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Isolation System Model Subjected to Random Vibrations

Fanel Scheaua

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Abstract

The construction of bridges or viaduct structures represents major infrastructure works of vital importance for human communities, and therefore they must be made to withstand both the traffic and the seismic events. Therefore, all necessary measures should be taken so that these structures can remain functional even after the action of earthquakes of considerable magnitude. A high level of safety for these structures can be ensured if within the resistance structure some special mechanical systems are mounted, which will be able to improve the building assembly behaviour when an earthquake occurs. This kind of mechanical system capable of ensuring a high level of safety for the isolated structure is described in this paper. The isolation system assembly consists of a rolling pendulum device combined with elastomeric system. This system was built and experimentally tested at random vibrations. The experimental results are presented regarding motion parameters recorded at the pier and superstructure level. The combination between effects of the two dissipating system types represents the optimum solution intended to achieve an improved response of the isolated structure when subjected at dynamic actions. Therefore, it represents a special system which can be successfully used in the endowment of bridge or viaduct structural type.

Keywords: Dissipation system, rolling friction, anti-seismic device, experimental modelling

1. Introduction

Within a region infrastructure elements such as highways, roads and rails has strategic importance because it determines the economic growth and the level of development for that region. The bridge or viaduct structural types represent special structures that provide access for crossing a river course or a valley, assuring a vital connection between human communities. Therefore, such structures must be kept in operation even when high-magnitude earthquakes occur. To be able to withstand the demands in dynamic regime to which these special structures

are subjected, the design engineers must consider the use of resistant materials and appropriate dimensioning of the resistance structure. In addition to these methods, special protective systems are being used that can provide structure isolation against destructive dynamic actions. Such systems are successfully used for the endowment of bridges and viaducts worldwide. These protective systems are mechanical systems capable of assuming some of the earthquake energy aiming to dissipate and transform it into another form of energy. Usually, the mounting solution for the dissipating energy devices is interposed between the structural frames of the bridge or viaducts. Therefore, the total energy of the earthquake is not reaching the superstructure being consumed at the isolation system level. An experimental model of the hybrid isolation system is described in this paper. This model consists of a rolling pendulum system combined with an elastomeric system. The idea of building such a system was to achieve the combined effects of the two systems types represented by rolling dissipative system and elastomeric system. This system has been experimentally tested on a reduced scale structure and the results are shown in the following.

2. Dissipation device model assembly

The mounting principle of the dissipation system can be accomplished through attachment to the structural frames of the isolated structure. It can be seen that it can be mounted between the foundation and the superstructure of the bridge ensuring a disconnection between the two structural elements. Therefore, the earthquake-induced efforts at the foundation level cannot be fully transmitted to the superstructure because they are consumed by the composed dissipation system. Figure 1 shows the mounting principle and mathematical model of isolation system at the bridge structure.

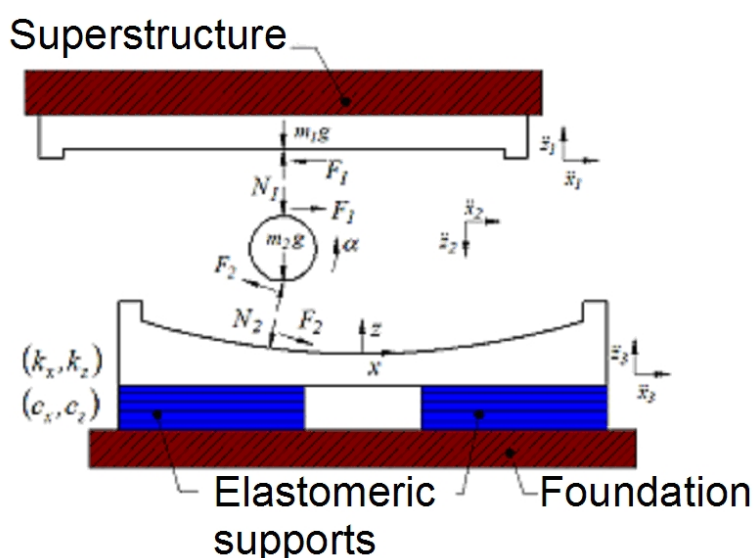


Figure 1. Composed isolation system mathematical model [1, 2].

