Earthquake Project Overview
(Structures Project)

RET Summer Program 2009

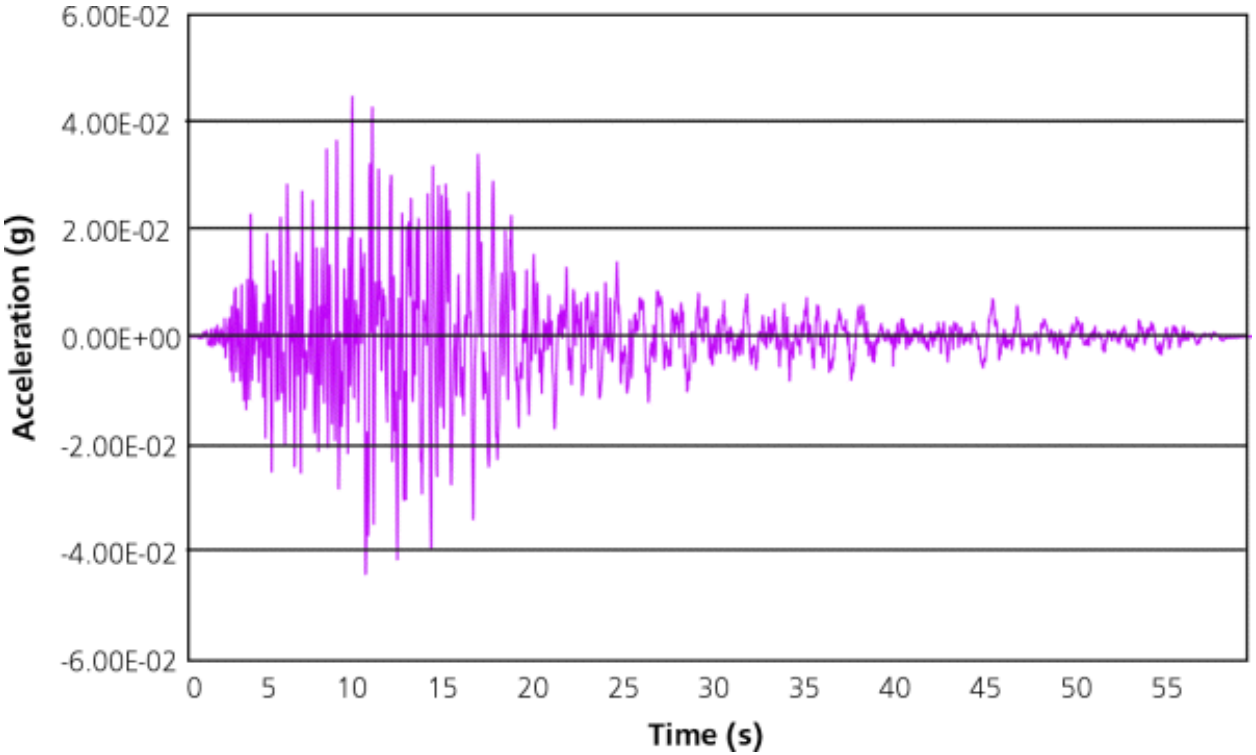
College of Engineering

University of Cincinnati

Overview

- Earthquakes
  - Northridge
  - Kobe
- Natural System Response
  - Natural Frequency
  - Damping Coefficient
- Control Methods to Reduce Vibrations
  - Base Isolation
  - Mass Dampers
- Lab Experiments
  - Small Structures Lab
    - Base Isolation
    - Passive Mass Damping
  - Intelligent Systems Aerospace Lab
    - Recreate Earthquake Vibrations
    - Active Mass Damping

An earthquake is the result of a sudden release of energy in the Earth's crust that creates seismic waves.



The 1994 Northridge earthquake acceleration time-history data recorded at the Fremont school site, California Division of Mines and Geology (CDMG) station 24461, in Alhambra and processed by Pacific Engineering.

Northridge, CA Earthquake

Northridge, CA Earthquake

The magnitude 6.7 Northridge earthquake occurred at 4:31 in the morning of January 17, 1994 on a national holiday when most Californians were at home asleep. Fifty - seven people lost their lives, nearly 9,000 were injured, and damage exceeded $20 billion.

Kobe, Japan Earthquake

- In January 18, 1995 an earthquake with a local magnitude of 7.2 struck close to Kobe, Japan.
- The quake was particularly damaging to the city because its focus was shallow -- less than 20 km below the surface -- and lasted about 20 seconds.
- Although the quake destroyed tens of thousands of buildings, many of the structures built since 1981 were generally undamaged.

