International Journal of Technical Innovation in
Modern Engineering & Science (IJTIMES)
Impact Factor: 5.22 (SJIF-2017), e-ISSN: 2455-2585
Volume 4, Issue 6, June-2018

SEISMIC BEHAVIOR OF MULTISTOREYED FRAME BUILDING WITH FLUID VISCOUS DAMPER

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Abstract: Multi-storeyed buildings are the most economical solution to accommodate the large amount of population in a small space. But as height of building increases lateral forces becomes a major concern to the designer. Providing fluid viscous dampers in multi-storeyed building is one of the effective methods to reduce the response of the structure, when subjected to lateral forces. Fluid viscous damper increases damping capacity of building structure and helps to dissipate energy when subjected to ground motion. In the present study, a building in which fluid viscous dampers are installed in two different positions are analysed for lateral forces when subjected to ground motion in ETABS 2016 by response spectrum method and their responses such as storey displacement and storey drift compared with the model without fluid viscous damper. A fluid viscous damper helps to reduce storey displacement and storey drift significantly.

Keywords: Storey Displacement, Storey drift, Viscous Damper, Damping, Response Spectrum Analysis.

INTRODUCTION

Seismic design of the structure is very essential to improve the performance of buildings subjected to dynamic loads. Due to increase in urbanization, there is great need to accommodate large population in a small area. This has led to a significant increase in demand of high-rise buildings. The increasing height of structure, pose challenges for designers, as stability and safety become main concern. In the past, there were so many catastrophic events has happened such as San Francisco (1906), Philippine earthquake (1990), Bhuj earthquake (2001) are some of them.

It is not economically feasible to design structure as earthquake proof. If the earthquake forces exceed the design forces the structure is designed in such a way that greater damage occurs without collapse. This approach was used for many decades, new design procedures are changing the traditional approach. For example, performance based design. The performance based design provides the structural engineer with the tools to predetermine the amount of damage that the user is willing to tolerate and design the structure accordingly. There are so many types of structural control technologies that shave been developed to resolve the safety and functional problems for structures under the excitation of external force. Structural control for seismic loads is a rapidly expanding field in the family of control systems, also known as earthquake protection systems. It includes passive, active and hybrid systems. Applications for buildings, bridges and industrial plant have been made in many of the seismically active countries of the world.

FLUID VISCOUS DAMPERS

Fluid viscous damper can be defined as a device which can be added to a system to add damping to the system, so that energy dissipation capacity of the system can be increased. The most common functional output equation for a damper can be characterized as:

$$F = C \cdot V^{\alpha}$$

Where F is the output force, V the relative velocity across the damper, C is the damping coefficient and α is a constant exponent which is usually a value between 0.3 and 2. It operates on the principle of fluid flow through orifices. A stainless steel piston moves through chambers that are filled with silicone oil. The silicone oil is inert, non flammable, non toxic and suitable for extremely long periods of time. The pressure difference between the two chambers cause silicone oil to flow through an orifice in the piston head and input energy is transformed into heat, which dissipates into the atmosphere.

