Comparative Study on Seismic Analysis of Irregular Tall Buildings with Varied Location of Fluid Viscous Damper

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Abstract - *Scarcity of space in metropolitan habitation, along with cost effectiveness, makes presence of high rise structures inevitable. But these high rise structures are more susceptible to significant lateral loads arising from earthquake loading. The response of structure to such loads in form of story displacement, story drift, overturning moment, base shear etc. is profound in high rise structures as compared to lower ones. A structure's primary function is to bear lateral loads and move them to the base. The dynamic nature of the lateral loads placed on a structure causes vibration within the structure. Fluid viscous dampers are used to make the structure earthquake resistant. Within the wider context of energy dissipation systems for structures, fluid viscous dampers (FVDs) are well established devices frequently adopted in earthquake-prone areas. This research consists of comparative analysis of tall building like G+30, G+40 G+50 story height and at different location with and without fluid viscous damper to identify different structural responses. In this study, different plan irregularity like L shape and C shape of the building is carried out. Time history analysis is considered for this study.*

Key Words: Fluid Viscous Damper, Plan Irregularities, ETABS, Time history analysis, Seismic response parameters.

1. INTRODUCTION

In our cutting edge times, as the inescapable consequence of developing populace and escalating urbanization, skyscraper private and business structures have gotten more predominant in numerous urban communities, supplanting immense spaces of vernacular houses. According to council on tall buildings and urban habitat (CTBUH), in view of tallness the structure it tends to be characterized into 'tall building' (<300m height), 'super tall building' (>300m but <600m), 'mega tall building' (>600m). The most recent twenty years have seen a prominent expansion in the pace of development of tall structures due to essentially scarceness of land around there, more noteworthy interest for business and private space, prudent rise, specialized headways, notoriety and human aspirations to fabricate higher. Engineers face new challenges as a result of them, especially in the areas of structural and geotechnical design.

1.1 Seismic Control Systems

In earthquake-resistant architecture, various types of seismic control systems are used to reduce the impact of earthquake forces on the main structural structure. Passive, active, and hybrid seismic control systems are the three main categories of seismic control systems.

1. Passive seismic control system
   - Energy Dissipation Devices
   - Base Isolation System
   - Dynamic Oscillators

2. Active Seismic Control System
   - Energy Dissipation Devices
   - Base Isolation System
   - Dynamic Oscillators

3. Hybrid Seismic Control System
   - Energy Dissipation Devices
   - Base Isolation System
   - Dynamic Oscillators

1.2 Damper

Damper devices capture seismic energy and reduce deformations in the building, thus protecting structural integrity, controlling structural losses, and preventing injury to inhabitants. Seismic dampers enable the system to withstand high input energy and reduce structural and occupant deflections, pressures, and accelerations. Viscous dampers, inertia dampers, yielding dampers, magnetic dampers, and tuned mass dampers are all examples of seismic dampers.

1.3 Fluid Viscous Damper

High-capacity fluid dampers have made the transition from defensive systems to industrial applications on buildings and bridges exposed to seismic and/or windstorm inputs in structural engineering. Because fluid damping technology has been proven to be extremely reliable and robust over decades of Cold War use, commercial structures have been quickly adopted.

The term "damping" in the context of a structural structure can mean different things to different engineers. To a civil engineer, damping may simply refer to a reference note on a seismic or wind spectral map, the most common notation being "5% damped spectra." Damping is described by structural engineers as variations in overall stress within a structure subject to shock and vibration, with regular debates about whether a structure can have “2%, 3%, 4%, but not more than 5%” structural damping.

As a result of these definitions, a damper is an aspect that can be applied to a device to provide forces that are resistive to motion, allowing energy to be dissipated. Alternatively, damping can be described as the property of a dynamic system that causes the amplitude of oscillation to decrease. Fluid viscous dampers work by applying a restraining force only while the fluid is flowing. They do not bring any stiffness to a frame and do not support any static loads.

