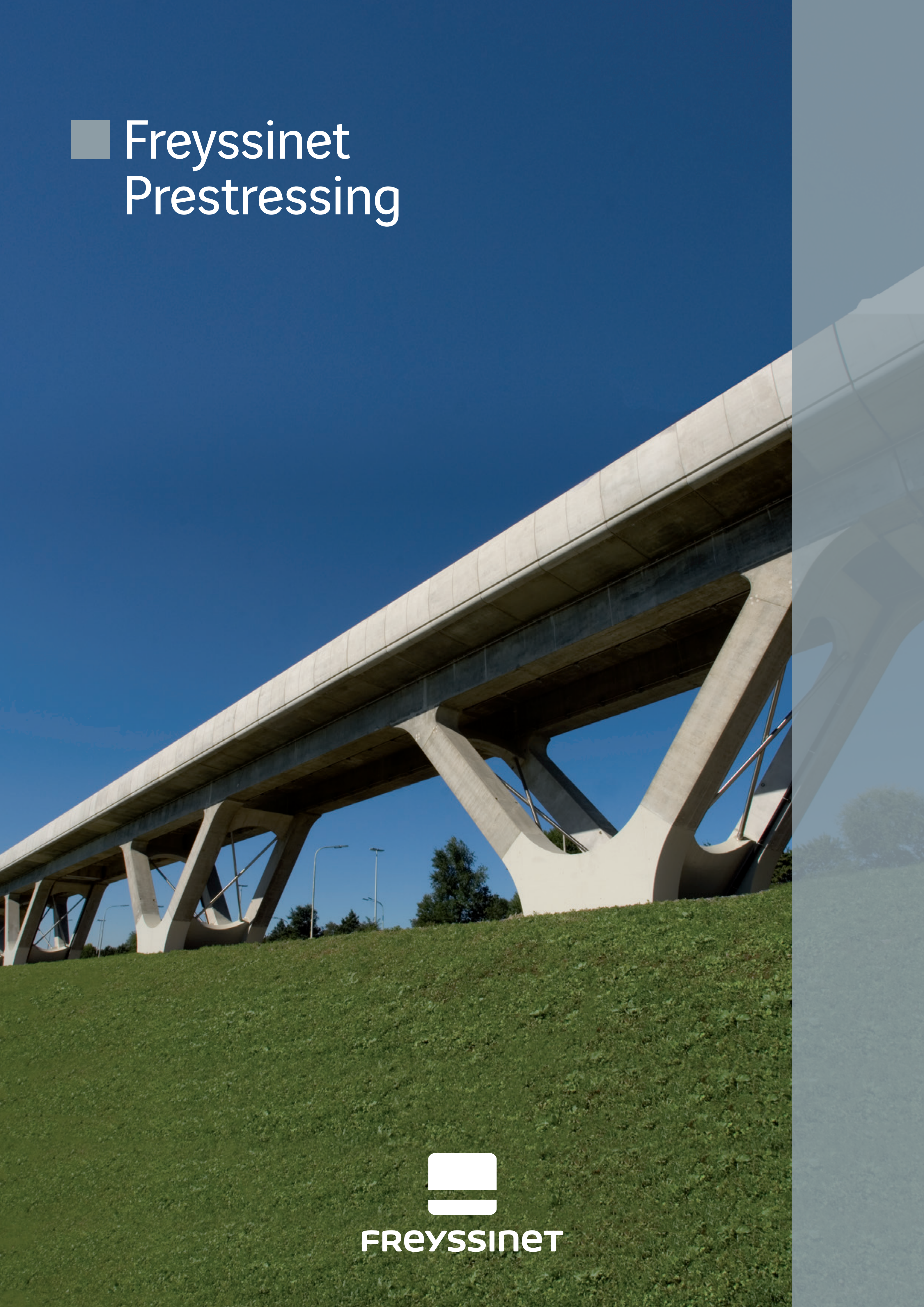
Freyssinet Prestressing



FREYSSINET

Contents

High durability prestressing

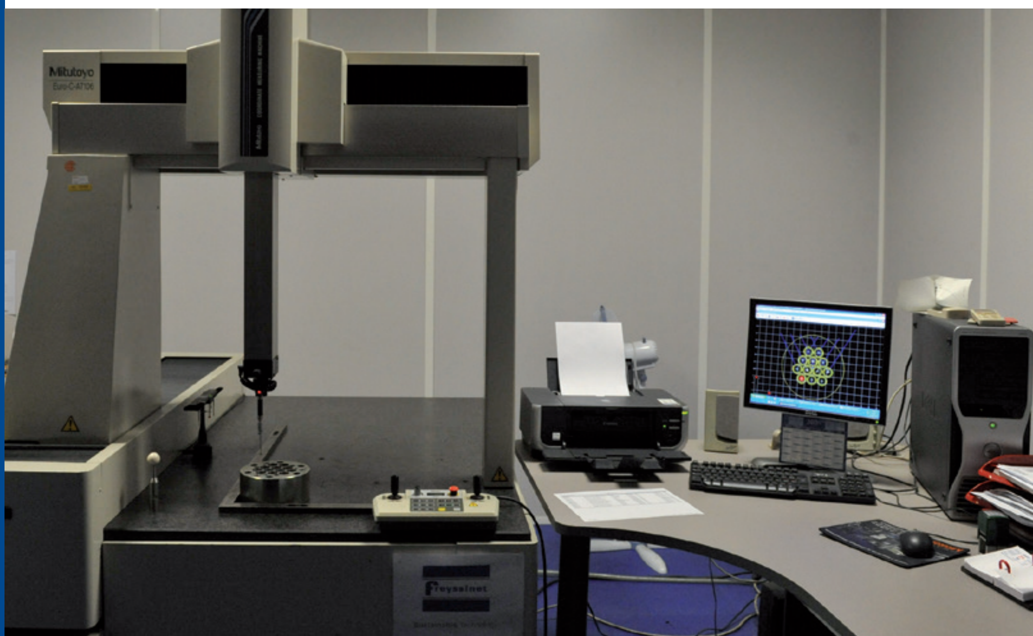
A pioneer in prestressing, Freyssinet has continually innovated over the years, and now offers the ultimate prestressing system combining high performance with durability.

Freyssinet's technical services design anchors, jacks and installation equipment, and also operate a test centre (including a 2,000 tonne tensile testing rig) and a laboratory for the formulation of prestressing grouts.

In order to guarantee high quality 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.

Freyssinet also trains its teams in installing prestressing at all of its subsidiaries. The **PT Academy** is Freyssinet's prestressing training school. Each year graduates of the school obtain qualifications certifying their skills as Works Directors, Prestressing Installation Specialists and Operators.

Freyssinet prestressing anchors, ranges C and F, have been proven in structures the world over to comply with the most stringent requirements: bridge decks and piers, nuclear reactor containment vessels, liquefied natural gas storage tanks, offshore platforms, wind towers, etc. Freyssinet has developed an optimised solution for every application.



European Technical Approval (ETA) and CE marking

Freyssinet has European Technical Approvals (ETA) N° 06/0226 for its prestressing process comprising anchor ranges:

- C for 3 to 55 strand tendons,
- F for 1 to 4 strand tendons.

It has also obtained CE Declaration of Conformity no. 1683-CPD-0004.
The European Technical Approval was 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 and CE marking are subject to continuous monitoring by an official body.

The prestressing kit includes all of the elements that make up a complete tendon.

Specific components

- Passive and active anchor blocks
- Fixed and mobile couplers
- Jaws
- Trumplates
- Protective covers
- Plastic sheaths

Standard components

- Metal sheaths and ducts
- Prestressing strands
- Corrosion-resistant protective materials

For practical reasons, hoop reinforcement is normally provided by the General Contractor.

Designers must check that the provisions adopted for a particular project based on elements in this brochure comply with any local regulations in force.

SYSTÈME DE PRÉCONTRAINTE FREYSSINET – AGRÉMENT TECHNIQUE EUROPÉEN

Service d'études techniques des routes et autoroutes
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Tel : + 33 (0)1 46 11 31 31
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Authorised and notified according to Article 10 of the Council Directive of 21 December 1988 on the approximation of laws, regulations and administrative provisions of Member States relating to construction products (89/106/EEC)

Sétra

MEMBRE DE L'EOTA
MEMBER OF EOTA

Agrément Technique Européen No. ETA-06/0226
(version originale en français)
European Technical Approval No. ETA-06/0226
(Original Version in French Language)

Nom commercial Trade name:	Système Freyssinet
Détenteur de l'ATE Holder of approval:	FREYSSINET 1 bis, rue du Petit Clamart F-78140 VELIZY
Type générique et utilisation prévue du produit de construction Generic type and use of construction product:	Kit de précontrainte de structures par posttension Post-tensioning kit for prestressing of structures
Valid from: to:	25.01.2007 24.01.2012
Producteur du procédé: Kit manufacturer	PPC Z.A. du Monay-Saint Eusèbe F-71210 SAINT EUSÈBE
Le présent agrément technique européen contient : This European Technical Approval contains:	91 pages comprenant 40 pages d'annexes (dessins) faisant partie intégrante du document. 91 pages including 40 pages of annexes (drawings) which form an integral part of the document

EOTA
Organisation pour l'Agrément Technique Européen
European Organisation for Technical Approvals

ASQPE

CERTIFICAT DE CONFORMITÉ
N° 1683 - CPD - 0004

CE

PROCÉDÉ DE PRÉCONTRAINTE PAR POST-TENSION

Certificat de conformité délivré par l'organisme certificateur : ASQPE
Numéro d'identification : 1683
Adresse : ASQPE 58 boulevard Lefebvre 75732 Paris Cedex 15

Détenteur de l'ATE : FREYSSINET
N° ATE : ETA - 06/0226 délivré par le SETRA le 25 janvier 2007

Producteur du procédé : PPC
Adresse : Z.A. du Monay-Saint-Eusèbe F – 71210 SAINT EUSÈBE

Produit certifié : Système Freyssinet

Dans le cadre de la Directive 89/106/CEE du Conseil des Communautés Européennes du 21 décembre 1988, relative au rapprochement des dispositions législatives, réglementaires et administratives des Etats Membres concernant les produits de construction (Directive Produits de Construction – DPC), modifiée par la Directive 93/68/CEE du Conseil des Communautés Européennes du 22 juillet 1993, il a été établi que :

le système de précontrainte par post-tension Freyssinet
produit par PPC

a été soumis aux essais de type initiaux et que le producteur assure un contrôle de la production en usine.

L'organisme notifié ASQPE a réalisé l'inspection initiale de l'usine et a vérifié la mise en place du contrôle de la production en usine. Ce certificat atteste que toutes les dispositions concernant l'attestation de conformité du contrôle de la production en usine décrites dans l'ATE N° ETA-06/0226 sont appliquées et que le procédé satisfait les exigences prescrites.

Ce certificat est délivré pour la première fois le 1er octobre 2007 et, sauf retrait ou suspension, demeure valide tant que les conditions précisées dans la spécification technique de référence, les conditions de fabrication en usine ou le contrôle de la production en usine lui-même ne sont pas modifiés de manière significative et au plus tard jusqu'au 24 janvier 2012.

Délivré à Paris, le 01/10/2007

le Président de l'ASQPE
ASQPE
Jacky SEANTIER

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ASQPE (Association Pour la Qualification de la Précontrainte et des Equipements des Ouvrages et de Génie Civil)
58, Boulevard Lefebvre - 75732 Paris cedex 15 - Tél: 33 (0)1 40 43 33 04 - Fax: 33 (0)1 40 43 65 22

ETAG 013 - "European Technical Approval" and the associated "CE Declaration of Conformity"

Sioule Viaduct, France

C RANGE HIGH STRENGTH PRESTRESSING

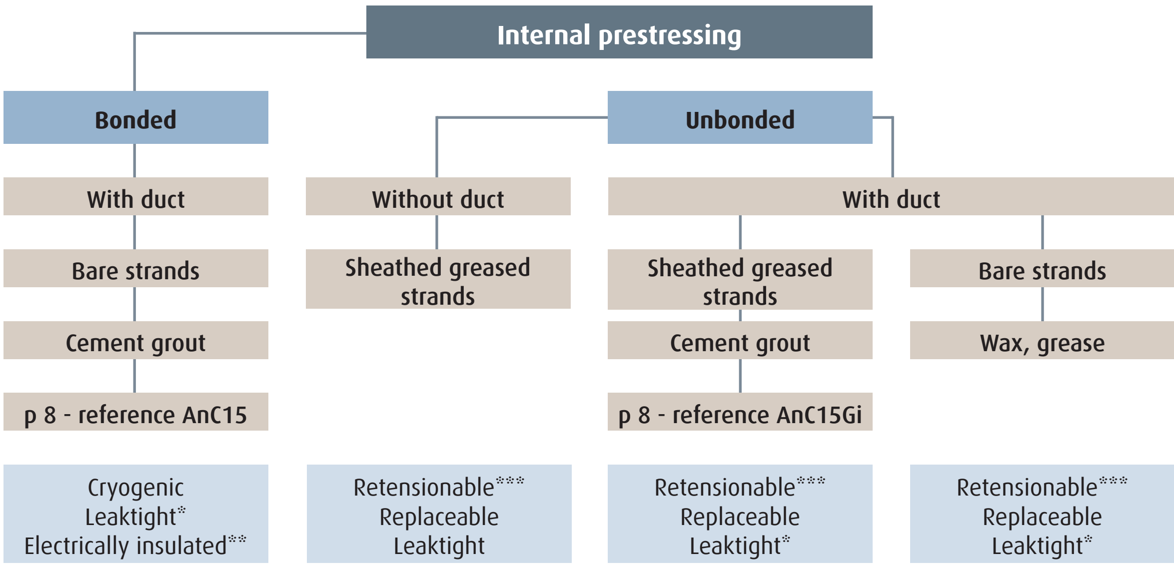
Application categories

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

- use of 13mm and 15mm strands of all grades (1,770 or 1,860 MPa) including galvanised strands or greased 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,
- replaceable, adjustable,
- detensioning possible,
- with electrical insulation,
- for cryogenic applications.