The equation of motion with rolling system can be written as:

$$m_1 \ddot{x}_1 + F_r \text{sign}(\dot{x}_1) = -m_1 \ddot{x}_3 \quad (1)$$

where F_r is the restoring force.

Also, the addition of elastomeric systems determines the following equations of motion:

$$\begin{cases} m \ddot{z}_3 + c_z \dot{z}_3 + k_z z_3 = 0 \\ m \ddot{x}_3 + c_x \dot{x}_3 + k_x x_3 = 0 \end{cases} \quad (2)$$

3. Experimental test

An experimental bridge structure was built at a reduced scale to which a composed isolation system, also built on a small scale, was added. The isolated structure assembly equipped with the dissipation system is schematically shown in Figure 2. The rolling friction device is composed of two main rolling plates (a flat and a spherical surface), a central spherical part positioned between the two main rolling surfaces which moves by rolling ensuring relative movement of the two main surfaces. Thus, a specific movement undertaken by the foundation ground along with the bridge pier is filtered through the rolling friction and the elastomeric isolation system, so that the request is not fully transmitted on vertical direction to the superstructure which tends to remain in equilibrium position during any dynamic action.

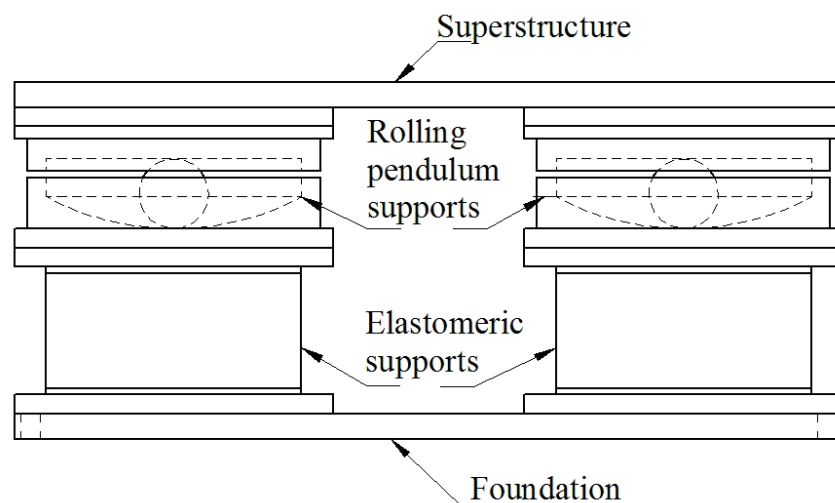


Figure 2. Schematic representation for the isolation system model assembly [3].

The bridge model has four isolation systems positioned at the ends of the beam or superstructure. Tri-axial accelerometers have been mounted in the bridge pier and beam. The excitation

is provided with a special device that provides a set of random vibrations at the pier level. Because of the excitation force of random value, at the isolation system level, the spherical steel parts are rolling on the main steel spherical surface, while the friction coefficient is in the range of 0.15–0.18 (Coulomb friction without lubrication) [4, 5].

The experimental results recorded are presented for the main transversal and longitudinal directions of movement at the level of support pier and the isolated superstructure. Figure 3 presents the values recorded at the pier support on the transversal direction of motion.

