*Table 1* shows the parameters for non-linear modeling of the device in commercial programs. It is recommended to use the "Friction Isolator" model. The values of $k_{eff}$, $R_{eff}$ y $W_a$ can be obtained from *Table 2* according to the needs of the project. The damping values, $\mu_e$, $\mu_d$ and the friction parameter $r_p$ are typical for all isolators presented in *Table 1*.

Table 1. Parameters for defining the Dampo Double Pendulum Seismic Isolator in structural analysis programs.

| Type of "*link*" | Mass | Weight | Rotational inertia | Damping |
|---|---|---|---|---|
| "Friction Isolator" | $M_A = W_A/g$ | $W_A$ | $R_1 = R_2 = R_3 = 0$ | $= 0$ |
| **Effective stiffness** | **Static friction coefficient** | **Dynamic friction coefficient** | **Friction parameter** | **Effective period** |
| $k_{eff} = W_{eff}\left(\frac{1}{R_{eff}} + \frac{\mu_e}{d_m}\right)$ | $\mu_e = 0.10$ | $\mu_d = 0.08$ | $r_p = 1\ (s/cm)$ | $T_{eff}$ |
| **Direction** | **Linear stiffness** | **Non-linear stiffness** | **Pendulum radius** | **Damping** |
| $U_2 = U_3$ | $k_{eff}$ | $k_{nl} = 10 * k_{eff}$ | $R_{eff}$ | $= 0$ |
| $U_1$ | $k_v = 100 * k_{eff}$ | $k_v = 100 * k_{eff}$ | $-$ | $= 0$ |

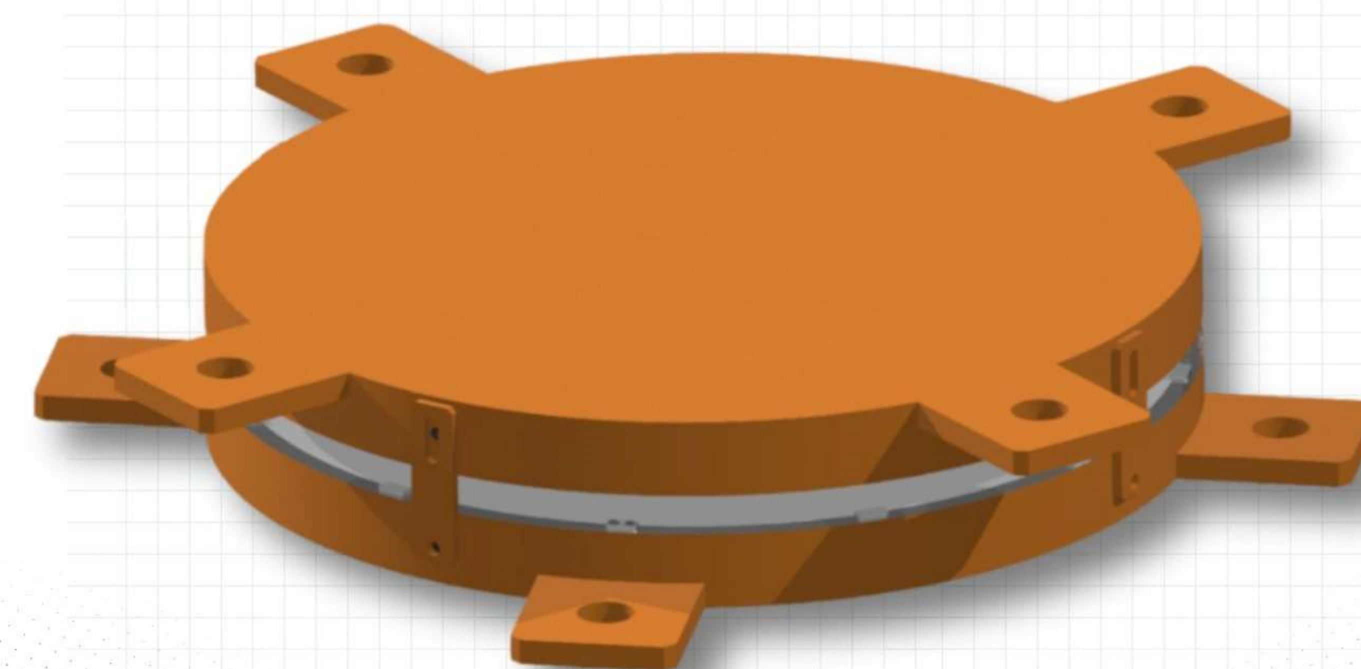
*Table 2* shows the properties of the Dampo Double Pendulum Seismic Isolator. The calculation of the horizontal load ($F_H$) and the effective stiffness ($k_{eff}$) were calculated with the maximum load capacity.

