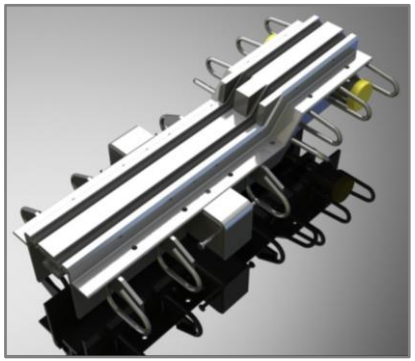
Seismic Protection Systems (Low to Medium Seismicity)

Marcel Gruber

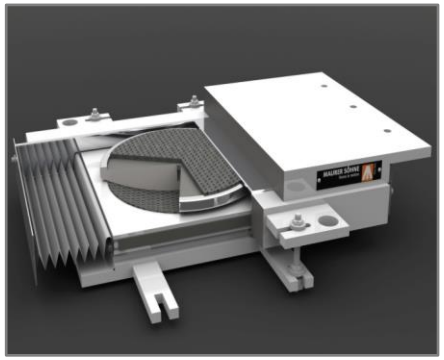
MAURER SE

German Engineering

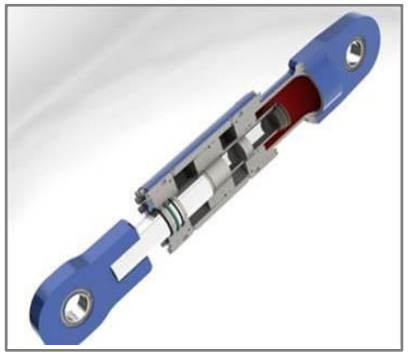
MAURER‘s wide product range



Expansion Joints



Bearings Seismic Isolators



Dampers

TMDs

MAURER does <u>all in-house</u>:

- Engineering
- Manufacturing
- Installing/Supervision

-> Achieve highest Quality

Seismic Protection Systems

Design Philosophies

Strengthening

- Design Loads -> Resistance
- Stiff + rigid
- Attracts energy
- High strucutural cost
- High accelerations of building

Mitigation

- Reduce Design Loads
- Remove energy from System (damping)
- Isolate ground movement
- Reduced accelerations of building

-> Seismic Protection Systems

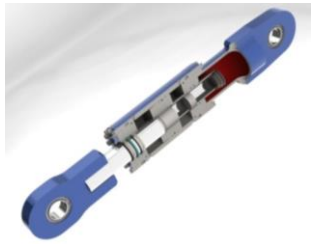
Seismic Protection Systems

How to achieve Mitigation?

- **Damping**

  -> Remove Energy

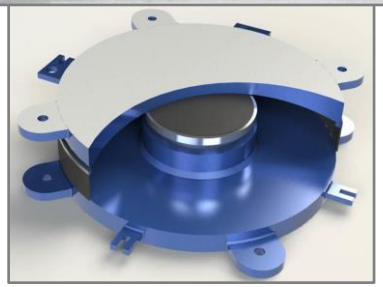
  - Viscous Dampers
  - Hysteretic Dampers
  - Friction



- **Isolation**

  -> Decouple structure from ground motion

  - Elastomeric Isolators
  - Sliding Isolation Pendulums
  - Hysteretic Sliding Isolators



Seismic Isolation

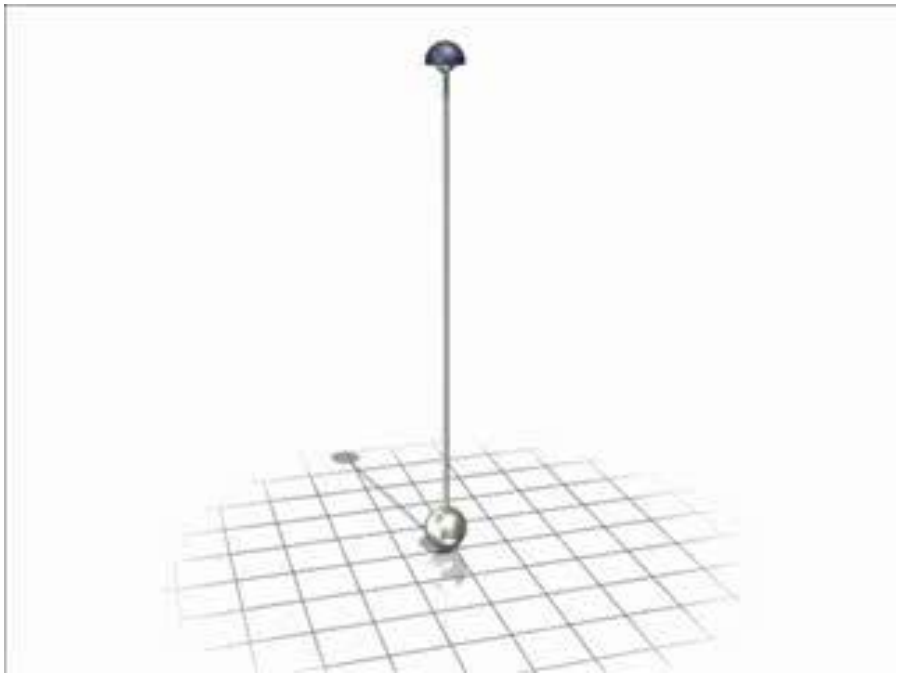
Isolated compared to non-isolated Structure

