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Seismic Performance of Reinforced Cement Concrete Structures with and Without Viscous Dampers

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ABSTRACT
Passive energy dissipation have been used so far to dissipate the unwanted energy due to earthquake and heavy wind actions. The complete failure of the structures that has occurred in the past due to catastrophic earthquakes may be avoided with the use of such devices. The study is concerned with the use of accordion metallic dampers that uses hysteretic energy to dissipate the unwanted energy due to earthquake. It consists of corrugated thin wall tubes installed as a brace connection in the frame. The axial deformation of the accordion damper enhances the lateral buckling capacity and results in maximum reduction of the damaging measures. The study emphasizes the use of such dampers and in-depth analysis is performed by subjecting the building to base excitations in order to assess the nonlinear performance of the dampers installed in the building

Keywords: Passive energy dissipating device, Base excitation, Damaging measures

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INTRODUCTION:

The philosophy in the conventional seismic design is that, structure is designed to resist the lateral loads corresponding to wind and small earthquake by its elastic action only, and the structure is permitted to damage but not the complete collapse when it is subjected to a lateral load associated with moderate or severe seismic events. As a result, plastic hinges in the structure must be developed in order to dissipate the seismic energy when the structure is subjected to severe shakings. The design methods on this philosophy are acceptable to account for needs for both economic consideration and life safety. However, the development of the plastic hinges relies on the large deformation and the ductility of the structure. If the structure is more ductile, it undergoes more deformation and more damage it suffers. Besides, some important structures such as hospitals have to remain in function after the major earthquake; the former mentioned design philosophy (life safety based) may not be appropriate. These structures should be strong enough to resist large displacement and acceleration so that they can maintain their function when excited by severe ground motions.

Structural passive control systems have been developed with the design philosophy different than the conventional design seismic design method, which have immediate effect of increasing the critical damping ratio right up 25-30 % (against 5% value usually used for metal structures) and at the same time reducing the response of the structure during seismic event.

Dampers are classified as follows:
1. Viscous Dampers
2. Visco-Elastic Dampers
3. Friction Dampers
4. Mass Dampers
5. Metallic Dampers

These are passive dampers which do not require external power or energy to actuate during seismic event. Depending upon the intensity of lateral forces acting on a structure it dissipates seismic energy thus reducing inter-storey drift and bending moment induced in the structure.

WORKING PRINCIPLE

Viscous damper consists of a cylinder and a stainless-steel piston. The cylinder is filled with silicone fluid. The damper is activated by the flow of silicone fluid between the chambers at the opposite ends of the unit through small orifice. Figure 1 shows the longitudinal cross section of viscous damper.

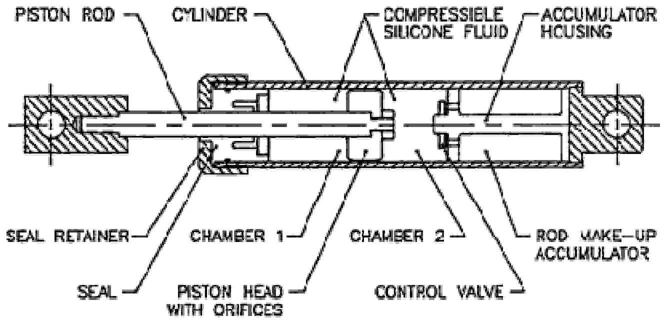


Figure1 Longitudinal Cross-section of a fluid damper

It consists of piston rod which moves to and fro depending upon the lateral force induced during an earthquake. High strength seal is used to avoid leakage of the fluid. Now to understand the mechanism how damper works. Let us assume that the piston rod is moving from left to right as seen in figure 1 (device subjected to compressive force). Fluid flows from chamber 1 to chamber 2. Accordingly, the force developed will be the pressure differential in these two chambers. However, the fluid volume is reduced by the product of travel and piston rod area. Since the fluid is compressible the amount of volume reduced is accompanied by the development of the restoring (spring like) force. This phenomenon can be prevented by either using an accumulator. This restoring force helps in reducing the response of the structure during an earthquake. The viscous dampers can be attached to existing or new structure as a bracing element as shown in figure 2.

Figure2 FVD as a toggle brace element

CASE STUDY

Study is carried out by selecting 3D RCC building, modeled in FE based software i.e. SAP 2000. Suitable shape plan and elevation of the building has been chosen and it is kept square shaped. Thorough study has been conducted in order to understand the working of dampers under base excitation. Total two sets of earthquakes of varying PGA have been chosen and provided as an input to SAP 2000 by creating a text file of ground acceleration data. Modal time history analysis also known as fast non-linear analysis (FNA) has been performed using above mentioned earthquakes for comprehensive analysis of building with and without non-linear FVD's. Table 1 shows the details of the earthquakes undertaken for the study. Damping ratio considered for all modes of vibration is 5%.

