Freyssinet Prestressing

The system of the inventor of prestressed concrete

DESIGN, BUILD, MAINTAIN

FREYSSINET

SUSTAINABLE TECHNOLOGY

High durability prestressing

Freyssinet Australia has been providing solutions for building post-tensioning, specialised civil and remedial engineering for more than fifty years in Australia, New Zealand, Papua New Guinea and the neighbouring islands of the Pacific Ocean.

We inherited the tradition of technical excellence and attention to detail from our founder Eugène Freyssinet, who made his first experiments on prestressed concrete in 1906 and took out a patent for prestressing in 1928.

Since then, Freyssinet has pioneered the use of high-strength prestressing wire and has continually innovated over the years, to now offer the best prestressing system combining high performance, durability and flexibility that can be applied to many different types of structures.

Freyssinet prestressing anchors from the C Range, F Range and the S Range have been proven in structures over the world to comply with the most stringent requirements: bridge decks and piers, nuclear reactor containment vessels, liquefied natural gas storage tanks, offshore platforms, wind towers, building slabs etc. With the X Range and the R Range, Freyssinet has also designed optimised solutions for existing structure strengthening applications as well as a full range of Freyssibar pre-stressing bars and fittings.

In order to guarantee the best quality of service to all of its clients around the world, Freyssinet manufactures its anchors at its industrial subsidiary FPC (Freyssinet Product Company) and operates a central bank of site equipment.

Because workmanship is essential to the quality and durability, Freyssinet trains its teams in properly installing and grouting post-tensioning. Each year, operators, prestressing installation specialists, supervisors and engineers obtain qualifications certifying their skills, to Freyssinet standards as well as local authority requirements.

Freyssinet Australia has an experienced team of Approved RMS Supervisors.

AS/NZS ISO 9001 Certified

AS/NZS 4801 Certified

AS/NZS ISO 14001 Certified

Freyssinet Australia & New Zealand's management system certifications

EUROPEAN TECHNICAL APPROVAL (ETA)

Freyssinet has been granted European Technical Approvals (ETA) for its **prestressing anchorage ranges:**

- C Range for 3 to 55 strand tendons (ETA 06/0226)
- B Range for 1 to 5 strand tendons (ETA 11/0172)
- F Range for 1 to 4 strand tendons (ETA 06/0226)
- X Range for 1 to 2 strand tendons (ETA 06/0226)

The European Technical Approvals were issued in particular after performance of the tests defined in ETAG 013 (European Technical Approval Guidelines for post-tensioning kits for prestressing of structures). ETA is subject to continuous monitoring by an official body.

Freyssinet is also the holder of the European Technical Approval (ETA) n° ETA 09/0169 for the Freyssibar post-tensioning kit for prestressing of structures.

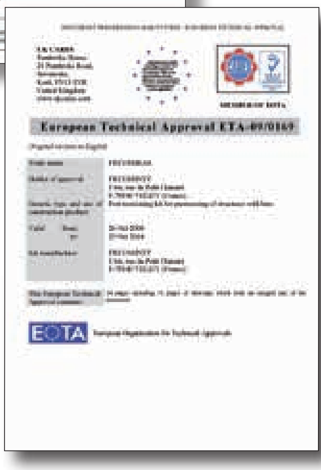
The Freyssibar flat anchorages and couplers for fully threaded bars up to 50mm are approved to the requirements of ETAG 013 (with exception of 29mm diameter).

Agrément Technique Européen No. ETA-06/0226

European Technical Approval No. ETA-06/0226

EOTA

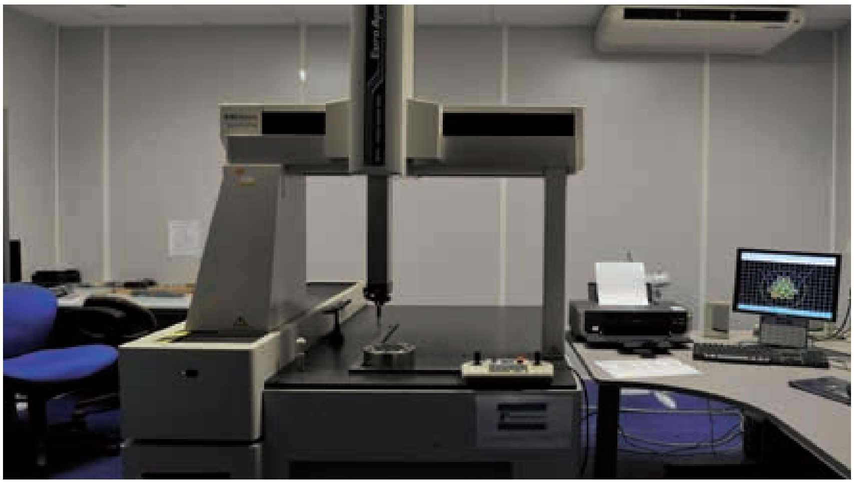
ETA 013 - "European Technical Approval"



European Technical Approval ETA-09/0169

EOTA

ETA 09/0169 - "European Technical Approval"



Testing facility

C Range stressing blocks

For confirmation of Prestressing and Bar Products approved by **RMS** *(Roads & Maritime Services, NSW) or* **TMR** *(Department of Transport & Main Roads, QLD) their respective approval lists should be consulted.*

The **S Range** *as defined in this brochure is used in Australia and New Zealand in lieu of the B Range. The S Range is not ETA approved.*

The R Range **1R15** *as defined in this brochure is approved for use with the* **NZTA** *(New Zealand Transport Authority) with a design life of 50+ years, and has been successfully used with project specific approval on* **RMS** *and* **VicRoads** *projects in Australia.*

C RANGE HIGH STRENGTH PRESTRESSING

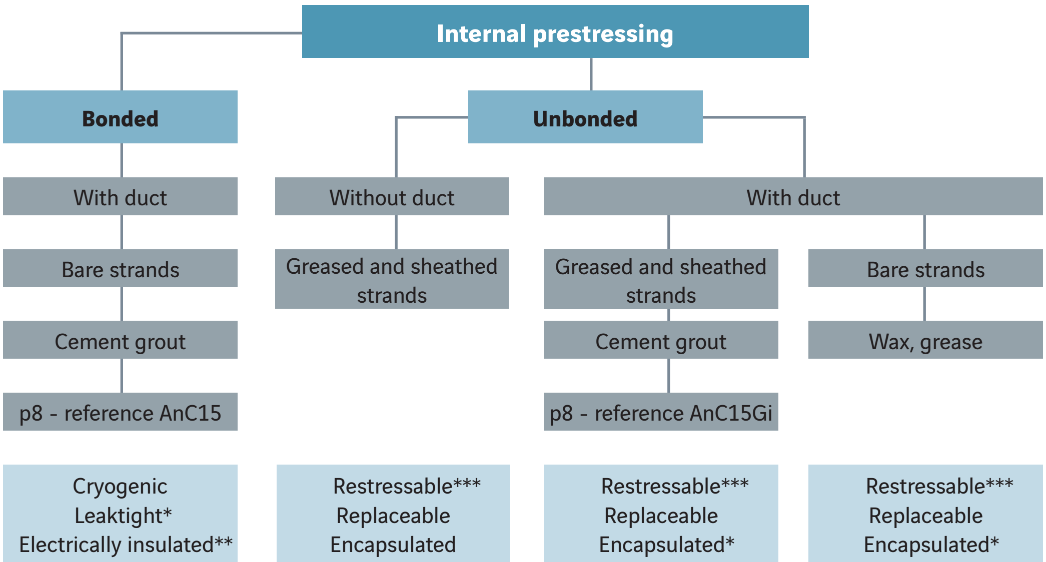
Introduction

The C Range prestressing system is designed and certified for a wide range of applications:

- 15.2 mm and 15.7 mm diameter strands, grade 1770 MPa to 1860 MPa including galvanised strands or greased and sheathed strands,
- prestressing units holding up to 55 strands.

The system can be used in **internal or external prestressing** for concrete, steel, timber or brick structures:

- bonded or unbonded
- with or without ducts
- retensioning possible
- replaceable
- adjustable
- detensioning possible
- with electrical insulation
- for cryogenic applications



** if there is continuous encapsulated sheathing   ** given special provisions - page 9   *** if strand overlengths are stressed*

Bonded internal prestressing configurations

The most common use of C Range anchors in bonded internal prestressing is based on the use of bare strands in a steel corrugated duct, galvanised or ungalvanised, bendable by hand and injected with cement grout after tensioning of the strands. In curved sections and to reduce the coefficient of friction between the strands and the sheath, Freyssinet offers factory lubrication of the steel corrugated sheath using a unique Freyssinet process known as LFC.

To increase the durability of the prestressing or for applications in very aggressive environments in terms of corrosion of prestressing steel, it can be advantageous to encapsulate the tendon with a plastic sheath (as well as its interconnections). Freyssinet has developed the Plyduct® prestressing duct, a HDPE sheath with a corrugated profile to ensure bonding of the tendon to the structure. Sheath thickness is chosen depending on the lateral pressure exerted in the curved sections and the movement of the strands during tensioning.

Internal bonded prestressing, blisters for tendon lapping

C RANGE HIGH STRENGTH PRESTRESSING

Bolte Bridge, Melbourne, Australia

Pluto LNG, Karratha, Australia

For encapsulated tendons on marine structures, Freyssinet also offers a steel duct made up of thick, plain steel tubes with robust joints created by lapping and resin sealed, by means of a heat-shrink sleeve.

For structures made of precast elements with match-cast joints, Freyssinet has developed the Liaseal® sheath coupler. This plastic coupler is watertight to prevent seepage of water between segment joints.

For each configuration there is an appropriate anchor head protection method by injection with the same protection product as used in the main run of the tendon. This can be done either by sealing (concreting the anchor head into a recess) or via a permanent cover made of cast iron (galvanised or painted) or plastic.

To protect tendons from stray currents or for electrical checks on watertightness of plastic sheaths, Freyssinet offers an electrically insulated prestressing system. This is based on the use of an insulating plate under the anchor head with a plastic sheath and cover to create a permanent, watertight casing completely enclosing the strands.

Unbonded internal prestressing configurations

Karuah Bypass Bridge, Australia

External post-tensioning with greased and sheathed strands, Pheasants Nest Bridge, Australia

Unbonded prestressing tendons are mainly used in applications where the tension of the tendon needs to be measured, or where it may need to be retensioned, detensioned or replaced.

To achieve unbonded prestressing it is possible simply to use a flexible, corrosion-resistant protective product instead of the cement grout, normally grease or wax, specially designed for this purpose. Special processes are then followed to detect any leakage along the ducts.

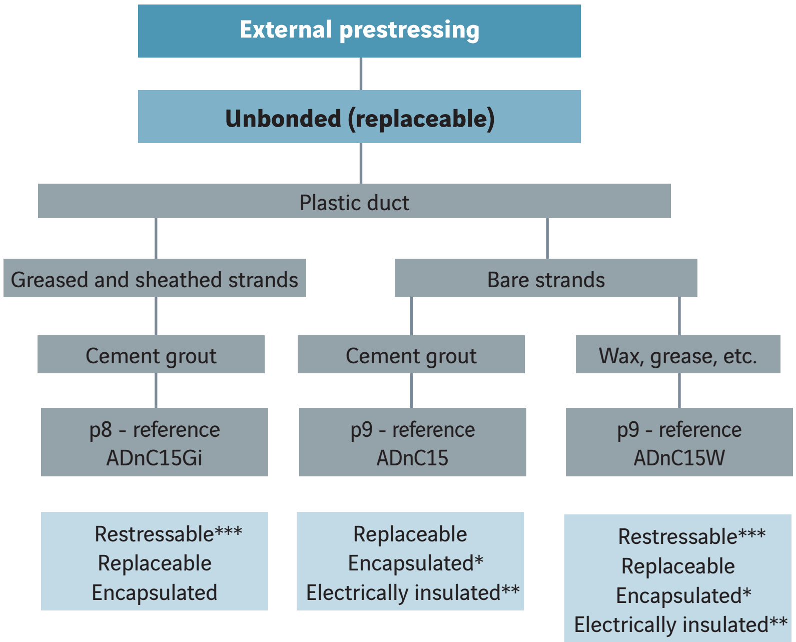
To increase the durability of the prestressing by using a number of corrosion protection barriers or to allow, for example, for individual strands to be replaced, Freyssinet recommends the use of greased and sheathed strands. These greased and sheathed strands can be placed inside a duct injected with cement grout before tensioning of the tendon or incorporated directly into the reinforcement before concreting.

Iron Cove Bridge, Sydney, Australia

C RANGE HIGH STRENGTH PRESTRESSING

Greased and sheathed strands being winched through

External prestressing, Western Link, Melbourne, Australia



** if there is a continuous encapsulated duct*
*** given special provisions - page 9*
**** if strand overlengths are stressed*

External prestressing configurations

External prestressing, West Gate Bridge, Melbourne, Australia

External prestressing is well suited to structures made of thin concrete and also allows for easy inspection of the main run of the tendons.

The most common use of C Range anchors in external prestressing is based on the use of bare strands placed inside sections of thick HDPE ducts assembled by mirror welding, which are injected with cement grout after tensioning of the tendon.

To ensure that the external prestressing can be removed without damaging the structure, the tendons are passing through a double tubing, at deviator and end block. The HDPE ducts run inside a formwork tube that separates the tendon from the structure and distributes the transverse loads caused by local deviation.

To produce tendons in which the strands are independent from each other, Freyssinet recommends using greased and sheathed strands placed in a duct injected with cement grout before tensioning of the tendon. This configuration has the advantage of increasing the durability of the prestressing by increasing the number of barriers against corrosion, by making each strand independent from each other such that the breakage of one strand doesn't affect the force in the remaining strands and by allowing for individual strands to be replaced if needed.

Another solution involves injecting the tendon with a flexible corrosion-resistant protective product, such as grease or wax specially designed for this purpose. Special care must be taken when hot-injecting these products.

C RANGE HIGH STRENGTH PRESTRESSING

ACTIVE ANCHORAGES

Composition

Each anchor consists of:

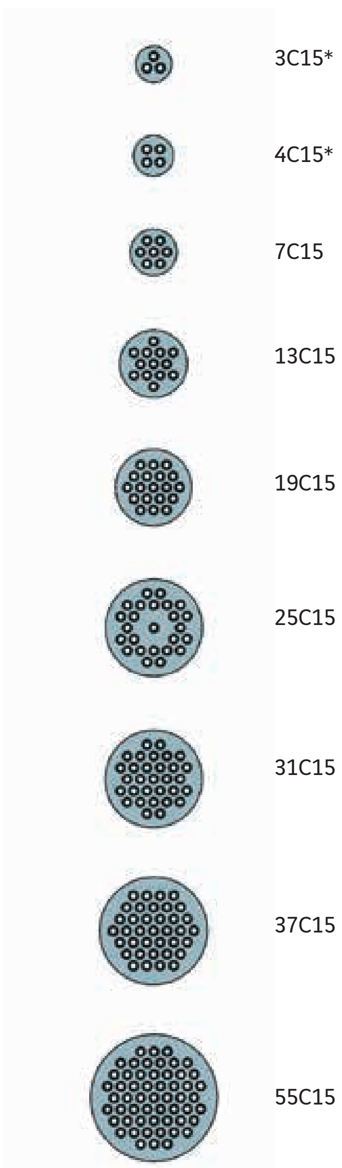
- Freyssinet "Unigrip" wedges (with high performances for strand anchorage under static or dynamic loading),
- anchorage block (circular steel block drilled with conical holes to suit the shape of the wedges),
- trumplate (multi-ribbed cast iron component for improved distribution of the prestressing force into the concrete),
- grout cap (temporary or permanent - optional).

Compact anchorage

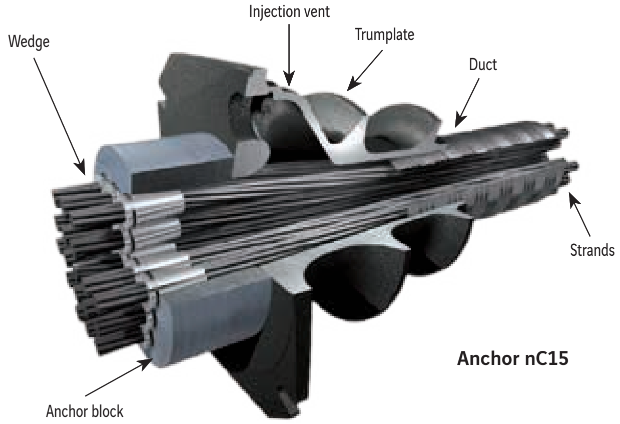
The small size of the C Range anchor allows for:

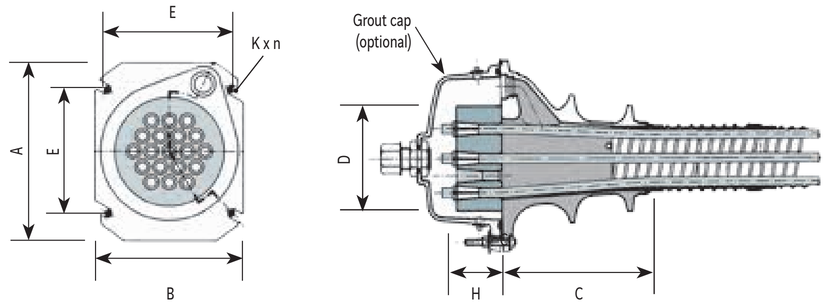
- reducing the thickness of the flanges and webs in a box girder,
- improved concentration of anchors at tendon termination,
- minimal strand deviation.

