Earthquake protection devices ISOSISM® range

D E S I G N ,   B U I L D ,   M A I N T A I N

FREYSSINET
SUSTAINABLE TECHNOLOGY

CV5

The Freyssinet Group

Freyssinet brings together **an unrivalled set of skills in the specialist civil engineering sector.** The Group implements solutions with high added value in two major fields: construction and repairs.

Freyssinet is involved in numerous projects across five continents, making it the world leader in its specialist areas of:

- Prestressing
- Construction methods
- Cable-stayed structures
- Structural accessories
- Repairs
- Structural reinforcement and maintenance

Freyssinet is highly involved in sustainable development issues and has set up a number of initiatives, particularly to reduce the environmental impact of its projects and enhance its social responsibility policy.

Freyssinet is a subsidiary of the Soletanche Freyssinet Group, a world leader in the soils, structures and nuclear sectors.

Cover photo: BTZ Bridge - Algeria
Top photo: ITER reactor - France

Our primary concern: ensuring everyone's safety

In order to ensure everyone's safety and prevent industrial accidents, the company has produced a set of common international safety rules.
Our primary duty is to protect the physical integrity of our employees and to do all we can to ensure that everyone goes home in good health at the end of the working day. This commitment is reflected in particular through our rules, in-house tools and exemplary behaviour.
It is accompanied by an extensive communication and risk awareness programme, implemented at all of Freyssinet's locations.

"The safe way is the only way"

Contents

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EARTHQUAKE PROTECTION DEVICES / INTRODUCTION

It was not until the mid-20th century that tangible steps were taken to protect structures in earthquake-prone areas. In most cases, only passive protection measures were used, such as wind-bracing walls for buildings and plasticisation based protection of predefined elements for bridges.

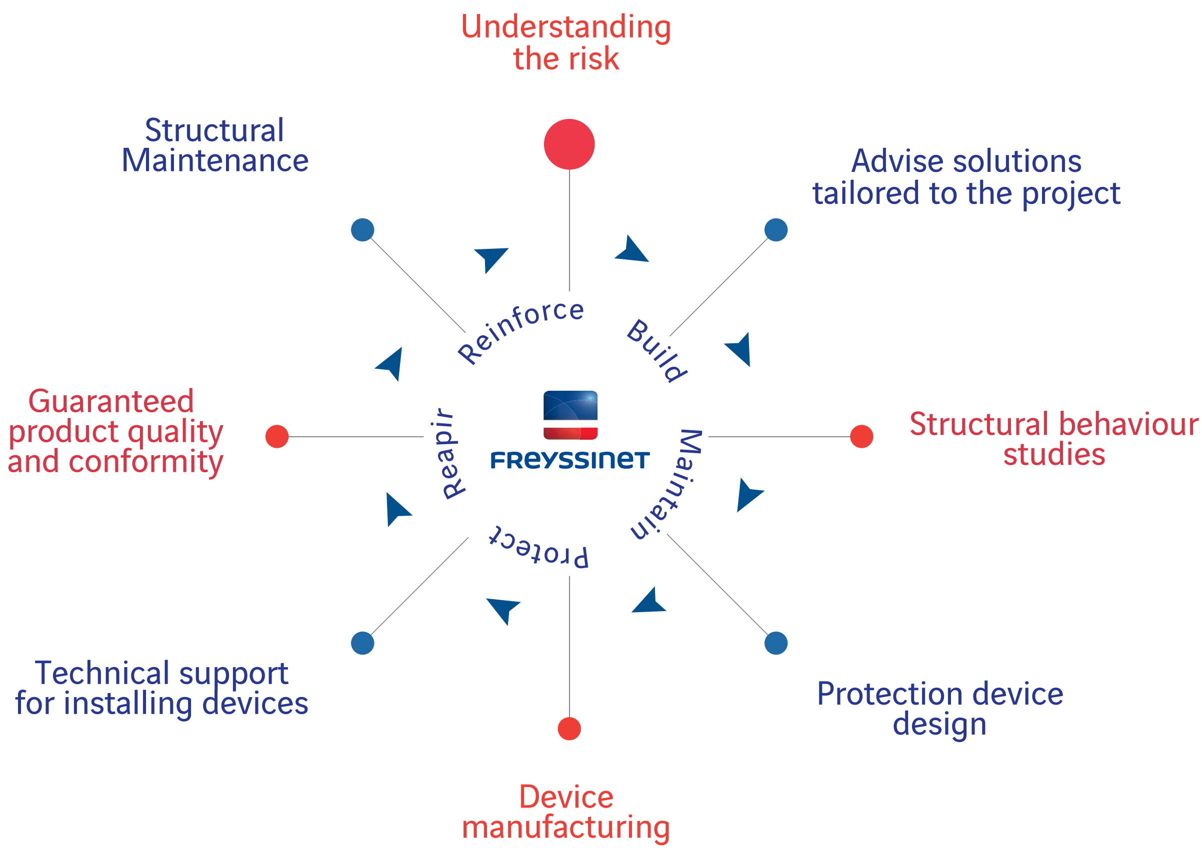
These types of protection may allow structures to withstand seismic design situations and protect human lives, but major repairs are required to the damaged protective elements following a high-intensity earthquake.

Modern societies are no longer willing to accept earthquakes as an unavoidable phenomenon, and the current trend is to fit structures in earthquake-prone areas with special devices capable of absorbing or restricting the effects of earthquakes on structures, while reducing civil engineering costs both during construction and rebuilding following a seismic event.

Freyssinet can draw on its end-to-end expertise, from design through to installation and fabrication, to deliver superior best-fit solutions for each project.

OUR SOLUTIONS INCORPORATE THE FOLLOWING CRITERIA:

From proposing an earthquake protection strategy geared towards a specific structure through to delivering and installing systems that have been designed, manufactured and tested in-house, Freyssinet's expertise in earthquake protection devices is fuelled by the company's extensive track record and brings structural designers and clients practical solutions for minimising their earthquake risks.



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PROTECTION PRINCIPLE: THE ISOSISM® RANGE

Leveraging its wealth of knowledge and experience in building and equipping structures, Freyssinet is a trailblazer in developing earthquake isolation devices and currently offers an end-to-end range of special products known as ISOSISM®.
These devices can be used alone or in combination to achieve the most effective and appropriate protection for each project.

Seismic protection is based on three fundamental operational modes which are:
- Dissipation
- Isolation
- Connection.

DISSIPATION

- Part of the energy generated by an earthquake can be dissipated by dampers to minimise the effects on the structures.
  Dampers offer only very low resistance to slow movements and are completely effective during quick stresses (earthquakes, boat impacts, etc.).
- Dampers can be used in combination with an isolation system, especially high damping elastomeric bearings, to reduce structural displacement while limiting the stresses to which structures are subjected.
- Dampers can be installed to significantly reduce the cost of structural repairs following an earthquake. In addition, they enable sensitive buildings, such as hospitals, to continue operating. Furthermore, they can provide effective protection for existing structures that were not originally designed to withstand seismic activity.

PRODUCTS


FD

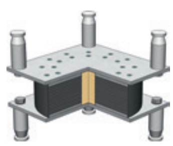

PDS

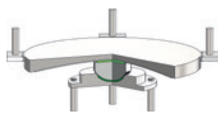
ISOLATION

- The structure is isolated from the movement of the ground using flexible connections, mainly reinforced elastomeric bearings or sliding systems, to increase the fundamental period of vibration of the structure to be protected and reduce the response to seismic acceleration. Acceleration can be divided by a factor of two or three on structures featuring such systems.
- Isolator efficiency is directly related to horizontal stiffness and leads to major displacement of the structure during a seismic event.
- The effects of structural isolation therefore result in a clean low frequency, low acceleration and high relative displacement.

PRODUCTS


HDRB

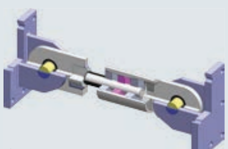

LRB


PS

CONNECTION

- A value-added approach is to limit the seismic displacement of structures in order to simplify the devices used to create a connection with the neighbouring structures (grids, expansion joints, etc.). In such cases, designers will either use:
  - Mechanical bearings to transfer all the service and seismic forces from the foundations to the structures (passive protection).
  - Seismic connectors, whose distinguishing feature is that they provide only very low resistance to slow displacements due to temperature variations, shrinkage and creep. They create a robust connection between the superstructure and the supporting structures during quick displacements mainly associated with seismic events.
- Connectors also have the advantage of sharing major horizontal seismic forces among all supporting structures (piers) where they are fitted.

PRODUCT


STU

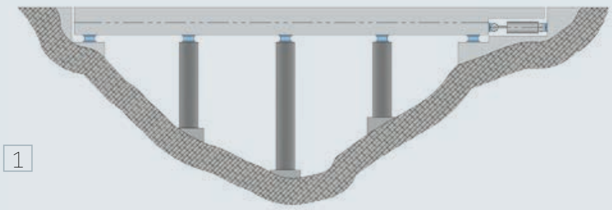
Protection examples

There are two approaches for effectively protecting structures against destructive forces:

1. Design the structure to withstand any kinds of static and dynamic stresses whatsoever.

2. Fit the structure with special devices that:
    - Can isolate the structure either totally or partially from its foundations.
    - Dissipate the energy that builds up during dynamic stresses.
    - Involve some of the structure's bearings that do not support any horizontal load during normal service.

