# Comparative Study on Seismic Performance of Reinforced Concrete Building with and Without Fluid Viscous Dampers

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***Abstract*— Controlling seismic damage and improving performance are creative ideas of earthquake designing in which uses definite demonstrating of the structure together with techniques. One of the most important tools to dissipate energy is dampers that are able to reduce vibrations. Especially Fluid Viscous dampers (FVD) which are used to investigate the response of Reinforced Concrete building when they are subjected to lateral load like seismic. A structure might be viewed as serviceable in the event where it can be satisfied by transferring loads to foundation. Since earthquake loads are imposed on a structure, vibrations occur. To resist responses and absorb energy, Fluid Viscous Dampers is used. With Equivalent Static, Response Spectrum and Time history method, it is vital to identify characteristics by (ETABS) finite element program where Models having ordinary RC moment- resisting frame by square column cross- sections with and without FVD. In this evaluation, it is utilized in linear and non- linear analysis where ETABS, Version (18.0.2), has been used. The results are shown that dampers (FVD) dramatically reduce the lateral deflection and enhance the performance of the structure. They also cause a decrease in Time period of maximum Psuedo Spectral Acceleration (PSA) in Response spectrum curves, increasing the story stiffness and decreasing the story Shear. Therefore, adding FVD to RC buildings is effective utilization due to its dissipation of energy.**

***Index Terms*— Response Spectrum Method, Equivalent Static Method, Time history Method, Fluid Viscous Dampers, Psuedo Spectral Acceleration, Dissipation.**

## I. INTRODUCTION

For controlling responses, the more usage is the viscous fluid damper in many countries, especially America [4]. The role of these tools is decreasing the responses under seismic effect[13].Heavy costs that paid in a research institute around the world with the purpose of reducing damage need more results from the earthquake in the analytical and experimental scales [15].Based on the distance of earthquake recorder from the fault, the classification of earthquake is occurred.[2-3] Later the effect of ground motion in the near- field earthquake is considered the main one on the seismic performance.[5-6] Many earthquakes like Northridge earthquake (1994), Kobe earthquake (1995), and Taiwan earthquake (1999) have the destructive output on the building which adjacent to fault[2-5], because of that it must indicate the significance of the research in India which also has many cities are located near the active faults. To avoid the collapse of buildings under seismic load, new techniques have been developed with the purpose of ductility. Energy dissipation tools are found as innovative solutions to save building in the modern codes. [17] Its concept about an energy lost over the time period .They also related to many variables such as materials, radiation of soil etc. Widely study of damping need for incorporating its effect to the building which decreases the magnitudes. [18] hence, it can be used Equivalent viscous damping as an effective tool to reduce the structural collapse.[18] For instance, there are four different sources, namely Material Damping, Structural Damping, Radiation Damping and External Damping. As shown in the Figure. 1

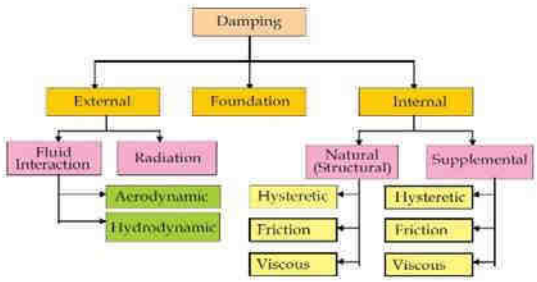


Fig 1 (Sources of Damping)

Based on performance, there are so many kinds of Dampers For example, Viscous, mass, friction, mental, and Viscoelastic. According to the benefits of using dampers, it can be noticed the high energy dissipation as well as coordination to other structure members. In this study, viscous fluid dampers were used because of their adaptability, ease of installation, and coordination with other members inside building.Moreover, viscous dampers have many applications in retrofitting. The section of viscous damper as shown as Figure 2.

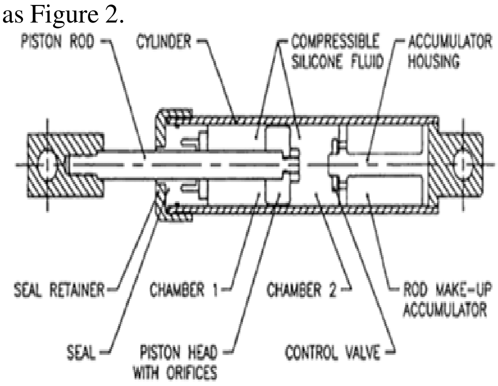


Fig 2 (Longitudinal Section of Viscous Damper)
Courtesy: https://goo.gl/images/EMl1MV

With Installation dampers to building as shown as Figure 3, there are three ways to connect:

- In the floor or foundation like the method of seismic isolation.
- In stern pericardial braces.
- In diagonal braces.

