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Effect of Viscoelastic dampers on Earthquake Resistance of High-Rise Building

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Abstract – Construction of high-rise buildings has become a fundamental part of planning modern cities to overcome rapid urbanization. They serve as multifunctional hubs for commerce, trading, residential living and social interaction by optimizing the land use in densely populated areas. Over the time, the intensity of earthquakes has been increased, therefore the HRB's designed for seismic loadings in the past may be vulnerable to the earthquakes in the near future. Apart from various techniques for fortification of existing structures against earthquakes, the current study aims to investigate the impact of application of Viscoelastic dampers on existing HRB's as a retrofitting measure against seismic loadings. To arrive at a conclusion, the study compares the seismic performance of a 40 story HRB with and without viscoelastic dampers. Nonlinear viscous dampers have been used in the current study. The effect of viscous dampers against seismic zone 2-B has been investigated in terms of the seismic parameters which are structure acceleration, story drifts, story displacements and energy dissipations. Adding the non-linear Viscoelastic Dampers (VEDs) in the structure caused a decreased the inter-story drift. Moreover, there has been a significant increase in the energy dissipation by the structure. Most of this energy is observed to be dissipated by the VEDs. The findings demonstrate that integrating non-linear Viscoelastic dampers into the current structure significantly improved the system's effectiveness in reducing undesired vibrations. This study's findings provide useful insights into applying non-linear visco elastic dampers to improve the seismic performance of existing buildings, as well as guidance for developing effective techniques to lessen the impact of seismic events on pre-existing structures.

Keywords – Retrofitting, Nonlinear Visco Elastic Dampers And Structural Acceleration.

I. INTRODUCTION

An earthquake is a quick, fast shaking of the surface of Earth, caused by an unexpected release of energy held inside the Earth's crust [1]. This energy accumulates over time as tectonic plates move and friction occurs. When these plates abruptly shift past one other, the collected energy is released, causing an earthquake [2]. This energy when released after relative displacements of rocks about a fault plane spreads radially in the form of seismic waves [1]. Seismic response of buildings is of utmost importance to the structural engineers because earthquakes have posed a great threat to the human infrastructure in the past [3]. Such events have not only cost us economically, but have also resulted into large number of causalities. Over the last century, earthquakes have claimed the lives of more than 2.32 million people. Aside from the devastating fatalities, these catastrophes have far-reaching economic consequences. Earthquakes cost more than $3.5 trillion USD globally, including damage to buildings and infrastructure, as well as economic disruptions [4]. Several guidelines and codes have been established to improve earthquake resistance in the construction industry. The ultimate goal of these guidelines is to improve public safety and mitigate the harmful effects of seismic activity on both people and the economy [5-7]. Over the past years, construction of high rise buildings has become increasingly popular because they provide a large amount of occupancy on a limited land while also benefiting from design and energy efficiency [8]. As HRB's are built to reach greater heights and have more thin profiles, analyzing their dynamic behaviour becomes an increasingly important part of the design process. Taller and thinner structures are more vulnerable to dynamic forces like wind and seismic activity [9]. Advances in construction industry have resulted in buildings that are strong but flexible. However, this flexibility may cause buildings to vibrate when subjected to wind or earthquakes loadings, causing considerable damage and discomfort for residents [10]. Developing nations are more vulnerable to earthquakes because of their low resources and weak infrastructure. When an earthquake happens, the extent of destruction is substantially higher in underdeveloped places because poorly designed structures are more prone to collapse, resulting in more deaths and considerable damage [11-13]. Pakistan being an underdeveloped country and lying within the seismically active region is prone to frequent earthquakes activities [14]. It has been through multiple severe earthquake events in its history. For example, the 2005 earthquake was amongst the deadliest seismic events, resulting into massive loss of life and property [15]. Despite these events, the trends for HRB's construction in Pakistan have been increasing in the metropolitan cities [16]. This is due to rapid increase in population and flawed policies to reduce urban sprawl, resulting into congestion and reduced land [17, 18]. Hence, conducting research to identify effective solutions for lowering the risk of building damage and fatalities due to earthquakes is critical for Pakistan

