DYNAMIC ANALYSIS OF 25 STOREY RCC BUILDING WITH AND WITHOUT VISCOUS DAMPERS

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Abstract— energy induced by strong earthquakes affects the structure. The seismic performance as well as response of the structure will be substantially improved if this energy is dissipated in a manner independent of structural components. Response spectrum analysis of 25 storey RCC building which will be used as commercial building, with concrete shear wall core and typical floor area 735 sq. meters was performed. The structure is modeled using the finite element program ETABS and is analyzed response spectrum analysis.

The building is situated in earthquake zone III, the design of which is conforming to recent IS code. Use of passive dampers for improvement of seismic performance and enhancing design of new structures has increased in recent years. The main objective of the study is to assess the improvement in response of structure achieved through use of the viscous damper devices.

KEY WORDS: Dynamic Analysis**.** Seismic performance, viscous dampers

1 INTRODUCTION

In recent years, there has been a constant development of the technology for seismic protection, as is the case of energy dissipation systems, resulting from the need to design increasingly taller buildings located in high seismicity areas, with the main goal being to improve the seismic performance.

Seismic Protection Systems

There are several types of seismic protection that, when included in a structure, improve the seismic behaviour (Guerreiro, 2008), classified as active or passive protection systems depending on whether or not it is necessary to provide energy for its operation. The most commonly used are the passive protection systems, due to its simplicity and proven effectiveness (Guerreiro, 2008), such as base isolation and the use of devices for energy dissipation.

Energy Dissipation Systems

The energy dissipation systems are devices specially designed and tested to dissipate large quantities of energy.

The most common energy dissipation systems are the viscous ones (force proportional to the velocity of deformation) and the hysteretic (force proportional to displacement), however there are also the visco-elastic, electro-inductive and by friction damping systems.

Viscous Dampers

Manufactured viscous dampers are hydraulic devices which can be installed in structures in order to mitigate the seismic effects through dissipation of the kinetic energy transmitted by the earthquake to the structure (Soong and Dargush 1997, Constantinou et al. 1998, Christopoulos and Filiatrault 2006,). These devices have been the objective of several research works since the 1980's (Constantinou and Tadjbakhsh 1983, Constantinou and Symans 1993, Singh and Moreschi 2002, Levy and Lavan 2006).

Viscous dampers devices consist of a cylinder containing a high viscosity fluid, as sketched in Figure 1

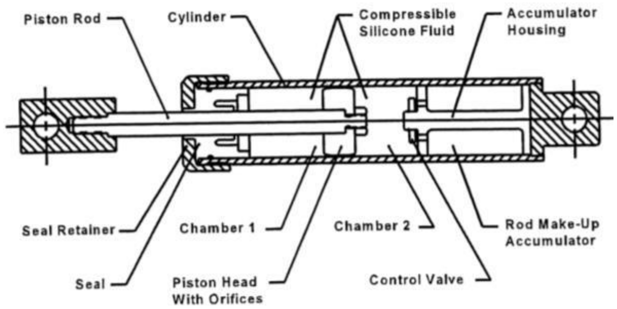

Figure 1 – Scheme of viscous damper (D. Lee, 2001).

This operation is simple: during an earthquake, the force generated by the imposed acceleration is transmitted to the damper, which regulates the passage of compressed fluid through small holes. The seismic energy is dissipated, as fast as the liquid flows through the holes.

The force generated in each viscous damper is characterized by the following constitutive expression:

$$F = C \times V^{\propto}$$

Where F= total output force provided by the damper

C= damping coefficient

V= relative velocity between the ends of the damper

$\propto$ = damping exponent (characteristic value of the fluid viscosity), value can vary between 0.1 to 2 (Guerreiro, 2006).

The main features of viscous dampers are presented:

- High damping coefficients;
- No need to high maintenance (Alga);
- The lifetime of the viscous dampers is on average higher than the lifetime of the building where they are installed (Taylor, Devices);
- The dampers are extremely versatile for any application, without compromising the building's architecture.
- These devices allow a reduction of the stresses and deformation of a structure, reducing the damages in the structural and non-structural elements during seismic action (Taylor, et al.). Experience shows that this dissipation system can decrease about 50% of the accelerations and displacements between floors (Constantinou, 1992) (Hussain, et al.).

2 EXISTING RESEARCH

Viscous dampers themselves are old technology, dating back to more than a century ago to full-scale usage on US large Caliber military cannons in the 1860s. This technology was not available for the public disclosure or usage until the Cold War ended. In 1990, Taylor Devices received the permission to sell this technology to the public. Despite the long history and well-established usage of viscous damper, it is still a relatively new building technology yet to be further developed and studied.

