TENSA
GRUPPO DE ECCHER

VOLUME	PRODUCTS CATALOGUE
06	**DAMPERS & STUS**

YOUR CHALLENGES,
OUR SOLUTIONS

VAS, Verona Shopping Centre, Verona (Italy)

01

COMPANY PROFILE

Our mission is to constantly improve the methods
and the quality of construction processes
through research, innovation and cooperation
with designers, engineers and contractors worldwide.

TENSA

Tensacciai, now renamed TENSA, was founded in 1951 with headquarters in Milan, Italy. It is now active in over 50 countries with a direct presence in 14 countries. TENSA is a leader in stay cables, post-tensioning, anti-seismic devices, structural bearings and expansion joints. TENSA has extensive references and numerous certifications for its products worldwide.

HISTORY

1951: Beginning of activity

1964: In the sixties Tensacciai undergoes a phase of remarkable growth in Italy. Post-tensioning is just at the beginning of its history and its application is still experimental.

1970: A programme of technological renewal begins with the adoption of the steel strand.

1980: Tensacciai develops new tensioning systems and equipment in the field of ground anchors, combining innovation with versatility and ease of use.

1990: New subsidiaries established in Brazil, India and Australia and in Europe, sister companies are established in Portugal, Greece and the Netherlands.

2000: The internationalization process of Tensacciai continues unabated.

2010: The company becomes directly involved in projects in all five continents.

2011: Tensacciai is acquired by Deal - world leading solutions provider in the field of bridge construction - and becomes part of De Eccher Group. Tensacciai is now member of an organisation capable of designing, manufacturing and installing systems worldwide, thanks to specialised technicians, engineers in the technical department and quality control. All production and delivery processes are attested by the ISO9001 certification.

2012: Tensacciai merges with Tesit, another successful concrete specialist contractor with international experience in post-tensioning, steel bars, structural bearings and expansion joints becoming a prominent player in the field of specialised subcontracting.
Tensacciai enters into a Worldwide Exclusive License Agreement with Rome-based TIS (Tecniche Idraulico-Stradali S.r.l.) - a leading company with experience in designing and producing structural bearings, expansion joints and anti-seismic devices since 1973.

2014: TIS is acquired by Tensacciai.

2015: TENSA is formed from the merging and development of the three important companies mentioned above: Tensacciai, Tesit, TIS.

MISSION

Our mission is to constantly improve the methods and the quality of construction processes through research, innovation and cooperation with designers, engineers and contractors worldwide. A strong commitment to quality is the only way to ensure safe and long-lasting structures. We support the design from the initial stage, challenging standards to develop custom solutions. We value timely execution and service as keys to building long-term relationships.

Our core knowledge lies within stay-cables and post-tensioning systems, anti-seismic devices, structural bearings and expansion joints as well as all the related accessories, equipment and services.
TENSA strives to push its vast experience towards new methods and variations of applications, developing ingenious solutions for building new structures, whether they are buildings or infrastructures, as well as the rehabilitation of existing ones.

PRODUCT CATALOGUES

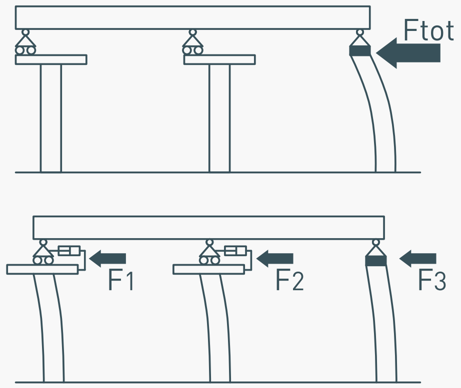
01 - STAY CABLES
02 - POST TENSIONING
03 - GROUND ANCHORS
04 - EXPANSION JOINTS
05 - BEARINGS
06 - DAMPERS & STUs
07 - SEISMIC ISOLATORS
08 - ELASTO PLASTIC DEVICES
09 - VIBRATION CONTROL

Wadi Hanifa Viaduct, Riyadh (Saudi Arabia)

02

SEISMIC PROTECTION

Seismic protection using hydraulic devices
is used to reduce the impact of seismic hazards and
protect both constructions and human lives.



SEISMIC PROTECTION

The protection of the structures that undergo seismic events represents one of the most fascinating challenges of structural engineering. The safeguarding of human lives and the functions for which the structure is conceived are certainly fundamental reasons behind the search for new solutions and the improvement of existing ones. The behavior of the structures undergoing dynamic forces, such as seismic, wind-related or from braking for example on railway bridges, depends on different factors, including:

- Overall rigidity of the system;
- Energy dissipation capabilities of the structural elements;
- Inertia of the structure.

Described below are two types of hydraulic device capable of modifying the structural response by intervening directly on the rigidity matrix and/or the energy dissipation capabilities. Both devices show a response that is dependent on an impulsive external dynamic action.

- **TSTD – Tens Shock Transmitter Device (temporary rigid connections):** is capable of varying the overall rigidity of the structure subjected to an impulsive force. When subjected to slow actions (such as shrinkage, creep, thermal variations), the device allows displacements exhibiting a negligible restoring force, while it behaves like a rigid link under an impulsive force, (such as seismic input, impacts and braking of moving loads).

- **TFVD – Tens Fluid Viscous Damper:** is characterised by a velocity dependent behavior and it exhibits limited restoring forces due to quasi static displacements. It guarantees, however, an elevated dissipation of energy in case of dynamic activity through the operation of a hydraulic circuit that forces the passage of a viscous fluid through calibrated valves and/or orifices.

Wadi Hanifa Viaduct, Riyadh (Saudi Arabia)

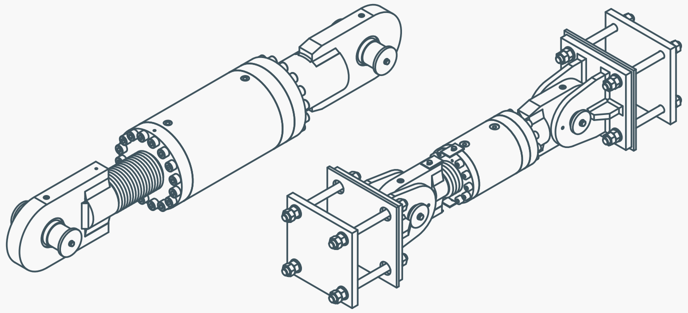
Wadi Hanifa Viaduct, Riyadh (Saudi Arabia)

Tevere Viaduct, Castelnuovo di Porto, Rome (Italy)

03

TENS SHOCK TRANSMITTER DEVICE (TSTD)

TENSA's temporary rigid connection devices are the most suitable solution when a modification on the structure's response is required.
In fact, they can modify the structure's behavior from the static to the dynamic and distribute the seismic input force in different structural positions.



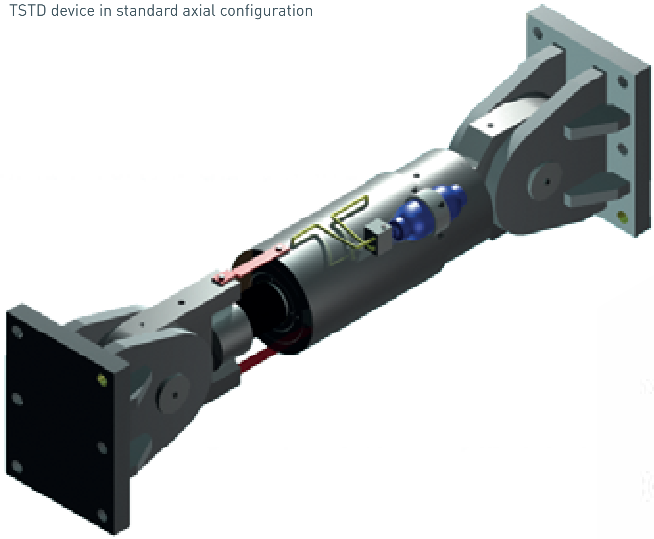
DESCRIPTION

The TENS SHOCK TRANSMITTER DEVICES (TSTD) are hydraulic temporary connection devices, designed to change the structure behavior from the static to the dynamic condition. They allow slow relative movements between the connected elements (typically but not limited at deck to pier & slab to column) without generating an appreciable restoring force. However, they supply a stiff reaction when confronted with a dynamic external input as for instance the one generated by a seismic event or by the braking of a moving load. The device response is symmetrical as it supplies the same behavior both in compression and tension.

