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CONSIDERATIONS ON FUNCTIONAL PARAMETERS OF DRY FRICTION SEISMIC ISOLATION SYSTEMS

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ABSTRACT

Many types of isolation systems against ground seismic activities which can be attached to the building structures have experienced an intensive development in recent years. The studies and researches carried out on different experimental models aim to obtain continuous improvements for the isolation systems component parts so they can provide maximum efficiency in operation, and offer an improved behavior for structures to which are mounted during seismic events. This paper shows the working principle of isolation systems with dry friction depending on the main parameters involved and the linear force-displacement diagrams obtained from the case studies using different values of these design parameters.

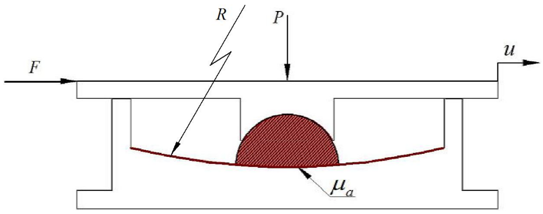
KEYWORDS: seismic isolation, base isolation, dry friction

1. INTRODUCTION

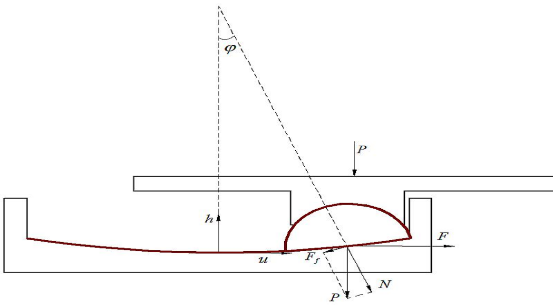
Seismic actions cause ground motions performed in dynamic regime that can generate effects on building structures, being threatened the both their integrity and stability. In order to prevent such events, several types of isolation systems are used, that can be installed inside building structures, aiming to change their behavior during earthquakes. Whether they are part of isolation or energy dissipation device category, these systems are able to reduce the direct effect of seismic actions on isolated structures, being successfully used worldwide for many years. Isolation systems operating with dry friction can provide base isolation for building structures, due to their positioning at the isolated structure. They can be used for the endowment of bridge and viaduct structural types or buildings with a reduced height. An analysis is performed which involves the functional parameters for the isolation system with sliding on a single spherical surface during operation.

2. MATHEMATICAL MODEL FOR DRY FRICTION ISOLATION SYSTEMS

In order to achieve the protection of a structure against seismic activities, a disconnection from the soil foundation was needed. This disconnection may be provided through the sliding isolation system, which is positioned between the foundation and the superstructure of the building. A schematic representation of the sliding isolation system structural frame is shown in Figure 2.1(a) together with the possibility of movement during operation realized in Figure 2.1(b). From the schematic representation, it can be observed the movement occurrence at the main spherical sliding surface level and 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) sliding isolation system framework



(b) possibility of movement during operation

Figure 2.1 Description of sliding isolation system and motion concept

By analyzing the displacement at isolation system level result the relations from decomposition of forces:[2]

$$P - N\cos\varphi + F_f \sin\varphi = 0 \qquad (2.1.)$$

$$F - N\sin\varphi - F_f \cos\varphi = 0 \qquad (2.2.)$$

From geometrical conditions it can be assumed that:[2]

$$\sin\varphi = \frac{u}{R};\cos\varphi = \frac{R-h}{R} \qquad (2.3.)$$

$$h = R - \sqrt{R^2 - u^2} \qquad (2.4.)$$

The linear equation for external forces which acts directly on the sliding isolation system can be written as follows:[1][2]

$$F = \frac{P}{R\cos\varphi}u + \frac{F_f}{\cos\varphi} \qquad (2.5.)$$

Where:

F-external force;
P-superstructure weight;
R-sliding surface radius of curvature;
φ -rotation angle;
F_f - friction force;
N-normal force to surface;
u-horizontal displacement;
h-vertical displacement.

3. HYSTERETIC MODEL FOR DRY FRICTION ISOLATION SYSTEM

A bilinear hysteretic force-displacement model can be achieved for sliding isolation system which is characterized by elastic and post-elastic rigidity as presented in Figure 3.1.

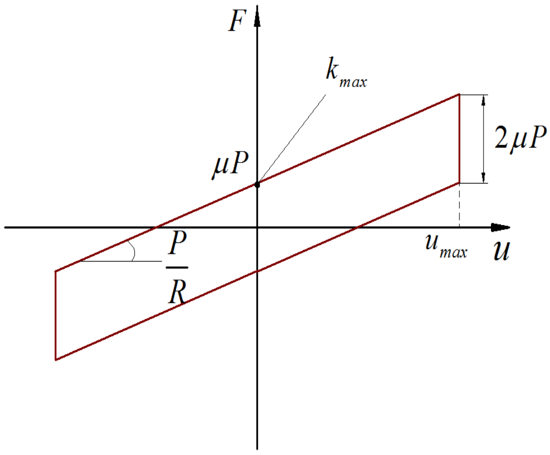


Figure 3.1. Sliding isolation system bilinear hysteretic model [1]

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, movement occurs at the sliding isolation system level. Because of the spherical sliding surface, the superstructure will return to its original position under proper weight action.