1



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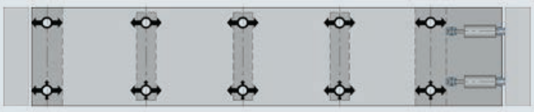

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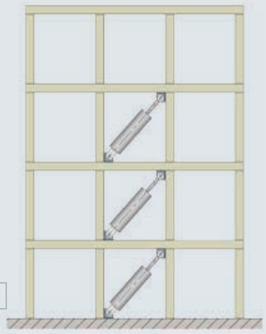

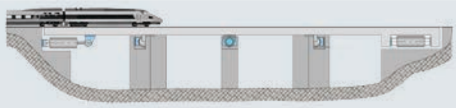

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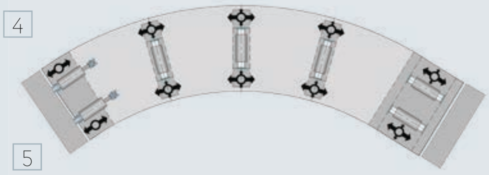
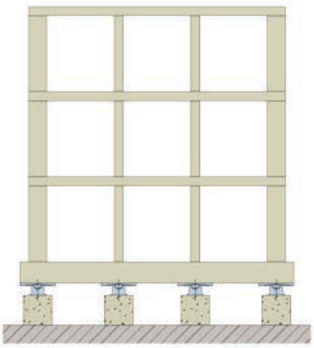


5

1. ISOSISM® FD on an abutment
2. ISOSISM® FD plan view
3. ISOSISM® FD in wind bracing
4. ISOSISM® PDS and FD beneath a railway bridge
5. ISOSISM® PDS and FD plan view

1



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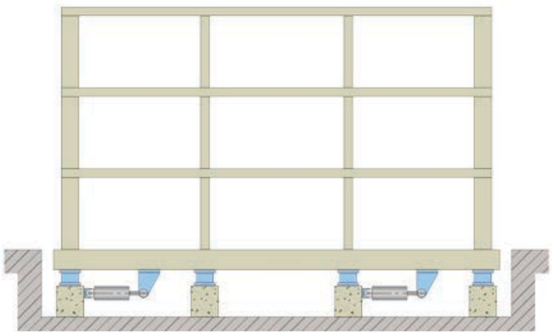
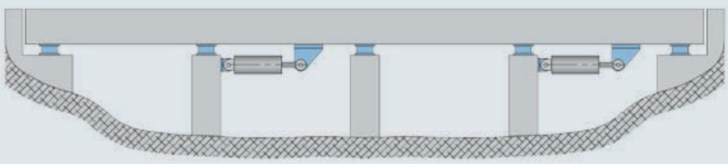


1. Building isolated with ISOSISM® PS isolators ISOSISM® HDRB or ISOSISM® LRB
2. ISOSISM® HDRB isolators and ISOSISM® FD dissipators beneath a building

1



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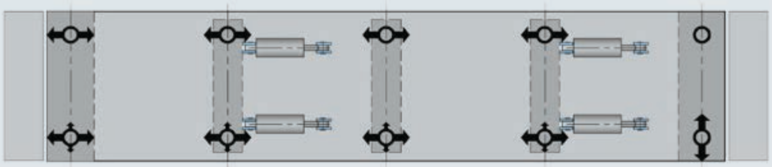
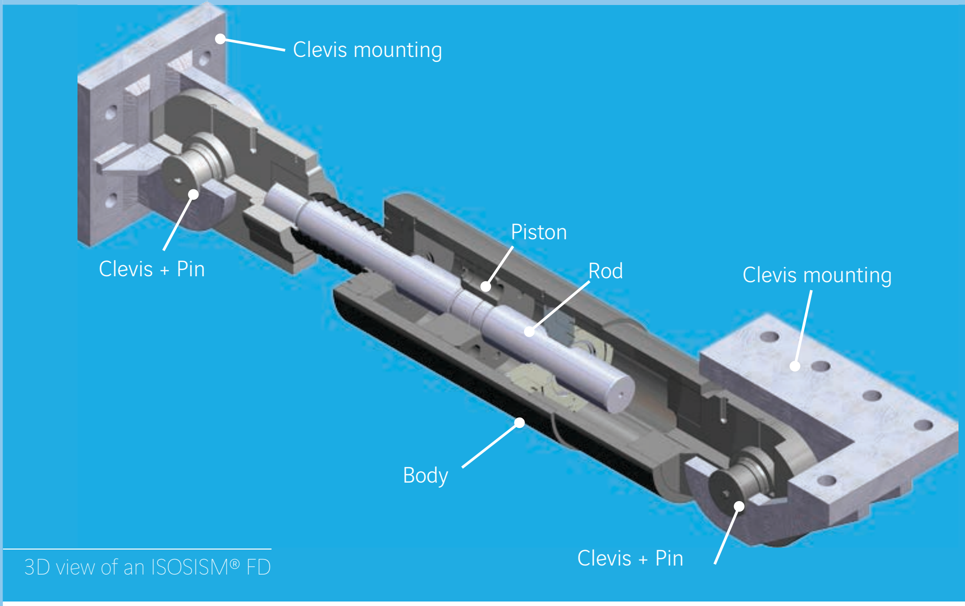


1. Installation of an ISOSISM® STU beneath a bridge
2 ISOSISM® STU plan view

Dissipation: ISOSISM® FD



3D view of an ISOSISM® FD

Design

- The ISOSISM® FD (Fluid Damper) is a hydraulic damper using a viscous fluid that is stable under temperature variations and over time.
It is made up of a body with two chambers separated by a piston. The piston is secured to a rod connected to one of the clevis mountings and the damper body is secured to the other clevis mounting. The damper works in both traction and compression.
- The damping provided by the FD is provided by the viscous fluid flowing through the piston, which is equipped with specially designed valves.

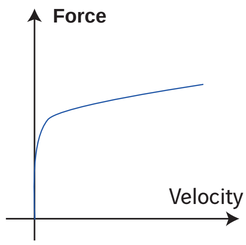
It conforms to EN 15129 and can be supplied with the CE marking to this effect.

Behaviour law

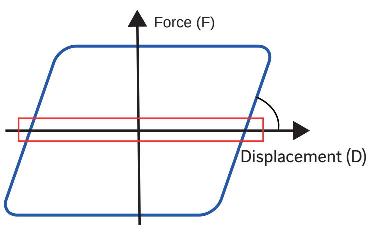
The ISOSISM® FD operates using a controlled-opening valve system. Its behaviour law can be modelled as follows:

$$\boxed{F = C.V^{\alpha}}$$

(α can range between 0.05 and 1. Typically between 0.1 and 0.2).



α: Damping cœfficient
F: Force
V: Velocity



Low Speed
High Speed

Main properties

- Provides only very low resistance to displacements while in service.
- Dissipates energy during an earthquake.
- It can be designed as a fixed point in service.

Specific features

ISOSISM® FD dampers do not prevent very slow displacements such as those due to thermal variations. They react in the event of an earthquake and dissipate some of the seismic energy.
These dampers can be used in addition to isolators, in order to increase the overall damping provided by the earthquake prevention equipment.
Fitting a structure with dampers reduces civil engineering costs. It also ensures the integrity of the structure during and after an earthquake and reduces maintenance costs.

Dampers can be installed in new structures or to bring existing structures in line with current standards.

