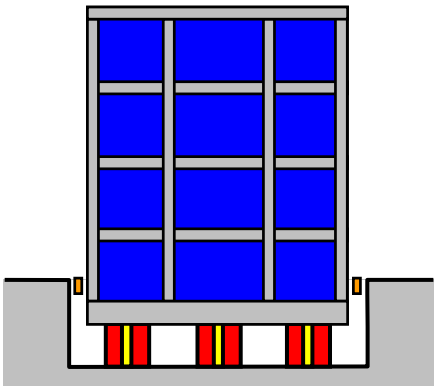
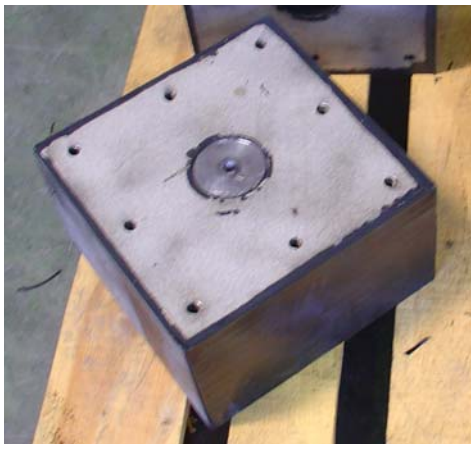
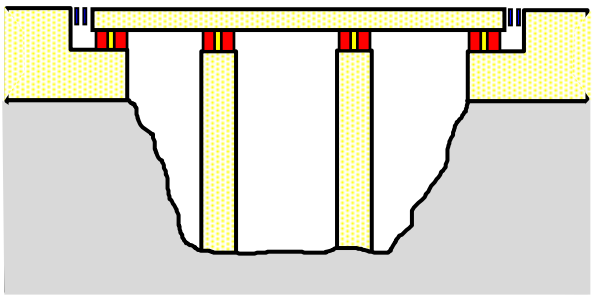
MAURER
Seismic Isolation Systems with Lead Rubber Bearings (MLRB)







Product and Technical Information

Basic Principle of Seismic Isolation by Energy Mitigation realized with MLRBs

MAURER Lead Rubber Bearings (MLRB) are based on the design principles of the EN1337 (Structural Bearings) and the prEN15129 (Anti Seismic Devices). The device is a regular rubber bearing for service condition and it is a seismic isolator for the seismic condition. The bearing plan shape can be round, square or rectangular, whereas the design rules according to the EN standards were applied.

The production of the MLRBs is within the DIN ISO 9001 quality management system.

MLRBs can be applied for buildings and for bridges.

The seismic isolation of a structure is based on the concept of ENERGY MITIGATION and costly strengthening measures are avoided as the resulting forces are mitigated within the structure.

Two methods are simultaneously applied:

1. **Seismic isolation by MLRBs:**
   The superstructure gets de-coupled from the ground. The so called seismic-isolation limits automatically the energy to a minimum to enter the superstructure during an earthquake. Due to this fact the natural period of the structure is increased, therefore reduces the spectral acceleration during a seismic attack (Fig. 1). Depending on the type of the employed multidirectional seismic isolators – in this case MLRBs - they grant for the vertical load transmission but also for the active re-centring of the superstructure during and after an earthquake (Fig. 2+3). Re-centring means that the bridge deck displaced due to the seismic energy input is automatically shifted back by the seismic isolators into its original position.

2. **Energy dissipation by MLRBs:**
   By means of passive energy dissipation (= energy transformation into heat) the seismic rest energy entering into the superstructure will be effectively dissipated by additional damping within the lead core of the MLRB relieving the entire structure from additional strain (Fig. 2+3).

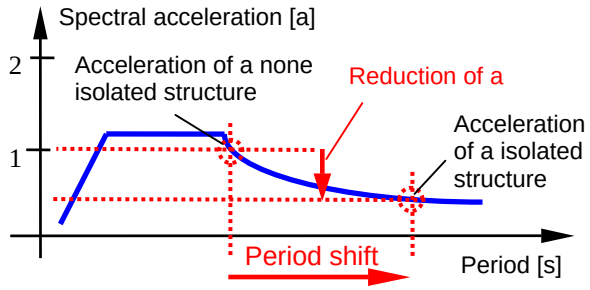


Fig. 1: Characteristic response spectrum of a bridge

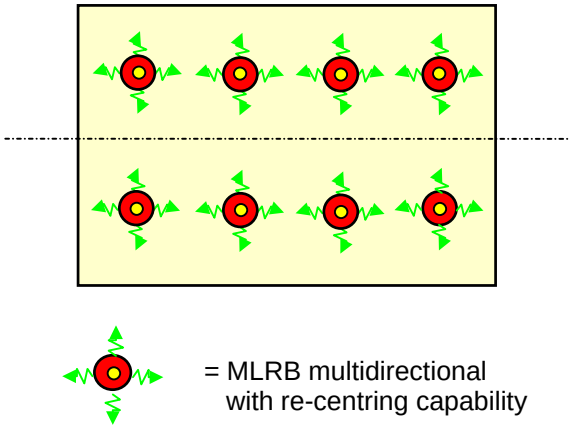


Fig. 2: Sample for a MLRB arrangement

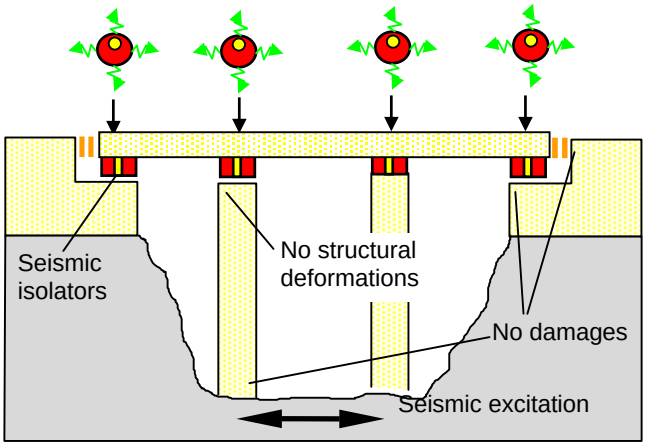


Fig 3: Bridge with MLRBs with passive energy dissipation and arrangement of Fig. 2

With the above suggested concept that combines seismic isolation with energy dissipation, a very good seismic protection for

The fundamental Functions of MAURER-LRBs

The four fundamental functions of MAURER LRBs are:

1. Transmission of vertical loads (Fig. 4).
2. Allowance of displacements on the horizontal plane (Fig. 5) providing the horizontal flexibility.
3. Dissipation of substantial quantities of energy (Fig. 6).
4. Assurance of self-re-centring (Fig. 7).

