THE ANNALS OF "DUNAREA DE JOS" UNIVERSITY OF GALATI
FASCICLE XIV MECHANICHAL ENGINEERING, ISSN 1224-5615
2014

FUNCTIONAL ASPECTS FOR ANTISEISMIC DOUBLE SLIDING ISOLATION SYSTEMS

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ABSTRACT

In order to counteract the soil sudden movements as a result of seismic actions, a disconnection between the primary components of a specific structure was needed, so that the efforts can not be transmitted on vertical direction. Thus occurred the need for isolation systems that can be attached to the base of structure, between foundation and superstructure. The isolation systems based on dry friction have been successfully used worldwide. At the beginning, simple isolation systems with sliding on a single spherical surface were used and later double systems have been designed which have two main sliding surfaces. In this paper it is shown the working principle of double isolation systems based on dry friction depending on the main variables involved and the linear force-displacement diagrams obtained from the case studies using different values.

KEYWORDS: seismic isolation, base isolation, double sliding, dry friction

1. INTRODUCTION

The earthquakes represent unpredictable natural phenomena, which according to their magnitude can have devastating effects on the stability of building structures and human communities. Therefore there is a permanent concern of researchers to set up various systems that once mounted at a structure can ensure enhanced protection from such events.

Following these research concerns, special isolation systems have been designed for positioning at the structure base, between the foundation and the superstructure creating in this way a disconnection between the two structural elements. These systems can be insulating elastomeric elements using elastic properties of elastomeric rubber and isolators based on dry sliding friction force.

The base isolation systems running on dry friction force are using planar or spherical sliding surface shapes.

Isolation systems have been developed sliding on flat surface which however had the disadvantage of changing the location of the structure after an earthquake, without the possibility of returning to the original position.

This problem has been solved with the development of systems with spherical sliding surface that ensures return of the isolated structure to its original position under its own weight.

To provide a reserve in terms of isolated superstructure displacement during seismic motions, a double system has been developed with sliding on two main surfaces.

In this paper are described the isolation systems based on the dry friction force, having components that are sliding along double spherical surfaces.

2. MATHEMATICAL MODELING FOR DOUBLE SLIDING ISOLATION SYSTEMS

In addition to the simple isolation system having a single spherical sliding surface, double spherical sliding surface systems have been developed, the so called double isolation systems. These operate on the same principle of operation as simple systems, except that they allow for a greater freedom of movement due to the relative movement between the two sliding surfaces. It can be said that these systems perform a proper seismic isolation of building structures since they are interposed between the foundation and superstructure, thus achieving ground motions disconnection for the isolated superstructure.

A double system consists of two metallic plates with special spherical surfaces by a particular radius value on the inside and an articulated metal piece interposed between the two sliding plates.

A schematic representation of the double sliding isolation system structural frame is shown in Figure 2.1, together with the acting efforts, while geometric limits involved in system modeling are shown in Figure 2.2.

Disconnection is important because it changes the vibration period for isolated structure as a significant increase, together with the increasing of structural lateral flexibility and finally reduction in the acceleration field, so to avoid its vertical transmission to the superstructure. Thus efforts are minimized due to the action of horizontal forces that can be applied to a certain structure in case of a major earthquake. Earthquake seismic input energy is dissipated via the isolator with the contribution of dry friction forces and transformed into thermal energy (heat) transmitted to external environment. Double sliding isolation system provides a significant change of structure behavior materialized in reducing its response after application of seismic forces.

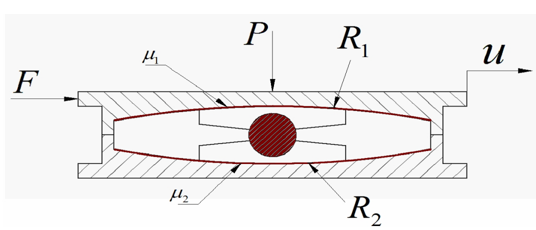


Figure 2.1 The efforts acting on the isolation system with sliding on double spherical surfaces