1. BTZ Bridge under construction in Algeria
2. ISOSISM® FD fixed on an abutment

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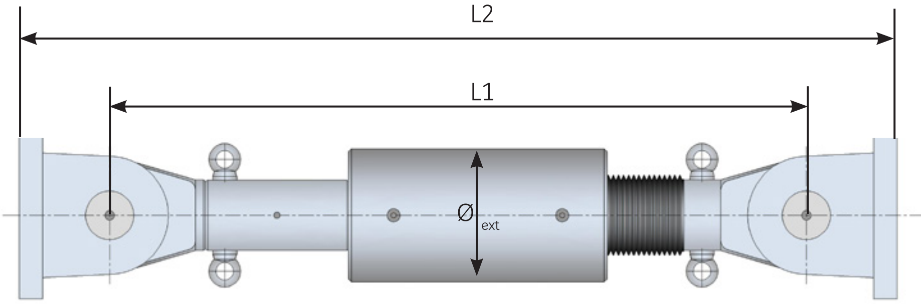
Range



$Ø_{ext}$: External diameter excluding accumulator
F_{Max}: Maximum force
D_{Max}: Maximum displacement
L2: Overall length at mid-stroke
L1: Length between axes at mid-stroke

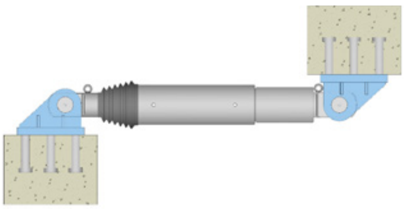
Type	F_{max} kN	D_{max} ± mm	L1 mm	L2 mm	$Ø_{ext}$ mm
FD 1000/200	1,000	± 100	1,345	1,710	298
FD 1000/400	1,000	± 200	1,895	2,260	298
FD 1500/200	1,500	± 100	1,410	1,840	313
FD 1500/400	1,500	± 200	1,960	2,390	313
FD 2000/200	2,000	± 100	1,500	2,000	324
FD 2000/400	2,000	± 200	2,050	2,550	324
FD 2500/200	2,500	± 100	1,565	2,115	358
FD 2500/400	2,500	± 200	2,116	2,665	358
FD 3000/200	3,000	± 100	1,680	2,280	396
FD 3000/400	3,000	± 200	2,230	2,830	396
FD 3500/200	3,500	± 100	1,795	2,475	424
FD 3500/400	3,500	± 200	2,345	3,025	424
FD 4000/200	4,000	± 100	1,865	2,575	448
FD 4000/400	4,000	± 200	2,415	3,125	448

Range given for guidance.
Other models can be considered upon request.

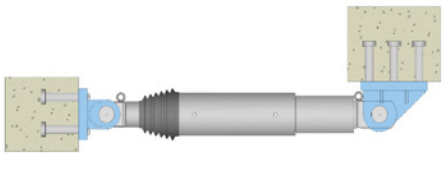
The maximum force in the above table includes magnification factors foreseen by the EN15129.

Structural connections

Different configurations for installation on the structure are possible.
Freyssinet offers an appropriate connection solution for each configuration.

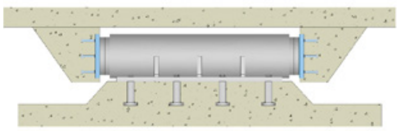


Shear/Shear Connection



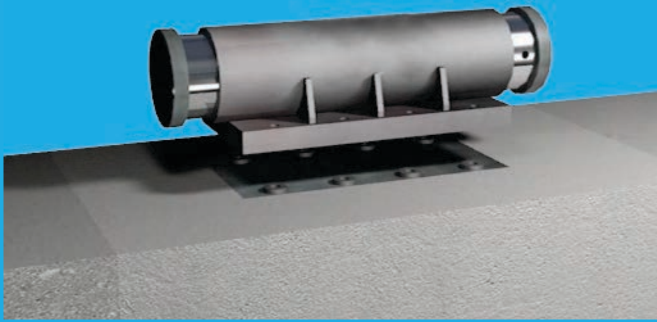
Traction/Shear Connection

Traction/Compression Connection



Connection with sliding plates

DISSIPATION: ISOSISM® PDS



3D view of an ISOSISM® PDS

Design

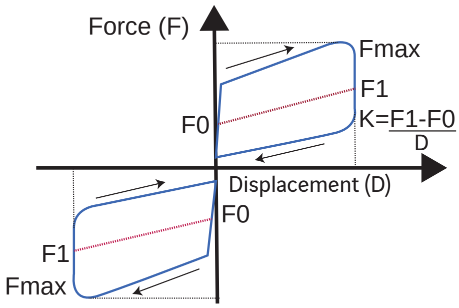
• The ISOSISM® PDS (Prestressed Damping Spring) combines the benefits of a viscous fluid damper and a prestressed hydraulic spring. In normal operating conditions, the ISOSISM® PDS acts as a fixed point. During an earthquake, it dissipates energy and then returns the structure to its initial position.

• The ISOSISM® PDS can be installed along the longitudinal or transverse axis of the deck. Its ends are equipped with a sliding material to accommodate the thermal expansion of the structure.
It conforms to EN 15129 and can be supplied with the CE marking to this effect.

Behaviour law

The behaviour law of the ISOSISM® PDS can be modelled as follows:

$\boxed{F=F_0+KD+C.V^{\alpha}}$ $\alpha \leq 0.1$



F: Reaction force

F_0: Prestressing

K: Stiffness

C: Damping constant

V: Velocity

α: Damping cœfficient

Main properties

- Opposes displacement in normal operating conditions.
- Dissipates energy during an earthquake.
- Recentres the structure after an earthquake.

Specific features

The prestressing force F_0 of the ISOSISM® PDS must be greater than the forces to be withstood while in service, such as thermal expansion, braking and wind. It must be less than the seismic forces.

The ISOSISM® PDS offers a number of benefits:

- Three major functions combined in a single device (stop, damper and spring).
- High reliability: the device is only placed under stress in the event of an earthquake.
- Compact design.
- Highly efficient.
- Zero maintenance.

ISOSISM® PDS devices are widely used to form the longitudinal fixed point of bridge decks.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1. Mardakan Bridge - Azerbaijan
2. Installation of an ISOSISM® PDS
3. 3D views of an ISOSISM® PDS

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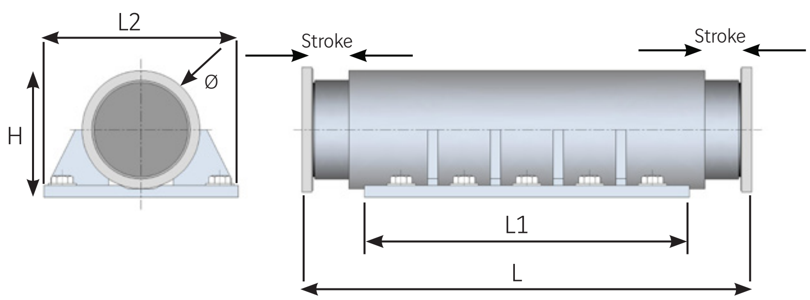
Range



F: Prestressing Force

F_{max}: Maximum Force

K: Stiffness

L: Length

H: Height

Ø: Diameter

L1: Length of mounting plate

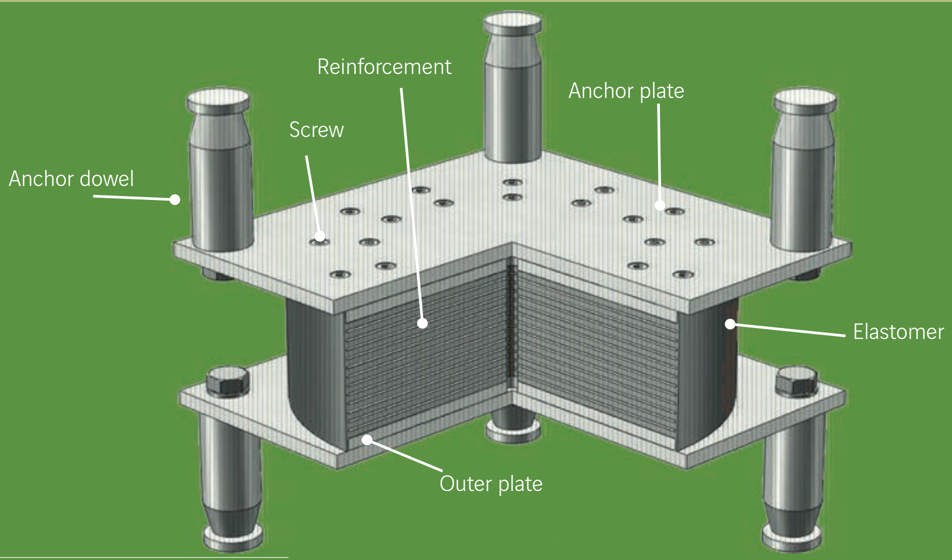
L2: Width of mounting plate

Structural connections

Type	F_0 kN	Stroke mm	F_{max} kN	K kN/mm	L mm	H mm	Ø mm	L1 mm	L2 mm
PDS 100-290-50	100	±50	290	1.6	660	155	130	520	260
PDS 100-290-100	100	± 100	290	0.8	1,020	165	130	780	260
PDS 250-670-50	250	±50	670	3	900	215	180	760	360
PDS 250-670-100	250	± 100	670	1.5	1,370	230	180	1,130	360
PDS 500-1210-50	500	±50	1,210	5	1,130	285	240	990	480
PDS 500-1210-100	500	± 100	1,210	2.5	1,680	305	240	1,440	480
PDS 750-1660-50	750	±50	1,660	7	1,220	320	270	1,080	540
PDS 750-1660-100	750	± 100	1,660	3.5	1,800	340	270	1,560	540
PDS 1000-2000-50	1,000	±50	2,000	10	1,300	345	290	1,160	580
PDS 1000-2000-100	1,000	± 100	2,000	5	1,870	360	290	1,630	580
PDS 1500-3000-50	1,500	±50	3,000	12	1,520	415	350	1,380	700
PDS 1500-3000-100	1,500	± 100	3,000	6	2,190	435	350	1,950	700
PDS 2000-3610-50	2,000	±50	3,610	20	1,610	460	390	1,470	780
PDS 2000-3610-100	2,000	± 100	3,610	10	2,240	480	390	2,000	780
PDS 2500-4520-50	2,500	±50	4,520	25	1,670	505	430	1,530	860
PDS 2500-4520-100	2,500	± 100	4,520	12.5	2,280	520	430	2,040	860
PDS 3000-5420-50	3,000	±50	5,420	30	1,740	545	470	1,600	940
PDS 3000-5420-100	3,000	± 100	5,420	15	2,350	565	470	2,110	940

Range given for guidance. Other models can be considered upon request.

