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EFFECT OF FLUID VISCOUS DAMPERS IN MULTI-STOREYED BUILDINGS

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ABSTRACT

Buildings are subjected to various loading conditions. Special protective systems have been developed to enhance safety and reduce damage of structures during earthquakes. Fluid viscous damper (FVD) comes into prominence here. This paper deals with the study of reinforced concrete buildings with and without fluid viscous dampers. A parametric study for finding optimum damper properties for the reinforced concrete frames was conducted. Nonlinear time history analysis is done on a symmetrical square building. Analysis is carried out using SAP2000 software and comparisons are shown in graphical format.

KEYWORDS: Fluid Viscous Damper, Pushover Analysis, Symmetrical Building, Time History Analysis

INTRODUCTION

Building design usually involves proportioning the elements of the structure such that the constraints on strength and serviceability limit states are satisfied. The conventional approach is to proportion the components to satisfy the strength limit states and then follow it up with serviceability checks. But based on the modern control theory, structural control has emerged to mitigate the negative effects that the external disturbances impose on the structures. Structural control has been investigated and shown great potential for reducing vibrations in various civil structures under dynamic loading. Structural control is usually classified by its method, or the type of device used to impart the control force. The three classes of structural control system are passive energy dissipation, active and semi-active energy dissipation. The first class of energy dissipating system, the passive systems are uncontrollable. The basic function of the passive devices is to absorb a part of input energy, reducing energy dissipation on structural members and minimizing the damage on structures. Contrary to semi-active or active systems there is no need of external power supply. The second class of energy dissipating devices, the active devices are controllable and require significant amount of external supply. The third class includes the semi-active devices which combine the aspects of active and passive devices.

Passive devices are frequently used type of control system implemented because they involve no external power and such devices are inherently stable. Passive devices encompasses a range of materials and devices for enhancing damping and strength such as fluid viscous dampers, friction dampers and metallic dampers have been developed since the 1990’s. This papers deal with the study of fluid viscous damper on reinforced concrete buildings.

GENERAL DESCRIPTION OF FLUID VISCOUS DAMPER

Fluid viscous dampers in recent years have been incorporated into a large number of civil engineering structures.

The major parts of FVD are shown in Figure 1 [1]. When the fluid viscous damper is subjected to external loads, the piston rod with piston will make reciprocating motion in the cylinder to force the damping medium move back and forth between the two cavities separated by the piston. In the process, the friction force occurred between the molecules of the damping medium, the medium and the shaft and piston, the medium and the cylinder, and throttling damping force produced by the damping medium through the piston, all these action work together composed the damping force. These damping forces are 90 degrees out of phase with the displacement driven forces in the structure. This benefit can allow the reduction of shear walls, use of smaller columns and beams, use of smaller and less complicated foundations and overall reductions of concrete or steel mass, generally offsetting the cost of the fluid viscous dampers [1].

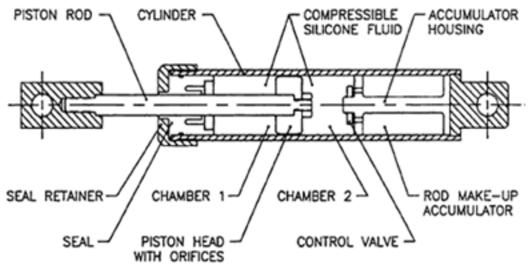


Figure 1: Fluid Viscous Damper

The viscous dampers are modeled as Maxwell element, which is a nonlinear damper with a nonlinear spring. Viscous damper system will be modelled as pure stiffness-free damping behaviour. Stiffness of damper element is considered zero in order to reach the pure damping in linear analyses. To eliminate the spring effect, its stiffness should be considered significantly high in nonlinear analyses where series model of spring damper is used. The energy dissipation per cycle of FVD is a function of different parameters. The ideal damping force of viscous damper is given by,

$$F = CV^{\alpha} \tag{1}$$

In (1), F is the damping force, C the damping coefficient, V the velocity of piston relative to cylinder and α is the damping exponent.

