

**DESIGN AND ANALYSIS G+36 STOREY RCC BUILDING USING VISCOELASTIC
DAMPER ON ETABS**

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ABSTRACT

During a major earthquake a large amount of energy is fed into a structure. The manner in which this energy is consumed determines the level of damage. The primary emphasis is on life safety with an expectation of substantial structural damage. In general reliance for survival is placed on the ductility of the structure to dissipate energy while undergoing large inelastic deformations causing bending, twisting and cracking. Earthquakes have clearly shown that conventional construction is even technologically advanced industrialized countries is not immune to destruction. Viscoelastic damper is one such passive control device with several advantages. Three types of dampers have been taken in present investigation. ETABS software has been used to model G+36 tall building structure and dampers. Analysis of structure without dampers and then with dampers has been done and difference in responses of structure like Storey drifts, Storey acceleration, Storey displacement etc. is presented here.

Keywords, Bracing, Storey Drift, Seismic analysis, Deflection, Viscoelastic Damper (V.E.).

INTRODUCTION

Earthquakes are one of man's most feared natural phenomena. Major earthquakes producing instantaneous destruction of building and other structure. The damage caused by earthquake is almost entirely associated with manmade structure such as Buildings, Dams, Bridges and other works of man. Unfortunately, many of earthquakes give very little or no warning before occurring and this is one of the reasons why earthquake engineering is complex. On average about 200 large magnitude earthquakes occur in each decade. About 10%-20% of these earthquakes occur mid-ocean and hence cause no problem in human settlement. No engineer can truly transform badly conceived building into an earthquake resisting building. Simplicity, Regularity and symmetry in both elevation and plan are the ideal aspects of the building. These properties are important to predict the forces and distribution of forces in structure while irregular structure causes increase in dynamic response at certain location of structure. Also, buildings which are tall as compared to their plan area will generate high overturning moment while building with large plan area may act differently. Structural members. The operation of these special devices is initiated by the motion of the structure and, guided by the control scheme; they reduce the overall response of the system and thus meet the design goal in mitigating seismic damage. Various response control methods have been implemented in the design procedures and can be generally divided into three groups: passive control, active control, and semi-active.

This paper discusses the use of Viscoelastic dampers (passive control) as they are capable of reducing the building motion or responses by converting a portion of the mechanical energy into heat. The function of passive energy dissipation systems, on the other hand, is to absorb energy generated by the seismic or wind excitation. These are installed strategically in the structure to link various parts of the framing system, and provide supplemental damping to dissipate the energy. Since these added dampers can be designed to consume a major portion of the input energy so that less is available to the main structure, the deformation in the primary members is significantly reduced, hence limiting the structural damage.

Many research works is going on Viscoelastic dampers which show that the analysis and their working is complex in nature. The feasibility of using viscoelastic dampers to mitigate earthquake-induced structural response has also been studied by various authors. Chang Y.Y. Lin & M.L. Lai compared seismic performance

between the viscoelastically damped structure and a conventional special moment resisting frame. The temperature variation formula during an earthquake excitation was introduced. They also studied the change in the natural frequency due to addition of viscoelastic damper. Julius Marko showed that bitumen rubber compound VE damper induces large damping forces to shear deformation and can sustain shear strains of about 300% and can reduce seismic response by 50% and super-plastic silicone rubber VE damper reduces response up to 60%. Different models were cited and dynamic analysis of the frames with viscoelastic damper was carried to derive the formula for energy dissipation by R. Lewandowski et al. B. Samali & K.C.S Kwok showed that amount of energy stored in damper is about 2-4% and thus rest of it is dissipated. Many others have studied the seismic analysis and performance of structures with VE damper and this paper also addresses issue even for wind effects on performance.

