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Subject: Introduction to Earthquake Engineering

Assignment: 2

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Check by:

Write a detail note on the following

1. **Tuned Mass Dampers**

A tuned mass damper (TMD) is a vibrating mass that moves out of phase with the motion of the structure it is suspended to. With it's out of phase motion, the inertial force of the TMD mass abates the resonant vibration of the structure by dissipating its energy. The ideal extent of phase difference between the motion of the TMD mass and that of the structure, i.e., 90 degrees, is attained by tuning the TMD to the natural frequency of the structural mode targeted for damping.

Tuned mass dampers have been used for adding tuned damping to various structures, successfully. Considering that the first vibrational mode of a structure plays a dominant role in its dynamic response, a TMD is normally (but not always) tuned to the first natural frequency of the structure. The energy dissipation effectiveness of a TMD depends on a) the accuracy of its tuning, b) the size of its mass compared to the modal mass of its target mode, i.e., its mass ratio, and c) the extent of internal damping built into the tuned mass damper.

The make-up of a tuned mass damper consists of an inertia element (a mass) and a suspension mechanism comprised of restoring and dissipative elements. The most commonly used suspension mechanism in TMDs is the parallel combination of coil springs and viscous dampers, but they can also be realized using other suspension mechanisms such as air, viscoelastic and pendulum. TMDs are variations of the more general tuned absorbers/dampers commonly used in treating narrow-band noise and vibration issues. A

The schematic of a translational and a pendulum tuned mass dampers (the red, 2nd order systems) appended to a vibrating structure (resembled by the black, 2nd order system M1-K1-C1) is shown in Figure 1.

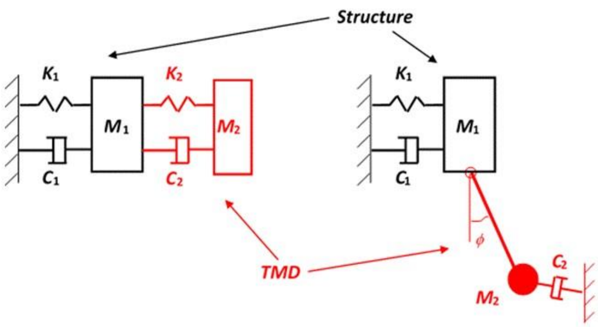

Figure 1

The schematic of tuned mass dampers installed on a structure

Tuned Mass Dampers (TMDs) are tuned by setting their natural frequencies substantially equal to the resonant frequencies of the structure targeted for damping.

Configuration of Tuned Mass Dampers

Tuned mass dampers (TMDs) come in various configurations. The commonality between all of them is their make-up which includes an inertia element (mass) suspended by a parallel combination of an energy dissipating (damping) device and a restoring mechanism.

Restoring Mechanism

In tuned mass dampers operating in vertical direction coil springs either by themselves as shown in Figure 2-a or in configuration with a horizontal pendulum act as the restoring mechanism.

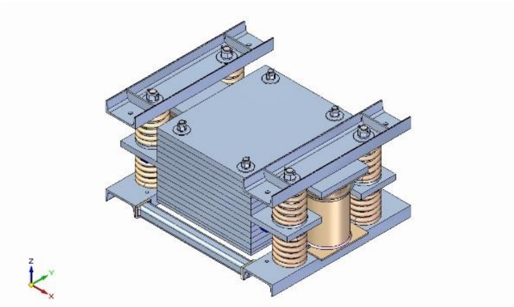

Figure 2-a A vertical tuned mass damper

Figure 2-b shows a tuned mass damper with the latter restoring mechanism, used for adding tuned damping to a piping system.

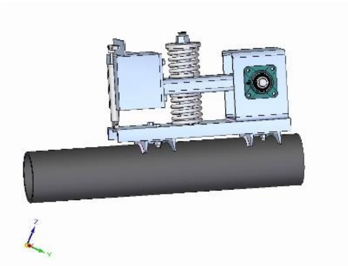

Figure 2-b A horizontal pendulum tuned mass damper

In lateral tuned mass dampers (TMDs operating in horizontal direction) leaf springs, vertical pendulums either by themselves or in conjunctions with coil springs are used as the restoring elements. Figure 2-c shows a lateral TMD using leaf springs as the restoring elements.

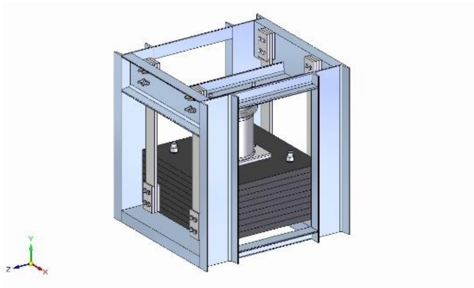

Figure 2-c a lateral tuned mass damper

if the required height of a lateral TMD associated with the above listed restoring mechanisms cannot be accommodated, the weight of the inertia element (mass) is supported by a set of linear guides and resilience is provided by compression coil springs.

