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DESIGN DETAILS FOR ANTI-SEISMIC ISOLATION SYSTEM BASED ON FRICTION FORCE

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ABSTRACT

Multiple solutions are currently used, in constructions domain regarding the structure isolation against seismic actions, operating on different principles such as seismic energy dissipation or dynamic motions isolation. For these purposes, special mechanical devices are built, that embedded between the structural frames of a building manage to reach the stated purpose of improving the structure behavior during high magnitude seismic actions. In this paper an isolation system is described meant for the base isolation of structures based on the dry friction force principle.
This is a composed device having from one to several spherical metallic friction surface plates that is mounted between the foundation and the superstructure of the building, ensuring freedom of movement for the foundation together with the ground when an earthquake occurs while the superstructure tends to remain in equilibrium position.

KEYWORDS: three-dimensional modeling, isolation system, seismic isolation, friction force, base isolation, building seismic management

1. INTRODUCTION

Over time, many constructive solutions for the isolation systems have been developed to combat seismic actions on civil engineering structures that, in the event of a high magnitude earthquake, must remain intact and operational.

The systems in use are classified as energy dissipation and isolation devices. Structural base isolation systems are considered as both seismic dissipation and isolation systems because by their operation are consuming energy from the earthquake total energy amount while acting for the structure isolation against the devastating effects that an earthquake can cause on a building.

2. THEORETICAL ASPECTS ON ANTI-SEISMIC ISOLATION DEVICE

It is presented the operating principle for a friction pendulum-type system having an spherical central pivot that moves by sliding on a curved surface. This insulating system can be mounted at the base of construction structures in order to isolate the structure from the dynamic earthquake actions.

They were constructed and used many such systems operating on the insulating principle of friction pendulum mounted to construction structures and a classification of these systems is realized in figure 1.

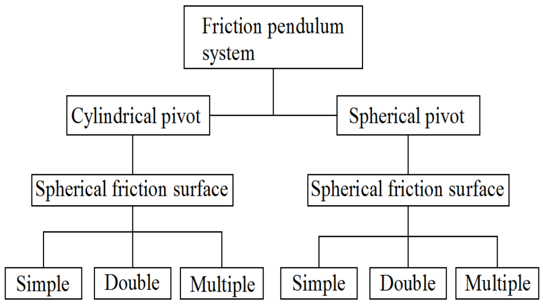


Figure 1 Classification of friction pendulum insulating systems

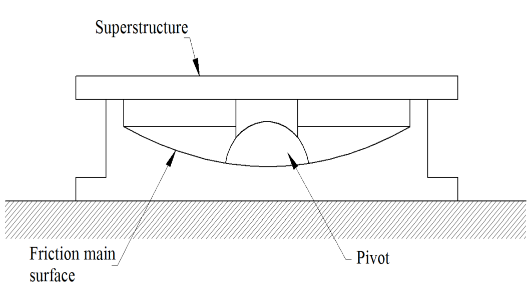
Through the constructive principle of the friction pendulum the disconnection between some structural elements is ensured, by interposing between, for example, between the building foundation and the superstructure, offering the moving possibility for the foundation with the ground when an earthquake occurs, so that the superstructure tends to remain in the equilibrium position.

3. ASSEMBLY MODEL FOR THE ISOLATION DEVICE OF PENDULUM TYPE

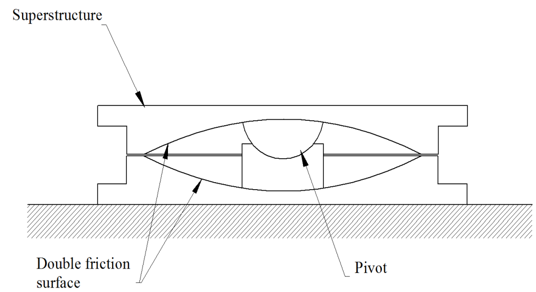
The friction pendulum system is included in the base insulation systems category mounted at the building structure.

Over time, several variant constructive types have been developed for this system in terms of the number of sliding surfaces included in the device assembly.

