**1.Introduction**

**1.1 Motivation**

In our daily life, oscillations impact a lot, especially for tall skyscrapers, due to their height is closer to the wavelength, normal wind blow can cause their oscillation. How do people deal with this problem?

By searching from various resources, we found a device called tuned mass damper (TMD), which is used to reduce the amplitude of mechanical vibration corresponding to the natural frequency of the oscillating structure by transferring the structure’s kinetic energy from the form of oscillation to harmonic motion.

We decided to build a TMD and explore the effects of different factors on efficiency of tuned mass damper by changing the weight of mass, the length of the pendulum and the magnitude of the friction. Moreover, we also built different types of TMD making use of spring, air resistance and the motion of water respectively and make comparisons.

**2. Design of project and experimental procedure**

**2.1 Model design**

A picture containing indoor, cabinet, wall, sitting

Description generated with very high confidenceThe general structure of the building is simulated using 4 wooden sticks with a square top. The model is then mounted on to a wooden base with wheels and the base shaken to induce an oscillation in the model due to lateral displacement. The Tuned Mass Damper (TMD) for the structure comes in the form of a wooden stick weighted with coins. The TMD is mounted to the roof of the structure with the pivot at the tip of the wooden stick between 2 L-brackets.

Figure 1: Final model

Based on the structural dimensions of the model building, Taipei 101, as stated in the motivations, it was determined that the ratio of height to base of our building should be 10:1. The height of the final model stands at 1.2m, while sides of the square base measure at 0.12m.

An accelerometer was mounted at the top of the model to measure the acceleration of the structure when its base is subjected to longitudinal displacement. The resulting data can then be used to plot an acceleration-time graph from which the displacement of the model with respect to time can be found and the damping coefficient identified.

A wooden bench

Description generated with high confidenceThe natural frequency of the structure without the TMD was determined to be \_\_\_\_\_s. Assuming the stick undergoes harmonic motion like that of a pendulum, and using the equation for the frequency of the pendulum, , the length of the pendulum required to match the natural frequency of the structure was determined to be 0.19m. Since the center of mass of the TMD was not at 19cm, the length of the wooden stick was increased and coins attached to the base to shift the center of mass to 0.19 to achieve the desired frequency of oscillation. The final length of the pendulum stick is 0.24m, as shown in the center of mass equation as follows: , where the mass of the stick is 0.0037kg, and the total mass of the coins is 0.0032kg.

Figure 2: Tuned Mass Damper

The TMD requires friction to increase the damping coefficient of the structure. In the case of the mode, the screw mounting the wooden stick of the damper was tightened so that the energy of the oscillation is dissipated.

**2.2 Experimental Procedure**

The base of the structure is manually accelerated for 0.5m before being stopped. The movement of the structure is recorded by the accelerometer and an acceleration-time graph is plotted. A total of 3 different experimental setups are used as follows:

* Undamped
  + The screw of the TMD pivot is loosened so the oscillation of the wooden stick is undamped apart from its internal damping
* Damped
  + The screw is tightened so that the friction between the stick and the L bracket acts as a damper while still allowing the TMD to oscillate
* Deadweight
  + The screw holding the wooden stick is tightened fully so that it does not oscillate

**3. Results and Analysis**

**3.1 Experimental Results and Analysis**

When a force is exerted on a tall structure, the structure will undergo harmonic oscillation when there is no friction. However, in the real world, all materials have an internal friction, which results in a damping coefficient , given by the equation below:

The change in amplitude of the oscillation with respect to time can also be found using the equation below:

The displacement of the top of the structure (where the accelerometer is placed) can thus be graphed with the following:

Using an accelerometer, the acceleration of the model can be measured. Using the data collected, an acceleration-time graph was plot and the displacement-time graph approximated. With the displacement-time graph, the coefficient of damp, , can be estimated using the equation .

Insert 24cm rod graph with attenuation coefficient modelled on same graph superimposed on graph where no damper was installed

With the addition of the damper, the damping coefficient was successfully increased by \_\_\_%, allowing the structure to return to equilibrium in \_\_s vs \_\_s undamped.

Comparatively, the setup with an uncontrolled oscillation resulted in the energy of the oscillation being transferred between the structure and the pendulum, resulting in the displacement-time graph below:

Insert graph of uncontrolled oscillation superimposed on graph where no damper was installed

The setup with the pendulum as a deadweight also did not aid in the damping of the structure, with its coefficient being almost identical to the structure without the TMD altogether:

Insert graph of 24cm with full friction superimposed on graph of model without damper

**3.2 Limitations**

The limitations of the model meant that the pendulum could only oscillate in 1 axis, limiting its ability to reduce the effects of external forces on the structure in multiple directions. This means that while the structure accurately displays the damping ability of the TMD, it is an inadequate model for a building.

**4. Future work**

**4.1 Pendulum**

To allow the TMD to counter external forces in all directions, a universal joint can be used and the pendulum mounted at the bottom to allow for the damper movement in all directions.

**4.2 Earthquake Simulation**

To better simulate the force from an earthquake, the base of the model can be attached to a motor by a metal arm and rotated, forcing the model to undergo longitudinal displacement like that which is caused by an earthquake.

**4.3 Wind simulation**

The surface area of the model can be increased with wooden boards of the same materials as the 4 “pillars”. This would allow the model to retain its natural frequency while making it more susceptible to wind force. A gust from a large fan can then be used to simulate the wind force on the structure, not unlike that which is experienced by large buildings.