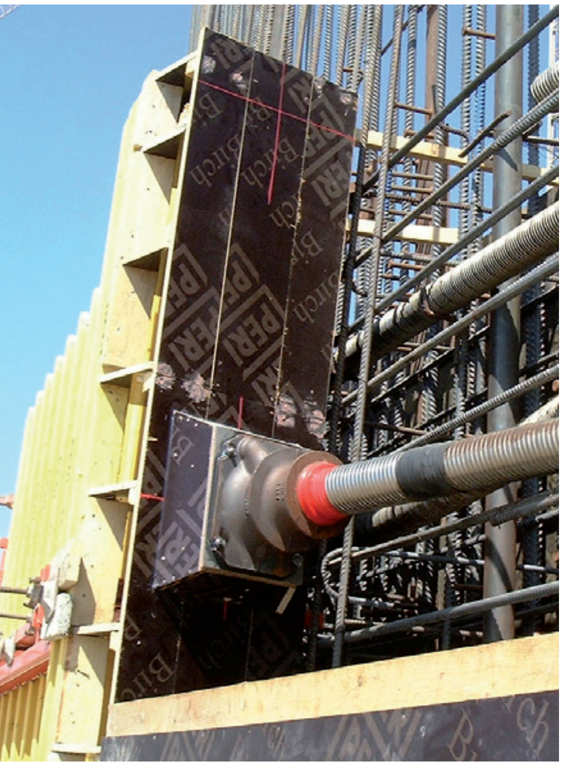


**if there is continuous leaktight sheathing* ***given special provisions - page 9*
****if strand overlengths are retained*

Bonded internal prestressing configurations

The most common use of C range anchors in bonded internal prestressing is based on the use of lubricated, uncoated strands in a corrugated metal sheath, 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 corrugated metal 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 replace the corrugated metal sheath with a leaktight 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.

For structures on maritime sites, Freyssinet also offers a leaktight steel duct made up of very 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: this can be done by sealing (concreting the anchor head into a recess), via a permanent cover made of cast iron (galvanised or painted), or plastic, injected with the same protection product as used in the main run of the tendon.

To protect tendons from stray currents or for electrical checks on watertightness of plastic sheaths, Freyssinet offers an electrically insulated prestressing system 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.

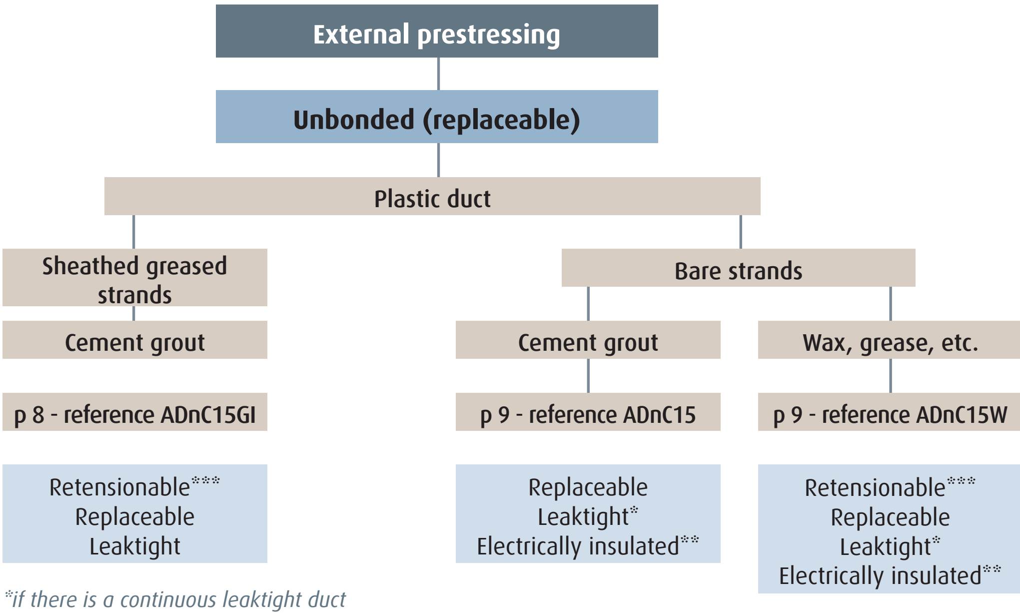
Unbonded internal prestressing configurations

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 attention is then paid to the leaktightness of 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 grease-protected strands, covered with an individual HDPE sheath. These bars can be placed inside a duct injected with cement grout before tensioning the tendon or incorporated directly into the reinforcement before concreting.

Pierre Pflimlin Bridge, Strasbourg - France



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

External prestressing configurations

External prestressing is well suited to structures made from 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 strands placed inside sections of thick HDPE tube, assembled by mirror welding, which are injected with cement grout after tendon tensioning.

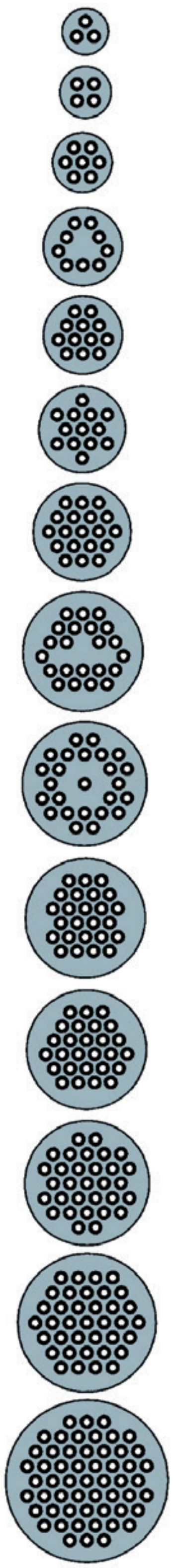
So that a tendon can be removed without damaging the structure, the ducts are of the double casing type at deviators and anchor diaphragms. The HDPE tube runs inside a rigid metal lining tube that separates the tendon from the structure and distributes the transverse loads caused by local deviation.

To produce tendons in which the strands are independent of each other, Freyssinet recommends using grease-protected strands with individual HDPE sheaths placed in a duct injected with cement grout before tendon tensioning. This configuration has the advantage of increasing the durability of the prestressing by incorporating a number of corrosion protection barriers and, for example, allowing for individual strands to be replaced..

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

C RANGE ANCHOR

Anchor units



- 3C15*
- 4C15*
- 7C15
- 9C15
- 12C15*
- 13C15
- 19C15
- 22C15*
- 25C15
- 25CC15*
- 27C15*
- 31C15
- 37C15
- 55C15

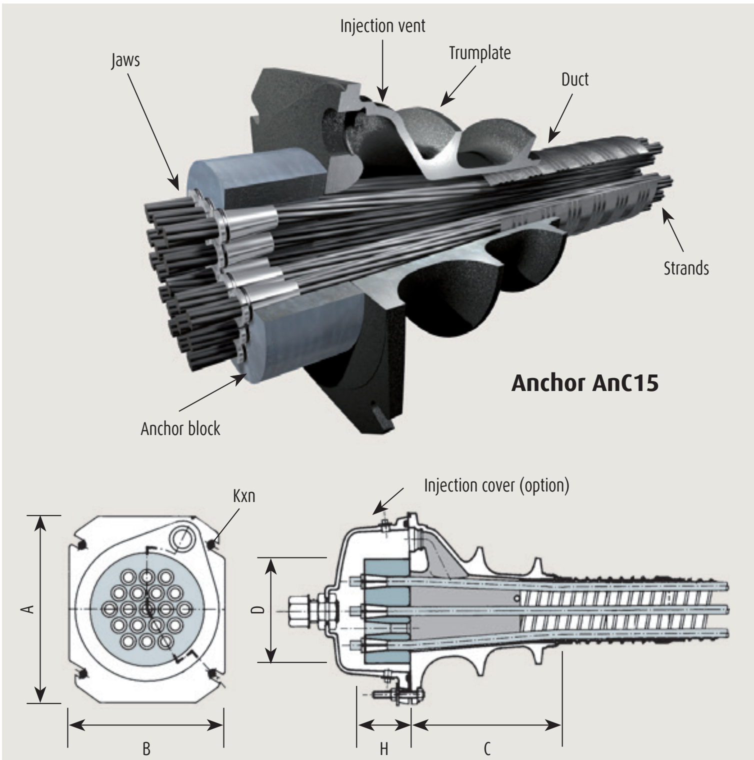
** Configuration of strands in anchor without central strand*

Composition

The anchors comprise:
- jaws guaranteeing high performance anchoring under static or dynamic stresses;
- circular steel anchor blocks drilled with tapered holes;
- multi-ribbed cast iron trumplates for improved distribution of the prestressing force in the concrete;
- optional permanent cover.

Compact anchors

The small size of range C anchors allows for:
- reduced thickness of beams and webs of box girders;
- improved concentration of anchors at ends;
- minimal strand deviation.



Units	A (mm)	B (mm)	C (mm)	D (mm)	H (mm)	Kxn (mm)
3C15	150	110	120	85	50	M10x2
4C15	150	120	125	95	50	M10x2
7C15	180	150	186	110	55	M12x2
9C15	225	185	260	150	55	M12x4
12C15	240	200	165	150	65	M12x4
13C15	250	210	246	160	70	M12x4
19C15	300	250	256	185	80	M12x4
22C15	330	275	430	220	90	M12x4
25C15	360	300	400	230	95	M16x4
25CC15	350	290	360	220	95	M16x4
27C15	350	290	360	220	100	M16x4
31C15	385	320	346	230	105	M16x4
37C15	420	350	466	255	110	M16x4
55C15	510	420	516	300	145	M20x4

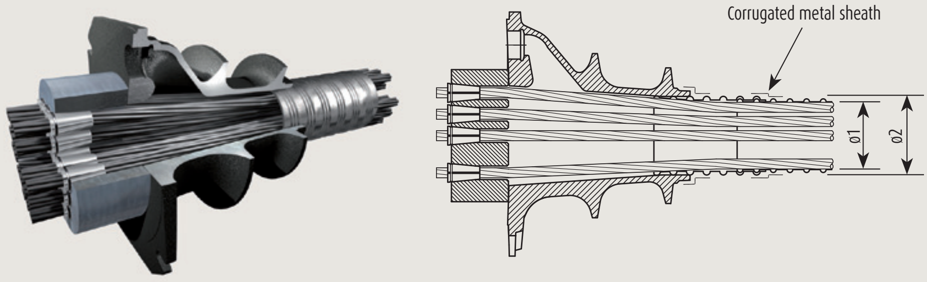
All units are CE marked

C RANGE ANCHOR (CONTINUED)

Application categories

▶ FOR BONDED INTERNAL PRESTRESSING WITH BARE STRANDS WITH CEMENT GROUTING

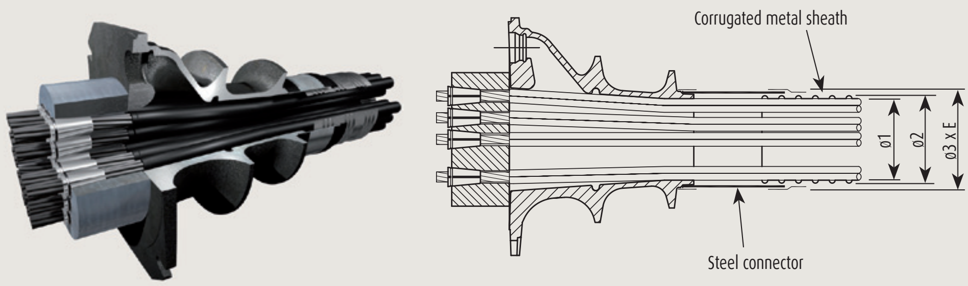
AnC15



Units	Ø1* (mm)	Ø2** (mm)
3C15	40	45
4C15	45	50
7C15	60	65
9C15	65	70
12C15	80	85
13C15	80	85
19C15	95	100
22C15	105	110
25C15	110	115
25CC15	110	115
27C15	115	120
31C15	120	125
37C15	130	135
55C15	160	165

▶ FOR UNBONDED INTERNAL PRESTRESSING WITH GREASED SHEATHED STRANDS WITH CEMENT GROUTING

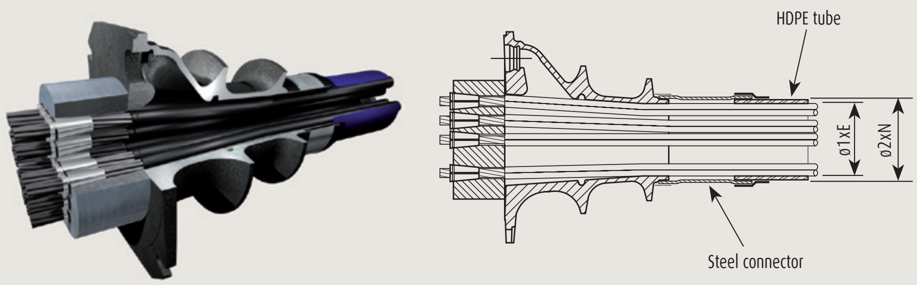
AnC15GI



Units	Ø1* (mm)	Ø2** (mm)	Ø3 (mm)	E (mm)
3C15	40	45	70	2.9
4C15	65	70	82.5	3.2
7C15	65	70	82.5	3.2
9C15	80	85	101.6	5
12C15	95	100	114.3	3.6
13C15	95	100	114.3	3.6
19C15	115	120	133	4
22C15	120	125	139.7	4
25C15	130	135	152.4	4.5
25CC15	130	135	152.4	4.5
27C15	130	135	152.4	4.5
31C15	145	150	177.8	5
37C15	145	150	177.8	5