MECHANISM OF VISCOELASTIC DAMPER

When stress is applied to a viscoelastic material such as a polymer, part of the long polymer chain change positions. This movement or rearrangement is called Creep. Polymers remain a solid material even when these parts of their chains are rearranging in order to accompany the stress, and as this occurs, it creates a back stress in the material. When the back stress is the same magnitude as the applied stress, the material no longer creeps. When the original stress is taken away, the accumulated back stresses will cause the polymer to return to its original form. The material creeps, who gives the prefix visco-, and the material fully recovers, which gives the suffix - elasticity. After loading over time, the material recovers their initial strength, which the amount of this recovery depends on the temperature of the material, stimulant frequency and strain amplitude. In short, there is an increase in stiffness and damping in the structural system by installation of this material. Installation of the dampers should not be limited only to braces, but they can be used with special arrangements throughout the structure in which shear deformations occur.

MODELLING OF G+36 RCC BUILDING ON ETABS2015

To incorporate viscoelastic dampers in a high-rise building which could improve the dynamics performance of the building by using E-TABS modeling and also to study the reduction in deflection and base shear of structure with and without viscoelastic dampers. The building is analyzed in 2 stages, first is without any dampers and second is using D3 type of damper, best brace configuration and best location of the dampers will be concluded. And using three different dampers, differences in response will be studied. Analysis is done on ETAB software. The height of the building is 130.5m (high rise). The building is situated in Mumbai with medium soil condition. Total load (DL+LL) is assumed to be 15 kN/m². Seismic Coefficient method as per IS 1893 (Part 1): 2002 is used for seismic load analysis and Gust analysis is used for wind loading as per IS 875 (Part 3): 1987. Load Combination was used as per specified by IS 456: 2000. Various properties of the elements used to model in ETABS are given in the Table1-5.