Seismic energy is captured by silicone-based fluid flowing between piston-cylinder arrangements in viscous dampers. In earthquake zones, viscous dampers are used in high-rise structures. It can work in temperatures ranging from 40 to 70 degrees Celsius. Vibrations caused by heavy winds and earthquakes are reduced by a viscous damper.

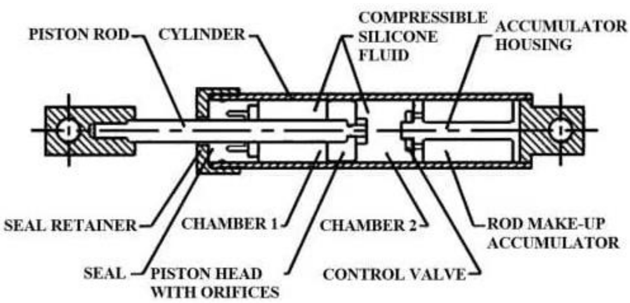

Fig -1: Schematic detailing of fluid viscous damper components

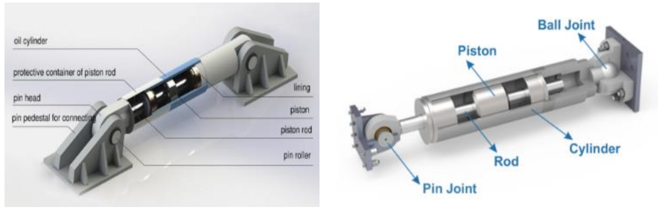

Fig -2: 3D Image of Fluid Viscous Damper

2. AIM, OBJECTIVE & SCOPE OF WORK

2.1 Aim of Work

The aim of my work is “Comparative Study on Seismic Analysis of Irregular Tall Buildings with Varied Location of Fluid Viscous Damper”

2.2 Objective of study

The main objective of present work is as follows:

- To study the seismic responses of structure with and without Fluid Viscous Damper installed at various locations of tall building using standard analysis software ETABS.
- To check the effectiveness and optimum location of the Fluid Viscous Dampers and compare the result of the seismic responses such as story drift, story displacement and time period.

2.3 Scope of Work

- RC-framed tall buildings with G+30, G+40, and G+50 stories are considered for analysis.
- The fluid viscous damper is located at corner, center and alternate center position.
- L shape and C shape plan irregularities are carried out for RC frame tall building.
- To compare the seismic response of RC frame buildings with and without fluid viscous dampers at different structural locations.
- ETABS, a computer program, is used to conduct the analysis.
- IS 1893 Part-1:2016 and IS 16700:2017 guidelines being followed.
- A time-history analysis is being conducted.
- The study considers seismic zone V and soil type medium.
- To compare the outcomes of all models for different seismic responses such as story displacement, story drift and time period.

3. RESEARCH GAP

From the literature review, the research can also be done by using with and without Fluid Viscous Damper at varied location of the building at different story. As this damper is not used for Tall Building like G+30, G+40 and G+50 story with different type of plan irregularity like L shape and C shape of plan from which the various seismic responses can be evaluated.

4. BASIC DESIGN DESCRIPTION

A fluid damper has a small number of critical design elements. The detailing of these elements, on the other hand, differs considerably and can be both difficult and complex in some instances. A standard fluid damper and its components are shown in Figure 3.

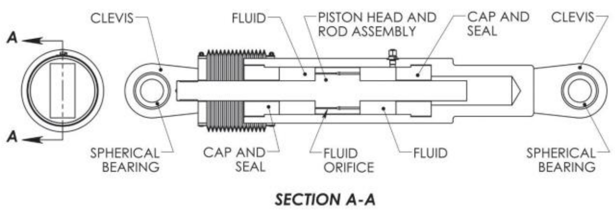

Fig -3: Typical Fluid Viscous Damper & Parts

Figure 3 depicts the Damper in its mid-stroke role. The Cylinder is the name given to the main pressure chamber (not labeled). The volumes on both sides of the Piston Head are full of fluid. The Piston Rod connects the Piston Head to the Piston Rod. A Clevis is located on the Piston Rod's left end for attachment to the structure. This Clevis, the Piston Rod, and the Piston Head all shift together when the damper reciprocates during a complex case. Many of the other components remain in place. The Fluid on either side of the Piston Head is squeezed into orifices in the Piston Head as it passes.

