THE ANNALS OF "DUNAREA DE JOS" UNIVERSITY OF GALATI
FASCICLE XIV MECHANICHAL ENGINEERING, ISSN 1224-5615
2013

EXPERIMENTAL DYNAMICS OF A BRIDGE DECK ISOLATED WITH ROLLING PENDULUM SYSTEM (RPS)

Junior Teaching Assist. Fanel SCHEAUA, PhD.c. Eng.
"Dunărea de Jos" University of Galați
"MECMET" Research Center

ABSTRACT

Base isolation of building structures represents the most important technique used worldwide at this moment. An innovative isolation system is presented in this article, whose passive type operating principle is based on rolling of spherical pieces on concave surface part. The isolation system is composed of two main plates and a spherical steel piece is interposed between. Spherical part is the piece that makes disconnection between foundation and superstructure, being able to roll on a concave surface. The disconnection between foundation and superstructure is essential so that ground movements as results of seismic actions are filtered and efforts that may request the structure are much lower in value. An experiment was performed in which a scaled bridge deck structure type was isolated with four isolation systems, in order to observe the behavior of the structure during a seismic action. The experimental results obtained are presented for acceleration in time and frequency, for the three main directions of movement.

KEYWORDS*:* seismic isolation, base isolation, rolling pendulum bearing

1. INTRODUCTION

In order to improve the performances of structures based on ductility design concept during major earthquakes the engineers always look for the best solutions in terms of isolation against dynamic actions.

The construction of a bridge or viaduct structural type requires the best available techniques in the field of building structures currently in use worldwide. The great test for such a building is to withstand an earthquake of major intensity, which can occur at a moment in time. That is why must be taken into account certain devices that may be placed inside the building structure in order to change the behavior of the structural system during major earthquakes.

For an improved response of some of the latest built structures have been successfully used specific devices based on dry friction force to achieve energy consumption from earthquake input amount.

Isolation devices like friction pendulum systems (FPS) have been used as part of base isolation procedure. This method of isolation is considered as base isolation for building structures, because the component devices are positioned at the base of the building, practically interposed between the foundation and superstructure. The friction pendulum bearing (FPS) enables sliding of an articulated pivot type part, positioned between two main plates, on a concave surface by a certain radius.

This isolation process is usually applied on bridge or viaduct structural types or buildings that are not very high.

2. MATHEMATICAL MODEL OF (RPS) ISOLATION SYSTEM

It is presented an innovative isolation system, as rolling pendulum system (RPS) that uses rolling of a spherical piece on a concave surface. This system works similarly to friction pendulum system (FPS) whose operating principle is based on sliding, but here it comes about rolling on the same concave surface. The rolling pendulum system (RPS) is not focusing on friction force to achieve energy consumption and limited displacements, but only on providing disconnection between foundation and superstructure. A seismic dynamic action causes ground motions which involve the structures foundation. The efforts are transmitted forward on vertical direction to the superstructure. Because of the disconnection ensured by rolling pendulum bearing (RPS) isolation system, bridge deck superstructure tends to remain in the equilibrium position.

A rolling pendulum bearing (RPS) isolation system works on the same principle as a simple pendulum. It can be activated in the occurrence of an earthquake, when the rolling spherical pieces moves along the concave surface causing the structure to move in small simple harmonic motions, as illustrated in Fig 1.

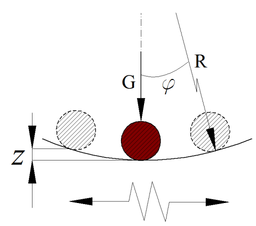


Figure 1. Description of rolling pendulum motion concept

Because the operating principle is based on rolling spheres, an increased natural period for the isolated structural system is ensured. The rolling movements on bearings according to surface shape turns into horizontal displacements but also combined with vertical lifting. The horizontal displacements greatly reduce the forces transmitted to the superstructure in the occurrence of high magnitude earthquakes. This type of isolation system also possesses an improved re-centering capability, which allows the structure to center itself, under its own weight action, if any displacement occurs during a seismic event, because of the rolling concave surface shape of the bearings and gravitational load force.

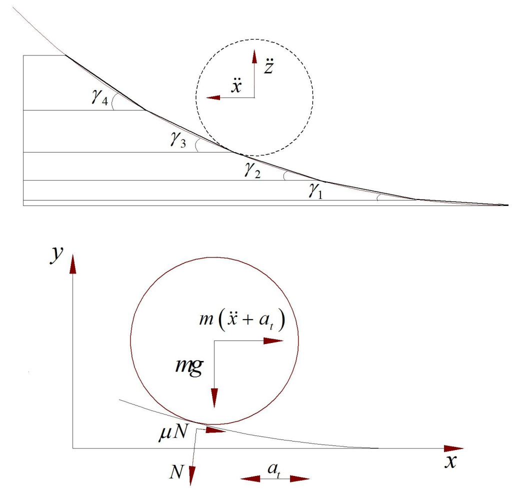


Figure 2. Schematic representation of planar model view for rolling spherical part

Considering a bridge deck structure supported on rolling pendulum system (RPS), subjected by an excitation in horizontally plane, external forces acting on the structural system are as follows:

- mg- gravitational load force;
- $m(\ddot{x}+a_t)$-inertial force;
- N - normal reaction at the rolling surface;
- μN - the rolling friction force.