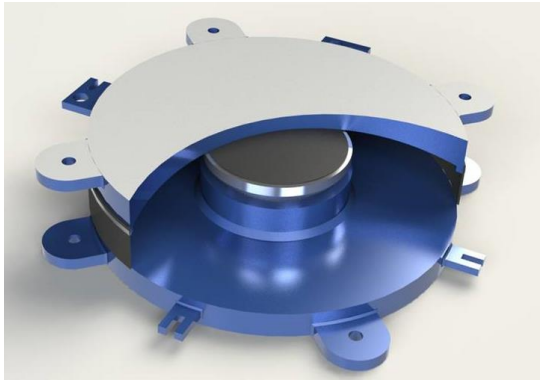
Sliding Isolation Pendulum

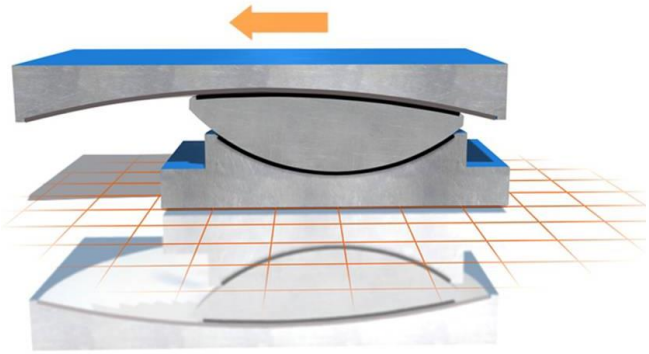
Concept

Isolation + Damping combined

- Pendulum Period determined by radius
- Damping through friction







$$T = 2\pi\sqrt{\frac{R}{g}}$$

Sliding Isolation Pendulum

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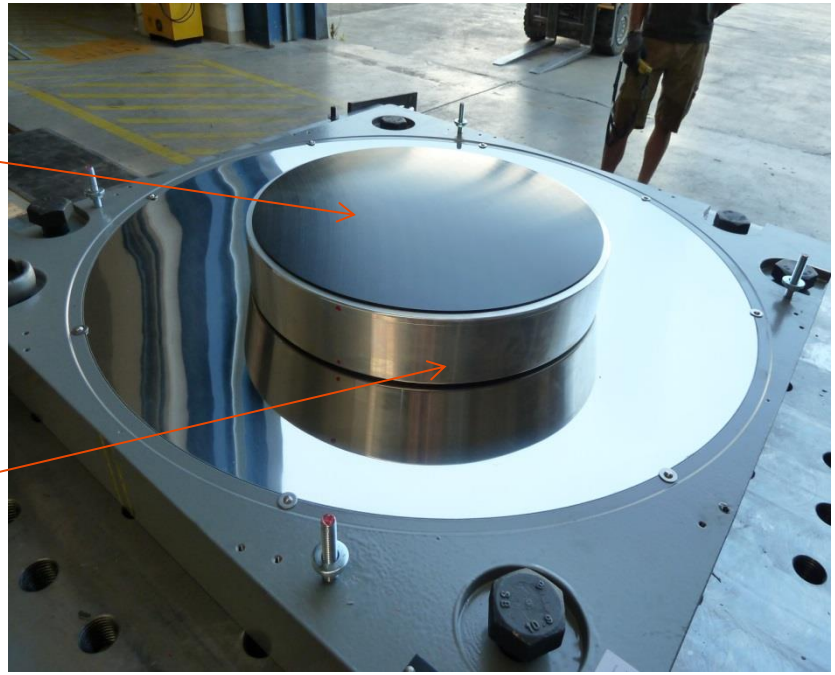
Right choice of material important