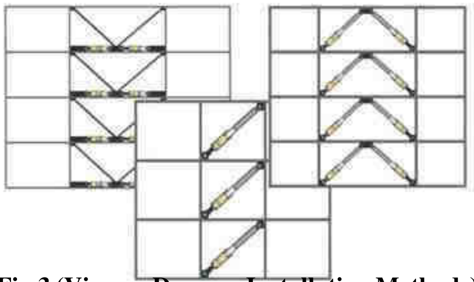

**Fig.3 (Viscous Damper Installation Methods)**

Courtesy: [https://goo.gl/images/iM3nwQ](https://goo.gl/images/iM3nwQ)

To explain the viscous dampers works as shown as figure 4, it is based on fluid flow through orifices. [13], it has a piston with a number of small orifices, covered with a silicon or a liquid like oil, where the fluid passes from one side to another.

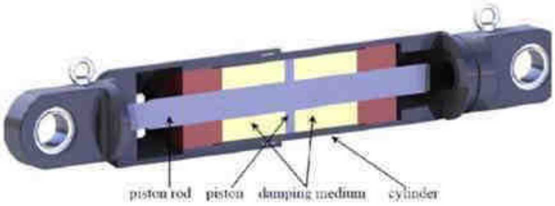


**Fig.4 (Viscous Damper Cross-section)**

## II. LITERATURE SURVEY

Different sources of damping that are considered depending on the nature of the building. Furthermore, many types of dampers are studied, in which viscous dampers were deeply enlightened with its importance.

- **V. Umachagi, K. Venkataramana, G. R. Reddy, and R. Verma**
  Stefano et al., 2010 have made the viscous damper and it was used in 3 storey building structure to control of the performance of structure .Attar et al., 2007 have proposed optimal viscous damper to decrease the displacement of steel building.[13]
- **R. Kazi and et al. (2015)**
  They studied comparative analysis of a ground floor +44 storey RC building using viscoelastic dampers. With respect to response spectrum analysis, the results are shown changes in the displacement, velocity, and acceleration for the damper building. Totally, the response of structure can be reduced by using a viscoelastic damper without increasing the stiffness. [14]
- **S. Amir and H. Jiaxin**
  "With using Viscous Damper under Seismic and Wind load" it is conducted that decreases the vibration in most structures and significantly decreases energy dissipation. It is explained how a Non-linear characteristic is required for a damping system to reduce the vibration. [20].
- **Y.Zhou et al. (2012)**
  They presented a new concept for design the tall building, and energy absorbing where nonlinear time history analysis performed on a 252 meters high – rise building model. The displacement, additional damping ration, and base shears were analysed in detail. It concluded that energy dissipation story systems can effectively increase the model damping ratio and its effective position is at the middle of the structure. [27]
- **Y. Zhou, X. Lu, D. Weng, and R. Zhang**
  In "RC building with the effect of viscous damper" presented the behavior with the retrofitting technology, in which the installation of viscous dampers to buildings has valuable effect due to easy construction. Otherwise, the design of viscous dampers was relatively new application in China.[28]
- **B. S. Taranath**
  In "Design of Tall Buildings" explains the nonlinear time history analysis and the results of the modelling are conducted to ensure the design meets the desired level of safety. The result of rigorous approach yields are referred to the safe and reliable design.[29]
- **Liya Mathew & C. Prabha**
  In 2014 conducted "Effect of Fluid Viscous Dampers in Multi-Storeyed Buildings" where they noticed that Structural systems have been developed to ensure safety and decrease the collapse under seismic load. Fluid viscous damper (FVD) has the main roll in procedure. It is used as a tool in the study of reinforced concrete buildings with and without dampers. Furthermore, Non- linear time history and Pushover Analysis have been done on a symmetrical square building by using software and comparisons are shown in graphical format.[26]

## III. RESEARCH STATEMENT

It can be defined as the term dynamic as time – varying. Hence, the dynamic load differs with time in any direction. [2] In order the high-rise building needs to be designed by the adequate balance, ductility and strength that are achieved. To reduce the dynamic response under lateral load, it is necessary to add supplementary damping, it is also possible for reduction of flexural stiffness to minimize seismic base shear with controlling response. In this study the FVD are used from the provider (Taylor devices) as a basic property where its variation can change the results which will be generated from response. The damping fluid of FVD comes from the silicone oil that is inert, non- flammable, non-toxic, and stable for extremely long periods of time. It is evaluated as innovative technology based on aerospace fluid elements. The properties of FVD with Different Capacities (Taylor devices) are shown in Figure 4.