In lateral tuned mass dampers operating in more than one direction, steel wire-rope suspended pendulum is commonly used as the restoring mechanism. The length of the steel wire-rope normally sets the tuning frequency of such tuned mass dampers. These TMDs are commonly used in quieting the lateral vibration of tall structures such as high rises, towers, and exhaust stacks. Figure 2-d shows a multi-directional lateral tuned mass damper using steel wire ropes as the restoring elements.

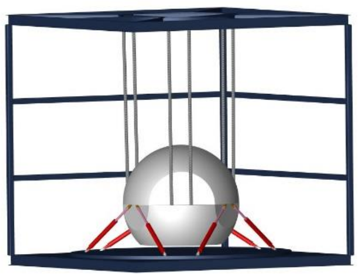

Figure 2-d a pendulum tuned mass damper

Damping Mechanisms of Tuned Mass Dampers

Viscous damping are commonly used as the energy dissipation mechanism in TMDs. Such damping, which is either provided by 'laminar flow viscous damping units' (dashpots) utilizing a high viscosity damping fluid or 'turbulent flow viscous dampers' using a low viscosity damping fluid. The latter type is somewhat similar in make up to shock absorbers in automobile suspensions.

Dashpots do not have temperature compensation mechanism built into their make-up. But the use of proper damping fluid as well as the novel design of the TMDs using dashpots as their energy dissipation devices, enable such tuned mass dampers to maintain their effectiveness when subject to large temperature variations. The advantages of dashpots are a) their simple design and being maintenance-free, and b) being multi-directional.

Turbulent Flow Viscous Damping Units are similar in make up to shock absorbers on an automobile suspension system. Shock absorber type viscous dampers are one-directional. Moreover, they require periodic maintenance mainly in terms of replacing their seals which could leak after so many cycles of oscillation. The advantages of this type of damping devices are a) the temperature compensation mechanism built into their make-up, enabling them to be less sensitive to variation in temperature, and b) being able to provide long strokes.

Sizing Tuned Mass Dampers

Tuned mass dampers are sized so that a) their inertia/mass is large enough to ensure their effectiveness, b) their resilience in conjunction with their inertia/mass realizes the desired tuning frequency, and c) optimal amount of energy dissipation capability (internal damping) is built into them so that they effectively damp the vibration of their target modes.

The frequency response functions of an underdamped structure without and with two different tuned mass dampers are shown in Figure 3. One TMD has a small and the other has a large mass ratio. The optimal value of damping ratio in the smaller TMD is in excess of 3 times less than the larger TMD.
Clear from Figure 3, increase in the mass ratio (and the corresponding damping ratio) of a TMD increases the energy dissipation (damping) effectiveness as well as the bandwidth of that TMD. Moreover, it lowers the TMD excursion (the motion of the TMD mass relative to the structure).

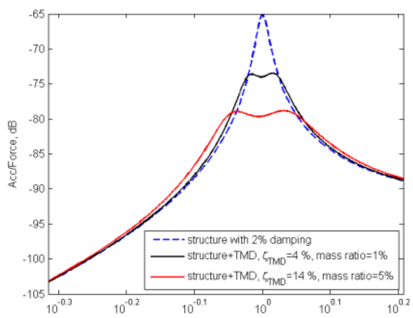

Figure 3 Frequency response functions of a structure without and with a small TMD and a large TMD

When a structure cannot either take the weight of or accommodate an optimally sized tuned mass damper and/or more than one vibration mode of which are in need of damping, then an active tuned mass damper (ATMD) is a more suitable choice.

2. **Base Isolation**

Base isolation is simply defined as decoupling or separating the structure from its foundation. In layman terms, base isolation can be understood by comparing it to suspension system used in automobiles.

Advantages of Base Isolation

- **Apart from protecting structures from seismic activities, base isolation also protects them from GSA blast loads as the ability to move reduces the overall impact of the blast on the structures.**
- **Base isolated structures are predictable, hence reliability of them is very high as compared to conventional structural components.**
- **Need of strengthening measures such as frames, bracing and shear walls in cut down by reducing the earthquake forces transmitted to the building.**
- **Simplification of seismic analysis as compared to the conventional structures by allowing reduction in structural elements.**
- **In case of large unexpected seismic activities, damage is only concentrated in isolation system, where elements can be easily substituted.**
- **Base isolation can also be retrofitted to suitable existing structures. Moreover, the building can remain serviceable throughout the construction.**

Disadvantages of Base Isolation

- **Base isolation can’t be done on every structure, for example: it is not suitable for structures resting on soft soils.**
- **Becomes less efficient for high rise buildings.**
- **Unlike other retrofitting base isolation cannot be applied partially to the structure.**
- **Implementation is efficient manner is difficult and often requires highly skilled labours and engineers.**