A Study on Seismic Response of Multi-storeyed Buildings with Shear Walls and Fluid Viscous Dampers using ETABS

M. Shyam Sundar[1] G. Madhu Sudhan[2]
[1]M. Tech Student [2]Assistant Professor
[1,2]Annamacharya Institute of Technology & Sciences, Tirupati, India

Abstract— Earthquake is the one of the significant disaster that can affect the performance and safety of any RCC building to the highest level possible. Hence there is imminent need to arrest the damage by seismic forces and make the RCC structures to withstand for earthquakes. Many alternate retrofitting techniques have emerged which can alter the response of RCC structures in resisting the seismic forces. Retrofitting the existing structures with dampers or providing shear wall as an integral part of the structure was among them. Dampers have a wide range of advantages like they can be erected in an easy way, cost effective and can be installed in the desired orientation such that the strength and stiffness requirements will be met. The present work deals with comparison of response of RC framed structures with fluid viscous dampers and shear walls. For this study, a reinforced concrete framed building (G + 9) was modeled and analyzed in three parts 1) Model without shear wall and Fluid viscous damper (Base model) 2) Model with shear wall 3) Model with Fluid viscous dampers. The response of the structure for the above conditions have been evaluated using E-Tabs 2015 for seismic forces for different seismic zones. In this study parameters like Lateral displacement, Storey shear and Storey drift have been carefully evaluated and were used to compare the seismic response of RCC structures with fluid viscous dampers and shear walls.

Keywords: Shear Wall, Fluid Viscous Damper, Storey Displacement, Storey Drift, Storey Shear

I. INTRODUCTION

Any RCC building exhibits its response to ground motions during earth quake in the form of deformations across the various elements of load-bearing system. Hence internal forces arise with in the structural members and displacements are meant to be unavoidable in such scenarios. With varying stiffness and mass of the buildings, the resultant displacement demands varies from structure to structure.

In general, buildings with stiffness being of higher magnitude and mass being of lower value exerts smaller horizontal displacements demands. Thus it can be concluded that the maximum amount of horizontal displacement that a building can withstand is limited by its stiffness and mass. As a structural engineer one have to select appropriate strengthening method such that the displacement demand of a building will be maintained well below its displacement capacity.

This can be achieved by decreasing the displacement demand or by improvising the displacement capacity of the structure. Dampers or shear walls are found to be excellent resisting systems for buildings subjected to high lateral loads such as seismic or wind loads. The process of increasing the lateral resistance of RCC framed is achieved by fusing RCC framed structures with either shear walls or by dampers as the structures are seismically inadequate by themselves.

Dampers have potential advantages in terms of practical and economic aspects. Because of their lighter mass they can be easily retrofitted into any existing structure. They can be installed with minimal disruption to the building.

II. MODELLING & ANALYSIS

For this study, an RCC building (G + 9) fused with Fluid viscous dampers and shear walls in various seismic zones (i.e., zone- II, III, IV and V) was selected. Using IS456:2000 for gravity loads and IS 1893:2002 (part 1) for lateral loads (earthquake loads) each floor in the frame was analysed and designed. To estimate the performance of Fluid viscous dampers and shear wall in RCC building there is a need to study parameters as Lateral displacement, Story shear, Story drift. The structure is analysed with liner static and dynamic analysis method using ETABS 2015. The following load combinations are accounted as per IS 1893-2002, clause 6.3.1.2

1) 1.5(DL+IL)
2) 1.2(DL+IL±EL)
3) 1.5(DL±EL)
4) 0.9DL±1.5EL

The different types of models that are used for the study are

1) Model without Fluid viscous dampers and shear wall (Base model)
2) Model with Shear wall
3) Model with Fluid viscous dampers

Fluid viscous dampers and shear walls are placed at the middle bays and all these models were analysed for seismic forces at different seismic zones using E tabs 2015 software.