| FORCE (kN) | TAYLOR DEVICES MODEL NUMBER | SPHERICAL BEARING BORE DIAMETER (mm) | MID-STROKE LENGTH (mm) | STROKE (mm) | CLEVIS THICKNESS (mm) | MAXIMUM CLEVIS WIDTH (mm) | CLEVIS DEPTH (mm) | BEARING THICKNESS (mm) | MAXIMUM CYLINDER DIAMETER (mm) | WEIGHT (kg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 250 | 17120 | 38.10 | 787 | ±75 | 43 | 100 | 83 | 33 | 114 | 44 |
| 500 | 17130 | 50.80 | 997 | ±100 | 55 | 127 | 102 | 44 | 150 | 98 |
| 750 | 17140 | 57.15 | 1016 | ±100 | 59 | 155 | 129 | 50 | 184 | 168 |
| 1000 | 17150 | 69.85 | 1048 | ±100 | 71 | 185 | 150 | 61 | 210 | 254 |
| 1500 | 17160 | 76.20 | 1105 | ±100 | 77 | 205 | 162 | 67 | 241 | 306 |
| 2000 | 17170 | 88.90 | 1346 | ±125 | 91 | 230 | 191 | 78 | 286 | 500 |
| 3000 | 17180 | 101.60 | 1441 | ±125 | 117 | 290 | 203 | 89 | 350 | 800 |
| 4000 | 17190 | 127.00 | 1645 | ±125 | 142 | 325 | 273 | 111 | 425 | 1088 |
| 6500 | 17200 | 152.40 | 1752 | ±125 | 154 | 350 | 305 | 121 | 515 | 1930 |
| 8000 | 17210 | 177.80 | 1867 | ±125 | 178 | 415 | 317 | 135 | 565 | 2625 |

Fig.4 (FVD with Different Capacities Force kN ).

## IV. OBJECTIVE OF STUDY

- To compare the seismic behavior of buildings with and without fluid viscous dampers that have ordinary RC moment- resisting frames by using square column cross- sections.
- To determine displacements changes in the structure because of adding FVD.
- To determine the reduction in base shear after using FVD in Reinforced Concrete buildings.
- To study the seismic characteristics With Equivalent Static, Response Spectrum and Time history method for the same building with and without FVD.

## V. MODELING AND MATERIAL PROPERTIES

1. *Modeling*

The seismic performance of the model has been studied with ordinary RC moment- resisting frames by noting the effect of changes on seismic parameters where Equivalent Static, Response Spectrum, and (EL-Centro) time history method occurred. To compare between the case with FVD and the case without FVD, in which considering linear and Non- linear analysis, It is used ETABS, Version (18.0.2), finite element program by four models. According to modeling, a Ground floor +15-storey RC building was conducted with dimensions (30 x 30), a height (52.5) meters, and the compressive strength of concrete (25) MPa [1]. The analysis (Standard) was occurred by considering the connection between columns and beams is completely fixed, as well as the connection between slabs and beams [1]. Regarding the study, it was compared between the values of displacement, draft, shear base, and stiffness.

Model analysis can be classified in to two types linear and Non-linear where it was used the same seismic variables as per IS: 1893 (2002) criteria [9] for Equivalent Static and Response Spectrum method:

a) *Response reduction factor (R)*
- R= 3 for shear wall system (ordinary RC moment- resisting frame).

b) *Zone factor (Z) = 0.36, where Seismic Zone = V*

c) *Importance factor (I)*
- I = 1.0 for other building( not important service and community)

d) *Soil types (I)*

e) *Function Damping Ratio (0.05)*

f) *Eccentricity ratio (0.05)*

The function graph of spectrum is shown in Figure 5. [1]

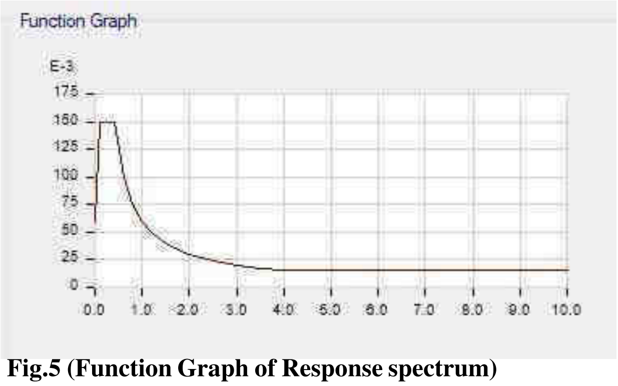


**Fig.5 (Function Graph of Response spectrum)**

For time history, the function graph of (EL-Centro) is shown in Figure 6. [1]

