

A Study on Earthquake Resistant Construction Techniques

Aman Kumar¹, Bhanu Pratap Singh², Keshav Kumar², Mayank Kumar², Mohit Kumar²

Assistant Professor, Department of Civil Engineering MIT, Moradabad, UP, India¹

Civil Engineering Student, MIT, Moradabad, UP, India²

ABSTRACT: This article gives a review on two global retrofitting techniques in the world; base isolation technique and Tuned Mass Damper, for manufacturing the buildings earthquake resistant. The properties of both structures are highlighted. The aim of retrofitting technique is to improve the lateral strength of the structure and increase the strength and ductility of structure. Earthquakes are one of the nature's most noteworthy hazards on our planet which have taken overwhelming toll on human life and property since ancient times. This design of structures depends on certain parameters like ductility, deformation capacity, strength and amount of deflection. This paper deals with the review of techniques applied in the design of earthquake resistant structures, which are- Base Isolation, Tuned Mass Damper. Principles and applications of these methods will be discussed under this study. This study will contribute to the conceptual data.

KEYWORDS: Earthquake, Earthquake Resistant structure, Base isolation, Tuned mass Damper.

I. INTRODUCTION

Earthquakes are one of the most destructive of natural hazards. Earthquake occurs due to sudden transient motion of the ground as a result of release of elastic energy in a matter of few seconds. The impact of the event is most traumatic because it affects large area, occurs all on a sudden and unpredictable. They can cause large loss of life and property and disrupts essential services such as water supply, transport etc. They do not destroy villages, town and cities but the aftermath leads to destabilize the economic and social structure of the nation. Earthquake is sudden rolling or shaking events caused by movement under the earth surface, resulting from the sudden release of energy in the earth's crust that creates seismic waves. Earthquakes are measured using observations from seismometers. Earthquake-resistant structures are those structures designed to withstand earthquakes. While no structure can be entirely immune to damage from earthquakes, the goal of earthquake resistant construction is to erect structures that fare better during seismic activity than their conventional counterparts. There are many techniques to resist earthquake, but they are costly & generally not used by normal people. In this article we will discuss four techniques via which we can construct earthquake resistant structure so that the structure and the building will face least effects when earthquake occurs. These are Base Isolation, Hollow Foundation, Tuned Mass Damper and Bands. Base isolation is a method in which a suspension is introduced between structure and the base. The structure above the ground, which is most affected during earthquake is separated from the effects of earthquake forces by introducing a mechanism that will help the structure to remain in the air. The concept of base isolation is quite easy to understand. It can be explained as a bird flying during an earthquake is not affected. In simple words if structure is floating on its base, the movement of ground will have no effect on the structure. Purpose of base isolation is to reduce the seismic demand instead of increasing the capacity. Controlling ground motion is impossible, but we can modify the demand on structure by preventing/reducing the motions being transferred to the structure from foundations. A tuned mass damper is a device mounted in structures to prevent discomfort, damage, or outright structural failure caused by vibration. They are used in high rise buildings to prevent failure of buildings during earthquakes. They are also known as an active mass damper (AMD) or harmonic absorber.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 4, April 2017

II. OBJECTIVES OF THE STUDY

This research is based on secondary data, and this is exploratory in nature. The main objective behind this study is to understand the basic concept of earthquake. Techniques of earthquake resistant construction will be identified by the researchers under this study. Our research is focused on two methods of constructing Earthquake Resistant buildings, Base Isolation Method and Tuned Mass Dampers. Their effects on the current day's scenario will be identified under the study.

