Freyssinet
HD Stay Cable

Design, Build, Maintain

Freyssinet
SUSTAINABLE TECHNOLOGY

Freyssinet HD stay cables

Freyssinet stay cable technology was first developed in the mid-1970s, and has been improved continuously ever since. It is the reference in terms of fatigue resistance, protection against corrosion, inspectability and replaceability.

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The inventor of the multistrand stay cable

A parallel strand system: robust and flexible

Freyssinet invented the multistrand parallel system in 1976. The Freyssinet HD stay cable is based on each strand being completely independent.

This principle has many advantages, including:

- installation and tensioning of each strand individually;
- individual protection against corrosion;
- individual removal and replacement if necessary.

The standard range of HD stay cables varies from 1 to 169 strands. However, there is no limit to the capacity or the length of stay cables. The largest stay cables yet installed were for the Collserola telecommunications tower in Spain (205-strands) and the longest are the stabilization stay cables for Ting Kau bridge in Hong Kong (465 m long).

Ting Kau bridge / Hong Kong

Collserola tower / Spain

The Freyssinet monostrand
A galvanised strand with a semi-bonded sheath

The tension element of the Freyssinet HD stay cable consists of a group of parallel individually protected T15.7 strands named “Freyssinet monostrand”.
This patented stay cable strand has excellent durability and provides perfect protection against corrosion due to two complementary nested barriers formed by galvanisation and a semi-bonded individual HDPE sheath extruded onto the strand after the interstices have been filled with a specifically developed wax.

The bundle of Freyssinet monostrands is usually contained in an HDPE (High Density Polyethylene) co-extruded outer pipe specially designed to satisfy stay cable needs and to give excellent durability.