The first function means that the MLRB acts as a conventional rubber bearing, i.e. transfers vertical loads in the intended location from the superstructure to the substructure (Fig. 4).

The second function produces uncoupling between foundation and superstructure and thus reduces transmitted forces or the amount of mechanical energy, which is essentially the same. The uncoupling allows horizontal flexibility of the structure (Fig. 5). The flexibility is provided by the rubber of the MLRB.

The dissipation of energy limits relative displacement of the isolated structural mass and provides better structural control with bigger safety for the structure (Fig. 6). The energy dissipation is realized by the rubber and by the inner lead core of the MLRB.

The purpose of the self-re-centring capability requirement – return of the structure to former neutral mid position (Fig. 7) - is not so much to limit residual displacements at the end of a seismic attack, but rather, prevent cumulative displacements during the seismic event.
Self-re-centring assumes particular importance in structures located in close proximity to a fault, where earthquakes characterized by highly asymmetric accelerograms are expected (Near Field or Fling effect). The re-centring effect is based on the natural elasticity of the applied rubber.

It should be noted that energy dissipation and self-centring capability (sometimes referred to as restoring force) are two antithetic functions and their relative importance depends primarily on the case under examination.

Basically the structural designer is providing certain conceptual requirements of the isolation unit, like for load capacity, damping, stiffness, etc. and the MLRB unit will then be adapted to these requirement by MAURER.

