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Description of a Composed Seismic Isolation System for Bridge Structures

From the design stage of a specific structural project, achieving a high level of safety is desired for structures, necessary to withstand dynamic actions that could have destructive effects on the resistant structure. In order to obtain the optimum level of safety against dynamic actions different types of isolation systems are placed into the structural system. The most commonly isolation method used is the base isolation method through which a disconnection between foundation and superstructure can be achieved. The isolation method presented uses special mechanical systems which are able to consume an amount from dynamic actions energy through their action. This study presents a base isolation method for building structures along with an overview of the different system solutions used to achieve the desired objective: ensuring a high level of safety for a bridge or viaduct structural type during a seismic event.

Keywords*: elastomeric bearing, energy dissipation, seismic isolation*

1. Introduction

Along with the construction of bridge or viaduct structures the connections between human communities are assured and therefore it is important that they can remain functional for an extended period of time, offering also a high level of safety during seismic activities of significant intensity. This goal can be achieved by using special systems attached to the bridge structure having the main purpose to improve its behavior during stress efforts induced by vibrations resulting from road and rail heavy traffic, but also from seismic events of major intensity. A complete and effective protection against dynamic actions for bridge or viaduct structure can be achieved using simultaneously elastomeric bearings and hydraulic dissipation devices that effectively help to strengthen the stability when the dynamic stress actions occur. This model can be classified as a combination of isolation and energy dissipation procedures working on passive principle.

2. Isolation system for bridge or viaduct structures

When small magnitude earthquakes are occurring in a short time period, a specific structure behaves corresponding to elastic domain, receiving all efforts below yield level. On the other hand when a major seismic ground motion appears the structure will not respond always in the same elastic domain. The structural engineers are considering the ductility concept in order to prevent the building total collapse, while accepting a certain level of structural and nonstructural damage. [1]

This practice was used until the occurrence of isolation and energy dissipation systems that are able to change the isolated structure behavior so that seismic efforts coming from the foundation soil do not fully reach the superstructure. This is possible due to disconnection achieved by the isolation system at the base level by interposing its components between the foundation and superstructure of the building. Some of the most used systems are elastomeric bearings made of rubber alternating with steel layers, mainly used in bridges, viaducts and buildings with a special height regime. The elastomeric bearings, presented as three-dimensional models in Figure 1 provide high values of rigidity on vertical direction necessary to support the service loads and also high flexibility in horizontal plane to permit the displacements and rotations required by the superstructure at a specific moment in time. [3]

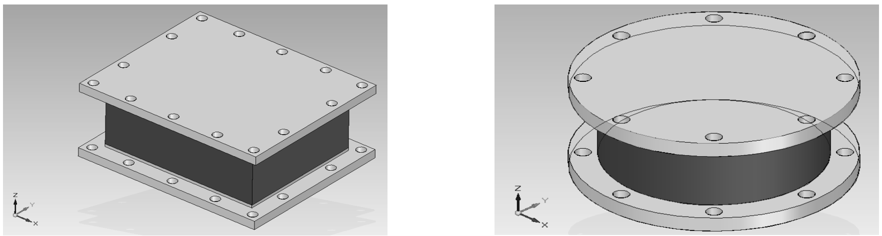


Figure 1. Rectangular and circular three-dimensional models of elastomeric bearings

The basic materials used for elastomeric bearings are natural rubber (polyisoprene) or neoprene (poly-chloroprene) in combination with steel plates, joined by vulcanization. Because of their special positioning between bridge pier and superstructure, during a seismic event, that moves the foundation soil, elastomeric isolation system allows foundation movement relative to the superstructure according to elastic limit of elastomeric material. In this way the superstructure is isolated from the horizontal efforts induced by earthquake while is providing a very stable support for the vertical loads. The elastomeric bearings can be designed for a wide range of stiffness values and isolation properties and manufactured at relatively low production costs. They are also easy to install, requiring minimal maintenance over time. [4]

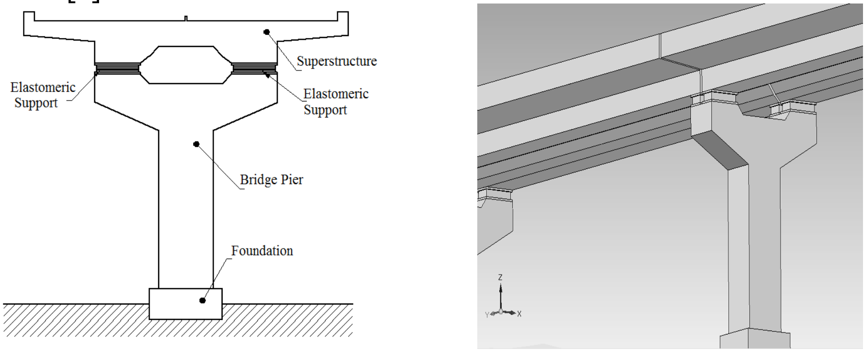


Figure 1. Model of bridge structure seismic isolated with elastomeric bearings

In 0 there are illustrated the mounting possibilities of elastomeric bearings at a specific bridge or viaduct structure.

3. Energy dissipation devices for bridge structures

For an improved safety of bridge or viaduct structures during strong ground movements caused by earthquakes, in addition to the endowment with elastomeric supports is necessary to be used hydraulic systems which are designed to ensure energy dissipation but also as anchoring systems for the bridge superstructure.

The hydraulic energy dissipation device (Figure 2) comprises a cylinder with piston, filled with a special viscous and less compressible fluid. The piston is positioned centrally and divides the cylinder in two chambers. Inside the piston head a set of orifices are made that allow fluid circulation and make possible the translational motions performed by the piston inside the cylinder.