The necessary condition to achieve superstructure realignment to the original position is:[1][2]

$$F > F_f \qquad (3.1.)$$

$$F_f = \mu P \qquad (3.2.)$$

The post-elastic rigidity can be described according to the following equation:[2]

$$k = \frac{P}{R} \qquad (3.3.)$$

The sliding surface radius of curvature and the coefficient of friction influence the efficiency of the sliding isolation system. The vibration period for sliding isolation system can be written as: [1]

$$T = 2\pi\sqrt{\frac{R}{g}} \tag{3.4.}$$

4. CASE STUDY RESULTS

Two distinct cases have been considered for which it was analyzed the behavior of sliding bearings by changing the characteristic values for static load *(P)* and sliding surface radius of curvature *(R)* shown in (Table 4.1), which are involved in sliding isolation devices operation and the results are presented as follows.

Table 4.1.

Case No.	Static Load (P)	Radius of curvature (R)	Friction coefficient (μ)
1	100 kN	5 m	0.02
	200 kN		
	300 kN		
2	200 kN	4 m	0.02
		5 m	
		6 m	

Due to sliding surface spherical geometry, the displacement at the isolation system level is basically composed of a horizontally translational component and vertically lift. This is emphasized in Figure 4.1, according to the input data introduced in calculation.

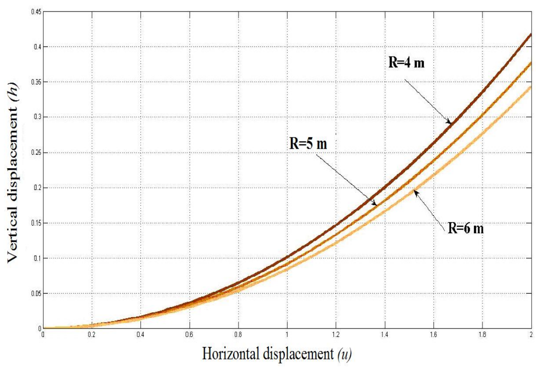


Figure 4.1. Sliding isolation system displacement

For the first case were introduced into calculation three different values for static load which acts directly on the isolation system, while the coefficient of friction and radius of curvature has been considered at constant values.

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.

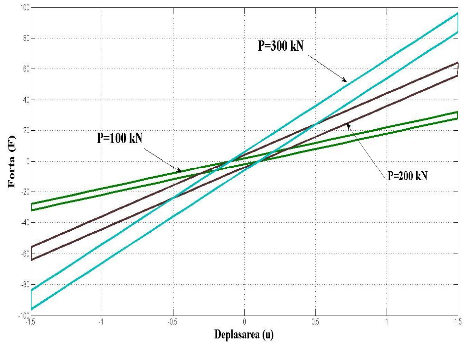


Figure 4.2. Results for static load value modification

For the second case three different values for the radius of the spherical sliding surface have been introduced in the calculation, while static load and coefficient of friction have been maintained at constant values.

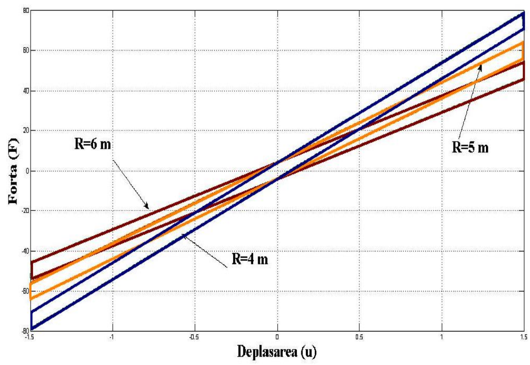


Figure 4.3. Results for radius of spherical surface value modification

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.

5. CONCLUDING REMARKS

Based on this analysis, it can be concluded that the sliding isolation system can provide an improved behavior for isolated structures due to optimal positioning between the foundation and 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 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 lateral force exceeds the friction force level. Because of the sliding surface spherical geometry, the displacement is carried out with a proportional increasing resistance force.

It can be said that for using higher values of the spherical sliding surface radius of curvature, it can be observed that there is a lower lateral force, there are system rigidity values and an increased period of vibration for isolation system.

For the case in which the static load values have been changed during calculation, the hysteretic diagrams show the same shape but a different area according to the amount of seismic dissipated energy.

Sliding isolation systems are successfully used worldwide mounted at bridge, viaduct or reduced elevation building structures but for each structure the isolation system must be dimensioned appropriately and it may only be composed of sliding systems but also in combination with the elastomeric systems or hydraulic systems for displacements limitation.

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