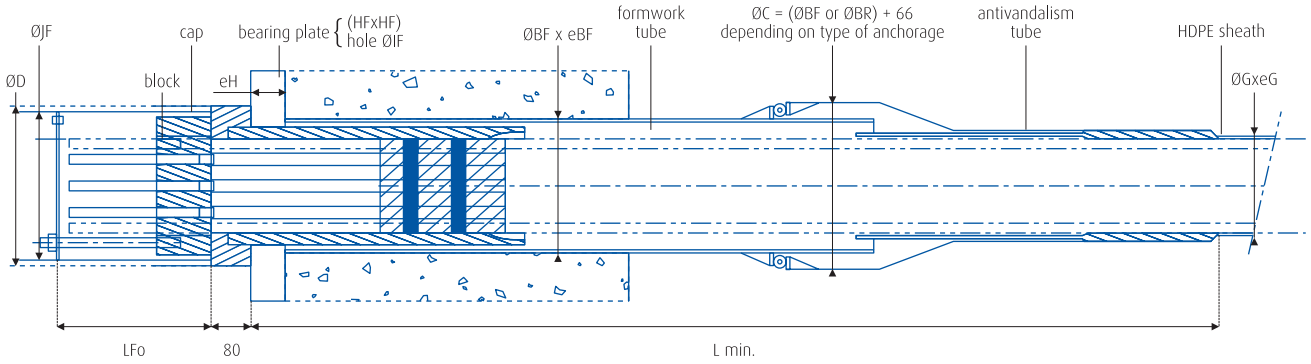
The Freyssinet anchorage

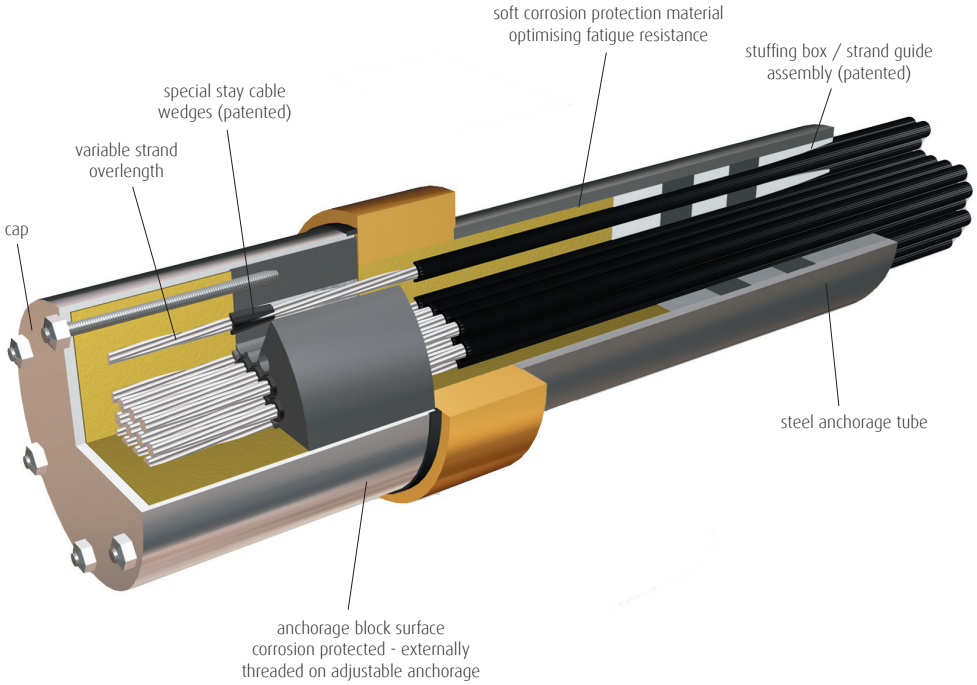
Bending filtration, high fatigue and corrosion resistance

The Freyssinet HD anchor is the most compact stay cable system. It performs all functions required for a stay cable:

- protection against corrosion at unsheathed ends of the strands using a patented stuffing box provided with the latest developments in waterproofing;
- resistance to axial fatigue, largely due to the Freyssinet wedges specially designed to resist 300 MPa stress amplitude at 45% of ultimate strength for 2 million cycles;
- resistance to bending fatigue using a "**filtering guide/stuffing box**" device capable of filtering radial forces;
- very easy individual installation and adjustment of strand forces. This particular arrangement also enables monitoring of cables by replacing a test strand at regular intervals.

BOTTOM
fixed anchorage

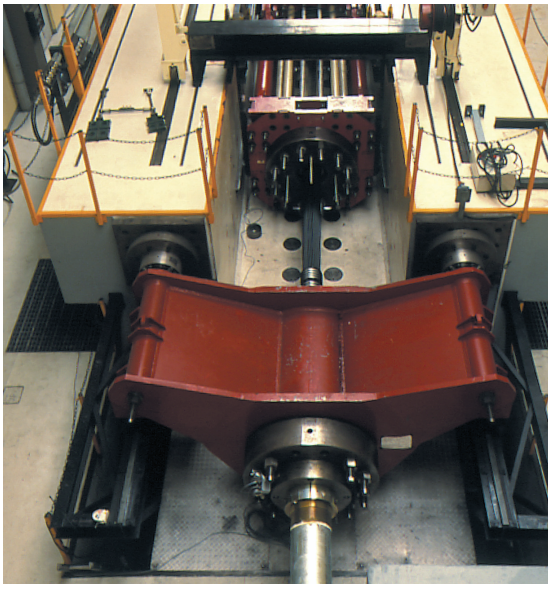




It is recommended that each stay cable should have a fixed anchor at one end and an adjustable anchor at the other.

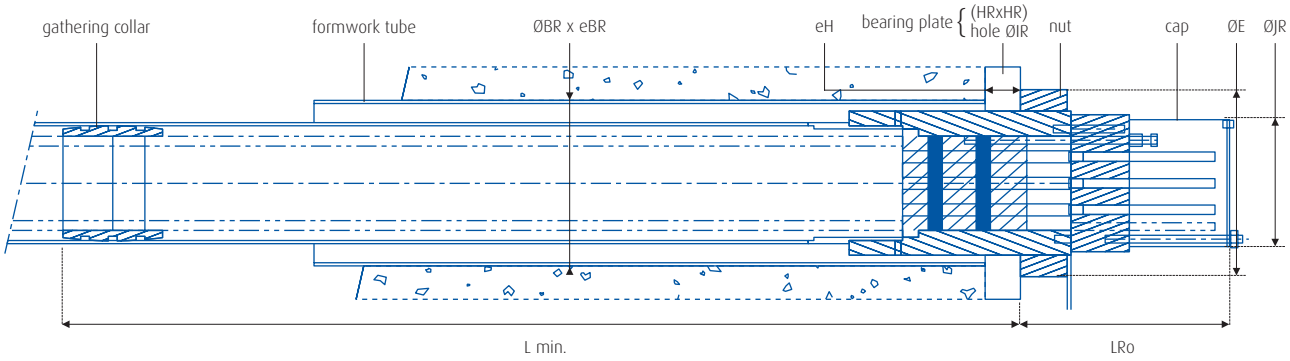
Fixed and adjustable anchors can be installed in the tower or in the deck indifferently and may or may not be the stressing end.
Anchors are designed to provide optimum mechanical performance that results in a very high fatigue limit and residual breaking strength after fatigue.

