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# Seismic Response Study of Multi-Storied Regular and Irregular Reinforced Concrete Buildings with and without Fluid Viscous Dampers

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**ABSTRACT**
Damping Plays important role in design of Earthquake Resistant Structures, which reduces the response of the structure when they are subjected to seismic loads. There are many different types of dampers in use. In the present study Fluid Viscous dampers (FVD 500) are used to evaluate the response of Regular and Irregular RC buildings.
Our main task is to make the structure withstand the lateral loads and transfer them to the foundation. Ever since the lateral loads imposed on a structure are dynamic in nature, they cause vibrations in the building. In order to have earthquake resistant structures, fluid viscous dampers have been used at corners. Buildings having regular and irregular plans are analyzed, with and without FVD. In the present study the software ETABS 2016 have been used. Using Linear and Non Linear Analyses, the response of all 4 RC buildings considered in the present study is evaluated and compared with and without FVD at corners.
**Keywords –** Irregular Plan , Equivalent Static Analysis, Response Spectrum Analysis, Time History Analysis, Pushover Analysis, Fast Non Linear Analysis, Fluid Viscous Dampers, Earthquake Resistant Buildings.

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## I. INTRODUCTION

The viscous fluid dampers (VFD) are the more applied tools for controlling responses of the structures. These tools are applied based on different construction technologies in order to decrease the structural responses to the seismic excitation.

Though over the recent years heavy costs have been paid for accurate recognition of force of an earthquake in the research institutes of the world with the purpose of decreasing its damage, the increasing need for more research studies on the effects resulted from the earthquake is felt in the theoretical and laboratorial scales. Over the last fifty years, the earthquakes are categorized into two groups of near-field earthquakes and far-field earthquakes based on the distance of the place of recording the earthquake from the fault. Later, this definition was modified and other factors also influenced this categorization. Over the recent years, the research studies concentrated on the study of impacts of ground motion in the near-field earthquake on the structural performance. The devastative effects of the recent earthquakes such as Northridge earthquake (1994), Kobe earthquake (1995), and Taiwan earthquake (1999) on the buildings of the cities adjacent to fault, and with regard to the close location of many of the cities of India to the active faults indicate the significance of the research.

In last few years, many essential developments in seismic codes are turned up. Utmost of the modification in the seismic design area derive from greater awareness of actual poor buildings performances in contemporary earthquakes. Due to the renewed knowledge of the existing buildings behaviour, retrofit of buildings is a paramount task in reducing seismic risk. New techniques for protecting buildings against earthquake have been developed with the aim of improving their capacity. Seismic isolation and energy dissipation are widely recognized as effective protection techniques for reaching the performance objectives of modern codes. However, many codes include design specifications for seismically isolated buildings, while there is still need of improved rules for energy dissipation protective systems.

### 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

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.

### 1.3 SOURCES

The 4 different sources are Material Damping, Structural Damping, Radiation Damping and External Damping.

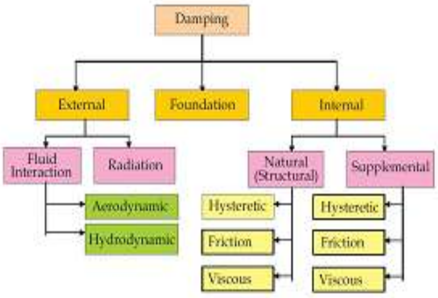


**Figure 1**: Sources of Damping.

### 1.3.1 Viscous Dampers

In this damper, by using viscous fluid inside a cylinder, energy is dissipated. Due to ease of installation, adaptability and coordination with other members also diversity in their sizes, viscous dampers have many applications in designing and retrofitting

These types of dampers are connected to the structure in three ways:

Damper installation in the floor or foundation (in the method of seismic isolation). Connecting dampers in stern pericardial braces. Damper installation in diagonal braces.In connecting dampers on the floor or foundation of structures, we can use a combination of dampers with isolators.

