"Reduction in Seismic Response of Structure using Fluid Viscous Damper Over Static and Dynamic Analysis"

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Abstract - *Damping and utilization of Dampers plays fundamental role in design of earthquake resistant Structures, which reduces the seismic reaction of the structure when they are exposed to horizontal (lateral loads). There are wide range of dampers being used. In this research fluid viscous dampers (FVD) are utilized to find the seismic reaction of RCC building of 12 stories with various bay sizes (2x2 and 3x3). The basic principle of a structure is to bear the horizontal loads and transfer them to the beams, columns and slabs. Since the horizontal loads imposed on a structure are dynamic in nature, they cause vibrations in the structure. So as to have earthquake (seismic) safe structures, fluid viscous dampers (FVD) have been utilized. Structures having different bay sizes cross-areas are analyzed with and without fluid viscous damper (FVD). In this research ETABS 2018 software have been utilized. Utilizing Push over and Time history analysis, the seismic reaction of the RCC building considered in this study is assessed and compared with and without FVD. It has been seen that in Time History analysis, up to 90% reduction in the time period is observed when FVD are utilized. FVD250 reduces the Base Shear of the structures up to 70%. Consequently, FVD's can be utilized in RCC multistory structures to reduce the seismic reaction successfully.*

Key Words*: *Damping, Dampers, Fluid viscous Damper (FVD), Time history Analysis, Push over Analysis, etc.

1. INTRODUCTION

The fluid viscous dampers (FVD) are the most utilized tools for monitoring seismic responses of the structures. Similar techniques are implemented based on different construction technologies to raising structural responses to seismic excitation. While heavy costs have been charged in recent years to accurately identifying the indemnity of an earthquake in the worlds research institutes in order to minimize its impacts, there is growing need for future research studies on the effect of the earthquake on the theoretical and laboratory scales. In the last 50 years earthquake have been divided in to 2 categories of the near filed earthquakes and far field earthquake based on the distance between the location where the earthquake was reported and fault. This description was changed later and categorization was affected by the other factors too. In the last few years, the studies centered on researching structure efficiency of impacts of ground motion in the near filed earthquake. The catastrophic effect of earthquake such as Northridge earthquake (1994), the Kobe earthquake (1995) and the Taiwan (1999) on the buildings of the cities adjacent to the fault and the importance on the work in the terms of the proximity of several of India's cities to the active fault, suggest. Some essential development in seismic code have emerged in recent years. Because of the renewed awareness of the current behavior of the building, retrofitting of building is a critical role in reducing seismic risk. New techniques have been developed to protect buildings from earthquake, in order to boost their abilities. Seismic isolations and dissipation of energy are commonly accepted as efficient security strategies to meet output goals of modern codes. Most standard, however, provide design requirements for seismically isolated structures, while updated rules for protective systems for energy dissipation are also required.

1.1 Damping

It is defined as energy loss in the response over the time period. Energy dissipation involves factors such as materials, radiation of soil etc. Clear understanding of damping is required for incorporating its effect to the structure. The shape of response curve doesn't change by damping but the magnitudes are reduced.

1.2 Importance of Damping Sources

When the structure has much absorbing capacity than the Seismic energy then it can withstand the structural damage. Equivalent viscous damping can be used as a feasible means of decreasing the structural damage.

The four different sources are material Damping, Structural Damping. Radiation Damping and External Damping.

1.3 Types of Dampers

1. Friction dampers
2. PVD Damper
3. Pall Friction Damper
4. Metallic Dampers
5. Lead Injection Damper (LED)
6. Shape Memory Alloy (SMA)
7. Viscous Dampers

8. Mass Damper
9. Regulatory Mass Damper TMD

1.4 Viscous Dampers

In this damper, by utilizing viscous liquid(fluid) inside a chamber, vitality(energy) is disseminated. Because of simplicity of establishment, versatility and coordination with different individuals additionally decent variety in their sizes, Viscous dampers have numerous applications in planning and retrofitting.