II. **MATERIALS AND METHOD**

A. *Site selection and Case study building*

For the current study, a shallow stiff soil has been selected in Islamabad. The case study building chosen is a G+40 commercial building with a total height of 473.73 ft. For a non-linear time-history analysis of the case building, CSI ETABS is used. Two finite element models were created, one with viscous dampers and one without viscous dampers as shown in figure 5. The salient features of the building are represented in the table 1. The actual number of stories of the selected case study building is 12. However, for the research purposes, model of the selected building was then replicated to 40.. The seismic details of the selected site as per UBC 97 are given in the table 2.

Table 1. Building Specfications

Specification	**Sizes**
Building Size	80 ft x 120 ft
Total Height	473.73 ft
Number of Stories	G+40
Beam Sizes (in.)	(9 x 24), (12 x 24)
Column Sizes (in.)	(30 x 30), (12 x 12)
Slab Thickness (in.)	6, 9

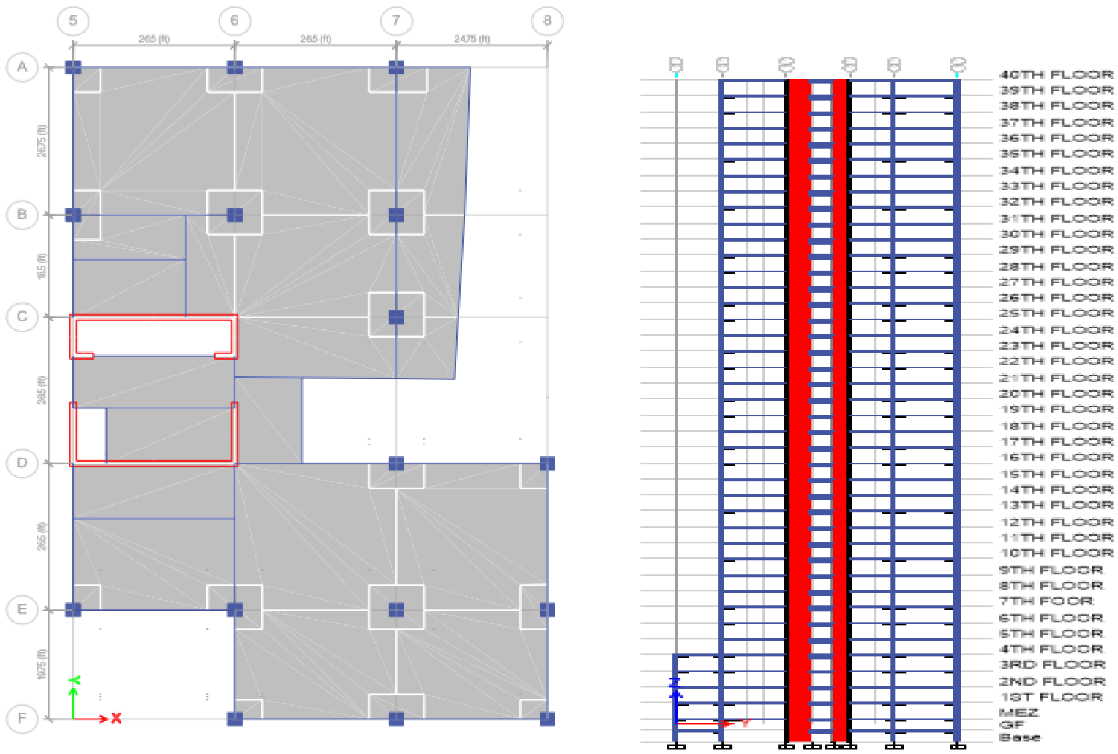

Fig. 1 Plan and Elevation of Building

B. *Ground Motion and Seismology of Area*

The selection of appropriate ground motion data is critical for proper seismic and analysis. Therefore, the ground motion for the current study has been chosen directly from the PEER ground motion database using the input parameter for Islamabad as shown in the table 2 and table 3. This ground motion was matched to the MCE (Maximum 133 Considered Earthquake) level at Islamabad using SeismoMatch. Figure 2 shows the original accelerogram of the selected ground motion. Figure 3 shows matched accelerogram version as per the targeted spectra for 5% damping ratio. By