THE EFFECT OF THE PLACEMENT OF VISCOUS FLUID LINEAR DEVICE IN THE DYNAMIC RESPONSE OF STRUCTURE

L. Djellouli[1] and A. Ounis[1]

[1] *Civil Eng. and Hydraulics Department, University of Biskra, Algeria*
Email: Lynda.djellouli@yahoo.fr

ABSTRACT:

For a seismic increased protection, new technologies have been developed among which are " the passive energy dissipation devices." The absorption of most of the seismic energy input in the primary structure of buildings and reducing as much as possible damage to structural elements is the main objective of these devices. In this work, a modeling of viscous fluid linear device is performed as passive energy dissipation system to control the dynamic response of structures due to a seismic motion. A comparative study with a traditional structure is conducted to analyze the influence of this type of damping on the dynamic behavior of the structure. The effect of the placement of these devices in the dynamic response of structure is also studied.

KEYWORDS: Seismic engineering, energy dissipation, viscous fluid damper, seismic response.

1. INTRODUCTION

Because of the seismic vulnerability of our country, the development of innovative technological concepts for increased protection of structures and people is a challenge for researchers engineering vis-à-vis the adverse effects generated during seismic movements.

Structural engineers cannot be unconscious of the damages caused by earthquakes on human and materials plans that have plagued our country, which explains the need to consider the challenge of integrating new technologies such as seismic protection systems.

The traditional approach in seismic design is based on the combination of the resistance with the ductility to mitigate the seismic loading. To do this, the engineer is based on the ductility provided by the materials in order to avoid disasters and ensure the stability of the structure to severe earthquakes. Structural damage is often caused by plastic deformation suffered by the structure due to the high level of energy generated during a seismic movement. For seismic protection, new technologies have been developed among which are the "energy dissipation devices passive

The main objective of the incorporation of the "energy dissipation devices" is to absorb of a significant part of the seismic energy and reducing as much as possible, the damage in the structural elements. Among the devices of passive energy dissipation, we find the viscous fluid dissipator. These devices are used successfully in new buildings as well as rehabilitation of existing structures. As an example of use of these devices, which proves to be an effective method of seismic protection, we can cite the San Francisco Civic Center (United States), the Raikai Hospital (Japan) and the Mayor tower (Mexico).

The objective of this study is the modeling of an energy dissipation device linear viscous fluid type such as seismic protection system to control the dynamic response of structures in seismic movements.

2. DESCRIPTION OF THE STRUCTURE

The structure used in our study is a building of reinforced concrete of 20 levels with rectangular form (Figure.1a and Figure.1b) in plan 16x20m² including three spans in the longitudinal direction and four in the transverse direction (Figure.1b).The main beams are of section 50x30 cm2 and the secondary section beams are 40x30 cm2, the sections columns are presented in Table 1, and the height of each stage is 3 m with thickness of the slap is 16cm (that not lose its shape in their plan) in order to satisfy the assumption of rigid diaphragm. It is assumed that the inherent damping ratio of the structure is 5%.

Table 1. The sections columns

levels	1-5	6-10	11-15	16-20
Section of column(cm^2)	70x60	60x50	50x40	40x30

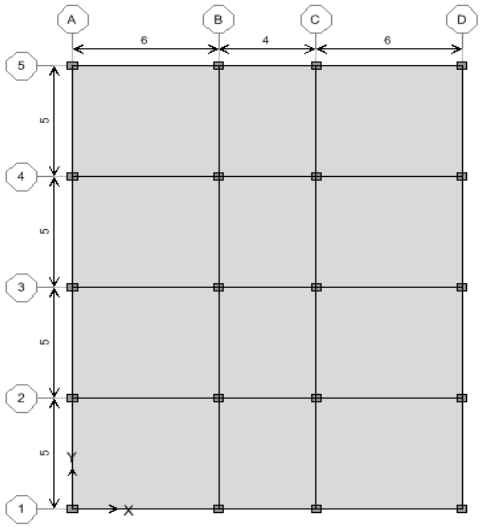


Figure 1. (a) Plan view of the structure

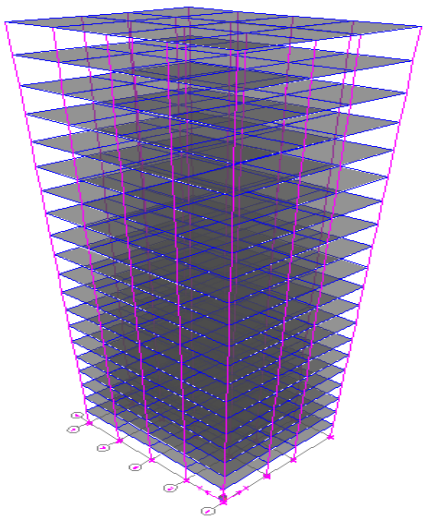


Figure 1. (b) 3D view of the structure without viscous fluid damper

3. MODELING OF FLUID VISCOUS DAMPER (VFD)

For the analysis of structures with added dampers different mathematical modeling techniques have been developed. Different models of increasing complexity are examined by Reinhorn and al. (1995) for viscous dampers. Symans and Constantinou (1993) showed that the Maxwell model is sufficient to capture the frequency dependence of the viscous damper (Fig.2a). And they also showed that, below a frequency of about 4 Hz, the model can be further simplified in a purely viscous damper model.

It is indicated in that the 274-FEMA damping force of viscous damper is proportional to the velocity with a constant exponent lying between 0.5 and 2. In the preliminary stages of analysis and design, exponent velocity 1 is recommended for more simplicity. In this study, based on these references, the behavior of fluid viscous dampers is modeled by a linear damper (Fig.2.b), and modeling of ETABS 9.7 is made by the data block NLlink property.

