



Seismic
Devices
Connection
Isolation
Dissipation



Seismic Devices

s u m m a r y

Introduction

PAGE 3

The Freyssinet solutions

Isolation

- Structural elastomeric bearings
- Sliding devices

PAGE 4

Connection

- Connectors
 - mechanical connectors TRANSPEC® S
 - hydraulic connectors TRANSPEC® SHT

PAGE 6

Positive protection

Dissipation of energy

- Dampers
 - hydraulic dampers TRANSPEC® SHA
 - elastoplastic dampers

PAGE 12

Choice of protection

PAGE 15



The protection of structures subject to the risk of earthquakes only really began in the middle of the 20th century.

In the majority of cases, structures used passive protection such as shear walls in buildings or even protection based on the plastification of elements chosen in advance for bridges. Even though this type of protection allows the structures to resist design earthquakes and ensure the protection of human lives, after a high-intensity earthquake it often meant major repairs to the damaged protective elements.

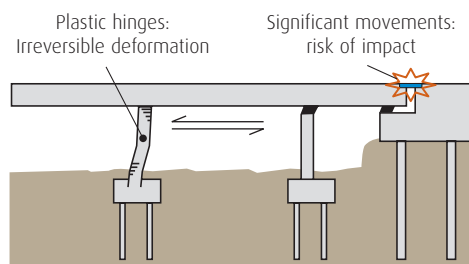
Modern society no longer accepts that the consequences of earthquakes are inevitable and the current trend is to equip structures in seismic zones with special devices that absorb or limit the effects of earthquakes on structures. This is positive protection.

Using its involvement and experience in the field of construction and works equipment, Freyssinet has contributed to the development of these seismic devices and today offers a complete range of special products called TRANSPEC®.

These devices can be used alone or in combination to achieve the most efficient and suitable protection for the project. This protection is based on the three fundamental operational modes, namely: **isolation**, **connection**, **dissipation**.

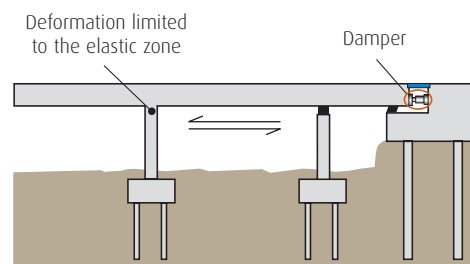
Passive protection

Deck subjected to the earthquake
(not equipped with seismic devices)



Positive protection

Deck subjected to the earthquake
(equipped with seismic devices)



The Freyssinet solutions

Isolation

The principle involves isolating the structure from the movement of the ground by using flexible connectors, mainly structural elastomeric bearings or sliding devices, to increase the natural period of the structure to protect it from, and reduce the response to, the seismic acceleration. This results in a reduction of the acceleration of the structures thus equipped by a factor of 2 or 3.

The efficiency of the isolators is directly linked to the transverse rigidity of the structural bearings and leads to significant movements of the structure during the earthquake.

The effect of the isolation of the structure can therefore be seen in the low natural frequency, slow acceleration and significant relative movements.

Connection

It may be advantageous to limit the seismic movement of the structures to simplify the equipment linking them to neighbouring structures (expansion joints, etc.).

In these cases the designer will use either mechanical structural bearings to transmit directly and in totality the service and seismic loads from the foundations to the structures (passive protection), or seismic connectors. Seismic connectors have the characteristic of only providing very low resistance to slow movements such as those due to temperature and stress-strain variations. In contrast, they provide a rigid link between the superstructure and its supports during rapid movements such as those caused by seismic events.

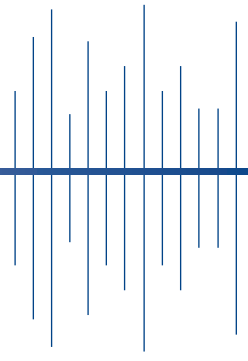
Another advantage of connectors is the distribution of the major seismic horizontal forces between all the supports (piers) where installed.

Dissipation of energy

The energy developed by earthquakes may be dissipated using dampers to reduce their effects on the protected structures. In the same way as the connectors, the dampers only provide very low resistance to slow movements but are completely efficient during rapid movements (earthquakes, collision fenders, etc.).

These dampers are generally used together with an isolation, produced for example by structural elastomeric bearings, to reduce the movement of structures while limiting the forces to which they are subjected.

Dampers very significantly reduce the overall repair cost of the structures and keep them functional after an earthquake, this is particularly critical in, for example, hospitals where an immediate return to full functionality is essential. They also efficiently protect existing structures which were not originally designed to withstand seismic activity.



Seismic devices: The Freyssinet solutions

The choice of protective devices depends on various parameters: the seismic level of the site, the type and characteristics of the protected structure and the maximum response allowed.