Crucial for SIP Performance

- Precise, high quality production

- Right sliding material
  - ✓ MAURER MSM
    - + extreme temperature range
    - + highest compression (230 MPa)
    - + longest sliding path (> 50 km)

- Durable Sliding Disc
  - ✓ MAURER MSA
    - + non corrosive



Isolator ≠ Isolator

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Carefull selection of the product

- Different Types (Elastomeric, Pendulum)

→ Pendulum (SIP):
longer lifetime, load independent, better performance

- Different Models (SIP, SIP-Double, SIP-Adaptive)

→ Double: smaller
Adaptive: superb performance

- Different Manufacturers (low quality, high quality)

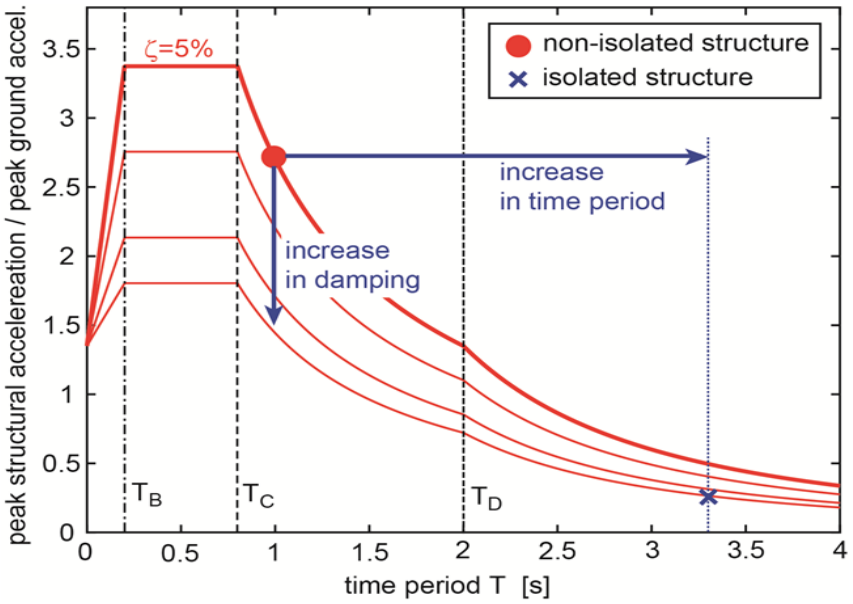
→ MSM Sliding Material, CE-mark, Engineering know-how

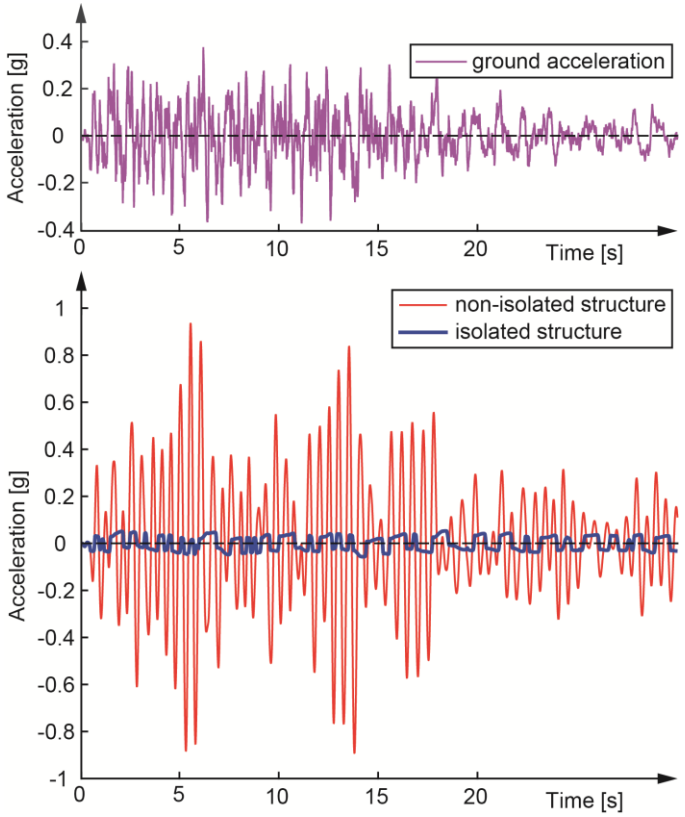
Every project requires unique isolator design