MODELLING OF THE BUILDING

Procedures have been developed through years for the seismic design of buildings equipped with fluid viscous dampers. The NEHRP (National Earthquake Hazards Reduction Program) [2] and other codes give a trial-and-error approach for identifying the mechanical characteristics of additional damping devices. A simple procedure for the determination of damping coefficient is been used in this study [3].

$$C = 2m\xi\omega \tag{2}$$

Equation (2) is used to find out the damping coefficient. In (2), m is the total floor mass is to be calculated by knowing the different dead loads acting on the structure, ξ is the damping coefficient and ω is the natural frequency of the structure. Modal analysis of the finite element model is done using SAP2000. From the modal analysis the time period T, is obtained. The natural frequency, ω of the structure can be calculate using,

$$\omega = \frac{2\pi}{T} \tag{3}$$

Knowing the value of ω and assuming a suitable value of damping ratio ξ, the damping coefficient is to be determined using (2). This value of damping coefficient C is used in the analysis of the structure in SAP2000.

A six and ten storeyed square buildings have been considered for the analysis. Height of each storey is 3.0 m. It is considered to be located in the seismic zone V. Soil structure interaction has not been considered and the columns are fixed at a depth of 1.5 m below the ground level. The material properties of the building are assigned. Beam and column members have been defined as frame elements of dimension (200x300) mm. Slabs are defined as area elements having the properties of shell elements with the thickness of 150 mm. The building plan taken for the study is shown in Figure 2.

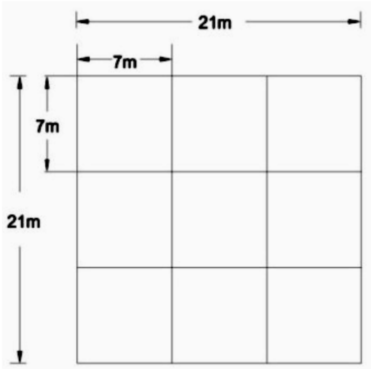


Figure 2: Plan of 21x21 m Model

After having modeled the structural components, the loads as per the codal provision are assigned. Gravity loads on the structure include the self weight of beams, columns, slabs and walls. The self weight of the beams and columns (frame members) and slabs (area sections) is automatically considered by the program itself. The wall loads have been calculated and assigned as uniformly distributed loads on the beams. Live loads have been assigned as uniform area loads on the slab elements as per IS: 875, (Part 2).

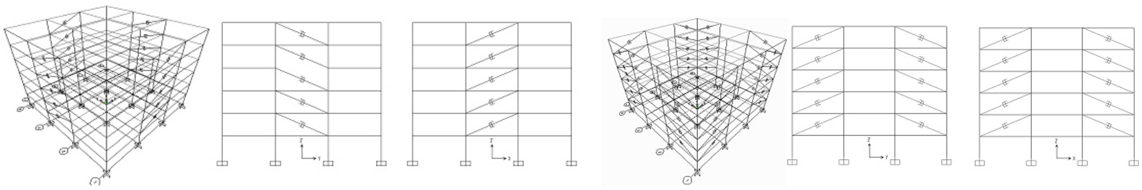
Nonlinear time history analysis with El Centro accelerogram [3] has been carried out for determining various structural parameters of the model. The value of damping ratio ξ, and velocity exponent α is fixed by analyzing single bay square and rectangular building frames. From the different dynamic responses values of ξ and α are fixed as 0.2 and 0.5 respectively. The damping coefficient for 21x21 m plan buildings are calculated using (2). This study is concerned with the behavior of the structure under the bidirectional ground motion with and without the presence of FVD at different positions.

PARAMETRIC STUDY

Analysis is done to evaluate the performance of buildings under bidirectional seismic loading with and without FVD at different locations along the width and height of the building. To study the effect of placement of FVD along the width, six storey square plan building are taken into consideration and nonlinear time history analysis is carried out for structural models with and without FVD. To assess the effectiveness of placement of FVD along the height study is being done on symmetric square plan building of six and ten storey.

