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Storey Response of G+40 Horizontally Connected Buildings with Dampers

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***Abstract*— Analyzing the response of structure to ground shaking caused by an earthquake is one the most important application of structural dynamics. Tall structures are more exposed to dynamic loads, earthquake and wind effects. Tall buildings are characterized by low natural frequency. Hence, they can vibrate significantly under lateral dynamic earthquake loads. This paper deals with the analysis of G+40 storey buildings connected horizontally with the truss bridge at 21st and 31st storey having fixed base and shows the storey response curves of buildings connected with dampers and without dampers. The building frame type used is ordinary moment resisting frame (OMRF). The dampers used are fluid viscous dampers (FVD) having force capacity of 500KN. The analysis is done using ETABS V16 software.**

Keywords*— *Dampers, fluid viscous damper, storey response curve, fixed base, seismic response, ordinary moment resisting frame, ETABS V16.

I. INTRODUCTION

As the business activities demands to be on the point of one another and at the town centre, tall buildings get a lot of attention in today's life. Also, because they form distinctive landmark, tall buildings are oftentimes developed in town centers as status image for company organization. Due to the speedy increase in population and reduction in accessibility of land, vertical accommodation is obtaining a lot of preference which is resulting in vertical town development. The higher land costs, reduction in urban sprawl and for agricultural production, residential buildings are growing upward. Buildings are designed primarily to serve the needs of occupancy whether residential or commercial. At the same time, clients requirement regarding aesthetic qualities plays important role.

The modeling of high rise structure for analysis is depends on the approach of research. The bottom shaking that occurs in an earthquake are often represented as a series of multidirectional random acceleration pulses. The seismal response of tall building will depend on the dynamic properties of the structure, ground motion at the foundation and mode of soil structure interaction. Response spectrometry shows that how the structure will respond if damping is elicited. Various curves are developed with different levels of damping. As damping increases, response spectra shift downward. As per typical earthquake resistant design, structure is designed for forces which are much less than the actual design earthquake forces. Therefore, throughout earthquake event, structure undergoes severe non resilient deformation with non repairable damages. RCC structure can be made ductile with the help of reinforcing steel. Thus, to grasp whether or not the structure can all collapse or part collapse or wont collapse throughout or after earthquake, time history analysis is required to perform. The results obtained from analysis are studied to know the actual behavior of structure.

Fig 1: Real horizontally connected structures.

II. EXAMPLE BUILDING

Building set up chosen for this project is as shown in figure below. Two buildings are connected by a truss bridge of 50m length at twenty first floor and thirty first floor. The structure is built with ordinary moment resisting frame (OMRF). Both buildings are symmetric to each other and considered to be served as residential building. Building is having forty storeys for accommodation purpose and top story as terrace. The columns are fixed at base. Two column sizes are utilized in

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structure. Column of size 0.85m x 0.65m are used up to 10th storey and 0.75m x 0.55m are used for rest of the storey. Beams having cross sectional size 0.3m x 0.6m. The floor to floor height is kept constant as 3m and slab thickness as 0.18m throughout the structure. 4 lifts are provided at each floor per building. Shear wall of 0.3m thick are used for the lift sections. Concrete grades used are M35 and M40 while steel used is of grade HYSD500. Instead of traditional brick wall Autoclave Aerated Concrete (AAC) Blocks are used as wall having unit weight ranging from 4.6 kN/m^3 to 7.5 kN/m^3 which is almost 1/3rd of normal concrete. Building is analyzed for all zones for earthquake. Load combinations are taken as per IS 456:2000 and earthquake loading is taken as per IS 1893:2002. Load combinations used are listed below:

1.5(DL+LL)
1.5(DL±EQx)
1.5(DL±EQy)
1.5(DL±WLx)
1.5(DL+±WLy)
1.2(DL+LL±EQx)
1.2(DL+LL±EQy)
1.2(DL+LL±WLx)
1.2(DL+LL±WLy)
0.9DL±1.5EQx
0.9DL±1.5EQy