▶ FOR UNBONDED EXTERNAL PRESTRESSING WITH GREASED SHEATHED STRANDS WITH CEMENT GROUTING

ADnC15GI

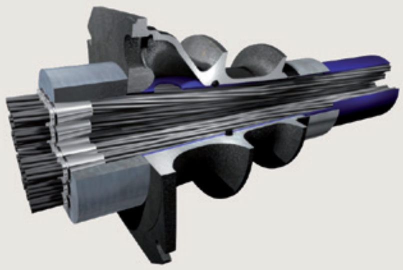


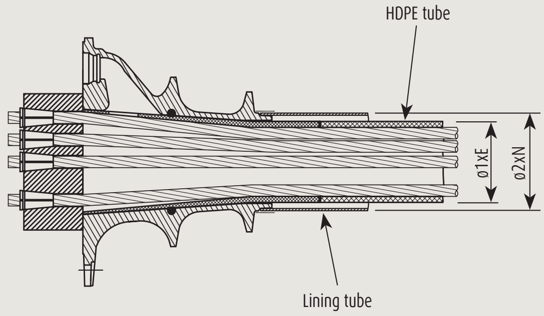
Units	Ø1* (mm)	E (mm)	Ø2** (mm)	N (mm)
3C15	70	2.9	63	4.7
4C15	82.5	3.2	75	5.5
7C15	82.5	3.2	90	6.6
9C15	101.6	5	90	6.6
12C15	114.3	3.6	110	5.3
13C15	114.3	3.6	110	5.3
19C15	133	4	125	6
22C15	139.7	4	125	6
25C15	152.4	4.5	140	6.7
25CC15	152.4	4.5	140	6.7
27C15	152.4	4.5	140	6.7
31C15	177.8	5	160	7.7
37C15	177.8	5	160	7.7
55C15	219.1	6.3	200	9.6

** Check sheath thickness complies with applicable regulations.*
*** ø: inner dimeter for corrugated sheath / outer diameter for PE or steel pipe. * and ** minimum recommended dimensions.*

▶ For unbonded external prestressing with bare strands with cement grouting

ADnC15

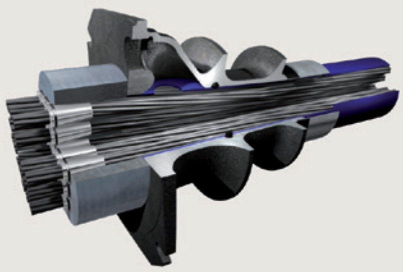


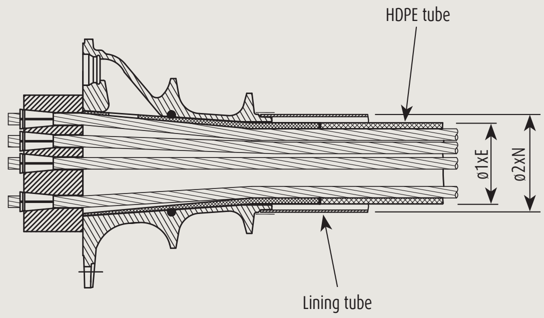


Units	Ø1* (mm)	E (mm)	Ø2** (mm)	N (mm)
3C15	50	3.7	70	2.9
4C15	63	4.7	82.5	3.2
7C15	63	4.7	82.5	3.2
9C15	75	5.5	101.6	5
12C15	90	6.6	114.3	3.6
13C15	90	6.6	114.3	3.6
19C15	110	5.3	133	4
22C15	110	5.3	139.7	4
25C15	125	6	152.4	4.5
25CC15	125	6	152.4	4.5
27C15	125	6	152.4	4.5
31C15	140	6.7	177.8	5
37C15	140	6.7	177.8	5

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

ADnC15W

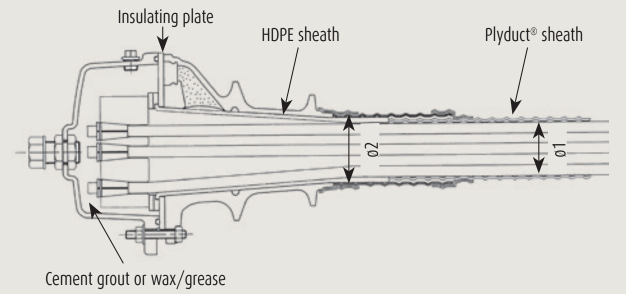




Units	Ø1* (mm)	E (mm)	Ø2** (mm)	N (mm)
3C15	50	3.7	70	2.9
4C15	63	4.7	82.5	3.2
7C15	63	4.7	82.5	3.2
9C15	75	5.5	101.6	5
12C15	90	6.6	114.3	3.6
13C15	90	6.6	114.3	3.6
19C15	110	8.1	133	4
22C15	110	8.1	139.7	4
25C15	125	9.2	152.4	4.5
25CC15	125	9.2	152.4	4.5
27C15	125	9.2	152.4	4.5
31C15	140	10.3	177.8	5
37C15	140	10.3	177.8	5

▶ For prestressing with electrical insulation

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.



Units	Ø1* (mm)	Ø2** (mm)
3C15	40	45
4C15	45	50
7C15	60	65
9C15	65	70
12C15	80	85
13C15	80	85
19C15	95	100
22C15	105	110
25C15	110	115
25CC15	110	115
27C15	115	120
31C15	120	125
37C15	130	135
55C15	160	165

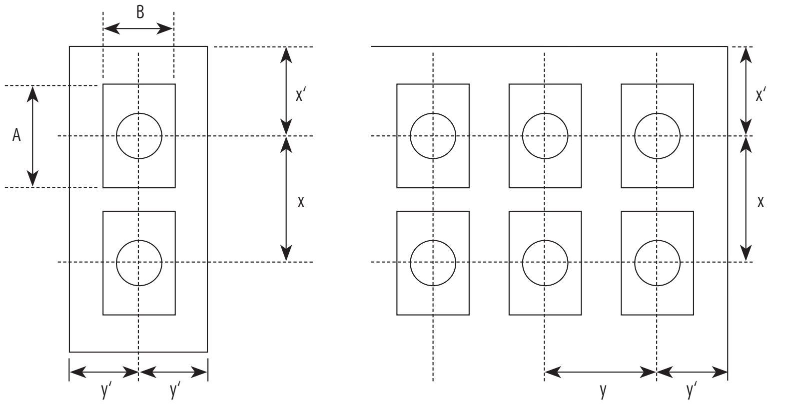
** Check sheath thickness complies with applicable regulations.*
*** ø: inner dimeter for corrugated sheath / outer diameter for PE or steel pipe.. * and ** minimum recommended dimensions.*

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:

$x \geq A + 30$ (mm)
$y \geq B + 30$ (mm)
$x \cdot y \geq a \cdot b$
$x \geq 0.85\, a$
$y \geq 0.85\, b$
$x' \geq 0.5\, x$ + concrete cover — 10 (mm)
$y' \geq 0.5\, y$ + concrete cover — 10 (mm)

Distances a and b

	a = b (mm)		
	$f_{cm,o}$ (MPa)		
Units	**24**	**44**	**60**
3C15	220	200	180
4C15	250	220	200
7C15	330	260	240
9C15	380	300	280
12C15	430	320	300
13C15	450	340	310
19C15	530	400	380
22C15	590	430	410
25C15	630	460	440
27C15	650	480	470
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 détermine 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 table 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 $f_{cm,o}$, 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 table opposite and that at 30% of this force, the required strength for the concrete can be brought down to half of the values shown.

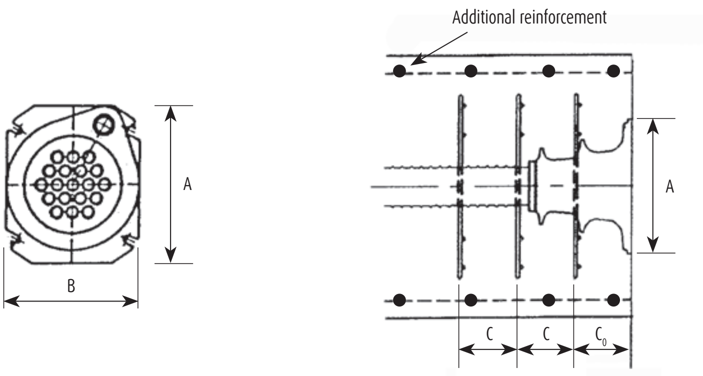
Hoop reinforcement for C range anchors

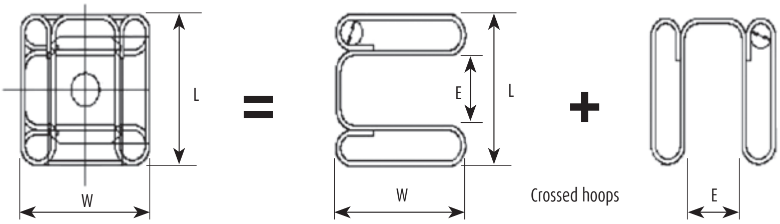
The concentrated forces applied by the prestressed units require the installation of hoop reinforcement in the vicinity of the anchors in the case of concrete structures. This local reinforcement includes anti-burst reinforcement and additional reinforcement. To take account of normal construction provisions in certain countries, anti-burst reinforcement has been defined as being provided either by crossed hoops or spiral reinforcement.

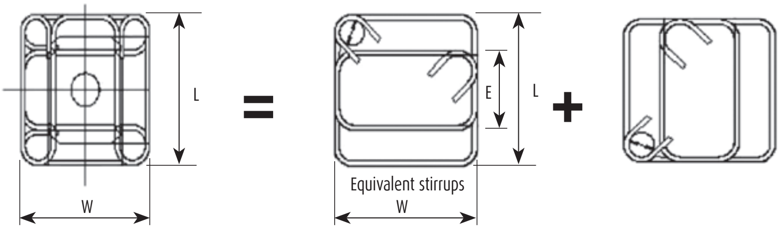
The hoops shown in the tables below are deduced from the reinforcement used in test prisms and for a concrete cylinder strength equivalent to 24 or 44 MPa. For concrete strength equal to 60 MPa, refer to the Freyssinet System European Technical Approval. For other strengths the values from the tables can be interpolated.

1/ Crossed hoops (or stirrups)

The following diagrams show the general layout of the anti-burst reinforcement if using crossed hoops. Two crossed hoops are positioned on each layer. For practical reasons each hoop may be replaced by two stirrups with equivalent load resisting section as shown in the diagram below.







Hoop reinforcement for C range anchors (continued)

For anchors in several rows, in general the W and L dimensions are equal to a single value Lo shown in the tables below. For anchors in one row, W is smaller and L increases but still respecting the minimum value E given in the tables below.
The specifications for anti-burst reinforcement vary depending on the average compressive strength of the concrete on tensioning: fcm,0 (measured on cylinder). They are described in the tables below for two strength values.

Units	Crossed hoops or equivalent stirrups (Fy 235)							(Fy500) Additional reinforcements (stirrups)		
	Number of layers	Co (mm)	C (mm)	Diameter d (mm)	Mandrel diameter D (mm)	min Centre distance E (mm)	Overall dimension LO (mm)	Pitch (mm)	Diameter d (mm)	Number
3C15	3	100	75	8	31	90	200	110	8	3
4C15	3	100	75	8	46	90	230	115	12	3
7C15	3	120	90	12	74	130	310	120	12	4
9C15	3	120	110	12	74	140	360	125	14	4
12C15	3	120	120	14	83	160	410	140	16	4
13C15	3	140	125	14	88	170	430	130	16	4
19C15	3	160	125	16	117	200	520	180	20	4
22C15	3	170	140	20	118	215	570	130	16	6
25C15	3	200	160	20	135	220	610	175	20	5
27C15	3	175	170	20	130	250	630	130	20	6
31C15	3	210	150	20	130	255	670	140	20	6
37C15	4	250	225	20	130	270	740	130	25	5
55C15	5	290	200	25	160	340	1050	200	20	6

fcm,0 = 24 MPa

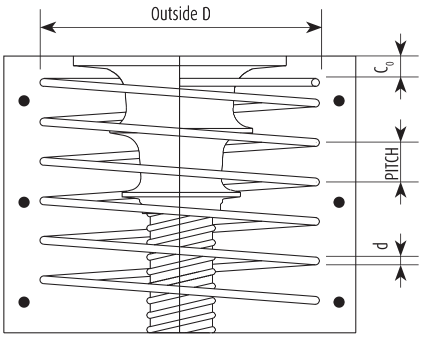
Units	Crossed hoops or equivalent stirrups (Fy 235)								(Fy500) Additional reinforcements (stirrups)		
	Number of layers	Co (mm)	C (mm)	Range	Diameter d (mm)	Mandrel diameter D (mm)	min Centre distance E (mm)	Total length LO (mm)	Pitch (mm)	Diameter d (mm)	Number
3C15	3	100	75	FC	8	26	90	190	150	8	2
4C15	3	100	75	FC	8	31	90	200	250	8	3
7C15	3	120	90	FC	12	39	130	240	140	10	4
9C15	3	120	110	FC	12	39	140	290	150	14	3
12C15	3	120	120	C	14	84	160	300	240	14	3
13C15	3	140	125	C	14	84	170	330	120	14	4
19C15	3	160	125	C	16	96	200	380	200	16	3
22C15	3	170	140	C	20	120	215	410	160	14	4
25C15	3	200	160	C	20	120	220	440	165	16	3
27C15	3	175	170	C	20	120	250	460	165	16	3
31C15	3	210	190	C	20	120	255	500	210	20	3
37C15	4	250	225	C	20	120	270	600	210	20	4
55C15	4	290	255	C	25	150	340	730	200	20	4

fcm,0 = 44 MPa

FC: crossed hoops or equivalent stirrups
C: stirrups only

2/ Helical reinforcements

The diagram opposite defines the general layout of anti-burst reinforcement if using a spiral. This layout is especially suitable for isolated anchors.



