A Review Paper on Seismic Analysis of Structure Introducing Weak Story on Top as Tuned Mass Damper

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Abstract

Tuned Mass Damper (TMD) is a passive control device which absorbs energy and reduces response of vibration. TMD is found to be a simple effective inexpensive and reliable means for suppressing undesirable vibration of structure caused by harmonic or wind excitation. In this study the effect of TMD on the structure and the method of obtaining the optimum parameters of TMD are discussed. For Indian conditions, in RCC multi-storeyed building a much simpler form of TMD will have to be developed. The review paper of literature also deals with the simplest form of TMD considering environmental conditions.

Key Words: - Dynamic response, Optimum parameters, TMD, SDOF, MDOF.

1. Introduction

In structural engineering the major goal has been the maintenance of structural stability against effect of various forces acting on the structure. Earthquake and wind are the two important external forces that must be taken in account when designing a structure, as they can greatly affect stability of structure. The objective of seismic analysis of structure is to mitigate or reduce the seismic risk. The seismic risk refers to various factors like seismic hazard, exposure and vulnerability. Seismic hazard refers to damage in the built environment because of earthquake. Exposure refers to the population, building, installation and infrastructure located where earthquake effect could occur. Vulnerability represents the likely hood of damage being sustained by a structure when exposed to a particular earthquake effect. Rapid urbanization and industrialization has led to increase in the multi-storeyed structure construction. Efforts are being taken since many days for introducing a device for reducing or controlling the seismic response of structure due to lateral loading. The efforts have resulted in the introduction of active control device and passive control device. Active control device are found to be quite costly for buildings in India as compared with passive control device. Keeping in mind this parameter a simple form of tuned mass damper is to be designed for controlling seismic excitation of structure. TMD are the simplest form of vibration absorbers which is relatively easy to be implemented. By adding a small additional mass where the stiffness and damping are designed in proper way, the vibration of the building can be reduced. In order the TMD work properly, the properties of TMD have to be designed so that the response of building can be reduced.

2. Parameters of TMD for Seismic Application

To reduce the response of the structure subjected to seismic loading by application of simplest form of tuned mass damper, the optimum parameters of TMD are needed to be considered for design. The mass ratio, frequency, and damping ratio are the criteria that should be considered while obtaining the optimum parameters. By considering the optimum parameters of TMD in several single and multi degree of freedom structures the displacement and acceleration response reduces significantly. For structures with higher damping ratio large mass ratios must be used in order for TMD to be effective. The top floor with approximate stiffness and damping can be considered as a vibration absorber for lower floor.

In this paper to obtain the optimum parameters of TMD a single degree of freedom structure and multiple degree of freedom structure is considered. Also for reducing the response of the structure to earthquake loading the effectiveness of the parameters which are obtained is examined. Equations are obtained to find the optimum parameters of TMD for SDOF and MDOF system. For un-damped structure the tuning ratio *'f'* is found to be equal to 1/ (1+μ) and the damping ratio 'ξ' is equal to $\sqrt{\mu / (1+\mu)}$. Also for damped structure the following equations were obtained,

$$f = \frac{1}{1+\mu}\,[1 - \beta\sqrt{\frac{\mu}{1+\mu}}]$$

$$\xi = \frac{\beta}{1+\mu} + \sqrt{\frac{\mu}{1+\mu}}$$

Were μ is mass ratio, β is damping ratio. Also it was found that the tuning ratio *'f'* for a MDOF system is nearly equal to tuning ratio of SODF system for mass ratio of μϕ. Were ϕ is amplitude of first mode of vibration for a unit modal participation factor. Also damping ratio of MDOF is equal to SDOF system multiplied by ϕ.

$$f = \frac{1}{1+\mu\phi}\,[1 - \beta\sqrt{\frac{\mu\phi}{1+\mu\phi}}]$$

$$\xi = \phi\,[\frac{\beta}{1+\mu} + \sqrt{\frac{\mu}{1+\mu}}]$$

By using the above formulas and optimum parameters of TMD can be obtained, which results considerable reduction in response to earthquake loading.

Fahim Sadek, Bijan Mohraz, Andrew Taylor and Riley Chung

3. Tuned Mass Damper

A simplest form of TMD is introduced by O R.Jaiswal and Sachin Bakre in the form of a weak story at the top of the structure. The mass of the top story is kept around 3 to 5 % of the total weight of the structure. To satisfy this condition the sizes of column, beam and slab are reduced. Also walls are not provided to this story. The optimum parameters of TMD are obtained by using the parameters proposed by Fahim Sadek, Bijan Mohraz, Andrew Taylor and Riley Chung (1997). Keeping in mind these parameters the column and beam sizes are obtained. A multi-storeyed building is analyzed. The response spectrum analysis and Time history analysis of structure is carried out. The result obtained by response spectrum analysis of structure with TMD showed that the forces in column reduce by 20% to 40%. Same results were obtained by time history analysis. (O R.Jaiswal and Sachin Bakre- 2002)

There are many studies on use of TMD to control seismic response of structure John R. Sadek and Richard E. Klinger have studied in effect of TMD on seismic response. In this study a 25 story building was analyzed using the TMD mass ratio of 0.65% it was found that there is no reduction in the lateral forces using optimum of TMD. It was found that the vibration absorbers are not effective in tall building.

T. Miyama (1992) proposed an energy absorbing elastic plastic storey at the top of multistory. By analyzing this system for three different earthquake motions, he showed that a top with 5% mass ratio can reduce the seismic response significantly. 80% of energy absorption is possible if mass of top story is 5% of the total mass.

The research by Arlekar J.N, Jain S.K, and Murthy C V R highlights the problems occurring due to provision of soft storey on first floor. The seismic response of the RC frame building with soft first story is studied. In many of the structure open first storey is provided which perform poorly during the earthquake. The most commonly found reason of failure of structure during earthquake is this soft storey. A simple building is analyzed in this paper and it is observed that the drift and strength demands in the first story column are very large.

Y. Arfiadi and M N S Handi have worked on the optimum placement and properties of TMD. Genetic algorithm (Gas) is used to optimize the location and properties of TMD. Binary coded genetic algorithm is used to obtain the location of TMD and real coded genetic algorithm is used to obtain properties of TMD.

The results obtained showed that TMD is effective in reducing the vibration and if more reduction is expected active TMD must be used.

Dr. M. Murudi and Mr. S M. Mane have studied on the effectiveness of TMD for different ground motion parameters. And a TMD is modeled as a mass with spring and damper attached to SDOF system. The study resulted that TMD is effective for controlling structure response to harmonic base excitation and is most effective for lightly damped structure and may decrease with increase in damping.

4. Conclusion

TMD is one of the most important devices used to control the seismic excitation of structures. As provision of weak story as vibration absorber is the cheapest source of designing earthquake resisting structure. Also effect of weak storey on any structure with a soft first storey on ground floor is also needed to be analyzed and also till what height this TMD is effective must be found. Study on the effect of TMD on the various structures is needed. Also for various intensities of earthquake the structure with TMD must be analyzed and the effect of weak story as TMD on the structure with varying number of floors is also needed be analyzed.

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