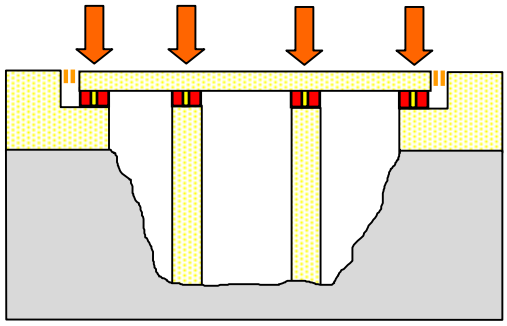


Fig. 4: MLRBs for vertical load transmission

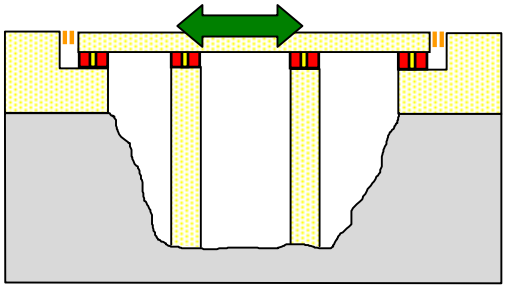


Fig. 5: MLRBs for horizontal flexibility

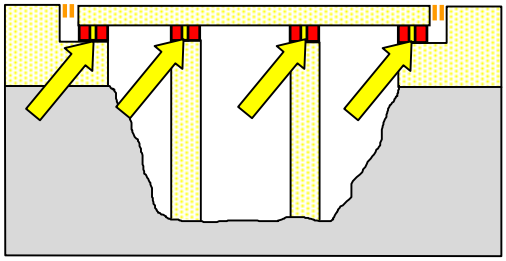


Fig. 6: LRBs for energy dissipation

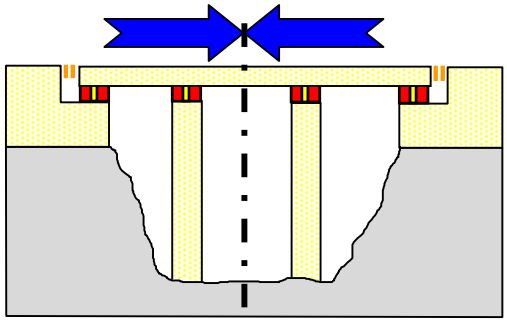


Fig. 7: LRBs for self-re-centring to the mid position

The Design and Characteristics of MAURER-LRBs

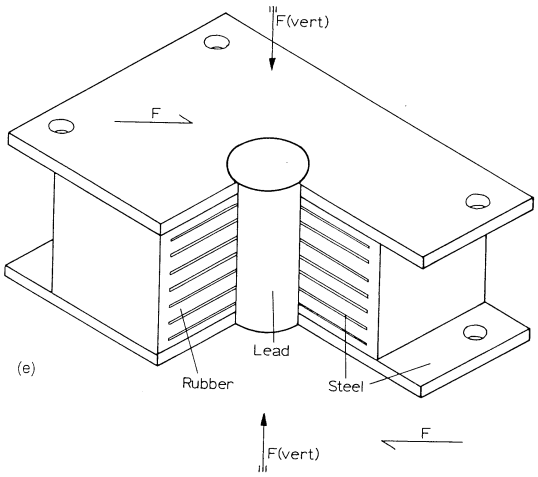


Fig. 8: Principle design of a rectangular MLRB

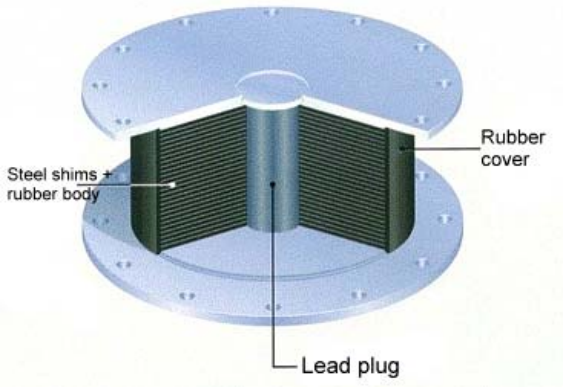


Fig. 9: Principle design of a round MLRB

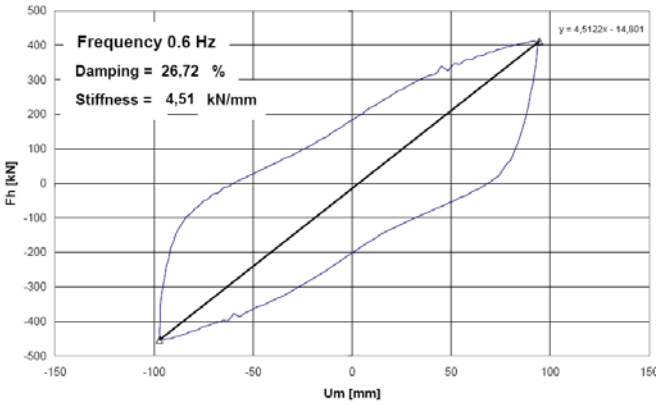


Fig. 10: Hysteretic loop of LRB tested at University Bochum/Germany

MLRBs are consisting of a regular elastomeric laminated rubber bearing. The rubber compound can be made of natural rubber (NR) or chloroprene rubber (CR), while usually European Standards were considered. On request other standards like SETRA, ASSHTO, etc. can be applied.

The shape can be either round, square or rectangular (Fig. 8 and 9).

The MLRBs are generally constructed with low-damping (unfilled) elastomers with shear moduli of 0,6-1,35 N/mm² and lead cores with diameters ranging 15% and 33% of the bonded bearing diameter for round bearings. The surface relation is kept the same for rectangular bearings.

The elastomer provides the isolation and re-centring, while the lead core offers the necessary energy dissipation or damping component.

The maximum shear strain value for MLRBs is generally between 125% and 200%.

The inner steel shims do not only grant for good load capacity, but also for a proper confinement of the lead core.

As described in Fig. 10 the yield stress of lead is depending on the temperature. Therefore after one load cycle it can be assumed that the yield stress is 13MPA and after three it is 10,5MPA.

The MAURER LRBs are also able to transmit ULS-up-lift-forces on request!

The load capacity of MLRBs is starting from 50kN up to 22.000 kN.

For installation general installation guidelines will be provided, which have to be adapted to any individual structure.

For transport, storage and installation the EN1337-11 is valid.

For the inspection and maintenance the EN1337-10 is applicable.

The service life span for MLRBs is similar to regular rubber bearing according to EN1337 and can be assumed with approx. 30 years or longer, depending on the environmental conditions.

Possible Design of the Anchoring for MLRBs

Remark:
- Other designs are possible on request.
- The number of anchors and the anchor plate size is depending on the static and dynamical design requirements