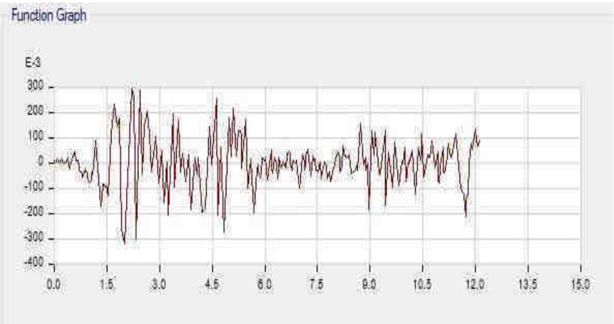


Fig.6 (Function Graph of EL-Centro)

The parameters are different in the time history approach between linear and Non- linear analysis. Therefore, there is the linear analysis model time history and the fast nonlinear analysis (FNA) modal time history analysis.

- With the linear analysis model time history, the properties are:

Number of output Time steps = 600
Output Time step Size = 0.02 sec
Damping = 0.05

- With the fast nonlinear analysis (FNA) modal time history analysis, the properties are:

Number of output Time steps = 5000
Output Time step Size = 0.002 sec
Damping = 0.999
Moreover, with Non-linear time history, it was added RAMP Time history which has the properties:
RAMP Time = 10
Amplitude = 1 Maximum Time = 20

For RAMP time history, the function graph is shown in Figure 7. [1]

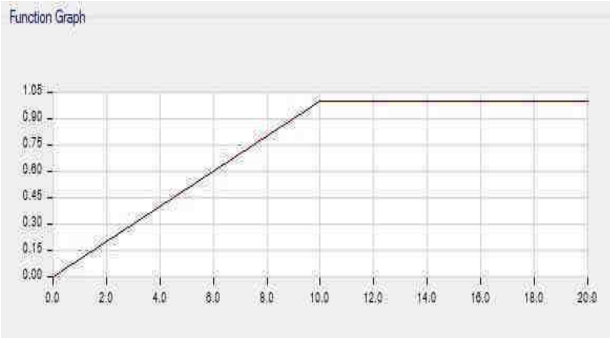

Fig.7 (Function Graph of RAMP time history)

Therefore, the nonlinear hinges are used during fast nonlinear analysis (FNA) modal time history analysis, and nonlinear direct integration time history analysis. For all other types of analysis, the hinges are rigid and have no effect on the behaviour of the member

The procedure is generated by using ETABS.

- Linear cases always start from zero. Hence, the corresponding time function must also start from zero.
- Nonlinear cases can either start from zero or continue from a previous case. Otherwise, it is preferred to start from Zero (Initial condition) in this study.
- Because Fast Nonlinear Analysis (FNA) is useful for the static or dynamic evaluation of linear or nonlinear structural systems, it is essential to use FNA for time-history analysis and usually recommended over direct-integration applications.

With introducing FVD to building, the procedure will not be changed for analysis methods. Hence, it was used FVD (500) in the case with dampers by taking the properties of it from Figure 4.

- The models are:

Model (1) which is without FVD under linear analysis.
Model (2) which is with FVD under linear analysis.
Model (3) which is without FVD under Fast Nonlinear Analysis (FNA).
Model( 4) which is with FVD under Fast Nonlinear Analysis (FNA).

2. *Material and Loads consideration :[11]*

a) The grade of concrete : M25
b) the strength of steel : Fe 415 N/mm$^2$
c) For concrete: E (25000) Mpa.
- E (modulus of elasticity)

d) Dead load (4 k N/m$^2$) to self –weight of slab
e) Live load (3 k N /m$^2$) to self –weight of slab

3. *Dimension Members*

It is the same for all models as shown in the table I

Table. I (Dimension) [1]

| Story | Dimensions | |
|---|---|---|
| | Column (mm) | Beams (mm) |
| From basement to 5 story | 700 x 700 | 250 x 250 |
| From 5 story to 10 story | 600 x 600 | 250 x 250 |
| From 10 story to 15 story | 500 x 500 | 250 x 250 |
| Thickness of slab (20cm) | | |

4. *PLAN*

a) The models without FVD like model(1,3) are shown in Figure 8.

