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OPTIMIZATION OF VISCOUS DAMPER PROPERTIES IN R.C.C. FRAME STRUCTURE

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Abstract: - *Conventionally, the structures are designed to resist dynamic forces through the combination of strength, deformability and the energy absorption. These structures deform well beyond elastic limit in a severe earthquake. The extent of damage the earthquake may cause to the structure may depend on severity of the earthquake, distance from the epicenter and many other factors. The damage can be reduced by proper analysis and design of the structure. To avoid the damage of the structure due to conventional ductility based design, Structural engineers are working to figure out different alternative systems that could be robust and can withstand strong motions. Energy dissipation devices is one of the system that work by absorbing or reflecting a portion of the input energy that would otherwise be transmitted to the structure itself and would damage the structure. In such situations structural control techniques are more promising for earthquake resistant design. The concept of these techniques is to absorb the vibration energy of the structure and hence reduce the stresses in the structure. Fluid Viscous Dampers when used in the structure in high seismic areas, reduces the vibration, displacement and the stresses induced by both the wind and the earthquakes. In the present study the effectiveness of the fluid viscous damper in reducing the stresses and the deflections in a structure in a seismic event is evaluated analytically for a 6 story structure which is symmetrical in plan, modelled and analyzed using E-tabs 2016 software. The earthquake loads are defined as per IS 1893-2016 (part 1). To analyze the structure static and dynamic methods are adopted. Non Linear time history analysis is done to obtain the real time deflections and stresses in the actual structure. The results show the procedure that how the values of the damping coefficient and the effective stiffness of the brace damper can be arrived at in the E-tabs software. This is could be done by the iterative process.*

Keywords: *Brace stiffness, Fluid viscous damper, Non- Linear Time History Analysis, Optimization of Damper properties, Energy Dissipation Device*

I. INTRODUCTION

Earthquake is vibration of ground by seismic waves which erupts due to sudden release of energy in the lithosphere. From the past records we have seen the damage it can do to the buildings that we built. EQs induce a large amount of lateral force in the building which results in excessive deflection and stress concentration depending on the type of the structure. Collapse of the structure leads to loss of life and properties of the individual causing a large amount of financial loss and social sufferings. Hence we need to design earthquake resistant structures. Over long period of time Ductility based design concept is used to dissipate the seismic energy induced in the structural systems, but the damage control cannot be achieved to the required level. Because of these limitations many structural control techniques have been developed over the years and gaining importance nowadays. These systems dissipate major portion of seismic energy and reduce the forces on the primary structure, thereby limiting the structural deformations. The structural control systems are classified under following basic headings as passive, active and semi-active control systems. In the present study attempt is made as how to arrive at the final values of viscous damper properties to be entered in the E-tabs software.

1.1 DAMPERS

Dampers are the devices which are used to absorb or dissipate the vibration caused by the earthquake by increasing the damping and stiffness of the structure. Damper is a device that deadens, restrains or depresses.

Types of dampers:

1. Friction damper
2. Metallic damper
3. Viscous damper
4. Visco-elastic damper
5. Tuned mass damper

1.2 Fluid viscous dampers

Among the various energy dissipation devices, fluid viscous dampers have been widely used in the vibration control in the structural and mechanical systems. These dampers were widely used by the military and the aerospace industry for years and recently it has been adapted in the structural applications in civil engineering. FVDs have a unique ability to reduce the deflection and stresses in the structure subjected to lateral loading. This is because a FVD varies its force only with the velocity, which delivers a response that is essentially out of phase with stresses. This type of damper is generally less expensive to purchase, install and maintain compared to other types of dampers.

1.3 Components

FVDs consists of a stainless steel piston rod with a bronze orifice head and a self-contained piston displacement accumulator. The damper cylinder is filled with a compressible viscous fluid (silicone oil) which is generally non-toxic, non-flammable, thermally stable and environmentally safe. A typical longitudinal section of fluid viscous damper is shown in figure-1.