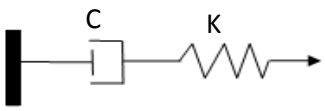


Figure 2. (a) Maxwell model

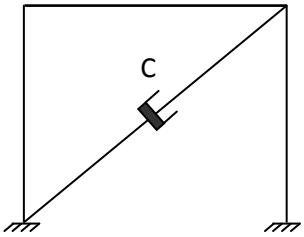


Figure 2. (b) Structure with diagonal viscous fluid damper

4. LOCATION OF FLUID VISCOUS DAMPERS

The structures will be analyzed and studied with and without energy dissipators viscous fluid. These dampers will be placed in the diagonal bracing structures. Each floor contains two dissipators in the X direction and two dissipators in the Y direction. Fig. 3 shows a plan view of the location of structures with dampers and Figures 4 shows the elevation view of the structure. The additional damping is ξ= 15% and ξ= 20%, while the critical damping of the structure is 5%, the effective damping ratios of the structure will be ξ_{eff} =20% and $\xi_{eff=}$ 25%.

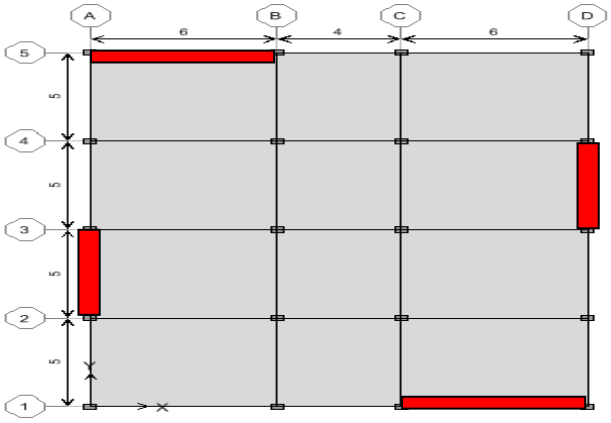


Figure 3. Plan view of the structure with the location of dissipators

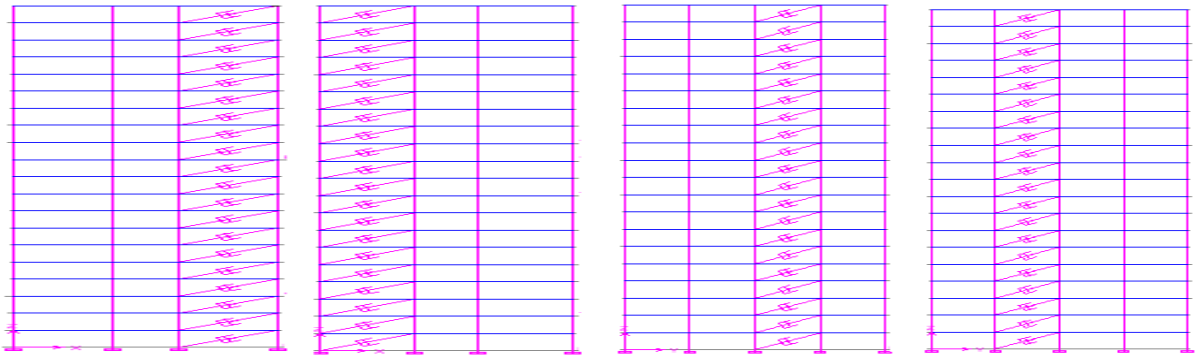


Figure 4. Elevation view of the structure a) portico axis 1, b) portico axis 5

c) portico file A and d) portico file D

5. SEISMIC EXCITATIONS

The structures were studied under the influence of the components 140 ° and 230 ° of El Centro earthquake (Imperial Valley) (1979) recorded by Array # 6 station with maximum acceleration, PGA = 0.376g and PGA= 0.436 g respectively. These two components are applied in the X direction and Y direction respectively (Figures 5 and 6). And the components 0 ° and 90 ° of the Loma Prieta earthquake (1989) recorded by Hollister station with maximum acceleration PGA= 0.369g and PGA = 0.178g respectively, these two components are applied in the X direction and Y direction respectively (Figures 7 and 8).

