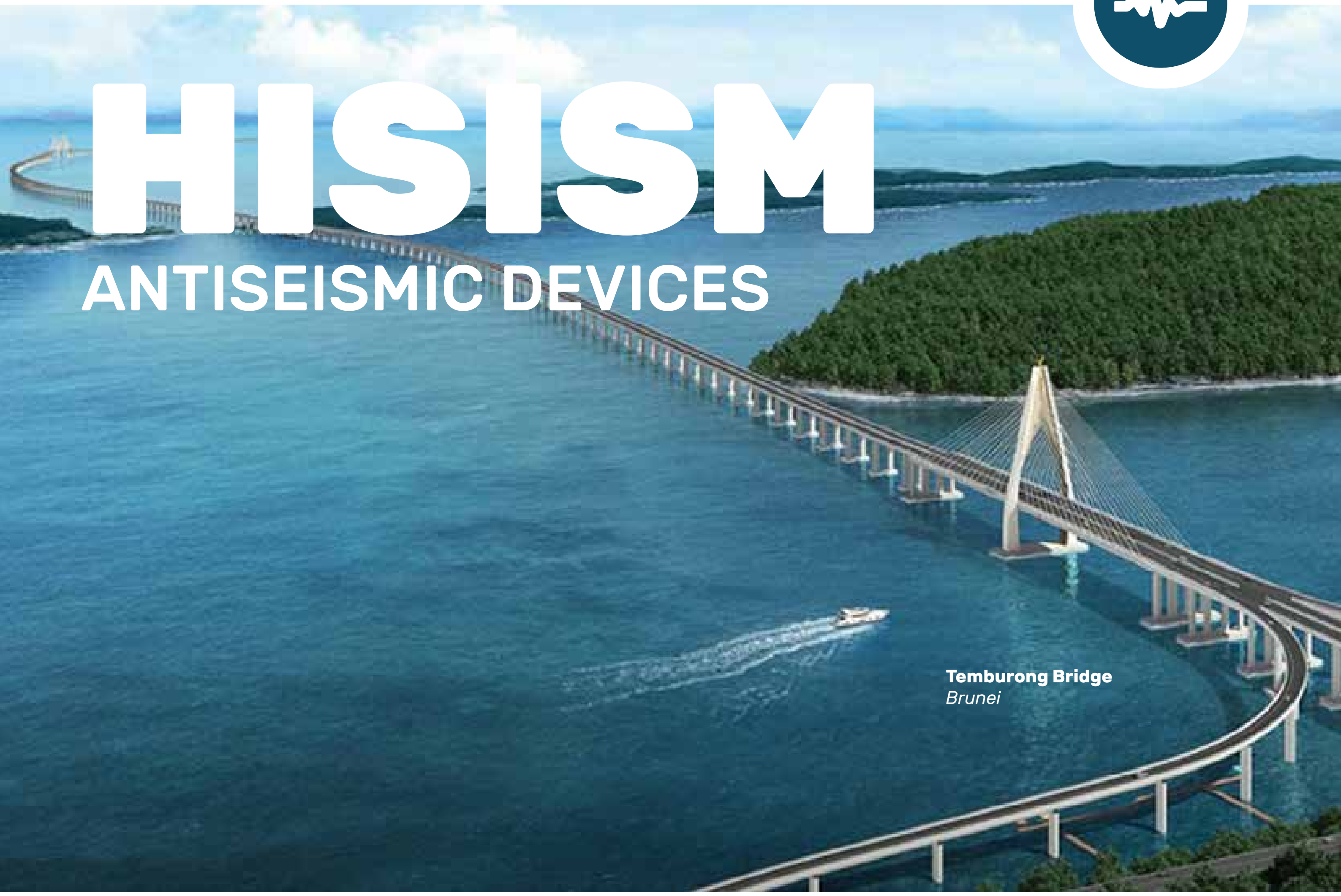
HISISM
ANTISEISMIC DEVICES



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CECO-HIRUN

We are a professional design, production, testing and installation company of structural devices with over 50 years' experience in the field. CECO-HIRUN has been involved in the design of bearings, antiseismic devices, post tensioning and expansion joints for the most important infrastructure lines of the world and for strategic buildings like hospitals schools and administrative compounds.
CECO-HIRUN is an engineering company having its roots in the deep heart of the most modern and advanced civil engineering technologies.
The core of the company is composed by pioneers that in the last 50 years had a leading position in developing worldwide very important technologies such as: structural bearings, expansion joints, postte sioning system, anti-vibration and anti-seismic systems. The Directors of the company in the past years were proudly involved in the definition of international standards or key specifications such as:EN1337 (European standard for structural bearings), EN15129 (European standard for antiseismic devices), special bearings for High speed railway lines (as examples in Italy, Taiwan and China) and Metro lines (as example the Bangkok metro system).

In the past years, the evidence of the strong innovation attitude is represented by several patents issued and this aim is still well alive in the company. Patents and customized unique solutions such as: special dampers, new materials for different applications, customized combinations and applications of different structural devices. This attitude is pushing the company to a never ending improvement.

We are now a specialized company for the application, the design, the production, the installation and the testing of all the following engineering technologies: Structural bearings, Seismic devices, Expansion joints, Post-tensioning systems, Anti-vibration devices.

A special attention is dedicated to the quality of the products.

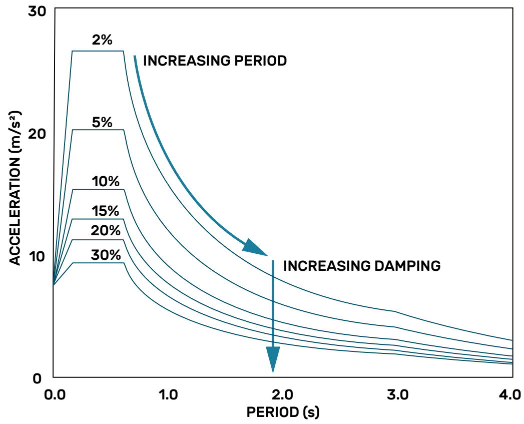
We design and produce starting from the control of the internal process; we are qualified ISO:9001 and we got several international qualifications such as the CE marking certificate for our products.

To achieve the above mentioned targets we created a very successful cooperation with partners in many fields such as: industries producing innovative materials, factories, universities and seismic laboratories in many parts of the world. Our partners are diversified for location and capacity in order to create an active and efficient network which can cooperate to match the most challenging needs of all the clients.

We aim to become the leading specialized company for the most peculiar and important civil engineer projects in the world:
THE ENGINEERING SOLUTION.

Basic principles of the base isolation and the seismic protection of structures

A response spectrum is a diagram giving the response of a structure forced into motion in function of its natural frequency. The response can be given in terms of displacement, velocity or acceleration,
The acceleration response spectrum is a very useful tool for the seismic design of structures.
Normally the acceleration response spectrum is given by the relevant seismic codes and provides to the designer all the useful information allowing designing the structure.
In the response spectrum in particular are given the information about the intensity of the earthquake and the effect of the soil properties
In the following figures are shown as an example the acceleration response spectra given by the European Standard in function of the damping.



The strategies for the reduction of the seismic action in a structure shown on a typical response spectrum

Looking at the typical feature of a response spectrum it appears quite evident which strategy shall be used to reduce the seismic action in a structure:
- Increase the natural period
- Increase the damping, or the energy dissipation

We can divide the anti-seismic devices in three main categories:

1. Base isolators
They apply both strategies: increasing the period and the damping

2. Dampers
They apply one strategy: increasing the damping

3. Dynamic connections
They do not modify the seismic action: they create supplementary links in case of dynamic actions like earthquake, braking force or wind.

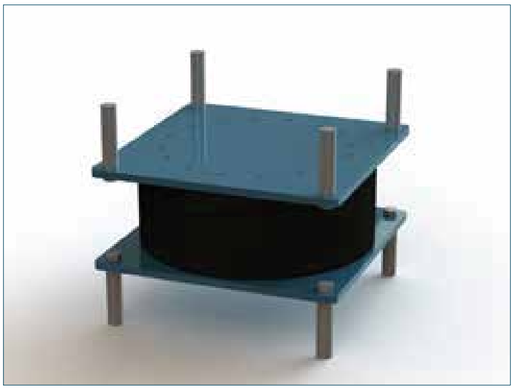
Base isolators

Base isolators, as defined in the EN 15129 are the devices or the combination of devices providing the following four functions:
1. Support the weight of the structures.
2. Provide lateral displacement capability.
3. Provide re-centring capability
4. Dissipate energy

They apply the two strategies for the reduction of the seismic action:
• Increasing the natural period of the structure
• Increasing the damping of the structure by dissipating energy.

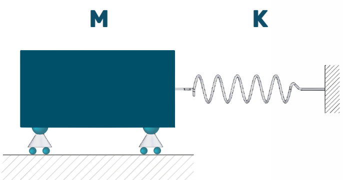
How can the isolators increase the natural period of a structure?
• They shall be placed between the structure and the foundations
• They force the structure to swing according to their own natural period

The natural period T of the isolators is the following



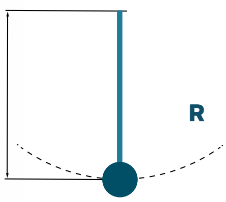
High Damping Rubber Bearing

Rubber isolators (HDRB and LRB) are equivalent to a spring-mass system with stiffness K and mass M

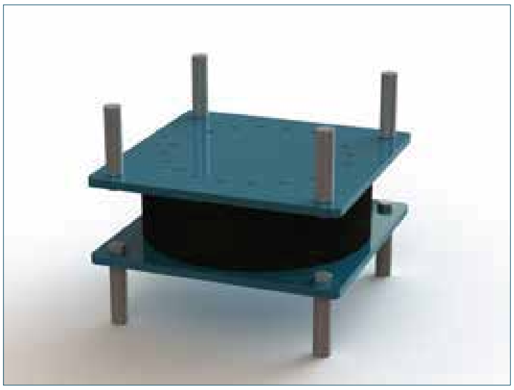


$$T = 2\pi\sqrt{\frac{M}{K}}$$

Sliding Pendulum Isolators are equivalent to a pendulum with length R.
g is the gravity constant.

