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ASPECTS REGARDING ROLLING PENDULUM SEISMIC ISOLATION SYSTEMS

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ABSTRACT

Special systems capable to ensure a proper isolation for building structures against dynamic actions have experienced a continuous development in the recent years. These systems are designed to provide increased safety for buildings subjected to destructive dynamic actions such as shocks, vibrations, but also seismic ground motions. Depending on their role within the structural components, this kind of devices may be classified as isolation systems providing isolation against different occurring motion, but also energy dissipating elements. Within the category of isolation systems there is a special mechanical device that can be used for the structure base isolation of bridges or buildings with reduced height. The mounting position is at the base, namely between the foundation and the superstructure. The device works on the principle of pendulum and consists of two metal plates between which there is a spherical piece that performs a rolling motion. This fitting method ensures freedom of movement for the lower part of the device together with foundation and ground, while the upper part together with superstructure tends to remain in the equilibrium position. This paper presents the model of rolling pendulum system (RPS), but also the experimental results obtained on a small-scaled bridge structure isolated with this kind of system.

KEYWORDS*:* rolling pendulum, base isolation, dry friction

1. INTRODUCTION

There are many types of devices used for structural isolation and energy dissipation that are placed inside the engineering buildings, but, if we refer to the process of structure base isolation, we can mention the special devices which act as a damping device for ground motions mitigation based on dry friction force.

Systems that provide protection of structures against the dynamic actions can be categorized as isolation systems and energy dissipating systems. The isolation systems positioned at the base of the structure are included in the category of the base isolation systems, while dissipative systems are included in the category of energy consuming systems.

An isolation system positioned at the base of structure introduces a disconnection between structural elements, namely between the foundation and the superstructure. Besides the isolation systems using sliding friction force and working on the principle of physical pendulum, there have also appeared special systems that use the rolling friction force.

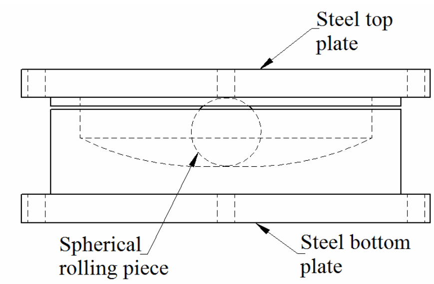
Thanks to the significantly lower values of the rolling friction coefficient it is obtained a greater freedom of movement for the structure foundation together with ground when a seismic event occurs.

2. THE MODEL OF ROLLING PENDULUM ISOLATION SYSTEM

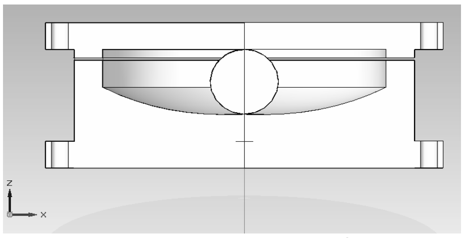
In the event of an earthquake, the ground describes a sudden motion which causes simultaneously structure movements. The resistance of building structures to earthquake can be ensured by the proper dimensioning of the resistance structure within buildings (columns, beams) which have to face the great efforts induced by seismic movements.

The rolling pendulum isolation system can be mounted on structural types as bridge or viaduct, but also on buildings with a reduced height. Through this special mounting solution, the isolation system ensures visibly improved stability for the isolated structure when an earthquake occurs.

An isolation system with rolling pendulum is composed of two metal plates between which there is interposed a spherical metal piece that can perform rolling displacement when there is relative motion between the plates due to the ground movements.



a) Schematic representation of the rolling pendulum isolation system



b) Three-dimensional model of the rolling pendulum isolation system

Figure 2.1 Description of the rolling isolation system

The mounting of this type of system device on isolated structure can be achieved at the base level, namely between the foundation and the superstructure, ensuring in this manner a disconnection from the foundation ground, where the efforts propagates in case of an earthquake. Since the occurring efforts are vertically transmitted, they no longer arrive to the superstructure, which is thus protected from the destructive action of a major magnitude earthquake.

