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Seismic Dampers and the Factors Affecting its Efficacy
A Review Paper

Aniket D. Patil
Prof. Dept. of Civil Engineering,
MIT School of Engineering, MIT ADT University,Pune,
Maharashtra, India

Ashish Kumar
Dept. of Civil Engineering,
MIT School of Engineering, MIT ADT University,Pune,
Maharashtra, India

Raunak Joshi
Dept. of Civil Engineering,
MIT School of Engineering, MIT ADT University,Pune,
Maharashtra, India

Abhishek Arge
Dept. of Civil Engineering,
MIT School of Engineering, MIT ADT University,
Pune, Maharashtra, India

Abstract:- Seismic damping technology has been used for years in order to protect structures from adverse effects of earthquake. Thus, it is important to study seismic damping technologies in order to use them effectively. The purpose of this paper is to broadly classify the dampers currently in popular use, and explain their functioning. Friction Dampers, Viscous Dampers, Visco-Elastic Dampers and Tuned Mass Dampers are the majorly used dampers in the market nowadays. Viscous Dampers are considered the most efficient type of dampers. The efficiencies of various dampers also differ from each other and thus can be used at various places based on requirements. On further studies, it was found that the efficiencies of dampers not only depend on their type but also on their location and orientation. Dynamic analysis is used for the assessment of effects of dampers on structures. There are two types of Dynamic Analysis methods – Response Spectrum Analysis and Time History Analysis.

Keywords:- *Seismic Damper; Location; Orientation; Time History Analysis; Response Spectrum Analysis.*

I. INTRODUCTION

Traditionally reinforced concrete structures were made earthquake resistant by designing the frame for a predicted magnitude of earthquake. However, the frame elements designed using the traditional method were not feasible due to the uneconomical large sizes of frame elements. Thus traditional seismic design methods were eventually replaced by energy dissipation devices like dampers and base isolators. Seismic dampers are the most commonly used energy dissipation devices. There are multiple types of seismic dampers available in the market - Viscous Damper, Visco-Elastic Dampers, Friction Dampers, Tuned Mass Dampers, etc. It is imperative to understand the classification of dampers in order to decide their appropriate utility in any structural setup.

Dynamic Analysis Methods are used to analyze the efficacy of dampers. There are two types of dynamic analysis methods - Response Spectrum Analysis and Time History Method. A unique sort of mode superposition is used in the response spectrum approach. The goal is to offer an input that specifies a limit on how much an eigen mode with a given natural frequency and damping can be aroused by a given event. The structural reaction to short, nondeterministic, transient dynamic events is estimated using response spectrum analysis. The response of a structure under historical earthquake or wind acceleration data is studied using time-history analysis. The structure does not have to be an SDoF system. A plot of amplitude or acceleration vs. time is known as a time-history. The structural reaction is computed at a number of consecutive time instants in time history analyses. When placing the dampers in a building, it must not be done in a random fashion.The efficacy of damper does not only depend on its type but also its location and orientation.

II. TYPES OF DAMPERS

A. Types of Dampers

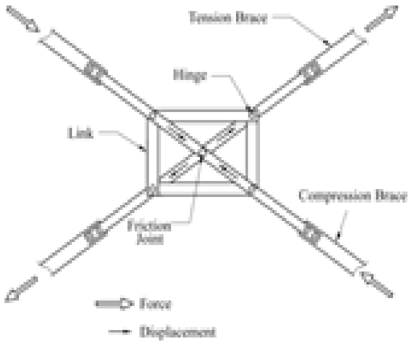
The major types of dampers available in the market are asfollows -

a. Friction Dampers
b. Tuned Mass Dampers
c. Viscous Dampers
d. Visco-Elastic Dampers

B. Friction Dampers

It is one of the most effective, easily available and inexpensive types of dampers present in the market. The seismic energy created by ground motion is converted into friction caused between the two surfaces sliding over each other. According tothe authors Chandnani, Joshi and Trivedi; a larger amount of seismic energy can be dissipated when using friction dampers as compared to viscous dampers or yielding dampers[2]. Author Heysami states that the performance of a friction damper is not affected by parameters like temperature and velocity[1]. It has very low maintenance and thus is a very popular kind of damper.

