Kurdistan Engineers Union

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Special Report about :

Viscous fluid damper

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March 2024

Submitted to :

Kurdistan Engineers Union

Abstract :

Structural control techniques have been more important in earthquake and wind resistance designs worldwide in recent years. Buildings throughout the classical period were only designed to support vertical loads. The modern age brought dynamic computation techniques and techniques.

Technologies for releasing energy are often applied to improve the responsiveness of structures subjected to dynamic stresses produced by earthquakes and wind. Especially, viscous dampers are hydraulic devices widely used in structural engineering that dissipate mechanical energy by producing a damping force against the motion. The dampers can mitigate transversal and longitudinal or vertical displacement. It can be set up in different kinds of structures. The purpose of this study is to define the VFD instrument and explain how to use it in seismically active constructions. In order to do this, a search through several publications focusing on the characteristics of fluid viscous dampers was taken into consideration for analysis using a range of parameters. The results showed that installing Fluid viscous damper can significantly reduce the seismic response by selecting affordable damping parameters, including velocity, stiffness, and damping coefficient.

Bycarefully studying structures with various fluid viscous damper dampin g charact-eristics, the ideal damping parameters may be determined.

Keywords: Damper parameters, Damping coefficient, silicone or an oil combination, Velocity exponent, stiffness, Seismic performance

Table of content

1-Introduction :

When a structure is subjected to earthquake, wind, blast, or other sorts of transitory shock and vibration disturbances, damping effectively helps it function at its best. According to a typical method, the structure must combine strength, flexibility, and deformability in order to naturally attenuate or disperse the impacts of transitory inputs. By adding viscous fluid dampers, the structure and the additional dampers work together to absorb the energy input from a burst rather than the structure alone (Mcnamara and Taylor, 2003).

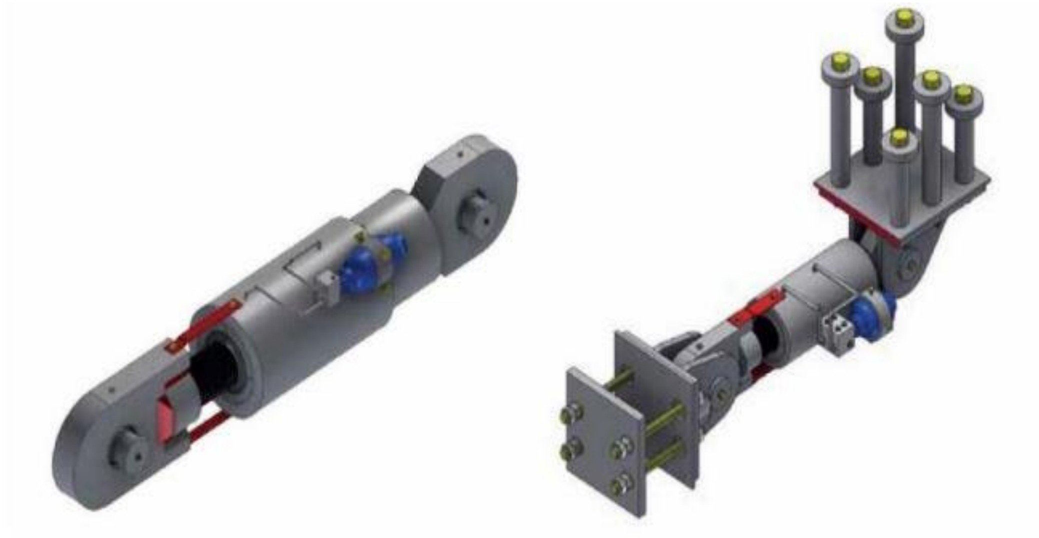
Fluid viscous dampers were first employed in the aviation and military industries. They were created in the late 1980s and early 1990s specifically for use in structural engineering. Typically, FVD are made up of a cylinder filled with a very viscous fluid (commonly silicone or an oil combination) and a piston head with orifices within. When the piston head passes through the fluid hole in the damper, energy is released (Ras and Boumechra, 2016).