picking ground vibrations from the PEER database, the study attempts to correctly foresee how the specific location in Islamabad would behave during an earthquake. Figure 1 shows the 5% damped response spectrum for the target response and mean matched response.

Table 2. Seismic Parameters as per UBC 97

Parameter	Values	Reference
Zone	2-B	Table -16-I
Seismic Source Type	B	Table -16-U
Soil Profile	SD	Table -16-J
Seismic Importance Factor (I)	1.00	Table -16-K
Over Strength Factor R	5.5	Table -16-N
Seismic Coefficients (C_a)	0.12	Table -16-Q

Table 3. Seismology of Area

Parameter	Values	Reference
0.2 Sec Response Spectra (Ss) as per Building Code of Pakistan	1.30g	0.2 Sec Response Spectra (Ss) as per Building Code of Pakistan
1 Sec Response Spectra (S1) as per Building Code of Pakistan	0.38g	1 Sec Response Spectra (S1) as per Building Code of Pakistan
Transition Long Period (s)	8	Transition Long Period (s)
Earthquake Magnitude	6, 6.3	Earthquake Magnitude
Fault Type	Reverse + Strike Slip	Fault Type
Restrict range of Joyner-Boore distance RJB (km).	10, 40	Restrict range of Joyner-Boore distance RJB (km).
Rrup (km) Restrict range of closest distance to rupture plane	10, 40	Rrup (km) Restrict range of closest distance to rupture plane
Average shear wave velocity of top 30 meters of the site Vs30 (m/s)	180, 360	Average shear wave velocity of top 30 meters of the site Vs30 (m/s)
Damping Ratio	5% or 0.05	Damping Ratio
0.2 Sec Response Spectra (Ss) as per Building Code of Pakistan	1.30g	0.2 Sec Response Spectra (Ss) as per Building Code of Pakistan
1 Sec Response Spectra (S1) as per Building Code of Pakistan	0.38g	1 Sec Response Spectra (S1) as per Building Code of Pakistan