This sort of dampers are associated with the structure in three different ways:

- Damper establishment in the floor or foundation (in the technique for seismic seclusion).
- Damper establishment in corner to corner supports(braces).
- Interfacing dampers in harsh pericardial supports.

1.5 Methods of Control

Various methods and experiments are tried to produce better control against wind and earthquake excitation. These can be classified into four broad categories: passive control, active control, semi-dynamic(active) control and hybrid control.

1.5.1 Passive Control

Passive control framework is the most precisely basic arrangement of control plans is encased, which has been generally acknowledged for structural building application. The basic purpose of passive control system are:

- Reducing the stiffness
- Increasing the natural period of the system.
- Provision of increased damping to increase the energy dissipation in the system.

1.5.2 Active control

Dynamic control is relatively, approaching subfield of basic building. It gives us better outcome and improved reaction when contrasted with inactive frameworks at the expense of vitality and progressively complex frameworks.

Dynamic control framework is a sort of control framework in which an outside power source is required to give supplement or extra powers to the structure in a controlled way, by the utilization of actuators.

1.5.3 Semi-Dynamic Control

A semi dynamic control framework requires less outer energy than that of dynamic control framework which influences it to contrast from dynamic control framework yet they both work on a similar guideline. Semi dynamic gadgets(devices) have a basic solidness as far as limited info and yield as these don't add mechanical energy to the essential framework. Along these lines, it might be viewed as controllable detached gadgets.

1.5.4 Hybrid Control

Hybrid control frameworks deals with the consolidated utilization of passive and dynamic(active) control framework. For instance, a base disconnected structure which is furnished with actuator which effectively controls the improvement of its execution.

2. OBJECTIVES

- In this study following investigations are considered for RCC buildings.
- To compare the seismic reaction of structures and diverse bay sizes (2x2 and 3x3) with and without FVD.
- To determine displacements(relocation) variations in the structure due to implementation of FVD.
- To find the lowering in base shear by using FVD in RC buildings.
- To examine the variations in time period for different structures with and without FVD.

3. ANALYSIS PERFORMED IN THIS STUDY

1. Modal analysis
    - Energy method
    - Modal response
    - Modal participation factor
2. Determined analysis by ETABS
    - Equality static analysis
    - Response spectrum analysis
    - Multimodal or SRSS lateral load pattern
3. Time history analysis
4. Push over analysis

4. MODELLING OF STRUCTURE AND PROPERTIES:

Table 1: Structural Properties:

Properties	Values
Location	Bhuj
Zone	V
Z	0.36
Seismic intensity	Moderate
R	5 for SMRF
Soil type	Type III
I	1.5
No. of stories	12
Total height	36000mm
Column size	300x450 mm
Beam size	300x450 mm
Slab thickness	125 mm
Grade of concrete	M-20

Grade of steel	Fe-415
Fluid viscous damper	FVD250 by Taylor devices Inc. (USA)

Models:

There are 2 models taken in this analysis with and without fluid viscous damper (FVD):

1. 2x2 bay size structure with each bay 3.5 m apart.
2. 3x3 bay size structure with each bay 3.5 m apart.

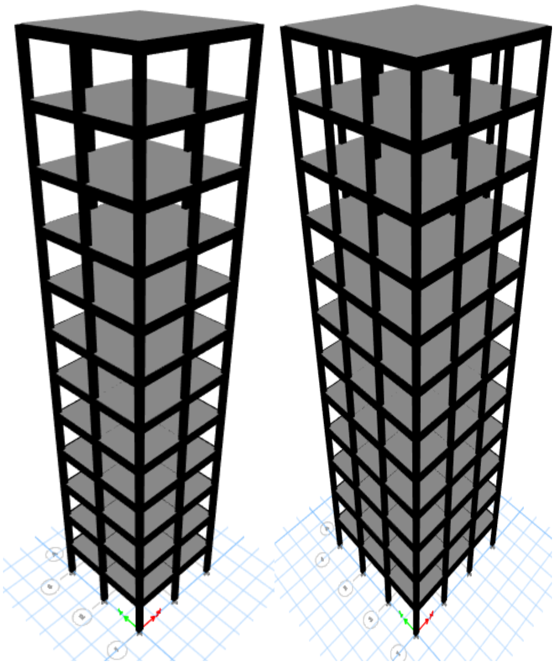

Fig.1: Structures with without FVD.