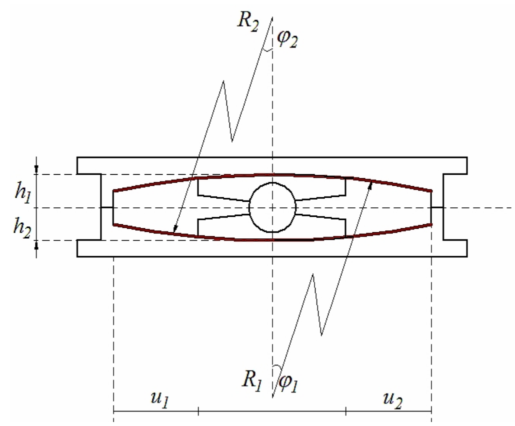
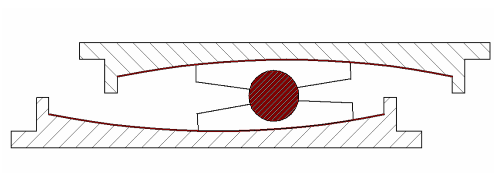
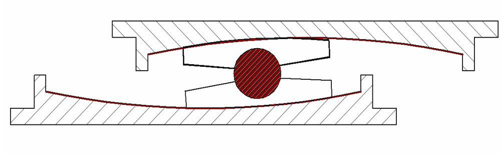


Figure 2.2 Geometric limits involved in modeling of the double sliding isolation system operation

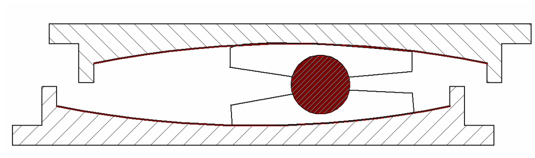
From the schematic representation shown in Figure 2.2, it can be observed the movement occurrence on the superior spherical sliding surface while its radius of curvature is an essential parameter in the functioning of the isolation system together with the sliding friction coefficient which is also a major importance parameter.



a) The sliding movement occurrence on the inferior sliding surface



b) Movement on both main sliding surfaces



c) Support stabilization trend

Figure 2.3 Movement stages allowed by the double sliding isolation system

For the case where there is movement on both surfaces, the isolation system response can be described by means of elastic force and dry friction force whose relation are presented below: [1][10]

$$F_{el} = \frac{P}{R_1 - h_1 + R_2 - h_2} \cdot u \qquad (2.1.)$$

$$F_f = \frac{\mu_1 \left(R_1 - h_1\right) \cdot P + \mu_2 \left(R_2 - h_2\right)}{R_1 - h_1 + R_2 - h_2} \qquad (2.2.)$$

Where:

F_{el} -elastic force;
P-superstructure weight;
R-sliding surface radius of curvature;
F_f - friction force;
u-horizontal displacement;
R_1, R_2 -radii of curvature;
μ_1, μ_2 - friction coefficients;
h_1, h_2 -vertical displacements.

3. HYSTERETIC BEHAVIOUR FOR DOUBLE SLIDING ISOLATION SYSTEMS

A bilinear hysteretic force-displacement model can be achieved for double sliding isolation systems when are introduced in calculation the specific parameters involved in operation, having as result a diagram presented in Figure 3.1.

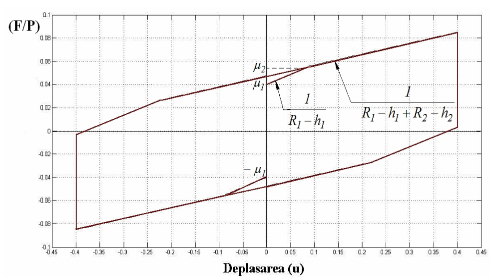


Figure 3.1. Specific hysteretic diagram for double sliding isolation systems

It can be observed that up to a limited value corresponding to the value of the friction force, there is no displacement, but proportionally with increasing lateral force the movement is occuring at the first sliding isolation system level. Because of the double spherical sliding surfaces, the superstructure will return to its original position under the proper weight action.

The sliding surface radius of curvature and the coefficient of friction influence the efficiency of the double sliding isolation system.

4. CASE STUDY RESULTS

Two distinct cases have been considered for which it was analyzed the behavior of double sliding bearings by changing the characteristic values for one or both of the sliding surface radius of curvature *(R)* and the coefficient of friction values, which are involved in sliding isolation, according to device operation process and the results are presented as follows (Table 4.1).