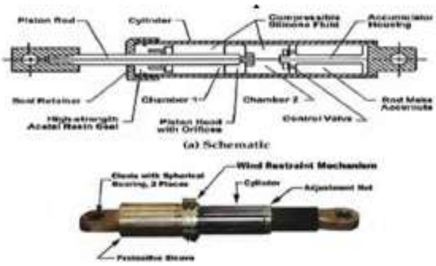


**Figure 2:** Longitudinal Section of Viscous Damper

## II. LITERATURE REVIEW

**V. Umachagi, K. Venkataramana, G. R. Reddy, and R. Verma** in "Applications of Dampers for Vibration Control of Structures: An overview" has briefly explained that Viscous dampers works based on fluid flow through orifices. Viscous damper is as shown in Fig.18 (Feng Qian et al., 2012) consisted viscous wall, piston with a number of small orifices, cover filled with a silicon or some liquid material like oil, through which the fluid pass from one side of the piston to the other. Stefano et al., 2010 have manufactured the viscous damper and it was implemented in 3 storey building structure for seismic control of structure with additional viscous damper. Attar et al., 2007 have proposed optimal viscous damper to reduce the interstory displacement of steel building.

**S. Amir and H. Jiaxin** in "Optimum Parameter of a Viscous Damper for Seismic and Wind Vibration" found that in most structures, even a relative low damping can also provide a significant energy dissipation which considerably decreases the vibration of a structure. The description in that explains how a nonlinear characteristic is required for a damping system to optimize the vibration of a simple moment frame.

**Y. Zhou, X. Lu, D. Weng, and R. Zhang** in "A practical design method for reinforced concrete structures with viscous dampers" shown how compared to the retrofitting technology of seismic isolation, the installation of viscous dampers to those existing buildings are more realistic because of easy construction. However, the design of viscous dampers, which provides a high level of damping in a structure, was relatively new application in China for a well-established and proven technology in other seismically active regions in the world.

**Özgur Atlayan** in 2008 "Effect of Viscous Fluid Dampers on Steel Moment Frame Designed for Strength and Hybrid Steel Moment Frame Design," Said, it was found that as the damping of the structure increases with the help of added dampers, the structural response gets better. Maximum and residual roof displacements, interstory drifts, and IDA (Incremental Dynamic Analysis) dispersion decreases with increasing damping. In addition, by using supplemental damping, most of the collapses that occur for the inherently damped frames are prevented.

### 2.1 CODAL PROVISIONS

**IS 1893:2002 (Part 1):** Criteria for Earthquake Resistant Design of Structures, Part 1: General Provisions and Buildings (Fifth Revision).

**IS 875 (Part 1, 2, 3and5):** Code of Practice for Design Loads (Other Than Earthquake) For Buildings and Structures.

Part 1: Dead Loads--Unit Weights of Building Materials and Stored Materials (Second Revision)

Part 2: Imposed Loads (Second Revision) by Bureau of Indian Standards (BIS)

Part 3: Wind Loads (Second Revision)

Part 5: Special Loads and Load Combinations (Second Revision).
**IS 4326:** Earthquake Resistant Design and Construction of Buildings--Code of Practice (Second Revision).
**IS 456:2000:** Plain and Reinforced Concrete - Code of Practice.
**SP 16:** Design Aids for Reinforced Concrete to IS 456.
**IBC-2006:** International Building Code, 2006 Edition, Published by the International Code Council, INC.
**ACI 318-14:** Building Code Requirements for Structural Concrete and Commentary

**2.2 SUMMARY**

This literature review shows the published papers till now on the issue of FVD with reference to their authors. It is briefly discussed about response of FVD on structural model, the analysis done using Etabs and the Codal provisions used in this thesis.

**2.3 OBJECTIVES**

- To compare the seismic response of buildings with regular and irregular building plans with and without FVD.
- To determine displacements variations in the structure due to introduction of FVD.
- To compare variations in base shear by using FVD in RC buildings.
- To study the variations in time period for different structures with and without FVD.
- To justify the effect of dampers in all building models considered.

## III. RESEARCH METHODOLOGY

**3.1 Equivalent static analysis**

The natural Period of the building is calculated by the expression t given in IS 1893:2002 where are h is the height and d is the base dimension of the building in the considered direction of vibration. Does the natural periods for all the models in this method is the same the lateral load calculation and its distribution around the height are done as per IS: 1893-1984 the seismic weight is calculated using full dead load + 50% of live load.

