

STRUCTURAL LINKS AND VIBRATION CONTROL FOR BRIDGES



Structural Bearings

Expansion Joints

Tuned Mass Dampers

Viscous Fluid Devices

Services



VICODA

Vibration Control › Devices › Applications

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STRUCTURAL LINKS AND VIBRATION CONTROL FOR BRIDGES

VICODA is an engineering company, specialized in the field of structural dynamics and vibration control. As a globally active company **VICODA** serves customers in the plant engineering, the civil engineering and the railways sector as well as many other industries.

Solutions to minimize unwanted vibrations in industrial piping systems, products for seismic protection of bridges or techniques to reduce the effect of traffic induced vibrations on buildings are just a part of **VICODA's** product and service portfolio.

It is **VICODA's** special ambition to always find the optimum solution for a given task. This is why **VICODA** has decided to combine all state of the art product technologies and engineering methodologies under one roof thus allowing to provide the best products and services for its customers.

With the acquisition of **SCHREIBER** in 2015, **VICODA** has widened its product range by a special set of solutions for bridges and infrastructures. **SCHREIBER**, a German company with more than 40 years of experience in the design, manufacture and supply of bridge bearings and expansion joints, is an important global player in the civil and infrastructure sector.

The combination of **VICODA's** and **Schreiber's** know-how offers to customers in the bridge construction industry a unique set of products and services.



VICODA

SCHREIBER
Brücken-Dehntechnik

TECHNICAL INTRODUCTION

Although bridges at first sight seem to be fixed and motionless, they are in fact flexible structures. Their movement is due to various phenomena like temperature expansion,

traffic loads, concrete creep or shrinkage, wind or earthquakes. The forces induced by the movement are adding to the dead and live loads of the bridge.



Expansion joints

The basic function of expansion joints is to allow smooth traffic flow while accommodating movements due to thermal expansion of the bridge, creep and shrinkage of concrete or of composite structures.

Depending on the deck, the general bridge design and the expected movements both in longitudinal and transversal direction, different types of expansion joints are available.

VICODA offers a broad spectrum of expansion joints including single gap, finger and reinforced rubber expansion joints.



Viscous fluid devices

Lock up devices and viscous fluid dampers are largely used in bridge design to provide additional rigid links or to increase the damping capacity of a structure.

They are very efficient to counteract traffic, wind and earthquake actions.

Any bridge needs to be designed in a way that it can move within predefined limits and that the sum of the acting forces does not overstress the mechanical structure.

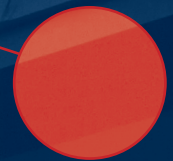
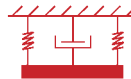
Structural bearings, expansion joints, tuned mass dampers and viscous fluid devices are special products that support these design requirements.

Tuned mass dampers

Tuned mass dampers (TMDs) are special vibration control devices designed to minimize unwanted vibrations due to traffic, wind or earthquakes.

With TMDs dynamic loads can be significantly reduced thus allowing to simplify the overall structural layout.

Through this bridges can be designed in a more slender, cost effective and safer way.



Structural bearings

Bridge bearings are designed to transmit forces from the bridge superstructure (deck) to the substructure (piers, abutments and foundations) within the limits of the design requirements regarding forces, displacements and rotations.

In line with the definition given by the European Standard EN 1337 "Structural bearings are elements allowing rotation between two members of a structure and

transmitting the loads defined in the relevant requirements as well as preventing displacements (fixed bearings), allowing displacements in only one direction (guided bearings) or in all directions of a plane (free bearings) as required".

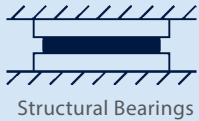
In order to meet these requirements VICODA has designed a wide range of elastomeric bearings, pot bearings, spherical bearings and shear keys.



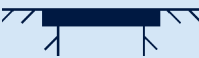
PRODUCT RANGE

VICODA has developed a wide range of structural bearings, expansion joints, tuned mass dampers and viscous fluid devices for the bridge construction industry. With these products all typical design require-

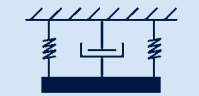
ments can be met. In order to define the right product for every application, VICODA's technical experts are available to give all necessary assistance.



Structural Bearings



Expansion Joints



Tuned Mass Dampers



Viscous Fluid Devices



Services

Structural Bearings

Type	Design		Max vertical load V [MN]
Standard elastomeric bearings	Free, movable in all horizontal directions 5 different layouts depending on anchoring system	→ VS-EB 1, 2, 3, 4, 5	15
Restrained elastomeric bearings	Fixed, with both horizontal directions restrained Movable, with 1 horizontal direction restrained	→ VS-RBF → VS-RBU	15
Sliding elastomeric bearings	Movable, with 1 horizontal direction restrained Free, movable in all horizontal directions	→ VS-SBU → VS-SBM	15
Pot bearings	Fixed, with both horizontal directions restrained Movable, with 1 horizontal direction restrained Free, movable in all horizontal directions	→ VS-P → VS-PU → VS-PM	50
Spherical bearings	Fixed, with both horizontal directions restrained Movable, with 1 horizontal direction restrained Free, movable in all horizontal directions	→ VS-S → VS-SU → VS-SM	50
Shear keys	Fixed, with both horizontal directions restrained Movable, with 1 horizontal direction restrained	→ VS-K → VS-KU	No vertical load allowed

Expansion Joints

Type		Movements [mm]			Noise reduction	Service life [years]
		Longitudinal	Transversal	Vertical		
Single gap expansion joints	→ VS-JS	80	120	10	No	50
Single gap expansion joints with noise reduction	→ VS-JSR	120	120	10	Yes	50
Finger expansion joints	→ VS-F	Up to 400	No design limits	10	Yes	50
Reinforced rubber expansion joints	→ VS-Flex	Up to 320	Up to 320	20	No	20

Viscous Fluid Devices

Type		Behaviour with slow movements (thermal, creep, shrinkage)	Behaviour with dynamic actions (vehicle braking, wind, earthquakes)	Max axial load [MN]	Max stroke [mm]	Service life [years]
Viscous fluid dampers	→ VS-VD	Allow movement with negligible reaction force	Reduce dynamic force by damping energy (up to 75%)	5	1000	50
Lock up devices (STUs)	→ VS-STU	Allow movement with negligible reaction force	Transmit dynamic force as a rigid link	7	1000	50

In the below table, a quick overview to VICODA's product range is presented. This should serve as a basic guideline to select the right product type from the wide available range.

Further technical details on the products and their specific applications are given on the following pages.

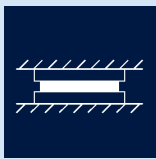
Max horizontal load H [MN]	Max horizontal movement	Max rotation [rad]	Service life [years]
5% of V	Depending on rubber height. max shear deformation $\tan \gamma = 1.0$	0.015 Value depends on the rubber height	25
Up to 50% of V in the restrained dir. 5% of V in non restrained dir.	Depending on rubber height. max shear deformation $\tan \gamma = 1.0$	0.015 Value depends on the rubber height	25
Up to 50% of V in the restrained dir.	No design limits	0.015 Value depends on the rubber height	25
Up to 70% of V	No design limits	0.02	50
Up to 100% of V	No design limits	0.15 and more	50
No design limits	No horizontal movements No design limits	0.15 and more	50

Tuned Mass Dampers

Type	Design	Service life [years]
TMD	Special products to reduce unwanted vibrations and structural-borne noise due to wind, earthquakes, traffic loads or induced by other causes Different layouts are available to act in horizontal and/or vertical direction Adaptable to all kinds of structures	50

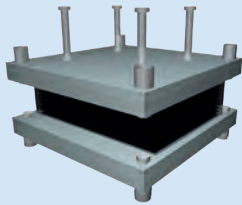
Services

Available engineering services
■ Structural engineering ■ Vibration measurements ■ Special product design ■ Installation ■ Repair and maintenance ■ Monitoring systems

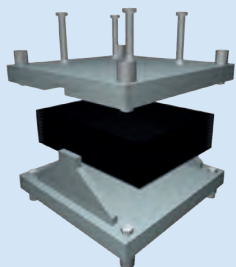


STRUCTURAL BEARINGS

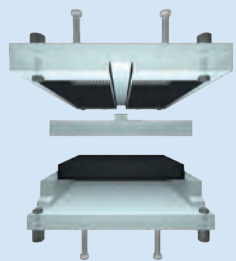
ELASTOMERIC BEARINGS



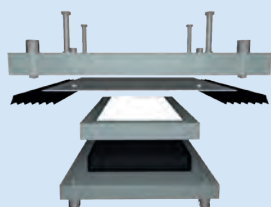
Elastomeric bearing
Type VS-EB4



Restrained elastomeric
bearing Type VS-RBF



Unidirectional sliding
elastomeric bearing
Type VS-SBU



Free sliding elastomeric
bearing Type VS-SBM

VICODA elastomeric bearings are suitable to connect different sections of a structure, transferring loads in vertical and horizontal direction and allowing horizontal displacements as well as rotations. Thanks to their flexible design and to the wide range of anchoring layouts, they can be used in almost every kind of structure.

DESIGN

Elastomeric bearings in general consist of a rubber (elastomeric) block, reinforced with internal steel plates vulcanized to the elastomer. The steel plates increase the vertical stiffness of the device thus increasing the bearing capacity. Embedded in the elastomer, they are efficiently protected against corrosion.

Elastomeric bearings provide an elastic counteraction to an initial movement. Typical allowable vertical loads of VICODA elastomeric bearings are up to 15 MN. The typical allowable horizontal loads range between 5% and 10% of the vertical load. For higher loads special layouts can be developed following standardized design processes.

The allowable horizontal movements depend on the height of the elastomeric block and correspond normally to a tangential deformation $\gamma = 1$.

