Optimization of a Tuned Mass Damper

Course: PHY 480, Section 1

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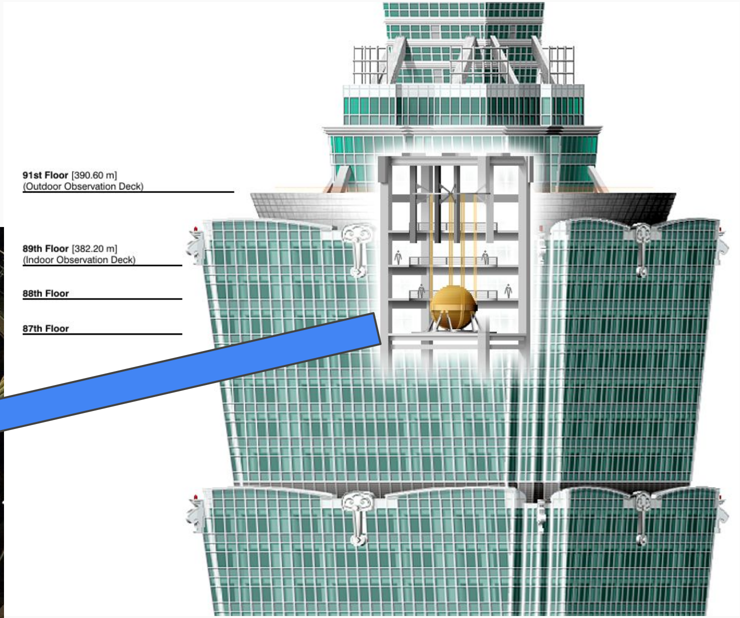
Background and Motivation

- External forces (wind, earthquakes) can induce oscillations in man-made structures like bridges and skyscrapers
- These oscillations can be dangerous to occupants and building integrity
- Tuned Mass dampers (TMDs) can be used within structures to counteract these effects

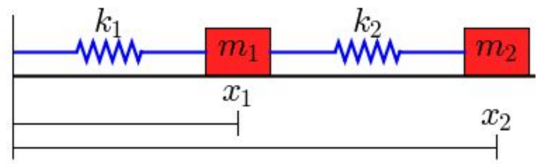


TMD at Taipei 101 in Taiwan

Project Goals

- Can we model a coupled mass-spring system?
- Do we observe damped oscillations of the larger mass?
- Can we develop an algorithm to optimize the physical parameters of the system (spring constant and mass of dampener)?
- Can we use a coupled mass-spring system as a stepping stone to more complicated models?
- Can we optimize in this case?