A Cap and Seal on the left side of the Cylinder encapsulates the Fluid from static and dynamic friction. Another Cap and Seal can be found on the right side of the Cylinder. When one end of the Piston Rod pushes into the Cylinder, the other moves back, ensuring fluid volume conservation and preventing static pressure build-up. Spherical bearings are commonly used in both Clevises to compensate for any misalignment with the surrounding structure.

5. ANALYSIS METHODOLOGY IN ETABS

The analysis was carried out by considering different parameters to understand the behavior of fluid viscous damper with plan irregularities. A tall building G+30, G+40 and G+50 story buildings with FVD are modelled. The analysis is carried out on the 42 models using time history analysis in ETABS 2017. IS 1893:2016 codal provisions is considered for the analysis. The plan dimensions considered for analysis are L shape building has 40m x 40m and C shape building has 40m x 40m. Each bay having 5 m span in both directions.

6. MODEL DATA

Table -1: Model data for G+30

Description	MODEL L SHAPE	MODEL C SHAPE
Material Property		
Concrete Grade	M35	M35
Steel Grade	Fe500	Fe500
Building Data		
story	G+30	G+30
story Height	3 m	3 m
Beam Size (mm)	300x750	300x750
Column Size (mm)	900x900, 750x750, 500x500	900x900, 750x750, 500x500
Slab thickness (mm)	150 mm	150 mm
Seismic Parameters		
Seismic Zone	zone - V	zone – V
Soil type	Type II	Type II
Importance factor	1	1
Response reduction factor	5	5
Loading Data		
Floor Finish at typical floor	1.5 KN/m^2	1.5 KN/m^2

Table -2: Model data for G+40

Description	MODEL L SHAPE	MODEL C SHAPE
Material Property		
Concrete Grade	M40	M40
Steel Grade	Fe500	Fe500
Building Data		
story	G+40	G+40
story Height	3 m	3 m
Beam Size (mm)	300x750	300x750
Column Size (mm)	900x900, 750x750	900x900, 750x750

Table -3: Model data for G+50

Description	MODEL L SHAPE	MODEL C SHAPE
Material Property		
Concrete Grade	M40	M40
Steel Grade	Fe500	Fe500
Building Data		
story	G+50	G+50
story Height	3 m	3 m
Beam Size (mm)	300x750	300x750
Column Size (mm)	900x900	900x900

Table -2: Damper Parameters in ETABS

Fluid viscous damper Parameters	
Mass	44kg
Weight	250kN
Nonlinear Properties	
Stiffness	857485.85 kN/m
Coefficient of damping	2791 kN*(s/m)^Cexp
Damping exponent	0.5

[**Note:** This values are taken from Taylor Devices inc.][9]

