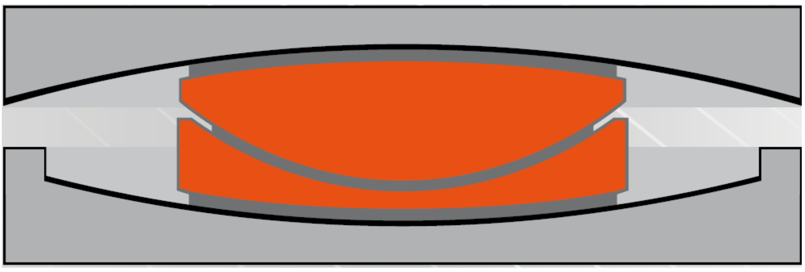
Manual for Design and Modelling of MAURER SIP®-Adaptive



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1. MAURER SIP®-Adaptive

1.1. Concept

The MAURER SIP®-Adaptive is a curved surface slider of type double, i.e., with two primary sliding surfaces, whose sliding motions are decoupled by the articulated slider (Figure 1, Figure 2). The fact that the two sliding motions are decoupled allows designing the two primary sliding surfaces with different friction coefficients and effective radii. The resulting **adaptive behaviour** generates **enhanced structural isolation over a wide range of ground shaking levels**:

- **WEAK but frequent earthquakes (WEAK earthquake),**
- **Design Basis Earthquake (DBE), and**
- **Maximum Considered Earthquake (MCE).**

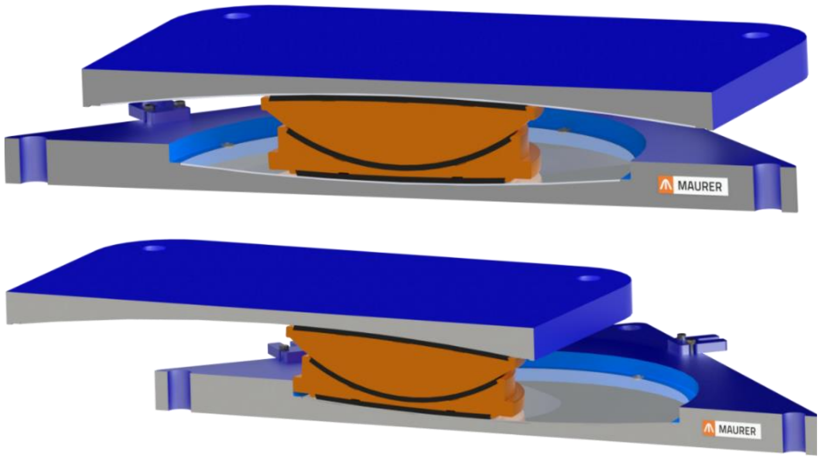

Figure 1. Schematic cross section views of MAURER SIP®-Adaptive in centre position (above) and fully deflected position (below).

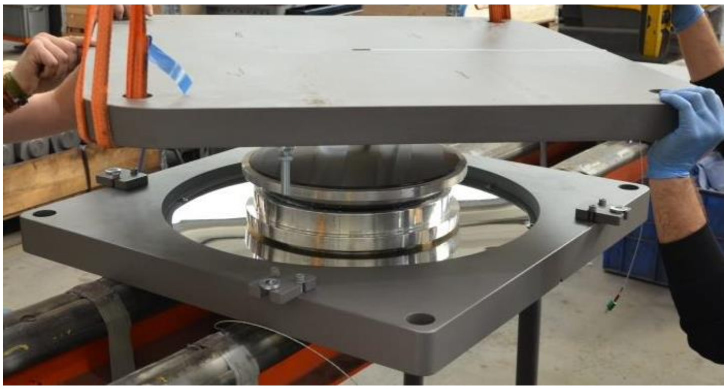

Figure 2. MAURER SIP®-Adaptive during assembly at MAURER SE, Munich, Germany.

1.2. Design for frequent earthquakes, DBE and MCE

The design of the MAURER SIP®-Adaptive is based on three different ground shaking levels:

a) **Enhanced structural isolation for WEAK but frequent earthquakes:** The friction of primary sliding surface 1 is designed to activate sliding motion at ground shaking levels below DBE to activate structural isolation for weak but frequent earthquakes (Figure 3, top left).
b) **Optimum structural isolation for DBE:** At DBE excitation simultaneous sliding on both primary sliding surfaces is envisaged. The activation of both effective radii generates the desirable softening effect for optimum structural isolation at DBE (Figure 3, top right).
c) **Controlled displacement and base shear for MCE:** At MCE excitation the primary sliding surface with greater friction controls the total isolator displacement and the maximum base shear

(Figure 3, bottom). The total isolator displacement and the maximum base shear are optimized by the appropriate designs of the greater friction and effective radius of the primary sliding surface 2 and the recess on the primary sliding surface 1 which limits the sliding motion at lower friction.