1) Anchoring by bolted anchor plates

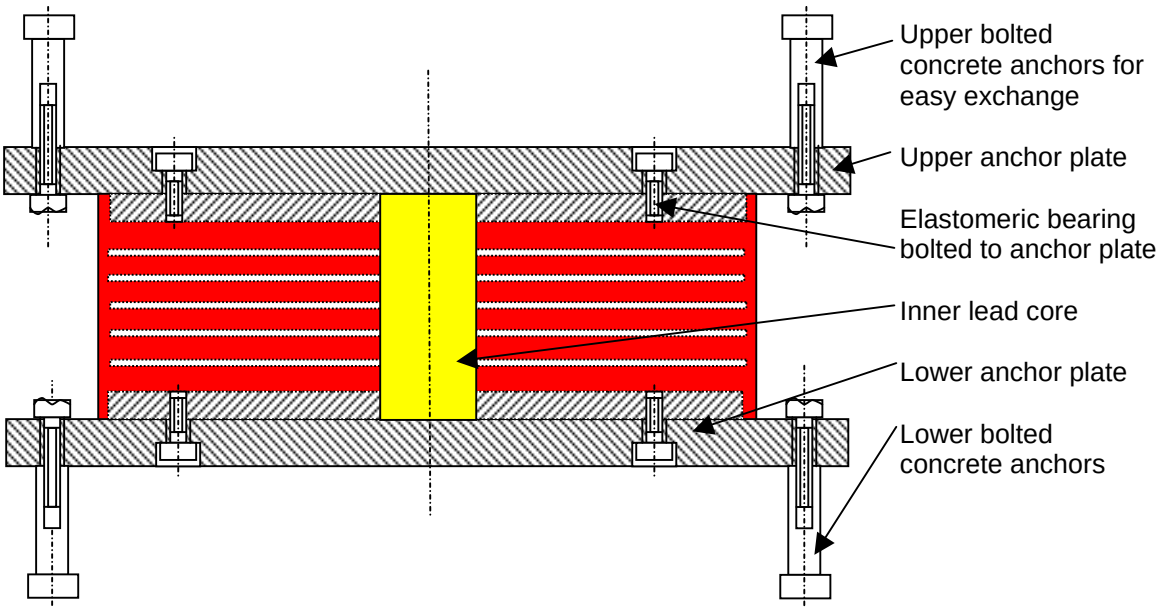


Fig. 11: Anchoring by bolted anchor plates

2) Anchoring by recessed anchor plates

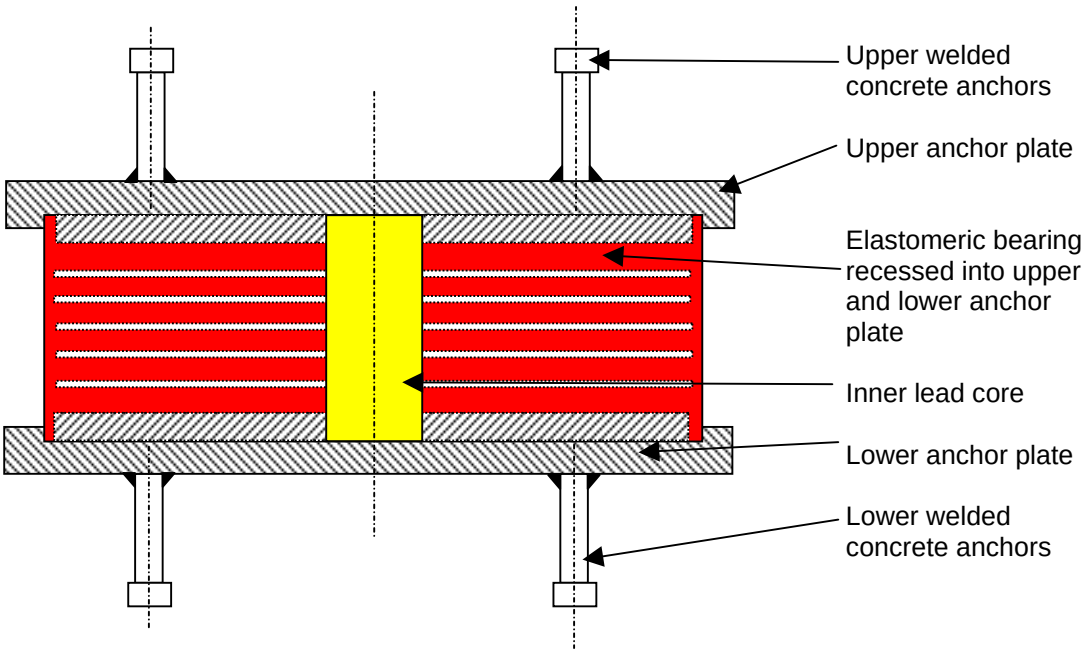


Fig. 12: Anchoring by recessed anchor plates

3) Anchoring by masonry plate with recessed anchor bolts

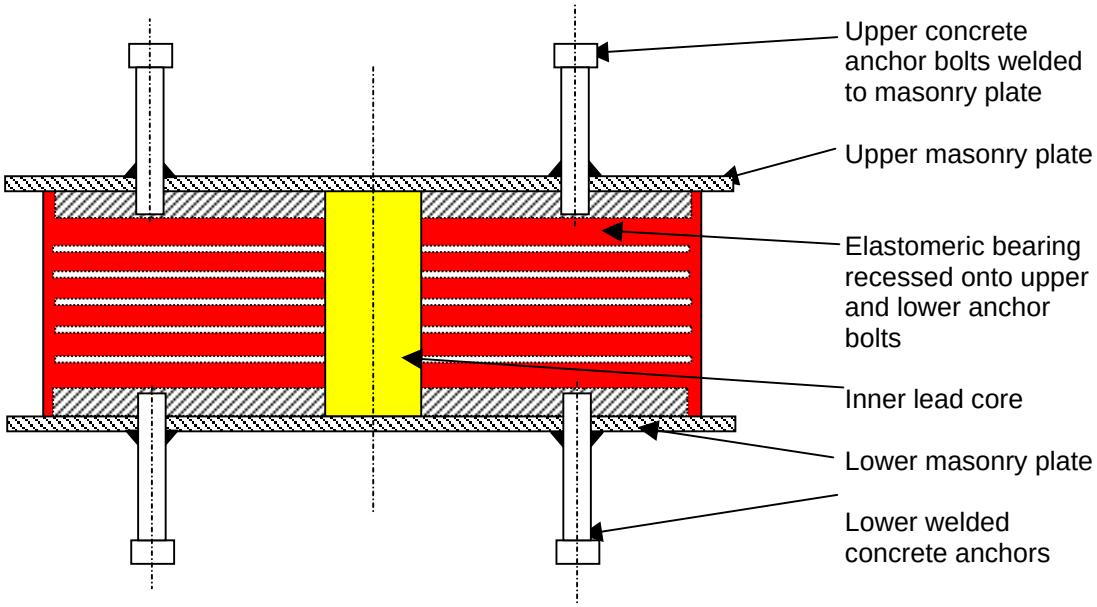


Fig. 13: Anchoring by recessed anchor bolts

Seismic Characteristics of MAURER-LRBs

The calculation of characteristic values of the hysteretic loop of a MLRB can be carried our like this:

Stiffness (K) and characteristic strength (CS) are considered like follows:

=> $CS = (\pi \times d_{PB}^2 / 4) \times \sigma_{PB}$

With π= 3,14, d_{PB} = diameter of lead core, σ_{PB} = average yield strength of lead = 10,5 MPa

=> K = G x Ar / t

With G = shear modulus = 0,6-1,35 MPa, Ar = rubber area of plan view rubber bearing size, t = total rubber thickness, to be selected