Effect of FVD along the Width

To study the effect of FVD along the height, analysis was done on 49x35 m six storied and ten storied buildings. From the previous section, it was concluded that, for rectangular plan case RTEC i.e., FVD on all the external corners was found to be the most effective. The different cases that are taken into consideration to understand the effectiveness along the height are,

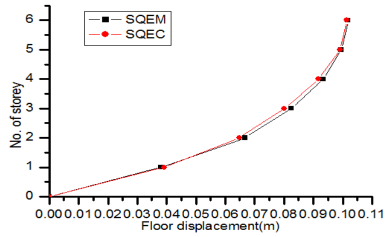


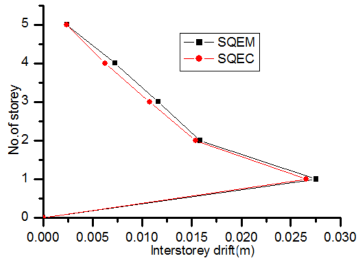
(a) SQEM (b) SQEC

Figure 3: Position of FVD in Square Plan (21x21 m)

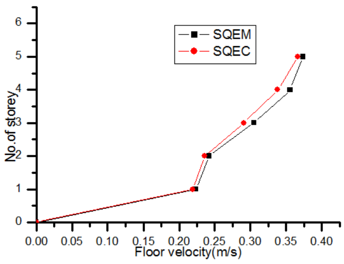
The different cases (Figure 3) which were considered for the square plan were,

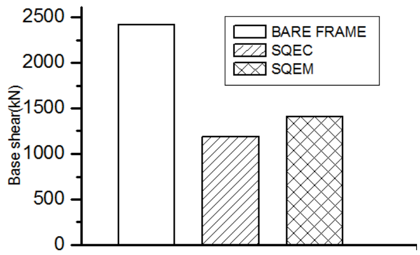
- SQEM: FVD are placed in all the exterior middle bays. A total of 4 FVD will be there in each floor.
- SQEC: FVD are placed in all the exterior corners. A total of 8 FVD will be there in each floor.





(a) Floor Displacement vs No. of Storey **(b) Storey Drift vs No. of Storey**





(c) Floor Velocity vs No. of Storey **(d) Base Shear**

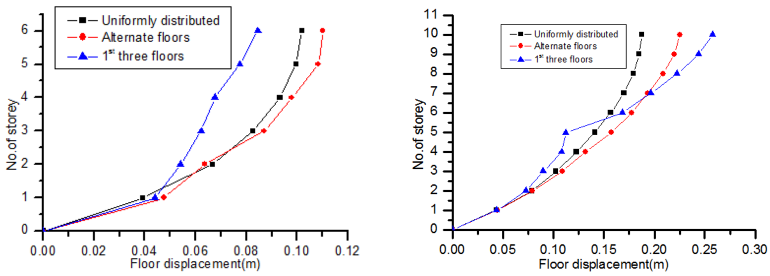
Figure 4: Floor Responses for Square Plan

Analysis results of the square plan with three different cases of damper position when subjected to bidirectional earthquake are obtained. From the analysis results it can be inferred that the percentage reduction in the peak displacement with respect to the bare frame is obtained to be 74% in all the three cases. From Figure 4 it can be inferred that the storey drift is maximum at the lower stories and it gradually decreases with the height. It was found out that the percentage reduction in base shear with respect to the bare frame for SQEM was 40% and for SQEC was 51%. From the floor responses of square plan it can be inferred that the percentage reduction in the base shear, interstorey drift and floor velocity is maximum in case SQEC. Thus for a square plan the most effective distribution of FVD is obtained as SQEC from the dynamic responses.

Effect of FVD along the Height

To study the effect of FVD along the height, analysis was done on square plans of six and ten storey's. From the previous section, it was concluded that, for the square plan case SQEC i.e., FVD on external corners was found to be the most effective. To understand the effect of FVD along the height, the above case was used for the further study. The different cases that are taken into consideration to understand the effectiveness along the height are