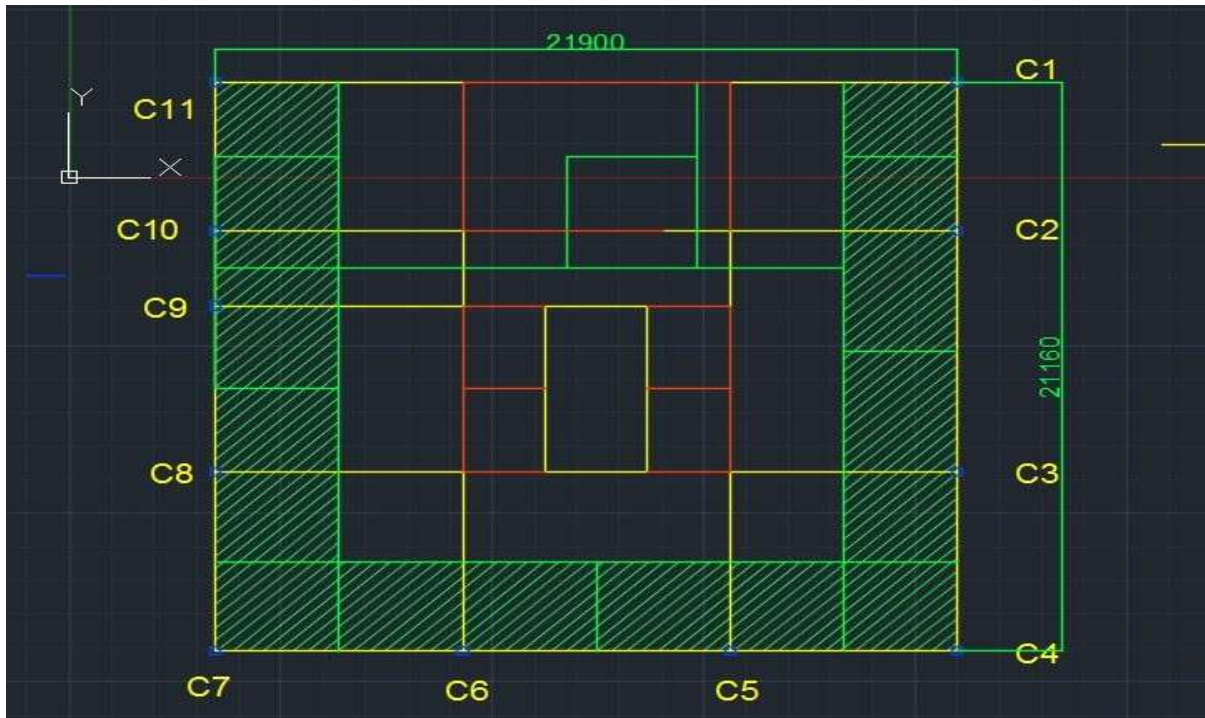


Figure 1: Typical Plan of G+35 RCC Building

Table 1. Concrete grade used for different structural elements in building

Member	Levels	Concrete grade
Footing	-	M50
Columns	Ground floor to 8th floor	M50
	9th floor to 17th floor	M40
	18th floor to terrace (Storey 36)	M30
Shear Wall	Ground floor to 8th floor	M50
	9th floor to 17th floor	M40
	18th floor to terrace (Storey 36)	M30
Beams / Slabs / Staircase	All slabs	M40
	All beams	M40

Table 2. Grouping of Columns

From Foundation up to 8 th Floor (mm) (Grade M50 & Fe 500)								
C1,C4,C7,C11	650	650	C2,C3,C6,C8	1800	500	C9,C10	1100	500
From 9 the up to 17th Floor (mm) (Grade M40 & Fe500)								
C1,C4,C7,C11	600	600	C2,C3,C6,C8	1800	400	C9,C10	1100	450
From 18th up to 35th Floor (mm) (Grade 30 & Fe500)								
C1,C4,C7,C11	500	500	C2,C3,C6,C8	1800	300	C9,C10	1100	300

Table 3. Beams Properties of Structural Elements of the Building

Frame Element	Material	Area of section
External Beam connected to shear wall of staircase and columns & internal beam connected to lift Depth = 600 mm; Width = 400 mm	Concrete	0.24 m ²
Internal Beam connected to shear wall Depth = 600 mm; Width = 500 mm	Concrete	0.30 m ²
Internal beam connected to shear wall of lift Depth = 1200 mm; Width = 600 mm & Depth = 600 mm; Width = 300 mm	Concrete	0.72m ² 0.18m ²
Other internal beams Depth = 600 mm; Width = 650 mm & Depth = 1200 mm; Width = 500 mm	Concrete	0.39m ² & 0.6m ²

Table 4. Slab Properties

Slab type	Dimension	Thickness
Two way	6.68mx5.5m	225mm
Two way	6.68mx9m	250mm
Two way	6.68mx6.66m	225mm
Two way	7.92mx6.66m	225mm
Two way	7.3mx6.66m	225mm
Two way	7.3mx6.2m	225mm
One way	7.3mx2.8m(Passage)	150mm
One way	7.92mx2.8m(Passage)	150mm
One way	2.8mx6.2m(Passage)	150mm
One way	7.92mx5.5m	225mm
One way	7.3mx5.5m	225mm

Table 5. Damper Properties⁷

Damper Name (Notation)		3M ISD 110 (D1-30C Temp)	3M ISD 110 (D2-20C Temp)	D3-K57-D12
Type of Damper		Exponential	Exponential	Exponential
Non Linear		Yes	Yes	Yes
Linear Properties	Effective Stiffness (kN/m)	17839.01	62750.13	57000
	Effective Damping (kN-s/m)	19808.12	69676.63	12000
Non Linear Properties	Stiffness (kN/m)	17839.01	62750.13	57000
	Damping (kN-(s/m) ^{Cexp})	19808.12	69676.63	12000
	Damping Exponent	1	1	1
Effective temperature (in degree)		30	20	Ignored

RESULTS AND DISCUSSION

Configuration Selection for Bracing for dampers

V.E. Dampers are fixed on Bracings. Hence various configurations of diagonal bracing were studied to decide the best configuration for fixing of dampers. This was based on reduction in critical displacement which is in Y Direction for Wind forces. The amount of bracing material was kept same & the configuration was changed to get configuration with minimum deflection. For this bracing with Damper D3 K57D12 where applied in 8 no.s per floor from 36-2nd Storey.