ISOLATION: ISOSISM® HDRB



3D view of an ISOSISM® HDRB

Design

• The ISOSISM® HDRB (High Damping Rubber Bearing) is an isolator designed using an elastomeric block (natural rubber) reinforced with steel bonded by vulcanising. **It conforms to EN 15129 and can be supplied with the CE marking to this effect.**

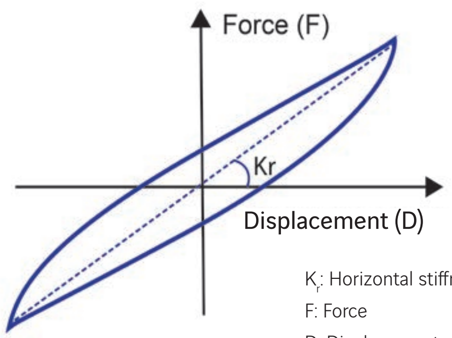
• It is usually a type C (fitted with outer plates) isolator manufactured to the dimensions required for the project. It is available in square or round formats.
The damping provided by the ISOSISM® HDRB results from the nature of the elastomeric compound and reduces the acceleration and displacement of structures during a seismic event.

• It can be designed and manufactured according to other international standards like AASHTO, ASCE, etc.

Behaviour law

The behaviour law of the ISOSISM® HDRB can be modelled as follows:

$$\boxed{F = K_r . D}$$



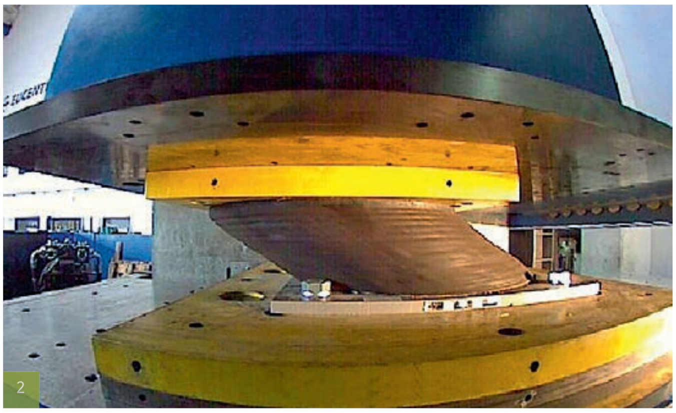
K_r: Horizontal stiffness
F: Force
D: Displacement

Main properties

- High recentring capability.
- Moderate damping capacity (ξ ≤ 16% and ≥ 10%).
- Moderate maximum displacement.
- No maintenance needed.

Specific features

The ISOSISM® HDRB has numerous applications in buildings, nuclear power plants, civil engineering structures, etc. It isolates the structure from the movement of the ground by forming flexible connections that increase the fundamental period of vibration of the structure to be protected and reduce its acceleration by a ratio from two to three.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1. ITER reactor - France
2. Dynamic and static testing of an ISOSISM® HDRB
3 ISOSISM® HDRB, ITER reactor - France
4 ISOSISM® HDRB fixed to an upper structure

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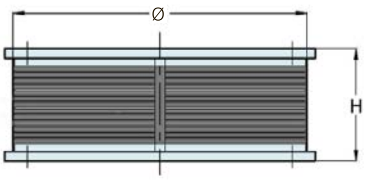
Range

The composition of the elastomeric mixture determines the damping capacity of the ISOSISM® HDRB isolator.
The mechanical characteristics of the elastomer make the isolator capable of withstanding seismic deformation of up to tanγ = 2.5.

Three types of mixture are available for different shear modulus G and damping values:

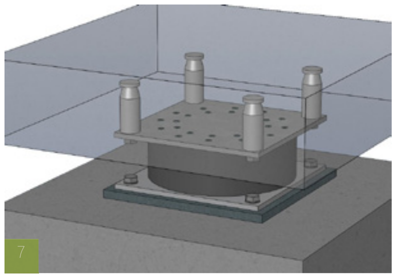
- Model HDRB 0.4-10: Modulus G=0.4 MPa – Damping = 10% (at tanγ=1)
- Model HDRB 0.8-10: Modulus G=0.8 MPa – Damping = 10% (at tanγ=1)
- Model HDRB 1.4-16: Modulus G=1.4 MPa – Damping = 16% (at tanγ=1)

Ø: Diameter
T_r: Total thickness of elastomer
H: Total height of isolator
Δ_{max}: Maximum horizontal displacement
V_{max}: Maximum vertical load under zero displacement
V_{seism}: Maximum vertical load under maximum displacement
K_r: Horizontal stiffness



Structural connections

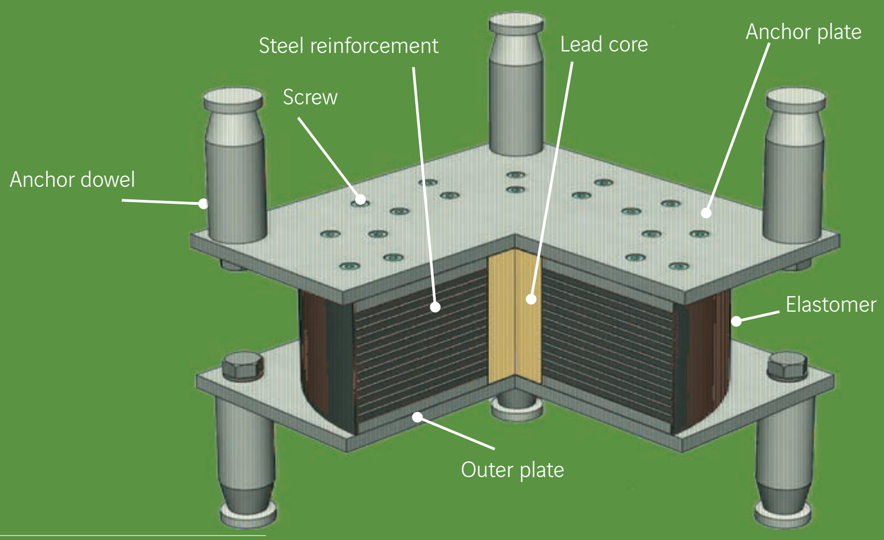
The isolators are connected to metal structures using bolts. They are connected to concrete structures using anchor tubes or studs.
ISOSISM® HDRB isolators can be installed in new or existing structures.



Ø	T_r	HDRB 0.4 - 10					HDRB 0.8 - 10					HDRB 1.4 - 16				
		H	Δ_{max}	V_{max}	V_{seism}	K_r	H	Δ_{max}	V_{max}	V_{seism}	K_r	H	Δ_{max}	V_{max}	V_{seism}	K_r
mm	mm	mm	mm	kN	kN	kN/mm	mm	mm	kN	kN	kN/mm	mm	mm	kN	kN	kN/mm
Ø300	45	129	110	1,640	940	0.63	129	95	3,280	1,990	1.26	129	75	5,410	3,760	2.20
Ø300	70	169	170	1,050	320	0.40	169	150	2,110	790	0.81	169	120	3,700	1,740	1.41
Ø350	55	145	135	2,540	1,420	0.70	165	115	5,080	3,050	1.40	165	95	7,430	5,480	2.45
Ø350	75	177	185	1,860	660	0.51	197	160	3,730	1,550	1.03	197	130	6,530	3,080	1.80
Ø400	60	147	150	3,290	1,910	0.84	167	130	6,590	4,060	1.68	167	100	8,150	7,710	2.93
Ø400	90	192	225	2,240	690	0.56	212	195	4,480	1,700	1.12	212	155	7,850	3,640	1.95
Ø450	72	165	180	4,540	2,510	0.88	185	155	9,080	5,230	1.77	185	125	10,380	9,230	3.09
Ø450	108	219	260	3,020	840	0.59	239	230	6,050	1,980	1.18	238	185	1,380	4,250	2.06
Ø500	84	197	210	5,130	2,770	0.93	217	180	10,260	5,810	1.87	217	145	11,030	10,450	3.27
Ø500	126	257	290	3,420	960	0.62	277	270	6,840	2,030	1.25	277	215	11,030	4,670	2.18
Ø550	88	198	220	6,320	3,500	1.08	218	190	11,720	7,470	2.16	228	150	15,630	13,740	3.78
Ø550	144	275	320	3,860	1,090	0.66	295	310	7,720	2,090	1.32	312	250	13,520	4,970	2.31
Ø600	96	209	240	8,260	4,580	1.18	249	205	13,990	9,620	2.36	260	165	18,660	16,890	4.12
Ø600	144	275	350	5,500	1,510	0.79	315	310	11,010	3,560	1.57	332	250	18,660	7,630	2.75
Ø650	108	241	270	9,030	4,920	1.23	272	230	18,070	10,380	2.46	272	185	19,520	18,510	4.30
Ø650	162	313	380	6,020	1,660	0.82	350	350	12,050	3,620	1.64	350	280	19,520	8,180	2.87
Ø700	120	253	300	9,890	5,300	1.28	304	260	19,780	10,990	2.57	315	205	25,520	20,250	4.49
Ø700	170	318	410	6,980	1,940	0.91	374	365	13,960	4,600	1.81	390	295	34,430	9,970	3.17
Ø750	130	286	325	12,070	6,230	1.36	338	280	23,480	12,900	2.72	350	225	29,360	23,260	4.76
Ø750	170	338	425	9,230	2,780	1.04	394	365	18,470	6,770	2.08	410	295	29,360	13,790	3.64
Ø800	132	285	330	14,040	7,690	1.52	336	285	24,330	16,000	3.05	358	225	36,500	28,870	5.33
Ø800	176	341	440	10,530	3,480	1.14	396	380	21,060	8,210	2.28	426	305	36,500	16,640	4.00

Range given for guidance. Other models can be considered upon request.