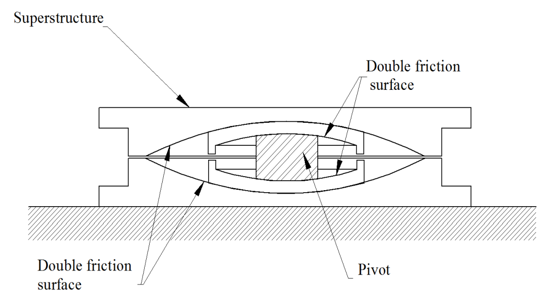
The main friction pendulum models that are currently used worldwide at various construction structures such as not very high-rise buildings, bridges and viaducts in order to counteract the destructive earthquake effects are presented. Figure 2 shows the schematic representations for these insulating system construction types.



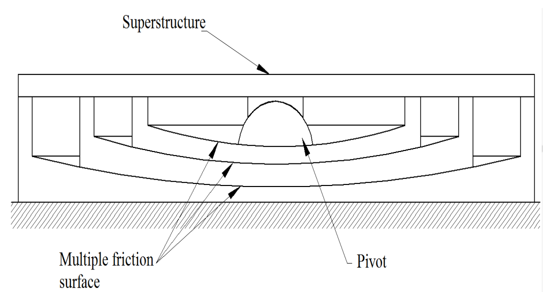
a) Simple surface pendulum system



b) Double surface pendulum system



c) Triple pendulum system



d) Multiple pendulum isolation system

Figure 2 Isolation system patterns of pendulum type

4. THEORETICAL PRINCIPLE OF THE PENDULUM ISOLATION SYSTEM

The theoretical operation principle regarding the pendulum isolation system refers to the functional parameters involved in the isolation action. It is about the loading force on the supports for the case of an isolated structure and the displacement according to the overall dimensions of the sliding surfaces.

The relative displacement of the insulating system components occurs when an earthquake is recorded so that the pivot engages a pendulum motion on the spherical surface. It is thus ensured through the disconnection between the foundation and the superstructure of the isolated building a freedom of movement for the foundation together with the ground and the superstructure tends to remain inertial in the equilibrium position.

The pivot movement on the spherical surface may be performed up to a maximum angle value of 30-35 degrees between the vertical direction and the radius of curvature of the sliding surface. This angle is considered as the maximum angular elongation and can be described by the relationship (according to EUROCODE 4):

$$\beta = \frac{D}{R} \tag{1}$$

The relative displacement is calculated according to the radius of the sliding surface and the angular elongation:

$$D = R \sin\left(\beta + \frac{\beta}{2}\right) \tag{2}$$

By using seismic isolation systems based on friction force at buildings, an increase in the horizontal flexibility degree of the structure base is ensured, which indicates an increase of the vibration period during an earthquakes and finally the acceleration values transmitted on building vertical direction are much diminished.

The main efforts acting on the insulation system are represented by static loading (isolated building weight), ground acceleration during the earthquake and twisting moment. The relationship between these efforts acting on the isolating system is as follows: [4]

$$N = P\left(1 + \frac{\ddot{u}_v}{g} + \frac{M}{P}\right) \tag{3}$$

The linear equation describing the external forces acting on the friction pendulum system is as follows: [4]

$$F = \frac{P}{R} \cdot u + \mu \cdot P \cdot \operatorname{sgn}(\dot{u}) \tag{4}$$

The hysteretic behavior during the seismic action for the spherical surface friction insulator is shown in Figure 3. Displacement occurs when the force limit value coincides with the frictional force value. As a result of the decrease in lateral force value, the structure is returned and placed at its original position by the static load.

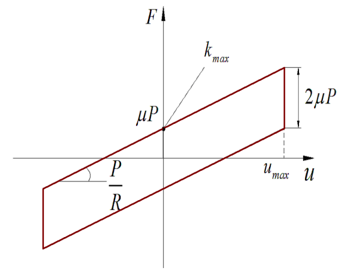


Figure 3 Hysteresis diagram for an insulation pendulum type friction (force-displacement)

The radius of curvature of the sliding surface is the essential parameter in the operation of insulation friction device and it influences the yield of isolation or energy dissipation.

Also, the friction coefficient between the surfaces in contact, interferes in the behavior of the insulating system and the insulated structure.