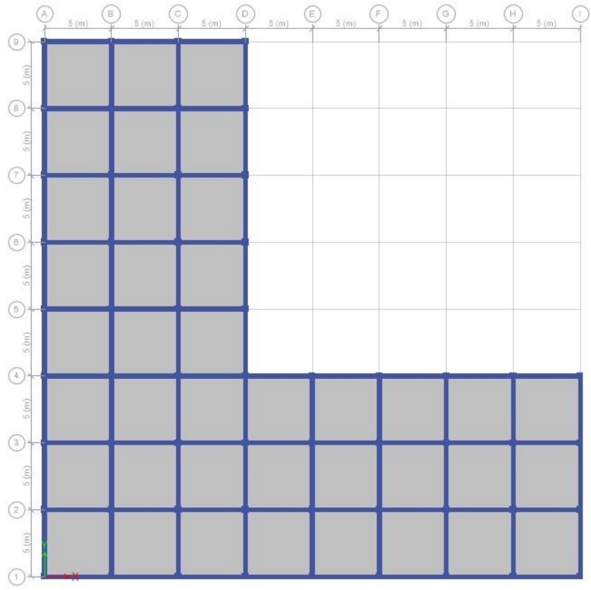

Fig -4: L Shape Plan

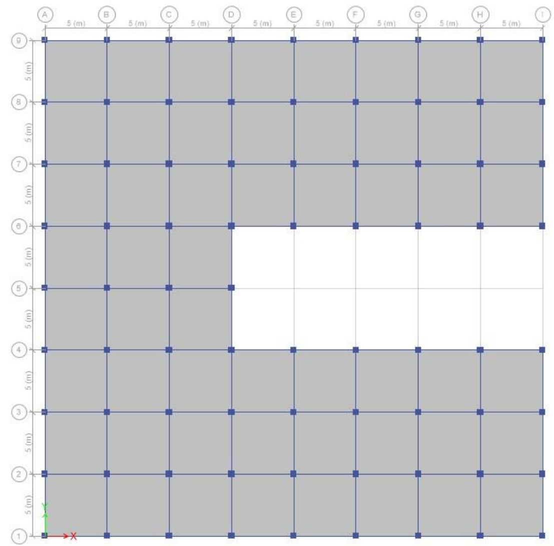

Fig -5: C Shape Plan

6.1 Damper Position in ETABS software

Without damper

Damper at all external corner (zigzag)

Damper at center (zigzag)

Damper at center alternate (zigzag)

Damper at all external corner (diagonally)

Damper at center (diagonally)

Damper at center alternate (diagonally)

