Seismic Response Study and Evaluation of Vibration Control of High-Rise Structures: Viscous Fluid Damper, Viscoelastic Damper, Friction Dampers, Mass-Tuned Dampers(Vibration Damper) and MR Dampers

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I. ABSTRACT

The large engineering building structures are very expensive and too much intricated to maintain due to their chances of failure under various hazardous conditions. These buildings are needed to be protected against the damage due to the hazards conditions viz. earthquake and seismic waves. Damping acts a vital role in earthquake resistant structural design which decreases the response of the building when they are subjected to the lateral forces. In order to have these structure earthquakes resistant fluid viscous damper, viscoelastic dampers, friction damper, MR damper, pendulum mass tuned dampers are used. This paper study also deals with assessing the performance of fluid viscous damper, viscoelastic dampers, friction damper, MR damper, pendulum mass tuned dampers to reduce the seismic response of high-rise irregular structures. My main aim is to study a high-rise composite structural model to analyse different types of analysis and show my model as an earthquake proof structure.

Keywords: Seismic response, fluid viscous damper, viscoelastic dampers, friction damper, MR damper, pendulum mass tuned damper, time history analysis, vibration mechanism.

II. INTRODUCTION

In earthquake engineering vibration control devices are used to mitigate the seismic impact in different structural member. The main goal of earthquake resistant design to attain a structure with sufficient strength and ductility to assure life safety. Nowadays, three basic technologies are used to protect buildings from earthquakes effects. These are base isolation, passive energy dissipation devices and active control devices. **A variety of passive energy dissipation devices (such as viscous dampers, viscoelastic dampers and friction dampers) have been developed. Including these MR dampers and Pendulum tuned mass damper (TMD) will also be implemented.**

III. DETAIL DESCRIPTION OF DIFFERENT DAMPERS

a. Viscous Damper (VD)

Viscous dampers of varieties of materials & damping parameters were proposed and developed for seismic protection. Viscous fluid dampers commonly used as passive energy dissipation devices for seismic protection of structures are principally composed of a piston rod, a piston head and a cylinder filled with a viscous fluid. Fluid viscous dampers which operate on the principle of fluid flow through orifices are installed in a number of structural applications. Example of construction of viscous fluid viscous damper is shown in Fig: 1.

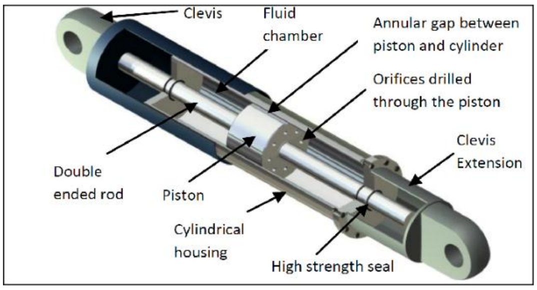

Figure 1.Viscous Fluid Damper

b. Viscoelastic Dampers (VED)

Viscoelastic dampers have been cojoined in a number of high structures as an effective power or energy dissipating system to restrain wind and earthquake induced motion of heavy high structural system. Viscoelastic Damper spatters the tall structure system's mechanical energy by converting it into heat.

c. Friction damper

A friction damper device was designed to diminish and absorb the input energy in order to increase the building's safety from natural disaster. It can be used in retrofitting or in designing of new buildings. The friction damper was tested intensively in order to verify its characteristics and performance. This device consists of several steel plates that rotate against each other in opposite directions, producing friction between its parts.

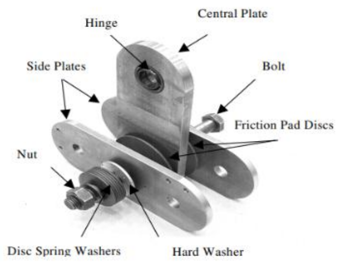

Figure 1: Details of the friction damper device

d. Magnetorheological Damper (MR Damper)

Magneto-rheological dampers more commonly called as MR dampers. MR damper is also called as an intelligent damper. It is used for controlling the vibration of automobile suspension.

