Earthquake protection devices ISOSISM® range

FREYSSINET

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"

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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.

Understanding the risk

Structural Maintenance

Advise solutions tailored to the project

Reinforce

Build

Reapir

Maintain

Guaranteed product quality and conformity

FREYSSINET

Structural behaviour studies

Protect

Technical support for installing devices

Protection device design

Device manufacturing
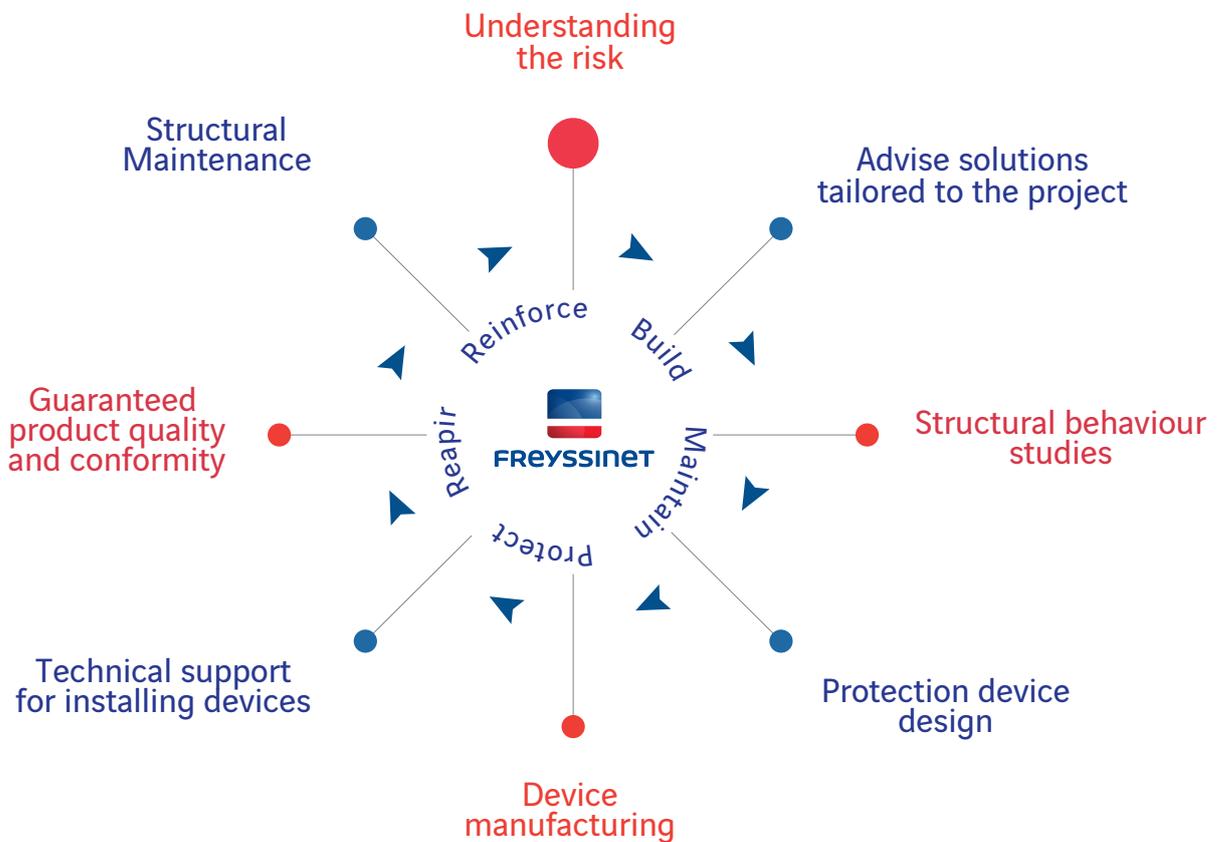
Protection principle: the ISOSISM® range

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   **FD-HR**   **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**
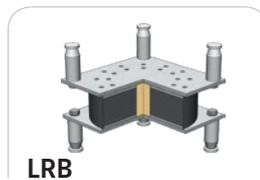
CONNECTION

- 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
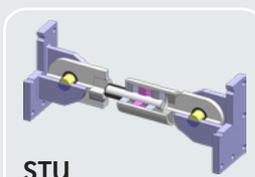
Protection examples

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.
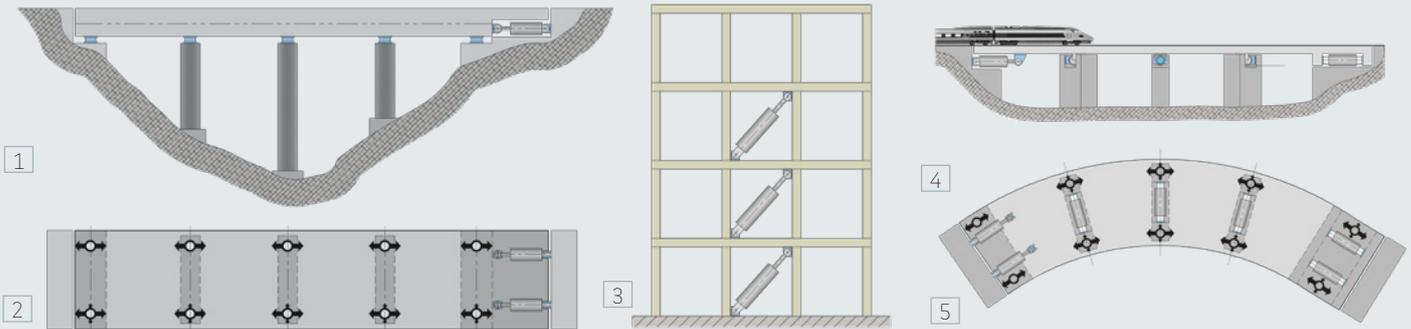
1. ISOSISM® FD on an abutment
2. ISOSISM® FD plan view
3. ISOSISM® FD in wind bracing
4. ISOSISM® PDS and FD beneath a railway bridge
5. ISOSISM® PDS and FD plan view
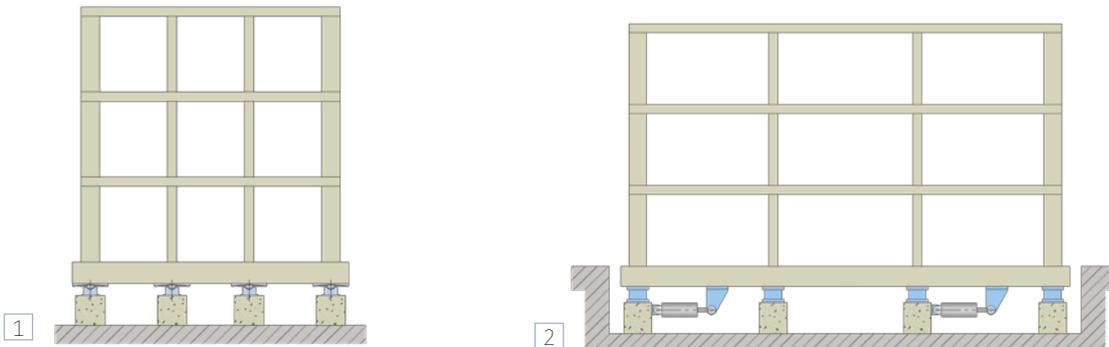
1. Building isolated with ISOSISM® PS isolators ISOSISM® HDRB or ISOSISM® LRB
2. ISOSISM® HDRB isolators and ISOSISM® FD dissipators beneath a building
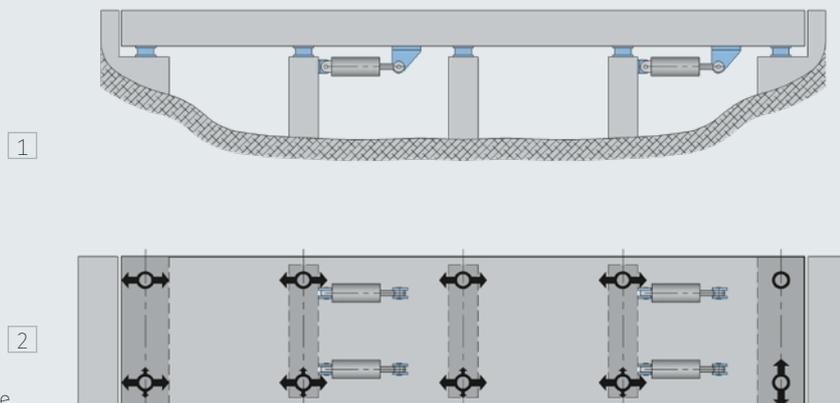
1. Installation of an ISOSISM® STU beneath a bridge
2 ISOSISM® STU plan view