According to the requirements in horizontal direction, VICODA elastomeric bearings may be classified into three groups:

■ Standard elastomeric bearings – type VS-EB

Standard elastomeric bearings of type VS-EB consist of only a reinforced elastomeric block that can be provided with external steel plates in order to improve the anchoring to the surrounding structure.

The load transfer and movement characteristics in horizontal direction of these bearings are only defined by the elastomer resistance and the deformation capacity.

■ Restrained elastomeric bearings – type VS-RB

Restrained elastomeric bearings of type VS-RB consist of an elastomeric block, upper and lower connection plates and a steel frame preventing horizontal movements of the elastomeric block in one or two directions.

Here the steel frame instead of the elastomeric block transfers the horizontal loads in the respective directions.

For bearings of type VS-RBF a complete steel frame allows the transfer of high horizontal loads in all directions. In case of bearings of type VS-RBU steel restraints limit the movement of the elastomeric block to only one direction thus allowing the transfer of high loads in that direction and allowing horizontal movement in the perpendicular direction.

■ Sliding elastomeric bearings – type VS-SB

The designs of the sliding elastomeric bearings of type VS-SB are similar to the designs of the standard or restrained elastomeric bearings. The only difference is that these bearings are equipped with an external sliding element. The sliding element itself consists of a stainless steel plate and a PTFE sheet. Suitably greased this element has a very low friction coefficient.

As horizontal displacements are made possible by the sliding element - and not by the deformation of the elastomeric block - sliding elastomeric bearings allow significantly bigger horizontal displacements than the standard or restrained elastomeric bearings.

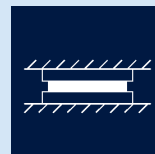
Bearings of type VS-SBM allow displacements in both horizontal directions. Bearings of type VS-SBU with additional steel restraints only allow displacement in one horizontal direction.

CONFIGURATION OF ELASTOMERIC BEARINGS

VICODA elastomeric bearings are designed according to EN1337 and provided with CE Mark. If required, they can also be designed and manufactured in compliance with different international standards like AASHTO, BS or DIN.

In order to select the right bearing type and to choose the best solution, VICODA engineers are available to support you. The data required to configure elastomeric bearings are:

- Load cases i.e. vertical and horizontal loads, horizontal displacements and rotations corresponding to minimum and maximum vertical load and to maximum horizontal load at the ultimate limit state (ULS)
- General description of the structure, space or anchoring requirements



ELASTOMERIC BEARINGS PRODUCT RANGE

Standard elastomeric bearings

Type	Design
VS-EB1	Reinforced elastomeric block with no additional anchors to the structure
VS-EB2	Reinforced elastomeric block with external steel plates, provided with pin housing or threaded holes to allow connection to the structure
VS-EB3	Reinforced elastomeric block with external steel plates provided with or without anchors
VS-EB4	Reinforced elastomeric block with external plates vulcanized to the elastomer and connected to anchoring plates
VS-EB5	Reinforced elastomeric block with external checkered steel plates vulcanized to the elastomer – these plates provide a higher friction and thus allow a higher horizontal load transfers



Restrained elastomeric bearing Type VS-RBU installed



Final assembly of elastomeric bearings at VICODA's factory

- ① Reinforced elastomeric block
- ② External steel plates
- ③ Anchors
- ④ Steel restraints
- ⑤ Sliding element

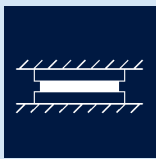
Restrained elastomeric bearings

Type	Design
VS-RBF	Elastomeric bearing with complete steel frame (restraints) suitable to transfer high horizontal forces in all directions
VS-RBU	Elastomeric bearing provided with steel restraints suitable to transfer high horizontal forces in one direction – in the perpendicular direction it has similar characteristics as a standard VS-EB bearing

An overview of the typical loads, allowable displacements and rotations is given on page 6.

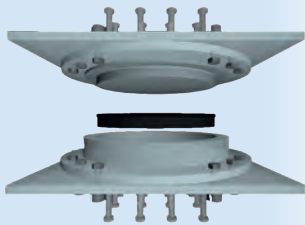
Sliding elastomeric bearings

Type	Design
VS-SBU	Elastomeric bearing with a guided sliding element allowing large displacements in one direction
VS-SBM	Elastomeric bearing with a sliding element allowing large displacements in all horizontal directions

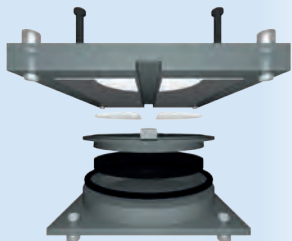


STRUCTURAL BEARINGS

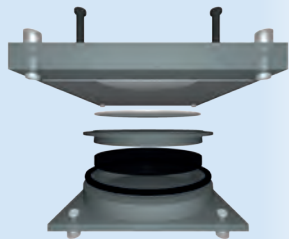
POT BEARINGS



Fixed pot bearing Type VS-P
with counterplates



Unidirectional pot bearing
Type VS-PU



Free sliding pot bearing
Type VS-PM

- ① Piston
- ② Elastomeric disc
- ③ Baseplate
- ④ Guide
- ⑤ Sliding plate
- ⑥ Sliding surface (PTFE + stainless steel)
- ⑦ Gasket

Pot bearings are designed to connect adjacent sections of a structure, transferring the vertical loads from e.g. the deck of a bridge to its piers and foundations.

With regard to horizontal displacements pot bearings can act as a restraint in one (unidirectional) or two directions (fixed), or they can allow free movements in all directions (free sliding). They also allow rotations around all axes.

DESIGN

Pot bearings consist of a round steel baseplate (pot) in which an elastomeric disc is inserted. A steel piston is placed above the elastomeric disc, so that vertical loads are transferred from the piston to the baseplate through the disc. In order to prevent the elastomeric disc to flow out the baseplate when compressed, a special gasket is installed at the disc's edge.

The elastomer, when compressed, acts as an incompressible fluid preventing vertical deflections, but through its deformability allows rotations around all axes.

Horizontal loads are transmitted through the steel-steel contact between the piston and the baseplate. This solution allows the transfer of very high horizontal loads.

Movable bearings (unidirectional and free sliding) are equipped with a sliding plate above the piston. The sliding plate is composed of a steel plate and a thin stainless steel sheet. This steel sheet is in contact with a PTFE sheet covering the upper side of the piston. Suitably greased, this arrangement – the sliding surface – has very low friction and thus negligible reaction.

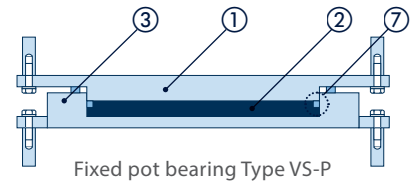
In unidirectional pot bearings, a guide allows movements in one direction and restrains the perpendicular one while transmitting the correspondent loads.

Pot bearings can be provided with different anchoring systems depending on the design requirements. Anchors are installed directly on the baseplate, on the piston (in fixed bearings) or on the sliding plate (in unidirectional and free sliding bearings).

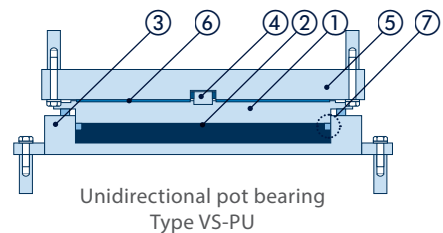
External counterplates can be provided to facilitate installation and replacement. In this case, the anchors are installed on the counterplate itself.

CONFIGURATION OF POT BEARINGS

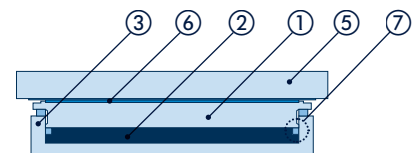
VICODA pot bearings are designed according to EN1337 and provided with a CE Mark. If required, they can also be designed and manufactured in compliance with other international standards like AASHTO, BS or DIN.



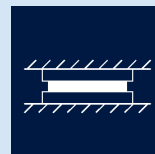
Fixed pot bearing Type VS-P



Unidirectional pot bearing
Type VS-PU



Free sliding pot bearing
Type VS-PM

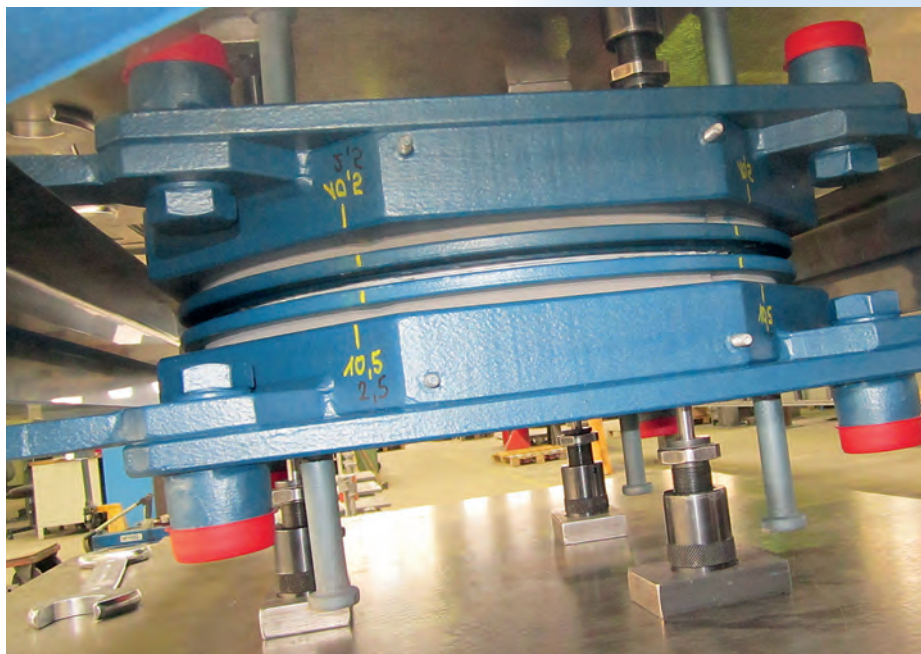


Assembly of free sliding pot bearings

In order to select the right bearing type and to choose the best solution, VICODA engineers are available to support you.