Central hole anchor units



** Configuration of strands in anchor without central holes - other units without a central hole are available on request*





Units	A (mm)	B (mm)	C (mm)	D (mm)	E (mm)	H (mm)	Kxn (mm)
3C15	150	110	120	85	91	50	M10x2
4C15	150	120	125	95	101	50	M10x2
7C15	180	150	186	110	128	55	M12x2
13C15	250	210	246	160	168	70	M12x4
19C15	300	250	256	185	208	80	M12x4
25C15	360	300	400	230	268	95	M16x4
31C15	385	320	346	230	268	105	M16x4
37C15	420	350	466	255	300	110	M16x4
55C15	510	420	516	300	370	145	M20x4

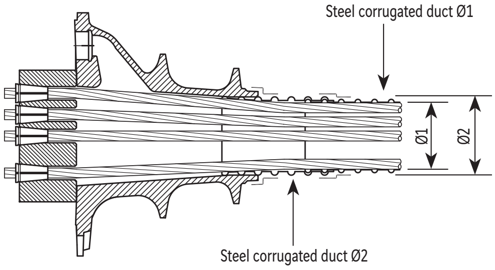
C RANGE HIGH STRENGTH PRESTRESSING

APPLICATION CATEGORIES

ID: Inside Diameter
OD: Outside Diameter
Ø1: Main Duct
Ø2: Transitional Duct

For **bonded internal** prestressing with bare strands with cement grouting

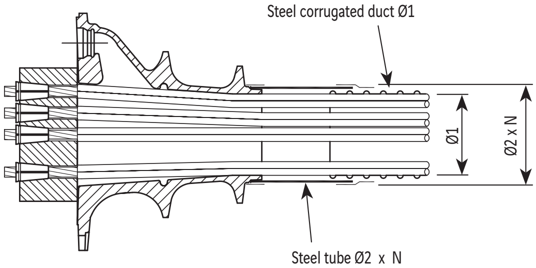
AnC15



Units	ID Ø1 (mm)	ID Ø2 (mm)
3C15	40	45
4C15	45	50
7C15	60	65
13C15	80	85
19C15	95	100
25C15	110	115
31C15	120	125
37C15	130	135
55C15	160	165

For **unbonded internal** prestressing with greased and sheathed strands with cement grouting (before tensioning)

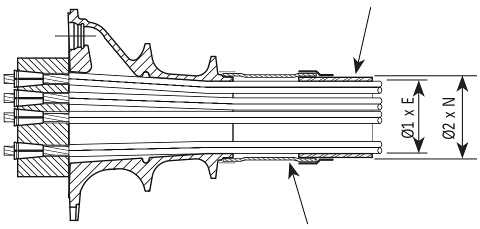
AnC15Gi



Units	ID Ø1 (mm)	OD Ø2 (mm)	N (mm)
3C15	40	76.1	3.6
4C15	65	88.9	4.0
7C15	65	101.6	4.0
13C15	95	114.3	3.2
19C15	115	139.7	5.0
25C15	130	165.1	5.4
31C15	145	168.3	4.8
37C15	145	168.3	4.8

For **unbonded external** prestressing with greased and sheathed strands with cement grouting (before tensioning)

ADnC15Gi



Units	OD Ø1 (mm)	E (mm)	OD Ø2 (mm)	N (mm)
3C15	63	4.7	76.1	3.6
4C15	75	5.5	88.9	4.0
7C15	90	6.6	101.6	4.0
13C15	110	5.3	114.3	3.2
19C15	125	6.0	139.7	5.0
25C15	140	6.7	165.1	5.4
31C15	160	7.7	168.3	4.8
37C15	160	7.7	168.3	4.8
55C15	200	9.6	219.1	6.4

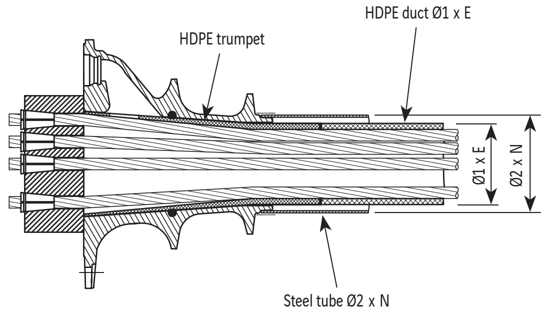
C RANGE HIGH STRENGTH PRESTRESSING

ID: Inside Diameter
OD: Outside Diameter
Ø1: Main Duct
Ø2: Transitional Duct

For **unbonded external** prestressing with bare strands with cement grouting

Units	OD Ø1 (mm)	E (mm)	OD Ø2 (mm)	N (mm)
3C15	50	3.7	76.1	3.6
4C15	63	4.7	88.9	4.0
7C15	63	4.7	101.6	4.0
13C15	90	6.6	114.3	3.2
19C15	110	5.3	139.7	5.0
25C15	125	6.0	165.1	5.4
31C15	140	6.7	168.3	4.8
37C15	140	6.7	168.3	4.8

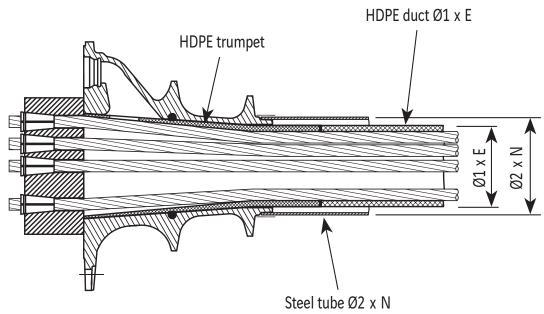
ADnC15



For **unbonded external** prestressing with bare strands with injection of flexible product

Units	OD Ø1 (mm)	E (mm)	OD Ø2 (mm)	N (mm)
3C15	50	3.7	76.1	3.6
4C15	63	4.7	88.9	4.0
7C15	63	4.7	101.6	4.0
13C15	90	6.6	114.3	3.2
19C15	110	8.1	139.7	5.0
25C15	125	9.2	165.1	5.4
31C15	140	10.3	168.3	4.8
37C15	140	10.3	168.3	4.8

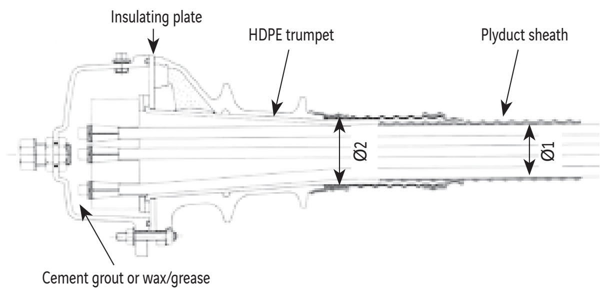
ADnC15W



For prestressing with electrical insulation

Units	ID Ø1 (mm)	ID Ø2 (mm)
3C15	40	45
4C15	45	50
7C15	60	65
13C15	80	85
19C15	95	100
25C15	110	115
31C15	120	125
37C15	130	135
55C15	160	165

Tendons with C Range anchors can be enclosed in continuous non-conductive sheathing to obtain an electrically insulated prestressing system. Typical applications are railway structures where stray currents can compromise tendon durability.



C RANGE HIGH STRENGTH PRESTRESSING

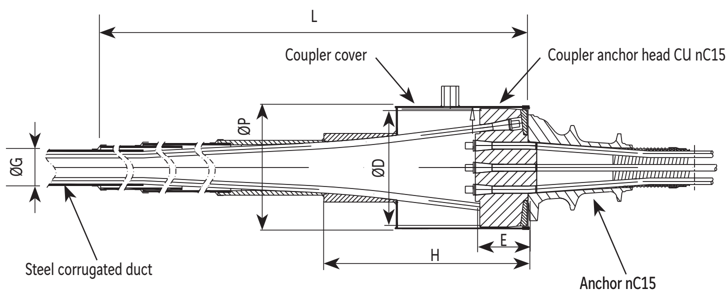
CU AND CC FIXED MULTI-STRAND COUPLERS

Couplers are needed when a continuous structure is built in successive phases with primary tendons already in place, tensioned and grouted in the previous segment. They are generally used in internal prestressing. Two types of multistrand couplers are available:

CU couplers

For these CU couplers, the stressing block of the primary tendon is modified to receive the anchoring wedges of the secondary tendon. The assembly is protected by a cover with a trumpet at one end to provide the connection with the duct of the secondary tendon. The CU couplers are covered by European Technical Approval ETA-10/0326.

Units	L (mm)	E (mm)	H (mm)	ØP (mm)	ØD (mm)	ØG (mm)
CU 3C15	410	120	150	146	140	40
CU 4C15	415	127	155	156	150	45
CU 7C15	615	120	275	206	200	60
CU 13C15	775	130	435	282	276	80
CU 19C15	785	140	445	312	306	95
CU 25C15	891	145	561	352	346	110
CU 31C15	1030	150	690	362	356	120
CU 37C15	1060	156	720	392	386	130

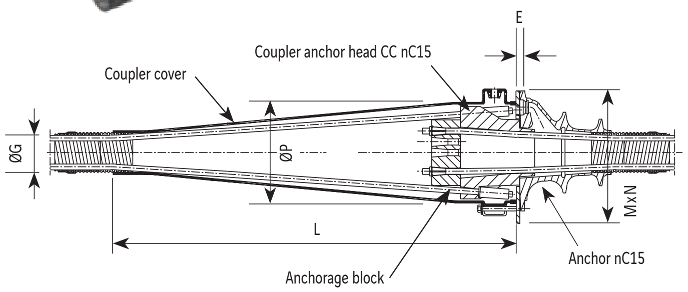


CC couplers

For these CC couplers, a notched collar is inserted between the trumplate and the stressing block of the primary tendon. The secondary tendon is attached by means of swages resting onto the collar.

Units	L (mm)	E (mm)	M x N * (mm)	ØP (mm)	ØG (mm)
CC 3C15**	570	10	220 x 220	210	40
CC 4C15**	600	10	240 x 240	220	45
CC 7C15**	670	10	260 x 260	230	60
CC 13C15	770	10	290 x 290	275	80
CC 19C15	825	12	320 x 320	305	95
CC 25C15	900	5	360 x 360	340	110
CC 31C15	1110	5	420 x 420	400	120

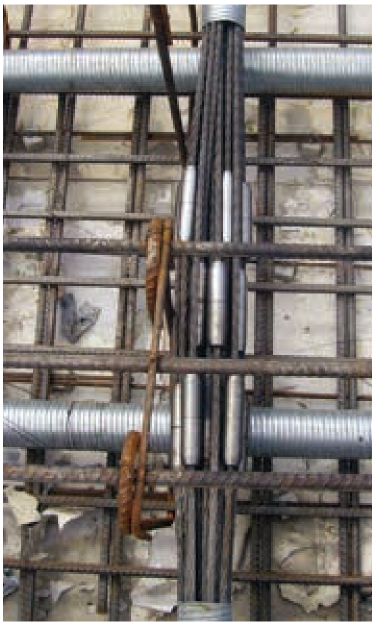
** Dimensions of the retaining plate.*
*** Available on request.*



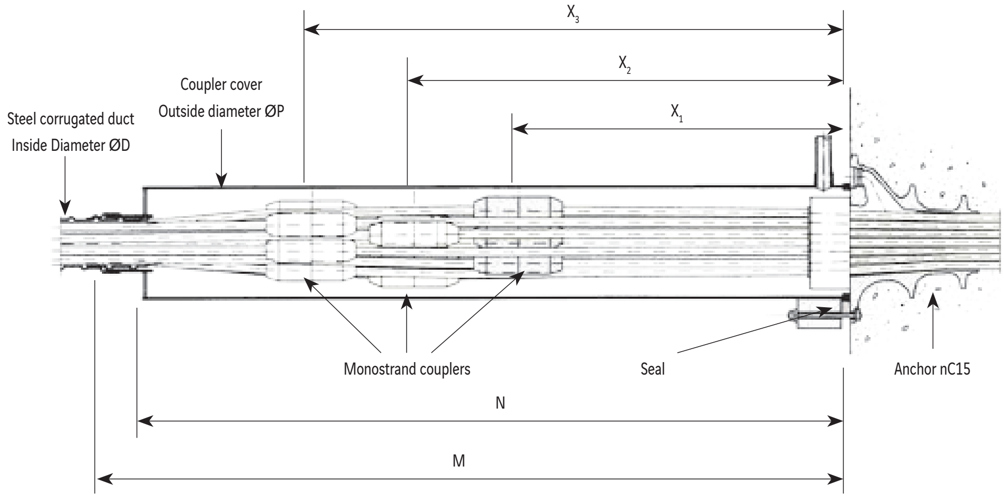
CI FIXED MONO-STRAND COUPLERS

CI couplers

CI fixed couplers allow for a secondary tendon to be connected to a primary tendon using machined monostrand couplers with automatic locking by a spring inserted between the two opposing wedges. The primary anchor is a typical C Range anchor. The monostrand couplers are staggered to offer a very compact configuration.



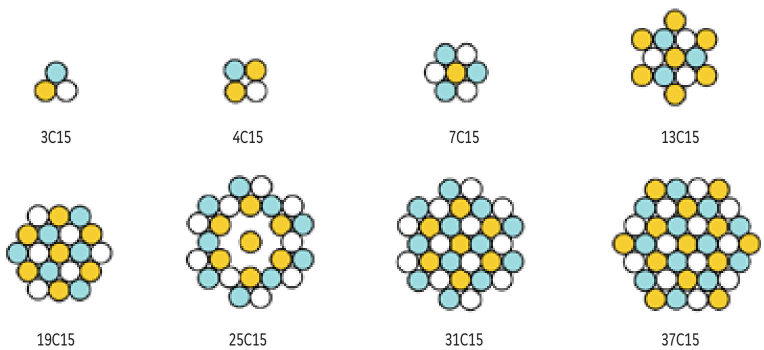
Monostrand couplers



Coupler cover installed

Units	ØD (mm)	M (mm)	N (mm)	ØP (mm)	X1 (mm)	X2 (mm)	X3 (mm)
CI 3C15	40	1,050	1,000	102	250	500	750
CI 4C15	45	1,050	1,000	127	250	500	750
CI 7C15	60	1,050	1,000	127	250	500	750
CI 13C15	80	1,200	1,150	219	300	550	800
CI 19C15	95	1,200	1,150	219	300	550	800
CI 25C15	110	1,250	1,200	273	350	600	850
CI 31C15	120	1,350	1,300	273	400	650	900
CI 37C15	130	1,530	1,480	324	400	650	900

Coupled tendons



C RANGE HIGH STRENGTH PRESTRESSING

PASSIVE ANCHORAGES

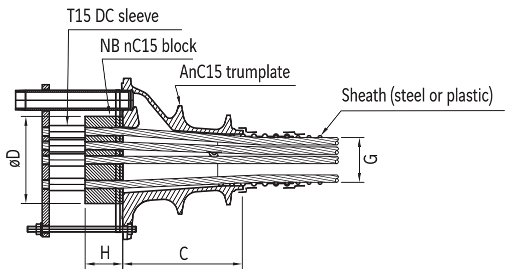
There are two types of cast in passive anchorages, embedded into concrete and used in combination with C Range active anchorages: NB and DE. In both cases, strands are installed before concreting.

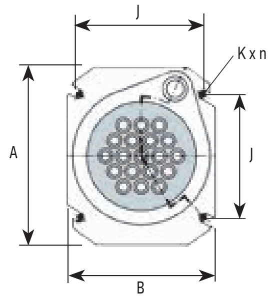
NB anchorage

NB anchorages comprise of a stressing block drilled with cylindrical holes and on which swages are maintained by a retaining plate.

Units	A (mm)	B (mm)	C (mm)	D (mm)	H (mm)	G (mm)	J (mm)	Kxn
3C15	150	110	120*	85	50	40**	91	M10x2
4C15	150	120	125*	95	50	45***	101	M10x2
7C15	180	150	186	110	55	60	128	M12x2
13C15	250	210	246	160	70	80	168	M12x4
19C15	300	250	256	185	80	95	208	M12x4
25C15	360	300	400	230	95	110	268	M16x4
31C15	385	320	346	230	105	120	268	M16x4
37C15	420	350	466	255	110	130	300	M16x4
55C15	510	420	516	300	145	160	370	M20x4

** 2-stage trumplate ** Oval duct version 58x21*
**** Oval duct version 75x21*

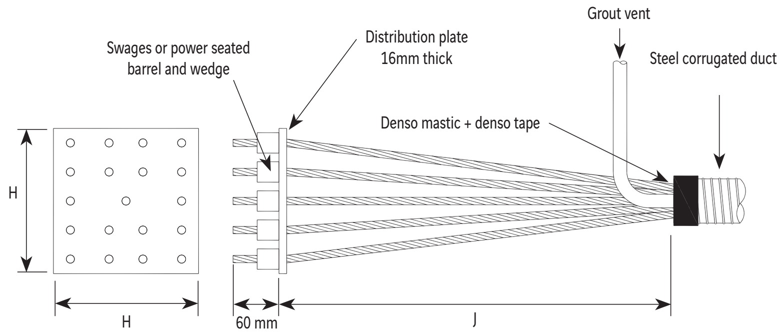




DE anchorage

DE (for Dead End) passive anchors are installed together with the strands, the ducts and the steel reinforcements inside the formwork before concreting. They are inaccessible once concrete is poured and during tensioning. DE anchors are made of a steel plate and swages or pre-blocked barrels and wedges (power seating load shall not be less than 75% of the strand load). Adequate local reinforcements shall be designed and installed around the anchorage as per AS-5100.5 section 12.2.