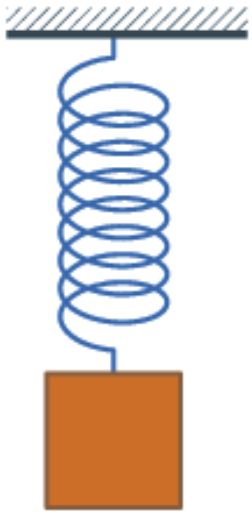
System Response

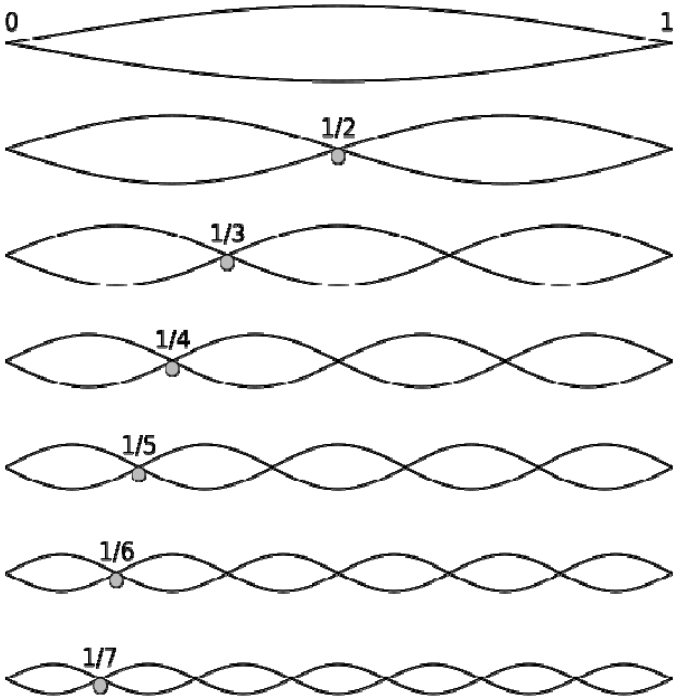
- <u>Natural Frequency:</u>

  The frequency at which a system naturally vibrates once it has been set into motion.

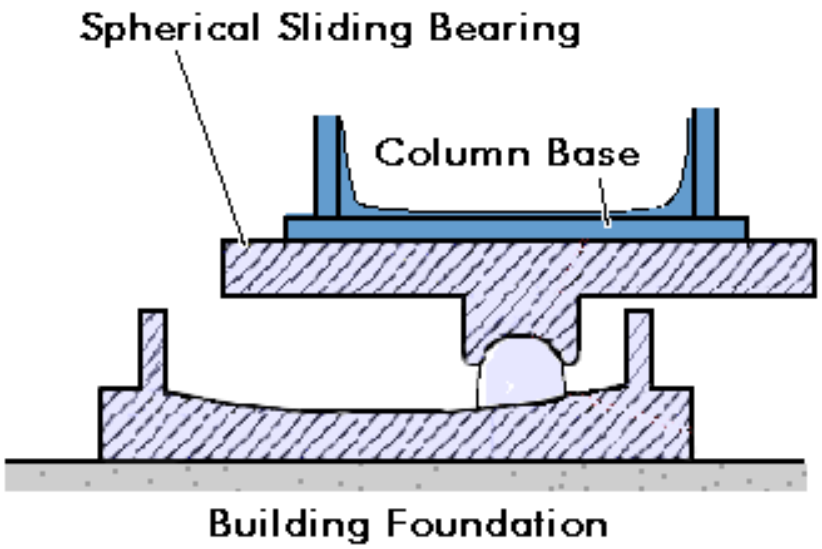
- <u>Damping Coefficient:</u>

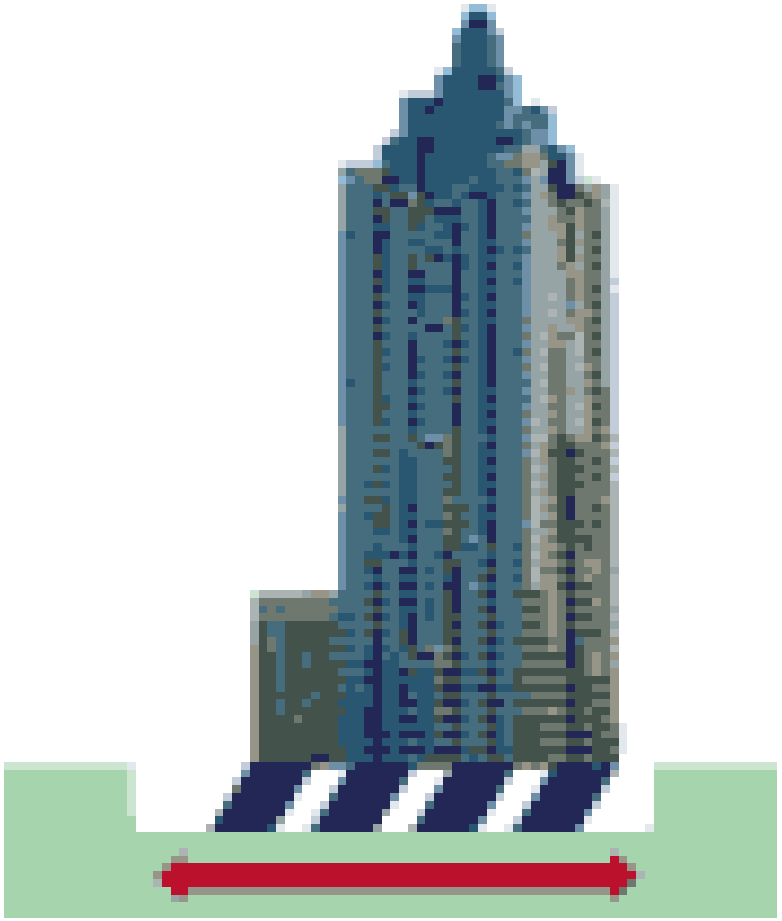
  The measure of describing how oscillations in a system die down after a disturbance.



