# INFLUENCE OF STRUCTURE MASS ON THE BEHAVIOR OF SEISMIC ENERGY HYDRAULIC DISSIPATION DEVICES

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## ABSTRACT

*Since many solutions exist today in the field of structure isolation against the destructive action of earthquakes, the authors present a simple solution that can provide complete protection against shock and vibration both as a result of road traffic and seismic actions. The proposed solution is represented by hydraulic energy dissipation device, as a passive system for structural isolation. Based on a case study, is highlighted the evolution of involved parameters in device operation according to isolated structure mass.*

KEYWORDS: hydraulic, energy dissipation, device, earthquake

## 1. INTRODUCTION

It should be noted that currently there are multiple solutions for isolation of building structures against the destructive action of a potential earthquake. It applies both to isolate new buildings and rehabilitation of existing structures that require consolidation. An isolation system device can be considered as passive when it does not require an additional control system, or active if the system is equipped with additional control devices. This study describes the operating principle of a hydraulic isolation device used as an energy absorber for isolation of structures against seismic destructive action. This device is categorized as passive since it operates without any other additional control devices.

## 2. HYDRAULIC DEVICE DESCRIPTION

The dissipation device design is presented as a hydraulic linear engine with piston that divides the cylinder in two chambers. Inside the cylinder there is fluid (silicone oil, synthetic oil) with special properties in terms of viscosity. Device operation is based on the friction that occurs between layers of fluid, generating a force that creates resistance to piston movement.

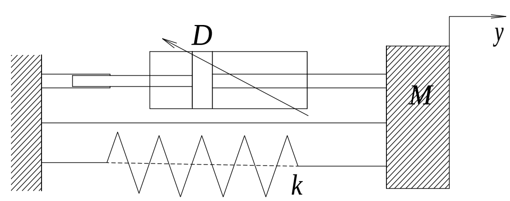


Figure1 Device hidraulic symbolization

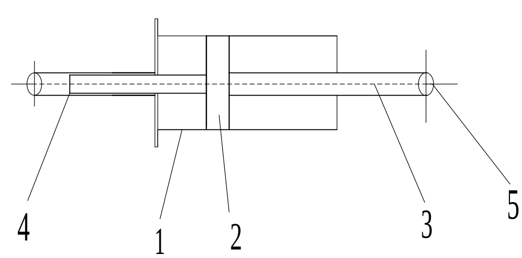


Figure 2 Constructive solution for hidraulic dissipation device

The hydraulic schematic symbolization of the dissipation device is presented in figure 1, where it can be seen a connection mode at the structure, one side fixed to the foundation and the other to the superstructure to be isolated. The design of the device energy dissipation is shown in Figure 2. The description of device component is as follows:

1. Cylinder;
2. Piston;
3. Piston rod;
4. Compensation chamber;
5. Articulated mounting joints.

The hydraulic device action is reversible for traction-compression alternative movements and dynamic behavior depends on the instantaneous excitation speed produced by the mechanical shock vibration or earthquake.When excitation occurs as a result of shock, vibration or seismic action, isolated structure mass tends to move, mechanical energy is transmited to the hydraulic dissipation device. This energy amount is taken and converted into heat by friction between fluid layers inside the device cylinder. Depending on hydraulic fluid viscosity, there is a result as piston movement resistance imposed by isolation system described as device stiffness.

## 3. THE DYNAMIC MODEL OF THE DISSIPATION DEVICE

A dynamic model of energy dissipation device results from the hydraulic fluid flow rate, circulated for piston translational motion and the equation of applied forces over the piston. The mathematical model describing the operation and the strongly nonlinear behavior of hydraulic dissipation system is shown as: [1]

$$\frac{dy}{dt} = \frac{D}{A}\sqrt{p} + \frac{V_0}{AE}\frac{dp}{dt}; \tag{1}$$

$$\frac{d^2y}{dt^2} + \frac{C}{M}\frac{dy}{dt} + \frac{K}{M}y = \frac{g}{10} - \frac{A}{M}p; \tag{2}$$

where:

$$D = \frac{\pi^2 d^3}{4k_r}\sqrt{\frac{2}{\xi\rho}}; \tag{3}$$

$$H = \pi d\delta\sqrt{\frac{2}{\xi\rho}}; \tag{4}$$

represent device constant,
$d$ – pressure controller slide diameter;
$\delta$ - passive stroke necessary for opening the pressure controller;
$k_r$ - pressure controller rigidity;
$\xi$ – local loss coefficient of hydraulic fluid load circulation by pressure regulator;
$K$ - hydraulic device stiffness;
$C$ – dissipation device damping factor;
$M$ – suspended mass on hydraulic dissipation device;
$A$ – frontal surface area of piston head;
$V_0$ - volume of hydraulic fluid;
$\rho$ , $E$ - density, elasticity of the hydraulic fluid.

Model variables are:
y - piston momentary displacement;
p- momentary set pressure.

The following variables are generally required to be studied:

$$\begin{aligned} &y = y(t);\\ &p = p(t);\\ &p = p(y);\\ &F = F(t) = A\cdot p(t);\\ &F = F(y). \end{aligned} \tag{5}$$

The mathematical model is based on the following assumptions:

- it has not been taken account of flow rate losses through the gaps, as the piston seals do not allow flow rate losses, being self-strain able on cylinder bore;

- flow rate losses on pressure controller, between locations of high and low pressure are considered negligible, given the small size of the regulator compared to the dissipation device cylinder.