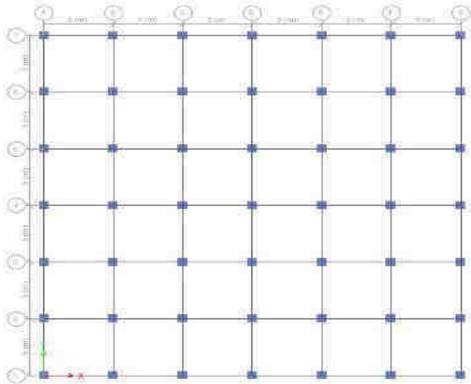
Fig.8 (Plan View) [1]

b) The models with FVD like model(2,4) are shown in Figure 9.

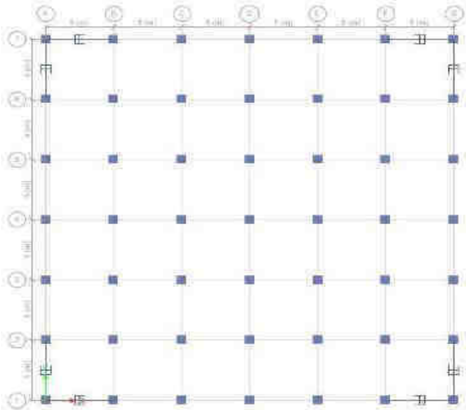
Fig.9 (Plan View) [1]

c) It used the dimensions and sections from the plan model without FVD to make (3D) model in which has slab as shown in Figure 10.

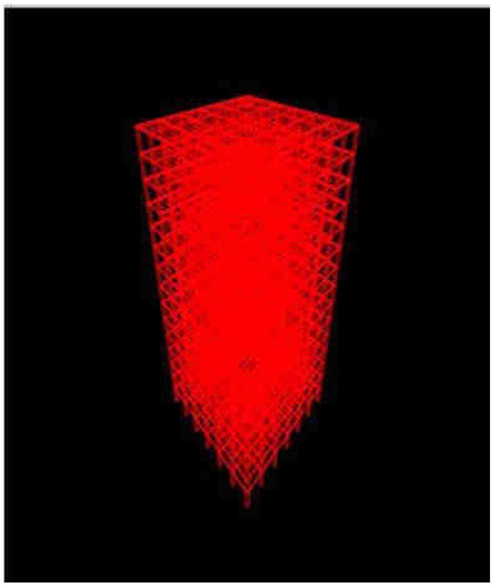
Fig.10 (Plan View) [1]

d) It used the dimensions and sections from the plan model with FVD to make (3D) model in which has slab as shown in Figure 11.

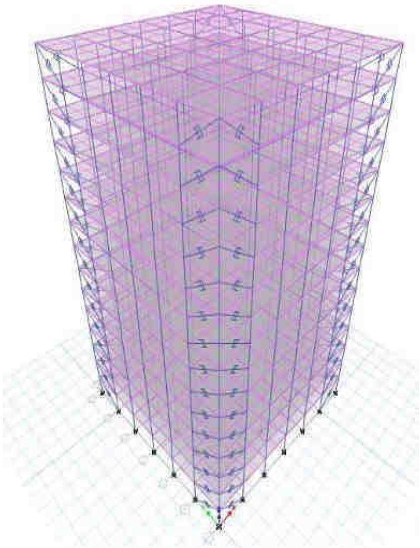

Fig.11 (Plan View) [1]

## VI. RESULTS AND DISCUSSION

The results are carried out by ETABS, Version (18.0.2), as below:

1) *Response Spectrum Curves from Time History*

This presents response spectrum plots obtained from time history results at a specified point for a specified time history load case. Where,

Name: Response Spectrum from Time History
Load Case: Time History X-X
Story15: Response Direction X-X
Spectrum Widening: 0 %