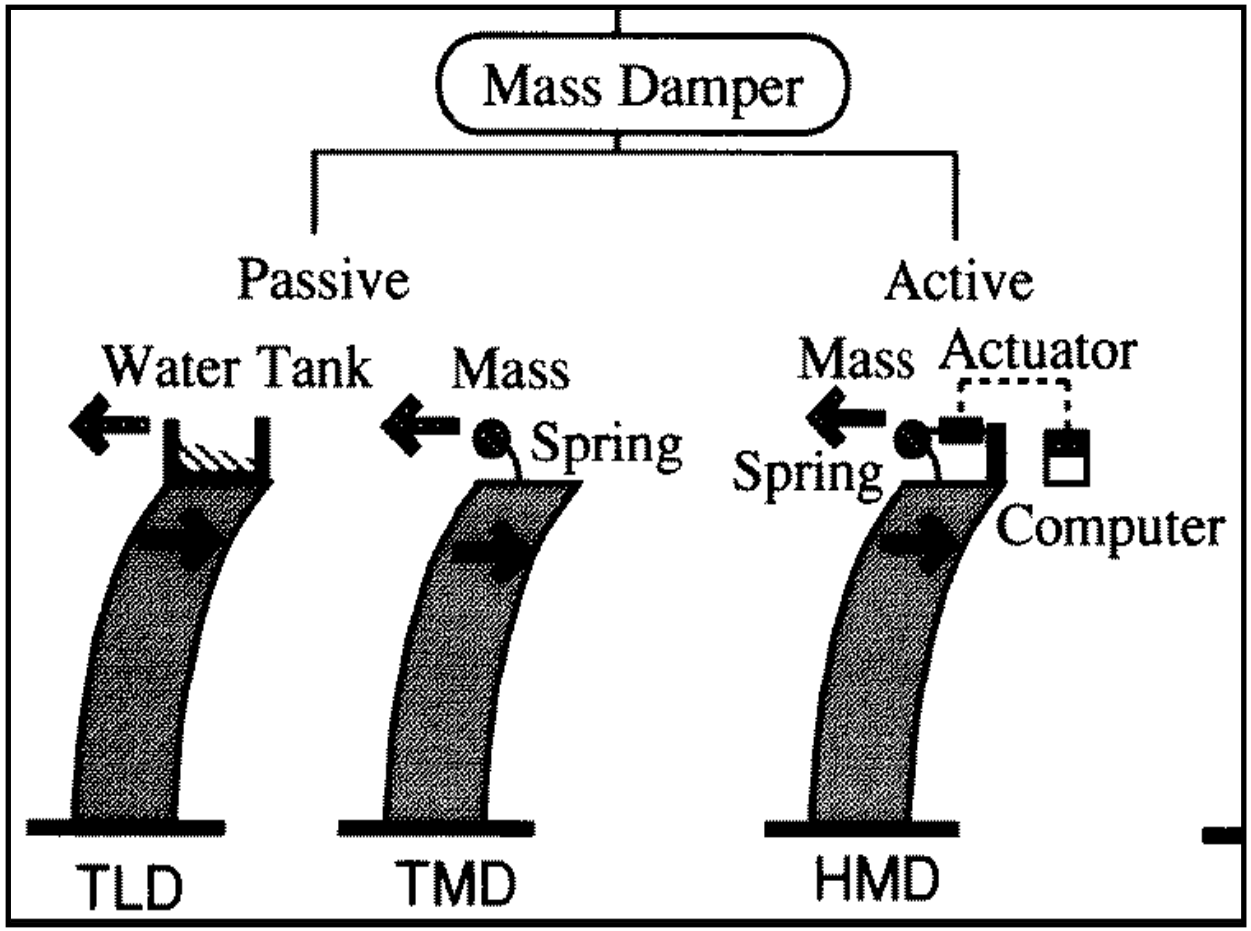


Damping by Base Isolation





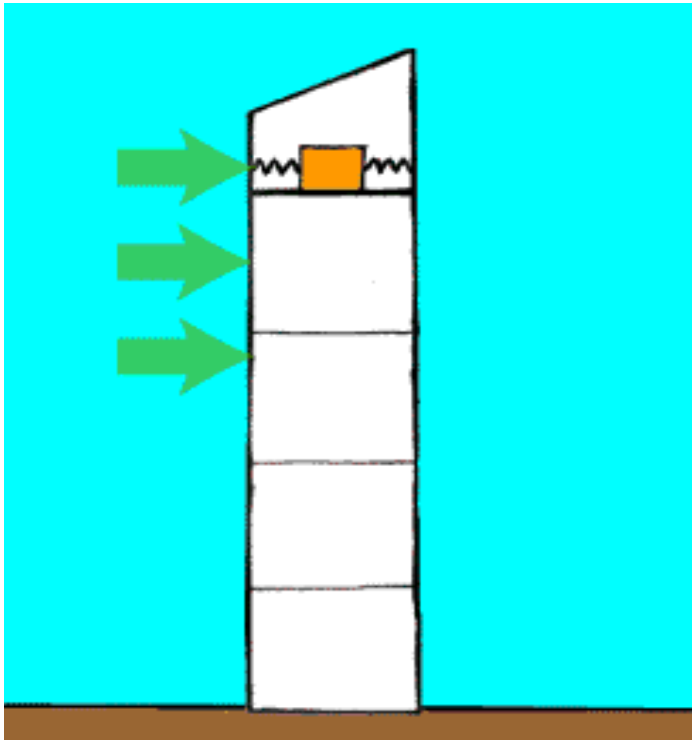
Active/Passive Vibration Control

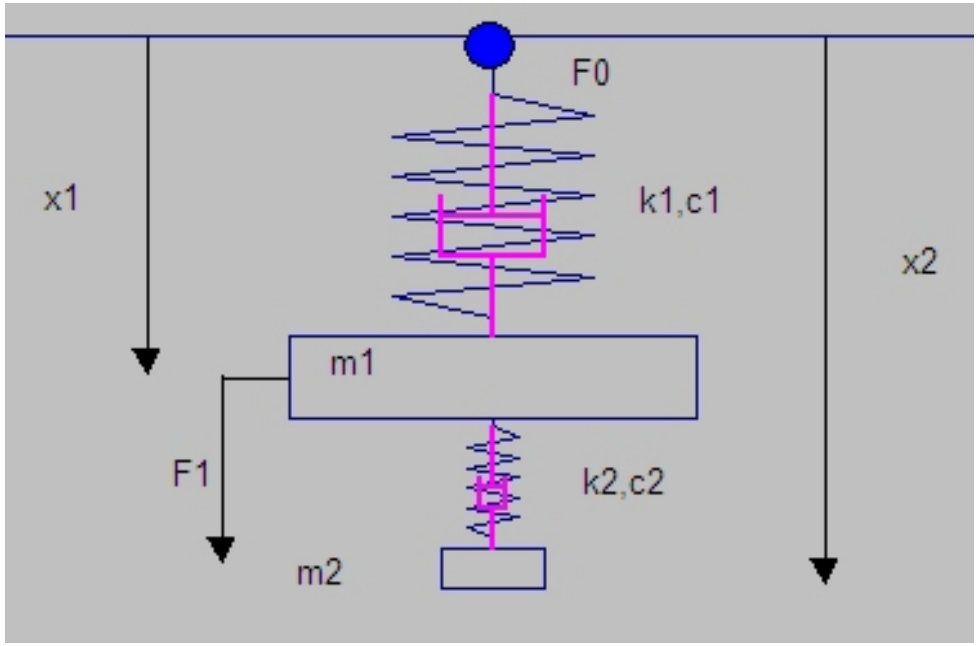


Tuned Mass Damper (TMD); Tuned Liquid Damper (TLD); Hybrid Mass Damper (HMD)

