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ANALYTICAL AND EXPERIMENTAL STUDY OF HYSTERETICAL DAMPER DEVICE

Raúl VERA[1], Sandra MIRANDA[2]

SUMMARY

In the present work the experimental test results of an hysteretic damper device are shown , this device consists of an internal frame formed by linear steel elements installed on a three-dimensional structure 1/2 scaled model with waffle type spans. The damper device is proposed to improve the structural behavior against dynamic loads in existent buildings with deficient dynamic behavior.

INTRODUCTION

The energy dissipation capacity of the structures built on seismic zones is an important goal, even do in the traditional structural systems increase this capacity results in expensive cost inadaptability to architectonic project, complicated construction process, etc.

For that reason, seismic damper device have been developed, looking for concentrate in them the major amount of energy dissipation during an earthquake without a significant damage in the other structural elements. This kind of device are more commonly used in new projects as well as the retrofitting works for existing constructions.

One way to get energy dissipation capacity is using the hysteretic behavior properties of some materials (hysteretic dampers), this damper elements look for generate inelastic deformation in their

[1] Professor and Researcher, Facultad de Ingeniería, UAEM, Toluca México, México, email rvn@uaemex.mx
[2] Projectist, Desarrollo de Ingeniería Estructural y Construcciones S.A. de C.V., Toluca México, México, email: diec_sa@hotmail.com

material meanwhile the rest elements in the buildings remain elastic or at least with controlled damage.

Objective

In the present work a hysteretic steel damper device is proposed and tested against lateral reversible loads, with the propose to evaluate their influence in the global behavior of existing buildings with high lateral flexibility.

With the goal to evaluate the performance of the hysteretic damper device (HDD) a prototype of this system was built on a 1/2 scale three-dimensional model, with waffle slab on a R/C columns.

The structure HDD system was tested for reversible lateral load cycles. The cycles were controlled by loads increments in the initial steps and lateral deformation increment in the rest of the test. The test was performed to evaluate the behavior of this system only against lateral actions.

Original Structure Configuration

The HDD was installed on a representative model of the waffle slab structure. This model had been tested in previous researches with different retrofitting techniques.

The structure consists in two level construction at 1/2 scale, it counts with 1 1/2 spans in the load direction and 1 1/4 spans in the other direction, using this model, the behavior on the tree spans are represented, because of the simulation of the inflexion point in the middle span by the addition of pine columns in the slab border.

On the transversal direction the model looks to predict the behavior of the border and interior connections, also a cross diagonal steel cables was places to avoid tensional displacements due to difference in stiffness and lateral load applied.

To posterior references the frames located parallels to the action line of loads, and taking in account the slab column connection type were called exterior frame and interior frame. Figure 1 shows the general model configuration and the load application system.

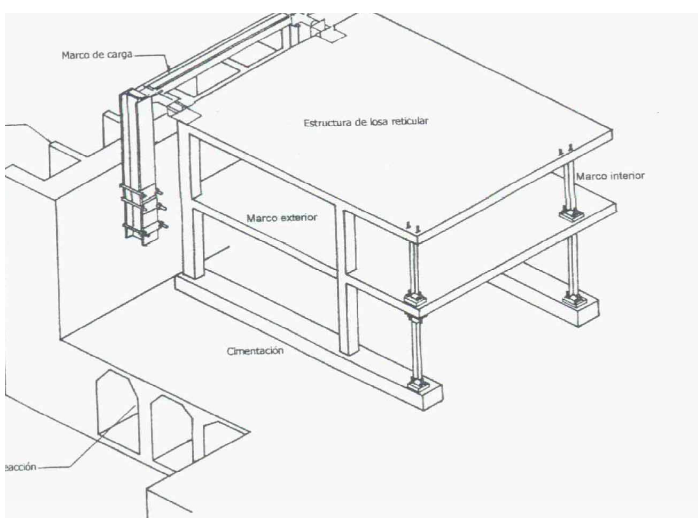


Figure 1. General view of the structure

The story high is 1.2 meters, and the slab system was formed by waffle slab with total thickness of 0.16 meters, with the alveolus of 0.3x0.3x0.135 meters, the columns had a squared section of 0.2x0.2 meters.