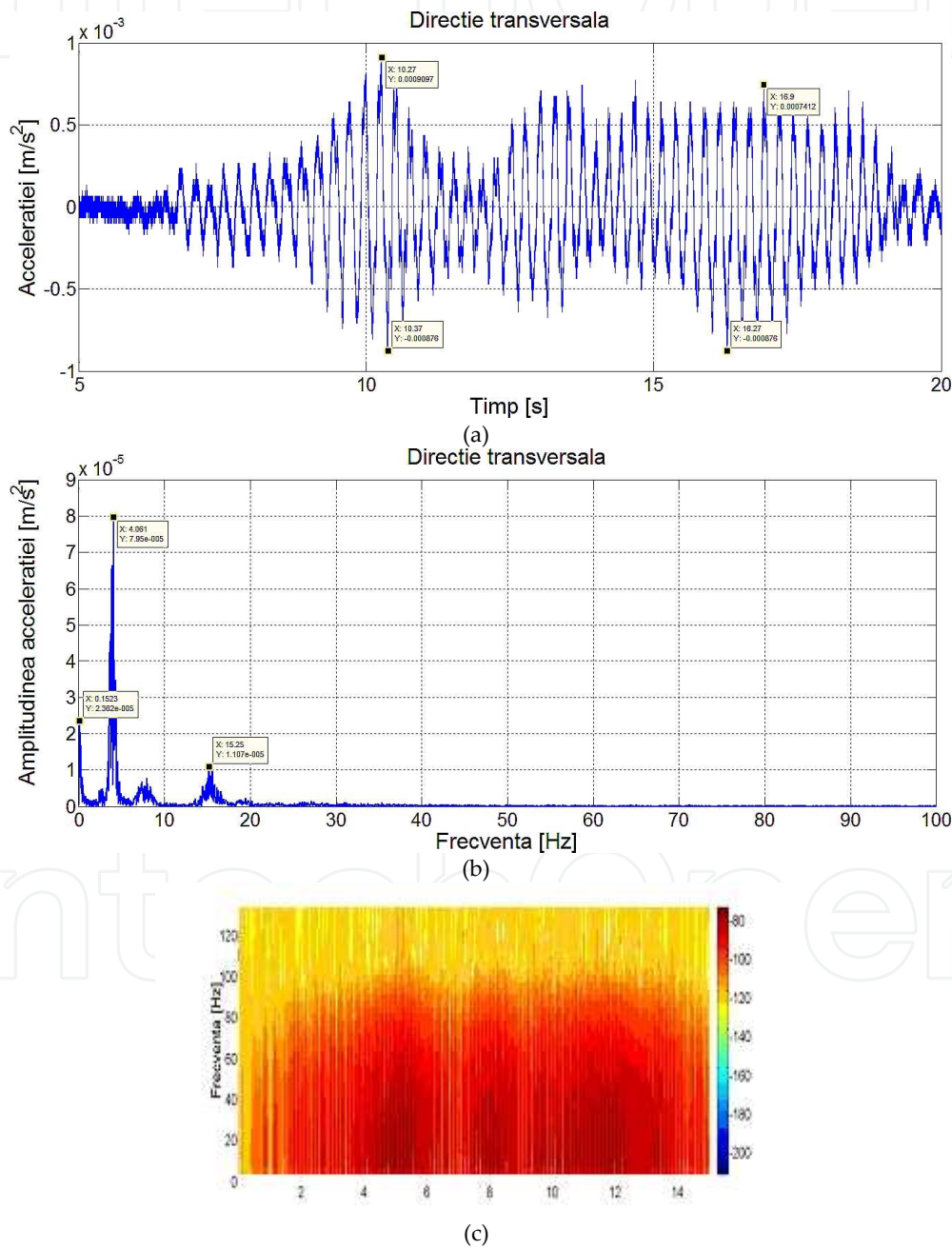
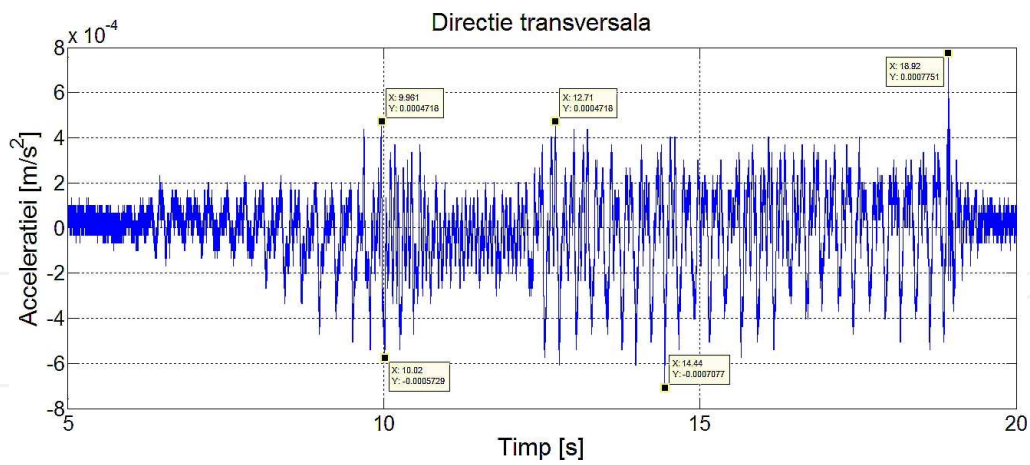
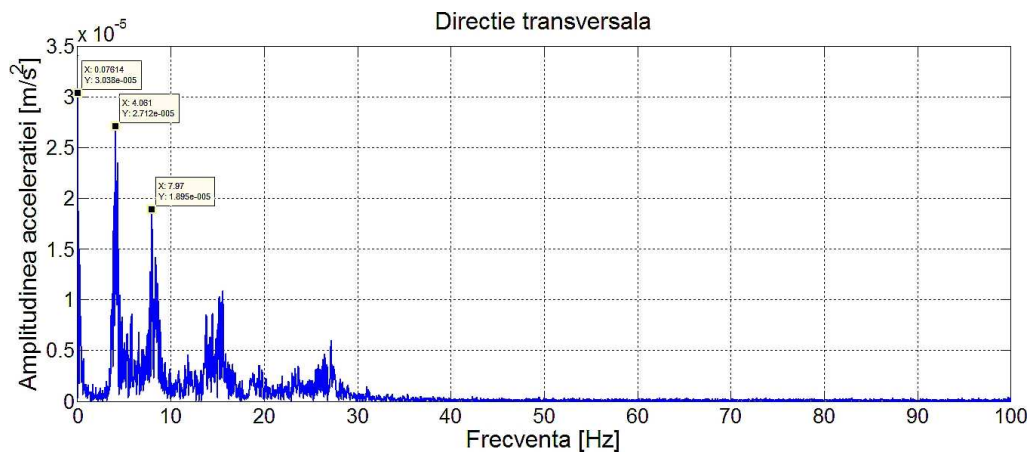