Units	H (mm)	J (mm)
3C15	120	300
4C15	140	300
7C15	180	400
13C15	245	600
19C15	300	800
25C15	340	950
31C15	380	1100
37C15	420	1200



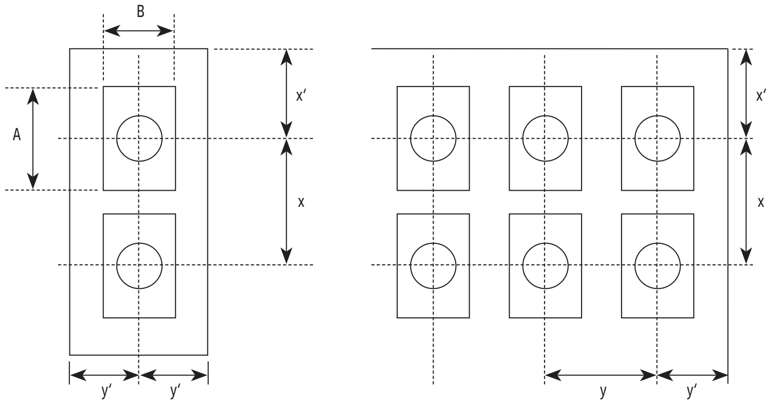
LAYOUTS OF C RANGE ANCHORS

The anchors must be positioned at an adequate distance from the wall and spaced at a minimum centre-to-centre distance. These distances are obtained using dimensions **a** and **b** of the test assemblies created under the European Technical Approval procedure.

In the following, it is taken that the anchors are positioned along two normal direction axes: **x** and **y**, with the short side of the trumplate aligned on the **y** axis.

Notation

- A, B: plane dimensions of the trumplate (A ≥ B).
- a, b: side lengths of test specimen (a ≥ b).
- x, y: minimum centre distance between two anchorages in the structure in x and y directions.
- x′, y′: minimum edge distance between anchorages and the closest external surface in x and y directions.
- $f_{cm,o}$: mean compressive strength measured on cylinder required before tensioning.



Dimensions x and y must meet the following conditions:

x ≥ A + 30 (mm)
y ≥ B + 30 (mm)
x . y ≥ a · b
x ≥ 0.85 a
y ≥ 0.85 b
x′ ≥ 0.5 x + concrete cover — 10 (mm)
y′ ≥ 0.5 y + concrete cover — 10 (mm)

Distances a and b

a=b (mm)			
Units	fcm,0 (MPa)		
	24	44	60
3C15	220	200	180
4C15	250	220	200
7C15	330	260	240
13C15	450	340	310
19C15	530	400	380
25C15	630	460	440
31C15	690	520	500
37C15	750	580	540
55C15	1070	750	690

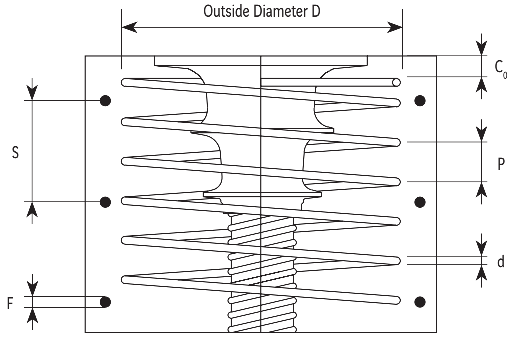
Values a and b are given in the table opposite, for three different classes of concrete strength $f_{cm,o}$.

If, for $f_{cm,o}$, the design provides for a value other than the values given in the table, straight-line interpolation can be used to determine the x and y values. However, tensioning cannot be carried out at full force if $f_{cm,o}$ is lower than the lowest of the values given in the tables opposite.

If the design provides for partial tensioning or a tensioning rate of less than min [0.8 F_{pk} ; 0.9 $F_{p0.1\%}$], interpolation can be used to determine the required value of fcm,o, given that at 50% of full force, the required strength for the concrete can be brought to 2/3 of the values given in the two previous tables and that at 30% of this force, the required strength for the concrete can be brought down to half of the values shown.

C RANGE HIGH STRENGTH PRESTRESSING

ANTI-BURST REINFORCEMENT



Helical steel and additional reinforcement

In anchorage zone, prestressing tendons impose to the structure concentrated forces requiring a specific arrangement of reinforcement. The C Range anchors use trumplates with three load spreading layers. These ribbed anchors are more compact than single plate anchors and are not covered by AS 5100.5 - 12.2 for bursting forces calculation.

Anti-burst reinforcement as defined hereunder results from load transfer testing. It consists of the superimposition of:

- Helical steel,
- Additional reinforcement.

Helical steel and additional reinforcements are defined in the tables below.

The shape of the additional reinforcement has to be designed to suit the concrete outlines around the anchorage and are generally made of rectangular stirrups.

The tables below have been adapted from Freyssinet European Technical Approval to reinforcement bars readily available in Australia.

The reinforcements detailed in the tables must, in most cases be supplemented by general reinforcement ensuring the general balance of the anchorage zones. With regards to multiple eccentric anchorages and spalling reinforcements, refer to Appendix G of AS-5100.5 called End Zones for prestressing anchorages.

Type	Helical Bursting Steel (grade R250N)					Complementary Stirrups (grade D500N)		
Anchor (-)	Pitch P (mm)	Bar Dia. d (mm)	Number (-)	Concrete cover C_0 (mm)	External Dia. D (mm)	Pitch (mm)	Bar Dia. F (mm)	Number (-)
3C15	50	10	5	40	160	110	10	3
4C15	60	10	5	40	190	115	10	3
7C15	60	16	6	40	270	120	10	3
13C15	70	16	7	40	390	130	16	4
19C15	60	16	8	40	470	180	20	4
25C15	80	20	7	40	550	175	20	5
31C15	80	20	7	40	600	180	20	5
37C15	90	20	7	40	660	130	24	6
55C15	100	24	9	40	930	200	24	6

For fcm,0 = 24 MPa

Type	Helical Bursting Steel (grade R250N)					Complementary Stirrups (grade D500N)		
Anchor (-)	Pitch P (mm)	Bar Dia. d (mm)	Number (-)	Concrete cover C_0 (mm)	External Dia. D (mm)	Pitch (mm)	Bar Dia. F (mm)	Number (-)
3C15	50	10	5	40	150	150	10	2
4C15	60	10	5	40	160	250	10	3
7C15	60	12	6	40	200	140	10	4
13C15	70	16	7	40	290	120	16	3
19C15	60	16	8	40	320	200	16	3
25C15	80	20	7	40	380	165	16	3
31C15	80	20	8	40	420	210	16	4
37C15	90	20	9	40	520	210	20	5
55C15	100	24	10	40	650	250	20	6

For fcm,0 = 44 MPa

Type	Helical Bursting Steel (grade R250N)					Complementary Stirrups (grade D500N)		
Anchor (-)	Pitch P (mm)	Bar Dia. d (mm)	Number (-)	Concrete cover C_0 (mm)	External Dia. D (mm)	Pitch (mm)	Bar Dia. F (mm)	Number (-)
3C15	50	10	5	40	150	150	10	2
4C15	60	10	5	40	160	150	10	2
7C15	60	12	6	40	200	160	10	3
13C15	70	16	7	40	290	135	12	3
19C15	60	16	8	40	320	250	12	3
25C15	80	20	7	40	390	220	16	3
31C15	80	20	8	40	420	220	16	4
37C15	90	20	9	40	470	180	16	4
55C15	100	24	10	40	600	180	16	4

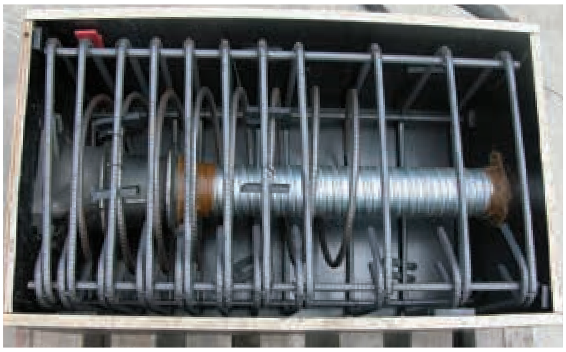
For fcm,0 = 60 MPa

The yield strength of the helical steel can be either fy=250 MPa or 500 MPa since anti-burst is governed by crack opening control and not by design for ultimate conditions thus the cross sectional area and the modulus prevail over the tensile strength.

If required for practical reasons, (to reduce congestion of the reinforcement or to overcome difficulties of the steel fixer to bend helix) helical steel and additional stirrups can be combined together. This alternative reinforcement arrangement provides the same or a greater cross sectional area, and the overall dimensions are similar to what is shown on the table.

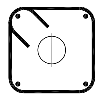
For example, for the 13C15 anchorage at fcm,0=44 MPa, it specifies helical steel at 7 loops of 16 mm diameter bar, pitch 70, outside diameter 290 plus 4 layers of additional reinforcement made of 12 mm diameter bar ligatures spaced at 120 mm spacing. They could be replaced by 10 square closed ligatures 350x350 made of 16 mm diameter bar spaced at 50 mm.

Another example, for the 19C15 anchorage at fcm,0=44 MPa, it specifies helical steel at 8 loops of 16 mm diameter bar, pitch 60, outside diameter 320 plus 3 layers of additional reinforcement made of 16 mm diameter bar ligatures spaced at 200 mm spacing. It can be replaced by only one helical steel at 11 loops of 16 mm diameter bar, outside diameter 320, pitch 50.

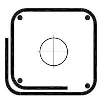


Reinforced concrete test prism for anti-burst test of 13C15 anchor

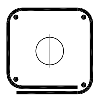
Example of anti-burst reinforcement



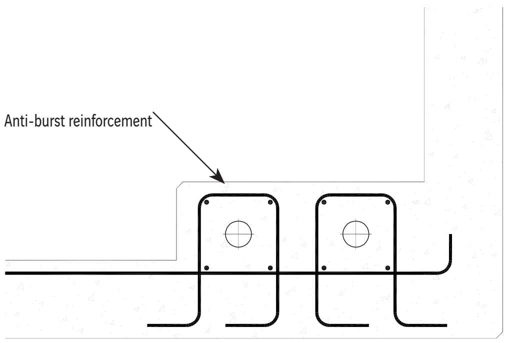
Closed Ligatures with 135 degrees hook
Check clash with central duct



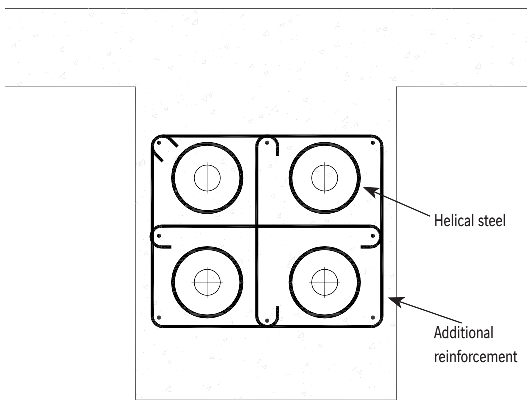
Closed Ligatures with 90 degrees cog



Closed Ligatures with 90 degrees cog
Check if enough lap length - weld if not



Typical anti-burst in a blister



Typical anti-burst for a group of anchors

S RANGE SLAB PRESTRESSING ANCHORAGE

Application Categories

Freyssinet developed the S Range post-tensioning system in order to offer a range of small tendons with flat anchorages, especially adapted for post-tensioning of slabs, walls, or for transverse post-tensioning of a bridge top slab.

The S Range is usually based on bonded tendons (bare strands threaded into a flat duct and injected with cement grout), but can also be used with unbonded tendons (greased and sheathed strands encased or not in a flat duct).

Components

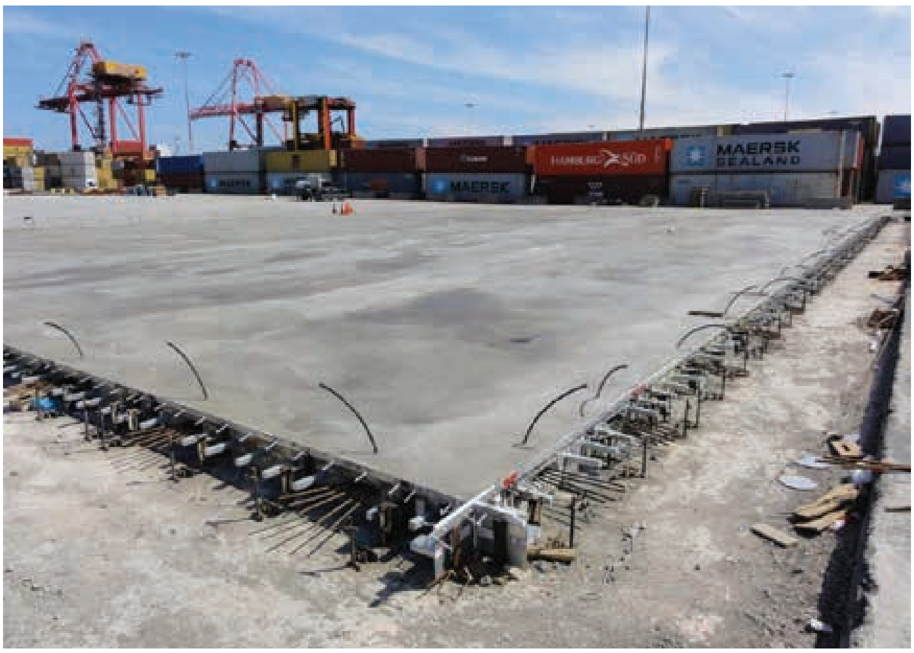
Strand and duct

Strands used with the S Range conform to AS4672 or prEN10138 (refer to paragraph on strands on page 20). Tendons are made of 2 to 5 strands, with 12.7 mm or 15.2 mm diameter placed inside a flat duct that can be either smooth or corrugated.

Anchorage

The strands are anchored individually by means of a 2 wedge pulled into the conical holes of the anchorage block that is bearing onto the trumplate. A recess former is used during concreting to connect the trumplate to the formwork.

5S13 Anchor



Slab post-tensioning using S Range Anchors

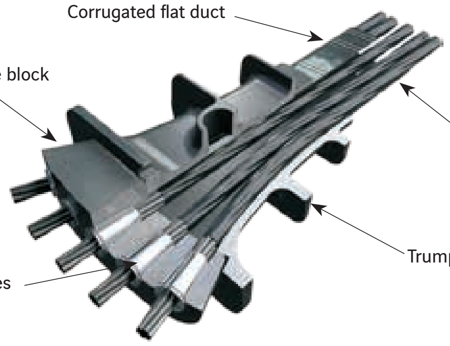
S RANGE SLAB PRESTRESSING ANCHORAGE

Active Anchorages

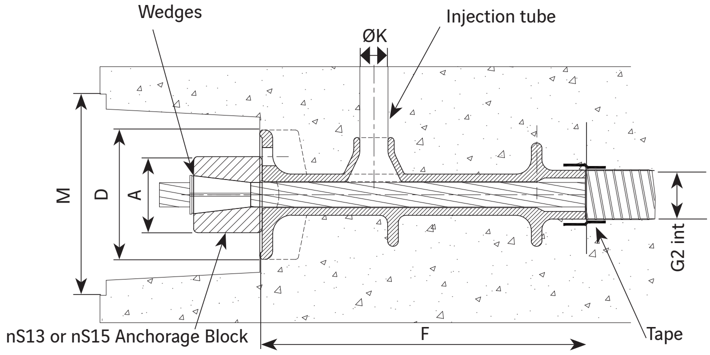
(mm) UNIT	No of Strands	Strand Diam (mm)	Anchorage Block A	Anchorage Block B	Anchorage Block C	Trumplate D	Trumplate E	Trumplate F
3S13	3	12.7	50	135	45	80	150	137
2S15	2	15.2						
4S13	4	12.7	50	214	45	83	233	215
5S13	5	12.7						
3S15	3	15.2						
4S15	4	15.2						
5S15	5	15.2	5 x monostrand anchor			77	260	269

(mm) UNIT	Corrugated Duct G1 x G2	Injection Tube ØK
2S13	40 x 19	18
4S13	70 x 19	18
3S13		
5S13		
3S15		
4S15		
5S15	90 x 19	18

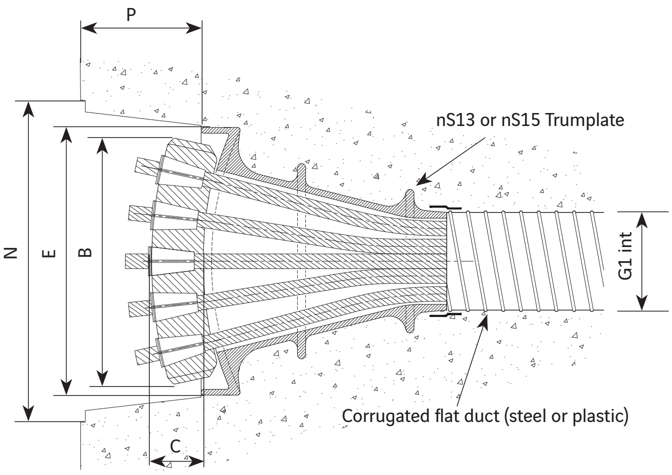
(mm) UNIT	Recess M	Recess N
3S13	240	130
2S15		
4S13	300	130
5S13		
3S15		
4S15		
5S15	380	130



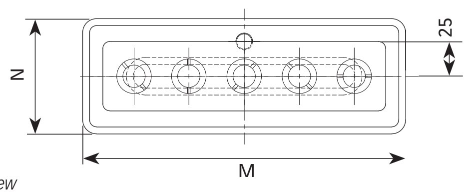
S Range Anchorage



S Range Anchorage - elevation



S Range Anchorage - plane view



S Range Anchorage Recess- front view

S RANGE SLAB PRESTRESSING ANCHORAGE

SPACING & EDGE DISTANCE

The anchorages must be positioned with a minimum spacing centre-to-centre and with a minimum slab thickness. These distances have been obtained using load transfer test results on concrete blocks under the European Technical Approval procedure and are summarised in the tables below.

In practice, flat anchorages are located at mid depth of the slab.

For intermediate values of spacing or slab thickness that are different from the values shown in the table, interpolation shall be used such as the area thickness x spacing remains identical.

For instance, if a slab thickness of 200 is used with 4S15 anchorages, the minimum spacing shall be 475 x 170 / 200 = 404 mm.