Dissipation: ISOSISM® FD

Clevis mounting

Clevis + Pin

Piston

Rod

Clevis mounting

Body

Clevis + Pin
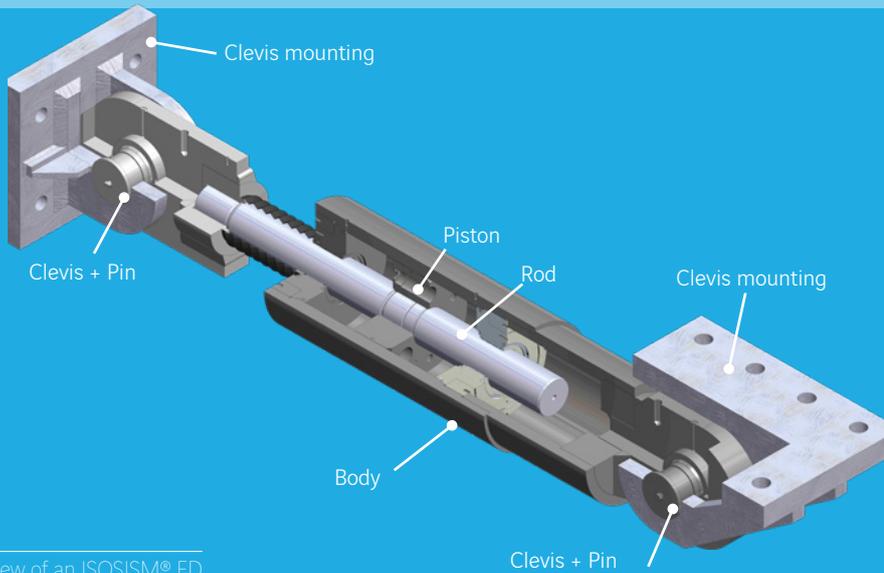
3D view of an ISOSISM® FD

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:

$$F = C.V^\alpha$$

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

α: Damping coefficient
F: Force
C: Damping constant
V: Velocity

Low Speed
High Speed
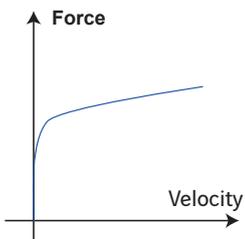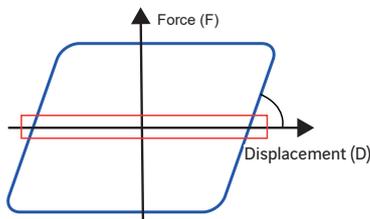
Specific features

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.

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.

Range
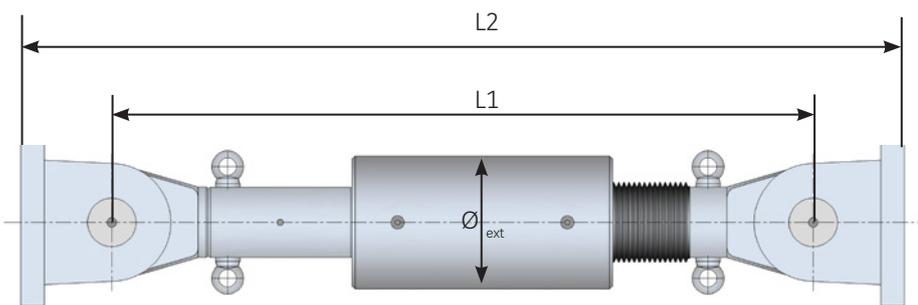
Ø$_{ext}$: External diameter excluding accumulator
F$_{Max}$: Maximum force
D$_{Max}$: Maximum displacement
L2: Overall length at mid-stroke
L1: Length between axes at mid-stroke

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
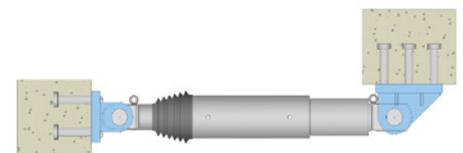
Traction/Shear Connection

Traction/Compression Connection
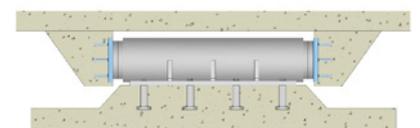
Connection with sliding plates