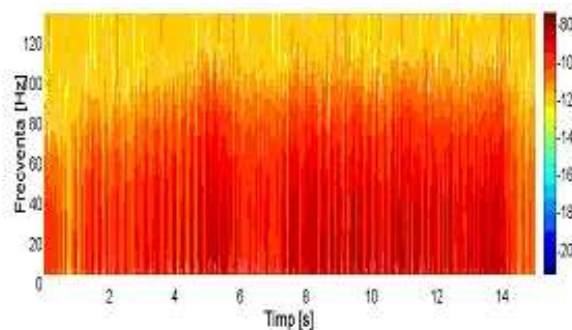
Figure 3. Experimental results obtained for pier transversal direction of motion. (a) Acceleration values vs. time. (b) Acceleration amplitude values vs. time. (c) Spectrogram of frequency values vs. time.



(a)



(b)



(c)

Figure 4. Experimental results obtained for superstructure transversal direction of motion. (a) Acceleration values vs. time. (b) Acceleration amplitude vs. frequency. (c) Spectrogram of frequency vs. time values.

The results obtained are presented in order to highlight the differences between the values obtained at the support pier and at the superstructure level. Figure 4 presents the recorded values at the superstructure level on the transversal direction of motion. Figure 5 presents the values obtained at the support pier for the longitudinal direction of movement.