General Condition Of Damaged Structure

As mentioned above, the structure had been used in previous researches. Initially with their original condition, next, a win walls were added and tested and finally the addition of steel elements reinforced as shown in figure 2 were probed. In all cases the test was performed applying lateral reversible cycles load.

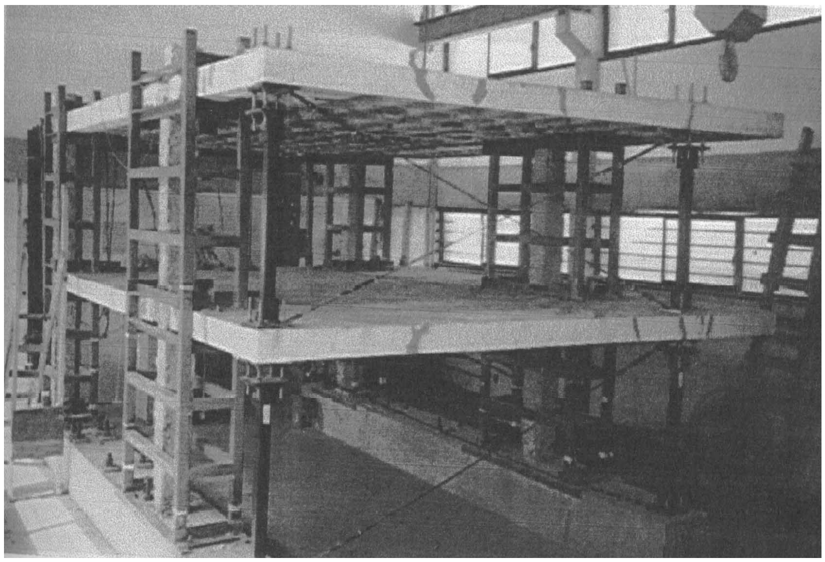


Figure 2. Structure condition

As a consequence of the last trial, cracking on the slab system appeared, mainly by bending stress, the major damage was observed in the perimeter beam in the 1st story near to the column zone in the load direction.

This damage were observed in a minor amount in the second level. In the column slab connection a cracking and partial losses of concrete were observed, columns also presents severe bending cracking and the inferior middle part of the first level columns.

The model preparations to the new test consists in:
a) To remove and to substitute the concrete in damaged zones.
b) To substitute the fractured longitudinal and transversal steel bars, using welded connections.
c) Cracks injection using epoxy resin (sikadur -50 by Sika) see figure 3.

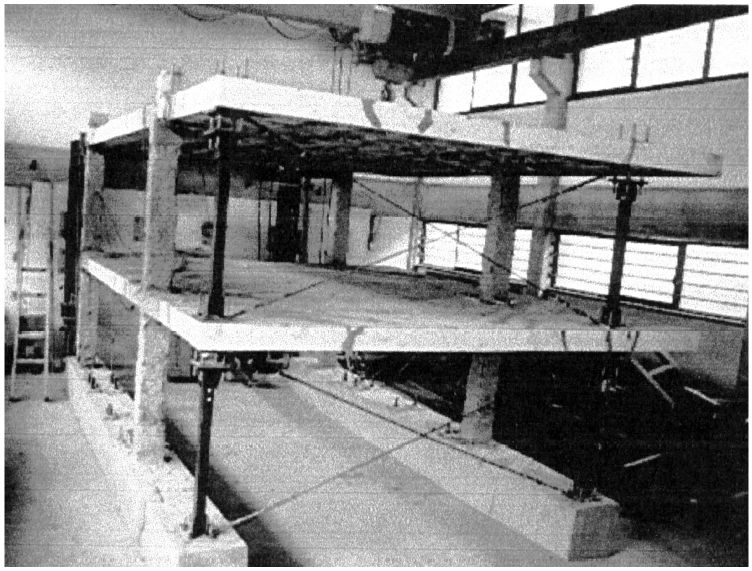


Figure 3. Repaired structure

With the goal of estimate the initial structural characteristics, a monotonic pull test was performed, in this step only a small load were applied, however some cracks appear in the columns above the repaired zones.