The objective in terms of protection is achieved by fitting the structure with one or more types of device depending on the options taken:

Seismic
devices

Positive protection

Isolation

- Structural elastomeric bearings
- Sliding devices

Connection

- TRANSPEC® S mechanical connectors
- TRANSPEC® SHT hydraulic connectors

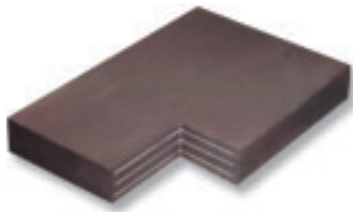
Dissipation of energy

- TRANSPEC® SHA hydraulic dampers
- TRANSPEC® SHA elastoplastic dampers

Passive protection

- Plastic hinges in the structure

Positive protection: Isolation /

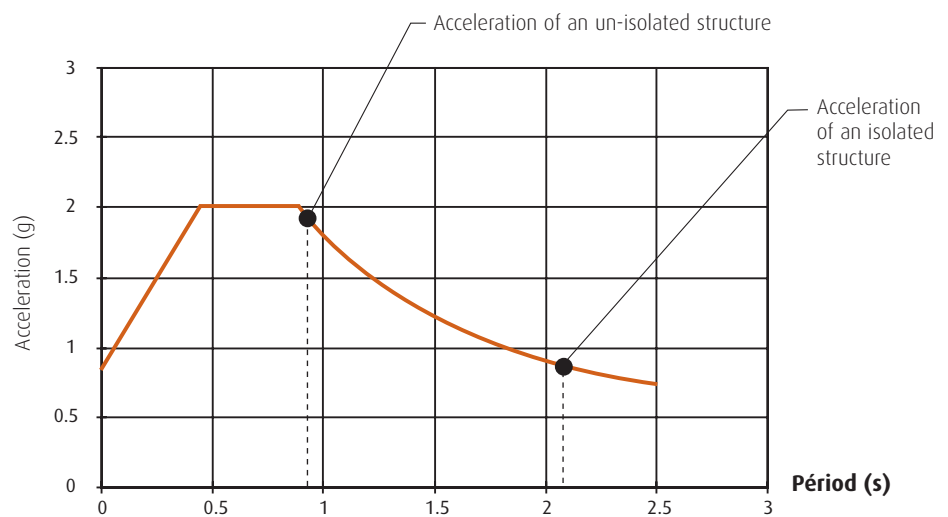


Elastomeric bearing

Structural elastomeric bearings

Isolation achieved with structural elastomeric bearings consists of increasing the natural period of the structure by extending the dominant values liable to be produced under the seismic activity. The isolation is characterised by a reduction in seismic forces.

The seismic isolators are particularly suited to massive, circular structures such as liquefied gas reservoirs and nuclear power stations and act as lateral springs which re-centre the structure after an earthquake. They also have an internal damping capability which gives them an energy absorption capacity which can be augmented by TRANSPEC® SHA dampers.



Spectral response of an isolated structure

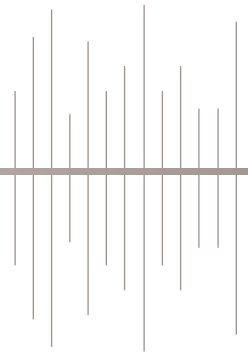
Sliding devices

These devices make almost perfect isolators. They are usually used in combination with lateral springs (e.g. structural elastomeric bearings) whose function is to limit overall movement during the earthquake and to return the structure to its original position.

Controlled friction devices, i.e. between a μ_{\min} value and a μ_{\max} value, limit structure accelerations to the $\mu_{\max}.g$ value while the ground acceleration less than $\mu_{\min}.g$ will be filtered by the elastic function of the structural elastomeric bearings.

Furthermore, it is important to construct sliding devices that guarantee sufficient friction to dissipate enough seismic energy and to reduce movements of the structure subject to the earthquake whilst maintaining

Connection



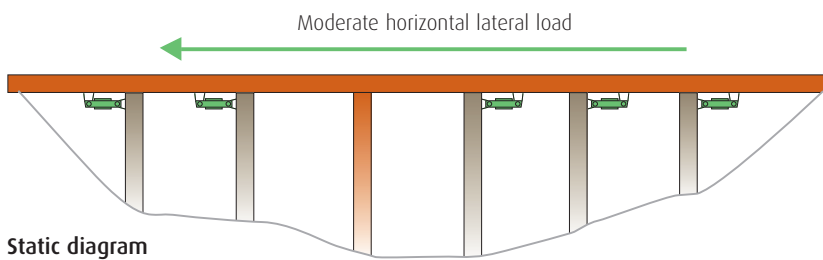
an acceptable acceleration level. This was the option taken by Freyssinet when providing 20% nominal friction elasto-sliding devices for the protection of nuclear power stations which guarantee nominal maximum acceleration of 0.2g.

Connectors

These devices react according to the speed of movement involved and act as “safety belts”: During slow movements, due to temperature variations, the connectors only provide very low resistance. However, in the event of rapid movements caused by an earthquake, the connectors are blocked and create a rigid connection between the structure and its supports. They thus transfer all the horizontal seismic forces.

