Structural Protection Systems

Structural Protection of Railway Bridges

Overview of MAURER System Solutions

MAURER SÖHNE
forces in motion
Since 1876

Introduction

Compared to road bridges, railway bridges are different, because the trains that pass bridges bring about different requirements. When trains pass a bridge, the traffic loads are higher, which means that the relation between dead load and live load is a different one as compared to road bridges. Further, High Speed Trains pass bridges considerably faster than conventional road traffic.

Translated into the language of the engineer, higher forces move relatively fast over a structure, having implications on the design of the bridge itself as well as for the protection system of the bridge.

As a consequence, products that are suitable for the use in road bridges might not be equally suitable in railway bridges, but have to consider these particularities.

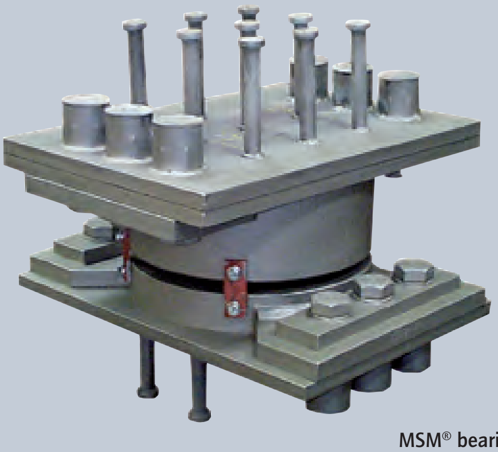
Below shall be demonstrated that Maurer Söhne can supply a complete product range of bridge accessories that especially cater for the requirements of railway traffic.

Our products – in particular the railway expansion joints and the bridge bearings – enjoy the approval of German Railways.

The innovative strength of MAURER can also be demonstrated by the many patents and approvals that Maurer Söhne holds, such as a patent for a special sliding material in bridge bearings.

Pot bearings with vertical load monitoring system installed at the railway track of the French TGV

MAURER shock transmitters with force limiter (MSTL), to be installed at the Northern Railway Bridge in Budapest, Hungary, implementing a floating support system in combination with MAURER SIP bearings.



MSM® bearings for the Maglev Train in Shanghai

Why MAURER Hydraulic Dampers are Best Value

In a project it is not necessarily the cheapest device that offers best value, but it is rather that kind of device that permits the biggest cost savings in the structure. This will be demonstrated below.

The constitutive law of the hydraulic damper is the following:

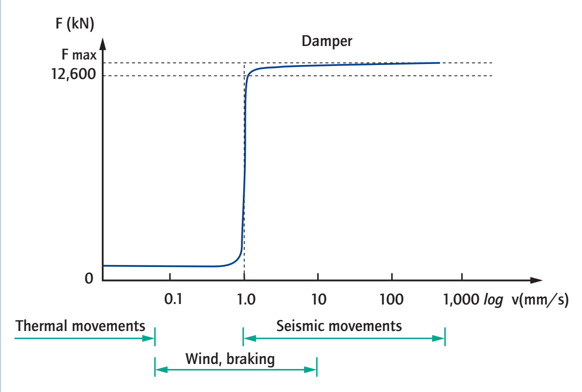
$$F = C \cdot v^a$$

F is the response force, C is a damper constant, v the displacement velocity in mm/s, and the exponent **a** represents an index of the hydraulic damper's grade (quality). The best of the competitors' devices display an **a** value of between 0.10 and 0.15. MAURER's **a** value is 0.015.

For the designer, the response force of the damper is the maximum force that must be taken into account when designing the anchor system as well as the adjacent structure.
Let's compare the maximum force F_{max} for the three above mentioned **a** values under the assumption that the maximum design velocity is equal to v_{max} = 300 mm/s:

a = 0.015	F_{max} = 12,600 x $300^{0.015}$	=	13.725 kN
a = 0.10	F_{max} = 12,600 x $300^{0.10}$	=	22.289 kN
a = 0.15	F_{max} = 12,600 x $300^{0.15}$	=	29.644 kN

The true added value of MAURER hydraulic dampers lies in the minimisation of the overall costs of a structure that is exposed to seismic events.



Actual characteristic force vs. velocity curve of a 12,600 kN hydraulic damper equipped with shock-transmission function

7.3.2 Over velocity

The design force shall be amplified by a reliability factor γ_v equal to the following:

$$\gamma_v = (1+t_d)\cdot(1,5)^{\alpha} \qquad (11)$$

where:

t_d is the design reaction tolerance guaranteed by the manufacturer

α is the exponent of the constitutive law guaranteed by the manufacturer

NOTE A typical design reaction tolerance guaranteed by the manufacturers at ambient temperature is ±15% (t_d=0,15). Anyway, the t_d value to be considered for design purposes should include temperature effects.