1.3. Improved rotation capability

The secondary (lubricated) sliding surface of the articulated slider ensures greatest rotation capability of the MAURER SIP®-Adaptive compared to conventional double curved surface sliders.

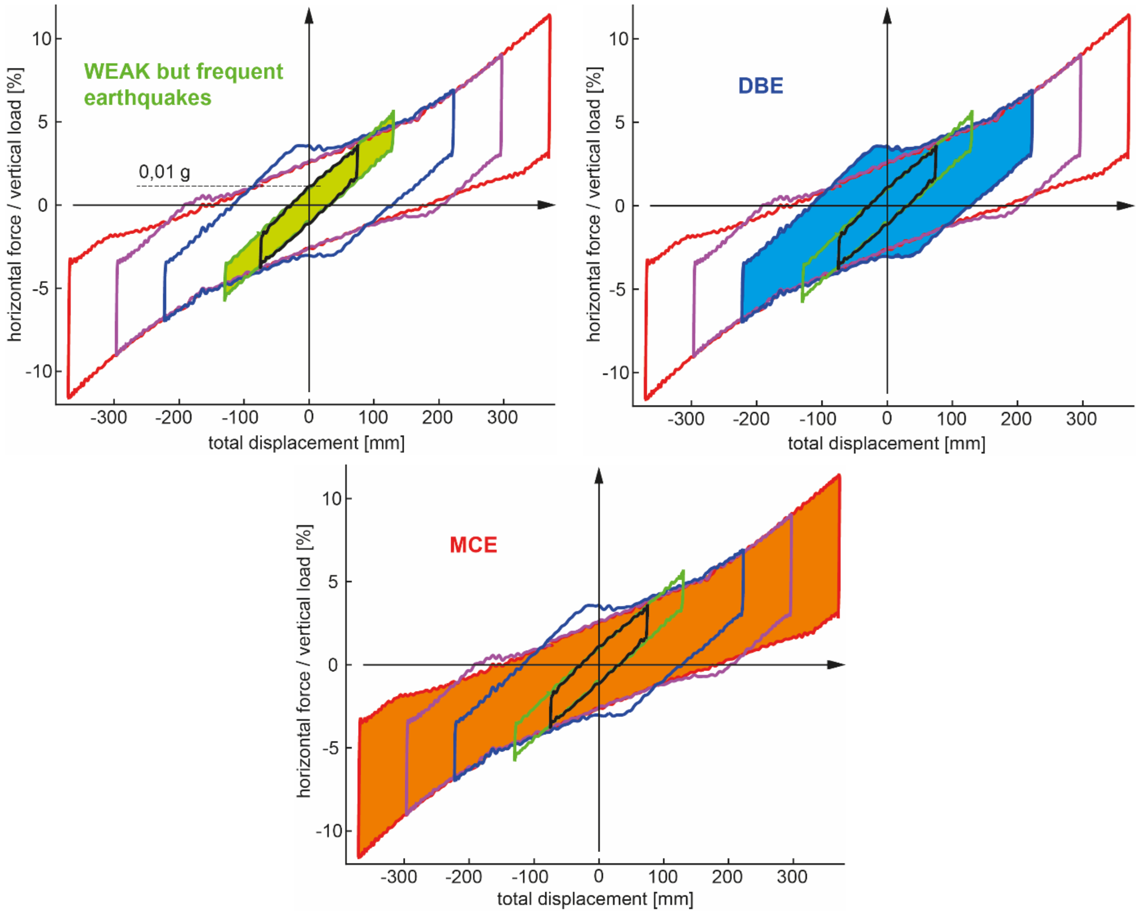

Figure 3. Adaptive behaviour of MAURER SIP®-Adaptive measured at EUCENTRE, Pavia, Italy.

1.4. CE-tested at EUCENTRE, Pavia, Italy

The MAURER SIP®-Adaptive is CE-tested at EUCENTRE, Pavia, Italy, under the third-party supervision of the University of Stuttgart (Figure 4).

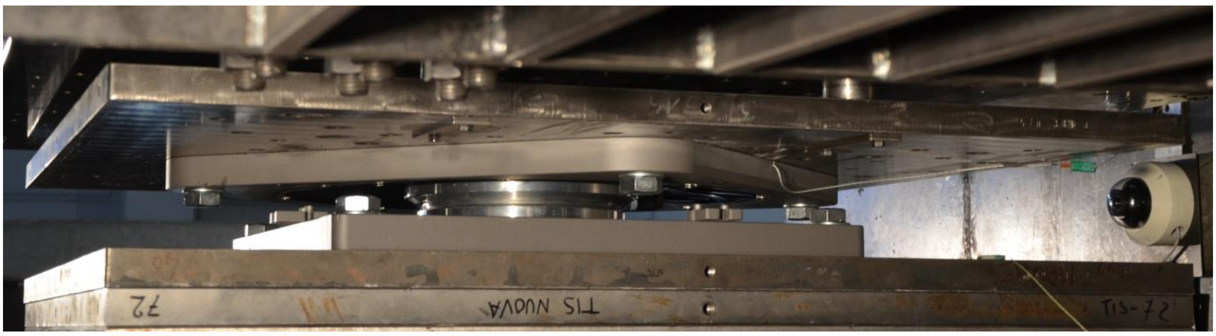

Figure 4. MAURER SIP®-Adaptive during CE-testing at EUCENTRE, Pavia, Italy.

