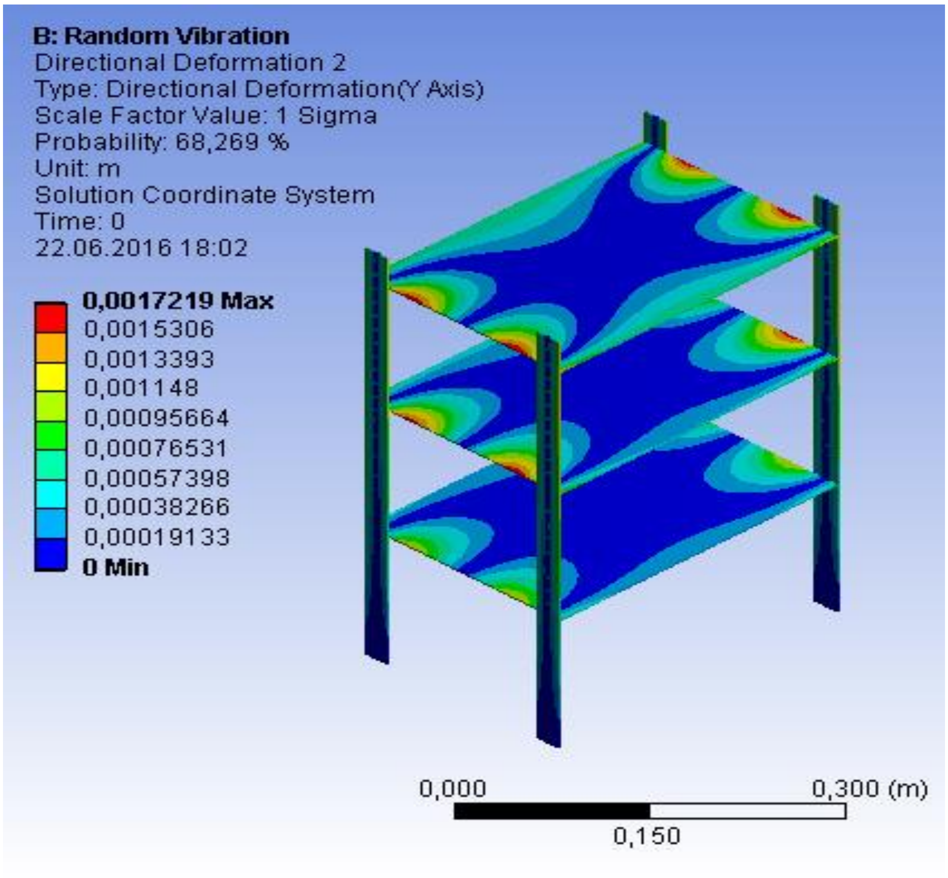

Fig. 5. Deformations on the y-axis

From Figure 4, it follows that the largest deformations on the z axis during forced vibration occur at the bottom of the top plate and the upper support legs of 1.3485 mm. The smallest deformations on the z-axis during forced vibration occur in the lower leg area (149.830 mm). In this case, the deformations on the z-axis are negligible compared to those on the x-axis.

In conclusion deformations along the x axis are determinant, they can be visualized and show the structure behavior chosen during the earthquake.

## 4. ANALYSIS OF FORCED VIBRATIONS WITH DAMPING OF THE STRUCTURE

### *4.1. Viscounting shock absorbers*

Viscous dampers are passive energy dissipation devices. The use of viscous dampers to control structural response is a world-class solution along with other passive control devices. By introducing them into the structural strength structure, a quantity of energy is dissipated during earthquakes, which would otherwise have to be taken over by other devices or through incursions in the field of postic. Typically, these devices are evenly spaced, with the same mechanical characteristics on the height of the buildings. The studies in the field reveal decreases in terms of displacements for structures that have vibration dampers. However, it is also possible to see that the forces transmitted in the elements adjacent to the silencers reach important values and in some cases lead to the collapse of the structure.[6]

The viscous shock absorber (Fig. 6.) is different from other types of shock absorbers by the fact that energy dissipation is achieved by friction produced by shearing a viscous fluid between two solid elements, at relative speed or by friction generated when the fluid is displaced by a pipe or through an orifice, but also by the fact that the force developed therein is mainly proportional to the velocity of deformation between the damper ends [6].

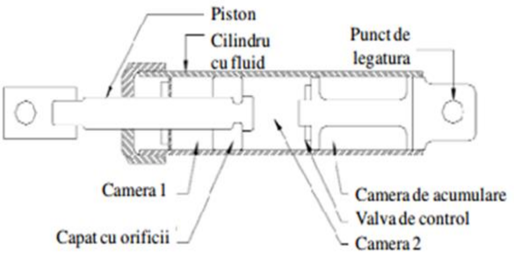

Fig. 6. Visor shock absorber

The viscous shock absorber consists of a closed cylinder containing a viscous fluid. The fluid may be silicone, oil or other fluid with controlled viscosity. A piston arm is connected to an element with holes. By forcing the fluid through the piston head holes a pressure is created resulting in a damping force, dissipating in this way of energy.