DISSIPATION: ISOSISM® FD-HR

Clevis mounting
Piston
Rod
Clevis mounting
Radial ball joint
Body
Radial ball joint
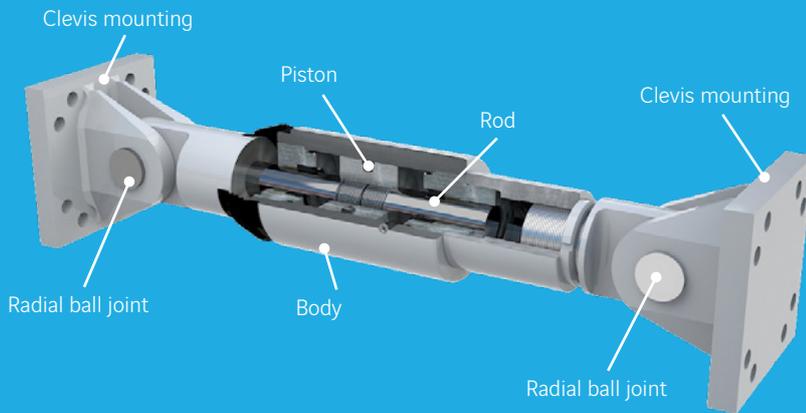
3D view of an ISOSISM® FD-HR

Design

- The ISOSISM® FD-HR (Fluid Damper – High Reactivity) is a viscous damper using a viscous fluid that is stable over time and under temperature variations.
- 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 tension and compression.
- The damping provided by the FD-HR is obtained by the fluid moving under pressure through the piston, which is equipped with specially designed dissipation zones.

Behaviour law

The ISOSISM® FD-HR operates through the lamination of the viscous fluid in the dissipation zones.
Its behaviour law can be modelled as follows:

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

(α = 0.12)

α: Damping coefficient
F: Force
C: Damping constant
V: Velocity

Low Speed
High Speed

Main properties

- Provides only very low resistance to displacements while in service.
- Dissipates energy during an earthquake.
- High reaction at very small displacement
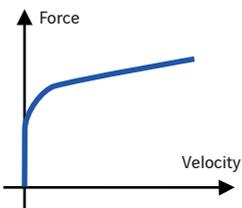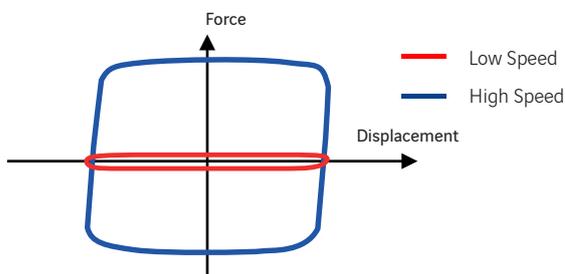
Specific features

ISOSISM® FD-HR dampers do not prevent very slow displacements such as those due to thermal variations. They react in the event of an earthquake and dissipate seismic energy.

These dampers are different from conventional dampers in that they are completely effective from first displacement. They are particularly suited to cases where the total stroke is small, for example in bracing in buildings.

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 on new structures or to bring existing structures in line with current standards.

±50 mm ±7.5 mm ±2.5 mm
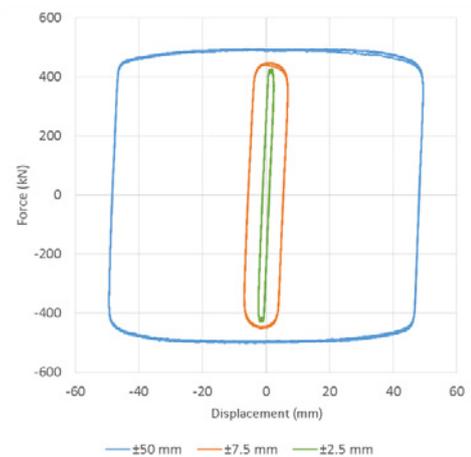
The device reacts from the first displacement

Range

F_{max}: Maximum force   L1: Length between pin centres

D_{max}: Maximum displacement   L2: Length overall

$Ø_{ext}$: External diameter

Type	F_{max} kN	D_{max} ± mm	$Ø_{ext}$ mm	L1 mm	L2 mm	Weight kg
FD-HR 300/100	300	50	120	880	970	65
FD-HR 650/100	650	50	170	945	1,140	85
FD-HR 1000/100	1000	50	200	1,150	1,310	160

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.

Protective gaiter

-15   +15
Mechanical adjustment

Structural connections

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

Tension/Shear Connection   *Shear/Shear Connection*   *Tension/Tension Connection*
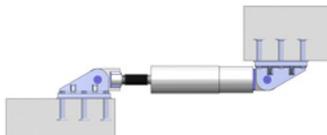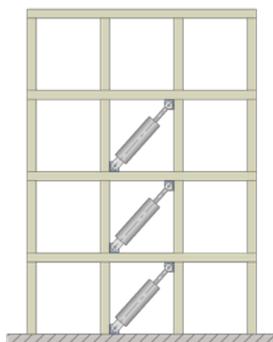
Seismic bracing installation
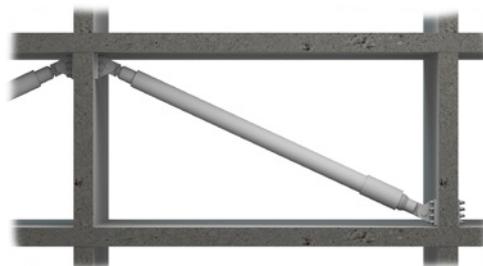
General view of wind bracing with an Isosism® FD-HR

DISSIPATION: ISOSISM® PDS

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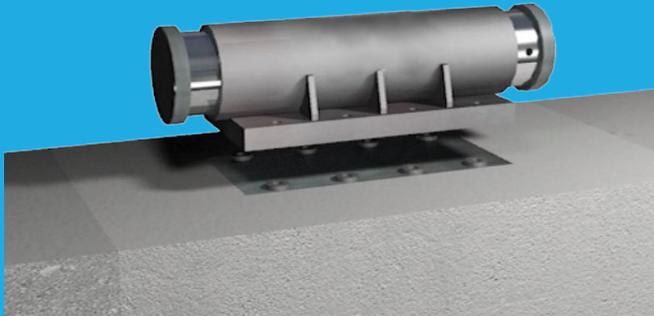
• The ISOSISM® PDS (Prestressed Damping Spring) combines the benefits of a viscous fluid damper and a prestressed hydraulic spring. In normal operating conditions, the ISOSISM® PDS acts as a fixed point. During an earthquake, it dissipates energy and then returns the structure to its initial position.

• 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.

3D view of an ISOSISM® PDS

Behaviour law

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

$$F = F_0 + KD + C.V^\alpha \qquad \alpha = 0.12$$
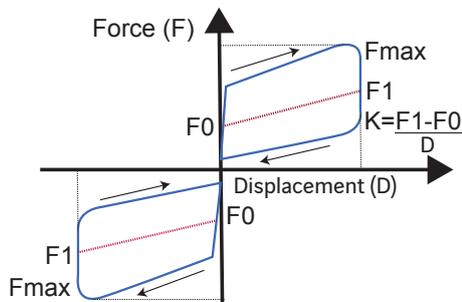
F: Reaction force

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.