III. LITERATURE REVIEW

Igusa and Xu (1994) examined the vibration control capability of multiple tuned mass dampers with natural frequency distributed over a certain frequency range for the structures subjected to wide band input. TMDs design was optimized by using calculus of variations with a constraint on the total mass. Results showed that the optimal designed multiple TMDs are more robust than a single TMD with equal total mass in vibration mitigation of main structure. **Hartog, D (1940)** developed analytical model for vibration control capabilities of TMDs. Later he optimized TMDs parameter for harmonic excitations as well as wide band input. The main drawback of a single TMD is its sensitivity of the effectiveness to the error in the natural frequency of the structure and the damping ratio of the tuned mass damper. The effectiveness of a tuned mass damper is reduced significantly by mistuning. As a result of more than one TMD with different dynamic characteristics has been proposed to improve the effectiveness. **Clark (1988)** studied the methodology for designing multiple tuned mass dampers for reducing building response. The method used was based on extending Den Hartog work from a single degree of freedom to multiple degrees of freedom system. A significant motion reduction was achieved for a structure by using simplified linear mathematical models and design technique under 1940 El Centro earthquake excitation. **Devi, S (2006)** Planning and Displacements in isolated structures are often large and attempts are made to add energy scattered or damping in the isolation method to reduce movements. The addition of damping to the isolation systems serves to reduce displacements in the seismic isolators. The entire superstructure is to be supported on discrete isolators whose dynamic properties are chosen to separate the ground motion. **Joshi and Jangid (1997)** in their research inspected the efficiency of optimally planned multiple tuned mass dampers (MTMD) for sinking the dynamic response of a base excited structure in a particular mode of vibration. The base excitation was modelled as a stationary white noise random process. The parameters like damping ratio, the tuning frequency ratio and the frequency bandwidth of the MTMD system were optimized based on the minimization of the root mean square (r.m.s.) displacement of the main structure. The stationary response of the structure with MTMD was analysed for the optimum parameters of the MTMD system. It was concluded that the optimally designed MTMD system is more effective for vibration control than the single tuned mass damper for same mass ratio, damping of the main system does not have any influence on the optimum damping ratio of both the single TMD and the MTMD system, number of TMDs also does not have much influence on the optimum tuning frequency and the corresponding effectiveness of the MTMD system. **Jangid (1999)** in his research examined the optimum parameters of Multiple Tuned Mass Dampers (MTMD) for an undamped system under harmonic base excitation using a numerical searching technique. The criteria used for the optimality was the minimization of steady-state displacement response of the main system. Curve fitting technique was used to find the formulae for the optimum parameters of MTMD (i.e. damping ratio, bandwidth and tuning frequency) which can further be used for engineering applications. The optimum parameters of the MTMD system were calculated for different mass ratios and number of dampers. From numerical study it was concluded that the optimum damping ratio of MTMD system decreases with the increase of the number of MTMD and increases with the increase of mass ratio, optimum band-width of the MTMD system increases with the increase of both the mass and number of MTMD and optimum tuning frequency increases with the increase of the number of MTMD and decreases with the increases of the mass ratio. **Christoph Adam et al. (2010)** Earthquake excited vibration prone structures are modeled as elastic single-degree-of-freedom oscillators and they are equipped with a single TMD. The TMD performance is assessed by means of response reduction coefficients, which are generated from the ratio of the structural response with and without TMD attached. It is found that TMDs are effective in reducing the dynamic response of seismic excited structures with light structural damping. The studies are based on a set of 40 recorded ordinary ground motions. The results presented that the application of Tuned Mass Dampers (TMDs) with mass ratios between 2% and 8% is an appropriate measure to mitigate the dynamic response of structures

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 4, April 2017

subjected to ordinary seismic ground motions. It applies both for stiff and soft structures. The seismic effectiveness of an optimally tuned TMD decreases with increasing initial structural damping of the vibrating structure. The optimal tuning of the TMD parameters under the assumption of white noise base acceleration is sufficiently accurate. The seismic performance of the TMD is robust against mistuning of the viscous element in the TMD. The accurate tuning of the TMD natural frequency is essential for its effectiveness.

IV. EARTHQUAKE RESISTANT STRUCTURE

A. BASE ISOLATION METHOD

Mazza. F and Vulcano. A (2004) explained that the base-isolation techniques prove to be very effective for the seismic protection of new framed buildings as well as for the seismic retrofitting of existing ones. Design guidelines have been developed in many countries with a high seismic hazard (e.g., United States, Japan, NewZealand) and, lately, suitable code provisions have been drafted also in Europe (Eurocode 8). However, under near-fault ground motions, even base-isolated structures designed according to recent seismic codes can undergo unforeseen structural damages. The objective behind this study is that the response of the structure is modified such that the ground below is capable of moving without transmitting minimum or no motion to the structure above. A complete separation is possible only in an ideal system. In a real world, it is necessary to have a vertical support to transfer the vertical loads to the base. Maximum acceleration and displacements are a function of earthquake for periods between zero to infinity. During earthquakes there will be a range of periods at which acceleration in the building will be increased beyond maximum ground acceleration, though relative displacements may not exceed peak ground displacements. **Base isolation** is the ideal method to fulfill this, by reducing the transfer of motion; the displacement of building is controlled. A house which is designed with the help of the technique Base Isolation, which helps to protect the building from the after effects of earthquake (following image is designed in Solid Works software, with elastomers rubber bearings). This house will get least affected by the earthquake because suspension is provided between the structure and its foundation. The main features of this method are: This method reduced the seismic demand of structure, thereby reducing the cost of structure. This method helps in lesser displacements during an earthquake. It improves the safety of Structures. It helps in reducing the damages caused during an earthquake. This helps in maintaining the performance of structure after event. It helps in enhancing the performance of structure under seismic loads. Preservation of property is another feature of base isolation method.