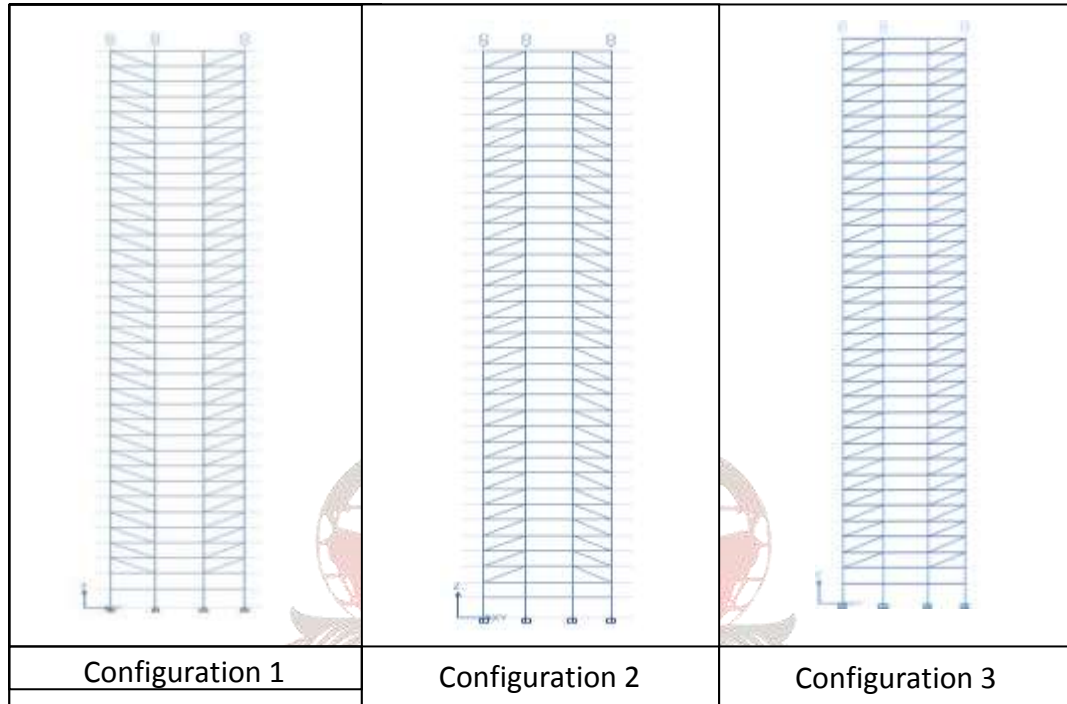


Figure 2: Various Bracing Configuration used

The building was modeled on ETABS and following results were found out which is summarized in Table 5,6& 7.

Table 6. Average Reduction in Displacement of Stories due to Spec (Seismic) under different Configurations

Configuration	X Direction (%)	Y Direction (%)
Config. 1 With D3	20.48	16.10
Config. 2 With D3	20.88	16.65
Config. 3 With D3	20.43	16.81

Table 7. Top Storey Displacement due to Spec under different Configurations

Configuration	X Direction (mm)	Y Direction (mm)
Without Dampers	120.5	142.9
Config. 1 With D3	98.71	121.00
Config. 2 With D3	98.21	120.81
Config. 3 With D3	98.49	120.11