Table 4.1.

Case	Radius of curvature [m]	Pivot height [m]	Friction coeficients
1	$R_1 = 4$	$h_1 = 0.15$; $h_2 = 0.2$	$\mu_1 = 0.04$ $\mu_2 = 0.055$
	$R_1 = 5$		
	$R_1 = 6$		
2	R1=6; R2=5;	$h_1 = 0.15$; $h_2 = 0.2$	$\mu_1 = 0.02$; $\mu_2 = 0.04$
			$\mu_1 = 0.04$; $\mu_2 = 0.06$

Due to sliding surface spherical geometry, the displacement at the double isolation system level is basically composed of a horizontally translational component combined with vertical lift.

For the first case were introduced into calculation three different values of the radius of curvature for a single sliding surface, with different values for friction coefficients, while the static load value is kept at constant value.

Three distinct force-displacement diagrams have been obtained which proves that for high loads were registered higher values for the lateral force and a large hysteretic area which means a larger amount of dissipated energy.

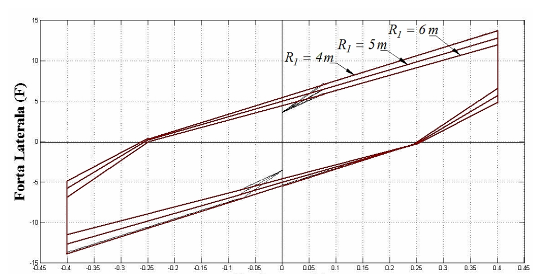


Figure 4.1.Force-displacement diagrams (case 1)

It can be seen that for large values of the radius of curvature are registered low levels of lateral force, while the hysteretic area is approximately constant due to the steady level of static load.

For the second case two different values for spherical sliding surface radius of curvature together with different friction coefficients values have been introduced in the calculation, while the static load had also been maintained at constant value (Figure 4.2).

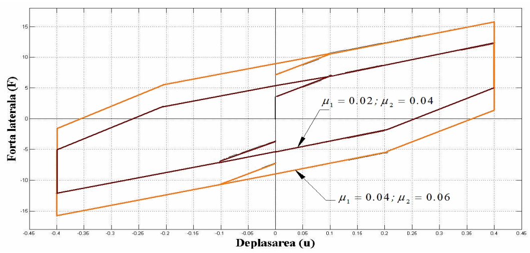


Figure 4.2. Force-displacement diagrams (case 2)

Difference can be observed between the two hysteretic loops obtained according to the two sets of considered input values. For the case in which the higher coefficient of friction are used it is obtained a larger lateral force and also a greater amount of dissipated energy.

5. CONCLUDING REMARKS

A double sliding isolation system can provide an improved behavior for isolated structures due to optimal positioning between the foundation and the superstructure. Because of this mounting position, the isolation system achieves a disconnection of superstructure from foundation and ground from where are vertically propagated the damaging efforts during a seismic action and in this way they can be avoided.

The system operation is based on dry friction, materialized by sliding of a pivoting piece on a double spherical surface.

The displacements occurrence at the isolation system level is a consequence of the lateral force action that occurs due to seismic ground movements.

The pivot piece begins to slide only when the lateral force exceeds the friction force level.

Because of the sliding surfaces spherical geometry, the displacement is carried out with a proportionally increasing resistance force.

It can be said that for using higher values for the radius of spherical sliding surfaces it can be observed that there are obtained lower lateral force and system rigidity values while increasing the vibration period for isolated structural system.

Compared to an isolation system with a single main sliding surface, the double system has the advantage of providing a greater displacement in case of high magnitude earthquakes.

The two main sliding surfaces can assure a free displacement for superstructure towards the foundation during seismic movements.

Load-displacement relationship for double isolation systems having two main sliding spherical surfaces forms a hysteresis loop that provides information on the amount of energy dissipated by the isolation system.

The total amount of dissipated energy is shown by the area contained within the hysteresis loop described function of input data initially reported.

Double sliding isolation systems can be mounted at bridge, viaduct or building structures with reduced elevation, but for each structure there must be dimensioned its appropriate isolation system.

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