The Structural details of the structure

General Description		
Plan dimension		20.11 x 20.11 m
Structure		OMRF
No. of storeys		G + 9
Floor to floor height		3.00 m
Foundation type		Isolated footing
Soil strata		Hard
Member Properties		
Slab Thickness		150mm
Beams		330 x 450 mm
Columns		500 x 650mm
Wall Thickness	Exterior wall	230mm
Interior wall		115mm
Shear wall thickness		175mm
Dampers		FVD 750 kN
Material Properties		
Grade of concrete		M40
Grade of steel		Fe 500
Density of concrete		25 kN/m^3
Density of brick		19.20 kN/m^3

Modulus of elasticity of concrete	31622.78 N/mm^2
Modulus of elasticity of steel	2 x 10^5 N/mm^2
Load Intensities	
Floor finish	1 kN/m^2
Live load	2 kN/m^2

Table 1: Structural Details

The following are the parameters of earthquake loads considered as Per IS 1393 – 2002 codal provisions for this study.

Parameters	values
Seismic Zone Factor	
Zone 5	0.36
Zone 4	0.24
Zone 3	0.16
Zone 2	0.10
Importance factor	1.0
Response reduction factor	3.0
Percentage of damping	5%
Soil type	Hard soil

Table 2: Parameters for Earthquake Loads

A. *Details of Dampers*

The dampers manufactured by Taylor Devices Inc. are generally available in two configurations. They are: -

1) Fluid viscous dampers & lock-up devices clevis – clevis configuration.
2) Fluid viscous dampers & lock-up devices clevis – base plate configuration.

For modelling the dampers the first configuration clevis – base plate was adopted.

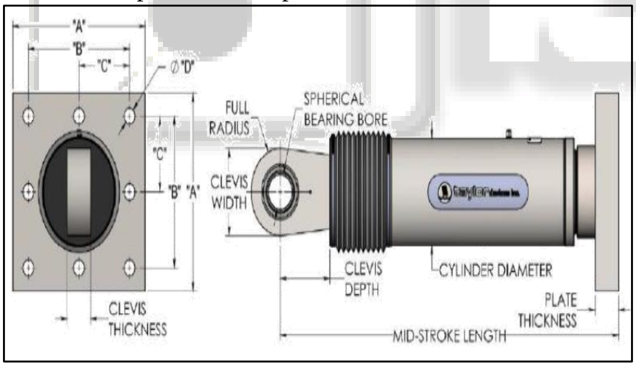

Fig. 1: Clevis – Base plate configuration of Fluid viscous damper

III. RESULTS & DISCUSSIONS

In order to evaluate the seismic response of concrete structures with shear walls and Fluid viscous dampers a detailed study have been carried out. All the models were analysed using response spectrum analysis and the parameters from those results like story displacements, story shear, and story drift were compared. The comparison was done in three levels.

1) Seismic performance of Base model lying in zone 2 to zone 5
2) Comparison of seismic performance of model with shear wall from zone 2 to zone 5
3) Comparison of seismic performance of model with Fluid viscous damper from zone 2 to zone 5