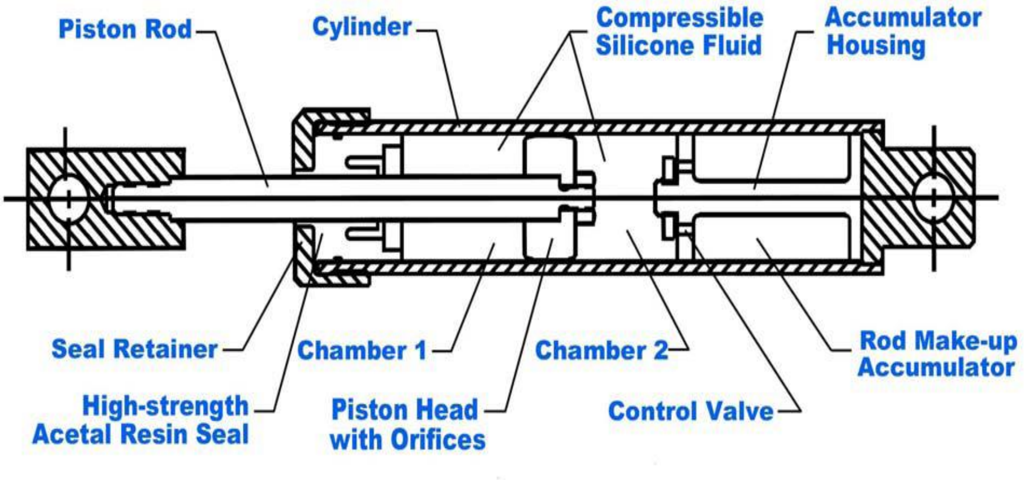

Figure 1 Cross-Section of Fluid Viscous Dampers

(Source: http://taylordevices.com/dampers-seismic-protection.html)

RESPONSE SPECTRUM METHOD

The dynamic equilibrium equations associated with the response of a structure to ground motion are given by:

$$\mathrm{K}\,\mathrm{u}(\mathrm{t}) + \mathrm{C}\,\dot{\mathrm{u}}(\mathrm{t}) + \mathrm{M}\,\ddot{\mathrm{u}}(\mathrm{t}) = \mathrm{m}_{\mathrm{X}}\,\ddot{\mathrm{u}}_{\mathrm{gx}}(\mathrm{t}) + \mathrm{m}_{\mathrm{y}}\,\ddot{\mathrm{u}}_{\mathrm{gy}}(\mathrm{t}) + \mathrm{m}_{\mathrm{z}}\,\ddot{\mathrm{u}}_{\mathrm{gz}}(\mathrm{t})\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (1)$$

Where, ***K*** is the stiffness matrix; ***C*** is the proportional damping matrix; ***M*** is the diagonal mass matrix; $\boldsymbol{u}$, $\dot{\boldsymbol{u}}$, and $\ddot{\boldsymbol{u}}$ are the relative displacements, velocities, and accelerations with respect to the ground; $\boldsymbol{m}_x$, $\boldsymbol{m}_y$, and $\boldsymbol{m}_z$ are the unit Acceleration Loads; and $\ddot{u}_{gx}$, $\ddot{u}_{gy}$, and $\ddot{u}_{gz}$ are the components of uniform ground acceleration. The response-spectrum analysis seeks the likely maximum response to these equations rather than the full time history.

Response spectrum method is one of the method which is used for the analysis of buildings when subjected to ground motion. Even though accelerations may be specified in three directions, only one positive result is produced for every response quantity. Displacements, forces, and stresses are the response. Each result represents a statistical measure of the likely maximum magnitude of that response quantity. Actual response can be varies in between positive value to its negative value. Response-spectrum analysis can be performed using mode superposition. Modes can be computed using eigen vector analysis or Ritz-vector analysis. Ritz vectors are mostly used because they provide more accurate results for the same number of Modes. Response-spectrum can consider high-frequency rigid response if requested and if appropriate modes have been computed. When eigen modes are used, then it is suggested that static correction vectors be computed. This information is automatically available in Ritz modes generated for ground acceleration. In either case, it should be sure to have sufficient dynamical modes below the rigid frequency of the ground motion. Any number of response- spectrum load cases can be defined. Each case can differ in the acceleration spectra applied and in the way that results are combined. Different cases can also be based upon different sets of modes computed in different modal load cases. For example, this would enable us to consider the response at different stages of construction, or to compare the results using eigenvectors and Ritz vectors.

MODEL OF THE PROJECT

An 8-storey building of plan dimensions 25 m × 15 m is modelled in ETABS 2016 having storey height 3.2 m each is considered in zone V and type II soil conditions.