## 4. DISSIPATION DEVICE MODELING RESULTS

In order to highlight the dynamic behavior of hydraulic dissipation device, a case study was approached with the following variables:

$$\begin{aligned} &k_r = (52;104;208)\,daN/cm;\\ &d = 0,45\,cm; \rho = 0,0009\,kg/cm^3; \xi = 1,8;\\ &A = 115,4\,cm^2; V_0 = 3460\,cm^3;\\ &M = (15000;25000;35000)kg;\\ &K = 8\ daN/cm; C = 10 daNs/cm;\\ &E = 16900 daN/cm^2; g = 981 cm/s^2;\\ &\delta = 0,9. \end{aligned}$$

The modeling results achieved for three different values of structure mass are shown in a graphical form as follows:

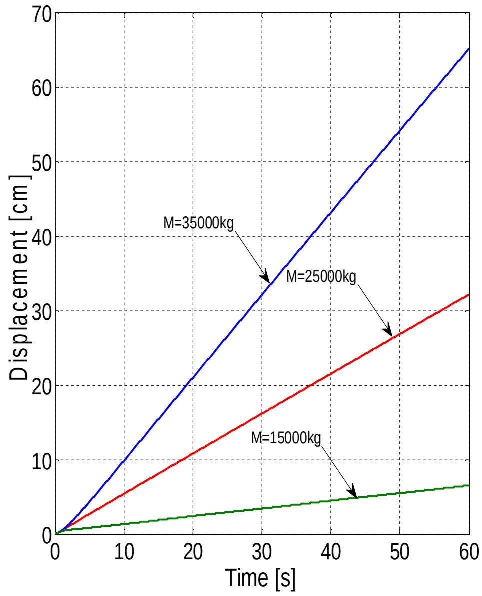


Figure 3 Displacement variation function of structure mass

Figure 3 shows the variation in piston displacement as a result of changing the value of isolated structure mass (*M*). For three different values it can be observed that displacement increases with the value of the isolated structure mass.

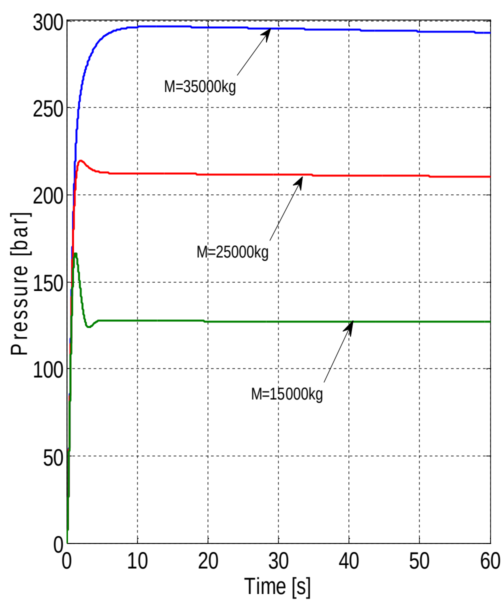


Figure 4 Pressure variation over time

An isolated structure action on the dissipation device is achieved as repeated mode of traction-compression alternative force resulting in increased hydraulic fluid pressure inside the cylinder, depending on flow orifices diameter, but also on fluid viscosity. In Figure 4, it can be seen the hydraulic working fluid pressure variation inside the device cylinder, depending on the value of the isolated structure mass and obvious differences may be observed.

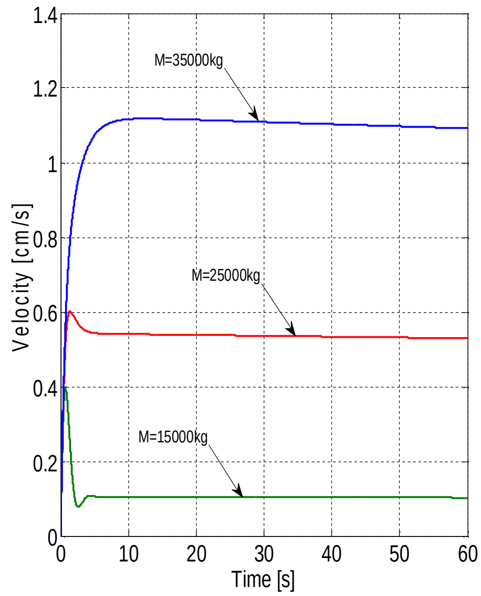


Figure 5 Velocity variation in time

By its action, a hydraulic system can achieve shock and vibration energy dissipation and is considered as a velocity dependent device. Figure 5 shows the graphical representation of the piston rod velocity for an excitation provided by a structure mass with values shown on graphic. Differences resulting in piston rod velocity value are obvious and give information on the device proper functioning.

## 5. CONCLUSIONS

A hydraulic device connected to a structure can perform shock and vibration energy dissipation that can occur from traffic or earthquakes. By using hydraulic energy dissipation devices, structure designers seek to improve a structure behavior at dynamic motions by increasing the damping and to obtain a necessary takeover and conversion of kinetic energy that occurs in the structure. Energy acquisition is in the form of mechanical energy and conversion in caloric energy (heat) transferred to the external environment through the hydraulic cylinder walls. This type of device has a strongly nonlinear behavior. A case study was performed in order to observe the evolution of involved parameters (displacement, pressure and velocity), function of time by changing the value of the isolated structure mass. The results confirm the function of energy dissipation. For a different value of the structure mass, we have greater displacement, high pressure inside the cylinder and piston rod increased speed. Hydraulic dissipation devices based on a simple principle of operation can provide structures with additional safety against seismic actions, are easy to make and long lasting. These special systems must be designed separately for each structure to be isolated depending on its proper dimensions and on the purpose for which it was conceived.

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