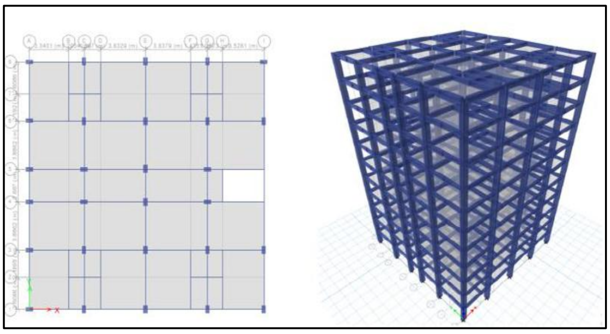

Fig. 2: Plan and 3D view of Base model

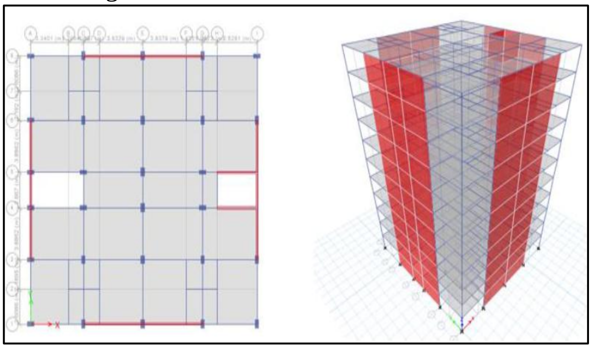

Fig. 3: Plan and 3D view of Shear wall model

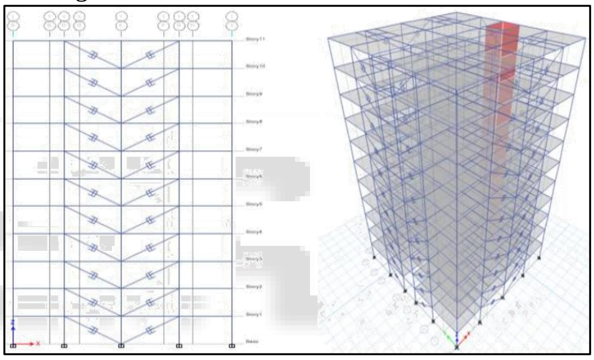

Fig. 4: Elevation and 3D view of Fluid viscous damper model

Story	Elevation (m)	Base Model (mm)	Shear Wall (mm)	FV Damper (mm)
Story11	33	23.5	14.8	19.2
Story10	30	22.7	14	18.4
Story9	27	21.5	12.9	17.3
Story8	24	19.8	11.8	15.9
Story7	21	17.8	10.5	14.4
Story6	18	15.5	9.1	12.6
Story5	15	13	7.7	10.7
Story4	12	10.4	6.4	8.8
Story3	9	7.7	5.1	6.7
Story2	6	4.9	3.8	4.7
Story1	3	1.7	2.8	2.5
Base	0	0	0	0

Table 3: Maximum Storey Displacements in Zone 2

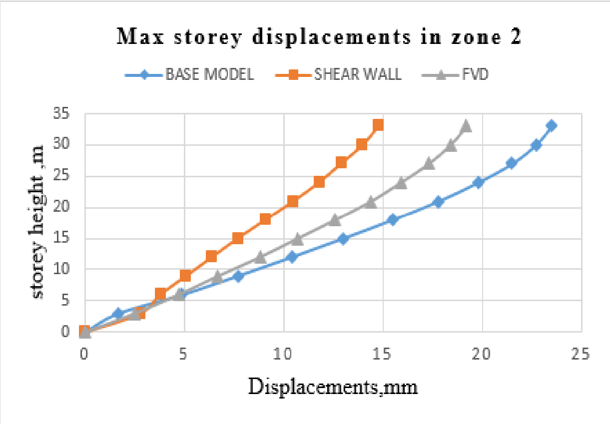

Fig. 5: Maximum Storey Displacements in Zone 2

Story	Elevation (m)	Base Model (mm)	Shear wall (mm)	FV Damper (mm)
Story11	33	37.5	23.9	28.9
Story10	30	36.3	22.4	27.6
Story9	27	34.3	20.7	26
Story8	24	31.6	18.8	23.8
Story7	21	28.4	16.8	21.4
Story6	18	24.7	14.6	18.8
Story5	15	20.8	12.4	16
Story4	12	16.6	10.2	13
Story3	9	12.3	8.1	10.1
Story2	6	7.8	6.1	7.1
Story1	3	2.6	4.4	4.1
Base	0	0	0	0

Table 4: Maximum Storey Displacements in Zone 3

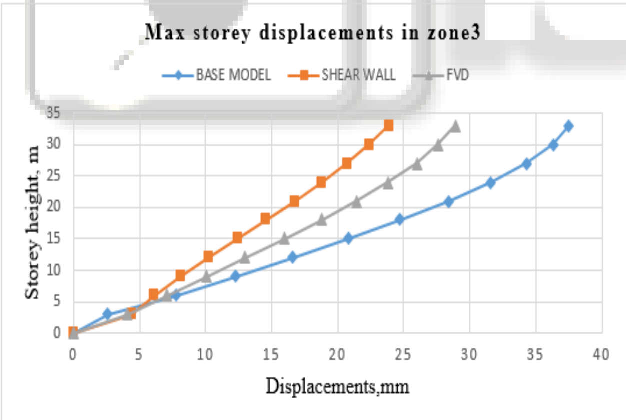

Fig. 6: Maximum Storey Displacements in Zone 3

Story	Elevation (m)	Base Model (mm)	Shear wall (mm)	FV Damper (mm)
Story11	33	56.3	35.5	41.8
Story10	30	54.5	33.4	40
Story9	27	51.5	30.8	37.5
Story8	24	47.5	27.9	34.4
Story7	21	42.6	24.8	30.9
Story6	18	37.1	21.5	27
Story5	15	31.1	18.3	22.9
Story4	12	24.9	15	18.7
Story3	9	18.4	12	14.5
Story2	6	11.7	9.1	10.3
Story1	3	3.9	6.7	6.1
Base	0	0	0	0