Hooping and additional reinforcements

Units	Spiral reinforcement (Fy 235)					(Fy500) Additional reinforcements (stirrups)		
	Pitch (mm)	Diameter d (mm)	Number	Co (mm)	Outside diameter D (mm)	Pitch (mm)	Diameter d (mm)	Number
3C15	50	8	5	40	160	110	8	3
4C15	60	10	5	40	190	115	10	3
7C15	60	14	6	40	270	120	10	4
9C15	70	14	6	40	320	125	12	4
12C15	70	14	7	40	370	140	16	4
13C15	70	14	7	40	390	130	16	4
19C15	60	16	8	40	470	180	20	4
22C15	70	16	8	40	510	130	20	5
25C15	80	20	7	40	550	150	20	5
27C15	80	20	7	40	570	160	20	5
31C15	80	20	7	40	600	140	20	6
37C15	90	20	7	40	660	130	25	5
55C15	100	25	9	40	930	200	20	6

fcm,0 = 24 MPa

Corgo Bridge, Portugal

Units	Spiral reinforcement (Fy 235)					(Fy500) Additional reinforcements (stirrups)		
	Pitch (mm)	Diameter d (mm)	Number	Co (mm)	Outside diameter D (mm)	Pitch (mm)	Diameter d (mm)	Number
3C15	50	8	5	40	150	150	8	2
4C15	60	10	5	40	160	250	8	3
7C15	60	12	6	40	200	140	10	4
9C15	70	14	6	40	250	150	12	3
12C15	50	14	7	40	260	240	14	3
13C15	70	14	7	40	290	120	14	4
19C15	60	16	8	40	320	200	16	3
22C15	70	16	8	40	350	160	14	4
25C15	80	20	7	40	380	165	16	3
27C15	80	20	7	40	400	165	16	3
31C15	80	20	8	40	420	210	16	3
37C15	90	20	9	40	520	210	20	4
55C15	100	25	10	40	650	250	20	3

fcm,0 = 44 MPa

3/Additional reinforcement

The anti-burst reinforcement in the anchor zone must be supplemented by the additional reinforcement used in the transfer test prisms, in the form of frames in accordance with the above tables or using correctly anchored bars of the same section.

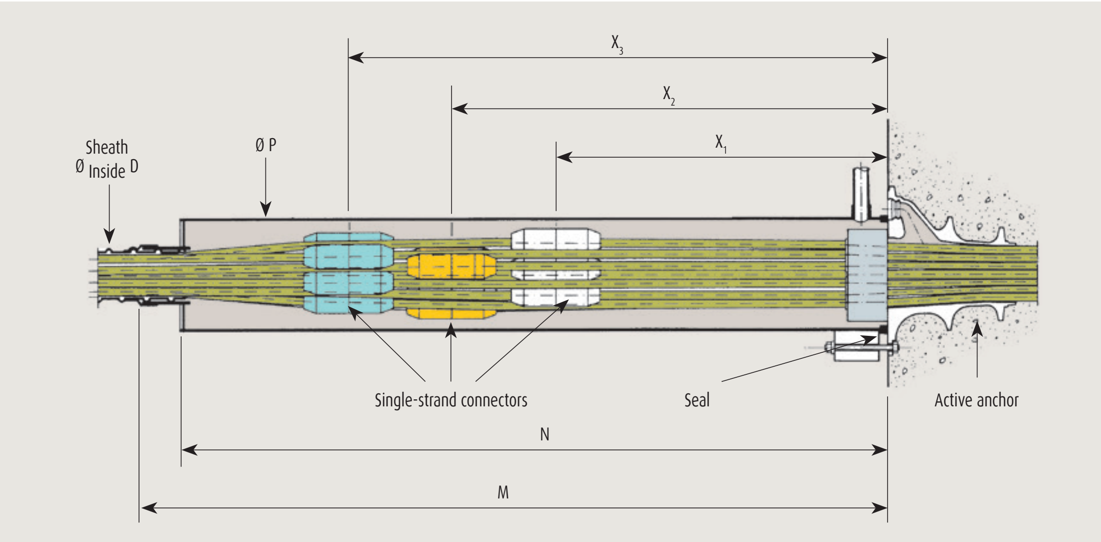
The reinforcement given in the tables above must in most cases be supplemented by general reinforcements not shown on the drawings, corresponding to the minimum required to guard against cracking and general equilibrium reinforcements. The project designer must check the general balance of the anchor zones.

CI SINGLE-STRAND FIXED COUPLERS

Couplers are needed when a continuous structure is built in successive phases with extension of the tendons already in place, tensioned and grouted in the previous segment. They are generally used in internal prestressing.

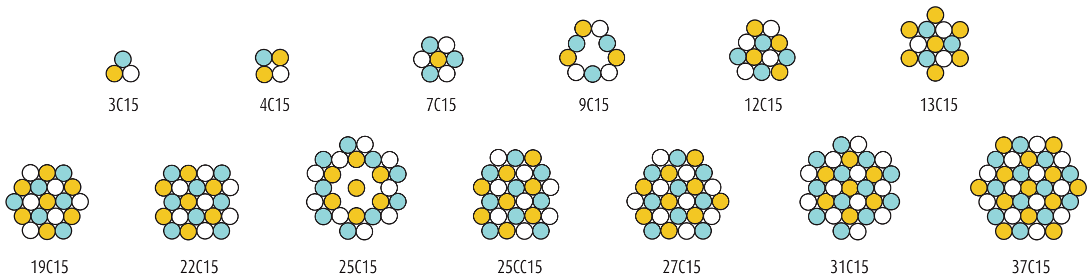
CI single-strand fixed couplers

CI fixed couplers allow for a secondary tendon to be connected to a primary tendon using machined or cast single-strand extenders with automatic locking by a spring inserted between the two opposing jaws. The primary anchor is a C range anchor. The single-strand extenders positioned on three levels offer a very compact configuration.



Units	D (mm)	M (mm)	N (mm)	P (mm)	X_1 (mm)	X_2 (mm)	X_3 (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 9C15	65	1,100	1,050	178	300	500	800
CI 12C15	80	1,150	1,100	194	300	550	800
CI 13C15	80	1,200	1,150	219	300	550	800
CI 19C15	95	1,200	1,150	219	300	550	800
CI 22C15	105	1,250	1,200	273	350	600	800
CI 25C15	110	1,250	1,200	273	350	600	850
CI 25CC15	110	1,300	1,250	273	350	600	850
CI 27C15	115	1,300	1,250	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

All units are CE marked



CU and CC fixed multi-strand couplers

Units	A (mm)	B (mm)	C (mm)	G (mm)	ØD (mm)	E (mm)	L (mm)	H (mm)	ØP (mm)
CU 3C15	150	110	120	40	140	120	150	150	150
CU 4C15	150	120	125	45	150	127	150	150	150
CU 7C15	180	150	186	60	200	120	180	180	180
CU 9C15	225	185	260	65	255	122	225	225	225
CU 12C15	240	200	165	80	265	130	240	240	240
CU 13C15	250	210	246	80	276	130	250	250	250
CU 19C15	300	250	256	95	306	140	300	300	300
CU 22C15	330	275	430	105	335	145	330	330	330
CU 25C15	360	300	400	110	346	145	360	360	360
CU 25CC15	350	290	360	110	354	150	350	350	350
CU 27C15	350	290	360	115	354	150	350	350	350
CU 31C15	385	320	346	120	356	150	385	385	385
CU 37C15	420	350	466	130	386	156	420	420	420

All units are CE marked

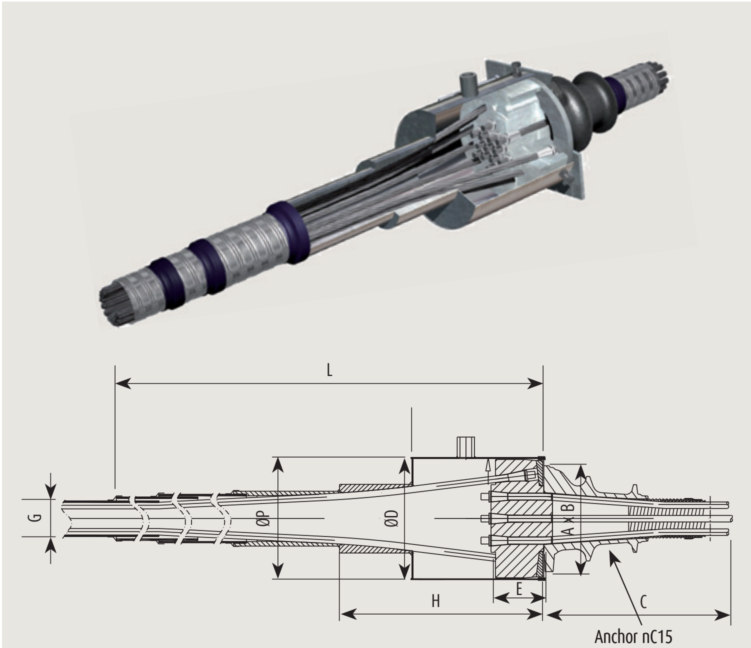
Units	E (mm)	L (mm)	M x N* (mm)	ØP (mm)	ØG (mm)
CC 3C15**	10	570	220 x 220	210	40
CC 4C15**	10	600	240 x 240	220	45
CC 7C15**	10	670	260 x 260	230	60
CC 9C15**	10	750	290 x 290	270	65
CC 12C15**	10	725	300 x 300	280	80
CC 13C15	10	770	290 x 290	275	80
CC 19C15	12	825	320 x 320	305	95
CC 22C15**	10	885	390 x 390	365	110
CC 25C15	5	900	360 x 360	340	110
CC 27C15**	10	955	390 x 390	365	110
CC 31C15	5	1,110	420 x 420	400	120

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

2 types of multi-strand coupler are possible:

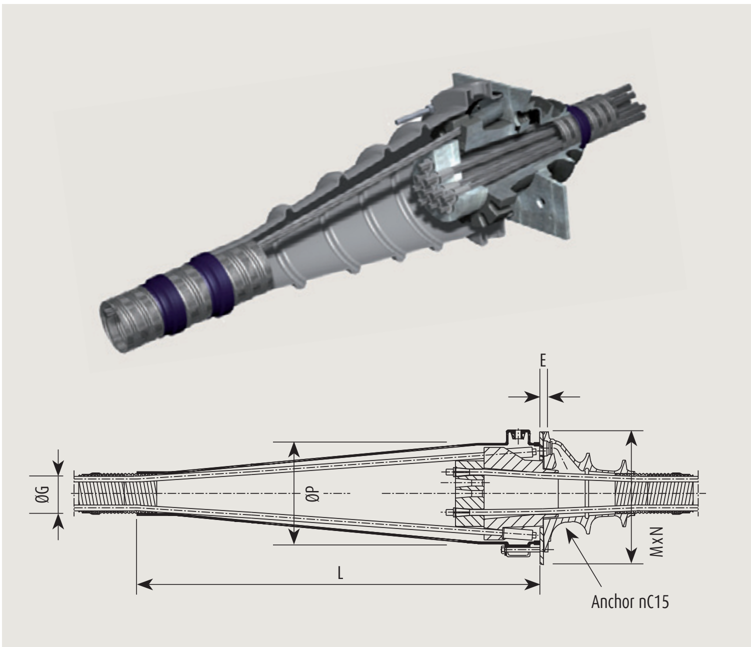
Type CU couplers

For these couplers the anchor block of the primary tendon is altered to take the anchoring jaws of the secondary tendon.
This assembly is protected by a cover with a trumpet at one end to provide the connection with the duct of the secondary tendon.



Type CC couplers

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

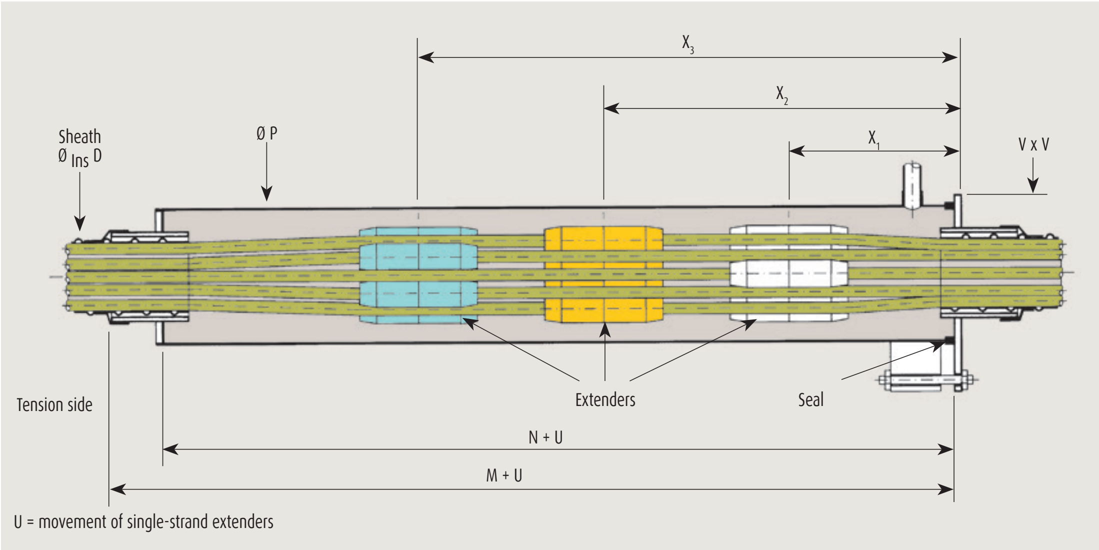


CM MOBILE MULTI-STRAND COUPLERS

Coupling for untensioned tendons

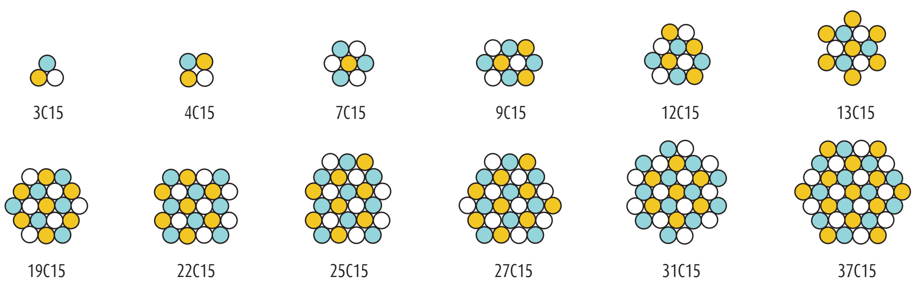
These connection devices enable end-to-end coupling of two untensioned tendons.