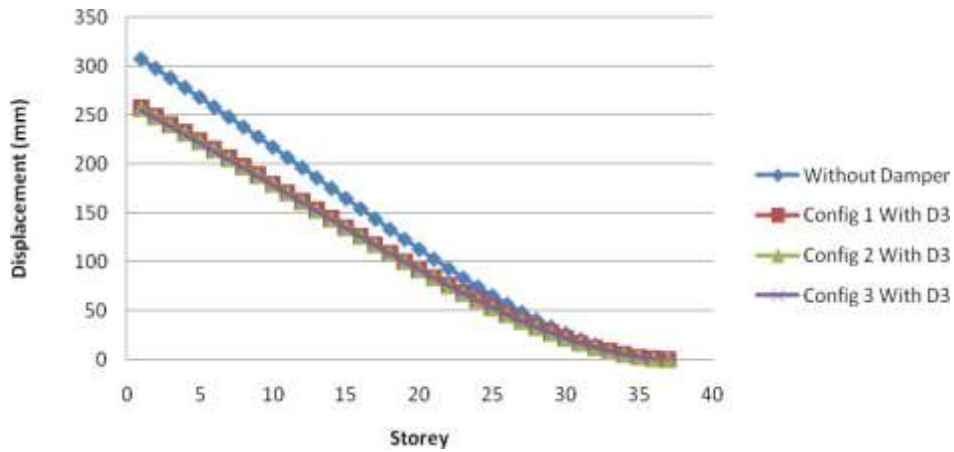


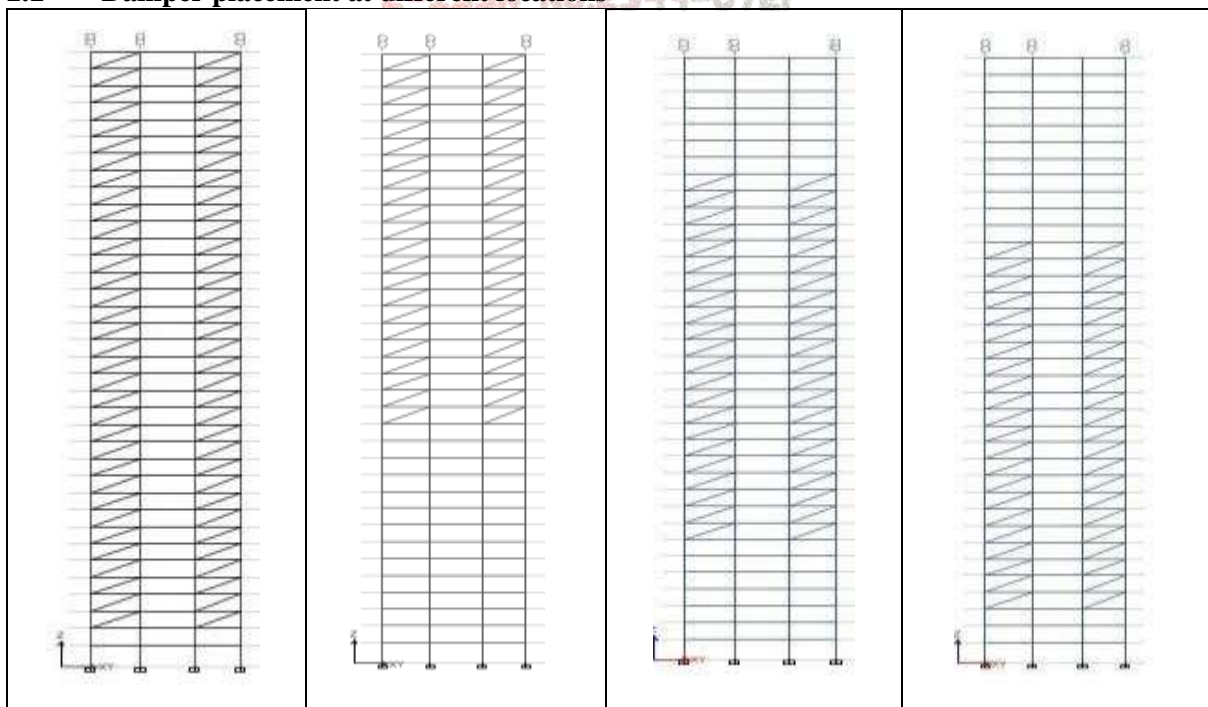
Figure 3: Displacement Due to Wind Y in Y Direction for Various