Table 5: Maximum Storey Displacements in Zone 4

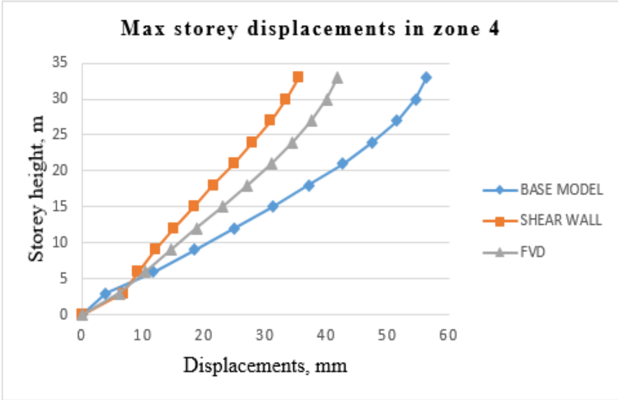

Fig. 7: Maximum Storey Displacements in Zone 4

Story	Elevation (m)	Base Model (mm)	Shear Wall (mm)	FV Damper (mm)
Story11	33	84.4	53.2	61.2
Story10	30	81.7	50.1	58.5
Story9	27	77.3	46.2	54.7
Story8	24	71.2	41.9	50.2
Story7	21	63.9	37.2	45
Story6	18	55.6	32.3	39.3
Story5	15	46.7	27.4	33.4
Story4	12	37.3	22.6	27.3
Story3	9	27.6	18	21.2
Story2	6	17.5	13.7	15.1
Story1	3	5.9	10	9.2
Base	0	0	0	0

Table 6: Maximum Storey Displacements in Zone 5

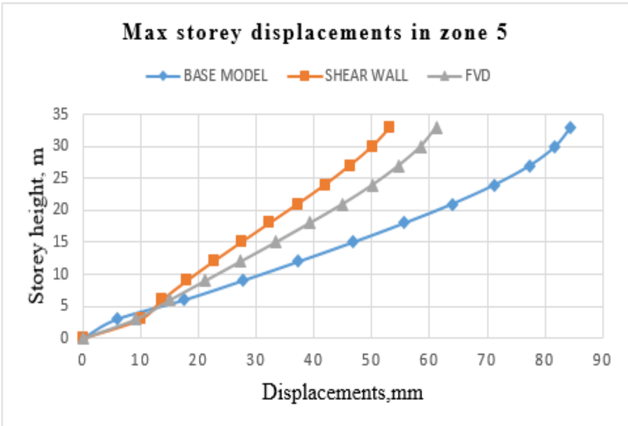

Fig. 8: Maximum Storey Displacements in Zone 5

Story	Elevation (m)	Base Model	Shear wall	FV Damper
Story9	33	0.8	0.8	0.8
Story8	30	1.2	1.1	1.1
Story7	27	1.7	1.1	1.4
Story6	24	2	1.3	1.5
Story5	18	2.3	1.4	1.8
Story4	16	2.5	1.4	1.9
Story3	15	2.6	1.3	1.9
Story2	12	2.7	1.3	2.1

Story1	9	2.8	1.3	2
GF	6	3.2	1	2.5

Table 7: Maximum Storey Drifts in Zone 2

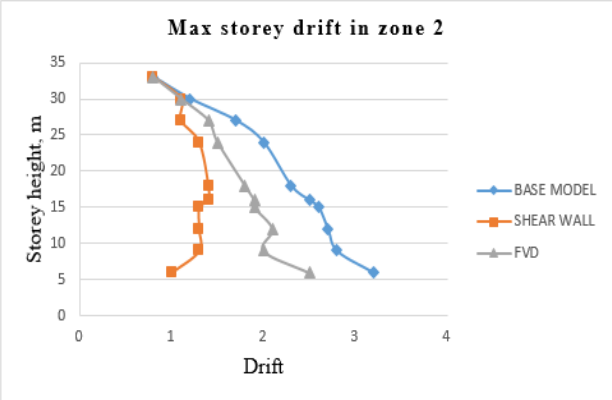

Fig. 9: Maximum Storey Drifts in Zone 2

Story	Elevation (m)	Base Model	Shear wall	FV Damper
Story9	33	1.2	1.5	1.3
Story8	30	2	1.7	1.6
Story7	27	2.7	1.9	2.2
Story6	24	3.2	2	2.4
Story5	21	3.7	2.2	2.6
Story4	18	3.9	2.2	2.8
Story3	15	4.2	2.2	3
Story2	12	4.3	2.1	2.9
Story1	9	4.5	2	3
GF	6	5.2	1.7	3