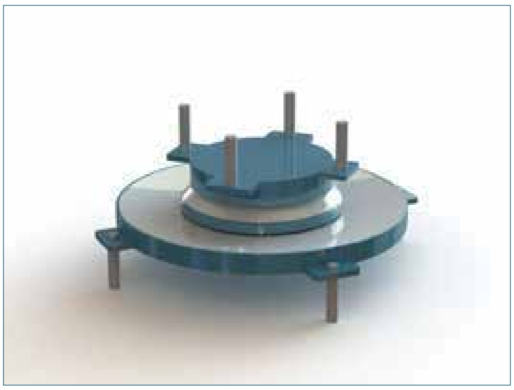


$$T = 2\pi\sqrt{\frac{R}{g}}$$



Lead Rubber Bearing

How can the isolators increase the damping of a structure?
They dissipate the energy by one of the following principles
• Friction (Sliding Pendulum Isolators)
• Yield of metals (Lead Rubber Bearings)
• Viscosity of rubber (High Damping Rubber Bearings)
In any case an amount of heath equivalent to the dissipated energy is generated.



Sliding pendulum

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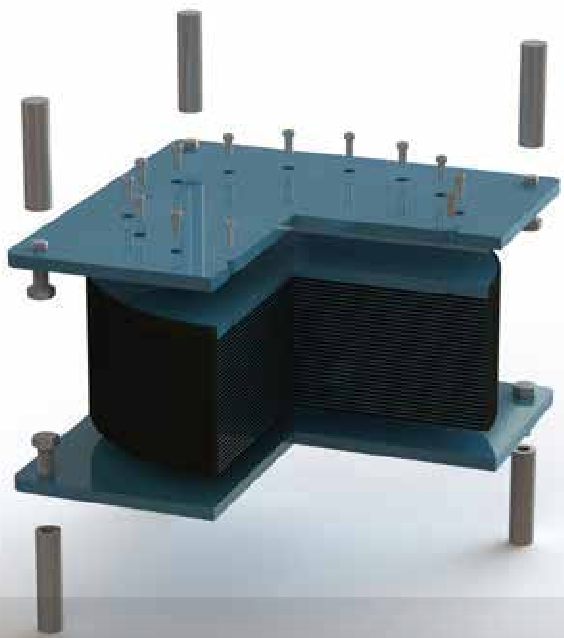
The economical solution for low to medium seismic areas.



In these isolators the re-centering capacity is given by the rubber elasticity, the energy dissipation is given by the viscosity of the special rubber compound.

HDRB also are an alternation of rubber and steel layers providing a very high vertical stiffness and a low horizontal stiffness hence providing a large vertical bearing capacity and a large horizontal displacement capacity. However they utilize a special rubber compound with additives that can provide energy dissipation when subjected to shear deformation.

- The spring effect is given by the rubber elasticity (elastic energy storage)
- The energy dissipation is given by the rubber viscosity

Main Field

Any kind of bridges and building

INSTALLATION	Requires trained team
DURABILITY	> 60 years
MAINTENANCE	Corrosion protection after 15 years
COST	AVERAGE

VERTICAL LOAD

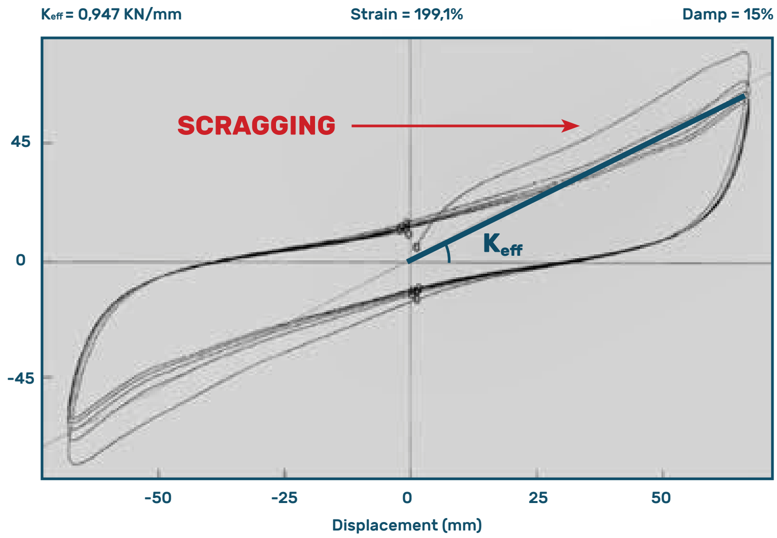
HORIZONTAL DISPLACEMENT

RE-CENTERING CAPACITY

DAMPING

FIRE RESISTANCE

Their mathematical model can be represented by two parameters only:
- The stiffness K_{eff}
- The equivalent viscous damping ξ



Typical load deflection plot of a HDRB

The equivalent viscous damping is given by the usual expression:

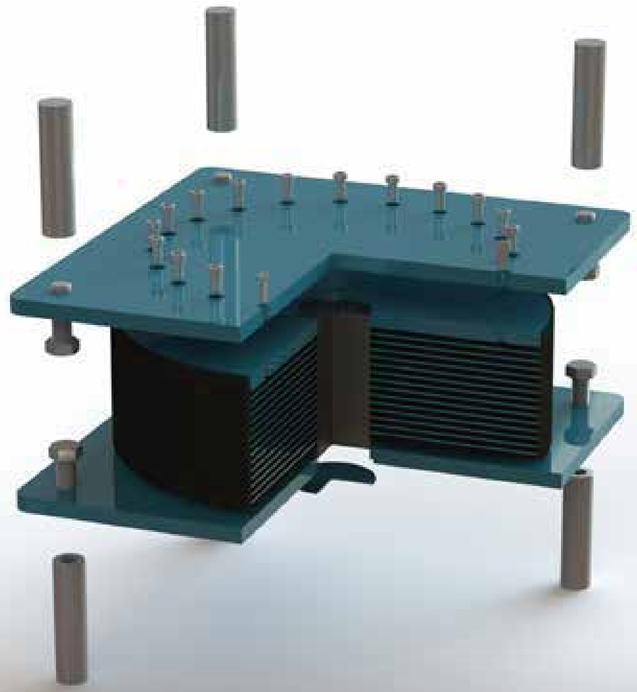
$$\xi = \frac{EDC}{2\pi K_{eff} D^2}$$

Where EDC is the energy dissipated per cycle, equivalent to the area of the hysteresis cycle. Since the cycles are not exactly the same, normally the 3rd cycle is assumed to evaluate the EDC.
In the HDRB the scragging phenomenon is particular evident. The scragging is the increased stiffness of the first cycle. It is a common behavior of any rubber bearing but for HDRB is particularly evident. The scragging temporarily disappears after a bearing has been tested but appears again after a few days.
Typical values of the equivalent viscous damping for HDRB can vary from 10 to 16% or in certain cases up to 20% or more.
In the design of a structure isolated with HDRB they are normally modelled as linear springs and the effect of the damping is taken into account through the factor η that is defined in the European Standard EN 1998:

$$\eta = \sqrt{\frac{10}{5+\xi}}$$

In other standard the effect of the damping is taken into account by similar coefficients.

The high amounts of energy dissipation solution.



In these isolators the re-centering capacity is given by the rubber elasticity and the energy dissipation is given by the lead core that is stressed over the yield limit.

They are a combination of a rubber bearing and a single or multiple lead cores.
A rubber bearing is an alternation of rubber and steel layers providing a very high vertical stiffness and a low horizontal stiffness, hence providing a large vertical bearing capacity and a large horizontal displacement capacity.
The lead core, as a consequence of the horizontal displacement of the bearing, is subjected to yield. One peculiar property of the lead is that after several yield cycles it can re-crystalize and get back to the initial properties. So in principle they could sustain an unlimited number of yield cycles.

Main Field

Bridges and building located in medium and high level earthquake areas

INSTALLATION	Requires trained team
DURABILITY	> 60 years
MAINTENANCE	Corrosion protection after 15 years
COST	AVERAGE

VERTICAL LOAD

HORIZONTAL DISPLACEMENT

RE-CENTERING CAPACITY

DAMPING

FIRE RESISTANCE

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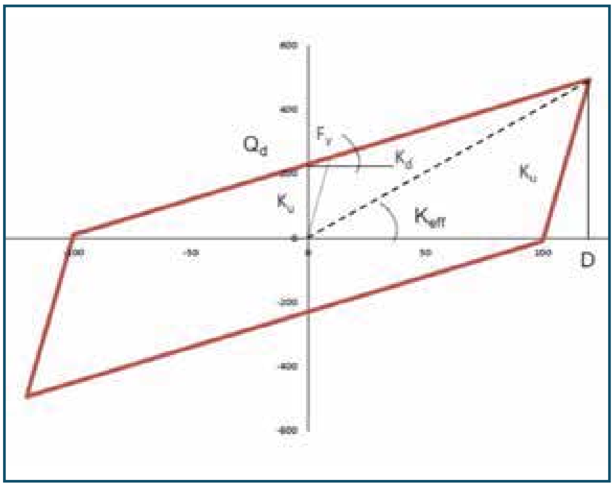
They are using the mass spring system:

- The spring is represented by the elasticity of the rubber
- The energy dissipation is provided by the lead core

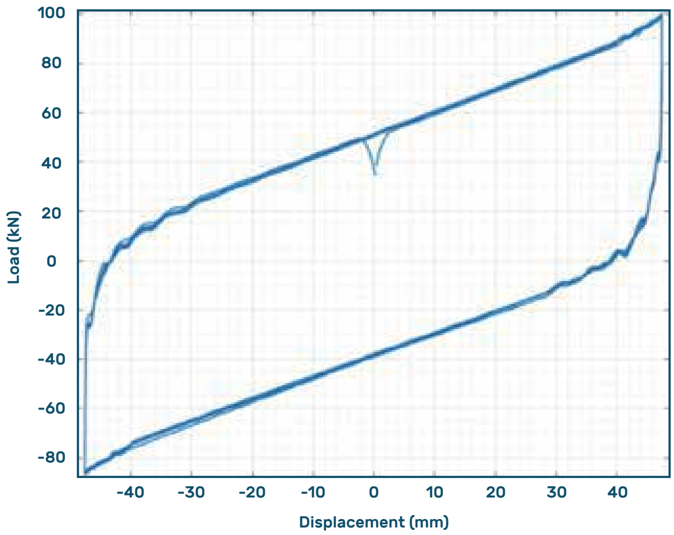
Their mathematical model can be expressed in function of two parameters only:

- The Rubber stiffness K_d
- The characteristic strength = the yield force of the lead core Q_d

The mathematical model of the LRB is represented in the following graph:



LRB Mathematical model



LRB real load – deflection plot from testing

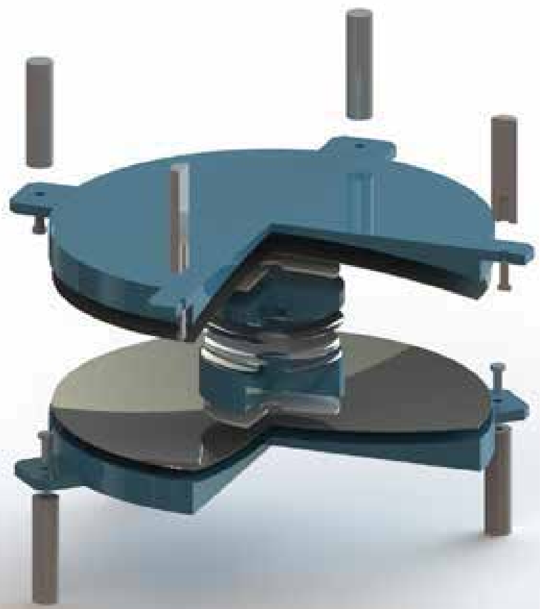
The relevant parameters of the mathematical model are the following:

- Q_d Characteristic strength = A_{lead} x τ_{lead} where:
- A_{lead} is the area of the lead core
- τ_{lead} is the yield shear stress of the lead, normally 10 MPa
- K_u is the elastic stiffness = G_{lead} x A_{lead} / h_r where:
- G_{lead} is the shear modulus of the lead, normally 130 GPa
- h_r is the net rubber thickness of the LRB
- F_y is the yield force = Q_d + K_d x h_r / G_{lead}
- D_y is the displacement corresponding to the yield force = τ_{lead} x h_r / G_{lead}
- K_d is the post-elastic stiffness, equal to the stiffness of the rubber only
- D is the design displacement
- K_{eff} is the effective stiffness = (Q_d + K_d x D)/D
- ξ is the equivalent viscous damping

$$\xi = \frac{EDC}{2\pi K_{eff} D^2} = \frac{4Q_d(D - D_y)}{2\pi K_{eff} D^2}$$

- EDC is the energy dissipated per cycle

The efficient solution in high seismic areas.



These isolators can dissipate very large amounts of energy. The dissipation is given by the friction of the sliding material. The re-centering capacity is given by the pendulum effect. The vertical component of the earthquake greatly amplifys the re-centering capacity.

They are suitable for any kind of structure, up to the most important bridges. They are not sensitive to fire action and can grant a very long service life with negligible maintenance.

Sliding pendulum isolators are very often the most cost/performance effective devices.

Main Field

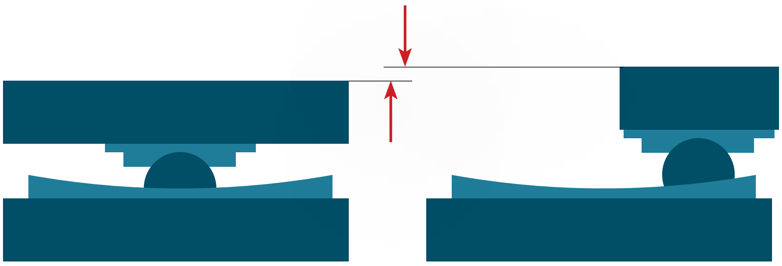
Any kind of bridges and building

INSTALLATION	Requires trained team
DURABILITY	> 100 years
MAINTENANCE	Corrosion protection after 15 years
COST	Best cost/performance ratio

VERTICAL LOAD | **HORIZONTAL DISPLACEMENT** | **RE-CENTERING CAPACITY** | **DAMPING** | **FIRE RESISTANCE**

The sliding pendulum is an isolator
• Is supporting the weight of the structure
• Is providing lateral flexibility
• Is providing a re-centering effect through the potential energy storage (is equivalent to a spring)
• The energy dissipation is provided by the friction of the sliding material

STRUCTURE UPLIFT = POTENTIAL ENERGY STORAGE



The cinematic behavior of the elementary pendulum is perfectly reproduced both by the pendulum with one main sliding surface and 2 sliding surfaces, with or without center articulation.
They reproduce the behavior of an elementary pendulum with length R where R corresponds to the equivalent radius of the sliding pendulum isolators.
The equivalent radius is not coincident with the radius of the spherical calottes of the sliding pendulum isolators but is a function of the 2 radii of them and their distance.

The mathematical model of the sliding pendulum can be represented by the following equations that are defined by two parameters only:
• R the equivalent radius
• μ the dynamic friction
and by the design displacement D and the weight of the supported structure W

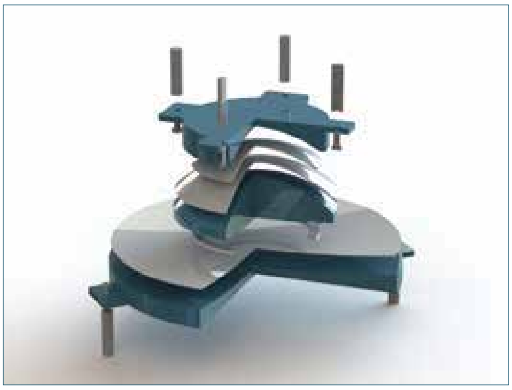
The equations representing the behavior of the sliding pendulum are the following:

Stiffness $$K = W\left(\frac{1}{R} + \frac{\mu}{D}\right)$$

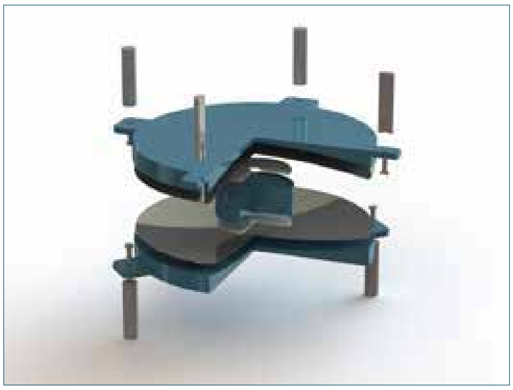
Stiffness $$T = 2\pi\sqrt{\frac{RD}{(D + \mu R)g}}$$

Equivalent viscous damping $$\xi = \frac{2\mu}{\pi\left(\mu + \frac{D}{R}\right)}$$

There are 3 types of sliding pendulum isolators:



HP1
Single sliding surface



HP2
Double sliding surface

HP2A
Double sliding surface
With center articulation

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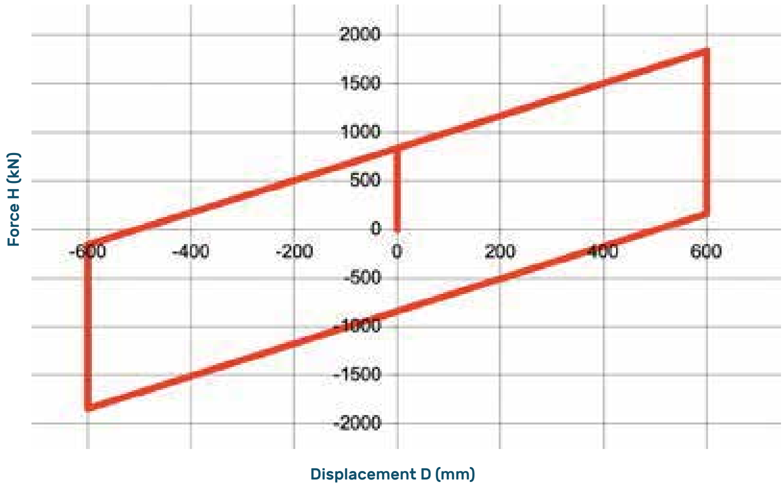
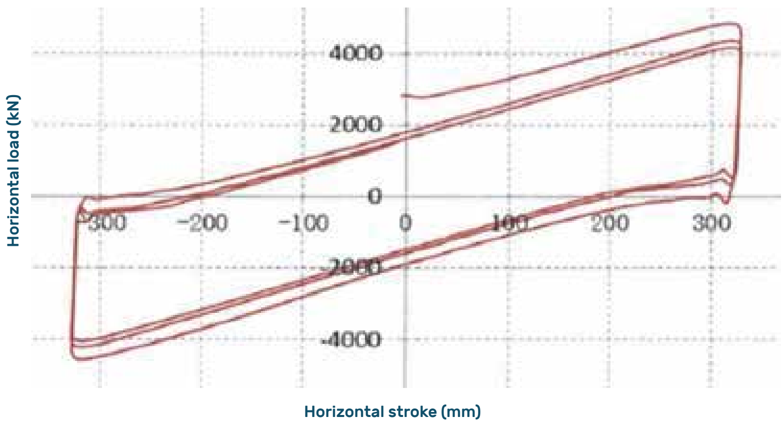
The mathematical model is represented geometrically in the following diagram



Mathematical model of the sliding pendulum isolator with one or two main sliding surfaces



Real load – deflection plot from a dynamic test on sliding pendulum isolator

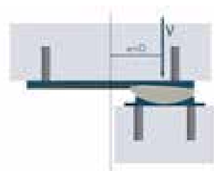
How to choose the right pendulum?