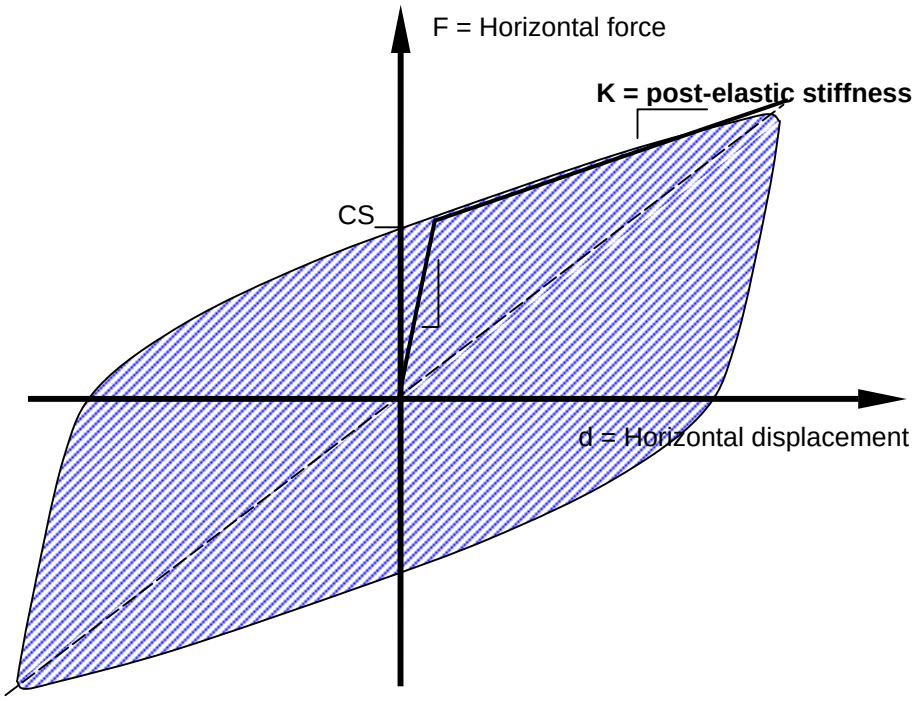


Fig. 14: Hysteretic Loop for a MLRB

- The response force is resulting in: $F = K \times d + \sigma_I \times Ar$
  With σ_{PB} = yield strength of lead (~10,5MPa), d = displacement

- The coefficient of damping can be considered between 15% and 35% depending on the lead core size. Therefore the damping is much higher than with High Damping Rubber Bearings (HDRB) but without having the disadvantages of HDRBs like scragging, load history, strain history, velocity, etc..

Quality Management of MAURER-LRBs

Each single MLRB is undergoing a quality check with a isolator “check card” and a check procedure of the single material testing certificates (Fig. 15).

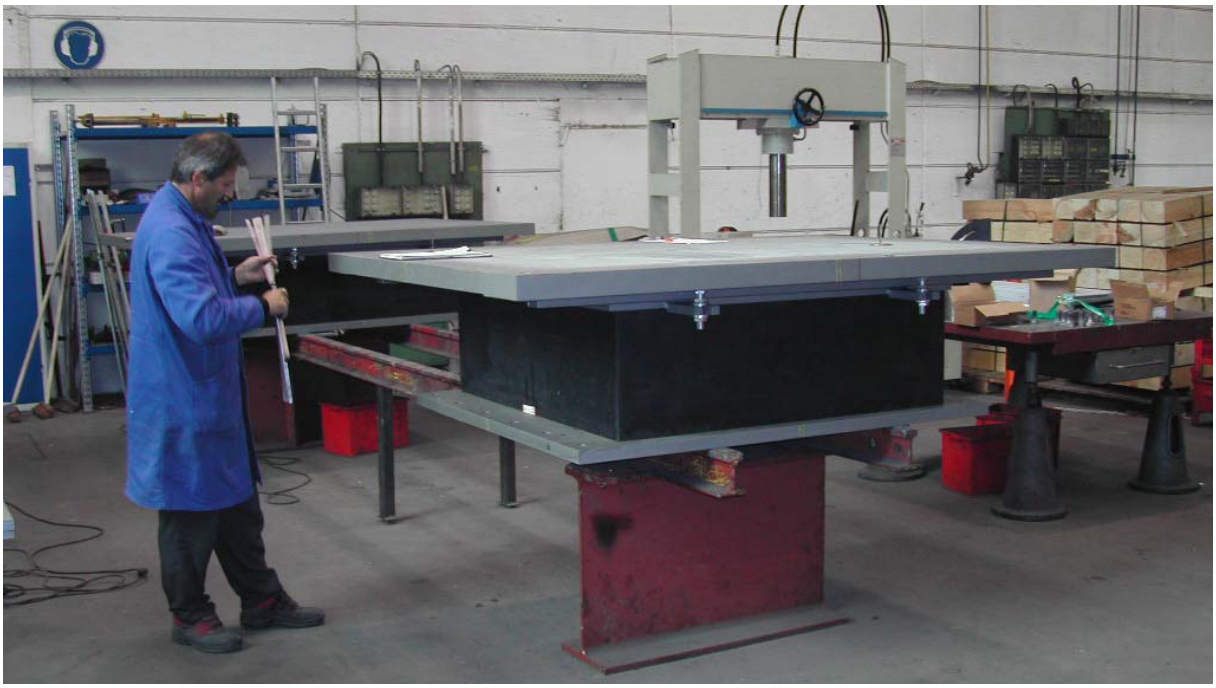


Fig. 15: Quality check after assembly of a MLRB with 1200 x 1200 x 440mm with lead core of 250mm diameter

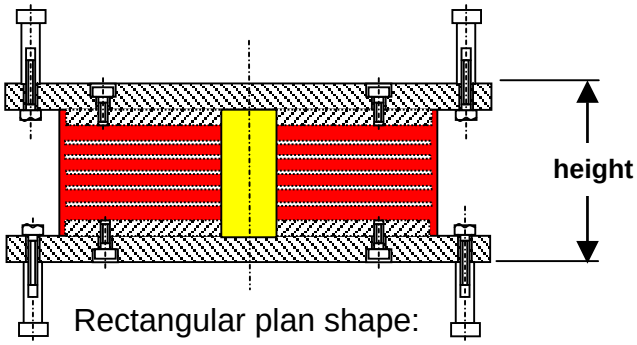
On request full scale or small scale testing of entire isolators are performed according to EN standards or particular client requirements (Fig. 16). The testing report is then showing in detail the technical characteristics of the isolators.