Structure Condition After Rehabilitation

As a result of a retrofitting works done in the structure it was observed the exterior frame reach a lateral stiffness near to this original state (without damage), but the interior frame only the 56% of the original stiffness was reached figure 4.

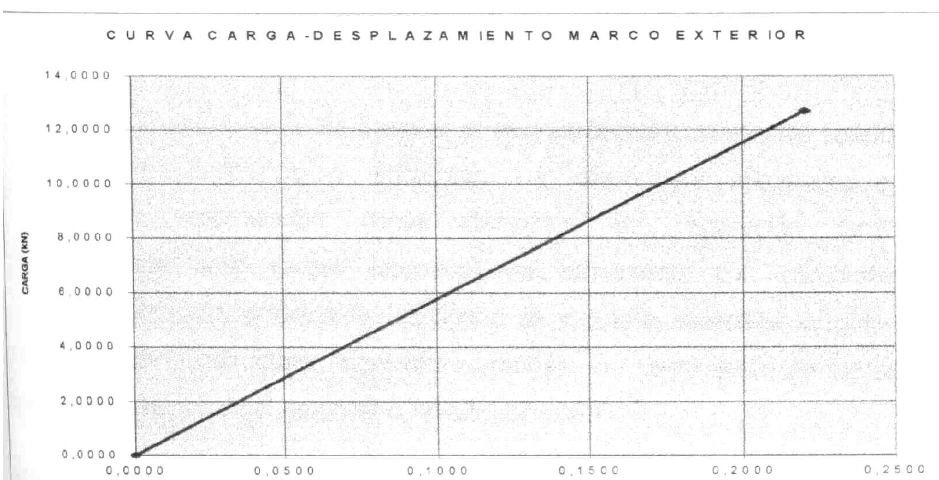


Figure 4. Curve load-displacement on exterior frame

Hysteretic Damper Device Description

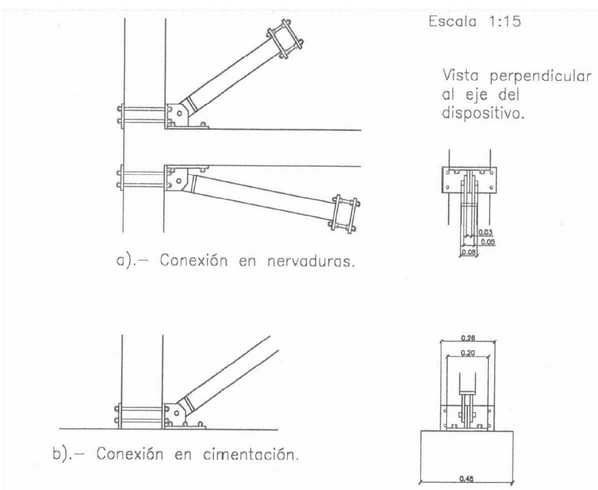
The damper device proposed can be classified as a seismic passive control system in the category of hysteretic dampers.

The damper consists in an interior frame formed by linear steel elements in whose configuration allow the plastic hinge formation on different zones.

The geometry of a device was proposed looking for the amplification of the inter story deformation, the main purpose is to warranty the plastic behavior of the damper material with the consequent energy dissipation even for small amount in the story drift.

Figure 5 shows the general device geometry, also the configuration inside the main structure is presented. The damper device was placed in both levels on the model, for interior and exterior frames.

Each damper is composed by diagonals formed by rectangular steel section (OR 76.2 X 32 mm) with yield stress of fy=313.8 MPa, this diagonals connect the interior frame with the main structure joints. The connection formed by steel plates with fy=248 MPa and 13.7 mm thickness, connected with the columns and slab by bolts of 12.7 mm diameter as shown in figure 6.