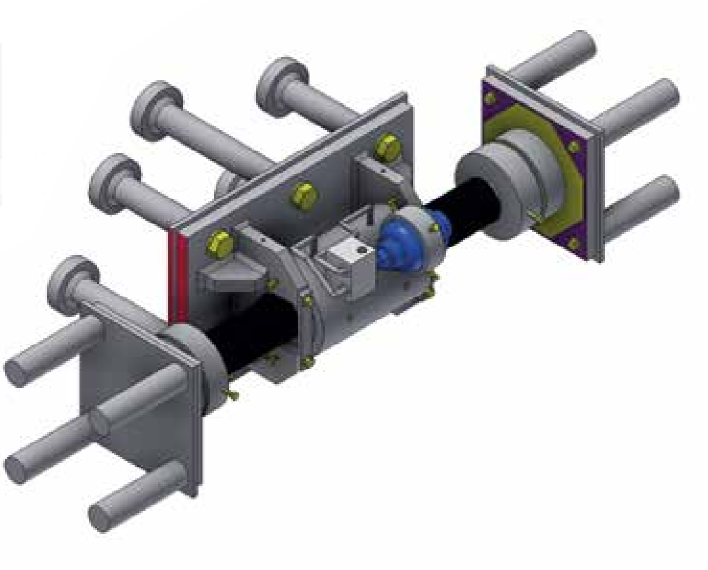
These devices consist of a cylinder, in which a piston moves, through which a suitable hydraulic circuit enables the passage of a viscous fluid from one chamber to the second one. Unlike TFVD devices, described in the next paragraph, which are able to generate a dissipation, the TSTDs are not equipped with valves and the fluid is forced to pass through specially calibrated orifices.

The system is designed in such a way that, due to slow motions, (such as those induced by thermal variation, creep and shrinkage) negligible forces are generated (the Eurocode imposes for the temporary connection devices the supply of a maximum restoring force lower than 10% of its maximum design force) and therefore the relative movement at the joint is allowed. However for dynamic actions, such as braking actions of moving loads or seismic events, the device prevents the relative displacement between the linked parts, guaranteeing in parallel the rigid transfer of the horizontal loads.

TSTD device in standard axial configuration



TSTD device with free transversal movements



They can be used beneficially when the structure is required to change its static scheme at the presence of an earthquake or other dynamic events. In this way, while slow deformations are freely permitted, during the seismic event the devices distribute the forces generated by the earthquake in several structure locations, properly chosen by the structural engineer in term of location and capacity.

TSTD devices are also commonly used in buildings, in order to connect separate parts of the building to each other in case of earthquakes, in order to have a single seismic response. This reduces the relative movements and consequently the costs for the transition joints.

The design displacement of the TSTD devices must take into account:

1) the long term effects
2) displacements caused by temperature changes
3) dynamic deformations
4) any adjustment in length required by the structural engineers including the one foreseen for a user-friendly and micrometric device installation.

The minimal design stroke, in compliance with EN15129, shall be ±50 mm for bridges and ±25 mm for buildings. The activation displacement depends on the compressibility of the hydraulic fluid included within the device chambers, while the activation speed is generally between 1.00 mm/s and 20.0 mm/s.

The standard operating design temperature range falls between -25 and + 50 °C in compliance with European norm EN15129. A larger temperature range will be considered upon particular request.

The TSTD are not designed to resist vertical actions, therefore they are normally used in parallel with structural constraints capable of supporting such loads, such as reinforced rubber bearings (TENS RUBBER), pot bearings (TENS POT) and spherical bearings (TENS SPHERICAL).

The TSTD devices may require the use of hydraulic accumulators, designed to compensate fluid volume variation over time, which is caused by temperatures that may generate internal pressure increases with consequent accelerated degradation of the seals.

The main performance features are resumed as follows:
- Invulnerability to temperature fluctuations
- Performance reliability over time as a consequence of the high quality of the fluid and internal seals used
- Reliability both in service condition and while undergoing seismic action
- Automatic compensation of volumetric changes due to thermal expansion, in order to avoid uncontrolled internal pressures and vacuum effects that may compromise the device durability over time
- Invulnerability to aging of the silicone fluid used
- Stable and consistent fluid viscosity over the device temperature range as temperatures fluctuate, with compressibility such that the volumetric compensation due to temperature variations is enabled
- Displacement capacity entrusted to a calibrated orifice, which enables the seeping of fluid for slow movements, while it acts as a closed valve for impulsive actions
- Spherical hinge pin extremities, capable of enabling rotations of ±2° (a larger rotation capacity is possible upon specific client request).

TSTD device in standard axial configuration

COMPONENTS

Described below are the components of the device, with particular reference to the materials and standards.

CYLINDER

The cylinder is made from a steel tube S355J2, S355J0, S355JR (EN10025) or equivalent, internally lapped.

On its outer surface two holes are provided for loading the fluid, plus two additional holes used as air ventilation; the aforementioned holes are equipped with fast joint valves for viscous filling and pressure charge (including its monitoring during device testing).

The external part of the cylinder is adequately protected against aggressive agents, following the painting cycle described in the section *General Provisions and Practices*.

ROD

The supporting rod is made of alloy steel 39NiCr-Mo3 (EN10083) or superior. The original rod, following grinding and plating treatments, is cut to size with a band saw. At both ends, threaded connections are made.

PISTON

The piston is made of alloy steel type S355J2, S355J0, S355JR (EN10025) or superior. The connection to the supporting rod is ensured by means of a suitably threaded central hole. On the piston-cylinder contact surface, a system of seals, guide strips and sealing rings is inserted, necessary to avoid the loss of internal fluid enclosed within the chambers. On the piston body, calibrated orifices are installed, necessary for the correct functionality of the device.

PINS

The creation of the hinge connections between device and structural elements is carried out through a system of 39NiCrMo3 steel connections (EN10083).

HYDRAULIC FLUID

The hydraulic fluid used is generally silicone oil, but other types of fluid may be provided in compliance with particular situations, design needs and/or technical specifications.

TSTD - details

MATERIALS

ELEMENT	MATERIAL	RELEVANT EUROPEAN STANDARD
Cylinder	S355J2, 0, JR or equivalent	EN10025
Caps and connections to the structure	S355J2, 0, JR or equivalent	EN10025
Pins	39NiCrMo3 or equivalent	EN10083
Rod	39NiCrMo3 or equivalent	EN10083
Piston	S355J2, 0, JR or equivalent	EN10025
Hydraulic fluid	Silicone oil	

Fontanarossa Airport, Catania (Italy)

MARKING

Each device is identified by the initials TSTD (TENSA SHOCK TRANSMITTER DEVICE) followed by two values. The first represents the design maximum horizontal device capacity (kN) while the second represents the maximum displacement expressed in mm, under the ULS load combination.

Below is an example:

Maximum horizontal
capacity (kN)

TSTD **1500/±200**

TENS
SHOCK TRANMITTER
DEVICE

Maximum displacement
(mm)

CATALOGUE PERFORMANCE HYPOTHESIS

The TSTD catalogue has been prepared in accordance with EN15129.

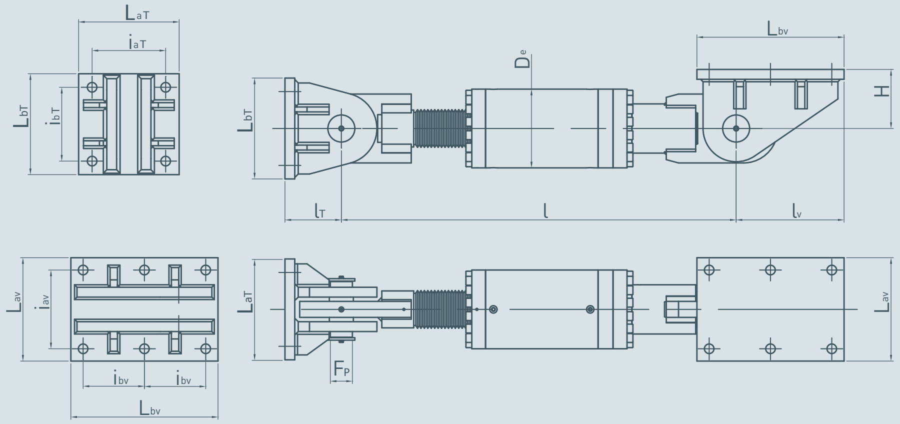
The maximum considered horizontal design load is equal to 5000 kN and for each device's nominal capacity, two displacement values are considered.

Devices with a larger horizontal capacity, displacement or by a different connection to the structure can be designed upon specific request.

TENSA's technical department is available to evaluate and design tailor-made solutions for buildings, bridges and any other type of structure that requires seismic protection.