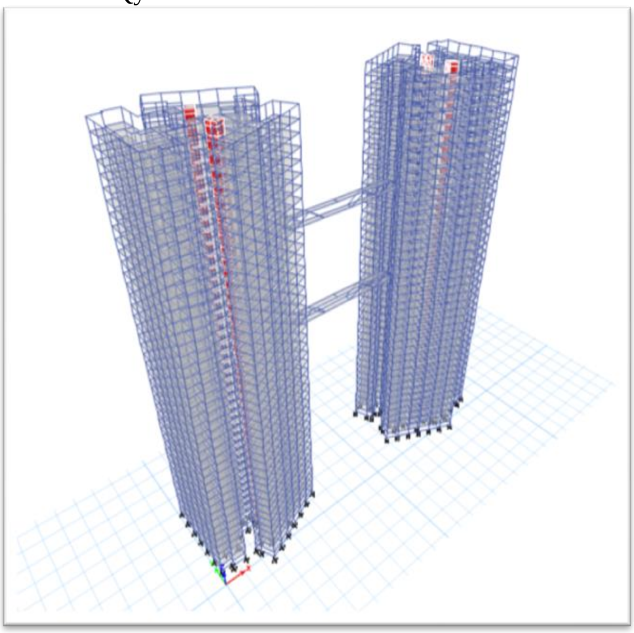

Fig 2: 3-D view of G+40 building.

A. *Fluid Viscous Dampers:*

The fluid viscous dampers are hydraulic devices that dissipate the mechanical energy of seismal events and cushion the impact between structures. They're versatile and might be designed to permit free movement in addition as controlled damping of a structure to safeguard from wind load, thermal motion or seismic events. The fluid viscous damper is consisting of oil cylinder, piston, piston rod, lining, medium, pin head and other main parts. The piston may create mutual motion within the oil cylinder. The piston is provided with damping structure and therefore the oil cylinder is jam-packed with fluid damping medium. Once the external stimulation (such as earthquake, wind vibration) reaches to the engineering structure, it'll be deformed and drive the damper to move, which will occur the pressure difference on the different side of the piston. Then the medium can undergo the damping structure and make damping power, which will occur the exchange of power (the mechanical power exchange to heat power). All which will reach the aim of reducing the engineering structure's vibration.

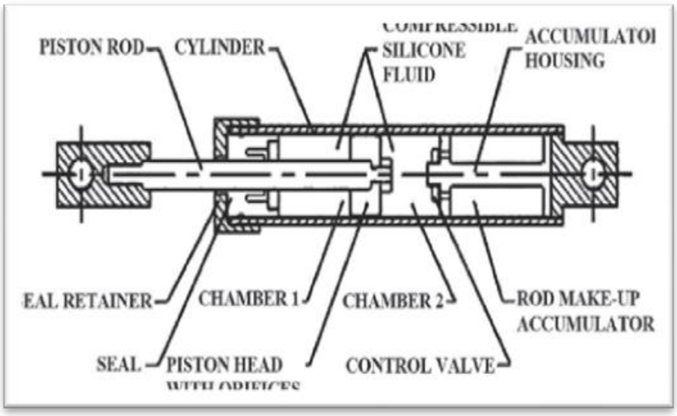

Fig 3: schematic diagram of Fluid Viscous Damper

Damper system are designed and made to safeguard structural integrities, management and stop structural damages by fascinating seismic energy and reduces deformations within the structure. Due to easy installation, adaptability, coordination with other members and variety in their sizes, viscous dampers have several applications in planning and retrofitting..