Principle Of Base Isolation Method

According to T. Subramani Themain, the purpose of base isolation technique is to transform the reaction of the building so that the ground shakes below the building without passing the motions to the building. When the ground shakes the acceleration induced in the structure must equalize to the ground acceleration and there should be a zero relative displacement between the structure and the ground. The main aim of this method is to increase lateral strength of the structure and to increase ductility of structure. This method is mainly found to be efficient for seismic protection of historical buildings where superstructure has a limited seismic resistance and main focus is required only at foundation level. By providing base isolation system the building must be able to move at least 100mm relative to ground. For basements install the isolators at the top, bottom or mid-height of basement columns and walls.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 4, April 2017

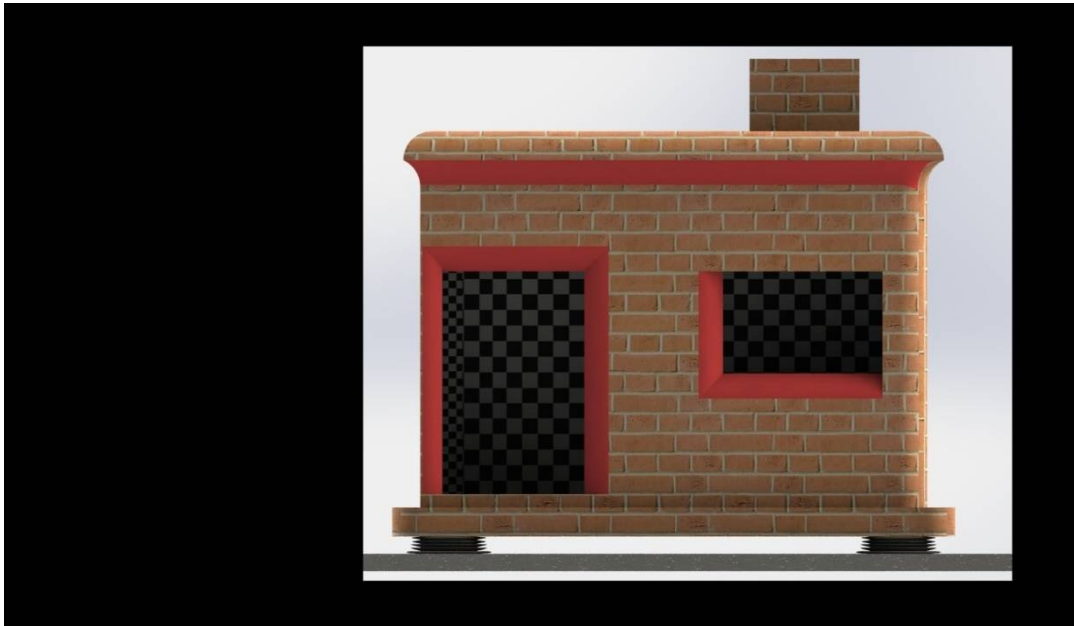


Figure -1,

(A house which is designed with Base Isolation method, which is help to protect the building by the affect of earthquake .This image is designed in Solid Works software , elastomers rubber bearings)