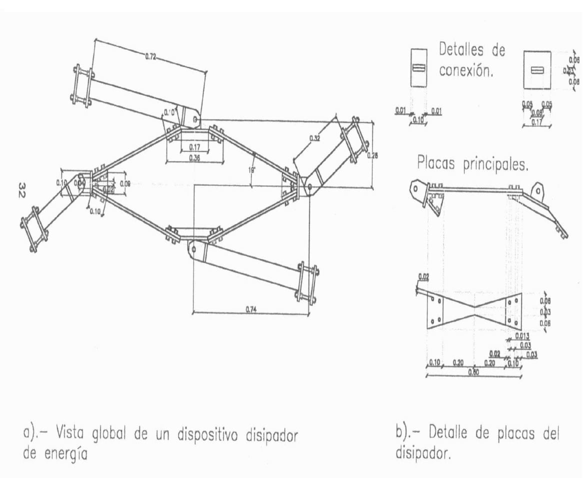


Figure 5. Foundation connection details

Figure 6. Damper devices

The diagonals are connected in the other side, with the interior frame with hinge connections, similar as the described above.

The interior frame was formed by four steel plates with fy= 249 MPa and 12.7 mm thickness, as is shown in figure 7, this plates were bolted in their borders with the diagonals by hinges. The interior frame is the damper properly said and is in the plate that formed this frame where the plasticization is expected.

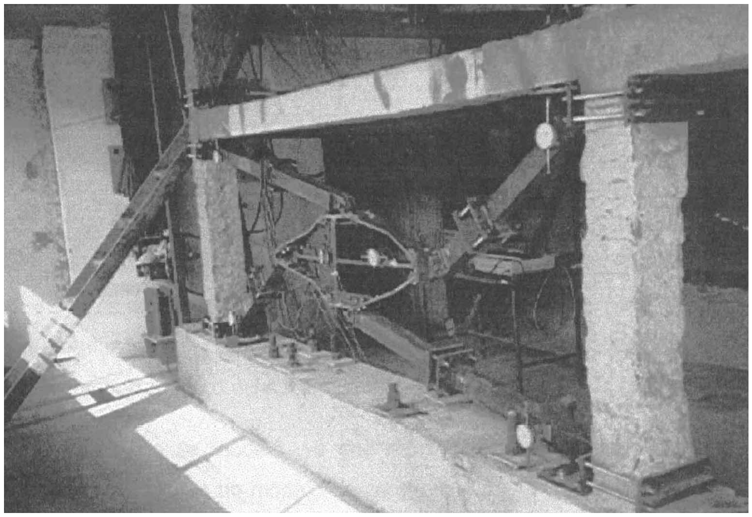


Figure 7.

MODEL TEST

Model Instrumentation

The instrumentation in the model and the damper was formed by strain gages to control the strain on steel plates and micrometers and verniers for lateral displacement control .

A preliminary test was conducted for calibration of the instrumentation system, and also it could be verified that the stress distribution on the steel plates in damper device was almost uniform in transversal direction, based on this, instrumentation in the plates of the damper was placed mainly in longitudinal direction. In the middle part of the plates the instrumentation was omitted due to the small values of the stress in this zone.

The exterior frame was extendible instrumented, this zone represents the control of the test. In their interior frame 8 strain gages was placed in each plate, 4 in each face, two of them were EA-06-120LZ-120 series for unitary strain at 0.003 and the other two were EP-08-250-BG-120 series (measurements group) for plastic deformation.

For the interior frame two plate of each damper were instrumented with four strain gages each one, two of them in the interior face and two in the exterior face, EA-06-120-L7-120 series. Two verniers were placed in the load direction to control the roof drift, one in the exterior frame and the other in the interior frame.

The analogy micrometers were used to control the story drift and were placed in the opposite side of load application.

Six micrometers were used for rotational measurements in the damper plates, also two micrometers were used in the central section of the interior frame (vertical and horizontal direction) for relative displacement controls. (figure 8).