Table 2. Properties of Dampo Double Pendulum Seismic Isolators.

| Effective radius - $R_{eff} = 2.7\ (m)$; $T$ = 3.3 s, Maximum displacement - $d_m = 300\ (mm)$. | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Maximum load | Effective period | Horizontal load | Oscillator diameter | Plate diameter | Base plate width | Isolator height | Effective stiffness | Equivalent viscous damping | Weight |
| **Model** | $P_{max}$ (t) | $T_{eff}$ (s) | $F_H$ (t) | $d$ (mm) | $D$ (mm) | $B$ (mm) | $H$ (mm) | $k_{eff}$ (t/m) | $\xi_{eff}$ (%) | $W_a$ (kg) |
| **DAS/125** | 125 | 2.4 | 26.4 | 250 | 550 | 750 | 210 | 87.9 | 30 | 420 |
| **DAS/250** | 245 | 2.4 | 52.8 | 350 | 650 | 850 | 210 | 175.9 | 30 | 460 |
| **DAS/320** | 320 | 2.4 | 67.6 | 400 | 700 | 900 | 210 | 225.1 | 30 | 490 |
| **DAS/500** | 500 | 2.4 | 105.6 | 500 | 800 | 1000 | 210 | 351.8 | 30 | 520 |

**Note: The tables show the characteristics of typical isolators; however, it is possible to adjust the characteristics according to the needs of each project.**

# DAMPO DOUBLE PENDULUM SEISMIC ISOLATOR



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The Dampo Double Pendulum Seismic Isolator *(Figure 1)* is a friction or sliding pendulum type structural isolation system developed in Mexico. In this system, the characteristics of the physical behavior of the pendulums are taken advantage of to lengthen the period of the structural system.

This seismic protection device aims to decouple the movement of the ground and the structure, allowing the latter to behave as a rigid body. This considerably reduces inter-story drifts and the internal forces in structural elements derived from earthquakes.

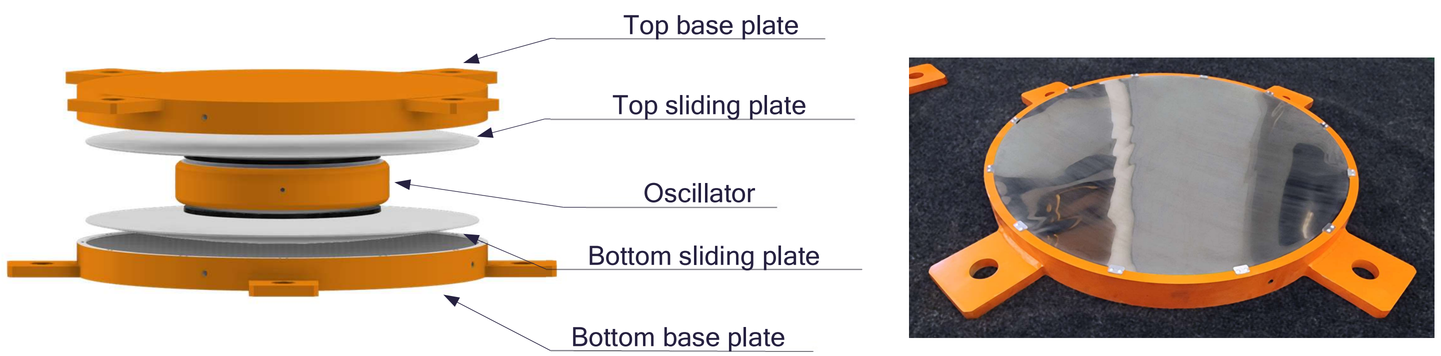



**Figure 1. General characteristics and details of the plate.**

Thanks to its design, Dampo's Double Pendulum Seismic Isolator increases damping and provides effective and long-lasting seismic isolation to the structure. The device presents a stable non-linear behavior in any direction as shown in *Figure 2a*. This performance allows obtaining the stiffness and eaaffective damping to perform structural analyses. The devices are typically installed at the base of the structure, as shown in *Figure 2b*.