Dead load= 2.5 kN/m^2

Live load= 3 kN/m^2

Load Bearing wall's load= 5 kN/m^2

Non load bearing wall's load= 7.5 kN/m^2

Eccentricity Ratio = 5% for all diaphragms

Seismic Zone Factor, Z [IS Table 2]

Z = 0.36

Response Reduction Factor, R [IS Table 7]

R = 5

Importance Factor, I = 1

Site Type = II

Beam 400 mm x 500 mm and columns 500 mm x 500 mm

Concrete grade M30

Steel grade Fe415

The study contains three models named as model 1, model 2 and model 3. Model 1 has no dampers as shown in Figure 2, model 2 has eight dampers in the plan at the corner position in both directions as shown in Figure 3 and are installed throughout the height of the buildings and model 3 has six dampers in one direction and two are installed in perpendicular direction throughout the height of the buildings. Table 1 shows the storey data modelled in ETABS and Table 2 shows the specifications of link property.

Table 1 Fluid Viscous Damper's Properties

Name	**Type**	**Degrees of Freedom**	**Mass** (kg)	**Weight** (kN)
FVD250	Damper - Exponential	U1	44	250

Table 2 Storey Data

Name	**Height** mm	**Elevation** mm	**Master Storey**	**Similar To**	**Splice Storey**
Storey8	3200	25600	Yes	None	No
Storey7	3200	22400	No	Storey8	No
Storey6	3200	19200	No	Storey8	No
Storey5	3200	16000	No	Storey8	No
Storey4	3200	12800	No	Storey8	No
Storey3	3200	9600	No	Storey8	No
Storey2	3200	6400	No	Storey8	No
Storey1	3200	3200	No	Storey8	No
Base	0	0	No	None	No

