MAURER Hydraulic Dampers
MAURER Shock Transmission Units

MAURER Hydraulic Devices

The hydraulic devices offered by MAURER can be split into two functional principles:

A) MAURER Shock Transmission Units - MSTU/MSTL

Shock transmission units are intended to allow free movement for slow velocities, such as thermal movements, and **temporarily rigidly lock-up during higher velocity events** (seismic/wind/traffic/impact). Since they do not provide any significant energy dissipation, they are applied to reduce movement, distribute forces to several locations but are not at all mitigating accelerations within the structure. Common applications include installation across expansion joints to reduce expansion joint sizes and prevent pounding as well as on bridges at expansion piers to share lateral forces.

B) MAURER Dampers – MHD

MAURER Hydraulic Dampers **transform while moving mechanical energy introduced into the structure during seismic, wind, or other transient events into heat.** This helps control structural accelerations and displacements, reducing damage and keeping drifts within the desired design limits. Energy dissipation is achieved by forcing special damping fluid through custom shaped orifices in the damper piston head as the damper is stroked. Dampers are velocity dependent devices that are used to mitigate a structure's dynamic motion during an earthquake without increasing demand on the structure or foundation. By varying viscosity of the damping fluid and the shape of the orifices, a wide variety of force-velocity response combinations can be offered to help optimize the performance of the structure.

Dampers can also be used with conventional bearings or isolator systems in order to effectively increase damping to achieve displacement reduction while providing greater rigidity during service load cases. This results in a more cost-effective high-performance solution due to the reduction in cost for elements where cost is proportional to displacement.

All applied fluid control systems have been extensively tested and have been utilized in building, bridge and powerplant industries for decades.

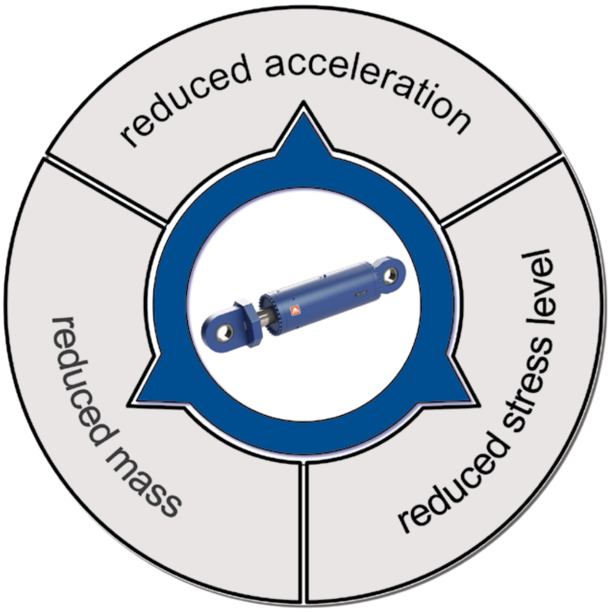
Schematic of two main designs for hydraulic devices

Long design with pin-hinge on both ends

Short design with pin-hinge and flange

Benefits for structural design

- Reduce accelerations, displacements, and significantly minimize stresses, simultaneously
- Controlled movements from service loads and earthquakes
- Reduction of building mass, resulting in cost savings
- Allows the structure to remain elastic and minimizes required repairs after a large earthquake
- Standards compliant and CE marking available
- Custom made for optimal performance of each structure



MAURER structural design

MAURER Damper safety concept

Benefits of MAURER Devices

- Individual parameter adjustment with regard to force and velocity
- Force limiter function available
- No significant prestressing and savely limited internal pressure
- Internal accumulator prevents excessive internal pressure due to fluid temperature change from ambient conditions or during transient events
- Long service life
- Suitable for bridge and other applications subject to daily movements

The devices can be applied in buildings or bridges

- Within bracing systems or
- in combination with seismic isolation bearing systems.




In most cases, seismic energy dissipation is the primary function of hydraulic dampers.

However, **in some cases additional features or hybrid functions** must be provided by the devices:

- **Lock-up** for wind or traffic load cases in railway or/and suspended bridges or soft buildings
- **Energy dissipation** for wind or traffic load cases in flexible buildings and bridge structures

When applying hydraulic devices dampers for frequent service load cases a detailed **investigation on fatigue and wear** must be carried out to safeguard a long service life!

MAURER devices can be designed and tested according to any required standards (EN15129 with CE marking; ASCE; AASHTO; etc.).