1. Mardakan Bridge - Azerbaijan
2. Installation of an ISOSISM® PDS
3. 3D views of an ISOSISM® PDS

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Range
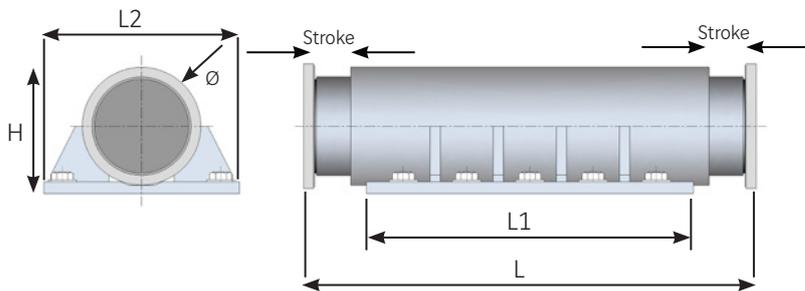
F: Prestressing Force

F_{max}: Maximum Force

K: Stiffness

L: Length

H: Height

Ø: Diameter

L1: Length of mounting plate

L2: Width of mounting plate

Structural connections
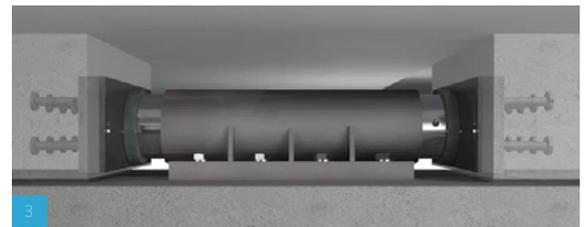
| Type	F_0 kN	Stroke mm	F_{max} kN	K kN/mm	L mm	H mm	Ø mm	L1 mm	L2 mm
PDS 100-290-50	100	±50	290	1.6	660	155	130	520	260
PDS 100-290-100	100	± 100	290	0.8	1,020	165	130	780	260
PDS 250-670-50	250	±50	670	3	900	215	180	760	360
PDS 250-670-100	250	± 100	670	1.5	1,370	230	180	1,130	360
PDS 500-1210-50	500	±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

Reinforcement
Anchor plate
Screw
Anchor dowel
Elastomer
Outer plate
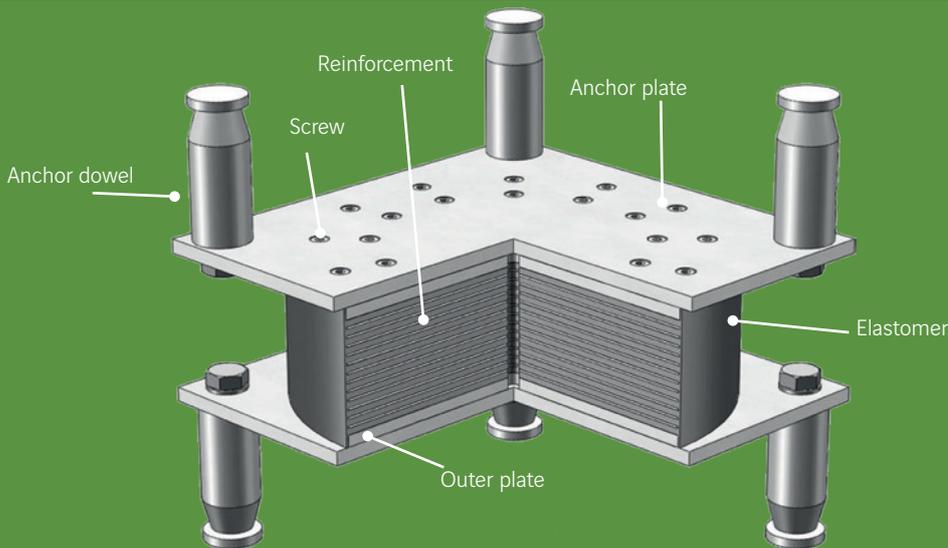
3D view of an ISOSISM® HDRB

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:

$$F = K_r D$$

K_r: Horizontal stiffness
F: Force
D: Displacement

Main properties

• High recentring capability.
• Moderate damping capacity ($\xi \leq 16\%$ and $\geq 10\%$).
• 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.

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

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.

Different types of rubber compound are available with nominal shear modulus G variable from 0.4 MPa till 1.15 MPa and nominal damping variable from 10 % till 15 %.

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
dbd: Seismic design displacement
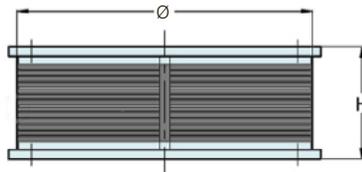
Structural connections

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.
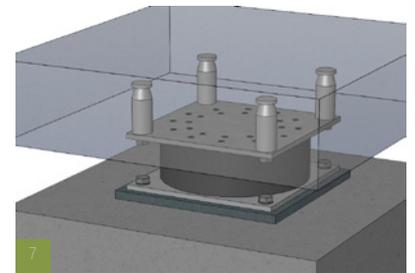
Ø	T_r	HDRB - S						HDRB - N						HDRB - H					
		H	Δ_{max}	dbd	V_{max}	V_{seism}	K_r	H	Δ_{max}	dbd	V_{max}	V_{seism}	K_r	H	Δ_{max}	dbd	V_{max}	V_{seism}	K_r
mm	mm	mm	mm	mm	kN	kN	kN/mm	mm	mm	mm	kN	kN	kN/mm	mm	mm	mm	kN	kN	kN/mm
300	45	114	110	65	1,300	800	0.63	114	95	55	2,700	1,800	1.26	114	75	42	3,300	2,800	1.81
300	70	154	170	97	900	300	0.40	154	150	83	1,800	700	0.81	154	120	63	2,600	1,400	1.16
350	55	130	135	82	2,200	1300	0.70	130	115	68	4,400	2,800	1.40	130	95	55	4,600	3,800	2.01
350	75	162	185	107	1,600	600	0.51	172	160	90	3,300	1,500	1.03	162	130	70	4,300	2,600	1.48
400	60	138	150	83	2,900	2,000	0.84	138	130	70	5,800	3,500	1.68	138	100	50	5,800	4,700	2.41
400	90	186	225	125	2,200	700	0.56	196	195	105	4,500	1,800	1.12	196	155	78	5,500	3,400	1.61
450	72	150	180	103	3,700	2,200	0.88	160	155	87	6,200	4,700	1.77	150	125	67	6,200	6,200	2.54
450	108	204	260	148	2,600	800	0.59	214	230	128	5,200	1,900	1.18	224	185	98	5,900	3,700	1.69
500	84	168	210	123	5,100	2,900	0.93	178	180	103	7,800	5,800	1.87	178	145	80	7,800	7,600	2.69
500	126	231	290	160	3,300	1,000	0.62	251	270	147	6,700	2,100	1.25	251	215	110	7,100	4,300	1.79
550	90	177	225	125	6,300	4,000	1.06	187	195	105	9,200	6,600	2.11	187	155	78	9,200	8,600	3.04
550	144	258	320	180	4,400	1,300	0.66	288	310	173	8,800	2,300	1.32	278	250	133	8,800	4,800	1.90
600	98	205	245	138	7,300	4,500	1.15	205	210	115	12,700	8,200	2.31	220	170	88	12,700	10,600	3.32
600	147	282	350	200	5,300	1,600	0.77	302	315	177	10,700	3,500	1.54	317	255	137	12,200	6,600	2.21
650	105	206	260	148	9,200	6,000	1.26	226	225	125	15,100	9,500	2.53	221	180	95	15,100	12,200	3.63
650	161	304	380	212	6,600	1,900	0.82	324	350	192	13,200	4,000	1.65	329	280	145	14,100	7,800	2.37
700	119	238	295	172	11,700	6,700	1.29	248	255	145	17,700	11,000	2.59	253	205	112	17,700	13,800	3.72
700	168	315	410	232	8,600	2,400	0.92	350	365	202	16,600	5,400	1.83	360	290	152	16,600	10,100	2.63
750	133	260	330	187	13,800	7,200	1.33	285	285	157	19,900	12,100	2.66	285	230	120	19,900	15,000	3.82
750	168	315	420	238	11,600	3,500	1.05	350	365	202	19,300	7,800	2.10	360	290	152	19,300	13,900	3.02
800	136	255	340	193	14,900	8,800	1.48	280	295	163	23,400	14,100	2.96	280	235	123	23,400	17,800	4.25
800	176	325	440	252	12,700	4,100	1.14	360	380	212	22,700	9,300	2.28	355	305	162	22,700	16,100	3.28