In this project, each building is connected with 6 fluid viscous dampers at alternate floors. Dampers having capacity of 500kN are used. Table showing damper capacity is shown below:

TABLE 1: FVD WITH DIFFERENT CAPACITIES FORCES (KN)

Force (kN)	Spherical Bearing Bore Diameter (mm)	Stroke (mm)	Clevis Thickness (mm)	Weight (kg)
250	38.10	±75	43	44
500	50.80	±100	55	98
750	57.15	±100	59	168
1000	69.85	±100	71	254
1500	76.20	±100	77	306
2000	88.90	±125	91	500
3000	101.60	±125	117	800
4000	127.00	±125	142	1088
6500	152.40	±125	154	1930

B. *Response Spectrum Analysis:*

Response spectra are curves plotted between maximum response of system subjected to specified earthquake ground motion and its time period (or frequency). Response spectrum can be interpreted as the locus of maximum response of a system for given damping ratio. Response spectra thus helps in obtaining the peak structural responses under linear range, which can be used for obtaining lateral forces developed in structure due to earthquake thus facilitates in earthquake-

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resistant design of structures. The three spectra i.e. displacement, pseudo velocity and pseudo acceleration provide the same information on the structural response. However, each one of them provides a physically meaningful quantity and therefore, all three spectra are useful in understanding the nature of an earthquake and its influence on the design. A combined plot showing all three of the spectral quantities is possible because of the relationship that exists between these three quantities.

C. *Time History Analysis:*

The actual method of mixing the various modal contributions is a probabilistic averaging technique and in some cases, results will not represent the actual behaviour of structure. Time history analysis overcomes this. However, it needs massive procedure efforts. The tactic consists of a step by step direct integration in which the time domain is discretized into a number of tiny increments and for every quantity the equation of motion is solved with the displacements and velocities of the previous step serving as initial functions. The tactic is applicable to both elastic and inelastic analyses. In elastic analysis, the stiffness characteristics of structure are assumed to be constant for whole duration of the earthquake. In inelastic analysis, the stiffness is assumed to be constant through the progressive time solely.

The proposed building in Zone V with site condition III is analysed for both response spectrum and time history analysis with time history data of El-Centro earthquake in 1940. The analysis is done for with damper condition and without damper condition also. 5% damping is allowed in the structure. The graphs of Spectral Displacement Vs Period, Pseudo Spectral Velocity Vs Period and Pseudo Spectral Acceleration Vs Period are obtained which are shown in result section.

III.RESULTS

The proposed building in analyzed in different zones of earthquake and the displacement value of each storey are tabulated for with damper and without damper condition for each zone. Chart 1 shows the displacement values of building in Zone II with site type I. Chart 2 shows the displacement values of building in Zone III with site type III. Chart 3 shows the displacement values for Zone IV with site type II and chart 4 shows displacement values for Zone V with site type III.

TABLE 2: STOREY DISPLACEMENT IN ZONE II (X-DIRECTION)

Storey	With Damper	Without Damper
top	66.266	79.234
40th floor	65.392	77.96
39th floor	64.115	76.563
38th floor	62.787	75.087
37th floor	61.397	73.549
36th floor	59.954	71.944
35th floor	58.478	70.269
34th floor	56.919	68.524
33rd floor	55.357	66.709
32ndfloor	53.686	64.828
31st floor	52.042	62.884
30th floor	50.269	60.88
29th floor	48.551	58.82
28th floor	46.69	56.707
27th floor	44.907	54.548
26th floor	42.974	52.346
25th floor	41.141	50.107
24th floor	39.152	47.836
23rd floor	37.285	45.539
22ndfloor	35.258	43.221
21st floor	33.373	40.888
20th floor	31.328	38.545
19th floor	29.446	36.199
18th floor	27.405	33.859
17th floor	25.545	31.533
16th floor	23.534	29.226
15th floor	21.718	26.941
14th floor	19.75	24.68
13th floor	17.997	22.449
12th floor	16.093	20.254
11th floor	14.426	18.102
10th floor	12.608	15.998
9th floor	11.054	13.951
8th floor	9.348	11.968
7th floor	7.94	10.059
6th floor	6.377	8.236
5th floor	5.17	6.511
4th floor	3.793	4.901
3rd floor	2.82	3.479
2nd floor	1.743	2.203
1st floor	1.067	1.13
PL	0.298	0.343
GL	0.105	0.044
Base	0	0