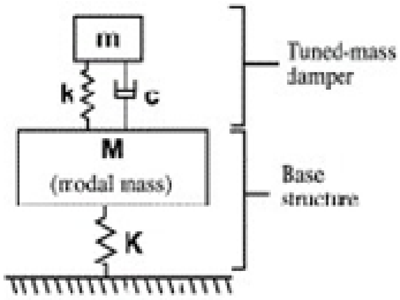
Figure 1: Friction Damper



C. Tuned Mass Damper

It is an energy dissipating system, consisting of an arrangement of mass and spring, which works on the principle of harmonic motion. By the help of the tuned mass damper, the oscillating frequency of the mass attached is tuned to match the frequency by which the structure oscillates. This helps to reduce structural failure. Tuned mass dampers can be broadly classified into 2 types based on control mechanism: Active and Passive. In an Active Mass Damper, an external source is used to alter the forces in a predetermined manner in order to match the resonating frequency of the structure[6]. On the contrary, the Passive Mass Damper does not use this external power source and imparts forces that are generated because of the motion of the structure. Shanghai Tower, CN Tower and Statue of Unity are a few examples of skyscrapers that use TMD.

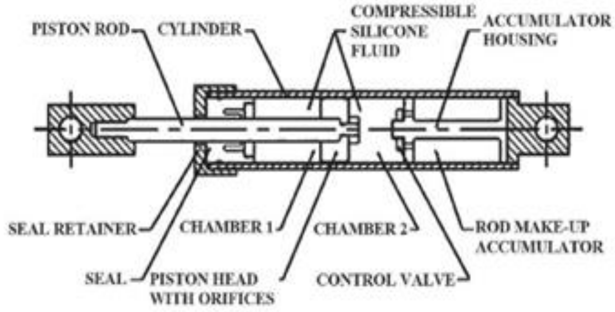
Figure 2: Tuned Mass Damper



D. Viscous Damper

Viscous damper is used to dissipate energy in a building's lateral system. It dissipates the energy by forcing a liquid through a small opening or orifice, which in turn creates a damping pressure that generates a force which results in considerable reduction in seismic energy or force. Accordingto author Darshane, the working methodology of a viscous is comparable to that of a car's shock absorber, but at a considerably higher force level[3]. They are inexpensive and can be easily installed to a new or an existing structure.

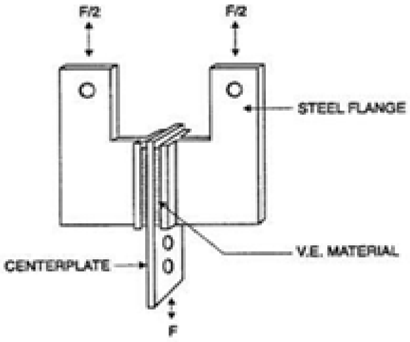
Figure 3: Viscous Damper



Visco-elastic Damper

Visco-elastic dampers dissipate energy by expanding an elastomer in combination with metallic plates. The energy acting on the body is absorbed by utilising the controlled shearing of solids. They are generally used in structures made of steel. Authors Bhatti and Varum state that visco-elastic dampers are easily installable and require low maintenance[4]. They are very effective against seismic and wind loads.

Figure 4: Viscoelastic Damper



III. TIME HISTORY METHOD AND RESPONSE SPECTRUMANALYSIS

Varying earthquakes have different intensities and magnitudes in different locations, and the destruction caused in all these locations are also different. As a result, it is critical to investigate the seismic behaviour of RC structures for various functions such as base shear, storey displacement, and so on.

Seismic analysis is required to calculate the building's seismic reaction; seismic analysis is an important aspect of the structural design process in areas where earthquakes are common.

A. Time History Method (THM)

This method calculates the response of a structure that has been subjected to earthquake stimulation in real time (hence the name Time History). Various seismic data, such as acceleration, velocity, displacement data, and so on, are required for seismic analysis and can be easily obtained from seismograph data analysis for every given earthquake. It's a crucial technique for structural seismic analysis, especially when the structural response being assessed is nonlinear.

B. Response Spectrum Analysis (RSA)

Time history analysis is the source of this method. A designer is not often concerned with the structure's response at all times; maximal response is sufficient information for designing a sufficiently robust structure. For certain ground acceleration, a graph between maximum spectral acceleration and various time periods of structure is generated in this method, but the structure's response at each point in time is not determined. The linear dynamic analysis approach is called the response spectrum method. In this procedure, only the maximum values of displacements and member forces in each mode of vibration are calculated. Smooth design spectra, which represent the average of numerous earthquake motions, are used in this procedure. Different earthquakes will have different response spectra, but IS 1893:2002 has provided a general purpose reaction spectra that was produced by examining a few large earthquakes in the past for the convenience of structural engineers.[10]