Due to the fact that the damping force varies only at the loading speed, the viscous shock absorber can be classified as a dependent energy dissipative device [6].

In general, viscous dampers are used as passive control systems, but through the control of the orifice or fluid viscosity of the fluid can also be used in semi-active control systems. Visor shock absorbers are an alternative to plasticizing or disposing of structural elements, such as a way to absorb seismic energy. They can almost dissipate the entire seismic energy, leaving the structure intact and ready for use immediately after the event.[6]

The resulting force of a viscous shock absorber depends on the relative speed between the two ends of the damper. The force-speed relationship depends in particular on the characteristics of the fluid and has the following general formula:

$$F = C\left[V\right]^{\alpha} \sin\left[V\right] \qquad (1)$$

where V - the relative velocity between the two ends of the damper, C and α - damping constants. Exponent α is representative of the non-linearity of the viscous shock absorber. The hysteretic curve for a linear shock absorber is a pure ellipse. As the damping exponent decreases, the shape of the hysteretic curve approaches a rectangular shape (Fig. 7). Parameter C produces an increase in the area within the hysteretic cycle, resulting in an increase in dissipated energy, but also an increase in the force in the silencer.[6]

Typically, structural shock absorbers have a coefficient α with values between 0.3 and 1.0; any value of α over 1.0 giving very poor performance for the shock absorber. Otherwise α is the lowest value that the damping exponent can normally have. Based on the relation $F = C\left[V\right]^{\alpha}$, it results that the effectiveness of the damper is a function of the degree of deformation. Therefore, the shock absorbers will have to be located between the points with the highest relative deformations [6].

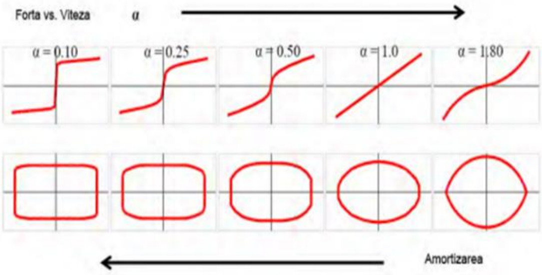

Fig. 7. Hysteretic curve for a linear damper

### *4.2. Impact of viscous dampers on structures*

The shock absorbers are subassemblies used for rapid dissipation of shock and vibration energy when friction losses in the elastic member are not sufficient [5].

In general, viscous dampers do not influence the stiffness of the structure. There are, however, dampers that either contain an elastomer or viscous liquid under pressure which, before dissipating energy through the action of the viscous liquid, must overcome a predetermined force given by either the elastomer or liquid pressure. A number of physical and numerical experiments have been undertaken to demonstrate the effectiveness of viscous liquid shock absorbers for structural applications. The results obtained for the experimental tests indicate decreases in displacements and the basic cutting force. A study by Reinhorn concludes that the forces transferred to the foundations remain the same, and in some cases they may even grow.[5]

### *4.3. Forced vibration of the system with damping*

The calculation of the forced damping vibrations applied to the structure was also carried out in the Ansys program.

For the calculation of forced vibrations without damping, the same discretization was used as in the case of free vibrations. Following the calculations using the Ansys program, variations of the deformations on the 3 axes of the Cartesian system were obtained.

From Figure 8, it results that the largest x-axis deformations during forced vibration occur in the upper plate (1.306100 mm). The structure legs have the highest x-axis deformations in the upper area (1.306100 mm), the values decreasing to the base where the deformation is 0.1451200 mm, this being the minimum deformation on the x-axis. The maximum 1.3 mm can be visualized and therefore those who participate in the laboratory work can appreciate what is happening with the structure with the shock absorbers during the vibrations produced by an earthquake.

