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REDUCTION OF EARTHQUAKE RESPONSE OF STEEL FRAMED BUILDINGS BY FLUID VISCOUS DAMPERS IN SAP 2000

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Abstract— This paper is focused on the fluid viscous dampers to be used as energy absorbing devices in buildings using SAP2000. Their advantages and disadvantages as well as their application on three model structures have been described. The analytical studies of the model structures exhibiting the structural response reduction due to these fluid viscous dampers are presented. In order to exhibit the benefits of these dampers, non linear analysis is carried out for all case studies: (a) a 3 storey steel frame, (b) a 10 storey steel frame and (c) a 20 storey steel frame. The parametric studies are about seismically efficient configuration and appropriate placement of fluid viscous dampers in all three models. The roof displacements as well as roof accelerations and base shear values obtained indicate that these fluid viscous dampers when incorporated into the super structure reduce earthquake response significantly when compared to base model.

Keywords— Base shear; Earthquake response; Fluid viscous dampers; Non linear time history analysis; Retrofitting; Roof displacements; Roof accelerations; SAP 2000

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 the1990's. This papers deal with the study of fluid viscous damper on steel moment resisting frames.

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].

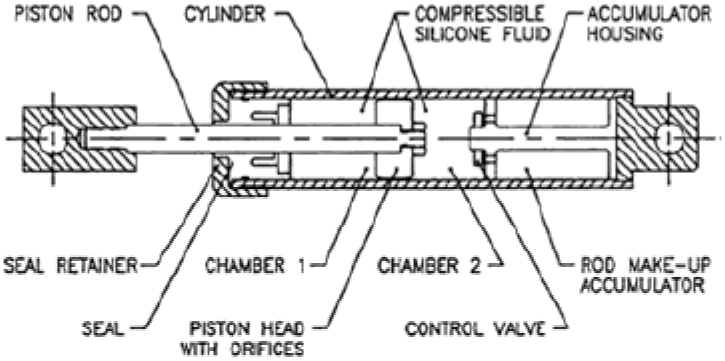


Figure 1: Fluid Viscous Damper

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,

$$F = CV^{\alpha} \quad (1)$$

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

$2m$ (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,

$$\omega = \frac{2\pi}{T} \quad (3)$$

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 three , ten and twenty storeyed steel moment resisting frames have been considered for the analysis for first parametric study. Height of each storey is 3.96 m for 3 storeyed buiding and height of each storey for 10 and 20 storeyed building is 3.2 m. Soil structure interaction has not been considered . The material properties of the building are assigned. Beam and column members have been defined as frame elements. Slabs are defined as area elements having the properties of shell elements with the thickness of 250 mm. The building plan taken for the study is shown in Figure 2 and 3.