Fig. 16: Testing of a MLRB with 22.000 kN load in the testing rig of the University of Bochum

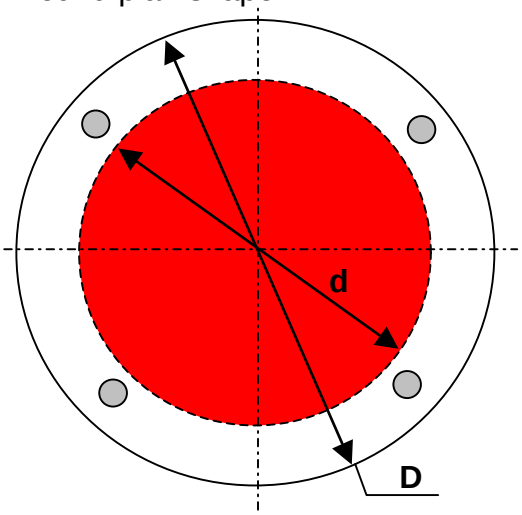
Samples for Dimensions of MAURER-LRBs

The Maurer-LRBs are available in round square and rectangular plan shapes. The size is individually adapted to the request and also the lead core is adopted individually. The below mentioned sizes are just possible sizes, which will be individually adapted on request!

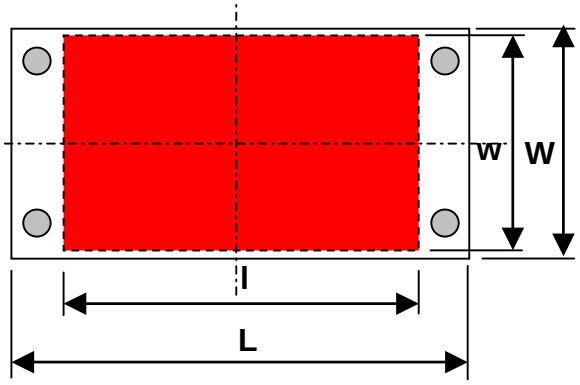
- **Shear modulus:** **0,6 to 1,35 N/mm²**
- **Damping:** **15% to 35%**
- **Sizes up to** **1200 x 1200 x 440 mm, Ø1200 x 440 mm**



Round plan shape:



Rectangular plan shape:



Vertical load* (MN)	Outline dimensions of isolator without anchor studs length (L) x width (W) or diameter (D) [mm]	Dimensions of rubber pad length (l) x width (w) or diameter (d) [mm]	Height values				Rubber layer thickness		
			Rubber height		Isolator height **		total		single layer
			min [mm]	max [mm]	min [mm]	max [mm]	min [mm]	max [mm]	[mm]
0,37 / 0,45	280 x 170 / 280 x 220	100 x 150 / 100 x 200	49	60	79	90	16	24	8
0,67 / 0,84 / 1,0 0,70 / 1,1	330 x 220 / 330 x 270 / 330 x 320 Ø 380 / Ø 430	150 x 200 / 150 x 250 / 150 x 300 Ø 200 / Ø 250	49	71	79	101	16	32	8
1,12 / 1,35 / 1,57 1,8 / 1,59	380 x 270 / 380 x 320 / 380 x 320 380 x 420 / Ø 480	200 x 250 / 200 x 300 / 200 x 350 200 x 400 / Ø 300	58	93	88	123	24	48	8
1,68 / 2,25 / 2,16	430 x 320 / 430 x 420 / Ø 530	250 x 300 / 250 x 400 / Ø 350	58	104	88	134	24	56	8
2,7 / 3,37 / 4,05 2,82 / 3,57	480 x 420 / 480 x 520 / 480 x 620 Ø 580 / Ø 630	300 x 400 / 300 x 500 / 300 x 600 Ø 400 / Ø 450	84	132	124	172	36	72	12
3,54 / 4,41	530 x 470 / Ø 680	350 x 450 / Ø 500	84	148	124	188	36	84	12
4,5 / 5,4 / 5,34	580 x 520 / 580 x 620 / Ø 730	400 x 500 / 400 x 600 / Ø 550	100	164	140	204	48	96	12
6,07 / 6,36	630 x 620 / Ø 780	450 x 600 / Ø 600	100	164	140	204	48	108	12
6,75 / 7,46	680 x 620 / Ø 830	500 x 600 / Ø 650	100	164	140	204	48	120	12
8,1 / 9,45 8,65 / 9,94	780 x 630 / 780 x 730 Ø 880 / Ø 930	600 x 600 / 600 x 700 Ø 700 / Ø 750	119	224	159	264	64	144	16
11,02 / 12,6 11,3 / 12,76	880 x 730 / 880 x 830 Ø 980 / Ø 1030	700 x 700 / 700 x 800 Ø 800 / Ø 850	119	224	159	264	64	160	16
14,4 / 14,3	980 x 830 / Ø 1080	800 x 800 / Ø 900	135	305	175	345	80	220	20
18,2	1080 x 930	900 x 900	135	305	175	345	80	220	20

* the final maximum vertical load is depending on applied standard and lead core size

** the LRB height value is without anchor stud length, which is normally 150 mm or longer

Fig. 17: Possible sizes of MLRBs

Extension for MAURER-LRBs with Steel Hysteretic Elements (SHD)

The Maurer-LRBs can be additionally provided with so called steel hysteretic elements - SHD. These SHD elements are acting in horizontal direction and are fixed with one end to the upper and with the other end to the lower MLRB-plate (Fig. 18).