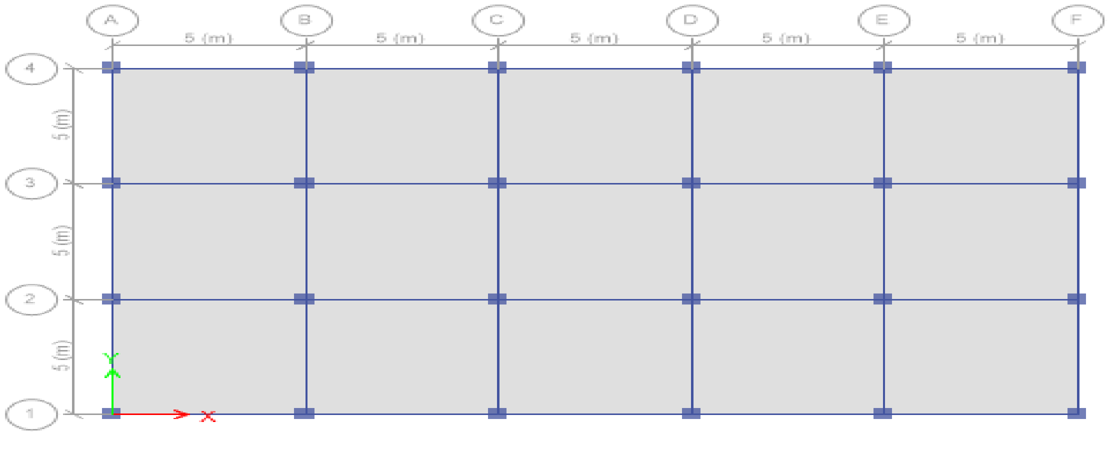

Figure 2 Plan of Model 1 Building

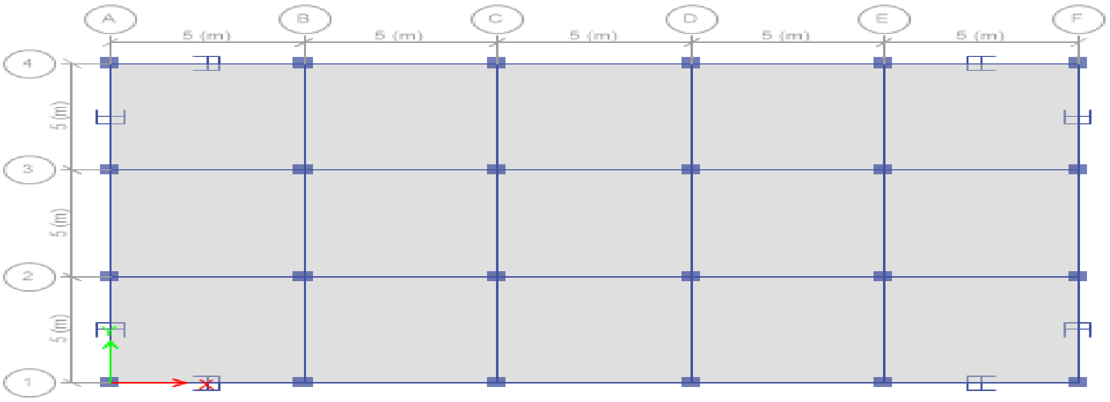

Figure 3 Plan of Model 2 Building

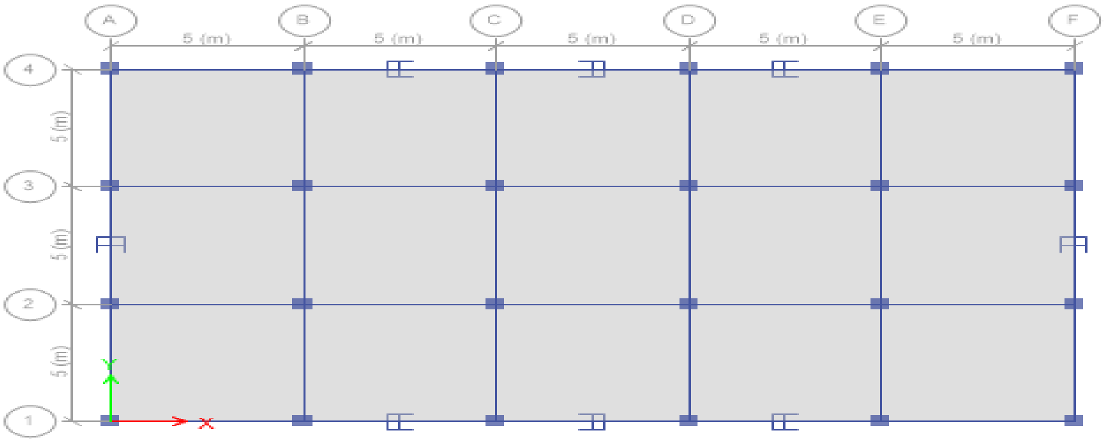

Figure 4 Plan of Model 3 building

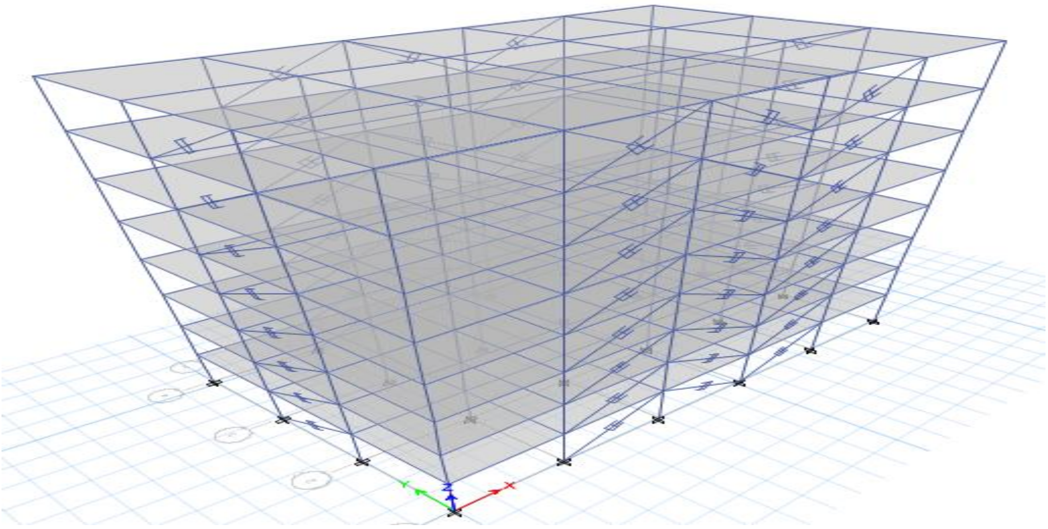

Figure 5 Isometric view of model 1

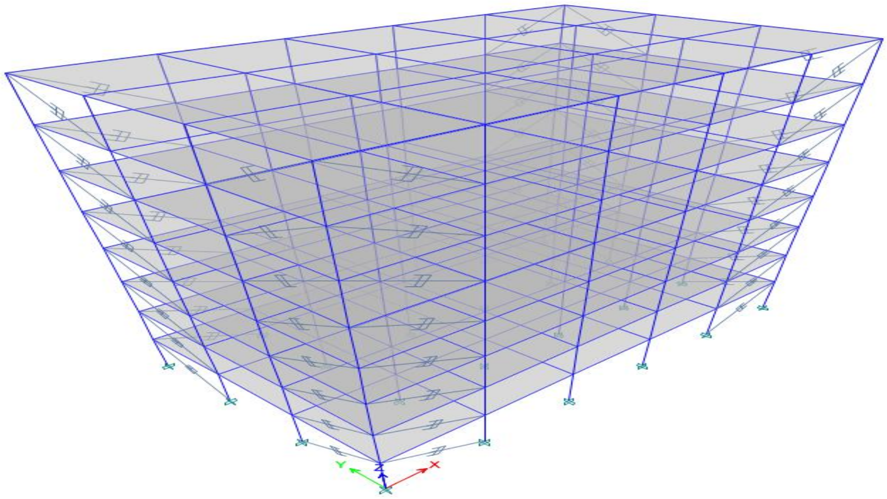

Figure 6 Isometric view of model 3

RESULTS AND INTERPRETATIONS

Fluid viscous dampers reduce the response, but the position of dampers also plays important role in response, reduction of storey displacement and storey drift. According to Indian standard code minimum 90 % of mass participation factor is required.

Storey Displacement: Table 3 shows the value of maximum storey displacement of different models in global – X direction and with the help of Table 3, a graph between maximum storey drift and storey levels is plotted as shown in Figure 7. It can be seen clearly from the Figure 5 that model 3 (having dampers at middle positions),

Model 2 having dampers at corner positions have less displacement, when compared with model 1 which is without dampers due to the fact that dampers increases the damping capacity of the building and results in less response and greater energy dissipation.

Table 1 Maximum Storey Displacements in global-X

Storey	Model 1	Model 2	Model 3
Base	0	0	0
Storey1	3.131	0	0
Storey2	8.211	1.23	0.451
Storey3	13.215	3.38	1.25
Storey4	17.649	6.166	2.298
Storey5	21.356	9.341	3.508
Storey6	24.235	12.703	4.806
Storey7	26.181	16.105	6.135
Storey8	27.199	19.467	7.462

Further to the positions of dampers, it can be seen from Figure 7 that model 3 which has six dampers in global-X direction, three on each side of the outer frame has lowest displacements. Model 2 also has less displacement than model 1 which has no dampers.

