HYSTERETIC DAMPER DEVICE WITH SYMMETRY FIXED STEEL PLATES.

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ABSTRACT:

In the present Project a hysteretic damper system for seismic control is proposed, this damper is based in the use of steel plates with bending yielding. The plate geometry and its connection system are proposed for allow the inelastic range of the material plate even for small amount in the inter story drift, also the sequential work of the damper plates are permitted. This characteristic makes possible the vibration control for small as well as great amplitude vibrations.

The design equations for the system are proposed as a function of yielding load and deformation. Experimental cycle load test were conduced for calibrate the design equations, the analytical and experimental results are contrasted and analyzed.

KEYWORDS:

Damper, Hysteretic damper, Energy dissipation, Cyclic loads.

1. INTODUCTION

In a retrofitting work, for repairing or strengthening a structure with unsatisfactory seismic performance, the main objective is to ensure that its elements have sufficient strength and stiffness to withstand safely earthquake actions. This means that structural system should provide adequate combination of strength, stiffness and ductility, this goal implies to provide the structure ability to dissipate the energy induced by earthquake excitation, without suffering irreparable damage or collapse.

The aim to improve the structure energy dissipation, as well as increase the deformation capacity, without excessive increment in the final costs, has led to the development of seismic control systems. This devises contribute whit the structural behavior dissipating the seismic energy in the building, limiting the structural damage and controlling the lateral deformation. This type of seismic control systems is increasingly used both in new projects and in existing buildings to improve their behavior.

The seismic control systems represent the most significant technological advance in seismic building protection; they bring greater safety and comfort to high-rise structures during strong winds and small earthquakes, they also reduce vibration during strong seismic events, in addition to significantly damage reduction.

One of the most success seismic control devices is the ADAS system, these devices require a rigid fixation system to secure the steel plates used, additionally it is necessary to provide a support structure that invades significantly the span in which it is placed, additionally if there are some increments in the gravitational load of the structure, the devices are subjected to combined axial and bending actions, which amends its efficiency, besides its high cost.

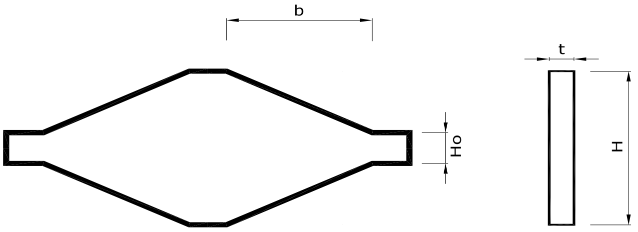
Seeking to overcome the limitations of the ADAS devices, it is proposed a new system based on similar principles, however the plates in this devise are fixed taking advantage of the symmetry in the proposed geometry, also their location in the structure it is simpler, less invasive and more economical. On the other hand, the gravitational loads increment does not alter the bending work of the plates, so their efficiency is not amended.

Additionally, the connection system allows define the lateral drift in which each plate should star its work; this condition generates a suitable system even for the small vibrations control, such as those generated by wind actions..

2. DEVICE DESCRIPTION

looking for improve the dynamic behavior of structures during a seismic event, a hysteretic damper prototype is proposed, it is formed with low yielding steel plates working in bending, the plates are attached to the structural system by braces elements, the connection details are simpler than equivalent systems, finally its cost is economic and the implementation within the structure is not overly invasive.

The proposed energy dissipation device (EDD) is catalogued as a seismic hysteretic damper. The seismic response control is getting by hysteretic behavior of steel plates working in its inelastic range. The plate's geometry is illustrated in figure 1; this geometry allows yielding material almost in the totality of the plates.



t: thickness plate.
H: Maximum height
Ho: Height in the support border.
b: Distance between points of maximum and minimum hight.

Figure 1. Geometry of the EDD´s plates.

The plates are proposed to be located in a support devise fixed to one extreme of a brace element, the devise location is designed for connect the central part of the plates orthogonally to the braced element. The lateral part of the plates are connected to the floor elements, whit this configuration the steel plates will work in bending for lateral floor displacement.

The connection configuration allows model the plates as a simple support beam subject to a concentrated load at the centre of span, as it is shown in Figure 2. The symmetry of the plate ensures that the elastic curve presents its maximum amplitude at the load application point, This condition is associated with a zero rotation, for that their behavior is similar to a fixed support in the middle plate section and this is de maximum bending moment zone, while providing a simple support to extreme sections, the bending moment will take small values. In accordance to the diagram moment variation, the width of the dissipation plate becomes vary linearly.