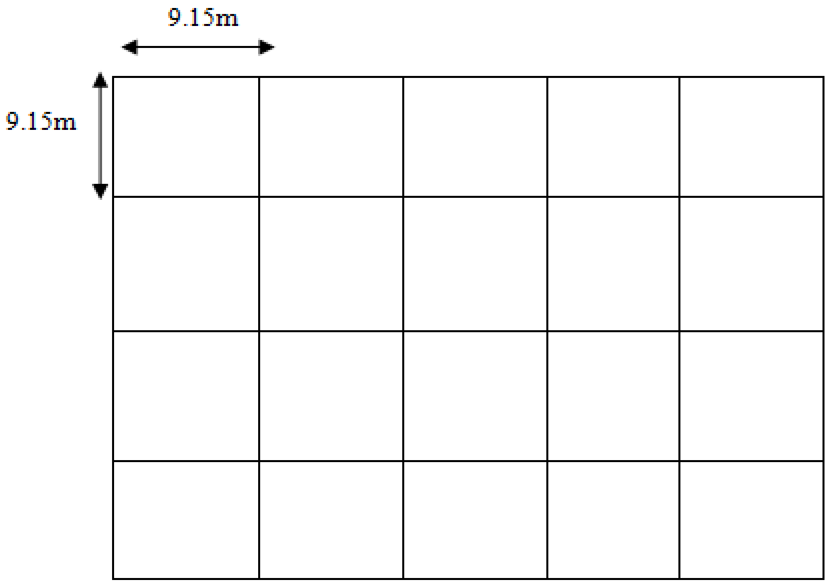


Figure 2: Plan of 3 storeyed steel building

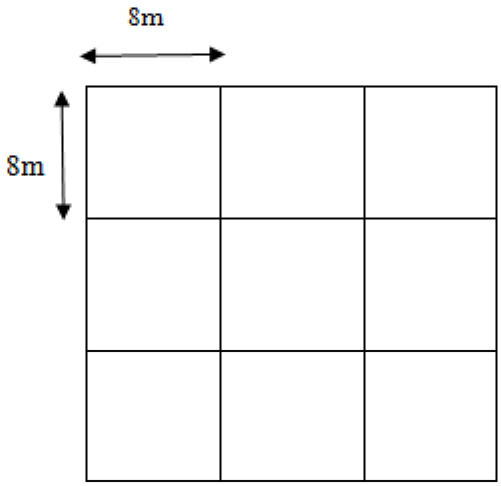


Figure 3: Plan of 10 and 20 storeyed steel buildings

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. Nonlinear time history analysis has been carried out for determining various structural parameters of the model. The value of damping exponent is 1 and consider it as linear fluid viscous damper . This study is concerned with the behavior of the structure under the unidirectional ground motion with and without the presence of FVD at different configurations and positions.

PARAMETRIC STUDY

Analysis is done to evaluate the performance of steel buildings under unidirectional seismic loading with and without FVD at different configurations and different locations along the width .To study the effectiveness of different damper placement configuration like chevron, diagonal, double diagonal, 3, 10 and 20 storeyed steel buildings are considered .To study the effect of placement of FVD along the width, 10 and 20 storeyed symmetric plan building are taken into consideration and nonlinear time history analysis is carried out for structural models with and without FVD in SAP2000.

Effect of FVD in different damper configuration

FVD is placed in different configurations like diagonal, chevron and double diagonal.