Table1 Details of components of Earthquake

Station Name	Earthquake	Peak Acceleration (g)
Oakland Harbor Wharf	Loma Prieta	0.27
Talf Lincoln Tunnel	Kern County	0.16

Figure 3 shows the Plans and elevation of the building considered for the analysis, assuming fixed base condition at the foundation. The plan area of the square building is kept 6.92 x 6.92 m. Height of each storey is kept uniform i.e. 3 m. The details of remaining components of the building are given in Table 2. The slab thickness is considered as 125 mm for all floors and diaphragm has been assigned at each floor so as to simulate rigidity offered due to slab action. Walls are provided at outer periphery of thickness 230 mm. Concrete of grade M 25 and steel Fe 415 is used to model the building. In the present paper, only analysis is restricted to square shaped building. After modeling the building, it is run for modal analysis and the fundamental dynamic characteristics of the building such as time period and mode shapes of the buildings are studied.

Table2 Detail of Components of Square Building

Beam	Size (mm)	Column	Size (mm)
B1	230 x 350	1	300 x 300
B2	230 x 350	2	400 x 400
		3	450 x 450

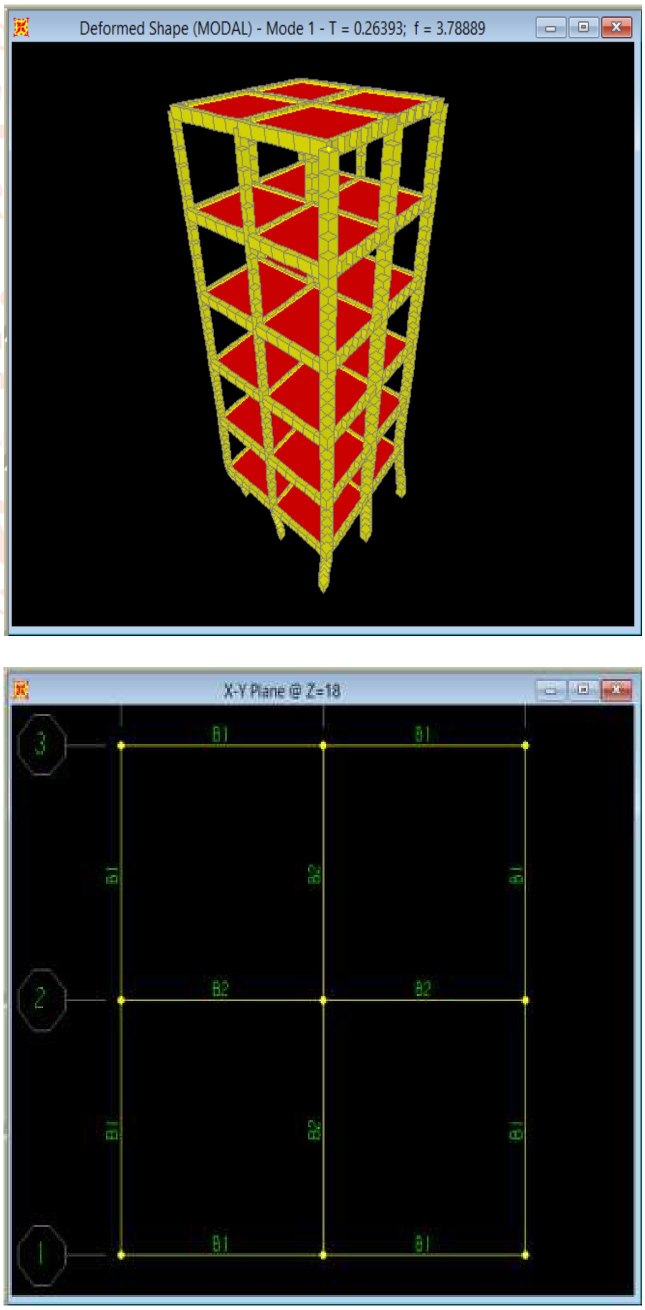
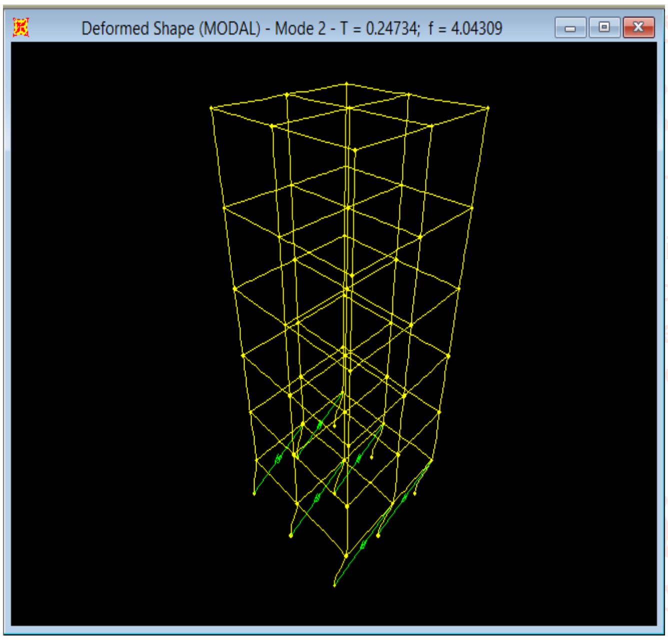
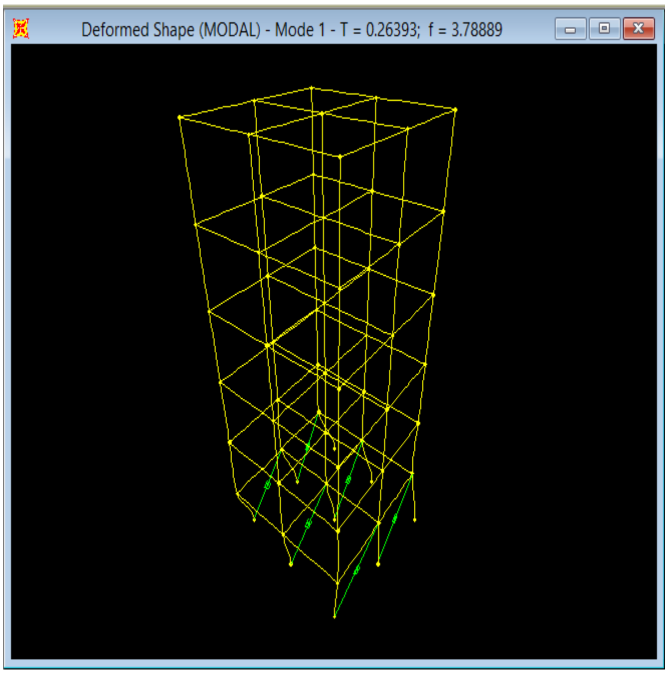