A. *Psuedo Spectral Acceleration , PSA, mm/sec² model as shown in Figure 12.*

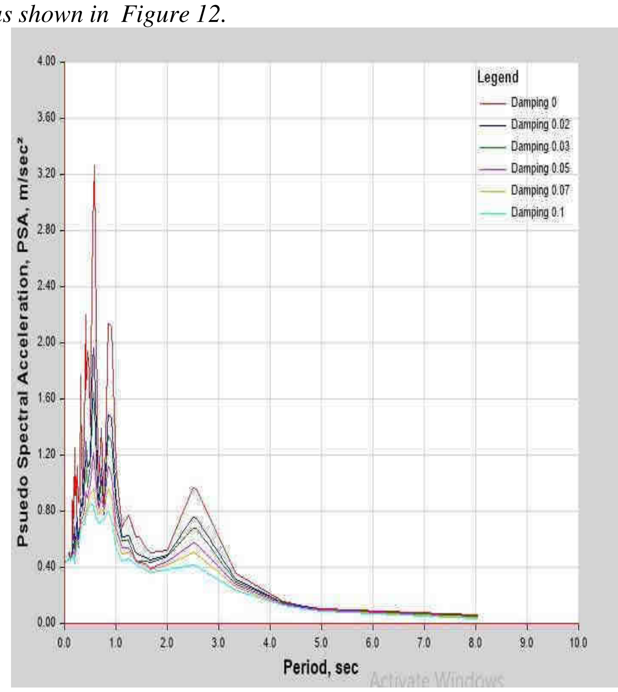


Fig.12 (Response Spectrum Curves from Time History)

B. *Psuedo Spectral Acceleration , PSA, mm/sec² model as shown in Figure 13.*

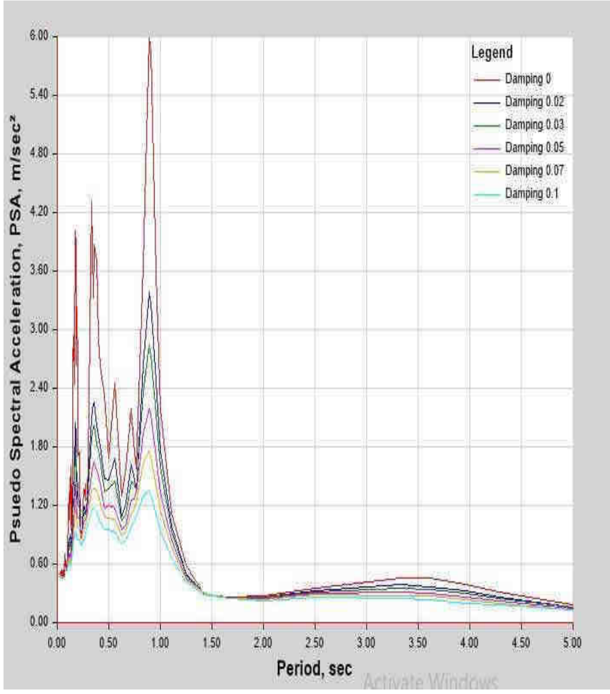


Fig.13 (Response Spectrum Curves from Time History)

C. Psuedo Spectral Acceleration , PSA, mm/sec² model as shown in Figure 14.

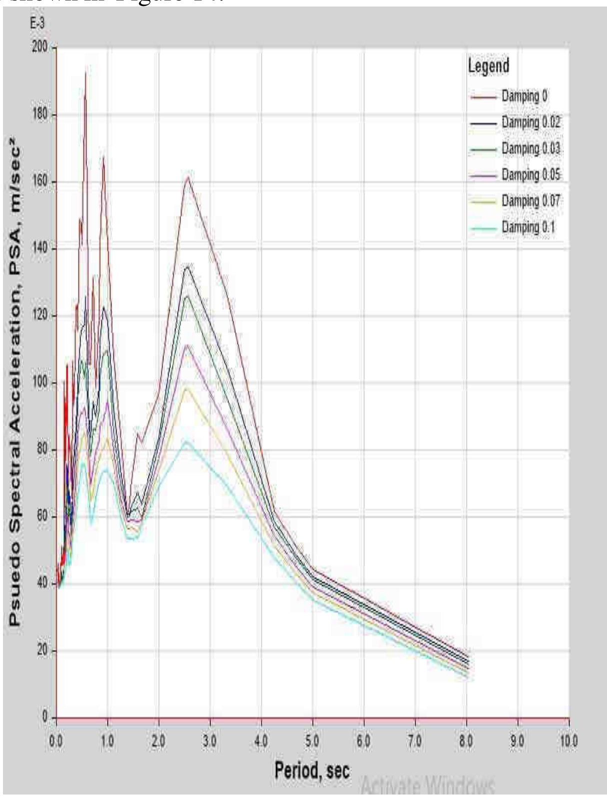


Fig.14 (Response Spectrum Curves from Time History)

D. Psuedo Spectral Acceleration , PSA, mm/sec² model as shown in Figure 15.

**Hence,**
There are reduction in Time period of maximum Psuedo Spectral Acceleration (PSA) in Response spectrum curves since FVD is used.

2) *Equivalent Static Method :(X-X Direction)*

a) Base Shear

- The values are shown in the table II.

