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European Technical Assessment

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Technical Assessment Body issuing the ETA:	Cerema Direction technique infrastructures de transport et matériaux
Trade name of the construction product	VSL AF System
Product family to which the construction product belongs	16. Reinforcing and prestressing steel for concrete (and ancillaries). Post tensioning kits.
Manufacturer	VSL INTERNATIONAL Ltd. Wankdorfallee, 5 CH-3014 Bern SWITZERLAND http://www.vsl.com/
Manufacturing plant(s)	VSL Systems Manufacturer S.L. Ribera del Congost, s/n - P. I. El Congost 08520 Les Franqueses del Vallès Barcelona SPAIN
This European Technical Assessment contains	38 pages including 3 Annexes (26 pages) which form an integral part of this assessment.
This European Technical Assessment is issued in accordance with regulation (EU) No 305/2011, on the basis of	EAD 160004-00-0301 edition September 2016

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EUROPEAN TECHNICAL ASSESSMENT –
VSL AF POST-TENSIONING SYSTEM

1 TECHNICAL DESCRIPTION OF THE PRODUCTS

This European Technical Assessment (ETA) applies to the following post-tensioning kit:

VSL AF System

The VSL AF system, defined in Annex 1, is a system for dead end anchorages that is particularly suited for vertical or close to vertical tendons without access to the dead-end anchorages.

It consists of the following components:

- Casting AF for units 6-4 to 6-31
- AF6 compression fittings
- High performance AF anchorage grout
- Tendons made out of 4 to 31 strands (using 0.6" - 7 wire strand, Ø15.3 or Ø15.7, as defined in the prEN 10138-3). As long as EN 10138 does not exist, 7 wire strands in accordance with national standards shall be used. The strands specified above are either bare strands for the system with injection or individually sheathed and protected strands (for instance as per the norm XP-A-35-037-3 or another national standard) for the system without injection.
- Ducting system:
  - Corrugated steel duct
  - Corrugated VSL PT-PLUS® polymeric duct
  - Smooth steel or HDPE pipes
  - No duct (the AF system can also be used with sheathed and protected strands without duct)
- Grouting products for the free length where applicable (cement base injection grout) for bonded tendons:
  - Grouts in accordance with EN 447
  - Products covered by an ETA

The dead-end anchorages of the AF system are used in combination with the VSL stressing-end anchorages of the types E, E-WT, CS or GC. The current length between anchorages and the stressing- end anchorages are described in the European Technical Assessment ETA 06/0006.

2 SPECIFICATIONS OF THE INTENDED USE IN ACCORDANCE WITH THE APPLICABLE EUROPEAN ASSESSMENT DOCUMENT

The VSL AF System has been designed to be used for the prestressing of structures as a dead-end anchorage. Its main field of use are the vertical tendons where the lower anchorage is embedded in the foundations of vertical or inclined structures, such as bridge piles, building cores, wind towers or confinement silos. The VSL AF System may be employed in structures made of other materials than concrete, such as steel, masonry, timber or combinations of several materials.

The tendons assembled as part of the VSL AF system may have the following basic use categories:

- Internal bonded tendon for concrete and composite structures
- Internal unbonded tendon for concrete and composite structures
- External tendon for concrete structures with a tendon path situated outside the cross section of the structure or member but inside its envelope

The VSL AF is a fixed dead-end anchorage. When it is used in combination with the adequate anchorage on the stressing end, the following optional use categories are possible:

- Restressable tendon (internal or external)
- Tendon for cryogenic applications
- Internal bonded tendon with plastic duct
- Encapsulated tendon
- Tendon for use in structural steel or composite construction as external tendon
- Tendon for use in structural masonry construction as internal and/or external tendon
- Tendon for use in structural timber as internal and/or external tendon

The use categories above can be combined for particular applications, for instance as follows:

- External tendon with grouted duct
- External tendon with soft filler and duct
- External tendon using adherent protected and sheathed strands

The tables presented in § 1.4 and § 2.2.1 of Annex 1 establish the possible categories for each of the approved anchorages.

The provisions made in the relevant European Assessment Document and in this European Technical Assessment are based on an assumed intended working life of 100 years. The indications given on the design working life of a product cannot be interpreted as a guarantee given by the producer (or the Technical Assessment Body) but are to be regarded only as a means for selecting the appropriate product in relation to the expected economically reasonable working life of the construction works.

3 PERFORMANCE OF THE PRODUCTS AND METHODS USED FOR ITS ASSESSMENT

This European Technical Assessment for the VSL AF post-tensioning system is issued on the basis of relevant data that have been deposited at Cerema, and identify the post-tensioning system that has been assessed.

Assessment of the performance of the post-tensioning system described in this document has been made in accordance with the EAD 160004-00-0301 of post-tensioning kits for the prestressing of structures, in the sense of basic requirement for construction work 1 (mechanical resistance and stability), based on the provisions for all systems.