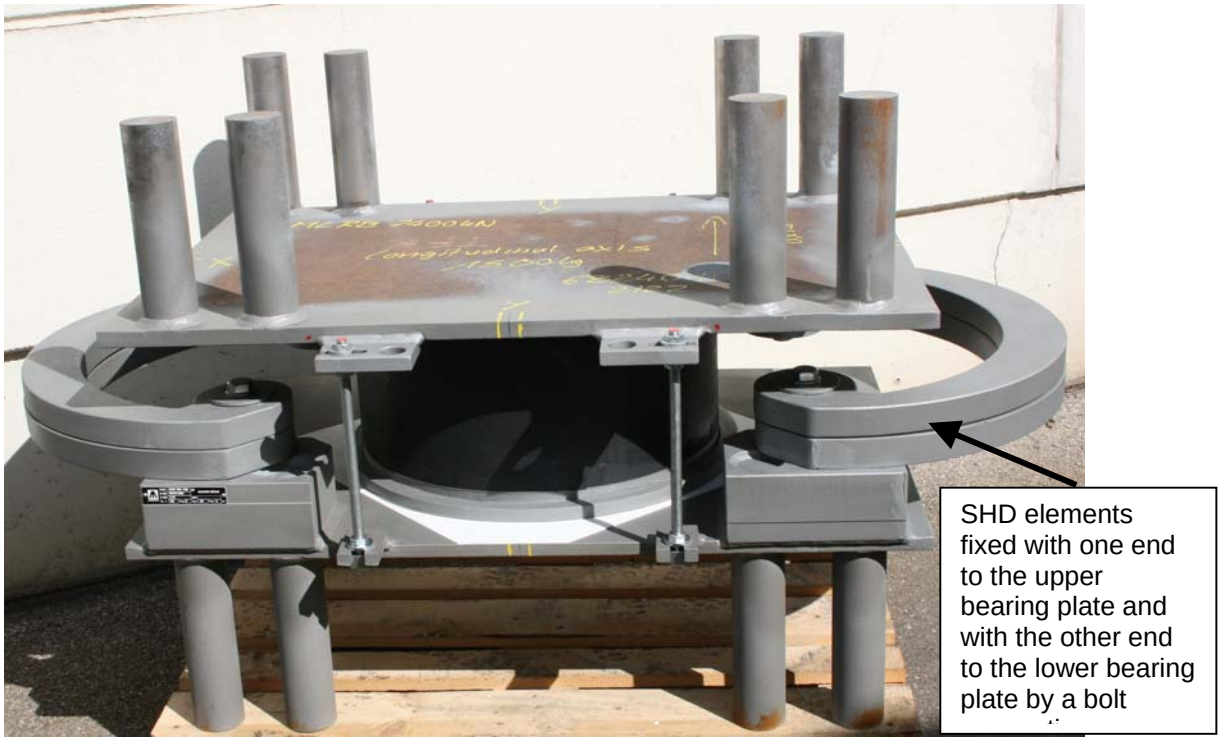


Fig. 18: MLRB isolator with SHD elements at both ends

The hysteretic element acts like a guide element for service conditions and is transmitting horizontal forces like a guide. In case of an earthquake the function is similar to the lead core inside the MLRB, i.e. the SHD will be deformed and is dissipating energy by converting it from kinetic energy into heat energy. The SHD is applied if the energy dissipation by the lead core inside the rubber bearing is not sufficient. Then these elements made or regular steel (S355J2G3) support the lead core of the MLRB to dissipate more energy. The total energy dissipated by the bearing is the sum from the hysteretic loop of the MLRB (Fig. 10) and the loop of the SHD (Fig. 20)

The structural designer is specifying the total amount of energy to be dissipated by the lead rubber bearing, in case the amount is bigger than the lead can accommodate, the additional SHD element is designed according to the required energy amount or to the required resisting force respectively. The SHD is just a supporting element to reduce structural horizontal displacements in certain directions and is not transmitting any vertical loads like the lead rubber bearings do.

The design of the SHD devices is according to prEN15129 chapter 6 “Displacement dependent Devices”.

The testing of SHD at the University of Munich was performed with the specimen shown in Fig. 19.

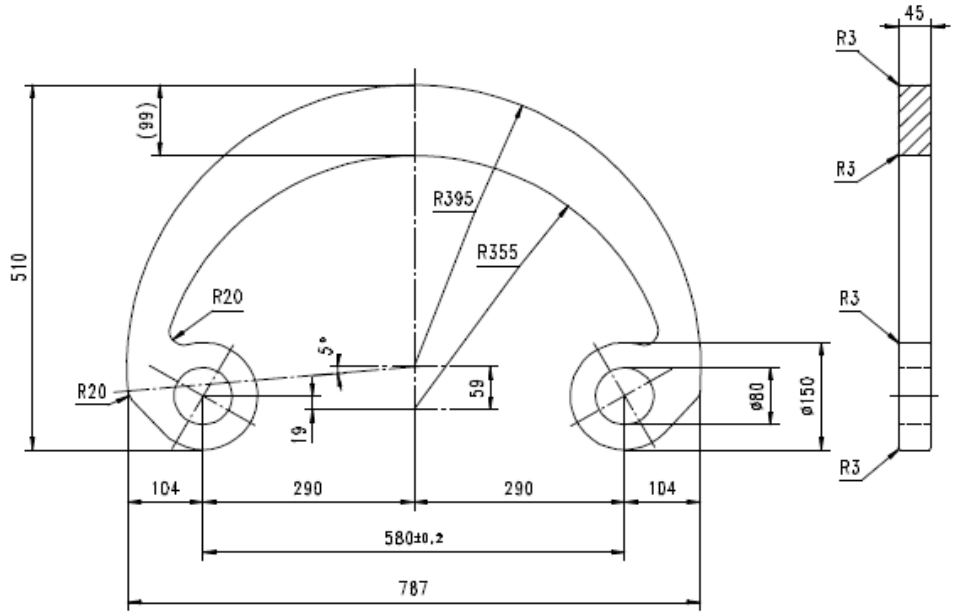


Fig. 19: Single SHD element applied for testing at the University of Munich

The testing was performed to show the energy dissipation capability of the device by plotting the hysteretic loop (Fig. 20).