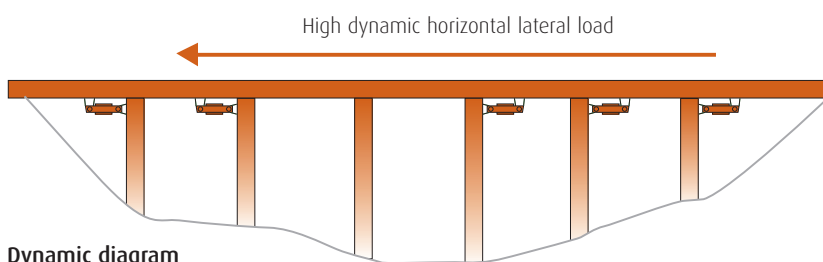
Freyssinet offers two connector models:

- TRANSPEC® S mechanical connector
- TRANSPEC® SHT hydraulic connector



Static diagram

Elements not under stress in grey



Dynamic diagram

Elements under stress in orange

Advantages:

- Transfer of high-intensity loads
- Movements limited to the deformation of substructure in the event of an earthquake.
- Distribution of the horizontal seismic forces to all piles provided.
- Simplification of equipment (structural bearings and expansion joints).

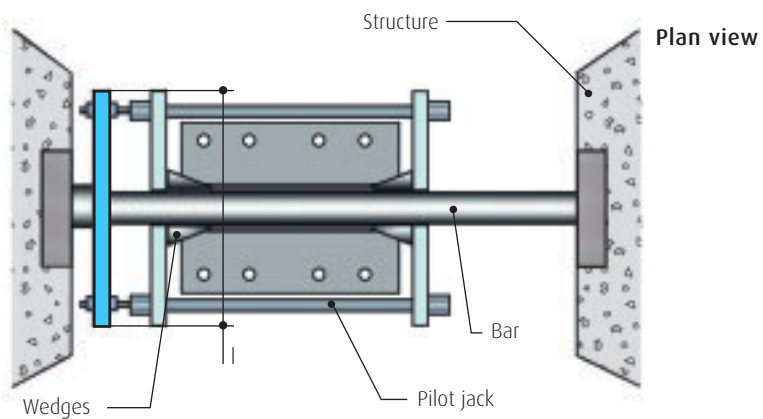
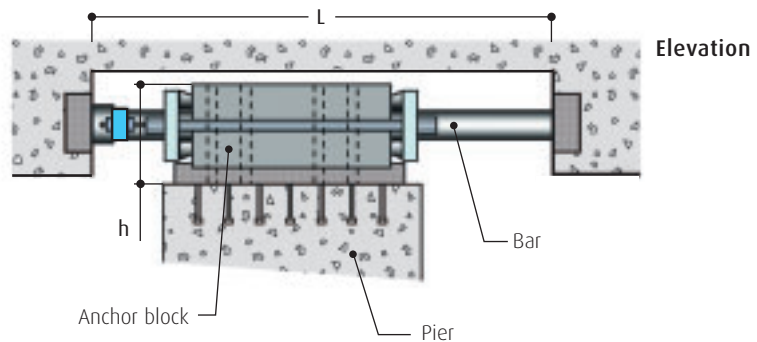
Positive protection : Connection



TRANSPEC® S

TRANSPEC® S Mechanical Connector

The TRANSPEC® S mechanical connector (patented system) comprises an anchor block through which runs a steel bar. The ends of this bar are supported by the structure to be connected while the anchor block is connected to its supports. Specially designed partner pilot jacks follow the movement of the bar in slow structural movements. When a rapid stress acts on the TRANSPEC® S, these devices act as a gate and block the bar, and thus the structure, with the wedges. If the movement is reversed, the TRANSPEC® S reacts in the opposite direction.



The advantages of TRANSPEC® S are:

- Compactness and robustness.
- Less maintenance.
- Ease of installation.

| Model | Nominal Force (kN) | Length L (mm) | Width l (mm) | Height h (mm) |
|--------------------|--------------------|---------------|--------------|---------------|
| ST 500-100 | 500 | 610 | 330 | 205 |
| ST 1000-100 | 1000 | 690 | 420 | 255 |
| ST 1500-100 | 1500 | 775 | 510 | 305 |
| ST 2000-100 | 2000 | 835 | 570 | 340 |
| ST 2500-100 | 2500 | 905 | 630 | 375 |
| ST 3000-100 | 3000 | 950 | 670 | 395 |

