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RESULTS OBTAINED FROM TESTING A HYBRID MODEL OF VIBRATION ISOLATION SYSTEM

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ABSTRACT

The achievement of new civil and industrial buildings or the rehabilitation of old ones involves using special systems designed to avoid the dynamic requests represented by shocks, vibrations or seismic actions. Such systems are already used worldwide in various modern building structures but also for bridges or viaducts. Whether it is about isolation or energy dissipative systems they provide a high degree of stability and safety in exploitation for the structures to which they are attached. Elastomeric bearings and dry friction based systems are already used for equipping bridges and viaducts structural types in order to avoid the sudden ground movements that can occur with the advent of an earthquake. This paper proposes an experimental model for a hybrid isolation system composed of elastomeric bearings and rolling pendulum system, disposed on the vertical direction in the same assembly. It is expected that from both systems a better isolation can be achieved against the effects of dynamic loads that affect the structures. Laboratory tests were carried out using a reduced scale experimental model of the hybrid isolation system and the results are shown in the following.

KEYWORDS: isolation system, elastomeric, rolling friction, vibration mitigation, experimental modeling

1. INTRODUCTION

Nowadays a continuous evolution in the construction practice of building structures is observed regarding modern techniques used, made possible by the raising quality and characteristics of the materials used. At the same time the structural isolation solutions are constantly improved for avoiding the effects of dynamic actions such shocks, vibrations, or seismic actions.

The vibration isolation and energy dissipation methods show a great influence in the structural behavior, ensuring the optimal operational safety and comfort improvement for the structures to which they are attached.

The development regarding design technologies, manufacturing and installation of these devices was made possible thanks to the continuous research activities performed in the field by different research groups and institutions.

This paper presents a hybrid isolation system having two main components, namely an isolating elastomeric bearing and a rolling pendulum bearing. This kind of system can be attached to bridge or viaduct structural types in order to counteract the effects of vibrations from traffic or seismic ground motions.

Through this system a disconnection is provided at the base level between structural elements namely foundation and superstructure.

2. HYBRID ISOLATION SYSTEM ASSEMBLY MODEL

By using this hybrid system the isolation is combined with the energy dissipating role of the elastomeric bearing coupled with rolling pendulum bearing.

In figure 1, it is presented the schematic representation for the hybrid isolation system mounted in the working position at a structure.

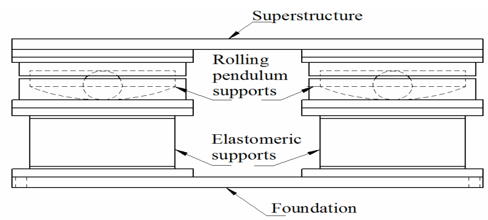


Fig. 1. Schematic representation for the hybrid isolation system model assembly

The rolling pendulum bearing is composed of two main metallic parts including a concave and a flat surface and a central spherical piece placed between as rolling part. The elastomeric bearing is composed of elastomeric layers alternating with steel plates joined by the vulcanization process.

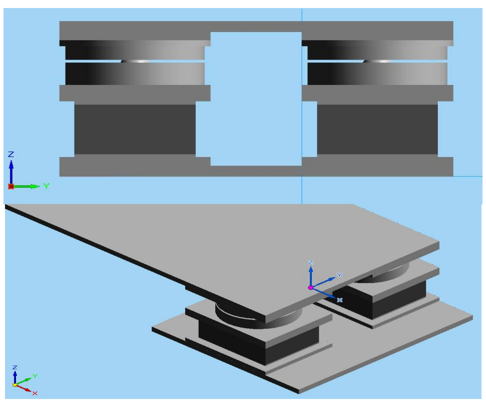


Fig. 2. Three-dimensional assembly model for a hybrid isolation system

The main advantage when using this hybrid system is represented by the possibility for the foundation to perform free movements relative to the superstructure in the occurrence of an earthquake. This means that the efforts are no longer transmitted on the vertical direction to the bridge pathway (superstructure).