ISOLATION: ISOSISM® LRB



3D view of an ISOSISM® LRB

Design

- The ISOSISM® LRB (Lead Rubber Bearing) is an isolator designed using an elastomeric block (natural rubber) reinforced with steel bonded by vulcanising. It has one or more cylindrical lead cores. The damping provided by the ISOSISM® LRB results from the nature of the elastomeric compound and the lead cylinder, and reduces the acceleration and displacement of structures during a seismic event. **It conforms to EN 15129 and can be supplied with the CE marking to this effect.**
- It is usually a type C isolator (fitted with outer plates) manufactured to the dimensions required for the project. It is available in square or round formats.
- It can be designed and manufactured according to other international standards like AASHTO, ASCE, etc.

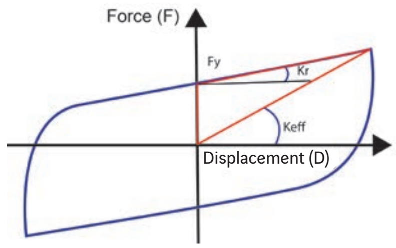
Behaviour law

The behaviour law of the ISOSISM® LRB can be modelled as follows:

There are two possible structural design approaches:

Linear calculation: $\boxed{F = K_{eff}\, D}$

Non-linear calculation: $\boxed{F = F_y + K_r\, D}$



K_r: Second branch stiffness
K_{eff}: Effective stiffness
F: Horizontal force
D: Displacement
F_y: Elastic force of the lead

The damping is obtained by the properties of the lead core and the nature of the elastomer.

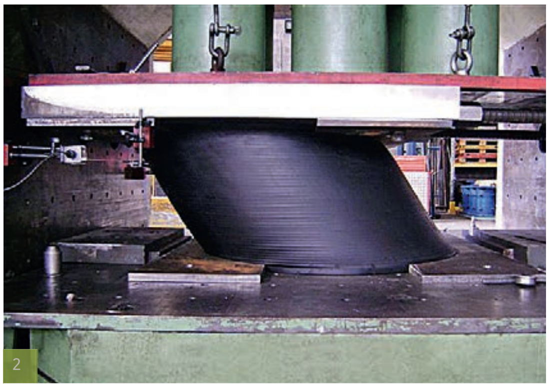
Main properties

- High recentring capability.
- High damping capacity ($\xi \leq 30\%$).
- Moderate maximum displacement.
- Zero maintenance.

Specific features

The ISOSISM® LRB has numerous applications in buildings, nuclear power plants, civil engineering structures, etc.

It isolates the structure from the movement of the ground by forming flexible connections that increase the fundamental period of vibration of the structure to be protected and reduce its acceleration by a ratio from two to three.



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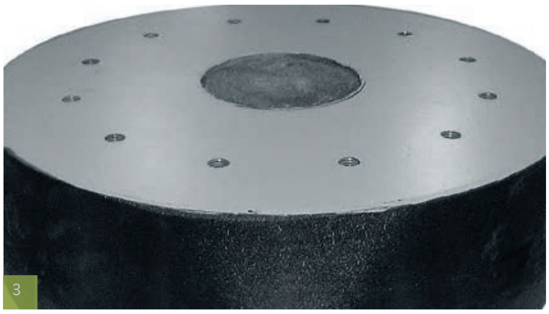

3

1. Antalya Airport, retrofitting with ISOSISM® LRB isolators - Turkey
2. Testing an ISOSISM® LRB
3. ISOSISM® LRB with a lead core

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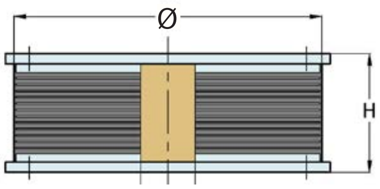
Range

Two types of mixture are available for different shear modulus G values:

- Model LRB 0.4 - 10: Modulus G=0.4 MPa
- Model LRB 0.8 - 10: Modulus G=0.8 MPa

Ø: Isolator diameter
V_{max}: Maximum vertical load under zero displacement
V_{seism}: Maximum vertical load under maximum displacement
K_{eff}: Effective stiffness of the isolator
H: Total height of the isolator
T_r: Total elastomer thickness
Δ_{max}: Maximum horizontal displacement
F_y: Elastic force of the lead
K_r: Horizontal stiffness of the elastomer
ξ_{eff}: Effective damping
K_{lp}: Stiffness of the lead



Structural connections

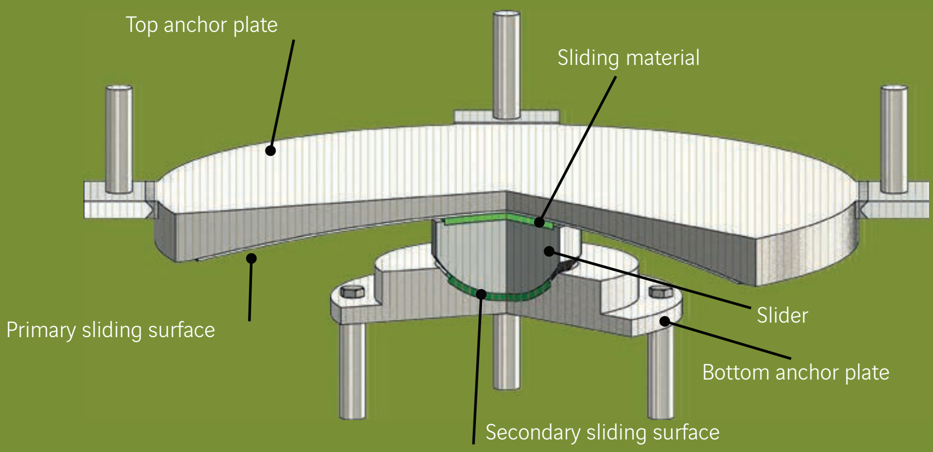
Different configurations for installation on the structure are possible.

The isolators are connected to steel structures using bolts.
They are connected to concrete structures using anchor dowels or studs.
The fixing principle is the same as for ISOSISM® HDRB isolators.