Table .II (Base Shear)

| Equivalent Static Method - Base Shear | |
|---|---|
| Model | Max (k N) |
| model 1 | 4220.0 |
| model 2 | 1868.0 |
| model 3 | 5525.6 |
| model 4 | 2750.7 |
| RATIO | |
| MODEL | Value |
| (1-2) | 2.25910 |
| (3-4) | 2.00880 |

The Comparison of values with FVD and without FVD in the case of Equivalent Static Method for Base Shear presents that the Shear values are decreasing with damper as shown in Figure 16.

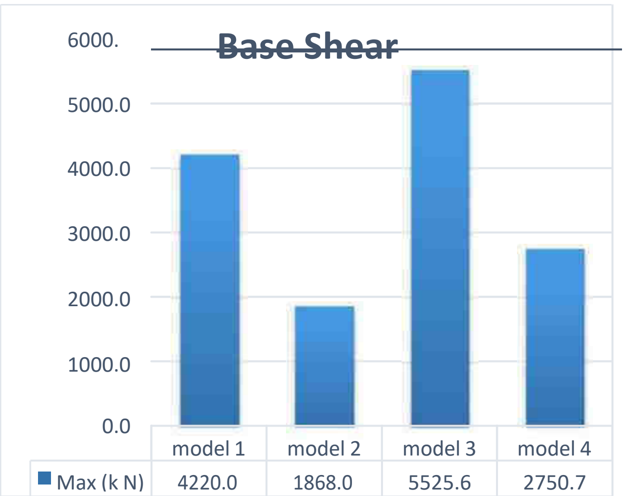


Fig.16 (Equivalent Static Method - Base Shear)

b) Stiffness

- The values are shown in the table III.

Table .III (Stiffness)

| Equivalent Static Method - stiffness | |
|---|---|
| Model | Max (k N /m) |
| model 1 | 53349.0 |
| model 2 | 103858.0 |
| model 3 | 52333.0 |
| model 4 | 122068.0 |
| RATIO | |
| MODEL | Value |
| (1-2) | 0.51367 |
| (3-4) | 0.42872 |

The Comparison of values with FVD and without FVD in the case of Equivalent Static Method for Stiffness presents that the Stiffness values are increasing with damper as shown in Figure 17.


**Fig.17 (Equivalent Static Method - Stiffness)**

c) Max Displacement

- The values are shown in the table IV.

Table .IV (Displacement)

| Equivalent Static Method - Displacement | |
|---|---|
| Model | Max (m) |
| model 1 | 0.490905 |
| model 2 | 0.138709 |
| model 3 | 0.638698 |
| model 4 | 0.2 |
| RATIO | |
| MODEL | Value |
| (1-2) | 3.53910 |
| (3-4) | 3.08346 |

The Comparison of values with FVD and without FVD in the case of Equivalent Static Method for Displacement presents that the Displacement values are decreasing with damper as shown in Figure 18.


**Fig.18 (Equivalent Static Method - Displacement)**

*3) Response Spectrum Method :(X-X Direction)*

A. Base Shear

- The values are shown in the table VI.

Table .VI (Base Shear)

| Response Spectrum Method - Base Shear | |
|---|---|
| Model | Max (k N) |
| model 1 | 1185.5 |
| model 2 | 425.02 |
| model 3 | 2095.4 |
| model 4 | 1288.4 |
| RATIO | |
| MODEL | Value |
| (1-2) | 2.78928 |
| (3-4) | 1.62634 |

The Comparison of values with FVD and without FVD in the case of Response Spectrum Method for Base Shear presents that the Shear values are decreasing with damper as shown in Figure 19


**Fig.19 (Response Spectrum Method – Base Shear)**

B. Stiffness

- The values are shown in the table VII.

Table .VII (Stiffness)

| Response Spectrum Method - stiffness | |
|---|---|
| Model | Max (k N /m) |
| model 1 | 85425.4 |
| model 2 | 104396.0 |
| model 3 | 123812.0 |
| model 4 | 166130.0 |
| RATIO | |
| MODEL | Value |
| (1-2) | 0.81828 |
| (3-4) | 0.74527 |

The Comparison of values with FVD and without FVD in the case of Response Spectrum Method for Stiffness presents that the Stiffness values are increasing with damper as shown in the Figure 20.


**Fig.20 (Response Spectrum Method - Stiffness)**

C. Max Displacement

- The values are shown in the table IV.

Table .VIII (Displacement)

| Response Spectrum Method - Displacement | |
|---|---|
| Model | Max (m) |
| model 1 | 0.029810 |
| model 2 | 0.020769 |
| model 3 | 0.037129 |
| model 4 | 0.011603 |
| RATIO | |
| MODEL | Value |
| (1-2) | 1.43531 |
| (3-4) | 3.20000 |

The Comparison of values with FVD and without FVD in the case of Response Spectrum Method for Displacement presents that the Displacement values are decreasing with damper as shown in Figure 21.