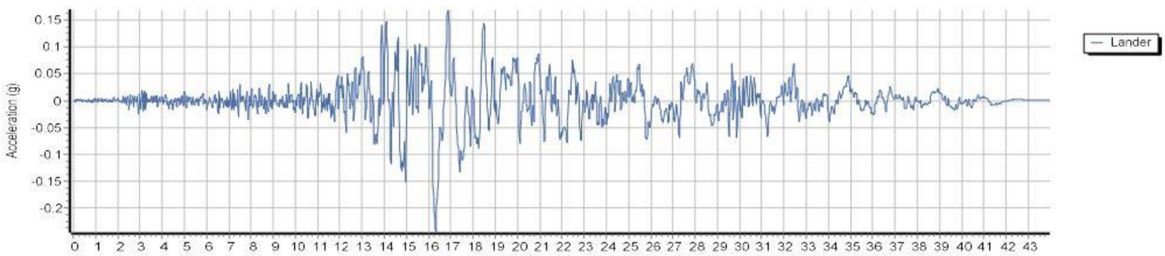

Fig. 2 Original Acceleration from PEER ground motion database

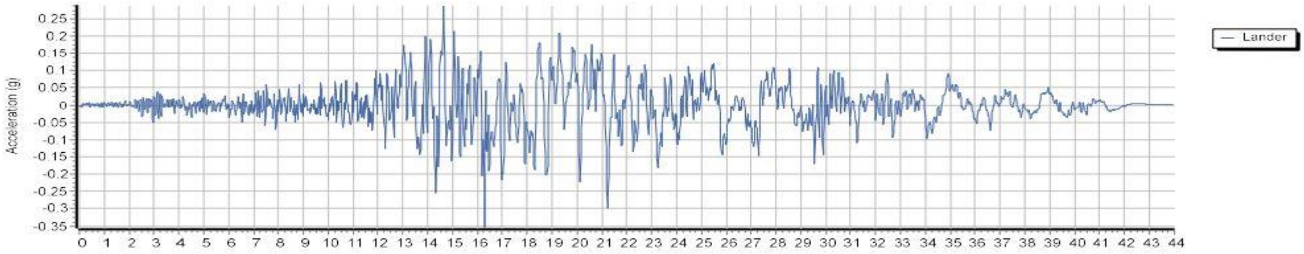

Fig. 3 Matched Acceleration from PEER ground motion database

C. *Viscoelastic Dampers*

The viscoelastic dampers were modelled as per the references per the study of Vijay et al. [33] viscoelastic dampers were modelled as "Plastic". Viscoelastic damper as shown in figure 4.

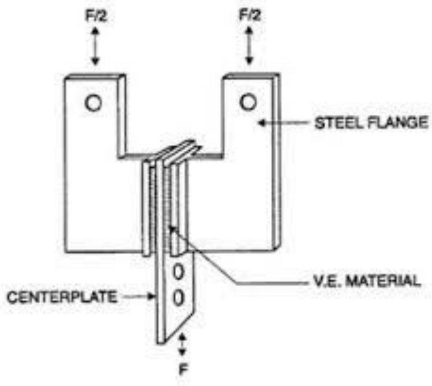

Fig. 4 Viscoelastic Damper

III. **RESULTS AND DISCUSSION**

A. *Story Displacenment*

Storey displacement is the lateral movement of a specific level of a structure caused by external factors like wind or earthquake stresses. The figure explains the behavior of HRB with and without VED when subjected to real time earthquake loading. The maximum displacement of the structure is 4.4 inch at the the 40th storey level. Addition of VEDs reduced it to 0.4 inches. It can be seen in both cases that the graph follows a linear behavior where displacement increases with respect to the height of the structure.