The data required to configure a pot bearing are:

- Load cases i.e. vertical and horizontal loads, horizontal displacements and rotations corresponding to minimum and maximum vertical load and to maximum horizontal load at the ultimate limit state (ULS)
- General description of the structure, geometrical limitations like installation height and anchoring requirements



▲ Final quality control of free sliding pot bearing

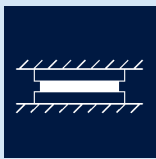


Pot bearings during installation and ...



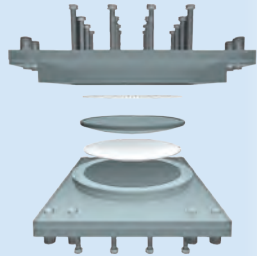
... after installation is completed

Type	Design		Max vertical load V [MN]	Max horizontal load H [MN]	Max horizontal movement	Max rotation [rad]	Service life [years]
Pot bearings	Fixed, with both horizontal directions restrained	→ VS-P	50	Up to 70% of V	No design limits	0.02	50
	Movable, with 1 horizontal direction restrained	→ VS-PU					
	Free, movable in all horizontal directions	→ VS-PM					

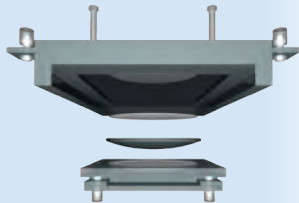


STRUCTURAL BEARINGS

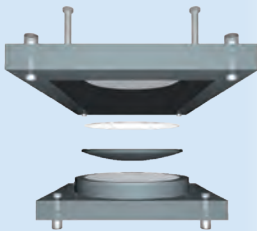
SPHERICAL BEARINGS



Fixed spherical bearing
Type VS-S



Unidirectional spherical
bearing Type VS-SU



Free sliding spherical
bearing Type VS-SM

- ① Top plate
- ② Spherical cap
- ③ Baseplate
- ④ Sliding surface (PTFE + stainless steel)
- ⑤ 2nd sliding surface (PTFE + hard chromium)
- ⑥ Sliding plate

VICODA spherical bearings represent the state of the art in the structural bearings range. They are suitable to transfer very high loads connecting the bridge deck to the substructure i.e. piers and abutments.

VICODA spherical bearings can restrain or allow movements in horizontal directions and, thanks to the internal spherical hinge, allow big rotations around every axis.

DESIGN

Spherical bearings are made of a round steel top plate, a hard chromium plated spherical cap and a convex steel baseplate. Two circular PTFE sheets are inserted in recesses machined on the top of the convex baseplate and on the top of the spherical cap respectively. The PTFE sheet inserted in the baseplate is in contact with the lower hard chromium surface of the cap, while the one inserted in the cap is in contact with a stainless steel sheet that is welded or bolted to the top plate.

Thanks to the low friction between the PTFE sheets and their stainless steel or hard chromium plated counter surfaces, the top plate, the baseplate and the cap can slide against one another, thus allowing displacements and rotations with only negligible reaction. In order to keep the friction as low as possible, the PTFE is suitable greased. Moreover, the stainless steel surface is machined with a smooth surface.

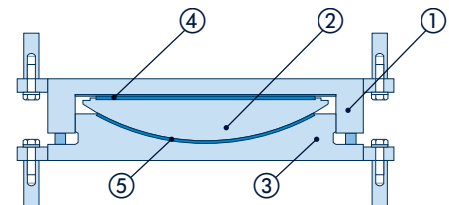
Vertical loads are transferred from the top to the baseplate through the PTFE surfaces and the spherical cap. Horizontal loads are transmitted through the steel-steel contact between the top and baseplate, without any load transfer through the spherical cap. Therefore spherical bearings allow the transfer of very high horizontal loads.

Movable bearings - unidirectional and free sliding - are accommodated by different designs of the top plate. In unidirectional bearings a guiding element limits displacements of the baseplate and the cap to only one direction. In free sliding bearings the top plate is replaced by a round or rectangular sliding plate, which is free to slide in every direction.

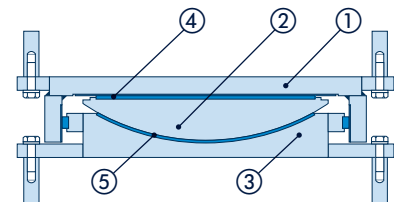
Spherical bearings can be provided with different anchoring systems depending on the design requirements. Anchors are normally installed directly on the base and on the top plates. External counterplates can be also provided to facilitate installation and replacement. In this case, the anchors are installed on the counterplate.

CONFIGURATION OF SPHERICAL BEARINGS

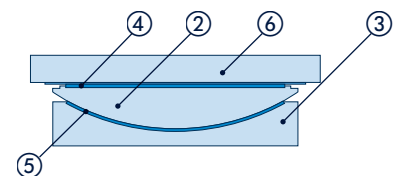
VICODA spherical bearings are designed according to EN1337 and provided with CE Mark. If required, they can also be designed and manufactured in compliance with other international standards like AASHTO, BS or DIN.



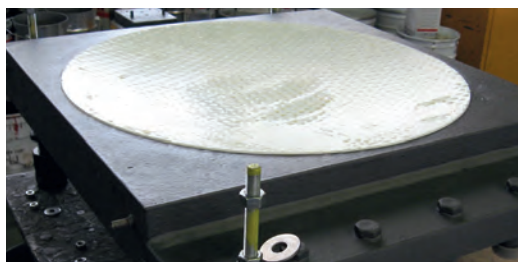
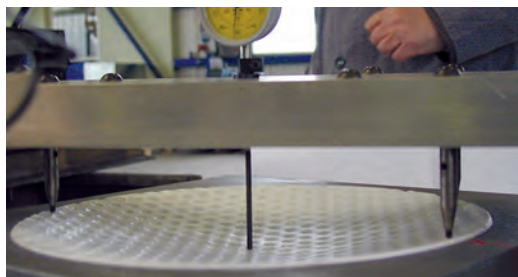
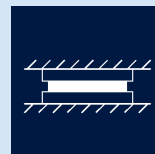
Fixed spherical bearing
Type VS-S



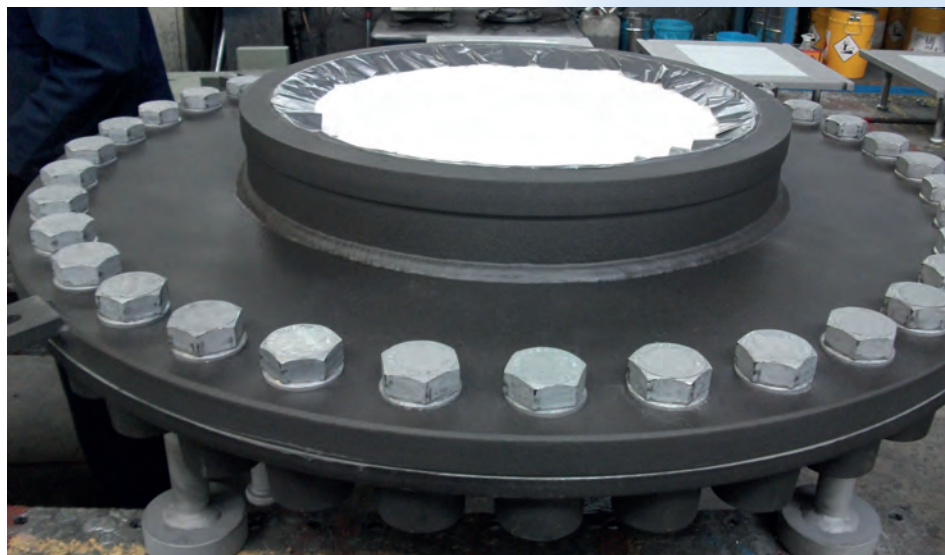
Unidirectional spherical bearing
Type VS-SU



Free sliding spherical bearing
Type VS-SM



Assembly of spherical bearings



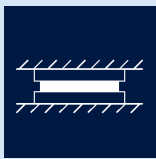
In order to select the right bearing type and to choose the best solution, VICODA engineers are available to support you. The data required to configure a spherical bearing are:

- Load cases i.e. vertical and horizontal loads, horizontal displacements and rotations corresponding to minimum and maximum vertical load and to maximum horizontal load at the ultimate limit state (ULS)
- General description of the structure, space or anchoring requirements



Spherical bearings ready for shipment

Type	Design		Max vertical load V [MN]	Max horizontal load H [MN]	Max horizontal movement	Max rotation [rad]	Service life [years]
Spherical bearings	Fixed, with both horizontal directions restrained	→ VS-S					
	Movable, with 1 horizontal direction restrained	→ VS-SU	50	Up to 100% of V	No design limits	0.15 and more	50
	Free, movable in all horizontal directions	→ VS-SM					



STRUCTURAL BEARINGS

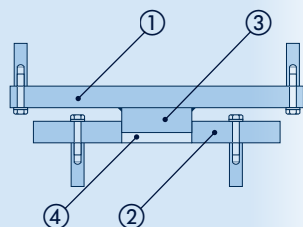
SHEAR KEYS



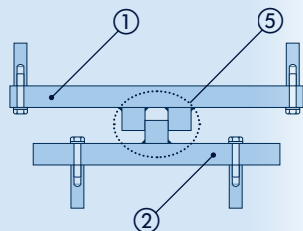
Installation of a fixed shear key



Movable shear key ready for shipment



Fixed shear key – type VS-K



Movable shear key – type VS-KU

- ① Top element
- ② Base element
- ③ Pin
- ④ Pin housing
- ⑤ Guide

Shear keys are structural components designed to transfer horizontal loads and to accommodate rotations. They do not transfer vertical loads.