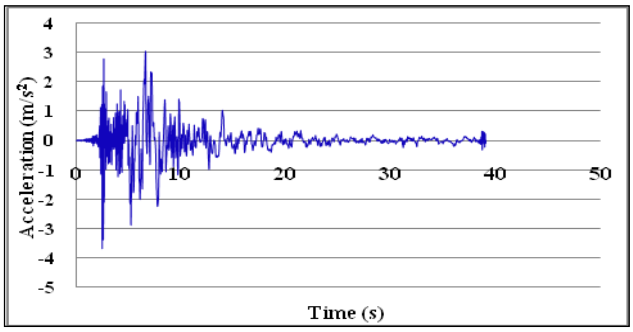


Figure 5. Time history of Array # 6 of the seismic El Centro in X direction

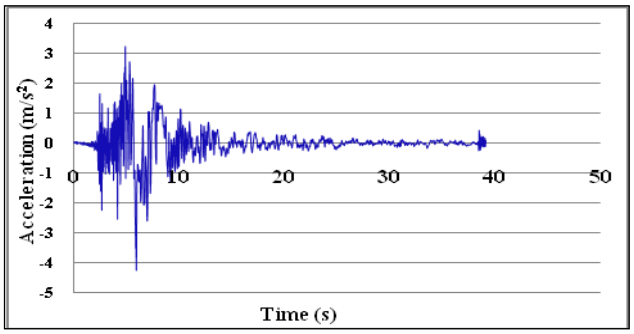


Figure 6. Time history of Array # 6 of the seismic El Centro in Y direction

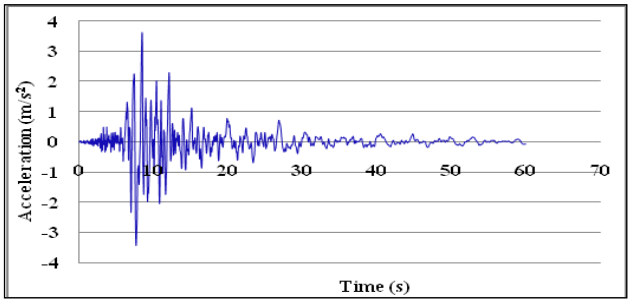


Figure 7. Time history of Hollister of the seismic Loma Prieta in X direction

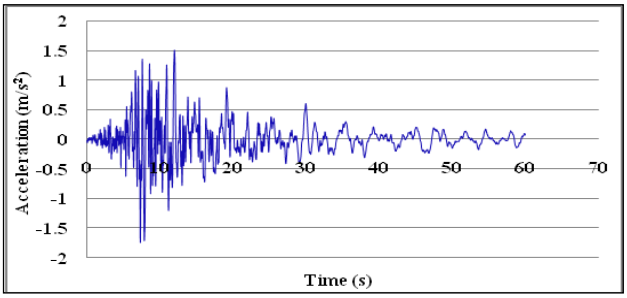


Figure 8. Time history of Hollister of the seismic Loma Prieta in Y direction

6. COMPARISONS OF THE RESULTS

6.1. Comparison "Structure with and without Viscous Fluid Damper"

The dynamic analysis carried out for the two structures (with and without VFD) enabled us to compare the results of displacements in the levels, and the base shears force in the two directions. These results are represented as follows:

6.1.1. Displacements

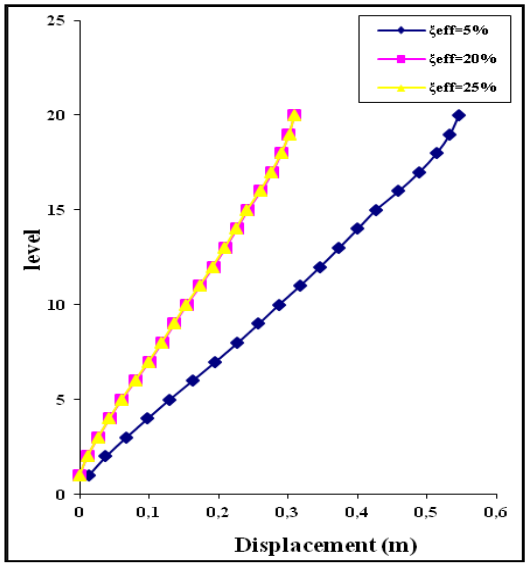


Figure 9. Comparison of displacements Under the El Centro earthquake in X direction

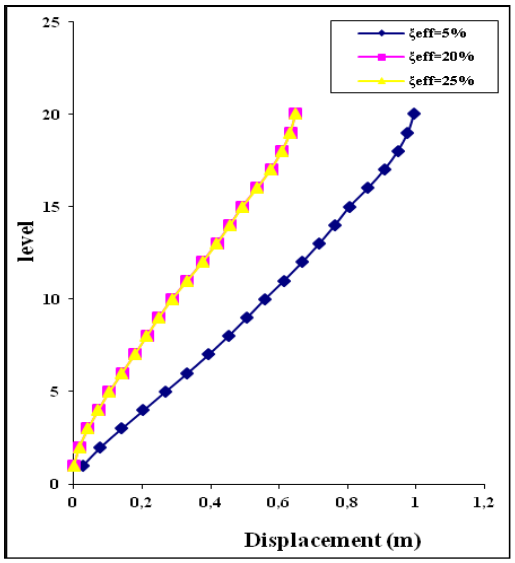


Figure 10. Comparison of displacements Under the El Centro earthquake in Y direction

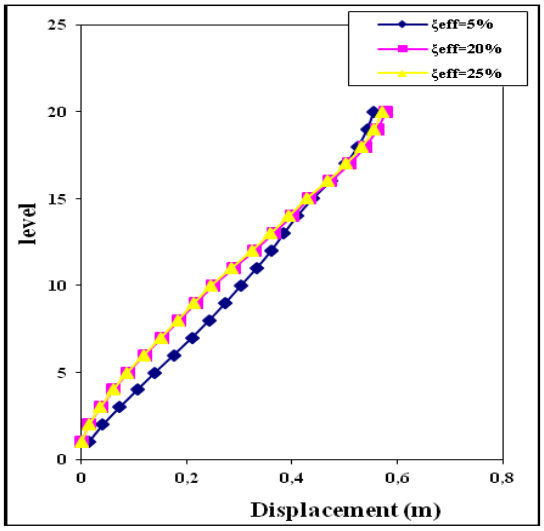


Figure 11. Comparison of displacements Under the Loma-Prieta earthquake in X direction

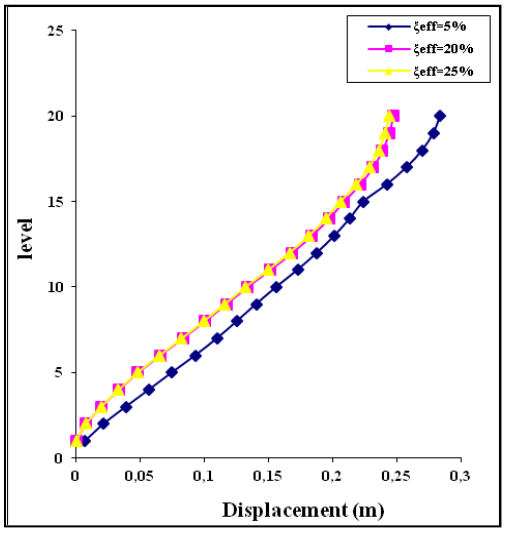


Figure 12. Comparison of displacements Under the Loma-Prieta earthquake in Y direction

According to the figures (9, 10, 11, 12) that illustrate the displacement in the levels of the structure with and without viscous fluid damper for different effective damping ratios (ξ_{eff}= 5%, ξ_{ef}= 20% and ξ_{ef}= 25%). we notice a decrease in displacement of the structure with additional damping compared to without dampers in all seismic excitations except the component loma-prieta in the X direction.

6.1.2. Base Shear Forces

According to the figures 13, that illustrate the base shear forces of the structure with and without viscous fluid damper for different effective damping ratios (ξ_{eff}= 5%, ξ_{ef}= 20% and ξ_{ef}= 25%). we notice a decrease in base shear forces of the structure with additional damping compared to without dampers in all seismic excitations excepted the component loma-prieta in the Y direction for ξ_{eff} = 20%, Were the base shear forces is augmented.