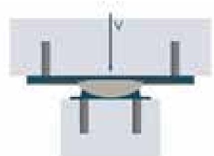
Sliding pendulum isolators are perfectly defined by 2 parameters only:
- The equivalent radius R
- The dynamic friction μ

To choose the right one you also need to know the following values
- Vertical load in all loading combinations
- Horizontal displacement for all kind of actions
- Rotation

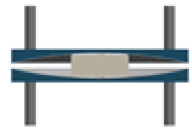
Sliding pendulum isolators types **HP1** and **HP2** are perfectly equivalent from the cinematic point of view, bearing, displacement and rotation capability.
The only difference are the dimensions in plan and the displacement of the vertical resultant when a horizontal displacement is applied:
- **HP1** shifts the resultant at the top only (or at the bottom only if upside down installed)
- **HP2** shift the resultant at top and bottom for half the total value.
HP1 and HP2 (with or without center articulation) can accommodate big rotations (common value of the rotation is 0.01 rad but rotations up to 0.05 rad can be accommodated if required to compensate prefabrication tolerances)

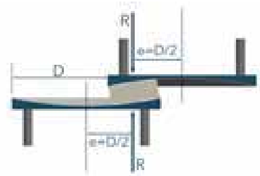
HP1 typical function

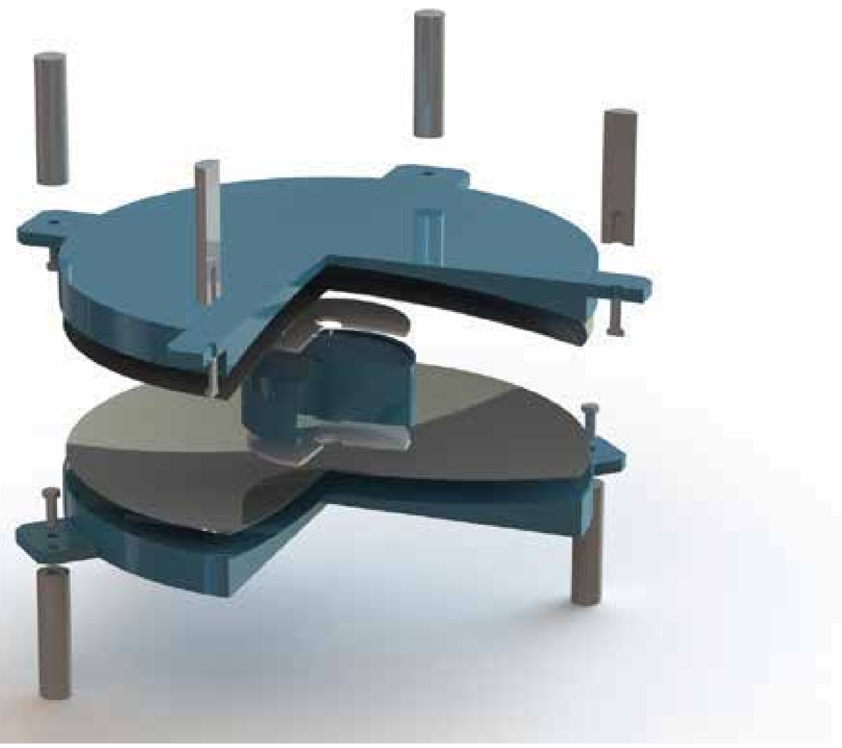




HP2 typical function







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Rubber isolators or Pendulum? How to choose?

HDRB & LRB	PENDULUM
For the Rubber Isolators the period is a function of: • M = mass • K = stiffness M may vary (Live Load may change) K can vary in function of temperature and aging THE PERIOD T CAN VARY	For the Pendulum the period is a function of: • g = gravity constant: cannot vary • R = radius: cannot vary THE PERIOD T CANNOT VARY
For the HDRB & LRB the stiffness is an intrinsecal property. •The center of stiffness may not be coincident with the center of mass	For the Pendulum the stiffness is proportional to the mass $K = Mg(\frac{1}{R} + \frac{\mu}{D})$ • The center of stiffness is always coincident with the center of mass
Limited performances in terms of period shift $T = 2\pi\sqrt{\frac{M}{K}}$ INCREASING PERIOD = REDUCING STIFFNESS • THE LIMIT: BUCKLING • PRACTICALLY T ≤ 3 - 3.5 s	Very high performances in terms of period shift $T = 2\pi\sqrt{\frac{R}{g}}$ INCREASING PERIOD = INCREASING RADIUS • THE LIMIT: RE-CENTERING • PRACTICALLY T ≤ 6 s Sliding pendulum isolators can allow a higher period shift However Pendulum is not suitable if the period shall be less than 2 s
Service life ≤ 60 year	Service life ≥ 100 year
Behavior dependent from aging and environmental conditions	Behavior independent from aging and environmental conditions
May be damaged from fire	Fire resistant
	Unlimited bearing capacity Very good cost/efficiency ratio

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How to design a base isolated structure?

The design of a base isolated structure normally is much easier than a non-isolated one, for the reason that the base isolated structure normally will remain in the elastic field.
A detailed design can be performed by modal spectral or time history analysis and many suitable software are available in the market.
As a preliminary approach the linear analysis with one degree of freedom is always advisable because it allows to easily select the best base isolation solution.

The considered isolators can be modelled by two parameters only

ISOLATOR	PARAMETERS	ANALYSIS
HDRB	K effective stiffness ξ equivalent viscous damping	Linear
LRB	K_r rubber stiffness Q_d Yield of lead core	Linear iteration
PENDULUM	R equivalent radius μ dynamic friction	Linear iteration

Example of linear iteration analysis for a HILEAD isolator

The iteration may be performed with a very simple excel table

1. First step is to introduce the input values:
- Weight supported by the isolator
- Characteristic strength of the lead core
- Rubber stiffness
- Definition of the spectrum
- A tentative displacement

2. Second step is to calculate the other values (stiffness period, etc.) using the mathematical model of the isolators

3. Third step is to input the obtained displacement in the second iteration

4. The procedure is completed when the input displacement is equal to the output

LRB - ITERATION ANALYSIS - NOMINAL STIFFNESS							
	Symbol	Formula	Unit	1	2	3	4
weight	V	input	kN	650	650	650	650
mass	M	V/g	t	66,3	66,3	66,3	66,3
characteristic strength	Qd	input	kN	80	80	80	80
rubber stiffness	Kd	input	kN/mm	0,48	0,48	0,48	0,48
displacement guessed	D_0	input	mm	150	164,7	168,7	169,7
stiffness	K_{eff}	$K_d + Q_d/D$	kN/mm	1,01	0,97	0,95	0,95
period	T_{eff}	$2\pi\sqrt{\frac{M}{K_{eff}}}$	s	1,61	1,65	1,66	1,66
equivalent viscous damping	ξ	$\frac{0.95 \times Q_d}{\pi \times K_{eff} D}$	%	31,8	30,4	30,1	30,0
damping coefficient	η	$\sqrt{\frac{10}{\xi + 5}}$		0,550	0,550	0,550	0,550
acceleration	A	$\frac{g \eta S_{D1}}{T_{eff}}$	m/s^2	2,519	2,459	2,444	2,440
displacement	D	$A\left(\frac{T_{eff}}{2\pi}\right)^2$	mm	164,7	168,7	169,7	170,0
horizontal load	H	AxV/g	kN	167	163	162	162
Spectrum definition							
Reference acceleration	S_{D1}	g		0,750			

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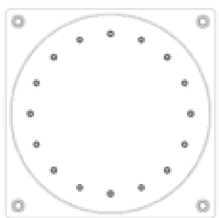
Dimensions Table

HIDAMP HDRB

They are identified
by the following Mark
HRI
S for soft
N for normal,
H for hard.
350 Diameter of rubber (mm)
77 Rubber thickness (mm)

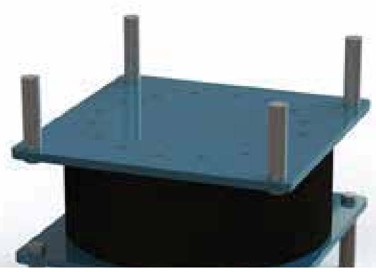


Plan

Section

Dimensions and performances are given for guidance only.

Any dimension up to 1500 mm diameter and 1000 mm displacement can be designed, tested and manufactured



	DESIGN DISPLACEMENT d=150	Rubber Diameter	Total Height	Rubber Thickness	Mounting Plate Dimension	Horizontal Stiffness	Vertical Load ULS	Seisimic Vertical Load	Damping
	Types	*mm*	*mm*	*mm*	*mm*	*kN/mm*	*kN*	*kN*	
SOFT	HRIS-350-77	350	227	77	400X400	0.50	2400	1440	10%
	HRIS-400-77	400	227	77	450X450	0.65	3100	1860	10%
	HRIS-450-77	450	226	80	500X500	0.80	3900	2340	10%
	HRIS-500-77	500	223	81	550X550	0.97	4900	2940	10%
	HRIS-550-77	550	218	80	600X600	1.19	5900	3540	10%
	HRIS-600-77	600	218	80	650X650	1.41	7000	4200	10%
	HRIS-650-77	650	211	77	700X700	1.72	8200	4920	10%
	HRIS-700-77	700	202	72	750X750	2.14	9600	5760	10%
	HRIS-750-77	750	201	75	800X800	2.36	11000	6600	10%
	HRIS-800-77	800	201	75	850X850	2.68	12500	7500	10%
NORMAL	HRIN-350-77	350	227	77	400X400	1.00	2400	1440	10%
	HRIN-400-77	400	227	77	450X450	1.31	3100	1860	10%
	HRIN-450-80	450	226	80	500X500	1.59	3900	2340	10%
	HRIN-500-72	500	210	72	550X550	2.18	4900	2940	10%
	HRIN-550-80	550	218	80	600X600	2.38	5900	3540	10%
	HRIN-600-80	600	218	80	650X650	2.83	7000	4200	10%
	HRIN-650-77	650	211	77	700X700	3.45	8200	4920	10%
	HRIN-700-72	700	202	72	750X750	4.28	9600	5760	10%
	HRIN-750-75	750	201	75	800X800	4.71	11000	6600	10%
	HRIN 800-75	800	201	75	850X850	5.36	12500	7500	10%
HARD	HRIH-350-77	350	227	77	400X400	1.75	2400	1440	15%
	HRIH-400-77	400	227	77	450X450	2.28	3100	1860	15%
	HRIH-450-80	450	226	80	500X500	2.78	3900	2340	15%
	HRIH-500-72	500	210	72	550X550	3.82	4900	2940	15%
	HRIH-550-80	550	218	80	600X600	4.16	5900	3540	15%
	HRIH-600-80	600	218	80	650X650	4.95	7000	4200	15%
	HRIH-650-77	650	211	77	700X700	6.03	8200	4920	15%
	HRIH-700-72	700	202	72	750X750	7.48	9600	5760	15%
	HRIH-750-75	750	201	75	800X800	8.25	11000	6600	15%
	HRIH-800-75	800	201	75	850X850	9.38	12500	7500	15%

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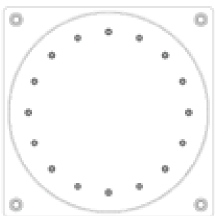
Dependable Joining Technology

Dimensions Table

HIDAMP HDRB

They are identified
by the following Mark
HRI
S for soft
N for normal,
H for hard.
350 Diameter of rubber (mm)
77 Rubber thickness (mm)



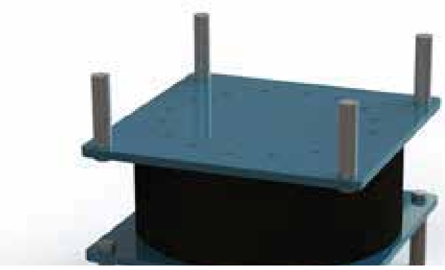
Plan

Section

Dimensions and performances are given for guidance only.