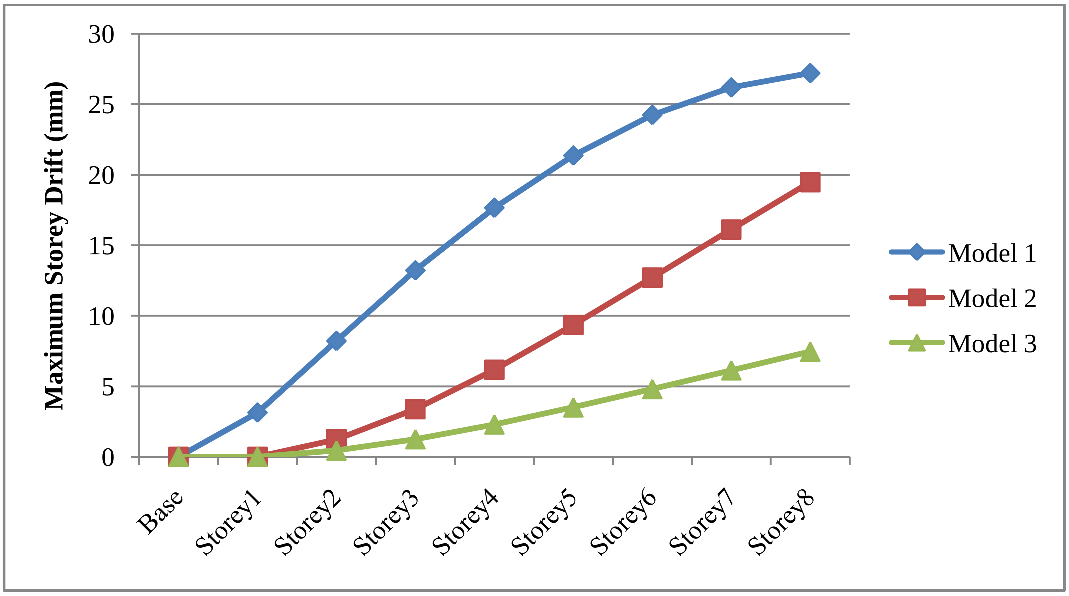

Figure 7 Maximum Storey Displacements in global-X

Table 2 Maximum Storey Displacements in global-Y

Storey	Model 1	Model 2	Model 3
Base	0	0	0
Storey1	3.167	0	0.918
Storey2	8.412	1.226	3.159
Storey3	13.624	3.366	6.266
Storey4	18.261	6.135	9.874
Storey5	22.157	9.286	13.699
Storey6	25.212	12.617	17.533
Storey7	27.314	15.98	21.253
Storey8	28.469	19.295	24.82

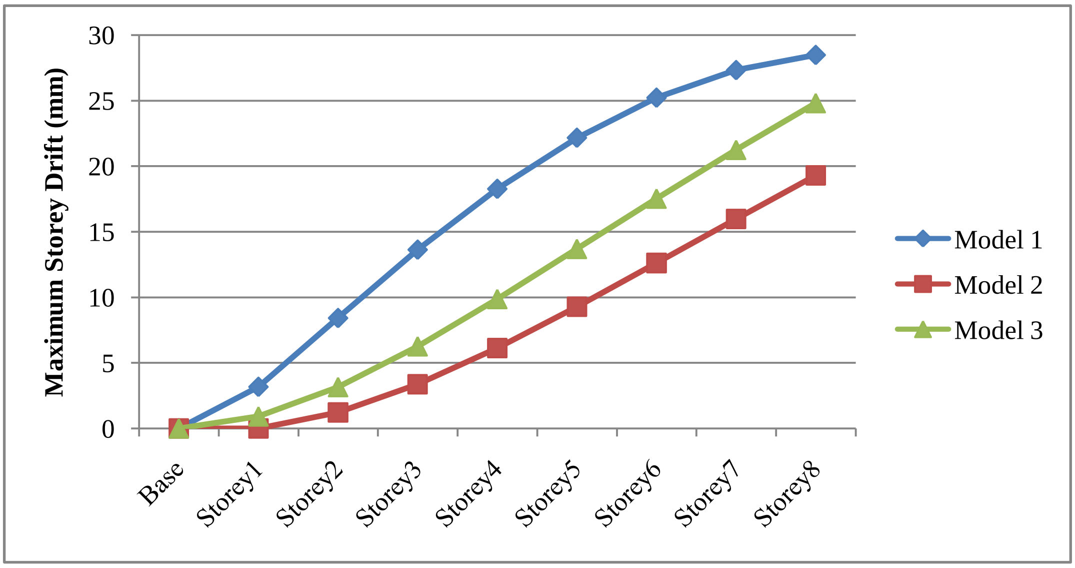

Figure 8 Maximum Storey Displacements in global-Y

Table 4 shows the maximum Storey displacement in global-Y direction and with the help of Table 4 a graph is plotted between maximum storey displacement in global-Y and storey levels as shown in Figure 8. In this case model 2 has less displacement than model 2due to the fact that in model 2 dampers are installed in a symmetric way at the corner positions, so it shows comparable response on both sides.