Ø	T_r	LRB 0.4 - 10									LRB 0.8 - 10								
		H	Δ_{max}	V_{max}	V_{seism}	K_r	K_{lp}	F_y	K_{eff}	ξ_{eff}	H	Δ_{max}	V_{max}	V_{seism}	K_r	K_{lp}	F_y	K_{eff}	ξ_{eff}
mm	mm	mm	mm	kN	kN	kN/mm	kN/mm	kN	kN/mm	%	mm	mm	kN	kN	kN/mm	kN/mm	kN	kN/mm	%
Ø300	45	129	110	1,430	820	0.59	5.89	34	0.87	26	129	95	2,380	1,550	1.12	11.17	60	1.70	27
Ø300	70	169	170	920	290	0.38	3.79	34	0.56	26	169	150	1,640	680	0.72	7.18	60	1.08	27
Ø350	55	145	135	2,200	1,230	0.65	6.53	49	0.98	27	165	115	3,290	2,390	1.25	12.48	80	1.88	27
Ø350	75	177	185	1,610	600	0.48	4.79	49	0.72	27	197	160	2,920	1,350	0.92	9.15	80	1.37	27
Ø400	60	147	150	2,870	1,670	0.79	7.85	60	1.15	26	167	130	3,620	3,200	1.50	14.99	102	2.21	26
Ø400	90	192	225	1,950	630	0.52	5.24	60	0.77	26	212	195	3,540	1,490	1.00	9.99	102	1.48	26
Ø450	72	165	180	3,940	2,180	0.83	8.26	80	1.23	27	185	155	4,580	4,190	1.57	15.71	136	2.37	27
Ø450	108	219	260	2,620	770	0.55	5.51	80	0.83	27	239	230	4,580	1,740	1.05	10.47	136	1.59	27
Ø500	84	197	210	4,380	2,360	0.87	8.67	110	1.34	28	217	180	4,890	4,680	1.67	16.66	165	2.50	27
Ø500	126	257	290	2,920	870	0.58	5.78	110	0.92	29	277	270	4,890	1,780	1.11	11.11	165	1.67	27
Ø550	88	198	220	5,460	3,050	1.01	10.10	119	1.50	27	228	190	6,940	5,900	1.93	19.29	196	2.87	27
Ø550	144	275	320	3,360	1,000	0.62	6.17	119	0.95	28	312	310	6,100	1,840	1.18	11.79	196	1.75	27
Ø600	96	209	240	6,540	4,010	1.10	11.04	136	1.62	26	260	205	8,250	7,690	2.09	20.94	242	3.17	27
Ø600	144	275	350	4,810	1,390	0.74	7.36	136	1.09	26	332	310	8,250	3,120	1.40	13.96	242	2.11	27
Ø650	108	252	270	7,870	4,290	1.15	11.50	165	1.70	26	272	230	8,650	8,340	2.19	21.89	280	3.29	27
Ø650	162	330	380	5,250	1,530	0.77	7.67	165	1.16	27	350	350	8,650	3,180	1.46	14.59	280	2.19	27
Ø700	120	264	300	8,590	4,600	1.20	11.98	196	1.79	27	315	260	11,340	8,980	2.29	22.89	320	3.41	27
Ø700	170	334	410	6,060	1,780	0.85	8.46	196	1.28	27	390	365	11,030	4,040	1.62	16.16	320	2.41	27
Ø750	130	298	325	10,370	5,530	1.26	12.63	242	1.94	28	350	280	13,000	10,870	2.42	24.17	378	3.64	27
Ø750	170	354	425	7,930	2,540	0.97	9.66	242	1.48	28	410	365	13,000	5,950	1.85	18.48	378	2.79	27
Ø800	132	296	330	11,220	6,540	1.41	14.08	293	2.21	28	358	285	16,190	12,950	2.71	27.12	425	4.07	27
Ø800	176	356	440	8,960	3,150	1.06	10.56	293	1.66	28	426	380	16,190	7,220	2.03	20.34	425	3.05	27

Range given for guidance. Other models can be considered upon request.

ISOLATION: ISOSISM® PS



3D view of an ISOSISM® PS

Design

• The ISOSISM® PS (Pendulum System) is an isolator designed using one or two spherical surfaces and a slider.
It conforms to EN 15129 and can be supplied with the CE marking to this effect.

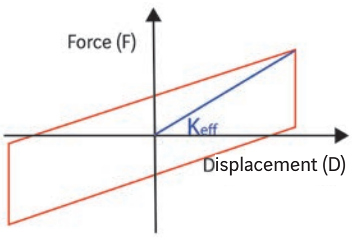
• The ISOSISM® PS is suitable for all types of bridge and building. It has the property of aligning the centre of stiffness and the centre of gravity of the isolated structure. It therefore naturally prevents twisting movements of the structure in the event of an earthquake and thus reduces the shear constraint.

• It can be designed and manufactured according to other international standards like AASHTO, ASCE, etc.

Behaviour law

The behaviour law of the ISOSISM® PS can be modelled as follows:

$$\boxed{F=V\ (\mu+D/R)}$$



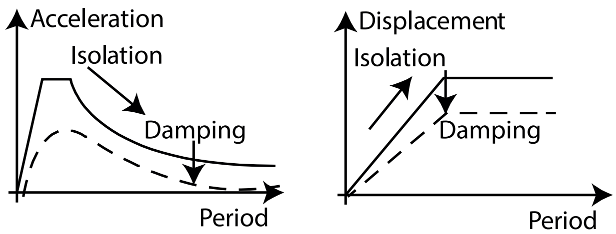
K_{eff}: Effective stiffness
F: Horizontal force
D: Displacement
V: Vertical force
μ: Dynamic coefficient of friction
R: Radius

Main properties

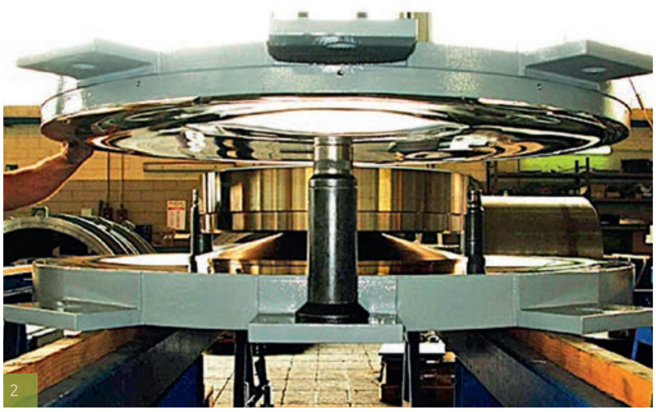
- Recentring capability.
- High damping capacity (ξ ≤ 35%).
- High relative displacement.

Specific features

The stiffness of the isolator is determined by the radius of the spherical surfaces, while the damping is provided by the friction between the sliding surfaces. The PS isolator is a bearing that typically provides a threefold reduction in the horizontal force exerted on the structure during an earthquake:



- Increasing the lateral flexibility by installing the isolator between the foundations and the superstructure greatly increases the natural period, which leads to a reduction in the acceleration and therefore the seismic force.
- By dissipating the energy during seismic movement, the ISOSISM® PS limits displacement.



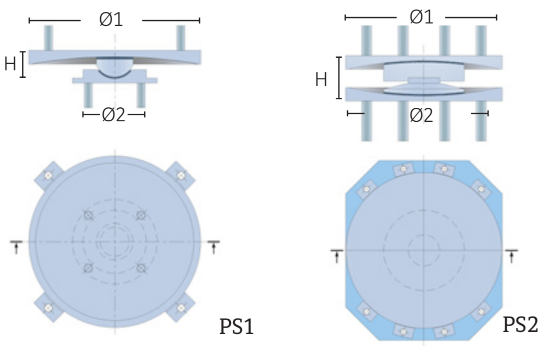
2

1. Retrofitting with ISOSISM® PS to the Building Orione - Italy
2. ISOSISM® PS being assembled
3&4 3D diagrams of an ISOSISM® PS


1

Range

The type of PS isolator chosen depends on the nature of the structure to be isolated, the permitted displacement and the space available.



D_{max}: Maximum displacement
N_{Sd}: Maximum non-seismic force
H: Height

$N_{Ed,max}$: Maximum seismic force
Ø1: Diameter 1
Ø2: Diameter 2

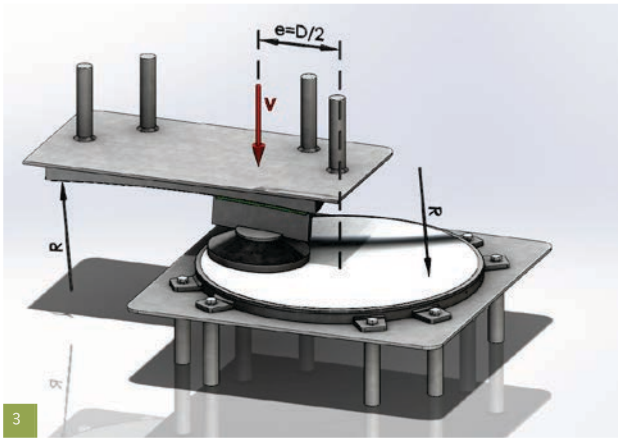
Type	D_{max}	$N_{Ed,max}$	N_{Sd}	PS1			PS2		
				Ø1	Ø2	H	Ø1	Ø2	H
	± mm	kN	kN	mm	mm	mm	mm	mm	mm
PS 1000/300	± 150	1,000	800	450	205	100	345	345	180
PS 1000/500	± 250	1,000	800	680	220	105	450	450	180
PS 1500/300	± 150	1,500	1,140	490	250	105	385	385	205
PS 1500/500	± 250	1,500	1,140	720	265	120	490	490	205
PS 2000/300	± 150	2,000	1,540	510	285	115	415	415	235
PS 2000/500	± 250	2,000	1,540	750	310	130	520	520	235
PS 2500/300	± 150	2,500	1,940	530	315	125	445	445	260
PS 2500/500	± 250	2,500	1,940	780	340	135	555	555	260
PS 3000/300	± 150	3,000	2,280	560	345	135	490	490	295
PS 3000/500	± 250	3,000	2,280	800	375	150	600	600	295
PS 4000/300	± 150	4,000	3,080	600	395	145	530	530	335
PS 4000/500	± 250	4,000	3,080	850	430	165	640	640	335
PS 5000/300	± 150	5,000	3,820	640	445	160	555	555	355
PS 5000/500	± 250	5,000	3,820	890	475	180	670	670	360

Range given for guidance. Other models can be considered upon request.