Since the fluid in the cylinder is almost incompressible, the piston rod area movement causes the fluid volume inside the cylinder to decrease when the damper is compressed. A restoring force is produced as the volume decreases. An accumulator is used to stop this unwanted force. The way an accumulator functions is by gathering and storing the amount of fluid that the piston rod displaces in the makeup region. The fluid will be drawn out by the vacuum formed when the rod retracts. An example of an accumulator-equipped damper can be seen (Symans and Constantinou, 1998).

2- Material and methods

The FVD is consist of a cylinder, piston, hydraulic valve, piston rod, and silicone oil shown in (Figure 1). The movement of the structure pulls the cylinder and piston to produce relative displacement under the earthquake stress. Thus, the silicone oil flow is propelled by the piston's reciprocator action. The fluid generates heat due to the friction between the molecules and the surface of the cylinder; so, the seismic energy may be converted into heat, and consequently, the damping impact may be realized. The simplest model of a viscous damper system (an oil damper) is the viscous type model (Aguirre et al., 2013).

It is acknowledged that the stiffness of the damper system and the surrounding sub assemblage affect the dampers' performance. The damper force is related to the relative velocity between the two ends with a constant coefficient. In practical structural designs utilizing oil dampers, a relief mechanism is typically used, which changes the constant viscous



damping coefficient to a smaller value, thereby restricting the most damping force (Shen and Kookalani, 2020).

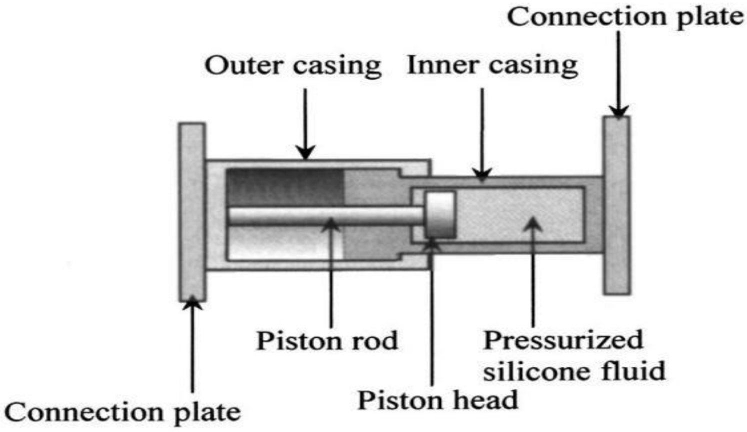


Figure 1: (i) Fluid Viscous Damper (Shen and Kookalani, 2020) (ii) Cross section of pressurized silicone FVD (Sorace et al ,2008)

3- The steps for designing of viscous fluid dampers :

The steps for designing FVDs are as follows: (1) Determine the total number of FVDs; (2) compute the parameters of FVDs; and (3) place the FVDs in a desired location. In another stage, the structural damping ratio.

$F= CV^{\alpha}$ ………………. (equ.1) (Shen, and Kookalani, 2020)

That

F: Damping force, KN. In the piston head, the damping force is created by a pressure differential. As a result, the damping force will rise until the pressure within the servo valve reaches a value, at which point it will stable.

V: Relative Velocity, m/sec V is the velocity of the piston concerning the cylinder.

C: Damping Coefficient, KN/ (m/sec).

$\boldsymbol{\alpha}$: is the damping coefficient that depends on the fluid properties, the piston's diameter, and the orifice areas.

$\boldsymbol{\alpha}$: Velocity Exponent. The velocity exponent, which is dependent on the piston head's structure, is a real positive exponent that describes the nonlinearity of the damper. It could have a definition in a range between 0.1 and 2.0.

Three criteria could be used to categorize viscous dampers according to their value:

a- if $\alpha = 1$ is called a linear viscous damper.
b- if $\alpha < 1$ is called a linear viscous damper.
c- if $\alpha > 1$ is called an ultra-linear viscous damper.

The force-velocity diagram of an FVD with varying α is shown in (Figure 2) where the displacement amplitude, damping coefficient, and energy dissipation remain constant. In the ranges with lower velocities, a nonlinear FVD with smaller α generates bigger damper forces.