The advantages of MR dampers are that, (i) this type of dampers required very less control power, (ii) whose construction mechanism is very simple, (iii) Due to this simple construction mechanism it has also a very quick response mechanism to control the signal and (iv) it has less numbers of moving parts. MR dampers have a lot of potential technology to deal with semi-active control power system. It is very much important to understand the dynamic behaviour of such devices.

Magnetorheological (MR) fluids, are different type of materials that, respond to an applied magnetic field with a glittering change in rheological behaviour i.e; the branch of physics that deals with the deformation and the flow of matter, specially the non-Newtonian flow of fluid and the plastic flow of solids. In the absence of magnetic field MR fluid act in a state of free-flowing liquid state. But under the strong magnetic field it's viscosity can be increased by more than two orders of magnitude in very very short time and it exhibits a solid-like characteristics. The strength of an MR fluid can be described by shear yield stress.

e. Pendulum Tuned Mass Damper or Vibration damper

A mass tuned damper is called seismic damper. It is also called harmonic absorber. It is Special type of device which is used in the structures to minimize the vibration. TMD is used to prevent the discomfort, damage of the structures. These types of dampers are used in power transmission, automobiles and high-rise buildings. Tuned mass dampers stabilize against violent motion caused by harmonic absorber. These types of dampers are used as a lightweight component to reduce the vibration of a system so that, in worst-case condition vibrations will be very less. The natural frequency of the tuned mass damper is basically defined by its spring constant and the damping ratio determined by the dashpot systems elements.

IV. LITERATURE REVIEW

- Analytical computations which were conducted by **Shaik Khadervali et. al. [1]** highlighted about the displacement, shear and moment which were compared for two models i.e., w/o dampers & with dampers at top storey of a high rise building in zone-III & zone -V in each soil and it was observed that 50% (approx.) displacement, shear and moment were reduced when the dampers were provided at each elevation.

- **Mitsuo Asano et. al. [2]** concluded based on their study are summarized as follows: Based on dynamic loading experiment, the mechanical properties of the dampers were roughly divided into two groups. The first group showed non-linearity and reaction force degradation with small dependency on frequency. The second group showed noticeable dependency on frequency, but non-linearity and reaction force degradation was small. The mechanical model of the dampers, which had dependency on frequency, was modelled by using ARX method. As the results of earthquake response analysis of a building equipped with VE dampers, the inter-story displacement as well as the acceleration response of the building was reduced.

- **Sang-Hyun Lee et. al. [3]** presented a procedure for the optimum design of the VED by assigning eigenvalues required to achieve the desired structural response. Their optimization method provides information on the optimal location as well as the magnitude of the damper parameters to achieve a given target by thorough study of the numerical analyses of a 10-story shear building and a plan-wise asymmetric structure. Their proposed method can provide a reasonable distribution of the VED in structures with a symmetric or an asymmetric plan to meet a given target displacement.

- **Waseem SARWAR [4]** describes that, DMA is a hypersensitive approach for investigating the dynamic scope of VEM. Dynamic properties of VE material are investigated, the DMA (Q800) apparatus reported fair differences in properties at various frequencies and temperatures. Storage modulus, loss modulus, and loss factor increases with the increase in excitation frequency and decrease as the temperature increases.

- **Majd Armali et. al.** [5] describes the results presented in this study for the nonlinear modal time history analysis were carried out on a high rise reinforced concrete building formed by 40 storeys. They were represented by storey responses and time history plots for various parameters. They illustrate that the incorporation of friction dampers into the structure reduces considerably the building response compared to a conventional shear wall system for the same building. The results analysis of structural period, roof displacement, storey displacements, roof acceleration and storey accelerations show a considerable reduction by using dampers against the conventional building without damping by optimizing their numbers and locations.

