Vibration Control of Adjacent Building using Shared Tuned Mass Damper

Meet Ankola[1], Prof. Vishalkumar Patel[2], Dr. Snehal Mevada[3]

[1]*PG Scholar, Structural Engineering Department, BVM Engineering College, Anand, Gujarat, India*
[2]*Assistant Professor, Structural Engineering Department, BVM Engineering College, Anand, Gujarat, India*
[3]*Assistant Professor, Structural Engineering Department, BVM Engineering College, Anand, Gujarat, India*

***

Abstract - *The natural disturbances like strong earthquakes and winds have caused severe damages to large scale infrastructures, which create discomfort to human and many times lead to catastrophic structural failure. The dynamic response of tall structures under strong earthquakes and winds is very important to civil engineers. Many energy dissipation devices available for control the behavior or response of tall structures under earthquakes. TMD (Tuned Mass Damper) is one of the best energy dissipation device to reduce the response of structures. This research involves attaching adjacent structures in which one structure is more flexible than other one with a shared tuned mass damper (STMD) to reduce both the structures vibration. Here the TMD is provided on rigid structure while viscous damper on flexible structure. This research shows the connection of two dynamically dissimilar building using STMD. For identify the effectiveness of STMD, here two SDOF system connected with each other by means of STMD and find out the response of the adjacent structure.*

Key Words: Tuned Mas Damper (TMD) Shared Tuned Mass Damper (STMD), Viscous Damper, Tall Structure, Adjacent Structure, MATLAB.

1. INTRODUCTION

Recent massive earthquakes around the world have confirmed that seismic performance of the structures still requires lots of improvements in knowledge on behavior and design of earthquake resistant structures, even in countries, which are supposed to be at the cutting edge of science and technology. To safeguard structures from remarkable damage and response reduction of structures under severe earthquakes has become more important and it is demanding task for the civil engineering profession. The control of structural vibrations produced by earthquakes can be achieved by various measures such as modifying rigidities, masses, damping or shape, and by providing passive or active counter forces. The basic concept to safeguard the structures to withstand seismic excitation is either designing structures with sufficient strength, stiffness, elastic deformation capacity and ability to deform in ductile manner, or using control devices to reduce force acting on the structure. TMD is the very effective device to control of structural vibration. It is noted that the single tuned mass damper is commonly placed at top floor, and tuned to the fundamental frequency of the main (parent) structure. Common findings of researchers indicate that the TMD is significantly effective only when it is perfectly tuned to the first (dominant) modal frequency. They have strongly recommended the TMD to control structural response under wind excitations, especially for flexible structures. The concept of the multiple tuned mass dampers (MTMDs) has been proposed, and it has generally been found to be more effective as compared to the single TMD. [10] Location of TMD also play an important role to reduce the displacement of structure. The displacement of the structure reduces particularly when the frequency of excitation is near to the fundamental frequency of the structure. By changing the location of TMD to different floors, the appropriate location for adjusting the TMD is found to be near the top of the building.

A shared TMD first introduced by Abdullah, Hanif. In their research, they attached two adjacent structures with a shared tuned mass damper (STMD) to reduce both the structures vibration and probability of pounding. The results have shown that overall, the design of the STMD reduced the vibration of the buildings better than the individually placed TMDs. These results prove that implementing a STMD to reduce structural vibrations and mitigate pounding is an effective design. This research involves attaching adjacent structures with a shared tuned mass damper (STMD) to reduce vibration of structures. Because the STMD is connected to adjacent buildings, the problem of tuning the STMD parameters such as stiffness and damping becomes not easy. Here rigid SDOF system connected to the flexible SDOF system by means of shared tuned mass damper. TMD provided on the top of the rigid SDOF system and shared with adjacent flexible SDOF system.