Studies have been published regarding viscous dampers design methodology. Constantinou and Symans [1] proposed a simplified method for calculating the modal characteristics of structures with added fluid dampers. The method was used to obtain estimates of peak response of the tested structures by utilizing the response spectrum approach. Gluck et al. [2] suggested a design method for supplemental dampers in multi-story structures, adapting the optimal control theory by using a linear quadratic regulator (LQR) to design linear passive viscous (VS) or viscoelastic (VE) devices depending on their deformation and velocity. Fu and Kasai [3] compared frames dynamic behavior using VE or pure VS dampers, where identical mathematical expressions were derived in terms of two fundamental non dimensional parameters.

Kasai et al. [4] proposed a simplified theory to predict and compare the seismic performance of VE and elastoplastic (EP) damping devices. Yang et al. [5] proposed two optimal design methodologies for passive energy dissipation devices based on active control theories leading to the determination of VS and VE dampers, defining different forms of performance functions. Lee and Taylor [6] developed the energy dissipation technology and suggested that approximately 15–25% of additional damping is a desirable range in the damper designed buildings. Lin et al. [7] presented a seismic displacement-based design method for new and regular buildings equipped with passive energy dissipation systems. Using the substitute structure approach for the building structure and simulating the mechanical properties of the passive energy dissipation devices by the effective stiffness and effective viscous damping ratio, a rational linear iteration method was proposed.

3 MODELLING OF STRUCTURE

Description of the Building

Building analyzed is a twenty five story, 100 meter high commercial building made up of RCC structure with plan dimension as 35m X 21 meter located in Mumbai with a gross area of 735 sq. meters. The columns are placed on grid of 7 meters in X direction as well as in Y direction. The building was designed as per IS code.

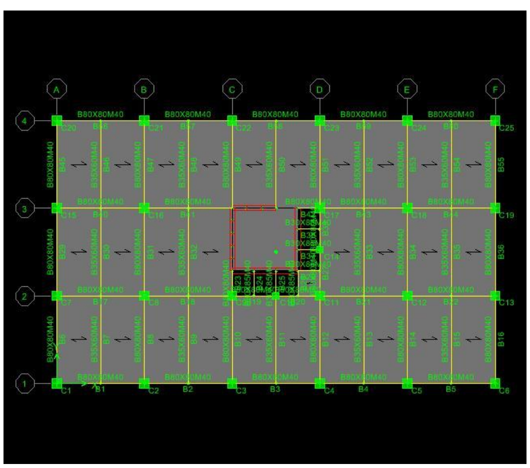

Figure 2: Plan view of building model in ETABS

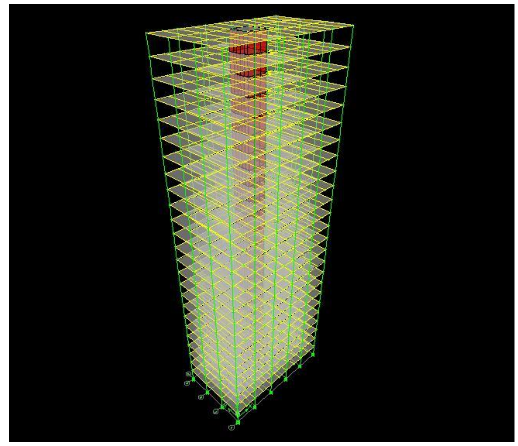

Figure 3: 3D view of building model in ETABS

Modeling of viscous dampers

Viscous Damping properties are based on the Maxwell model of viscous damper having a nonlinear damper in series with a non linear spring.

Fig. 4: Viscous Damper modeled as a Maxwell element

The design parameters for this model of viscous dampers are: K (spring stiffness), C (damping coefficient) and (characteristic of fluid).

Three different properties of viscous dampers have been used in present study. After request, properties were provided by Taylor Devices India for the analysis purpose.

Damper Notation	Coefficient -kN. s/m	Exponent	Stiffness-kN/m
AL1.0	700	0.3	35000
AL2.0	500	0.3	30000
AL3.0	300	0.3	25000

Table1: shows effect of varying raft thickness on pile raft

ETABS (Non linear version)

ETABS is structural program for analysis and design of civil structures. It offers an intuitive yet powerful user interface with many tools to aid in the quick and accurate construction of models, along with the sophisticated analytical techniques needed to do the most complex projects, so in the present study three dimensional analyses with the help of ETABS 9.7 (Non-linear version) is used for modeling and analysis of the structure.