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

ISOLATION: ISOSISM® LRB

3D view of an ISOSISM® LRB

Labels: Anchor dowel, Screw, Steel reinforcement, Lead core, Anchor plate, Elastomer, Outer plate
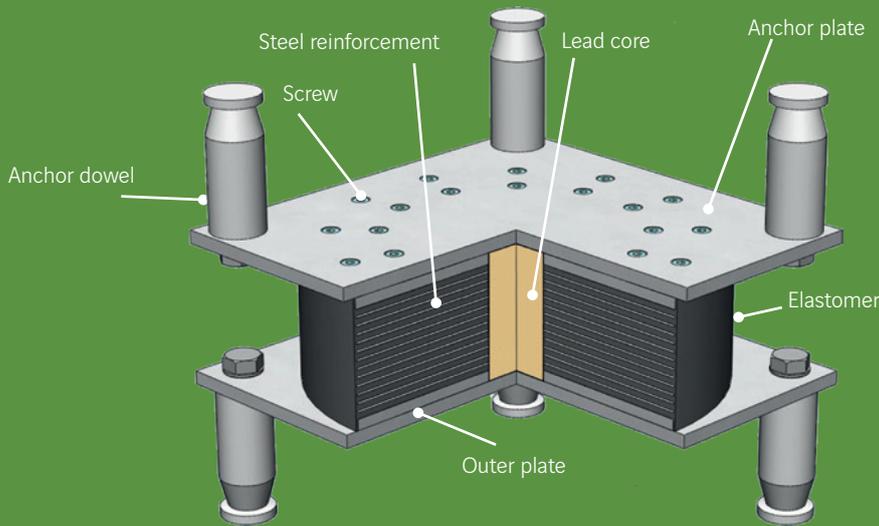
Design

• 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:
$$F = K_{eff}\, D$$

Non-linear calculation:
$$F = F_y + K_r\, D$$
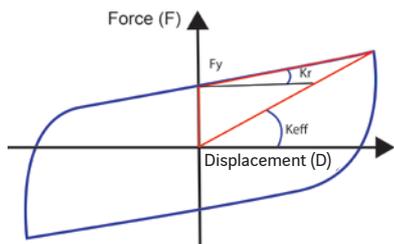
K_r: Second branch stiffness
K_{eff}: Effective stiffness
F: Horizontal force
D: Displacement
F_y: Elastic force of the lead

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.

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

Range

Different types of rubber compound are available with nominal shear modulus G variable from 0.4 MPa till 1.15 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 at dbd
H: Total height of the isolator
T_r: Total elastomer thickness
Δ_{max}: Maximum horizontal displacement
Q_d: Characteristic strength
K_r: Post-elastic stiffness at dbd
ξ_{eff}: Effective damping at dbd
dbd: Seismic design displacement
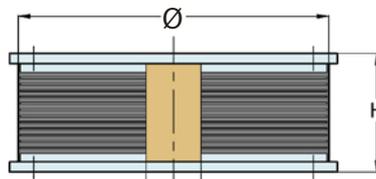
Structural connections

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 - S									LRB - N								
		H	Δ_{max}	dbd	V_{max}	V_{seism}	K_r(dbd)	Q_d(dbd)	K_{eff}(dbd)	ξ_{eff}(dbd)	H	Δ_{max}	dbd	V_{max}	V_{seism}	K_r(dbd)	Q_d(dbd)	K_{eff}(dbd)	ξ_{eff}(dbd)
mm	mm	mm	mm	mm	kN	kN	kN/mm	kN	kN/mm	%	mm	mm	mm	kN	kN	kN/mm	kN	kN/mm	%
300	45	114	110	65	1,200	1,000	0.45	29	0.90	29	114	95	55	1,500	1,800	0.80	48	1.68	29
300	70	154	170	97	800	300	0.29	29	0.60	29	154	150	83	1,400	700	0.51	48	1.09	29
350	55	130	135	82	2,000	1,400	0.49	39	0.97	29	130	115	68	2,100	2,600	0.89	69	1.90	30
350	75	162	185	107	1,500	600	0.37	39	0.74	29	172	160	90	2,000	1,400	0.65	69	1.42	30
400	60	138	150	83	2,600	2,000	0.61	52	1.24	29	138	130	70	2,700	3,300	1.08	86	2.30	29
400	90	186	225	125	2,000	700	0.40	51	0.82	29	196	195	105	2,500	1,700	0.71	85	1.52	30
450	72	150	180	103	2,900	2,400	0.62	65	1.25	29	160	155	87	2,900	4,300	1.12	112	2.41	30
450	108	204	260	148	2,400	800	0.42	64	0.86	29	214	230	128	2,700	1,800	0.74	111	1.61	30
500	84	168	210	123	3,700	2,900	0.65	79	1.29	29	178	180	103	3,600	5,400	1.18	132	2.45	29
500	126	231	290	160	3,000	1,000	0.47	80	0.98	29	251	270	147	3,300	2,000	0.79	131	1.68	30
550	90	187	225	125	4,400	3,900	0.76	97	1.53	29	187	195	105	4,200	6,200	1.34	166	2.92	30
550	144	268	320	180	4,000	1,200	0.51	97	1.05	29	278	310	173	4,000	2,200	0.83	164	1.77	30
600	98	205	245	138	6,000	4,600	0.82	115	1.66	29	205	210	115	5,900	7,600	1.47	191	3.13	29
600	147	282	350	200	4,900	1,500	0.56	115	1.13	29	302	315	177	5,600	3,300	0.97	189	2.04	29
650	105	216	260	148	7,200	5,700	0.90	135	1.81	29	231	225	125	7,000	8,900	1.61	231	3.46	30
650	161	304	380	212	6,000	1,800	0.61	136	1.26	29	329	350	192	6,500	3,800	1.04	230	2.24	30
700	119	238	295	172	8,400	6,400	0.91	156	1.81	29	253	255	145	8,200	10,300	1.64	259	3.43	29
700	168	315	410	232	7,900	2,300	0.66	156	1.33	29	350	365	202	7,700	5,100	1.16	258	2.44	29
750	133	260	330	187	9,500	6,900	0.95	179	1.91	29	285	285	157	9,200	11,300	1.69	306	3.64	30
750	168	325	420	238	9,200	3,400	0.74	178	1.49	29	350	365	202	8,900	7,400	1.33	304	2.83	30
800	136	270	340	193	11,100	8,400	1.04	203	2.09	29	270	295	163	10,800	13,200	1.87	337	3.93	29
800	176	330	440	252	10,800	4,000	0.80	201	1.60	29	350	380	212	10,500	8,800	1.44	335	3.02	30