The equation of motion for the isolated bridge deck superstructure supported on rolling pendulum bearing (RPS), in the horizontal direction can be written as: [1]

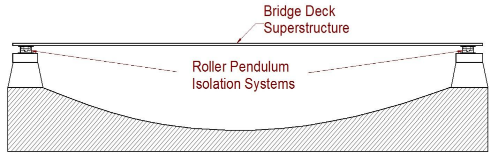
$$m(\ddot{x}+a_t)+N\sin\gamma\cdot sgn(\dot{x})+\mu N\cos\gamma\cdot sgn(\dot{x})=0 \qquad (1)$$

where:

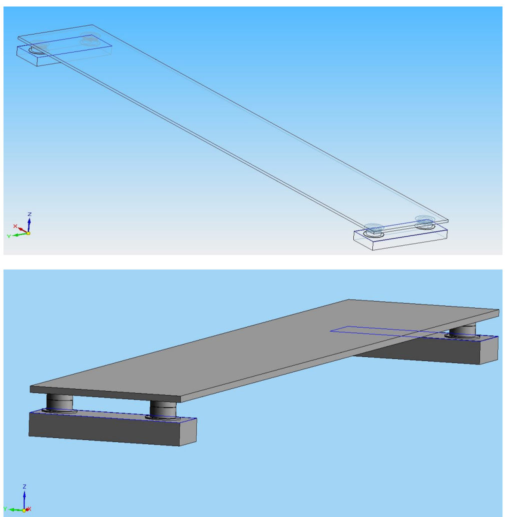
- $\ddot{x}$ - spherical part acceleration relative to the rolling surface;
- a_t - ground acceleration.

3. MODELING OF A BRIDGE DECK SUPERSTRUCTURE ISOLATED WITH ROLLING PENDULUM SYSTEM (RPS)

A bridge or viaduct structure type was built, on a small scale, to be equipped with rolling pendulum isolation system (RPS), with the aim to observe the behavior of the structure when applying an excitation in dynamic regime. It is important to notice if the decoupling ensured by the isolation system may provide additional stability for the isolated structural system.



a) 2D - model view of a bridge superstructure isolated with RPS



b) 3D - model view of structure - isolation system assembly

Figure 3. Schematic view of a base isolated bridge deck superstructure type

Ground movements are expected to be filtered at the level of the isolation system, so that bridge deck superstructure can perform small pendulum movements during an earthquake, according to rolling concave surface.

4. EXPERIMENTAL RESULTS

Shaking table test was carried out for this experimental study. The aim was to observe the dynamic characteristics and seismic response for a reduced scale bridge deck superstructure isolated with rolling pendulum systems against dynamic actions which simulate seismic actions. The bridge deck superstructure equipped with four isolation system devices was shaken with a dynamic exciter. Experimental results are presented in terms of acceleration in time and frequency for the three main directions of motion.

Graphical representations for the acceleration amplitude values acting on bridge superstructure are shown in the following figures, depending on time interval and frequency values.

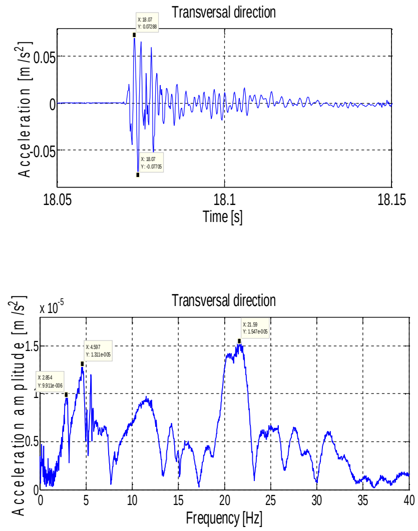


Figure 4. Transversal direction results

The transversal direction of motion for bridge deck superstructure base isolated with rolling pendulum system devices (RPS) is shown in figure4.

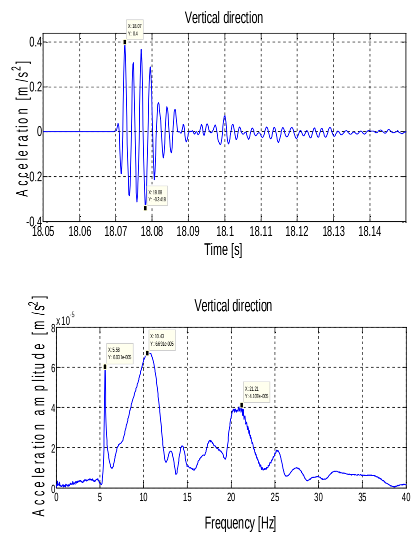


Figure 5. Vertical direction results

Figure 5 presents acceleration values in time and acceleration amplitude for frequency interval in the vertical direction function of motion coming from the support leg.