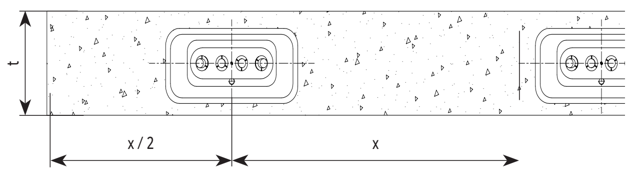
The minimum compressive strength measured on concrete cylinder required before tensioning is:

- 20 MPa if strands are 12.7 mm diameter to AS4672.
- 22 MPa if strands are 15.2 mm diameter to AS4672.

t=tmin

UNIT	x	t
	(mm)	(mm)
3S13	350	150
4S13	415	170
5S13	475	170
3S15	415	170
4S15	475	170
5S15	525	190

Minimum spacing when t=tmin



S Range anchorages spacing and slab thickness

x=xmin

UNIT	x	t
	(mm)	(mm)
3S13	255	210
4S13	300	235
5S13	340	240
3S15	300	235
4S15	340	240
5S15	385	260

Minimum slab thickness when x=xmin

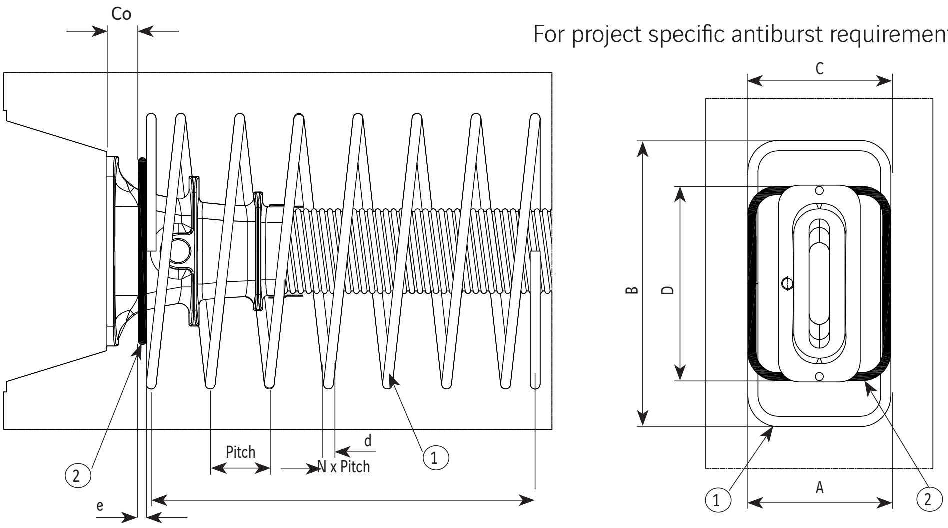
S Range anchorages prior to placing concrete

S RANGE SLAB PRESTRESSING ANCHORAGE

ANTI-BURST REINFORCEMENT

Anti-burst reinforcement shall be placed around the anchorage to adequately transfer the prestressing force from the anchorage to the structure while limiting the concrete cracking. Anti-burst arrangement is the result of load transfer test results on concrete blocks under European Technical Approval procedure and is defined by the following tables as a combination of helical steel (1) and additional reinforcement (2).

For project specific antiburst requirements, please consult Freyssinet design engineers.



S Range anchorages anti-burst reinforcement

S Range anchorages anti-burst reinforcement

The following table has been adapted from Freyssinet European Technical Approval and S Range testing to reinforcement bars readily available in Australia.

UNIT	Helical Steel (1)						Additional reinforcement (2)		
	Pitch	d	N	A	B	Co	e	C	D
3S13	60	10	4	120	200	45	10	120	120
4S13	60	10	6	140	240	45	10	140	160
5S13	60	10	6	140	260	45	10	140	190
3S15	60	10	6	140	240	45	10	140	160
4S15	60	10	6	140	280	45	10	140	190
5S15	60	12	6	140	320	45	10	140	240

Anti-burst reinforcement schedule – grade D500N

COMPONENTS COMMON TO C & S RANGES

PRESTRESSING STRANDS

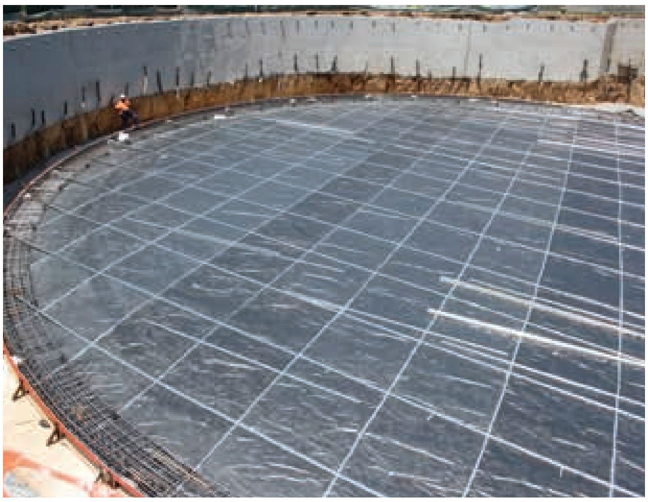
The table below gives the main characteristics of the most common strands used in Australia with the Freyssinet prestressing system:

Characteristics of **strands** to Australian and European Standards

Standard	AS 4672	AS 4672	AS 4672	pr EN 10138
Nominal diameter	12.7 mm	15.2 mm	15.2 mm	15.7 mm
Minimum tensile strength	1870 MPa	1750 MPa	1830 MPa	1860 MPa
Nominal cross sectional area	99 mm2	143 mm2	143 mm2	150 mm2
Nominal mass per length	0.774 kg/m	1.122 kg/m	1.122 kg/m	1.172 kg/m
Nominal modulus of elasticity	195 GPa	195 GPa	195 GPa	195 GPa
Minimum breaking load Fpk	184 kN	250 kN	262 kN	279 kN
Minimum 0.1% Proof force Fp0,1 (Yield Load)	151 kN	205 kN	214 kN	246 kN
Minimum elongation at maximum Load	3.5 %	3.5 %	3.5 %	3.5 %
Maximum relaxation 1000 hours at 70% of Min. Breaking load	2.5 %	2.5 %	2.5 %	2.5 %
Maximum relaxation 1000 hours at 80% of Min. Breaking load	3.5 %	3.5 %	3.5 %	4.5 %

Characteristics of **tendons** made up of 15.7 mm diameter strands

Units	15.7mm diameter strand to pr EN-10138		
Number of strands	Nominal cross-section (mm2)	Mass per metre (kg/m)	Tendon minimum breaking load (kN)
1	150	1.17	279
2	300	2.34	558
3	450	3.52	837
4	600	4.69	1,116
7	1050	8.20	1,953
13	1950	15.24	3,627
19	2850	22.27	5,301
25	3750	29.30	6,975
31	4650	36.33	8,649
37	5550	43.36	10,323
55	8250	64.46	15,345



Bli Bli Reservoir, Australia

COMPONENTS COMMON TO C & R RANGES

DUCTS

The following duct types are used for C Range and S Range tendons:

Internal

Steel corrugated duct

Steel corrugated duct

The recommended dimensions for ducts are given in the tables associated with each anchor. However, it must be checked that the suggested dimensions are compatible with applicable regulations. When a lower coefficient of friction is required, a phosphate treated/soaped corrugated metal duct (L.F.C.) can be used.

Corrugated plastic Plyduct duct

Developed and patented by Freyssinet to meet the requirements of FIB (International Federation for Structural Concrete) recommendations

"Corrugated Plastic Ducts for Internal Bonded Post-Tensioning Systems" (2000) and the Concrete Society TR47 "Durable Bonded Post-tensioned Concrete Bridges", this duct is air and watertight.

Inside diameter of PLYDUCT duct (with sleeve = d + 10)									
Thickness 2.5 mm	40	45	50	60	65	70	80	90	95
Thickness 3.0 mm	100	105	110	115	120	130	160	-	-

Liaseal

Liaseal

Developed by Freyssinet, the Liaseal duct coupler ensures leaktightness of ducts at segment joints, in particular if they are match-cast and are no longer accessible. Used in association with the Plyduct duct, it allows for the creation of continuous, leaktight plastic ducts.

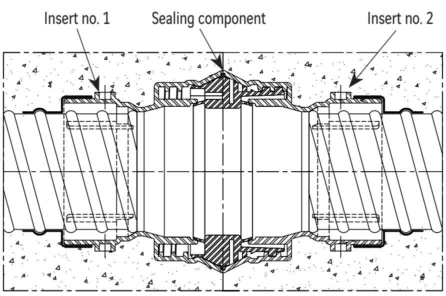
LIASEAL			
Outside diameter of LIASEAL (mm)	125	140*	155*
Inside diameter of sheath (mm)	65	80	95

Available on request

Steel tubes

For totally leaktight or highly deviated ducts.

External



Tendons injected with cement grout

High Density Polyethylene (HDPE) duct in zones external to the concrete. The material is to be grade PE80 or PE100. Use of tubes with nominal pressure rating PN 6.3 is recommended, steel tube in end block, diaphragms and deviators blocks.

Tendons injected with grease or wax

Use of HDPE duct with nominal pressure rating PN 10 is recommended, unless preliminary study suggests otherwise.

COMPONENTS COMMON TO C & S RANGES

GEOMETRY

Special case

If LFC sheaths are used, it is possible to reduce the radius of curvature of sheaths bendable by hand, while maintaining correct transmission of the prestressing forces. The lower limit of the radius of curvature is then $R_{min} \geq 1.35\sqrt{n}$, n representing the number of strands in the tendon.

Internal

The radius of curvature of the duct must be at least equal to:

- 100 Ø for circular or flat rigid ducts bendable by hand (with Ø = inside diameter of duct),
- 3 m for steel tubes.

As an exception, the radius of curvature may be reduced to 20 Ø for steel tubes on the condition that:

- this radius is not less than 1.3 m for 15.2 mm or 15.7 mm dia. strands,
- the tension does not exceed 70% of the minimum breaking load of the tendon in the area where the radius is less than three metres,
- the sum of the angular deviations along the length of the tendon does not exceed 3 π radians,
- the highly curved area is considered as a dead end when the angular deviation is greater than π radians.

HDPE ducts for external prestressing

Units	Minimum radius of curvature in anchors (m)	Minimum radius of curvature in deviators (m)
7C15	3.0	2.0
13C15	3.5*	2.5*
19C15	4.0*	3.0*
25C15	4.5	3.5
37C15	5.0*	4.0

** as per standard ENV 1992-1-5:1994*

External

In the absence of more stringent national requirements, the radius of curvature of the tendon in deviators, generally comprising bent steel tubing, shall comply with the minimum values indicated in the table on the side.

For greased and sheathed strands placed in ducts pre-injected with cement grout, the following curvature radius should be maintained:

- isolated strands: R min ≥ 1 m
- strands grouped in bundles: R min ≥ 2.5 m

LFC duct

LOSSES AND FRICTION

Coefficient of friction

For the calculation of the prestressing force and the tendon elongation, the values of the friction coefficient (μ) and the unintended angular deviation or wobble coefficient (k), vary depending on the type of ducts and surface treatment. The force along the tendon is given by $P(x)=P_{jacking}e^{-\mu[j(x)+kx]}$

Use	Type of duct	Friction coefficient μ (rad^{-1})		Wobble coefficient k (rad/m)
		lubricated strand	unlubricated strand	
Bonded internal prestressing	Steel corrugated duct	0.17	0.19	0.007
	LFC duct	0.10	0.12	0.007
	Plyduct	0.10	0.12	0.007
	Steel tube	0.16	0.24	0.007
Unbonded internal prestressing	Single strand	0.05	-	0.007
	Bundle of pre-injected single strands	0.05	-	0.012
External prestressing	HDPE tube	0.10	0.12	0
	Steel tube	0.16	0.24	0

Fluctuation in the coefficient of friction is normally ± 25%.

COMPONENTS

COMPONENTS COMMON TO C & R RANGES

INJECTION PRODUCTS

Prestressing strands, if not individually greased and sheathed, are protected by injecting the duct containing them. The fill product can be a cement grout, which provides a passivating layer on the surface of the steel to protect against corrosion, or a flexible product that encapsulates strands in a watertight casing.

Cement **grout**

To ensure perfect filling of the ducts and therefore durable protection of the prestressing steels, the properties of the cement grout must be adjusted to suit the injection technique, which differs depending on the tendon layout, site temperatures, the position of vents and injection points, etc.

Based on test results to meet specific requirements and using locally available products, Freyssinet Australia has developed its own prestressing grout.

Freyssinet Grout


Freyssinet Grout

Freyssinet Grout grout is a low shrink, cementitious grout. It is non-metallic and contains no chlorides and no fines (sand free). Freyssinet Grout compensates for shrinkage in both the plastic and hardened states.

FreyssiGrout is accredited as RMS approved grout product for post-tensioning tendons, and as such, was developed to meet requirements of RMS specifications B113.

Properties of Freyssinet Grout

Parameters	Freyssinet Grout
Packaging	10 kg bag 200 kg cement
Yield	Between 128L and 133L per 10 kg bag + 200 kg cement
Water/Cement ratio	Between 0.28 and 0.33
Compressive strength	1 day 20 MPa 7 days 65 MPa 28 days 80 MPa
Bleeding	4 hours: <0.5%
Shrinkage	24 hours: <1%
Storage	Store in cool conditions Shelf life is 12 months


Grouting

Grout mixing

Flexible product

Flexible corrosion-resistant products are chemically inert with regards to prestressing steels. They can be split into two main categories: greases and waxes (hot-injected). Freyssinet uses microcrystalline wax, a long-chain synthetic wax specifically designed to be stable over time and to minimise bleed.

INSTALLATION

Installation of the Freyssinet Prestressing System follows 5 main stages:

- installing the ducts and trumplates (and thread strands for flat ducts),
- pour concrete then remove recess and formwork,
- threading the strands and installing the anchorage blocks,
- tensioning,
- injection and sealing.

Installing the **ducts and trumplates**

For internal prestressing, the ducts are positioned before concreting. Corrugated steel or HDPE ducts are the most commonly used. Special care is taken with positioning and supporting the ducts

For external prestressing, HDPE tubes are used. Strands are threaded through flat ducts before pouring concrete to avoid duct crushing.

Removing recess and formwork

- undo bolts connecting recess former (if any) to formwork and anchorage after stripping formwork,
- for slab post-tensioning, a tool enables extraction of the plastic recess former.

Threading the strands and installing the anchors

After checking on free passage in the ducts, the tendons are, in general, threaded by pushing each strand from one end. Freyssinet's threading equipment can be used to produce prestressing tendons over 200m in length.

Tensioning

C Range tendons are tensioned using multi-strand hydraulic jacks. Monostrand jacks can be used under certain conditions. S Range tendons are stressed with a monostrand jack.

The maximum stressing force applied to the prestressing tendon before lock-off during tensioning shall be 80% of the tendon minimum breaking load.

In the case of the slippage or breakage of one or more strands, or in case of unexpected high friction along the tendon, overstressing is permitted if the force in the jack can be measured to accuracy of +/-5% of the final value of the prestressing force. In such cases, the maximum stressing force may be increased to 85% of the tendon minimum breaking load.

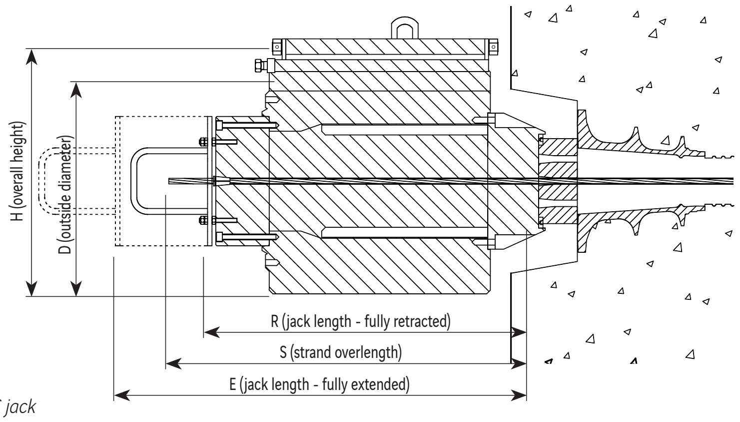
The tensioning operation can only start once the compressive strength of the concrete, is greater than the value $f_{cm,0}$ defined for the project. Refer to page 13 for C Range and page 18 for S Range.

Multistrand jacks

TENSIONING C RANGE

There are a number of hydraulics jacks that can be used to stress the tendons using C Range anchors. However, the most common jacks used by Freyssinet Australia are the KC350, KC500, KC700, KC1000 and CC350, CC500 & CC1000.

Tendons can be stressed with a monostrand jack if the tendon is straight, short and with parallel strands or if the strands are individually greased and sheathed.



KC jack

KC jacks

KC jacks are the jacks historically used by Freyssinet Australia.

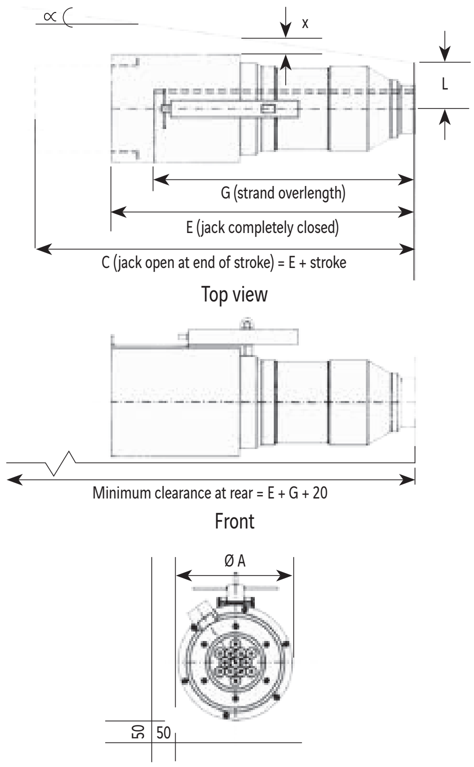
Jack	No of strands	D (mm)	H (mm)	R (mm)	E (mm)	S (mm)
KC 350	7 - 13	395	475	1160	1410	1200
KC 500	14 - 19	500	580	1160	1410	1200
KC 700	20 - 31	610	690	1290	1540	1400
KC 1000	32 - 37	720	800	1400	1650	1400

CC jacks

CC jacks are very compact and as such have the following advantages:

- hydraulic locking off of the anchorage wedges,
- reducing the dimensions of the recess and the volume of concrete to patch the recess,
- increase tendon eccentricity leading to greater drape from centroid and therefore increase the efficiency of post-tensioning,
- facilitate handling and tensioning operations.

