Dynamic Hydraulic Dampers for Earthquake Isolated Structural Systems

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Abstract: This paper presents some solutions on hydraulic devices such as linear motors with direct and reverse reaction with the stabilizing role of building movement under the earthquake action. It emphasizes the possibilities of modelling, analysis and serviceable realization of hydraulic dampers with two main functions: dissipation of the transmitted energy to a building, on the one hand, and providing a relatively constant speed with sufficiently low values, on the other hand.

Keywords: Hydraulic, Damper, Earthquake, Isolation, Building, Energy.

1. INTRODUCTION

Earthquakes are natural events that threaten potential lives, destroys properties and interrupt services necessary to maintain life and social relationships.

In conventional seismic design, an acceptable level of performance of the building during a seismic action, consists in the ability of the resistance structure to absorb and dissipate energy in a manner as stable and as many cycles of application.

Lately, the world, many structures are designed to withstand seismic action using a relatively new concept to introduce special devices in resistance structure designed to absorb and / or dissipate the energy induced by the seismic action to the structure.

2. THE DYNAMIC BEHAVIOUR OF STRUCTURES ON A SEISMIC ACTION

Seismic action on a building is on components of translation after three orthogonal axes (two horizontal and one vertical). Generally, the seismic action such as lateral displacements of the structure nodes, efforts and tensions in the structural elements is due to both components of the seismic action. Seismic forces Fx and Fy are considered as the horizontal components of the action of both seismic components. The total horizontal effect N1 but not equal to the seismic action effects considered separately by the two directions N1x and N1y if a lateral force calculation.

This is because the calculation methods directly estimate peak effect.

Peak ground acceleration values for the horizontal components of seismic motion have no place at the same time period. In addition, because of stiffness in general different on the two horizontal directions, the structure will have its own period of vibration on two different directions.

Because seismic time response of a structure is strongly influenced by its own vibration period, seismic effects on different components of the structure will take place at different times.

In conclusion, peak values of the effects on different components of the seismic action are not statistically correlated (not recorded at the same time period). Therefore, when calculation methods are used to directly determine peak values of seismic effects, we will use a method of combining seismic effects reflect the fact that those values are not statistically correlated.

Effects combination on horizontal components of seismic action can be made as follows:

- Structural response is separately assessed for each direction of seismic action;
- Peak effect of seismic action represented by the simultaneous action on two orthogonal horizontal components, we obtain the relationship:

\[ E_{Ed} = \sqrt{E_{Edx}^2 + E_{Edy}^2} \] (1)
where: $E_{Edx}$ - represents effects due to application of seismic motion on the horizontal axis $x$ direction chosen for the structure, $E_{Edy}$ represents effects due to application of seismic motion on the horizontal axis direction $y$ perpendicular to the axis $x$ of the structure.

As an alternative method above, effects due to the combination of horizontal components of seismic action can be calculated using the following combinations:

$$E_{Edx} + 0.3 \cdot E_{Edy}$$

$$0.3E_{Edx} + E_{Edy}$$

where “+” means “to combine with”.

The sign of each component in the combinations above will be taken so that the effect of action considered to be unfavorable.

If that takes into account the vertical component of seismic motion relations:

$$E_{Edz} = \sqrt{E_{Edx}^2 + E_{Edy}^2 + E_{Edz}^2}$$

$$0.3E_{Edx} + 0.3E_{Edy} + E_{Edz}$$

$$E_{Edx} + 0.3E_{Edy} + 0.3E_{Edz}$$

$$0.3E_{Edx} + E_{Edy} + 0.3E_{Edz}$$

which $E_{Edz}$ represents effects due to application of the vertical component of seismic action.

Vertical component of seismic motion can be neglected for most of the current.

According to Eurocode 8.2003, vertical component of seismic motion should be considered when peak vertical acceleration exceeds 0.25g land and structure is one of the following characteristics:

- contains elements horizontal openings over 20 m, contains elements in console length of 5 meters, contains horizontal prestressing elements, contains poles leaning against the rulers, is isolated at the base. [1]

Damping is one of many different methods that have been proposed for allowing a structure to achieve optimal performance when it is subjected to seismic, wind storm, blast or other types of transient shock and vibration disturbances. Conventional approach would dictate that the structure must inherently attenuate or dissipate the effects of transient inputs through a combination of strength, flexibility, and deformability.

The level of damping in a conventional elastic structure is very low, and hence the amount of energy dissipated during transient disturbances is also very low. During strong motions, such as earthquakes, conventional structures usually deform well beyond their elastic limits, and eventually fail or collapse. Therefore, most of the energy dissipated is absorbed by the structure itself through localized damage as it fails.

The concept of supplemental dampers added to a structure assumes that much of the energy input to the structure from a transient will be absorbed, not by the structure itself, but rather by supplemental damping elements.