Configurations Table 8. Top Storey Displacement due to Wind under

Config.	X Direction (mm)	Y Direction (mm)
Without Dampers	307.5	307.6
Config. 1 With D3	163.60	257.61
Config. 2 With D3	161.50	256.70
Config. 3 With D3	162.71	255.31

For G+35 Storey Building with Height 130.5m permissible deflection in Wind is H/500 i.e. 261mm & For Earthquake is H/250 i.e. 522mm. From the above tables it can be seen that there is maximum reduction in Storey displacement in Direction Y for Wind Y is by Configuration no. 3 where top Storey displacement reduced from 307.5mm (more than permissible 261mm) to 255.3mm (within permissible) hence it is to be used for further analysis.

1.1 Damper placement at different locations



36-2 Storey	36-15 Storey	29-8 Storey	24-3 Storey
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Figure 4: Various Damper Placement Locations

Here 4 cases of damper placement have been studied & these are shown below. In first case dampers have been placed throughout & in second case at the position of maximum absolute displacement in building while in 3rd case dampers have been placed at position of maximum Storey drifts & in 4th in lower stories. At each story 8 dampers have been placed. Main objective of this study is to know the best possible position in building for dampers placements so that damper can be utilized in reducing structure responses in more effective ways.

Table 9. Top Storey Displacement due to Wind under different Configurations

Damper Location	X Direction (mm)	Y Direction (mm)
Without Damper	239.3	307.6
36-2 Floor	162.70	255.30
36-15 Floor	190.70	281.50
29-8 Floor	171.00	259.99
24-3 Floor	177.9	275.6

Table 10. Top Storey Displacement due to Spec (seismic) under different damper location

Damper Location	X Direction (mm)	Y Direction (mm)
Without Damper	120.58	142.81
36-2 Floor	98.50	120.10
36-15 Floor	103.80	128.40
29-8 Floor	101.59	121.61
24-3 Floor	102.09	124

From the above tables it can be seen that there is maximum (economical) reduction in Storey displacement in Direction Y for Wind Y is by placing the dampers at 29-8 Storey where the Storey drift was maximum. The percentage reduction in displacement is 15-16% for both wind and spectral (seismic) forces. The top Storey displacement reduced from 307.5mm (more than permissible 261mm) to 259.98mm (within permissible) hence this location is to be used for further analysis. The main reason for Location 29-8 Storey to be best is that placing dampers here help to reduce the Storey drift & thus reduce displacement. Placing dampers in top stories is not advantageous. Further placing dampers in lower operation 24-3 Storey reduces displacement in lower stories but not top Storey displacement. Placing dampers from 36-2 Storey (i.e. at all floors) reduces just 1.5mm more deflection then that by 29-8 Storey. Thus it is not economical to go for 36-2 Storey location i.e. using 112 No. of extra dampers for 1.5mm displacement reduction.

Analysis with Best Bracing Configuration & Damper Location

After Successful Deciding Best Configuration of Bracing & Best Location of Dampers we will use Configuration No.3 for 8-29 Storey Damper location & further carry out analysis for studying various characteristics of structure & various types of Dampers.

Table 11. Time period reduction of building due to dampers

Various Mode	D1	D2	D3
Average Time period %reduction	12.35802	13.29827	13.0469

It can be seen from above Table 11 that there is reduction in time period of structure by addition of Viscoelastic dampers due to increase in stiffness of structure. Further D2 K70D63 -20°C being the most stiffness have the lowest time period while followed by D3 K57D12 -30°C which has second highest stiffness has second lowest time period & D1 K18D20 having lowest stiffness & highest time period.