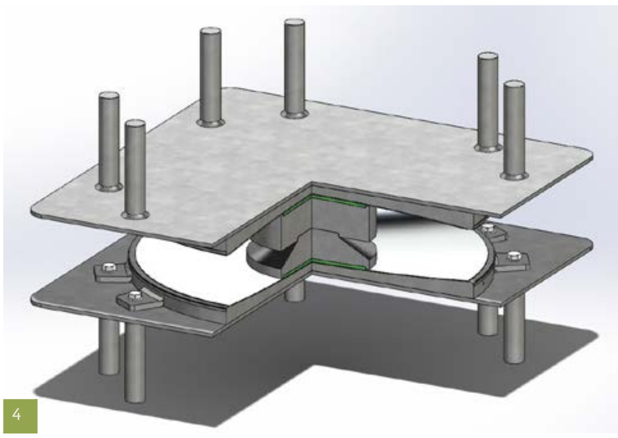
The above table is based on 3% nominal friction and effective radius equal to 4000mm.

Structural connections

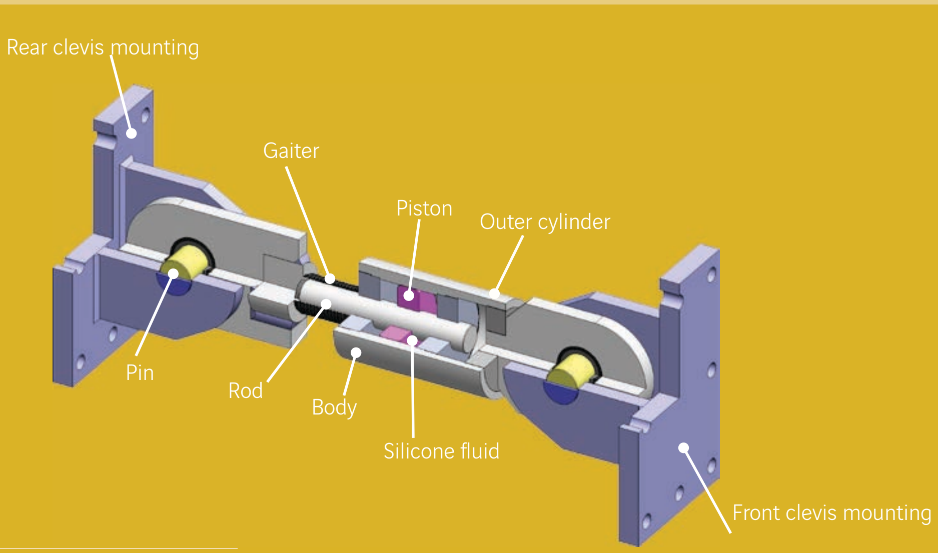
Different configurations for installation on the structure are possible. Freyssinet offers an appropriate connection solution for each configuration.



3


4

CONNECTION: ISOSISM® STU



3D view of an ISOSISM® STU

Design

- The ISOSISM® STU (Shock Transmission Unit) is a connector that works like a high-pressure hydraulic jack.

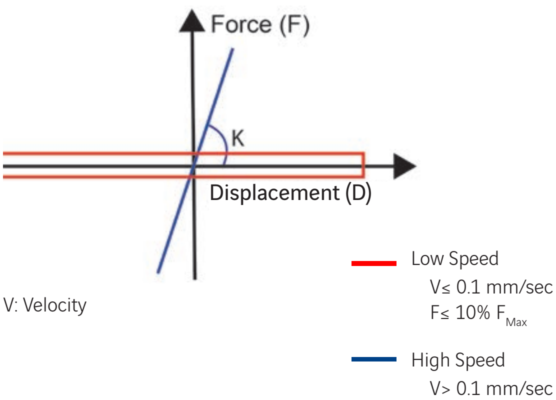
It is made up of a body with two chambers separated by a piston. The piston is secured to a rod connected to one of the clevis mountings and the damper body is secured to the other clevis mounting.

It conforms to EN 15129 and can be supplied with the CE marking to this effect.

- The ISOSISM® STU works in both traction and compression.
- It can be designed and manufactured according to other international standards like AASHTO, ASCE, etc.

Behaviour law

The behaviour law of the ISOSISM® STU depends on velocity of load application.



V: Velocity

Main properties

- Provides only very low resistance to displacements.
- The ISOSISM® STU operates by means of one or more stop valves housed in the piston. As an option, the force transmitted by the unit can be restricted by adding a force limiter.

Specific features

The ISOSISM® STU has numerous applications in buildings, nuclear power plants, civil engineering structures, etc.

It is used to connect buildings together, or to create a fixed point on a civil engineering structure in the event of an earthquake, emergency braking by a high-speed train or a gust of wind.

The units then act as rigid connections, distributing the horizontal forces over all of the piers on which they are installed.

2

1. Struma Bridge - Bulgaria
2. ISOSISM® STU
3. 3D diagram of an ISOSISM® STU

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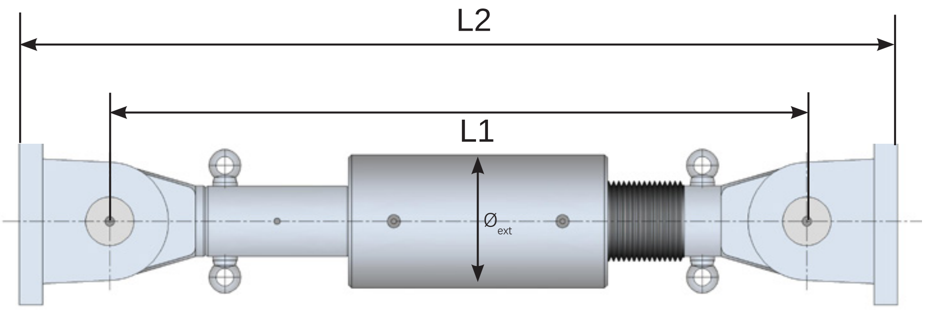
1

Range



$Ø_{ext}$: External diameter

F_{Max}: Maximum force

D_{Max}: Maximum displacement

L2: Overall length at mid-stroke

L1: Length between axes at mid-stroke

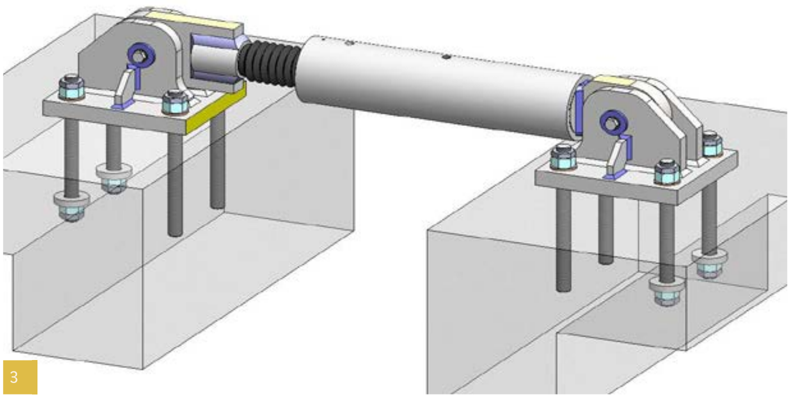
Type	F_{max} kN	D_{max} ± mm	L1 mm	L2 mm	$Ø_{ext}$ mm
STU 500/100	500	± 50	880	1,145	172
STU 500/200	500	± 100	1,155	1,420	172
STU 750/100	750	± 50	925	1,245	210
STU 750/200	750	± 100	1,200	1,520	210
STU 1000/100	1,000	± 50	1,055	1,420	236
STU 1000/200	1,000	± 100	1,330	1,695	236
STU 1500/100	1,500	± 50	1,125	1,555	267
STU 1500/200	1,500	± 100	1,400	1,830	267
STU 2000/100	2,000	± 50	1,225	1,725	300
STU 2000/200	2,000	± 100	1,500	2,000	300
STU 2500/100	2,500	± 50	1,290	1,840	325
STU 2500/200	2,500	± 100	1,565	2,115	325
STU 3000/100	3,000	± 50	1,405	2,005	362
STU 3000/200	3,000	± 100	1,680	2,280	362
STU 3500/100	3,500	± 50	1,520	2,200	388
STU 3500/200	3,500	± 100	1,795	2,475	388
STU 4000/100	4,000	± 50	1,590	2,300	414
STU 4000/200	4,000	± 100	1,865	2,575	414

Range given for guidance.
Other models can be considered upon request.

The maximum force in the above table is including the magnification factor equal to 1.5.

Structural connections

Different configurations for installation on the structure are possible.
Freyssinet offers an appropriate connection solution for each configuration.



3

DESIGNS: STRUCTURAL DESIGN

The seismic behaviour of structures can be analysed by means of a linear spectral analysis and a non-linear time history analysis.

A spectral analysis is easier to implement and provides access to equivalent static forces and displacements. It is suitable for structures that are damped up to 30% and fitted with devices featuring a linear behaviour law.

