TENSA

VOLUME	PRODUCTS CATALOGUE
01	STAY CABLES

YOUR CHALLENGES,
OUR SOLUTIONS

High Speed Train line from Milan to Naples, Cable stayed bridge over the river Po, Piacenza (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 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 everywhere in the world, 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.

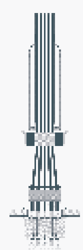
PRODUCT CATALOGUES

Erasmus bridge, Rotterdam (The Netherlands)

02

STAY CABLE SYSTEMS

The stay cable system is suitable for use
in different applications such as cable stayed bridges,
arch bridges, suspended structures,
buildings and structures for technological services.



PREVIEW

TENSA started to develop its technology for cable stayed bridges in the eighties.

The first small cable stayed bridge was built in 1988, paving the way for the development of the resin-coated wedge anchorage system that found its mature application in the bridge over the Garigliano river in Formia.

Further on, the technical solution with waxed, polyethylene coated strands was adopted, finding its most famous application in the renowned Erasmus bridge in Rotterdam, with huge stays of 127 strands reaching more than 300 meters in length.

Through the years, continuous improvements have allowed TENSA to stay at the forefront of this technology, resulting in the construction of more than 50 cable stayed bridges, using its TSR stay cable system.

One of the most prestigious is the cable stayed bridge over the river Po, designed for the high speed railway line from Milan to Bologna, in Italy. It is the first known example of this kind of structure.

Later on, TENSA completed the erection of a cable stayed bridge over the river Adige in Italy with 169 strands stays, giving a maximum breaking load of more than 47.000 kN.

Several kinds of cable stayed bridges were built in different places, with the TSR system being adopted also in the USA, India, Middle East along with the usual market place of Europe.

At this moment TENSA is directly involved in cable stayed bridges projects in all five continents.

As a specialized contractor with decades of experience in the field, TENSA's Engineering Department is able to provide all services related to the design, manufacture, and installation as well as monitoring of stay cables.

Starting from the analysis of the whole structure, the design of stays is executed, with shop drawings and specifications for manufacturing, issuing of installation procedures with load and elongation checks along with further engineering services.
New and customized solutions are continuously released, in order to accommodate different projects.

TENSA directly follows all installation operations, with its own specialized teams and equipment being fully accountable and operating under ISO 9001 quality assurance system.

The TENSA stay cable system can be used for several different construction applications such as:

Cable stayed bridges
Stays are used to connect pylons to deck, allowing a considerable increase of span length.

Arch bridges
Stays act as vertical or inclined hangers connecting arch to deck.

Suspended structures
Roofs, walkway coverages and lightweight domes can be easily suspended with stay cables.

Buildings and Structures for technological services
TLC Towers, wind power stations, exhibition columns can be erected and stabilized with stay cables.

Erasmus bridge, Rotterdam
(The Netherlands)

PARALLEL STRANDS STAY CABLE SYSTEM

The TENSA stay cable system has been designed and tested in order to guarantee the highest levels of performance, meeting the most stringent market requirements.

Key advantages can be summarized as:

Higher protection against corrosion both in the anchorage area and in the free length of stays
Corrosion protection has been handled by adding different layers of protection surrounding the main tension element (i.e. steel strand). Anchorages and transition zones are provided with high performance anti-corrosion protection; seals and water tight connections along the stays' length guarantee complete protection and enhanced durability.

Resistance to axial and bending fatigue loads
The use of high performance wedges and bending filtering devices placed in the stay cables transition zone provides an outstandingly safe solution towards the long-term performance of stay cables.

Easy replaceability and maintenance
A modular designed multi-strand system allows single strands substitution and easy inspection for all components. The system meets the demand for a sustainable technology that minimizes costs for maintenance and reduces waste during the entire life cycle of the product.

Vibration control of the stays
The joint combination of compacted size ducts provided with ribs over the external surface and different types of dampers, both internal and external, provides an adequate solution for minimizing wind drag and reducing stay vibrations.

Easy and efficient installation
Special lightweight dedicated equipment and installation procedures, which improve continuously, allow flexible erection schedules to meet the Contractor's demand for a reduced number of stay installation activities on the critical path.

Improved aesthetics
The use of compact size coloured ducts, special pin shape anchorages and a variety of technical solutions for different applications allow Owners and Designers to create stylish solutions appealing to all users.

Cable stayed bridge in Alves, Bressanone (Italy)

TSR STAY CABLE SYSTEM

The TSR stay cable system consists of a compact bundle of parallel seven-wire steel strands enclosed in a co-extruded (black and coloured layers) high density polyethylene circular duct.
According to a principle of modularity, stay cables of several sizes can be obtained, from the smallest (e.g. the 3TSR15) to the largest and more complex ones (e.g. the 169TSR15).
Further bigger dimensions are available on request.
Currently the most utilised type of strand has a 15.7mm (0.62") diameter, grade 1860 MPa and low relaxation; but the use of the 15.2mm (0.6") diameter is also foreseen.
Different corrosion protection treatments are available such as galvanization of single wires, layers of corrosion inhibitor (wax or grease) and continuous UV stabilized extruded hdpe coating.
Three nested barriers on the tensile element are always provided.