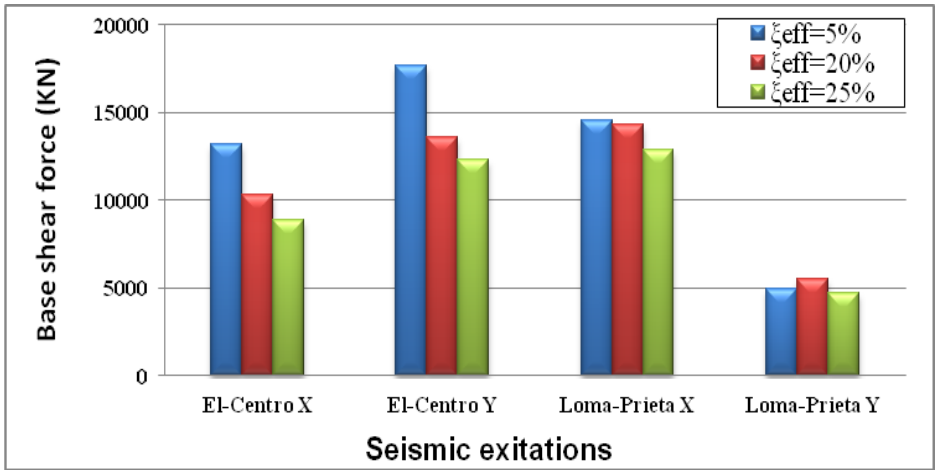
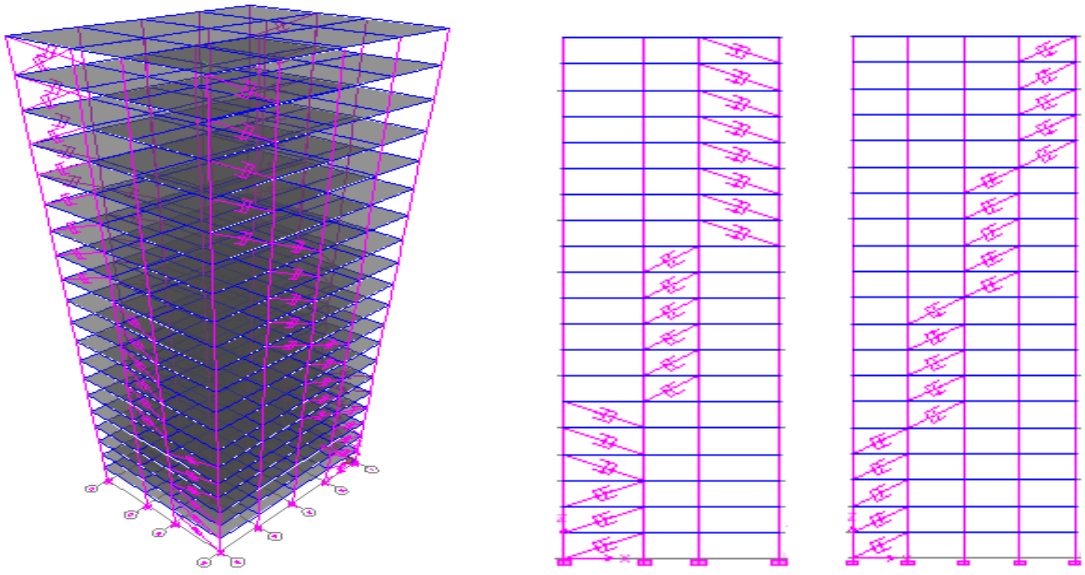


Figure 13. Comparison of base shear forces

Observation

We conclude that it is not only increasing the percentage damping ratios of the dissipator, it ensures good displacement and stability of the structure. To achieve acceptable results, we changed the distribution of fluid viscous dampers in the structure and examined several structures with different locations of damper. In this paper we present the location that given best results (Fig.14).



a) b) c)

Fig. 14: Elevation view of the structure with VFD a) 3D, b) portico axis 1 and 5, c) portico file A and D

6.1.3. Displacements

After the analysis of the new structure we obtained curves shown in Figures (15, 16, 17 and 18) reflecting the displacements of each level.

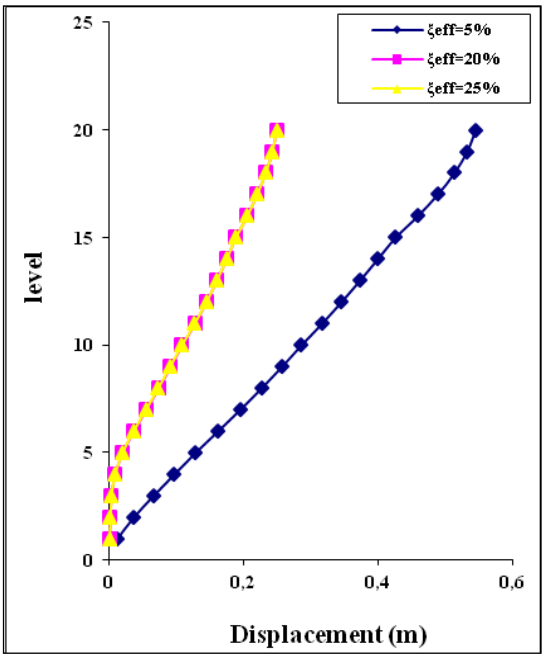


Figure 15. Comparison of displacements Under the El Centro earthquake in X direction