Analysis for Seismic Forces

Table 12. Average Reduction in Acceleration of Stories due to Spec under different VE dampers

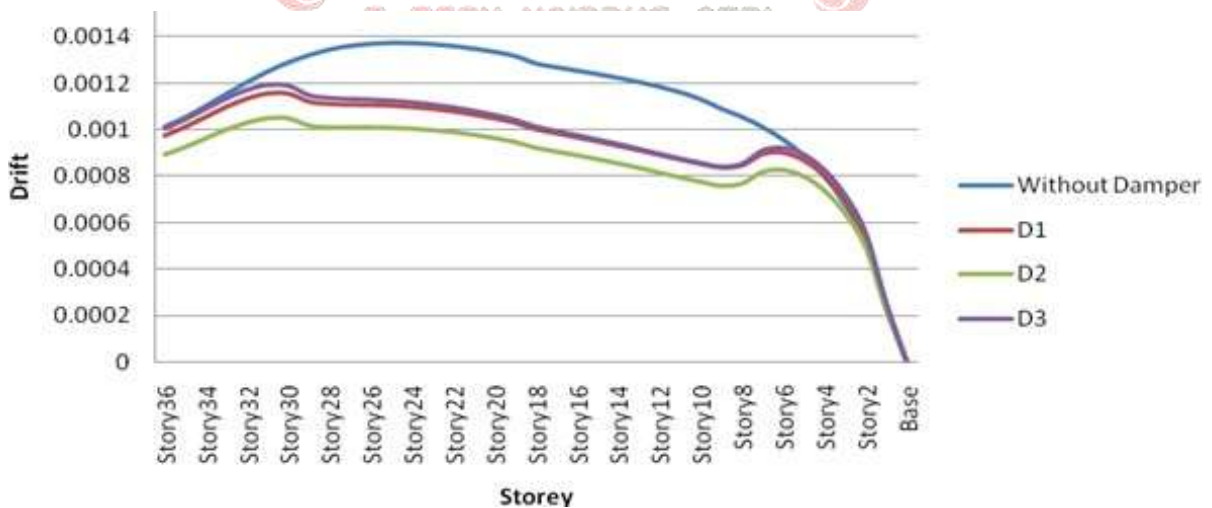
Damper	X Direction (%)	Y Direction (%)
D1	9.65	3.25
D2	24.64	15.61
D3	14.87	4.75

It can be seen from above Table 12 that there is reduction in acceleration response of structure due to addition of VE damper. Compare to X-direction, response reduction in Y-direction is less may be because of presence of shear walls in that direction. Dampers having higher damping coefficient + higher stiffness (D1 K70D63) perform well in reducing Storey acceleration than dampers with higher stiffness value + less damping value (D3 K57D12). So it can be concluded that damping plays important role in reducing Storey acceleration.

Table 13. Average Reduction in Storey Drift under Spec under different dampers

Damper	X Direction (%)	Y Direction (%)
D1	14.35	12.01
D2	21.63	17.94
D3	12.59	13.93

Figure 5 shows the considerable reduction in Storey drift in X-direction of the structure with respect to that



of the structure without damper. Similarly, it was also found for Y-direction.

Figure 5: Storey drift response of structure in X-direction (SpecX)

Reduction in drift is because of added stiffness and damping of structure because of addition of dampers. Here also damping component of damper plays important role. This is the sole aim of using dampers. Table 14 shows the percentage reduction in displacement in two directions which is also quite considerable for a

high rise structure. Base shear is also important for design of foundations hence its reduction was also analyzed (shown in Table 15).

Table 14. Average Reduction in Displacement of Stories under Spec under different dampers

Damper	X Direction (%)	Y Direction (%)
D1	14.79	14.51
D2	21.61	18.12
D3	13.17	14.39

Table 15. Reduction in Base shear

Dampers	D1	D2	D3
X-Direction Reduction %	16.33	28.33	2.59
Y direction Reduction %	10.48	22.72	2.62

Analysis for Wind Forces

Following Table 16 shows percentage reduction in displacement of top Storey due to damper system. From above table it can be seen that there is a reduction in Storey displacement in both directions by addition of viscoelastic damper. Compare to earthquake response, response reduction for wind is less because wind is applied as static load. Table 17 shows that reduction in drift is high as 25% in X-direction.

Table 16. Average Reduction in Displacement of Stories due to Wind under different dampers.