C. Comparison between THM and RSA

The top displacement provided by time history analysis is on average 10% to 15% smaller than the displacement provided by response spectrum analysis. In base shear, a similar trend emerges: response spectrum yields a 15 percent to 20% greater base shear value on average than time history. This overestimation of base shear in the response spectrum would result in larger stresses in structural components, making design based on such an analysis uneconomical because large dimension members are required to resist large displacements and stresses. The difference in the results of the response spectrum approach is large at higher storeys (above the 5th floor), hence the time history method should be used for high- rise structures. Because the response spectrum and time history methods produce nearly identical results for smaller buildings, the response spectrum method should be preferred. The time history method is time consuming due to the input it requires (earthquake excitation), and the results interpretation is not straightforward. Because the time history method provides a more accurate and close-to-perfect visualisation of a structure's behaviour during an earthquake, sensitive structures such as long bridges, nuclear power plants, or any hazardous industrial building should be designed using the time history method, which incorporates a large number of historically devastating earthquake data. The time history method is superior to the reaction spectrum approach, and it should be used whenever extensive analysis is required. However, the response spectrum method is not a terrible approximation; it delivers pretty accurate findings and overestimates on the conservative side for low-rise buildings.[10]

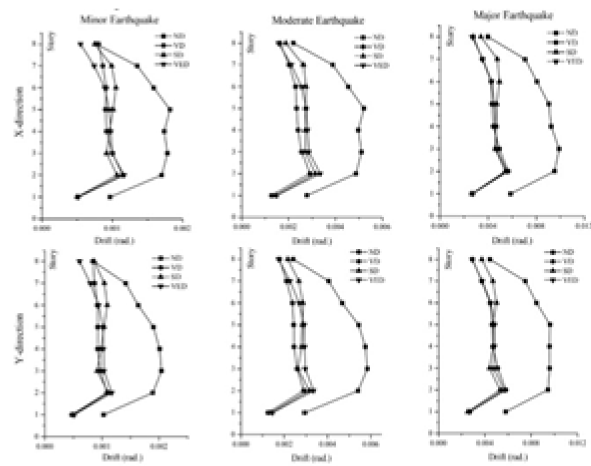
In Unsymmetrical structure, the above-mentioned trend is more pronounced. Because the results of time history approaches are strongly reliant on earthquake excitation, a number of different earthquakes of differing intensities should be collected and the best of these should be evaluated.

Time history provides the time distribution of base shear and displacement, which may be utilised to predict the failure mode of a structure. These data can be extremely beneficial when constructing sensitive and significant structures.

Because the response spectrum approach cannot account for the time fluctuation of base shear and deflection, it is difficult to anticipate the location and manner of failure under dynamic load using response spectrum.

IV. DAMPER EFFICIENCY

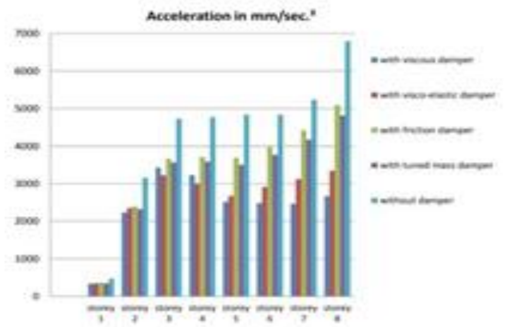
Authors Lu, Ding, Weng, Kasai and Wada conducted an experiment to see the changes on response of a 8-story RC Frame Building when different dampers namely viscous damper (VD), steel damper (SD) and viscoelastic damper (VED) were used[5]. They accounted various intensities of earthquakes when testing the various dampers for inter-story drift. When compared to a frame where no damper is used, all the dampers show a significant reduction in story drift across all intensities of earthquake. It can be inferred that when there is a minor earthquake, viscoelastic damper proves to be the more efficient than steel damper and viscous damper. In case of a moderate earthquake, viscous damper has the least inter storey drift and thus is the most efficient damper in this case. In case of areas with major earthquakes, both viscous dampers and viscoelastic dampers reduce the story drift considerably. It can also be observed that steel dampers are less efficient in damping the structure as compared to the other dampers irrespective of the intensity of the earthquake in the zone.



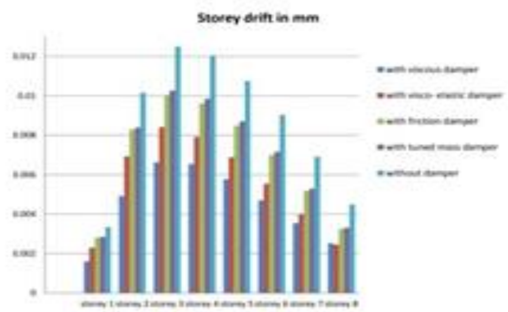
Graph 1: Seismic response of various dampers[5]