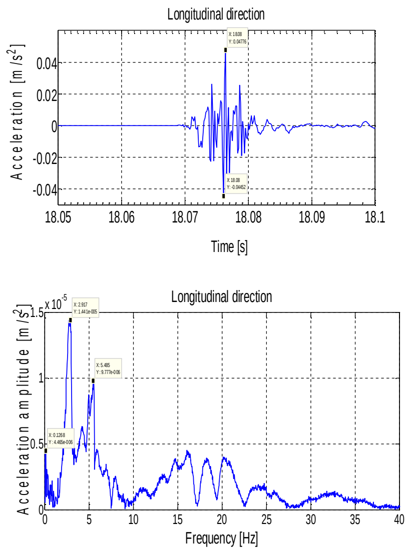


Figure 6. Longitudinal direction results

The experimental results obtained for the longitudinal direction are presented in figure 6.

5. CONCLUDING REMARKS

The rolling pendulum system (RPS) represents a seismic base isolation concept capable to ensure low level for accelerations and reduced superstructure relative displacements.

This kind of isolation system can be used for seismic base isolation of not very large bridge or viaduct structural type. Freedom of movement for the superstructure is ensured by the main rolling surface on witch spherical piece is moving. In order to achieve an optimal seismic isolation in addition to rolling pendulum system (RPS) can be used hydraulic dissipation devices as anchorage points for the bridge deck superstructure. It is reduced in this way the flexibility in the lateral plane for rolling pendulum system and hydraulic dissipation devices are able to take over a part of the seismic energy and to turn it into heat. Rolling pendulum system (RPS) is considered a passive base isolation device and because of the disconnection performed between foundation and superstructure it has a significant role in maintaining the bridge deck structural stability. The experimental results have shown that there is a tendency to mitigate the acceleration values in time and frequency, which means that efforts coming from ground motions are not transmitted vertically to the bridge deck due to the isolation system interposed between the two structural elements.

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 20 Hz for all directions of movement.

REFERENCES

[1] **Tsai M. H., Chang K.C., Wu S. Y.,** *Seismic isolation of a scaled bridge model using rolling-type bearings*, 4th International Conference in earthquake engineering, Taipei, Taiwan, 2006

[2] **Lee G. C., Ou Y. C., Song J., Niu T., Liang Z.,** *A roller seismic isolation bearing for highway bridges*, 14th International Conference in earthquake engineering Beijing, China, 2008

[3] **Bratu, P., Drăgan, N.,** *L'analyse des mouvements désaccouplés appliquée au modèle de solide rigide aux liaisons élastiques,* Analele Universităţii “Dunărea de Jos” din Galaţi, Fascicula XIV, 1997.

[4] **Symans M. D., -** *Seismic Protective Systems: Passive Energy Dissipation*. Instructional Material Complementing FEMA 451, Design Examples, 2004

[5] **Battain M., Marioni A.,** *Development of a new sliding pendulum for seismic isolation of structure,* R&D Manager, ALGA S.p.A., Milano – Italy.

[6] **M. Eröz , R. DesRoches,** *Bridge seismic response as a function of the Friction Pendulum System (FPS) modeling assumptions,* Engineering Structures, November, 2008.

[7] **Jangid R.S.,** *Optimum friction pendulum system for near-fault motion,* Department of Civil Engineering, Indian Institute of Technology Bombay, Powai, Mumbai 400 076, India.

[8] **Martelli, A. -** *Modern Seismic Protection Systems for Civil and Industrial Structures.* SAMCO Final Report 2006, F11 Selected Paper, 2006.

[9] **Naeim F., Kelly, J. M. -** *Design of Isolated Structures from Theory to Practice,* John Wiley & Sons, Inc., Canada, 1999.

[10] **Ealangi, I.** *Earthquake* ***protection*** *of buildings by seismic isolation. devices and* ***concepts****,* Technical University of Civil Engineering Bucharest.

[11] **Șcheaua, F., Axinti G.,** *Seismic protection of structures using hydraulic damper devices* , The annals of Dunarea de Jos University, Vol II, 2010.

[12] **Șcheaua F., Nedelcut F.,** *“Study on a seismic isolation method suitable for an architectural monument”,* The Annals of “Dunarea de Jos” University of Galati, Fascicle XIV Mechanical Engineering Volume 1 Issue XIX, ISSN 1224-5615, Galaţi, 2012

[13] **Leopa A., Nastac S.,** *Characterization of bearings nonlinearities influences on viaducts dynamic responses,* The Annals of “Dunarea de Jos” University of Galati, Fascicle XIV Mechanical Engineering Volume 2 Issue XIX, ISSN 1224-5615, Galaţi, 2012

[14] **Șcheaua F., Nedelcut F.,** *Energy dissipation device using fluid dampers,* The Annals of “Dunarea de Jos” University of Galati, Fascicle XIV Mechanical Engineering Volume 2 Issue XX, ISSN 1224-5615, Galaţi, 2012

[15] **Nastac S.,** *Working characteristics of the special isolation devices against vibratory actions,* The Annals of “Dunarea de Jos” University of Galati, Fascicle XIV Mechanical Engineering, ISSN 1224-5615, Galaţi, 2007