Jacks	Units	ØA (mm)	E (mm)	G (mm)	L(mm)	∝ for x ≈ 50 (°)	Stroke mm)
CC 350	7C15	360	1,105	690	120	11°	250
	13C15		1,074	660	150	9°	
CC 500	7C15	438	1,085	688	120	15°	250
	13C15		1,100	703	150	12°	
	19C15		1,071	674	170	11°	
CC 1000	19C15	593	1,160	723	170	16°	250
	25C15		1,175	738	210	13°	
	31C15		1,146	709	210	13°	
CC 1500	37C15	722	1,151	714	240	10°	350
	37C15		1,550	770	240	9°	
	55C15		1,986	700	280	8°	

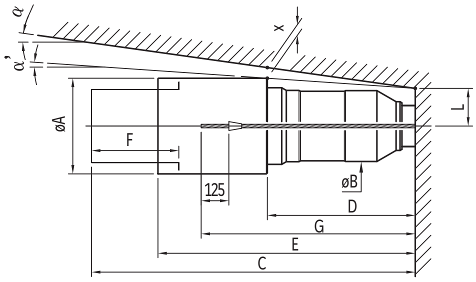


CC jacks

The sketch above is based on a jack suspension device located in a plane perpendicular to the plane of the sketch.

INSTALLATION

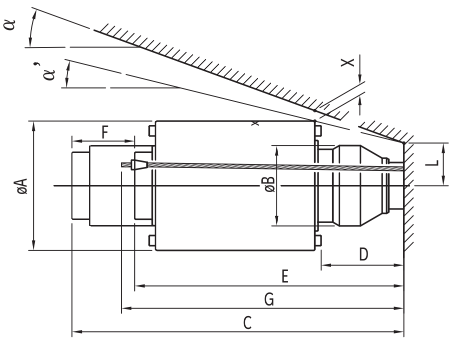
C/F jacks



C/F jacks

Jacks	Units	ØA (mm)	ØB (mm)	C (mm)	D (mm)	E (mm)	F (mm)	G (mm)	L (mm)	a' actual	a for x=50
C350F	7C15	355	263	1,415	731	1,165	250	1,120	120	4°30′	8°
	13C15			1,374	675	1,124		1,080	150	2°20′	7°
C500F	7C15	432	320	1,513	714	1,213	300	1,080	120	7°39′	12°
	13C15			1,538	724	1,238		1,100	150	5°13′	9°
	19C15			1,482	668	1,182		1,050	170	3°56′	8°
C1000F	19C15	582	417	1,583	754	1,283	300	1,110	170	9°	13°
	25C15			1,593	764	1,293		1,120	210	6°03′	10°
	31C15			1,603	774	1,303		1,130	210	5°58′	10°
	37C15			1,552	718	1,252		1,080	240	4°04′	8°
C1500F	31C15	707	512	2,423	134	1,923	500	1,250	210	7°13′	10°
	37C15			2,438	1,144	1,938		1,270	140	5°39′	8°
	55C15			2,375	1,076	1,875		1,200	280	3°54′	7°

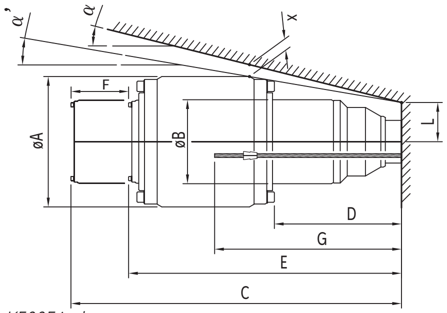
K/C jacks



K/C jacks

Jacks	Units	ØA (mm)	ØB (mm)	C (mm)	D (mm)	E (mm)	F (mm)	G (mm)	L (mm)	a' actual	a for x=50
K100C	3C15	290	220	913	256	713	250	820	100	9°21′	19°
	4C15			918	256	718		820	100	9°21′	19°
K200C	7C15	350	263	1,154	435	954	200	1,060	120	6°52′	13°
K350C	13C15	440	263	1,168	339	918	250	1,020	150	9°33′	16°
K500C	19C15	515	320	1,333	361	1,083	250	1,136	170	13°23′	21°
K700C	25C15	640	419	1,465	420	1,215	250	1,320	210	12°25′	18°
	31C15			1,475	430	1,225		1,330	210	12°09′	18°
K1000C	37C15	770	492	1,497	434	1,247	250	1,350	240	14°23′	20°

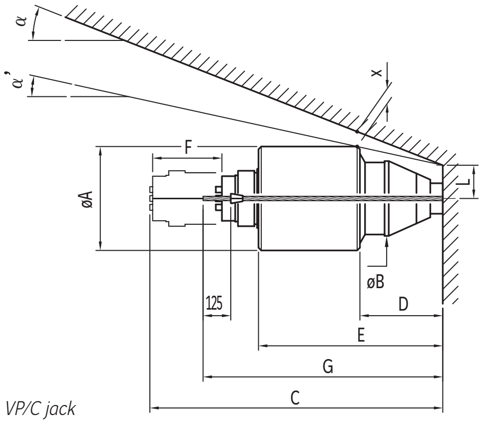
K500F jacks



K500F jacks

Jacks	Units	ØA (mm)	ØB (mm)	C (mm)	D (mm)	E (mm)	F (mm)	G (mm)	L (mm)	a' actual	a for x=50
K500F	13C15	565	364	1,462	580	1,212	250	840	150	9°41′	14°
	19C15			1,433	551	1,183		810	170	9°17′	13°

VP/C jacks



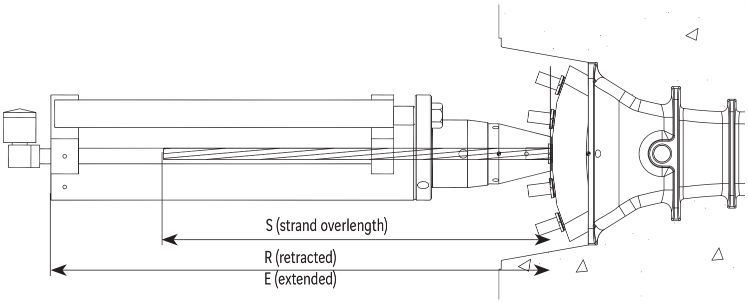
VP/C jack

Jacks	Units	ØA (mm)	ØB (mm)	C (mm)	D (mm)	E (mm)	F (mm)	G (mm)	L (mm)	a' actual	a for x=50
VP260C	7C15	375	270	1,151	299	735	250	980	120	12°19′	21°
	13C15			1,126	264	700		945	150	8°5′	19°
VP650C	19C15	560	395	1,602	310	1,052	300	1,400	170	19°32′	28°
	31C15			1,441	320	973		1,410	210	12°20′	21°

The sketches above are based on a jack suspension device located in a plane perpendicular to the plane of the sketch.

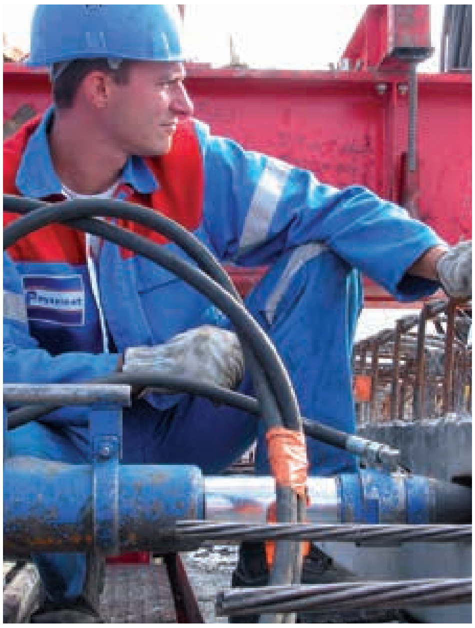
TENSIONING S RANGE

Tendons with S Range anchorages are tensioned with AJ150 or AJ300 monostrand jacks.



Monostrand jack

Jack	AJ150	AJ300
R (mm)	360	510
E (mm)	515	815
S (mm)	300	300



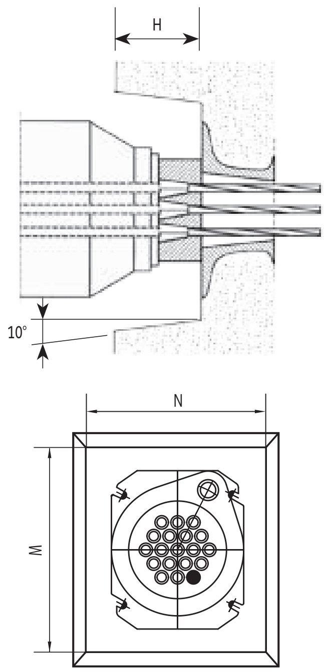
Sioule Viaduct, France

RECESS

Permanent recess of anchors

Units	M (mm)	N (mm)	H (mm)
3C15	200	170	120
4C15	200	180	125
7C15	230	210	125
13C15	300	270	150
19C15	350	310	160
25C15	410	360	170
31C15	435	380	180
37C15	470	410	195
55C15	560	480	230

C Range



C Range recess

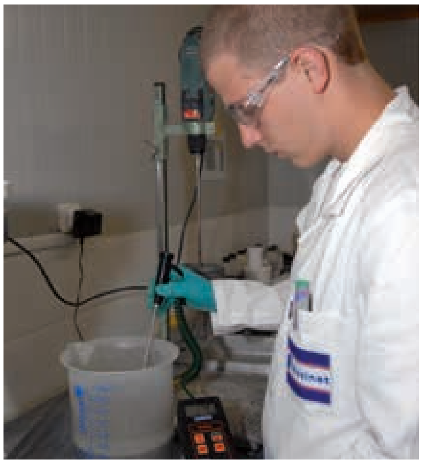
INSTALLATION

INJECTION & SEALING

The purpose of injecting the free length of the tendons and sealing the anchors is to protect the tendons against corrosion. Tendons are injected using either cement grout containing a passivating agent for steel, or using hydrophobic products, grease or wax, which create a continuous encapsulated cover to fully protect against aggressive agents.

In order for corrosion protection to be effective, the ducts must be completely filled, without any air pockets that could constitute an area where water seepage could accumulate. Such a result is generally achieved by selecting the correct speed at which the grout fills the duct and by vents at high points in deviated tendons.

For complex tendon layout, for example highly deviated or vertical tendons, or to overcome any problems installing drain openings at high points, Freyssinet has developed specific injection techniques, described below.



Formulation of cement grout in a Freyssinet laboratory

Vacuum injection

The purpose of this technique is to create a partial air vacuum in the duct before filling in order to avoid trapping air pockets. This technique is only used for leaktight ducts and is very suitable for tendons which it is not possible to have high point vents.

In the case of deviated horizontal tendons, it can be combined with the use of Freyssiflow TX thixotropic grout to achieve better fill results.

It also allows for the injection of U-shaped tendons from a top anchor without having to worry about the effects of the grout interface collapsing.

Injection caps

Reinjection of high points

When there is significant risk of bleed at high points of a tendon profile, highly deviated or vertical tendons, these high points should be reinjected to drain any weak grout. The volume to be bled is assessed case by case on the basis of experience acquired by Freyssinet.

Freyssinet has also developed special technological provisions for cases where it is not possible to locate a reinjection tube in the facing.

Injection of **tendons** with greased and sheathed strands before tensioning

Tendons comprising greased and sheathed strands within a duct must be injected with cement grout prior to tensioning. Once hardened, the grout performs the role of strand separator and prevents crushing of individual plastic sheaths where the tendon route deviates. This technique, designed and perfected by Freyssinet, guarantees that the sheathing of every strand is leaktight and smooth operation of the tensioning process.

Low pressure injection filling

To reduce hydraulic pressure losses at injection points, Freyssinet has designed a special injection device so that the injection product can be injected at the rear of the anchor block through a large diameter tube.

This arrangement is well suited to very high vertical tendons. It also facilitates any anchor head reinjection operations.

Low pressure injection device

Permanent **caps**

The prestressing anchors are protected either by a concrete seal if the anchor is in a recess, or a permanent cover if they have to remain accessible for later interventions. Permanent covers are also used for duct injection. They can be made from cast iron (galvanised or painted) or plastic.

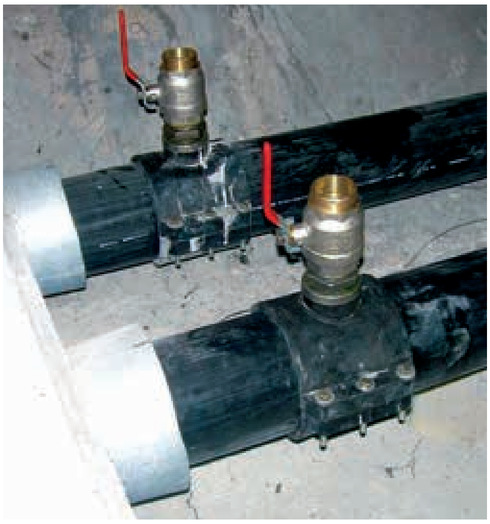
Vents and drain **openings**

The diagrams below show the positioning of vents and injection tubes for relatively simple tendon profiles.

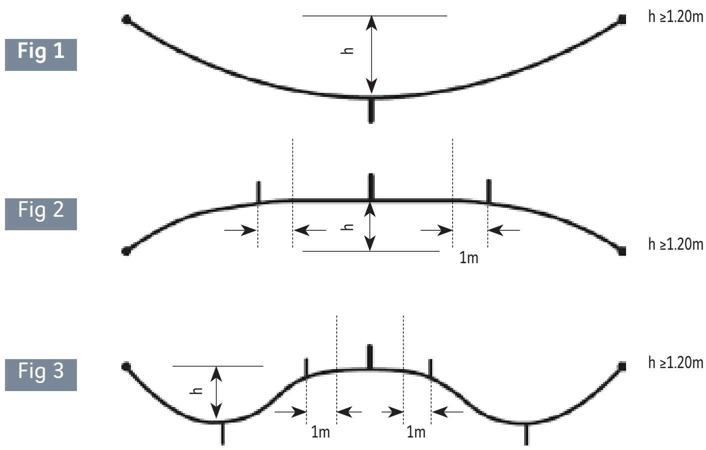
Figure 1 For U-shaped parabolic profiles with height variation greater than 1.2 m, the low point is fitted with an injection tube.

Figure 2 For inverted U-shape parabolic profiles with height variation greater than 1.2 m, the high point is fitted with a vent and two offset tubes. On reinjection of the high point, one of them serves as an injection tube while the other serves as a drain opening.

Figure 3 Horizontal tendons with two U-shaped drapes separated by a straight section, and with height variation greater than 1.2m, must be injected from one of the low points including the straight section, then reinjected from the other high point while draining the horizontal section.



Injection inlets on HDPE pipes



For more complex profiles consult Freyssinet Australia Technical Services.

Injection caps

Plastic permanent caps

F RANGE ANCHORS FOR THIN ELEMENTS

Composition of F range anchor

F range anchors comprise:

- an anchor body embedded in the concrete and acting as both anchor
- head and distribution element,
- jaws, to anchor the strands,
- elements for permanent protection of the jaws, comprising HDPE (or metal) covers, filled with grease.

Application categories

F range anchors are intended for the prestressing of thin elements (slabs, concrete floors, etc.).

They are used for:

- unbonded prestressed concrete,
- bonded prestressed concrete,
- Seismic strengthening of walls (URM and concrete), floors, beams, and columns

Bonded internal prestressing configurations

The most common use of type F anchors in bonded internal prestressing is based on the use of uncoated strands in a corrugated metal sheath, galvanised or ungalvanised, generally flat for easier insertion into thin elements, and injected with cement grout after tensioning of the strands.

The anchors, sheath and prestressing reinforcements are installed before concreting the structure. In particular, this prevents the risk of flat ducts being crushed during concreting which would prevent the subsequent threading of the strands.

Unbonded internal prestressing configurations

F range anchors for unbonded internal prestressing are used with grease-protected strands, each with individual HDPE sheathing. These elements are directly incorporated into the reinforcement before concreting, with precautions being taken not to damage each individual sheath.

The individual AF13/15 anchor for 13mm and 15mm strands respectively allows for the beneficial effects of the prestressing to be distributed very evenly in thin elements.

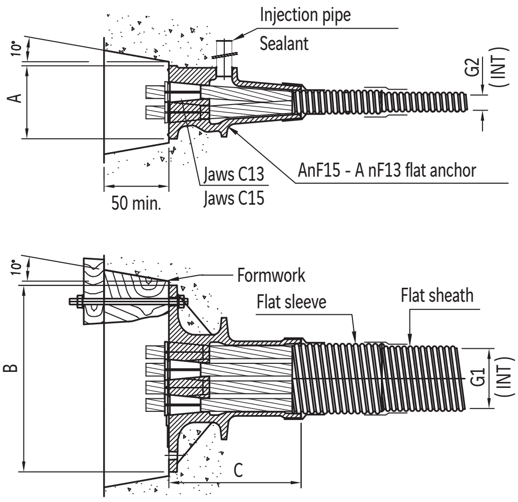
Jamuna Bridge, Bangladesh

F RANGE ANCHORS FOR THIN ELEMENTS

BONDED INTERNAL PRESTRESSING

Multi-strand units 3 to 5 F13/F15

Notes: F range anchors are designed for minimum concrete strength fcmin= 22 MPa (on cylinder). The usual installation method is threading the strands into the ducts (flat sheaths) before concreting. However, if necessary, it is also possible to thread the strands after concreting the structure, on condition that special provisions are made.



