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Hydrostatic Devices used for Construction of Seismic Energy Dissipation Systems

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Modern structures made today benefit from quality materials that ensure their considerably long life. In addition to these materials, specific methods are used in order to counteract the dynamic actions that may require their structural strength and engineers greatest concern is to ensure an optimal degree of earthquake stability. Among the methods are used insulation and dissipation solutions by using special mechanical systems, which can counteract the earthquake action. A hydrostatic drive is described in this paper, which can also be attached to the structure in order to consume some of the earthquake energy, resulting in a diminished amount of energy transmitted to the structural frames. It is considered an energy dissipation system, whose operating principle is highly nonlinear.

***Keywords**: hydrostatic device, energy dissipation, seismic action, building structural isolation*

1. Introduction.

The concerns of structural engineers have been directed toward achieving an optimal building stability and durability over time. That is why some special protection systems that are attached to the building structures have been conceived and developed, with the declared purpose of helping the structure in case of seismic phenomena that may require the structure at a certain moment. These special systems are mechanical devices that act as insulator and energy dissipation device, because they have the opportunity to consume some of the earthquake energy, transforming it into another form of energy, namely in heat. By the action of these devices, the building behavior at earthquakes is highly improved, the structure's structural strength remains intact, without any residual deformation, and the building can remain functional even after a considerable magnitude earthquake has passed.

2. Hydrostatic protection systems for use attached to building structures

There are a multitude of protection devices that are currently in use, mounted within structural frames of buildings, whether if it is about the seismic insulation of bridges, viaducts or buildings.

Among these, is necessary to be mentioned the insulation systems positioned at the structure base, as the friction pendulum type or elastomeric supports, but also the dissipation hydrostatic device type, which is designed as a hydraulic linear motor with piston. The piston is positioned inside the cylinder, so that it forms two distinct chambers in the cylinder body. The connection between the two chambers is provided by means of a number of orifices made in the piston head. The cylinder body is filled with a working fluid, which may be silicone oil whose properties influence the energy dissipation performance of the hydrostatic device (Figure 1).

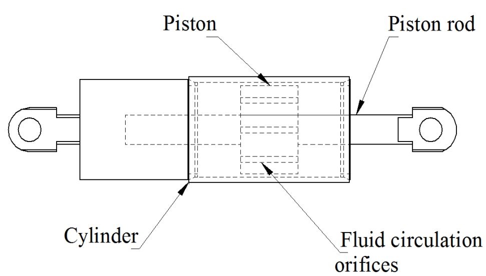


Figure 1. The schematically representation of hydrostatic seismic energy dissipation system

These systems are considered that work on the passive principle because they do not require any additional energy source to operate and are activated by the motion generated by the earthquake. The use of these types of devices embedded within the building structural frames can provide the dissipation of a large amount of seismic energy due to the resistance force that occurs at the device piston stem motion when it is activated by earthquake.

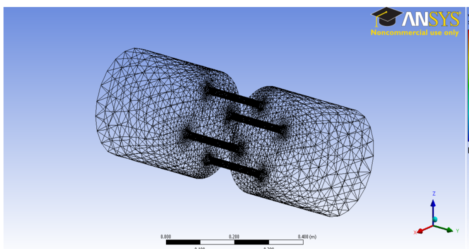
3. Virtual operation analysis of a hydrostatic dissipation device model

A CFD analysis was performed using the ANSYS CFX academic program for a hydro-static dissipation device model assembly having a 30 cm piston diameter with a number of 4 orifices made inside the piston head, each having a diameter of

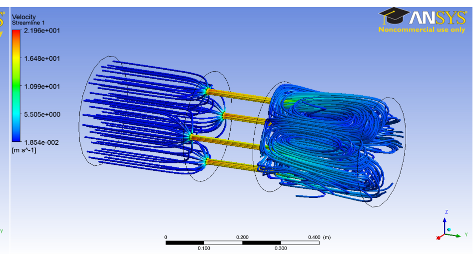
2 cm. The hydro-static cylinder has a length of 80 cm. The hydraulic fluid used was silicone oil with 6 different kinematic viscosity values ranging from 50 to 1000 CST.