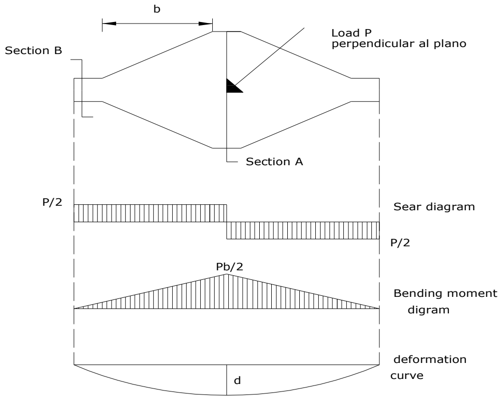


Figure 2. Mechanical elements in a EDD´s plate

3. EDD´S PLATES DESIGN

The geometry design of the energy dissipation plates, yielding load and deformation, ductility and energy dissipated, are determined by the classical mechanics of materials theories. Considering the dimensions shown in Figures 1 and 2 it is possible to obtain that:

The yielding stress in the section is:

$$f_y = \frac{M_y}{s} \tag{1}$$

Where the section modulus (S) is defined as:

$$S = \frac{Ht^2}{6} \tag{2}$$

Defining the bending moment associated with the yielding stress, as:

$$M_y = \frac{P_y b}{2} \tag{3}$$

The section yielding load is:

$$P_y = fy\frac{Ht^2}{3b} \tag{4}$$

The maximum deflection in the plate, generated for this load (Py) is obtained as:

$$\Delta_y = fy\frac{Ht^2 b^2}{18EI} \tag{5}$$

In the previous expressions:
H: Maximum height of the plate.
t: Thickness of the plate.
fy: Yielding stress.
b: Horizontal distance corresponding to the area of variable height of the plate
S: Section Modulus of the cross section of plate
Py: Load associated with the yielding stress.
Δy: deflection on the device generated for the yielding load.
E: Steel Young Modulus.
I: Inertia moment of the cross section area.

Similarly during the non linear behavior stage, the yielding stress could be defined in terms of the plastic bending moment as:

$$f_y = \frac{M_p}{z} \tag{6}$$

Where the plastic section module (z) is defined as:

$$Z = \frac{Ht^2}{4} \tag{7}$$

For the proposed section the ic moment is:

$$M_p = \frac{P_p b}{2} \tag{8}$$

The maximum plastic (Pp) is:

$$P_p = fy\frac{Ht^2}{2b} \tag{9}$$

The strain associated with this load(Δp) is:

$$\Delta_p = fy\frac{Ht^2b^2}{12EI} \tag{10}$$

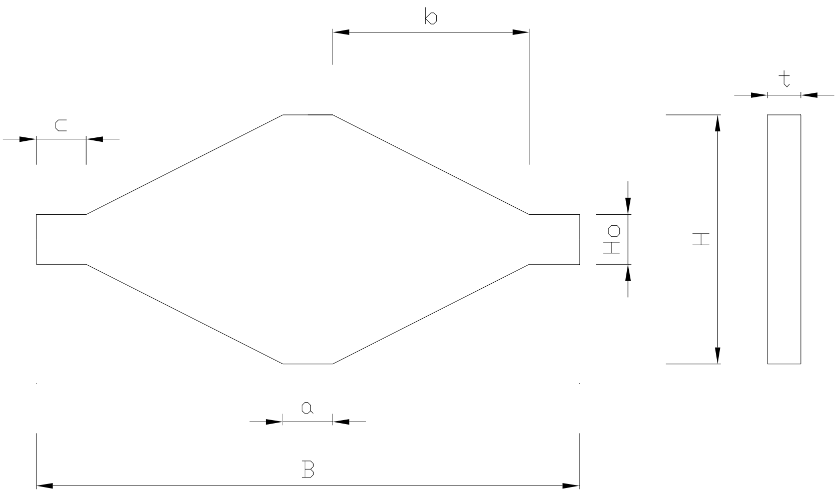
Where:
z: Plastic cross-section modulus of the plate
Pp: Plastic load
Δ p: Plastic deflection.

4. EXPERIMENTAL STUDY

To validate the analytical results and verify the stability and shape of hysteresis loops, the experimental test was conducted, in this test, the energy dissipation plates were subjected to the reversible cyclic loading action. The loads were generated through a hydraulic actuator.

During the test, yielding loads and deformations, ductility and stability of hysteresis cycles were observed, this information allow characterize the plate behavior and get the basic parameters for modeling within a structural analysis.

For the experimental study, there were used structural steel plates (A36), with the geometry shown in figures 3 and 4. The mechanical properties of the steel were identified in a tension tests.