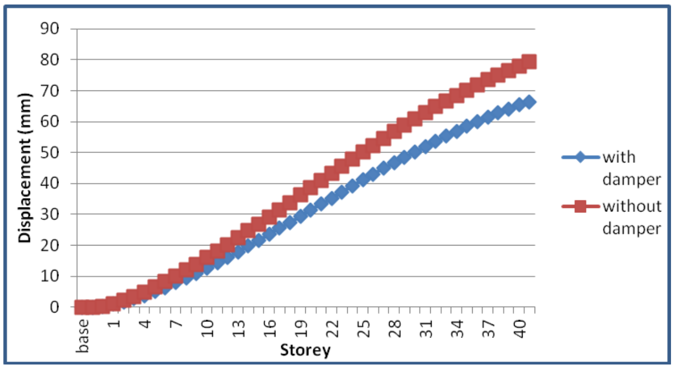

Chart -1(a): Comparison of storey displacement in Zone II (x-direction)

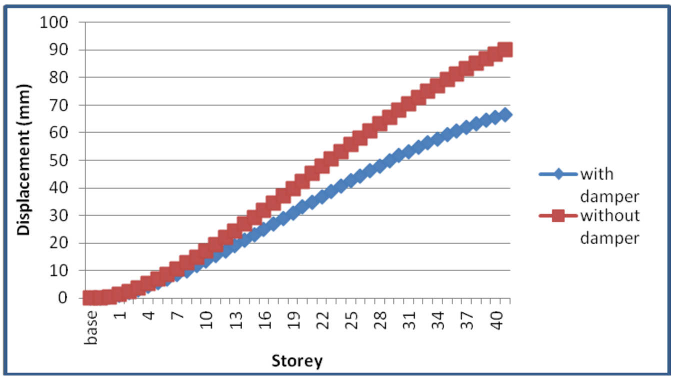

Chart -1(b): Comparison of storey displacement in Zone II (y-direction)

TABLE 3: STORY DISPLACEMENT IN ZONE III (X-DIRECTION)

Storey	With Damper	Without Damper
top	144.194	172.414
40th floor	142.293	169.641
39th floor	139.513	166.601
38th floor	136.626	163.389
37th floor	133.599	160.042
36th floor	130.46	156.549

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35th floor	127.249	152.905
34th floor	123.855	149.107
33rd floor	120.457	145.16
32nd floor	116.821	141.066
31st floor	113.243	136.835
30th floor	109.386	132.474
29th floor	105.647	127.992
28th floor	101.597	123.395
27th floor	97.719	118.696
26th floor	93.511	113.905
25th floor	89.523	109.033
24th floor	85.194	104.092
23rd floor	81.131	99.093
22nd floor	76.721	94.049
21st floor	72.62	88.971
20th floor	68.17	83.873
19th floor	64.074	78.769
18th floor	59.632	73.677
17th floor	55.587	68.616
16th floor	51.21	63.597
15th floor	47.258	58.623
14th floor	42.975	53.703
13th floor	39.162	48.849
12th floor	35.018	44.073
11th floor	31.392	39.39
10th floor	27.435	34.812
9th floor	24.054	30.357
8th floor	20.34	26.042
7th floor	17.277	21.888
6th floor	13.876	17.921
5th floor	11.25	14.168
4th floor	8.254	10.665
3rd floor	6.136	7.57
2nd floor	3.793	4.793
1st floor	2.321	2.459
PL	0.648	0.746
GL	0.229	0.096
Base	0	0