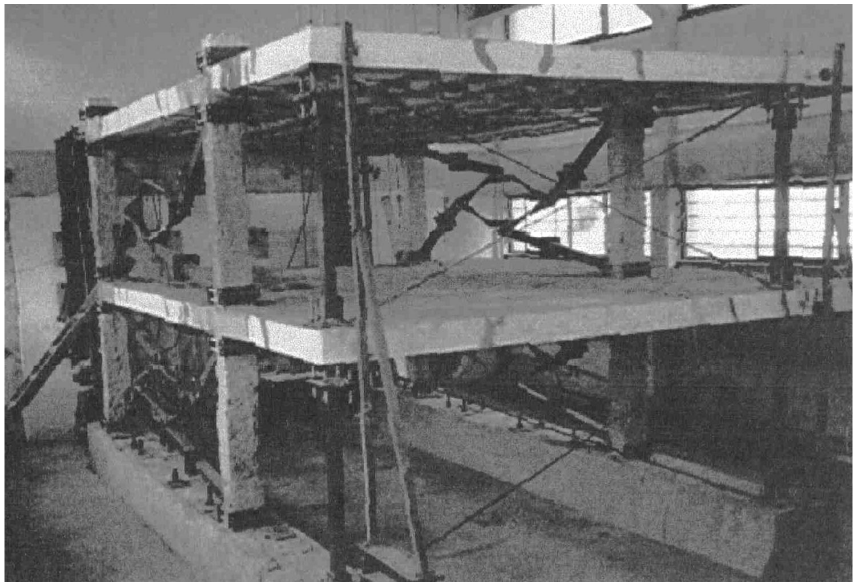


Figure 8. Model instrumentation

Load Device System

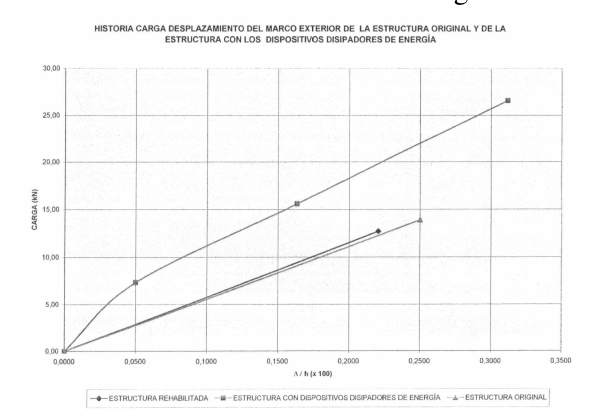
The lateral load was applied in the second level of the model, over the main slab beam. Enerpac double action hydraulic jacket with 890 KN pull capacity were used.

The jackets were operated by manual pump of high flow the load was controlled by digital manometers (Enerpac DGB) of 69 MPa capacity.

Test Development

The test consists in the application of the static lateral reversible loads over the model, the test was conducted by constants increments of the story drifts and the lateral load, strain and displacements were measured.

24 cycles of lateral load were applied over the model with 13.37 KN push increments and 12.85 KN pull increments. For each load level 3 cycles push and pull direction were conducted the lectures were taken for each load increment. Figure 9 shows the load history applied to the model.



