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).

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.
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-centering, 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 out like this:

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

\[ CS = \left( \pi \times d_{PB}^2 / 4 \right) \times \sigma_{PB} \]

With \( \pi = 3.14 \), \( d_{PB} \) = diameter of lead core, \( \sigma_{PB} \) = average yield strength of lead = 10.5 MPa

\[ K = G \times Ar / t \]

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

- The response force is resulting in: \( F = K \times d + \sigma_{PB} \times Ar \)
  With \( \sigma_{PB} \) = 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

<table>
<thead>
<tr>
<th>Vertical load* (MN)</th>
<th>Outline dimensions of isolator without anchor studs length (L) x width (W) or diameter (D) [mm]</th>
<th>Dimensions of rubber pad length (l) x width (w) or diameter (d) [mm]</th>
<th>Height values Rubber height [mm] min max Isolator height ** [mm] min max total height [mm] min max single layer [mm]</th>
<th>Rubber layer thickness [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.37 / 0.45</td>
<td>280 x 170 / 280 x 220</td>
<td>100 x 150 / 100 x 200</td>
<td>49 / 60 79 / 90 16 / 24 8</td>
<td></td>
</tr>
<tr>
<td>0.67 / 0.84 / 1.0</td>
<td>330 x 220 / 330 x 270 / 330 x 320 Ø 380 / Ø 430</td>
<td>150 x 200 / 150 x 250 / 150 x 300 Ø 200 / Ø 250</td>
<td>49 / 71 79 / 101 16 / 32 8</td>
<td></td>
</tr>
<tr>
<td>1.12 / 1.35 / 1.57</td>
<td>380 x 270 / 380 x 320 / 380 x 320 Ø 420 / Ø 480</td>
<td>200 x 250 / 200 x 300 / 200 x 350 Ø 300</td>
<td>58 / 93 88 / 123 24 / 48 8</td>
<td></td>
</tr>
<tr>
<td>1.68 / 2.25 / 2.16</td>
<td>430 x 320 / 430 x 420 / Ø 530</td>
<td>250 x 300 / 250 x 400 / Ø 350</td>
<td>58 / 104 88 / 134 24 / 56 8</td>
<td></td>
</tr>
<tr>
<td>2.7 / 3.37 / 4.05</td>
<td>480 x 420 / 480 x 520 / 480 x 620 Ø 580 / Ø 630</td>
<td>300 x 400 / 300 x 500 / 300 x 600 Ø 400 / Ø 450</td>
<td>84 / 132 124 / 172 36 / 72 12</td>
<td></td>
</tr>
<tr>
<td>2.82 / 3.57</td>
<td>350 x 470 / Ø 680</td>
<td>350 x 450 / Ø 500</td>
<td>84 / 148 124 / 188 36 / 84 12</td>
<td></td>
</tr>
<tr>
<td>3.54 / 4.41</td>
<td>580 x 520 / 580 x 620 / Ø 730</td>
<td>400 x 500 / 400 x 600 / Ø 550</td>
<td>100 / 164 140 / 204 48 / 96 12</td>
<td></td>
</tr>
<tr>
<td>4.5 / 5.4 / 5.34</td>
<td>630 x 620 / Ø 780</td>
<td>450 x 600 / Ø 600</td>
<td>100 / 164 140 / 204 48 / 108 12</td>
<td></td>
</tr>
<tr>
<td>6.07 / 6.36</td>
<td>680 x 630 / Ø 830</td>
<td>500 x 600 / Ø 650</td>
<td>100 / 164 140 / 204 48 / 120 12</td>
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</tr>
<tr>
<td>6.75 / 7.46</td>
<td>780 x 630 / Ø 930</td>
<td>600 x 600 / Ø 700</td>
<td>119 / 224 159 / 264 64 / 144 16</td>
<td></td>
</tr>
<tr>
<td>8.1 / 9.45</td>
<td>880 x 730 / Ø 1030</td>
<td>700 x 700 / Ø 750</td>
<td>119 / 224 159 / 264 64 / 160 16</td>
<td></td>
</tr>
<tr>
<td>8.65 / 9.94</td>
<td>11.02 / 12.6</td>
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<td>119 / 224 159 / 264 64 / 160 16</td>
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<tr>
<td>11.3 / 12.76</td>
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<td>800 x 800 / Ø 900</td>
<td>135 / 305 175 / 345 80 / 220 20</td>
<td></td>
</tr>
<tr>
<td>14.4 / 14.3</td>
<td></td>
<td>150 / 305 175 / 345</td>
<td>80 / 220 20</td>
<td></td>
</tr>
<tr>
<td>18.2</td>
<td></td>
<td>1080 x 930</td>
<td>900 / 900 135 / 305 175 / 345</td>
<td>80 / 220 20</td>
</tr>
</tbody>
</table>

* 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).

![MLRB isolator with SHD elements at both ends](image)

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”.

SHD elements fixed with one end to the upper bearing plate and with the other end to the lower bearing plate by a bolt.
The testing of SHD at the University of Munich was performed with the specimen shown in Fig. 19.

![Figure 19: Single SHD element applied for testing at the University of Munich](image1)

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

![Figure 20: Hysteretic loop of a SHD element applied for testing at the University of Munich](image2)
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%.

<table>
<thead>
<tr>
<th>Horizontal Force [kN]</th>
<th>Length L [mm]</th>
<th>Radius external RE [mm]</th>
<th>Thickness T [mm]</th>
<th>Displacement [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>600</td>
<td>305</td>
<td>10</td>
<td>50-170</td>
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<td>50</td>
<td>670</td>
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<tr>
<td>500</td>
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<td>470</td>
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<td>750</td>
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</tr>
<tr>
<td>2000</td>
<td>1080</td>
<td>550</td>
<td>140</td>
<td>50-250</td>
</tr>
</tbody>
</table>

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