The analysis was carried out in two steps, for the first step (case 1) the calculation was made for a declared piston velocity of 0.3 m/s, and in the second stage (case 2) the calculation was made for a declared velocity of 0.5 m/s at the piston.

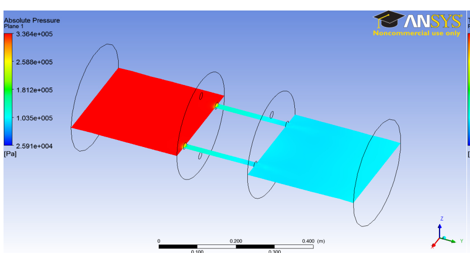
The results are presented in terms of velocity and pressure of the working fluid used inside the cylinder of the hydrostatic dissipation device.



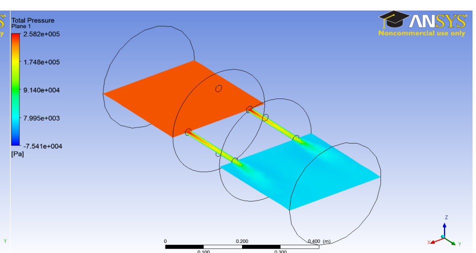
The fluid region mesh of 27512 nodes and 134136 elements



The streamlines for fluid velocity



Absolute pressure values



Total pressure values

Figure 2. The analysis results for hydrostatic seismic energy dissipation system model

Thus, based on the result values obtained for the two analyzed cases, the piston displacement force can be calculated as the main component of the energy dissipation amount that can be assured using the hydrostatic dissipative device attached to a building during a seismic event. The numerical values obtained are shown in Tables 1 and 2, in part for each analyzed case.

Table 1. The obtained result values for the first analyzed case

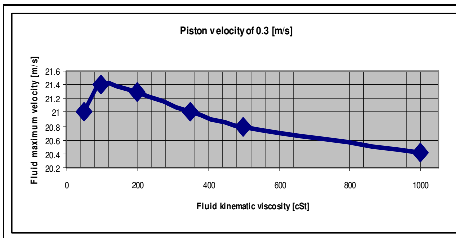
Fluid velocity [m/s]	Total pressure [bar]	Absolute pressure [bar]	Total force [daN]
21	2.5	3.36	1735.25
21.4	2.49	3.51	1728.309
21.3	2.78	3.6	1929.598
21	2.91	3.74	2019.831
20.8	3.05	3.94	2117.005
20.42	3.87	4.81	2686.167

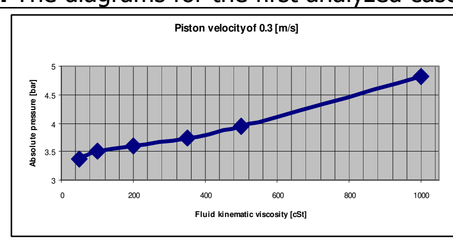
Table 2. The obtained result values for the second analyzed case

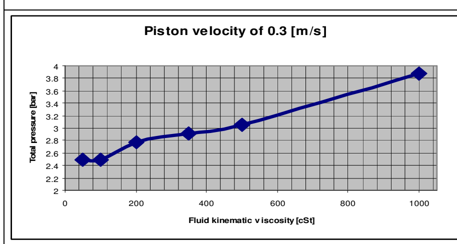
Fluid velocity [m/s]	Total pressure [bar]	Absolute pressure [bar]	Total force [daN]
36	7.1	7.5	4928.11
36	7.29	7.65	5059.989
35.6	7.57	8.08	5254.337
35.4	7.7	8.17	5344.57
35.24	7.99	8.43	5545.859
34.57	8.79	9.51	6101.139

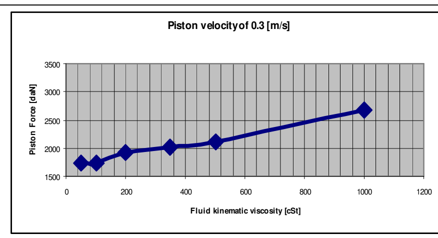
Using the obtained numerical results, the variation diagrams for velocity, total pressure, absolute pressure and piston displacement force for the two analyzed cases were made, as shown in Table 3 for Case 1 and Table 4 for Case 2.