Dimensions of the TRANSPEC® S with a stroke of 100 mm

Principles

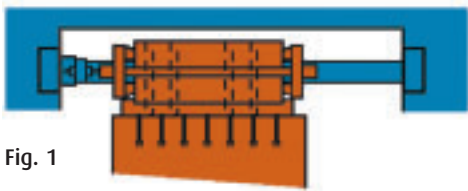


Fig. 1

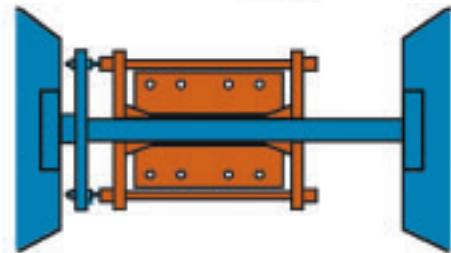


Fig. 2

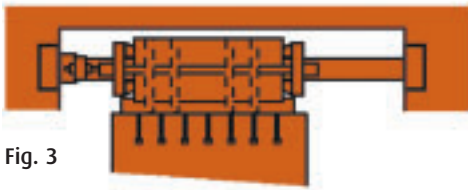


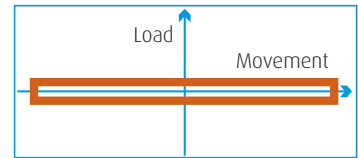
Fig. 3

Slow movements (Fig. 1 et 2)

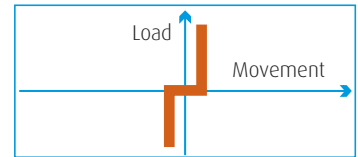
Free elements displaced in blue
Fixed elements in red

Rapid movements (Fig.3)

Tests under imposed dynamic stresses



Behaviour in normal operation



Behaviour during a seismic event

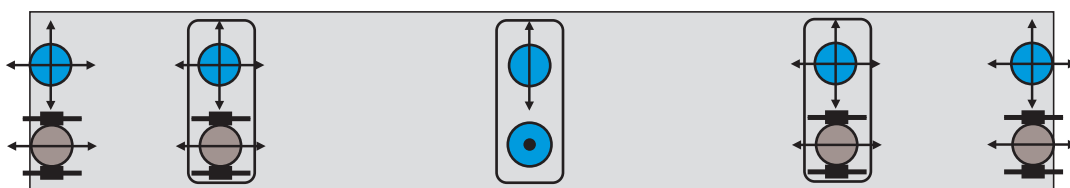
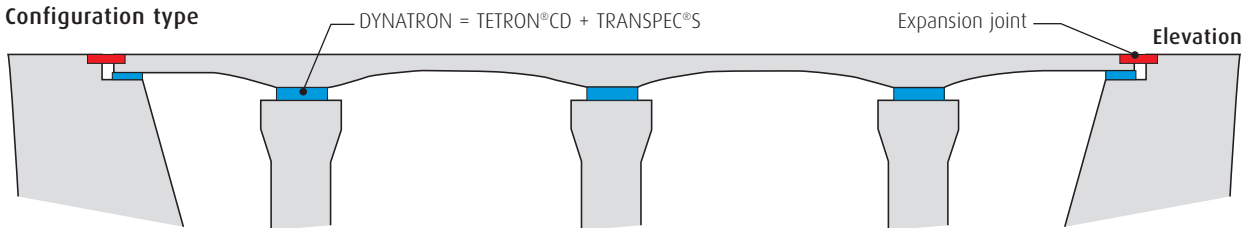
Tests have shown the remarkable efficiency of TRANSPEC® S and verified its behavioural principle.

Bearing in mind their small size, TRANSPEC® S can be connected to a guided sliding cylinder support device to form a compact set called DYNATRON.



DYNATRON

Configuration type



Plan view

Guided sliding
TETRON®CD

TETRON®CD
Free sliding

DYNATRON

Fixed TETRON®CD

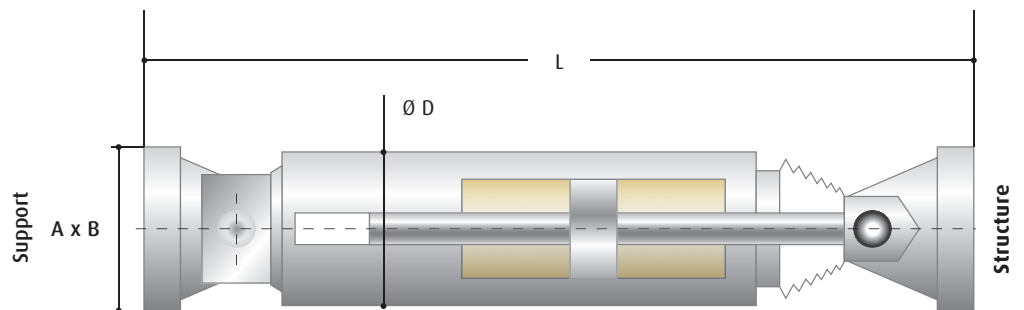
Positive Protection: Connection

TRANSPEC® SHT hydraulic connector

The TRANSPEC® SHT hydraulic connector comprises a cylinder filled with a special fluid in which a rod with a piston moves. A valve with a calibrated opening allows for communication between the two internal chambers separated by the piston. When the rod moves, the fluid moves freely from one chamber to the other. In the event of a rapid movement, the valve opening is blocked, thus preventing any flow of fluid and therefore any relative movement of the structures to which the connector is fixed.