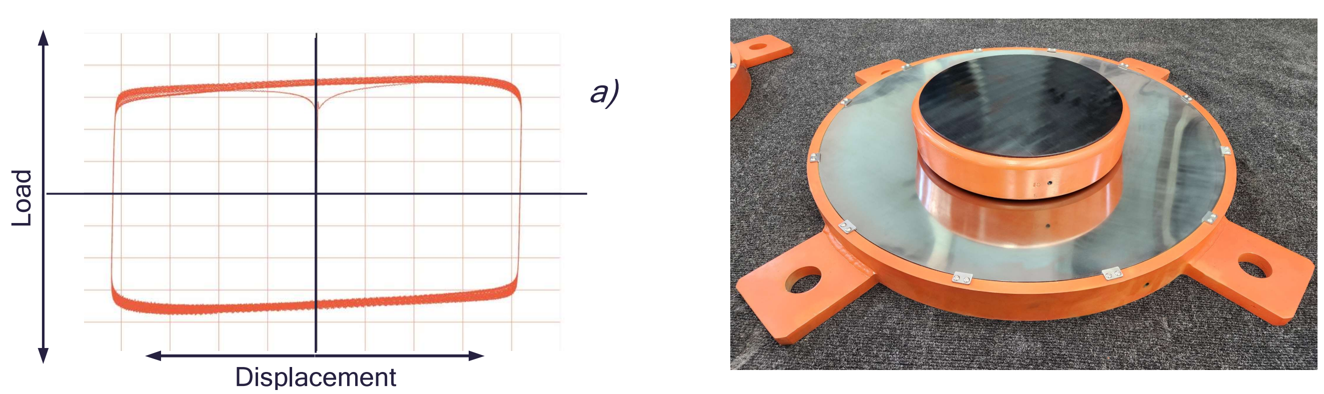



**Figure 2. Hysteresis curves and photograph of an isolator.**



Dampo's Double Pendulum Seismic Isolators are installed by anchoring them to the structure and require contact surfaces in both the foundation and the superstructure. The dimensions of the anchoring surface will depend on the load and maximum displacements required for efficient seismic protection. *Figure 3* shows the variables that define the dimensions of the device and are related to the values in *Table 2*.

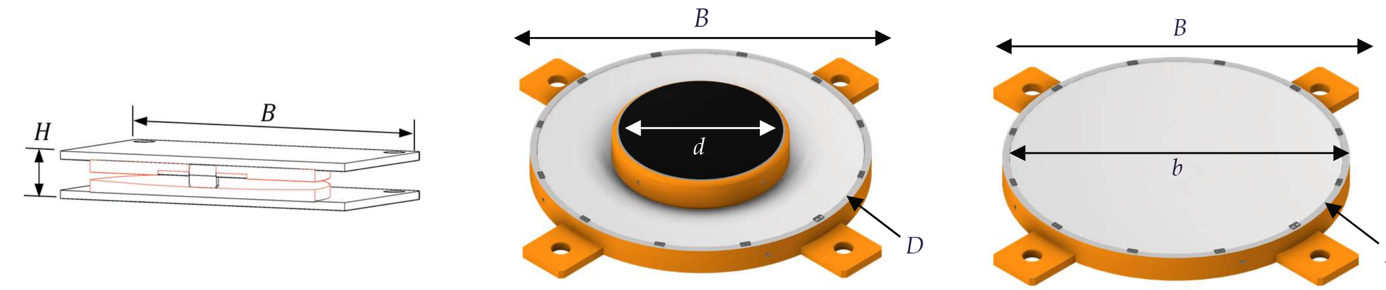
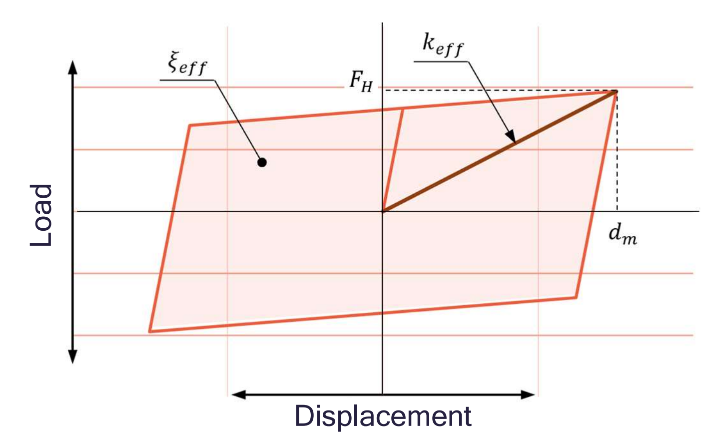



**Figure 3. Dimensions of the Dampo Double Pendulum Seismic Isolator.**

The Dampo Double Pendulum Seismic Isolator can be modeled in commercial programs as an equivalent element with non-linear behavior. In some programs the equivalent element is defined as "link". The main parameters to model the behavior of the isolator are presented in *Figure 4*, and are the effective stiffness ($k_{eff}$), which is defined as the secant stiffness of the hysteresis curve of the isolator, the static and dynamic friction coefficients ($\mu_e$ and $\mu_d$, respectively), which depend on the material, the effective radius of the pendulum ($R_{eff}$) and the friction parameter $r_p$, that defines the change between the static and dynamic friction coefficients. It should be noted that the Dampo Double Pendulum Seismic Isolator has the same properties (curvature and friction coefficients) on both plates (top and bottom).




$$k_{eff} = W_{eff}\left(\frac{1}{R_{eff}} + \frac{\mu_e}{d_m}\right) = \text{ Effective stiffness}$$

$$F_H = k_{eff} * d_m = \text{ Horizontal load}$$

$$T_{eff} = 2\pi\sqrt{\frac{R_{eff} * d_{max}}{g(d_{max} + \mu_d * R_{eff})}} = \text{ Effective period}$$

$$\xi_{eff} = 2\pi\frac{\mu_d * R_{eff}}{d_{max} + \mu_d * R_{eff}} = \text{ Damping}$$

**Figure 4. Definition of variables for modeling the Dampo Double Pendulum Seismic Isolator.**