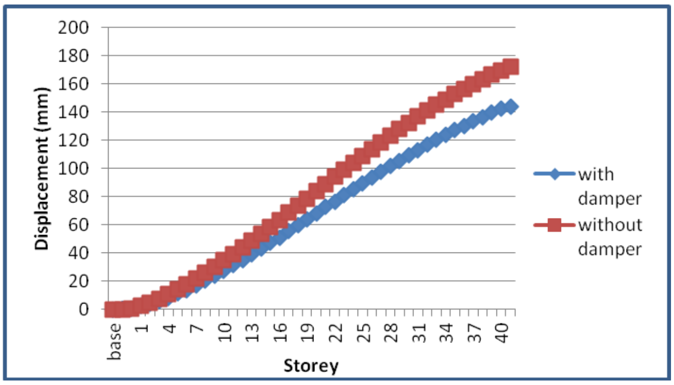

Chart 2(a): Comparison of story displacement in Zone III (x-direction)

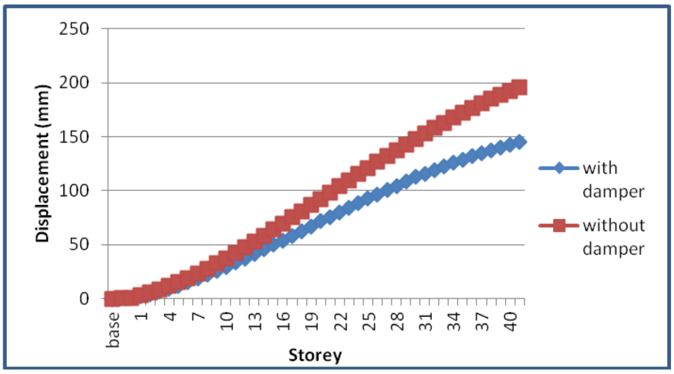

Chart 2(b): Comparison of storey displacement in Zone III (y-direction)

TABLE 4: STOREY DISPLACEMENT IN ZONE IV (X-DIRECTION)

Storey	With Damper	Without Damper
top	265.593	317.571
40th floor	262.092	312.463
39th floor	256.971	306.865
38th floor	251.652	300.949
37th floor	246.078	294.783
36th floor	240.296	288.35
35th floor	234.381	281.637
34th floor	228.131	274.643
33rd floor	221.872	267.371
32nd floor	215.173	259.832
31st floor	208.584	252.038
30th floor	201.48	244.005
29th floor	194.592	235.75
28th floor	187.133	227.283
27th floor	179.989	218.627
26th floor	172.239	209.802
25th floor	164.894	200.829
24th floor	156.92	191.728
23rd floor	149.437	182.521
22nd floor	141.313	173.23
21st floor	133.761	163.877
20th floor	125.564	154.487
19th floor	118.019	145.086
18th floor	109.838	135.706
17th floor	102.386	126.384
16th floor	94.324	117.14
15th floor	87.046	107.978
14th floor	79.156	98.916
13th floor	72.133	89.976
12th floor	64.499	81.179
11th floor	57.821	72.552
10th floor	50.532	64.121
9th floor	44.306	55.915
8th floor	37.465	47.967
7th floor	31.823	40.316
6th floor	25.559	33.008
5th floor	20.721	26.096
4th floor	15.204	19.644
3rd floor	11.302	13.943
2nd floor	6.987	8.828
1st floor	4.275	4.529
PL	1.193	1.374
GL	0.422	0.176
Base	0	0

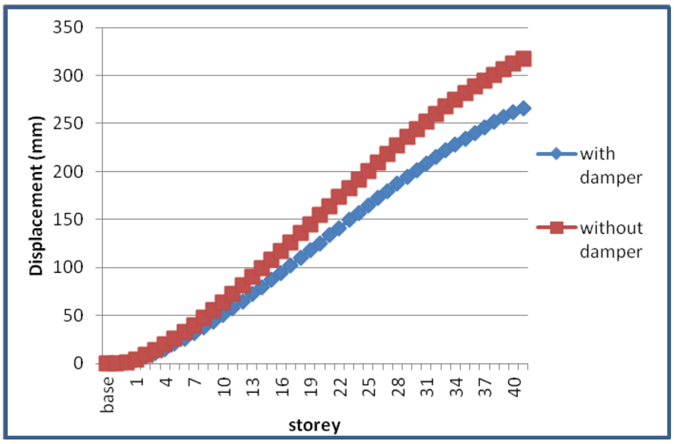

Chart 3(a): Comparison of storey displacement in Zone IV (x-direction)