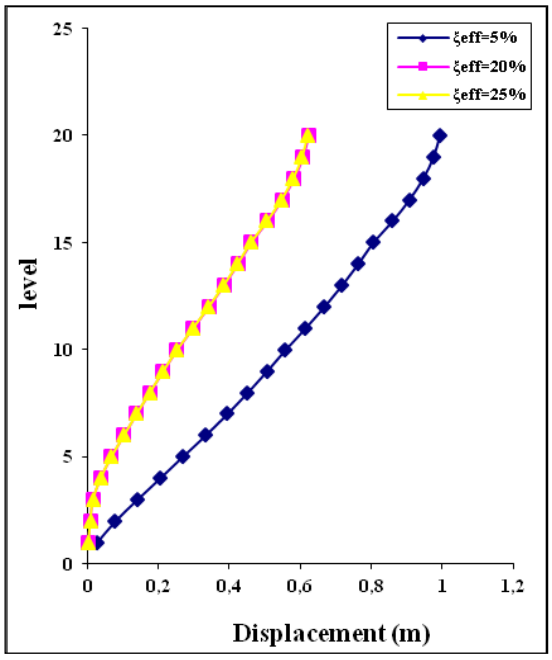


Figure 16. Comparison of displacements Under the El Centro earthquake in Y direction

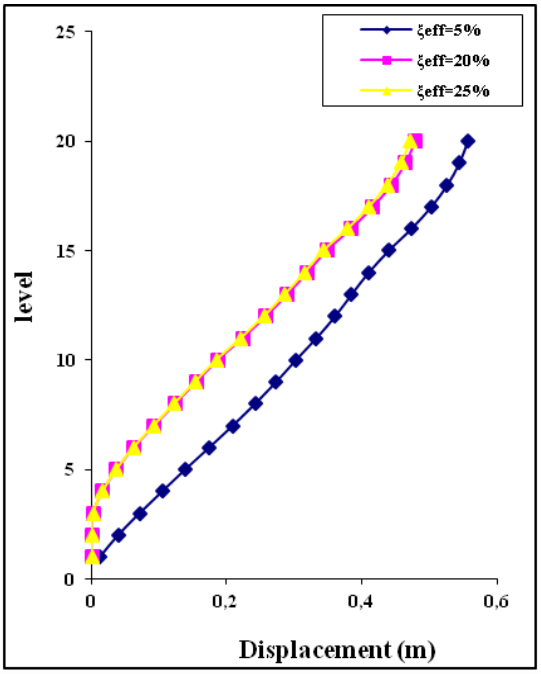


Figure 17. Comparison of displacements Under the Loma-Prieta earthquake in X direction

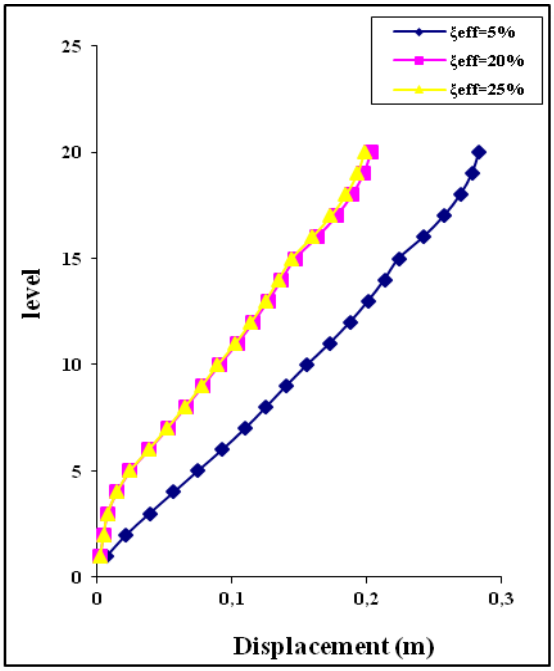


Figure 18. Comparison of displacements under the Loma-Prieta earthquake in Y direction

These figures clearly show that the incorporation of viscous dampers in the structure of this new distribution reduces displacement in all levels under all seismic excitations.

6.1.4. Base Shear Forces

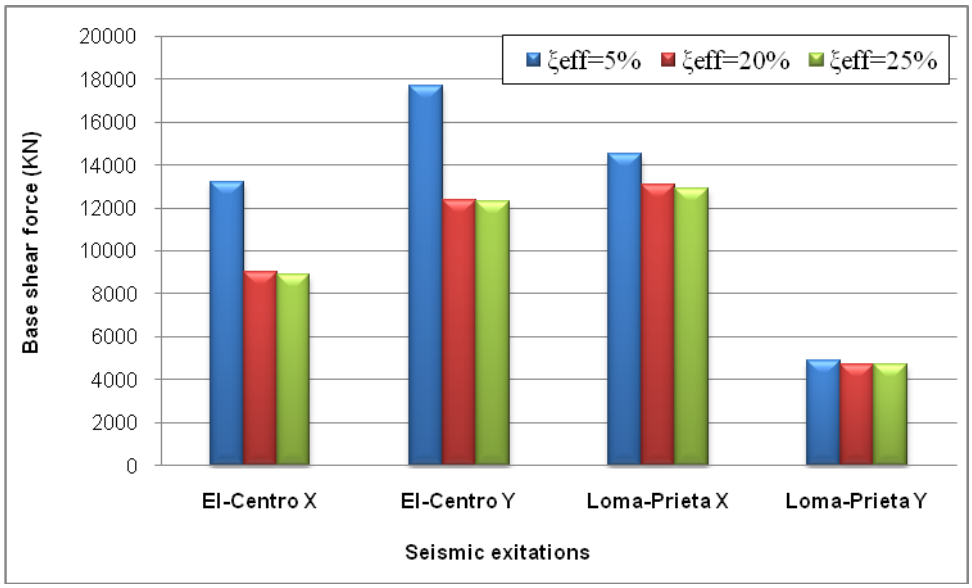


Figure 19. Comparison of base shear forces

6.2. Comparison "Structure with the First Emplacement / Structure with the Second Emplacement"

The dynamic analysis carried out for the two structures (the first emplacement and the second emplacement) enabled us to compare the results of displacements and the base shears force in the two directions X and Y as follows.

