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CANADIAN MUSEUM OF ARCHITECTURE

IN PERSPECTIVE

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IN THE SWING OF THINGS

Despite their apparent rigidity, tall buildings sway in the wind. The top of a 60 story building can oscillate as much as a meter in a stiff breeze. Though this doesn't necessarily damage the building, it stresses the structure's frame and the motion makes some occupants very uncomfortable.

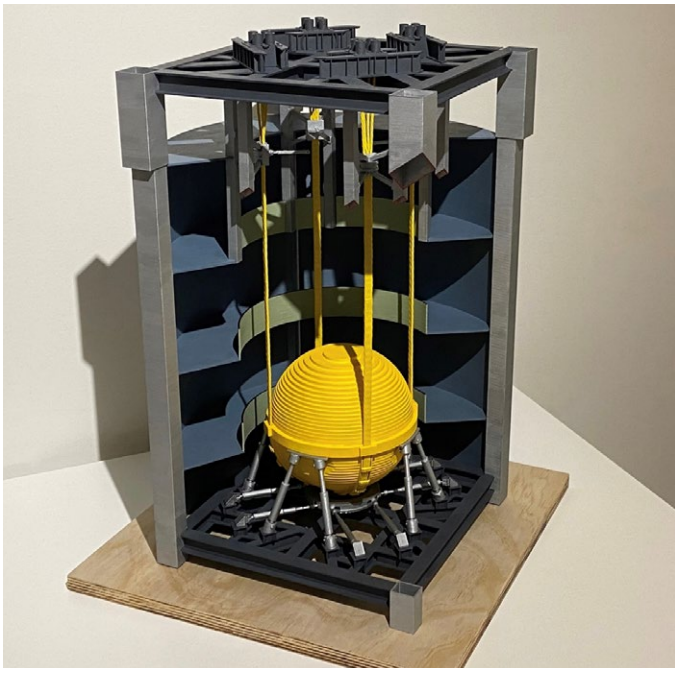
Consequently, the architectural design will usually incorporate a damper to reduce the extent of the movement. Lanxin Yang, a fourth year student at Laurentian University's McEwen School of Architecture, has constructed a scale model illustrating this interesting device.

- Peter Brueckner

TUNED MASS DAMPERS

Technology to control vibrations was developed in the early decades of the twentieth century by Hermann Frahm (1867-1939), an engineer. His dynamic vibration absorber, patented in 1909, pioneered the application of the principles to reduce vibrations in ships caused by the motion of the large pistons in diesel engines. Improvements led to the invention of the tuned mass damper (TMD) in 1928. The method was not applied to buildings till about forty years later, initially to deal with swaying caused by wind and later to respond to earth tremors.

Lanxin (Zoey) Yang.



The CMA's model of the Taipei 101 TMD.

In architecture, the function of the TMD is to counteract the natural swaying motion of a building by installing, near its top, a large mass that can move independently of the structure. The mass is connected to the structure with springs or hydraulic devices that are tuned (adjusted) so it tends to move out of phase (in the opposite direction) of the structure. It thereby reduces the extent of the movement by absorbing, converting and dissipating the kinetic energy of the moving building.

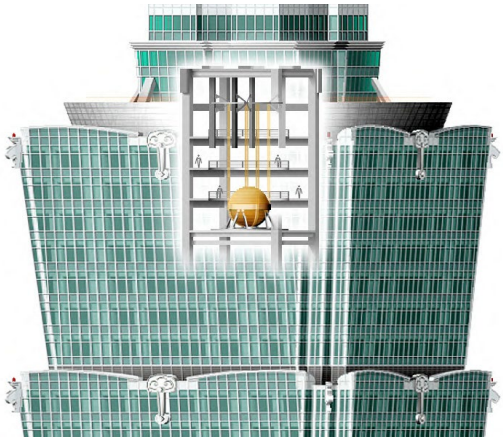
One of the world's largest and heaviest TMDs is in the Taipei 101 skyscraper in Taiwan. Completed in 2003, Taipei 101 is 508 m (1667 ft) high and was the world's tallest building from 2003 to 2010. Typhoon winds up to 200 km/hr and earthquake tremors occur frequently in the area.

Motioneering, a Canadian engineering firm specializing in motion control, performed the design build of the damper that is installed between the 89th and 92nd floors. It is a 660 tonne spherical arrangement of 41 steel plates and comprises about 0.24% of the total weight of the building. The 42 meter steel cables on which it is suspended enable it to swing as a pendulum. A bumper ring limits its movement to 150 cm with respect to the building.

Eight primary hydraulic dampers connect the mass to the building and facilitate the dissipation of energy gained by the structure from wind forces. The sway of the building is reduced by about 40%. In fact there are several other TMDs installed in the Taipei 101 to respond to various types of movement.

The Taipei 101 skyscraper.

We gratefully acknowledge the assistance provided by Motioneering that enabled the CMA to construct a scale model of the Taipei 101 TMD. Using the original drawings a plan of the model was drafted in Rhinoceros. After division into suitable components printable files were created at a scale of 1:40. After printing, the plastic model was assembled and finished in the colours of the actual damper.

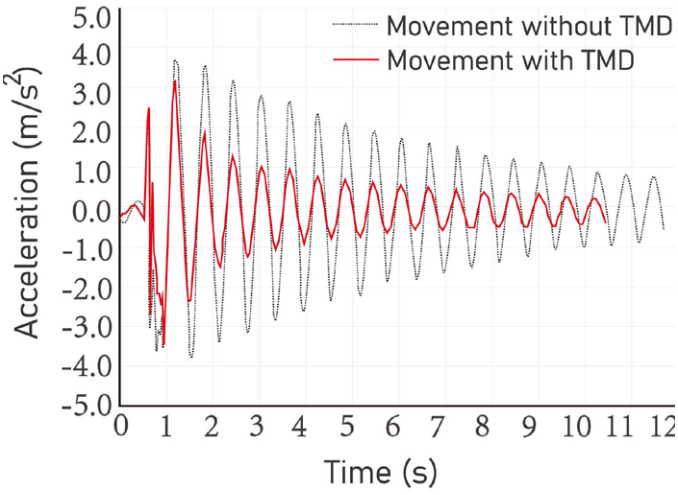


The damper is located at the top of Taipei 101.

Further work is underway to construct a mechanical model to display a TMD in action. This will serve to illustrate its operation as the underlying mathematics are complex.

A visitors' gallery provides a close up view of the Taipei 101 TMD in operation.

As building designs become taller and thinner and structural support reliant on steel frames, the propensity for oscillations increases. TMDs are now commonly used to ensure safety and comfort.



Schematic illustration of the effect of a TMD in reducing the oscillating motion of a building.

In addition to the pendulum type that we modeled, dampers using masses on rollers, tanks of water, air, magnetic forces, and so on have been developed. Furthermore, not only buildings but other structures such as bridges and towers make use of the technology. Climate change, with increasingly severe weather events, may be expected to make further demands on methods of vibration control.

- Lanxin Yang

Image 3: Adjusted the brightness of Taipei 101 during sunset. Photo by tsaiian: https://www.flickr.com/photos/95504465@N00/19472808621
Image 4: Removed the labels of Taipei 101 Tuned Mass Damper. Photo by Bambosz, Someformofhuman: https://commons.wikimedia.org/wiki/File:Taipei_101_Tuned_Mass_Damper.png
Image 6: Photo by Practical Engineering: https://practical.engineering/blog/2016/2/14/tuned-mass-dampers-in-skyscrapers