The configuration is similar to that of fixed couplings using the same individual extenders, but without a primary anchor. The cover is longer to allow the extenders to move when the whole tendon is being tensioned.



Units	D (mm)	M (mm)	N (mm)	P (mm)	X_1 (mm)	X_2 (mm)	X_3 (mm)	V (mm)
CM 3C15	40	1,050	1,000	102	250	500	750	130
CM 4C15	45	1,050	1,000	108	250	500	750	140
CM 7C15	60	1,050	1,000	114	250	500	750	150
CM 9C15	65	1,100	1,050	159	300	550	800	200
CM 12C15	80	1,150	1,100	159	300	550	800	200
CM 13C15	80	1,200	1,150	168	300	550	800	200
CM 19C15	95	1,200	1,150	194	300	550	800	230
CM 22C15	105	1,250	1,200	219	350	600	800	230
CM 25C15	110	1,250	1,200	219	350	600	850	250
CMI 27C15	115	1,300	1,250	219	350	600	850	250
CM 31C15	120	1,350	1,300	244	400	650	900	280
CM 37C15	130	1,530	1,480	273	400	650	900	310

All units are CE marked

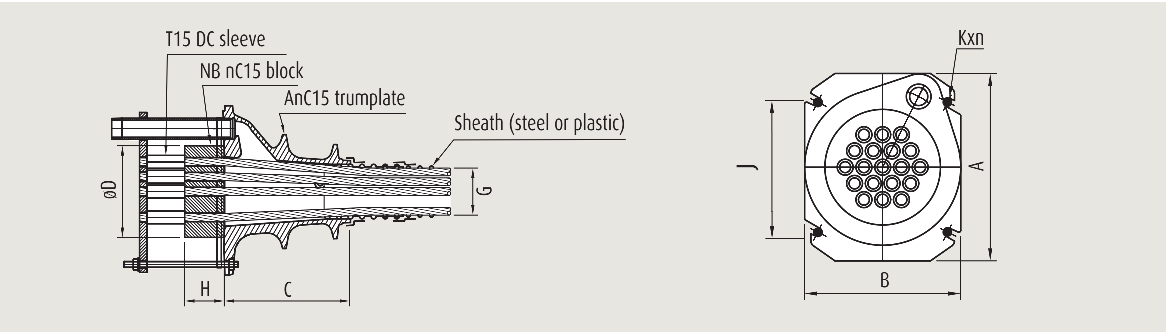


Embedded anchors

There are three types of passive anchor embedded in concrete and used in combination with C range active anchors: NB, N and G. The tendons are positioned before concreting.

Type NB embedded anchor

NB anchors comprise an anchor block drilled with cylindrical holes and on which extruded sleeves are held by a rear 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
9C15	225	185	260	150	55	65	153	M12x4
12C15	240	200	165	150	65	80	168	M12x4
13C15	250	210	246	160	70	80	168	M12x4
19C15	300	250	256	185	80	95	208	M12x4
22C15	330	275	430	220	90	105	248	M12x4
25C15	360	300	400	230	95	110	268	M16x4
25CC15	350	290	360	220	95	110	258	M16x4
27C15	350	290	360	220	100	115	258	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

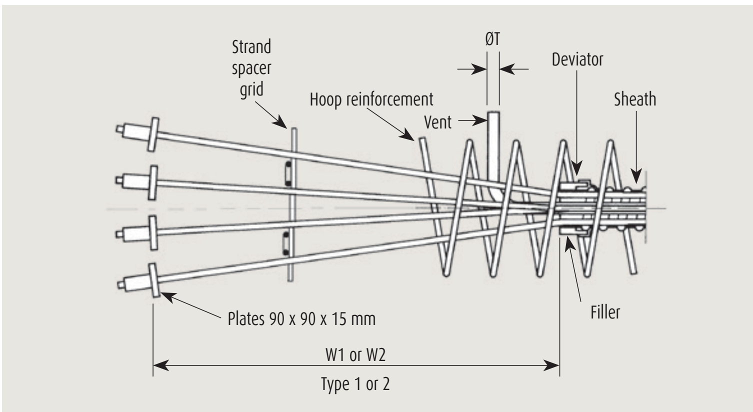
All units are CE marked

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

Units	W1 (mm)	W2 (mm)	ØT (mm)
3C15	300	300	G 1/2″
4C15	350	350	G 1/2″
7C15	500	400	G 1/2″
9C15	600	400	G 1/2″
12C15	900	500	G 1/2″
13C15	1,200	500	G 1/2″
19C15	1,500	650	G 1″
22C15	1,800	750	G 1″
25C15	2,000	850	G 1″
27C15	2,000	1,000	G 1″
31C15	2,200	1,100	G 1″
37C15	2,500	1,280	G 1 1/2″
55C15	2,800	1,400	G 1 1/2″

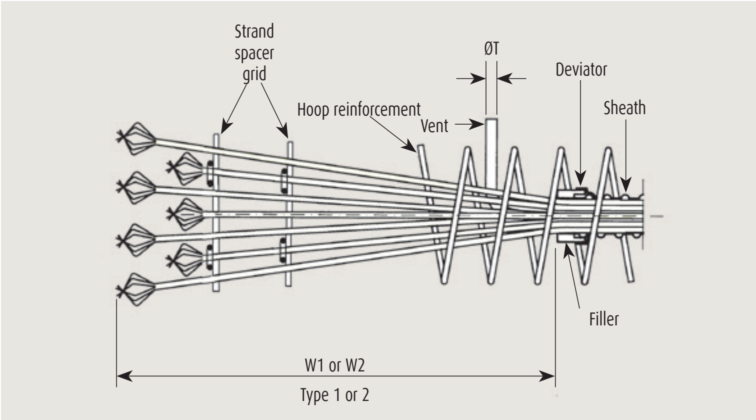
Type N embedded anchor

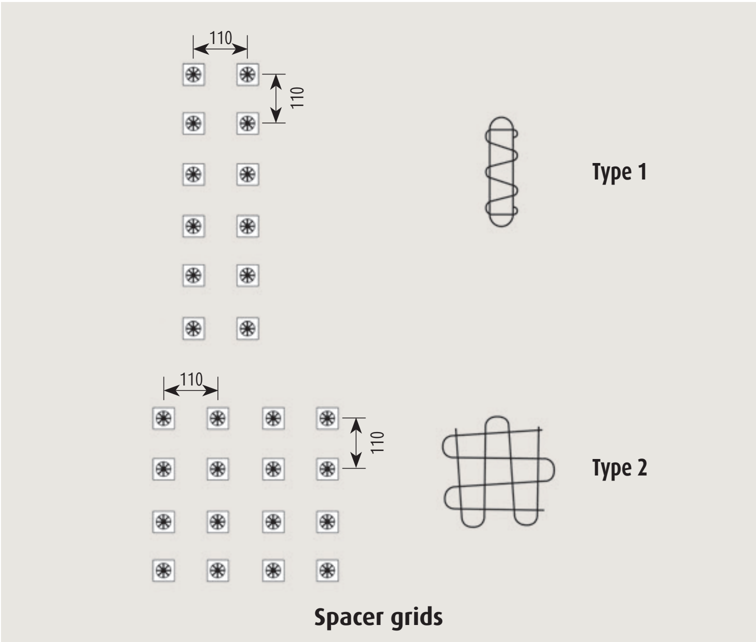
In the type N anchor, each strand has an extruded sleeve, each supported individually by a steel plate.



Type G embedded anchor

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





Units	W1 (mm)	W2 (mm)	ØT (mm)
3C15	950	450	G 1/2"
4C15	950	500	G 1/2"
7C15	950	550	G 1/2"
9C15	950	550	G 1/2"
12C15	1,300	650	G 1/2"
13C15	1,300	650	G 1/2"
19C15	1,300	800	G 1"
22C15	1,500	1,000	G 1"
25C15	1,500	1,000	G 1"
27C15	1,700	1,250	G 1"
31C15	1,700	1,250	G 1"
37C15	2,000	1,250	G 1 1/2"
55C15	2,500	1,250	G 1 1/2"

Nuclear containment vessel, China

F RANGE ANCHORS FOR THIN ELEMENTS


Jamuna Bridge, Bangladesh

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.

Bonded internal prestressing configurations

The most common use of F range 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.

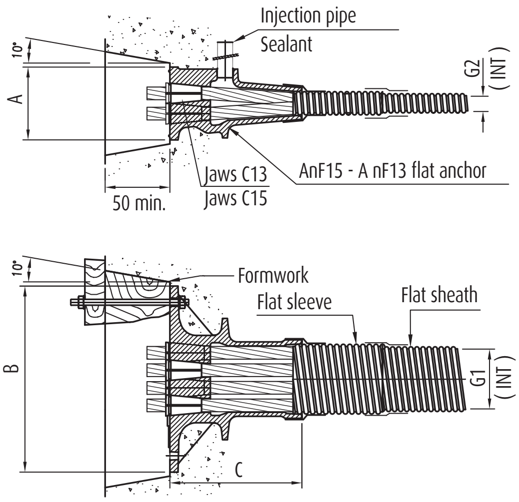
The anchors, sheath and prestressing reinforcements are installed before concreting the structure. In particular, this prevents the risk of flat ducts being crushed during concreting which would prevent the subsequent threading of the strands.

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 13^{mm} and 15^{mm} strands respectively allows for the beneficial effects of the prestressing to be distributed very evenly in thin elements.

Multi-strand units 3 to 5 F13/F15



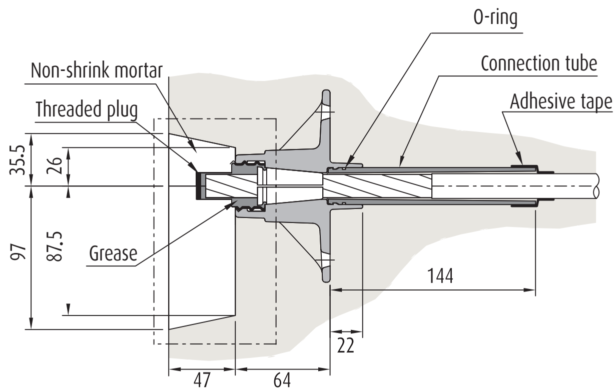
Notes: F range anchors are designed for minimum concrete strength fcmin= 22 MPa (on cylinder).
The usual installation method is threading the strands into the ducts (flat sheaths) before concreting.
However, if necessary, it is also possible to thread the strands after concreting the structure, on condition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

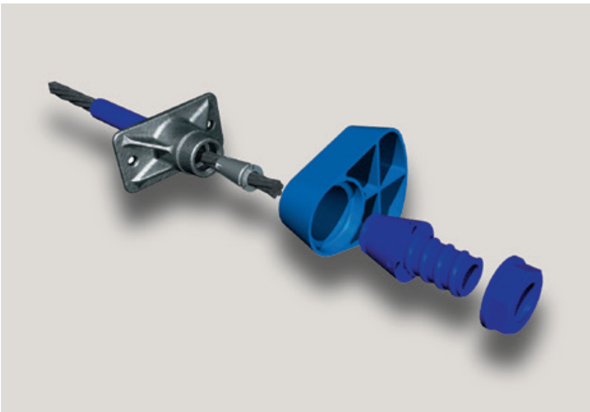
Units	A (mm)	B (mm)	C (mm)	G1 x G2 (mm^2)	G (mm)	H (mm)
CE A3 F13/15	85	190	163	58 x 21	95	200
CE A4 F13/15	90	230	163	75 x 21	100	240
A5 F13/15	90	270	163	90 x 21	100	280

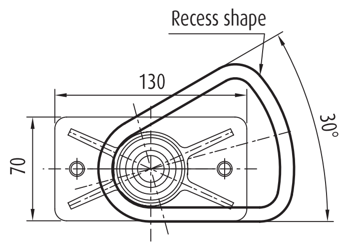
Bridge at Rousson, France

Unbonded internal prestressing with greased sheathed strands

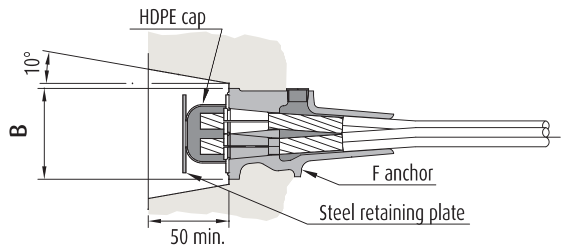
1/ Single-strand unit (1F13/1F15) CE

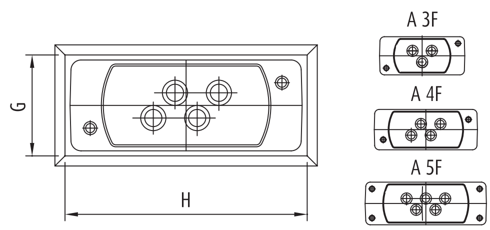


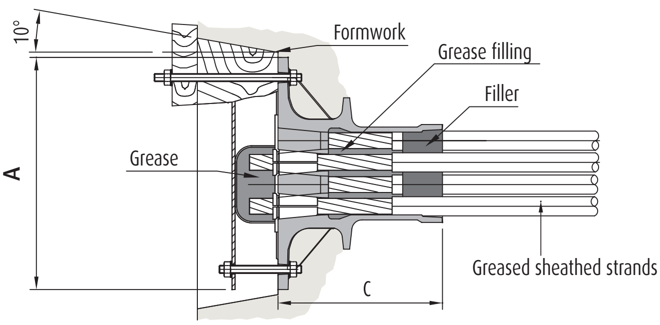




2/ Multi-strand units (3 to 5 F13/15)