2. Design of MAURER SIP®-Adaptive

2.1. Recommended design properties

The recommended design properties to ensure the adaptive behaviour of the MAURER SIP®-Adaptive are given in Table 1. The nomenclature is given in Figure 5.

Table 1. Recommended SIP®-Adaptive design properties.

Primary sliding surface	Dynamic coefficient of friction	Effective radius	Distance to recess
1	General: μ_1 = [2,8 % to 6 %] Typical: μ_1 = [2,8 % to 5 %]	General: $R_{eff,1}$ = [2 m to 6 m] Typical: $R_{eff,1}$ = [3 m to 4,5 m]	d_1 = 0,5×(disp. capacity) – 2×(recess thickness) (60 mm to 80 mm)
2	General: μ_2 = [4,8 % to 9 %] Typical: μ_2 = [5,5 % to 8 %]	General: $R_{eff,2}$ = [2 m to 6 m] Typical: $R_{eff,2}$ = [3,5 m to 5 m]	NA (no recess)

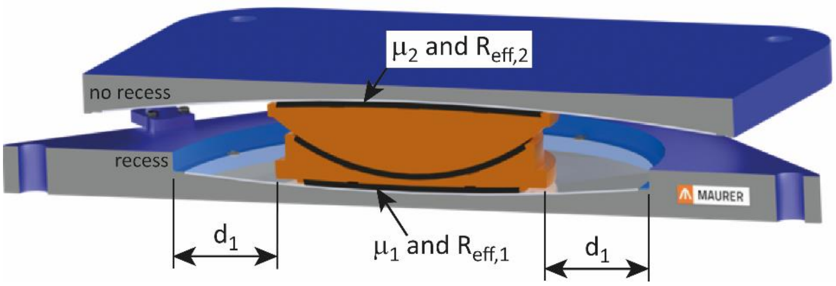

Figure 5. Design properties of MAURER SIP®-Adaptive.

Additional comments:

- The design values of the smaller and greater dynamic coefficients of friction shall be well separated. The recommended minimum difference between the smaller and greater dynamic coefficients of friction is 2 %.
- The displacement capacity of primary sliding surface 2 is not limited by any means (in agreement with EN 1998 and EN 15129).
- For most SIP®-Adaptive applications it the effective radius $R_{eff,1}$ is [60 % to 100 %] of the effective radius $R_{eff,2}$ to ensure that sliding on the primary sliding surface 2 is activated by the force equilibrium between the friction force of surface 2 and the sum of the friction force and stiffness force of surface 1:

$$W\,\mu_2 = W\,(\mu_1 + u_1/R_{eff,1}) \quad (1)$$

  where u_1 denotes the sliding displacement on surface 1 when sliding on surface 2 is activated.

- If the primary sliding surface 1 shall be designed to generate the isolation at DBE by itself, then it is recommended that the effective radius $R_{eff,1}$ is [100 % to 150 %] of the effective radius $R_{eff,2}$ to ensure that sliding on surface 2 with greater friction is activated by the recess of surface 1:

$$W\,\mu_2 \geq W\,(\mu_1 + d_1/R_{eff,1}) \quad (2)$$

- To accommodate thermal movements bridges at lowest possible isolator forces it is recommended to lubricate the sliding liner of surface 1. Then the dynamic coefficient of friction μ_1 is [1 % to 2 %].

2.2. Modelling MAURER SIP®-Adaptive with SAP 2000, ETABS etc.

The graphical user interface (GUI) of the triple friction pendulum (TFP) of the software tools SAP 2000, ETABS etc. to model the MAURER SIP®-Adaptive shall be used as described in Figure 6.