Any dimension up to 1500 mm diameter and 1000 mm displacement can be designed, tested and manufactured

	DESIGN DISPLACEMENT d=200	Rubber Diameter	Total Height	Rubber Thickness	Mounting Plate Dimension	Horizontal Stiffness	Vertical Load ULS	Seismic Vertical Load	Damping
	Types	*mm*	*mm*	*mm*	*mm*	*kN/mm*	*kN*	*kN*	
SOFT	HRIS-350-105	350	271	105	400X400	0.37	2400	1440	10%
	HRIS-400-105	400	271	105	450X450	0.48	3100	1860	10%
	HRIS-450-104	450	262	104	500X500	0.61	3900	2340	10%
	HRIS-500-99	500	249	99	550X550	0.79	4900	2940	10%
	HRIS-550-100	550	246	100	600X600	0.95	5900	3540	10%
	HRIS-600-100	600	246	100	650X650	1.13	7000	4200	10%
	HRIS-650-99	650	241	99	700X700	1.34	8200	4920	10%
	HRIS-700-96	700	234	96	750X750	1.60	9600	5760	10%
	HRIS-750-98	750	232	98	800X800	1.80	11000	6600	10%
	HRIS-800-98	800	232	98	850X850	2.05	12500	7500	10%
NORMAL	HRIN-350-105	350	271	105	400X400	0.73	2400	1440	10%
	HRIN-400-105	400	271	105	450X450	0.96	3100	1860	10%
	HRIN-450-104	450	262	104	500X500	1.22	3900	2340	10%
	HRIN-500-99	500	249	99	550X550	1.59	4900	2940	10%
	HRIN-550-100	550	246	100	600X600	1.90	5900	3540	10%
	HRIN-600-100	600	246	100	650X650	2.26	7000	4200	10%
	HRIN-650-99	650	241	99	700X700	2.68	8200	4920	10%
	HRIN-700-96	700	234	96	750X750	3.21	9600	5760	10%
	HRIN-750-98	750	232	98	800X800	3.61	11000	6600	10%
	HRIN-800-98	800	232	98	850X850	4.10	12500	7500	10%
HARD	HRIH-350-105	350	271	105	400X400	1.28	2400	1440	15%
	HRIH-400-105	400	271	105	450X450	1.68	3100	1860	15%
	HRIH-450-104	450	262	104	500X500	2.14	3900	2340	15%
	HRIH-500-99	500	249	99	550X550	2.78	4900	2940	15%
	HRIH-550-100	550	246	100	600X600	3.33	5900	3540	15%
	HRIH-600-100	600	246	100	650X650	3.96	7000	4200	15%
	HRIH-650-99	650	241	99	700X700	4.69	8200	4920	15%
	HRIH-700-96	700	234	96	750X750	5.61	9600	5760	15%
	HRIH-750-98	750	232	98	800X800	6.31	11000	6600	15%
	HRIH-800-98	800	232	98	850X850	7.18	12500	7500	15%



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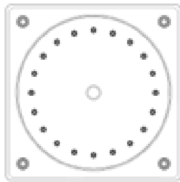
Dependable Joining Technology

Dimensions Table

HILEAD LRB

They are identified by the following Mark
HLRI
S for soft
N for normal,
H for hard.
350 Diameter of rubber (mm)
77/105 Rubber thickness
/ Lead core diameter (mm)



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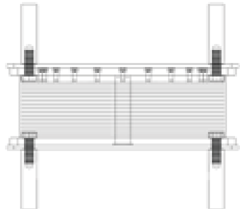
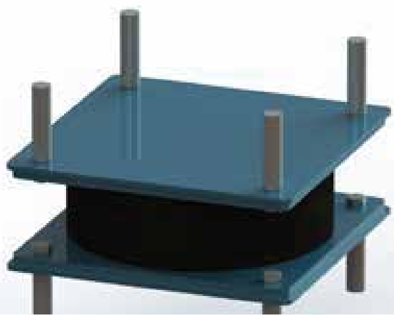


Section

	DESIGN DISPLACEMENT d=150	Rubber Diameter	Lead Diameter	Total Height	Rubber Thickness	Mounting Plate Dimension	Horizontal Stiffness of isolator	Horizontal Stiffness of lead	Horizontal Stiffness of rubber	Vertical Load ULS	Seisimic Vertical Load	Damping
	Types	*mm*	*mm*	*mm*	*mm*	*mm*	*kN/mm*	*kN/mm*	*kN/mm*	*kN*	*kN*	
NORMAL	**HLRIN-350-77/115**	350	115	247	77	400X400	1.65	17.54	1.00	2400	1440	30%
	HLRIN-400-77/130	400	130	247	77	450X450	2.14	22.41	1.31	3100	1860	30%
	HLRIN-450-80/145	450	145	244	80	500X500	2.64	26.83	1.60	3900	2340	30%
	HLRIN-500-72/160	500	160	224	72	550X550	3.54	36.30	2.20	4900	2940	30%
	HLRIN-550-80/180	550	180	252	80	600X600	3.98	41.35	2.39	5900	3540	30%
	HLRIN-600-80/195	600	195	252	80	650X650	4.71	44.53	2.84	7000	4200	30%
	HLRIN-650-77/210	650	210	243	77	700X700	5.64	58.48	3.47	8200	4920	30%
	HLRIN-700-72/230	700	230	232	72	750X750	7.06	75.02	4.29	9600	5760	30%
	HLRIN-750-75/245	750	245	229	75	800X800	7.88	81.72	4.74	11000	6600	30%
	HLRIN-800-75/260	800	260	229	75	850X850	8.93	92.03	5.39	12500	7500	30%

Dimensions and performances are given for guidance only.
Any dimension up to 1500 mm diameter and 1000 mm displacement can be designed, tested and manufactured



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Dimensions Table

HILEAD LRB

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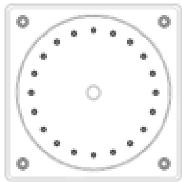

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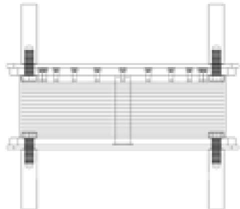
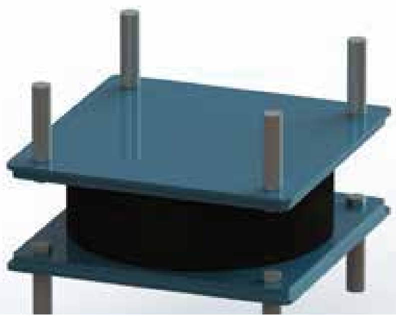


Section

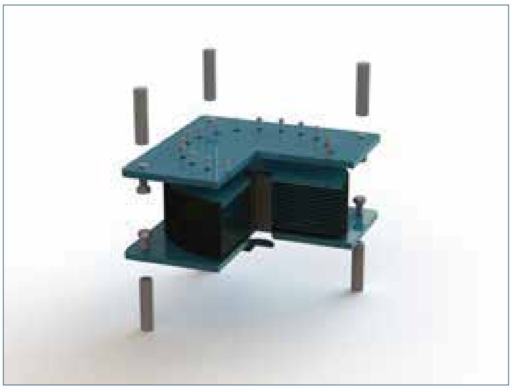
	DESIGN DISPLACEMENT d=200	Rubber Diameter	Lead Diameter	Total Height	Rubber Thickness	Mounting Plate Dimension	Horizontal Stiffness of isolator	Horizontal Stiffness of lead	Horizontal Stiffness of rubber	Vertical Load ULS	Seismic Vertical Load	Damping
	Types	*mm*	*mm*	*mm*	*mm*	*mm*	*kN/mm*	*kN/mm*	*kN/mm*	*kN*	*kN*	
NORMAL	**HLRIN-350-105/115**	350	115	299	105	400X400	1.23	12.86	0.74	2400	1440	30%
	HLRIN-400-105/130	400	130	299	105	450X450	1.60	16.43	0.96	3100	1860	30%
	HLRIN-450-104/145	450	145	286	104	500X500	2.02	20.64	1.23	3900	2340	30%
	HLRIN-500-99/160	500	160	269	99	550X550	2.61	26.40	1.60	4900	2940	30%
	HLRIN-550-100/180	550	180	284	100	600X600	3.18	33.08	1.91	5900	3540	30%
	HLRIN-600-100/195	600	195	284	100	650X650	3.77	38.82	2.28	7000	4200	30%
	HLRIN-650-99/210	650	210	277	99	700X700	4.43	45.48	2.70	8200	4920	30%
	HLRIN-700-96/230	700	230	268	96	750X750	5.30	56.26	3.22	9600	5760	30%
	HLRIN-750-98/245	750	245	264	98	800X800	5.98	62.54	3.62	11000	6600	30%
	HLRIN-800-98/260	800	260	264	98	850X850	6.78	70.43	4.13	12500	7500	30%

Dimensions and performances are given for guidance only.
Any dimension up to 1500 mm diameter and 1000 mm displacement can be designed, tested and manufactured



HILEAD Low Damping Rubber Bearings LDRB

They are similar to the HDRB but have an equivalent viscous damping
They may be used in low seismic areas or in combination with other kinds of rubber isolators, LRB or HDRB

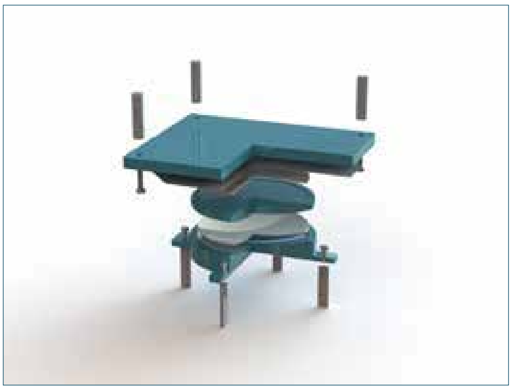


Low damping rubber bearing

Sliders

Sliders are not base isolators as they have no damping and no re-centering capacity.
They may be combined with rubber isolators to reduce the stiffness of the base isolation system and therefore increase the natural period
They consist of free sliding bearings and may be pot, spherical or elastomeric bearings with sliding surfaces.