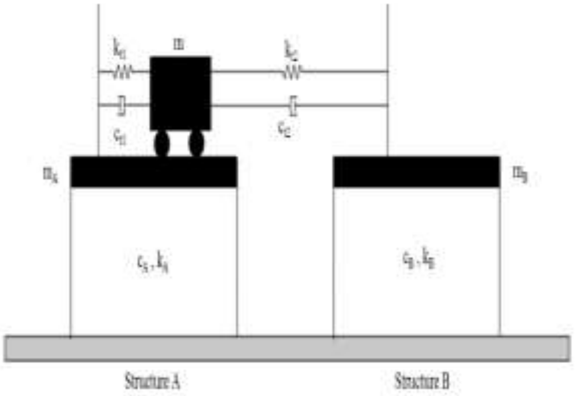
1.1 Aim And Objective Of Research

1. To study the effect of frequency ratio on dynamically dissimilar building for Peak displacement response.

2. Effect on different adjacent structures which have different heights when connected with STMD.

2. Proposed System

As discussed above, response of controlled SDOF systems find out in which TMD attached on top of rigid SDOF system shared with flexible SDOF system as shown in figure 1. In below figure, there are two adjacent buildings A and B shown. We provide building A is more stiff than building B. Here notations c_a, k_a, m_a are damping constant, stiffness and mass of building A respectively. Similarly c_b, k_b, m_b are damping constant, stiffness and mass of building B respectively.



3. Optimum STMD Parameters

The STMD system shown in figure can be describes as following equation of motion:

$$\mathbf{M\,\ddot{x}\,(t) + C\,\dot{x}\,(t) + K\,x\,(t) = F_e(t) = -h\,\ddot{x}g\,(t)}$$

Here, $\mathbf{M} = \begin{bmatrix} ma & 0 & 0 \\ 0 & mb & 0 \\ 0 & 0 & m \end{bmatrix}$

$$\mathbf{K} = \begin{bmatrix} ka + kt1 & 0 & -kt1 \\ 0 & kb + kt2 & -kt2 \\ -kt1 & -kt2 & kt1 + t2 \end{bmatrix}$$

$$\mathbf{C} = \begin{bmatrix} ca + ct1 & 0 & -ct1 \\ 0 & cb + ct2 & -ct2 \\ -ct1 & -ct2 & ct1 + ct2 \end{bmatrix}$$

Where,
M = Mass matrix of system
C = Damping matrix of system
K = Stiffness matrix of system
$\ddot{x}$ (t) = Relative acceleration vector
$\dot{x}$ (t) = Relative velocity vector
x (t) = Relative displacement vector
$\ddot{x}$g (t) = Earthquake acceleration
h = Participation vector

For STMD System, properties of structure A and B structure given in below table:

Table 1: Building Properties

m_a = 90 tons	**$kt_2 = 2.592*10^5$ N/m**	**ω_b = Variable**
m_b = 90 tons	**$c_a = 1.02*10^5$ Ns/m**	**ωt_1 = 8.43 rad/sec**
m = 4.5 tons	**$c_b = 9.16*10^4$ Ns/m**	**ωt_2 = 4.22 rad/sec**
$k_a = 3.2*10^7$ N/m	**$ct_1 = 7.6*10^3$ Ns/m**	**f = 0 to 1**
k_b = Variable	**$ct_2 = 6.83*10^3$ Ns/m**	**β_a = 3 %**
$kt_1 = 3.2*10^5$ N/m	**ω_a = 18.86 rad/sec**	**ξt_1 = 10 %**

The peak displacement response for the system for different frequency ratio is found out using the MATLAB programming. Here the following time histories are used as excitation for system:

1. Modified El-Centro Earthquake Time History (1940).
2. Imperial Valley Earthquake Time History (1979).
3. Loma Prieta Earthquake Time History (1989).
4. Northridge Earthquake Time History (1994).

4. Result and Discussion

By comparing all the graphs for peak displacement results when STMD system is excited to different time histories that in range of 0.6 - 1 the displacement of the system is reduced to great extent. But when frequency ratio is between 0 - 0.6 the displacement is on higher side.