For an structure isolated by means of rolling pendulum isolation system, subjected to forced movements in a horizontal plane, there are shown external forces acting on the structural system as follows:

- G_s - gravitational loading force generated by the superstructure weight;
- F_i - inertial force;
- F_{rf} - rolling friction force.

$$G_s = mg \quad (2.1.)$$

$$F_i = m(\ddot{y} + a_g) \quad (2.2.)$$

$$F_{rf} = \mu_r mg \quad (2.3.)$$

The structural dynamic equilibrium of the isolation system on the horizontal direction can be assumed based on the geometrical conditions as follows:[4]

$$F_i + F_{rf} = 0 \quad (2.4.)$$

$$m(\ddot{y} + a_g) + \mu_r mg = 0 \quad (2.5.)$$

where

a_g - ground acceleration;

μ_r - rolling friction coefficient;

γ - rolling surface angle with horizontal direction;

h - vertical displacement.

It can be observed that the maximum acceleration transmitted through the rolling insulation system is dependent on the maximum ground acceleration, the angle of the main surface rolling and the rolling friction coefficient.

3. STUDY OF A BRIDGE DECK ISOLATED WITH THE ROLLING PENDULUM ISOLATION SYSTEM

In order to determine the proper isolation characteristics for the rolling pendulum system, a small-scaled model was built, on which it has been attached a rigid beam structure, simply supported by a number of four rolling supports positioned at the extremities. The three-dimensional model of the isolated structure is presented in Figure 3.1.

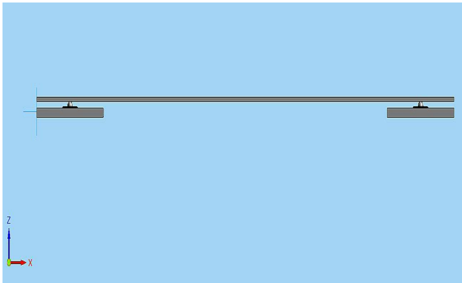


Figure 3.1. Three-dimensional model for a structure base isolated with the rolling pendulum isolation system

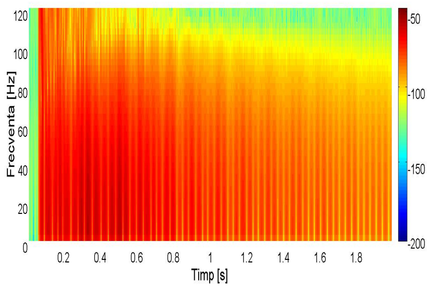
In Figure 3.2 it is presented the experimental model for the rolling pendulum supports fixed on the basic plate which represents the bridge pier.

Figure 3.2. Reduced scale model of the rolling pendulum isolation system

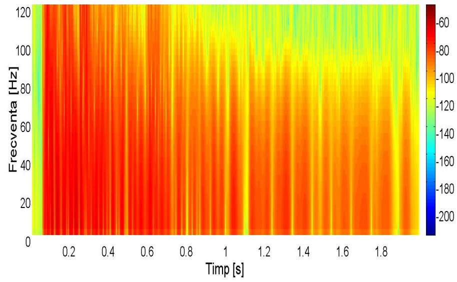
4. EXPERIMENTAL RESULTS

The isolated experimental structure was required using a mechanical excitatory device that is capable to induce an impact strike with an energy amount of about 4.5 J at the pier level. It is important to determine the behavior of the beam during this applied excitation. The results obtained show frequency oscillations in time, which are recorded both at the support pier level and at the beam level or isolated superstructure on the main directions of movement.

The frequency spectrograms are presented for the support pier and beam.