Table 8: Maximum Storey Drifts in Zone 3

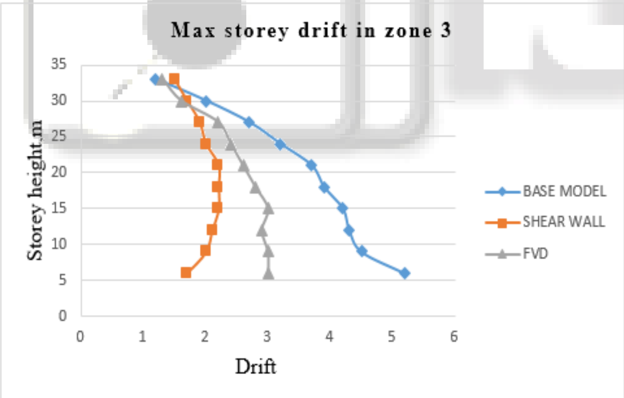

Fig. 10: Maximum Storey Drifts in Zone 3

Story	Elevation (m)	Base Model	Shear wall	FV Damper
Story9	33	1.8	2.1	1.8
Story8	30	3	2.6	2.5
Story7	27	4	2.9	3.1
Story6	24	4.9	3.1	3.5
Story5	21	5.5	3.3	3.9
Story4	18	6	3.2	3.4
Story3	15	6.2	3.3	3.2
Story2	12	6.5	3	3.2
Story1	9	6.7	2.9	2.9
GF	6	7.8	2.4	2.6

Table 9: Maximum Storey Drifts in Zone 4

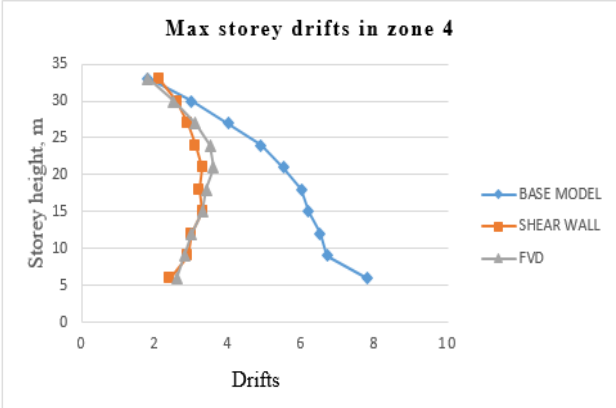

Fig. 11: Maximum Storey Drifts in Zone 4

Story	Elevation (m)	Base Model	Shear Wall	FV Damper
Story9	33	2.7	3.1	2.7
Story8	30	4.4	3.9	3.8
Story7	27	6.1	4.3	4.5
Story6	24	7.3	4.5	4.6
Story5	21	8.3	4.7	4.9
Story4	18	8.9	4.9	5.3
Story3	15	9.4	4.8	5.2
Story2	12	9.7	4.6	5
Story1	9	10.1	4.3	4.8
GF	6	11.6	3.7	4.1