Adaptive Performance of Hydraulic Dampers – MHD and Shock Transmission Units (MSTU/MSTL)

Hydraulic dampers and shock transmission units are devices following the same physical function equation. All these devices respond with a certain force depending on velocity which for MAURER devices is an **adaptive performance** as damping constant and **damping exponents can be individually chosen.**

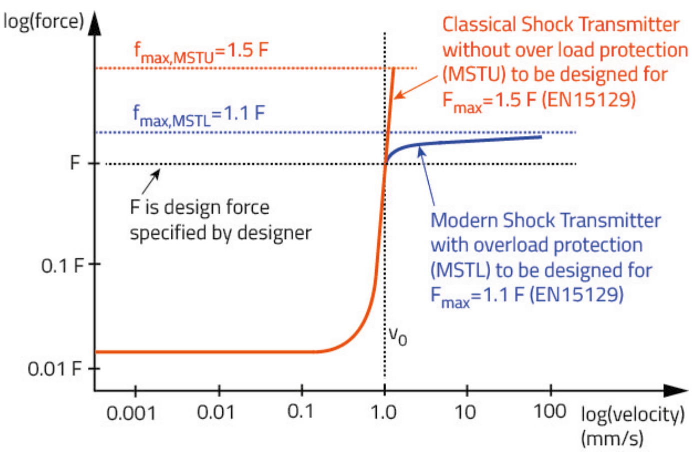
$$F = C \cdot v^{\alpha}$$

F = response force required for energy dissipation or lock-up
C = damping constant can be individually chosen!
v = displacement velocity along damper center axis
α = damping exponent can be individually chosen between 0.04 up to 2.0

Depending on the final field of application the force-velocity plots of MAURER hydraulic devices can be chosen to be linear viscous, progressive, degressive or even a combined mixture!

Samples for <u>adaptive performance</u> of MHD and MSTU/MSTL devices

Lock-up for shock-transmitter function plus integrated damping:

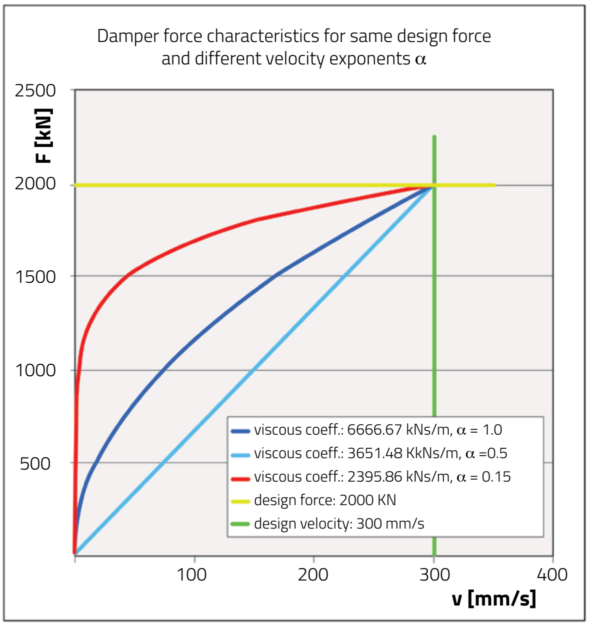


Immediate lock-up for service load cases like traffic (=> railway or severely wind-loaded structures) with damping **exponent α = 2.00** while force will increase even more than design limit (orange line). Alternatively, the damping **exponent α = 0.04** will provide a force limiter function (blue line).

Lock-up function starts from 0.1mm/s velocity - can be further adjusted on request - and continues to a specified force level. When exceeding this force level, the device will start to move while still responding with the pre-defined specific constant force independent from the initial velocity!

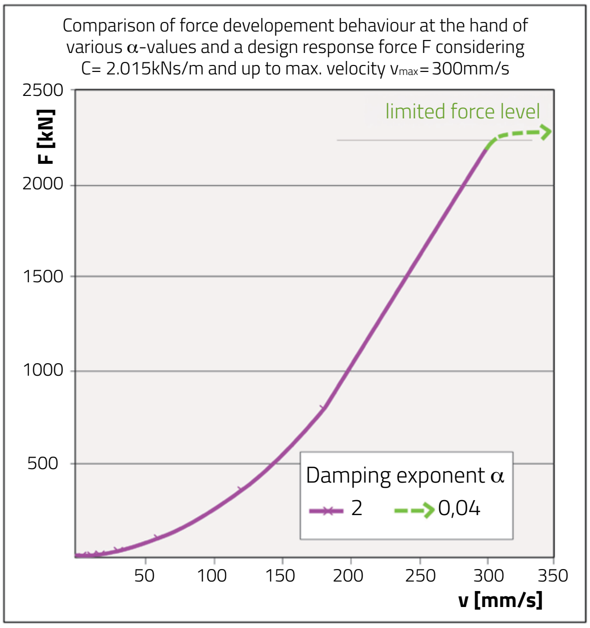
Benefits:

- Locking like a lock-up device for service impacts or even for seismic impacts on request.
- Dissipating energy during earthquakes on request.
- Force limiter function prevents overloading of device, attachments and even the structure!
- A nice side effect is the smooth and equal distribution of forces within several parallel and serial arranged devices within the structure! This function allows the use of lower safety/reliability factors and can reduce the size of structural elements, foundations and the device!
- Overall cost savings.



Soft to moderate force development function:

Design of linear, or even degressive, behavior for the force-velocity relation especially suitable for protection of building content for DBE load cases and still avoids large displacements for MCE load cases with damping **exponent** α **= 0.15 to 1.0**.



Very soft force development function:

Low initial force followed by **proportional progressive force development** for protection of content in operational earthquake load cases and limited displacements for MCE events at higher force levels with a damping **exponent** α **= 2.0**.