In general pot bearings or spherical bearings are suitable to transfer both vertical and horizontal loads. However, if the horizontal forces acting in the structure are significantly higher than the vertical ones, the design of these bearings may no longer be efficient. In such cases shear keys offer a good solution, as they allow the transfer of high horizontal loads but only require limited space.

Therefore they are normally used in combination with free sliding bearings thus splitting the transfer of horizontal and vertical loads.

DESIGN

There are two basic designs of shear keys depending on their ability to transfer loads in only one or in both horizontal directions:

- fixed shear keys or *pins*, if they transfer forces in all directions
- movable shear keys or *guides*, if they transfer forces in one direction only allowing movements in the perpendicular one

In general shear keys are made of two steel elements forming a male-female joint, transferring the forces within the structure through proper anchorages. The male-female joint has to be designed in a way that the required rotations are possible.

The detailed design of shear keys may vary considerably depending on the magnitude of the acting forces, the required movements, and rotations as well as the available space.

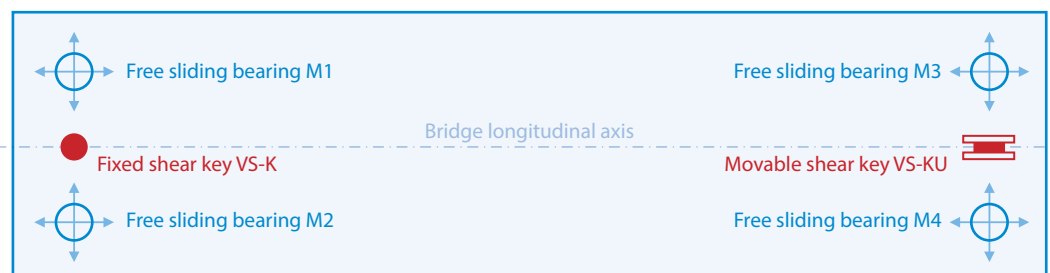
CONFIGURATION OF SHEAR KEYS

VICODA shear keys are designed according to EN1337 and provided with CE Mark. If required, they can also be designed and manufactured in compliance with other international standards like AASHTO, BS or DIN.

In order to design a shear key and to choose the best solution, VICODA engineers are available to support you. The data required to configure shear keys are:

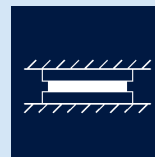
- Maximum horizontal load at the ultimate limit state (ULS) and corresponding horizontal displacements and rotations
- General description of the structure, space and anchoring requirements

Type	Design		Max vertical load V [MN]	Max horizontal load H [MN]	Max horizontal movement	Max rotation [rad]	Service life [years]
Shear keys	Fixed, with both horizontal directions restrained	→ VS-K	No vertical load allowed	No design limits	No horizontal movements	0.15 and more	50
	Movable, with 1 horizontal direction restrained	→ VS-KU	No vertical load allowed	No design limits	No design limits	0.15 and more	50



Shear keys – typical setup with structural bearings

SPECIAL BEARINGS



Elastomeric, pot and spherical bearings represent the most common solutions in bridge construction in order to form structural links between superstructure and substructure.

However, in specific cases, special bearings with different designs might be required. In particular, they are often indispensable in bridge maintenance, whenever the replacement of existing special components is needed without changing the layout of the structure.

VICODA, with the long experience of Schreiber Brückendehntechnik, is able to design and provide a wide set of special bearings e.g.

■ Roller bearings

These bearings are composed by one or more cylindrical rollers placed between an upper and a lower steel plate. The vertical loads are transmitted through a linear contact between rollers and steel plates and the horizontal movement occurs through the rolling of the cylindrical component.

■ Rocker bearings

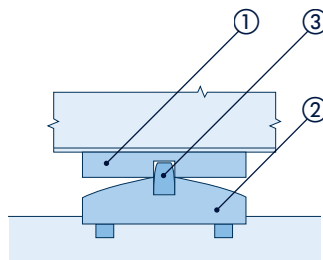
In rocker bearings the vertical loads are transmitted through a linear (line rockers) or point (point rockers) contact, between a curved steel plate and a rocker plate. Rocker bearings also allow rotations in one (line rockers) or every direction (point rockers) through the rotation of the curved component up on the rocker plate.

The transmission of the horizontal loads can be improved with the insertion of pins between the curved and the rocker plate.

■ Tailor-made solutions

There are many more applications where tailor-made solutions with very special functionality and layouts may be necessary. VICODA's technical department provides assistance and solutions in every phase of a bridge bearing project, from design to construction, installation and maintenance.

Special bearings can be designed and manufactured according to EN1337. If needed, they can also be supplied in compliance with different international standards like AASHTO, BS or DIN.



Rocker bearing

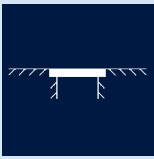


Roller bearing

- ① Rocker plate
- ② Curved plate
- ③ Pin



Special solution for high horizontal forces



EXPANSION JOINTS

SINGLE GAP EXPANSION JOINTS



Single gap expansion joint

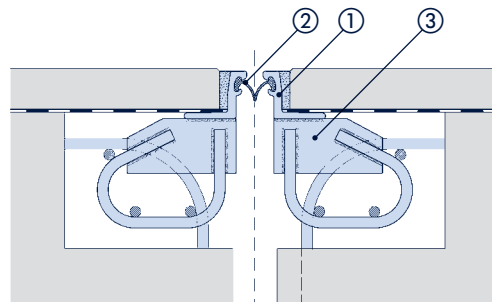
The single gap expansion joint type VS-JS is designed to cover longitudinal movements of a bridge of up to 80mm and transversal movements of up to 120mm. Small vertical movements and rotations between the two adjacent sections are also allowed. In this way, small inaccuracies in the bridge alignment as well as structural settlements can be easily accommodated.

DESIGN

Type VS-JS

The VS-JS expansion joint is composed by two symmetric steel profiles. These profiles are connected by an elastomeric profile covering the bridge gap thus providing water tightness to the expansion joint. The water tightness of the VICODA VS-JS expansion joints has been tested at the Stuttgart MPA laboratory according to the TL/TP FÜ (03/05) German standard.

- ① Steel profile
- ② Elastomeric waterproof profile
- ③ Anchor



Type VS-JS

The elastomeric compound has been developed in order to resist oil, grease, salt and other aggressive media thus guaranteeing a long service life of the joint.

In order to connect the joint to the bridge, anchors welded on the steel profiles are poured in the concrete of the deck. This ensures a very robust connection and an excellent fatigue resistance.

A number of different steel profiles and anchoring systems are available so that the VS-JS can be installed in all typical bridge structures. Moreover, thanks to the little

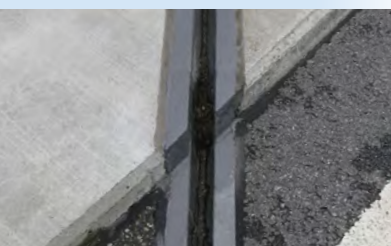
space required for installation, it is particularly suitable for replacements on existing bridges.

The detailed layout of an expansion joint e.g. the layout of the anchoring system is depending on the loads acting on the joint. Obviously the vertical loads on sidewalks are significantly smaller than the ones on the driving lanes of the bridge. Therefore the design can be adapted depending on the load. For typical loads on sidewalks a design based on a simple aluminium or stainless steel plate is often sufficient.

The effective design together with the high quality of the materials, guarantees a long service life of these products.



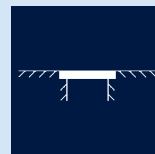
Aluminium side walk



Shaped steel profile sidewalk



Quality control on VS-JS joints



Type VS-JSR with noise reduction

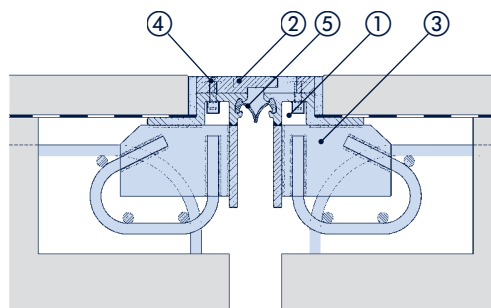
Whenever noise protection is mandatory single gap expansion joints can be equipped with noise reduction profiles.

The VS-JSR consists of two base profiles, similar to those of the standard VS-JS, on which two special wave-shaped steel plates are bolted. When driving over the expansion joint, a wheel always touches at least one of the steel plates, thus crossing the joint more smoothly.

Thanks to the wave-shaped plates the longitudinal allowable movement of the VS-JSR is increased to 120mm. Special designs can be provided if the longitudinal movement is not perpendicular to the expansion joint.

CONFIGURATION OF A SINGLE GAP EXPANSION JOINT

In order to select the right expansion joint type and to choose the best solution, VICODA engineers are available to support you.