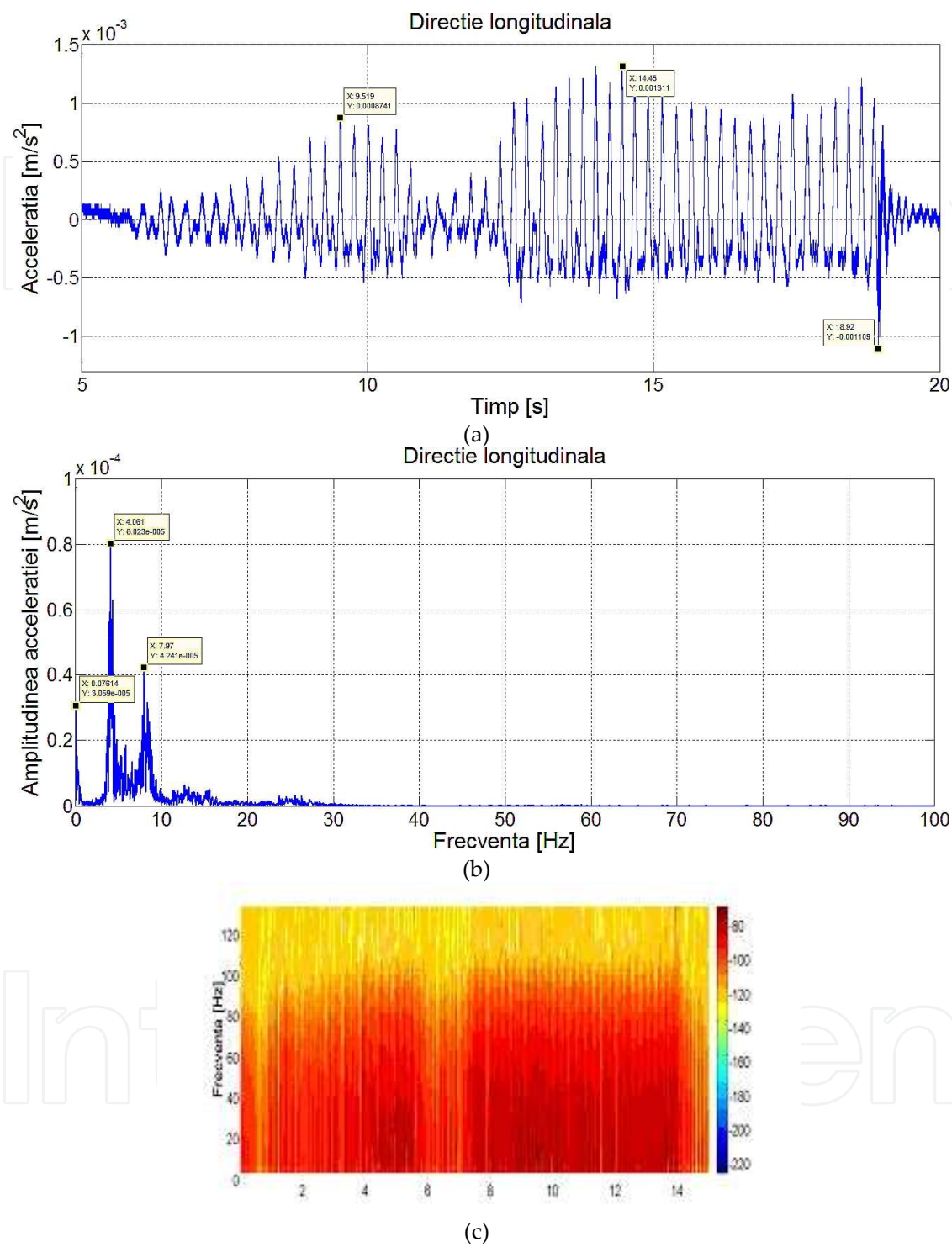


Figure 5. Experimental results obtained for pier longitudinal direction of motion. (a) Acceleration values vs. time. (b) Acceleration amplitude vs. frequency values. (c) Spectrogram of frequency values vs. time.

Figure 6 presents the obtained result values at the superstructure level for the longitudinal direction of movement.