Table 10: Maximum Storey Drifts in Zone 5

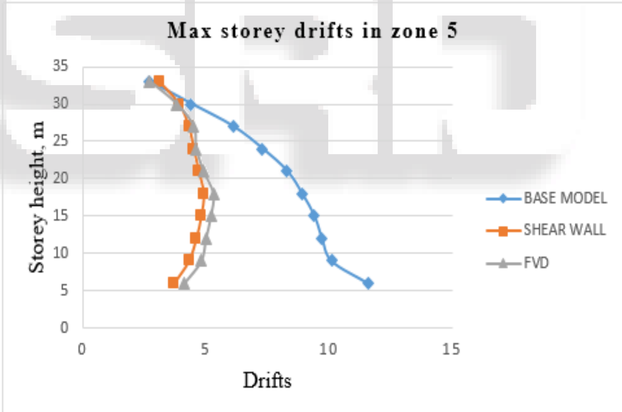

Fig. 12: Maximum Storey Drifts in Zone 5

Story	Elevation (m)	Base Model (kN)	Shear wall (kN)	FV Damper (kN)
Story11	33	176.6095	337.6879	288.7383
Story10	30	335.092	642.8866	548.773
Story9	27	462.9798	889.1673	758.6084
Story8	24	563.5509	1082.843	923.6232
Story7	21	640.0833	1230.225	1049.196
Story6	18	695.8549	1337.628	1140.705
Story5	15	734.1439	1411.363	1203.528
Story4	12	758.2281	1457.744	1243.045
Story3	9	771.3857	1483.082	1264.634
Story2	6	776.8946	1493.691	1273.673
Story1	3	777.2459	1494.374	1274.252
Base	0	0	0	0

Table 11: Maximum Storey Shear in Zone 2

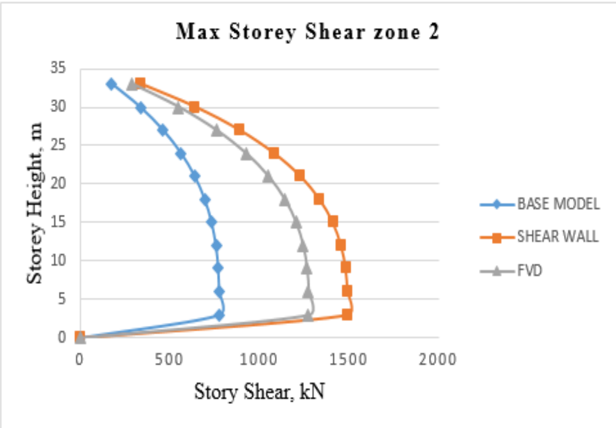

Fig. 13: Maximum Storey Shear in Zone 2

Story	Elevation (m)	Base Model (kN)	Shear Wall (kN)	FV Damper (kN)
Story11	33	282.5751	540.3006	461.9813
Story10	30	536.1472	1028.6186	878.0367
Story9	27	740.7677	1422.6678	1213.7735
Story8	24	901.6815	1732.5483	1477.7972
Story7	21	1024.1333	1968.3606	1678.7133
Story6	18	1113.3679	2140.2048	1825.1276
Story5	15	1174.6302	2258.181	1925.6454
Story4	12	1213.165	2332.3896	1988.8724
Story3	9	1234.2171	2372.9308	2023.4142
Story2	6	1243.0313	2389.9048	2037.8764
Story1	3	1243.5935	2390.9978	2038.8032
Base	0	0	0	0

Table 12: Maximum Storey Shear in Zone 3

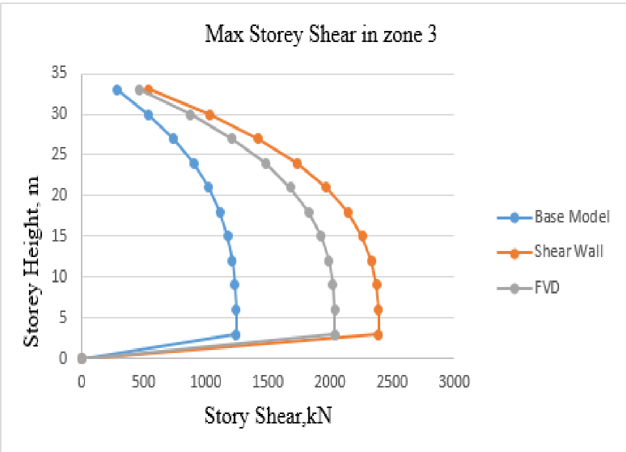

Fig. 14: Maximum Storey Shear in Zone 3

Story	Elevation (m)	Base Model (kN)	Shear Wall (kN)	FV Damper (kN)
Story11	33	423.8627	810.451	629.9719
Story10	30	804.2208	1542.9279	1317.0551
Story9	27	1111.1516	2134.0016	1820.6602
Story8	24	1352.5222	2598.8225	2216.6958
Story7	21	1536.1999	2952.5409	2518.07
Story6	18	1670.0519	3210.3071	2737.6913
Story5	15	1761.9453	3387.2715	2888.4681
Story4	12	1819.7475	3498.5845	2983.3086
Story3	9	1851.3257	3559.3962	3035.1214
Story2	6	1864.547	3584.8572	3056.8146
Story1	3	1865.3902	3586.4968	3058.2048
Base	0	0	0	0