Figure3 Elevation and plan of building

The size of beam and column are chosen in such a manner to satisfy the limit state of collapse. The building is designed for gravity loading combinations using IS 456:2000. The basic aim of the analysis is to study the dynamic behavior of the building with and without damper. Initially, in order to obtain the dynamic characteristics, time period and mode shapes are determined with the help of FE based software i.e. SAP 2000. The wall is provided on the outer periphery of the building, live load is assumed to be 3 kN/m^2 using the provision of IS 875: 1987 part I and II. The building is assumed to rest on hard strata in seismic zone IV of India. The earthquake loading is applied at the base of the structure by using the earthquake acceleration data which is fed in SAP 2000 in the form of text file. The software has inbuilt function through which non-linear Time History analysis can be formed. The analysis of structure equipped with damper can be assessed very well by this method. Modal time history analysis is adopted to carry out analysis. Figure 4 shows the natural time period and mode shapes of the square shaped building, moreover there is no change in dynamic characteristics of building equipped with dampers. Total 6 dampers were equipped at the base of the building.





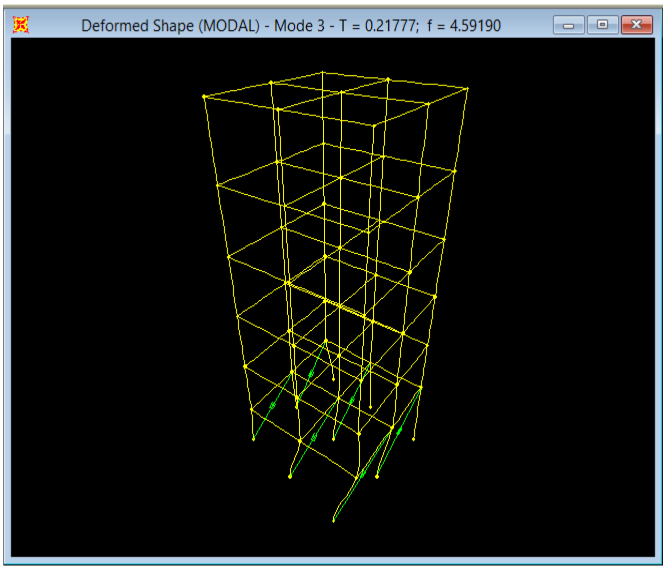


Figure4 Natural time period and mode shapes of the square shaped building

Initially, time history response of top storey displacement is analysed with and without dampers, it was found that top storey displacement is reduced to a great extent. Figure 5 shows the time history response of top storey displacement of square shape building. This reduction clearly states that the reduction in damage caused during earthquake without dampers.