**3.2 Response spectrum analysis**

Response spectrum analysis of the building models is performed in on ETABS. The lateral load distribution generated by ETABS respond to the seismic zone 4 and the 5% damped response spectrum given in IS: 1893-2002. In Analysis only one invariant lateral load pattern was utilised to represent the likely distribution of inertia forces imposed on the frames during an earthquake and the utilised lateral load pattern is described as follows. Note that the story forces are normalised with the Base shear to have a total Base shear equals to Unity.

**3.3 Time history analysis/Fast Nonlinear Analysis (FNA)**

It is a modal analysis method useful for the static or dynamic evaluation of linear or nonlinear structural systems. Because of its computationally efficient formulation, FNA is well-suited for time-history analysis, and often recommended over direct-integration applications.

**3.4 Pushover Analysis**

Federal Emergency Management Agency (FEMA) and Applied Technical Council (ATC) are the two agencies which formulated and suggested the Non-linear Static Analysis or Pushover Analysis under seismic rehabilitation programs and guidelines. This included documents FEMA-356, FEMA-273 and ATC-40.

**3.4.1 Introduction to FEMA-356**

The primary purpose of FEMA-356 document is to provide technically sound and nationally acceptable guidelines for the seismic rehabilitation of buildings. The guidelines for the seismic rehabilitation of the buildings are intended to serve as a ready tool for design professional for carrying out the design and analysis of the buildings, a reference document for the building regulatory officials and a foundation for the future development and implementation of the building code provisions and standards.

**3.4.2 Introduction to ATC-40**

Seismic evaluation and retrofit of concrete buildings commonly referred to as ATC-40 was developed by the Applied Technology Council (ATC) with funding from California Safety Commission. Although the procedures recommended in this document are for concrete buildings, they are applicable to most building types.

Pushover analysis can be performed as either force control or displacement controlled depending on the physical nature of the Lateral load and behaviour expected from the structure force. Controlled procedure is useful when the load is known such as gravity loading and the structure is expected to be able to support the load. Displacement controlled procedure should be used when a specified source such as in seismic loading where the magnitude of the applied load is not known in advance or when the structure can be expected to lose strength or become unstable

## IV. MODELLING DESCRIPTION

| | |
|---|---|
| Live load | :4.0 kN/m$^2$ at typical floor |
| | : 1.5 kN/m$^2$ on terrace |
| Floor finish | : 1.0 kN/m$^2$ |
| Water proofing | : 2.0 kN/m$^2$ on terrace |
| Terrace finish | : 1.0 kN/m$^2$ |
| Zone Type | : Zone III |
| Earthquake load | : As per IS-1893 (Part 1) - 2002 |
| Depth of foundation below ground | : 2.4 m |
| Type of soil | : Type II, Medium as per IS:1893 |
| Floors | : Typical floor: 5 m, GF: 5 m |
| | : G.F. + 11 upper floors. |
| Ground beams | : To be provided at 100 mm below G.L. |
| | : 0.6 m |
| Plinth level Walls | : 230 mm thick brick masonry walls only at periphery. |
| Material Properties | Concrete All components unless specified in design: M30 grade |
| | Steel HYSD reinforcement of grade Fe 415 |
| Main beam | 450X900 |
| Sec beam | 350X700 |
| Column dimension | 1000X1000 |