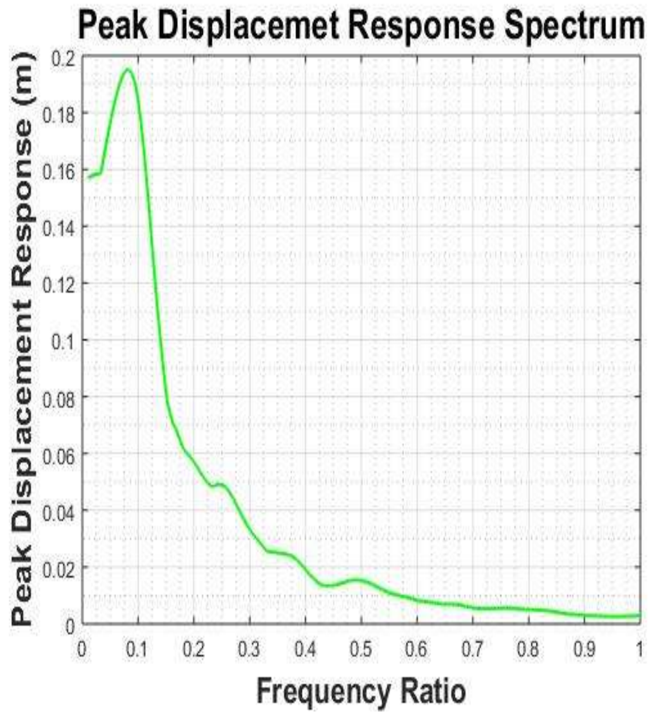


Chart 1: Peak Displacement Response for Modified El-Centro Earthquake time history