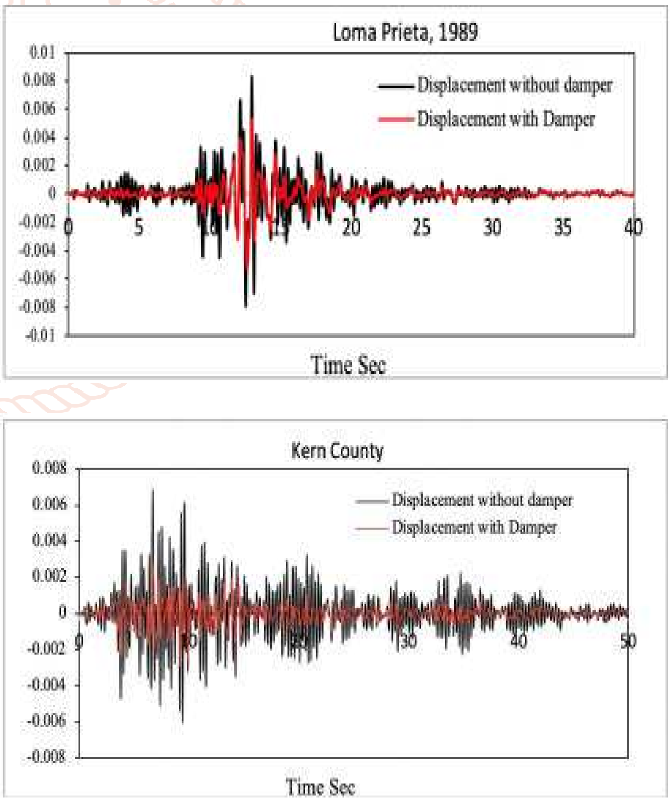


Figure 5 Time History Response of Top Storey Displacement

As Earthquake is transient loading, the damaging measures also changes with time, the time history response of bending moment of bottom storey column is checked with and without damper, it was found that bending moment reduces by almost 30% to 35%, which clearly signifies the potential of dampers in minimizing the critical damaging response of structure. Figure 6 shows the time history response of bending moment with and without dampers.

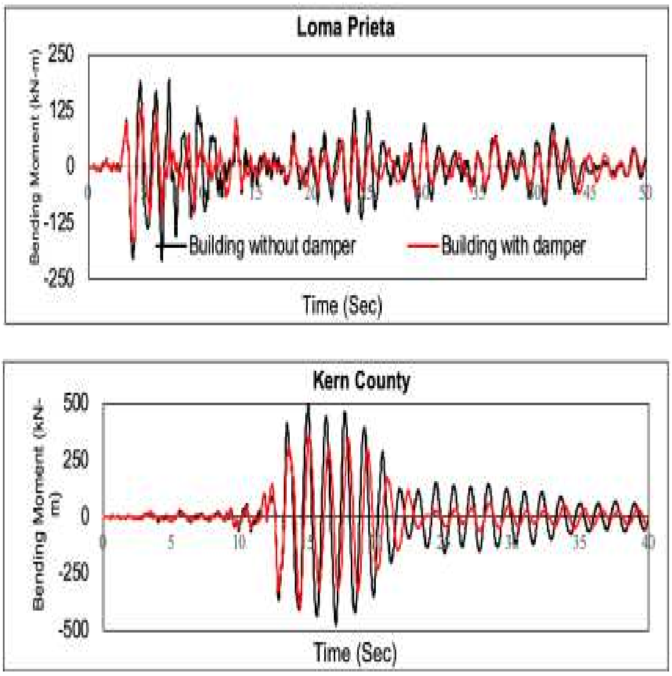


Figure6 Time History Response of Bending Moment

Further, Force – Displacement relation is worked out, whose area give the amount of work done by dampers during damping action. Figure 7 shows the hysteresis curves of damper which shows viscoelastic behaviour.