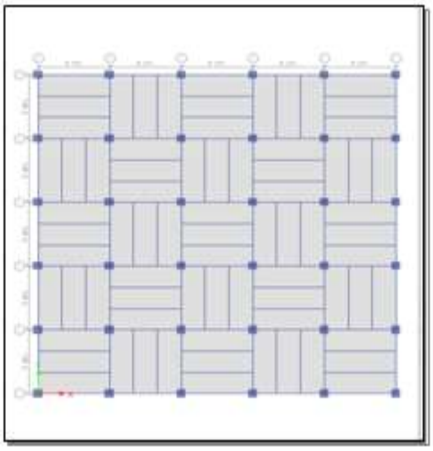

**Figure 3:** Plan of Regular Building Model

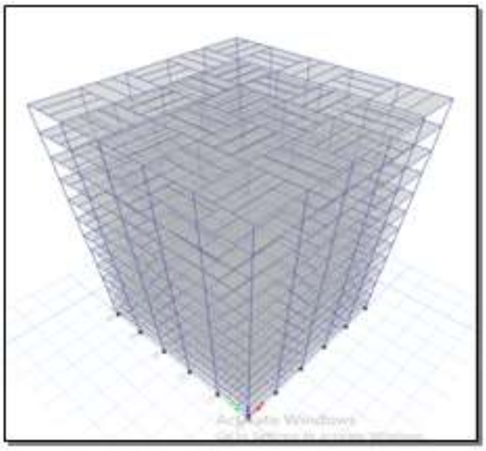

**Figure 4**: 3D View of Regular Building Model without FVD

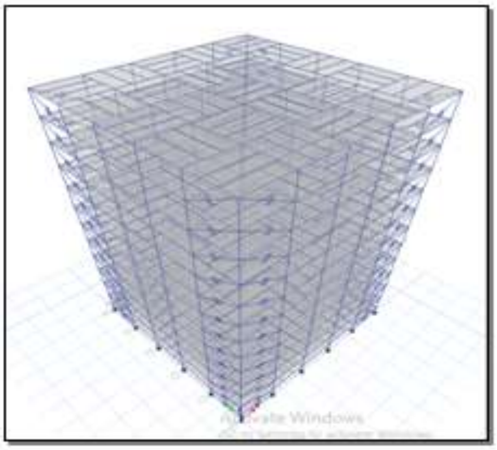

**Figure 5**: 3D View of Regular Building Model with FVD

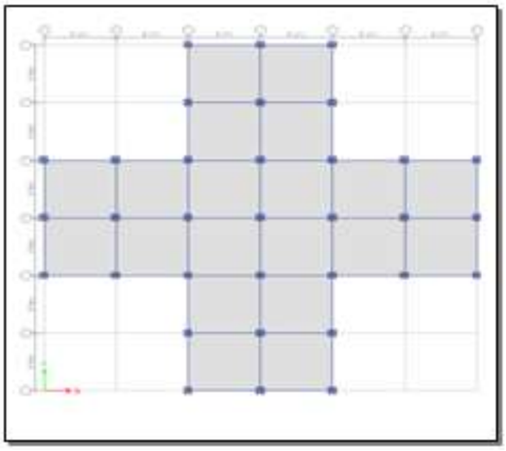

**Figure 6:** Plan of Irregular Building Model

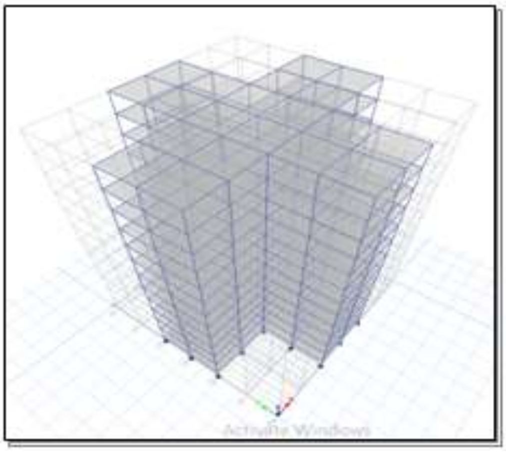

**Figure 7**: 3D View of Irregular Building Model without FVD

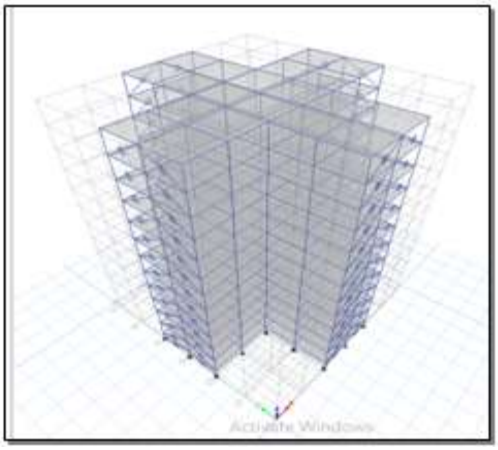

**Figure 8:** 3D View of Irregular Building Model with FVD

Types of Building Models considered:

- Regular Building without Dampers
- Regular Building with Dampers
- Irregular Building without Dampers
- Irregular Building with Dampers

## V. RESULTS AND DISCUSSIONS

### 5.1 Equivalent Static Analysis

#### 5.1.1 Modal Periods


**Figure 9:** Modal Periods

From above figure, we can observe that modal periods of buildings without dampers are higher than that of those with dampers. Similar performance is observed with Irregular buildings.

