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PRINCIPLE OF ELASTOMERIC SUPPORTS AS ANTISEISMIC ISOLATION SYSTEMS

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

ABSTRACT

Special systems have been designed to be mounted at building structures acting against the effects of ground dynamic motions caused by earthquakes. Such systems considered as isolators working on dynamic regime are based on the elastomeric supports. The elastomeric isolators are typically installed at structure base and meet the conditions of base isolation principle by interposing between the foundation and the superstructure. Achieved mainly of rubber in combination with stainless steel plates to increase the compressive strength, this type of support can ensure the limited free movement of foundation together with ground during an earthquake, materialized in horizontal displacement or rotation in the horizontal plane. This paper describes two types of elastomeric systems, the simple model, but also the lead core model, showing the hysteretic behavior for each of them. The elastomeric supports can be used for base isolation of bridge or viaduct type structures, but also low-rise buildings that are located on stiff soil. The base isolation procedure for these structural types have results in increased natural vibration period obtained together with the movement provided by the isolation system.

KEYWORDS: seismic isolation, base isolation, elastomeric support

1. INTRODUCTION

There are multiple concerns of engineers to develop structural protection systems that attached to a building can provide a high level of safety during earthquakes and can be able to withstand for a long time.

Structural elastomeric supports help to increase the buildings lifespan to which they are attached by reducing the effects of seismic actions. They help to reduce the vertical transmission of seismic forces and act as natural elastic elements that bring the structure to the original position after an earthquake.

The elastomeric supports are typically mounted at isolated structures in combination with structural sliding devices or hydraulic dissipation systems in order to reduce the movements of the structure during an earthquake and the exposure of building to the seismic energy.

Achieved mainly of elastomeric rubber in combination with steel plates that give resistance, the isolator system is positioned between the foundation and the superstructure of a building. Through rubber elastic deformation during an earthquake are allowed horizontal movements for the superstructure but also small rotations in various directions.

As part of base isolation category systems, the elastomeric supports can be used successfully to isolate bridge or viaduct type structures or buildings with a reduced height, which are located on the stiff ground.

2. MODELING OF ELASTOMERIC SUPPORT

An elastomeric support represents a rubber unit having reinforced steel plates vulcanized during the fabrication process. The rubber layers alternate with fixed stainless steel plates. Elastomeric rubber is used because of its elastic properties that can provide lateral flexibility to the isolated structure.

The stainless steel plates add endurance to the isolation system so to make it able to support the weight of the superstructure.

The elastomeric systems are relatively simple to model and manufacture, offer a good resilience over time, working in a wide temperature range, but require additional damping systems.

Figure 2.1 schematically presents an elastomeric isolation system made of alternating layers of rubber and steel plates together with two mounting metal plates in which the fixing holes are made.

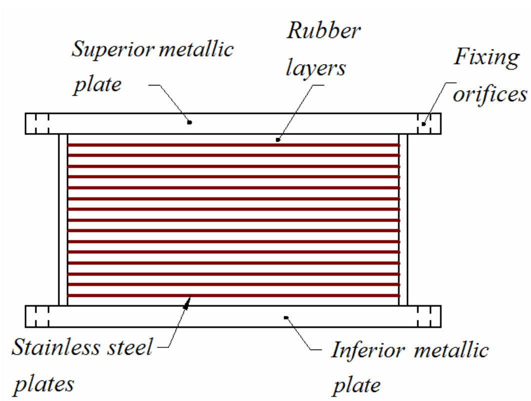

Figure 2.1 Schematic representation for elastomeric support

When lateral force is applied to the elastomeric system, it is obtained a displacement allowed by the system rigidity as described by the relation: [1], [4]

$$F = k \cdot d \quad (2.1.)$$

$$F(t) = k \cdot d(t) + c \cdot \dot{d}(t) \quad (2.2.)$$

Where:
F - lateral force;
k - effective rigidity;
c - damping coefficient;
d - displacement.

In the occurrence of a seismic ground motion that provides lateral force to the isolation system, a relative movement between the two structural elements is achieved and the displacement values are function of the elastomeric system effective stiffness.

The theoretical force-displacement hysteretic diagram is presented in Figure 2.2 for the simple elastomeric system.

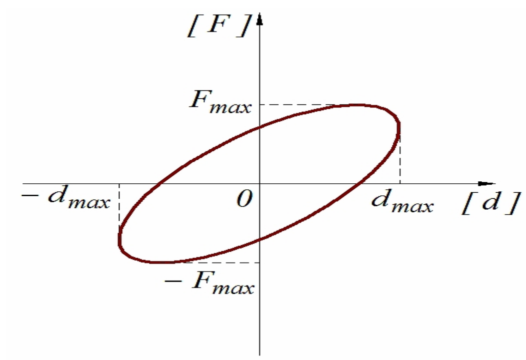

Figure 2.2 Force-displacement diagram for the elastomeric support

3. LEAD CORE ELASTOMERIC SUPPORT

Lead core elastomeric systems were designed for the first time in New Zealand (1975) and then adopted in Japan and the United States to isolate bridge, viaduct and buildings with a reduced height. [1]

This isolation system has the same components based on rubber layers in combination with steel plates except that it is introduced a cylindrical lead core positioned in the center that increases the support vertical stiffness and constitutes also a source of dissipating energy.

Lead as a high density metal provides a high initial stiffness which is reduced during an earthquake occurrence that is requiring the isolation system. Due to cyclic bending movements, the lead core begins to heat up, which leads to a decreased stiffness but through this process a quantity of seismic energy is consumed.