TSTD device in standard axial configuration

CATALOGUE TECHNICAL TABLES



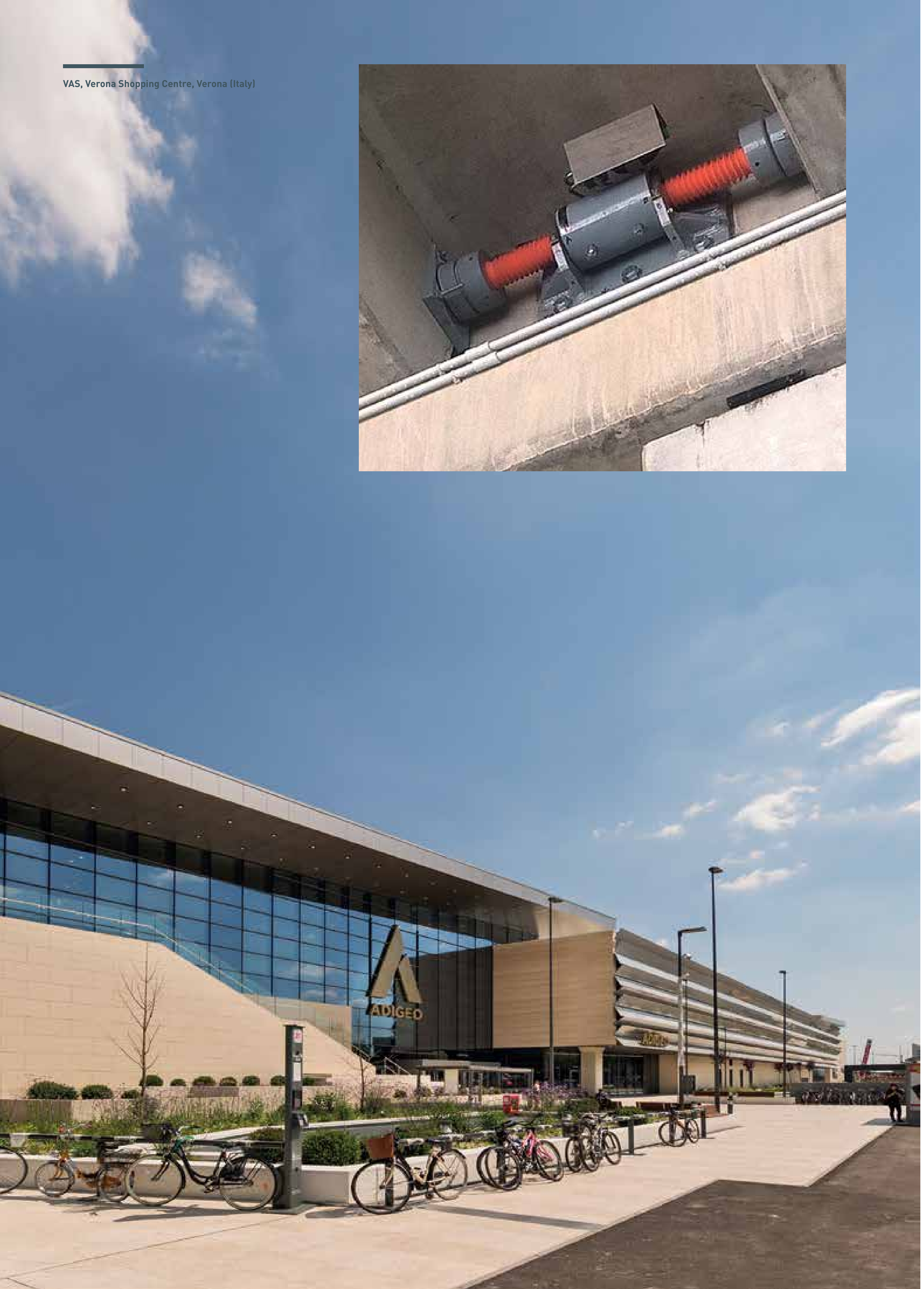
TYPICAL DIMENSIONS FOR BUILDINGS

DEVICE	F (ULS)	d (ULS)	D	L	l_T	l_V	F_P	L_{aT}	L_{bT}	i_{aT}	i_{bT}	N°	L_{aV}	L_{bv}	i_{aV}	i_{bV}	N°	H
	[kN]	[±mm]	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)		(mm)	(mm)	(mm)	(mm)		(mm)
TSTD 500/±25	500	25	185	760	195	330	60	250	300	190	240	4 M24	250	400	190	160	6 M30	200
TSTD 500/±50	500	50	185	850	195	330	60	250	300	190	240	4 M24	250	400	190	160	6 M30	200
TSTD 750/±25	750	25	215	850	220	330	70	300	350	220	275	4 M30	300	410	220	160	6 M36	200
TSTD 750/±50	750	50	215	940	220	330	70	300	350	220	275	4 M30	300	410	220	160	6 M36	200
TSTD 1000/±25	1000	25	250	960	245	330	80	325	350	230	260	4 M36	325	420	230	155	6 M42	200
TSTD 1000/±50	1000	50	250	1040	245	330	80	325	350	230	260	4 M36	325	420	230	155	6 M42	200
TSTD 1250/±25	1250	25	290	1080	265	430	90	350	400	260	310	4 M36	350	530	260	205	6 M48	250
TSTD 1250/±50	1250	50	290	1160	265	430	90	350	400	260	310	4 M36	350	530	260	205	6 M48	250
TSTD 1500/±25	1500	25	300	1180	280	425	90	400	450	290	345	4 M42	400	530	290	205	6 M48	250
TSTD 1500/±50	1500	50	300	1260	280	425	90	400	450	290	345	4 M42	400	530	290	205	6 M48	250
TSTD 2000/±25	2000	25	350	1365	325	505	110	450	500	330	380	4 M48	450	630	330	170	8 M48	275
TSTD 2000/±50	2000	50	350	1445	325	505	110	450	500	330	380	4 M48	450	630	330	170	8 M48	275

TYPICAL DIMENSIONS FOR BRIDGES

DEVICE	F (ULS)	d (ULS)	D	L	l_T	l_V	F_P	L_{aT}	L_{bT}	i_{aT}	i_{bT}	N°	L_{aV}	L_{bv}	i_{aV}	i_{bV}	N°	H
	[kN]	[±mm]	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)		(mm)	(mm)	(mm)	(mm)		(mm)
TSTD 500/±200	500	200	185	1650	195	330	60	250	300	190	240	4 M24	250	400	190	160	6 M30	200
TSTD 500/±300	500	300	185	2175	195	330	60	250	300	190	240	4 M24	250	400	190	160	6 M30	200
TSTD 750/±200	750	200	215	1735	220	330	70	300	350	220	275	4 M30	300	410	220	160	6 M36	200
TSTD 750/±300	750	300	220	2275	220	330	70	300	350	220	275	4 M30	300	410	220	160	6 M36	200
TSTD 1000/±200	1000	200	250	1820	245	330	80	325	350	230	260	4 M36	325	420	230	155	6 M42	200
TSTD 1000/±300	1000	300	250	2350	245	330	80	325	350	230	260	4 M36	325	420	230	155	6 M42	200
TSTD 1250/±200	1250	200	290	1905	265	430	90	350	400	260	310	4 M36	350	530	260	205	6 M48	250
TSTD 1250/±300	1250	300	290	2435	265	430	90	350	400	260	310	4 M36	350	530	260	205	6 M48	250
TSTD 1500/±200	1500	200	300	1955	280	425	90	400	450	290	345	4 M42	400	530	290	205	6 M48	250
TSTD 1500/±300	1500	300	300	2485	280	425	90	400	450	290	345	4 M42	400	530	290	205	6 M48	250
TSTD 2000/±200	2000	200	350	2080	325	505	110	450	500	330	380	4 M48	450	630	330	170	8 M48	275
TSTD 2000/±300	2000	300	350	2610	325	505	110	450	500	330	380	4 M48	450	630	330	170	8 M48	275
TSTD 2500/±200	2500	200	390	2165	350	535	120	450	550	340	220	6 M42	450	680	340	190	8 M48	300
TSTD 2500/±300	2500	300	390	2700	350	535	120	450	550	340	220	6 M42	450	680	340	190	8 M48	300
TSTD 2500/±400	2500	400	390	3230	350	535	120	450	550	340	220	6 M42	450	680	340	190	8 M48	300
TSTD 3000/±200	3000	200	430	2300	400	585	140	500	600	380	240	6 M48	500	740	380	200	8 M56	350
TSTD 3000/±300	3000	300	430	2830	400	585	140	500	600	380	240	6 M48	500	740	380	200	8 M56	350
TSTD 3000/±400	3000	400	430	3360	400	585	140	500	600	380	240	6 M48	500	740	380	200	8 M56	350
TSTD 4000/±200	4000	200	500	2440	450	710	160	550	650	430	175	8 M48	550	890	430	190	10 M56	350
TSTD 4000/±300	4000	300	500	2970	450	710	160	550	650	430	175	8 M48	550	890	430	190	10 M56	350
TSTD 4000/±400	4000	400	500	3500	450	710	160	550	650	430	175	8 M48	550	890	430	190	10 M56	350
TSTD 5000/±200	5000	200	580	2620	495	940	180	600	750	480	210	8 M48	600	1140	480	200	12 M56	450
TSTD 5000/±300	5000	300	580	3150	495	940	180	600	750	480	210	8 M48	600	1140	480	200	12 M56	450
TSTD 5000/±400	5000	400	580	3680	495	940	180	600	750	480	210	8 M48	600	1140	480	200	12 M56	450