Ho = 0.03 m.
b = 0.11 m.
H = 0.15 m.
a = 0.03 m.

fy = 307 Mpa.
E = 2.0 x 10^5 Mpa
t = 0.02 m.
c = 0.03 m.

Figure 3. Tested plate dimensions.

Figure 4. Tested steel plate.

A support devise was constructed to fix de dissipating plates; this support is shown in Figure 5. and it was placed in a support steel beam, as shown in Figure 6. The configuration of the test support permit to apply the actuator load in the middle part of the plate, this situation pretended model the plate work in the same way as in the analytical model.

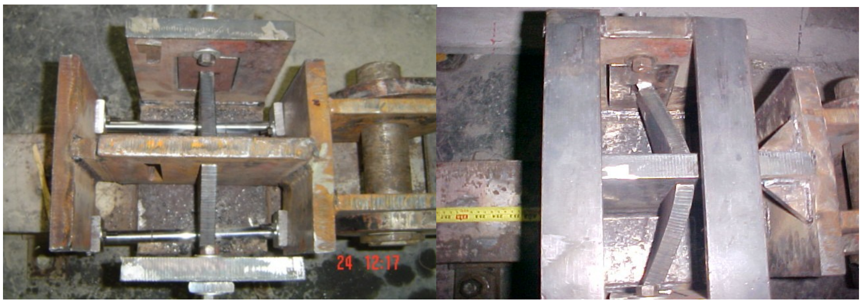


Figure 5. Location of the energy dissipating plates inside the test support.

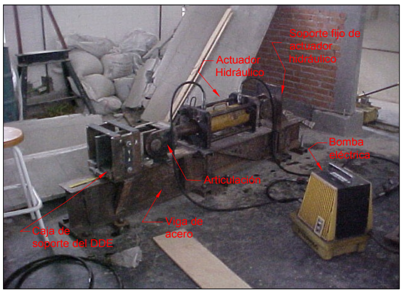
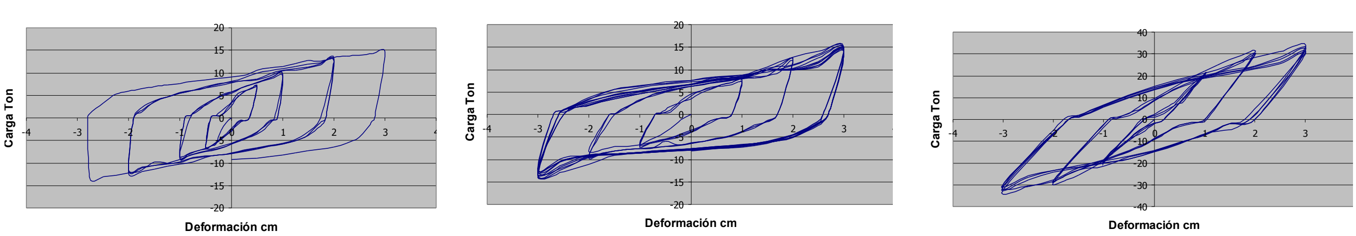


Figure 6. Overview of the test.

The experimental study was divided in two phases. In the first part of the experiment, three trials study was conducted; the following is a brief description of each one, as well as the most relevant results.

The specimen one were subject to three complete cycles with maximum displacement of 0.5cm, 3 cycles at 1cm, 5 cycles at 2cm, and 1 cycle of 3 cm. Figure 7.a. presents hysteretic cycles for this test.



a) specimen 1. b) specimen 2. c) specimen 3.

Figure 7. Hysteretic cycles phase 1

Figure 7.b. shows the hysteretic load-deformation curves for the specimen 2, which were applied 3 cycles with maximum displacement of 1 cm, 3 cycles at 2 cm and 5 cycles at a maximum deflection of 3cm.

The third test has the particularity that 2 energy dissipation plates were used simultaneously (Figure 8), in this case3 cycles at 1 cm, 3 cycles at 2cm, and finally 10 cycles with a maximum deflection of 3cm of maximum deflection were applied. Figure 7.c.