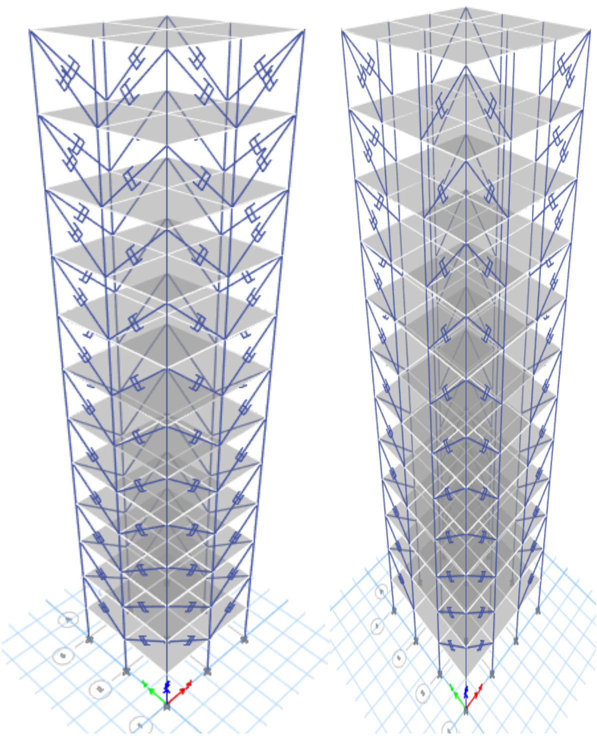

Fig.2: Structures with FVD at Corners.

Table 2: Load cases summary:

Name	Type
Dead	Linear static
Live	Linear static
EQ-x	Linear static
EQ-y	Linear static
WL-x	Linear static
WL-y	Linear static
RS-x	Response spectrum
RS-y	Response spectrum
Th-x	Nonlinear Modal History (FNA)
Th-y	Nonlinear Modal History (FNA)
Push-x	Nonlinear static
Push-y	Nonlinear static

5. Result and Discussion:

5.1 Response Spectrum Curves from Time History

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

Table 3: Input Data

Name	Response Spectrum from Time History		
Load Case	Th-x	Coordinate System	Modal
Story	Story 12	Response Direction	x
Point	1	Spectrum Widening	0%

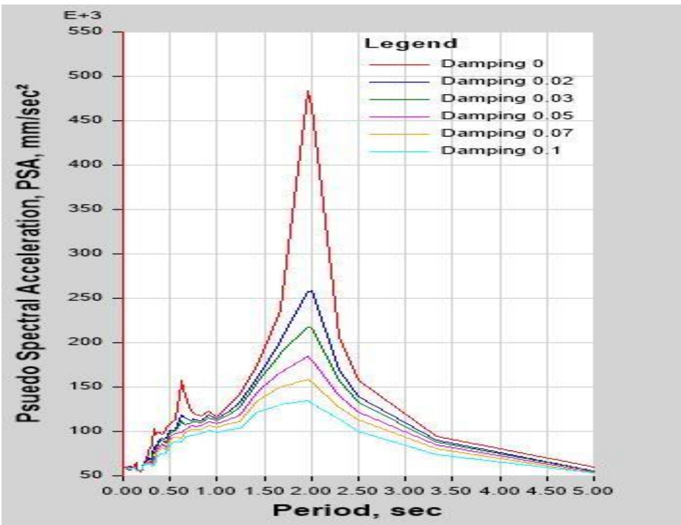

Fig.3: RS curve for 2x2 without FVD.