### 5.2 Response Spectrum Analysis

#### 5.2.1 Storey Displacements


**Figure 10:** Storey Displacements for regular buildings


**Figure 11**: Storey Displacements for Irregular buildings


**Figure 12:** Comparison of Storey Displacements for all buildings

The above plots shows the comparison of storey displacements for regular and irregular building models with and without dampers.
From fig 10, we can observe that displacements of regular building models with dampers are reduced by 60%.
From fig 11, we can observe that displacements of irregular building models with dampers are significantly reduced.
From fig 12, shows the displacements undergone by all 4 buildings.
We can observe that building models strengthened with dampers displaces significantly less than those buildings without dampers.

**5.2.2 Storey Drifts**


**Figure 13**: Storey Drifts for regular buildings

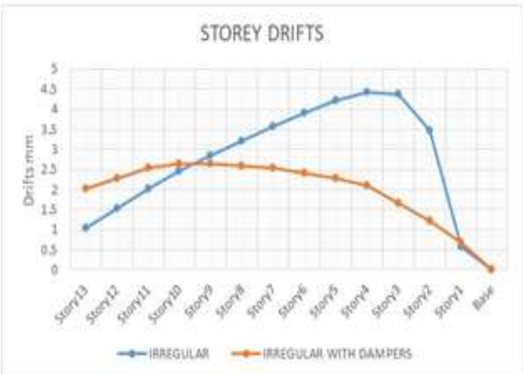


**Figure 14:** Storey Drifts for Irregular buildings


**Figure 15:** Comparison of Storey Drifts for all buildings

Storey Drifts is the relative motion of each storey with respect to its previous storey.
From fig 13, maximum storey drift occur at storey 5 in regular building and the drifts are controlled sufficiently when strengthened with FVD.
From fig 14, maximum storey drift occur at storey 4 in Irregular building and the drifts are controlled sufficiently when strengthened with FVD.
As evident from the fig 15, we can infer that building models strengthened with dampers drifted considerably less than those buildings without dampers.

**5.3 Time History Analysis/ Fast Non Linear Analysis**

**5.3.1 Response Spectrum Curves from Time History**

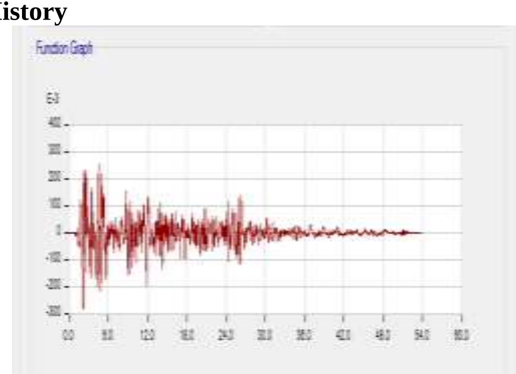


**Figure 16:** El Centro Earthquake Accelerogram

In this analysis, El Centro Accelerogram data have been utilised which can be helpful for predicting structural behaviour of buildings under actual earthquake.

The number of steps and step sizes has been considered as 1000 and 0.01 respectively. Hence, the result data is available up to 10 seconds only.
The figures below shows response spectrum plots obtained from time history results at a specified point for a specified time history load case.