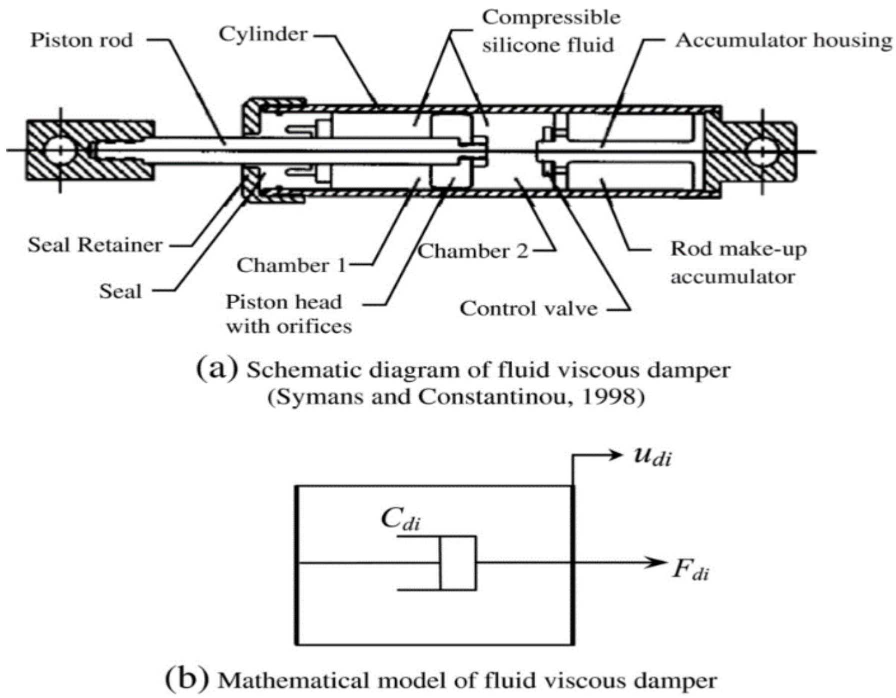

Figure 1: Typical longitudinal section of fluid viscous damper

1.4 Working

Fluid viscous dampers work on the principle of fluid flow through orifices. These devices resemble the common shock absorbers found in the vehicles. FVDs consist of a stainless steel piston that travels through the chambers filled with silicone oil. The oil flows through an orifice in the piston head due to pressure difference between the two chambers and the seismic energy is transformed into heat and dissipated in the atmosphere. When external force acts the piston will make the reciprocating motion and force the damping fluid medium to move from one chamber to another. In this process the friction will be produced between the molecules of the damping medium, medium with the shaft and the piston and also with the cylinder which will produce the damping force. The dampers absorb the mechanical energy and converts it into heat energy which will eventually be cooled by the natural cooling process of the atmosphere and this is how the structure is protected from the transient motions. FVDs can operate over a temperature of -40^{0}c to 70^{0}c. The ideal damping force of the fluid viscous damper is given by: -

$$F=CV^{\alpha}$$

Where F is the damping force, c is damping co-efficient, V is the velocity of piston relative to the cylinder and α is the velocity exponent.