Base isolation is one of the most widely accepted global retrofitting techniques in earthquake prone areas. Seismic isolation or base isolation is a unique approach, which uncouples the structure for the damaging effect of the ground motion. The other purpose of an isolation system is to provide an additional means of energy dissipation. The isolators permit the building to act more flexibly which improves its response to an earthquake. It is a powerful and relatively cheaper method of seismic restoration of building. There are several retrofitting technique to make the structure safe against the earthquake force such as adding bracings, wing wall buttresses, shear wall, base isolation etc. In Current scenario the base isolation technique is used all around the world. It gives better protection against earthquake by decrement in shear. The superstructure needs no reinforcement and least temporary work is required. Base isolation is not suitable for all the buildings. According to IS:4326-1993 base isolation is suitable for low to medium rise buildings rested on hard soil underneath. Buildings rested on soft soils are not suitable for base isolation. **Base isolation** is of four types which are as follows:

a) Elastomeric Rubber Bearings

Bearings formed of horizontal layers of synthetic or natural rubber in thin layers bound between steel plates. These bearings are capable of supporting high vertical loads with very small deformations. These bearings are flexible under lateral loads. Steel plates prevent the rubber layers from bulging. Lead cores are provided to increase damping capacity as plain elastomeric bearings does not provide significant damping. They are usually soft in horizontal direction and hard in vertical direction

b) Roller and Ball Bearings

For isolation applications in machinery isolation, roller and ball bearing are used. It includes cylindrical rollers and balls. It is sufficient to resist service movements and damping depending on the material used.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 4, April 2017

c) Springs

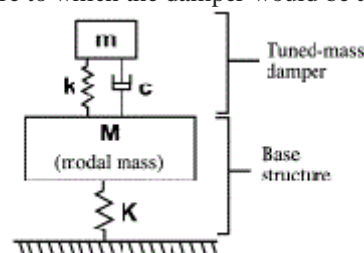
Steel springs are most likely used in mechanical applications as in roller bearings. It is not adopted in structural applications because it is flexible in both vertical and horizontal directions. This will increase service deflections.

d) Sliding Bearing

Sliding systems with a predefined coefficient of friction can provide base isolation by limiting acceleration and forces that are transferred. Sliders are capable of providing resistance under service Flexibility and Damping are the two major components of base isolation system. Flexibility of the isolation has predominant effect in response modification. Viscous dampers or Hysteretic dampers are often provided to enhance isolation. Response reduction using dampers is independent of the structure stiffness conditions, flexibility and force-displacements by sliding movement. Shaped or spherical sliders are often preferred over flat sliding systems because of their restoring effect. Flat sliders provide no restoring force and there are possibilities of displacement with aftershocks.

B. TUNED MASS DAMPERS METHOD

A tuned mass damper is a device mounted in structures to prevent discomfort, damage, or outright structural failure caused by vibration. They are used in high rise buildings to prevent failure of buildings during earthquakes. They are also known as an active mass damper (AMD) or harmonic absorber. A **tuned mass damper (TMD)** consists of a mass (m), a spring (k), and a damping device (c), which dissipates the energy created by the motion of the mass (usually in a form of heat). In this figure, M is the structure to which the damper would be attached.



(Figure- 2) TMD and Structure

From the laws of physics, we know that $F = ma$ and $a = F/m$. This means that when an external force is applied to a system, such as wind pushing on a skyscraper, there has to be acceleration. Consequently, the people in the skyscraper would feel this acceleration. In order to make the occupants of the building feel more comfortable, tuned mass dampers are placed in structures where the horizontal deflections from the wind's force are felt the greatest, effectively making the building stand relatively still. When the building begins to oscillate or sway, it sets the TMD into motion by means of the spring and, when the building is forced right, the TMD simultaneously forces it to the left. Ideally, the frequencies and amplitudes of the TMD and the structure should nearly match so that EVERY time the wind pushes the building, the TMD creates an equal and opposite push on the building, keeping its horizontal displacement at or near zero. If their frequencies were significantly different, the TMD would create pushes that were out of sync with the pushes from the wind, and the building's motion would still be uncomfortable for the occupants. If their amplitudes were significantly different, the TMD would, for example, create pushes that were in sync with the pushes from the wind but not quite the same size and the building would still experience too much motion. The effectiveness of a TMD is dependent on the mass ratio (of the TMD to the structure itself), the ratio of the frequency of the TMD to the frequency of the structure (which is ideally equal to one), and the damping ratio of the TMD (how well the damping device dissipates energy). Wide span structures (bridges, spectator stands, large stairs, stadium roofs) as well as slender tall structures (chimneys, high rises) tend to be easily excited to high vibration amplitudes in one of their basic mode shapes, for example by wind or marching and jumping people. Low natural frequencies are typical for this type of structures, due to their dimensions, as is their low damping. With GERB Tuned Mass Dampers (TMD), these vibrations can be reduced very effectively.