Extract from prEN15129 – Anti seismic devices

What the European Standard prEN15129 states about Hydraulic Dampers

An additional safety for the structure is a by-product of the small **a** value. Because, just in case the actual movement velocity should exceed the design velocity, a small **a** value very much limits the additional response force that the designer has to take care of. A hydraulic damper with a low **a** value thus acts in the same time as a force limiter.

The European Standard prEN15129 (draft) governs the use of anti-seismic devices. Chapter 7.3.2 introduces a formula according to which the design force shall be increased as a function of this **a** value, when an over-velocity occurs.

If we consider this formula, and assume the design reaction tolerance to be equal for all **a** values, the reliability factor, i.e. the increase of the design force in percentage would be as follows:

To come back to our example, the design force that should have to be considered at the maximum speed of 300 mm/sec and a nominal response force of 12,600 kN, including reliability factor, would be:

MAURER damper
a = 0.015: td = 5%
13,725 kN x 1.056 = 14,494 kN

Competitor damper
a = 0.10: td = 15%
22,289 kN x 1.197 = 26,679 kN

a = 0.15: td = 15%
29,644 kN x 1.221 = 36,195 kN

In short, NOT considering a MAURER hydraulic damper would have as a consequence to consider a design force for the structurally adjacent parts to be up to 250% of the respective "MAURER damper" design force.

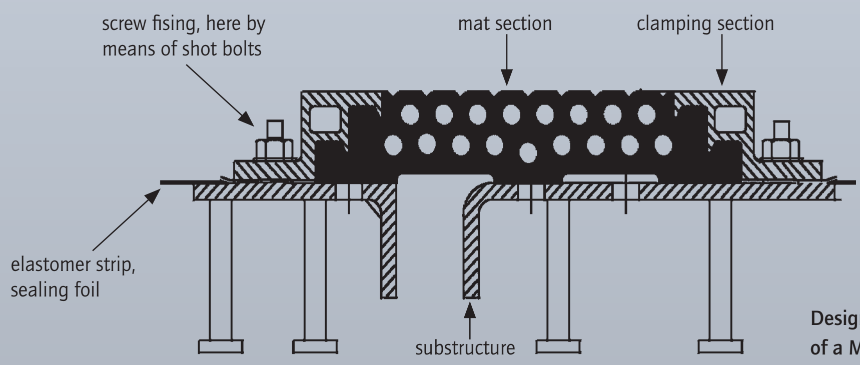
MAURER hydraulic dampers with 2,500 kN design force and 700 mm movement capacity for the Domovinski Bridge in Croatia

Railway Expansion Joints

Various products cater for various needs, from the low cost elastoblock expansion joint to our flagship, the DB mat series. Whereas the former 2 varieties are designed for ballasted tracks, MAURER also offers a conventional type of expansion joint for ballastless tracks. All types ensure absolute watertightness.

TYPE	Movement in x direction (perpendicular to joint axis)	Movement in y direction (parallel joint axis)	Vertical movement
DB 40	± 20 mm	± 40 mm	± 20 mm
DB 80	± 40 mm	± 60 mm	± 40 mm
DB 130	± 65 mm	± 100 mm	± 65 mm
DB 160	± 80 mm	± 120 mm	± 80 mm
DB 260	± 130 mm	± 200 mm	± 130 mm

Maurer DB movement joint types. DB 160 and DB 260 consist of 2 mats.