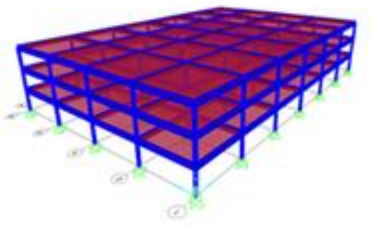


Figure 4: Bare 3 storeyed steel building

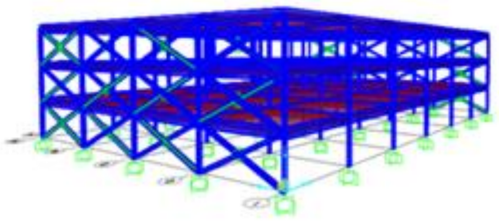


Figure 5: FVD in double diagonal configuration

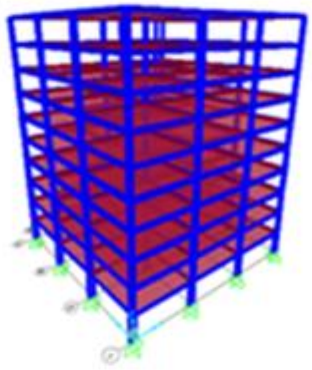


Figure 6: Bare 10 storeyed steel building

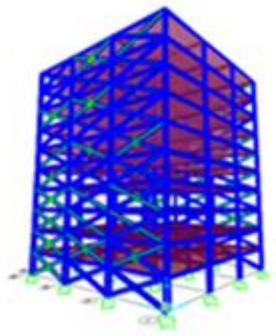


Figure 7: FVD in double diagonal configuration

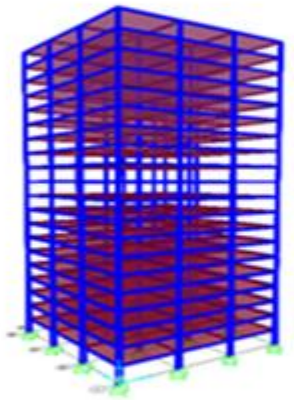


Figure 8: Bare 20 storeyed steel building

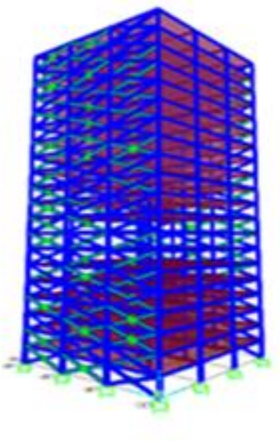


Figure 9: FVD in double diagonal configuration

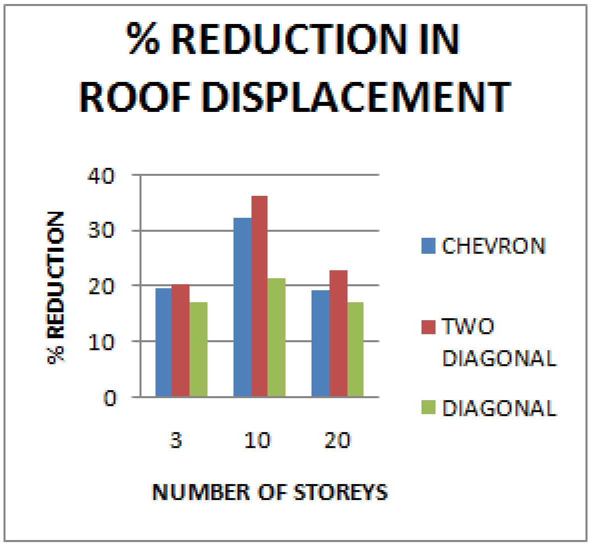


Figure 10: Percentage reduction in roof displacement compared to bare model

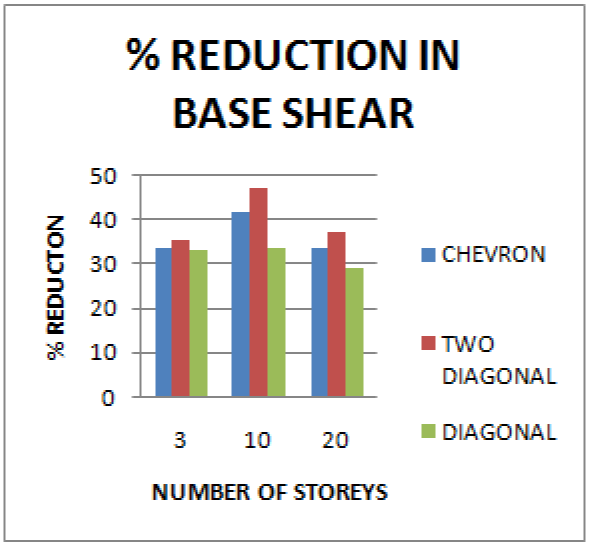


Figure 11: Percentage reduction in base shear compared to bare model

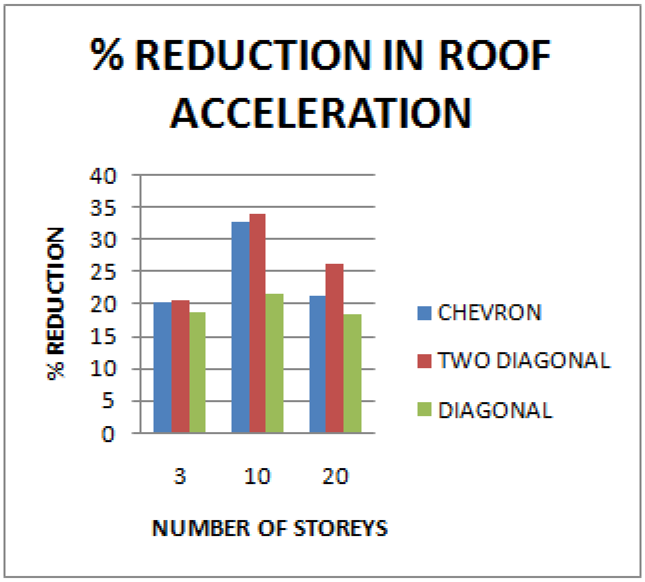


Figure 12: Percentage reduction in roof accelerations compared to bare model

Nonlinear time history analysis are carried out and from the result it is clearly obtained that the building with FVD in double diagonal configuration shows more reduction in base shear, roof displacement and roof acceleration compared to base model. In the case of 3 buildings, double diagonal configuration of FVD placement shows more reduction in base shear, roof acceleration and displacement. Installation of FVD in 10 storeyed steel building shows more reduction in response during earthquake compared to bare model.

Effect of FVD along the Width

To study the effect of FVD along the width, analysis was done on ten storied and twenty storied buildings. From the previous section, it was concluded that, FVD in double diagonal configuration was found to be the most effective. The different cases that are taken into consideration to understand the effectiveness along the width are,

- Case1:Steel buildings without FVD
- Case 2:FVD are placed in all bays uniformly
- Case3:FVD are placed in all the exterior middle bays
- Case4:FVD are placed in all the exterior corners

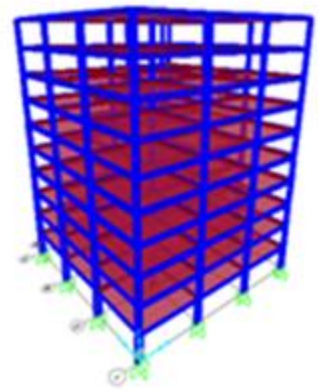


Figure 13: Case 1 (10 storeys)

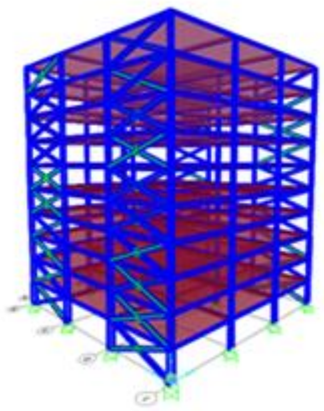


Figure 14: Case 4 (10 storeys)