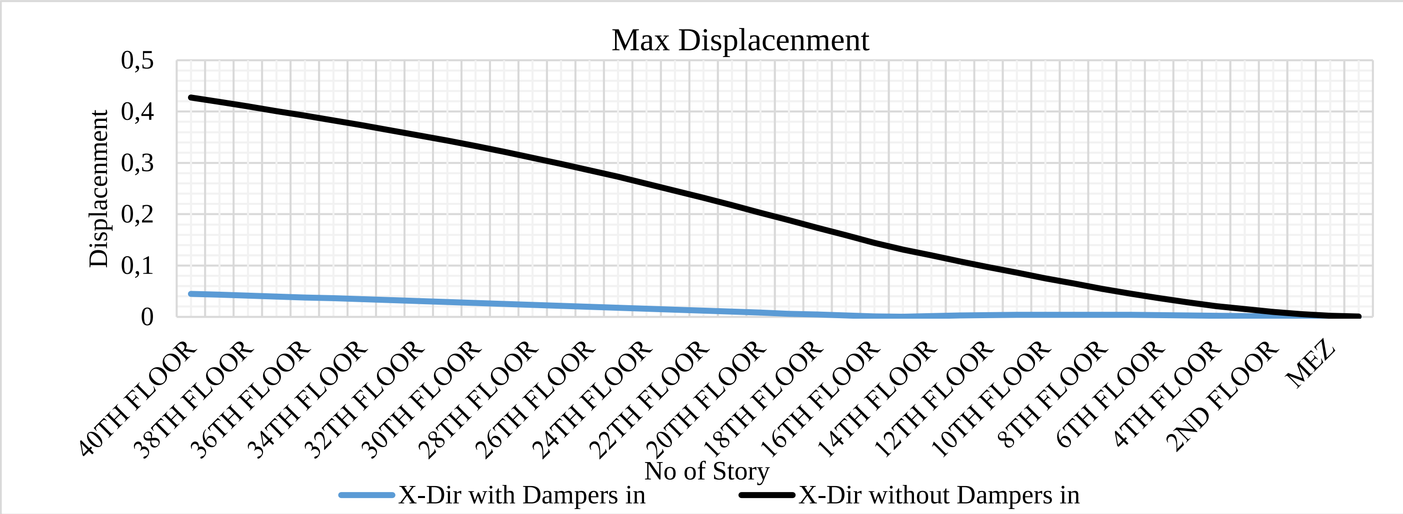

Fig. 5 Max Story Displacement

B. Story Drift

VEDs significantly reduce the story drift as can be seen from the figure. The graph shows that maximum drift of the structure was 9.2 x 10^{-4}. Addition of VEDs to the structure reduced it to 0.9 x 10^{-4}. Moreover, addition of VEDs has changed the drift pattern from non-linear to linear.

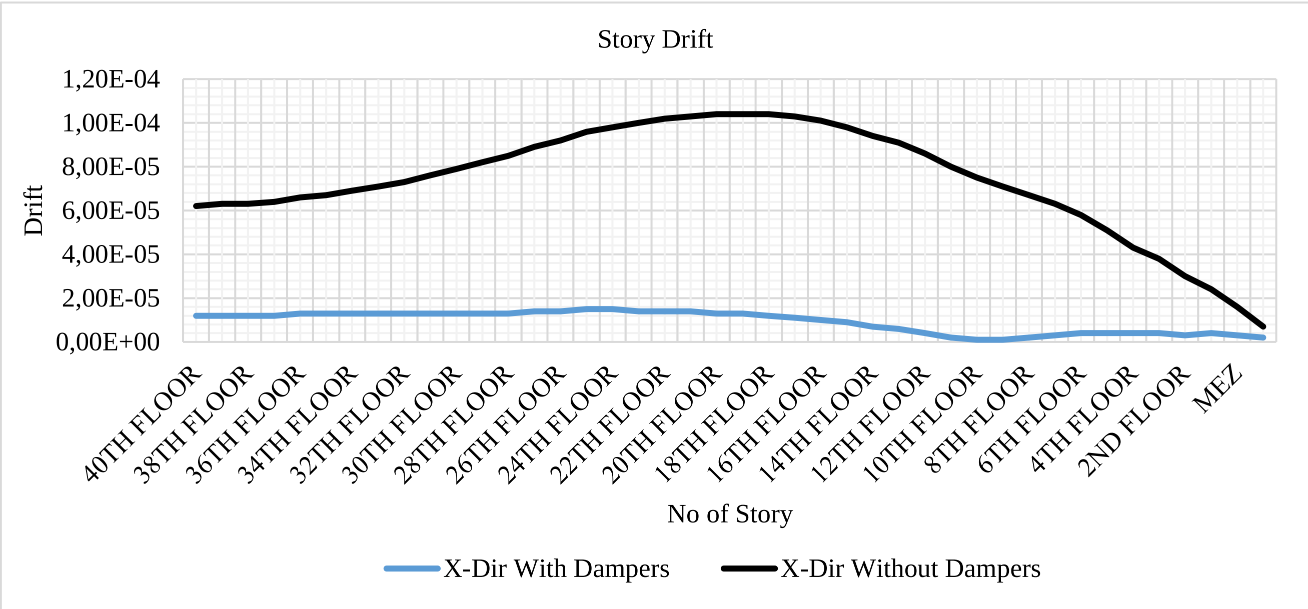

Fig. 6 Max Story Drift

C. Energy Dissipation

The graph represents the total energy dissipated by the various members of the structure during the seismic activity. The energy absorption of the structure increases significantly due to the addition of VEDs.