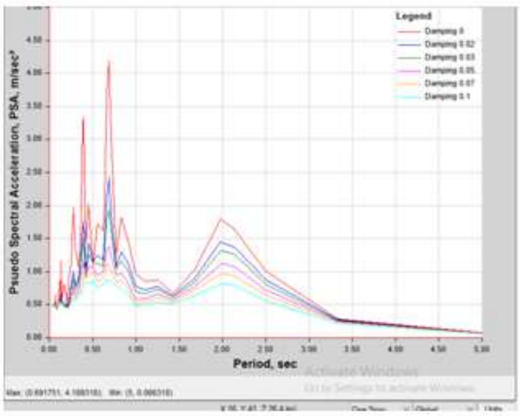


**Figure 17:** Regular Building RS Curves

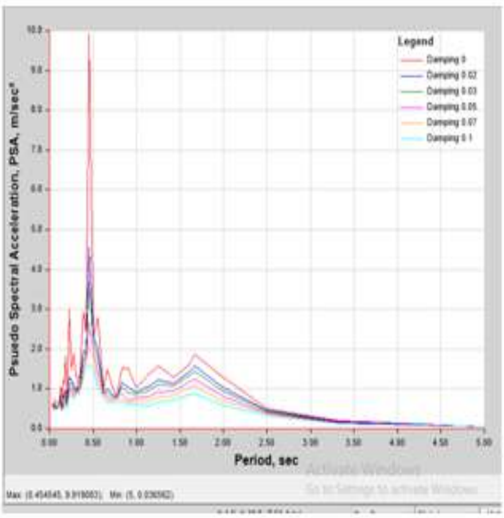


**Figure 18**: Regular Building with FVD RS Curves

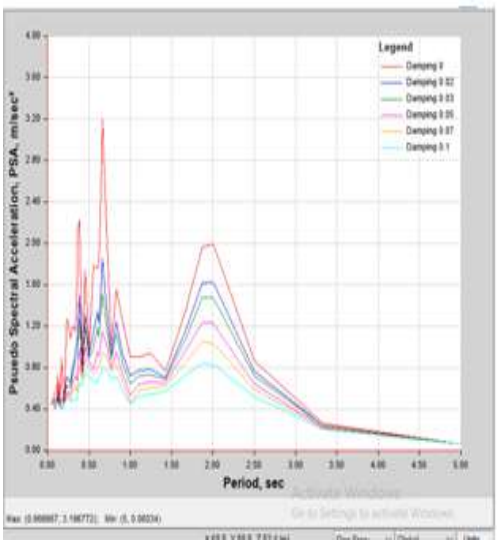


**Figure 19:** Irregular Building RS Curves

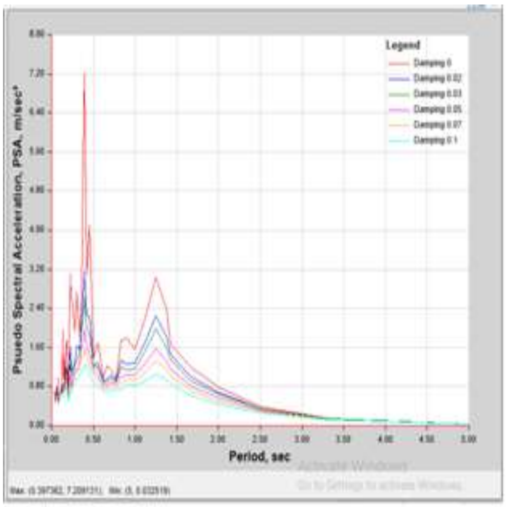


**Figure 20:** Irregular Building with FVD RS Curves

**TABLE 1**: MAXIMUM PSA AT ZERO DAMPING

| MAX VALUES | LOAD CASES DIRECTIONS | | | |
|---|---|---|---|---|
| | ELCENTRO X DIRECTION | | ELCENTRO Y DIRECTION | |
| MODEL TYPE | TIME PERIOD (sec) | PSA( m/sec$^2$) | TIME PERIOD (sec) | PSA( m/sec$^2$) |
| REGULAR NO DAMPERS | 0.692 | 4.19 | 0.692 | 4.19 |
| REGULAR WITH DAMPERS | 0.45 | 9.9 | 0.45 | 9.9 |
| IRREGULAR NO DAMPERS | 0.66 | 3.19 | 0.66 | 3.2 |
| IRREGULAR WITH DAMPERS | 0.39 | 7.2 | 0.39 | 7.2 |

Velocity and Pseudo-velocity response spectra are divergent for systems with long periods and high damping ratios, and are not exchangeable. Response spectrum values for high periods are very sensitive to source and site conditions.

It can be observed that buildings with FVD has low periodic values whereas buildings without FVD show long periodic values for maximum PSA with zero damping, which is sensitive. These structures show more than 50% decrease in periodic values when used with FVD for regular buildings and 70% for irregular buildings.

### 5.3 Pushover Analysis

Plot of base shear vs monitored displacement is known as pushover curve.

Here in this Pushover analysis, displacement controlled is performed.