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

Isolation: ISOSISM® PS

Top anchor plate
Sliding material
Primary sliding surface
Slider
Bottom anchor plate
Secondary sliding surface
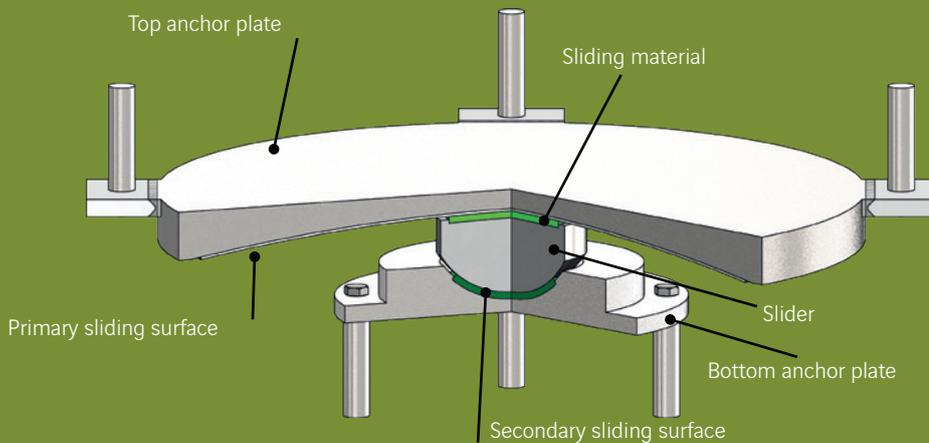
3D view of an ISOSISM® PS

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:

$$F = V\,(\mu + D/R)$$
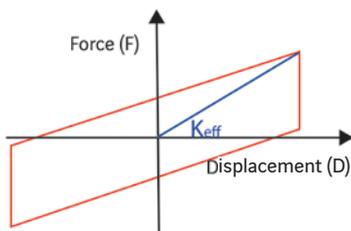
K_{eff}: Effective stiffness
F: Horizontal force
D: Displacement
V: Vertical force
μ: Dynamic coefficient of friction
R: Radius

Main properties

- Recentring capability.
- High damping capacity ($\xi \le 35\%$).
- 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:
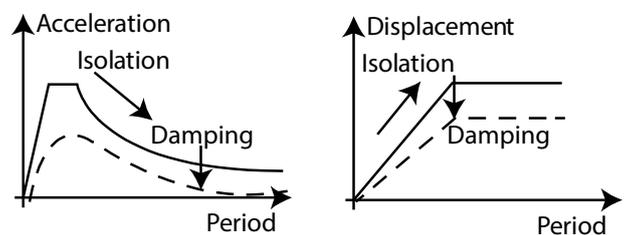
- Increasing the lateral flexibility by installing the isolator between the foundations and the superstructure greatly increases the natural period, which leads to a reduction in the acceleration and therefore the seismic force.
- By dissipating the energy during seismic movement, the ISOSISM® PS limits displacement.

Range

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

PS1

PS2
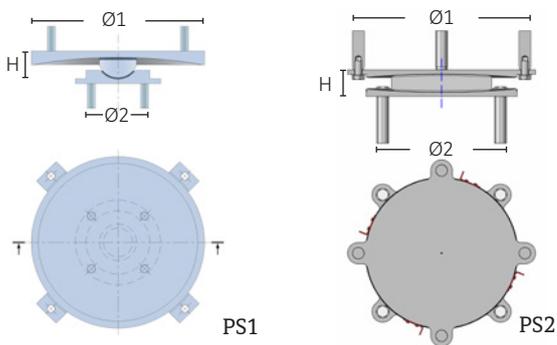
D_{max}: Maximum displacement

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	485	185	92.5	335	335	57.0
PS 1000/500	± 250	1,000	800	680	185	96.0	435	435	69.0
PS 1500/300	± 150	1,500	1,140	515	220	94.0	365	365	58.5
PS 1500/500	± 250	1,500	1,140	705	220	100.5	465	465	71.5
PS 2000/300	± 150	2,000	1,540	545	255	102.0	400	400	60.4
PS 2000/500	± 250	2,000	1,540	740	255	109.0	500	500	75.5
PS 2500/300	± 150	2,500	1,940	570	285	108.0	425	425	64.0
PS 2500/500	± 250	2,500	1,940	760	285	116.0	525	525	80.0
PS 3000/300	± 150	3,000	2,280	585	310	119.0	445	445	70.4
PS 3000/500	± 250	3,000	2,280	780	310	127.0	545	545	86.5
PS 4000/300	± 150	4,000	3,080	630	360	132.0	490	490	77.0
PS 4000/500	± 250	4,000	3,080	820	360	139.0	590	590	95.0
PS 5000/300	± 150	5,000	3,820	665	400	145.0	525	525	88.0
PS 5000/300	± 250	5,000	3,820	850	400	152.0	625	625	104.0

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

The above table is based on 5% 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.