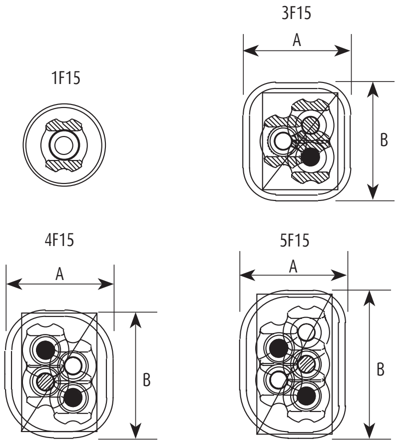


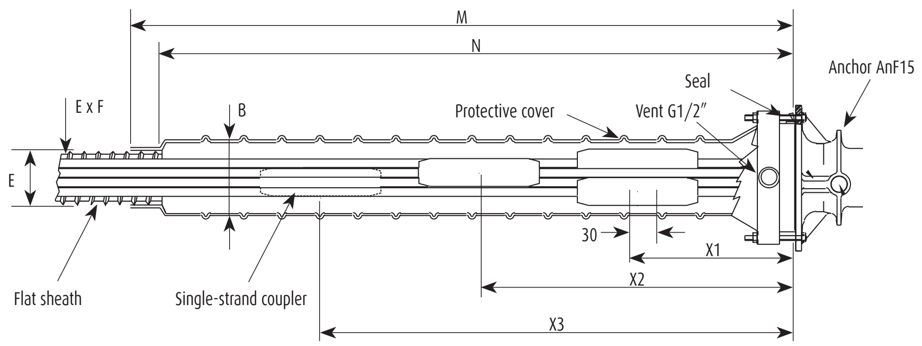


Units	A (mm)	B (mm)	C (mm)	G (mm)	H (mm)
CE A 3F 13/15	190	85	163	95	200
CE A 4F 13/15	230	90	163	100	240
A 5F 13/15	270	90	163	100	280

CI
SINGLE-STRAND FIXED COUPLERS

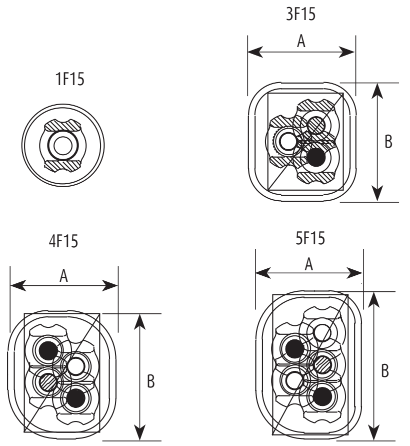
Bonded prestressing

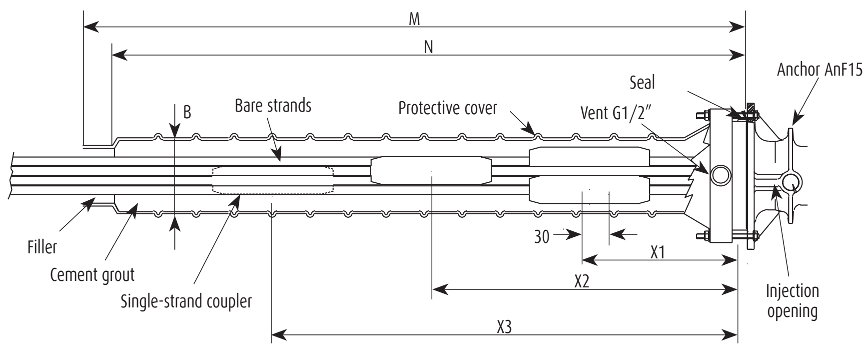




Units	A (mm)	B (mm)	E (mm)	F (mm)	M (mm)	N (mm)	X1 (mm)	X2 (mm)	X3 (mm)
CI 1F13/15	-	-	-	-	550	550	250	-	-
CI 3F13/15	100	100	58	20	800	750	250	500	750
CI 4F13/115	100	110	75	20	1,050	1,000	250	500	750
CI 5F13/15	100	140	90	20	1,050	1,000	250	500	750

Unbonded prestressing





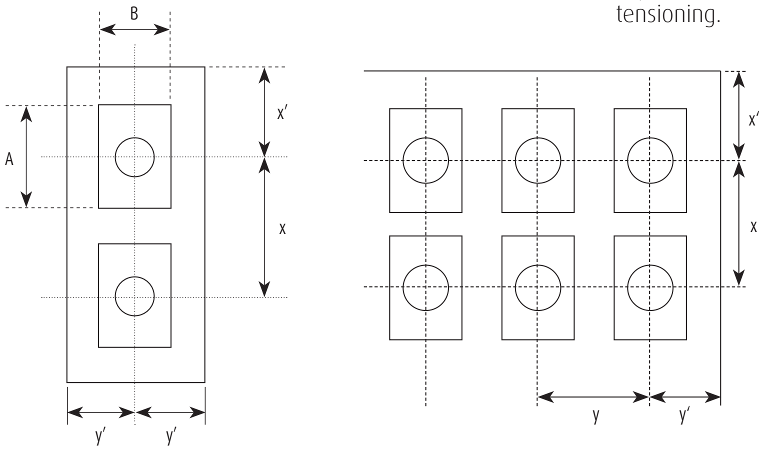
Units	A (mm)	B (mm)	M (mm)	N (mm)	X1 (mm)	X2 (mm)	X3 (mm)
CI 1F13/15	-	-	550	500	250	-	-
CI 3F13/15	100	100	800	750	250	500	750
CI 4F13/15	100	110	1,050	1,000	250	500	750
CI 5F13/15	100	140	1,050	1,000	250	500	750

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 ($A \geq B$).
- a , b: side lengths of test specimen ($a \geq b$).
- 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:

$x \geq A + 30$ (mm)
$y > B + 30$ (mm)
$x \, . \, y \geq a \cdot b$
$x \geq 0.85 \, a$
$y \geq 0.85 \, b$
$x' \geq 0.5 \, x$ + concrete cover — 10 (mm)
$y' \geq 0.5 \, y$ + concrete cover — 10 (mm)

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

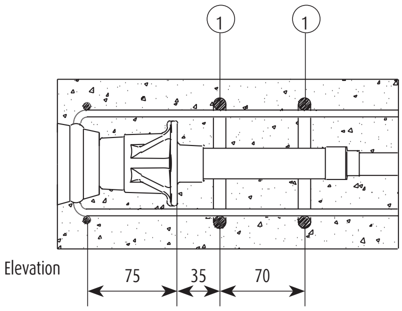
Values a and b are given in the table opposite, for three different concrete strength $f_{cm,o}$ in the case of F range.

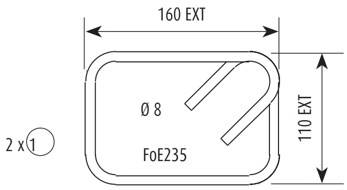
If the design provides for partial tensioning or a tensioning rate of less than min [0.8 F_{pk} ; 0.9 $F_{p0.1\%}$], interpolation can be used to determine the required value of $f_{cm,o}$, bearing in mind that at 50% of full force, the required strength for the concrete can be brought to 2/3 of the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

Hoop reinforcement for F range anchors

1/ Single-strand unit

A 1F13
A 1F15

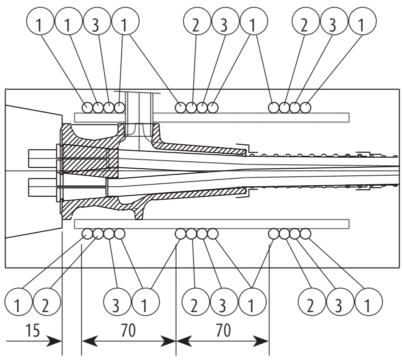




Dimensions in mm

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

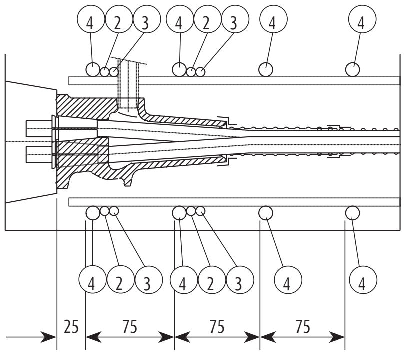
A 3F13
A 4F13



Type	No.	Ø (mm)	L1 (mm)	L2 (mm)	L3 (mm)	h (mm)
1	12	8	320			
2	3	8	320	20	160	140
3	3	8	320	20	160	140

See types of bars below.

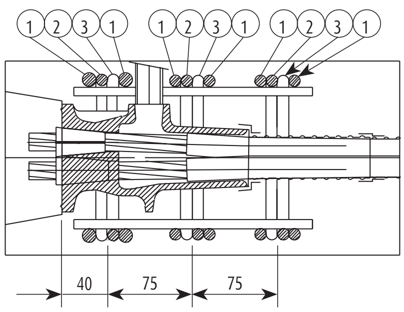
A 3F15
A 4F15



Type	No.	Ø (mm)	L1 (mm)	L2 (mm)	L3 (mm)	h (mm)
2	2	8	350	60	160	160
3	2	8	350	60	160	160
4	4	12	350		160	160

See types of bars below.

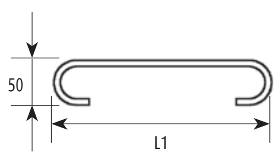
A 5F15
A 5F13



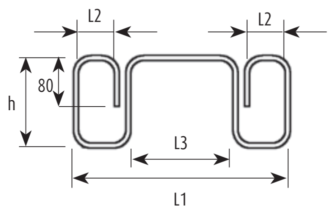
Type	No.	Ø (mm)	L1 (mm)	L2 (mm)	L3 (mm)	h (mm)
1	12	10	380	-	-	-
2	3	10	380	55	190	145
3	3	10	380	55	190	145

See types of bars below.

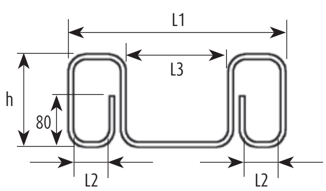
Type No. 1



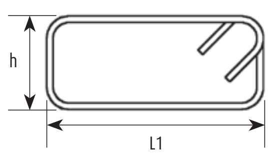
Type No. 2



Type No. 3



Type No. 4

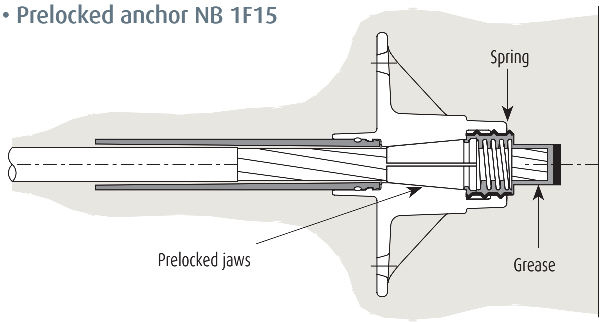


Embedded anchors for F range

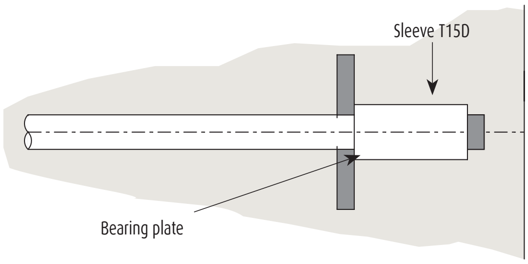
There are three types of passive anchors embedded in concrete used in combination with F range active anchors: prelocked anchor NB1F15, type N using an individual plate supporting an extruded sleeve and the type G dead end anchor. The tendons are positioned before concreting.