Considering a bridge structure supported on rolling bearings, subjected to horizontal excitation, the external forces acting on the structural system are:

- gravitational force generated by the superstructure loading, (mg);
- inertial force, (F_i);
- normal reaction at the main rolling surface level (N);
- rolling friction (μN).

$$F_i = m(\ddot{x} + a_t) \qquad (1)$$

- a_t is the ground acceleration;

Under the influence of these external forces at a specific moment of time, the equation of motion for a specific structure isolated with rolling bearings in the horizontal direction can be described as: [14][5]

$$m(\ddot{x} + a_t) + N \sin\alpha \, sgn(\dot{x}) + \\ + \mu N \cos\alpha \, sgn(\dot{x}) = 0 \qquad (2)$$

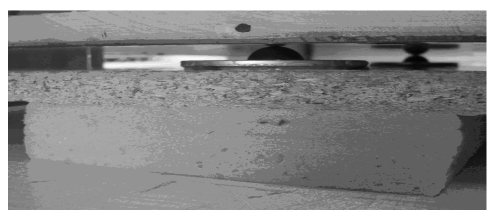
- α represents the slope angle of the rolling surface.

Elastomeric bearings are able to take over the vertical loads, allowing the horizontal displacements and providing lateral shear movement. The elastomeric bearings represent the most economical isolation solution attached to bridges, viaducts or buildings.

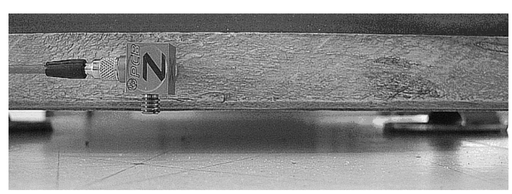
3. EXPERIMENTAL RESULTS OBTAINED

An experimental hybrid isolation system on a reduced scale was built having two main components: a rolling pendulum bearing and an elastomeric support, mounted in the same assembly on a vertical direction arrangement.

A rigid structure was mounted over four hybrid isolation systems which represent a bridge superstructure and the assembly model was analyzed using shaking table procedure and the motion parameters were registered using accelerometers mounted at the base and at the superstructure level.



a) model for isolation system with elastomeric device mounted



b) model for isolation system having only rolling pendulum devices mounted

Fig. 3.The experimental assembly model for the hybrid isolation system

Two distinct cases were analyzed with different configurations of the isolation system.

For the first case it was used only the rolling pendulum system to support the superstructure, while for the second case it was mounted the hybrid isolation device composed of rolling pendulum device and elastomeric supports.

The results are presented below in terms of graphic representations for acceleration amplitude vs. frequency recorded for two horizontal directions namely longitudinal and transversal.

For the rolling pendulum bearing, as part of the experimental model, a special concave surface with spherical steel rolling piece mounted was achieved, while for the elastomeric material low density polyurethane (PU) foam blocks were used having a nominal density of 48kg/m³.

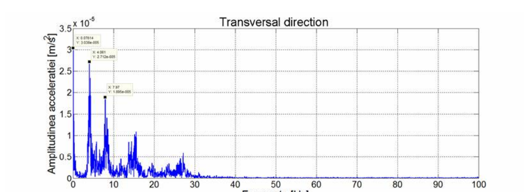
The excitation has been applied at the base level (foundation) having a value of 4.5 J.

In order to realize the experimental signal recording an acquisition plaque type OCTAV SINUS HARMONIE was used, having 8 channels, with two tri-axial accelerometers together with the required connectors.

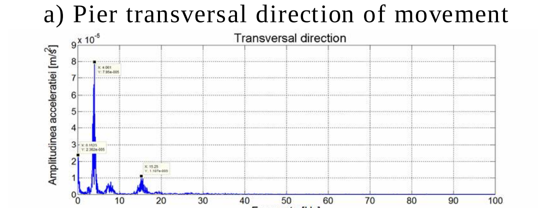
The accelerometer installation at the structure has been conducted so as for the signals to be received at the level of the support leg (pier) and at the level of the beam (superstructure).

The aim was to observe the dynamic characteristics and virtual seismic response for a reduced scale bridge deck superstructure isolated with rolling pendulum systems against dynamic actions which simulate seismic actions.

The transversal direction of motion for pier and superstructure isolated only with rolling pendulum system is shown in figure 4.