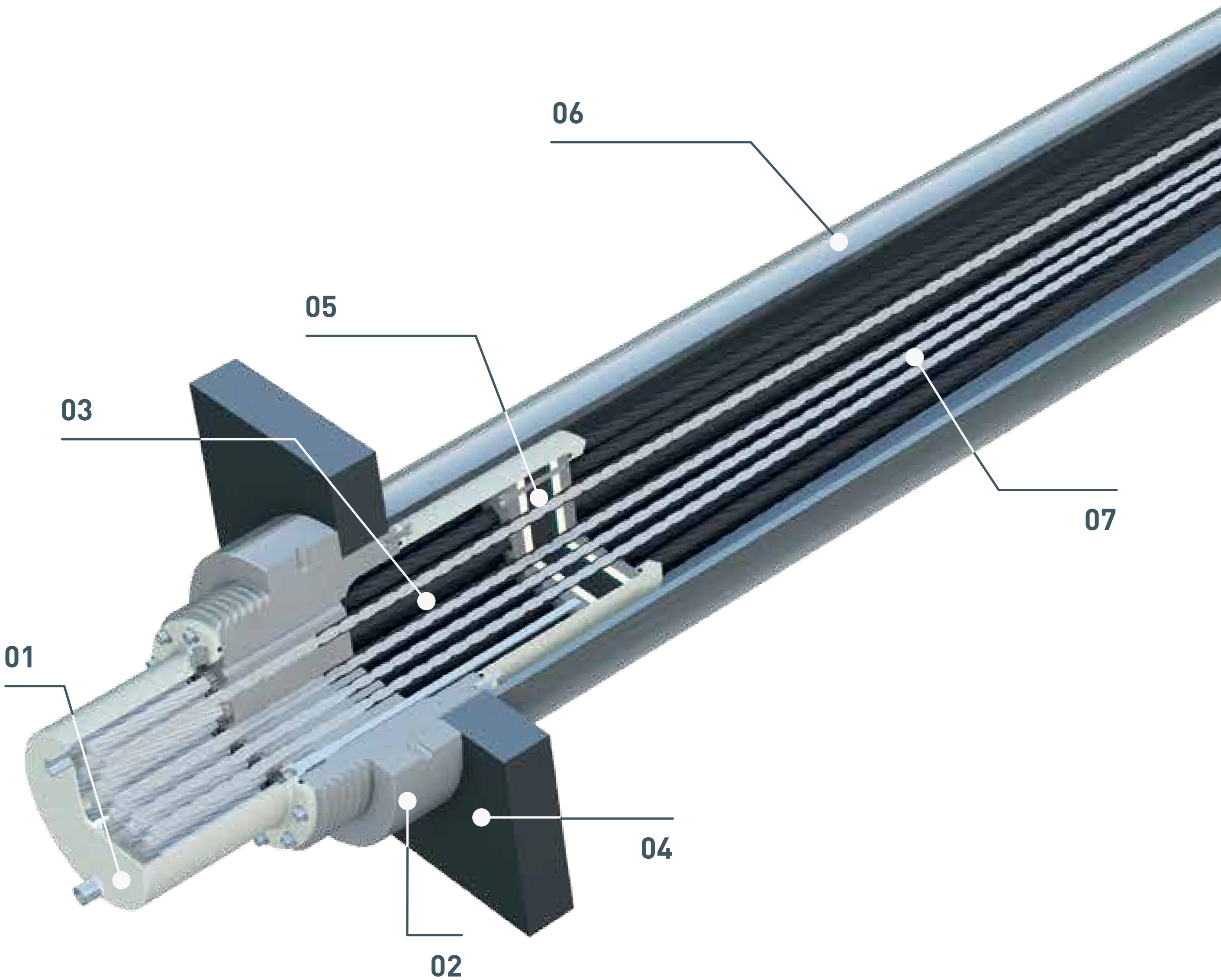
TSRF STAY CABLE SYSTEM

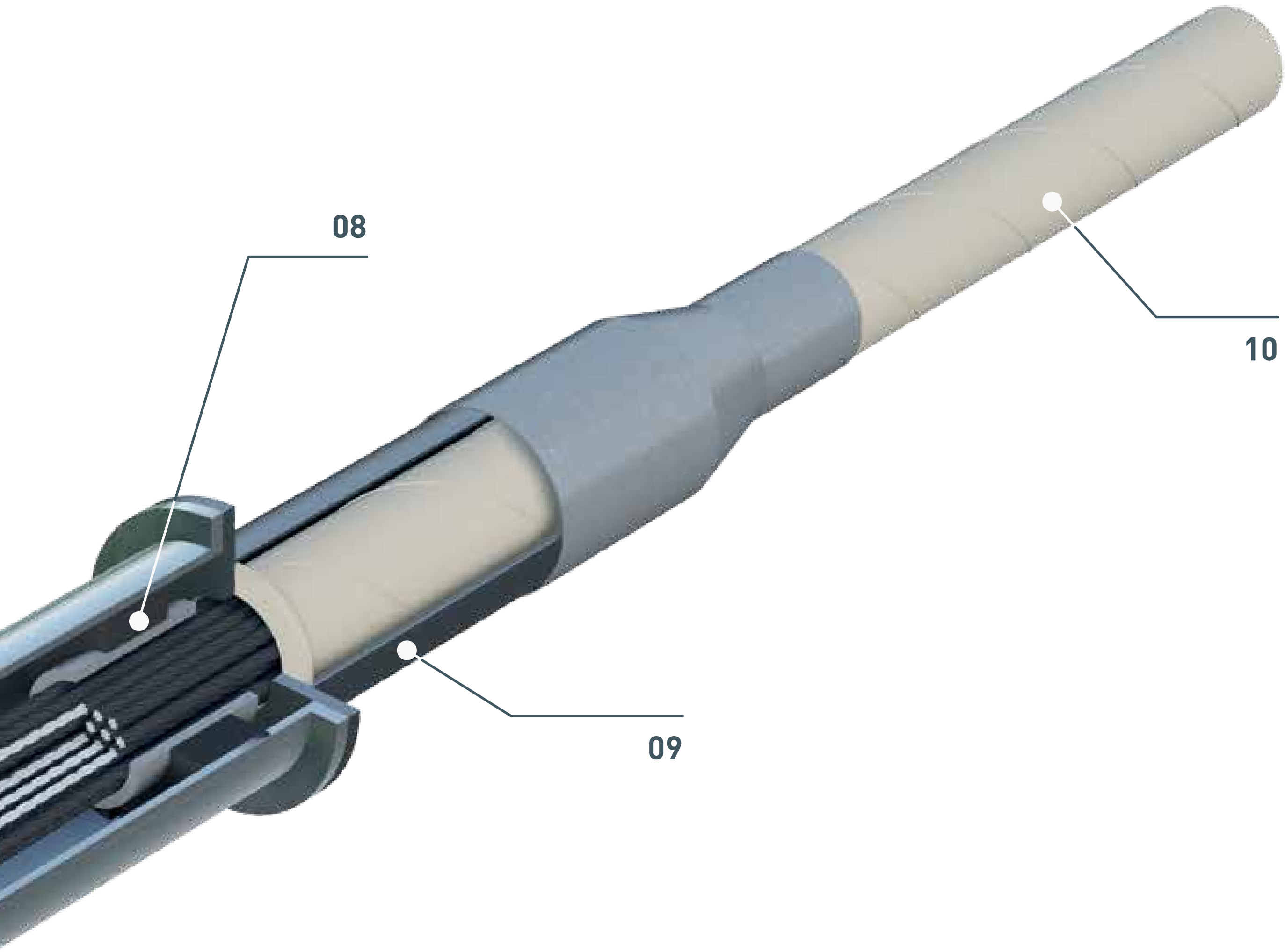
This system features all the main advantages of the TSR system and it is provided with a fork and pin connection that links to a clevis plate on the structure.
It is available with fixed and adjustable anchorages.
It is suitable for all cable stayed bridges where there is a lack of space in the pylon and deck connection area.
It is also frequently used in suspended structures where cables are used as suspension systems.
In these solutions the TSRF system is also provided with a series of special clamps to fix vertical hangers to suspension cables.

The system design and the manufacturing of all the components meet the severe requirements of the most important International standards such as FIB bulletin 30 "Acceptance of stay cable systems using prestressing steels", PTI "Recommendations for stay cable design, testing, and installation" and SETRA (CIP) "Cable stays – Recommendations of French Interministerial commission on Prestressing".