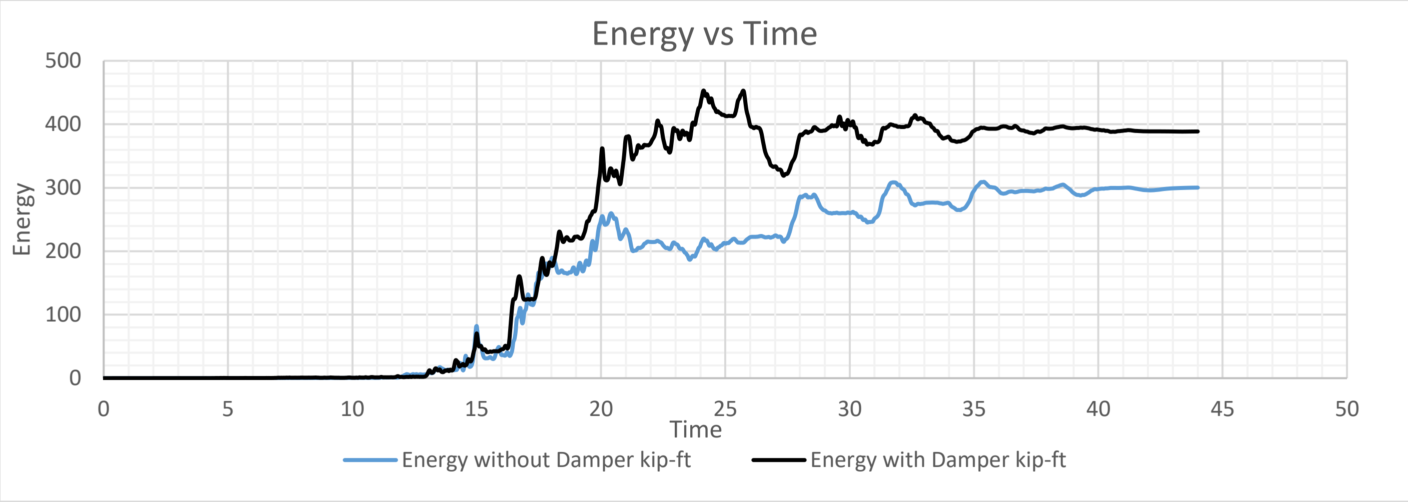

Fig. 7 Energy vs Time

D. *Acceleration vs Time*

Acceleration response of the structure with respect to time is explained in the figure. The graph shows that peak acceleration value throughout the seismic activity has been reduced by the addition of VEDs.