International Journal of Innovative Research in Science, Engineering and Technology

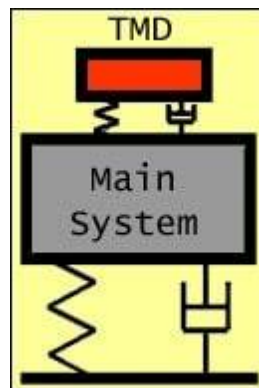
(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 4, April 2017

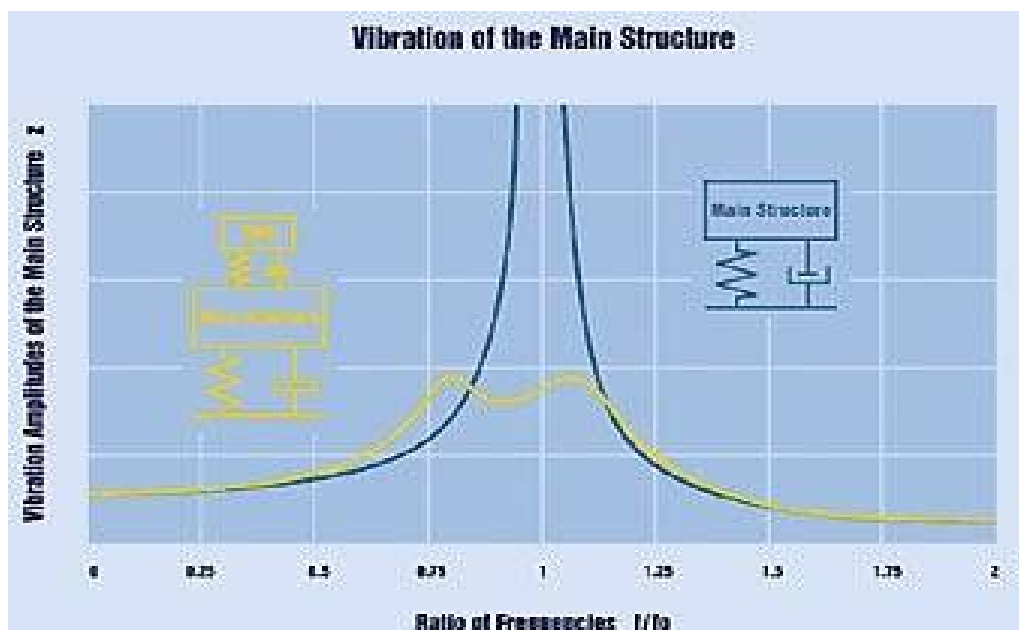
The Tuned Mass Damper may consist of:

- Spring
- Oscillating Mass
- Viscodamper



(Figure -3, Tuned Mass Damper)

It may be designed as a pendulum, also in combination with a Viscodamper. Each TMD is tuned exactly to the structure and a certain natural frequency of it. Such TMD have been designed and built with an oscillating mass of 40 to 10.000 kg (90 to 22.000 lbs) and natural frequencies from 0.3 to 30 Hz. Vertical TMD are typically a combination of coil springs and Viscodampers, while in case of horizontal and torsional excitation in the corresponding horizontal TMD the coil springs are replaced by leaf springs or pendulum suspensions.



(Figure-4, Amplitude – Frequency response of a low damped system without (blue) and with (yellow) tuned mass damper)

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 4, April 2017

Tuned mass dampers are mainly used in the following applications:

- Tall and slender free-standing structures (bridges, pylons of bridges, chimneys, TV towers) which tend to be excited dangerously in one of their mode shapes by wind,
- Stairs, spectator stands, pedestrian bridges excited by marching or jumping people. These vibrations are usually not dangerous for the structure itself, but may become very unpleasant for the people,
- Steel structures like factory floors excited in one of their natural frequencies by machines, such as screens, centrifuges, fans etc.,
- Ships excited in one of their natural frequencies by the main engines or even by ship motion.

Tuned Mass Dampers may be already part of the structure's original design or may be designed and installed later.

Tuned Mass damper A large mass or a large space is needed for their installation. The effectiveness of a tuned mass dampers considered constrained by the maximum weight that can be practically placed on top of the structure, plastic deformation of the spring, exceeding the limit of deformation.