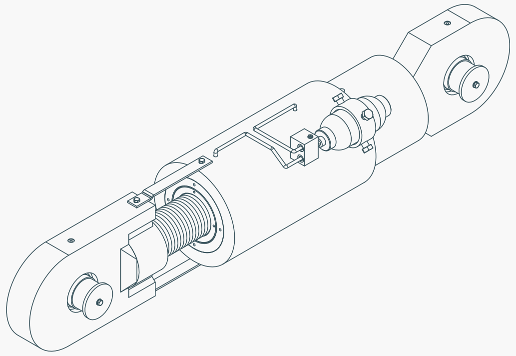
VAS, Verona Shopping Centre, Verona (Italy)



04

TENS FLUID VISCOUS DAMPER (TFVD)

The TFVD are designed to reduce the seismic structural response by adding important energy dissipation to the system.
They are used in parallel with bearings and isolators.



DESCRIPTION

TENS FLUID VISCOUS DAMPERS (TFVD) are velocity-dependent and dissipative hydraulic devices. These devices ensure a better structural response when undergoing dynamic actions, including those induced by earthquakes, providing an important contribution in terms of energy dissipation. From a construction point of view each device consists of a steel cylinder, divided into two chambers by means of a piston. The chambers are filled with a silicone-based viscous fluid.

When undergoing dynamic input a relative motion is generated between the piston and the cylinder, which forces the fluid to pass from one chamber of the hydraulic device to the other, through an hydraulic system. The system is designed in such a way that for slow motions, (such as temperature variations and shrinkage), a negligible restoring force is induced (lower than 10% of device design capacity), therefore ensuring the relative movement between the joints, avoiding the effects of fatigue.

As the load speed increases, so does the reaction force generated by the device, behaviour which is in compliance with the following constitutive law:

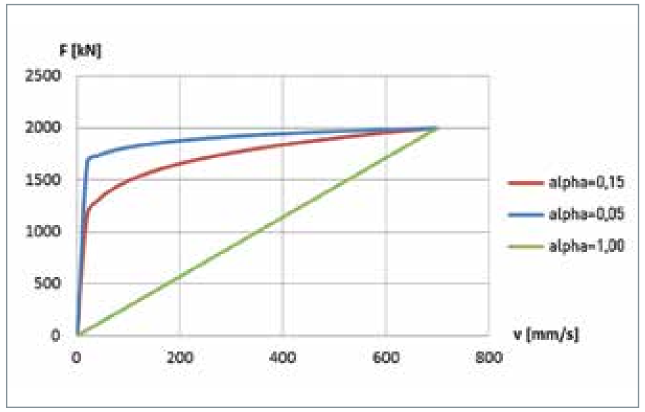
$F = C \cdot V^{\alpha}$

where:

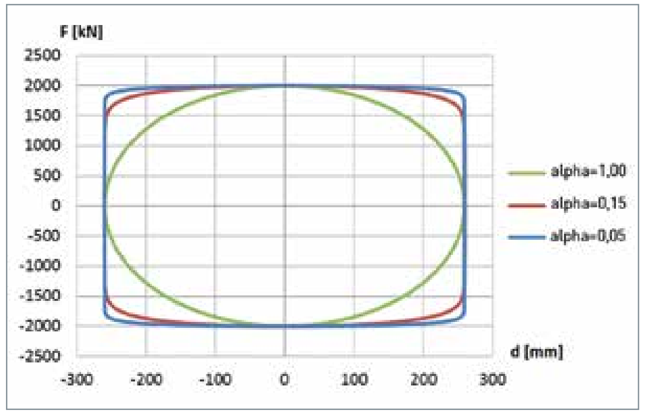
F = Force transmitted by the device (kN);
C = kN/(mm/sec)$^{\alpha}$;
V = load velocity application rate (mm/sec);
α = term that takes into account the damping properties of the device.

When considering fluid-dynamic dampers, the value of the coefficient alpha is lower than 1 (typically equal to 0.15). Device with lower value of alpha, are able to ensure higher dissipation of energy.

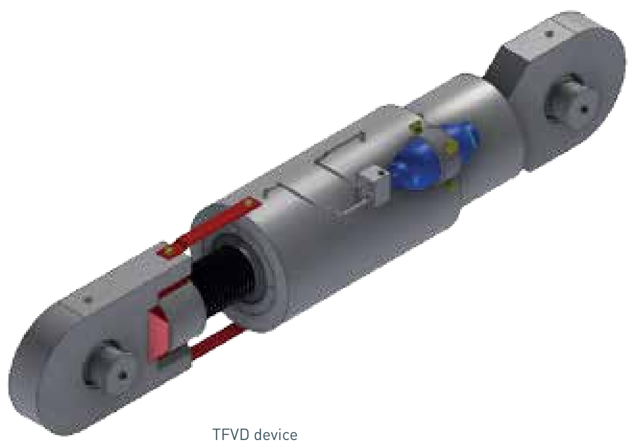
Highway A24 L'Aquila Teramo, Cantiere Pizzoli (Italy)



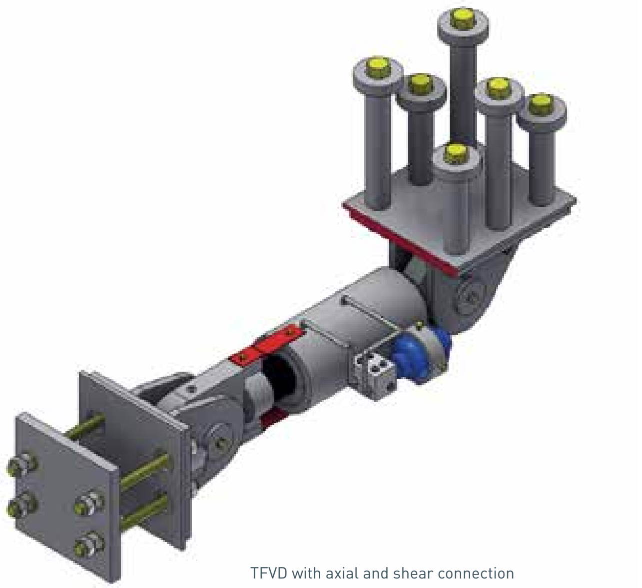
Typical response diagram Force / Velocity (alpha variable from 1.00 to 0.05)



Typical response diagram Force / Displacement (alpha variable from 1.00 to 0.015)



TFVD device



TFVD with axial and shear connection

Unlike the TSTD devices, the TFVD devices never exhibit *pseudo-rigid* behavior along its full operational speed range.

The TFVD dampers are capable of transferring both compressive and tensile forces. In order to keep the transmitted load aligned along the axis of the device, and to avoid undesired bending effects, the device is equipped with spherical hinges at both ends.

The design displacement of the TFVD devices must take into account:

1) Long-term effects
2) Displacements caused by temperature change
3) Dynamic deformations
4) Any adjustment in length required by the structural engineer including for a user-friendly and micrometric device installation.

The stroke cannot under any circumstances be less than ±50 mm for bridges and ±25 mm for buildings. The standard operating design temperature range falls between -25 and + 50 °C in compliance with European Standard EN15129. A larger temperature range will be considered under specific request.

The TFVD devices are not able to resist vertical actions and are therefore normally used in parallel with the following types of device: reinforced rubber bearings (TENS RUBBER), pot bearings (TENS POT), spherical bearings (TENS SPHERICAL), and seismic isolators (TDRI, TLRI and TFPD). They can also be used as dissipative bracings and would not need to be supported by the structural bearings in this application listed above.

The TFVD devices may require the use of appropriate external hydraulic accumulators in order to compensate potential cavitation, which can occur with high velocity loads and potential fluid volume variations over time from fluctuations in temperature, which can cause internal pressure increases with consequent accelerated deterioration of the seals.