4 RESULTS AND DISCUSSION

Response spectrum analysis is carried out with four different models of 25 story RCC buildings. First model is conventional building model without dampers (AL0), and other three building models (AL1.0, AL2.0, and AL3.0) are modified building models with three different properties of dampers given in table no 1. And the response of structures is compared with all four building models.

The main aspects of comparison between structures modeled with and without viscous dampers can be treated under three headings:

- Story Drift
- Story Displacement
- story shear of structures

Comparison of story drifts of structures with and without viscous dampers

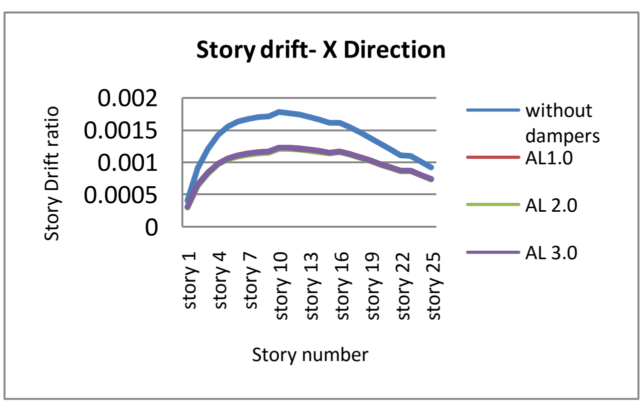

Fig. 5: Storey drifts response of structure in X-direction

When first damper properties is used (AL1.0), given in table 1, there is a reduction in story drift in X direction is 27% as compare to building model without viscous dampers. When second damper properties (AL2.0) is used, given in table 1, there is a reduction in story drift in X direction is 29% as compare to building model without viscous dampers. When third damper properties is used (AL3.0), given in table 1, there is a reduction in story drift in X direction is 28% as compare to building model without viscous dampers.

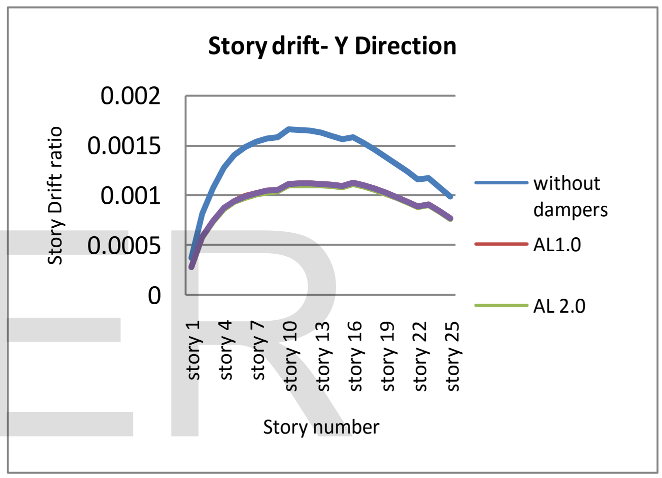

Fig. 6: Storey drifts response of structure in Y-direction

When first damper properties is used (AL 1.0), given in table 1, there is a reduction in story drift in Y direction is 29% as compare to building model without viscous dampers. When second damper properties is used (AL 2.0), given in table 1, there is a reduction in story drift in Y direction is 30% as compare to building model without viscous dampers. When third damper properties is used (AL 3.0), given in table 1, there is a reduction in story drift in Y direction is 29% as compare to building model without viscous dampers.

Comparison of story displacement of structures with and without viscous dampers

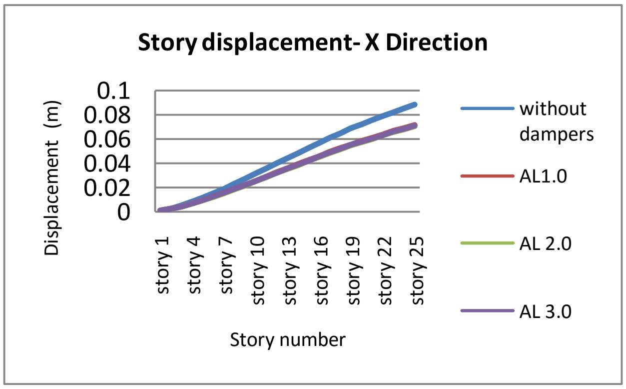

Fig. 7: Storey displacement response of structure in X-direction

When first damper properties is used, given in table 1, there is a reduction in story displacement in X direction is 19% as compare to building without viscous dampers. When second damper properties is used, given in table 1, there is a reduction in story displacement in X direction is 20% as compare to building without viscous dampers. When third damper properties is used, given in table 1, there is a reduction in story displacement in X direction is 19% as compare to building without viscous dampers.