- **S. Lakshmi Shireen Banu et. al.** [6] describes about the storey responses from the time history analysis in terms of PSA, PSV and SD have been reduced with the use of friction dampers. The response spectrum curves of PSA, PSV and SD shows the reduction over time period with the use of dampers compared to the buildings without dampers. The base shear in case of building with damper can be attributed to the increased mass by addition of damper brace system at each storey level. The responses can be further reduced by the selection of damper, position of damper and shape and type of construction of the building involved.

- **Claude PASQUIN et. al.** [7] provide the analytical studies have shown that the friction-damped structure should perform well in the event of a major earthquake. As the seismic forces exerted on the structure are significantly reduced, the system offered savings in upgrade costs. The use of friction dampers has shown to provide a practical and economical solution for the seismic upgrade of the building.

- **Hongyan Gu et. al.** [8] describes in their article, a reliable earthquake protection system is developed using ACO optimization and decentralization mechanism in order to provide the protective scheme for tall building survivability as well as to safeguard the occupants. A dynamically decentralized approach is proposed in this work using the PID controller for the self-regulation during the faulty condition in case, any of the sub-system goes down. The combination of optimization, decentralization and self-regulation provides better outcomes for the numerical simulation of tracking and control mechanism during the earthquake scenario.

- **S K Mangal et. al.** [9] describe in this paper, the optimization of geometric and response parameters of an MR damper using statistical tools coupled with FEM is presented. The geometric parameters are searched between lower and upper bounds having two/three levels for each of these parameters. The process illustrated in their paper will be useful for future automotive design engineers for predicting an optimized damping force of an MR damper.

- **Bhagyashree et. al.** [10] describe about the placement of damper in different position shows variation in the response of the structure and the force produced by the MR damper. When damper placed in any of the floor shows reduction in the response but damper predicted force and response control vary. Therefore, from the result it can be inferred that MR damper placement in first floor is better situated to mitigate response of the structure because the force required to reduce the response is small when compared to other positioning of MR damper.

- **M. Setareh et. al.** [11] describe this paper presented a study of PTMDs to control excessive vibrations of floors. From the results presented here it can be concluded that PTMDs can provide a practical method of vibration control.

V. RESEARCH OBJECTIVES

1.) To model the “High-Rise Composite Structure”- RCC and steel framed structure located in seismic zone-V region of India.

2.) Structural modelling will consist of both: composite structure with and without incorporation of dampers at foundation level.

3.) Conduct "Response Spectra Analysis" for earthquake in accordance with IS 1893:2016.

4.) "Seismic Performance Evaluation" with and without various types of dampers: viscous dampers, viscoelastic dampers, friction dampers, MR dampers, Mass Tuned dampers.

5.) Conduct comparative study on all structural models based on following parameters: Lateral Force Distribution (Q), Base Shear (V_b), Inter-Storey Drift ($\Delta_{interstorey}$), Load vs Rooftop Displacement Graph (P vs $\Delta_{rooftop}$).

6.) Recommend incorporation of dampers ideal for the building model (among all dampers)

7.) Cost Analysis.

VI. CONCLUSION

- The fundamental ideas of different dampers and seismic control devices are covered in this study along with recent advancement and applications. The observation suggests that a variety of technologies can be utilized to reduce seismic response.
- Generally, when an earthquake strikes a building or other structure, seismic waves penetrate the building and induce vibration. The seismic dampers then come into play and thus minimize the damaging effect and enhance the seismic performance of the structure. These are extensively used in buildings and bridge construction. Seismic dampers are used in place of structural elements such as a diagonal brace. These dampers are used- to protect the structure against earthquakes, to reduce the structural damages and increase the strength of the structure, to decrease the effects of the seismic forces and to reduce the deformations of the structure.
- Viscous dampers are very efficient in absorbing minor as well as strong earthquakes as well as wind. Due to this reason, such dampers are extensively used in high-rise buildings. Viscous dampers can function at ambient temperatures ranging from 40 degrees to 70 degrees Celsius.

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