CONNECTION: ISOSISM® STU

Rear clevis mounting
Gaiter
Piston
Outer cylinder
Pin
Rod
Body
Silicone fluid
Front clevis mounting
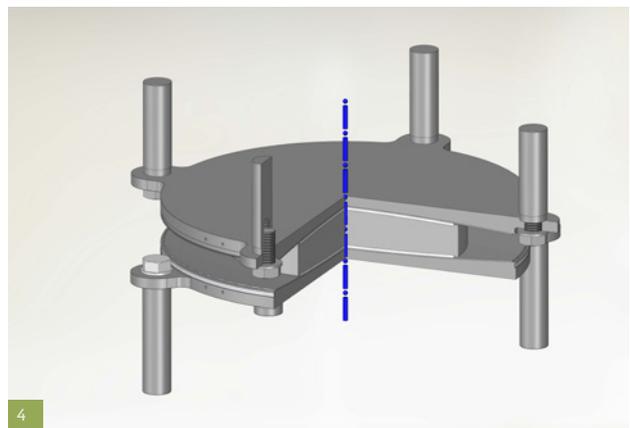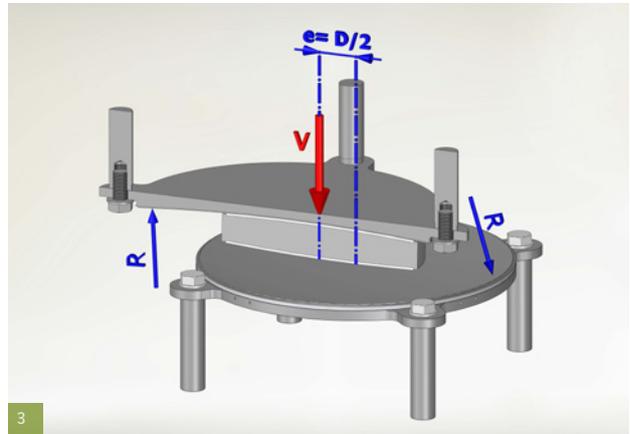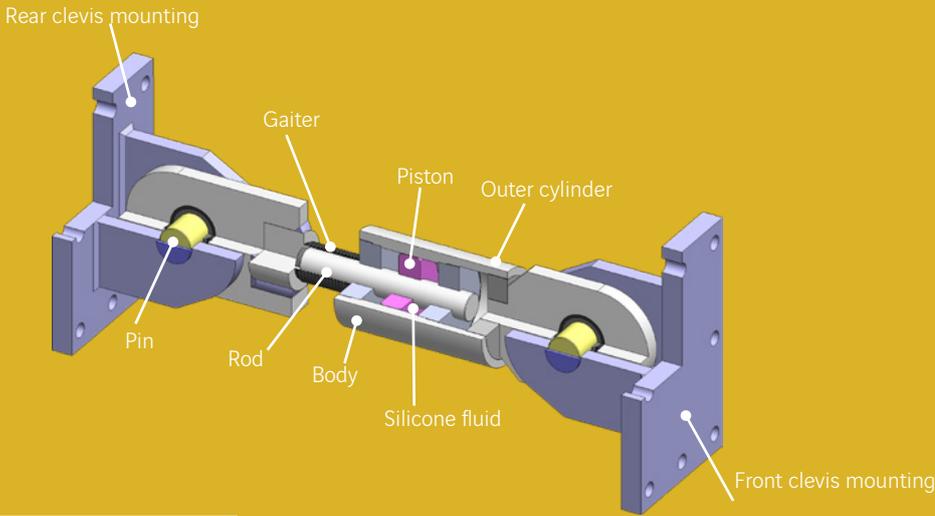
3D view of an ISOSISM® STU

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

Low Speed
V≤ 0.1 mm/sec
F≤ 10% F_{Max}

High Speed
V> 0.1 mm/sec
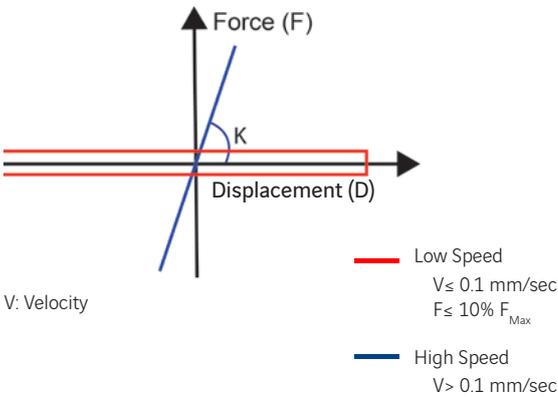
Main properties

- 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.

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

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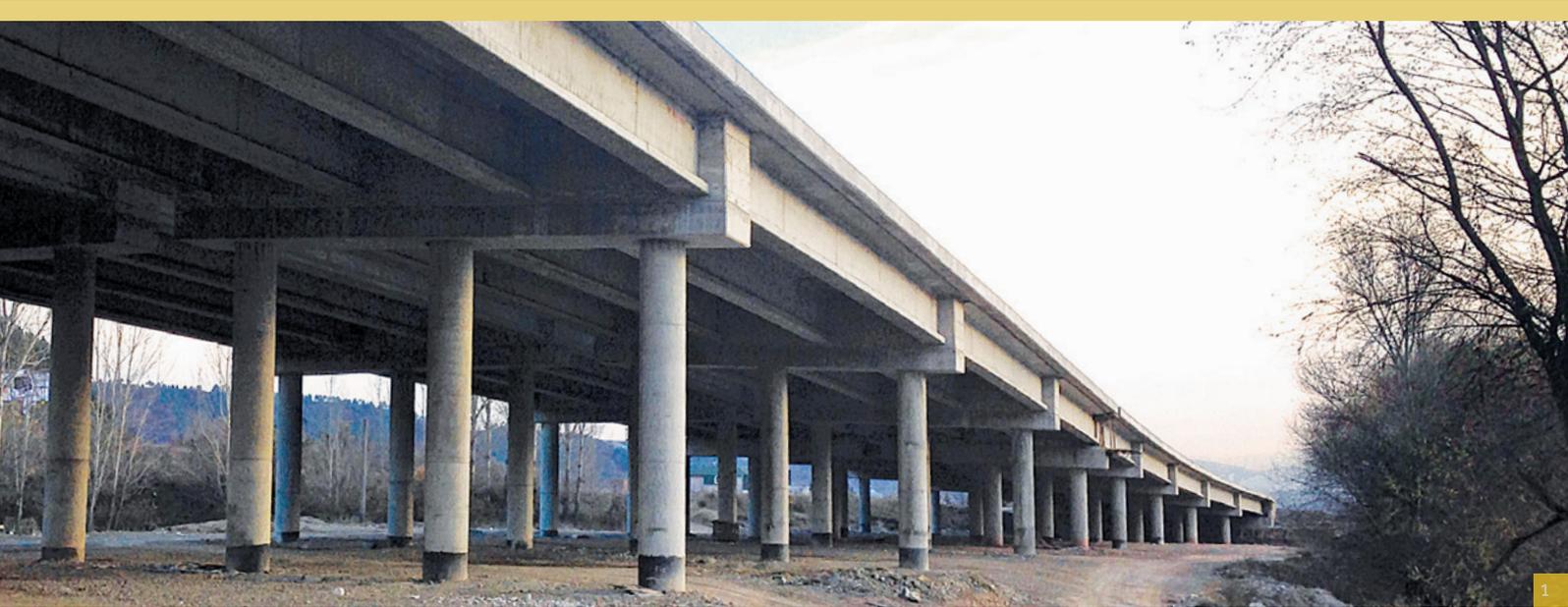
Range
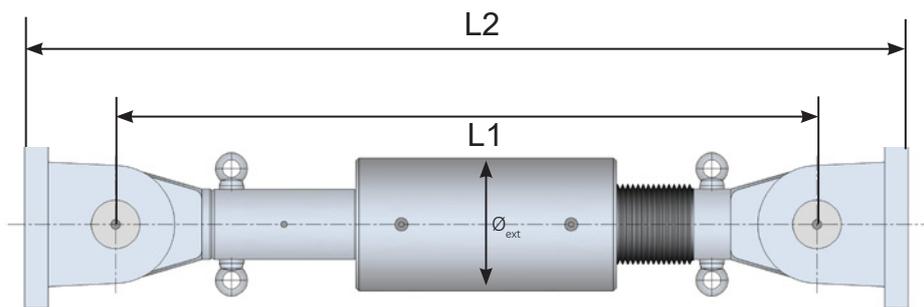
Ø$_{ext}$: External diameter