Important: If the max. velocities are not well known, the final max. forces within the dampers are also not well known with a conventional orifice! To avoid overloading, it is recommended to apply a damping exponent of 0.04 for **force limitation** starting from a well pre-defined force and velocity level to protect the device and the structure! See green line. This function is applied for large TMD systems within high rise structures, too.

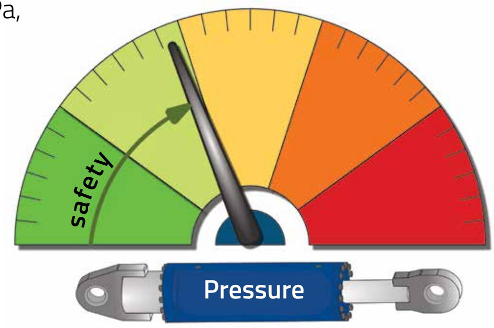
Safety and durability of MAURER Hydraulic Devices

The MHD devices are designed and manufactured according to highest possibly safety and durability considerations.

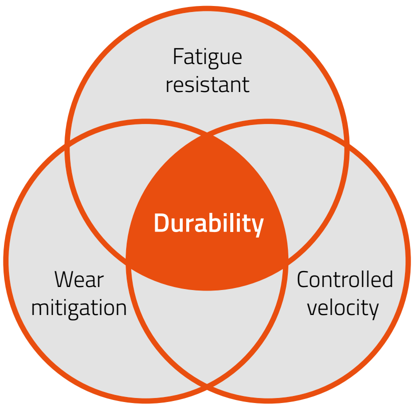
The specific MAURER design approach concentrates on strict conformance with design parameters, avoiding leaks, and minimizing fatigue together with wear for moving parts.

Safety concept with pressure and burst control

- **Burst protection** by passive automatic pressure limitation function.
- **No pre-pressurizing** or permanent at rest pressure greater than 1MPa, regardless of temperature!
- Max. pressure under service conditions is 25MPa.
- Max. pressure under rare short-term ultimate conditions is 60MPa.
- **No internal pressure increases due to temperature increase** caused by external environment or internal energy dissipation!
- No internal air lag due to fluid contraction at cold temperatures.
- Damper performance always considers all relevant load cases for SLS, ULS and earthquake!
- Non-flammable and non-toxic fluids.
- High internal reaction stiffness as fluid has high compression resistance.



Durability - Fatigue and wear control



- **Adapted fatigue resistant design** of steel parts for frequent service load cases of 2 Million load cycles or more.
- **Wear mitigation with specific low friction seal systems** to achieve 100,000m to 400,000m accumulated travel.
- Dust protection system by external dust cover and specific dust wiper system in front of seal system.
- Failsafe orifice and valve system developed from atomic power plant systems!
- Low velocity resistance between 0.5% to 3% of nominal rated force level.
- Leaking prevented by multi-seal-system.
- No scheduled maintenance necessary for regular service conditions.
- Large operating temperature range from -50°C to +80°C.
- Service life span of more than 50 years is the goal.

Monitoring

MAURER can offer a project-related monitoring system on request. The following data can be provided on an online platform or directly at the damper:

- Temperature of the structure
- Displacements
- Forces

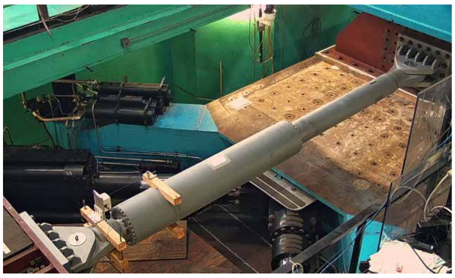
Testing of hydraulic devices

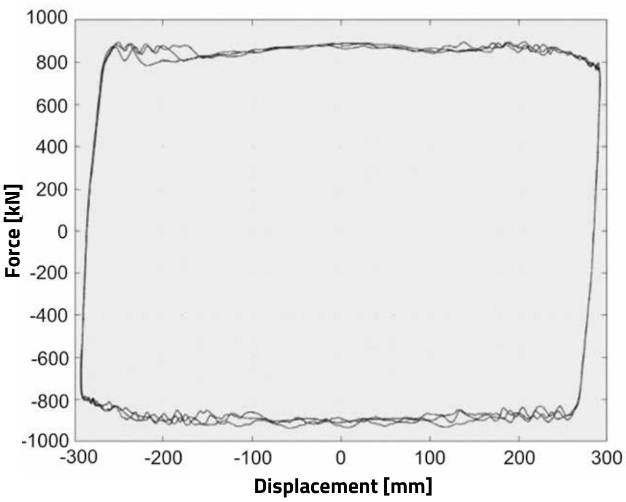
Before shipment, testing will be performed in accordance with any specified standard at an external testing institute for greatest authenticity of results or within the MAURER facilities if a reduction in cost is desired. Clients are always welcomed and encouraged to attend the testing.