Sliders will not vary their height when the lateral displacement is applied and therefore:
• They cannot be combined with sliding pendulum isolators
• When combined with LRB and HDRB their supplementary deflection when the lateral displacement is applied shall be carefully computed. The structure shall be carefully verified taking into account the differential deflection of the sliders and the isolators.



Free sliding pot or spherical bearings may be used as sliders.

Example of linear iteration analysis for a HISLIDE isolator

The iteration may be performed with a very simple excel table

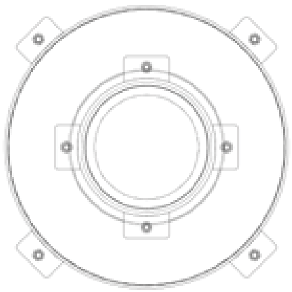
1. First step is to introduce the input values:
- Weight supported by the isolator
- Equivalent radius
- Dynamic friction
- Definition of the spectrum
- A tentative displacement

2. Second step is to calculate the other values (stiffness period, etc) using the mathematical model of the isolators

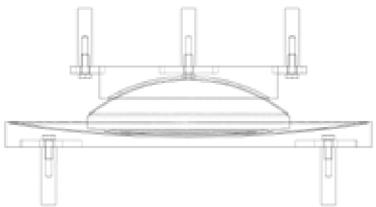
3. Third step is to input the obtained displacement in the second iteration

4. The procedure is completed when the input displacement is equal to the output

PENDULUM - ITERATION ANALYSIS - NOMINAL VALUE							
	Symbol	Formula	Unit	1	2	3	4
weight	V	input	kN	1000	1000	1000	1000
friction coefficient	μ	input		0,05	0,05	0,05	0,05
equivalent radius	R	input	mm	8000	8000	8000	8000
displacement guessed	D_0	input	mm	400	389,6	384,9	382,7
stiffness	K_{eff}	$V\left(\frac{1}{R}+\frac{\mu}{D_0}\right)$	kN/mm	0,25	0,25	0,25	0,26
period	T_{eff}	$2\pi\sqrt{\frac{V}{K_{eff}g}}$	s	4,01	3,99	3,97	3,97
equivalent viscous damping	ξ	$\frac{2}{\pi}\left(\frac{\mu}{\mu+\frac{D_0}{R}}\right)$	%	31,8	32,2	32,4	32,5
damping coefficient	η	$\sqrt{\frac{10}{5+\xi}}$		0,521	0,518	0,517	0,516
acceleration	A	$\frac{g\eta S_{D1}}{T_{eff}}$	m/s^2	0,956	0,956	0,957	0,957
displacement	D	$A\left(\frac{T_{eff}}{2\pi}\right)^2$	mm	389,6	384,9	382,7	381,6
horizontal load	H	$V\left(\frac{D}{R}+\mu\right)$	kN	99	98	98	98
Spectrum definition							
Reference acceleration	S_{D1}	g		0,750			



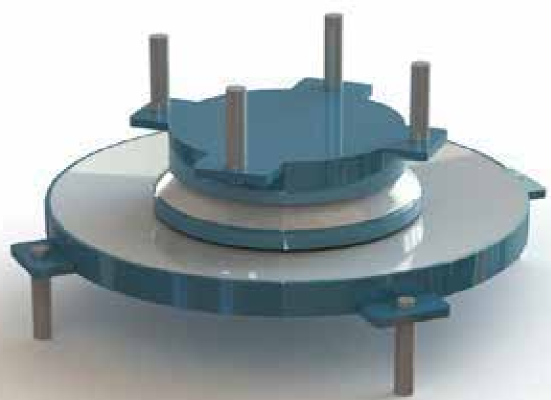
Plan



Section

Dimensions and performances are given for guidance only.

HISLIDE pendulum with any bearing capacity and displacement can be designed, tested and manufactured.



Dimensions Table

HISLIDE HP1

They are identified by the following Mark: **HP1 N_{Sd}(kN)/d_{Ed}(mm)**
EXAMPLE: **HP1 4000/500**: Friction Pendulum with single sliding surface with 4000 kN characteristic vertical load and 500 mm horizontal displacement (±250)

N_{sd}	N_{max}	d_{Ed}	A	B	HT
kN	*kN*	*±mm*	*mm*	*mm*	*mm*
1000	1400	250	190	690	88
2000	2800	250	270	770	102
3000	4200	250	330	830	112
4000	5600	250	380	880	119
5000	7000	250	430	930	127
6000	8400	250	470	970	134
7000	9800	250	500	1000	140
8000	11299	250	540	1040	147
9000	12600	250	570	1070	150
10000	14000	250	600	1100	169
11000	15400	250	630	1130	174
12000	16800	250	660	1160	179
13000	18200	250	680	1180	183
15000	21000	250	730	1230	192
17500	24500	250	790	1290	200
20000	28000	250	850	1350	210
25000	35000	250	950	1450	227
30000	42000	250	1040	1540	243
40000	56000	250	1190	1690	269
50000	70000	250	1340	1840	292
60000	84000	250	1460	1960	314

N_{Sd}: quasi static load (SLS)
N_{max}: max load (ULS)
d_{Ed}: horizontal displacement (±D_{Ed})
A: bottom plate dimension
B: Upper plate dimension
HT: Total height
R: equivalent radius (from 1500mm to 6000mm)
μ: dynamic friction coefficient (from 1,5% to 10%)

Note: The dimension B is given in the table
for the standard design displacement D_{Ed} = ±250 mm
For different values of D the dimension B will be increased by 2 Δd_{Ed}
For instance if d_{Ed} = ±500 mm will be B = B_{250} + 500 mm

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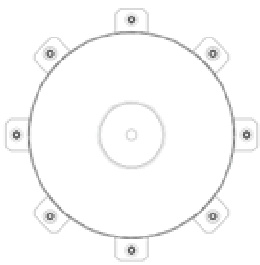
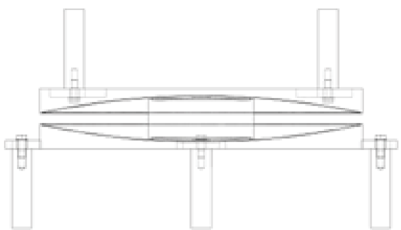


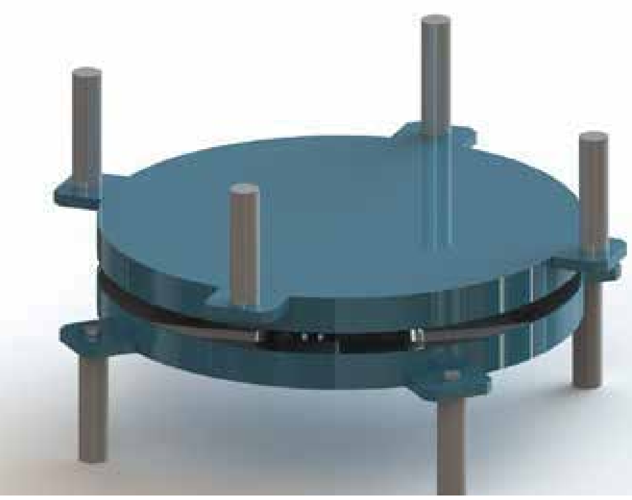
Plan



Section

Dimensions and performances are given for guidance only.

HISLIDE pendulum with any bearing capacity and displacement can be designed, tested and manufactured.



Dimensions Table

HISLIDE HP2

They are identified by the following Mark: **HP2 N_{Sd}(kN)/d_{Ed}(mm)**
EXAMPLE: **HP2 3000/500**: Friction Pendulum with single sliding surface with 4000 kN characteristic vertical load and 500 mm horizontal displacement (±250)

N_{sd}	N_{max}	d_{Ed}	A	HT
kN	*kN*	*±mm*	*mm*	*mm*
1000	1400	250	440	108
2000	2800	250	520	122
3000	4200	250	580	132
4000	5600	250	630	139
5000	7000	250	680	147
6000	8400	250	720	154
7000	9800	250	750	160
8000	11299	250	790	167
9000	12600	250	820	170
10000	14000	250	850	189
11000	15400	250	880	194
12000	16800	250	910	199
13000	18200	250	930	203
15000	21000	250	980	212
17500	24500	250	1040	220
20000	28000	250	1100	230
25000	35000	250	1200	247
30000	42000	250	1290	263
40000	56000	250	1440	289
50000	70000	250	1590	312
60000	84000	250	1710	334

N_{Sd}: quasi static load (SLS)
N_{max}: max load (ULS)
d_{Ed}: horizontal displacement (±D_{Ed})
A: bottom plate dimension
B: Upper plate dimension
HT: Total height
R: equivalent radius (from 1500mm to 6000mm)
μ: dynamic friction coefficient (from 1,5% to 10%)

Note: The dimension B is given in the table
for the standard design displacement D_{Ed} = ±250 mm
For different values of D the dimension B will be increased by 2 Δd_{Ed}
For instance if d_{Ed} = ±500 mm will be B = B_{250} + 250 mm