Seismic Isolation

Most effective seismic protection

- **Advantages:**
  - ✓ Period shift
  - ✓ Damping (if required)
  - ✓ Automatic Re-centering (ideal)

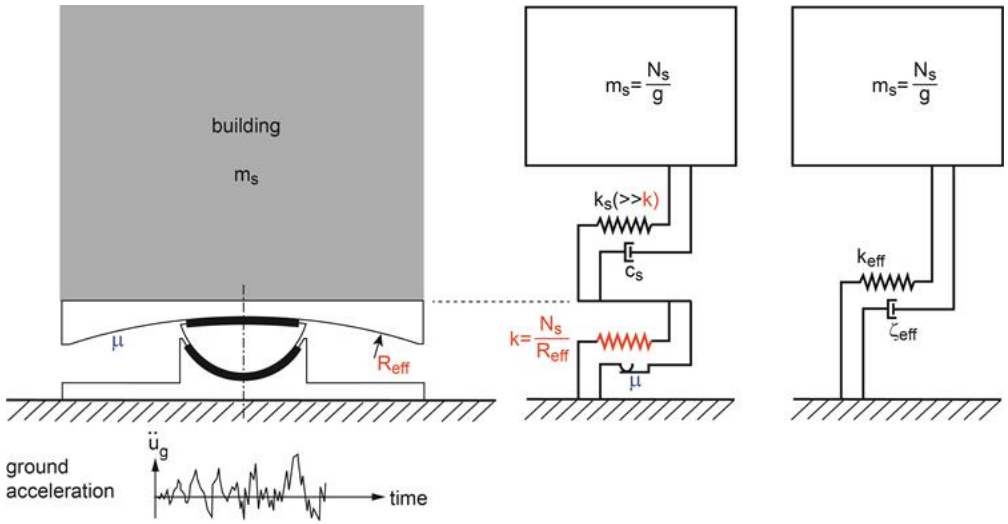




Seismic Isolator Design

Simplified Model

- Computation of Isolator design



simplification

1st Goal: Low coupling stiffness ➔ long T_{iso} ➔ large R_{eff}

(limited due to re-centering condition)

2nd Goal: Additional vibration reduction by damping (friction μ)

Assumptions, simplifications:

- Structure: rigid mass, 5% inherent damping
- SIP determines time period and damping
- Ground acceleration given

Seismic Isolator Design

Simplified Model

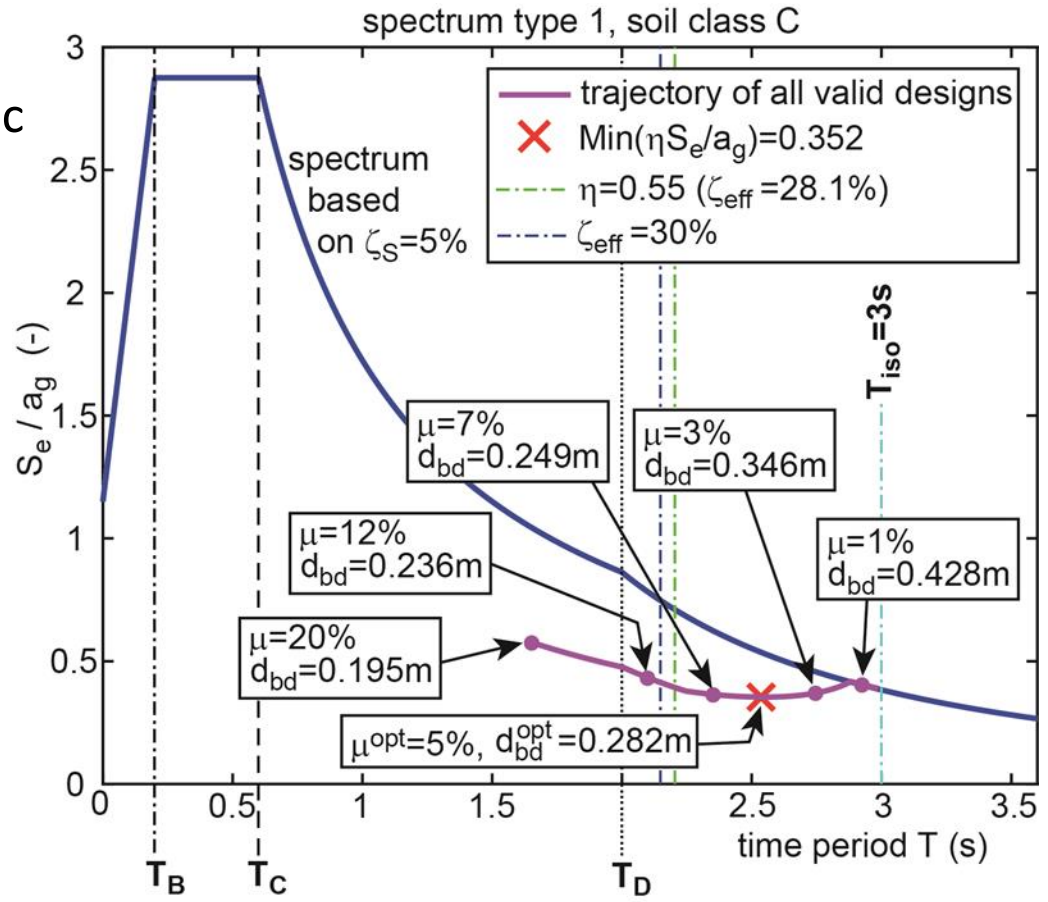
1. **Step**: Selection of isolation time period ➔ range with low seismic energy density (2,5 s - 4,5 s)