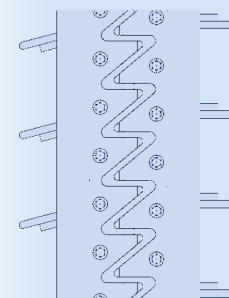


Type VS-JSR

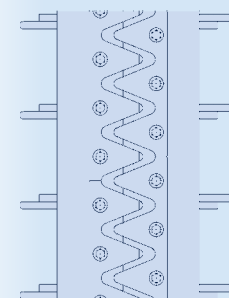
- ① Base profile
- ② Wave plate
- ③ Anchor
- ④ Connecting bolt
- ⑤ Elastomeric waterproof profile

Required data in order to design a single gap expansion joint are

- Max longitudinal and transversal movement (mm)
- Gap width (mm)
- Road cross section
- Special requirements like sidewalks layout, preset, surface treatment, noise reduction feature

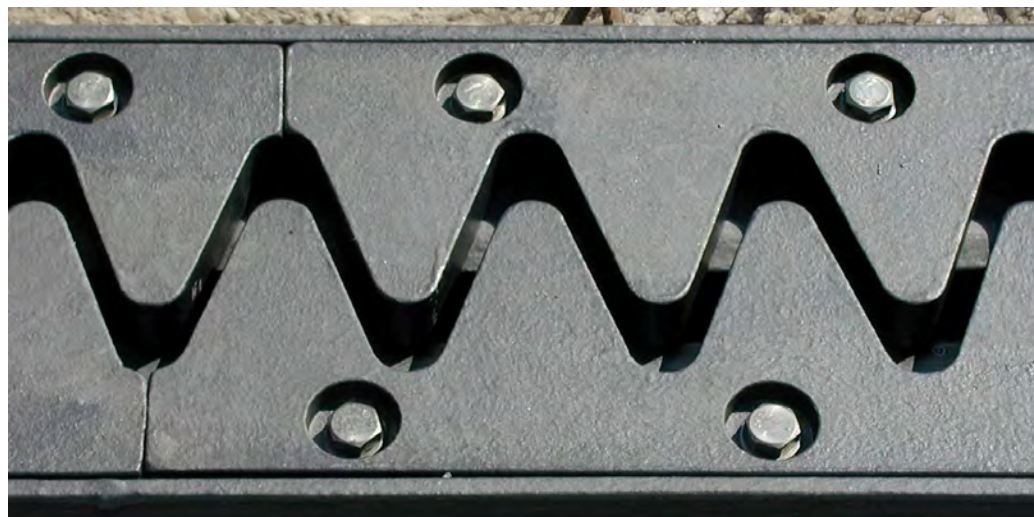


Type VS-JSR with skew angle

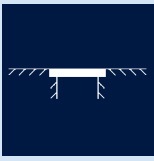


Type VS-JSR

Type		Movements [mm]			Noise reduction	Service life [years]
		Longitudinal	Transversal	Vertical		
Single gap expansion joints	→ VS-JS	80	120	10	No	50
Single gap expansion joints with noise reduction	→ VS-JSR	120	120	10	Yes	50



Single gap expansion joint with noise reduction installed



EXPANSION JOINTS

REINFORCED RUBBER EXPANSION JOINTS

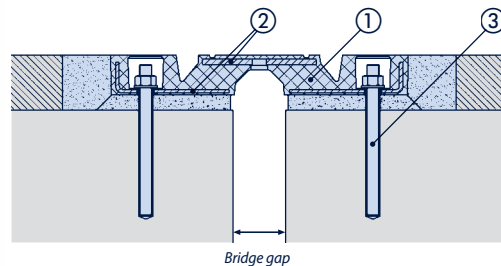
VICODA reinforced rubber expansion joints type VS-Flex are designed to cover longitudinal and transversal movements of a bridge from 50mm up to 320mm. Small vertical movements and rotations between the two adjacent sections are also allowed. In this way, small inaccuracies in the bridge alignment as well as structural settlements can be easily accommodated.

VICODA VS-Flex expansion joints represent a very compact and cost effective solution, particularly suitable for replacements due to the little space required for installation and the simple installation concept.

DESIGN

VICODA VS-Flex expansion joints consist of a rubber mat reinforced by inserted steel profiles. The joint compensates the movements of the bridge by the deformation of the rubber. The steel profiles provide resistance and stiffness to the product.

- ① Rubber mat
- ② Steel profiles
- ③ Anchors



The environmental conditions in which these expansion joints are installed are sometimes harsh. For this reason the rubber compound has been specially developed in order to resist oil, grease, salt and other aggressive media without suffering from premature aging.

VICODA joints type VS-Flex are manufactured in modules with a length of two meters. They are installed next to each other to cover the complete cross section of a bridge.

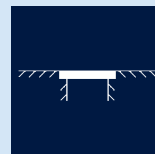
A male-female joint permits to connect each rubber module with the next one. In case a damaged module needs to be replaced, this feature allows the substitution of only the respective module instead of the entire expansion joint. An additional advantage is that for the replacement of a module only a part of the bridge needs to be blocked thus allowing quicker maintenance and above all continuous traffic.

Depending on the width of the gap and the expected movements different types of reinforced rubber expansion joint are available.

Together with the rubber modules, VICODA supplies all the necessary anchoring equipment. Anchors are designed to resist heavy traffic loads, including horizontal forces induced by braking vehicles. They need to be tightened with a dynamometric key thus ensuring a permanent compression of the rubber. This prevents the modules from lifting up when the joint is closing.

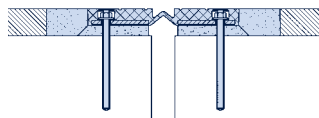


Viaduct over the river Neckar – Germany

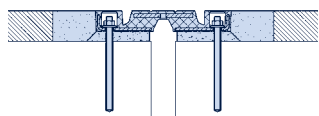


VS-FLEX PRODUCT RANGE

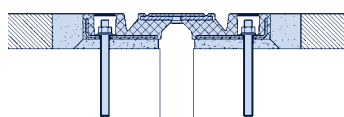
VS – Flex 50



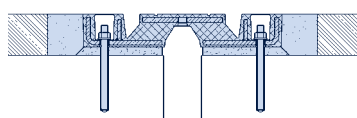
VS – Flex 80



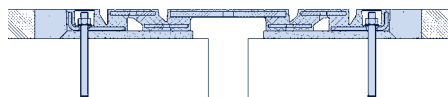
VS – Flex 120



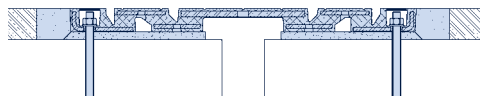
VS – Flex 160



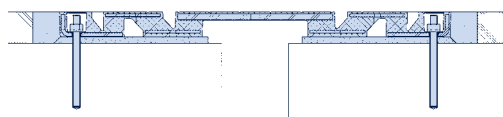
VS – Flex 200



VS – Flex 250



VS – Flex 320



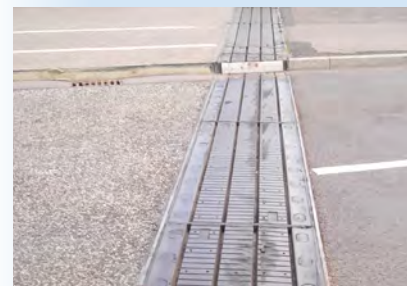
A special surface layout of the joints reduces noise emissions due to vehicles driving over the expansion joints and preserves good tyre adhesion. VICODA VS-Flex expansion joints are waterproof. Water tightness is provided by a rubber flashing which is fixed on the edges of the gap. The shape of the flashing easily allows longitudinal and transversal movements.

Reinforced rubber expansion joints can be supplied with aluminium or stainless steel covers for the sidewalk gaps.

CONFIGURATION OF A REINFORCED RUBBER EXPANSION JOINT

In order to select the right expansion joint type and to choose the best solution, VICODA engineers are available to support you. Required data to design a reinforced rubber expansion joint are

- Max longitudinal and transversal movement (mm)
- Gap width (mm)
- Road cross section
- Special requirements like sidewalks layout or preset

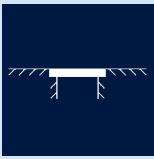


VS-Flex installed



VS-Flex in operation

Reinforced rubber expansion joints Type	Movements [mm]		Bridge gap [mm]	Service life [years]
	Longitudinal and transversal	Vertical		
VS-Flex 50	50	20	45	20
VS-Flex 80	80	20	50	20
VS-Flex 120	120	20	70	20
VS-Flex 160	160	20	90	20
VS-Flex 200	200	20	110	20
VS-Flex 250	250	20	140	20
VS-Flex 320	320	20	220	20



EXPANSION JOINTS

FINGER EXPANSION JOINTS



Finger expansion joint with stainless steel sidewalk

VICODA finger expansion joints type VS-F are designed to cover longitudinal movements of the bridge deck from 50mm up to 400mm. Their robust design allows high traffic loads and ensures extreme resistance to fatigue, guaranteeing a long service life.

DESIGN

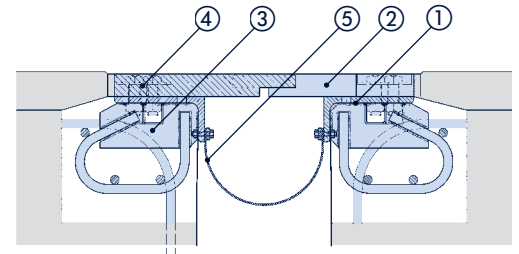
VICODA finger expansion joints are composed of two symmetric finger-shaped plates bolted to two base profiles.

Transversal movements may be accommodated through a special layout. To provide this feature one of the two finger-shaped plates needs to be disconnected from the anchoring profile in order to allow the joint to move. Through this simple concept, there is no limitation to the transversal movement.

In order to connect the joint to the bridge, anchors welded on the steel profiles are poured in the concrete of the deck. This ensures a very robust connection and an excellent fatigue resistance. VICODA finger expansion joints are waterproof. Water tightness is provided by a rubber flashing which is fixed on the edges of the gap. The shape of the flashing allows longitudinal and transversal movements.

Like in the case of the single gap expansion joints with noise reduction type VS-JSR, wheels crossing the joint always touch at least one of the finger-shaped plates.

Due to this geometry of VICODA's finger expansion joints, the noise emissions whenever vehicles drive over the joints are very low. Finger expansion joints can be supplied with aluminium or stainless steel covers for the sidewalk gaps.