Table 3. The diagrams for the first analyzed case



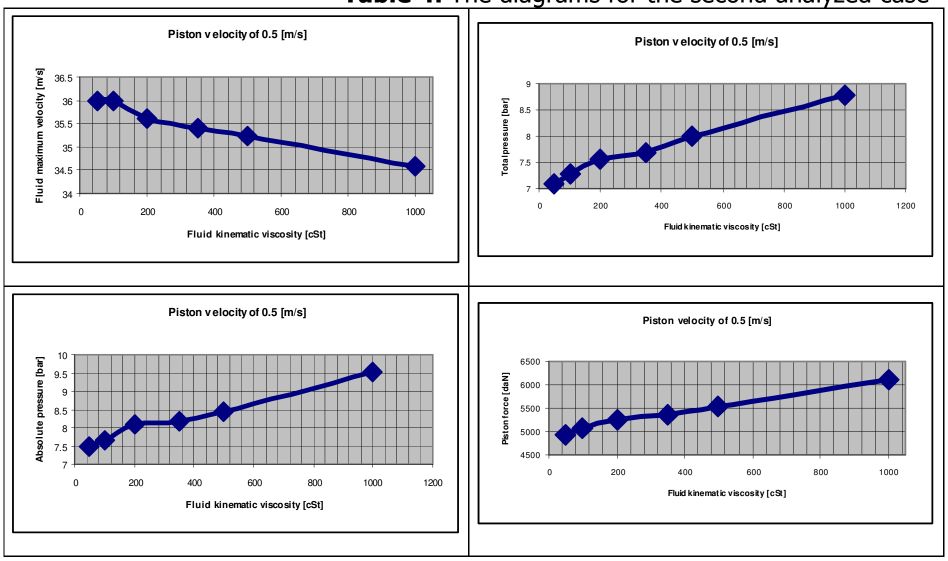






Higher values for the circulation velocity of the working fluid through the piston orifices can be observed at low kinematic viscosity values, while the absolute and total pressure values are proportionally higher for higher viscosity fluids, this trend being followed also for the resistant force values at the piston movement inside the device cylinder.

Table 4. The diagrams for the second analyzed case



The same tendency it is maintained for the second case where the piston velocity was declared at 0.5 m/s. Thus, using higher values of kinematic viscosity for the working fluid, a higher value of the resistance to the piston displacement of the hydrostatic dissipation device is obtained.

4. Conclusion

Energy dissipative systems are used in the complex insulation assemblies, with the declared aim of achieving a better building structures insulation against the earthquakes destructive actions that may appear at a certain point in time.

Together with the structure isolation systems, they are part of the same class of passive systems in terms of operating principle since they do not have any other active control system in their composition, and are activated by the motion generated by the earthquake itself.

These systems are designed to dissipate a significant amount of seismic energy supplied by a seismic event, being hydrostatic devices that work with special fluids whose properties provide a good resistance to the piston rod. Thus, efforts that tend to distort the building's structural strength during a considerable magnitude earthquake are greatly diminished due to the action of these dissipative hydrostatic devices.

Seismic isolation and passive energy dissipation are the most used methods of passive control over the behavior of construction structures. Using these methods at building structures additional damping during is provided needed to significantly reduce the structural response to seismic movements of structures.

The passive hydrostatic dissipation systems presented represent viable seismic isolation technologies that are currently used in building structures. There are many situations where they are used in combination with springs, torsion bars, or elastomeric supports in order to control the vibrations from dynamic actions or to change the dynamic behavior of structures.

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