$$R_{eff} = g\left(\frac{T_{iso}}{2\pi}\right)^2$$

2. **Step**: Optimize Damping ➔ Friction μ

3. **Step:** check maximum displacements d_{bd} (increase damping if too big)

Accelerations <-> Displacements



Advantages of Seismic Isolation

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Attractive in Areas with new Seismic Code

- Superstructure remains in the elastic design range
  - ➔ No need to re-educate all engineers
  - ➔ Retrofit attractive
- Most effective protection against earthquakes
- Economic
  - ➔ Only about 1% of structural cost
  - ➔ Material savings in superstructure
  - ➔ Least economic impact in case of major earthquake event

When to apply?

Focus: Low to medium seismicity

Content needs to be protected?

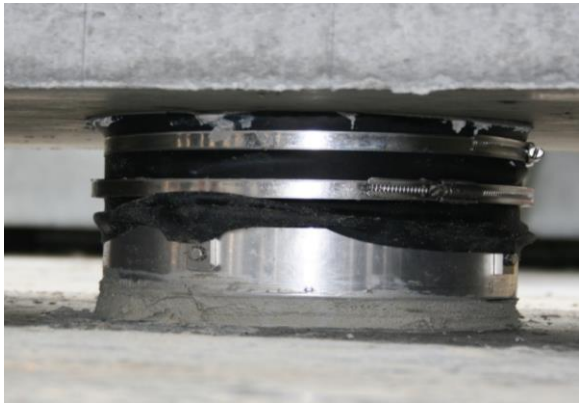
- Museums:
  - ➔ Irreplaceable cultural value
- Schools:
  - ➔ Children
- Hospitals:
  - ➔ Sensitive equipment (needs to stay operational in case of disaster)
- Important Buildings (government, symbols, transport hubs, data centers…)

SIP-Double Isolation in Netherlands

Reference

Seismic Retrofit with SIP-Double Bearings

- Manmade artificial earthquakes due to gas exploration
- Quick and economic solution was required
- Structural Monitoring System in the bearings
- Total corrosion protection with MSA (MAURER Sliding Alloy)
- No lifting equipment due to lightweight bearings (25 kg)