TFVD device in standard axial configuration

The main performance features of the TFVDs are summarized below:

- Invulnerability to temperature variations
- Performance reliability over time as a consequence of the high quality of the fluid used and the internal seals
- Reliability both in service conditions and while undergoing seismic action
- Automatic compensation of volumetric changes due to thermal expansion, in order to avoid uncontrolled internal pressure increases and vacuum effects that may compromise the durability over time
- Invulnerability to aging of the silicone fluid used
- Stable and consistent fluid viscosity over the device temperature range, with compressibility such that the volumetric compensation due to temperature variations is enabled
- Guaranteed relative motion between the connected structural elements in case of low velocities, ensured by the presence of a specific calibrated orifice that allows the passage of the fluid between the two chambers of the hydraulic system. As is underlined by the European Standard EN 15129, the transmitted horizontal force generated by the TFVD in case of slow motions shall be lower than 10% of its nominal capacity
- Activation of the internal hydraulic system under impulsive action, in order to ensure the dissipation of energy required and the design reactive force
- Spherical hinge, capable of enabling rotations of ±2° (larger rotations are possible upon specific client request).

COMPONENTS

Described below are the components of the device, with particular reference to the materials and standards.

CYLINDER

The cylinder is made from a steel tube S355J2, S355J0, S355JR (EN10025) or equivalent, internally lapped.

On its outer surface two holes are provided for loading the fluid, plus two additional holes used as air ventilation; the aforementioned holes are equipped with fast joint valves for viscous filling and pressure charge (including its monitoring during device testing).

The external part of the cylinder is adequately protected against aggressive agents, following the painting cycle described in the section *General Provisions and Practices*.

ROD

The supporting rod is made of alloy steel 39NiCrMo3 (EN10083) or superior. The original rod, following grinding and plating treatments, is cut to size with a band saw. At both ends, threaded connections are made.

PISTON

The piston is made of alloy steel type S355J2, S355J0, S355JR (EN10025) or superior. The connection to the supporting rod is ensured by means of a suitably threaded central hole. On the piston-cylinder contact surface, a system of seals, guide strips and sealing rings is inserted, necessary to avoid the loss of internal fluid enclosed within the chambers. On the piston body, calibrated orifices are installed, necessary for the correct functionality of the device.

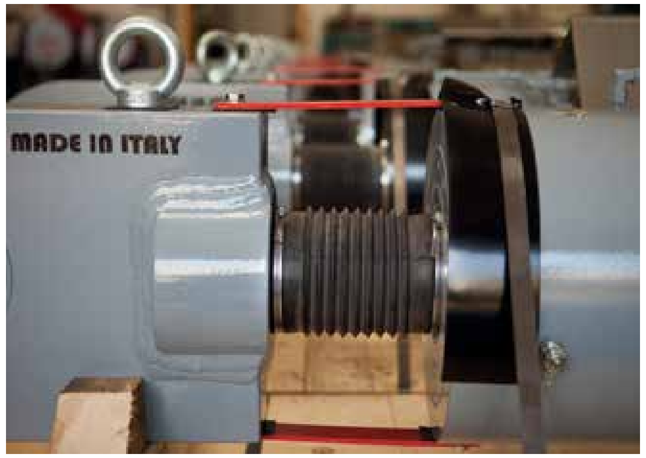
PINS

The creation of the hinge connections between device and structural elements is carried out through a system of 39NiCrMo3 steel connections (EN10083).

HYDRAULIC FLUID

The hydraulic fluid used affects the damping capacity of the device. In particular, in the case of the viscous dampers, the different type of material used allows the variation, depending on the needs of the project, of the parameters that govern the constitutive law and therefore the reaction force and load velocity. Silicone oil is generally used, but other types of fluid may be provided in compliance with particular design requirements and technical specifications.

TFVD - details



MATERIALS

ELEMENT	MATERIAL	RELEVANT EUROPEAN STANDARD
Cylinder	S355J2, J0, JR or equivalent	EN10025
Caps and connections to the structure	S355J2, J0, JR or equivalent	EN10025
Pins	39NiCrMo3 or equivalent	EN10083
Rod	39NiCrMo3 or equivalent	EN10083
Piston	S355J2, J0, JR or equivalent	EN10025
Hydraulic fluid	Silicone oil	

MARKING

Each device is identified by the initials TFVD (TENS FLUID VISCOUS DAMPER) followed by two values. The first represents the maximum horizontal design capacity of the device (kN) while the second represents the maximum displacement expressed in mm, under the load ULS combination.

Below is an example:

Maximum horizontal
capacity (kN)

TFVD 1500/±200

TENS
FLUID VISCOUS
DAMPER

Maximum displacement
(mm)

CATALOGUE PERFORMANCE HYPOTHESIS

The TFVD catalogue has been prepared in accordance with EN15129.

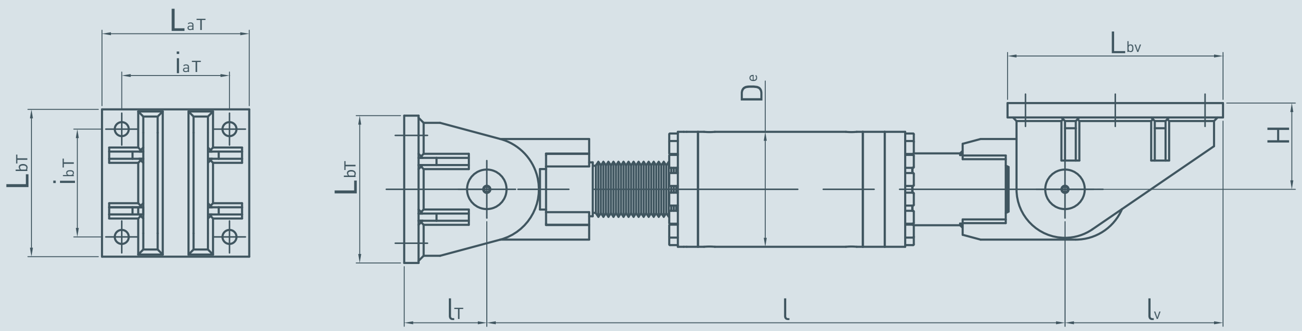
The maximum considered horizontal design load is equal to 5000 kN and for each device's nominal capacity two displacement values are studied. The considered alpha is 0,15.

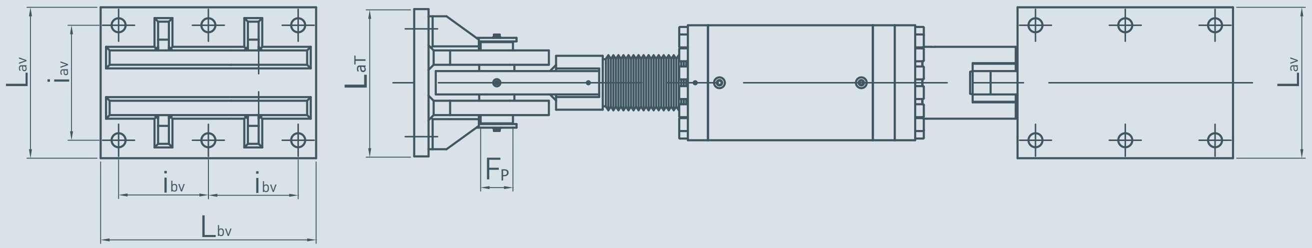
Devices characterized by a larger horizontal capacity, alpha value, displacement or by a different connection to the structure can be designed upon specific request.

TENSA's technical department is available to evaluate and design tailor-made solutions for buildings, bridges and any other type of structure that requires seismic protection.

TSTD device with free sliding movement
orthogonally to the device's coupling direction

CATALOGUE TECHNICAL TABLES





TYPICAL DIMENSIONS FOR BUILDINGS

DEVICE	F (ULS)	d (ULS)	D	L	l_T	l_V	F_P	L_{aT}	L_{bT}	i_{aT}	i_{bT}	N°	L_{aV}	L_{bv}	i_{aV}	i_{bV}	N°	H
	[kN]	[±mm]	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)		(mm)	(mm)	(mm)	(mm)		(mm)
TFVD 500/±25	500	25	190	770	195	330	60	250	300	190	240	4 M24	250	400	190	165	6 M27	200
TFVD 500/±50	500	50	190	870	195	330	60	250	300	190	240	4 M24	250	400	190	165	6 M27	200
TFVD 750/±25	750	25	225	835	200	380	60	250	300	190	240	4 M24	250	450	190	185	6 M30	200
TFVD 750/±50	750	50	225	915	200	380	60	250	300	190	240	4 M24	250	450	190	185	6 M30	200
TFVD 1000/±25	1000	25	260	905	230	430	70	300	350	220	275	4 M30	300	510	220	210	6 M36	200
TFVD 1000/±50	1000	50	260	985	230	430	70	300	350	220	275	4 M30	300	510	220	210	6 M36	200
TFVD 1250/±25	1250	25	295	995	245	430	80	325	350	230	260	4 M36	325	520	230	205	6 M42	250
TFVD 1250/±50	1250	50	295	1075	245	430	80	325	350	230	260	4 M36	325	520	230	205	6 M42	250
TFVD 1500/±25	1500	25	320	1015	265	430	90	350	400	260	310	4 M36	350	530	260	205	6 M48	250
TFVD 1500/±50	1500	50	320	1105	265	430	90	350	400	260	310	4 M36	350	530	260	205	6 M48	250
TFVD 2000/±25	2000	25	365	1145	300	515	100	450	450	330	330	4 M48	450	630	330	255	6 M48	250
TFVD 2000/±50	2000	50	365	1225	300	515	100	450	450	330	330	4 M48	450	630	330	255	6 M48	250