6.2.1. Comparison of Displacements

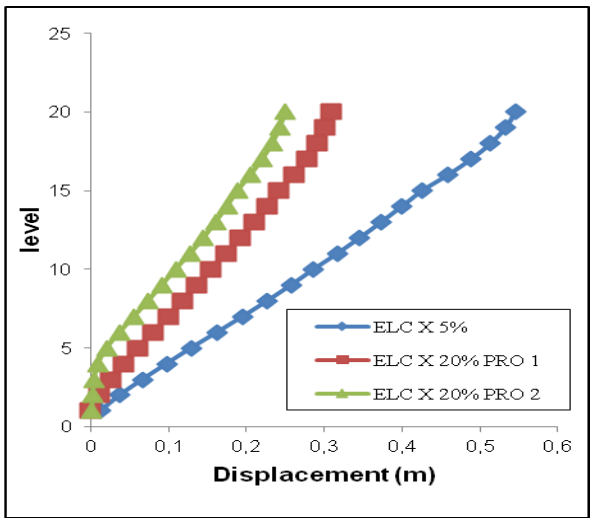


Figure 20. Comparison of displacements Under the El Centro earthquake in X direction

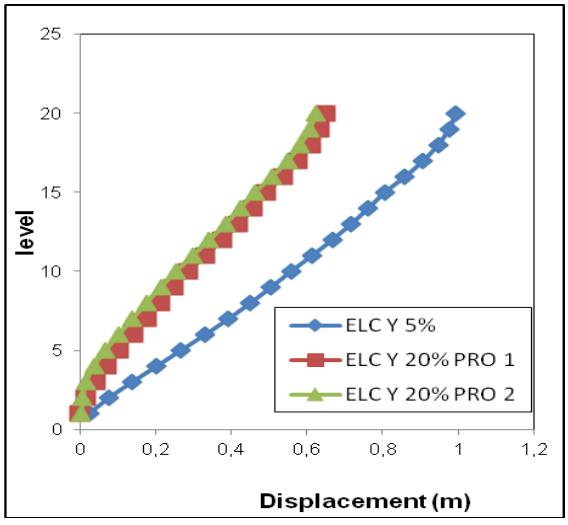


Figure 21. Comparison of displacements Under the El Centro earthquake in Y direction

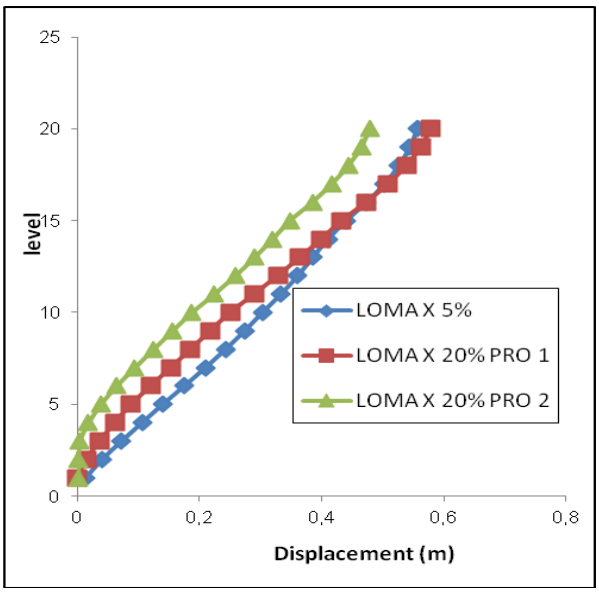


Figure 22. Comparison of displacements Under the Loma-Prieta earthquake in X

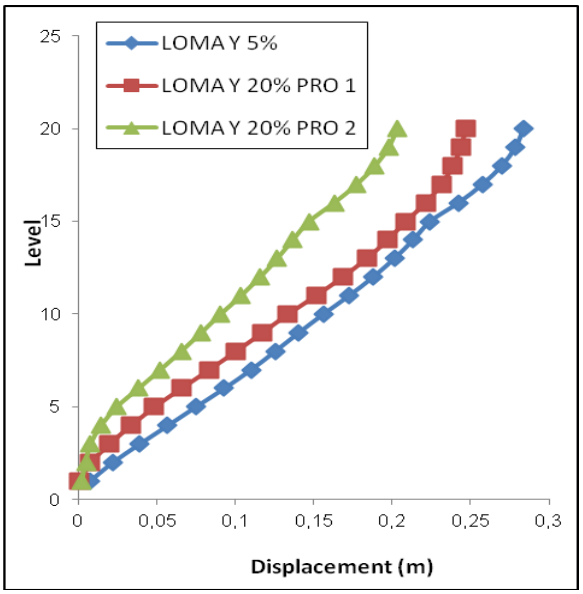


Figure 23. Comparison of displacements Under the Loma-Prieta earthquake in Y direction

According to the results of comparison, the Figures 20, 21, 22 and 23 shows that the structure with the second emplacement gives a significant reduction in displacement in the levels compared to the structure with the first emplacement of viscous fluid damper.

6.2.2. Comparison of Base Shear Forces

The comparison of the base shear forces for the two structures (first and second emplacement of viscous fluid damper) in two directions X and Y is represented on the Figure 24. This result shows that the second location reduces the base shear best then the first location.