II. DISCRIPTION OF THE ANALYTICAL MODEL: -

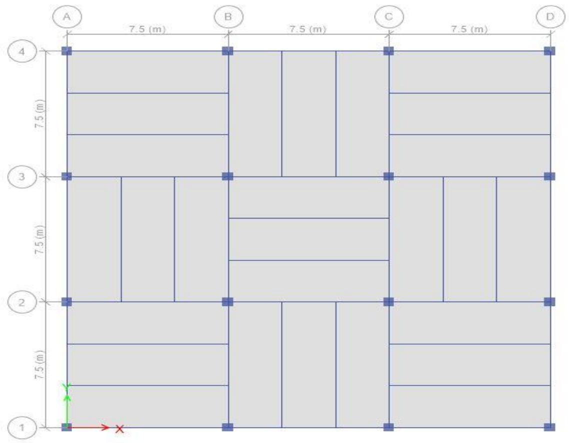

Figure 2: - Plan of the model without damper

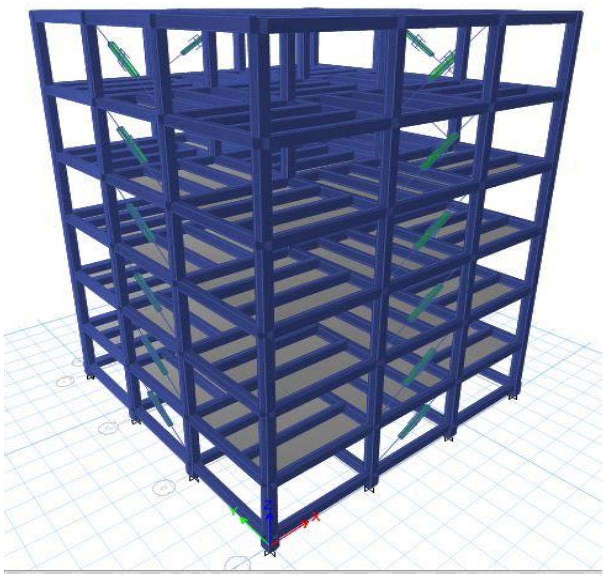

Figure 3: - 3d view of model with damper

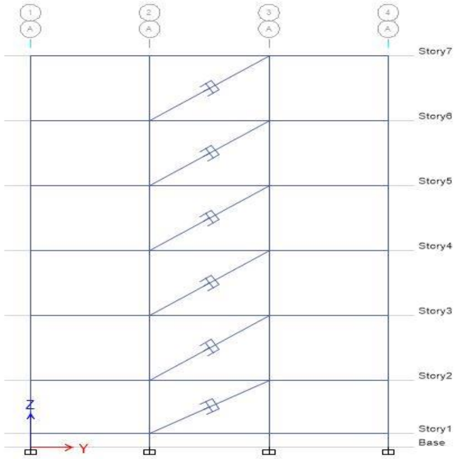

Figure 4: - Elevation view of the model with damper

A 3 bay 6 story reinforced concrete building for a commercial complex is taken from the document no: IITK-GSDMA-EQ26-v3.0 and is considered in the study. Bay width considered here is 7.5m in each direction and the height of the building as Plinth level at 1.1m, ground floor height as 4.1m and from first floor to fifth floor the height is 5m. support conditions are taken as fixed. The material and section properties are as follows:

Table 1: -Section/Material properties

Main Beam	300mm X 600mm
Secondary Beam	200mm X 600mm
Column	500mm X 500mm
	600mm X 600mm
Slab Thickness	100mm
Masonry Wall Thickness	230mm
Grade of Concrete	M25
	M30
Grade of Steel	Fe-415

A live load of 4 kN/m^2 on all the floors and 1.5 kN/m^2 on the roof is considered in addition floor finish of 1 kN/m^2 is considered on all floors and 3 kN/m^2 on the roof. As per IS 1893-2016 Part 1 a live load reduction factor of 0.5 for all the floors except roof is applied in the seismic analysis.
Dampers are applied symmetrically in the center frames on all the four sides of the building. A total of 24 dampers are applied in the building. However, in actual case optimal position of the dampers are to be found out by iterative process.

III. MODELLING AND ANALYSIS

The modelling and the analysis of the building frame with and without dampers is carried out in E-tabs2016 software. For the modelling of the fluid viscous dampers here Link element called damper exponential is used to model the dampers. The mass and the weight of the damper to be considered is to be entered. The link elements are mounted in diagonal fashion only and is active only in its local axial direction. Therefore, only one active degree of freedom U1 is selected in the directional properties and since its behavior is nonlinear, nonlinear option is selected. As there will not be any provision for the rotation the values of Rotational inertia R1, R2 and R3 will be taken as zero. After assigning the directional properties the nonlinear properties of the damper in that particular direction have to be assigned. The values of the effective stiffness, damping coefficient and the velocity exponent values have to be specified. Non-linear time history analysis is carried out using Bhuj acceleration time history.

IV. DETERMINATION OF THE OPTIMAL PROPERTIES OF THE DAMPERS

These paper will finally lead to the procedure of optimization of the damper properties for a particular type of building subjected to time history database. The optimal properties are the final values of effective stiffness of the brace connected to the damper, the value of damping coefficient and the value of velocity exponent. We will begin our trial and error procedure by selecting the values of damping coefficient equal to 30, the value of effective stiffness as 1000 and the value of velocity exponent as 0.3(These values are arbitrary and any such value may be taken for the starting the optimization).

V. RESULTS AND DISCUSSIONS

After entering the preliminary values in the software and running the analysis the graphs of story displacement, story drifts, moment and shear force diagram of the building are obtained and compared with the values obtained from the bare frame model without damper. Then the values of the damping coefficient are altered to obtain the desired objective. The graphs of the story displacement and the story drifts for the time history case of the bare frame without damper and the frame with different values of damping coefficient and the stiffness are shown below. Here we can see that not only the displacement but values of moment and the shears also show variations depending on the values of the damper properties entered. By taking in to account these values together with the hysteresis plot for all the damper properties a value of damping coefficient equal to 30 and the effective stiffness equal to 10000 was considered for the further analysis. From the following results it was clear that if the value of damping coefficient will be further increased than there will be increase in the displacement, drifts, moments and also the shears which is not desirable (fig.5,6). And finally the values of displacement equal to 75.255mm and drift equal to 0.00263 is obtained as of the original values in the bare frame of 101.944mm and 0.004774 respectively.