TSR STAY CABLE SYSTEM

The TSR stay cable system is made of some basic elements designed and combined to provide the highest structural and corrosion protection performance.





PART	NAME
01	PROTECTION CAP
02	ADJUSTABLE ANCHORAGE (TYPE TSRA)
03	ANTICORROSIVE COMPOUND
04	BEARING PLATE
05	WAX BOX SYSTEM
06	FORM PIPE
07	GALVANIZED, WAXED AND HDPE COATED STRAND
08	DAMPER SYSTEM/DEVIATION SYSTEM
09	ANTIVANDALISM/TELESCOPIC TUBE
10	EXTERNAL HDPE PIPE

SADDLE SYSTEM

Through the years TENSA has been developing its technology for saddles, for both cable stayed and extra-dosed bridges, as a response to issues affecting existing saddle designs concerning fatigue, fretting corrosion and replacement of cables.
One of the greatest advantages of the TSS saddle systems is to allow designers to simplify the pylon structure and use very slender profiles to achieve an attractive appearance.

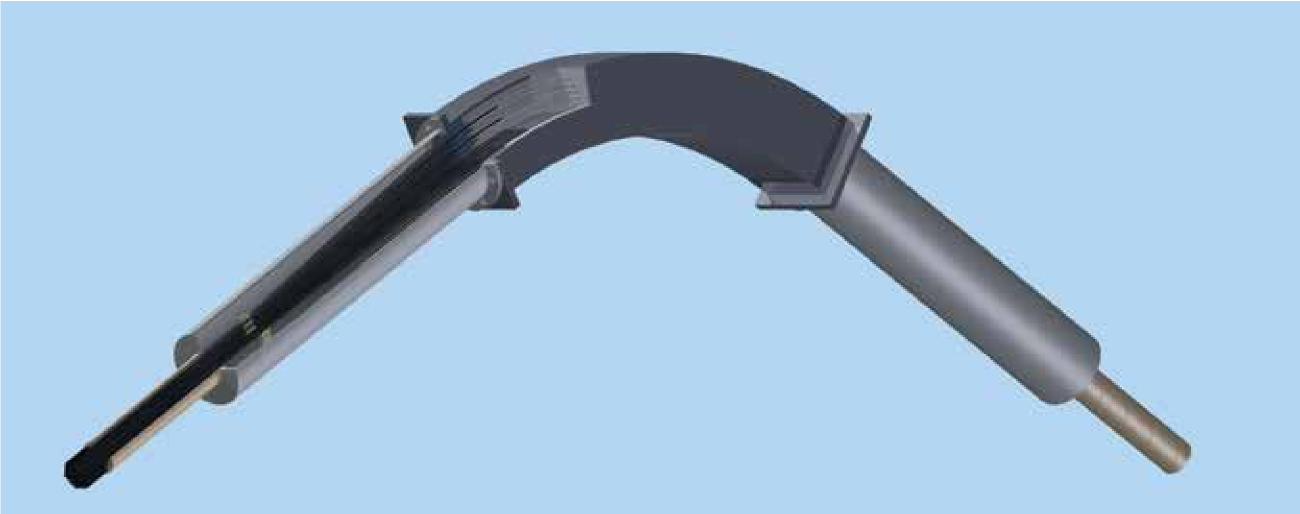
The flagship system is the TSS-T multi-tube saddle, where single protected strands run individually within single recesses with adequate corrosion protection and provide guaranteed differential forces resistance.
Each strand is deviated individually in a specific hole, giving the following advantages:

- **Durability of corrosion protection,**
- **Individual replacement of strands,**
- **Resistance to fatigue identical to a standard stay cable anchorage.**

A different kind of saddle, the TSS-B type, composed of a rectangular steel box filled with a high-strength compound, can be used if the project's technical specifications allow it.
The entire bundle of strands is bonded to the pylon with high friction between the cable and the saddle.
Full cables can be replaced, while strands can be tensioned independently during installation phases.

A third type, the TSS-ST steel box saddle system, is designed as a curved steel structure embedded into the pylon, able to accommodate standard TENSA TSR stay cable anchorages at both ends.
Differential forces between the two stays connecting to the same saddle TSS-ST are absorbed by the steel saddle itself, anchored tightly to the pylon; anchorages are kept outside of the pylon.
They remain accessible and inspectionable for any maintenance from the outside of the pylon.
For this reason there is no need to have the inside of the pylon shaped to accommodate ladders or spaces for accessibility.
The steel saddle is then designed and manufactured according to steel construction standards, i.e. Eurocode, and does not need to be assessed through complicated and often unfeasible laboratory tests.

Saddle System Type TSS-T



Cable stayed bridge, Montodine d'Adda (Italy)

STAY COMPONENTS

ANCHORAGES

Anchorages have to guarantee the proper load transfer from the cable to the structure.
Hence they must withstand severe load conditions, with dynamic actions due to vehicular traffic and wind forces acting on the free length of the cable.
They have been designed to safely withstand the ultimate breaking load of the strands bundle and to guarantee excellent performance under cyclical fatigue loads.
Moreover they are capable of absorbing local bending stresses due to construction tolerances and and angular cyclic deviations of the stays due to dynamic loads through a rear stress filtering device.
Strands are gripped inside anchorages with specially designed wedges, tested against the highest fatigue and efficiency limits.
Anchorages are watertight tight as assessed by full scale leak tightness tests.

Two kinds of anchorages are available:
Adjustable (type TSRA or TSRAF), provided with a regulation nut, and **Fixed** (type TSR or TSRF).

Both types can be used either on the pylon or on the deck, according to installation and project requirements.
Mono-strand stressing can be performed either from an adjustable or fixed anchorage.
Adjustable anchorages allow regulation of loads whenever needed, even during the operational life of the bridge, with a special adjusting jack acting over the entire threaded anchorhead.

STEEL STRANDS

TENSA stay cable systems are made with strands meeting the requirements of Fib and PTI recommendations.
Stay cables generally feature the use of low relaxation seven-wire steel strands with a nominal diameter of 15.7 mm (nominal cross section of 150 mm^2) or 15.2 mm (139 mm^2) and characteristic tensile strength of 1.860 MPa.
Prestressing strands with lower nominal values may also be used.