Simple Model: Coupled Mass Spring System

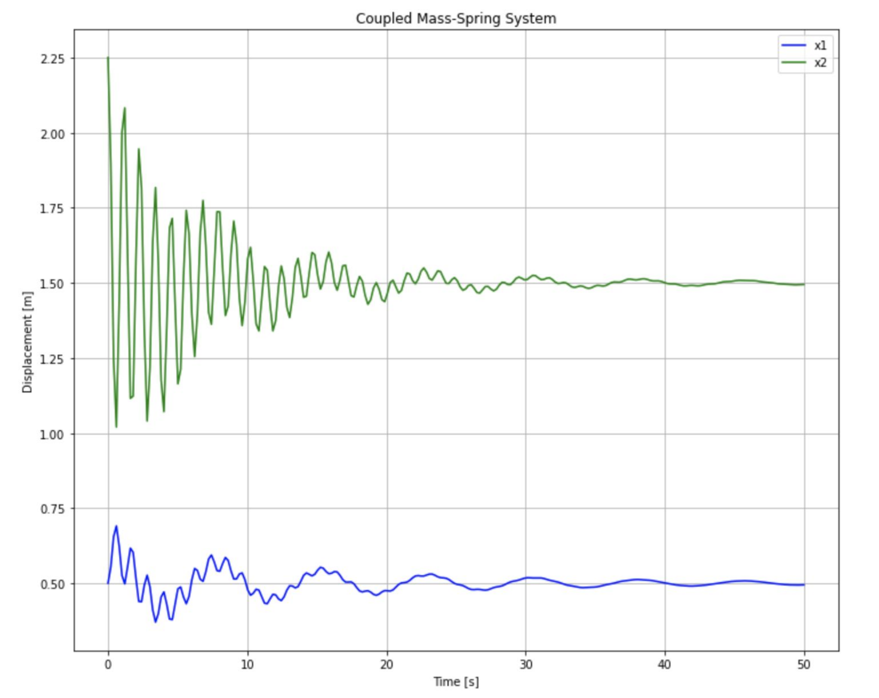


$$m_1\ddot{x}_1 + b_1\dot{x}_1 + k_1(x_1 - L_1) - k_2(x_2 - x_1 - L_2) = 0$$

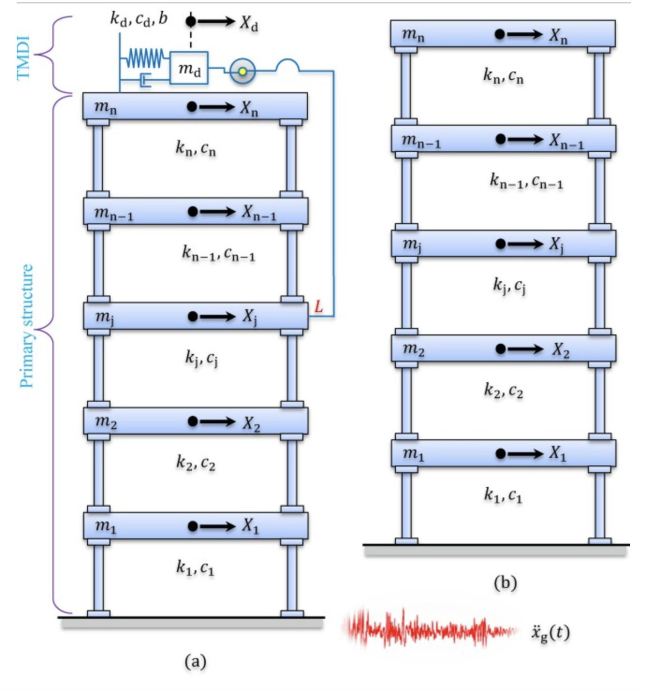
$$m_2\ddot{x}_2 + b_2\dot{x}_2 + k_2(x_2 - x_1 - L_2) = 0$$

- A 2nd order D.E. can describe this case
- Decoupling the system with a series of 1st order D.E. allows for easy solving with numerical methods
- Parameters m_2 and k_2 can then be optimized

Results and Optimization



TMD: Multiple story building



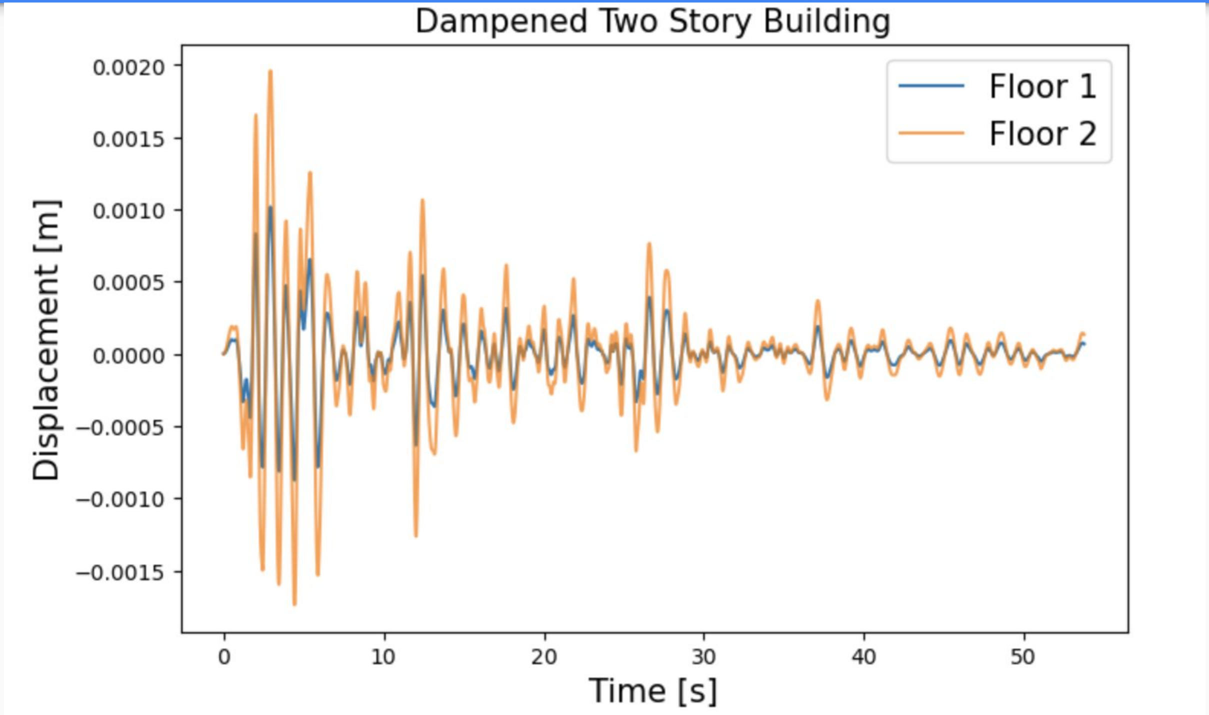
$$\mathbf{M}\ddot{\mathbf{X}}(t) + \mathbf{C}\dot{\mathbf{X}}(t) + \mathbf{K}\mathbf{X}(t) = -\mathbf{m}\ddot{x}_g(t)$$

- A more complicated 2nd order D.E. with matrices describes this case
- Matrices determine coupling between each floor

$$\mathbf{K} = \begin{bmatrix} (k_1+k_2) & -k_2 & & & & \\ -k_2 & (k_2+k_3) & -k_3 & & 0 & \\ & -k_3 & \cdot & \cdot & & \\ & & \cdot & \cdot & -k_n & \\ & 0 & & -k_n & (k_n+k_d) & -k_d \\ & & & & -k_d & k_d \end{bmatrix}$$

$$\mathbf{C} = \begin{bmatrix} (c_1+c_2) & -c_2 & & & & \\ -c_2 & (c_2+c_3) & -c_3 & & 0 & \\ & -c_3 & \cdot & \cdot & & \\ & & \cdot & \cdot & -c_n & \\ & 0 & & -c_n & (c_n+c_d) & -c_d \\ & & & & -c_d & c_d \end{bmatrix}$$

2-Story Building: Results



Conclusion and Next Steps

Accomplishments:

- Coupled mass spring system modeled and oscillations dampened
- Optimization of coupled mass spring system
- Extension of coupled mass spring system to TMD in multi-story building

Next Steps:

- Optimization of TMD parameters