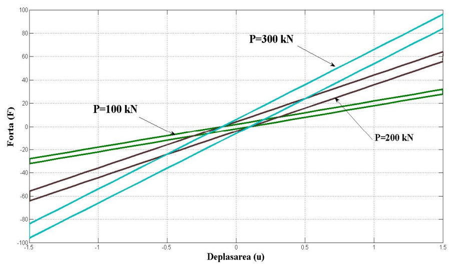
The geometry of the spherical sliding surface develops the return force during seismic action and the vibration period is described by the relationship: [3]

$$T = 2\pi\sqrt{\frac{R}{g}} \tag{5}$$

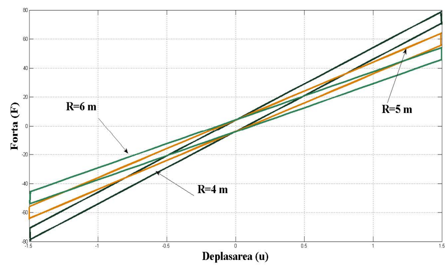
Using the numerical analysis conducted with MATLAB Academic program were considered input data regarding the static load applied to the friction isolator (P = 100: 300 kN), values for the radius of curvature of the sliding surface (R = 4: 6 m), but also values for the friction coefficient between the surfaces in contact (μ = 0.01: 0.04).

Three cases were analyzed as follows:

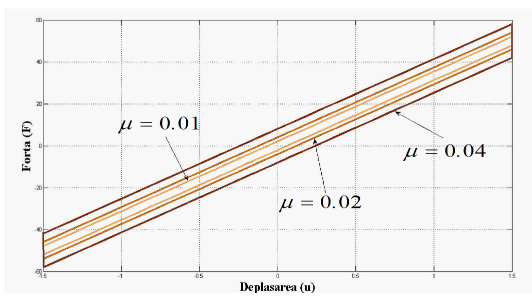
• case 1, were considered the values for the radius of curvature of the sliding surface (R) as well as the coefficient of friction between the surfaces in contact were kept constant, while three different values for the static load P) acting on the insulating system and the obtained results are shown in figure 4 (a);
• case 2, the value for the radius of curvature of the main sliding surface has been altered and the results are shown in figure 4 (b);
• case 3, the value of the coefficient of friction between the sliding surfaces in contact was changed and the results are presented in figure 4 (c).



a) Different values of static load, [3]



b) Different values of the radius of curvature of the sliding surface, [3]



c) Different values for friction coefficient

Figure 4 The force-displacement hysteresis curves for the dry friction insulation system with sliding on the spherical surface

The results in Figure 4 show the modification of the hysteresis curve for the friction isolation system when changing one of the basic parameters.

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

These insulating devices are specially designed for each insulated structure, depending on load requirements, earthquake drift, soil conditions, and structural dimensions.

Increasing the value of the curvature radius of the sliding surface have the result in a decrease in the force values as well as the approximation of the hysteresis curve shape relative to the horizontal axis.

When an earthquake occurs, movement is effected on the sliding surface due to the basic lateral force, the axial force opposes the movement along with the frictional force and these two resistors are added to the spherical surface geometry of the sliding surface that enhances the movement resistance and finally achieving the dissipation of input seismic energy on the isolated structure.

The displacement is a combined motion depending on the sliding surface geometry consisting of a translation combined with a vertical lift of the superstructure relative to the foundation, while rotations are allowed due to the geometry of the articulated piece (central pivot).

5. CONCLUSIONS

The insulation systems described and presented in this paper works on the dry friction force principle (Coulombs).

These mechanical devices have been created and continuously developed over time, now being used all over the world in order to counteract the destructive effects of seismic events on construction structures.

They can be mounted both at low height buildings, but also at bridges or viaducts due to achieve the rehabilitation of old buildings or for the endowment of the new structures.

The main parameters involved in the operation of these devices are vertical loading force, the value of the sliding displacement on the spherical surface and the lateral force recorded in the occurrence of the terrain seismic motion.

By mounting friction pendulum isolation systems to a specific structure a modification in the fundamental vibration period of the building it is achieved during an earthquake due to the disconnection made between the superstructure and the foundation, modification required for an improved behavior of the superstructure when a seismic event is occurring.

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