All components forming part of the Freyssinet HD anchorage system have been intensively tested in independent laboratories, and the results have exceeded the main international acceptance criteria (over 95% of ultimate after fatigue testing).
The Freyssinet anchorage has been qualified according to latest PTI and CIP standards.



Strand stay cable fatigue test (LCPC, Nantes, France)

TOP
Adjustable anchorage



	Formwork tube				Flange/Nut		Outer pipe		Bearing plate*					Cap				Gathering collar
Type	ØBF	eBF	ØBR	eBR	ØD	ØE	ØG	eG	HF	HR	eH*	ØIF	ØIR	ØJF	ØJR	LFo	LRo	L min
12	177.8	6.3	219.1	6.3	210	235	125	6	275	300	50	151	192	200	160	275	346	1 200
19	219.1	6.3	244.5	6.3	250	284	140	6	340	350	50	186	230	240	194	275	356	1 400
27	244.5	6.3	298.5	8	280	336	160	6	400	420	60	212	260	270	222	285	376	1 750
31	244.5	6.3	298.5	8	290	346	160	6	420	440	60	221	270	280	233	290	386	1 750
37	273	6.3	323.9	8	320	368	180	6	460	470	70	239	290	300	252	305	411	1 900
48	323,9	8	368	8	356	415	200	6,2	520	540	80	273	330	345	291	315	434	2 100
55	323.9	8	368	8	370	438	200	6.2	550	570	80	285	350	360	304	320	446	2 200
61	355.6	8.8	406.4	8.8	405	460	225	6.9	600	610	90	318	375	395	336	330	466	2 400
75	368	8.8	445	10	433	506	250	7.7	640	670	100	342	405	423	368	340	481	2 500
91	419	10	482.6	11	480	546	280	8.6	720	750	110	374	450	470	410	360	524	2 850
109	431.8	10	530	12.5	500	600	315	9.7	770	815	120	386	480	490	435	380	560	3 100
127	457.2	10	558.8	12.5	545	640	315	9.7	810	850	130	424	525	535	478	400	600	3 250
169	530	12.5	635	12.5	625	740	355	10.9	950	980	140	490	605	615	555	430	660	3 700

Options

Freyssinet offers a wide choice of solutions to satisfy all functional and aesthetic considerations.

Cohestrand®: cables for very aggressive environment

The Freyssinet HD stay cable can be adapted to provide better anti-corrosion performance for specific environments, by replacing Freyssinet Monostrand by Cohestrand® strand.
This is a sheathed strand with seven galvanised or galfanised (coating composed of a 95% zinc and 5% aluminum alloy) steel wires, covered by a system capable of resisting corrosion in very corrosive environments and also taking axial loads through the sheath when required.

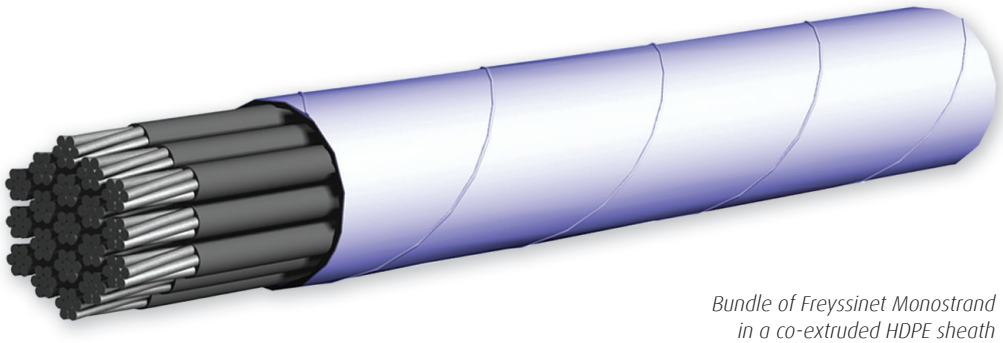
Freyssinet outer sheath: outstanding durability