Passive Control Devices

A passive control device is a device that develops forces at the location of the device by utilizing the motion of the structure. Through the forces developed, a passive control device reduces the energy dissipation demand on the structure by absorbing some of the input energy (Soong and Dargush 1997). Thus, a passive control device cannot add energy to the structural system. Furthermore, a passive control device does not require an external power supply. Examples of passive devices include base isolation, tuned mass dampers (TMD), tuned liquid dampers (TLD), metallic yield dampers, viscous fluid dampers and friction dampers.

Active Control Devices

The active control systems frameworks are the inverse side of latent frameworks, since they can give extra vitality to the controlled structure and inverse to that conveyed by the dynamic stacking (Soong 1990). Dynamic control device require extensive measure of outer energy to work actuators that supply a control compel to the structure. A dynamic control system can quantify and gauge the reaction over the whole structure to decide fitting control powers. Thus, dynamic control devices are more mind boggling than detached methodologies, requiring sensors and evaluator/controller types of gear. Cost and upkeep of such frameworks are additionally essentially higher than that of latent gadgets (Soong and Spencer 2002). Cases among dynamic control gadgets incorporate dynamic tuned mass damper, dynamic tuned fluid segment damper and dynamic variable solidness damper..

V. CONCLUSION

With the assistance of above dialog we can finish up here by saying that the Base isolation system is the best worldwide retrofitting procedure as it is a savvy strategy than other retrofitting methods. Base isolation gives the best compositional effect and has a superior seismic execution among the other worldwide retrofitting systems. It spares a noteworthy measure of obliteration and its upkeep cost is likewise less. The accomplishment of this strategy is to a great extent relies on advancement of segregation gadgets and legitimate. Then again it has been seen in all the refereed literary works that TMD's are compelling in lessening vibrations. It can likewise be successful in decreasing building vibrations Multiple Tuned Mass Dampers are more powerful than single Tuned Mass Dampers. Programming examination is superior to test investigation. Programming examination is efficient, lessen human exertion and it contains assortments of investigation strategies Model with shear divider and models with TMD at different areas has been made for breaking down horizontal opposing power. TMD is best for gently damped structure, and its viability diminishes as with increment in auxiliary damping. TMD is more powerful for long term seismic tremor ground movements. TMD is best when the basic recurrence is near the focal recurrence of ground movement. TMD is sensibly viable for expansive grouped movements over the range of basic frequencies. Be that as it may, TMD is likewise viable for limited grouped movements, if the structure and ground movement frequencies are near each other. Adequacy and ideal parameters of TMD does not get influenced with expanding crest ground increasing speed values, keeping every single other parameter steady.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 4, April 2017

REFERENCES

1. Dr. Mohan M. Murudi, Mr. Sharadchandra M. Mane (2004) "Seismic Effectiveness Of Tuned Mass Damper (Tmd) For Different Ground Motion Parameters" 13th World Conference on Earthquake Engineering Vancouver, B.C., Canada August 1-6, 2004 Paper No. 2325.
2. Fahim Sadek, Bijan Mohraz, Andrew W. Taylor and Riley M. Chang (1997), "A Method of Estimating the Parameters of Tuned Mass Dampers for Seismic Applications", Journal of Earthquake Engineering and Structural Dynamics, Vol.26, pp 617- 635.
3. John R. Sladek and Richard E. Klingner(1982), "Effect of Tuned Mass Dampers on Seismic Response", Journal of the Structural Division, Vol.109, pp 2004-2009.
4. K.Krishne Gowda and K.K.Kiran, Earthquake resistance of structure using dampers- a review, International journal of advanced structures and geotechnical engineering ISSN 2319-5347, vol.02, No. 01 january 2013.
5. Mazza F, Vulcano A. "Seismic response of buildings with isolation & supplemental dissipation at the base." Proceedings of the 5th World Congress on Joints, Bearings and Seismic Systems for Concrete Structures, Rome, Italy, 2001, CD-ROM.
6. Savita Devi, Satyam Mehta, Harshit joshi, Shubham Natani, Review paper on base isolation method- the best retrofitting technique, SSRG International Journal of Civil Engineering (SSRG-IJCE), www.internationaljournalssrg.org page 274, ISSN 2348-8352, vol. 03 issue 05-may 2016.

Websites:

7. Theconstructor.org/structure-engg/tunedmassdamper.(Figure – 2,3,4)
8. www.civildigital.com/baseisolation.
9. www.engineeringcivil.org