Vibration Control of Tall Buildings

MAURER Tuned Mass Dampers
Experience in motion control

The MAURER Group is a leading specialist in mechanical engineering and steel construction and has been family-owned since it was formed back in 1876. The MAURER Group is currently one of the global technological leaders in steel and plant constructions in various specialist fields. We offer products and solutions which are particularly notable for their quality, durability and reliability.

Our fields of expertise are customised structural protection systems

An important part of our activities is monitoring climatic, seismic and traffic-induced forces and movements, which have an impact on buildings, bridges and complex dynamic structures. These effects can be controlled through the selective use of our expansion joints, structural bearings, tuned mass dampers and anti-seismic devices to protect the structures from damage.
Due to the urbanisation of the world’s population, which in some cases is occurring at rapid speed, politicians, city planners and transport system developers are facing new challenges. For many academics, the solution for the city of tomorrow lies in its compactness. “Buildings better connected, more compact cities based on mass public transport can save over $3 trillion in investment costs over the next 15 years. These measures will improve economic performance and reduce emissions, raising the quality of life.”

New Climate Economy Report

Short distances are the key. The creation of a vertical village in the city: apartment blocks are being stacked on top of one another rather than being built side-by-side, with roof gardens, playgrounds and courtyards included in the development.

Megacities of tomorrow will grow in population, infrastructure and height

8.5 BILLION

CURRENT MEGACITIES
FUTURE MEGACITIES*
POPULATION IN 2030*

Civil engineering structures may be prone to large amplitude vibrations due to wind and earthquake loading mechanisms because of their slenderness and low inherent damping ratio of approx. 1%. Without additional damping measures the following problems may arise:

- Wind loading mechanisms may evoke resonance and therefore large amplitude oscillations in high-rise buildings, which dramatically reduce the comfort (seasickness) and therefore limit the use of the building.

- Free vibrations of tall buildings after earthquake excitation may cause low cycle fatigue.

- Bending and torsional galloping and flatter vibrations in bridges lead to large amplitude and therefore dangerous resonant vibrations (Volgograd Bridge) that may even destroy the deck structure (Tacoma Narrows Bridge).

- Human-induced vibrations in stadiums, floors, and footbridges may yield vibration amplitudes that are beyond the acceptable maximum values (Millennium Bridge).
Dampers – designed to efficiently solve vibration problems

The MAURER solution

MAURER offers different types of tuned mass dampers (TMD) with up to 1,000 tonnes of tuned mass to optimally solve the vibration problem:

>> Passive tuned mass dampers:

- **standardTMDs**: TMDs constructed with springs for the mitigation of vertical and horizontal oscillations of bridges, stadiums and floors, and TMDs designed in pendulum form for the mitigation of horizontal vibrations of slender structures.

- **foldedTMDs**: TMDs constructed by two folded pendulums in order to significantly reduce the required vertical space in high-rise buildings.

- **compactTMDs**: pendulum TMDs with additional inverted pendulum for minimum required vertical space in super tall buildings.

>> Adaptive tuned mass dampers:

- **controlledTMDs**: real-time frequency and damping controls according to the actual frequency of vibration, whereby the vibration reduction is enhanced or the mass ratio can be reduced.
The key features of Tuned Mass Damper

Benefits of MAURER TMDs

- The different mass damper types guarantee the best solution to the vibration problem.
- Model-based optimal design of all mass damper types by MAURER as a service.
- Vibration measurement on the structure by MAURER.
- Quality control by measurement of TMD properties in the workshop and installed in the structure.
- MAURER TMDs are robust, maintenance-free and long-lasting (>20 years) due to their optimal design, precise manufacturing process and quality controls.