Storey Drift

Storey Drift defined here is the ratio of difference between displacements of storey above it and that storey to that of storey height.

$$Storey\ Drift = \frac{u_{i+1} - u_i}{H} \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Equation (2) shows the drift that is used in this study. IS code limit value of the maximum drift ratio to. 0004.

Table 5 shows maximum drift values of different model in global-X and with the help of Table 5 a graph is plotted between maximum storey drift and storey levels as shown in Figure 9. It can be seen from the Figure 9 that the pattern graph line of model 1 without damper is different from model 2 and model 3 which are installed with fluid viscous dampers. In model 1, storey drift value increases up to storey 2 and starts decreasing, but in model 2 and model 3, the graph line increases and becomes almost constant towards upper storeys.

Table 3 Maximum Storey Drift in Global-X

Storey	Model 1	Model 2	Model 3
Base	0	0	0
Storey1	0.000978	0	0
Storey2	0.00159	0.000384	0.000141
Storey3	0.001582	0.000672	0.00025
Storey4	0.001435	0.000871	0.000328
Storey5	0.001249	0.000994	0.000378
Storey6	0.001022	0.001053	0.000406
Storey7	0.000732	0.001066	0.000416
Storey8	0.000401	0.001053	0.000415

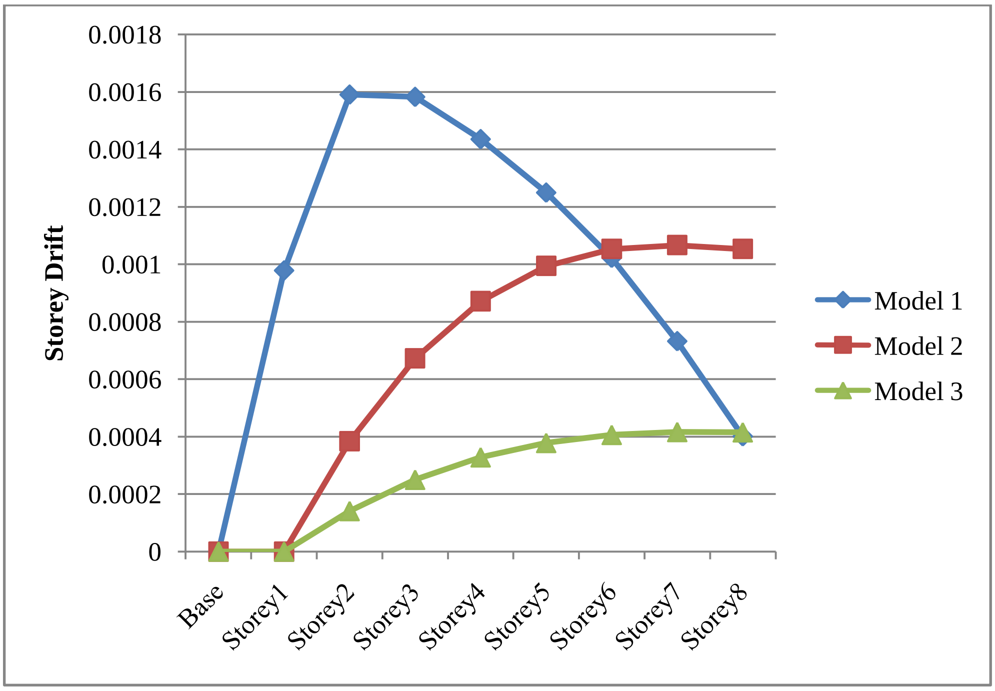

Figure 9 Maximum Storey Drift in global-X

Table 4 Maximum Storey Drift in Global-Y

Storey	Model 1	Model 2	Model 3
Base	0	0	0
Storey1	0.00099	0	0.000287
Storey2	0.001642	0.000383	0.000701
Storey3	0.001648	0.000669	0.000973
Storey4	0.001504	0.000866	0.001132
Storey5	0.001319	0.000986	0.001204
Storey6	0.001091	0.001043	0.00121
Storey7	0.000794	0.001053	0.001176