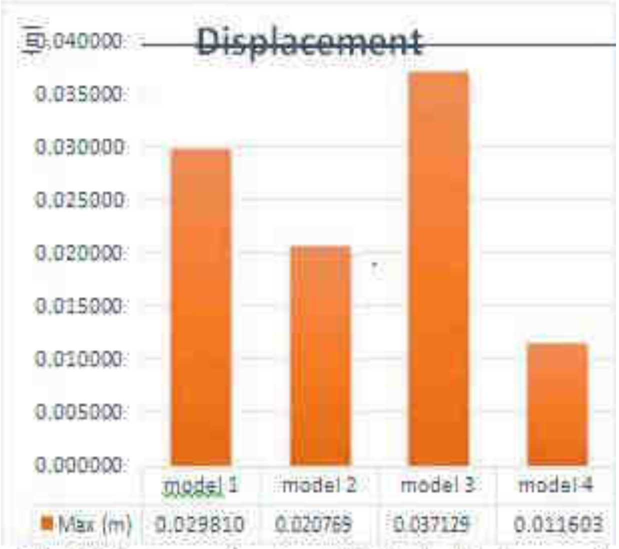


**Fig.21 (Response Spectrum Method - Displacement)**

*4) Time History Method :(X-X Direction)*

*A. Base Shear*

- The values are shown in the table X.

Table .X (Base Shear)

| Time History Method Base Shear | |
|---|---|
| Model | Max (k N) |
| model 1 | 1523.0 |
| model 2 | 739.10 |
| model 3 | 461.4 |
| model 4 | 191.8 |
| RATIO | |
| MODEL | Value |
| (1-2) | 2.06063 |
| (3-4) | 2.40584 |

The Comparison of values with FVD and without FVD in the case of Response Spectrum Method for Base Shear presents that the Shear values are decreasing with damper as shown in Figure 22.


**Fig.22 (Time History Method – Base Shear)**

*B. Stiffness*

- The values are shown in the table XI.

Table .XI (Stiffness)

| Time History Method - stiffness | |
|---|---|
| Model | Max (k N /m) |
| model 1 | 30418.0 |
| model 2 | 51402.0 |
| model 3 | 42180.0 |
| model 4 | 62280.0 |
| RATIO | |
| MODEL | Value |
| (1-2) | 0.59177 |
| (3-4) | 0.67726 |

The Comparison of values with FVD and without FVD in the case of Time History Method for Stiffness presents that the Stiffness values are increasing with damper as shown in Figure 23.


**Fig.23 (Time History Method – Stiffness)**

*C. Max Displacement*

- The values are shown in the table XII.

Table .XII (Displacement)

| Time History Method - Displacement | |
|---|---|
| Model | Max (m) |
| model 1 | 0.043373 |
| model 2 | 0.027500 |
| model 3 | 0.010770 |
| model 4 | 0.009570 |
| RATIO | |
| MODEL | Value |
| (1-2) | 1.57720 |
| (3-4) | 1.12539 |

The Comparison of values with FVD and without FVD in the case of Time History Method for Displacement presents that the Displacement values are decreasing with damper as shown in Figure 24.


Fig.24 (Time History Method – Displacement)

CONCLUSION

1. PSA from Response Spectrum Curves
   The structures with FVD have less periodic values leading to surpass the maximum PSA values.
2. Reduction in Time period of maximum PSA in Response spectrum curves when FVD is used.
3. FVD500 reduced the Base Shear of the structures in all models with Equivalent Static, Response Spectrum and Time history analysis.
4. The Max Displacements are dramatically decreased with use of FVD.
5. The increase of stiffness Values of the structure when FVD500 used for exterior corners.
6. It is noticed that buildings with FVD are performing well in terms of response of the structure.

- Increasing the story levels or making any changes to materials may fetch different conclusions.
- The Position of FVD can be changed to a particular solution.
- Changing the section of members will effect on the results included from this study.

➢ ***Design Recommendation:***

- It can be recommended to continue study by using many types of FVD due to a variety of "Taylor devices "where FVD500 may be not sufficient to the structures in exterior corners.
- Same structures can be modelled with FVD750 and can be used in exterior middle position.
- Push over Analysis can be conducted with Irregular buildings to extend this work.
- It can be used in Steel structures and Steel – Concrete Composite Structures which results in effective solutions.

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