There are various testing objectives:

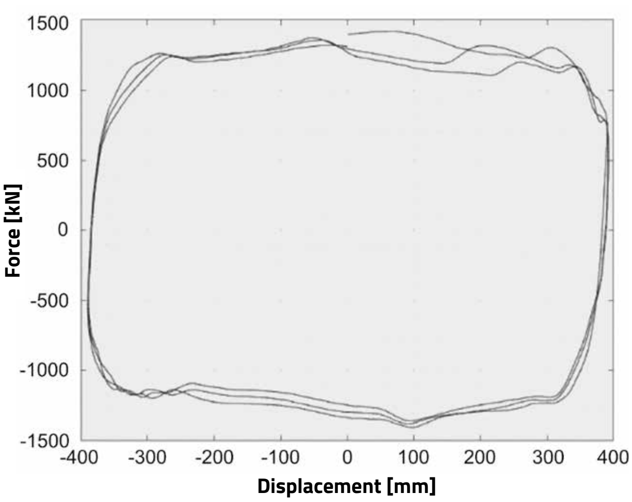
Prototype testing	Extensive testing with variations of velocity, amplitude, force, temperature, load cycles, etc.. One or two devices per type will be tested and depending on test intensity these can be refurbished and reused after testing.
Fatigue or wear testing	In structures with fatigue load cycles due to traffic, wind or other service phenomena the design of the devices must be properly adapted such that the testing for fatigue and/or wearing effects does not cause damage. The test forces and load cycles are according to design requirements of the individual project. The devices are usually not reused after testing.
Production testing	These tests are performed on a certain percentage of all devices or even on all devices. Depending on the standard or project requirements 3-5 dynamic cycles will be tested at one or more velocities. In addition, a static pressure proof test will be carried out on request.

The dynamic testing of MAURER devices was carried out with up to 6,500kN, 2.3m/s and +/-500mm. However, the force-velocity-displacement relation must be adapted to the test rig capacity, i.e. not all max. values for forces, velocity and displacement can be combined.



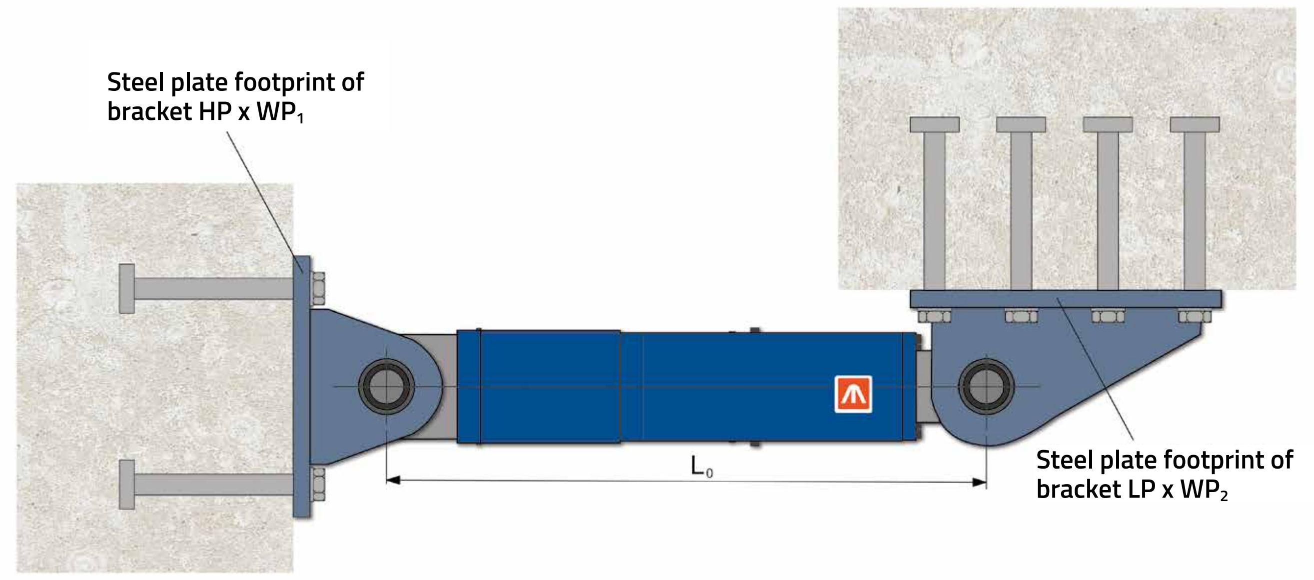


Velocity of 500 mm/s



Velocity of 2000 mm/s

Preliminary sizes for
MHD (MAURER Hydraulic Damper) and
MSTL (MAURER Shock Transmission Unit <u>with</u> Force Limiter)



Assumptions:

- Max. displacement velocity 500mm/s including an over-velocity assumption of 150% (=> see EN15129). Design can be up to 2,300mm/s!
- F_{max} is the max. design reaction force including reliabilities from earthquake input, upper bound limits and standards. The capacity limit force of the device is usually by factor 1.2 greater.
- For a frequent service force level it is assumed 25% of F_{max} and this is combined with 200,000 load cycles. Other individual load cycles histories are possible with modified design.
- Damping exponent is 0.04. Others are possible up to 2.00, while size may change.
- Displacement d_{max} is the total displacement, on which +/-10mm will be added for final capacity limit of device (i.e. max. theoretical stroke = +/-210mm).