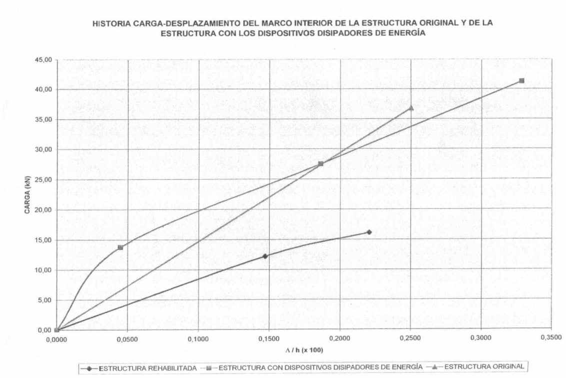
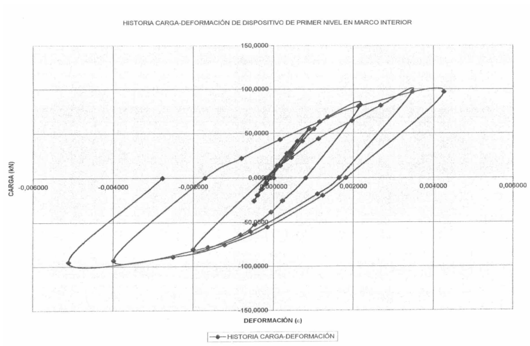
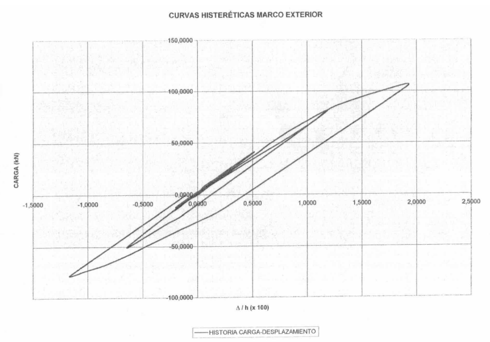


Figure 12 and 13 shows the lateral load displacement behavior structure-damper system of exterior and interior frames respectively. A stable hysteretic loops is observed for both frames also the stiffness and lateral capacity are sustained.





The maximum lateral capacity of the system (structure and damper device) is considered as the maximum lateral load applied over the system. Table 1 shows the maximum lateral load and the corresponding lateral displacement.

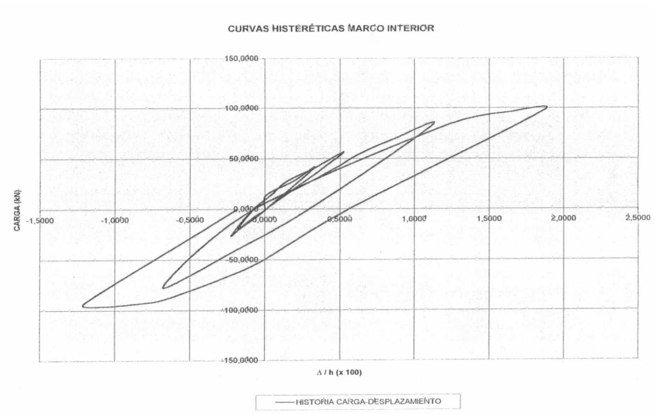
Table 1.

Frame	Displacement (m)	Push load applied (kN)	Displacement (m)	Traction load applied (kn)
Exterior	0.05208	104.44	0.05082	77.28
Interior	0.03146	98.07	0.03274	93.07

The Energy absorption capacity for both frames was evaluated as the area inside hysteretic loops. The exterior frame dissipated the 34.8% of the total energy an energy dissipate by interior frame was 65.16%. Table 2 shows that values.

Table 2. Energy dissipated contribution to the interior and exterior frames

	Dissipated energy
Total structure	5998.53
FRAME	Dissipated energy (J)
Exterior	2089.67
Interior	3908.86



The system remains elastic until lateral load of 78.85KN and the corresponding lateral displacement of 0.029/m in push direction and 67.86KN and 0.025/m for traction in the exterior frame. In the interior frame the corresponding values where 55.02KN and 0.014m for push direction and 76.79KN and 0.0144m for pull direction the stiffness degradation was notified in the initial load cycles mainly for interior frames, from 0.02m of lateral displacement the lateral stiffness degradation is similar for both of the frames, and this tendency was keep until the end of the test.

Conclusions

For the last load cycles the plastic deformation in the damper material reach strains of 0.0051 with the corresponding increment in the hysteretic damping of the system.

The global behavior of the structure against lateral loads was improved significantly due to lateral stiffness added as well as the stable hysteretic loops observed even for great lateral drifts

Based on this points, it can be say that this device is suitable for be used as a retrofitting technique for excessive flexible or damaged structures.

During this study an important improvement between the industrialized adobe walls and hand made adobe walls was observed.

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