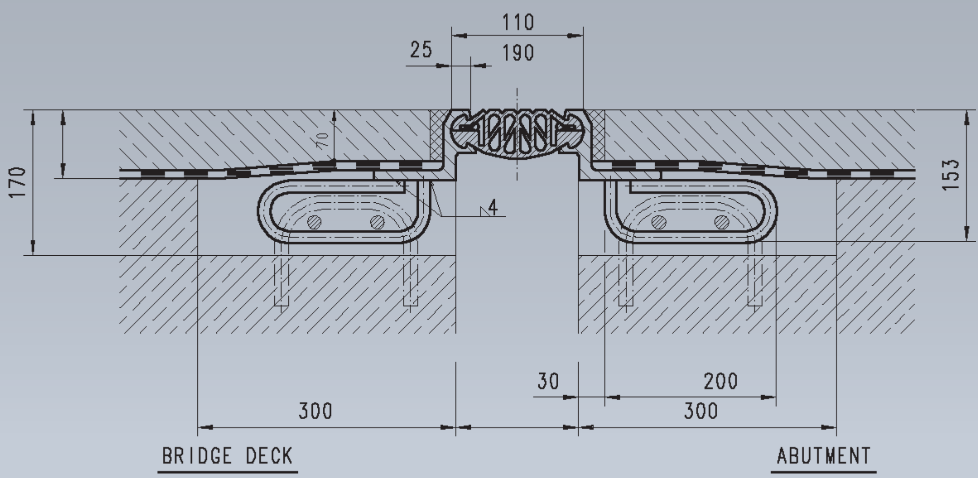


Design principle of a MAURER DB joint

Two different methods of installation
Depending on the mode of construction, DB joints can be installed the conventional way, that is into a blockout. Or alternatively, precast segments can be equipped with the substructure (i.e. the anchor system) of the expansion joints, which requires no blockout.

Conventional installation method, that is the prefabricated DB 160 expansion joint is lowered into an existing blockout and then concreted.

Alternative installation method. Here, the substructure is part of the precast segment, and the superstructure is fixed by means of shot bolts. This method requires no blockout and facilitates traffic on site.



Low cost elastoblock joint can be used in cases where no vulcanisation of mats is required.

MAURER Railway Joint Design Types
- DB series expansion joints
- Elastoblock expansion joints
- Ballastless track expansion joints
- Open joints
- Railway turnouts

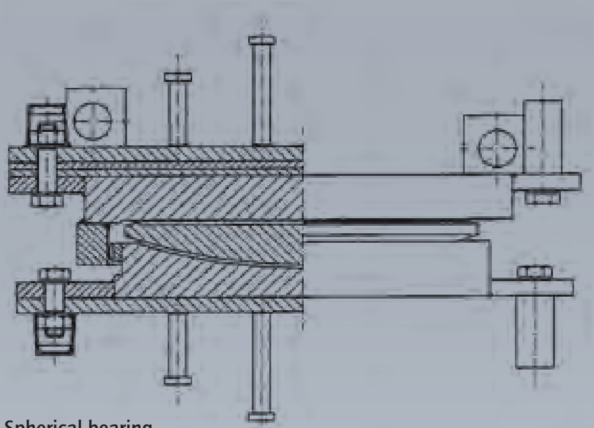
Bridge Bearings

Bridge bearings that are to be used in railway bridges, have to satisfy additional requirements that have their base in the nature of railway bridges:

The relationship of live load to total load is relatively high. So each time a train passes, the additional load is relatively high, causing considerable movements and reaction forces in the bridge bearings.

When train traffic passes in high speed, these movements have to be carried out in a very short time.

A Spherical Bearing with MSM® as high performance sliding material



Spherical bearing

Spherical Bearings

Spherical bearings enjoy a variety of advantages over conventional pot bearings:

- Spherical bearings do not contain an elastomeric pad, so in case of rotation no restoring moment (due to resistance of rubber to be compressed) need to be considered for the design of the bearing.
- With the lack of elastomeric pads, no sealing elements are required which are the limiting factor for the life time in pot bearings.
- Likewise, the permissible pressure in the bridge bearing is no longer governed by the permissible pressure in the elastomeric pad, which in most cases is the limiting factor for the size of pot bearings.

A new dimension in high performance bearings can be reached when spherical bearings are combined with MSM® as sliding element, instead of PTFE. In that case, performance at very low temperatures is greatly enhanced due to a reduced coefficient of friction. Further, MSM® facilitates a higher sliding velocity. Last but not least, the MSM® spherical bearings can take higher stresses than conventional PTFE sliding bearings, resulting in even smaller dimensions.

Spherical Bearings
Largest loads

- Large rotation angles
- Reduced, small dimensions
- Direct transmission of horizontal forces
- Rotation is pre-adjustable
- Design characteristics do not change within the bearings life time (no ageing material is used)
- Long life time

Pendulum Bearings for the Isolation of Piers from Horizontal Loads (SIPs)

SIP bearing installation at the shake table of the seismic test laboratory of the University of California in San Diego, USA. Here to be seen the special calotte with its 2 curvatures above and below.

With the advent of high speed traffic, higher speed may cause higher braking forces to be transferred. Older structures however were not designed to accommodate higher braking forces. The technical solution lies in so called "Sliding Isolation Pendulum Bearings" (SIPs), which isolate the superstructure from the substructure. Consequently, horizontal loads which are induced by the superstructure cannot be introduced into the substructure (or vice versa). This way, a floating support system combined with Shock Transmission Units can be realized, like in the Northern Railway Bridge in Budapest, Hungary.