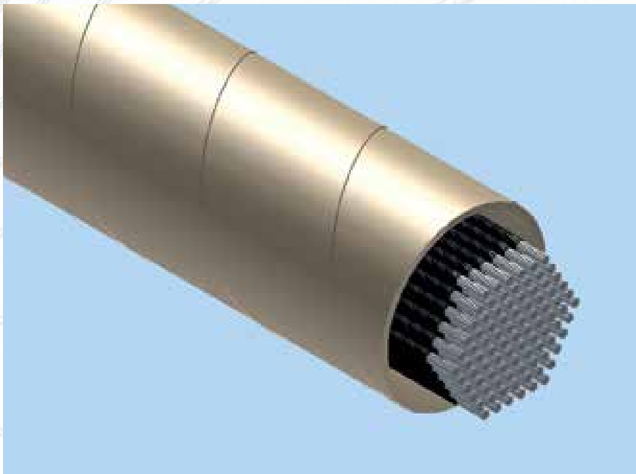
Supplementary corrosion protection layers are guaranteed with the use of galvanized wires, a thin layer of corrosion inhibitor (wax or grease) and a co-extruded hdpe coating.

A solution with the use of epoxy coated strands can also be provided.

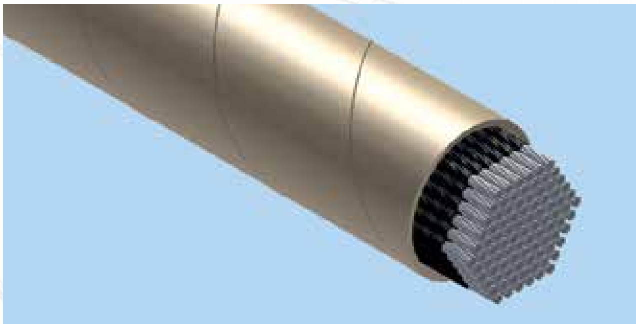
STAY PIPES

High density polyethylene (hdpe) pipes cover the strands' bundle in the free length, providing further protection against external agents, including UV rays.
They are usually made of a black base with a co-extruded thin coloured layer.
Accelerated ageing tests according to the most stringent international standards are available for the colours used in cable stayed bridges, guaranteeing satisfactory resistance against environmental degradation in any project location in the world.
In order to significantly reduce the risk of stay vibrations due to the combined effect of wind and rain, pipes can be installed with the external surface featuring a double helical rib.
Such a solution allows the deviation of water rivulets flowing down the cable, preventing the rise of vibration instability phenomena. Reports are available to demonstrate such performance.
For long span cable stayed bridges it is often necessary to reduce wind loads acting on the stays, and for such reason the outer cable diameter has to be reduced as much as possible.
In these cases it is preferred to choose the "slim" stay pipe (compacted), which significantly reduces the drag forces.
Such a solution requires dedicated installation procedures.

Steel or stainless steel external pipes are available on request.



Standard pipe



Slim pipe

SOLUTIONS FOR VIBRATIONS CONTROL

The mitigation of stay vibration is very important to avoid dangerous occurrences of instability, increase of movements and fatigue-related issues. Several solutions can be adopted to prevent and control unexpected events related to stay vibrations.

DUCTS' EXTERNAL SURFACE

The external shape of the outer ducts can affect the stays behaviour under the effect of rain and wind.
It has been proven under testing that a special shaped double helicoidal rib placed on the external surface of the ducts can significantly improve the efficiency in suppressing the risk of vibration amplification, minimizing the drag forces at the same time.

COMPACTED BUNDLE

The use of compacted bundles of strands ("slim stays") helps minimize the drag forces induced to the stays by the blowing wind. Such a countermeasure should be adopted with special care in the case of long span bridges, where transversal forces induced by wind may also affect the stays' connections to pylons and decks.

DAMPERS

Parallel strand stay cables are provided with a very low intrinsic logarithmic damping ratio, in the 0.5% - 2.5% range.
Different kinds of dampers are available to achieve the damping performance required by each project.
There can be internal or external dampers. The choice for the best solution depends on the level of performance required and the local conditions of the project (geometry, length of the stays, wind field).

Internal damper type TRD (Tens Rubber Damper)
It is the simplest device that can be used to mitigate stay vibrations and utilises a high damping elastomeric ring to dissipate the vibration energy. It is placed at the end of the transition zone, close to the end of the form tube, allowing easy access for maintenance activities. It is mainly used in medium-short stays.

Internal damper type TFVDi
(Tens Fluid Viscous Damper - internal)
Dampers, to be used in medium-long stays.
They achieve the scope of damping different vibration amplitudes in a wide range of frequencies, preventing the rise of visible oscillations (unpleasant to observe) and the subsequent emergence of dangerous fatigue-induced damage.
They remain within inner section of the stay, at the end of the transition zone and can be easily inspected and maintained.

External damper type TFVDe
(Tens Fluid Viscous Damper - external)
When long stays require a considerable amount of energy to be dissipated, it is preferable to use external dampers.
The dampers connect the stays to rigid steel structures placed on the deck. This way longer damping strokes are available as well as increased damping capacity.
The dampers can be made of one or two single devices.
This kind of solution is capable of achieving the highest damping requirements, far above the minimum logarithmic damping ratios needed on site (6% and more). Suitable calculation models are available to determine the damper properties (damping factor, load, stroke, other) for each single stay in a specific project and its relevant site conditions.

CROSS TIES

In some special cases where instability is a problem, it may be necessary to install cross-ties, placed in the vertical plane of stays. They act in order to increase the natural frequencies of cables and the wind speed threshold that triggers instability phenomena.
In any case it is important to highlight the difficulties with installation and maintenance. Proper function and efficiency are only guaranteed in the vertical plane.

Cable stayed bridge over the Adda river, Calolziocorte (Italy)

ADDITIONAL OPTIONS

All TENSA stay cable systems can be provided (if required) with supplementary options such as:

Structural Monitoring

Monitoring of stay cables is important during construction and service life of the bridge and it becomes critical in many cases.
Several parameters can be monitored, in order to collect data that help in:

- Validation of design and construction assumptions, to improve construction techniques;
- Detection of possible damage and unexpected behaviour;
- Developing efficient maintenance processes
- Reducing the costs in the life cycles of structures.

Loads can be monitored with the use of permanent load cells placed over anchorages.
The load cells can be mono-strand, where the load cell is placed over only one strand of the anchorage, giving the stay the full load, extrapolated as the single strand load. Or they can be annular, resting directly beneath the nut of the adjustable anchorage and providing readings of the load acting over the entire stay.
All load cells are designed to minimize sensitivity to unusual loads and bearing surfaces and can be connected to an data acquisition system, providing summary of readings taken from different cells.
This way full monitoring of all stays can be performed, giving a real-time status of the bridge during its lifetime.
Vibration monitoring systems can be provided, both with accelerometers placed directly over stays or through an innovative radar detection system, that allows detection of loads, vibration amplitudes and proper frequencies through interferometric radar devices.
This latter system guarantees proper readings and reduced project site activities, while providing accurate and reliable results.

Fire protection

Stays can be equipped with different fire protection systems in the lower portions, especially for bridges where there is an increased risk of exposure to fire due to heavy vehicular traffic.

Anti-vandalism tube protection

Where there is an increasing risk of damage caused by vandalism and other events, anti-vandalism steel tubes, made of one or two shells, can be installed. Stainless steel tubes provide also an aesthetically pleasing solution.