Depending on the design requirements, the hydraulic dissipation device can be designed and produced for a specific bridge or viaduct type of structure in order to dissipate an amount of earthquake energy.

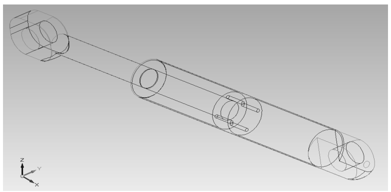


Figure 2. Hydraulic energy dissipation device assembly

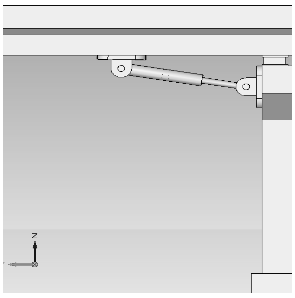


Figure 3. Model of bridge structure with elastomeric bearings and hydraulic devices mounted

The constitutive law for hydraulic dissipation devices can be presented as the relation: [5]

$$F_{HD} = A \cdot v^{e} \tag{1}$$

where:

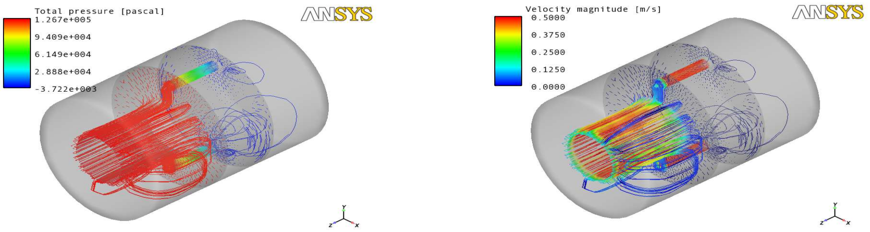
F_{HD} - represents the hydraulic dissipation device reaction force;
A - constant;
v - piston velocity;
e - hydraulic device damping coefficient.

Usually for hydraulic dissipation devices the value for the damping coefficient is within the range of (0 - 1). When the damping coefficient value is smaller, the damping carried out is higher.

4. The computational fluid dynamics analysis for a hydraulic dissipation device model

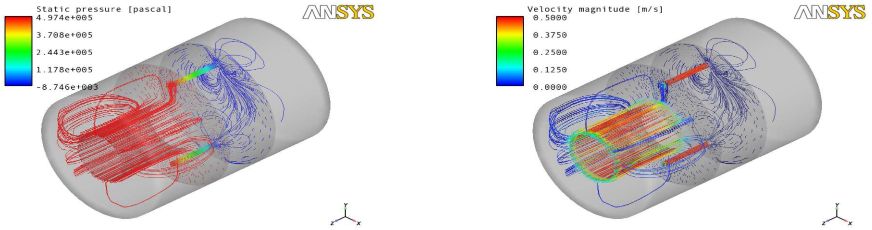
In order to highlight the operating principle of the hydraulic device and its energy dissipation character within the structure to which it is attached, a three-dimensional model of the device has been created and launched in numerical computational fluid dynamics (CFD) analysis performed with ANSYS-FLOWIZARD. The cylinder body has 200 [mm] in diameters and a length of 900 [mm]. There were analyzed two distinct cases when a number of two circulating orifices are practiced inside the piston head with a diameter of 20 mm for the first case and 10 mm diameter for the second case. The working fluid used is represented by a medium viscosity silicone oil having a density of $976\,\mathrm{kg/m^3}$, kinetic viscosity of $30\,\mathrm{kg/ms}$, and specific heat at $25^0\mathrm{C}$ of $0{,}36\,\mathrm{cal/g/^0C}$. [6]

The analysis results are presented in the following, showing the fluid flow inside the cylinder when for the piston is imposed a translational movement having a velocity of 0.4 (m/s).



a) Total pressure values b) Velocity magnitude on regions

Figure 4. Results for case 1



c) Static pressure values d) Velocity magnitude on regions

Figure 5. Results for case 2

In Table 1 are shown the force values obtained on boundaries for the both cases, with maximum values registered in the direction of piston movements.

Table 1. Force on boundaries [N]

Case 1 (20 mm)		Case 2 (10 mm)	
Force [N]		Force [N]	
Boundary	Z Component	Boundary	Z Component
Piston	5455.3	Piston	20277.3

The pressure values obtained for the two cases are presented in Table 2.

Table 2. Pressure values on boundaries [Pa]

Case 1 (20 mm)		Case 2 (10 mm)	
Pressure [Pa]		Pressure [Pa]	
Boundary	Maximum	Boundary	Maximum
Piston	126700.3	Piston	497400.5
Cylinder wall	126700.3	Cylinder wall	497400.5
Fluid	127500.4	Fluid	497700.6

The results obtained from the numerical analysis on virtual model highlights the hydraulic fluid device dissipative character. The dissipation device piston velocity and response force depends on both the fluid orifices diameter as well as its viscosity and compressibility properties.

5. Conclusion

The concept of using anti-seismic protection systems composed of elastomeric bearings and hydraulic energy dissipation devices represent a solution that can ensure a high level of stability for the bridge or viaduct type structures. A great amount of the earthquake input energy is absorbed by using supplemental hydraulic devices in addition to elastomeric bearings, energy transformed in heat and transferred to the external environment. The orifices diameter for the fluid passage is an important parameter in hydraulic dissipative system operation having direct influence on achieving of resistant force at the device rod.

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