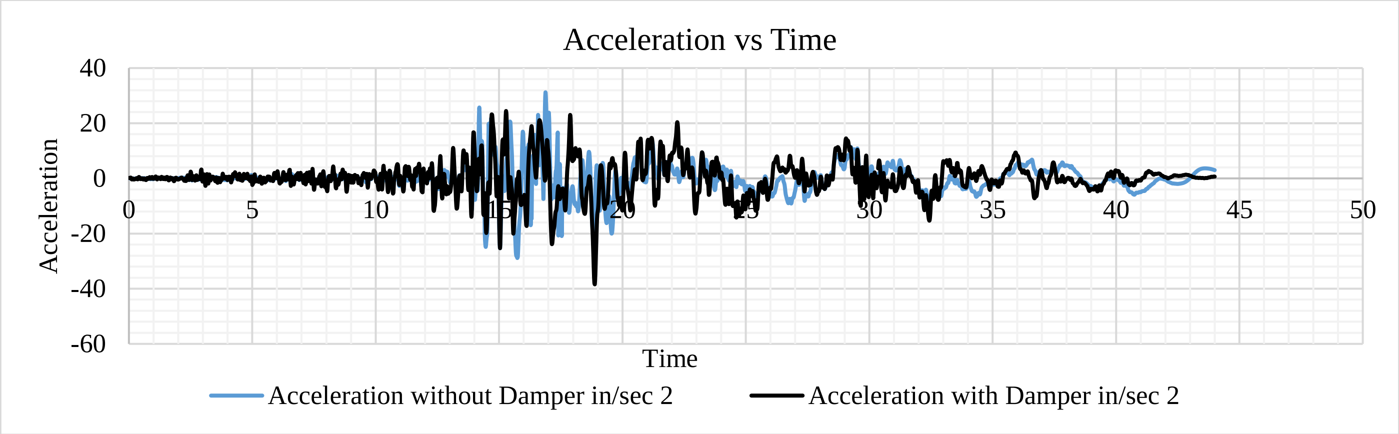

Fig. 8 Acceleration vs Time

E. *Displacement vs Time*

The figure explains the displacement patterns of the structure with and without addition of viscoelastic dampers. From the graph, it is evident that displacement of the structure with respect to the seismic activity has decreased due to addition of VEDs. The displacement increases as the seismic intensity increases upto 25 seconds

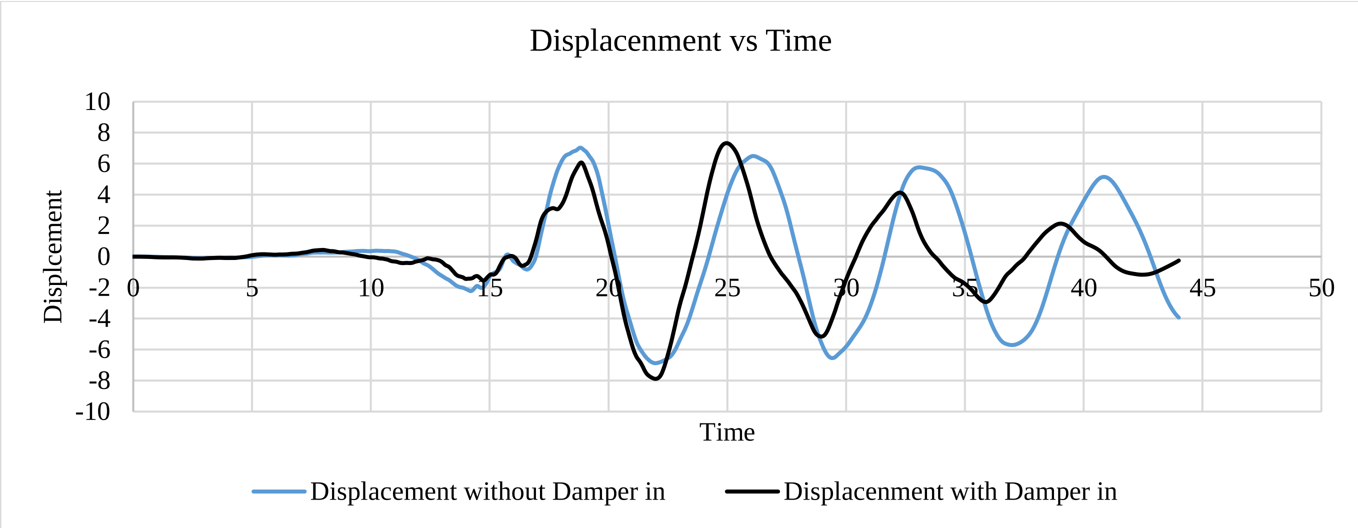

Fig. 9 Displacement vs Time

IV. CONCLUSION

From the above study, following conclusions have been deducted.

1. In Comparison to other techniques such as active, semi active and hybrid control system, use of VEDs as passive control system is relatively easy.
2. It is preferred over other techniques as it does not alter appearance or function of the structure.
3. It is observed that addition of VEDs to HRBs significantly reduces storey drift and storey displacement values
4. It is observed that dissipation of seismic energy increases due to addition of VED's.

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