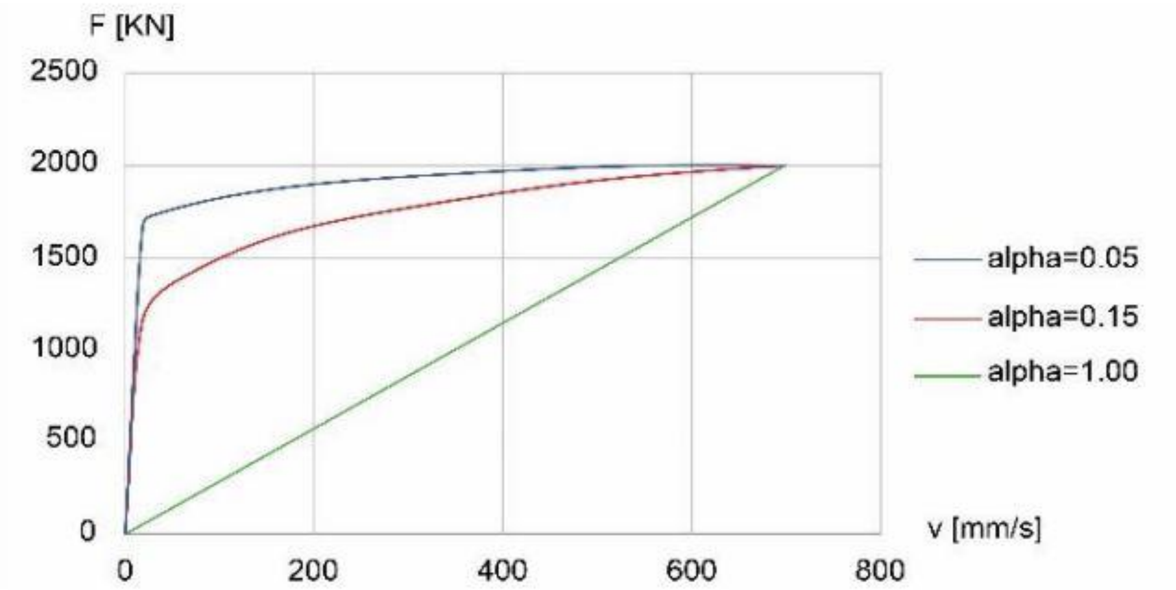


Figure 2. Typical response Force / Velocity diagram (alpha variable from 1.00 to 0.05) (Wang, 2017).

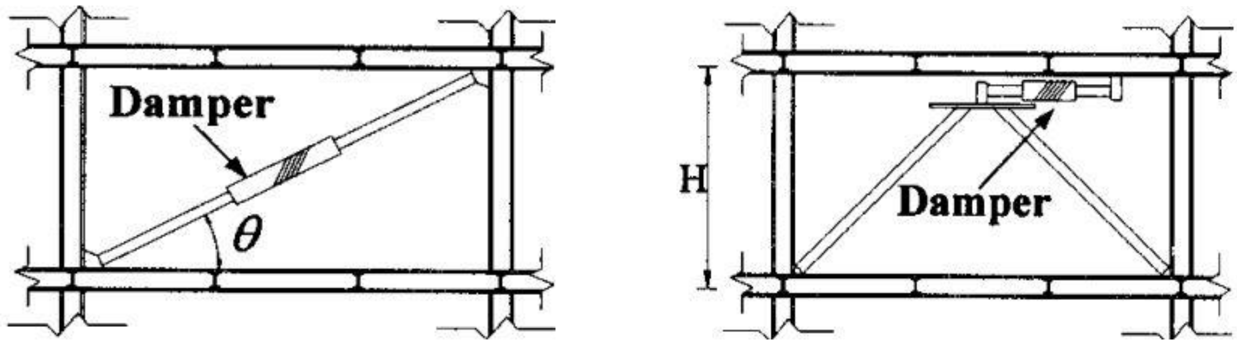
4- How to installation of VFD

Can fixed the viscous fluid damper as the shown in figure 3:

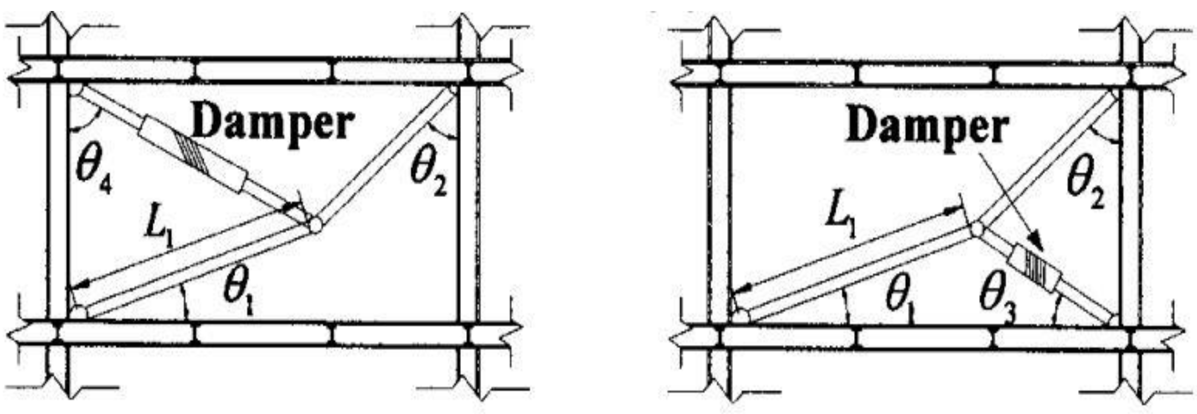
a) diagonal brace.

b) K shape bracing.

c) Upper toggle brace and lower toggle brace



(a). diagonal brace (b). K brace



(c)upper and lower toggle brace

Figure 3: Installation scheme of viscous dampers (Hwang et al, 2008)

5- Impact of FVD on the seismic system's capacity

Fluid viscous dampers FVDs, are one of the most widely used passive energy dissipation devices in civil engineering and have gained support recently (Shen and Kookalani, 2020) Effective energy dissipation devices FVDs improve structural responses to withstand seismic and wind loads. The physical characteristics of the fluid utilized in the device influence the damping force produced by the FVDs (Tezcan and Civi, 1992). Improving the earthquake resistance of both new and existing structures may be achieved effectively with the use of FVDs. FVD may be employed as a competent option to meet the needs of the ever-growing seismic design for retrofitting existing structures since it offers more damping without significantly raising the seismic stresses on components to prevent the overturning of the structure (Wang and Mahin, 2018). Many studies have shown that using the FVD's reasonably priced damping situations efficiently lowers the seismic response by examining various combinations of the damping coefficient and velocity exponents. Additionally, in order to achieve the optimum energy dissipation behavior, the ideal damping coefficient was found for a set quantity of exponent coefficient in their later investigation (Shen and Kookalani, 2020).

6- Existing Formulas for Computing the Additional Viscous Damping Ratio:

6.1 Linear Viscous Dampers :

The formula for calculating the damping ratio contributed by the added energy dissipation devices is provided by FEMA 273/274 and FEMA 356 in the form of:

$$\xi_{eq} = \frac{\sum_j E_j}{4\pi U_t} \quad \text{.......................................} \quad \text{(equ1)}$$

$$E_j = \frac{2\pi^2}{T} C_j \delta_{rj}^2 \quad \text{................................} \quad \text{(equ2)}$$

$$\sum_j E_j = \sum_j \int_0^{T_k} P_j d(\phi_j - \phi_{j-1}) \quad \text{.............} \quad \text{(equ3)}$$

$$P_j = C_j^1 \cos^2\theta(\phi_j - \phi_{j-1}) \frac{2\pi}{T_k} \cos\left(\frac{2\pi l}{T_k}\right) \quad \text{.............} \quad \text{(equ4)}$$

$$\sum_j E_j = \frac{2\pi^2}{T_k} \sum_j C_j \cos^2\theta_j(\phi_j - \phi_{j-1})^2 \quad \text{..............} \quad \text{(equ5)}$$

$$U_t = \frac{2\pi^2}{T_k^2} \sum_i m_i \phi_i^2 \quad \text{.........................} \quad \text{(equ6)}$$

$$\xi_k = \frac{T_k \sum_j C_j \cos^2\theta_j(\phi_j - \phi_{j-1})^2}{4\pi \sum m_i \phi_i^2} \quad \text{......................} \quad \text{(equ7)}$$

$$\xi_d = \frac{T \sum_j C_j \cos^2\theta_j {\phi_{rj}}^2}{4\pi \sum_i m_i \phi_i^2} \quad \text{......................} \quad \text{(equ8)}$$