1/ Single-strand unit

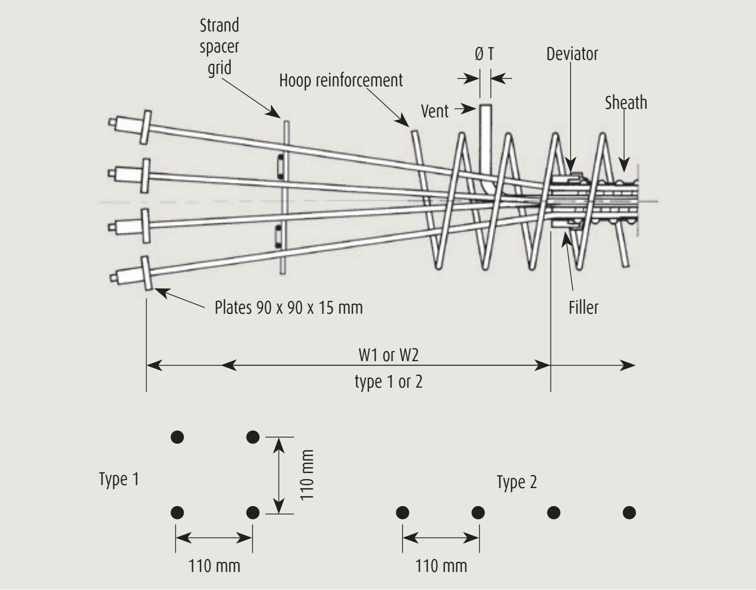
• Prelocked anchor NB 1F15



• Anchor with extruded sleeve



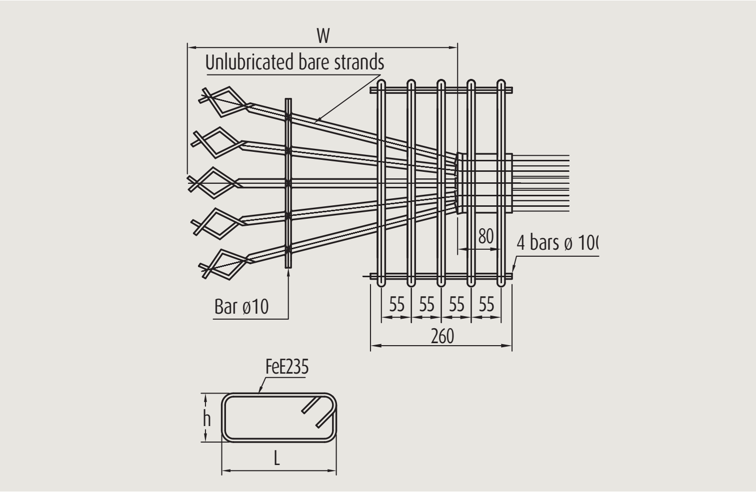
2/ Multi-strand units (3 to 5 F13/15)



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

Components common to ranges C and F

1/ Prestressing strands

The table below gives the main characteristics of the most common strands, useable with the Freyssinet prestressing system:

Characteristics of strands as per prEN10138-3

Standard	Grade MPa	Nominal diameter (mm)	Nominal reinforcement cross-section (mm²)	Nominal weight (kg/m)	Guaranteed breaking load (Fpk kN)	Elastic limit (Fp0.1 kN)
pr EN 10138-3	1,770	12.5	93	0.73	165	145
		12.9	100	0.78	177	156
		15.3	140	1.09	248	218
		15.7	150	1.18	265	234
	1,860	12.5	93	0.73	173	152
		12.9	100	0.78	186	164
		15.3	140	1.09	260	229
		15.7	150	1.18	279	246

- *Typical elongation under maximum load for all strands is ≥ 3.5%,*
- *maximum relaxation at 1,000 hours under 0.7 fpk for all strands is ≤ 2.5%.*

Characteristics of tendons made up of strands with nominal diameter 15.7mm and 0.6"

Units	Strand type						
	T 15.7 pr EN 10138-1 and 3				ASTM A-416-96 0.6 class 270		
Number of strands	Nominal cross-section (mm²)	Weight (kg/m)	Class 1770 (Fm kN)	Class 1860 (Fm kN)	Nominal cross-section (mm²)	Weight (kg/m)	Fm (kN)
1	150	1.17	265	279	140	1.102	260.7
2	300	2.34	530	558	280	2.205	521.4
3	450	3.54	795	837	420	3.306	782
4	600	4.72	1,060	1,116	560	4.41	1,043
7	1,050	8.26	1,855	1,953	980	7.71	1,825
9	1,350	10.62	2,385	2,511	1,260	9.92	2,346
12	1,800	14.16	3,180	3,348	1,680	13.22	3,128
13	1,950	15.34	3,445	3,627	1,820	14.33	3,389
19	2,850	22.42	5,035	5,301	2,660	20.94	4,953
22	3,300	25.95	5,830	6,138	3,080	24.24	5,735
25	3,750	29.50	6,625	6,975	3,500	27.55	6,518
27	4,050	31.85	7,155	7,533	3,780	29.75	7,039
31	4,650	36.58	8,215	8,649	4,340	34.16	8,082
37	5,550	43.66	9,805	10,323	5,180	40.77	9,646
55	8,250	64.9	14,575	15,345	7,700	60.61	14,339

Corrugated steel sheath

2/ Internal prestressing ducts

The following duct types are used for range C and F tendons:

Corrugated steel sheath

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 sheath (L.F.C.) can be used (see page 28).

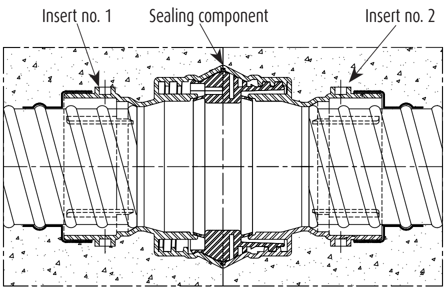
Corrugated plastic Plyduct sheath

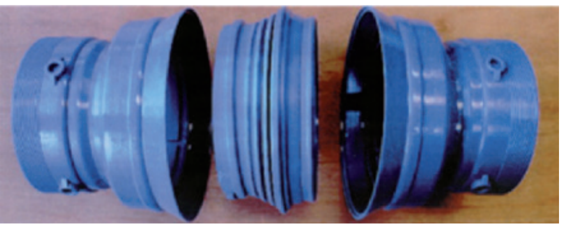
Developed and patented by Freyssinet to meet the requirements of FIB (International Federation for Structural Concrete) recommendations "Corrugated Plastic Ducts for Internal Bonded Post-Tensioning Systems" (2000) and the Concrete Society TR47 "Durable Bonded Post-tensioned Concrete Bridges", this sheath is totally air and watertight.

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

**Available on request*





Liaseal

Liaseal

Developed by Freyssinet, the Liaseal sheath 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 sheath, it allows for the creation of continuous, leaktight plastic ducts.

Steel tubes

For totally leaktight or highly deviated ducts.

Radius of curvature

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 1.1 m for T13 strands and 1.3 m for T15 strands,
- the tension does not exceed 70% of the guaranteed breaking load of the reinforcement in the area where the radius is less than three metres,
- the sum of the angular deviations along the length of the reinforcement does not exceed 3¶ /2 radians,
- the highly curved area is considered as a dead anchor when the angular deviation is greater than ¶/2 radians.

Special case

If L.F.C. 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.

Friction in the main run

For calculation of the prestressing force, the values of the coefficients of friction (μ) and wooble (k), vary depending on the uses and type of ducts, their surface treatment and the relationship $P(x)=P_{max}e^{-\mu(Ø+kx)}$.

HDPE ducts for external prestressing

Radius of curvature

Units	Minimum radius of curvature in anchors (m)	Minimum radius of curvature in deviators (m)
7C15	3.0	2.0
12C15	3.5*	2.5*
19C15	4.0*	3.0*
27C15	4.5	3.5
37C15	5.0*	4.0

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

L.F.C. sheath

3/ External prestressing ducts

Tendons injected with cement grout

- high density polethylene (HDPE) tube in zones external to the concrete. The tubes are type PE80 or PE100. Use of tubes with nominal pressure PN 6.3 is recommended.
- steel tube in anchor zones, diaphragms and deviators bushings.

Grease or wax injected tendons

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

Radius of curvature

In the absence of more stringent national requirements, the radius of curvature of the tendon in deviators, generally comprising bent steel tubing, complies with the minimum values opposite.

For greased, sheathed strands laid in ducts pre-injected with cement grout, the following should be respected:
- Isolated strands: R min ≥ 1m
- Strands grouped in bundles: R min ≥ 2.5m

Coefficient of friction

Use	Type of duct	Coefficient of friction μ(rad^{-1})		Coefficient k (rad/m)
		lubricated strand	unlubricated strand	
Bonded internal prestressing	Corrugated steel sheath	0.17	0.19	0.007
	LFC sheath	0.10	0.12	0.007
	Plyduct	0.10	0.12	0.007
	Plain 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	Plain HDPE tube	0.10	0.12	0
	Plain steel tube	0.16	0.24	0

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

4/ Injection products

Prestressing strands, if not individually sheathed and greased, are protected by injecting the duct containing them. The fill product is either cement grout, which produces a passivating layer on the surface of the steel to protect it against corrosion, or a flexible product that encloses 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.
On the basis of laboratory studies and the experience it has acquired in projects of all kinds, Freyssinet has developed a range of prestressing grouts to meet the specific conditions of every project type.

Thixotropic grout

• FREYSSIFLOW HP 215 high stability grout
These grouts are for injecting tendons with significant height variations without having to reinject thanks to their anti-bleed properties.

• FREYSSIFLOW RT 514 easy to use special long lasting grout
These grouts retain high fluidity over a long period and are thus suitable for injecting high volume tendons on sites where there are significant layout constraints such as nuclear reactor containment vaults.

• FREYSSIFLOW TX special thixotropic grout
These grouts, characterised by their high shear threshold, are especially recommended for injecting large diameter tendons which are geometrically complex. The stability of the propagation interface prevents the grout collapsing as it reaches the high points and so prevents the creation of air pockets. Using Freyssiflow TX grout means that the use of injection vents can be reduced or even eliminated.

For applications requiring low volumes of cement grout, it can be better to use a ready-to-use product, only needing the addition of water. For applications requiring high volumes of cement grout, Freyssinet can install an on-site mixer unit so that injection runs for complete families of tendons can be performed.

GENERAL PROPERTIES OF PRESTRESSING GROUTS

Property	Number of tests	Acceptance criterion	Test method
Particle size	1 test	No residue	EN 445 - Sieve
Fluidity	1 test immediately after mixing	$11s \leq t_0 \leq 20s$	EN 445 - Marsh Cone
	1 test at 15 min, 30 min, 60 min, 90 min and 120 min	$t \leq 25s$	
Temperature	1 measurement at t0, t0+30 min, t0+60 min and t0+120 min.	T ≤ 30°C	Thermometer
Bleed	3 tests	The average of the 3 measurements must not exceed 0.3% after 3hrs.	EN 445 - 1m Tube
Volumetric change	3 tests	The volumetric change must be between -1% and +5% at 1hr, 3hrs and 24hrs	EN 445 - 1m Tube
Compressive strength	3 tests	≥ 27 MPa at 7 days ≥ 30 MPa at 28 days	EN 196 - 1

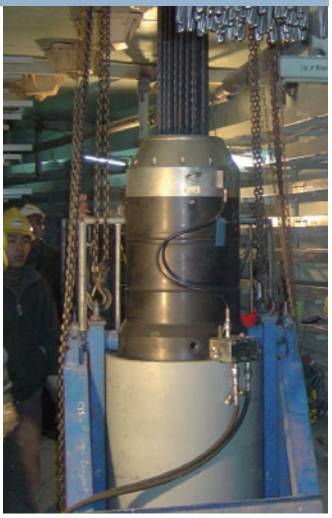
Flexible product

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

INSTALLATION

Installation of the Freyssinet system comprises the following 4 main stages:

1/ installing the ducts and trumplates;
2/ threading the strands and installing the anchors;
3/ tensioning;
4/ injection and sealing.



1/ Installing the ducts and trumplates

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

2/ 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.

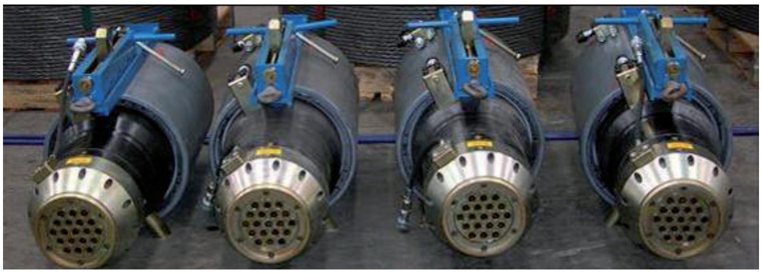
3/ Tensioning

Tendons with C and F range anchors are tensioned using single-strand or multi-strand hydraulic jacks with hyraulic locking-off of the anchor jaws. Jacks without hydraulic locking-off or single-strand jacks can be used if appropriate.

The initial force is:

• tensioning force after transfer to anchor for:
- Eurocode 2 (the lower of the two values 0.75 f_{pk} and 0.85 $f_{p0.1k}$),
- AASHTO regulations (0.7 f_{pk}),
• tensioning force before transfer to anchor for:
- Eurocode 2 and BPEL 91 regulations (the lower of the 2 values 0.8 f_{pk} and 0.9 $f_{p0.1}$)
- AASHTO regulations (0.7 f_{pk}).

The tensioning operation can only start if the on-site measured mechanical strength of the concrete, in the vicinity of the anchor zone, is greater than the value fcm,0 defined for the project.



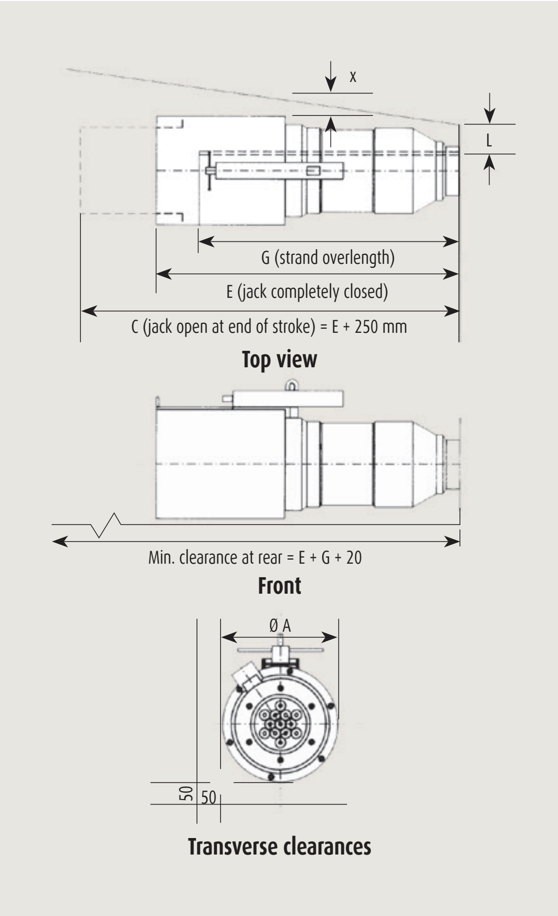
C RANGE

Type CC jacks

Type CC jacks, owing to their compactness, enable the reduction of:

· cachetages dimensions (small nose);
· distances to walls, and therefore parasitic moments;
· the concrete volume of cachetages and ribs needed at exit of span tendons;
· the possibility of increasing the offset and therefore the efficiency of the tendons.

The compactness and automation of type CC jacks facilitate handling and tensioning operations.