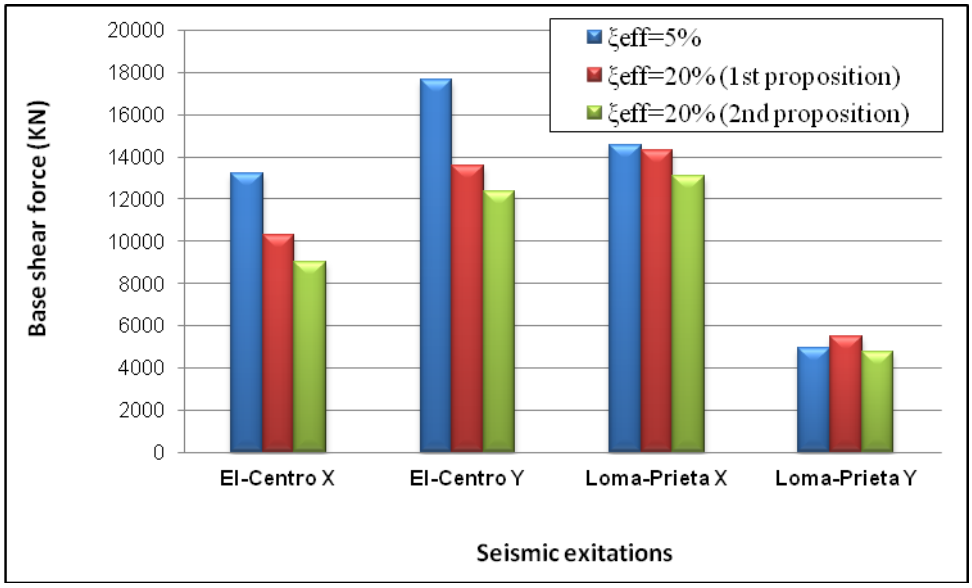


Figure 24. Comparison of the base shear forces for the two structures

The emplacement of the dissipators in the structure plays a very important role in the response of the structure. We note For this structure in the first proposal that the percentage reduction of the base shear force under the El-Centro-X component for ξ_{eff} = 20% is 22.06% while in the second proposition is 31.74%.

6.3. Hysteretic Behavior

A hysteretic behavior of the damper is described by a hysteresis loop (closed curve), which shows the force-displacement relationship, the surface or the area of the loop is the energy absorbed by the viscous fluid damper. To illustrate this dissipation, we have plotted the hysteresis loops of the viscous fluid damper on the 10th and 20th level of the structure under seismic excitations in both the X direction and for the effective damping ratio ξ_{eff} = 20% and ξ_{eff} = 25%.

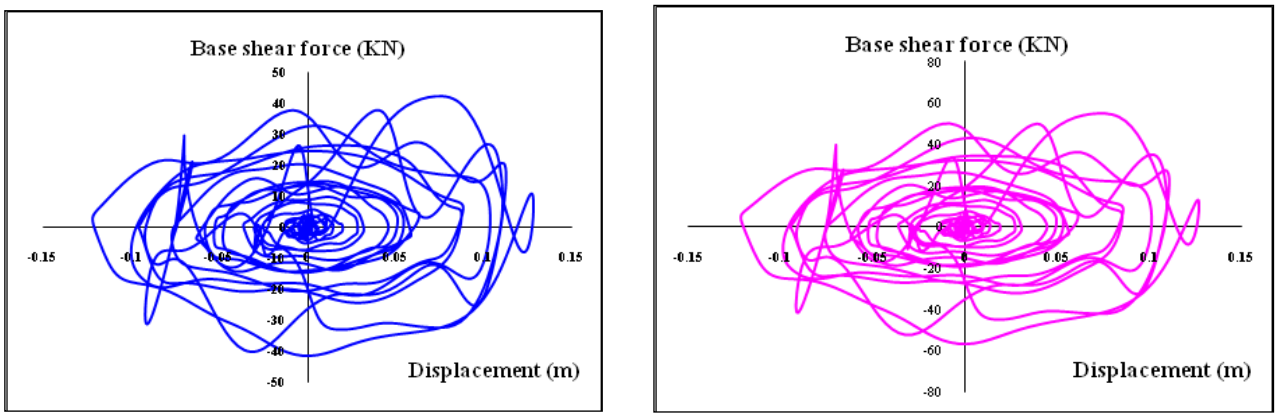


Figure 25. Hysteresis loops of the 10th level under the El Centro earthquake following X-axis, for a) ξ_{eff} =20% and b) ξ_{eff} =25%.

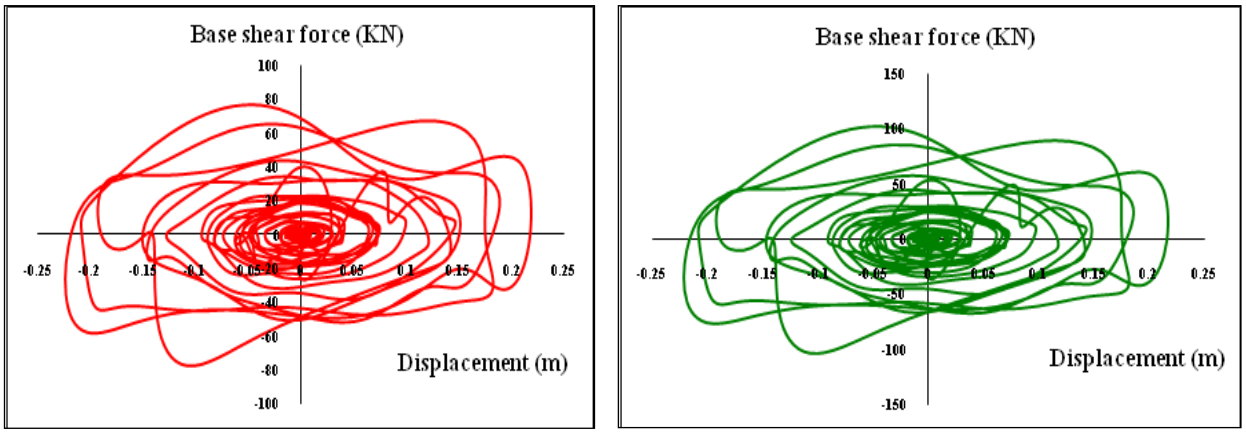


Figure 26. Hysteresis loops of the 10th level under the Loma-Prieta earthquake following the X axis for a) ξ_{eff} =20% and b) ξ_{eff} =25%.