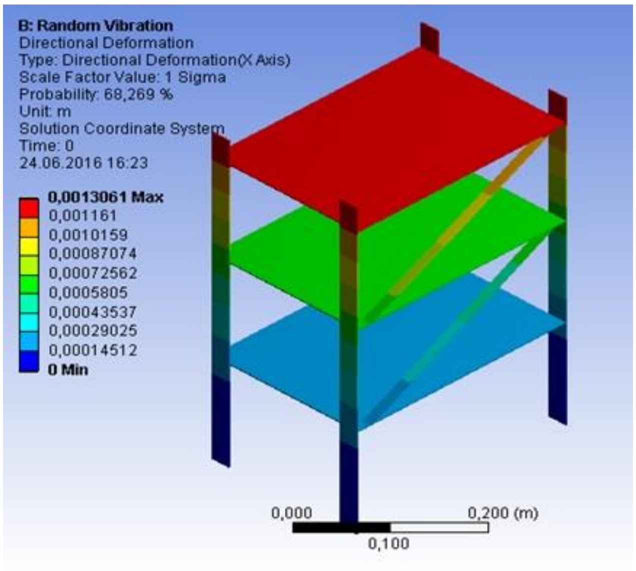

Fig. 8. Deformations on the x-axis

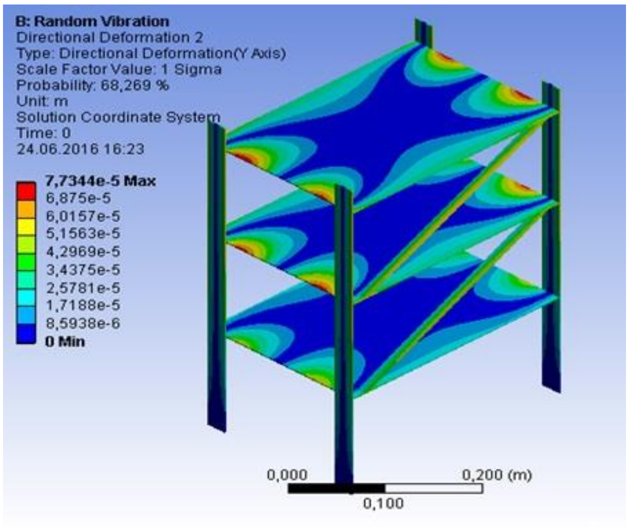

Fig. 9. Y-axis deformations

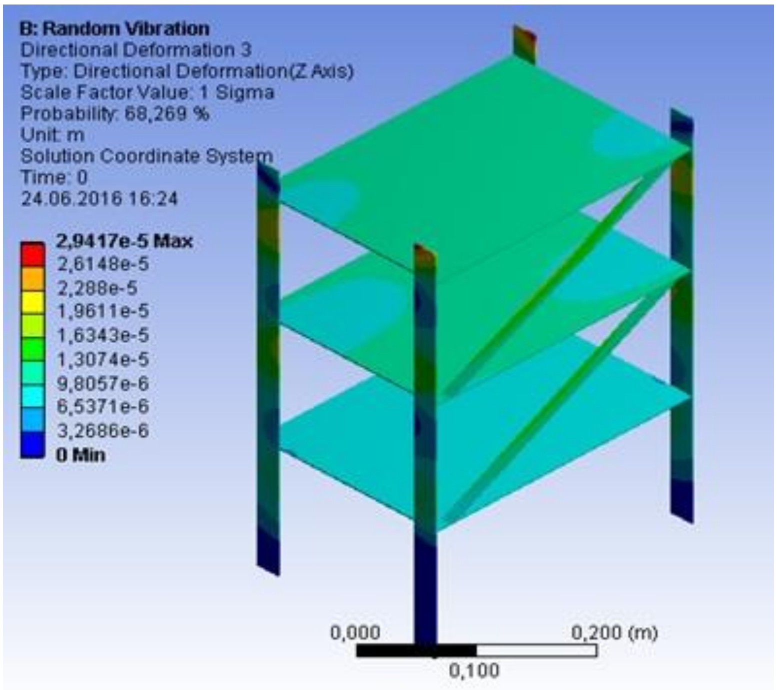

Fig. 10. Deformations on the z axis

From Figure 9, it follows that the greatest deformations on the y-axis during forced vibration appear on the widths of the level plates (0.07734400 mm). The smallest y-axis deformations during forced vibrations occur in the lower part of the legs and in the middle area of each level plate (0.008593800 mm). The y-axis deformations are negligible with respect to those on the x-axis.

From Figure 10, it follows that the largest deformations on the z-axis during forced vibration occur in the upper part of the two supporting legs, of 0.02941700 mm. The smallest deformations on the z axis during forced vibration occur in the lower area of the supporting legs (0.003268600 mm). In this case, the deformations on the z-axis are negligible compared to those on the x-axis

In conclusion, the deformations along the x axis has values greater than the deformations on the y and z axes, respectively. Deformations of the structure with shock absorbers are much lower than those of the non-damping structure, resulting both in the finite element analysis and in the values of deformations on the stand.

## 5. CONCLUSIONS

Lately, there has been an increase in seismic activities that cause both material damage and loss of human life. So, designing and verifying the effects of strong earthquakes of metallic construction has become very important.

Due to these intensifications of seismic activities that have caused significant damage, the authors chose to build a laboratory stand for the Mechanical Vibration Laboratory to emphasize the influence of shock absorbers on vibrations caused by an earthquake on a metal structure.

The laboratory stand is composed of two identical metal structures, placed on a flat surface, one of which is equipped with shock absorbers. The seismic movement will be simulated with the help of an electric motor that will transmit the oscillatory movements through a bi-crank system to the two structures which are located on the supporting plate. By varying the oscillation frequency deformations of the metallic structures are obtained, resonance can be viewed deformations of structure without shock absorbers, while the structure with shock absorbers has negligible deformations..

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