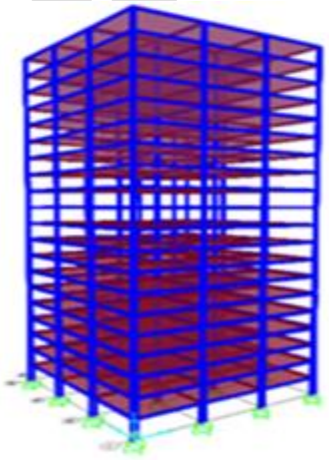


Figure 15: Case 1 (20 storeys)

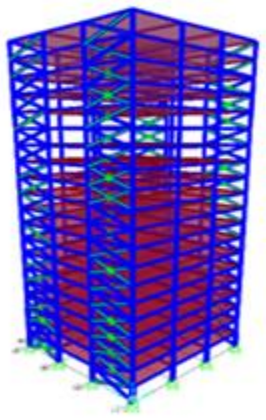
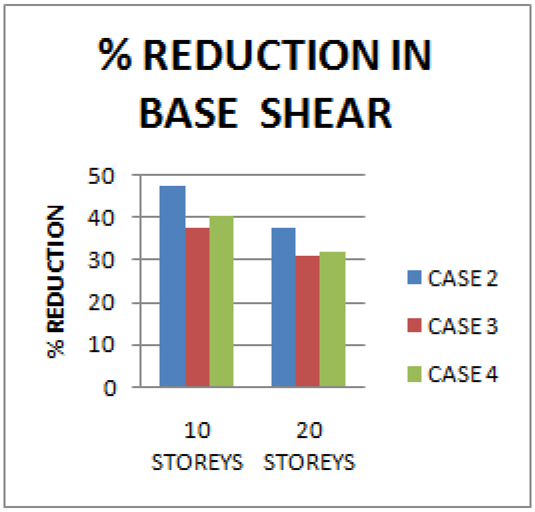


Figure 16 : Case 4 (20 storeys)

Analysis results of the 10 storeyed and 20 storeyed steel building with three different cases of damper position when subjected to unidirectional earthquake are obtained. From the results it is clearly obtained that case 2 is more effective compare to case 3 and case

4. But in an economic sense, case 2 requires a lot of dampers and cost will be very high. So usually by considering economy, case 4 is usually consider for installation in practical cases.



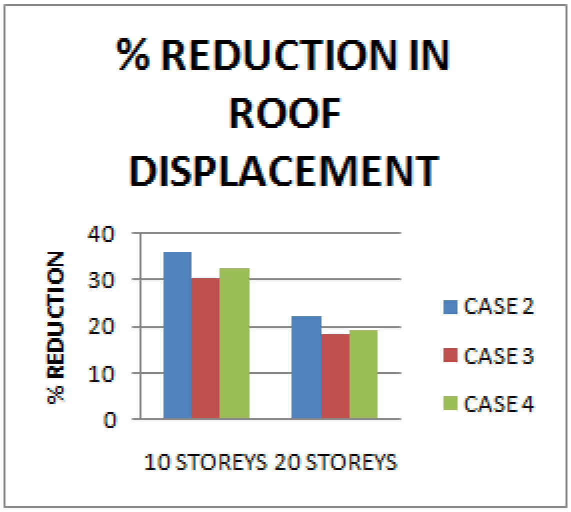


Figure 17: Percentage reduction in roof displacement compared to bare model

Figure 18: Percentage reduction in base shear compared to bare model

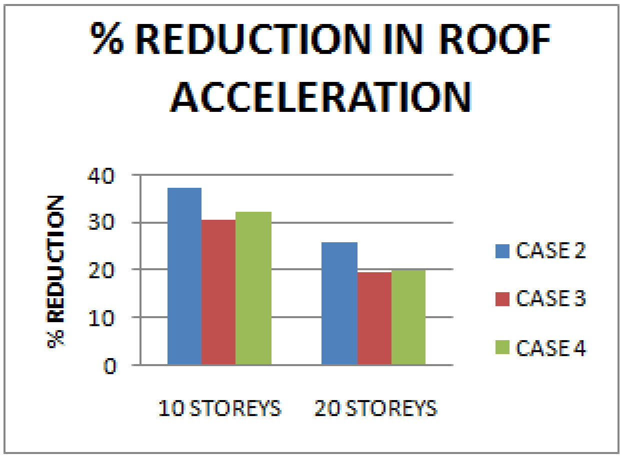


Figure 19: Percentage reduction in roof acceleration compared to bare model

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CONCLUSIONS

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

- The effect of FVD is more predominant in mid rise building

Effectiveness of FVD in different damper configuration

From non linear time history analysis , it is clear that damper placed in double diagonal configuration show more reduction in roof displacement, roof acceleration and base shear when compared to bare model.

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 of the building is effective for square plans.

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