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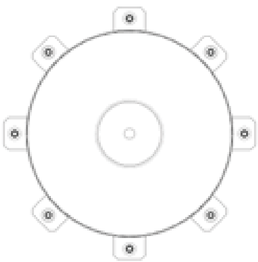

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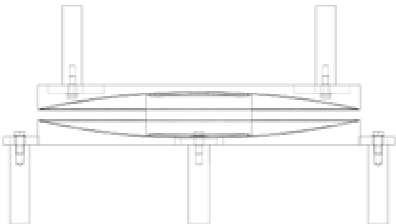
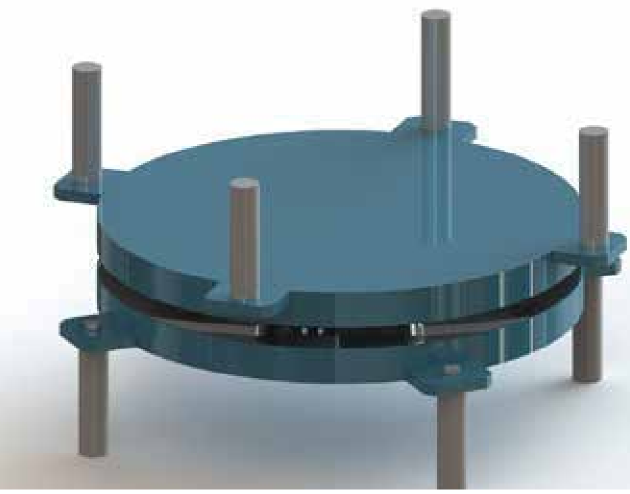


Section

Dimensions and performances are given for guidance only.

HISLIDE pendulum with any bearing capacity and displacement can be designed, tested and manufactured.



Dimensions Table

HISLIDE HP2A

They are identified by the following Mark: **HP2 N_{Sd}(kN)/d_{Ed}(mm)**
EXAMPLE: **HP2 3000/500**: Friction Pendulum with single sliding surface with 4000 kN characteristic vertical load and 500 mm horizontal displacement (±250)

N_{sd}	N_{max}	d_{Ed}	A	HT
kN	*kN*	*±mm*	*mm*	*mm*
1000	1400	250	440	108
2000	2800	250	520	122
3000	4200	250	580	132
4000	5600	250	630	139
5000	7000	250	680	147
6000	8400	250	720	154
7000	9800	250	750	160
8000	11299	250	790	167
9000	12600	250	820	170
10000	14000	250	850	189
11000	15400	250	880	194
12000	16800	250	910	199
13000	18200	250	930	203
15000	21000	250	980	212
17500	24500	250	1040	220
20000	28000	250	1100	230
25000	35000	250	1200	247
30000	42000	250	1290	263
40000	56000	250	1440	289
50000	70000	250	1590	312
60000	84000	250	1710	334

N_{sd}: quasi static load (SLS)
N_{max}: max load (ULS)
d_{Ed}: horizontal displacement (±D_{ed})
A: bottom plate dimension
B: Upper plate dimension
HT: Total height
R: equivalent radius (from 1500mm to 6000mm)
μ: dynamic friction coefficient (from 1,5% to 10%)

Note: The dimension B is given in the table
for the standard design displacement D_{Ed} = ±250 mm
For different values of D the dimension B will be increased by 2 Δd_{Ed}
For instance if d_{Ed} = ±500 mm will be B = B_{250} + 250 mm

Viscous Dampers and Dynamic Links

They are commonly grouped as Hydraulic devices
Hydraulic devices cannot be considered base isolators because they do not provide two of the required functions: they do not support the vertical load of the structure and they don't have re-centering capacity. When incorporated in a structure the re-centering capacity shall be provided by the structure itself or by other isolators working in parallel.
Under the name of hydraulic devices a wide variety of devices may be considered that utilize the viscosity properties of a fluid to reach some positive effect on the structures in order to improve their resistance against the effects of an earthquake.
Common feature of the different types of hydraulic dampers is the presence of a cylinder filled with oil. The cylinder is divided into two chambers by a piston. The device is fixed to the structure, normally through spherical hinges, in such a way that the relative movement of the structure causes the piston to move inside the cylinder. The movement of the cylinder causes the oil to flow from one chamber to the other through a Hydraulic circuit. The flow of the oil causes the behavior of the device that is depending from the viscosity of the fluid and the properties of the hydraulic circuit.

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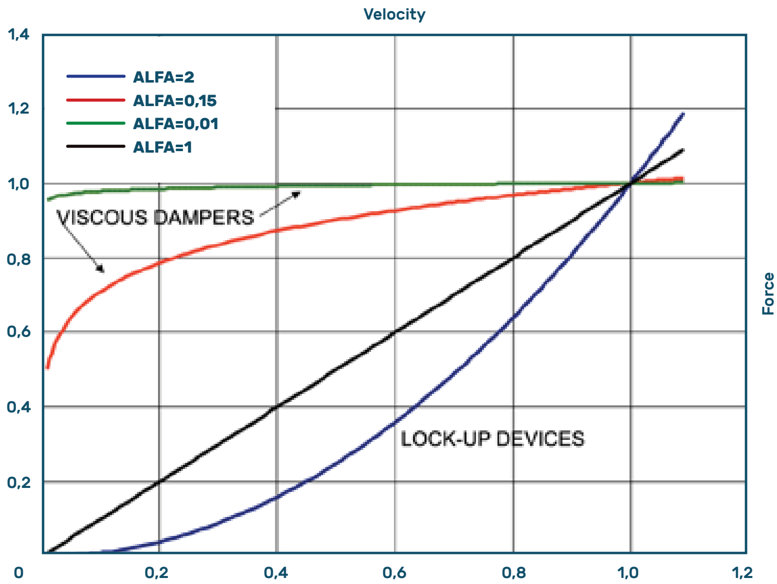
The behavior of viscous dampers can generally be described by the equation

$$F=CV^{\alpha}$$

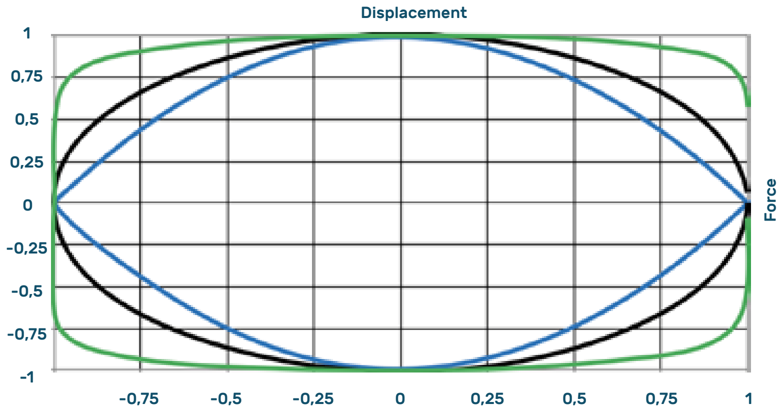
Where:
F is the force applied to the piston
V is the velocity at which a piston is moved
C is a constant depending on the size of the device
α is a constant depending on the properties of the fluid and the hydraulic circuit.
In the following schemes the force-velocity and force-displacements diagrams are plotted for different values of the exponent α.

From the side plots it is obvious that the exponent α =2 or greater will be preferred when the difference of force at low velocity and high velocity shall be maximized. This is the case when the device shall allow slow movements due to thermal variations, creep and shrinkage and became rigid in case of dynamic actions like wind or earthquake and when the energy dissipation is not required. These devices are commonly known as Shock Transmission Units (STU), Lock-Up Devices (LUD) or Hydraulic Couplers (HC).

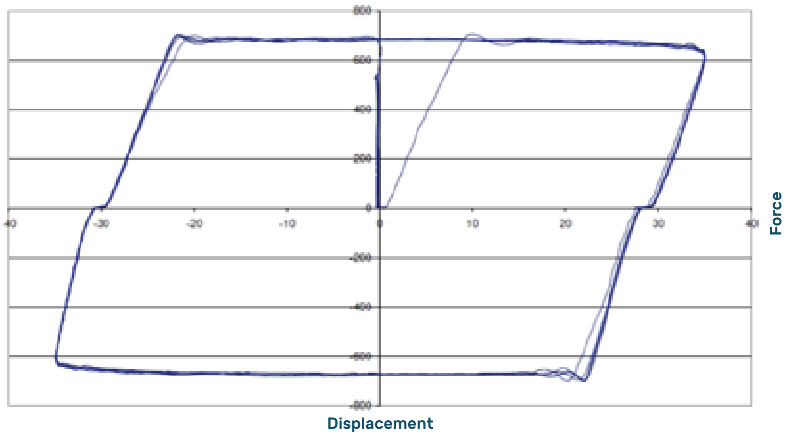
When the dissipation of energy is the principal performance required to the devices, exponent α = 0,2 or smaller is preferred since it is evident from the force-displacement diagram that the energy dissipation, that is proportional to the area of the plot, is increasing when the exponent is decreasing. In this case the devices are more commonly known as Viscous Dampers (VDD)



Force Velocity diagram for different values of the exponent α

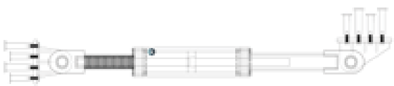


Force vs. Displacement plots (for a sinusoidal excitation) of Hydraulic Devices for different values of the exponent α, in an arbitrary scale.



Test verification of the energy dissipation of a viscous damper with exponent α = 0,02 subject to 5 sinusoidal cycles of ± 30 mm displacement at 20°C

Plan



Section

Dimensions and performances
are given for guidance only.

Different forces and displacements
can be considered upon request.