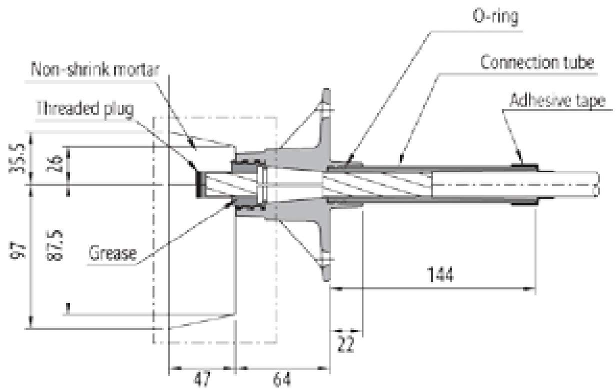
Units	A (mm)	B (mm)	C (mm)	G1 x G2 (mm²)	G (mm)	G (mm)	H (mm)
A3 F13/15	85	190	163	58 x 21	95	95	200
A4 F13/15	90	230	163	75 x 21	100	100	240
A5 F13/15	90	270	163	90 x 21	100	100	280

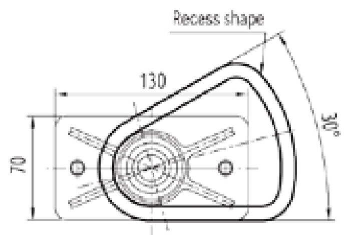
Bridge at Rousson, France

F RANGE ANCHORS FOR THIN ELEMENTS

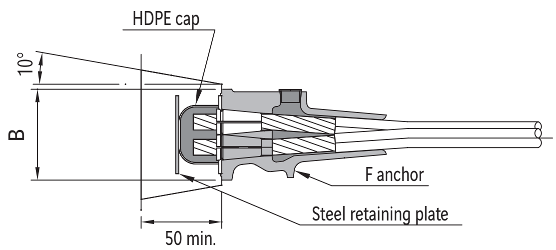
UNBONDED INTERNAL PRESTRESSING WITH GREASED SHEATHED STRANDS

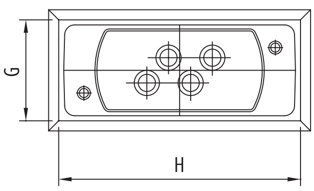
Single-strand unit (1F13/1F15)

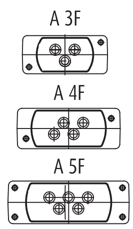


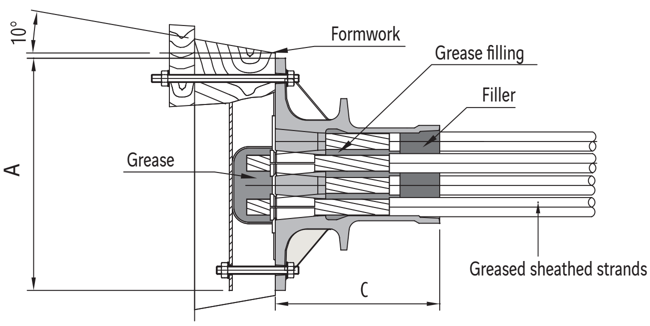


Multi-strand units (3 to 5 F13/15)







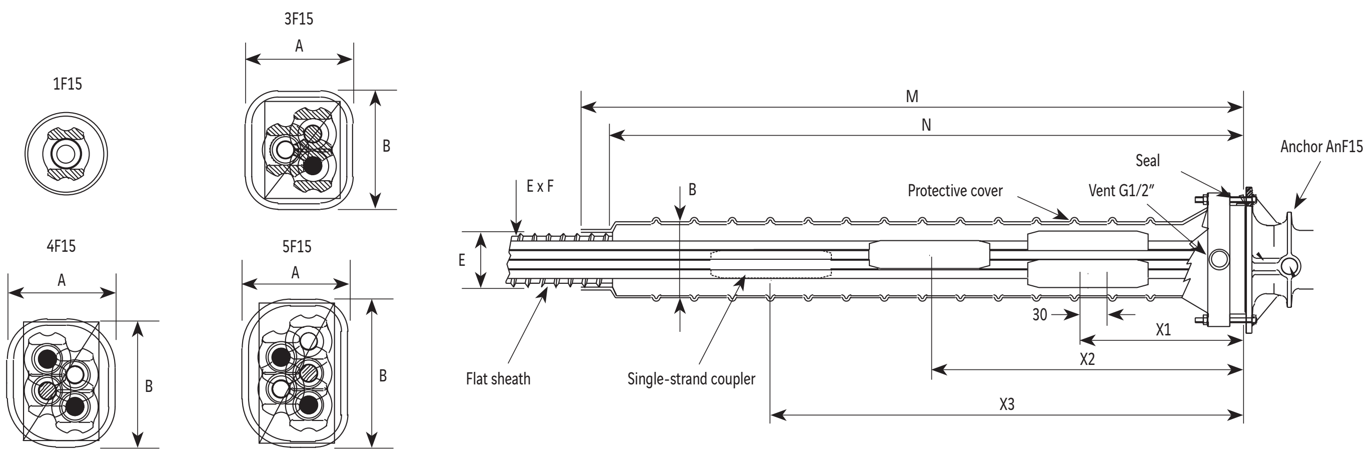


Units	A (mm)	B (mm)	C (mm)	G (mm)	H (mm)
A 3F 13/15	190	85	163	95	200
A 4F 13/15	230	90	163	100	240
A 5F 13/15	270	90	163	100	280

F RANGE ANCHORS FOR THIN ELEMENTS

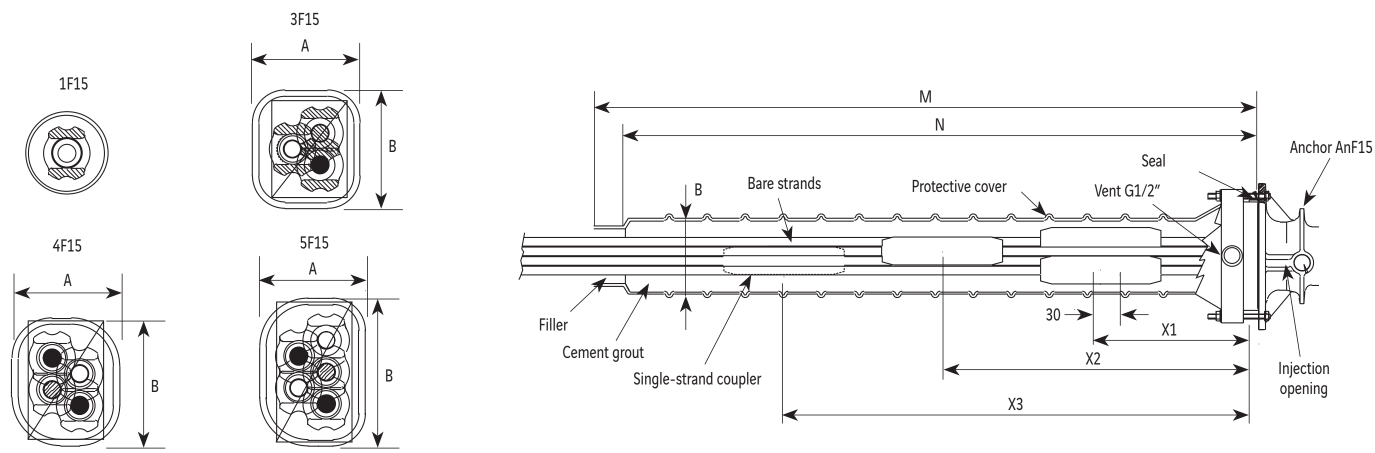
CI SINGLE-STRAND FIXED COUPLERS

Bonded prestressing



Units	A (mm)	B (mm)	E (mm)	F (mm)	M (mm)	N (mm)	X1 (mm)	X2 (mm)	X3 (mm)
CI 1F13/15	-	-	-	-	550	550	250	-	-
CI 3F13/15	100	100	58	20	800	750	250	500	750
CI 4F13/115	100	110	75	20	1,050	1,000	250	500	750
CI 5F13/15	100	140	90	20	1,050	1,000	250	500	750

Unbonded prestressing



Units	A (mm)	B (mm)	M (mm)	N (mm)	X1 (mm)	X2 (mm)	X3 (mm)
CI 1F13/15	-	-	550	500	250	-	-
CI 3F13/15	100	100	800	750	250	500	750
CI 4F13/15	100	110	1,050	1,000	250	500	750
CI 5F13/15	100	140	1,050	1,000	250	500	750

F RANGE ANCHORS FOR THIN ELEMENTS

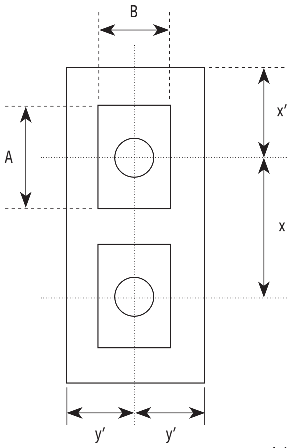
LAYOUTS FOR F RANGE ANCHORS

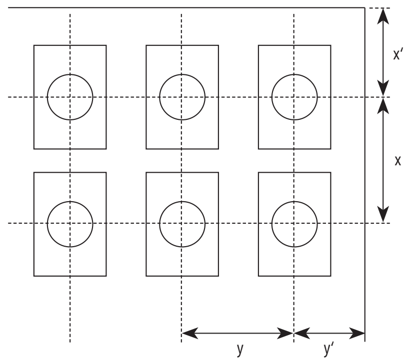
The anchors must be positioned at an adequate distance from the wall and spaced at a minimum centre-to-centre distance. These distances are obtained using dimensions a and b of the test assemblies created under the European Technical Approval procedure.

In the following, it is taken that the anchors are positioned along two normal direction axes: x and y, with the short side of the trumplate aligned on the y axis.

Notation

- A, B: plane dimensions of the trumplate (A ≥ B).
- a, b: side lengths of test specimen (a ≥ b).
- x, y: minimum centre distance between two anchorages in the structure in x and y directions.
- x′, y′: minimum edge distance between anchorages and the closest external surface in x and y directions.
- fcm,o: mean compressive strength measured on cylinder required before tensioning.





Dimensions x and y must meet the following conditions:

x ≥ A + 30 (mm)
y > B + 30 (mm)
x . y ≥ a · b
x ≥ 0.85 a
y ≥ 0.85 b
x′ ≥ 0.5 x + concrete cover — 10 (mm)
y′ ≥ 0.5 y + concrete cover — 10 (mm)

Values a and b are given in the table opposite, for three different concrete strengths $f_{cm,o}$ in the case of type F.

If the design provides for partial tensioning or a tensioning rate of less than min [0.8 F_{pk} ; 0.9 $F_{p0.1\%}$], interpolation can be used to determine the required value of $f_{cm,o}$, bearing in mind that at 50% of full force, the required strength for the concrete can be brought to 2/3 of the values given in the two tables above and that at 30% of this force, the required strength for the concrete can be brought down to half of the values given.

Distances a and b

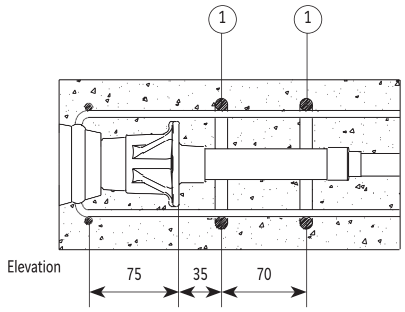
Units	$f_{cm,o}$ (MPa)	a (mm)	b (mm)
1F 13/15	22	190	140
3/4 F 13	22	500	160
3/4 F 15	22	390	190
5 F 13	22	570	260
5 F 15	22	510	240

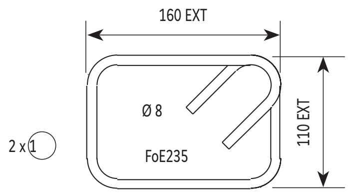
F RANGE ANCHORS FOR THIN ELEMENTS

HOOP REINFORCEMENT FOR TYPE F ANCHORS

Single-strand unit

A 1F13
A 1F15

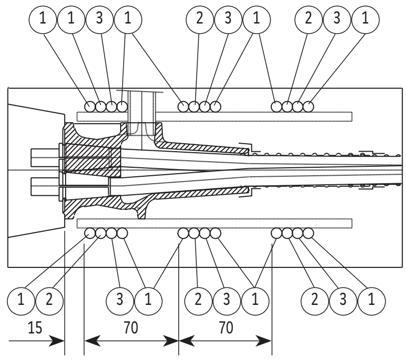




Dimensions in mm

Multi-strand units (3 to 5 F13/15)

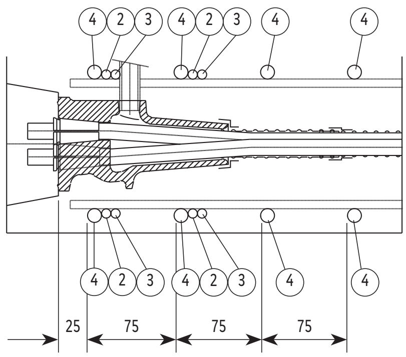
A 3F13
A 4F13



Type	No.	Ø (mm)	L1 (mm)	L2 (mm)	L3 (mm)	h (mm)
1	12	10	320			
2	3	10	320	20	160	140
3	3	10	320	20	160	140

See types of bars below.

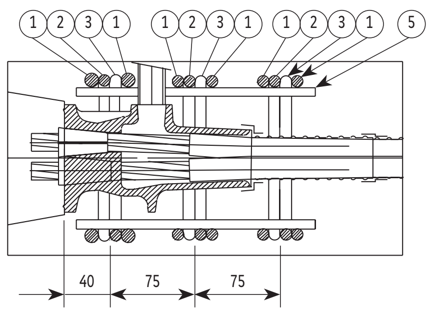
A 3F15
A 4F15



Type	No.	Ø (mm)	L1 (mm)	L2 (mm)	L3 (mm)	h (mm)
2	2	10	350	60	160	160
3	2	10	350	60	160	160
4	4	12	350		160	160

See types of bars below.

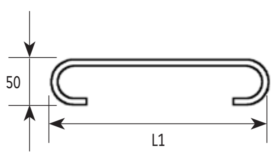
A 5F15
A 5F13



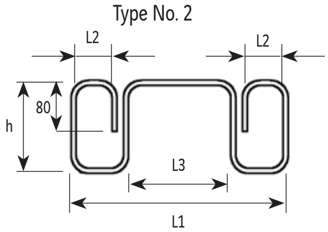
Type	No.	Ø (mm)	L1 (mm)	L2 (mm)	L3 (mm)	h (mm)
1	12	10	380	-	-	-
2	3	10	380	55	190	145
3	3	10	380	55	190	145

See types of bars below.

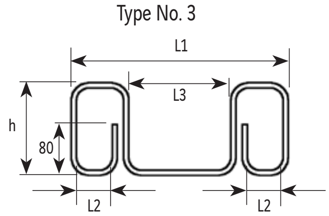
Type No. 1



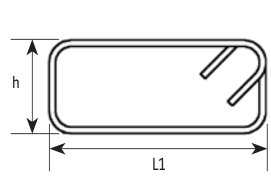
Type No. 2



Type No. 3



Type No. 4

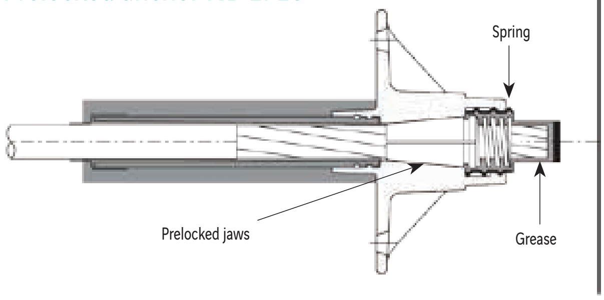


F RANGE ANCHORS FOR THIN ELEMENTS

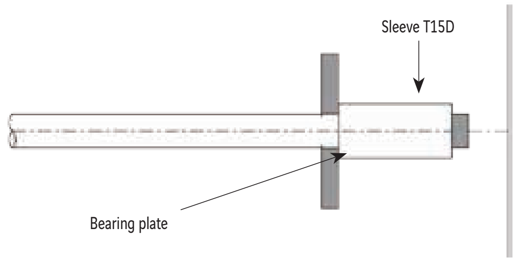
There are three types of passive anchors embedded in concrete used in combination with F range active anchors: prelocked anchor NB1F15, type N using an individual plate supporting an extruded sleeve and the type G dead end anchor. The tendons are positioned before concreting.

Single-strand unit

Prelocked anchor NB 1F15



Anchor with extruded sleeve

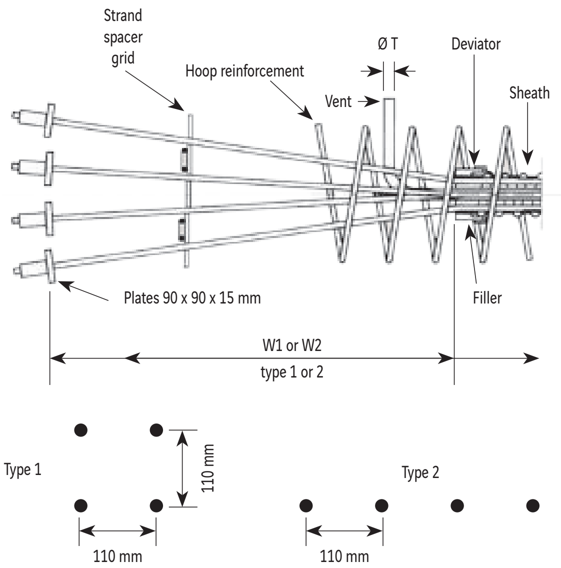


Multi-strand units (3 to 5 F13/15)

Type N embedded anchor

In the type N anchor, each strand has an extruded sleeve, each supported individually by a steel plate.