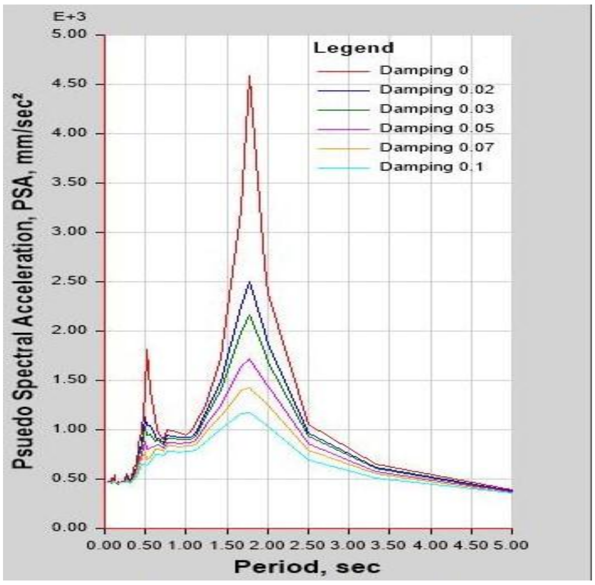

Fig.4: RS curve for 2x2 with FVD.

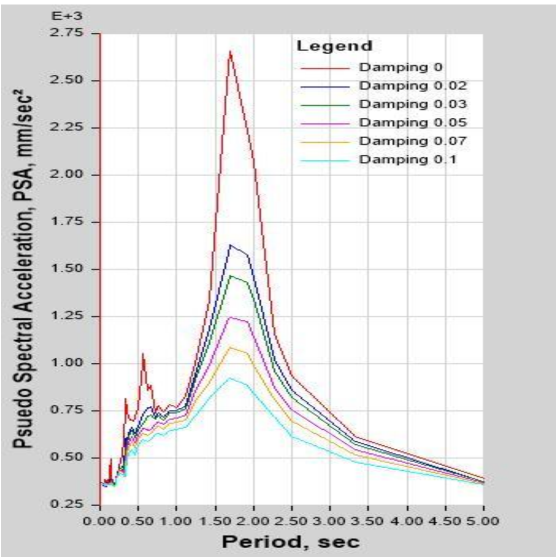

Fig.5: RS curve for 3x3 without FVD.

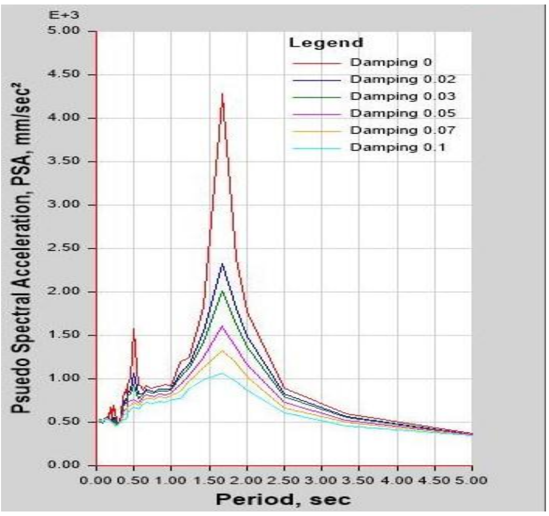

Fig.6: RS curve for 3x3 with FVD.

5.2 Modal period

One analysis technique for calculating the linear response of structures to dynamic loading is a modal analysis. In modal analysis, we decompose the response of the structure into several vibration modes. A mode is defined by its frequency and shape.

During dynamic loading, i.e. earthquake, wind or blast loading, not all modes are excited in the same manner. The extent to which dynamic loading excites a specific vibration mode depends on the spatial distribution and the frequency content of the load.