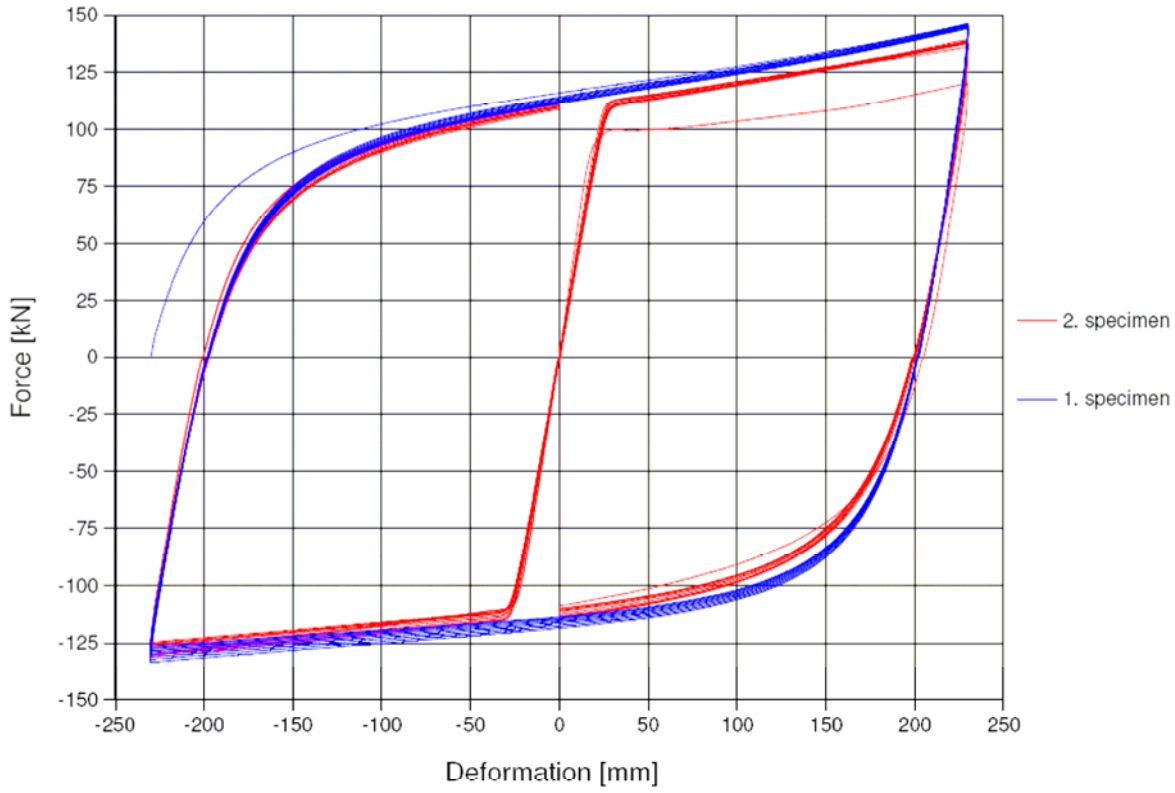
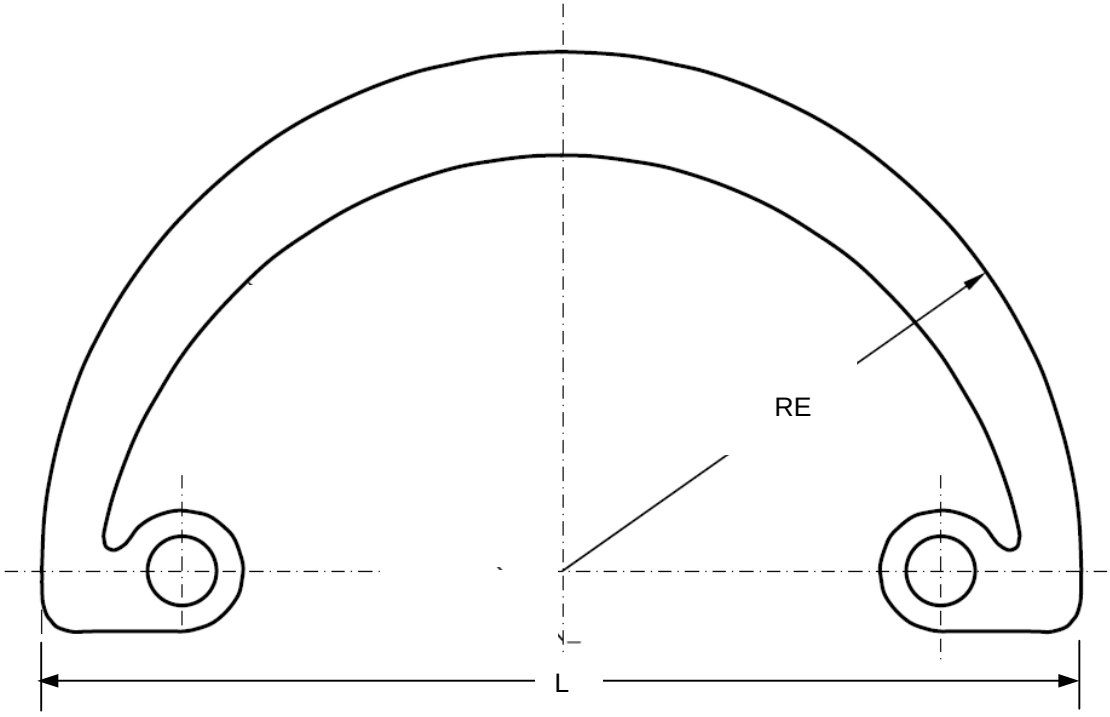


Fig. 20: Hysteretic loop of a SHD element applied for testing at the University of Munich

Samples for Dimensions of MAURER-SHD elements

The Maurer-SHD elements are available in round plan shapes. The size is individually adapted to the request of resistance. The below mentioned sizes are just possible sizes, which will be individually adapted on request!
The damping values is between 20% and 45%.



Horizontal Force [kN]	Length L [mm]	Radius external RE [mm]	Thickness T [mm]	Displacement [mm]
20	600	305	10	50-170
50	670	340	20	50-170
100	780	395	35	50-250
135	780	395	45	50-250
170	780	395	55	50-250
250	780	395	90	50-250
500	880	470	90	50-250
750	880	450	90	50-250
1000	980	500	90	50-250
1500	980	500	140	50-250
2000	1080	550	140	50-250

Fig. 21: Possible sizes of SHD elements (any other sizes are possible on individual request) – Sizes are approx. values only and may change on individual requirement