TYPICAL DIMENSIONS FOR BRIDGES

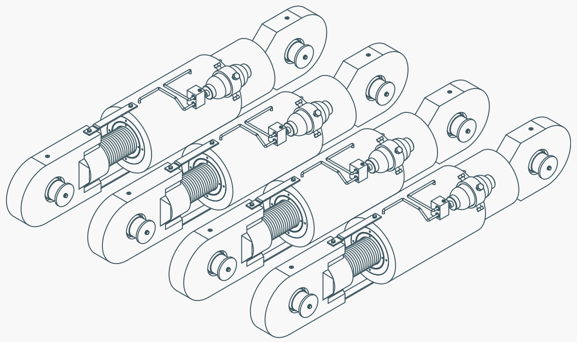
DEVICE	F (ULS)	d (ULS)	D	L	l_T	l_V	F_P	L_{aT}	L_{bT}	i_{aT}	i_{bT}	N°	L_{aV}	L_{bv}	i_{aV}	i_{bV}	N°	H
	[kN]	[±mm]	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)		(mm)	(mm)	(mm)	(mm)		(mm)
TFVD 500/±200	500	200	200	1670	195	330	60	250	300	190	240	4 M24	250	400	190	165	6 M27	200
TFVD 500/±300	500	300	200	2200	195	330	60	250	300	190	240	4 M24	250	400	190	165	6 M27	200
TFVD 750/±200	750	200	240	1705	200	380	60	250	300	190	240	4 M24	250	450	190	185	6 M30	200
TFVD 750/±300	750	300	240	2235	200	380	60	250	300	190	240	4 M24	250	450	190	185	6 M30	200
TFVD 1000/±200	1000	200	260	1760	230	430	70	300	350	220	275	4 M30	300	510	220	210	6 M36	200
TFVD 1000/±300	1000	300	260	2295	230	430	70	300	350	220	275	4 M30	300	510	220	210	6 M36	200
TFVD 1250/±200	1250	200	295	1835	245	430	80	325	350	230	260	4 M36	325	520	230	205	6 M42	250
TFVD 1250/±300	1250	300	295	2365	245	430	80	325	350	230	260	4 M36	325	520	230	205	6 M42	250
TFVD 1500/±200	1500	200	320	1900	265	430	90	350	400	260	310	4 M36	350	530	260	205	6 M48	250
TFVD 1500/±300	1500	300	320	2430	265	430	90	350	400	260	310	4 M36	350	530	260	205	6 M48	250
TFVD 2000/±200	2000	200	365	2015	300	515	100	450	450	330	330	4 M48	450	630	330	255	6 M48	250
TFVD 2000/±300	2000	300	365	2545	300	515	100	450	450	330	330	4 M48	450	630	330	255	6 M48	250
TFVD 2500/±200	2500	200	400	2105	330	555	110	450	500	330	380	4 M48	450	680	330	185	8 M48	300
TFVD 2500/±300	2500	300	400	2635	330	555	110	450	500	330	380	4 M48	450	680	330	185	8 M48	300
TFVD 2500/±400	2500	400	400	3165	330	555	110	450	500	330	380	4 M48	450	680	330	185	8 M48	300
TFVD 3000/±200	3000	200	450	2215	350	595	120	500	550	360	415	4 M56	500	730	360	200	8 M48	300
TFVD 3000/±300	3000	300	450	2745	350	595	120	500	550	360	415	4 M56	500	730	360	200	8 M48	300
TFVD 3000/±400	3000	400	450	3275	350	595	120	500	550	360	415	4 M56	500	730	360	200	8 M48	300
TFVD 4000/±200	4000	200	500	2375	405	730	140	500	600	380	240	6 M48	500	890	380	250	8 M56	350
TFVD 4000/±300	4000	300	500	2905	405	730	140	500	600	380	240	6 M48	500	890	380	250	8 M56	350
TFVD 4000/±400	4000	400	500	3435	405	730	140	500	600	380	240	6 M48	500	890	380	250	8 M56	350
TFVD 5000/±200	5000	200	590	2535	455	910	160	600	700	460	185	8 M56	600	1090	460	235	10 M56	400
TFVD 5000/±300	5000	300	590	3065	455	910	160	600	700	460	185	8 M56	600	1090	460	235	10 M56	400
TFVD 5000/±400	5000	400	590	3595	455	910	160	600	700	460	185	8 M56	600	1090	460	235	10 M56	400

Some of the 293 pcs Temporary dynamic connection devices ready for delivery to VAS, Verona Shopping Centre, Verona (Italy)

05

GENERAL PROVISIONS AND PRACTICES

An overview of the regulations and the operational procedures that warrant the efficiency of our hydraulic devices



ANTICORROSIVE TREATMENT

Excluding different client specifications, the metal parts exposed to aggressive agents undergo the following anti-corrosive treatment cycle:

- Surface cleaning with solvents;
- SA2,5 white metal sandblasting;
- Base primer made from epoxy-polyamide resins;
- High thickness protective paint made from modified epoxy resins;
- Finishing coat of paint made from aliphatic polyurethane resins.

Any kind of other treatment cycles can be provided upon request, in accordance with ISO 12944, also for expected durability of more than 15 years in industrial or marine environments (C5-I & C5-M).

Some of the 293 pcs Temporary dynamic connection devices ready for delivery to VAS, Verona Shopping Centre, Verona (Italy)

STORAGE AND HANDLING

The TFVD and TSTD devices must be stored in a clean, dry and protected place. For handling, the use of wooden pallets and fabric bands is preferable, strictly avoiding contact between the parts and steel rope and chains, lifting magnets, forklifts forks and metal surfaces in general. Special care should be taken for the handling of the part, in order to avoid any type of damage that could compromise the standard operation of the device.

Ensure the device is lifted using the connection points specified in the installation manual and/or design drawing or clearly indicated on the devices by the presence of eye connections.

The devices must not be left in overheated environments, as the uncontrolled overheating of the viscous fluid present in the cylinder chambers can cause internal pressures incompatible with the correct functioning of the seals (maximum temperature 50° C).

INSPECTION AND MAINTENANCE

The devices are designed and produced with the aim of minimising maintenance activity during their standard expected design life. If the structure and consequently the devices are not exposed to any exceptional conditions (earthquakes, fire, collisions etc) they should be visually inspected one year after installation and following that, with a frequency no greater than five years. Such inspections involve evaluation of the correct behavior of the device and the integrity of the individual components, verifying potential loss of fluid. Lastly, the periodic check includes the monitoring of the state of the anticorrosive protection, with the possibility to carry out localized maintenance by assessing the time and methods required for a potential restoration, in accordance with the international standard ISO 12944.

NECESSARY INPUT DATA FOR A CORRECT DESIGN

The design of the viscous fluid dampers TFVD and shock transmitter device TSTD is performed according to the European Standard EN 15129.

In order to require a quotation, the following information is necessary:

- Maximum temperature range;
- Maximum coupling force;
- Coupling displacement or rigidity of the device;
- Activation velocity (only for TFVD);
- Coefficient alpha (only for TFVD);
- Type of support to be connected (concrete or steel);
- Any preferences on anticorrosive protection.

The following information is also required, in order to provide an optimal technical solution:

- Structural drawings of the installation (plans, elevations and sections)
- Details and/or elements relating to the positioning area of the device, in order to evaluate potential geometric interferences.

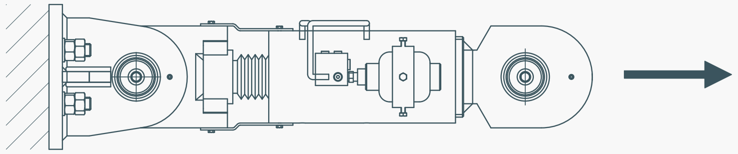
For any request or advice, please contact TENSA Technical Department, which will be glad to propose the most suitable solution in compliance with the project requirements.