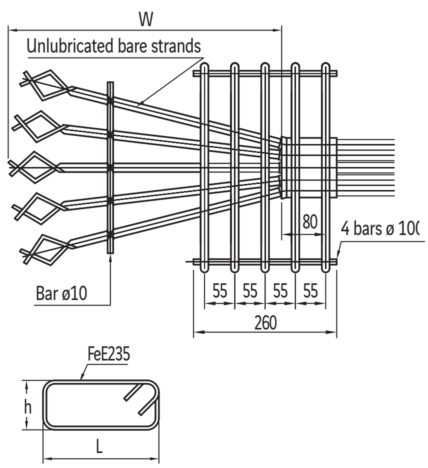
Units	N		ØT (mm)
	W1 (mm)	W2 (mm)	
N3 F13/15	300	300	G 1/2"
N4 F13/15	350	350	G 1/2"
N5 F13/15	500	400	G 1/2"



Type G embedded anchor

The type G anchor is a dead end anchor. The end of each strand is preformed into a bulb shape.

Units	W (mm)	Ø (mm)	H (mm)	L (mm)
3F13	950	10	120	300
4F13	950	10	120	320
5F13	950	12	120	340
3F15	950	10	120	300
4F15	950	12	145	340
5F15	950	14	145	380



R RANGE EXTERNAL MONOSTRAND ANCHORAGE

APPLICATION CATEGORIES

The 1R15 anchorage is an external prestressing monostrand anchorage designed for the strengthening of existing structures, especially for concrete beams or pier headstocks.

The longitudinal prestressing force of the strand is transferred to the structure by the friction between the 1R15 anchorage and the surface of the structure. This friction is created by stressing a clamping bar going through the structure or sealed in a blind hole. An epoxy resin is applied at the interface between the anchorage and the concrete, to enhance the friction.

The length of the 1R15 anchorage allows stressing with a monostrand jack fitted with a curved nose with minimum jacking clearances.

Compared to traditional solutions such as concrete anchor blocks or fabricated steel anchorages, the 1R15 anchorage provides multiple advantages:

- simple and fast installation (no grout or concrete cast on site),
- compact solution allowing stressing with light equipment (monostrand jack),
- reliable and competitive solution due to the industrialisation of a mechanical cast anchorage.

1R15 anchorages stressed

Live ends before stressing

Pier headstock strengthening, M2 Upgrade, Sydney, Australia

R RANGE EXTERNAL MONOSTRAND ANCHORAGE

COMPONENTS

Prestressing strand

- 15.7mm strand to prEN10138 (279 kN minimum breaking load),
- maximum tensioning force in the jack 223 kN (80% of the minimum breaking load),
- maximum effective force in the strand 200 kN (after losses due to curved nose and wedge draw-in).

Prestressing bar

- Freyssibar 26.5 mm diameter to AS 4672 (568 kN breaking load),
- clamping force 250 kN after losses.

Surface preparation

- epoxy resin Eponal 380 or Sikadur 30,
- concrete 20 MPa minimum strength, adequately scabbled.

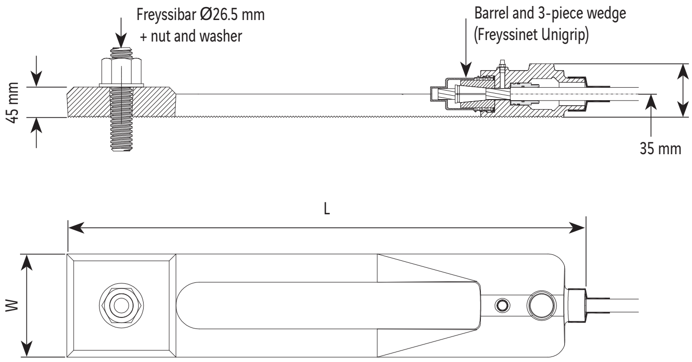
Stressing of the 1R15 anchorage with curved nose and monostrand jack

1R15 anchorage in final configuration

Anchorage

The 1R15 anchorage is made of cast iron. The bottom surface at the back end of the anchorage (below the nut) is provided with steel indentations to create shear interlock with concrete through the epoxy resin.

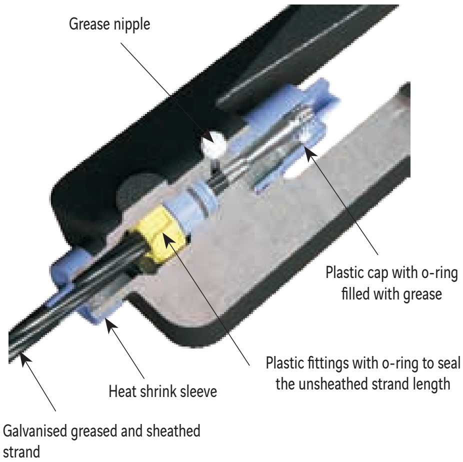
1R15 anchorage - 3D view



Units	L (mm)	W (mm)	H (mm)	Weight (kg)
Active	760	150	78	22
Passive	470	150	78	19

R RANGE EXTERNAL MONOSTRAND ANCHORAGE

CORROSION PROTECTION



1R15 Anchorage details, galvanised greased and sheathed strand

The longitudinal prestressing can be made of:

1. galvanised greased and sheathed strand – most common option,
2. greased and sheathed strand encased in a HDPE duct injected with grout before tensioning.

The prestressing bar is protected by hot metal spray (100Nm thickness 85% Zn - 15% Al cold process). The void around the bar is left ungrouted to allow for bar replacement if required.

The 1R15 anchorage is protected by fusion bonded nylon (performance available upon request). This coating is applied in the factory.

GEOMETRY

External prestressing tendon using 1R15 anchorages can be straight or draped. If the tendon is draped, it is recommended to provide a physical separation of the greased and sheathed strands along they entire profile. Otherwise in the curved section of the tendon, within the bundle of strands, the transverse pressure arising from stressing the tendon on a curve leads to ripping of the individual HDPE sheath which is too thin to withstand the corresponding strains. In practice, a multitube saddle with flared ends to allow for strand angular misalignment is generally provided.

Multitube deviation saddle

Southern Link Upgrade, Melbourne, more than 2000 No of 1R15 anchorages installed

X RANGE EXTERNAL HOOP TENDON ANCHORAGE

APPLICATION CATEGORIES

Freyssinet has developed the X Range anchorage system for the active strengthening of circular structures. These anchorages use external post-tensioning hoop tendons to apply a radial pressure onto the structure being strengthened and are suitable for all circular structures including silos, tanks, chimneys, cooling towers, pipes, old brickwork, etc.

COMPONENTS

Anchorage

1x15 Anchorage, Underbool Grain Silos, Australia

The anchorage is made of ductile cast iron and has the following functions:

- guiding the strand from the duct to the anchorage,
- anchorage of the strand with conical holes and 3 piece wedges (Freyssinet "Unigrip" wedges),
- connection between the duct and the anchorage, using HDPE fittings for cement grout injection.

The 1X15 anchorage is designed for single hoop tendon (one full loop around the structure).

The 2X15 anchorage is more suited for structures with high strengthening demand where the spacing between consecutive hoop tendons is significantly reduced. They can anchor:

- 2 hoop tendons (one full loop anchored at each end),
- 4 hoop tendons (each tendon is doing 2 loops around the structure prior to being anchored).

The 1X15 anchorage is suitable for structure diameters ranging from 13 m to 27.5 m.

The 2X15 anchorage is suitable for structure diameters ranging from 3.7 m to 5.5 m.

Other structural diameters are possible but they will require a specific case study.

Prestressing strand

Underbool Grain Silos strengthening, Australia

The hoop tendons are made of greased and sheathed strands encased in a HDPE outer duct injected with cement grout. The following strands may be used with the X Range anchorages:

- 15.2 mm diameter strand at 261 kN min. breaking load (to AS4672),
- 15.7 mm diameter strand at 279 kN min. breaking load (to prEN10138),
- 15.2 mm diameter strand at 300 kN min. breaking load (to AS4672) – compacted strand.

X RANGE EXTERNAL HOOP TENDON ANCHORAGE

CORROSION PROTECTION

The strands are greased and sheathed, which allow the strand to slide freely inside its sheath without bonding to the structure. For applications in a more aggressive environment or if longer durability is required, galvanised strands may also be used.

Cement grout is injected into the outer duct before tensioning the tendon so that the grease and sheathed strand is perfectly embedded and a more uniform pressure is applied on the concrete surface. The external tendon is then perfectly protected against corrosion by two barriers:

- the individual grease protection & HDPE sheath, to prevent the circulation of humidity,
- the HDPE outer duct, filled with cement grout.

The corrosion protection of the X Range anchorage is addressed as follows:

- inside the anchorage

  filling with grease through injection nipples and HDPE caps to protect the wedges and the unsheathed strand lengths,
- outside the anchorage

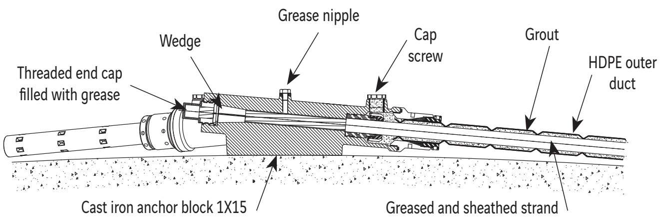
  coating of the anchorage with fusion bonded nylon applied in the factory (performance available upon request),

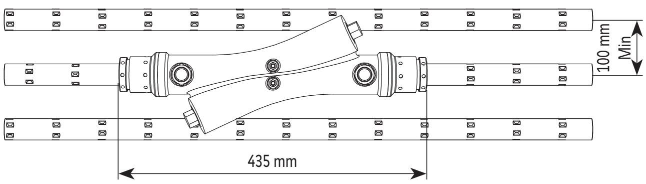
  or covering the anchorage with shotcrete.

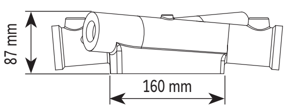
Plastic fittings to seal the outer HDPE duct

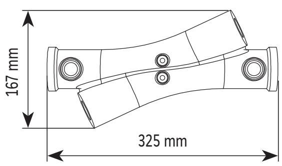
Geraldton Grain Silos, Australia

1X15 ANCHORAGE





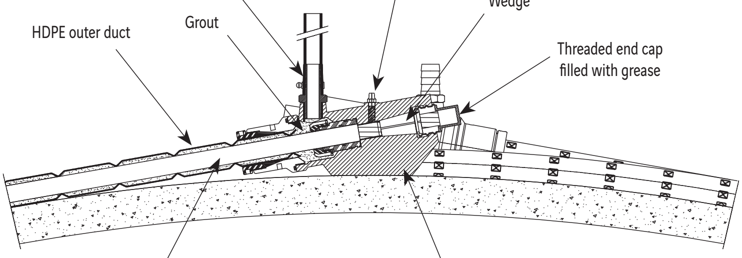


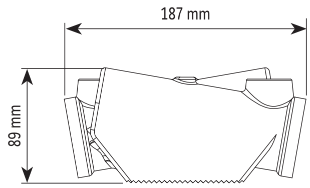


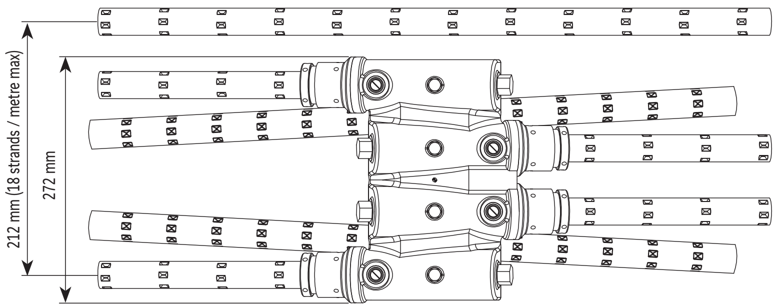
1X15 Anchorage

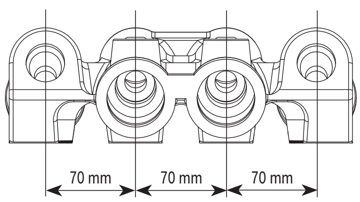
X RANGE EXTERNAL HOOP TENDON ANCHORAGE

2X15 ANCHORAGE

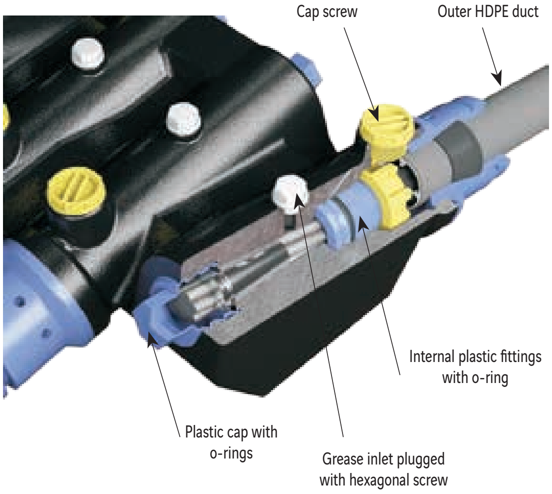








2X15 Anchorage



2X15 Anchorage anti corrosion protection

FREYSSIBAR

TECHNOLOGY

The **bars**

Lifting : prestressed connection between a segment and a beam.

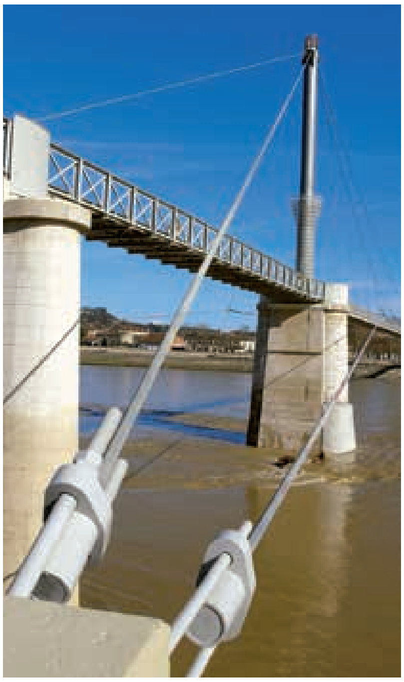
The bars are hot rolled from high strength alloyed steel. They are subsequently cold worked by stretching and then threaded over their full length or on the extremities by cold rolling. The standard range of nominal diameters is: 26.5; 32; 36; 40 and 50 mm. Non-standard diameter bars can be delivered on request.

The fabrication process provides a high quality thread ensuring high fatigue resistance and a low susceptibility to stress corrosion.

The nature of the Freyssibar manufacturing method also ensures that every single bar is stress tested to 85% of the guaranteed ultimate tensile strength of the bar.

The geometry of the thread is specifically designed to ensure ease of use on site, providing fast, accurate and easy tightening.

Bars are available in maximum lengths of 11.8 meters. Beyond this length, extension sleeves allow bars to be connected together.



Anchorage of steel ropes

The **anchorages**

- The anchor devices are designed to anchor the force in the bar and transfer it to the structure. Four types of anchorages are available:
- Standard anchorages with a nut and washer;
- Hinge anchorages using a nut with a spherical seat;
- Standard anchorages using a low rotation spherical nut and spherical washer;
- Fixed anchorages using a threaded end plate.

All nuts are hot forged. Also, couplers allow primary bars to be connected to secondary bars.

The **accessories**

Freyssinet offers a full range of sheathing that is easy to install.

In particular:

- Steel strip corrugated sheath, threaded over its full length, which allows easy and fast connections;
- High density polyethylene tube, with elements mirror welded to achieve a leak free and non-corrosive envelope;
- Sheathing accessories specific to the tensioning and coupling devices, required to fit the coupler geometry. The length of the ducting element used is project specific, so as to allow the coupler displacement over a sufficient length during the tensioning operations.

FREYSSIBAR

Properties

Fatigue : The system has a fatigue resistance in excess of two million cycles of loading over a tensile stress range of 590-670 N/mm2, exceeding the ETAG 013 requirements.

Relaxation : After 1000 hours the loss of stress due to relaxation in the Freyssibar system loaded to 70% Fpk is below 3% which is better than the 4% maximum as described in pr EN 10138-4.

Anchorage strength : Freyssibar post-tensioning system is tested to ensure that the failure load on the bar with coupler and anchorage is more than 95% of the strength of the bar alone.

Permanent ties for quay walls

Protection against corrosion

Stress corrosion tests have been performed in accordance to prEN 10138. The bars have been stressed under corrosive environment during 500 hours and passed the subsequent tensile test to failure. Freyssibar is not susceptible to stress corrosion but depending on the conditions of exposure, a specific corrosion protection can be applied under request.

The corrosion protection system is selected in accordance to the expected design life time and the conditions of exposure.

Surface coating

Hot dip galvanizing after sand blasting (no risk of hydrogen embrittlement due to acid pickling)

- Metalization (Dunois, etc.)
- Petrolatum tape
- Epoxy coating

Specific injection products

Wax : hot injection } Allow for subsequent re-tensioning of the bars
- Grease }
- Cement grout : alkaline environment

Ducting

- Corrugated ducts: light and easy to install
- Smooth pipes: stiff and resistant to shock

Ducts and pipes can be either in steel or in HDPE (non-corrosive).

Different protection systems can be combined to enhance the degree of protection.