Lighting systems

Special lighting systems can be installed, providing aesthetically pleasing illumination of the stays, complying with architectural requirements, which of course do not affect the function and the installation of the stays.

Cable stayed bridge Santa Apolonia, Lisbon (Portugal)

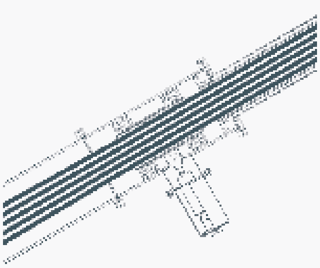
Cable stayed bridge
over the river Belbo,
Nizza Monferrato (Italy)

Cable stayed bridges on the Favazzina viaduct, Scilla (Italy)

03

PRODUCT DEVELOPMENT AND TESTING

Through the years the stay cable systems have undergone
a continuous process of improvement, to meet more stringent demand
from the market and the need for higher performing products,
together with a dedicated validation testing campaign.



PRODUCT DEVELOPMENT

Product development has been carried out through the years in order to meet special project requirements and to introduce stay cable systems within new application fields.
From simple pedestrian bridges, cable stays have been improved to be used with success within massive cable stayed bridges, where highly severe regulations were in use.
Systems have also been updated to meet demand for electrical insulation, higher corrosion protection and use for high speed railway applications.
New systems have been specifically developed to be used for suspended bridges, where both suspension cables and vertical hangers are made with parallel strands suitably protected against corrosion.
Specially designed clamps have been introduced to allow the connection between different cables and spread the use of stay cables systems within suspended structures.
The new generation of Type TSRF anchorages meets this requirement of use within a various range of applications such as suspended bridges and structures.
As a further improvement the system has also been designed to be used with epoxy coated strand: suspended bridges are now the best design solution to use this updated product.

Suspended structures at the EXPO 2015 Universal Exhibition, Milan (Italy)

Chihani suspended bridge, Wilaya El Tarf (Algeria)

TESTING

Imposing testing campaigns are continuously carried out in order to validate product development.
Tests have been carried out not only over full scale assembled stay cables but also over single components, like wedges, anchorages and dampers.

Samples have been assembled using 15.7 and 15.2mm diameter steel strands, with class 1860 MPa.

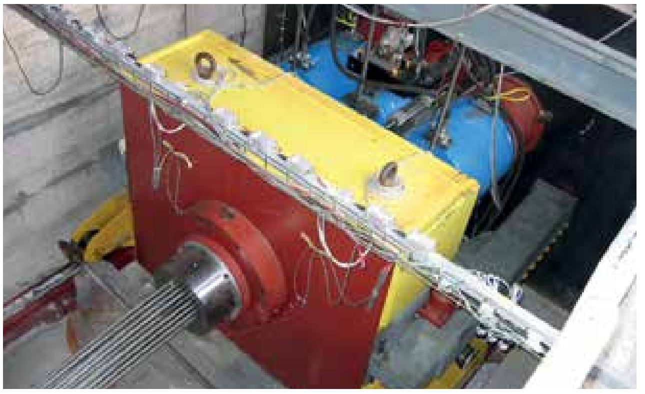
Axial fatigue tests at 45% GUTS with a stress range of 200 MPa and inclined 10 mrad shims at the anchorages have been performed over small, medium and large size full scale TSR stay cable samples.
These sample have also undergone tensile tests.

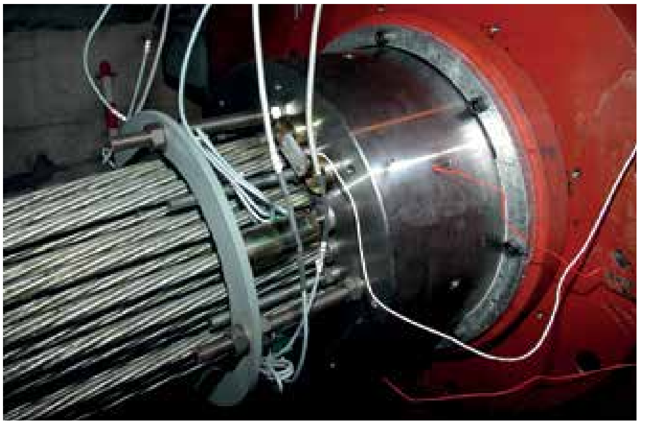
Bending fatigue tests with transversal displacement applied in the stay cable free length and subsequent tensile tests have also been carried out on large size TSR stay cable samples.

Axial deviated tensile tests have been performed over the TSRF system, introducing the supplementary stresses induced by clamping devices used in suspended structures applications.

Leak tightness tests have been performed over full scale specimens both according to PTI recommendations (stay cable immersed in room temperature water after fatigue testing) and SETRA (CIP) recommendations (stay cable under 1000 transversal fatigue cycles and water subject to 50°C temperature cycles along six weeks).

Tests have been performed in International third party laboratories according to main International Standards such as PTI "*Stay Cables Recommendations for Stay Cable Design Testing and Installation*", FIB Bulletin 30 "*Acceptance of stay cable systems using prestressing steels*" and SETRA (CIP) "*Cable stays – Recommendations of French Interministerial commission on Prestressing*".



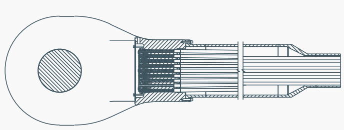


Arch bridge over
the Twente channel,
Eefde (The Netherlands)

04

SYSTEM PROPERTIES AND DIMENSIONS

An overlook of all the properties
and dimensions
listed in tables for each system.



PARALLEL STRANDS STAY CABLES SYSTEM MAIN CHARACTERISTICS

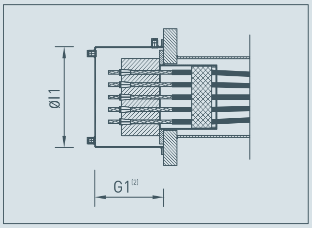
N° of STRANDS	Steel nominal cross section [1]	Steel nominal Mass [1]	Steel nominal Breaking Load [1]	Maximum working load [2]	Maximum working load [3]
	A_P [mm²]	M [kg/m]	F_{PK} [kN]	50% F_{PK} [kN]	60% F_{PK} [kN]
2	300	2.34	558	279	335
4	600	4.69	1 116	558	670
7	1 050	8.20	1 953	977	1 172
12	1 800	14.06	3 348	1 674	2 009
19	2 850	22.27	5 301	2 651	3 181
27	4 050	31.64	7 533	3 767	4 520
31	4 650	36.33	8 649	4 325	5 189
37	5 550	43.36	10 323	5 162	6 194
43	6 450	50.40	11 997	5 999	7 198
55	8 250	64.46	15 345	7 673	9 207
61	9 150	71.49	17 019	8 510	10 211
73	10 950	85.56	20 367	10 184	12 220
91	13 650	106.65	25 389	12 695	15 233
109	16 350	127.75	30 411	15 206	18 247
127	19 050	148.84	35 433	17 717	21 260
169	25 350	198.07	47 151	23 576	28 291