Table 4: Modal period comparison

Mode	Period(sec)			
	2x2	2x2(FVD)	3x3	3x3(FVD)
1	2.303	1.965	2.675	1.871
2	1.957	1.773	2.314	1.683
3	1.645	1.068	2.282	1.251
4	0.752	0.652	2.078	0.609
5	0.627	0.528	1.912	0.500
6	0.543	0.169	1.699	0.405
7	0.428	0.165	1.385	0.238
8	0.351	0.072	0.752	0.221
9	0.317	0.071	0.646	0.153
10	0.302	0.040	0.624	0.114
11	0.245	0.040	0.56	0.111
12	0.233	0.026	0.436	0.072

5.3 Story Max/Avg. Displacements

Suggested maximum drift at the top of buildings vary between H/50 and H/2000 Where H is the height of the building. A limiting value for the maximum displacement within the elastic limits was obtained as a function of the height of a story, the stiffness of a story, number of stories, effective depth d of a shear wall, the yield strain of steel ε_y and the maximum allowable concrete strain ε_c. However, the value H/50 suggested by UBC97 and IBC 2006 generates large strains at the bottom of a shear wall.

Hence for story 10, H=30m.

Limiting displacement =H/50=30000/50=600mm=0.6m
Therefore, obtained values are within limits.

From the interrelation, it is found that due to insertion of FVD in the structures the displacements have been reduced by around 90% for both the structures given below.

Table 5: Max. Disp. of Modal at different stories due to Push-x

Story	2x2	2x2 (FVD)	3x3	3x3(FVD)
12	187.172	22.851	131.59	29.014
11	183.171	20.906	128.837	27.025
10	178.159	18.965	125.101	24.959
9	172.106	17.039	120.338	22.797
8	165.034	15.145	114.559	20.54
7	156.968	13.307	107.782	18.207
6	147.839	11.554	100.018	15.838
5	137.307	9.923	91.139	13.494
4	124.778	8.456	80.787	11.263
3	108.046	7.205	68.345	9.258
2	81.982	6.224	51.761	7.634
1	43.672	5.573	27.23	6.572
BASE	0	0	0	0

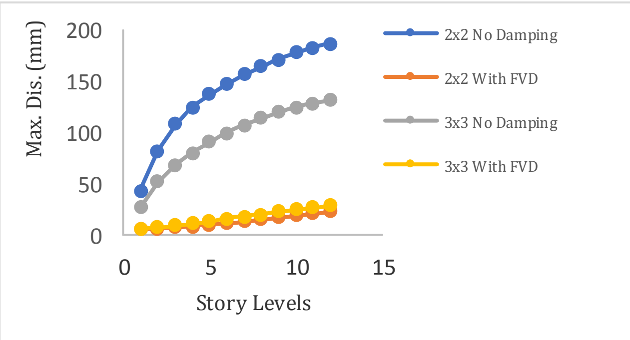

Fig.7: Comparison of Max. Story Displacement due to Push-x

Table 6: Max. Disp. of Modal at different stories due to Push-y

Story	2x2	2x2 (FVD)	3x3	3x3(FVD)
12	211.303	33.708	188.94	0.135
11	207.896	31.79	186.409	0.126
10	203.335	29.877	182.745	0.117
9	197.606	27.977	177.914	0.107
8	190.73	26.11	171.927	0.097
7	182.731	24.297	164.798	0.087
6	173.638	22.568	156.543	0.076
5	163.356	20.959	147.121	0.066
4	150.965	19.513	136.104	0.056
3	132.684	18.279	121.894	0.048
2	104.01	17.311	98.621	0.041
1	62.453	16.67	62.363	0.036
BASE	0	0	0	0

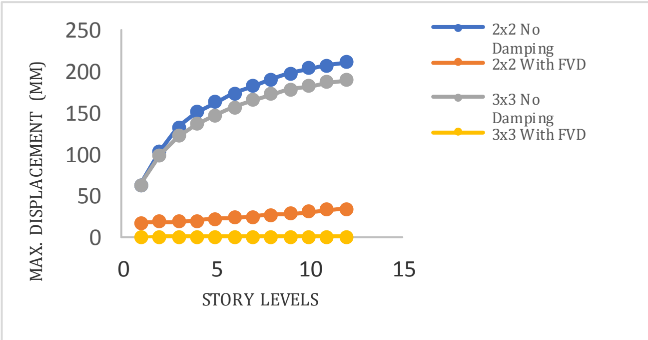

Fig.8: Comparison of Max. Story Displacement due to Push-y

5.4 Base reactions

Table 7: Base Reaction Comparison:

Load cases	2x2	2x2 (FVD)	3x3	3x3(FVD)
Th-x	1281.55	1088.39	1500.22	644.38
Th-y	1250.11	818.02	1349.19	539.77
Push-x	881.007	608.813	1608.82	1137.63
Push-y	681.899	599.049	1237.52	4.6258

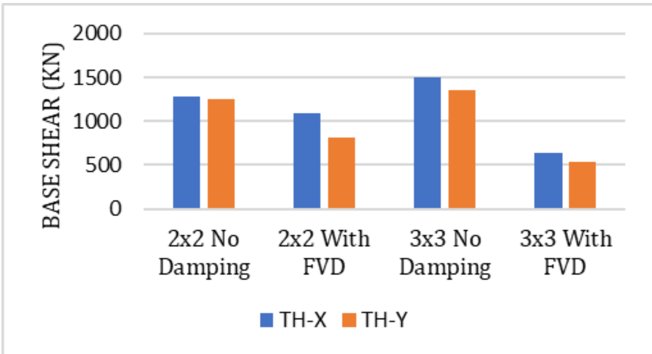

Fig.9: Comparison of Base Shear for Time History.

From the comparison values in figure 9, it can be clearly found that due to introduction of FVD in the structures the base shears have been diminish by around 20% for 2x2, 42% for 3x3 in TH-X/ X-direction. Similarly, the base shears have been reduced by around 33% for 2x2, 40% for 3x3 in TH-Y/ Y-direction.

From the correlation values in figure 10, it can be precisely found that due to installation of FVD in the structures the base shears have been minimized by 30% for 2x2, 30% for 3x3, in PUSH-X/ X-direction. Correspondingly the base shears have been reduced by 13% for 2x2, 99% for 3x3 in PUSH-Y/ Y-direction.

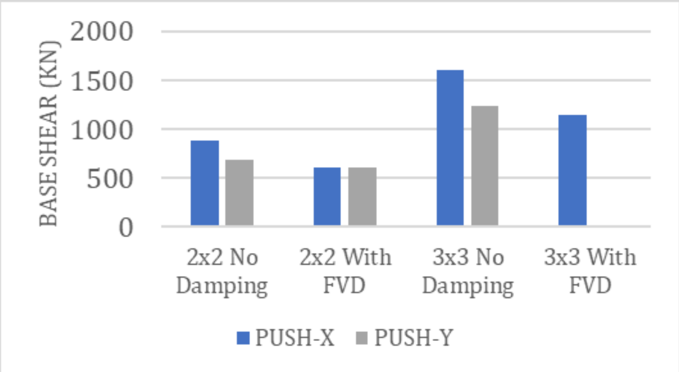

Fig.10: Comparison of Base Shear for Pushover

6. CONCLUSIONS

Based on the results and discussion given in chapter 5 the following conclusions are drawn.

- 80-90% decrease in Time period of maximum PSA in *Response spectrum* curves when FVD is used. FVD250 reducing the *Base Shear* of the structures 13-90% in Time history analysis. The top story *Displacements* are minimized by 90% with use of FVD. The increase of 80-90% are observed in *Eigen Values* shows the effective increment in the stiffness of the structure when FVD250 used for exterior corners.
- It is observed that symmetrical buildings are performing well in terms of response of the structure when compared to the unsymmetrical buildings irrespective of the floor plan.
- In evaluating the seismic performance of structures, the prediction of damage in structures is difficult to estimate by using the push-over analysis when compared with the Time history analysis.

6.1 Limitations to Conclusions:

- The following are the limitations have been considered while arriving to the conclusions.
- The following conclusions are limited to the context and comparative characteristics of FVD.
- Applied to other situations, these conclusions may yield incorrect solutions.
- These conclusions are relevant to the process of dwelling evolution in progressive development projects.
- Increasing the story levels or made any changes to properties may fetch different conclusions.
- Position of FVD also matters a lot when arriving at a particular solution.
- Using different cross section of members will change the results obtained from this study.

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