Intensive research has lead to a range of durable outer sheaths.
The outer sheath is composed of two layers of co extruded HDPE: an inner black layer and an outer coloured layer.

Tests have been carried out on all Freyssinet coloured sheaths to verify long term colour stability. Close control during manufacturing guarantees a durability three times longer than commercially available black and coloured polyethylene, for resistance to ultra-violet induced oxidation and stress cracking.

A special HDPE sheath has also been developed with a silver coloured in-depth metallized outer layer that resembles a brushed stainless steel sheath, while maintaining the ease of placement of HDPE sheaths and the presence of the helical rib aerodynamic protection.

For any location in the world, Freyssinet can provide justification of sheath durability.



Bundle of Freyssinet Monostrand in a co-extruded HDPE sheath with double helical fillets

Compact sheath

For large cable-stayed bridges with a span in excess of 400 m, the drag of the wind on the cables generates significant stresses on the pylon. In order to reduce this stress, and to meet design requirements, Freyssinet has developed a compact outer stay pipe that reduces the space between the bundle of strands and the pipe to a minimum. The durability of this pipe is identical to the standard pipe.

Øresund bridge
Denmark-Sweden

Outer sheath:
A wide range of colours*

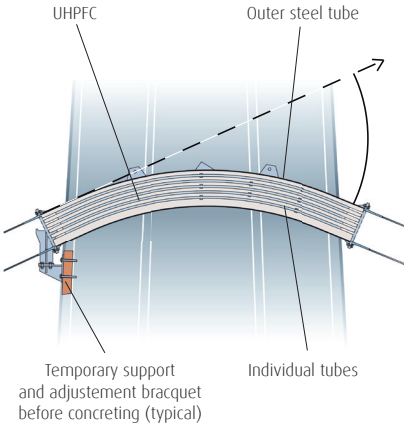
- RAL 9003 — White
- RAL 7035 — Light Grey
- RAL 5024 — Pastel blue
- RAL 5018 — Mediterranean blue
- RAL 1016 — Yellow
- RAL 3020 — Red
- RAL 6021 — Green
- Silver
- Black

** non-contractual colour chart*

Deviation saddles

When it is required that the stay cable continues through the pylon, Freyssinet offers a multitube saddle based on the use of the Cohestrand strand in order to take up the asymmetric frictional loads through the strand sheath. Each strand is deviated individually in a specific tube, giving the following advantages:

- Complete continuity of corrosion protection
- Possibility of individual replacement of strands
- Fatigue resistance identical to a standard stay cable anchor.

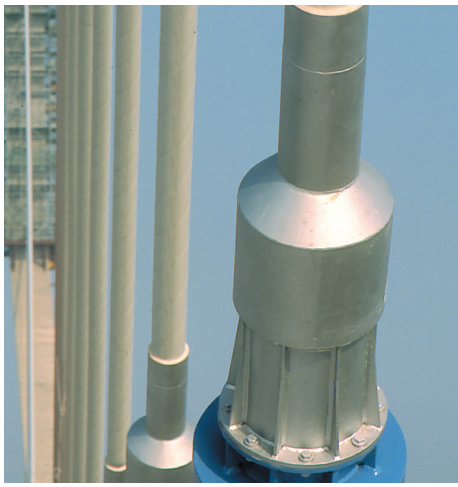


Complementary functions

Complementary functions are sometimes recommended, the most frequent being:

- **antivandalism** tubes on the lower part of the cables;
- **fire protection**, when justified, to take account of the fire risk, particularly on bridges carrying heavy traffic transporting hydrocarbons and on bridges with back stay cables gathered on an anchorage structure;
- **light fittings** fixed directly to the stay cables by a system in accordance with electrical safety standards without disturbing the aerodynamic stability of the cables.