7. RESULTS

7.1 G+30 L Shape

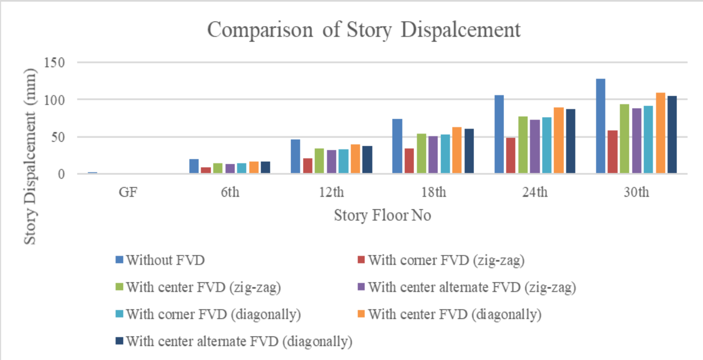

Chart -1: Story Displacement of G+30 L Shape

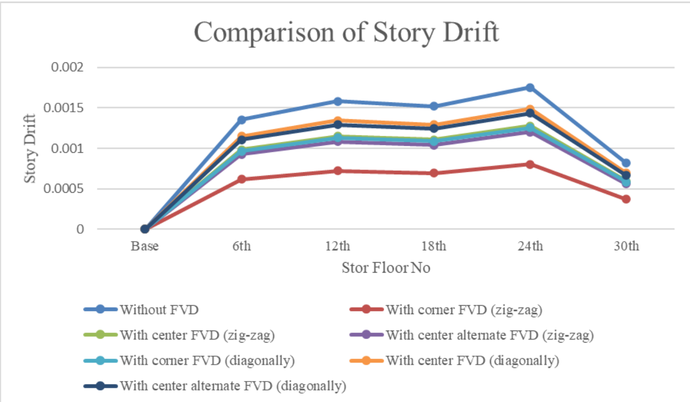

Chart -2: Story Drift of G+30 L Shape

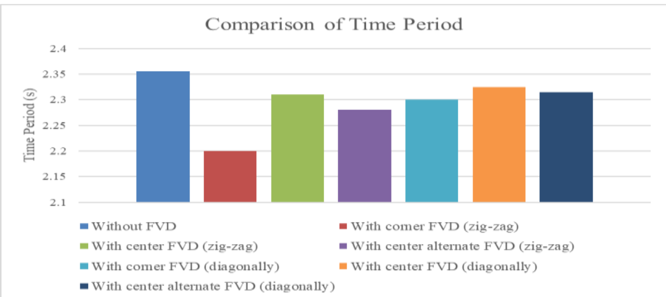

Chart -3: Time Period of G+30 L Shape

7.2 G+30 C Shape

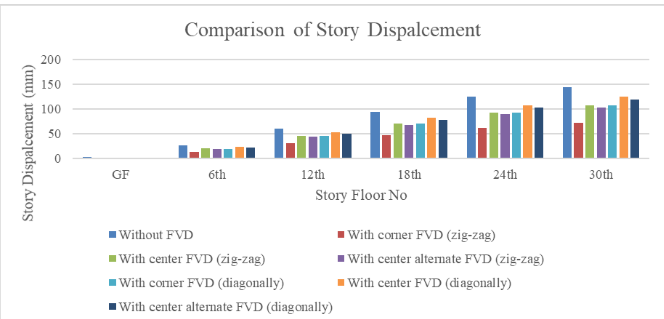

Chart -4: Story Displacement of G+30 C Shape

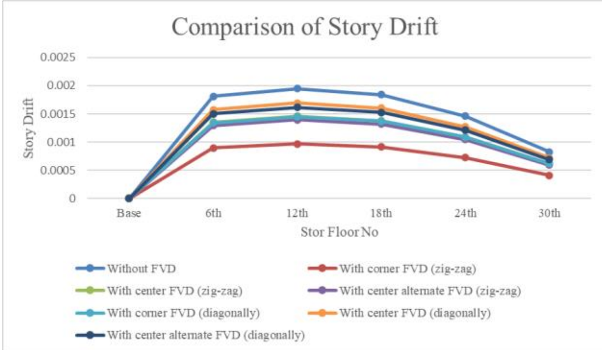

Chart -5: Story Drift of G+30 C Shape

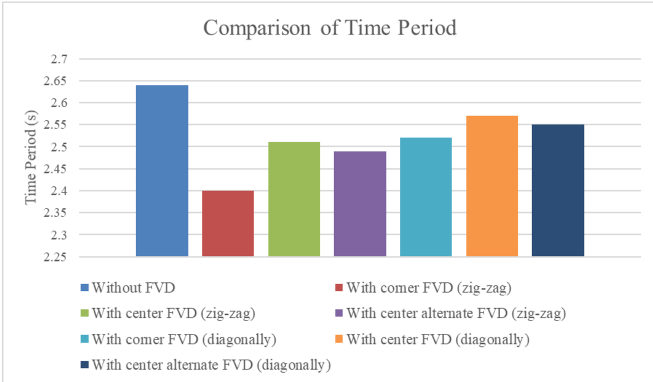

Chart -6: Time Period of G+30 C Shape

7.3 G+40 L Shape

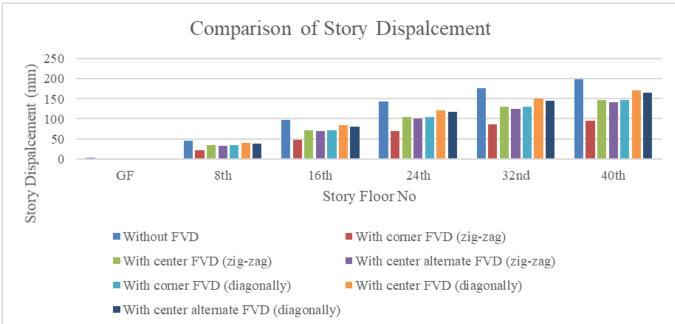

Chart -7: Story Displacement of G+40 L Shape

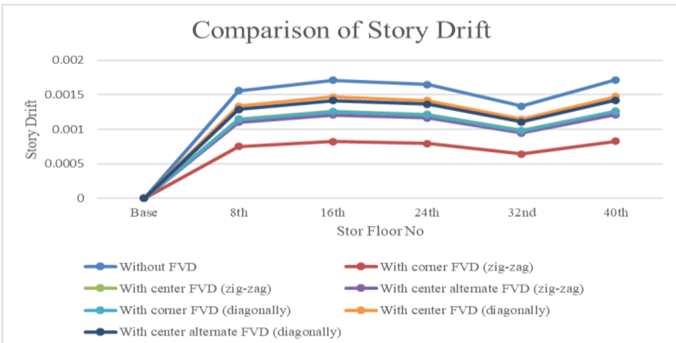

Chart -8: Story Drift of G+40 L Shape

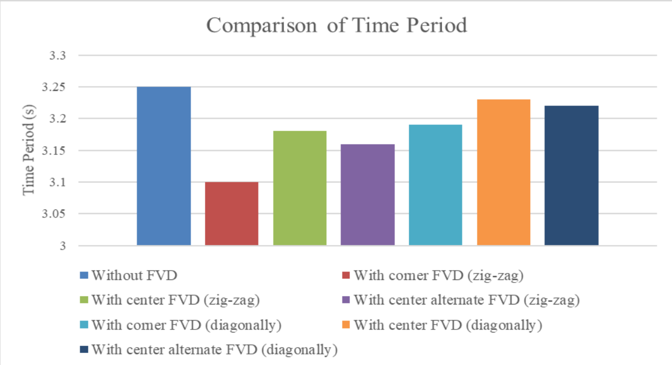

Chart -9: Time Period of G+40 L Shape

7.4 G+40 C Shape

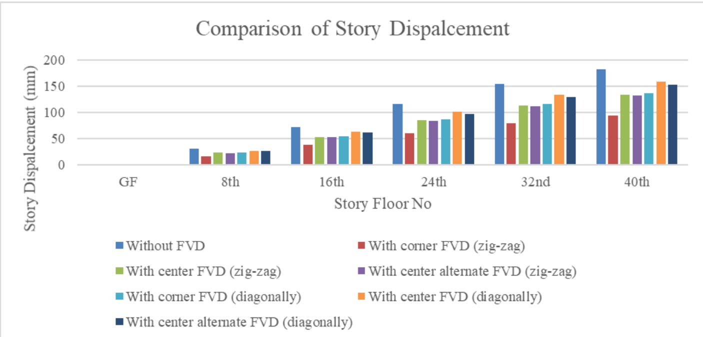

Chart -10: Story Displacement of G+40 C Shape

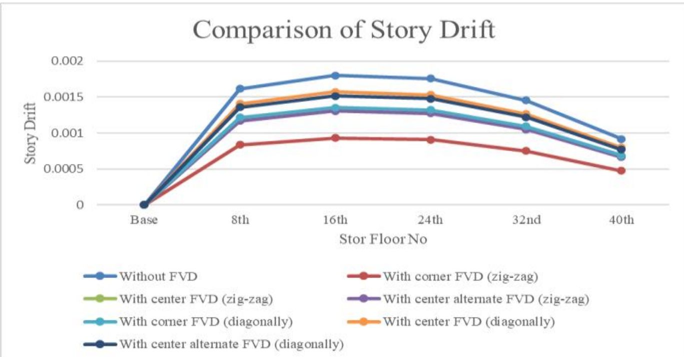

Chart -11: Story Drift of G+40 C Shape

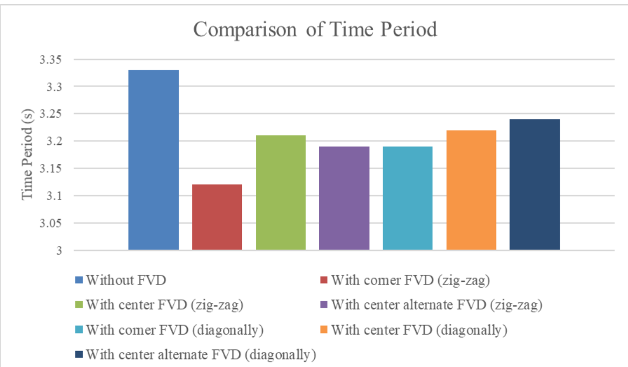

Chart -12: Time Period of G+40 C Shape

7.5 G+50 L Shape

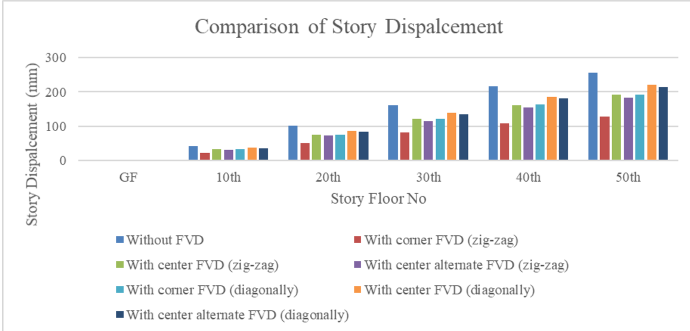