Finger expansion joint type VS-F

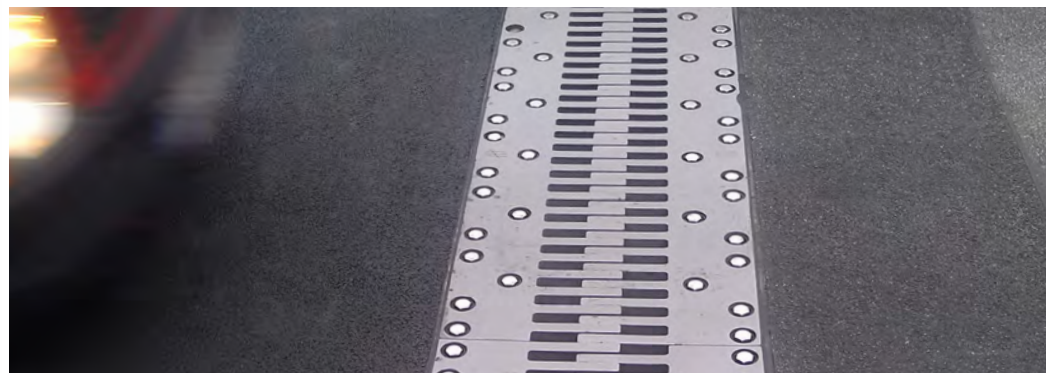
CONFIGURATION OF A FINGER EXPANSION JOINT

In order to select the right expansion joint type and to choose the best solution, VICODA engineers are available to support you. Required data in order to design a finger expansion joint are

- Max longitudinal and transversal movement (mm)
- Gap width (mm)
- Road cross section
- Special requirements like sidewalks layout, preset or surface treatment

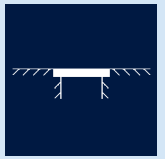
- ① Base profile
- ② Finger-shaped plate
- ③ Anchor
- ④ Connecting bolt
- ⑤ Rubber flashing

Type		Movements [mm]			Noise reduction	Service life [years]
		Longitudinal	Transversal	Vertical		
Finger expansion joints	→ VS-F	Up to 400	No design limits	10	Yes	50



Finger expansion joint in operation

SPECIAL EXPANSION JOINTS



Based on the long experience of Schreiber Brückendehntechnik VICODA is able to design and deliver a wide set of special expansion joints needed e.g. during bridge maintenance when replacing installed components e.g.

■ Roller shutter joints

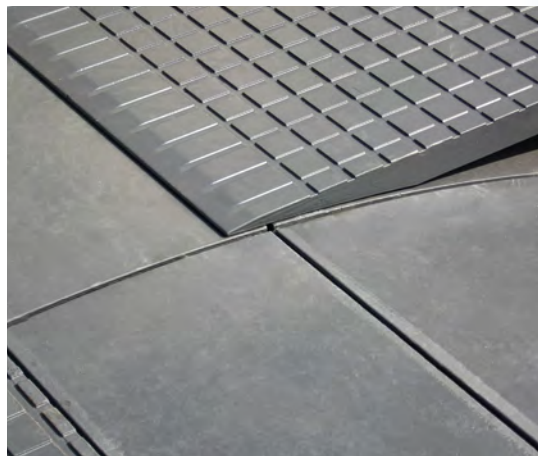
These extremely robust expansion joints are made by a set of steel plates which can roll along a curved support (roller shutter) – they allow very large longitudinal movements of up to 1000mm and more with a very reliable and safe design – VICODA designs and replaces these particular products for more than 30 years



Handling and positioning of multi steel profiles expansion joint

■ Multi steel profile expansion joints

These joints are suitable for large movements up to 400mm and more – they are composed of a set of steel profiles and supported by a kinematic mechanism installed in the joint gap



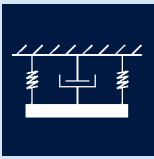
Roller shutter joint surface detail

■ Tailor-made solutions

There are many more applications where tailor-made solutions with very special functionality and layouts may be necessary – VICODA's technical department provides assistance and solutions in every phase of a bridge project, from design to construction, installation and maintenance



Roller shutter joint during installation



TUNED MASS DAMPERS

In bridges unwanted vibrations can occur due to different causes like wind, traffic or earthquakes. These vibrations, if not properly controlled, can lead to high stress resulting in early fatigue of the bridges' structures. In footbridges even walking pedestrians can excite oscillations of the bridge creating discomfort and structural risk.

A particularly dangerous situation appears if the frequency of an excitation is equal or close to one of the natural frequencies of the bridge. In this case the bridge enters into resonance resulting in oscillations of the bridge beyond an acceptable i.e. safe level.

VICODA tuned mass dampers (TMDs) represent a very efficient solution to control unwanted vibrations and to keep oscillations within acceptable limits.

DESIGN

The VICODA tuned mass damper is a device consisting of a mass, a spring and a damping element that when installed on a bridge reduces its dynamic response. In fact a TMD is able to efficiently absorb the energy of the bridge's vibrations. For an efficient absorption the TMD needs to be tuned to the main natural frequency of the bridge.

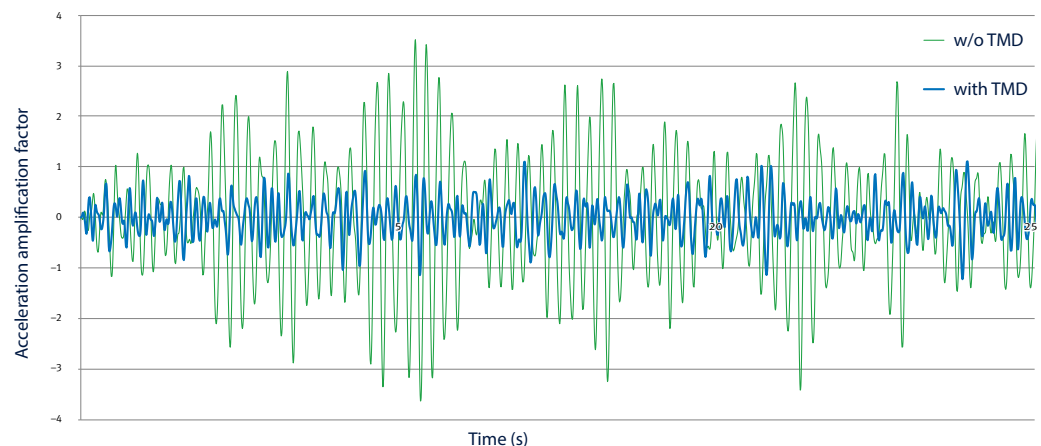
One of the advantages of TMDs is that they do not need any external abutment. They can be installed directly on the bridge. This makes it very simple to mount TMDs when building a new bridge or when retrofitting existing ones. VICODA, through its partner WOELFEL, designed its first TMD for the Erlach footbridge, Germany, in 1971.

VICODA TMDs are equipped with a damping element widening the TMD's range of application with regard to excitation frequencies. These damping elements typically are VICODA viscoelastic dampers dissipating energy by the movement of a steel piston in a viscous fluid.

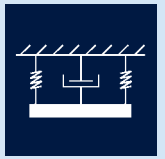
TMDs can act in up to three dimensions. VICODA can provide TMDs for a wide range of applications. Depending on the specific situation different designs like spring or pendulum type TMDs are used.



Murr valley viaduct – Germany



Dynamic response of a bridge with or without TMD



ADVANTAGES OF TMDs

- Efficient reduction of structural vibrations
- High savings in the overall structural costs
- No external abutment required
- Suitable both for new and existing structures
- Modular design for application in one to three dimensions

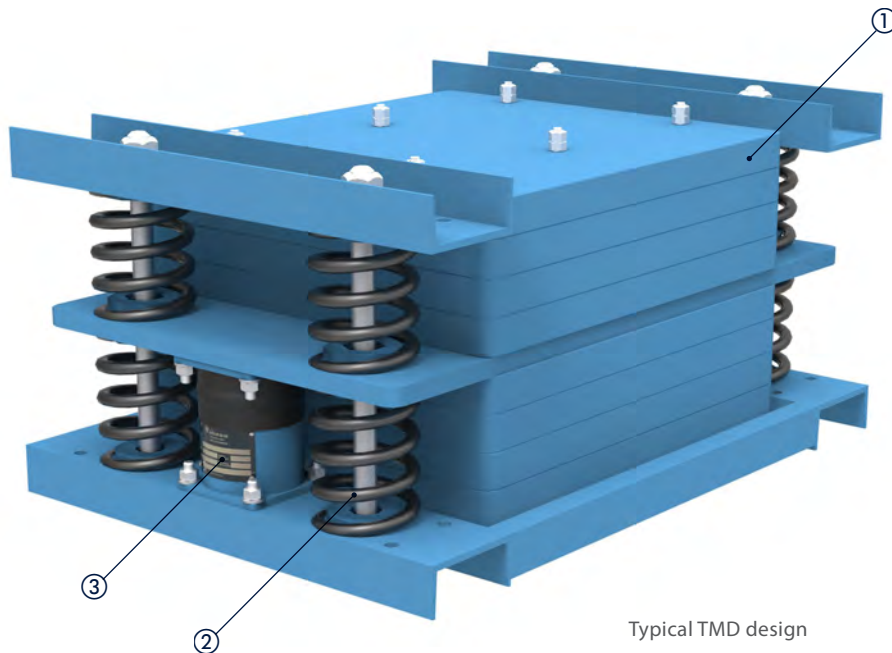


Pedestrian bridge over the river Main – Germany

CONFIGURATION OF A TMD

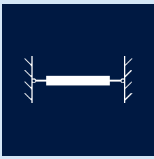
For proper design of a vibration control solution using VICODA TMDs, the support of VICODA's engineers is mandatory. The first step in the solution process is a detailed analysis of the vibration problem.

In case of retrofit of an existing structure, on-site measurements might be required. The optimum design will be defined in close cooperation with the customer.



- ① Mass
- ② Springs
- ③ Damping element

Typical TMD design



VISCOUS FLUID DEVICES

LOCK UP DEVICES

Apart from tuned mass dampers VICODA provides a set of viscous fluid devices to control unwanted vibrations and to resist shock or impulsive loads in bridges. These devices use different physical principles in order to protect the bridge structure e.g. in case of excitations due to strong winds, earthquakes or traffic. The two basic types of viscous fluid devices are viscous fluid dampers and lock up devices.