All these options are already used on large well known works throughout the world.



Antivandalism tubes
Seohae Grand bridge / South Korea

Multitube saddle
Sungai Muar / Malaysia

Light fittings
Vasco de Gama bridge / Portugal

Aerodynamic stability

Stay vibration is a concern for bridge designers and owners.
By supplying and installing stay cables for the largest stay cable bridges in recent years, Freyssinet has built up recognized expertise in the engineering of stay cable vibration control.
Thanks to its worldwide experience, Freyssinet can offer a precise diagnostic of the stability of stay cables and a wide range of vibration resistant devices adaptable to each project.

Double helical ribs on outer sheaths

The shape of the ribs and the pitch of the helix they form around the sheath is the result of intensive research based on wind tunnel tests carried out by several laboratories.

The double helical ribs formed on Freyssinet stay cable sheaths deviate water streams flowing along the cable and efficiently prevents instability due to the combined action of wind and rain.

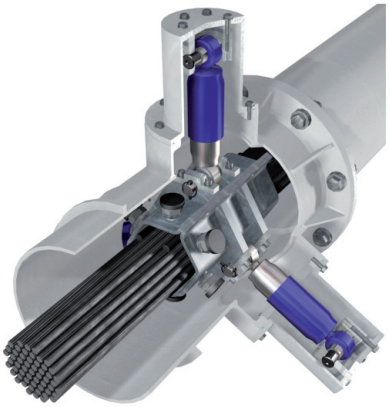
Internal dampers

Stay cables are sensitive to vibrations due to their low intrinsic damping. Freyssinet has developed a patented annular internal damper system to overcome this. These devices are located inside the anchor tubes and provide a smooth outer shape.
These patented devices (the IED - Internal Elastomeric Damper, the IHD- Internal Hydraulic Damper, and the IRD - Internal Radial Damper) damp vibrations of all amplitudes to prevent harmful fatigue phenomena and visible instability.
Freyssinet uses a specific computer model to calculate the damping needs of the stays on a structure and to size the most suitable dampers as a function of the stay cable characteristics.

Helical fillet
Millau bridge / France

IED damper

IHD damper



IRD damper

External dampers

For very long cables or when the geometry requires it, external dampers are more efficient than internal ones.

Two types of devices are available:

- the **fixed external damper FED**, composed of two piston dampers and a support structure;
- the **pendular external damper PED**, also uses piston dampers with a patented pendular lever system free to move around a rod hinged on a fixed support.

Cross ties

Dampers may be insufficient in some exceptional cases. In this case, specific cross ties have to be provided, particularly to cater for stay cable parametric instability.
These cross tie cables sometimes called “aiguilles” are installed on each stay cable plane and are continuous over their entire length. They have, for example, been installed on the Normandie bridge.

FED damper
Cooper bridge / USA

Normandie bridge cross tie / France

PED damper
Charilaos Trikoupis bridge / Greece

Installation

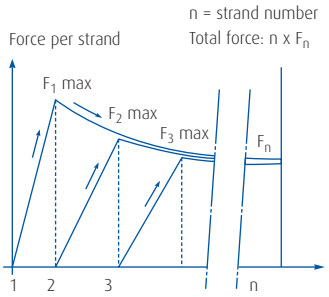
Cardiff Millennium stadium / UK

Seohae Grand bridge / South Korea

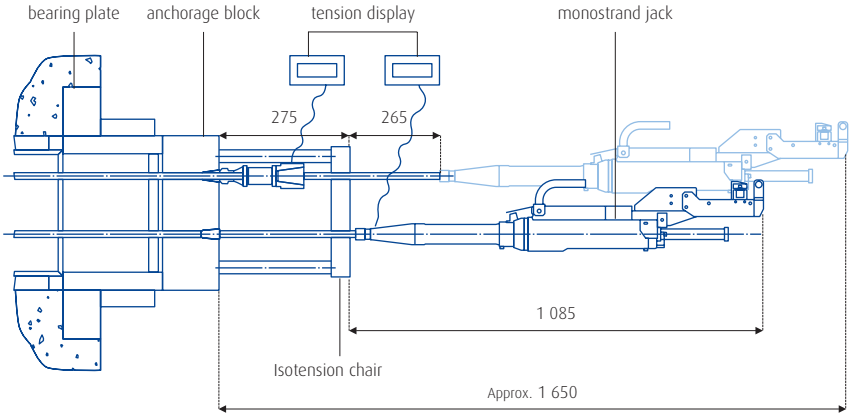
Rapid and fully integrated in the construction style