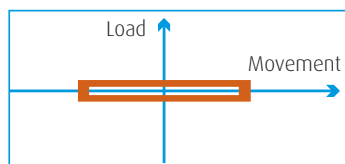
TRANSPEC® SHT IP6
Motorway (Algarve, Portugal)



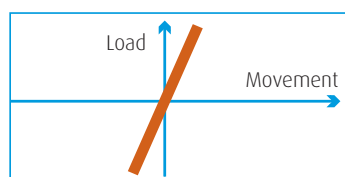
| Model | Nominal Force (kN) | Average length L (mm) | Body diameter ØD (mm) | Height Plate A (mm) | Width Plate B (mm) |
|---------------------|--------------------|-----------------------|-----------------------|---------------------|--------------------|
| SHT 200-100 | 200 | 820 | 106 | 150 | 100 |
| SHT 300-100 | 300 | 895 | 125 | 170 | 120 |
| SHT 500-100 | 500 | 985 | 140 | 200 | 170 |
| SHT 1000-100 | 1000 | 1235 | 210 | 260 | 200 |
| SHT 1500-100 | 1500 | 1415 | 245 | 330 | 240 |
| SHT 2000-100 | 2000 | 1565 | 290 | 390 | 300 |
| SHT 3000-100 | 3000 | 1875 | 355 | 420 | 380 |
| SHT 4000-100 | 4000 | 2110 | 405 | 490 | 490 |

Dimensions of the standard TRANSPEC® SHT with a stroke of 100 mm

Tests under alternated dynamic stresses



Behaviour in normal operation



Behaviour during a seismic event

Thanks to their tried and tested technology, the TRANSPEC® SHT connectors react immediately to rapid movements. Tests have shown their efficiency. The movements recorded correspond to the elastic deformation of the connector and remain limited to a few millimetres.

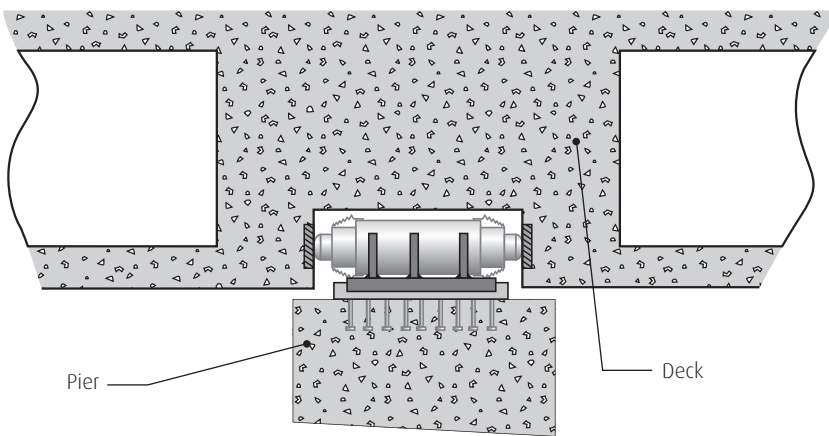
However, for some projects, it would be better to have a greater elastic reserve, TRANSPEC® SHT connectors are adapted for this.

TRANSPEC® SHT connectors are installed at the end of the deck, as the horizontal forces are absorbed only by the abutment walls, or even at the pierheads, so as to distribute the loads to several bearing points. As well as the TRANSPEC® SHT Standard, FREYSSINET has developed TRANSPEC® SHT Compact to be installed directly at the top of a pier. The operational layout is the same as for the standard model.



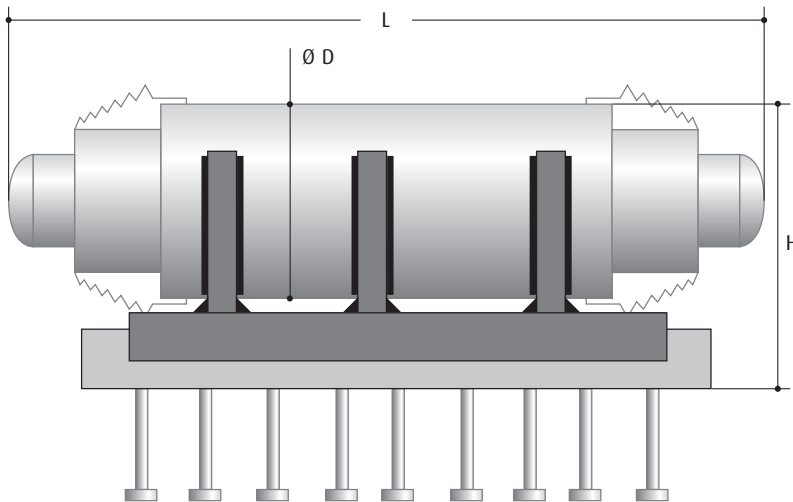
Placing on the pier head in the context of retrofitting (Hambrook bridge, UK)