(a) Frequency spectrogram for pier



(b) Frequency spectrogram for beam

Figure 4.1. Results of the transversal direction of movement

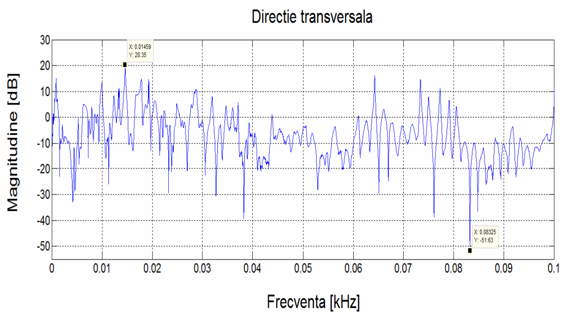
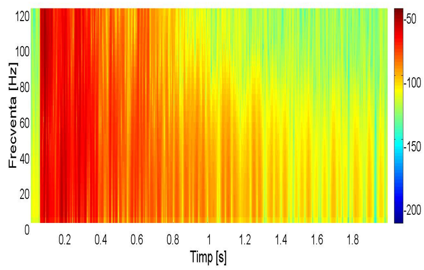
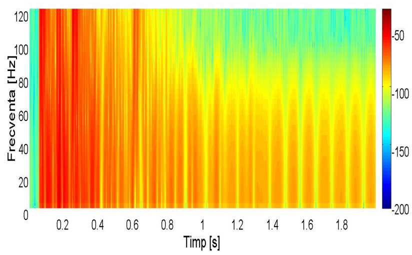


Figure 4.2. Transfer function for the transversal direction of movement



(a) Pier frequency spectrogram over time



(b) Beam frequency spectrogram over time

Figure 4.3. Movement results for the vertical direction

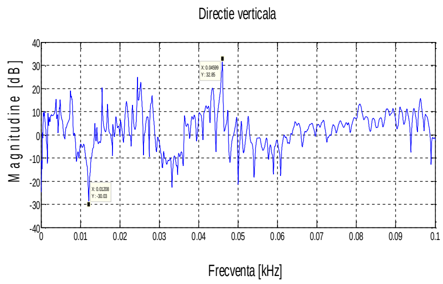
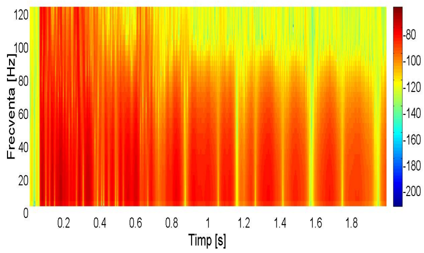
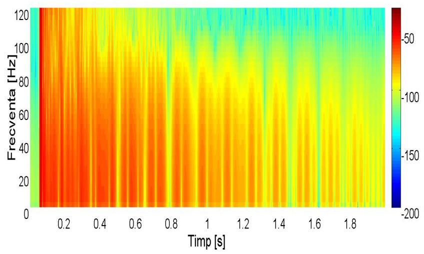


Figure 4.4. Transfer function for the vertical direction of movement



(a) Pier frequency spectrogram over time



(b) Beam frequency spectrogram over time

Figure 4.5. Results for the longitudinal direction of movement

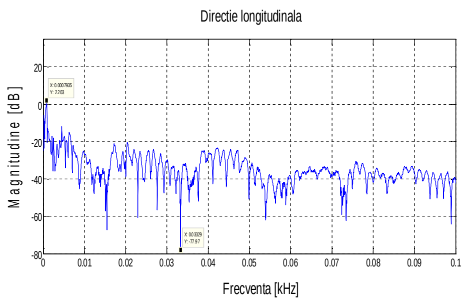


Figure 4.6. Transfer function for the longitudinal movement direction

Analyzing the result values obtained for the amplitude oscillations frequency produced as a result of applying shock in dynamic regime it can be observed that higher values are recorded for the support leg, while the lower values are recorded for the isolated superstructure beam due to the action of the rolling isolation system.

5. CONCLUDING REMARKS

From the analysis of the frequency spectrograms and transfer functions obtained in all the three main directions (transversal, vertical and longitudinal) it can be observed that the rolling pendulum isolation system achieves visible movement mitigation for the superstructure motion during excitation.

Because of the reduced value for the rolling friction coefficient, bridge pier movement is allowed being limited by geometric limits of the isolation system supports while the beam tends to remain in equilibrium position.

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