3. HYDRAULIC DAMPERS

The physical model of a damping element is shown in Figure 1, and how to do the connection and how symbolisation is presented in Figure 2:

![Figure 1 Construction of hydraulic damper](image)

A damper is achieved as a hydraulic cylinder (1) with two rooms separated by a piston (2), rooms filled with a viscous medium (synthetic oil, silicone oil, suspended particles) is in solidarity with piston rod (3) and a tube off a crossing of both sides of the piston rooms. The third room (4) is located inside the compensation tube and is intended to offset expansion or contraction under the effect of viscous heat environment.

![Figure 2 Hydraulic damper symbolization](image)

The reversible work to reciprocating traction-compression, and dynamic behavior depends on the instantaneous frequency (speed) excitation produced by the earthquake, mechanical shock or vibration.

Using dissipative energy devices seeks to improve the behavior of the structure by increasing...
the damping, necessary kinetic energy dissipation that occurs in the structure due to seismic motion.[2]

A general characterization of these devices can be made in terms of mechanism dependent of:
- displacement
- speed
- acceleration

These devices allow disconnection of foundations from the superstructure, modify the dynamic characteristics of the system, protecting excessive patterns and increase energy dissipation capacity of the structure under the action of seismic loads.

Equation of dynamic equilibrium that characterizes the movement of a structural system in general is evidenced by:

\[ Q_I(t) + Q_D(t) + Q_R(t) = -M \ddot{q}(t) \]  

(4)

where are presented generalized system forces; in particular the relation (4) can be explained as follows:

\[ M \ddot{q}(t) + C \dot{q}(t) + Q_R(q(t)) = -M \ddot{q}(t) \]  

(5)

were generalized system forces have the following meaning:
- \( Q_I(t) \) - inertial forces of the system;
- \( Q_D(t) \) - system damping forces;
- \( Q_R(t) \) - system recovery forces - in case of elastic response:
- \( M \) - system mass;
- \( q_s(t) \) - land acceleration;
- \( C \) - system damping constant;
- \( K \) - system stiffness.

Introduction of damper change equation (5) as:

\[ C \cdot \dot{q}(t) + K q(t) = -M [ \ddot{q}(t) + \dot{q}_s(t) ] + F_r = 0 \]  

(6)

where \( F_r \) is the force of reaction from the damper.

4. NECESSARY CHARACTERISTIC OF THE DAMPER

Necessary characteristic is the law of variation of resistant force according to race of the stem of the damper. As it is shown in figure (3) the theoretical characteristics of a strong force sinks without adjustment, and in figure (4) theoretical characteristics for sinks feature adjustable resistance force.

It is noted that this feature is actually dissipated energy to complete the race of the damper, according to maximum piston race.

This energy is the area contained within the parallelogram described power rod resistance.

In case of the force adjustment of the damper, is observed that the dissipated energy on each cycle of movement is variable depending on external commands made by a monitoring system for dynamic phenomenon.

Force adjustment in the system is achieved by adjusting the pressure with special pressure regulators between chambers of damper for the two directions of movement of the piston (stretching - compression).

Provided the characteristic of energy dissipation of damper form in figure (3) with the notation of figure characteristic is defined as analytical form:

\[ F_{rez} = \begin{cases} 
\frac{2F_0}{\delta} y; & y \in (0, \delta/2] \\
F_0; & y \in (\delta/2, x_0]
\end{cases} 
\]

\[ F_{rez} = \begin{cases} 
\frac{2F_0}{\delta} (y - y_0); & y \in (y_0, y_0 - \delta] \\
F_0 + \frac{2F_0}{\delta} y; & y \in (y_0 - \delta, -y_0] \\
-F_0 + \frac{2F_0}{\delta} (y + y_0); & y \in (-y_0, -y_0 + \delta] \\
F_0; & y \in (-y_0 + \delta, y_0]
\end{cases} \]  

(7)
where

\[ F_0 \quad \text{dissipation - adjusted force, regulated pressure multiplied by the surface area of the front damper piston;} \]

\[ \delta \quad \text{piston stroke to passive opening pressure regulator;} \]

\[ y \quad \text{damper momentarily stroke;} \]

\[ y_0 \quad \text{damper half-stroke .} \] [2]

5. CONCLUSIONS

Using energy dissipative devices seeks to improve the behavior of the structure by increasing the damping, necessary dissipation of kinetic energy that occurs in the structure due to seismic motion. Structural response is reduced by changing the left part of the equation. These devices are provided with special, easy to apply properties.

A general characterization of these devices can be made in terms of the damping mechanism can be dependent of displacement, velocity, acceleration or a combination thereof, referring to amend the relevant part of the equation of motion.

Both the new construction, and seismic rehabilitation of existing buildings on them or such elements should be located so that to exploit the different dynamic behavior of the parts connected and improve energy dissipation and damping response.

When hydraulic dampers are used for seismic or wind protection, the end result is a predictable reduction of both stress and deflection in the structure. Indeed, this simultaneous stress and deflection reduction is unique to hydraulic dampers. Optimal performance is dependent on the type of structure and the level of performance required.

REFERENCES