Chart -13: Story Displacement of G+50 L Shape

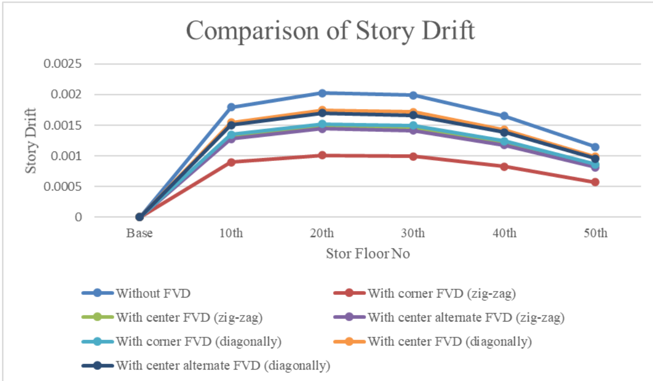

Chart -14: Story Drift of G+50 L Shape

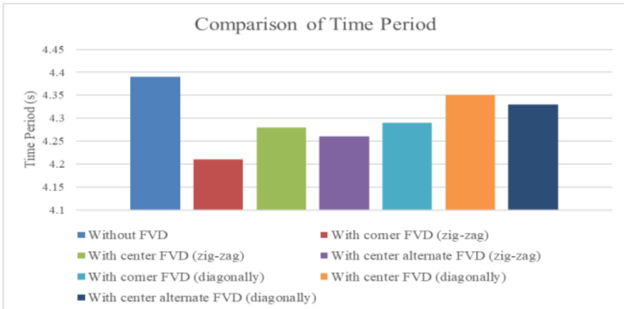

Chart -15: Time Period of G+50 L Shape

7.6 G+50 C Shape

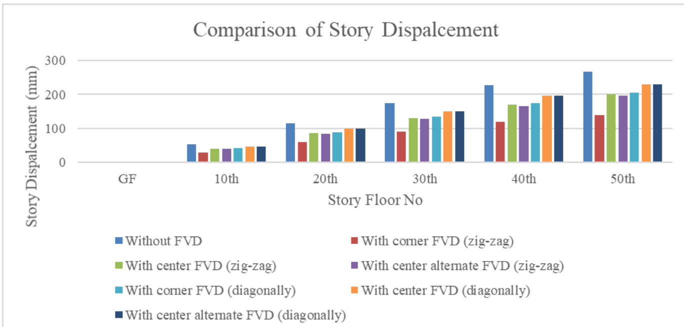

Chart -16: Story Displacement of G+50 C Shape

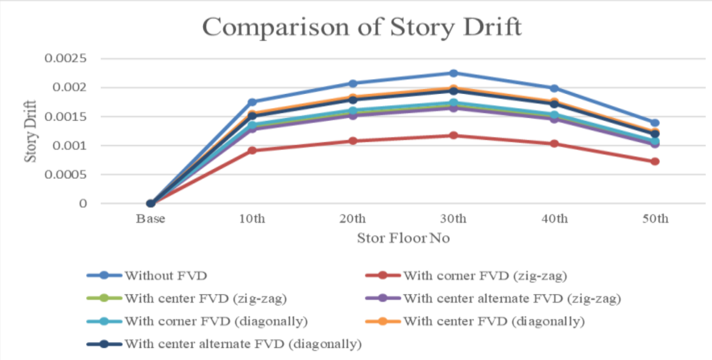

Chart -17: Story Drift of G+50 C Shape

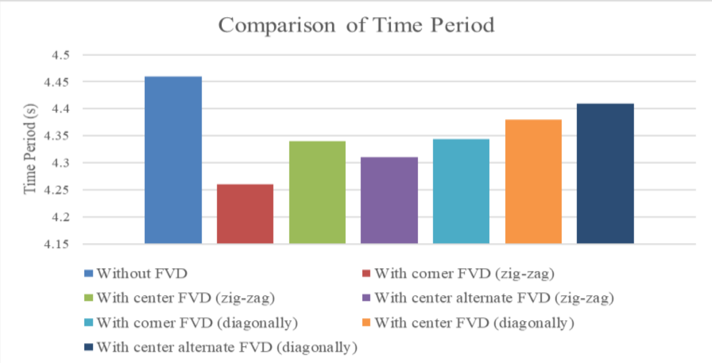

Chart -18: Time Period of G+50 C Shape

8. CONCLUSIONS

The main observations and conclusions are summarizedbelow.

1. From the study, it is observed that the fluid viscous damper installed at different building locations displays significant improvements in seismic parameters such as displacement, drift and time period.
2. The fluid viscous damper provided in zigzag pattern gives good result compared to which provide as diagonally way.
3. When FVD are provided in all external corner of floor in a zigzag pattern, story displacement is reduced by up to 54% compared to FVD provided in diagonally pattern is up to 29%
4. When FVD are provided at center of the building in a zigzag pattern, story displacement is reduced by up to 28% compared to FVD provided in diagonally pattern is up to 15%.