VAS, Verona Shopping Centre, Verona (Italy)

06

QUALITY AND TESTING

Testing and control are fundamental processes
that guarantee our clients the quality
and efficiency of our hydraulic devices

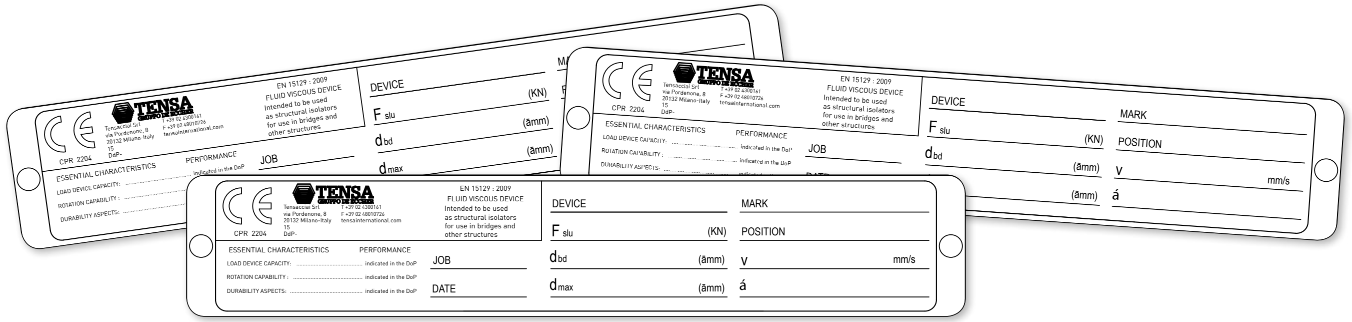


QUALITY AND CONTROL

TENSA TFVD and TSTD devices are produced in accordance with quality management system UNI EN ISO 9001:2008.

The entire design and production process concerning the TSTDs and TFVDs CE Marked (EN 15129) is controlled through operating instructions, quality control plans (QCP) and registration documents; in particular, controls on raw materials, semi-production processes and final assembly guarantee that all products delivered meet the regulatory requirements and performance required by the client. TENSA applies all the necessary checks and controls required by EN 15129, as well as the Type Tests and Factory Production Control, to verify the constancy of performance of the supplied products. TENSA is also regularly inspected by independent certification bodies.

The devices are accompanied by the "CE" Declaration of Constancy of Performance, in accordance with the provisions of the CPR 305/2011.



CE MARKING

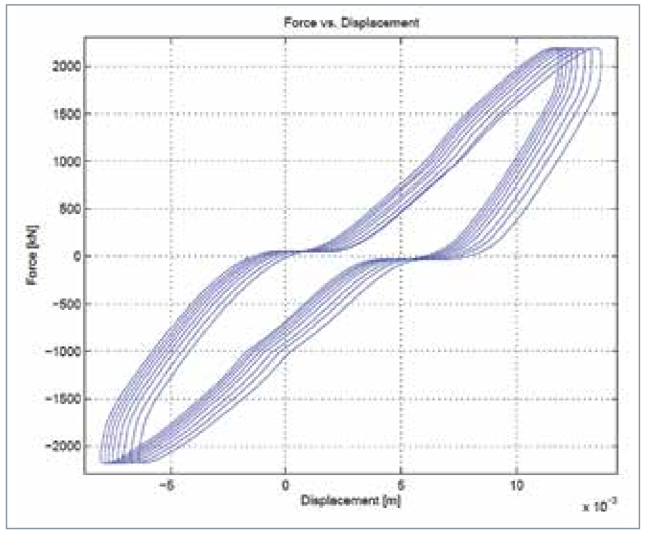
The hydraulic devices are fitted with aluminium identification plates with the following information:

- identification number from the certification body
- identification name or trademark of the producer;
- registered address of the producer;
- the last two digits of the year in which the CE Certification was acquired;
- CE Certificate of Constancy of Performance;
- Declaration of Constancy of Performance number;
- reference to the present European Standard;
- product description, generic name, materials, dimensions and intended use.

If required, the design can be carried out in accordance with common international standards, such as AASHTO, DIN, SETRA, ASCE, FEMA or other client specifications.

TESTING AND LABORATORY

TYPE TESTS TEMPORARY CONNECTION DEVICES (TSTD):



Typical response diagram Force / Displacement for Cyclic Test (TSTD 2200/±105)

Type tests are carried out to certify the device performance, becoming the reference for subsequent quality control tests.

Type testing shall be performed whenever a new device differs in capacity by more than ± 20% and/or its design displacement is larger than that of a previously tested unit.

The tests used are listed below:

- **Pressure test**: internal pressure equal to 125% of the maximum, maintained for 120 seconds. During the test no anomalies or visible leakage shall occur.
- **Low velocity test**: alternating cyclic test with constant velocity less or equal to 0.1 mm/s and amplitude equal to the design displacement expected for non-seismic actions. The maximum registered force shall be lower than 10% of the design maximum.
- **Seal Wear test**: the device undergoes a cyclic test for 10,000 cycles at an amplitude equal to the estimated maximum for thermal displacement. During the test no loss of fluid should be detected.
- **Impulsive load test**: the planned design load for seismic actions must be reached in less than 0.5 seconds and maintained constant for 5 seconds, reversed in less than 1 second, and finally maintained for another 5 seconds. The timing of the constant load may be increased by the structural engineer. During the test no anomalies or support problems should occur. The velocity measured during the constant load phase shall not exceed the activation velocity. The displacement recorded after the first 0.5 seconds shall not exceed the design value at the design force Fd, while the displacement during the load inversion shall not exceed twice the design value.
- **Overload test**: the planned design load for seismic actions amplified by a factor equal to 1.5 must be reached in less than 0.5 seconds and maintained constant for 5 seconds, reversed in less than 1 second, and finally maintained for another 5 seconds. The timing of the constant load may be increased by the structural engineer. During the test no anomalies or no visible leakage occur.
- **Cyclic test**: this test consists of applying the design load cyclically for a time equal to the duration of the intensive phase of the expected earthquake and for a time no less than 15 seconds in any case. Sinusoidal force cycles are applied: $F(t)=F_0*\sin(2\ \dots\ *f_o*t)$ where F_0, f_o and t are the design force, frequency and duration, respectively. During the test no anomalies and no visible leakage shall occur and the coupling displacement at the design load shall not be greater than the design value.
- **Stroke verification test**: The purpose of this test is to verify the displacement device capability. The device must therefore undergo a complete cycle to ensure that it has a minimal displacement capacity equal to the design value plus +1mm.

Pressure Test	Low Velocity Test	Seal Wear Test	Impulsive Load Test	Overload Test	Cyclic Load Test	Stroke Verification Test
X*	X	X*	X	X*	X	X*

(*) Test performed at (23±5)°C temperature

TEST FPC (FACTORY PRODUCTION CONTROL) TEMPORARY CONNECTION DEVICES (TSTD):

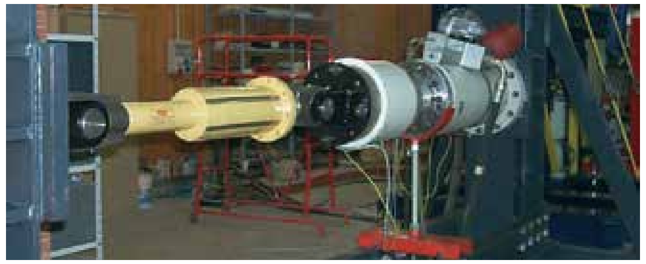
The factory production control tests are carried out to verify that the response of the device produced conforms to the design requirements. The FPC tests must be carried out on one device per batch produced, numbering lots of no more than 20 units with the same design features.

The tests carried out, at ambient temperature, are listed below:

- **Pressure test**: internal pressure equal to 125% of the maximum, maintained for 120 seconds. During the test no anomalies or no visible leakage shall occur.
- **Low velocity test**: alternating cyclic test with constant velocity less or equal to 0.1 mm/s and amplitude equal to the design displacement expected for non-seismic actions. The maximum registered force should be lower than 10% of the design maximum.
- **Impulsive load test**: the planned design load for seismic actions must be reached in less than 0.5 seconds and maintained constant for 5 seconds, reversed in less than 1 second, and finally maintained for another 5 seconds. The timing of the constant load may be increased by the structural engineer. During the test no anomalies or no visible leakage shall occur. The velocity measured during the constant load phase shall not exceed the activation velocity. The displacement recorded after the first 0.5 seconds shall not exceed the design value at the design force Fd, while the displacement during the load inversion shall not exceed twice the design value.