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Now if we are still interested in decreasing the stresses and the story displacement in the structure we can alter the value of the effective stiffness and can arrive to a more promising value. Following graphs and table shows the values of the story displacement and the drifts for the value of damping coefficient of 300 and different values of the effective stiffness (fig.7,8).

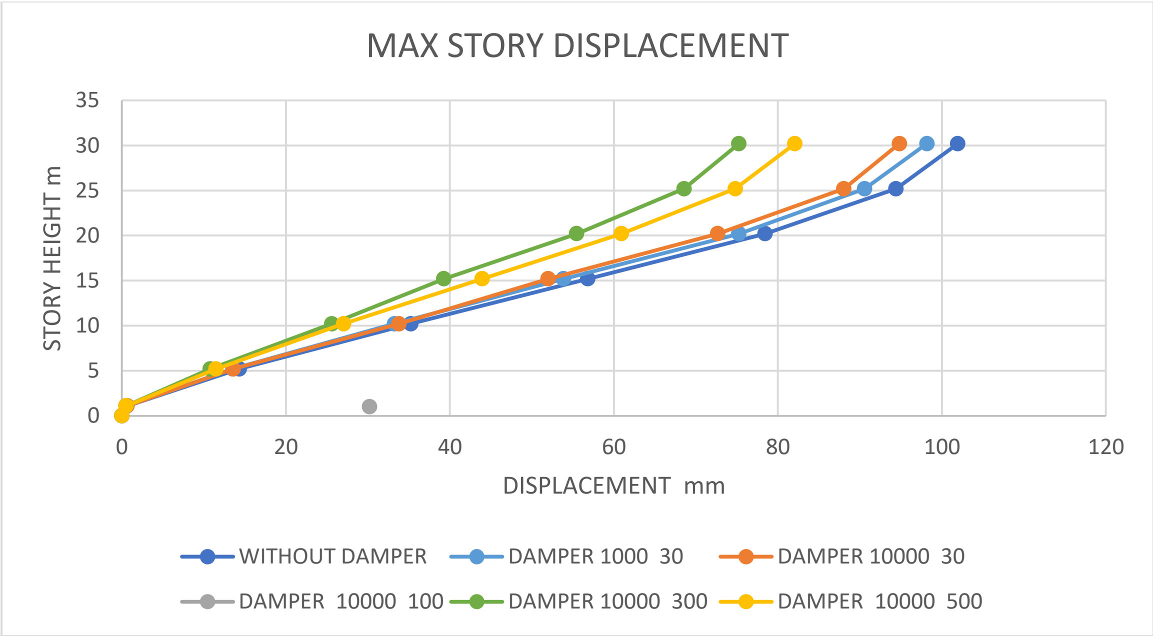

Figure 5: - Comparison of displacement

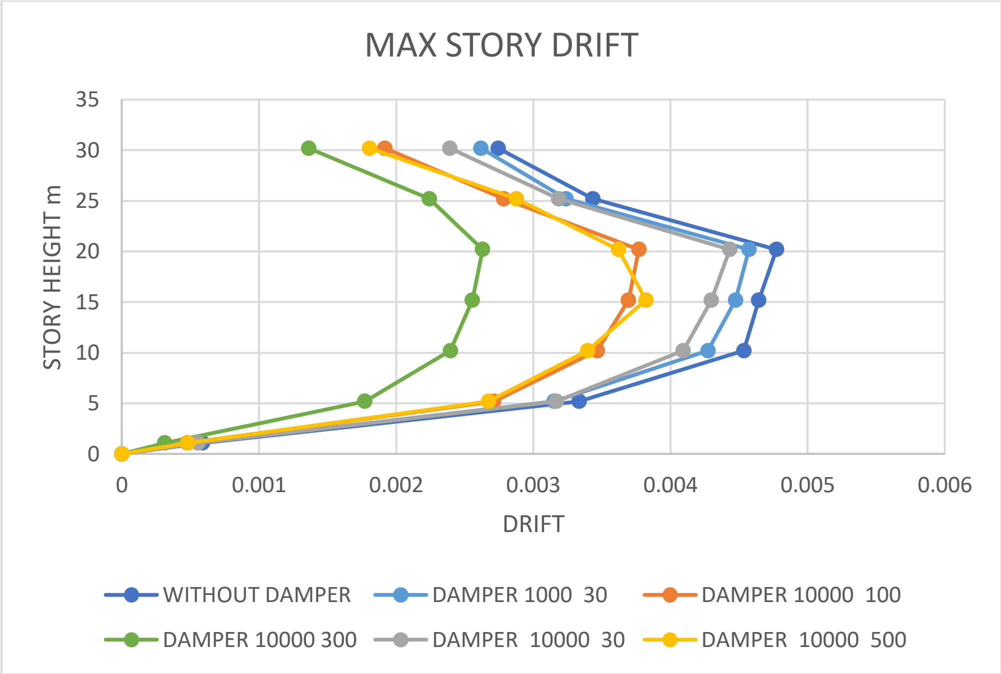

Figure 6: - Comparison of drift

Table 2: - Comparison of displacement (C=300)

STORY	HEIGHT	NO DAMPER	10000 kN/m	50000 kN/m	100000 kN/m	150000 kN/m
7	30.2	101.944	75.255	56.859	54.019	53.01
6	25.2	94.423	68.552	50.684	47.703	46.903
5	20.2	78.427	55.473	40.634	40.767	40.366
4	15.2	56.822	39.28	29.453	30.489	30.459
3	10.2	35.242	25.586	18.011	18.982	19.341
2	5.2	14.307	10.788	7.358	7.604	7.686
1	1.1	0.645	0.496	0.33	0.345	0.348
BASE	0	0	0	0	0	0

Table 3: - Comparison of drifts (C=300)

STORY	HEIGHT	NO DAMPER	10000 kN/m	50000 kN/m	100000 kN/m	150000 kN/m
7	30.2	0.002743	0.001766	0.001387	0.001362	0.001338
6	25.2	0.003434	0.00269	0.002351	0.002242	0.002183
5	20.2	0.004774	0.003419	0.002784	0.00263	0.002562
4	15.2	0.004644	0.003563	0.002754	0.002556	0.002484
3	10.2	0.004536	0.003203	0.002287	0.002396	0.002411
2	5.2	0.003334	0.002512	0.001714	0.001772	0.001791
1	1.1	0.000587	0.000451	0.0003	0.000313	0.000316
BASE	0	0	0	0	0	0