Hydraulic Damper (MHD) and Shock Transmitter <u>with</u> force limiter (MSTL)

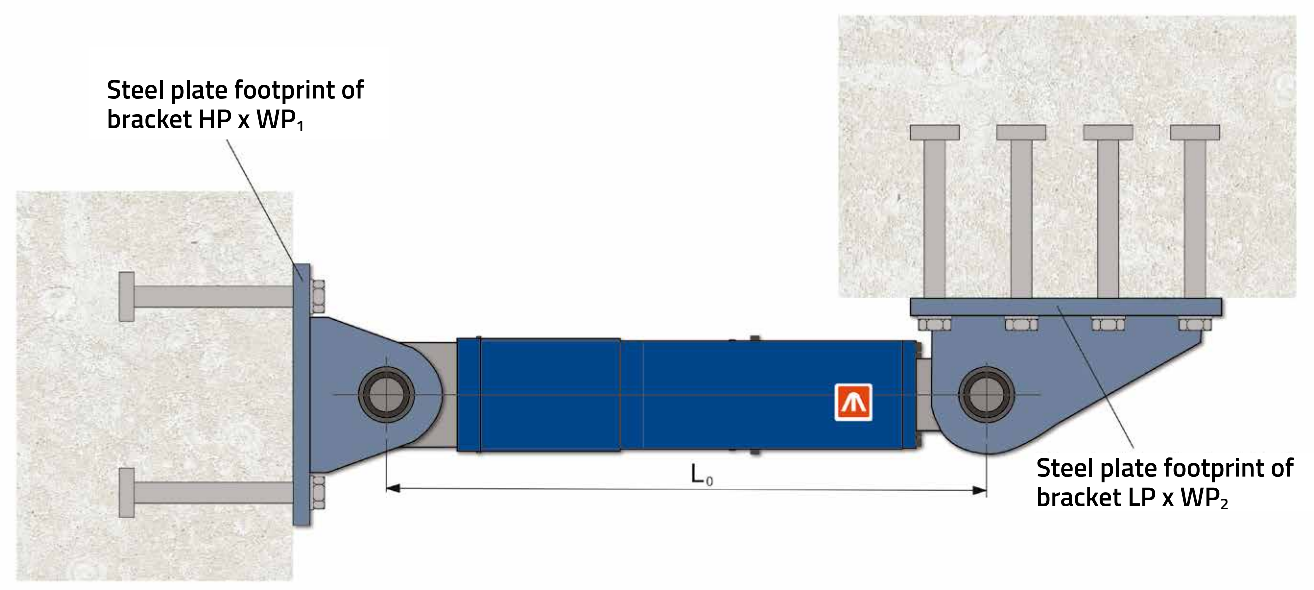
F_{max} [kN]	$\pm d_{max}$ [mm]	L_0 [mm]	HP [mm]	WP_1 [mm]	LP [mm]	WP_2 [mm]
800	200	1940	210	360	420	360
1400	200	2120	320	400	710	400
2100	200	2095	460	420	860	420
3000	200	2300	650	480	1010	480
3600	200	2500	730	540	1010	540
4600	200	2600	900	630	1310	630
5000	200	2750	900	630	1500	630
7250	200	3000	900	630	1500	900

Larger displacements are available but will increase value of L_0 by 5 times the additional stroke.

Sample: For +/-300mm, the delta compared to above displacement of +/-200mm is +/-100mm. Then 5 times 100mm is resulting in 500mm larger L_0.

For movement capacities beyond +/-500mm and velocities larger than 500mm/s the size of the devices may change disproportionately as other effects like buckling and energy dissipation will gain more dominant influence. Individual sizing is necessary then. Consult your MAURER representative for these dimensions.

Preliminary sizes for
MSTU (MAURER Shock Transmission Unit **without** Force Limiter)



Assumptions:

- Adjustable activation velocity v_0 = 0.1-5mm/s
- F_{max} is max design force while for capacity limit a further reliability of 1.5 will be added.
- Damping exponent without force limiter is 2.00.
- Displacement d_{max} is the total displacement, on which +/-10mm will be added for final capacity limit of device (i.e. max. theoretical stroke = +/-210mm).
- SLS load was assumed to be 25% of F_{max}, combined with 200,000 load cycles
- Sizes of MSTU are bigger compared to MSTL types as reliability factor without force limiter function must be set according to EN15129 - to 1.5!

Shock Transmitter without force limiter (MSTU)

F_{max} [kN]	$\pm d_{max}$ [mm]	L_0 [mm]	HP [mm]	WP_1 [mm]	LP [mm]	WP_2 [mm]
620	200	1940	210	360	420	360
1100	200	2120	320	400	710	400
1600	200	2095	460	420	860	420
2300	200	2300	650	480	1010	480
2750	200	2500	730	540	1010	540
3500	200	2600	900	630	1310	630
3800	200	2750	900	630	1500	630
5600	200	3000	900	630	1500	900

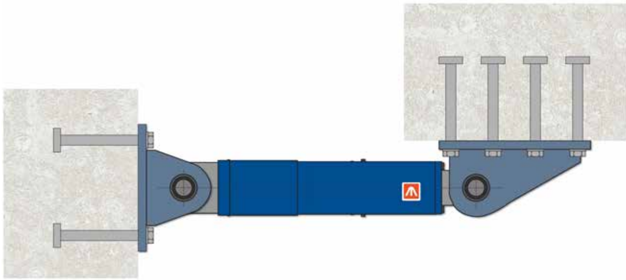
Larger displacement will increase value of L_0 by 5 times the additional stroke.