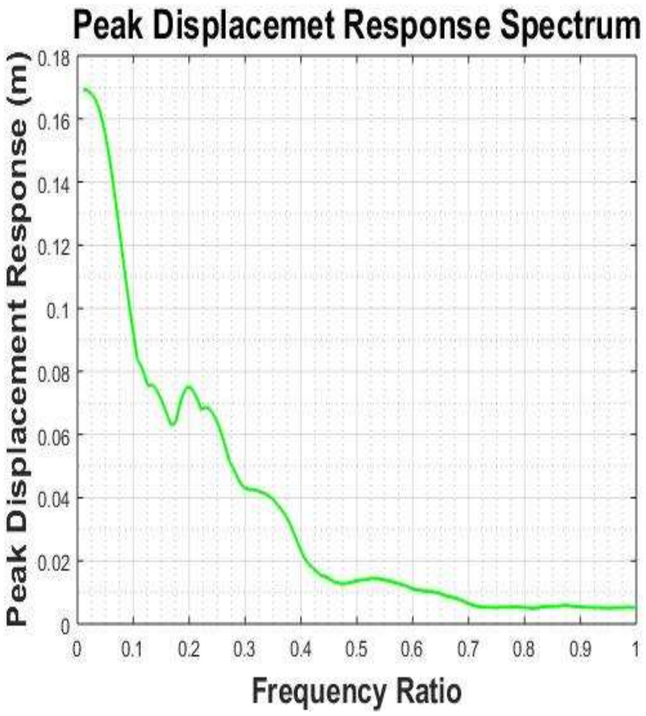


Chart 3: Peak Displacement Response for Loma Prieta Earthquake Time History

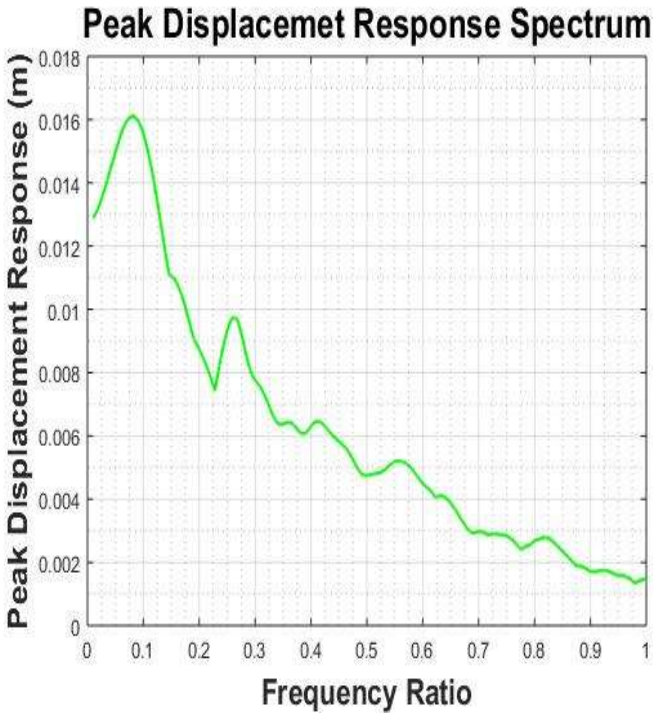


Chart 2: Peak Displacement Response for Imperial Valley Earthquake Time History

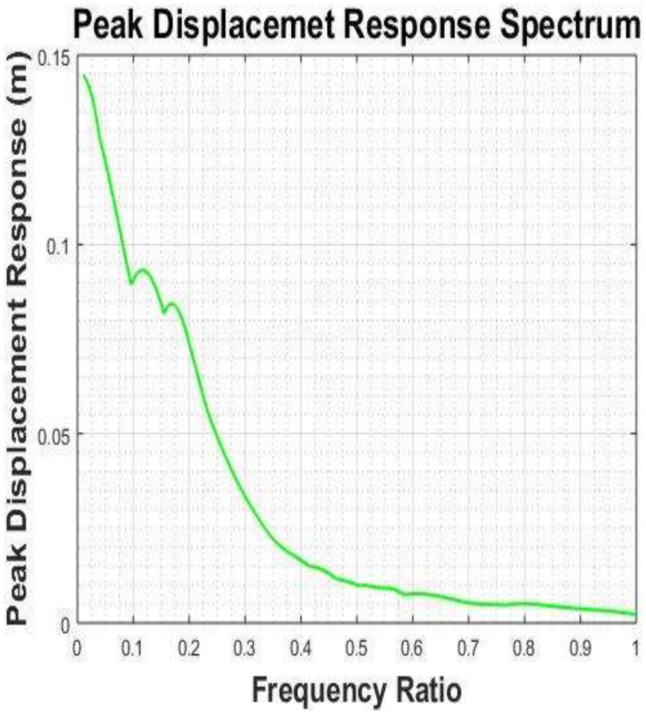


Chart 4: Peak Displacement Response for Northridge Earthquake Time History

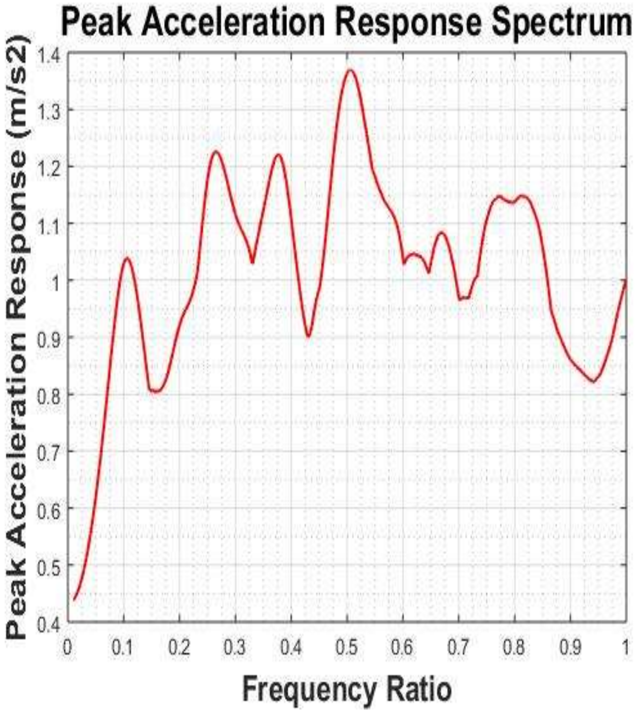


Chart 5: Peak Acceleration Response for Modified El-Centro Earthquake Time History