6.2 Nonlinear Viscous Dampers :

The damping ratio of a building structure supplied by additional nonlinear viscous dampers was determined by following the linear viscous damper formulation technique and taking into consideration just the first vibration mode (Hwang, et al, 2008). A linear viscous damper's energy dissipation is equal to the work performed by a nonlinear viscous damper in a single vibration cycle. The equivalent viscous damping ratio supplied by the nonlinear viscous dampers is then derived by applying the previously described derivation technique for linear viscous dampers.

$$\xi_d = \frac{T^{2-\alpha} \sum_j \eta_j C_j \lambda \cos^{1+\alpha} \theta_j (\phi_j - \phi_{j-1})^{1+\alpha}}{(2\pi)^{3-\alpha} A^{1-\alpha} \sum_i m_i \phi_i^2} \quad \text{.................... (equ9)}$$

$$\lambda = 2^{2+\alpha} \frac{\Gamma^2(1+\alpha/2)}{\Gamma(2+\alpha)} \quad \text{.............................. (equ10)}$$

All equations are taken from (Hwang, et al, 2008).

In summary, (equ8) and (equ9) have provided very useful and convenient tools for the practical engineers to preliminarily select the damping coefficients of linear and nonlinear viscous dampers corresponding to a desired added damping ratio to the structure. Once the damping coefficients are determined, more detailed analyses may be conducted for the final design check and revision (Hwang, et al, 2008).

Table 1: terms that used in equation (1 to 10) (Hwang, et al, 2008).

Terms	Properties
ξ	damping ratio
Ej	total energy dissipated by energy dissipation device
j	in a cycle of motion
Ut	maximum potential strain energy of the structure.
T	fundamental period of the building
Cj	damping coefficients of the damper j
δrj	relative displacement between the ends of the damper j along the axis of the damper.
Φj , $\Phi j - 1$	respectively, the horizontal modal displacements of the jth and j−1th story in the kth mode of vibration
Tk	natural period of the kth mode of vibration;
θj	inclination angle of the dampers in the jth story
Φrj	first mode relative displacement between the ends of the devices j in the horizontal direction.
Γ	is the gamma function
ηj	number of identical dampers with the same Cj in each story
α	damping exponent
A	roof response amplitude corresponding to modal displacement j normalized to a unit value at the roof
λ	parameter which can be calculated by equation 10

7- Conclusion :

Buildings may effectively reduce structural vibrations brought on by outside factors like wind or earthquakes by installing viscous fluid dampers. It helps to improving the overall structural resilience and stability by releasing energy through fluid shear and turning force to heat through the liquid inside the device. Basically, a typical viscous fluid damper makes up of a piston filled with silicone or oil compound. It has different work system linear viscous damper, non-liner viscous damper and ultra-linear viscous damper. This type of damper useful for modern design structure and useful for retrofitting of old building. viscous fluid damper is simply for making. Some factors effect on the working system of the viscous fluid damper such as temperature, type fluid, and compactness with respect to output force. The disadvantage these damping method by VFD the first one is difficult installation, second one is hardship with architectural composition.

8- Recommendation :

- the most essential that to be ensure the design of device is correct and suitable for this structure, because should not be cause stiffness or some time the device not useful for the structure.
- should be carefully doing fixing and placing the damper in the building, locating of device influence on the reaction of the external force earthquake and wind loads.
- However, shape of the VFD there are main factor cause benefit to decrease the pressure of the earthquake. must indicate type of VFD according to the structural properties.
- The viscous fluid damper's function is influenced by a few elements, including temperature, amount and type fluid, control them carefully.
- In my sight for retrofitting old building the viscous fluid damper workable and economical way compare to the other damper.
- In the end Use one of the method to reduce the damage of earthquake for all building is notable ,due to humans life is valuable.

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