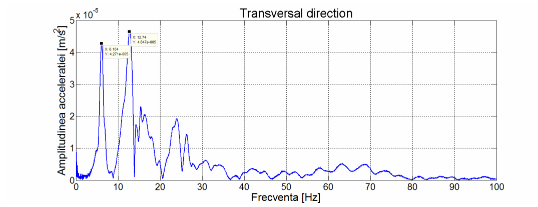


a) Pier transversal direction of movement

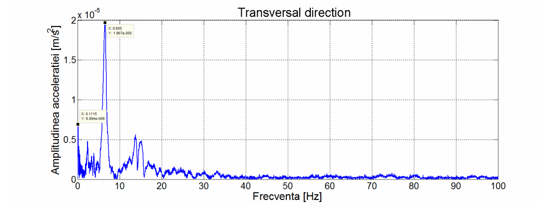


b) Superstructure transversal direction of movement

Fig. 4. Experimental values obtained for testing rolling pendulum system in transversal direction



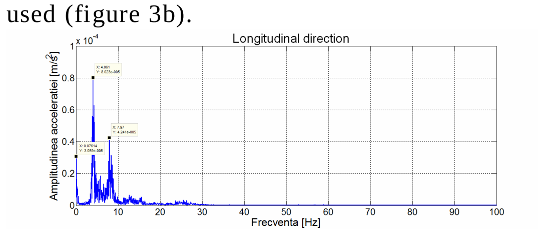
a) Pier transversal direction of movement



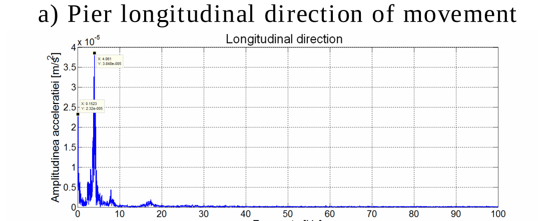
b) Superstructure transversal direction of movement

Fig. 5. Experimental values obtained for testing hybrid isolation system (rolling pendulum and elastomeric device) in transversal direction

In figure 5 the values obtained for acceleration amplitude vs. frequency interval in the transversal direction of movement are presented while the hybrid isolation system is used (figure 3b).

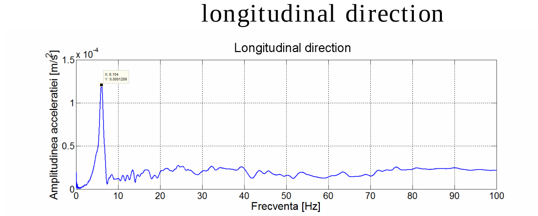


a) Pier longitudinal direction of movement

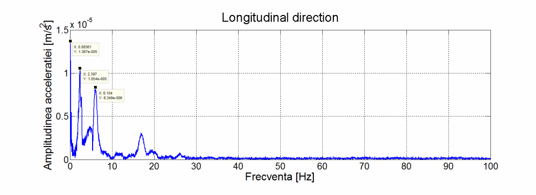


b) Superstructure longitudinal direction of movement

Fig. 6. Experimental values obtained for testing the rolling pendulum system in longitudinal direction



a) Pier longitudinal direction of movement



b) Superstructure longitudinal direction of movement

Fig. 7. Experimental values obtained for testing hybrid isolation system (rolling pendulum and elastomeric device) in longitudinal direction

The obtained results for both main directions (transversal and longitudinal) show higher values recorded for acceleration amplitude vs. frequency at the base level while at the superstructure level, even if there is a large oscillations range, a signal attenuation is obtained.

5. CONCLUSIONS

A hybrid isolation system has been described and experimentally analyzed in this paper in terms of isolation and dissipation character. This kind of innovative system that combines two isolation and dissipative actions achieved from both part components: one rolling pendulum bearing and the second elastomeric bearing can be used for the endowment of bridge or viaduct structural types in order to avoid the strong ground movements caused by earthquakes.

From the experimental results obtained it can be observed that the acceleration amplitude values are lower for the superstructure level where a larger domain of oscillations is recorded at lower amplitude values.

This demonstrates that the rolling pendulum system enables a free relative displacement between the two structural elements, oscillating on the rolling surface, ensuring superstructure protection from high amplitude values acting at the base level, by increasing the vibration period, while the elastomeric bearing assures the support for the vertical loads.

According to the nature of excitation, the time interval on which acceleration peaks appear is little and the acceleration amplitude peaks are predominant for a range of low frequencies up to 30 Hz for all movement directions.

It is important that the transmitted vibrations from support pier to the superstructure have the general attenuation tendency for the analyzed cases of movement.

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