Pot Bearings for Railway Bridges

In many countries, railway administrations consider pot bearings still to be state of the art, and spherical bearings are rather unknown. But even if railway administrations hesitate to change from the established pot bearings to the more sophisticated spherical bearings, some details have to be observed in order to ensure a sufficient life time.

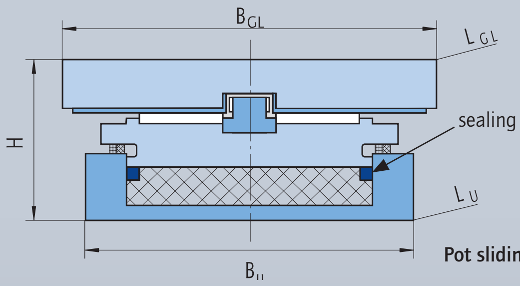
In railway bridges, where loads are relatively high, considerable rotations of the elastomeric pad are caused by passing train traffic. These rotations can be translated into up and down movements of the sealing elements, which add up over passing time to an accumulated sliding path.

At the European level, EN 1337-5 specifies the types of material available for sealing elements, and their maximum accumulated sliding path:

Sealing Material	Accumulated Sliding Path	Category acc. EN 1337-5
Stainless Steel	500 m	A
Brass Seal	1,000 m	B
POM (Polyoxymethylene)	2,000 m	C
Carbon filled PTFE	2,000 m	C

Classification of sealing elements according to EN 1337-5. Sealings of category C are required for railway bridges.

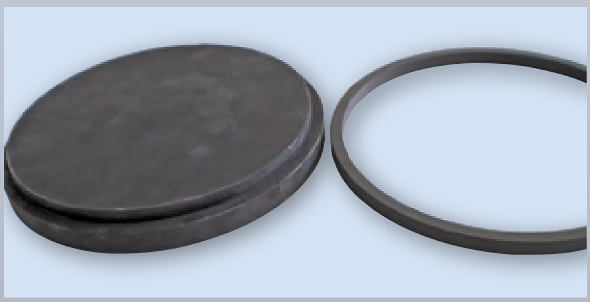
In railway bridges, only sealing elements of category c are permitted. MAURER Pot Bearings use carbon filled PTFE as sealing element, which is category C.



Pot sliding bearing

Monitoring

When under load, the elastomeric pads behave like a fluid, and there is a hydrostatic pressure in the pot. This hydrostatic pressure can be measured, and this way the vertical loads that act onto the pot bearings can be monitored. Pot bearings for the French TGV were equipped with sensors that monitor the vertical loads of the pot bearings. This way, changes in the load distribution of a bridge can be detected.



Elastomeric pad and carbon-PTFE sealing

MSM® – a New Sliding Material Especially Suited for High Speed Railways

Sliding bearings that have to cater for special requirements of fast and frequent movements, need to be upgraded with a new generation of sliding material that warrants the service life that we are used from conventional sliding bearings.

	PTFE	MSM®
Displacement velocity tested	2 mm/s (acc. EN 1337-2)	15 mm/s
Accumulated sliding displacement	10,242 m (acc. EN 1337-2)	50,000 m
Characteristic contact pressure f_k	90 N/mm^2	180 N/mm^2

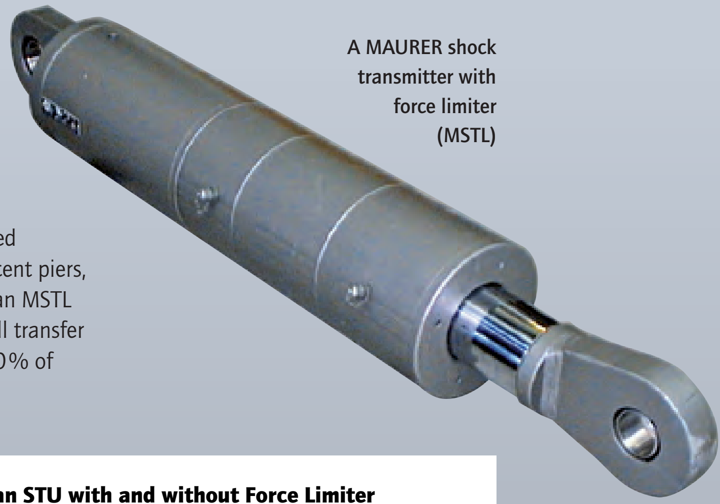
Comparison PTFE – MSM®

In the European Technical Approval (ETA) of MSM®, it is stated that *MAURER – MSM® – spherical bearings are particularly suitable for soft structures with relatively large and frequent displacements caused by traffic, next for structures that employ fast sliding displacements of the bearings, like in bridges for high speed railways, as well as for regions of continuously low (to –50°C) and very high (to +70°C) temperatures.*