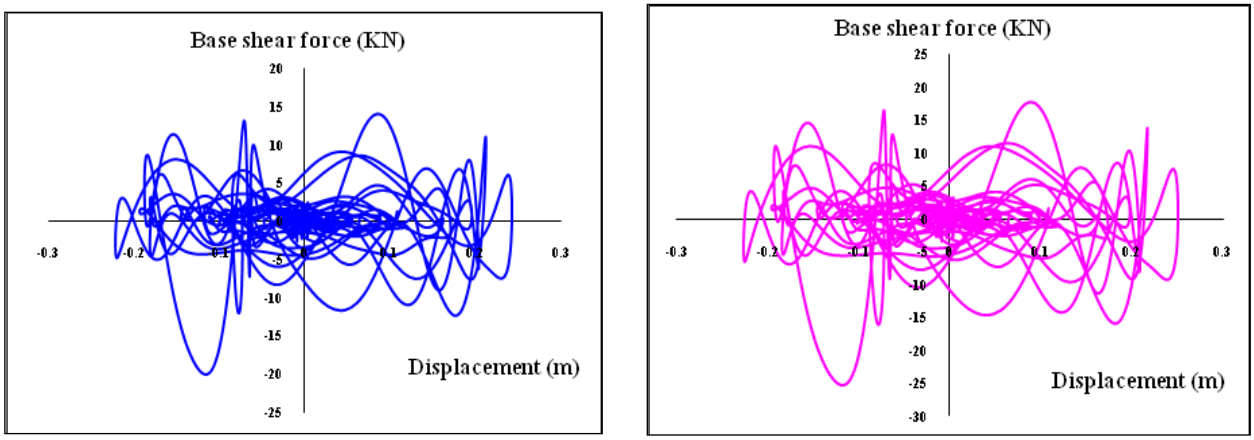


Figure 27. Hysteresis loops of the 20th level under the earthquake El Centro following the X-axis, for a) ξ_{eff} =20% and b) ξ_{eff} =25%.

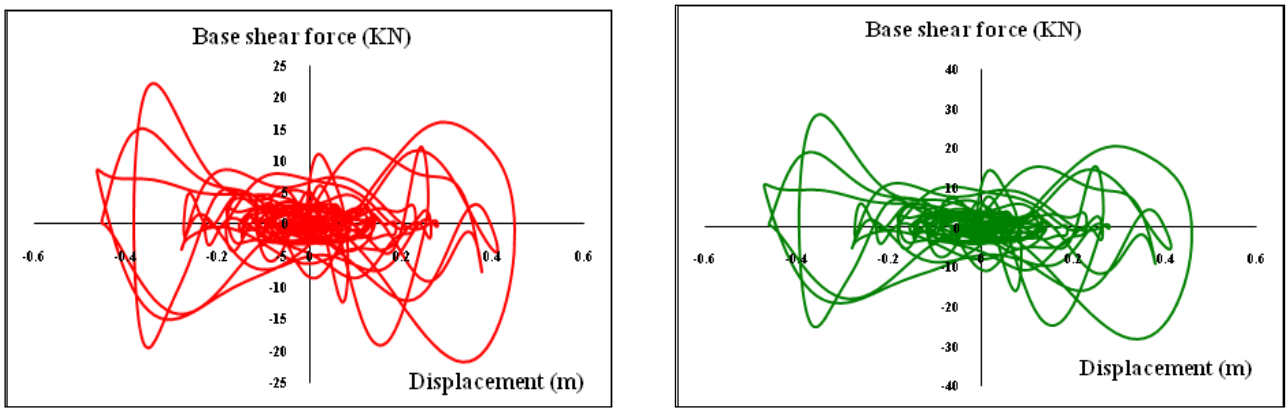


Figure 28. Hysteresis loops of the 20th level under the Loma Prieta earthquake following the X axis for a) ξ_{eff} =20% and b) ξ_{eff} =25%.

From the hysteresis loops presented above, we note that the surfaces of the loops increase according to the increased of damping ratio of the energy dissipator, and the damper in the Loma-Prieta earthquake dissipate more energy than those in El Centro.

7. CONCLUSION

In this paper the performance of the viscous fluid damper was investigated through comparative studies on structure of twenty levels, with and without damping device under various seismic excitations and different damping ratio and different locations of viscous fluid damper the comparative study enabled us to conclude that:

The incorporation of energy dissipation systems in a structure has reduced displacement and base shear forces, as they dissipate the energy induced by seismic excitations applied. On the other hand the increase in the effective damping ratio causes a reduction of displacement and base shear forces.

Surfaces that represent the hysteresis energy absorbed by the energy absorber increases viscous fluid loops in accordance with the increase in the additional damping ratio for all seismic excitations applied. As well as energy dissipators dissipate more energy at a medium or high long-term excitation (as part of Loma Prieta along the X-axis) and at medium or high excitement of short duration (component of El Centro along the X axis).

The location of the dissipators in the structure plays a very important role in the response of the structure. We remarks with the structure of twenty levels in the first proposal that the reduction percentage of the displacement under the El Centro-X component for ξ_{eff} = 20% is 43,44% while in the second proposal is 54,23%. And in the base shear force under the El Centro-X component for ξ_{eff} = 20% is 22.06% while in the second proposal is 31.74%.

REFERENCES

FEMA 274, (1997), "Guidelines for the Seismic Rehabilitation of Building", chapter 9, Seismic Isolation and Energy Dissipation, NEHRP.

T.T.Soong and M.C.C costantinou (1994). "Passive and active structural vibration control in civil engineering". State university of New York at buffalo.

Kelly T., (2001), "In Structure Camping and Energy Dissipation", Holmes Coulting Group Ltd

M.C.C costantinou and M.D.Symans "Experimental study of seismic response of buildings with supplemental fluid dampers". The structural design of tall building, vol.2, 93-132 (1993)

T.T.Soong and B.F. Spencer Jr. "Supplemental energy dissipation: state of the-art and state-of the practice". (2002) Elsevier Science Ltd. Engineering Structures 24 (2002) 243–259

Semih S. Tezcan , Ozan Uluca, "Reduction of earthquake response of plane frame buildings by viscoelastic dampers". 2003 Elsevier Ltd. Engineering Structures 25 (2003) 1755–1761.

Ali Sehat Tabatabaei, (2006), "Energy dissipation systems for seismic resistance" copyright, 2003-2006 Iran Civil Center.

George Vezeanu and Andrei Pricopie**,** "Design considerations for buildings with non linear viscous dampers"

CSI, ETABS (Extended Three Dimensional Analysis of Building Systems) *Nonlinear Version 9.7 (2003).*Integrated software for structural analysis and design. *Computers and structures, Inc, Berkeley, California, USA.*