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Mechanical Systems based on Dry Friction Force used for Building Isolation against Seismic Actions

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Today there are multiple solutions intended to avoid the earthquake damaging effects on building structures. There are methods based on the use of special mechanical systems attached directly to the structure's resistance frames, by means of which an improved building behavior is achieved during the earthquake. The systems used work on the principle of structure base isolation based on the dry friction force (Coulomb friction). Some constructive types of these isolation systems patterns are described in this paper.

***Keywords**: isolation device, base isolation, dry friction force*

1. Introduction.

Some geographic areas are under constant threats of seismic events. The construction activities in these areas and built structures must consider the occurrence probability of earthquake ground motions and a proper dimensioning of the resistance elements is needed. Besides these traditional methods, various isolation methods based on mechanical systems were designed in order to help the structure to withstand earthquakes. These methods are considering the use of insulation systems used mounted at building structures against seismic dynamic actions.

Thus, the isolation devices used mounted at the structure base achieve a superstructure disconnection from the foundation, necessary for the specific efforts arising as a result of the terrain movement to not be fully transmitted vertically to the upper level of the structure. These devices are making use of dry friction force while sliding on a surface (flat or spherical), or the properties of elastomeric materials.

2. Flat surface insulating systems.

Friction systems are the simplest types of building insulation systems, composed of two main sliding plates that work in tandem to achieve a shift on a common surface with a low friction coefficient. They are mainly used to isolate installations assemblies, but also to structures with a lower gauge.

Such systems are easy to mount to the isolated structure and have poor maintenance work. One of the plates is mounted at the foundation and the other is attached to the superstructure, the material between the two plates is having a reduced roughness in order to provide a very low friction coefficient on the contact surface, usually less than 0.1. In the event of an earthquake, this system has the possibility of allowing a free movement of the foundation with the ground, while the superstructure tends to remain in the equilibrium position. The permissible movements on the support can be both rotations and translations in different directions from the horizontal plane.[4]

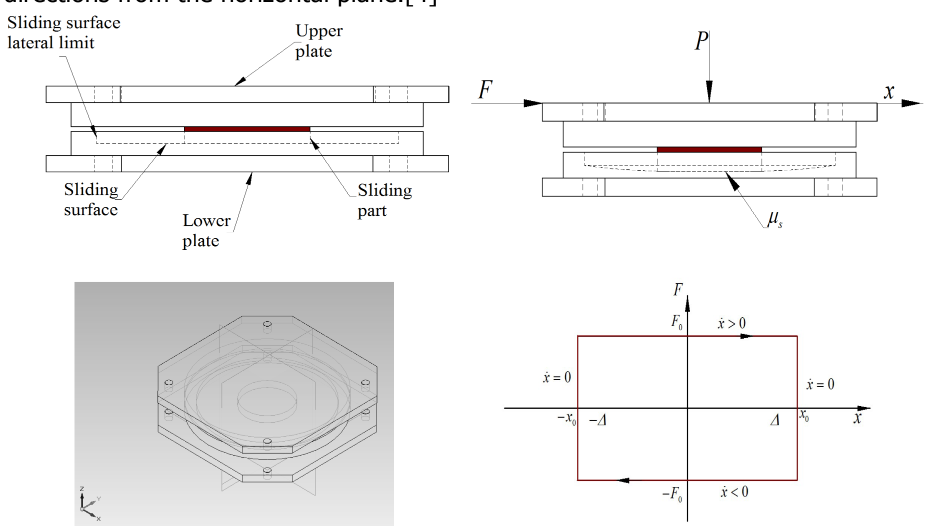


Figure 1. Assembly model and hysteresis loop for the flat surface sliding bearing

For a flat-sided insulator system, the radius of curvature of the surface tends to infinite, $(R \to \infty)$, so the relation describing the lateral force can be written as follows: [2]

$$F(t) = \mu_a P \operatorname{sgn}(\dot{x}) \quad (1)$$

Figure 1 shows the construction scheme of a flat surface friction insulating system as well as the theoretical hysteresis curve for this insulating system. The insulating system allows the structure foundation freedom of movement together with the ground only when the friction force is exceeded by the shear force and the superstructure tends to remain in balance. This system is considered to be a base isolation system that operate on the passive principle and can make a change in the response of the isolated structure so that it can assume a free movement of the land without transmitted efforts to the isolated structure.

Due to the flat geometry of the sliding surface, in the case of a bearing movement there is no possibility of returning for the superstructure to the initial position, which means that these types of insulation systems must be combined with other types of insulating devices such as elastomeric supports, springs or hydrostatic systems. [2]

3. Spherical surface friction-based insulating systems.

Another constructive version of the anti-seismic insulators using the dry friction force is represented by the spherical surface type system. Their use aims at concentrating the flexibility within the structural system and adds additional damping to the structure.

The simplest spherical slide model shown schematically in Figure 2 has a solid steel construction consisting of two main plates connecting with the structural systems in which the central pivot has the ability to slide on a spherical surface specially made on the lower plate. Thus, both displacements and limited rotations on supports are permissible. At the occurrence of a seism only when the value of the frictional force between the pivot piece and the main spherical surface is exceeded, the sliding motion on the bearing characterized by dry friction between the two surfaces, resulting in significant energy consumption, i.e. dissipation of seismic energy. There are two main parameters describing the behavior of these insulating systems, namely the friction coefficient, (μ), between the sliding surfaces and the radius of curvature, (R), of the main sliding surface.