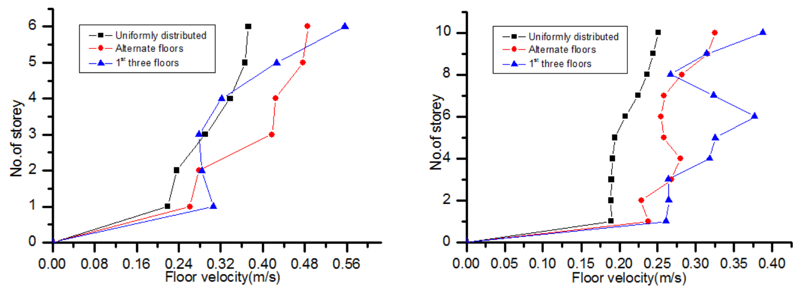
- FVD distributed uniformly
- FVD on alternative floors
- FVD on 1st three floor



(a) G+5 Storey **(b) G+9 Storey**

Figure 5: Peak Displacement vs No. of Storey for Square Plan (21x21 m)

Figure 5 shows the plot of peak displacement against the number of storey for the square plan for different cases. For the square plan with six storey building, the percentage reduction with respect to the bare frame in the displacement when FVD were placed uniformly on all floors, on alternative floors and 1st three floors along the height was obtained as 74%, 71% and 78% respectively. For the same square plan with G+9 storey, the percentage reduction with respect to the bare frames in the displacement when FVD were placed uniformly, on alternative floors and 1st three floors along the height was obtained as 65%, 58% and 52% respectively.

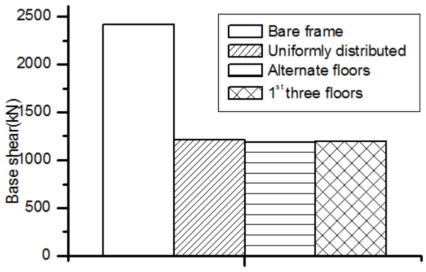


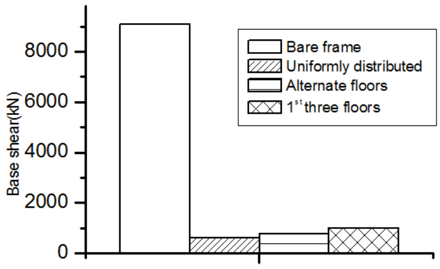
(a) G+5 Storey **(b) G+9 Storey**

Figure 6: Floor Velocity vs No. of Storey for Square Plan (21x21 m)

For the square plan the floor velocities were plotted against the number of storey as shown in Figure 6. For the square plan with G+5 storey building, the percentage reduction with respect to bare frames in the velocity when FVD were placed uniformly, on alternative floors and 1st three floors along the height was obtained as 71%, 62% and 57% respectively. For the G+9 storey building, the percentage reduction with respect to bare frames in the velocity when FVD were placed uniformly, on alternative floors and 1st three floors along the height was obtained as 87%, 82% and 78%

respectively.





(a) G+5 Storey **(b) G+9 Storey**

Figure 7: Base Shear vs No. of Storey for Square Plan (21x21 m)

The plot of base shear against the number of storey for the square plan is shown in Figure 7. For G+5 storey building, the percentage reduction with respect to bare frame in the base shear when FVD were placed uniformly, on alternative floors and 1st three floors along the height was obtained as 51%, 48% and 51% respectively. For the G+9 storey building, the percentage reduction with respect to bare frame in the base shear when FVD were placed uniformly, on alternative floors and 1st three floors along the height was obtained as 93%, 91% and 88% respectively.

CONCLUSIONS

The purpose of this study is to assess the seismic performance of buildings with fluid viscous dampers. Using nonlinear dynamic analysis, responses of structures have been evaluated and the following conclusions have been made.

- For maximum effectiveness in reducing the dynamic responses, a structure with FVD should be designed for damping ratio of 20% and the velocity exponent, α of the FVD as 0.5.

Effectiveness of FVD along the Width

From the dynamic floor responses of the buildings, it can be concluded that, placing FVD at the external corners on all four sides of the building is effective for square plans.

Effectiveness of FVD along the Height

The peak displacements and interstorey drifts are minimized most effectively by placing the FVD along the first three floors alone. But while considering the other dynamic responses such as the floor velocity and floor acceleration, placement of FVD all throughout the height is found to be effective.

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