Tuned Mass Dampers

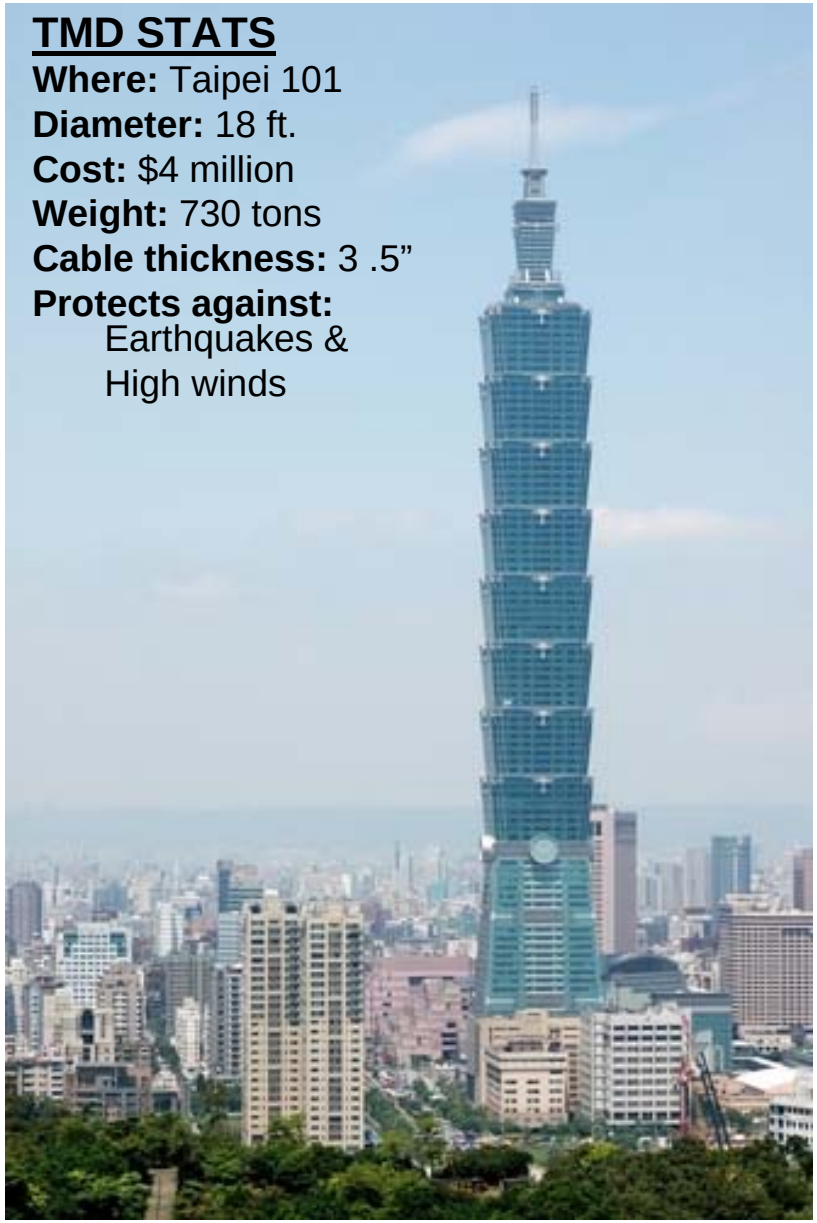
The tuned mass damper balances the vibration of a system with comparatively lightweight component so that the worst-case vibrations are less intense.