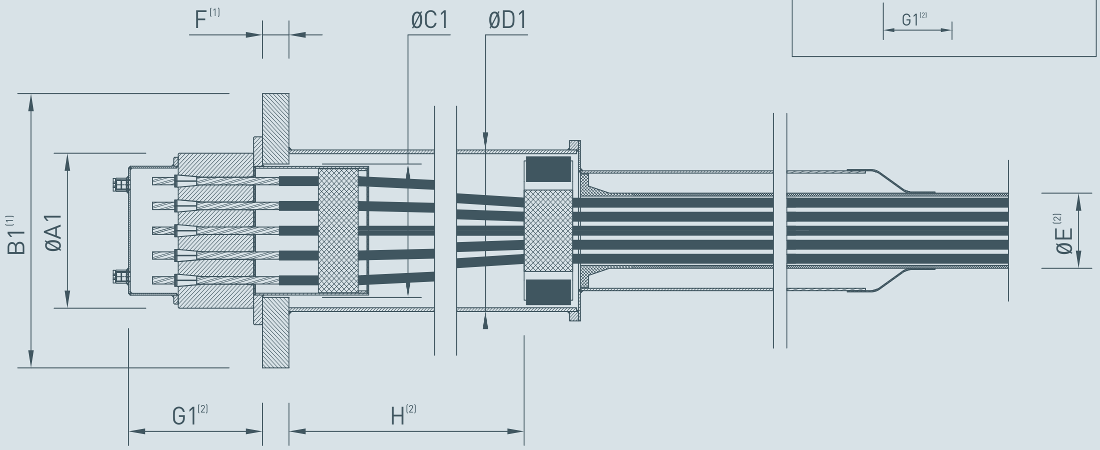
When the strands are used according to ASTM A416, the values specified above must be reduced accordingly
(1) Based on steel strand specification as per prEN 10138-3
(2) Recommended maximum service stress for stay cable as per FIB bulletin 30 and Setra
(3) Recommended maximum service stress for extra-dosed bridges as per Setra

Cable stayed bridge over the Bacchiglione river, Montegalda (Italy)

TSR SYSTEM

DECK CONNECTION WITH FIXED ANCHORAGE AND TRANSITION ZONE





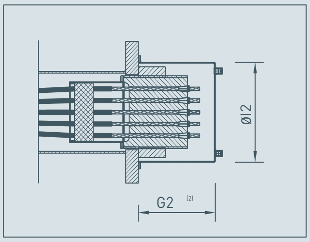
Main dimensions (using steel strand diameter 15.7 mm and grade 1 860 MPa)

N° of STRANDS	ØA1	B1[1]	ØC1	ØD1	ØE		F[1]	G1[2]	H		ØI1
					STANDARD	SLIM			STANDARD	SLIM	
	[mm]	[mm]	[mm]	[mm]	[mm]	[MM]	[mm]	[mm]	[mm]	[mm]	[mm]
4	130	280	100	127	63	63	20	285	460	610	190
7	150	300	122	152.4	75	63	30	295	580	790	210
12	190	375	160	193.7	110	110	40	300	910	1 250	255
19	225	390	180	219.1	125	110	50	320	1 010	1 420	290
27	260	410	217	254	160	140	60	390	1 330	1 860	330
31	275	415	230	267	160	140	70	400	1 330	1 860	345
37	280	430	237	273	180	160	80	410	1 460	2 070	355
43	320	475	267	305	200	180	80	425	1 660	2 360	400
55	335	475	282	323.9	200	180	90	445	1 770	2 490	425
61	360	550	305	355.6	225	200	100	475	1 920	2 730	445
73	390	590	325	368	250	225	100	525	2 080	2 950	475
91	425	650	365	419	280	250	120	555	2 330	3 340	525
109	450	700	380	431.8	280	250	125	585	2 500	3 560	550
127	500	750	425	482.6	315	280	130	615	2 800	4 010	600
169	570	900	485	558.8	400	315	145	655	3 220	4 620	680

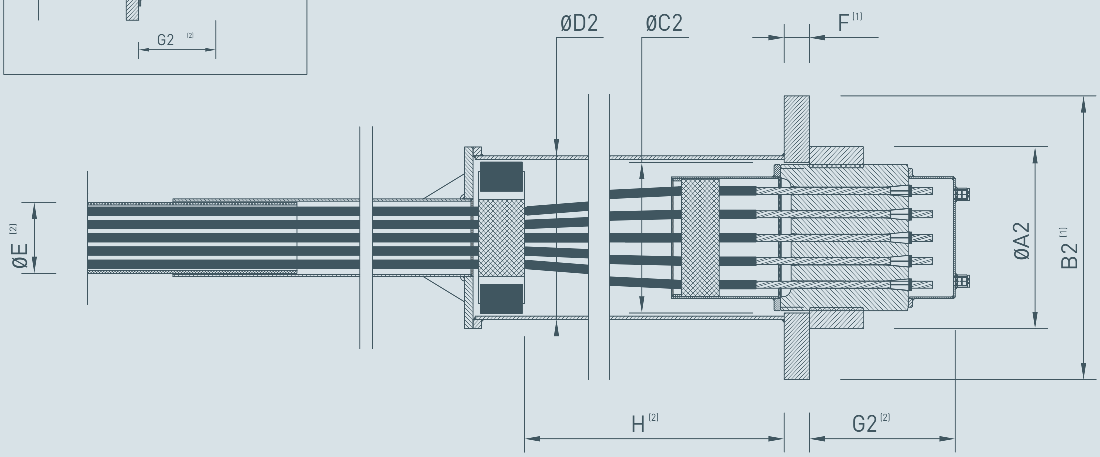
additional sizes available on request

(1) If bearing on concrete surface with fck = 45 MPa and considering 45% of Fpk

(2) Values subject to variations according to special project requirements



PYLON CONNECTION WITH ADJUSTABLE ANCHORAGE AND TRANSITION ZONE



N° of STRANDS	ØA2	B2[1]	ØC2	ØD2	E[2] STANDARD	E[2] SLIM	F[1]	G2[2]	H STANDARD	H SLIM	ØI2
	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]
4	160	300	140	168.3	63	63	20	325	430	580	190
7	180	340	160	193.7	75	63	30	345	550	760	210
12	220	440	200	229	110	110	40	345	860	1 200	250
19	280	450	235	267	125	110	50	360	960	1 370	310
27	320	480	270	305	160	140	60	380	1 280	1 810	350
31	330	500	285	323.9	160	140	70	390	1 280	1 810	360
37	345	500	290	323.9	180	160	80	400	1 410	2 020	375
43	390	560	330	368	200	180	80	435	1 610	2 310	420
55	410	560	345	394	200	180	90	450	1 720	2 440	445
61	440	610	370	419	225	200	100	450	1 870	2 680	475
73	475	650	400	445	250	225	100	470	2 030	2 900	510
91	520	700	435	482.6	280	250	120	505	2 280	3 290	555
109	545	740	460	508	280	250	125	540	2 400	3 460	580
127	600	800	510	558.8	315	280	130	580	2 700	3 910	640
169	680	900	580	635	400	315	145	670	3 120	4 520	720