For higher damping levels and for non-linear devices, a time history analysis is required.

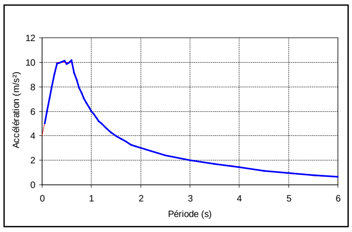
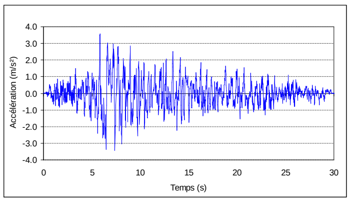
Freyssinet carries out both types of analysis and uses high-performance software for quickly calculating the non-linear time history response of isolated and wind-braced structures.

Freyssinet can therefore streamline global project costs, from beginning through to handover, by using earthquake protection devices to lighten the superstructure and foundations.

Types of analysis:

The analysis depends on the damping coefficient:

- Up to 30%: the calculation is linear, based on the use of the spectral analysis method.
- Over 30%: the calculation is non-linear and based on the use of specialised software.

ISOSISM® DEVICES	CALCULATION	INPUTS
STU	Linear Spectral analysis	
HDRB		
LRB	Linear or non-linear, depending on the ξ values	
PS		
FD	Non-linear Based on specialised software	
PDS		

1. Design office
2. 3D finite element analysis of the isolation system
3. Analysis of the fitting of the dampers on the pier heads

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Some projects

Freyssinet's strength lies in its expertise in the different technologies for designing structures subject to seismic forces and its expertise in protection device technologies, thereby enabling the company to offer an end-to-end service for streamlining global project costs.

Different options can be analysed in an effort to achieve the correct trade-off between displacements and forces in the superstructure and the foundations.

Projects where Freyssinet took part in seismic studies and also designed and supplied devices include:

- La Meynard Hospital - Martinique
- El Hachef and Loukkos high-speed train viaducts - Morocco.

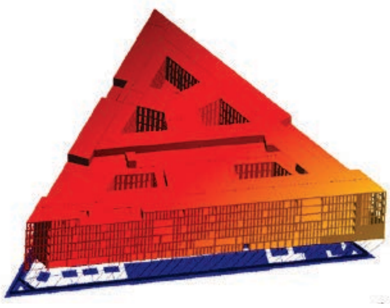
For these projects, fitting earthquake protection devices curbed construction costs by reducing floor accelerations and seismic reactions at the foundations.

La Meynard Hospital - Martinique

For this hospital, Freyssinet took part in the seismic study, and also designed, manufactured and installed:

- 283 ISOSISM® HDRB isolators
- 36 ISOSISM® FD dissipators.

BASE TO BE ISOLATED	DISPLACEMENT (mm)	ACCELERATION (m/s²)
Without dampers	340	2.5
With dampers	170	1.7

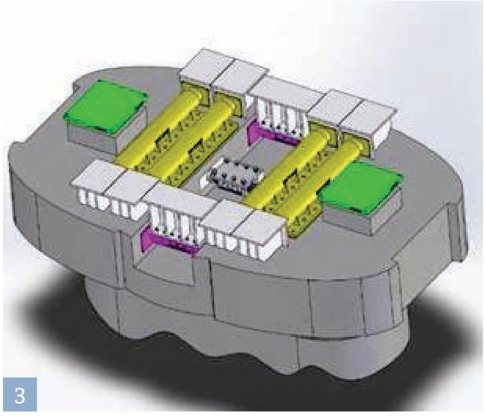


2

El Hachef and Loukkos high-speed train viaducts - Morocco

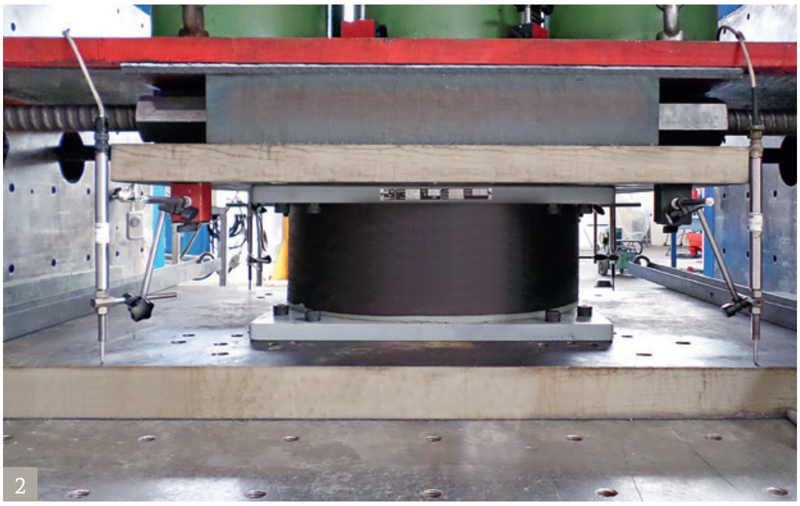
For these viaducts, Freyssinet took part in the seismic study, and also designed, manufactured and installed:

- 156 ISOSISM® PDS prestressed damping springs
- 152 ISOSISM® FD dissipators.



3

FREYSSINET'S EXPERTISE



We guarantee all our customers around the world the same level of excellence in our products and services by designing and manufacturing our own earthquake protection devices. We can draw on our expertise across the product and system lifecycle to gear our solutions towards a broad array of applications and extreme operating conditions.

Products designed and manufactured by Freyssinet

All our ISOSISM® products have undergone numerous dynamic tests to guide and validate Freyssinet's technical development process.

They are conceived and designed by an in-house technical department that fine-tunes products for conformity with applicable standards and project specifications. Coordination between the design, the manufacturing solutions and the choice of materials is critical for producing solutions, offering peak performance and providing reliable and durable products.

Our in-house mechanical testing centre with its broad array of specific materials carries out full-scale testing on most of our products during both the product development and approval stage as well as the production phase.

Certified products

Recognition of Freyssinet's expertise and high-quality processes is reflected in a number of certifications in a wide range of fields.

Our earthquake protection devices are world-renowned and certified by a number of specialised organisations.

1 Design office - ISOSISM® industrialisation
2 Dynamic testing on an ISOSISM® LRB
3 Certifications
4 Dimensional control of an ISOSISM® PDS
5 Assembly of an ISOSISM® PDS in the guide
6 Quality control
7 Plate surface treatment
8 Test equipment
9 Storage of ISOSISM® PDS

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Expertise and industrial know-how

Based in France, our FPC Industrial Division (Freyssinet Products Company) acts as a focal point for all of Freyssinet's expertise in materials, manufacturing, production engineering, control and logistics. It coordinates all of our production activities on a global scale. A large contingent of experts in smelting, elastomers, mechanical engineering and quality travels the length and breadth of the five continents in a bid to define and control the manufacturing processes and guarantee the same level of product quality, irrespective of the production site's location.

Guaranteed quality

The sprawling network of FPC-managed production sites requires daily involvement from the quality control department, which guarantees the quality and conformity of the products supplied. All products are checked by FPC at a given moment in time, using its array of cutting-edge measuring instruments.

All checkpoints are defined internally, and FPC issues a certificate of conformity for each product supplied.

ISOSISM® isolators are designed and manufactured according to EN 15129 and AASHTO. They can be supplied with the CE marking.

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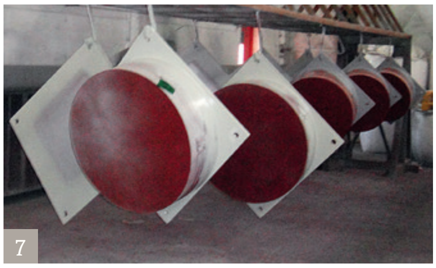
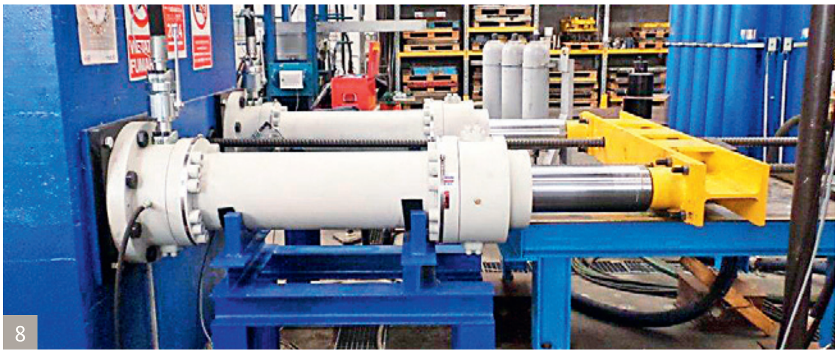

7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SOME COMPLETED STRUCTURES


Mardakan Bridge - Azerbaijan


BTZ Bridge - Algeria


ITER reactor - France


Marmara Hospital - Turkey

Coyuca Bridge - Mexico


Bucharest City Hall - Romania

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Publication: 02/2016 - C V 5 - Printed in France

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