Storey8	0.000453	0.001038	0.001127

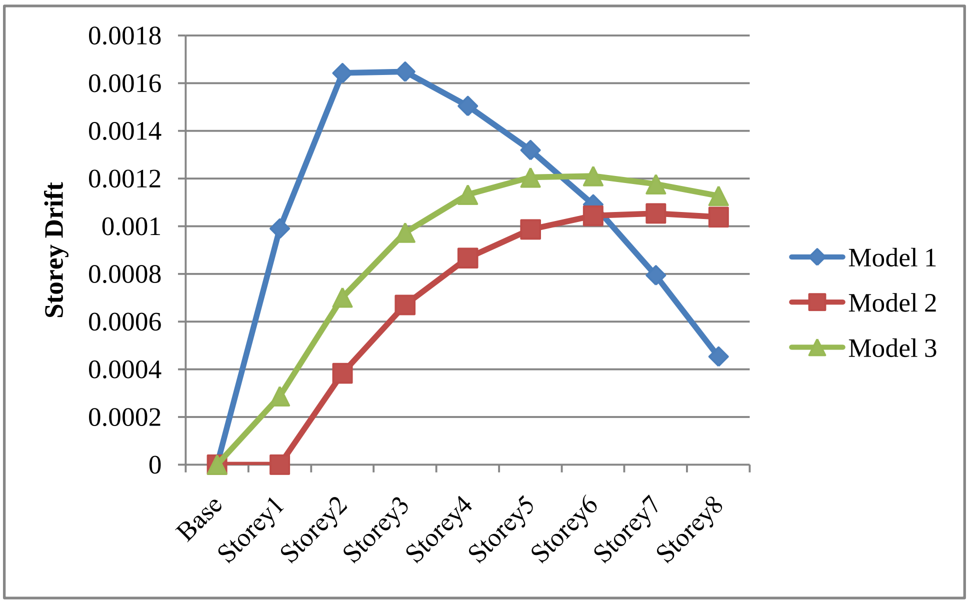

Figure 10 Maximum Storey Drift in global-Y

Table 6 shows maximum drift values of different model in global-Y and with the help of Table 6 a graph is plotted between maximum storey drift and storey levels as shown in Figure 10. It is observed from the graph shown in Figure 8 that, at 8th storey level storey drift of model 1 is less than model 2 and model 3, but have maximum value at storey 2 which is greater than other two.

CONCLUSION

It is observed that fluid viscous damper reduces storey drift and storey displacement reduces significantly when compared with bare model frame model.

It has been observed that

- There is a 28.3 % decrease in global-X and 32.3 % decrease in maximum storey displacements of model 2 when compared with bare model frame i.e. model 1 (without dampers).
- There is a 72.5 % decrease in global-X and 13 % decrease in maximum storey displacements of model 3 when compared with bare model frame i.e. model 1 (without dampers).
- There is a 33 % decrease in global-X and 36 % decrease in the maximum storey drift of model 2 when compared with bare model frame i.e. model 1 (without dampers).
- There is a 73.8 % decrease in global-X and 28.6 % decrease in the maximum storey drift of model 3 when compared with bare model frame i.e. model 1 (without dampers).

So it can be concluded that response of building reduced when building is installed with fluid viscous dampers, further positions of the fluid viscous dampers plays important role in response reduction.

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