Dimensions Table
HIFLUID
VISCOUS DAMPER DEVICES (VDD)

Mark	Max Force	Displa-cement	L	D	α
Type	*kN*	*mm*	*mm*	*mm*	*rad*
VDD 1000/300	1000	±150	1750	260	
VDD 1000/500	1000	±250	2350	260	0,02 – 1,0
VDD 1500/300	1500	±150	1850	270	0,02 – 1,0
VDD 1500/500	1500	±250	2450	270	0,02 – 1,0
VDD 2000/300	2000	±150	1950	310	0,02 – 1,0
VDD 2000/500	2000	±250	2550	310	0,02 – 1,0
VDD 2500/300	2500	±150	2050	350	0,02 – 1,0
VDD 2500/500	2500	±250	2650	350	0,02 – 1,0
VDD 3000/300	3000	±150	2150	370	0,02 – 1,0
VDD 3000/500	3000	±250	2750	370	0,02 – 1,0
VDD 3500/300	3500	±150	2300	410	0,02 – 1,0
VDD 3500/500	3500	±250	2900	410	0,02 – 1,0
VDD 4000/300	4000	±150	2400	430	0,02 – 1,0
VDD 4000/500	4000	±250	3000	430	0,02 – 1,0
VDD 5000/300	5000	±150	2600	480	0,02 – 1,0
VDD 5000/500	5000	±250	3200	480	0,02 – 1,0

The retrofitting solution.

The HILUD lock-up devices allow slow movement (creep, shrinkage and temperature effects) and maximize reactions for dynamic effects (braking force of trains and earthquake).

Main Field

Bridges or Railways bridges where is important to share the seismic load with different elements, to avoid hammer effect in building retrofitting of bridges.

INSTALLATION	Requires trained team
DURABILITY	> 30 years
MAINTENANCE	Corrosion protection after 15 years
COST	High

VERTICAL LOAD

HORIZONTAL DISPLACEMENT

RE-CENTERING CAPACITY

DAMPING

FIRE RESISTANCE

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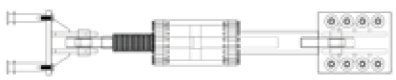

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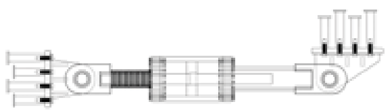

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Dimensions Table

HILUD

VISCOUS DAMPER DEVICES (VDD)

Mark	Max Force	Displa-cement	L	D
Type	*kN*	*mm*	*mm*	*mm*
LUD 200/50	200	±25	520	140
LUD 200/100	200	±50	670	140
LUD 300/50	300	±25	550	160
LUD 300/100	300	±50	690	160
LUD 500/50	500	±25	590	200
LUD 500/100	500	±50	740	200
LUD 1000/50	1000	±25	980	250
LUD 1000/100	1000	±50	1100	250
LUD 1500/50	1500	±25	1060	280
LUD 1500/100	1500	±50	1200	280
LUD 2000/300	2000	±150	1950	310
LUD 2000/500	2000	±250	2550	310
LUD 2500/300	2500	±150	2050	350
LUD 2500/500	2500	±250	2650	350
LUD 3000/300	3000	±150	2150	370
LUD 3000/500	3000	±250	2750	370
LUD 3500/300	3500	±150	2300	410
LUD 3500/500	3500	±250	2900	410
LUD 4000/300	4000	±150	2400	430
LUD 4000/500	4000	±250	3000	430
LUD 5000/300	5000	±150	2600	480
LUD 5000/500	5000	±250	3200	480

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Standard

Normally HISLIDE Sliding Pendulum Isolators are designed, manufactured and tested in accordance with EN 15129 and CE marked with supervision of the Notified Body ICECON that executes the regular audit visits as foreseen by the EN standard.

Quality Assurance

The whole production of CECO-HIRUN is subjected to a quality assurance program in accordance with ISO 9000 certified by CQC, member of the International Mutual Acknowledgment Body IQNET.
In addition the production of the Sliding Pendulum Isolators is subjected to a specific quality assurance program in accordance with EN 15129 Annex ZA for the CE marking with the supervision of the Notified Body ICECON. (The relevant certificates are shown on the side)

Sliding Materials

CECO-HIRUN developed outstanding sliding materials:
- HI-3 mainly for use in spherical bearings
- HI-M and HI-H for use in sliding pendulum isolators.
- Here below a comparison table of the most commonly used sliding materials

For the sliding pendulum isolators a dynamic friction from 3 to 9%, according to the Engineers's requirements, can be granted

SLIDING MATERIAL PROPERTY	PTFE	HI-3	HI-M	HI-H
Compressive strength	90 MPa	180 MPa	270 MPa	180 MPa
Heat resistance (long term)	48°C	90°C	120°C	90°C
Heat resistance (short term)	80°C	120°C	180°C	180°C
Wear resistance	10,000 m	50,000 m	50,000 m	10,000 m
Static friction	<3%	<3%	<6%	<10%
Dynamic friction	<3%	<3%	2,5%	6 10%

Corrosion protection

The corrosion protection of structural steel is normally performed in accordance with EN ISO 12944.
The working life of the protective coating system on the bearing can be assumed to be fulfilled with a protective system designed for the durability "high" of more than 15 years in accordance with EN ISO 12944-5:2007, 5.5 for corrosivity category C5-I (I=industrial) for inland locations and C5-M (M=marine) for sea side locations.
Surfaces in contact with concrete need no corrosion protection, however a layer of 50 μm of the first pack is applied in order to prevent oxidation during the storage before the installation. A return of at least 50 mm is applied.
In alternative paint will conform to the Project specifications, as specified by the purchaser

Fire resistance

HISLIDE Isolators are fire resistant and don't require special precautions to protect them from the fire. After a fire event an inspection is recommended and, depending on the fire intensity, the sliding material may need to be replaced

Fixings

The HISLIDE Sliding Pendulum isolators are provided with fixings made with bolts or dowels according to the type of structure. The fixing are connected to the Isolator in such a way to allow the easy replacement if necessary.

Fuses

In case of use of the HISLIDE Isolators in railway bridges it is recommended the use of mechanical fuses in order to grant the fixity of the bridge under service condition. In case of a strong earthquake the fuses will be sheared of and the isolators can start their antiseismic function

References

Asan Cheonan Expressway
South Korea

Bursa Hospital
Turkey

Dintai Building
Taiwan

Green Museum
Taiwan

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References

Cibubur LRT
Jakarta, Indonesia

Holtekamp bridge
Turkey

Kerch bridge
Russia, Crimea

Casaclima
Rimini, Italy

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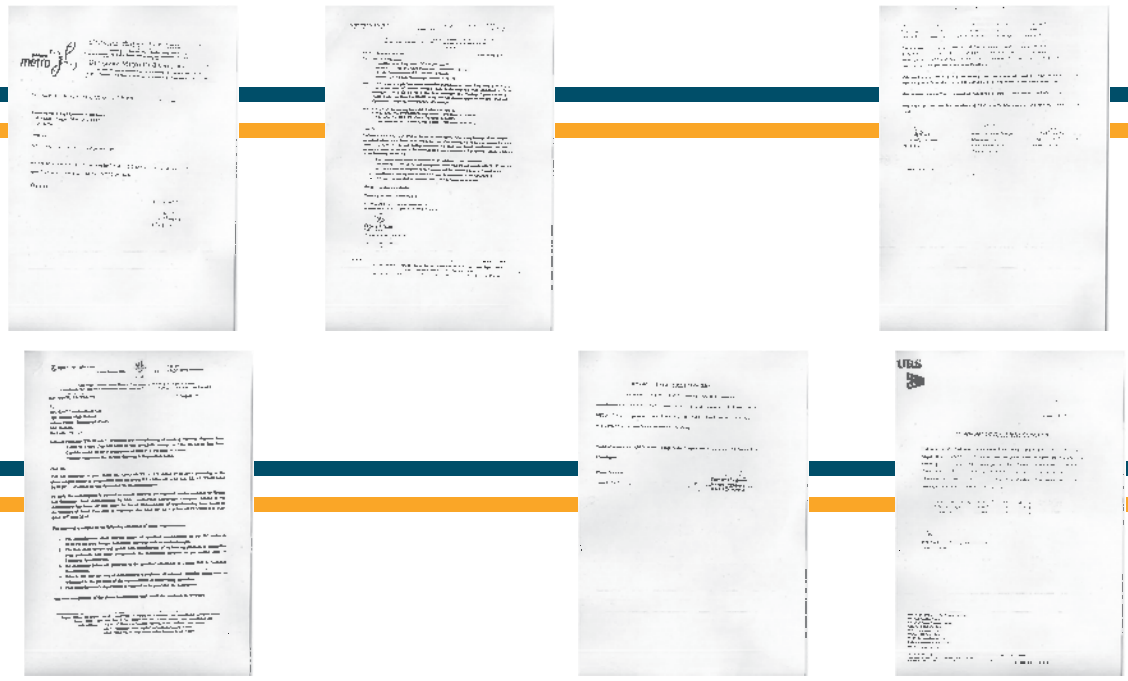
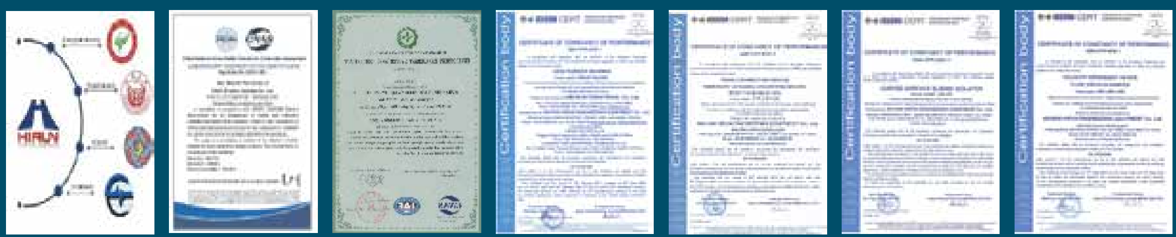
APPROVALS, APPRECIATIONS

CECO has long list of approvals, appreciation letters and satisfactory perfomance repotrs issued from various goverment agencies, many Indian & International cunsultants those who are working in India.



QUALITY CERTIFICATIONS

Hirun International and its partners cooperate with important international institutions in order to guarantee the test performances and the advanced research on materials and products



QUALITY | EUROPEAN CERTIFICATION - CE MARK

EUROPEAN CERTIFICATION - ETA

HIRUN INTERNATIONAL is actively working with its partner to obtain the European Technical Assessment for all its advanced products like special sliding materials, post tensioning kit, expansion joints

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