The dry friction force between the two surfaces provides shock and vibration damping, thus consuming energy at the sliding interface, and the return to the initial position occurs due to the weight action of the superstructure as well as the shape of the concave slip surface with the input of the lateral restoring forces.

The spherical sliding isolation system provides disconnection of the superstructure from the foundation, allowing the foundation to move with the foundation ground in an earthquake condition. This insulating system has very good performance, high fatigue strength, and the main feature is the sliding action combined with the return force due to the sliding surface geometry. With the emergence of a dynamic stress on the isolated structure, the foundation tends to move with the foundation ground, while the superstructure tends to remain in balance.

Due to the sliding surface geometry, a relative displacement in plan between the two structural elements is combined with a mandatory vertical displacement, which means a significant amount of energy required to lift the superstructure in a vertical direction.

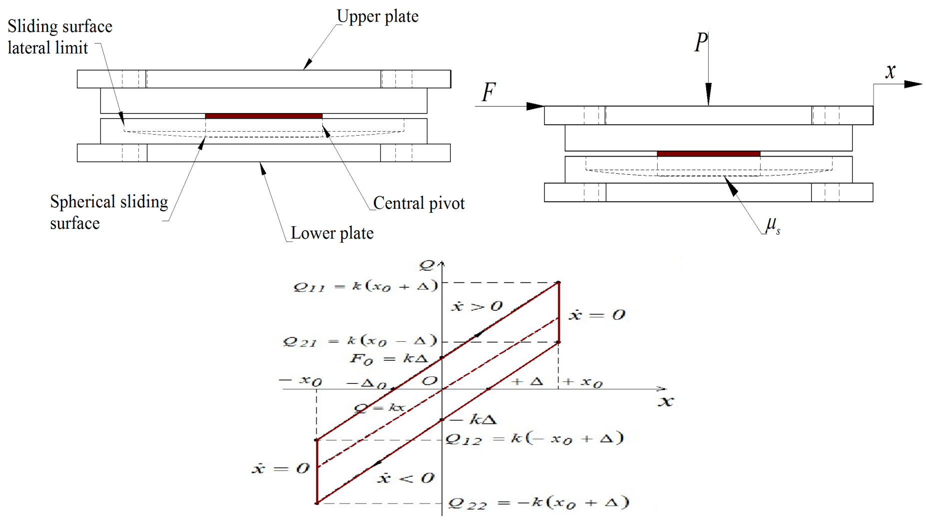


Figure 2. Schematically representation and hysteresis loop for spherical sliding bearing

The lateral force equation can be written as follows:[2]

$$F(t) = \frac{P}{R} x(t) + \mu_a P \operatorname{sgn}(\dot{x}) \tag{2}$$

where: x- displacements;

$\dot{x}$ - sliding velocity;

R - spherical surface radius of curvature;

μ_a - friction coeficient;

P - static load.

4. Numerical analysis results for spherical friction isolator.

Efforts that determine the spherical friction devices operation are three components represented by axial force normal exerted by the superstructure, the shear force that occurs as a result of the ground movement as a result of seismic action and displacement on the support which occurs when the value of the shear force exceeds the amount of frictional force between the pivot and the sliding surface.

The axial force opposes the movement along with the frictional force, and these two resistors are added to the spherical geometry of the slip surface that amplifies the motion resistance, helping to dissipate the seismic input energy.

Movement is a combined translational and lifting relative motion on the vertical direction of the superstructure from the foundation, while rotations are allowed due to the pivot geometry.

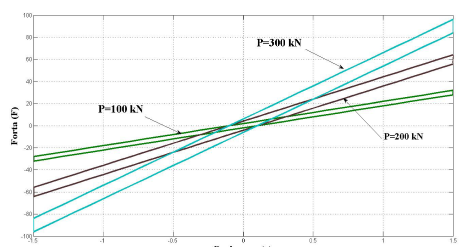
Energy efficiency is defined as the area of the polygon described by the hysteretic cycle of each device.

In order to illustrate the isolator and dissipation behavior of the spherical sliding device, a numerical analysis was launched in which it was considered a spherical sliding bearing with a 5 m radius of curvature, being successively subjected to a static load of 100, 200 and 300 [kN], and the friction coefficient is 0.02.

The analysis values and the results obtained are presented in Table 1, highlighting the hysteretic curve for each set of values used [2].

Table 1. Numerical analysis values and results diagram

Case number	Static load *(P)*	Spherical surface radius of curvature *(R)*	Friction coeficient (μ)
1.	100 kN	5	0.02
2.	200 kN	5	0.02
3.	300 kN	5	0.02



The increase in the radius of curvature value for the spherical sliding surface causes the force values decrease as well as the approximation of the hysteresis curve to the horizontal axis, which means proximity to the flat surface friction insulator.

5. Conclusion.

The two types of insulating and dissipative systems presented in this paper are currently used in construction structures to counteract the destructive effects of earthquakes being specifically designed for each insulated structure depending on the load requirements, earthquake displacement capacity, soil conditions and the supported size structure.

Spherical sliding bearings are designed to withstand earthquakes of varying magnitudes by simply adjusting the radius of curvature of the sliding surface.

The dissipative behavior of spherical surface isolators is shown on the diagrams obtained based on the values entered in the numerical performed analysis.

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