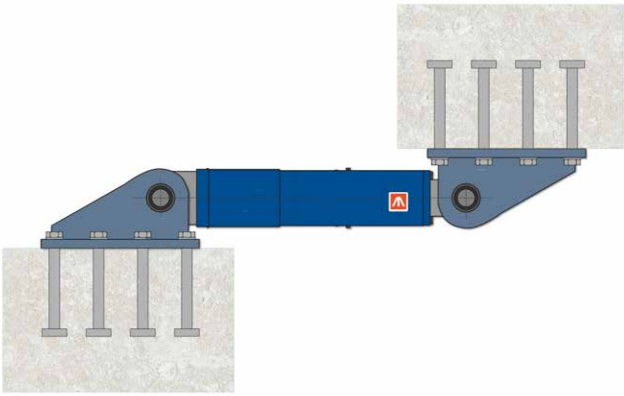
Sample: For +/-300mm, the delta compared to above displacement of +/-200mm is +/-100mm. Then 5 times 100mm is resulting in 500mm larger L_0.

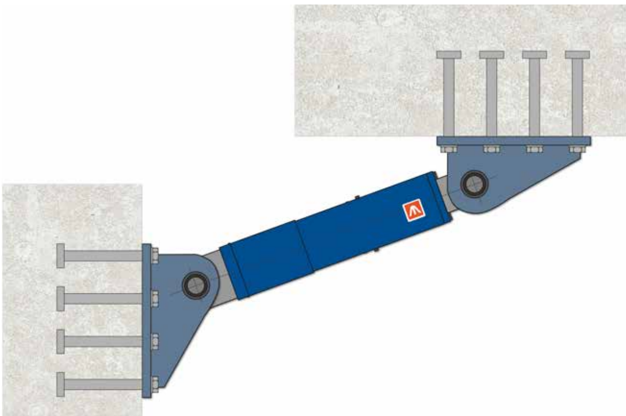
For movement capacities beyond +/-500mm the size of the devices may change disproportionately as other effects like buckling will have more dominant influence. Individual sizing is necessary then. Consult your MAURER representative for these dimensions.

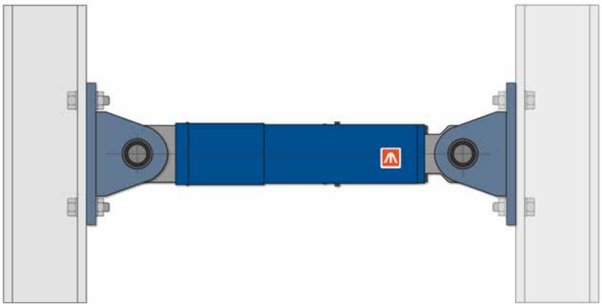
Options for various fixation methods for hydraulic devices to concrete or steel structures – any individual arrangements can be designed!

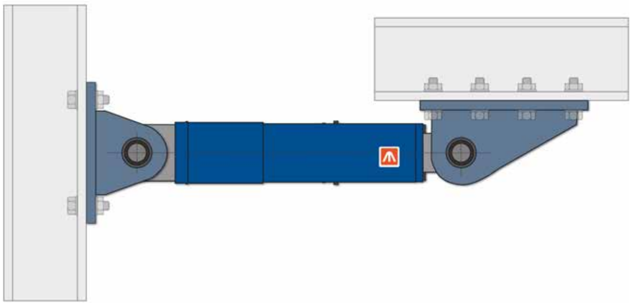

Both sides compression and tension on brackets

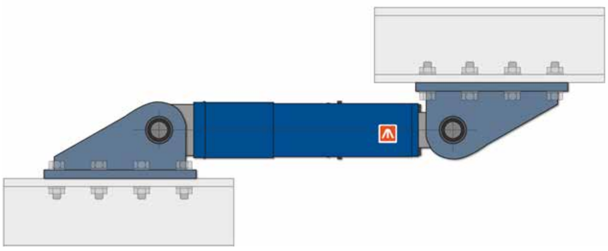

One side tension/compression and other side bending with overturning

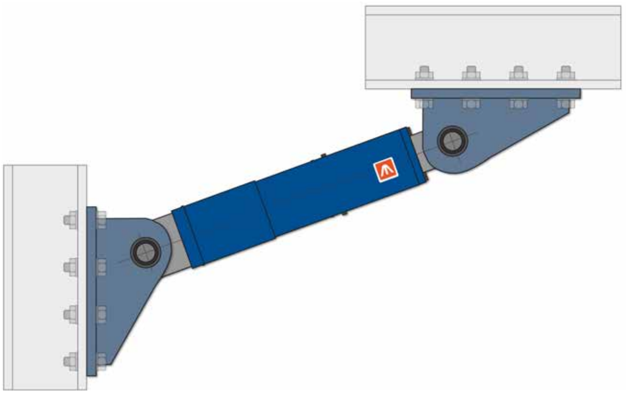

Both sides bending with overturning


Inclined arrangement with one side more of tension/compression and other side more of bending with overturning


Both sides compression and tension on brackets


One side tension/compression and other side bending with overturning


Both sides bending with overturning


Inclined arrangement with one side more of tension/compression and other side more of bending with overturning

A combination of steel and concrete connections is possible. All connection brackets can be individually designed on request.