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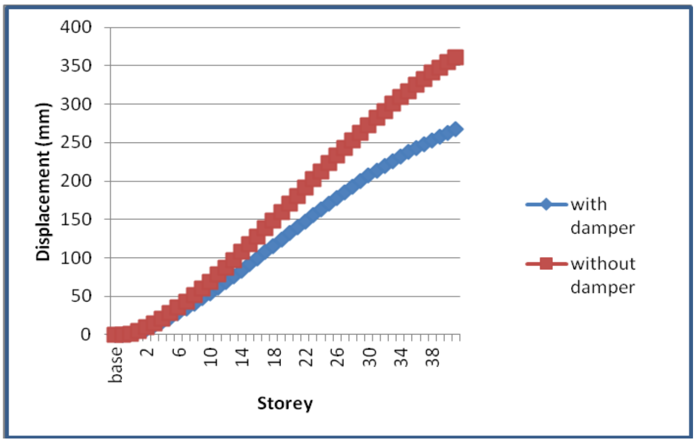

Chart 3(b): Comparison of storey displacement in Zone IV (y-direction)

TABLE 5: STOREY DISPLACEMENT IN ZONE V (X-DIRECTION)

Storey	With Damper	Without Damper
top	430.305	524.387
40th floor	424.678	516.047
39th floor	416.464	506.927
38th floor	407.940	497.3
37th floor	399.004	487.273
36th floor	389.745	476.814
35th floor	380.265	465.902
34th floor	370.256	454.533
33rd floor	360.223	442.712
32nd floor	349.494	430.453
31st floor	338.926	417.775
30th floor	327.539	404.701
29th floor	316.483	391.258
28th floor	304.514	377.458
27th floor	293.033	363.339
26th floor	280.580	348.931
25th floor	268.760	334.265
24th floor	255.925	319.373
23rd floor	243.863	304.289
22nd floor	230.761	289.049
21st floor	218.566	273.687
20th floor	205.320	258.241
19th floor	193.112	242.758
18th floor	179.861	227.285
17th floor	167.779	211.885
16th floor	154.689	196.588
15th floor	142.863	181.403
14th floor	130.021	166.357
13th floor	118.580	151.486
12th floor	106.121	136.829
11th floor	95.215	122.426
10th floor	83.285	108.324
9th floor	73.092	94.57
8th floor	61.861	81.223
7th floor	52.589	68.349
6th floor	42.272	56.027
5th floor	34.310	44.347
4th floor	25.189	33.421
3rd floor	18.756	23.749
2nd floor	11.610	15.054
1st floor	7.116	7.732
PL	1.988	2.344
GL	0.703	0.301
Base	0	0

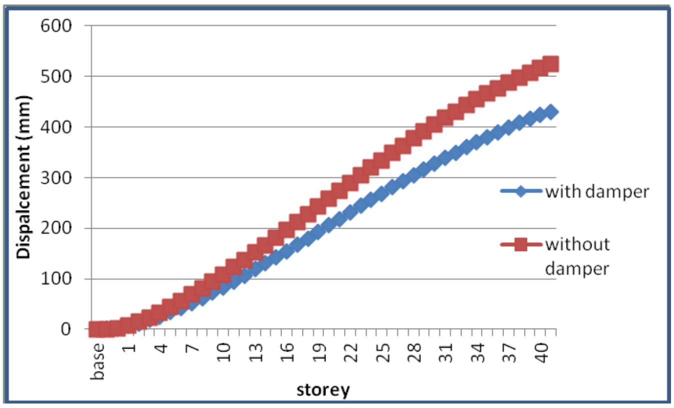

Chart 4(a): Comparison of storey displacement in Zone V (x-direction)