5. When FVD are provided at center alternate position of the building in a zigzag pattern, story displacement is reduced by up to 32% compared to FVD provided in diagonally pattern is up to 19%.
6. Story drift is also decreased up to 60% when FVD provided at all external corner of the building.
7. Around 20% time period was decreased when FVD provided in the building.
8. Based on the findings, it is clear that any high-rise building located in an earthquake-prone area needs to properly implement and install a damper to minimise the building's damage.

REFERENCES

[1] Kumar PS, Naidu MV, Mohan SM, Reddy SS. "Application of Fluid Viscous Dampers In Multi-Story Buildings. Application of Fluid Viscous Dampers In Multi-Story Buildings" International Journal of Innovative Research in Science, Engineering and Technology (IJIRSET). ISSN 2016:17064-9

[2] Sahu G, Sahu P. "Comparative Analysis Of Effects Of Base Isolator & Fluid Viscous Damper On Response Of A Rcc Structure" International Research Journal of Engineering and Technology (IRJET). e-ISSN 2019: 2395-0056

[3] Sherin P. Samuel, Surya Sasidharan. "Seismic Analysis Of Buildings Using Fluid Viscous Damper" International Journal Of Engineering Sciences & Research

[4] Almajhali KY, Xu B, Meng Q. "Seismic Response Evaluation of High-Rise Building with and Without Fluid Viscous Damper". American Journal of Civil Engineering (ASCE). ISSN:2018 Dec 24;6(5):167-77

[5] Balkanlou VS, Karimi MR, Azar BB, Behravesh A. "Evaluating effects of viscous dampers on optimizing seismic behavior of structures". International Journal of Current Engineering and Technology(IJCET). ISSN:2015 Oct;3(4):1150-7

[6] IS 16700: 2017, "Criteria for Structural Safety of Tall Concrete Buildings", New Delhi.

[7] IS 1893(Part 1): 2016, "Criteria for Earthquake Resistant Design of Structures", New Delhi.

[8] IS: 875(Part-3)-1987, "Code of practice for design loads (other than earthquake) for buildings and structures, wind loads". Bureau of Indian Standard, New Delhi.

[9] Taylor Devices inc. Fluid Viscous Dampers General Guidelines for Engineers Including a Brief History.

[10] NEHRP Guidelines for The Seismic Rehabilitation of Buildings Federal Emergency Management Agency, FEMA273