additional sizes available on request

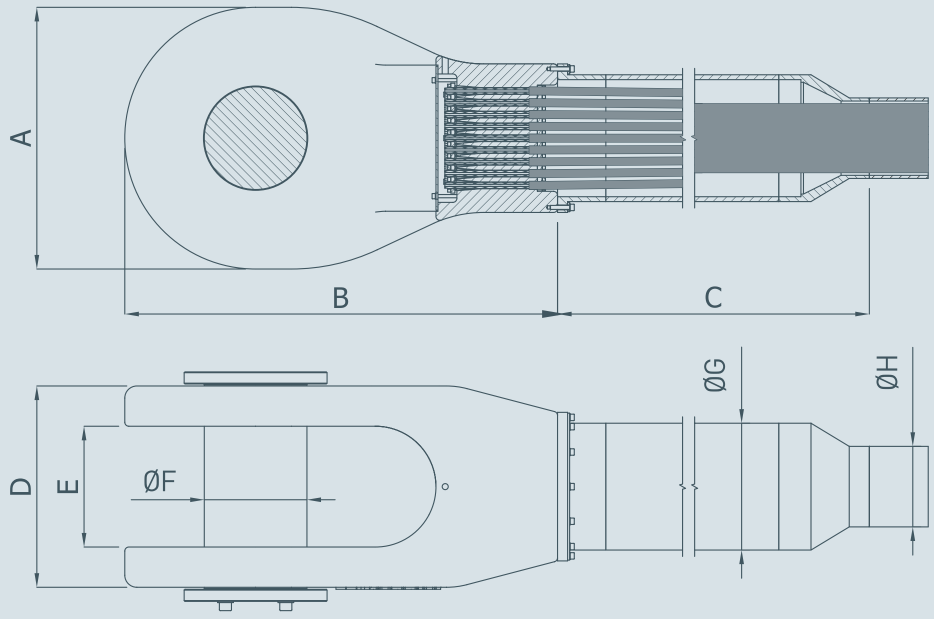
(1) If bearing on concrete surface with fck = 45 MPa and considering 45% of Fpk

(2) Values subject to variations according to special project requirements

Viaduct over wharf VII, Trieste (Italy)

TSRF SYSTEM

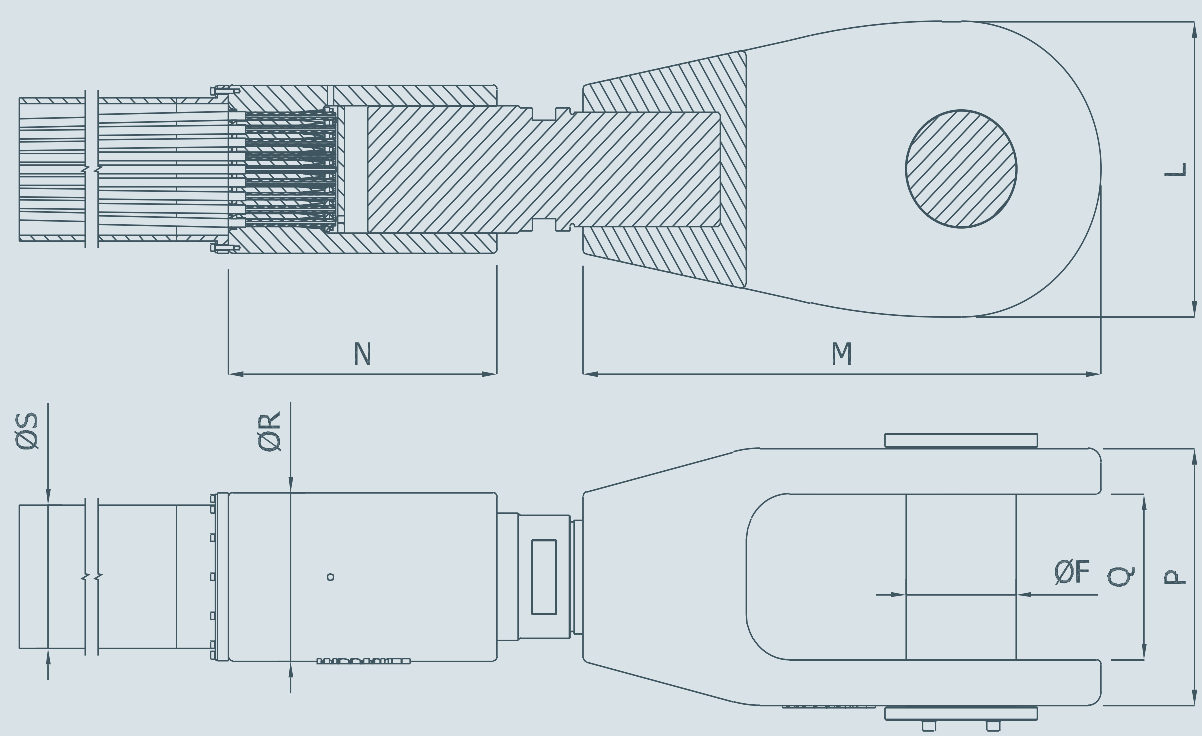
FIXED FORK CONNECTION



N° of STRANDS	A	B	C	D	E	ØF	ØG	ØH
	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]
2	110	285	400	80	56	44	63	50
4	135	325	650	120	84	54	110	63
7	180	390	900	145	105	72	110	63
12	240	470	1300	230	180	89	140	110
19	300	560	1600	300	240	119	160	110
31	410	670	2100	360	280	158	200	140
37	440	750	2100	360	280	173	225	160
43	510	890	2400	430	290	198	250	180
61	650	1075	2800	500	300	255	315	200

additional sizes available on request

ADJUSTABLE FORK CONNECTION



N° of STRANDS	L	M	N	P	Q	ØF	ØG	ØH
	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	[mm]
2	115	220	175	115	85	44	115	63
4	135	275	185	125	89	54	125	110
7	160	360	240	155	115	72	155	110
12	240	420	300	210	160	89	185	140
19	300	510	340	280	200	119	225	160
31	410	650	420	350	250	158	280	200
37	440	760	450	370	270	173	300	225
43	520	920	530	450	310	198	330	250
61	650	1200	625	565	365	255	370	315

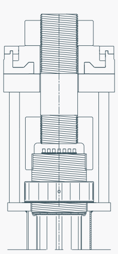
additional sizes available on request

Cable stayed bridge over the Sangone river, Giaveno (Italy)

05

INSTALLATION

Our teams take care of all installation phases,
thanks to decades of experience in the field
and dedicated working procedures.