Installation of the TRANSPEC® SHT compact



TRANSPEC® SHT compact

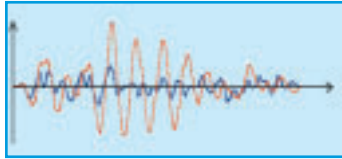
TRANSPEC® SHT compact



| Model | Nominal force (kN) | Length L (mm) | Total height H (mm) | Body Ø D (mm) |
|-----------------------------|--------------------|---------------|---------------------|---------------|
| SHT compact 200-100 | 200 | 575 | 200 | 85 |
| SHT compact 300-100 | 300 | 595 | 215 | 105 |
| SHT compact 500-100 | 500 | 620 | 240 | 130 |
| SHT compact 1000-100 | 1000 | 670 | 305 | 190 |
| SHT compact 1500-100 | 1500 | 720 | 340 | 230 |
| SHT compact 2000-100 | 2000 | 750 | 375 | 260 |

Dimensions of the TRANSPEC® SHT Compact with a stroke of 100 mm.

Positive protection : Dissipation



Un-dampened structure ———
Dampened structure ———

Dampers

Dampers are energy absorption devices which are able to limit both the movements and the loads to which the structures are subjected during an earthquake.

The dissipation of energy can be achieved using different means:

- Elastoplastic action
- Mechanical friction
- Viscous friction.

Viscous dampers are the most efficient.



TRANSPEC® SHA
Orival footbridge, Belgium

TRANSPEC® SHA hydraulic damper

Freyssinet has developed the TRANSPEC® SHA family of hydraulic dampers, which are used to protect any civil engineering or industrial construction exposed to seismic risk.

The TRANSPEC® SHA damper can be combined with isolators. It has a low resistance to slow relative movement of structures in normal service and actively reacts when they are subjected to rapid dynamic movements above a pre-set level.

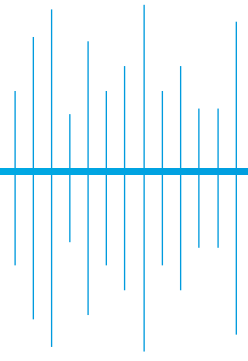
The TRANSPEC® SHA is a hydraulic damper which uses a viscous oil whose characteristics are constant under temperature variations and with time.

The TRANSPEC® SHA damper is almost identical to the TRANSPEC® SHT connectors in the standard and compact version, the difference being that it has a patented oil flow servo-system mechanism which allows it to optimise the amount of energy absorbed depending on the movement. Its overall dimensions are the same as those of the connectors.

| Model | Nominal force (kN) | Average length L (mm) | Body diameter Ø D (mm) | Height Plate A (mm) | Width Plate B (mm) |
|---------------------|--------------------|-----------------------|------------------------|---------------------|--------------------|
| SHA 200-100 | 200 | 820 | 106 | 150 | 100 |
| SHA 300-100 | 300 | 895 | 125 | 170 | 120 |
| SHA 500-100 | 500 | 985 | 140 | 200 | 170 |
| SHA 1000-100 | 1000 | 1235 | 210 | 260 | 200 |
| SHA 1500-100 | 1500 | 1415 | 245 | 330 | 240 |
| SHA 2000-100 | 2000 | 1565 | 290 | 390 | 300 |
| SHA 3000-100 | 3000 | 1875 | 355 | 420 | 380 |
| SHA 4000-100 | 4000 | 2110 | 405 | 490 | 490 |

Dimensions of the TRANSPEC® SHA standard with a stroke of 100 mm

of energy

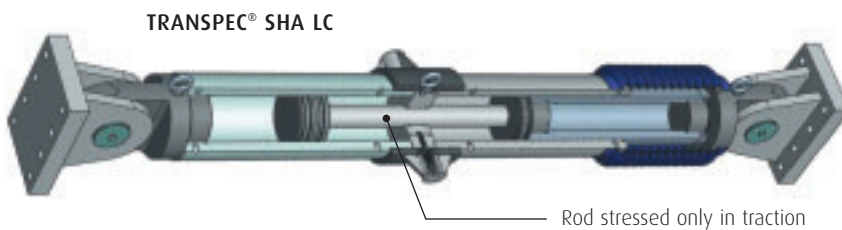


The TRANSPEC® SHA damper is peculiar in that it has a nil internal pressure in service. This property offers the following advantages:

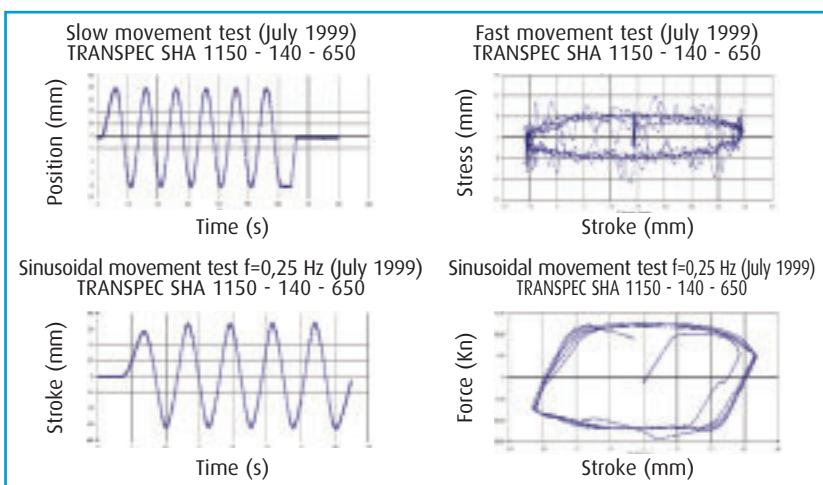
- Guarantees the efficiency of the damper during an earthquake as its efficiency is not related to the existence of an initial internal pressure which is uncertain to be maintained over time,
- Exceptional service-life of the gaskets and non-stressed mechanical parts.

The TRANSPEC® SHA also has an internal compensation chamber which allows to take into account the variations in oil volume when the temperature changes.

Freyssinet has extended its range of dampers to the TRANSPEC® SHA LC, which is intended for major movements (dampers placed on abutment). Using a special layout of the internal chambers, these dampers only function with the rod in tension, thus eliminating the risk of buckling whatever the direction of the force/movement.



Damper tests TRANSPEC® SHA



Damper test
TRANSPEC® SHA

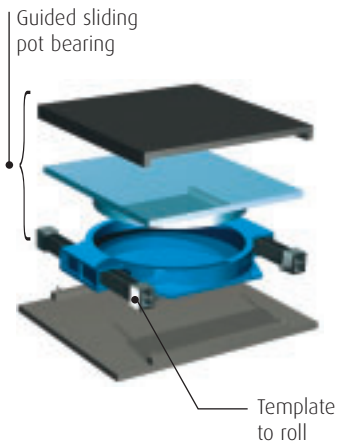
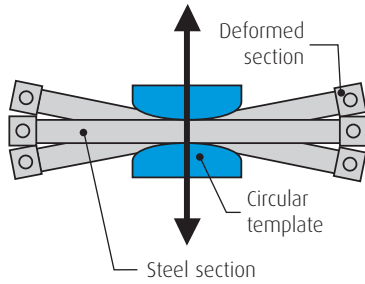
TRANSPEC® SHA dampers have been the subject of many fatigue tests which have backed up the technical and technological options adopted by Freyssinet.

As with the connectors, the dampers can be installed either at the end of the deck or at the top of the column.

Positive protection: Dissipation of Energy

Elastoplastic damper

Principle of coiling



In some cases, TRANSPEC®SHA hydraulic dampers are unnecessary and the use of elastoplastic dampers, which take advantage of the hysteretic character of the plastic deformation of steel to dissipate the energy, can be considered.

In contrast to traditional elastoplastic dampers, whose performance is limited particularly in movement terms, the coiled dampers offered by Freyssinet (patented system) use a steel section supported by two circular templates. This allows to control the flexural stresses thus preventing any localised rupture and increases the volume of plasticised steel.

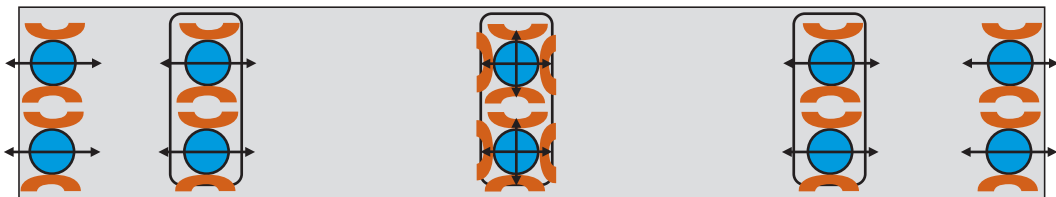
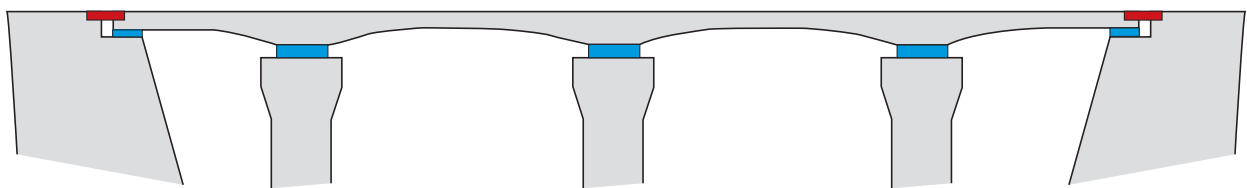
This device also functions as a spring for deformations within the elastic limit of the material.