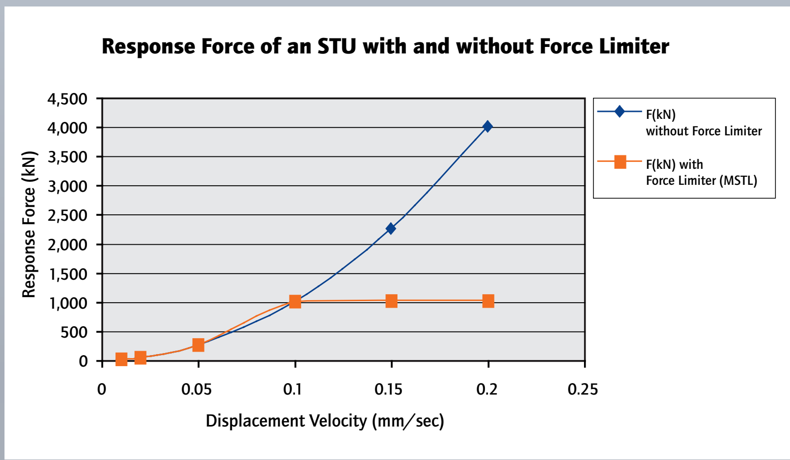
MAURER Shock Transmitter with Force Limiter (MSTL)

In railway bridges, apart from attacks caused by earthquake which might be relatively rare, a rather more likely occurrence might be braking forces of the train that are suddenly induced into the bridge structure, causing a high displacement velocity. A shock transmission unit (STU) will enact its function, coupling adjacent fields such that every pier will have to receive an equal share of the horizontal load. However, due to tolerances in construction, the load distribution might not be equal. For example, because of being stiffer due to whatever reason, some piers might get an undue share of the horizontal load, and will have to deflect much more until they can pass over their (horizontally acting) load to the adjacent pier. In a worst case, even when applying an STU, when an individual structural member defaults due to excess strain, the total structure may then be endangered, because the same high longitudinal force now has to be accommodated by fewer piers, causing perhaps the next pier to default.

A MAURER MSTL is a shock transmission unit with a force delimiter. Thus the MSTL ensures that only a certain maximum design force can be transferred. Once the actual horizontal force to be transferred would exceed the design force, the MSTL "opens" and starts to move, still allowing the limited forces to be transferred to adjacent piers, or the abutment. For example, an MSTL can be designed such that it will transfer to the pier not more than of 110% of the design force.



A MAURER shock transmitter with force limiter (MSTL)



Force vs. velocity graph of a 1,000 kN shock transmitter with and without force limiter (MSTL) that deploy their design force at 0.1 mm/sec

Cost Advantage for the Structure when employing an MSTL (with Force Limiter)

In chapter 5.3.3., prEN15129 states for STUs the following:

The reliability factor γ_x for the TCD shall be 1,5, unless an overload protection system is incorporated.

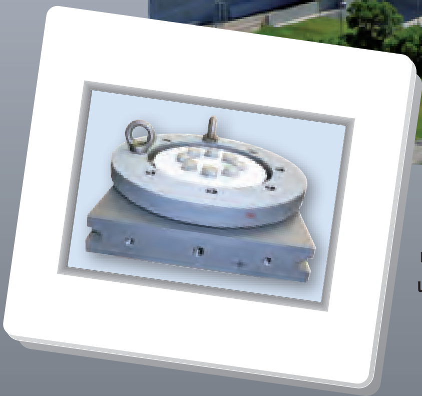
In the above example, the adjacent structures should have to be designed for 1,500 kN design force, unless an MSTL is employed. In that case, prEN15129 rules that the reliability factor for systems with overload protection shall be 1.1.

MAURER Hydraulic Dampers (MHD)

Hydraulic dampers are energy dissipators that so to speak swallow "bad" energy introduced into a structure, such as energy caused by a seismic attack. The particularity of a MAURER hydraulic damper (MHD) is that the response force is practically independent on the displacement velocity of the seismic attack. Consequently, knowing that under no circumstances the response force can be bigger than as per design, the adjacent structures can be designed more economically.

Testing a MAURER hydraulic damper at an independent test laboratory

MAURER Structural Protection of Railway Bridges



Because of the fast and frequent movements of the Tsing Ma Bridge bearings, caused by frequent rail traffic to Hongkong Airport, the bridge had to be refurbished with new and wear resistant MAURER MSM® spherical bearings – here an MSM® spherical uplift bearing in assembly stage.

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