Designs of MAURER Hydraulic Dampers – MHD and Shock Transmission Units (MSTU/MSTL)

Short design with pin-hinge and flange

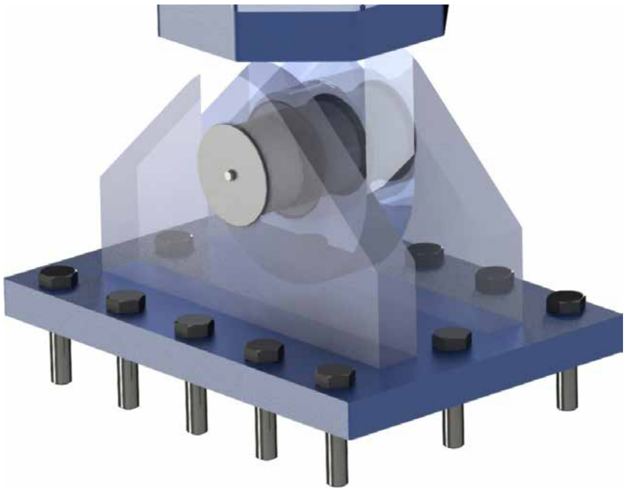
Damper systems in buildings are often integrated in braces. These diagonal braces require a hinged-flange type damper to allow out of plane rotation. The hinge can be designed for 4-8° rotation around any axis and is made of a maintenance-free spherical bearing. The flange connection will be designed to properly connect to the flange of the structural extender brace required by the engineer.

Short design with cardan joint on one or both ends

This damper allows high rotation performance while reducing the installation length. With this cardan hinge system 8-35° rotation around any axis can be realized. All hinges are made of sliding bushes or a maintenance-free spherical bearing. The hinge bracket connection will be designed for the bolt layout system required by the engineer. A reduction of length by 10%-25% is possible.

Long design with pin-hinge on both ends

Damper systems in buildings within chevron braces or in parallel with base isolation bearings or within bridges require hinges at both damper ends for proper connection and accommodation of rotations and displacements. The hinge can be designed for 4-8°(or even more) rotation around any axis and is made of a maintenance-free spherical bearings. Any brackets towards the bridge deck, pier or abutments will be individually designed to fit with concrete anchors or bolts to the structure.



Application samples of MAURER Hydraulic Devices

Depending on the final field of application of any damper or shock transmitter system, the devices must be designed individually to the needs of the specific building, bridge, industrial structure, artwork or any other structural system.

To achieve this, many influencing factors must be checked and investigated before recommendation of a damper/STU system is possible!

Weather phenomena **Traffic** **Creep and shrinking** **Earthquake**

Building applications

Bank Data Center Building - Napoleon Bolanos in El Salvador

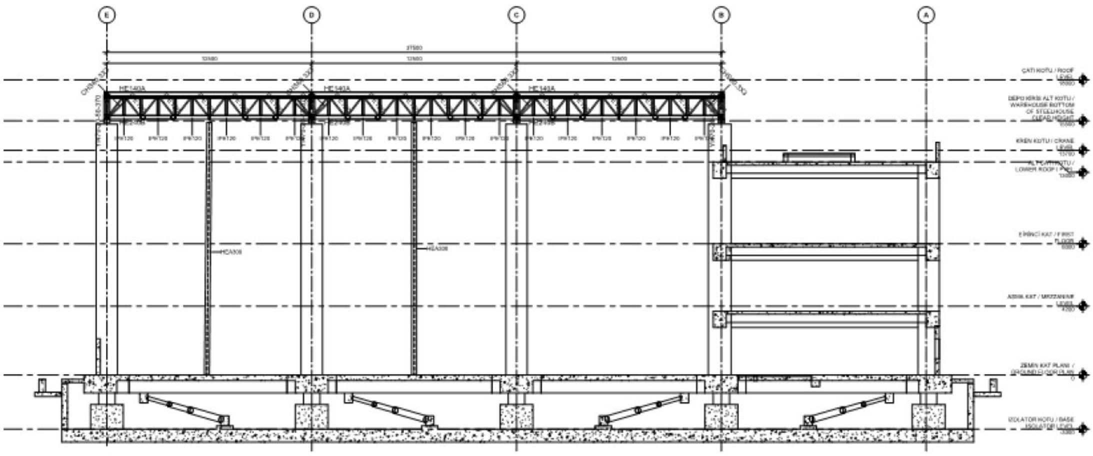
The bracing system within the Bank Data Center Building Napoleon Bolanos in San Salvador increased the level of inner system damping significantly. The dampers were designed for the MCE seismic event to reduce the inter-story drift from 3.5% to max. 1.0% and to reduce accelerations to max. 0.3g inside the structure for proper content and structural protection. There were 20 dampers for 1,000kN to 2,000kN with +/-60mm displacement capacity. The damping exponent was chosen to be 0.2 to allow immediate damping forces on a reasonable high level for effective displacement control of the rather stiff old structure.