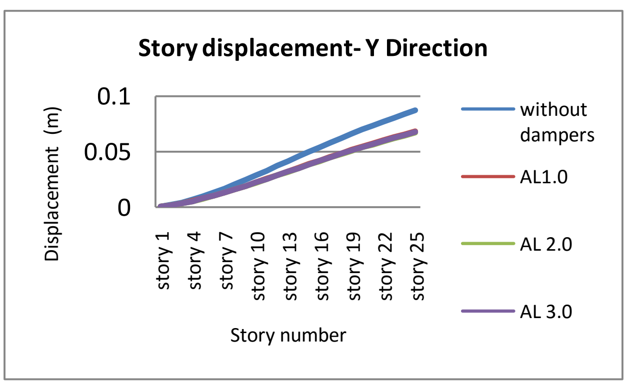

Fig. 8: Storey displacement response of structure in Y-direction

When first damper properties is used, given in table 1, there is a reduction in story displacement in Y direction is 22% as compare to building without viscous dampers. When second damper properties is used, given in table 1, there is a reduction in story displacement in Y direction is 23% as compare to building without viscous dampers. When third damper properties is used, given in table 1, there is a reduction in story displacement in Y direction is 22% as compare to building without viscous dampers.

Comparison of story shear of structures with and without viscous dampers

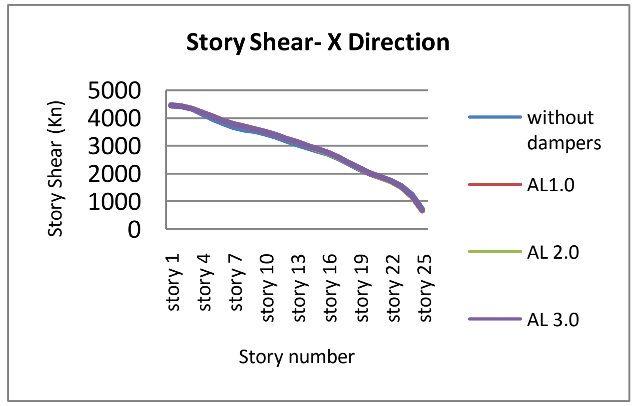

Fig. 9: Storey shear response of structure in X-direction

When first damper properties is used, given in table 1, there is a reduction in story shear in X direction is -1% as compare to building without viscous dampers. When second damper properties is used, given in table 1, there is a reduction in story shear in X direction is -1% as compare to building without viscous dampers. When third damper properties is used, given in table 1, there is a reduction in story shear in X direction is -1% as compare to building without viscous dampers.

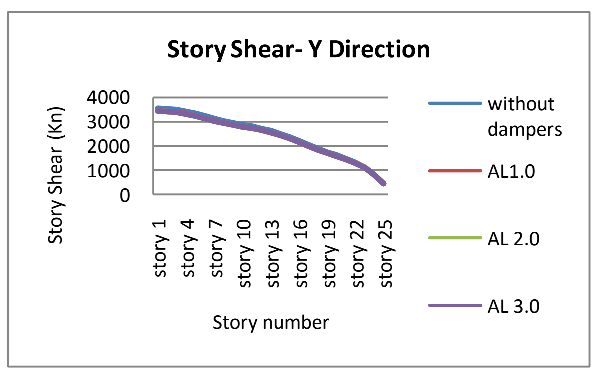

Fig. 10: Storey shear response of structure in Y-direction

When first damper properties is used, given in table 1, there is a reduction in story shear in Y direction is 2% as compare to building without viscous dampers. When second damper properties is used, given in table 1, there is a reduction in story shear in Y direction is 2% as compare to building without viscous dampers. When third damper properties is used, given in table 1, there is a reduction in story shear in Y direction is 2% as compare to building without viscous dampers.

CONCLUSION

From above results it is clear that by adding viscous dampers in a building response of a structure get reduced by significant amount.

It is seen that for response spectrum analysis in X and Y direction, the response of the structure such as the story drift and storey displacement reduces more as compare to the story shear. Reduction of story drift is around 29% to 30%, reduction of story displacement is around 20% to 23%, and reduction of story shear is around 0% to 2%.

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