Damper	X Direction (%)	Y Direction (%)
D1	25.15	14.42
D2	26.76	15.27
D3	26.25	15.00

Table 17. Average Reduction in Storey Drift due to Wind under different dampers

Damper	X Direction (%)	Y Direction (%)
D1	24.45	13.68
D2	25.93	14.50
D3	25.47	14.25

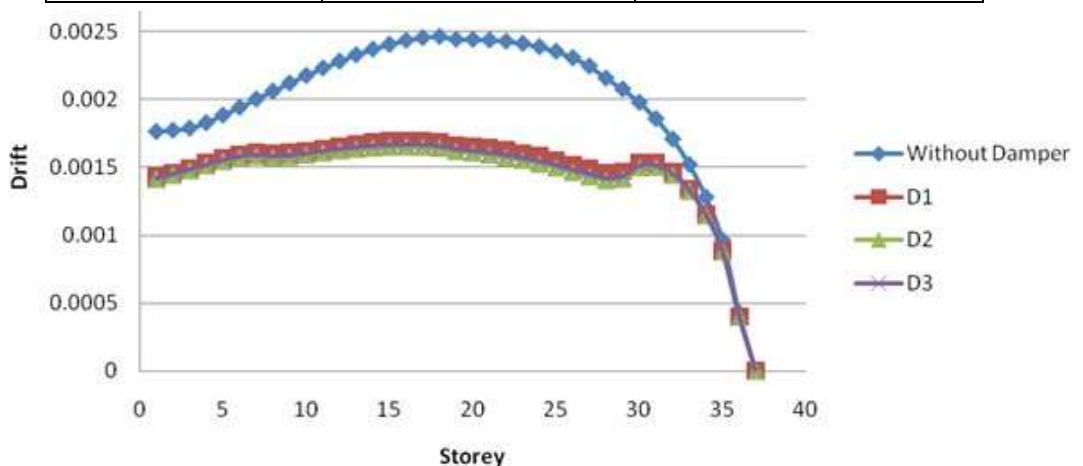


Figure 6: Storey drift response of structure in X-direction due to wind

It seen for Figure 6 that the there is considerable amount of reduction in story drift. Further commenting that it cannot be concluded which type of damper is the best as the difference in results are small. Also in the literature it is seen that many factors affect the performance of damper which has to be modeled and studied and detail. This will require deeper analysis of the responses with varying property of the structure

CONCLUSION

The present study was to analyze tall building without and with viscoelastic dampers and to assess the seismic behavior of structure. The main purpose of this study is to investigate the effectiveness of viscoelastic damper which provides both additional stiffness and damping to structure. From all of results presented above following conclusions have been made:

- 1) The results of this investigation show that, response of structure can be reduced to considerable amount by installation of viscoelastic dampers.
- 2) Properties of dampers i.e. stiffness and damping coefficient are highly sensitive to temperature changes but comparatively less sensitive to frequency change. Bracing plays an important role in reducing difference in efficiency of damper due to changes in temperature. Also properties of dampers are inversely proportional to temperature i.e. lower the temperature higher will be the damper properties.
- 3) Compare to reduction in displacement, reduction in Storey drifts and acceleration is more which indicates that dampers are prominently effective in reducing Storey acceleration and Storey drift than Storey displacement.
- 4) If alone bracing are provided it will make structure stiff & if dampers are provided it will provide passive flexibility i.e. dissipating energy & thus provide flexibility. As a result there will be reduction in area of steel (5-30%) & thus economy in design.
- 5) To reduce Wind Deflection, Stiffness Property of Damper is Important & to reduce Earthquake Deflection, Damping Property of Damper is important.

SCOPE OF FUTURE WORK

It is recommended that further research be undertaken in following areas:

- 1) Different damper locations or provision of damper in the core of building can also be studied.
- 2) Steel Structures can be used along with V.D
- 3) Determining effect of dampers on design of structural component like beams and column.
- 4) Determining the seismic behavior of tall building structures by using different arrangements of viscoelastic damper devices in the field of their locations in the building.

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