For small amplitude vibrations resulting from traffic or wind action, small displacements occur, but in the occurrence of an earthquake, cyclic movements are encountered at the isolation system level whose inertial forces succeed in overcoming the lead core stiffness.

Stability problems may arise when large

displacements occur. Therefore elastomeric systems can be used in combination with sliding or hydraulic dissipation systems that help in limiting these hazardous displacements caused by high magnitude seismic motions.

The hysteretic behavior for these types of isolation systems depends on the displacements performed during the earthquake.

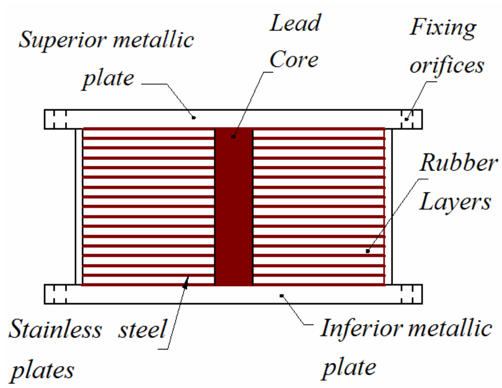

Figure 3.1. Schematic representation for lead core elastomeric support

The lead core system shows a greater stiffness than a simple system because there are large differences between the stiffness values of rubber and lead.

The significant horizontal forces are leading to relative displacements while at the lead core level occurs the transition from the elastic to plastic field.

For the field where both elastomeric rubber as well as lead show an elastic behavior there can be considered: [1], [2]

$$k_r = \frac{F_r}{d_r} \qquad (3.1.)$$

$$k_l = \frac{F_l}{d_l} \qquad (3.2.)$$

Where:

k_r - rubber rigidity;

F_r - applied force on the rubber element;

d_r - maximum displacement on the rubber element;

k_l - lead rigidity;

F_l - applied force on the lead element;

d_l - maximum displacement on the lead element.

The total stiffness of the lead core elastomeric isolation system can be described by the following relation: [1], [2]

$$k = k_r + k_l \qquad (3.3.)$$

$$k = \frac{F_r + F_l}{d_l} \qquad (3.4.)$$

When the horizontal forces acting on isolation system components are at higher values, the elastic limit is exceeded and lead changes in the plastic field, in this case the isolation system allows for a greater displacement.

For this case, the rigidity of the lead core isolation system will depend on the movement amplitude.

Figure 3.2 shows the theoretical force-displacement hysteretic diagram for the lead core elastomeric system.

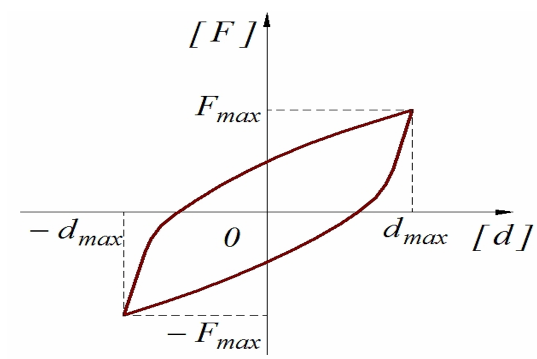

Figure 3.2. Force-displacement diagram for lead core elastomeric support

Typically, the elastomeric supports as part of base isolation systems are able to change the values for structural vibration period when significant seismic movements occur.

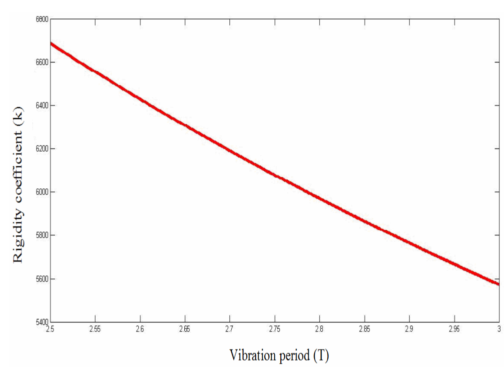

Figure 3.3. Theoretical variation for rigidity coefficient with structural system vibration period

When lead core elastomeric supports are in use, the vibration period modification occurs simultaneously with decreasing of device total rigidity. This is shown in Figure 3.3.

5. CONCLUDING REMARKS

The elastomeric support systems are providing viable solutions for isolation of bridge or viaduct structure type or buildings with a reduced height. These systems operate on the passive principle and are included in base isolation systems category due to base positioning between the foundation and the superstructure.

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

The elastomeric isolation system can provide an improved behavior for isolated structures because of the mounting position achieving 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 elastic properties of the rubber can ensure a free relative displacement between foundation and superstructure during ground seismic movements.

Load-displacement relationship for elastomeric supports provides hysteresis loops that give information about the dissipated energy amount through the isolation system during a seismic event.

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

The elastomeric supports may be used in combination with sliding isolation systems to be mounted at bridges, viaducts or building structures with reduced elevation, but for each structure the proper isolation system must be appropriately dimensioned.

The elastomeric supports are flexible elements that can provide an increased vibration period for the isolated structure. Due to lead core introduction, it is ensured the seismic energy dissipation that enhances the isolated structure stability in the same time with the displacements reduction during earthquakes. The lead core also provides high rigidity required to support the building weight.

Also the elastomeric supports as part of isolation systems can be successfully used to isolate structures with the center of gravity closer to the ground and placed on rigid soils.

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