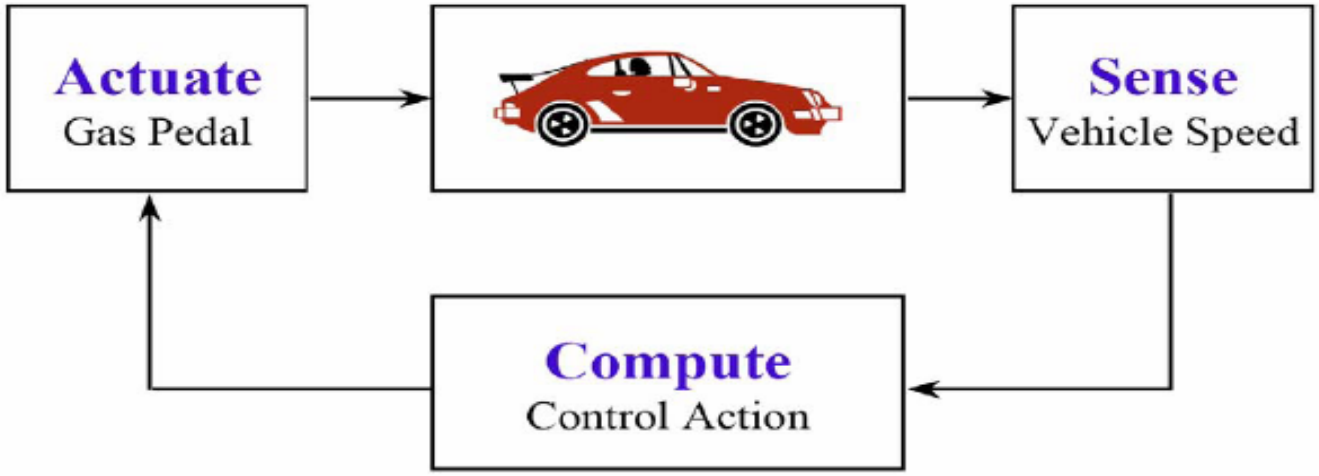
Tuned Mass Damper

- The Taipei 101 uses a tuned mass damper (TMD). It acts like a giant pendulum to counteract the building's movement--reducing sway due to wind by 30 to 40 percent.
- It has eight steel cables form a sling to support the ball, while eight viscous dampers act like shock absorbers when the sphere shifts.
- Able to move 5 ft. in any direction, the Taipei TMD is the world's largest and heaviest.