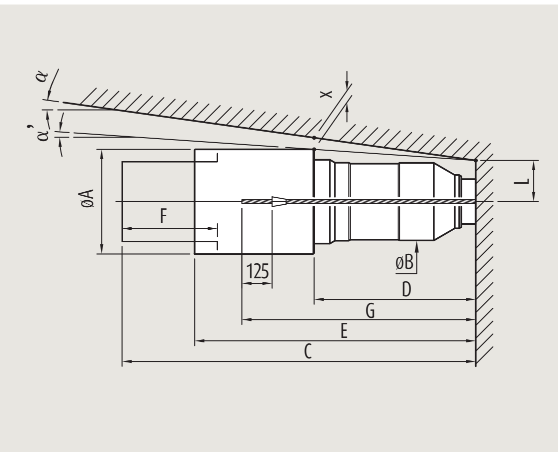


Outside dimensions of CC jacks

Jacks	Units	ØA (mm)	E (mm)	G (mm)	L (mm)	α for x ≈ 50	Stroke (mm)
CC 350	7C15	360	1,105	690	120	11°	250
	9C15		1,105	690	150	8°	
	12C15		1,115	700	150	8°	
	13C15		1,074	660	150	9°	
CC 500	7C15	438	1,085	688	120	15°	250
	9C15		1,085	688	150	13°	
	12C15		1,095	698	150	13°	
	13C15		1,100	703	150	12°	
	19C15		1,071	674	170	11°	
CC 1000	19C15	593	1,160	723	170	16°	250
	22C15		1,170	733	210	13°	
	25C15		1,175	738	210	13°	
	25C15P		1,175	738	210	13°	
	27C15		1,180	743	210	13°	
	31C15		1,146	709	210	13°	
	37C15		1,151	714	240	10°	
CC 1500	37C15	722	1,550	770	240	9°	350
	55C15		1,986	700	280	8°	

3 and 4C15 tendons are tensioned using a K100 jack (see next page).

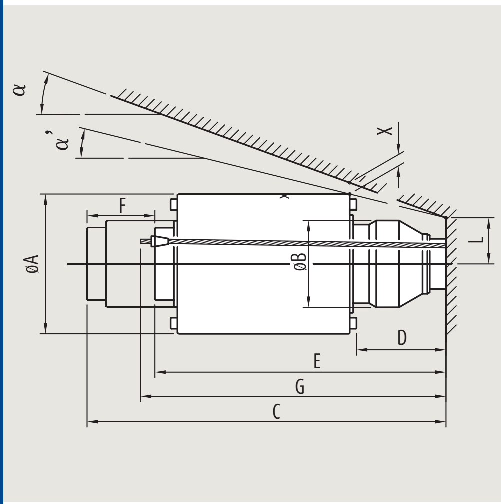
C/F range jacks



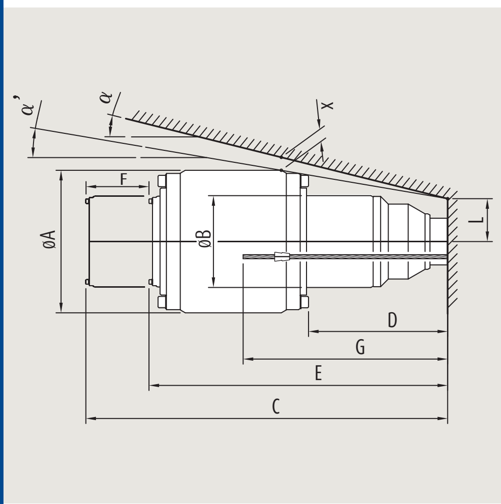
The sketch is based on a jack suspension device located in a plane perpendicular to that of the sketch.

Jacks	Units	ØA (mm)	ØB (mm)	C (mm)	D (mm)	E (mm)	F (mm)	G (mm)	L (mm)	α actual	α for x ≈ 50
C350F	7C15	355	263	1,415	731	1,165	250	1,120	120	4°30′	8°
	9C15*			1,415	731	1,165		1,120	150	2°54′	8°
	12C15*			1,115	741	1,175		1,130	150	3°50	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°
	9C15*			1,523	709	1,223		1,085	150	7°25′	13°
	12C15*			1,533	719	1,233		1,095	150	7°6′	13°
	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		1,110	170	9°	13°
	22C15*			1,593	764	1,293		1,120	210	7°4′	11°
	25C15			1,593	764	1,293		1,120		6°03′	10°
	25CC15*			1,593	764	1,293		1,120		6°01′	10°
	27C15*			1,598	769	1,298		1,125		6°01′	10°
	31C15			1,603	774	1,303		1,130		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°

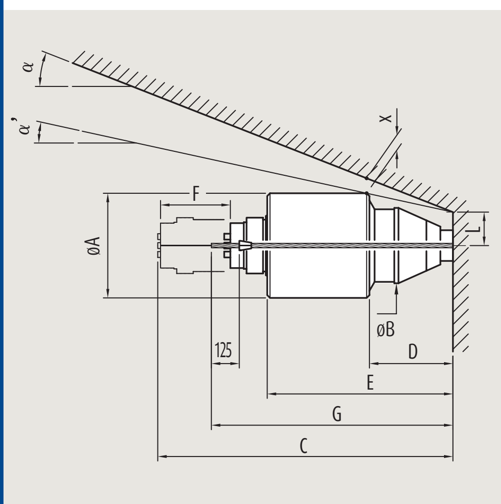
*Available on request



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



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



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

Type K/C jacks

Jacks	Units	ØA (mm)	ØB (mm)	C (mm)	D (mm)	E (mm)	F (mm)	G (mm)	L (mm)	α actual	α for x ≈ 50
K100C	3C15	290	220	913	256	713	200	820	100	9°21′	19°
	4C15			918		718					
K200C	7C15	350	263	1,154	435	954		1,060	120	6°52′	13°
K350C	9C15	440	263	1,153	324	903	250	1,005	150	9°09′	17°
	12C15			1,163	334	913		1,015	150	9°40′	16°
	13C15			1,168	339	918		1,020	150	9°33′	16°
K500C	19C15	515*	320	1,333	361	1,083		1,136	170	13°23′	21°
		508			353					13°57′	23°
	22C15	515*		1,343	349	1,093		1,146		15°59′	21°
		508			341					16°32′	23°
K700C	25C15	640*	419	1,465	420	1,215		1,320	210	12°25′	18°
	25CC15	609			454					11°45′	18°
	27C15	640*		1,465	438	1,215		1,320		11°33′	18°
		609			474					10°21′	16°
	31C15	640*		1,475	430	1,225		1,330		12°09′	18°
		609			464					11°30′	18°
K1000C		770*	492	1,548	490	1,298		1,400		15°59′	21°
		720			523					16°40′	21°
	37C15	770*	492	1,497	434	1,247		1,350	240	14°23′	20°
		720			467					15°20′	20°

*Available on request.

Type K500F jacks

Jacks	Units	ØA (mm)	ØB (mm)	C (mm)	D (mm)	E (mm)	F (mm)	G (mm)	L (mm)	α actual	α 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°

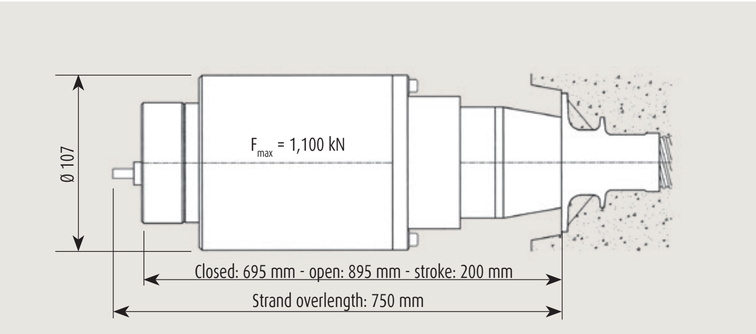
Type VP/C jacks

Jacks	Units	ØA (mm)	ØB (mm)	C (mm)	D (mm)	E (mm)	F (mm)	G (mm)	L (mm)	α actual	α 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°

F RANGE

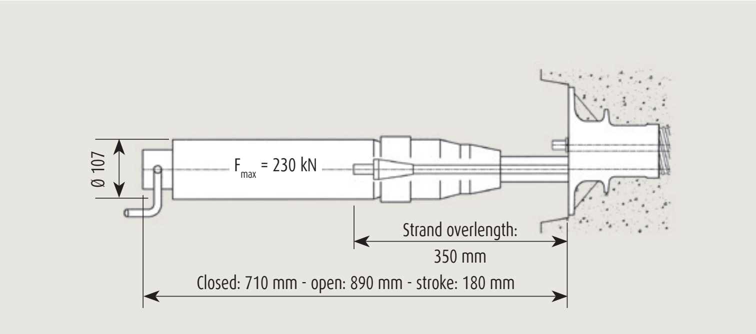
Tendons with 3F15, 4F15 and 5F15 anchors can be tensioned either by acting on the complete tendon with a K100 jack, or strand by strand with an M23 jack.

The main dimensions of these jacks are given below:

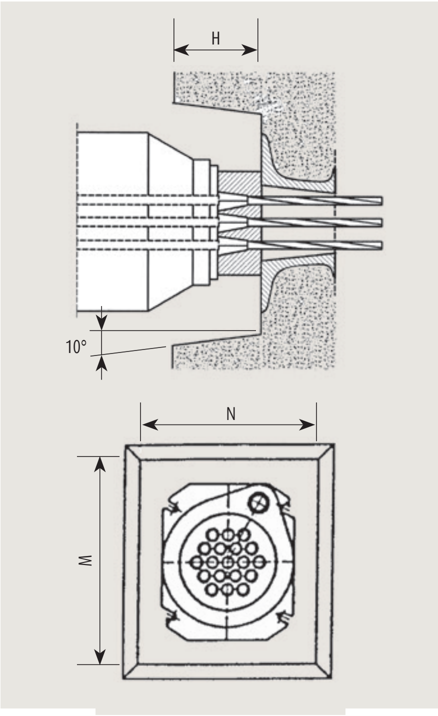


K 100

Sioule Viaduct, France



M 23



PERMANENT CACHETAGE OF ANCHORS

Units	M (mm)	N (mm)	H (mm)
3F15	200	95	50
3C15	200	170	120
4F15	240	100	50
4C15	200	180	125
5F15	280	100	50
7C15	230	210	125
9C15	275	245	125
12C15	290	260	150
13C15	300	270	150
19C15	350	310	160
22C15	380	335	170
25C15	410	360	170
25C15P	410	360	170
27C15	400	350	180
31C15	435	380	180
37C15	470	410	195
55C15	560	480	230

4/ Injection and cachetage

• 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, leaktight cover to fully protect against aggressive agents.

Formulation of cement grout in a Freyssinet laboratory

• 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 lay out, 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.

Vacuum injection

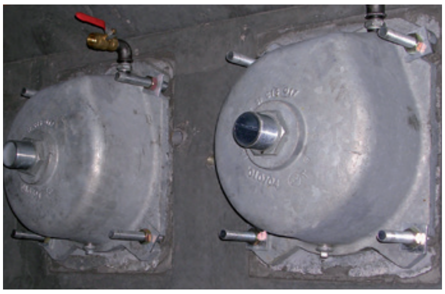
The purpose of this technique is to create a partial air vacuum in the duct before filling in order to avoid trapping air pockets. This technique is only used for leaktight ducts and is very suitable for tendons on which it is not possible to have high point vents.
In the case of deviated horizontal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

Reinjection of high points

When there is significant risk of bleed at high points of a tendon route, 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 protected sheathed strands before tensioning

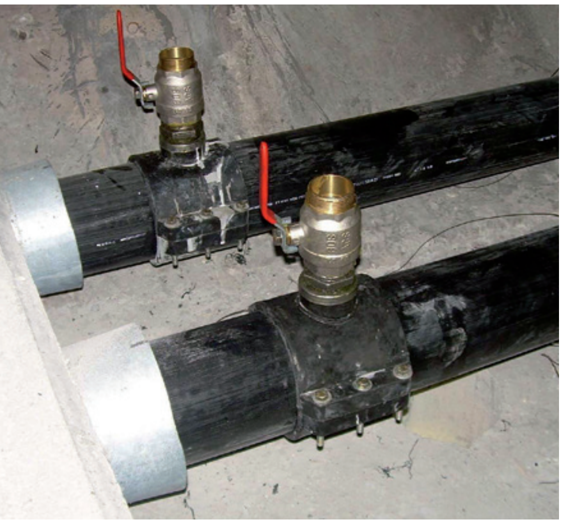
Tendons comprising protected sheathed strands within a duct must be injected with cement grout prior to tensioning. Once hardened, the grout performs the role of strand separator and prevents crushing of individual plastic sheaths where the tendon route deviates. This technique, designed and perfected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



Injection covers

To reduce hydraulic pressure losses at injection points, Freyssinet has designed sheath connectors so that the protective 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.

Plastic permanent caps



Injection inlets on HDPE pipes

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 as option) or plastic.

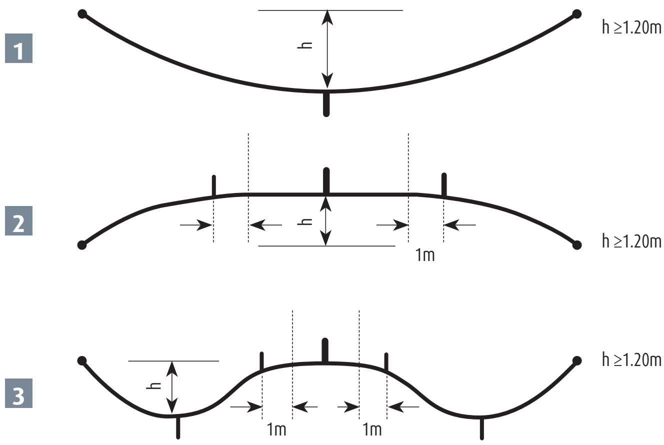
Vents and drain openings

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

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

Figure 2 For inverted U-shape parabolic routes 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 undulations 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.



For more complex routes consult Freyssinet Technical Services.

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