>> Specific benefits of MAURER TMDs

- **standardTMDs**: cost efficient
- **foldedTMDs & compactTMDs**:
  - $\#$ significant cost reduction in high-rise buildings due to minimised height of these TMD types
  - $\#$ optimal frequency tuning in both main directions due to innovative cable fixation tunings
- **controlledTMDs**:
  - $\#$ maximum comfort in buildings through improved vibration reduction of up to 80% compared to passive TMDs
  - $\#$ same vibration reduction as with passive TMDs but with reduced tuned mass (75% to 85% of nominal tuned mass)
  - $\#$ monitoring of structural vibrations included
The key features of Maurer Tuned Mass Dampers

CONTROLLED VERTICAL TMD

STANDARD HORIZONTAL TMD

FOLDED PENDULUM TMD

STANDARD VERTICAL TMD
Resilient structures in a fast-moving world

>> SOCAR Tower in Baku | Azerbaijan

**Task:** Mitigation of fundamental bending modes in both main directions with different eigenfrequencies

**Scope of project:**
- The total height of the folded pendulum including the steel frame construction, cable clamping devices and lead rubber bearings could be reduced from approx. 11 m of the conventional pendulum TMD to approx. 7 m of the folded TMD.
- The damper mass of 450 tonnes of the folded TMD corresponds to the mass ratio of 4.5%.
- The steel frame construction of the folded TMD and the passive oil dampers are designed to accommodate damper relative motion amplitudes of up to ± 480 mm.
- In operation

>> Danube City Tower in Vienna | Austria

**Task:** Controlled mitigation of first bending mode within the frequency range of 0.17 Hz to 0.21 Hz

**Scope of project:**
- The control force range of both real-time controlled semi-active dampers is given by the residual force of approx. 3 kN and the maximum force of approx. 90 kN.
- The tuned mass of 300 tonnes corresponds to the mass ratio of 0.75%.
- The adaptive damping control approach of the controlled TMD increases the damping disproportionately for damper relative motion amplitudes greater than ± 0.6 m in order to avoid non-acceptable large damper relative motion amplitudes; additionally, shock impact dampers are installed.
- In operation
**Alphabetic Tower in Batumi | Georgia**

**Task:** Mitigation of wind-induced vibrations in both main directions

**Scope of project:**
- The standard TMD in pendulum form is optimally tuned to the eigenfrequency of 0.498 Hz in both main directions of the Alphabetic Tower in Batumi.
- The damper mass of 62.85 tonnes of the standard TMD corresponds to the mass ratio of 3.5%.
- The joints and lengths of the pendulum rods and the cylindrical oil dampers are designed for the maximum damper relative motion amplitude of ± 0.24 m.
- In operation

**Marina Bay Sand Hotel | Singapore**

**Task:** Reducing the vertical vibrations of the cantilevered part due to wind and human-induced excitation

**Scope of project:**
- At a height of 200 m, these towers have been given a roof structure that consists of a garden with an area of 1 hectare, including a 150 m long pool and 250 trees.
- The garden is supported by 17 spherical bearings to allow for its required horizontal movement.
- A tuned mass damper system with 5,000 kg of tuned mass reduces the vertical vibrations of the cantilevered part of the garden.
- In operation

280 TONNE S OF STEEL = 7 FULLY LOADED SEMI-TRAILERS
Olympic Flame Monument in Sochi | Russia

Task: To dampen the vibration of a 45 m tall torch in the Sochi Olympic Park at the windy coast of the Black Sea

Scope of project:
- Each of the three dampers weighs one tonne, 750 kg of which damper mass.
- The natural frequencies of the standard TMDs can be optimally adjusted to the broad frequency range of 0.46 Hz to 1.55 Hz by the unique design of these standard TMDs that allows adding, removing or exchanging the coil springs on site.
- The standard TMDs are designed to accommodate the relative motion amplitude of +/- 70 mm.
- In operation

AlpSpix in Garmisch-Partenkirchen | Germany

Task: The vibration of the viewing platform needed to be reduced to a sensitive comfort level for visitors.

Scope of project:
- The four tuned mass dampers with a total weight of 340 kg each have the shape of flat square boxes with a footprint of 650 x 650 mm.
- The oscillating damper masses of 150 kg each are divided into several steel plates so that they can be adjusted retroactively.
- In operation
Quality and services for you

We also offer the following services:

- Construction services
- Installation supervision
- Inspection
- Maintenance
- Refurbishments
- Static & dynamic analyses
- Component testing
- Design planning
- Monitoring
- Research and development
- Training courses