Active Control Methods

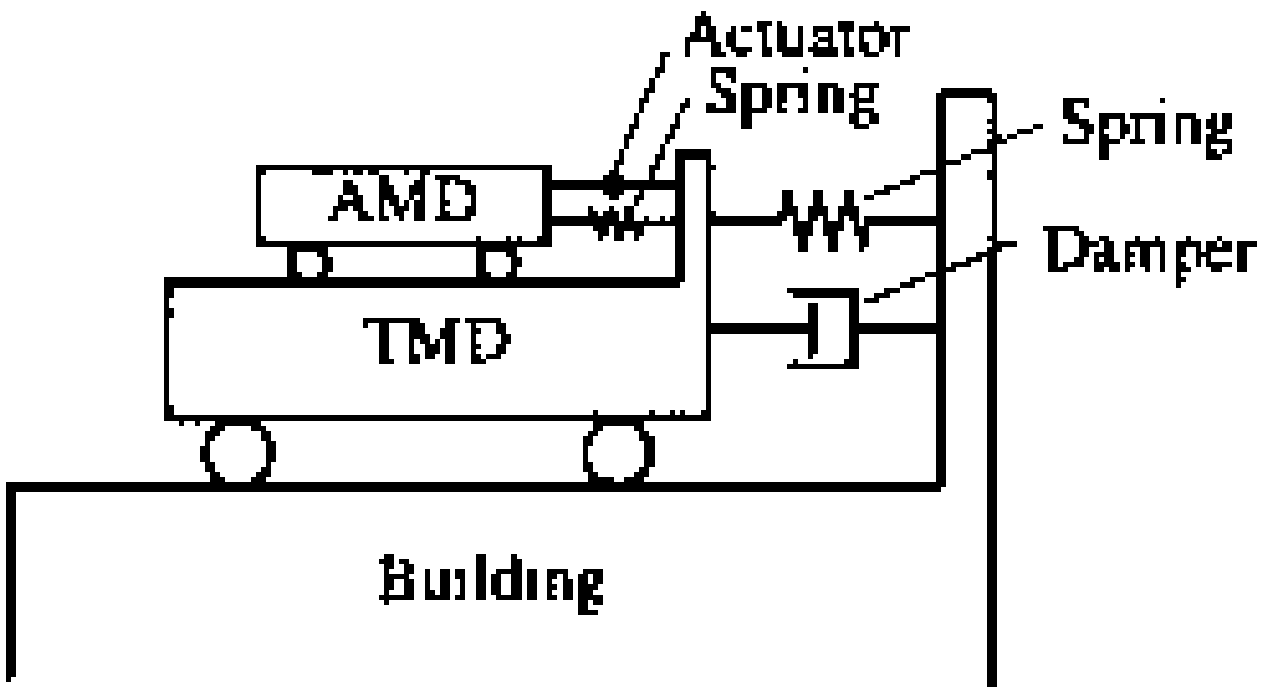
Active Control **= Sensing + Computation + Actuation**



Goals: Stability, Performance, Robustness

Active Mass Damper

Active damping of vibrations involves using sensors and actuators to continuously calculate the appropriate position of the AMD to counteract the oscillations.



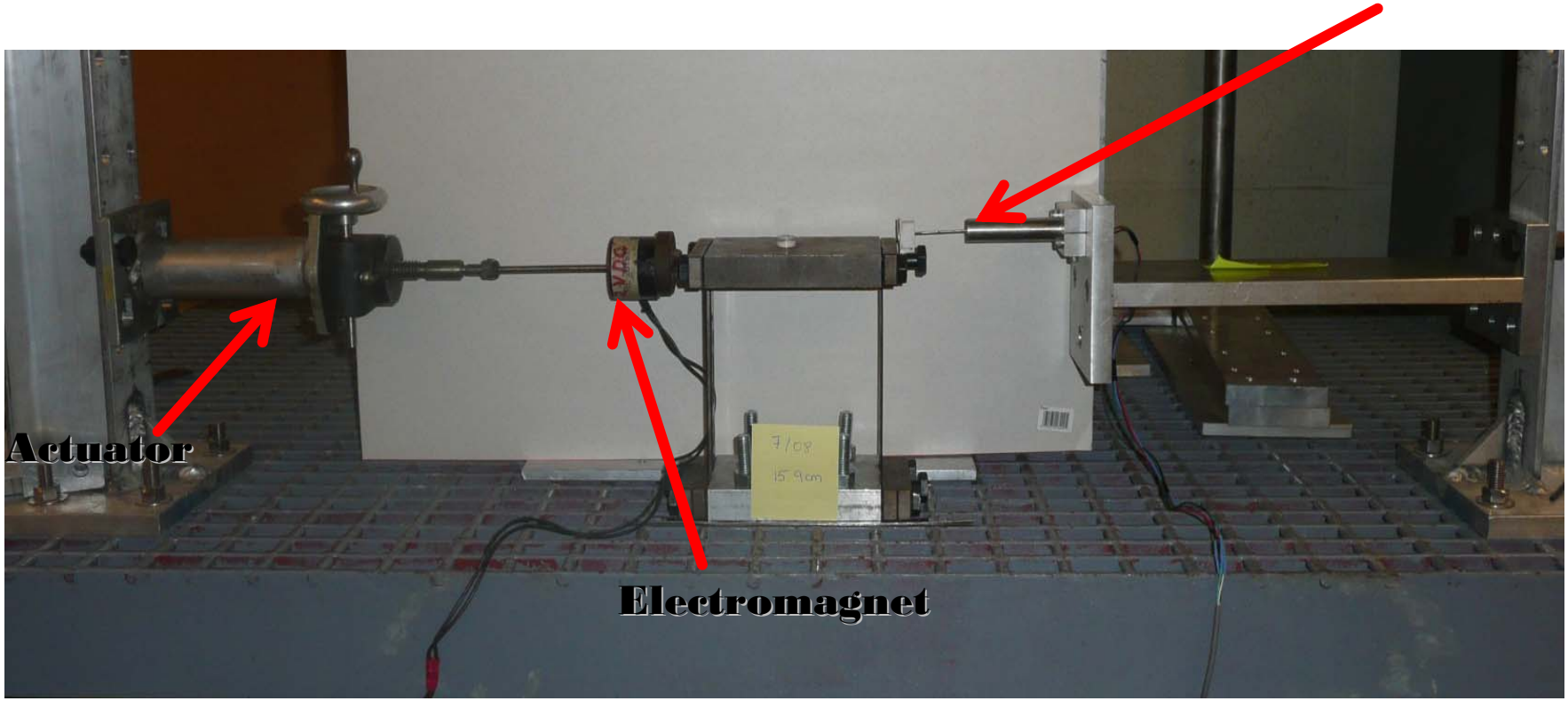
Active Mass Damper

Applause Tower, Osaka Prefecture, Japan

- Number of Floors: 3 below ground, 34 above ground
  Utilizes an AMD, mass weight 480 tons
- Objective: Suppression of building vibration in strong winds or small/medium earthquakes