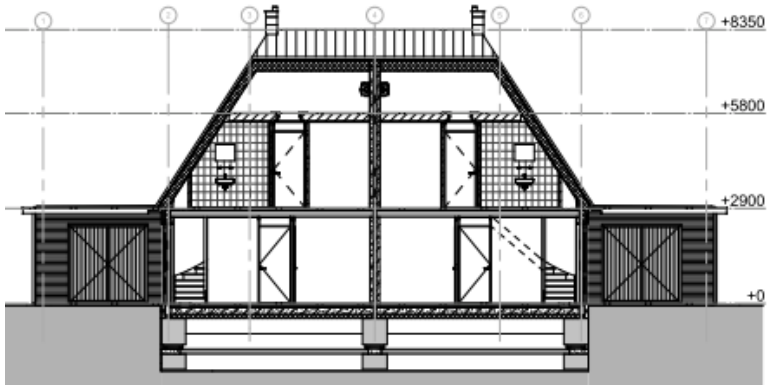


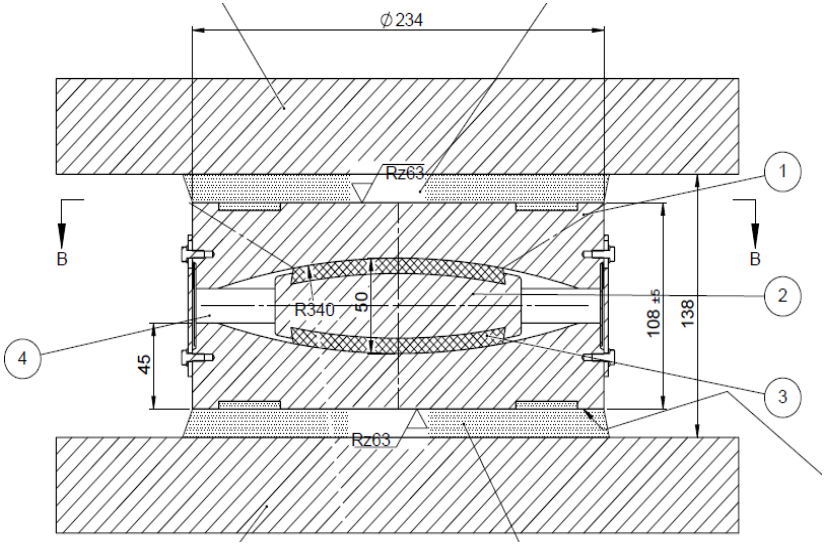
SIP-Double Isolation in Netherlands

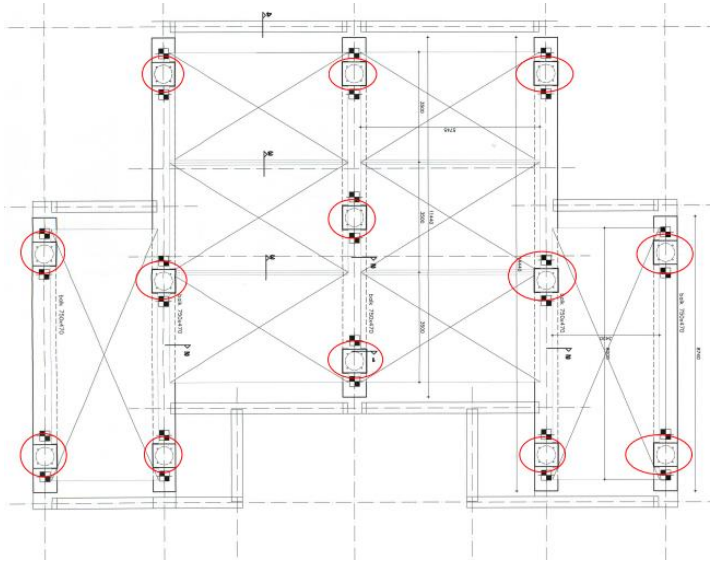
Reference

Success story:

- No change in superstructure
- Quick implementation
- Cheaper than demolition and new building
- Perfect protection







Semi-active TMD DC Tower Vienna

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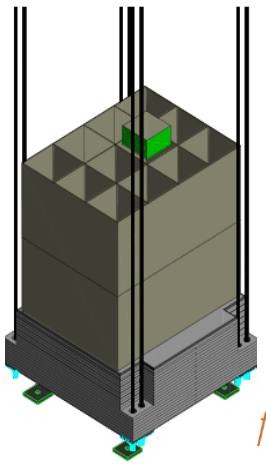
Reference

Reduction of Wind and Seismic Vibrations

- Tallest Building in Austria
- Extreme broad to width ratio
- Vibration problems exceeding Human Comfort Criteria
- Low-cycle fatigue (30 min sway after EQ)

➔ 300t pendulum tuned mass damper (TMD)
  - 0.2 Hz ; 0.7% mass ratio
  - Semi-active controlled damper for real time optimized minimal vibration

➔ **Vibrations after EQ decay within seconds due to TMD**



Thank you for your attention

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