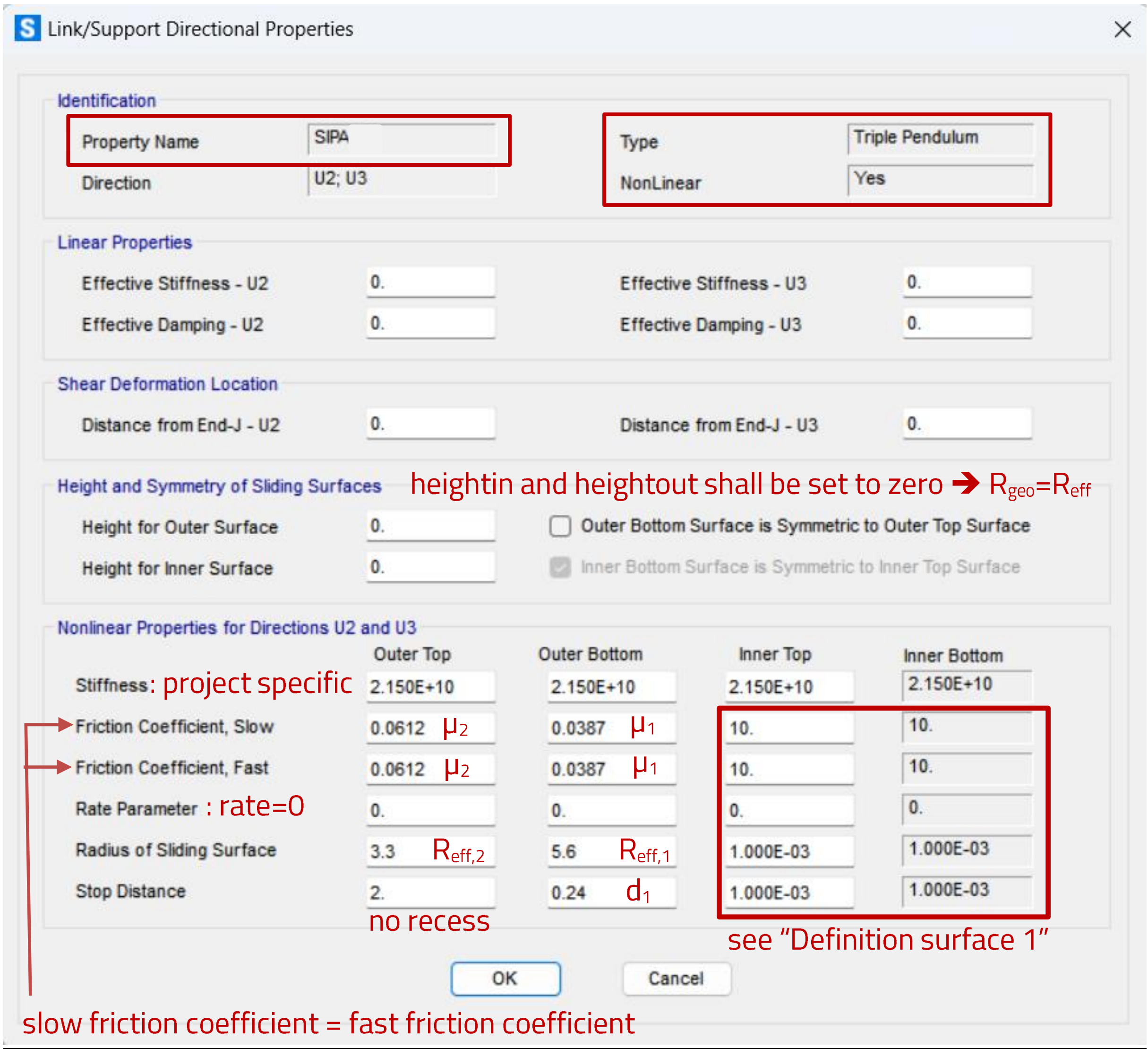

Figure 6. Correct use of GUI to model the MAURER SIP®-Adaptive.

Definition surface 1:

To ensure that the inner bearing of the GUI with index 1 does not influence the behaviour of the MAURER SIP®-Adaptive the parameters of surface 1 of the GUI shall be set as follows:

- Option 1: friction very high (10), radius very small (0,001 m), stop distance very small (0,001 m) ➔ this parameter set locks the inner bearing of the GUI.
- Option 2: friction very small (0,0001), radius very small (0,001 m), stop distance very large (10 m) ➔ this parameter set ensures that the force coupling between the two primary sliding surfaces of the MAURER SIP®-Adaptive is determined by the pre-sliding stiffness of the sliding liner MSM®.

Further explanations:

- The design properties of primary sliding surface 1 of the MAURER SIP®-Adaptive shall be inputted in surface 2 of the GUI.
- The design properties of primary sliding surface 2 of the MAURER SIP®-Adaptive shall be inputted in surface 3 of the GUI.
- Both parameters “heightin” and “heightout” shall be set to 0 such that the effective radii of the MAURER SIP®-Adaptive can be inputted at the places of the geometrical radii.
- For the sliding liner MSM® of MAURER the slow and fast dynamic coefficients of friction shall be set equal and the rate parameter shall be set to zero.

3. Consultancy by MAURER

For consultancy by MAURER please contact:

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