Authors Landge and Joshi conducted an experiment to check the efficacy of various dampers which are as follows: viscous dampers (VD), viscoelastic dampers (VED), friction damper (FD) and tuned mass damper (TMD)[9]. They checked the response of the structure on various parameters like displacement, acceleration, story drift and story shear on a 8 storey building. When comparison of the various types of dampers was done on basis of displacement, it was observed that all kinds of dampers were able to successfully reduce the displacements of the structure across all stories. Viscous damper was the most efficient kind of damper across all stories. It was observed that tuned mass damper was the least effective kind of damper among all other dampers. They are generally used in high rise buildings and that might not be that effective when used in smaller structures. As the acceleration in a building increases, the response of the building increases and thus damping needs to be increased. When various dampers were used in the structure, it is seen that viscous damper was the most efficient kind of damper on storey 1,2,5,6,7 and 8. On storey 3 and 4, viscoelastic dampers were most efficient in damping. It is also observed that as the number of story in a structure increases, the acceleration on the particular storey increases. When the storey drift was accounted for, it was observed that peak story drift was reached on storey 3 and it gradually decreased on the successive storeys. Viscous dampers and vicoelastic dampers prove to be the most efficient kind of dampers to reduce the storey drift followed by friction damper and tuned mass damper. Storey shear plays a vital role in deforming a structure. More the storey shear, more the damage done to the structure, thus it is important to minimize the storey shear acting on a building. Upon checking the structure for storey shear it was observed that viscous dampers were were the most effective kind of dampers to reduce storey shear. Out of all the dampers applied, friction dampers had the maximum storey shear. It was also observed that storey shear has it's highest magnitude at the first story and decreased in the consecutive storeys.

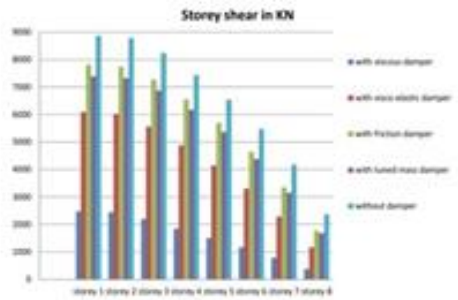
Graph 2: Displacement graph using various dampers[9]



Graph 3: Acceleration graph using various dampers[9]



Graph 4: Storey Drift graph using various dampers[9]



Graph 5: Storey Shear graph using various dampers[9]

From the above experiments it can be seen that various kind of dampers can be used to maintain structural integrity against earthquakes. From both the papers it can be inferred that for a medium rise structure, viscous damper and viscoelastic damper prove to be an ideal choice of damper.

V. POSITION AND ORIENTATION OF DAMPER

The authors Tovar and Lopez carried out an experiment where they tested the effect of number and placement of dampers on the response of the building[7]. They laid out several cases of varying number and position of dampers as shown in the figure. It was observed that the damper placement significantly affects the overall response of the structure. It was also observed that increasing the number of dampers increases the damping. However, it was noted that increasing the number of dampers and placing them randomly will not always yield a better result. Furthermore, authors Tovar and Lopez suggest that the dampers should be placed closer to the base of the building in order to reduce storey drift.

Figure 5: Use of single damper on a storey[7]

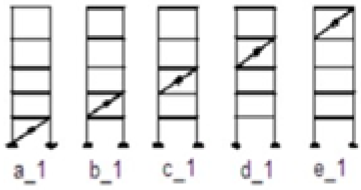


Figure 6: Use of 3 dampers on a frame[7]

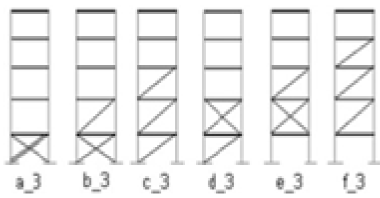
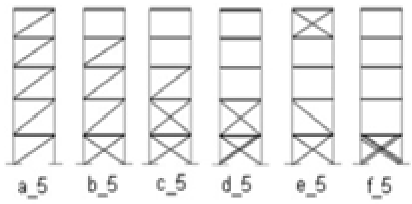


Figure 7: Use of 5 dampers on a frame[7]



The author Julius Marko conducted a series of experiments on a high rise structure, a 18 storey structure and a 12 storey structure to determine the building response in different conditions[8]. The author concludes that various kind of dampers can be used to control the response of a building. The author also concludes that viscoelastic dampers work best when placed at lower storeys. Friction dampers can be used in regions where maximum storey drift is expected. The author also suggests that for medium and high rise structures, passive dampers are an ideal choice of damper. The author suggests that friction dampers have the ability to reduce the initial strong strikes whereas viscoelastic dampers decrease the response of the structure at a slower rate. Thus, to prevent the structure from the initial strikes of the earthquake, friction dampers are an ideal selection.

Thus the above experiments conclusively state that the number, position and orientation of damper highly influence the seismic response of a structure.

VI. CONCLUSION

- Dampers highly influence the response of a building and it should be used in areas of high seismic activity.
- Dampers work best when placed at lower storeys.
- For a medium rise structure, viscous damper and viscoelastic dampers should be used.
- Friction dampers work best when placed at regions with high inter storey drift.
- The number, position and orientation of the damper highly influence the structural response of the building and thus should be placed carefully.

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