Pressure Test	Low Velocity Test	Impulsive Load Test
X*	X*	X*

(*) Test performed at (23±5)°C temperature



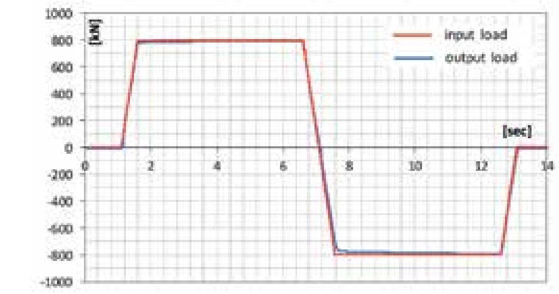
Type Test on TSTD device

TYPE TESTS VISCOUS FLUID DISSIPATION DEVICE (TFVD):

Type tests are carried out to "certify" the device performance, becoming the reference for subsequent quality control tests. Whenever a new device differs in load capacity by more than ± 20% and/or its design velocity is greater than that of a previously tested unit.

The tests used are listed below:

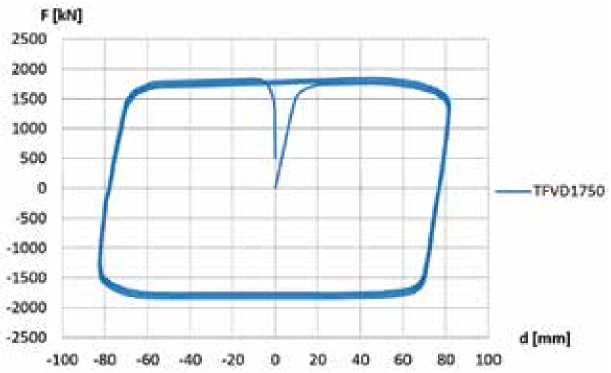
- **Pressure test**: internal pressure equal to 125% of the maximum, maintained for 120 seconds. During the test no anomalies or no visible leakage shall occur.
- **Low velocity test**: alternating cyclic test with constant velocity less or equal to 0.1 mm/s and amplitude equal to the design displacement expected for non-seismic actions. The maximum registered force shall be lower than 10% of the design maximum.
- **Seal Wear test**: the device undergoes a cyclic test for 10,000 cycles at an amplitude equal to the estimated maximum for thermal displacement. During the test no loss of fluid shall be detected.
- **Constitutive load test**: The purpose of this test is to determine the behavior curve of the devices. For each of the load application velocity values, 3 complete cycles at design displacement dbd must be completed. Tests shall be carried out at least 1%, 25%, 50%, 75% and 100% of the design velocity.
- **Damping efficiency test**: this test is necessary to assess the ability of the device to dissipate energy. Five complete harmonic displacement cycles are carried out at displacement: $d(t)=d_0*sin(2 \dots *f_o*t)$ where d_0, f_o and t are the design displacement, frequency and duration respectively. During the test the dissipation shall remain within the regulatory range.



Typical response diagram Force / Time for Impulsive Load Test (TSTD 800/±25)

Type Test on TFVD device

- **Wind load test**: if the wind load is considered to be critical, the device resistance against vibrations caused by wind must be assessed. The device shall undergo cyclic tests (200 cycles) on the design frequency and displacement (e.g. 0.4 Hz. with displacement of ± 12mm). During the test no anomalies or no visible leakage shall occur.
- **Stroke verification test**: the purpose of this test is to verify the device displacement capacity. The device must therefore undergo a complete displacement cycle to ensure that it has a sufficient stroke capacity (minimum equal to its design value +1 mm).



Typical response diagram Force / Displacement for Constitutive Load Test
(TFVD 1750/±80 - alfa=0.15 and velocity = 200mm/sec)

TEST FPC (FACTORY PRODUCTION CONTROL) FLUID VISCOUS DAMPER (TFVD):

The factory production control tests are carried out to verify that the response of the produced devices conforms to the design requirements.
The FPC tests must be carried out on one device per batch produced, numbering lots of no more than 20 units with the same design features.

The tests carried out, at ambient temperature, are listed below:

- **Pressure test**: internal pressure equal to 125% of the maximum, maintained for 120 seconds. During the test no anomalies or no visible leakage shall occur.
- **Low velocity test**: alternating cyclic test with constant velocity less or equal to 0.1 mm/s and amplitude equal to the design displacement expected for non-seismic actions. The maximum registered force should be lower than 10% of the design maximum.
- **Constitutive load test**: The purpose of this test is to determine the behavior curve of the devices. For each of the load application velocity values, 3 complete cycles at design displacement dbd. Tests shall be carried out at at least 1%, 25%, 50%, 75% and 100% of the design velocity.
- **Damping efficiency test**: this test is necessary to assess the ability of the device to dissipate energy. Five complete harmonic displacement cycles are carried out at displacement: $d(t)=d_0*sin(2 \dots *f_o*t)$ where d_0, f_o and t are the design displacement, frequency and duration respectively. During the test the dissipation must remain within the regulatory range.

Pressure Test	Low Velocity Test	Constitutive Law Test	Damping Efficiency Test
X*	X*	X*	X*

(*) Test performed at (23±5)°C temperature

Pressure Test	Low Velocity Test	Constitutive Law Test	Damping Efficiency Test	Wind Load Test	Seal Wear Test	Stroke Verification Test
X*	X	X	X	X*	X*	X*

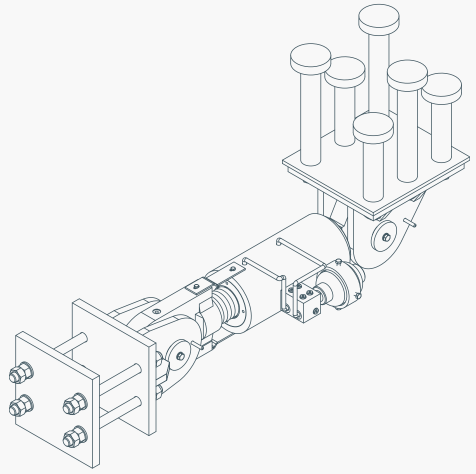
(*) Test performed at (23±5)°C temperature

Wadi Hanifa Viaduct, Riyadh (Saudi Arabia)

07

INSTALLATION

The installation methods are conceived during the first phases of the device design



INSTALLATION

For correct installation of TFVDs and TSTDs devices it is recommended to refer to the installation manual provided by TENSA, and the construction drawings. Before installation, the devices must also be stored in environments that ensure protection from exposure to direct rain, possible damages etc.

INSTALLATION DURING CASTING

It is possible to install the devices before the completion of the superstructure erection.

This possibility is normally the simpler solution, even if the risk of device damage rises due to site operations. It is recommended to:

- Verify that the device length, with reference to the design stroke, takes into account potential presetting, taking into consideration the effects of shrinkage and creep, as well as the temperature conditions. These indications must be provided by the structural engineer. For the adjustment of length, follow the instructions given in the instruction manual.
- Adequately protect the device so that during the casting phase, the device avoids being damaged or exposed to binder and/or dust, particularly the rod.

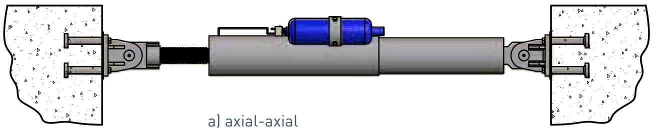
INSTALLATION AFTER CASTING

Installation of the device after the casting operations represents the best option as the hydraulic device is not exposed to the dangers connected with the site operations (impacts, dirt etc.).

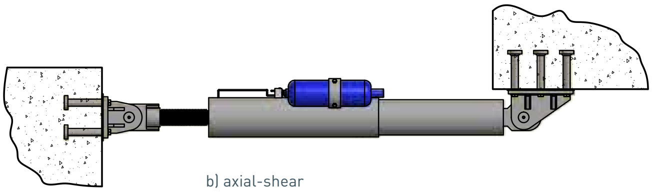
It is recommended to:

- Firmly connect by grouting only one anchorage end of the device. Necessary adjustment in length, alignment and rotation is possible to carry out on the unanchored end of the device, ensuring optimal device stroke and rotation capacity are not lost. Therefore one of the two connections will be grouted only after having positioned the device.
- It is necessary that the design allows suitable accessibility for the installation of the devices, considering all possible handling requirements.

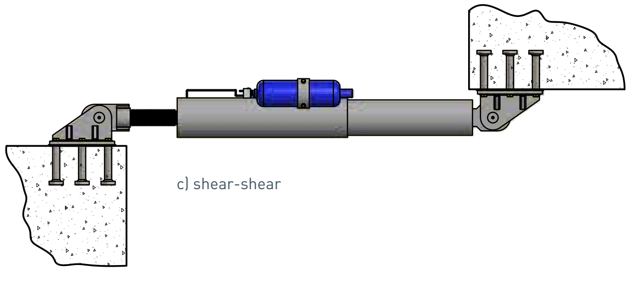
Different configuration of connection:



a) axial-axial



b) axial-shear



c) shear-shear

TENSA
GRUPPO DE ECCHER

Job title		Job No.
Design by	Date	Sheet No.
Item		

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