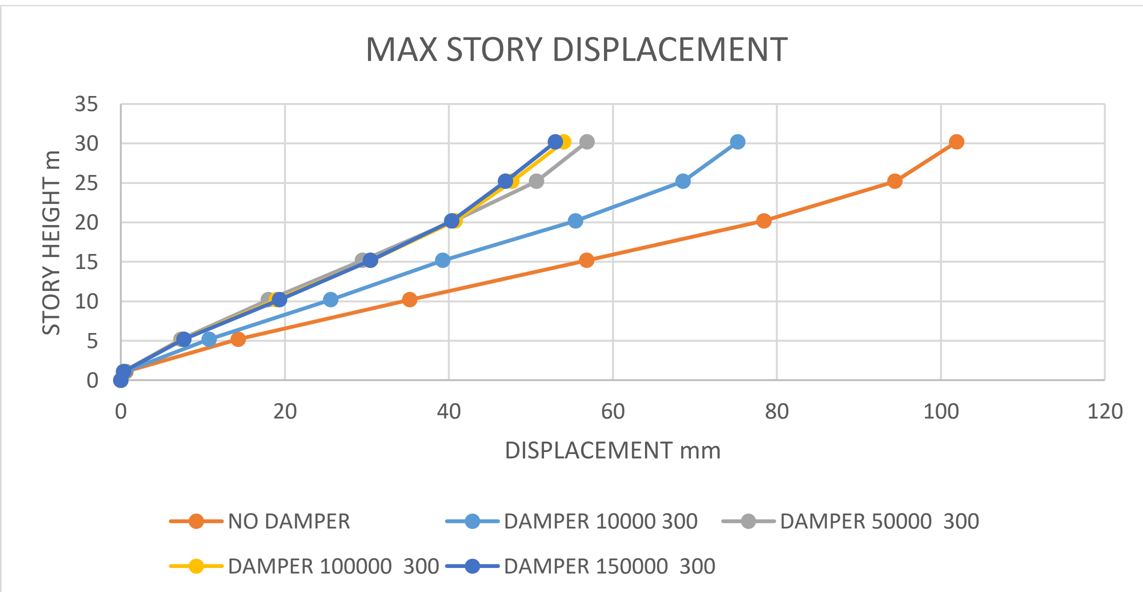

Figure 7: - Comparison of displacement for C=300

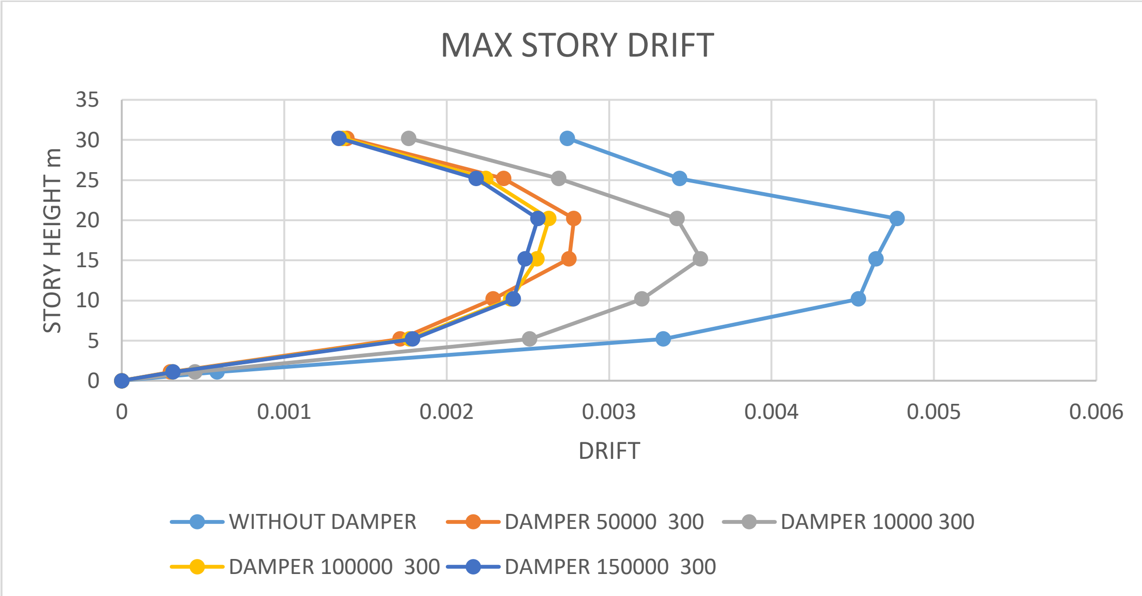

Figure 8: - Comparison of drift for C=300

VI. CONCLUSION

In the present study, viscous damper is used to reduce the seismic response of the structure which is subjected to earthquake load. Non-linear time history analysis is used for dynamic analysis. After the analysis of the structure the results obtained are compared and iterated to obtain the final values of the damper properties. The values taken here of the stiffness are random and any values in between can be taken in the analysis and the design to obtain a more optimum value of the damping coefficient and the value of effective stiffness. The following conclusion are obtained:

[1] The more promising values of the effective stiffness and the damping coefficient considered for the final building are 50000 and 300 respectively.
[2] The brace element for this particular stiffness could be a hollow circular steel section with outer diameter equal to 88.9mm and thickness equal to 4.8mm.
[3] The above values are not the only values that can used. Different values can be used as per the choice of the Structure Engineer if they are happy with the stresses and deflections in the structure.
[4] The value of the displacement for the bare frame and the model with above damping properties are as 101.944 mm and 56.895 mm respectively.
[5] The value of the drift for the bare frame and the model with above damping properties are as 0.004774 and 0.002784 mm respectively.
[6] The value of the max moment at base for the bare frame and the model with above damping properties are as 375 kNm and 201 kNm respectively.
[7] The value of the max shear at the base for the bare frame and the model with above damping properties are as 161 kN and 79 kN respectively.
[8] The value of the base shear for the bare frame and the model with above damping properties are as 2158 kN and 1616 kN respectively.
[9] There is about 56% reduction in the displacement and 58% reduction in drift for the final damping properties considered.
[10] There is about 54% reduction in the moment and 49% reduction in shear for the final damping properties considered.
[11] By observing the following it can be concluded that dampers reduce the stresses and displacements in the structures and can play a vital role in seismic resistant design in the building by reducing the response of the structure.

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