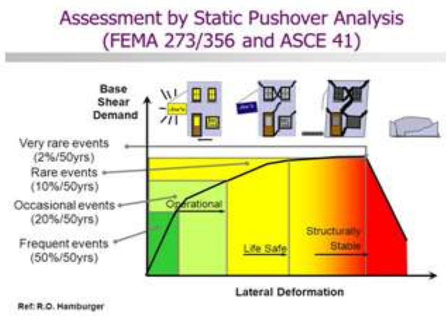


**Figure 21:** Pushover Curve

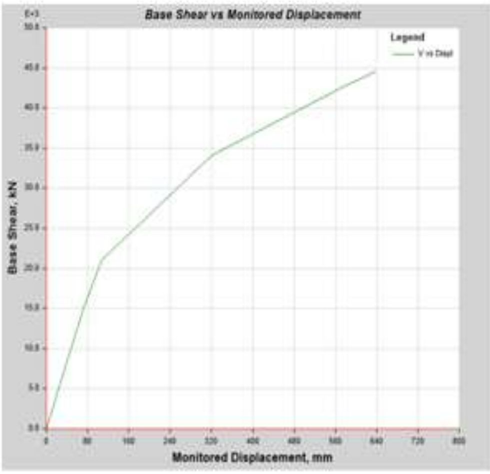


**Figure 22:** Pushover Curve for regular building without FVD


**Figure 23:** Pushover Curve for regular building with FVD

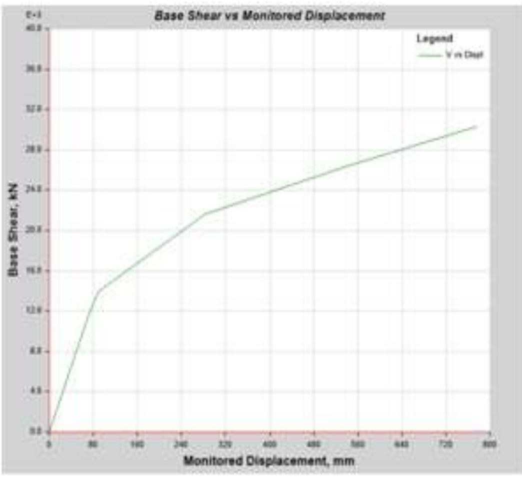


**Figure 24**: Pushover Curve for Irregular building without FVD

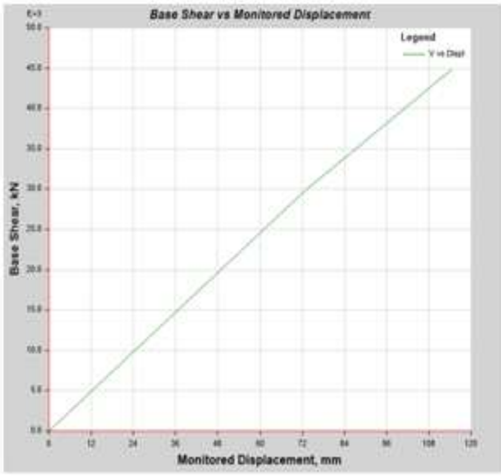


**Figure 25**: Pushover Curve for Irregular building with FVD

From figures 22 and 24, we can observe that buildings without FVD has deformed beyond yield point and it is on verge of collapse.
This proves to be dangerous for inhabitants to reside after earthquake.
Thus there is a strong need to retrofit / strengthen such buildings with lateral resisting systems like FVD.
Hence, after strengthening the building models with FVD, there is an improvement in performance in resisting lateral forces (as shown in fig 23 and 25).
Buildings with FVD are under operational category as per guidelines illustrated in fig 21.

## VI. CONCLUSION

Based on the results and discussion given in section 5 the following conclusions were drawn.

1) The modal periods of buildings without dampers are higher than that of those with dampers. Similar performance is observed with Irregular buildings.
2) Building models strengthened with dampers displaces significantly less than those buildings without dampers.
3) Building models strengthened with dampers drifted considerably less than those buildings without dampers.
4) Buildings with FVD has low periodic values whereas buildings without FVD show long periodic values for maximum PSA with zero damping, which is sensitive. These structures show more than 50% decrease in periodic values when used with FVD for regular buildings and 70% for irregular buildings.
5) It is observed that buildings with FVD are performing well in terms of response of the structure when compared to those without FVD.
6) 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.