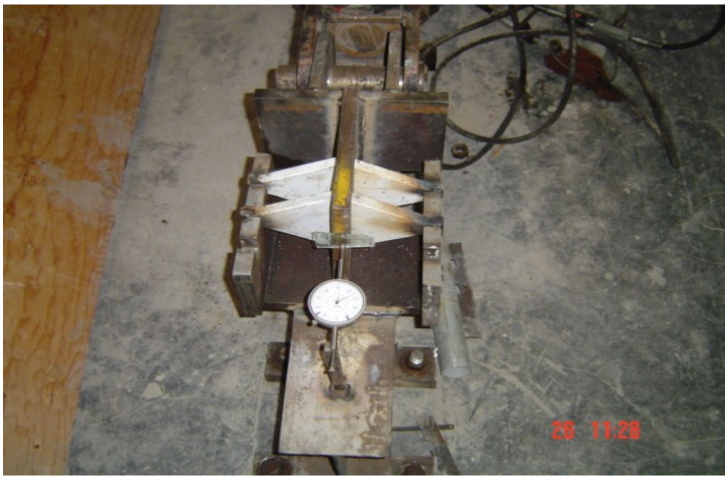
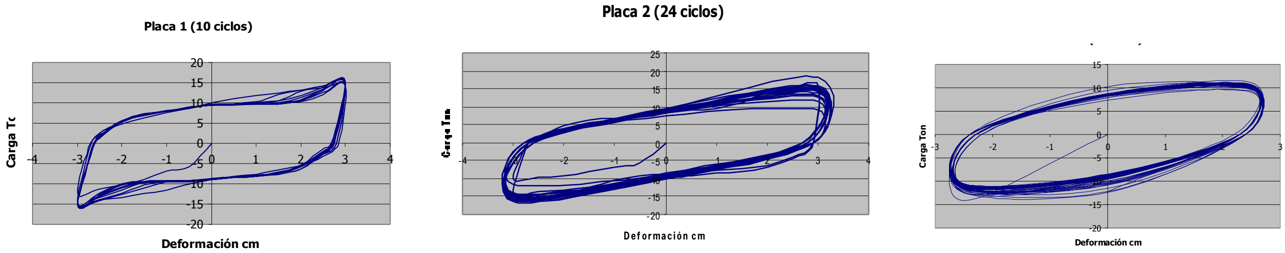


Figure 8. General view test 3.

In the second phase of the experimental study additional three specimens (4,5 y 6) were tested using a single plate in each case, this part of the study was conducted in order to verify the stability of hysteric's loops of the plates in large deformations range.

In the fourth specimen 10 cycles of alternating loads, with a maximum deflection of 3 cm in each direction were applied. It is worth mentioning that this specimen was not led to the failure since at the end of the 10 cycles, the plate was still in perfect condition (Figure 9.a).



a) specimen 4. b) specimen 4 c) specimen 6

Figure 9 . Hysteretic cycles phase 2

In the fifth specimen loads were applied in alternating cycles with deformation amplitude of 3 cm. This process was repeated until the fault of the plate, after 24 cycles. (Figure. 9.b.). In the sixth specimen, load cycles with displacement amplitude of 2.5 cm were applied. In this case the fault of the plate was presented after 49 cycles. (Figure. 9.c.)

5. RESULTS ANALYSIS.

The most relevant results of the experimental study for the plates 4, 5 and 6 are presented in Table 1.

Table 1 .- Summary Results

	Specimen 4	Specimen 5	Specimen 6
Number of load cycles	10 cycles	20 cycles	49 cycles
Damage plate degree	Without damage	Fail	Fail
Maximum deformation	0.03 m each direction	0.03 m each direction	0.025 m each direction
Maximum load at maximum displacement	155.1 KN	182.2 KN	141.0 KN
Minimum load at maximum displacement	142.9 KN	91.6 KN	104.8 KN
Load degradation	7.9 %	49.7 %	25.6 %
Energy dissipation/Cycle	9.68 KN - m.	9.31 KN - m.	6.95 KN - m.
Total energy dissipation	94.68 KN - m.	183.94 KN - m.	336.82 KN - m.
Initial Stiffness	11750 KN / m.	11320 KN / m.	5640 KN / m.
Final stiffness	7940 KN / m.	3050 KN / m.	3..550 KN / m.
Stiffness degradation	*32.46 %*	*73.08 %*	*37.05 %*

Table 2 compares the yielding and maximum load measured against the analytically estimated values.

Table 2 .- Theoretical vs experimental load

	Theoretical load	**Experimental load**		
		Plate 4	**Plate 5**	**Plate 6**
Py (KN.)	50.65	60.00	62.00	64.00
Pu (KN.)	139.07	155.00	182.20	141.00

6. CONCLUSIONS:

As a result of this work may pose the following conclusions:

The geometry of proposed system, as well as its connection arrangement, offers an attractive alternative for improving the seismic behavior of a structure.

The geometry of the plates could be varied to cover a wide range of values of the parameters that define the behavior of the system, such as yielding load and deformation, plastic load, stiffness, etc.

The energy dissipation devise shows well defined parameters and also its hysteretic behavior is stable even for large deformations.
With the setting system proposed, the increases in gravitational load dose not change its bending work, so their efficiency is not amended.

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