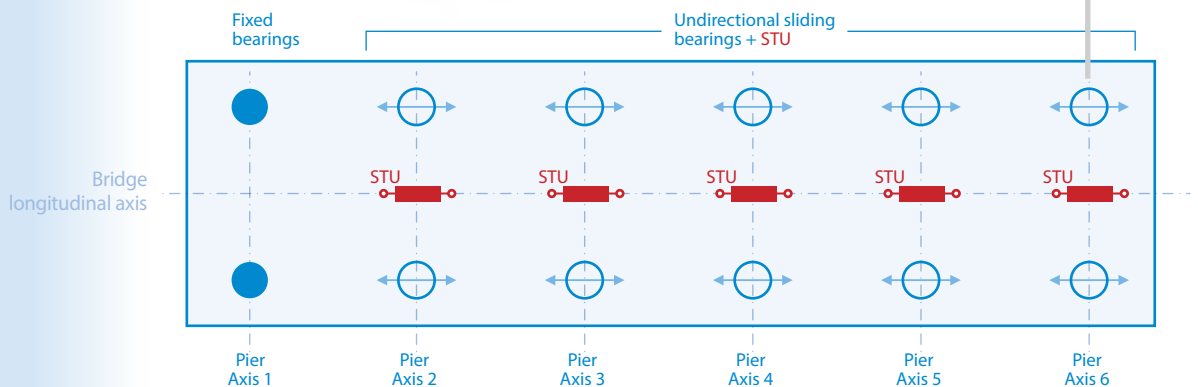
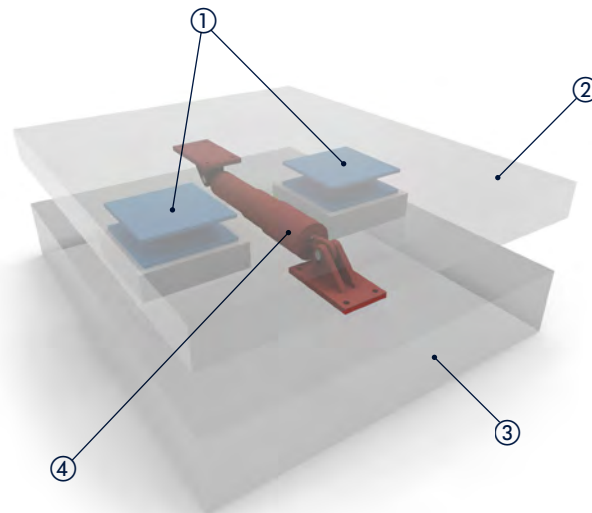
LOCK UP DEVICES

Lock up devices or shock transmission units (STUs) are used to protect bridges from dangerous dynamic stresses, in particular due to earthquakes. STUs are typically installed between the bridge deck and the substructure, i.e. piers and abutments, to control horizontal movements.

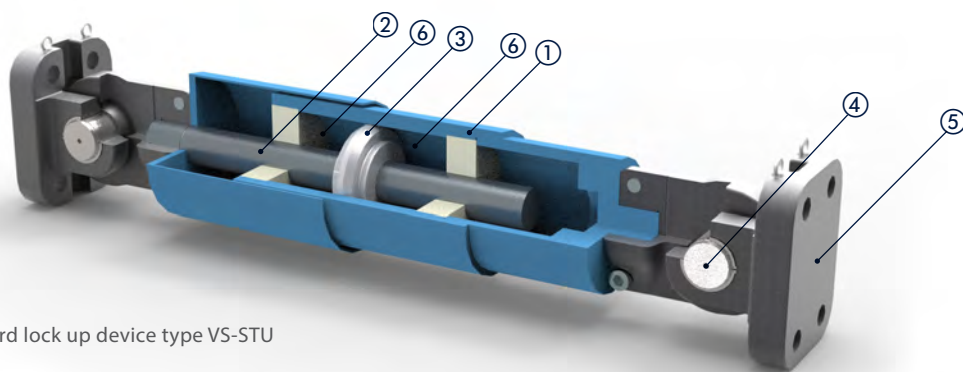
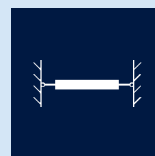
STUs operate in two different modes

- in “standard mode”, i.e. under normal conditions – in this case slow movements between the bridge deck and the substructure as a response to thermal expansion, concrete creep and shrinkage are possible with a negligible resistance from the STU
- in “safety or lock up mode”, i.e. under high dynamic excitation – in this case the STU internally blocks and reacts as a rigid link between the bridge deck and the substructure so that exciting forces are completely transferred – by that all horizontal forces will be spread among several points defined by the designer thus avoiding stress peaks in particular locations

- ① Movable structural bearings
- ② Bridge deck
- ③ Pier head
- ④ STU



STUs - typical setup with structural bearings



Standard lock up device type VS-STU

- ① Steel cylinder
- ② Rod
- ③ Piston
- ④ Spherical hinge
- ⑤ Anchor
- ⑥ Chambers

DESIGN

Standard design

VICODA's standard lock up devices consist of a steel cylinder filled with a special silicone fluid, a rod and a piston. The piston divides the cylinder into two chambers. In case of slow movements of the piston i.e. velocities of less than 0.1mm/s, the fluid can flow from one to the other chamber through the gap between piston and cylinder. In case of quick movements, i.e. velocities of more than 1mm/s, the viscosity of the fluid increases significantly preventing any further flow between the two chambers and by that blocking the internal movement of the device.

Spherical hinges between the cylinder and the connecting anchors simplify installation of the damper and avoid bending of the piston rod.

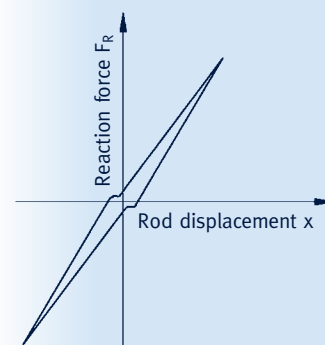
The reaction force F_R of the device as a function of the rod displacement x is shown in the adjacent figure, showing only a small hysteresis loop.

Special design

VICODA also offers special i.e. highly precise lock up devices. LISEGA, VICODA's parent company, is one of the global market leaders for STUs and the preferred supplier for technically demanding STUs solutions e.g. for application in nuclear plants. It is the

internal control valve that makes the main difference between standard and special devices. This valve allows significantly tighter tolerances leading to lower friction within the device, i.e. about only 1% of nominal load instead of 10%. Based on LISEGA's long research and development experience regarding valves VICODA is able to customize valves to a wide range of special requirements.

A special feature of the VICODA STUs is that the valve unit can be replaced without removing an installed device. By that, recurrent tests of the valve units are easily possible and can be effected with minimum effort.

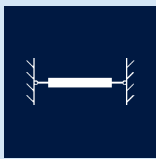


Typical hysteresis of a lock up device during an earthquake



STUs ready for shipment

Type	Behaviour with slow movements (thermal, creep, shrinkage)	Behaviour with dynamic actions (vehicle braking, wind, earthquakes)	Max axial load [MN]	Max stroke [mm]	Service life [years]
Lock up devices (STUs) → VS-STU	Allow movement with negligible reaction force	Transmit dynamic force as a rigid link	7	1000	50



VISCOUS FLUID DEVICES

VISCOUS FLUID DAMPERS

- F_R = Reaction force
 c = Damping parameter
 v = Velocity
 α = Damping exponent

Strong winds and earthquakes often induce excessive dynamic loads into bridge structures. In order to ensure no structural damages, these forces and the consequential displacements need to be reduced to a harmless level. VICODA's viscous fluid dampers reduce these vibrations and impulsive dynamic forces by the technique of energy dissipation.

As viscous fluid dampers reduce the kinetic energy in the structure itself, design engineers of bridges can use smaller structural elements and less complex foundations thus reducing the overall cost for the structure.

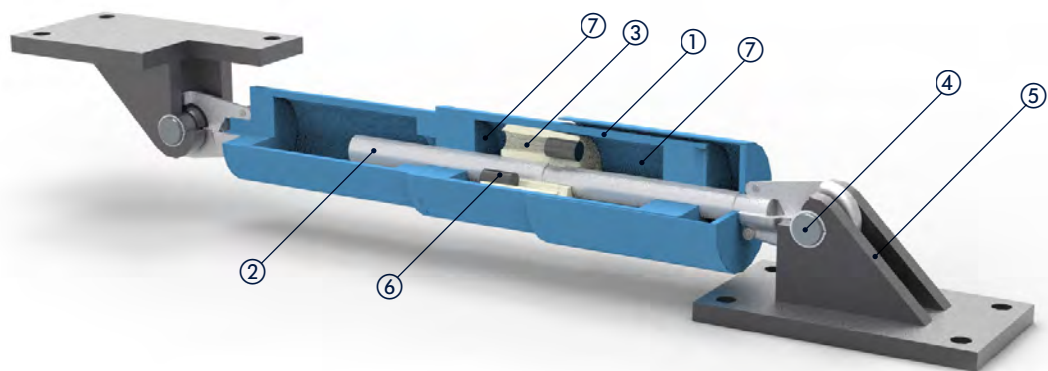
Hydraulic dampers counteract external forces with a reaction force F_R that can be typically described by

$$F_R = cv^\alpha$$

Typical values for the damping exponent α range from 0.01 to 0.4. The effect of different damping exponents on the resulting reaction force at a given velocity is given in the adjacent graph.

The energy dissipated in the damper is a function of the reaction force F_R and the displacement x . The size of the elliptical areas in the second graph is proportional to the respective dissipated energy.