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## **REFERENCES**.

[1]. M. R. Arefi, "A study on the damping ratio of the viscous fluid dampers in the braced frames," vol. 3, no. 4, pp. 1223–1235, 2014.

[2]. J. Marti, M. Crespo, and F. Martinez, "Seismic Isolation and Protection Systems," Seism. Isol. Prot. Syst., vol. 1, no. 1, pp. 125–140, 2010.

[3]. M. K. Muthukumar G, "Analytical modeling of damping," indian Concr. J., vol. 88, no. 4, 2014.

[4]. I. López, J. M. Busturia, and H. Nijmeijer, "Energy dissipation of a friction damper," J. Sound Vib., vol. 278, no. 3, pp. 539–561, 2004.

[5]. J. A. Inaudi and J. M. Kelly, "Mass Damper Using Friction-Dissipating Devices," J. od Eng. Mech., vol. 121, no. 1, pp. 142–149, 1995.

[6]. w. J. William H. Robinson, "Lead Damper for base isolution.pdf." Proceedings of 9th world conference on Earthquake, 1998.

[7]. J. Otten, J. Luntz, D. Brei, K. A. Strom, A. L. Browne, and N. L. Johnson, "Proof-of-Concept of the Shape Memory Alloy ReseTtable Dual Chamber Lift Device for Pedestrian Protection With Tailorable Performance," J. Mech. Des., vol. 135, no. 6, p. 61008, Apr. 2013.

[8]. D. Demetriou, N. Nikitas, and K. D. Tsavdaridis, "Semi active tuned mass dampers of buildings: A simple control option," Am. J. Eng. Appl. Sci., vol. 8, no. 4, pp. 620–632, 2015.

[9]. E. L. Anderson, "Performance-Based Design of Seismically Isolated Bridges," p. 494, 2003.

[10]. S. Infanti, J. Robinson, and R. Smith, "Viscous Dampers For High-Rise Buildings," 14th World Conf. Earthq. Eng., 2008.

[11]. V. Umachagi, K. Venkataramana, G. R. Reddy, and R. Verma, "Applications of Dampers for Vibration Control of Structures : an Overview," Int. J. Res. Eng. Technol., pp. 6–11, 2013.

[12]. J. Marko, D. Thambiratnam, and N. Perera, "Influence of damping systems on building 90 structures subject to seismic effects," Eng. Struct., vol. 26, no. 13, pp. 1939–1956, 2004.

[13]. V. S. Balkanlou, M. R. Bagerzadeh, B. B. Azar, and A. Behravesh, "Evaluating Effects of Viscous Dampers on optimizing Seismic Behavior of Structures," no. 2007, 2013.

[14]. A. Chopra, "Dynamics of structures," 2012.

[15]. K.-H. Chang, Structural Analysis, vol. 163. 2009.

[16]. Y. G. Zhao and T. Ono, "Moment methods for structural reliability," Struct. Saf., vol. 23, no. 1, pp. 47–75, 2001.

[17]. M. Paz, "Structural Dynamics.pdf." Van Nostrand Reinhold Comapany, NYC., p. 574, 1985.

[18]. S. Amir and H. Jiaxin, "Optimum Parameter of a Viscous Damper for Seismic and Wind Vibration," vol. 8, no. 2, pp. 192–196, 2014.

[19]. Y. Zhou, X. Lu, D. Weng, and R. Zhang, "A practical design method for reinforced concrete structures with viscous dampers," Eng. Struct., vol. 39, pp. 187–198, 2012.

[20]. Ö. Atlayan, "Effect of Viscous Fluid Dampers on Steel Moment Frame Designed for Strength and Hybrid Steel Moment Frame Design," Environ. Eng., 2008.

[21]. B. S. Taranath, Reinforced Concrete Design of Tall Buildings. .

[22]. LIYA MATHEW & C. PRABHA, "Effect of Fluid Viscous Dampers in Multi-Storeyed Buildings," IMPACT Int. J. Res. Eng. Technol. (IMPACT IJRET), vol. 2, no. 9, pp. 59–64, 2014.

[23]. R. Gettu and M. Santhanam, "Retrofit of non-engineered buildings," Handb. Seism. retrofit Build., no. April, p. 471, 2007

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