Ferrero Hazelnut Cracking Plant

The isolation system of the new Ferrero Hazelnut Cracking Plant with 63,700 ton total weight was realized with isolation pendulum bearings (SIP®-D) and lead rubber bearings (MLRB). Addtional hydraulic dampers for effective displacement control and to reduce the original displacements from more than +/-1.5m down to +/-1m amplitude were applied.

This was achieved with 20 pcs up to 4,400kN MHD devices with damping exponent α of 0.3 combined with 1.4m/s displacement velocity. Together with the amount of damping from the isolator system and the hydraulic devices, a base shear of max. 20-25% could be achieved, as the hydraulic dampers work out of phase compared to the isolator system shear.



Orhideea Towers in Bucharest

In the soft direction of the slim towers, which are only 15m wide but 80m tall, a damper diagonal bracing system was installed for proper displacement control during wind and earthquakes. The dampers were designed for the MCE seismic event to limit inter-story drift to maximum of 1.5%. There were 56 dampers for 1,100kN to 1,550kN with +/-50mm. The damping exponent was chosen to be 0.15 to help generate forces in case of strong wind loads with remarkable damping effects, too.

Bridge applications

Ponte Sao Joan in Porto, Portugal

This 1,140m long existing concrete bridge is loaded by frequent and heavy railway traffic. The 68m tall piers monolithically connected to the deck are set into the water of river Douro. This configuration would result in a significant unacceptable longitudinal inelastic movement of the entire deck due to train emergency braking forces or earthquakes. To limit these movements for protection of the railway joints at both deck ends, 2 pcs. of MHD units for 3,600kN were considered in both abutments and further 2 in the transition joint of the approach viaduct. The original and much smaller dampers had to be removed within this retrofit project since they did not meet current requirements with regard to the new service nor to recent earthquake load levels. The damping exponent of 0.2 allows rather high forces at lower velocities to keep the deck in position even for ultimate service braking forces. In case of earthquake up to +/-80mm movement will result in energy dissipation. To compensate for uncertainties of the rather big installation tolerances of the already existing structure, it was decided to apply on both damper ends cardan joints, which in addition allowed a very short damper design with rotational capability around any axis bigger than +/-8°.

Railway Bridge SG26 in Greece

The 300m long new arch bridge is part of the Tithorea–Domokos railroad network and is located near city Domokos. The sliding isolation bearings provide horizontal isolationand recentering. The 16 pcs. lateral and longitudinal hydraulic dampers for 750-3,000kN have four main requirements. First, to allow slow thermal movement with less than 3% of nominal response force. Second, to immediately lock up for any service braking forces by utilizing a damping exponent of 0.04. Third, to dissipate energy during earthquake to limit structural movement to +/-300mm. And fourth, to provide overload protection for velocities beyond 500mm/s not to overload piers and weak foundations, this is achieved with a damping exponent of 0.04.

Albatros Bridge in Lázaros Gárdenas - Mexico

The Albatros Bridge is a double bascule bridge offering a 50m width for the passage of big ships when opened. It was decided due to the rotation opening mechanism, to keep the structure exactly in position on top of the piers during an earthquake and not let it move while dissipating energy. Consequently, the pier structure and the related hydraulic shock transmission units had to be designed to be rather massive. The required 46 pcs. MSTL devices (MAURER Shock Transmission Unit with Force Limiter) were designed for 2,500kN to 3,500kN. The MSTL is locking up starting from 0.5mm/s. The lock-up force is kept until 110% design level. Beyond this level the MSTL force limiter releases, while keeping the resistance force constantly on design locking level. This unique force limiter mechanism allows activation of all 46 units equally and simultaneously, while not overloading the structure nor the single devices! All MSTLs distribute the forces evenly within the structure and protect it. A very nice side effect of the force limiter function is, that according to EN15129 it is allowed to decrease the reliability factor on the STU forces from 1.5 to 1.1, having a direct effect on the STU size, and also on structural design with a related significant cost savings!

Toluca Railway Bridge near Mexico City

Viaduct 2 with a total length of 4,000m is part of the metropolitan railway between Mexico City and Toluca. There are 12 pcs 3,000kN MHDs per 700-850m long single deck section. To achieve good, even seismic longitudinal performance and reduction of seismic forces, the deck will move for MCE level earthquake +/-450mm. The damping exponent α=0.04 was chosen to provide the best possible overload protection and extremely good force limitation as max. displacement velocities are likely to be exceeded in this seismic region.

Product Information

MAURER Hydraulic Dampers
MAURER Shock Transmission Units

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