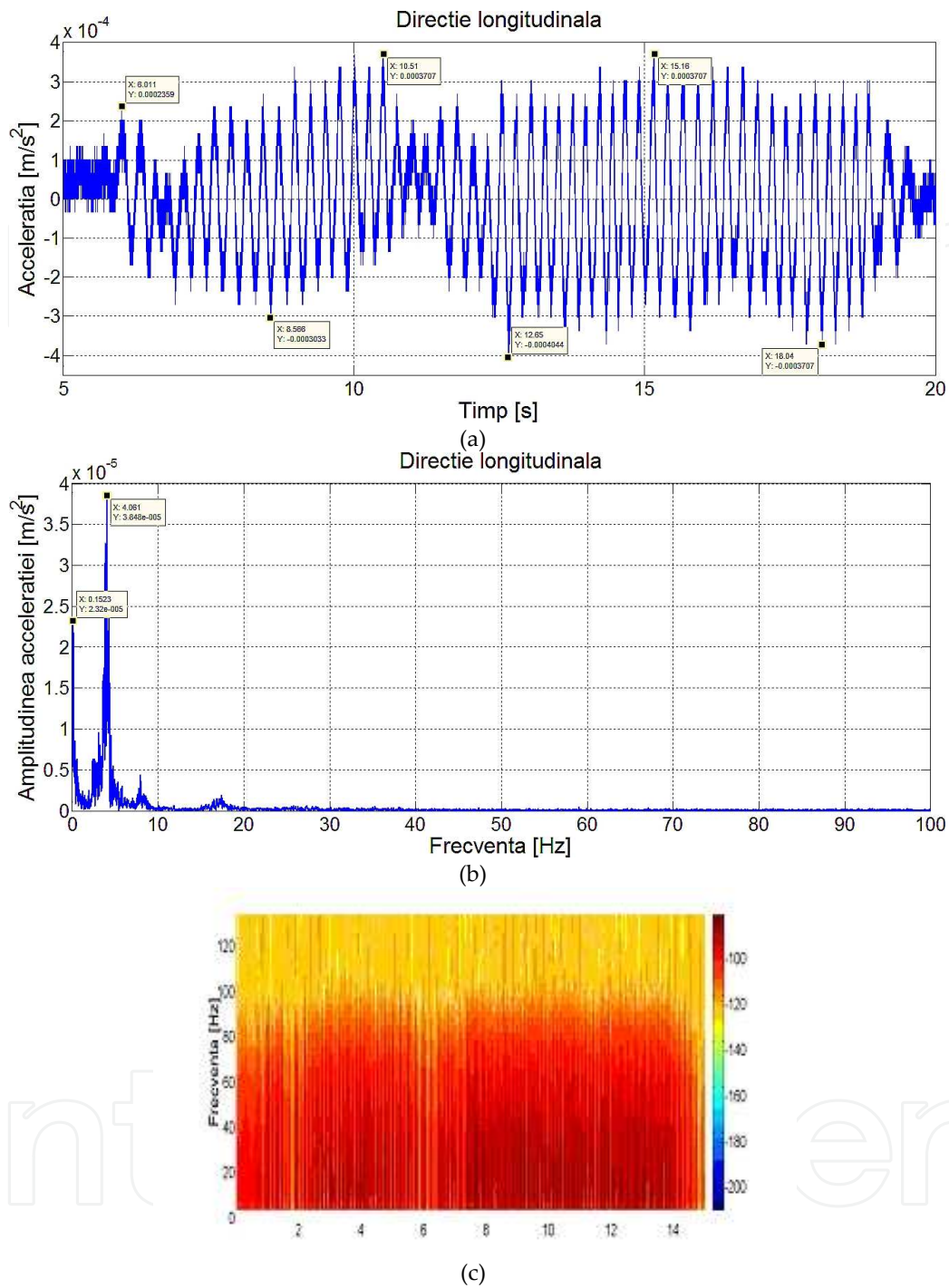


Figure 6. Experimental values obtained for superstructure longitudinal direction of motion. (a) Acceleration values vs. time. (b) Acceleration amplitude values vs. frequency. (c) Spectrogram of frequency values vs. time.