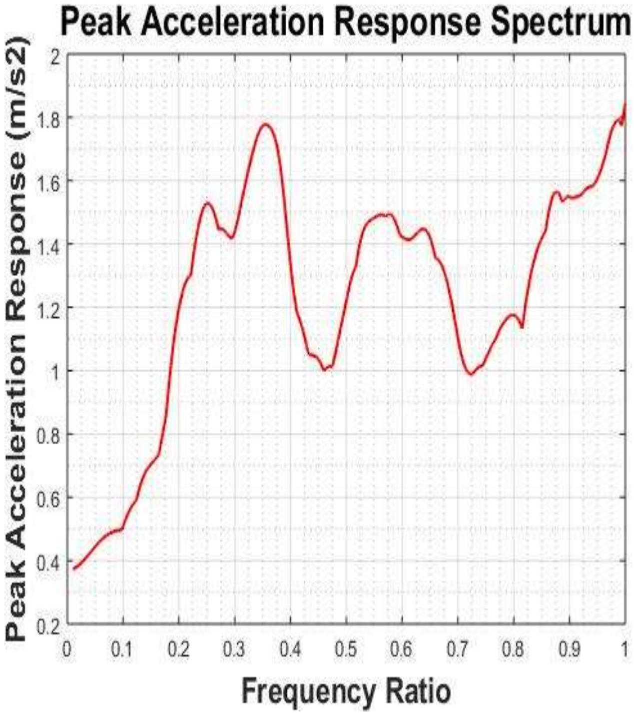


Chart 7: Peak Acceleration Response for Loma Prieta Earthquake Time History

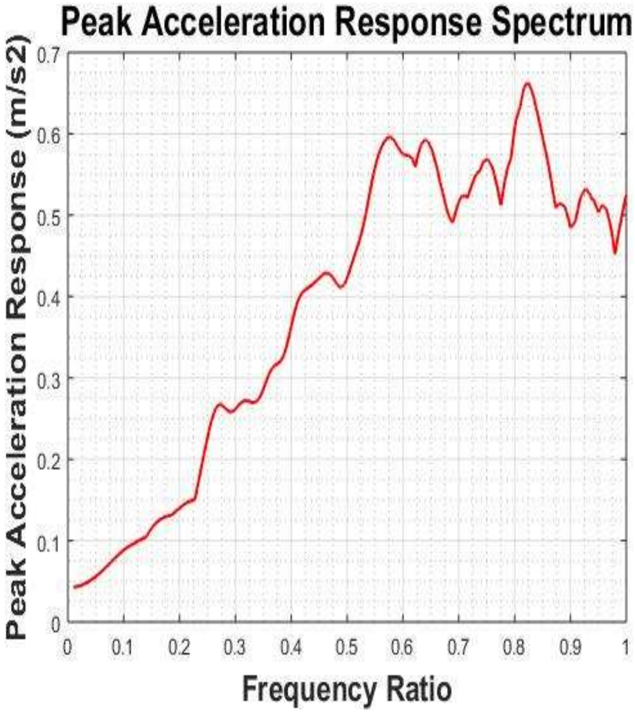


Chart 6: Peak Acceleration Response for Imperial Valley Earthquake Time History

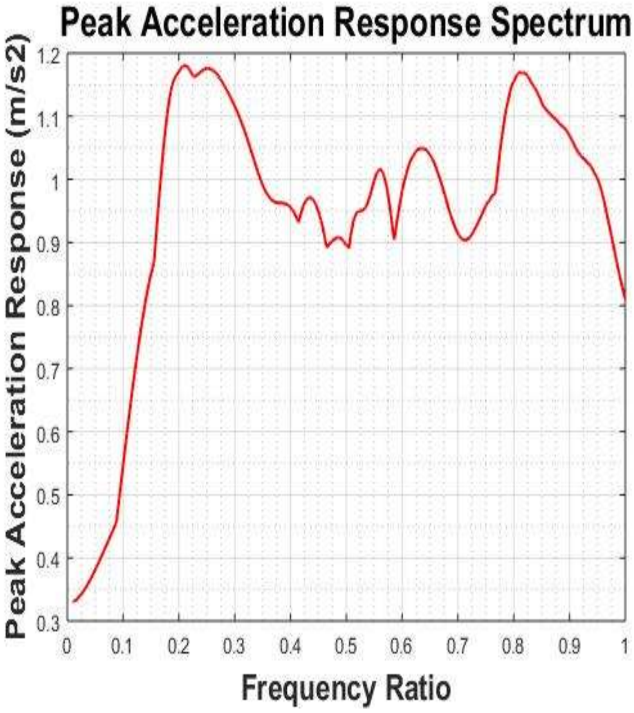


Chart 8: Peak Acceleration Response for Northridge Earthquake Time History

5. Conclusion

The purpose of the research was to find out the range of frequency ratio for two adjacent building for which we get minimum displacement response. We can see that there is a reduction in the Peak Structural Displacement Response for the structures when the frequency ratio is between 0.6 – 1. It need to be taken care that frequency ratio of the two buildings connected should not be in range of 0 – 0.2 can prove hazardous to the structure. It also shows how we can connect the two dynamically dissimilar building with the help of STMD and reduce the displacement response of the structures. It found difficult to conclude the behavior the Peak acceleration response of the system within the frequency domain. Moreover, STMD mechanism prevents the pounding of structure.

6. References

1) Ahsan Kareem and Samuel Kline (1995), "Performance of multiple mass dampers under random loading", Journal of structural engineering, 121(2): 348-361.

2) Fahim Sadek et al. (1997), "A method of estimating the parameters of tuned mass dampers for seismic applications", Earthquake engineering and structural dynamics, Vol.26.617-635.

3) Houshyar et al. (2018), "Wind-induced vibration control of super-tall buildings using a new combined structural system", Journal of Wind Engineering and Industrial Aerodynamics, Research Gate 172 (2018) 256-266.

4) John R. Sladek and Richard E. Klingner (1983),"Effect Of Tuned Mass Dampers on Seismic Response", Journal of Structural Engineering, Vol. 109, No. 8, ASCE, ISSN 0733- 9445/83/0008 2004.