Prefabricated bar tendons

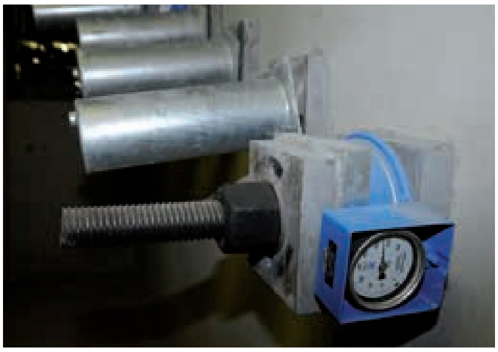
Quality control

The fabrication of the bars and the anchorages is carried out under a quality assurance system in compliance with the quality standard ISO 9000 : 2000. Flat anchorages and bars have passed all the tests required in ETAG 013.

Ground anchors

INSTALLATION

The accuracy of the prestressing force actually introduced into the structure and the durability of the tendons depend on the quality of the installation. The detailed installation procedure is available on request.


Load cell

Shimming of the **anchorages**

When anchorages are applied onto an existing concrete element, it is recommended to shim under the bearing plate using a non-shrink mortar, free from chlorides.

Tensioning

The tensioning equipment provided by Freyssinet ensures the accuracy of the load applied within +/- 2%. This is achieved through regular calibration of the pump pressure gauge and the jacks.


Stressing with the hinged jack

Safety factors

The maximum allowable stressing force in the prestressing bars is given by the relevant design standards. Recommendations are given below as examples: (Note: Fpk means the guaranteed tendon tensile breaking load and Fp0.1% means the proof load).

A/ In post-tensioned structures, the Eurocode limits the tension to either 0.9 Fp0.1% or 0.8 Fpk, whichever is lower.

B/ In prestressed ground anchors, the norm EN 1537 prescribes a final force limited to 0.75 Fp0.1% for temporary ground anchors and 0.60 Fp0.1% for permanent ground anchors.

C/ In case of re-use, the tensioning force of the bar is limited to 0.60 Fpk for the first use, and to 0.50 Fpk for all subsequent uses.


Injection

Two types of **jacks**

Two types of jacks can be used: with a tie rod connected to the tendon or with a direct connection. Jacks should be used in conjunction with Freyssinet hydraulic pumps, with high pressure and a low flow rate to allow a progressive tensioning of the bar. Space must be allocated around the anchorage to allow the correct installation of the jack.

Precast segments assembly

Service

Freyssinet, world leader in prestressing, offers:

- worldwide advice for specific works, from our specialists,
- a huge material park providing jacks and equipment for the best application of the Freyssibar installation,
- on-site technical assistance given by our highly qualified technicians, at the time of installation.

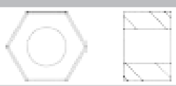

Injection accessories

Bar

Characteristic	Unit	Nominal diameter (mm)						Ref.
		26.5	29*	32	36	40	50	
Steel grade	MPa	1030	1030	1030	1030	1030	1030	B
Cross section area	mm2	552	661	804	1018	1257	1964	
Linear mass	kg/m	4.56	5.18	6.66	8.45	10.41	16.02	
Characteristic value of maximum force: Fpk	kN	568	681	828	1048	1295	2022	
Characteristic value of 0.1% proof force: Fp0.1%	kN	461	552	672	850	1049	1640	
Maximum tensioning force	kN	414	496	604	765	944	1475	
Thread pitch	mm	6	6	6	6	8	8	
Average Young's modulus	GPa	170	170	170	170	170	170	
Minimum elongation at maximum force	%	3.5	3.5	3.5	3.5	3.5	3.5	

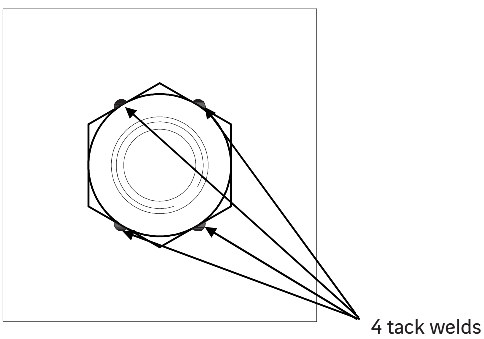
** 29mm diameter not ETA approved*

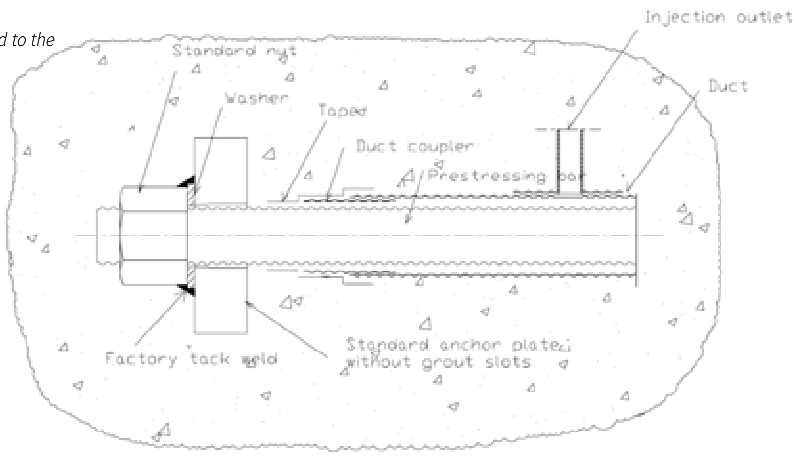
Flat and fixed anchorage

Item	Sketch	Dimensions	Unit	Nominal diameter (mm)						Ref.
				26.5	29*	32	36	40	50	
Flat nut		Length	mm	37	41	41	46	55	71	N
		Width on flat surface	mm	50	56	56	62	65	90	
Flat washer		External diameter	mm	65	70	70	75	80	105	W
		Thickness	mm	6	6	6	6	6	6	
Flat plate		Dimensions	mm	110x125	125x125	125x125	140x160	160x160	200x200	FP
		Thickness	mm	35	35	35	40	40	45	
		Hole diameter	mm	34	37	40	44	50	60	
Injection plate		Dimensions	mm	110x125	125x125	125x125	140x160	160x160	200x200	FPG
		Thickness	mm	35	35	35	40	40	45	
		Hole diameter	mm	34	37	40	44	50	60	
		Slot Length (from hole centre)	mm	45	47.5	47.5	55	55	71	
		Recess Depth	mm	10	10	10	10	10	10	

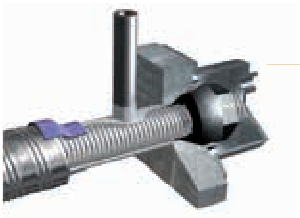
** 29mm diameter not ETA approved*

NOTE: For fixed anchorage a flat washer and nut must be tack welded to the anchorage plate in 4No. locations as detailed in these diagrams.

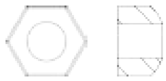




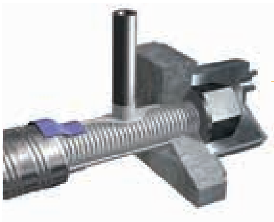
FREYSSIBAR



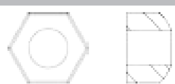
Spherical anchorage type 1 ± 3°

Item	Sketch	Dimensions	Unit	Nominal diameter (mm) 26.5	29*	32	36	40	50	Ref.
Spherical nut		Length	mm	45	51	51	56	60	71	SN
		Width on flat surface	mm	50	56	56	62	65	90	
Spherical plate		Dimensions	mm	160x115	160x125	160x125	160x140	160x160	190x190	SP
		Thickness	mm	40	40	40	40	40	60	

** 29mm diameter not ETA approved*



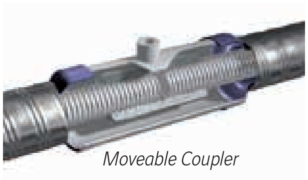
Spherical anchorage type 2 ± 0.6°

Item	Sketch	Dimensions	Unit	Nominal diameter (mm) 26.5	29*	32	36	40	50	Ref.
Spherical nut Type 2		Length	mm	37	41	41	46	55	71	SN Type 2
		Width on flat surface	mm	50	56	56	62	65	90	
Spherical washer		External diameter	mm	75	80	80	90	95	125	SW Type 2
		Thickness	mm	10	10	10	10	10	15	
Flat plate		Dimensions	mm	110x125	125x125	125x125	140x160	160x160	200x200	FP
		Thickness	mm	35	35	35	40	40	45	
		Hole diameter	mm	34	37	40	44	50	60	
Injection plate		Dimensions	mm	110x125	125x125	125x125	140x160	160x160	200x200	FPG
		Thickness	mm	35	35	35	40	40	45	
		Hole diameter	mm	34	37	40	44	50	60	
		Slot Length (from hole centre)	mm	45	47.5	47.5	55	55	71	
		Recess Depth	mm	10	10	10	10	10	10	

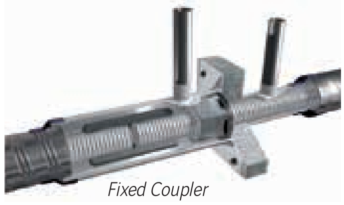
** 29mm diameter not ETA approved*

CHARACTERISTICS

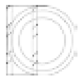
Couplers



Moveable Coupler



Fixed Coupler

Sketch	Dimensions	Unit	Nominal diameter (mm)						Ref.
			26.5	29*	32	36	40	50	
	External diameter	mm	45	50	50	60	65	76	C
	Length	mm	90	105	115	130	140	170	

** 29mm diameter not ETA approved*

Accessories

Item		Dimensions	Unit	Nominal diameter (mm)						Ref.
				26.5	29*	32	36	40	50	
Formwork tube		Length	mm	250	250	250	250	250	250	C
		External diameter	mm	42.9	48.5	48.5	50.8	57.2	70	
		Thickness	mm	2	2	2	2	2	2	
		Air vent connection	mm	1/2	1/2	1/2	1/2	1/2	1/2	V
Caps	Short caps	Length	mm	95	100	100	120	120	150	CS
	Long caps	Length	mm	210	234	220	220	220	280	CL

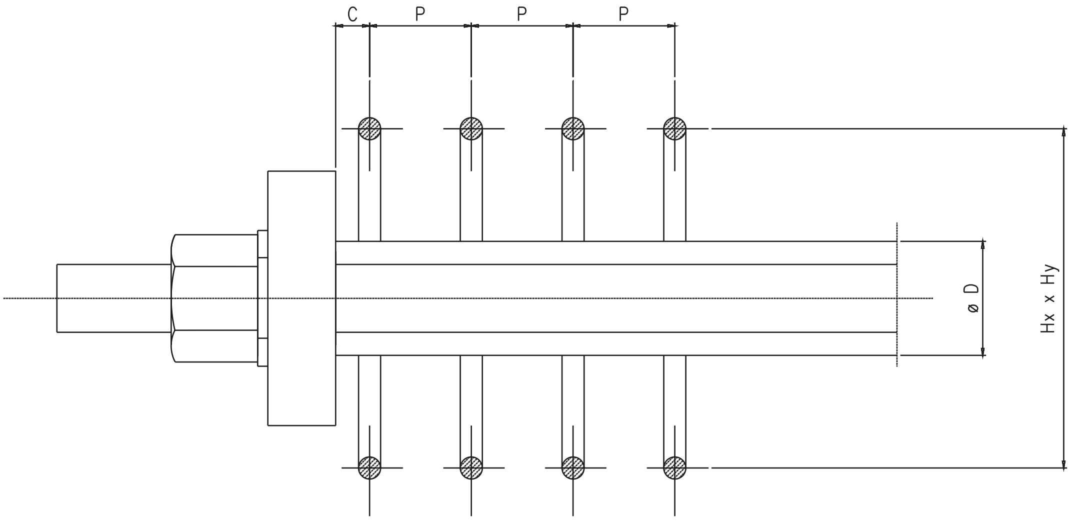
** 29mm diameter not ETA approved*

Ducts

Item	Dimensions	Unit	Nominal diameter (mm)						Ref.
			26.5	29*	32	36	40	50	
Steel corrugated sheath	Internal diameter	mm	45	50	50	55	60	75	G1
	Thickness	mm	0.45	0.45	0.45	0.45	0.45	0.50	
	Volume of grout	L/m	1.0	1.2	1.2	1.4	1.6	2.5	
	Connection element (internal diameter)	mm	50	55	55	65	70	85	G1
HDPE tube	External diameter	mm	63	63	63	75	75	90	G2
	Thickness	mm	5.8	5.8	5.8	6.8	6.8	8.2	
	Volume of grout	L/m	1.5	1.3	1.3	1.9	1.7	2.3	
For prolongation sleeve	External diameter	mm	70	76.2	76.2	88.9	95	114.3	GR
	Thickness	mm	2	2	2	2	2	2	
	Minimum length (L = sleeve)	mm	180 + L	205 + L	205 + L	220 + L	230 + L	260 + L	
For coupling sleeve	External diameter	mm	88.9	88.9	88.9	101.6	114.3	152.4	GC
	Thickness	mm	2	2	2	2	2	2	
	Maximum length	mm	210	235	235	255	265	320	

** 29mm diameter not ETA approved*

ANTI-BURST REINFORCEMENT



Freyssibar anti-burst reinforcement

BURSTING REINFORCEMENT						
Nominal Bar Diameter (mm)	Rebar Diameter (mm)	Number of Frames (-)	C (mm)	P (mm)	Ø Dmax mm	Hx x Hy (mm x mm)
26.5	12	4	20	40	42.9	160 x 160
29	12	4	20	50	48.5	175 x 175
32	12	4	20	50	48.5	185 x 185
36	12	5	20	50	50.8	210 x 210
40	12	7	20	60	57.2	240 x 240
50	16	6	20	60	70	310 x 310

FREYSSIBAR

GROUND AND ROCK ANCHORS

The Freyssibar prestressing bars, thanks to their thread over their full length, allow to build ground and rock anchors fulfilling the requirements of international standards. Lengths over 12 m can be obtained by means of one or several sleeves.

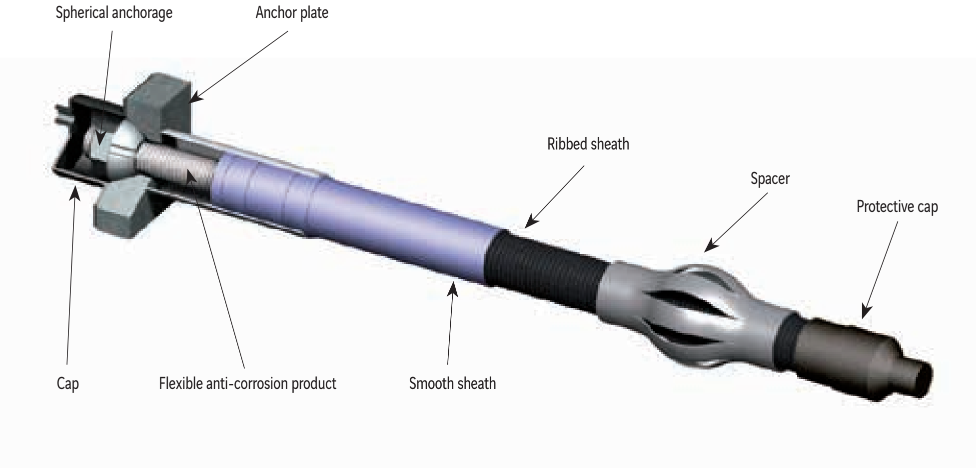
The ducting accessories and the anchorage corrosion protection systems are adjusted to the design life time of the anchor: temporary or permanent.

In addition, the anchors can be fitted with injection tubes to fill the bore hole and reinjection tubes to improve the bonding to the substrate.

Permanent

Item	Dim.	Nominal diameter bars (mm)						Ref.
		26.5	29*	32	36	40	50	
Steel formwork tube	Ø	80	89	89	89	89	108	FTUB
Plastic smooth sheath	Ø	60	70	70	70	75	90	STUB
Plastic ribbed sheath	Ø	55	65	65	65	70	85	RTUB
Plastic spacer	Ø	95	105	105	105	110	125	SPC
End protective cap	Ø	95	101,6	101,6	114,3	114,3	139,7	CE

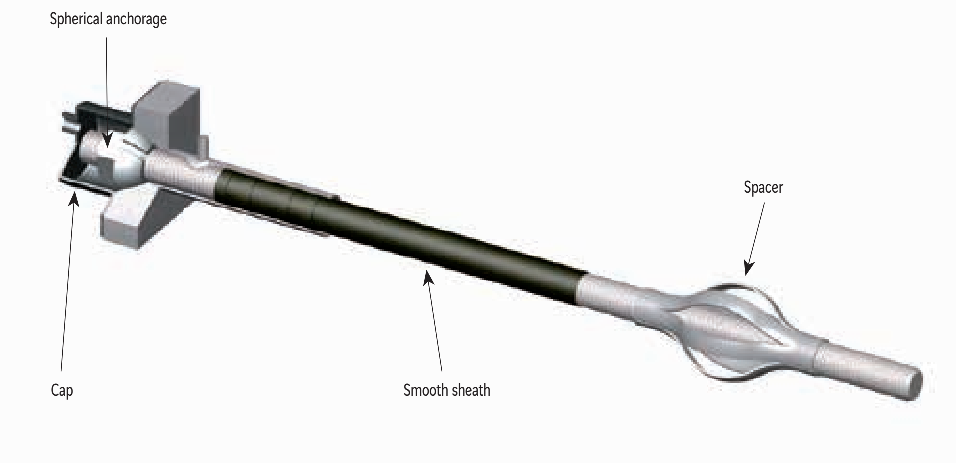
** 29mm diameter not ETA approved*



Temporary

Item	Dim.	Nominal diameter bars (mm)						Ref.
		26.5	29*	32	36	40	50	
Plastic smooth sheath	Ø	50	50	50	50	60	65	SPC
Plastic spacer	Ø	55	60	60	65	80	90	CE

** 29mm diameter not ETA approved*



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