- ① Steel cylinder
- ② Rod
- ③ Piston
- ④ Spherical hinge
- ⑤ Anchor
- ⑥ Valve
- ⑦ Chambers



Viscous fluid damper type VS-VD

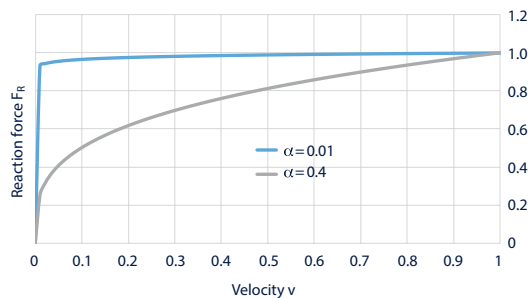
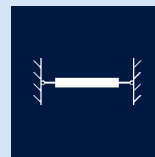
DESIGN

Viscous fluid dampers consist of a hydraulic cylinder, a rod, a piston and a valve regulating the flow of the hydraulic fluid from one chamber of the cylinder to the other. The piston is equipped with seals in order to prevent leakage between the chambers and to the environment.

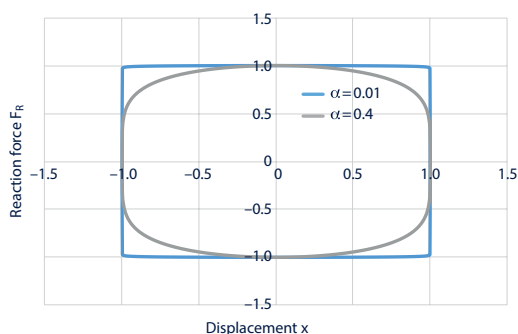
Spherical hinges between the cylinder and the connecting anchors simplify installation of the damper and avoid bending of the piston rod.

Standard valve configurations of viscous fluid dampers typically have very low reaction forces for velocities of less than 0.1mm/s. Whenever the motion speed due to an excitation or vibration exceeds 1mm/s the viscous fluid damper starts to counteract with an increasing reaction force, as shown in the graph.

With customized valves specific force – velocity dependencies can be realized thus creating different dynamic responses of the damper. All valves are designed, manufactured and tested in our facilities.



Typical force / velocity diagram for a VICODA viscous fluid damper



Typical force / displacement diagram



Thyra valley bridge – Germany

CONFIGURATION OF LOCK UP DEVICES AND VISCOUS FLUID DAMPERS

In general VICODA's STUs and viscous fluid dampers are designed according to EN15129 and provided with a CE Mark. If required, they can also be designed and manufactured in compliance with other international standards or specific customer requirements. VICODA engineers will help you to specify the devices in line with your requirements.



Valves of a VICODA viscous fluid damper

	Type	Behaviour with slow movements (thermal, creep, shrinkage)	Behaviour with dynamic actions (vehicle braking, wind, earthquakes)	Max axial load [MN]	Max stroke [mm]	Service life [years]
Viscous fluid dampers	→ VS-VD	Allow movement with negligible reaction force	Reduce dynamic force by damping energy (up to 75%)	5	1000	50



SERVICES

VICODA is not only a high quality product manufacturer but also a reliable service and solution provider. With its wide experience VICODA can supplement any product offer with a comprehensive set of technical services, from engineering at the design stage to installation and maintenance or general technical assistance.

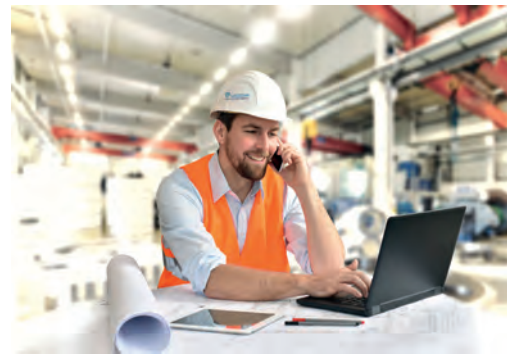
1. STRUCTURAL ENGINEERING

VICODA offers the entire scope of structural engineering for bridges, with special emphasis on the assessment of dynamic load cases. Structural engineering services can be provided for highway, railroad, pedestrian and pipe bridges in concrete, steel, composite and lightweight construction:

- static and dynamic analysis for all load cases including wind loads, seismic loads as well as pedestrian or traffic induced loads
- general design support according to German, European or international standards
- seismic evaluation of existing structures, including assessment of damage caused by earthquakes with classification of the damage and development of retrofit measures
- definition of measures to reduce unwanted vibrations
- design support for seismic protection devices

2. VIBRATION MEASUREMENTS

VICODA can support its customers with the vast experience of highly-specialized measurement engineers. With their comprehensive equipment VICODA engineers can perform all types of related vibration measurements, from one-day data acquisition to a long-term monitoring setup producing daily or weekly reports.



3. SPECIAL PRODUCT DESIGN

Besides the wide range of standard products, VICODA can develop and manufacture special products in line with exceptional technical specifications:

- extreme loads, strokes or rotations
- negative loads (uplift devices)
- special seismic protection devices
- temporary links or dampers for specific construction phases
- solutions with minimum space requirement



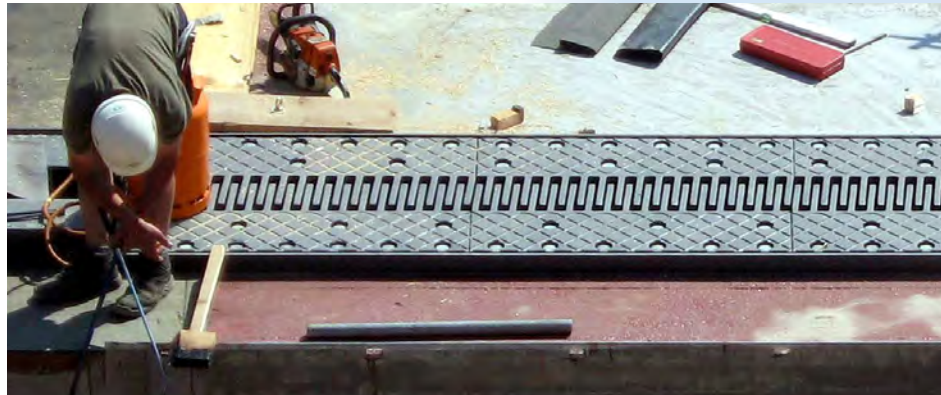
4. INSTALLATION

All VICODA products are supplied with comprehensive installation manuals where the correct handling, transport, installation and commissioning of products are described in detail. If required, complete installation can be provided by a VICODA team or the installation process can be overseen by an experienced supervisor.

5. REPAIR AND MAINTENANCE

For the repair and maintenance of structural bearings, expansion joints, TMDs or viscous fluid devices, VICODA engineers can provide all the necessary technical support at all stages of these processes:

- site inspections and structural assessment
- bridge lifting, bearings retrofit or replacement
- expansion joints, viscous fluid devices and dampers retrofit or replacement
- seismic assessment of existing bridges and implementation of seismic protection measures
- vibration analysis, design and implementation of vibration control solutions



Installation of a finger expansion joint

6. MONITORING SYSTEMS

VICODA's monitoring systems are highly suitable for remote monitoring of bridges. They can provide detailed information about the status of VICODA products and comprehensive structures.

For this purpose sensors are mounted on the structure and connected with a data acquisition unit on site. The evaluation and storage of data is effected by a central computer system. Data access is made available for customers via web services.

VICODA's bridge monitoring systems are characterized by a modular structure. Configuration is carried out individually according to customer requirements.



Typical VICODA on-site measuring equipment

QUALITY

1. QUALITY

One of the fundamental company principles at VICODA is the continuous delivery of superior product quality. This quality culture necessitates close and concise interaction with VICODA's business partners and drives the organization and actions of VICODA personnel as well.

The particular measures of the Quality Management Department, ensuring product quality, are outlined in the Quality Management Program. These measures and activities to promote quality are an integral component in the processing cycle and are firmly rooted in all procedures.

Following international codes and standards, the Quality Management Program is described in detail in the Management Manual. This manual takes into account all the recognized European and international standards. VICODA is an ISO9001 certified company.

2. MANUFACTURING

One of the strengths of VICODA is that not only the design, but almost the complete manufacturing process of the products is performed in house. All production phases, from oxycutting to machining, drilling, welding, painting and assembly are executed within VICODA's or LISEGA's own facilities. The LISEGA Group can fulfil the highest quality standards thanks to more than 50 years of industrial manufacturing experience in delivering high quality products to the power industry and the oil & gas sector.

All steel components are built in line with EN-DIN, ASTM or CN steel material standards. In general, welding is carried out according to EN 1090.

3. CORROSION PROTECTION

VICODA products are designed for a long service life. Depending on customer requirements, different surface protection systems are available, providing corrosion protection in line with the corrosion categories defined in EN ISO 12944.

Unless specified differently, all products receive standard surface protection corresponding to corrosion category C3, medium protection period (M), appropriate for environments with a moderate industrial atmosphere.



Quality control on a VICODA STU

4. TESTING

VICODA's own testing laboratory is equipped to perform static and dynamic tests in axial or multi-dimensional layouts. Apart from standard tests customer-specific tests can be performed:

- type tests and final inspection tests for viscous fluid dampers and shock transmission units (STUs) according to EN15129
- final testing for structural bearings according to EN1337
- dynamic tests, damping assessment and tuning of dampers (viscous fluid dampers or tuned mass dampers)
- fatigue tests on different products (dampers, structural bearings, expansion joints)

5. RESEARCH AND DEVELOPMENT

VICODA's wide product range and comprehensive service portfolio allow designers and operators of bridges to handle technical problems linked to the structural design, construction and maintenance of bridges. This is the result of VICODA's strong commitment in conceiving new solutions and improving existing ones.

VICODA engineers are on standby to support you. Their ambition is to always provide the optimum solution.



Dynamic test on viscous fluid damper at VICODA testing laboratory



3D test stand at VICODA testing laboratory



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