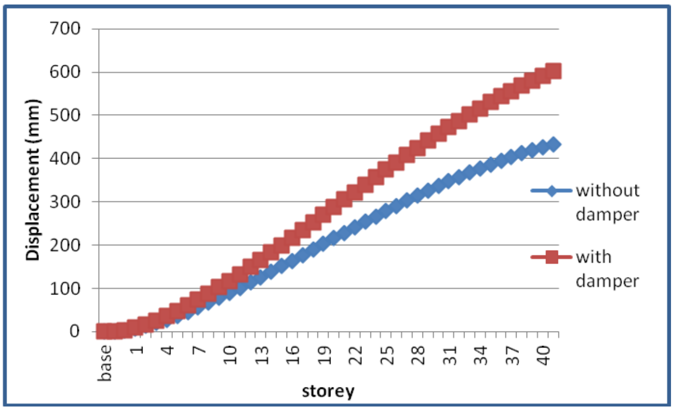

Chart 4(b): Comparison of storey displacement in Zone V (y-direction)

TABLE 6: COMPARISON OF MAXIMUM DISPLACEMENTS OF BUILDING (X-DIRECTION)

ZONE	II	III	IV	V
with damper	66.266	144.195	267.07	430.3
without damper	79.234	172.41	317.57	524.387

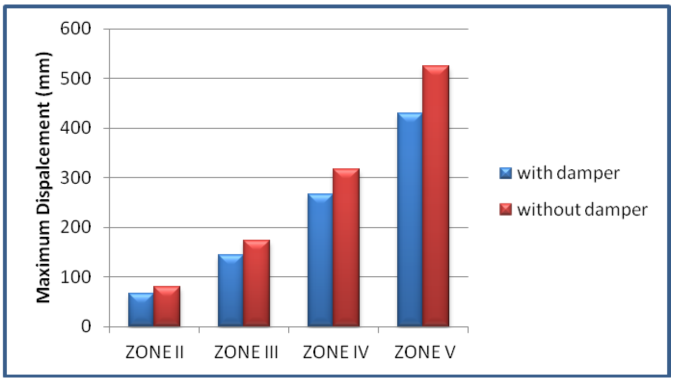

Chart 5(a): Comparison of maximum displacements of building (x-direction)

TABLE 7: COMPARISON OF MAXIMUM DISPLACEMENTS OF BUILDING (Y-DIRECTION)

ZONE	II	III	IV	V
with damper	66.636	145	265.59	434.029
without damper	90.069	195.96	360.99	601.809

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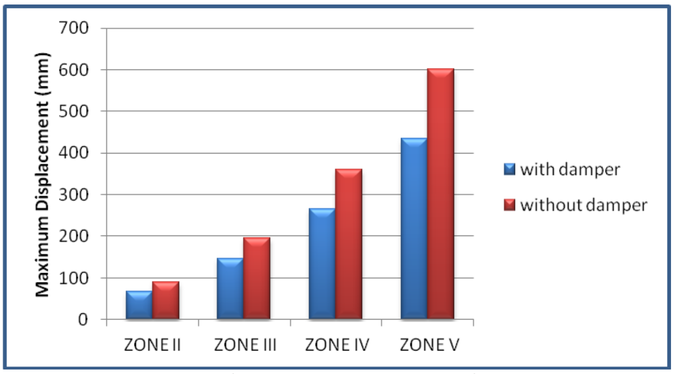

Chart 5(b): Comparison of maximum displacements of building (y-direction)

Building in Zone V is again analysed for time history analysis with time history data of El-Centro earthquake in order to compare the difference in spectral acceleration, spectral velocity and spectral displacement of building for with damper and without damper condition. The obtained response spectrum curves having 5% damping are shown below. Table 7 summarizes maximum and minimum values of acceleration, velocity and displacement at 0% damping and 0.1% damping.