The values obtained for acceleration amplitude at the level of pier and superstructure are presented in Table 1 for both transversal and longitudinal directions. The differences between the values obtained at the support pier and the superstructure for both directions of movement can be observed due to isolation system action.

Values for transversal direction of motion			
Pier		Superstructure	
Acceleration [m/s ²] $\times 10^{-5}$	Acc. amplit. [m/s ²] $\times 10^{-5}$	Acceleration [m/s ²] $\times 10^{-5}$	Acc. amplit. [m/s ²] $\times 10^{-5}$
9.97	2.362	4.718	3.03
7.412	7.95	7.751	2.712
	1.107		1.895
Values for longitudinal direction of motion			
Pier		Superstructure	
Acc [m/s ²] $\times 10^{-5}$	Acc amplit [m/s ²] $\times 10^{-5}$	Acc [m/s ²] $\times 10^{-5}$	Acc amplit [m/s ²] $\times 10^{-5}$
8.741	3.059	2.359	2.32
13.11	8.023	3.707	3.848
13.11	4.241	3.707	3.848

Table 1. Numerical values obtained for both transversal and longitudinal directions of movement

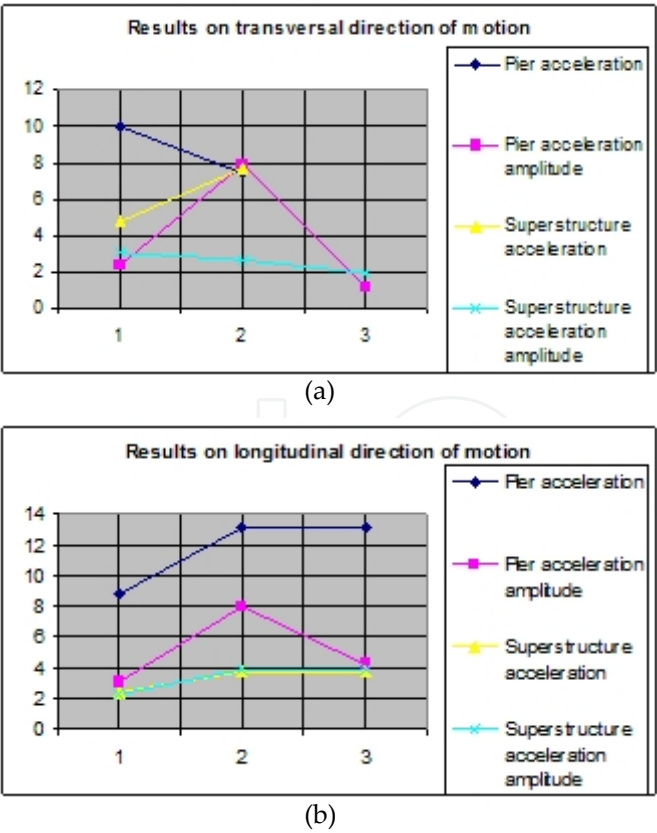


Figure 7. Graphical representation for the recorded values on the transversal and longitudinal directions of motion. (a) Transversal direction of motion. (b) Longitudinal direction of motion.

Figure 7 presents the graphical representation of numerical results obtained on transversal and longitudinal directions of movement.

On the graphs, representations of the values obtained and the motion mitigation trend at the isolated superstructure level can be observed due to action of the hybrid isolation system mounted.

4. Conclusions

A composed isolation system has been described and experimentally tested in this paper. For the presentation of experimental results obtained the spectral analysis was used. The images obtained by decomposing of the waves produced as a result of the application of excitation on the structural model were recorded and arranged by wavelength and frequency. The values obtained are presented taking into account the isolated structural element and the recording on main directions of movement. The main maximum values recorded for the motion amplitude at the level of support pier and superstructure were highlighted. The general trend is of motion mitigation for the superstructure as can be seen in the both transversal and longitudinal direction of movement. A set of random vibrations was chosen in order to move the structure because it simulates the action of a real earthquake.

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