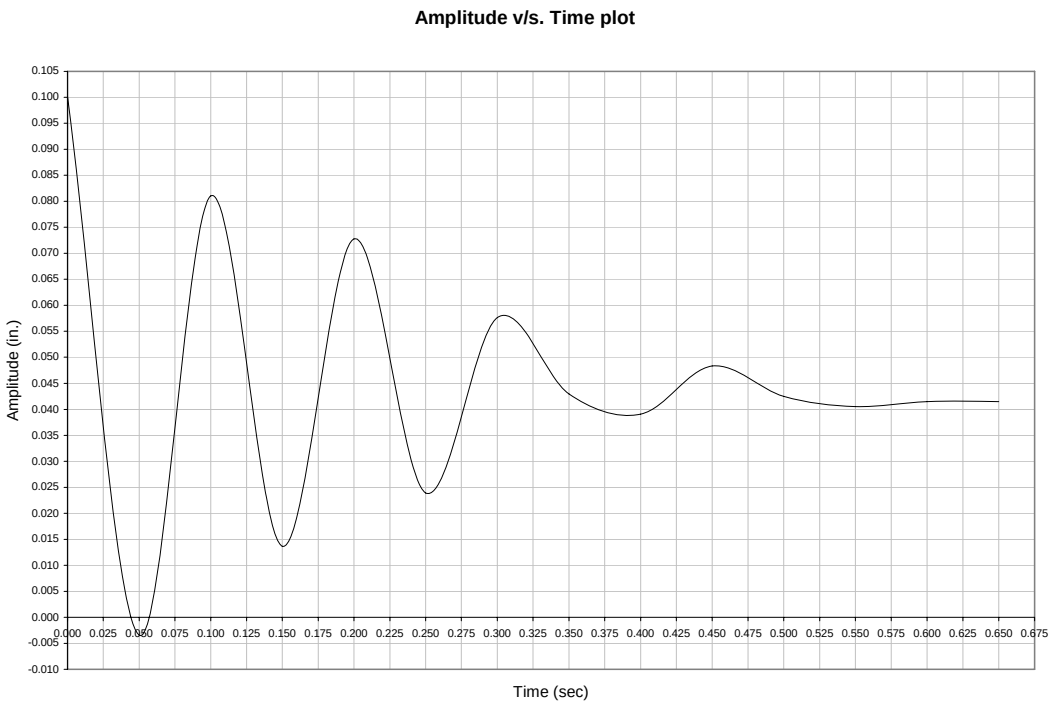
Small Structures Lab

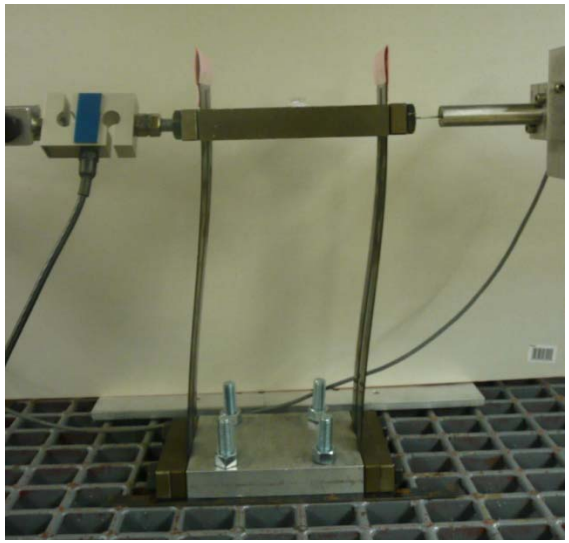
Introduce disturbances and take measurements to determine the system's natural response.



Small Structures Lab

Natural System Response to Disturbances:

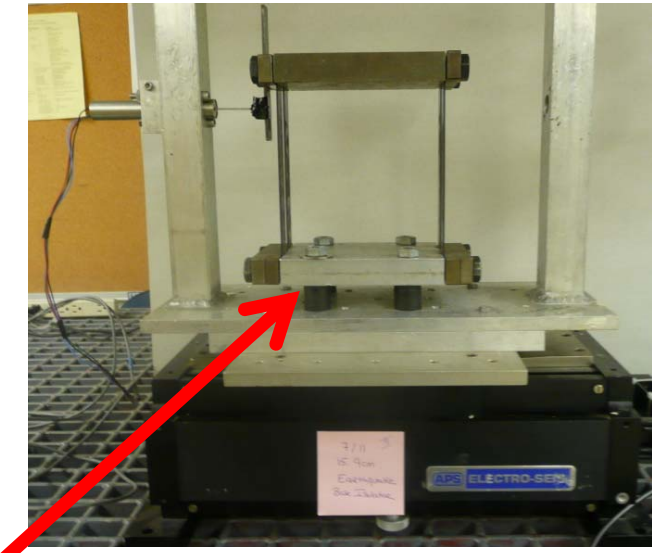




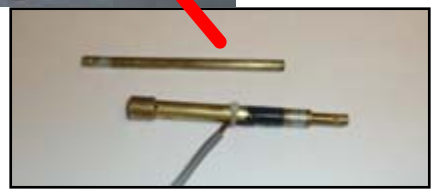
Small Structures Lab

Introduce passive methods to dissipate vibrations in the system.

Base Isolation



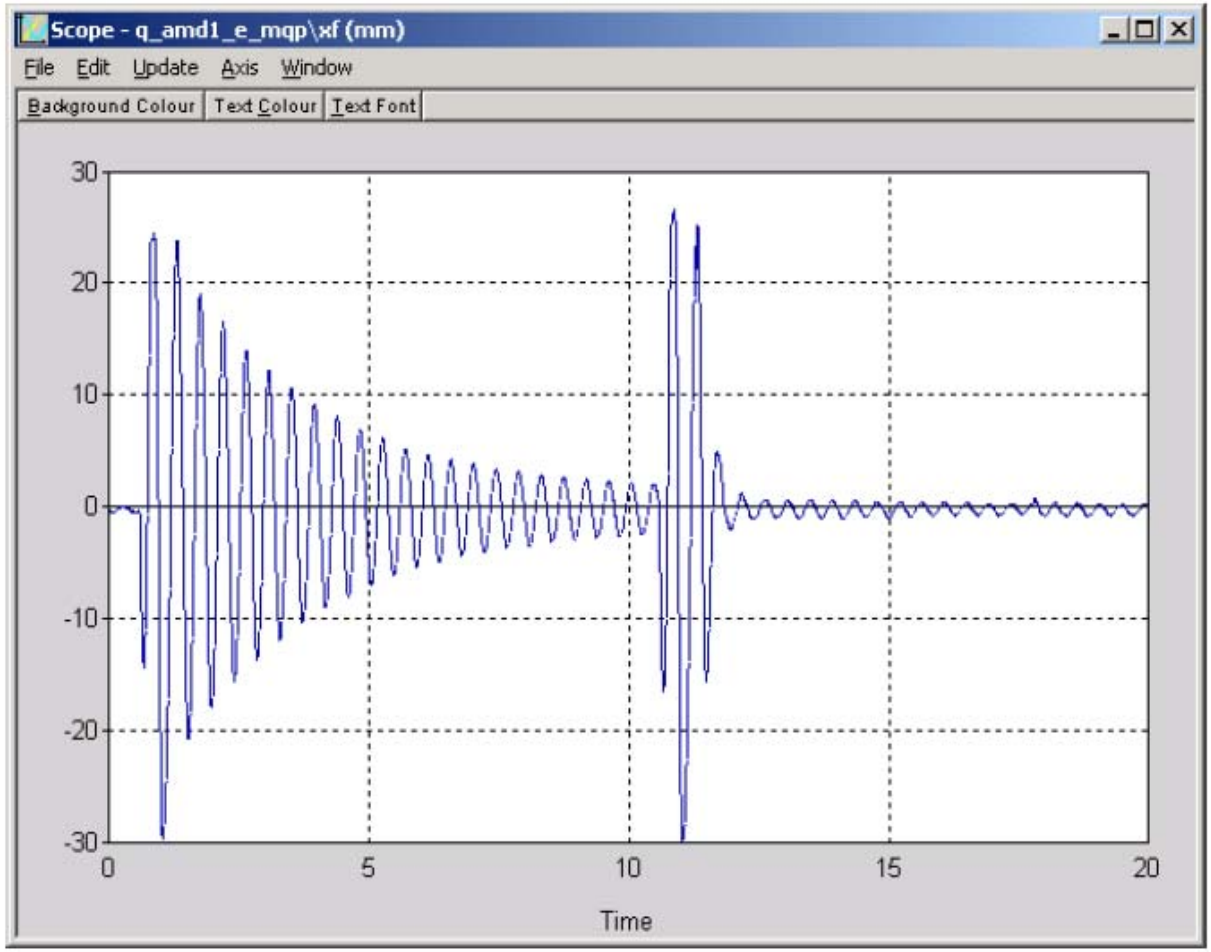
Dampers



IS Aerospace Lab

- One floor plant that emulates building vibrations being controlled by an Active Mass Damper (AMD).
- Plant consists of a linear cart (active mass) atop of a single-story building.
- Building can be excited by impulse disturbances and continuous vibrations.
  - Shake Table simulates the accelerations experienced by earthquakes of interest
  - Allows for the study of natural system response
  - Allows for the study of system response when introducing controllers

Vibration Response of Floor



Experiment oscillates between no damping and damping (as shown). Plot is of floor estimated displacement (mm) versus time.

References

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Questions?

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