The Freyssinet HD stay cable system has been used on more than a hundred structures throughout the world, from the smallest to the most ambitious.
The individual installation of strands and automatic adjustment using the Isotension® process patented by Freyssinet, enables outstanding flexibility during installation while ensuring that forces within the stay cables are uniform.
This process also facilitates the monitoring and maintenance of stay cables to ensure long life.
Freyssinet works in partnership with the Advitam company to offer computer aided systems for assistance with monitoring of stay cables and for permanent acoustic monitoring.
The adjustable anchors offer the possibility to adjust the stay cable forces using annular jacks with or without extension.

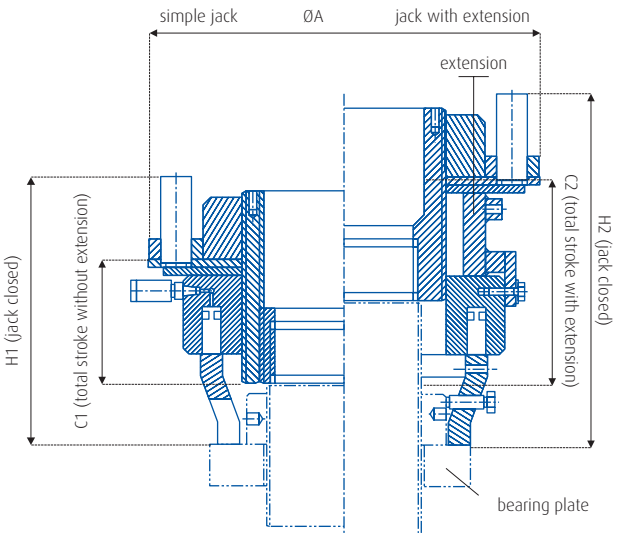
Isotension® principle diagram



Jack clearance for Isotension stressing:



Adjustment dimensions unit:



Stay cables	ØA	H1	H2	C1	C2
12H15	518	370	470	140	240
19H15	518	370	470	130	230
27H15	598	400	500	150	250
31H15	598	400	500	145	245
37H15	598	400	500	135	235
55H15	700	500	600	150	250
61H15	740	510	610	150	250
75H15	740	510	610	150	250
91H15	878	560	660	180	280
109H15	878	560	660	160	260
127H15	938	610	710	185	285

Some references

1/ Shindae (South Korea)

2/ Penang (Malaysia)

3/ Panama

4/ Orinoco (Venezuela)

5/ Serebryany Bor (Russia)

6/ Millau (France)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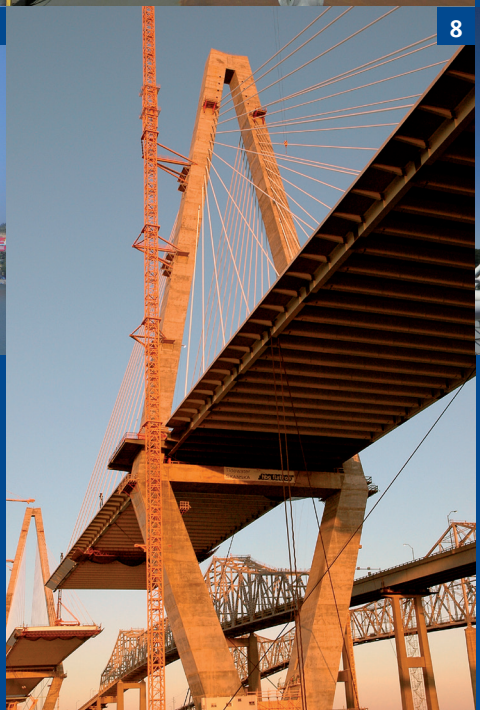
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9

7/ Bai Chay (Vietnam)

8/ Cooper (USA)

9/ Kanne (Belgium)

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May 2010