Table 13: Maximum Storey Shear in Zone 4

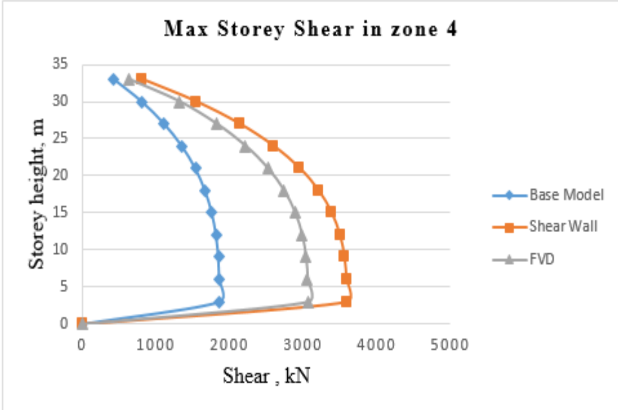

Fig. 15: Maximum Storey Shear in Zone 4

Story	Elevation (m)	Base Model (kN)	Shear Wall (kN)	FV Damper (kN)
Story11	33	635.794	1215.6764	1039.4579
Story10	30	1206.3312	2314.3918	1975.5826
Story9	27	1666.7274	3201.0024	2730.9904
Story8	24	2028.7833	3898.2338	3325.0436
Story7	21	2304.2999	4428.8114	3777.105
Story6	18	2505.0778	4815.4607	4106.537
Story5	15	2642.918	5080.9073	4332.7021
Story4	12	2729.6213	5247.8767	4474.963
Story3	9	2776.9885	5339.0944	4552.682
Story2	6	2796.8205	5377.2859	4585.2218
Story1	3	2798.0853	5379.7451	4587.3072
Base	0	0	0	0

Table 14: Maximum Storey Shear in Zone 5

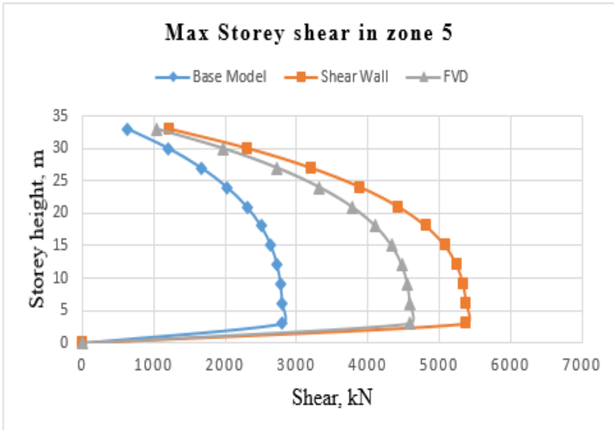

Fig. 16: Maximum Storey Shear in Zone 5

IV. CONCLUSIONS

1) In Zone 3, the maximum storey displacements of is base model reduced by 36.26% and 22.93% by shear wall and FVD models respectively.
2) In Zone 4, the percentage reduction of maximum storey displacements were found to be 36.94% and 25.75% by use of shear wall and FVD model respectively.

3) In Zone 5, maximum storey displacements observed in base model is reduced by 36.96% and 27.48% by shear wall and FVD models respectively.
4) Moreover the difference in percentage reduction of story drift between shear wall model and FVD model was not more that 2%.

REFERENCES

[1] IS: 456, Indian Standard Plain and Reinforced Concrete- Code of Practice. Bureau of Indian Standards; 2002; New Delhi.
[2] IS:1893, Indian Standard Criteria for Earthquake Resistant Design of Structures. Part– I General Provisions and Building. Bureau of Indian Standards; 2002; New Delhi.
[3] 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.
[4] M. K. Muthukumar G, "Analytical modeling of damping," indian Concr. J., vol. 88, no. 4, 2014.
[5] S. Infanti, J. Robinson, and R. Smith, "Viscous Dampers for High-Rise Buildings," 14th World Conf. Earthq. Eng., 2008.
[6] 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.
[7] 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.
[8] J. Marko, D. Thambiratnam, and N. Perera, "Influence of damping systems on building structures subject to seismic effects," Eng. Struct., vol. 26, no. 13, pp. 1939–1956, 2004.
[9] 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.
[10] Chopra, "Dynamics of structures," 2012.