5) Kwok KCS and Samali B. (1995), "Performance of tuned mass dampers under wind loads", Engineering Structures 17(9):655–667.

6) Makola M. Abdullah, Jameel H. Hanif, Andy Richardson and John Sobanjo (2001), "Use of a shared tuned mass damper (STMD) to reduce vibration and pounding in adjacent structures" Earthquake Engineering & Structural Dynamics, Wiley InterScience 30(8), 1185–1201.

7) M.H.Tso, J.Yuan, W.O.Wong (2013), "Design and experimental study of a hybrid vibration absorber for global vibration control", Engineering Structures 56 (2013) 1058–1069.

8) Nirav Zadafiya and Vishal Patel and Snehal Mevada (2019), "Vibration Control Using Shared Tuned Mass Damper for SDOF System", International Journal of Emerging Technologies and Innovative Research, Vol.6 (4) 283-288.

9) S.K. Rasouli and M. Yahyai (2002), "Control of response of structures with passive and active tuned mass damper" Structural Design of Tall Building, Wiley InterScience 11, 1–14.

10) S. Elias and V. Matsagar (2014), "Wind response control of 76-storey benchmark building with distributed multiple tuned mass dampers," Journal of Wind and Engineering, vol. 11, no. 2, pp. 37–49.

11) Said Elias and Vasant Matsagar (2017), "Research developments in vibration control of structures using passive tuned mass dampers" Annual review in control, Elsevier 44 (2017) 129-156.

12) Said Elias and Vasant Matsagar (2018), "Wind response control of tall buildings with a tuned mass damper" Journal of Building Engineering, Elsevier 15 (2018) 51-60.

13) T.T.Soong et al. (2015), "Vibration control performance of tuned mass dampers with resettable variable stiffness", Engineering Structures, Elsevier 83 (2015) 187-197.

14) Z.Guenidi et al. (2017), "Control of Adjacent Buildings Using Shared Tuned Mass Damper", Science Direct Procedia Engineering 199 (2017) 1568–1573.