As the elastoplastic dampers are small they can be connected to TETRON® CD cylinder structural bearings to form the compact DYNAROLL® assembly. This extremely simple assembly reduces the lateral forces from earthquakes or fenders on the columns and foundations.

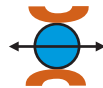
Furthermore, these robust devices need no special maintenance. The plasticised parts should however be changed after a high-intensity earthquake.

Configuration type

Elevation



Fixed elastic
TETRON®CD



Guided sliding elastic
TETRON®CD

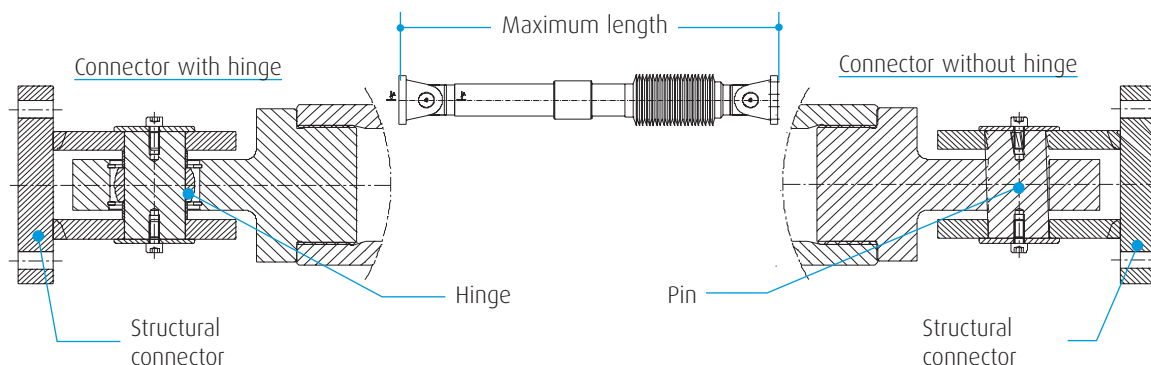
Plan view

Choice of Protection

Bearing in mind the diversity of projects, Freyssinet suggests that the specification sheet below is completed. On the basis of the information supplied the Freyssinet engineers will assess the problem and design the most suitable equipment.

In addition, using the information supplied on the structure to be protected (mass, rigidity and principal dimensions, type: bridge or building) and the seismic conditions of the site, Freyssinet will be able to advise the designers on the most suitable seismic protection system to be adopted from the many solutions offered by Freyssinet.

| Data for Transpec devices / Données pour les appareils Transpec | | | | |
|--|--|---|---------------|---------------|
| Date | | Revision / Révision : | | |
| Job name / Nom de l'affaire : | | | | |
| Reference number / Numéro de l'affaire : | | | | |
| Number of Transpec / Numéro de Transpec | | 1 | 2 | 3 |
| Transpec identification / Type de Transpec [Shock Transmitter Unit / bloqueur or damper / amortisseur] | | STU / Damper | STU / Damper | STU / Damper |
| Quantity / Quantité | | | | |
| Force / Effort (kN) | | Nominal / Nominal | | |
| Bursting security factor / Coefficient de sécurité à l'éclatement | | | | |
| Total stroke / Course totale (mm) | | Nominal under low action (creep, temperature...) / Nominal sous action lente (fluage, température...) | +/- | +/- |
| | | Nominal under dynamic action (braking, earthquake...) / Nominal sous action rapide (freinage, séisme...) | +/- | +/- |
| Connections / Connexions | Connections fitted with hinges or with single pins / Appareil équipé de rotule ou équipé d'un simple axe | Hinges / Pins | Hinges / Pins | Hinges / Pins |
| | Supply of structural connections / Fourniture des charpes de structure | Yes/No | Yes/No | Yes/No |
| | Supply of fixings (bolts) for structural connections / Fourniture des fixations (vis) pour les charpes de structure | Yes/No | Yes/No | Yes/No |
| Protection / Protection | | Paint or other (to be specify) / Peinture ou autre (à spécifier) | | |
| Damping coefficient for damper $F = C \cdot V^2$ / Loi d'amortissement pour l'amortisseur | | C (kN) / (m ² /s) | | |
| Environment / environnement | | New structure or retrofit structure / Ouvrage neuf ou réparation | | |
| | | Type of structure (bridge, building...) / Type d'ouvrage (pont, bâtiment...) | | |
| | | Connection on pier or on abutment / Connexion sur pile ou culée | | |
| | | Maximum length / Longueur maximum (mm) | | |
| | | Pinset / Poinçonnage (mm) | | |
| Tests / Tests | | Static tests (specifications to be attached) / Essais statiques (joindre les spécifications) | | |
| | | Yes/No | Yes/No | Yes/No |
| | | Dynamic tests (specifications to be attached) / Essais dynamiques (joindre les spécifications) | | |
| | | Yes/No | Yes/No | Yes/No |
| Observations | | | | |
| Commercial contact / Contact commercial | | | | |
| Technical contact / Contact technique | | | | |





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