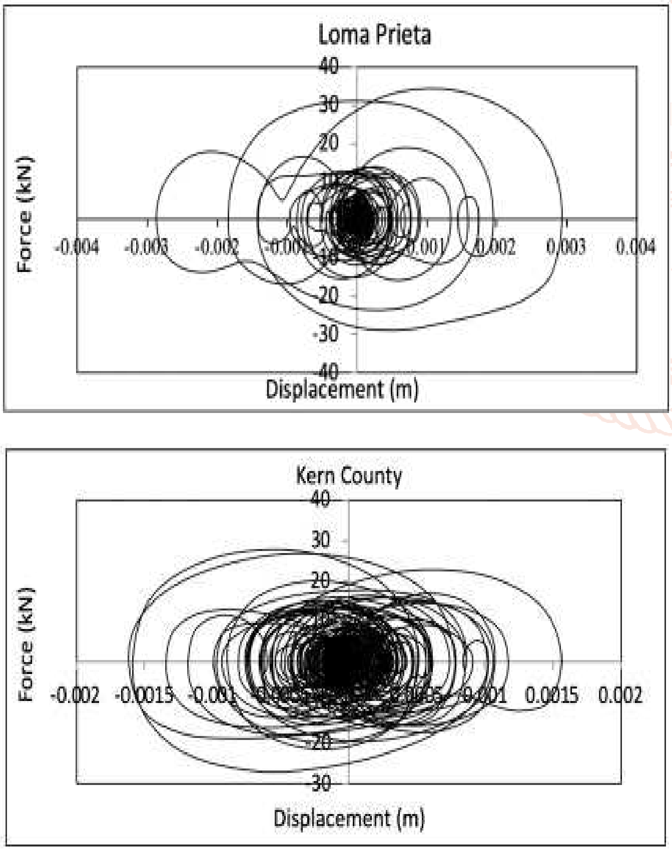


Figure7 Hysteretic curve of damper

Finally, energy curves of the building with damper is shown in Figure 8 it can be seen that damper dissipates much of earthquake energy, thus avoiding complete yielding of structure.

Complete damage may be avoided by using such Passive Energy Dissipating devices more than 50% of energy is absorbed by dampers.

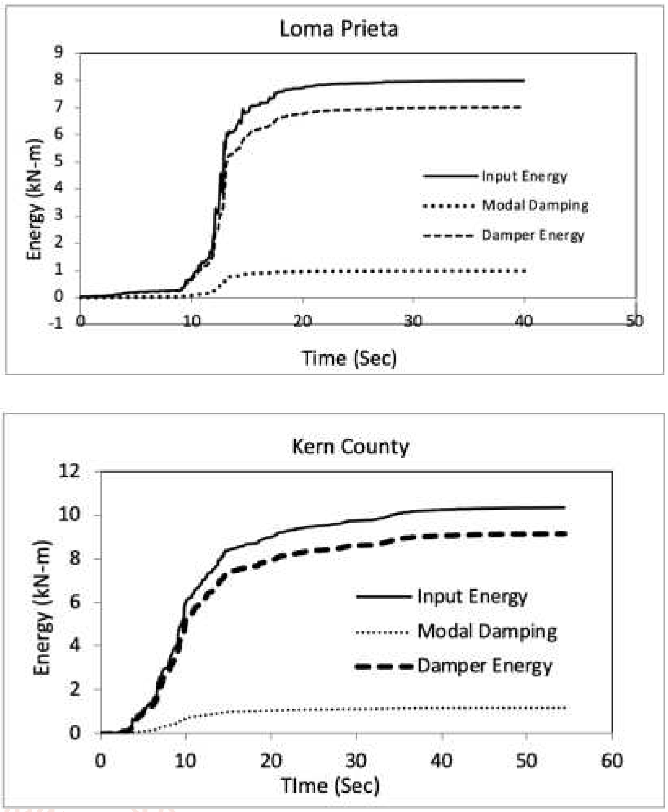


Figure8 Energy curve

CONCLUSION

The seismic response of the structure with and without damper under severe earthquake ground motion is investigated with the help of SAP 2000 by modelling a 3D, 5 storey RC building. Following interesting conclusions are obtained from the results of the study.

1. The fluid viscous dampers are found to be very effective to control the response of structures under severe base excitation.
2. Lesser dampers at appropriate location can significantly reduce structural response due to base excitation.
3. Bottom storey dampers undergoes more deformation and produces higher damping force as compare to top storey dampers.
4. Fluid dampers with velocity exponent less than unity shows visco-elastic behaviour and is found to resist more velocity shocks, absorbs significant energy as compare to dampers with velocity exponent equal to unity.
5. Energy dissipated by the dampers for the considered earthquake is up to 50%
6. Top storey displacement reduction in the range of 30-40%.
7. Time history response of bending moment and shear force is found to be reduced in the range of 25-40%.

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