F$_{Max}$: Maximum force

D$_{Max}$: Maximum displacement

L2: Overall length at mid-stroke

L1: Length between axes at mid-stroke

Structural connections

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

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.
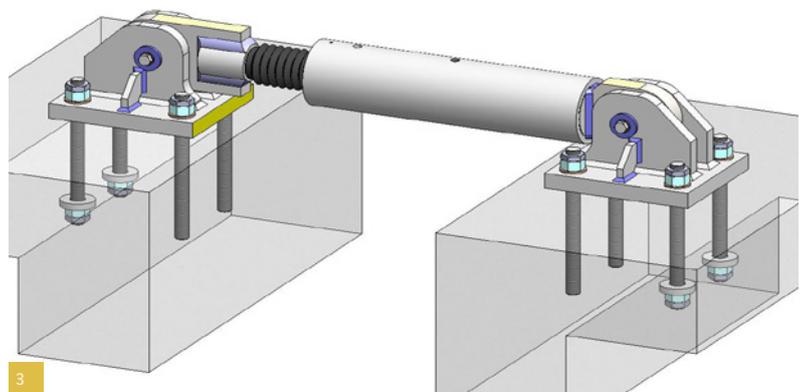
Designs: Structural design

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		
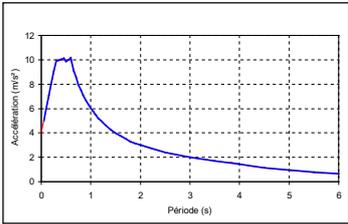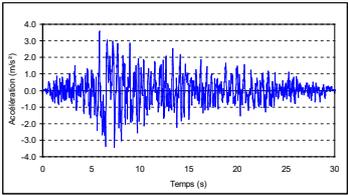
Some projects

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

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

For this hospital, Freyssinet took part in the seismic study, and also designed, manufactured and installed:
- 283 ISOSISM® HDRB isolators
- 36 ISOSISM® FD dissipators.
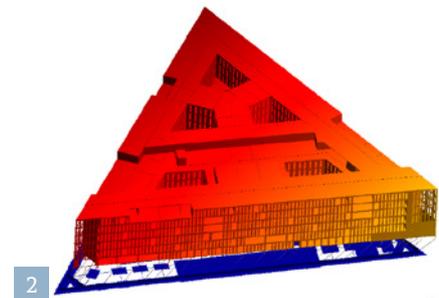
El Hachef and Loukkos high-speed train viaducts - Morocco

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.
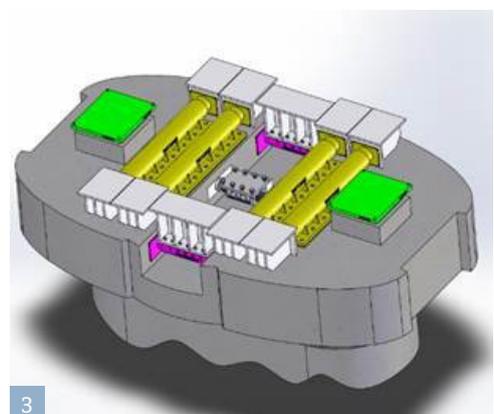
FREYSSINET'S EXPERTISE

1

2

3

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.

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.

1   Design office - ISOSISM® industrialisation
2   70 MN testing equipment
3   Certifications

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.

ISOSLAB Testing Laboratory

ISOLAB testing facility based in Italy has been developed during over 20 years of experience in seismic engineering, manufacturing and testing of bearing and seismic protection devices.

Freyssinet can now count on an innovative laboratory, where devices are tested for Type Tests and **Factory Production Control Tests**, in accordance to the main relevant European and worldwide Standards as well as for special **R&D projects**.

ISOLAB and FPC Italia Technical Department are working together under the supervision of Freyssinet Technical Department to design, test and develop ISOSISM® products.

ISOLAB is accredited with the **UNI EN ISO 9001:2008 and certification ISO 7500 and ASTM E4**.

Thanks to several dedicated testing equipment, partially fabricated on exclusive design, ISOLAB is able to perform testing of devices in dynamic or static conditions.

Here below are described the main available equipment.

Static tests
Equipment for tests with vertical axial load up to 70.000 kN and horizontal load up to 20.000 kN.

Dynamic tests
Actuator with different load capacity and stroke, variable from axial load up to 18.000 kN and horizontal load up to 3.000 kN, used with different frame configurations.

These equipment are usually used to carry out dynamic tests for seismic devices also with large size. The devices to be tested can be subjected to forces and displacements applied with different shape waves.

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

SOME REFERENCES

Logistic Hub at Trieste port – Italy

Kayseri Bridge – Turkey

Alibeikoy and Kagithane Bridges – Turkey

Curicò Hospital – Chile

London Bridge Station – London – UK

LRT Project Jakarta – Indonesia

SOME REFERENCES

Mardakan Bridge - Azerbaijan

BTZ Bridge - Algeria

ITER reactor - France

Marmara Hospital - Turkey

Coyuca Bridge - Mexico

Bucharest City Hall - Romania

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Argentina
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