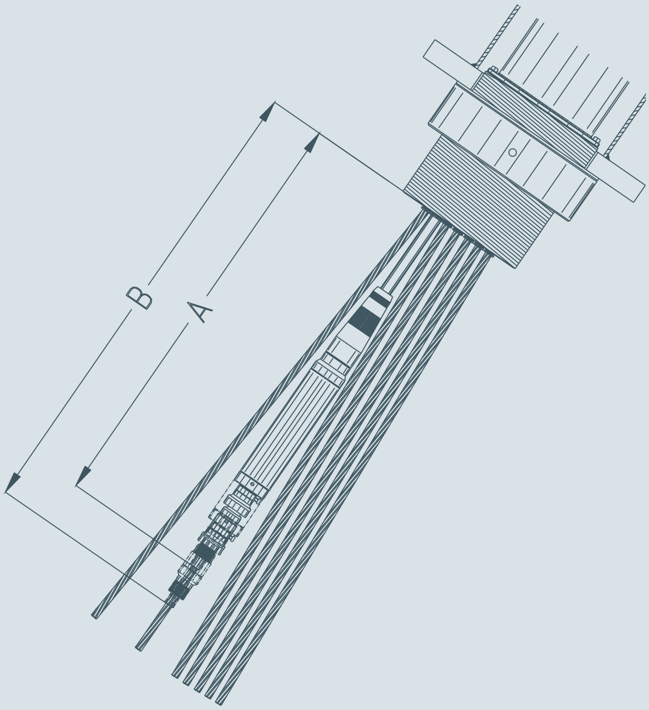


INSTALLATION

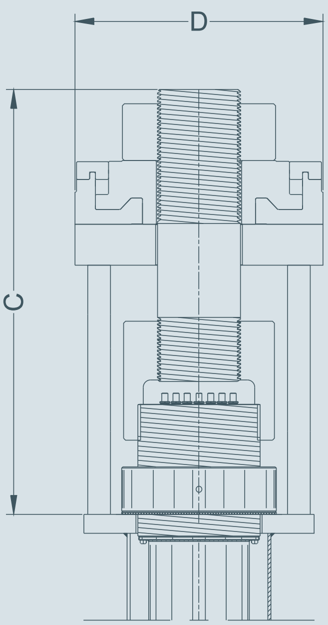
Installation plays an extremely critical role in the proper performance of the systems. Decades of experience and trained specialized teams are the key for good performance.

Installation of the TSR / TSRF systems is always carried out on site by experienced TENSA teams, all over the world. Our teams take care of all phases, on the back of many decades of experience in the field and thanks to dedicated working procedures.
Installation is carried out with a strand by strand sequence, guaranteed by means of lightweight specially designed installation equipment.
Preliminary operations consist of the welding of the external pipes to the final length and the cutting of strands over special benches, starting from coils, to reach the correct measurements.
With the anchorages already placed at pylon and deck level, the pipe is lifted with a tower crane and the first strand is threaded, following a pre-defined sequence.
Stressing is carried out while placing strands, one by one, with the use of a special TENSA mono-strand jack, provided with a system of load and elongation measuring.
This step is carried out using the iso-elongation principle: stressing is done comparing the same position of marks placed over strands, guaranteeing the same load acting over each strand of the bundle.
Once the entire stay is installed, further stressing with the mono-strand jack may be carried out.
Final small regulations of loads are performed with the use of a TENSA adjusting jack, acting directly over the adjustable anchorage and turning the nut to its final position.
Once the stressing operations are completed, final injections and closures are carried out.
Installation can be also carried out with pre-fabricated stays depending on site conditions and construction needs.
Stays load adjustment, single strand and full stay cables substitution can be carried out anytime with reduced impact on the structure's performance.

Cable stayed bridge over the Kwanza river, Barra do Kwanza (Angola)



TYPE OF	A (MIN)	B (MAX STOKE)
JACK	[mm]	[mm]
PTP 140	560	560
PTP 150	1050	1050



N° of STRANDS	D	C_{MAX}
	[mm]	[mm]
4 - 7 - 12	425x425	950
19-31-37-42-55	585x585	1165
61	650x650	1165
73	705x705	1295
91	750x750	1320
127 - 169	950x950	1850

Cable stayed bridge over the Adige river, Piacenza d'Adige (Italy)

TENSA

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

TENSA AROUND THE WORLD

TENSA HEADQUARTERS

TENSA – HEAD OFFICE
Via Pordenone, 8
20132 Milano - ITALY
T +39 02 4300161
F +39 02 48010726
mail@tensainternational.com

Business Development
Post Tensioning, Stay-cables,
Bars, Ground Anchors
T +39 02 4300161
F +39 02 48010726

TENSA – ROME OFFICE
Via Cremona, 15b
00161 Roma - ITALY
T +39 06 8084621
F +39 06 8085427
mail@tensainternational.com

Business Development
Bearings, Joints,
Antiseismic devices
T +39 06 8084621
F +39 06 8085427

TENSA – WORKSHOP
Via Buttrio, 36
33050 Pozzuolo del Friuli (UD) - ITALY
T +39 0432 6071
mail@tensainternational.com

BRANCHES

TENSA AMERICA LLC
1111 Kane Concourse, S.te 200
Bay Harbor Island – 33154 FL
T +1 305 8669917
mail@tensaamerica.com
www.tensaamerica.com

TENSA RUSSIA
5th Yamskogo Polya Street, 5
Bldg 1, 16th Floor
125040 Moscow
T +7 495 2300024
mail@tensarussia.com
www.tensarussia.com

TENSA PORTOGALLO
Constr. Civil e Obras Publicas
Rua Eng. Frederico Ulrich, 3210-3
Sala 314
4470-605 Moreira da Maia
mail@tensainternational.com
www.tensainternational.com

TENSA AUSTRALIA
Level 1, 488 Botany Road
Alexandria, NSW 2015
Mr. Giammaria Gentile
T +61 2 8332 6151
F +61 2 8332 6101
mail@tensainternational.com
www.tensainternational.com

TENSA QATAR
C Ring road block 289 st 230
Doha
Mr Daniele Scalfati
T +974 447 19853
mail@tensainternational.com
www.tensainternational.com

TENSA

TENSA
Via Pordenone, 8
20132 Milano, Italy
T +39 02 4300161
F +39 02 48010726
mail@tensainternational.com
www.tensainternational.com

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