TABLE 8: MAXIMUM AND MINIMUM VALUES OF RESPONSE SPECTRUM CHARACTERISTICS

Characteristics	With damper		Without damper	
	0% damping	0.10% damping	0% damping	0.10% damping
Pseudo spectral Acceleration (mm/sec²)	4060.08	440.9	7206.58	497.55
Pseudo spectral velocity (mm/sec)	1092.26	2.35	1485	2.5
Spectral displacement(mm)	968.5	0.011	1492.238	0.012

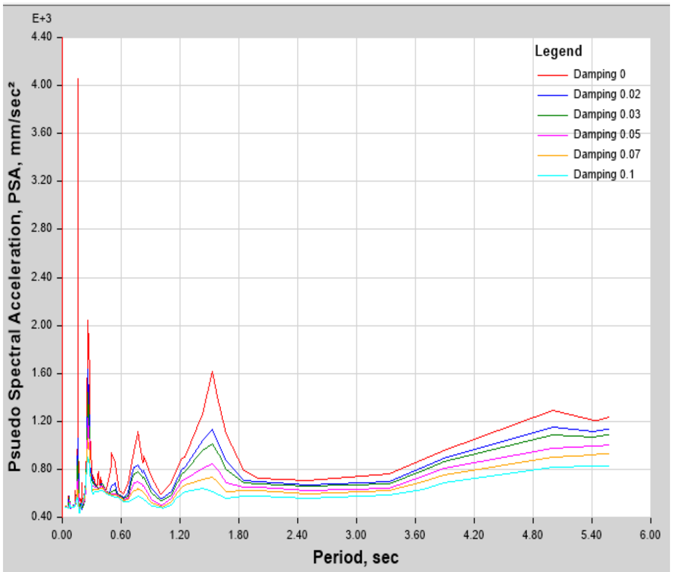

Fig 4(a): PSA Vs Time period (with damper condition)

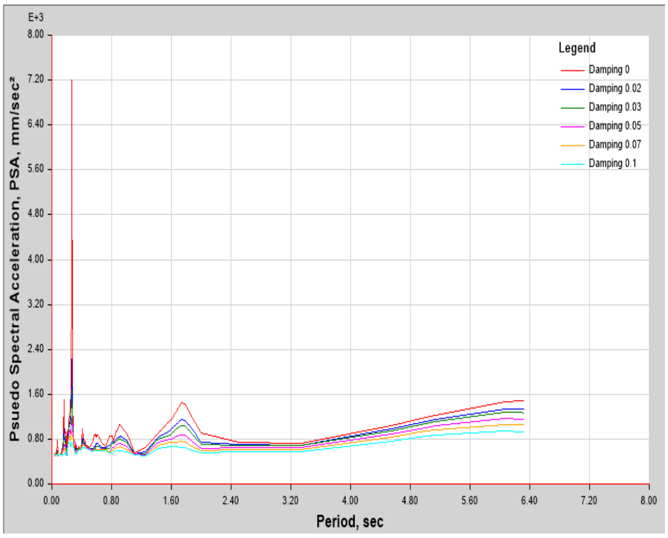

Fig 4(b): PSA Vs Time period (without damper condition)

IV.CONCLUSION

From Table 6 and Table 7 it is observed that by providing dampers overall displacement of building in each zone is considerably reduced. Percentage reduction in displacement for Zone II, Zone III and Zone IV is approximately 16% whereas for Zone V it is approximately 18% for x-direction. On other hand, for y-direction percentage reduction in displacement for Zone II, Zone III and Zone IV is approximately 26% and for Zone V is approximately 28%. From Table 7 it is observed that although having 5% damping in the building, the response spectrum characteristics such as pseudo spectral acceleration, pseudo spectral velocity and spectral displacement are much reduced after the application of dampers in the building. For 0% damping, pseudo spectral acceleration is reduced by approximately 44% while for 0.1% damping it is reduced by approximately 11%. It may be possible to increase the percentage reduction in displacement by increasing the capacity of fluid viscous dampers and the dampers are found to be very effective in reducing earthquake responses.

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