Product type: Post–Tensioning Kit		**Intended use:** Prestressing of structures (all basic use categories)
No	**Essential characteristic** (acc. to EAD 160004-00-0301)	**Type of expression of product performance**
Basic Works Requirement 1: Mechanical resistance and stability		
1	Resistance to static load	≥95% of Actual Ultimate Tensile Strength – AUTS (acceptance criteria given in clause 2.2.1 of EAD 160004-00-0301)
2	Resistance to fatigue	No fatigue failure in anchorage and not more than 5% loss on cross section after 2 million cycles (acceptance criteria given in in clause 2.2.2 of EAD 160004-00-0301)
3	Load transfer to the structure	Stabilization of crack width under cyclic load and ultimate resistance ≥110% characteristic load (acceptance criteria given in clause 2.2.3 of EAD 160004-00-0301)
7	Assessment of assembly	Installation of strands, duct filling (acceptance criteria given in clause 2.2.7 of EAD 160004-00-0301)
8	Resistance to static load under cryogenic conditions for applications with anchorage/coupling outside the possible cryogenic zone	≥95% of Actual Ultimate Tensile Strength – AUTS (acceptance criteria given in clause 2.2.8 of EAD 160004-00-0301)
9	Resistance to static load under cryogenic conditions for applications with anchorage/coupling inside the possible cryogenic zone	≥95% of Actual Ultimate Tensile Strength – AUTS (acceptance criteria given in clause 2.2.9 of EAD 160004-00-0301)

4 ASSESSMENT AND VERIFICATION OF CONSTANCY OF PERFORMANCE SYSTEM APPLIED, WITH REFERENCE TO ITS LEGAL BASE

The components of the VSL AF System comply with the drawings and conditions described in Annex 1 of this European Technical Assessment. More detailed information related to confidential specifications (e.g.: materials, processing, surface, dimensions, tolerances, manufacturing methods and control procedures) are included in the Technical Evaluation file concerning this European Technical Assessment, which has been deposited at Cerema. This set of information is also to be sent, whenever necessary, to the Notified Body responsible for the Assessment and Verification of the Constancy of Performances (AVCP).

In accordance with the decision 98/456/EC[1] of the European Commission, the system 1+ of assessment and verification of constancy of performances (see Annex V to Regulation (EU) No 305/2011), given in the following table applies:

Product(s)	Intended use(s)	Level(s) or class(es)	System(s)
Post-tensioning Kits	For the prestressing of structures	-	1+

The AVCP system 1+ includes the following:

(a) Tasks of the Manufacturer
 (1) Factory Production Control (FPC)
 (2) Further testing of samples taken at the factory by the manufacturer in accordance with a prescribed test plan

(b) Tasks for the Notified Body
 (3) Determination of the product-type on the basis of type testing (including sampling), type calculation, tabulated values or descriptive documentation of the product
 (4) Initial inspection of factory and of factory production control
 (5) Continuous surveillance, assessment and approval of factory production control
 (6) Audit testing of samples taken at the factory

A set of specific tests were carried out as stated in EAD 160004-00-0301 for the following optional use category: cryogenic application.

The methods for verifying, evaluating and assessing suitability and test procedures comply with those detailed in the EAD 160004-00-0301.

[1] Official Journal of the European communities L201/112 of 3 July 1998

5 TECHNICAL DETAILS NECESSARY FOR THE IMPLEMENTATION OF THE AVCP SYSTEM, AS FORESEEN IN THE APPLICABLE EAD

5.1 TASKS FOR THE MANUFACTURER

5.1.1 General responsibilities of the Manufacturer

The Manufacturer is responsible for the production and quality of components manufactured or ordered.

The Manufacturer shall keep available an updated list of all Component Manufacturers. This list shall be submitted to the Notified Body and the Technical Assessment Body.

Each Component Manufacturer shall be audited by the manufacturer at least once per year. Each audit report shall be made available to the Notified Body.

These audit reports include:

- Identification of the Component Manufacturer
- Date of audit of the Component Manufacturer
- Summary of the results and records of the FPC since last audit
- Summary of the complaint records
- Evaluation of the Component Manufacturer concerning FPC
- Specific remarks as relevant
- Results of controls and tests and comparison with the requirements
- Name and position of signatory
- Date of signature
- Signature.

At least once a year specimens are taken by the Manufacturer from the Manufacturing Plant. One series of single tensile element tests shall be performed according to Annex 2 of this ETA (Annex C.7 of EAD 160004-00-0301) by the Manufacturer with these specimens. The results of these test series are made available to the Notified Body. These reports include:

- Identification of the plant where the components have been taken
- Date of sampling
- Identification of the components (i. e. anchorage, strand, etc.)
- Place and date of testing
- Summary of the results including a test report
- Specific remarks as relevant
- Name and position of signatory
- Date of signature
- Signature

The Manufacturer makes available for at least 10 years all records of relevant results concerning the ETA and the audit reports concerning the components manufacturers.

5.1.2 Factory Production Control (FPC)

The Manufacturing Plant or the designated factory (formerly designated as Kit Manufacturer) exercises permanent internal control of the production. All the elements, requirements and provisions adopted by the Manufacturer are documented in a systematic manner in the form of written policies and procedures. This control system ensures that the PT System is in conformity with this European Technical Assessment.

The Factory Production Control is in accordance with the Quality Manual of the Manufacturer which is part of the technical documentation that has been submitted to the Technical Assessment Body.

The FPC complies with the Table 3 of EAD 160004-00-0301. The results of the FPC are recorded and evaluated in accordance with the provisions of the Prescribed Test Plan presented in Annex 2 of this ETA.

Parts of the FPC may be transferred to an independent test laboratory. Nevertheless, the Manufacturer has the full responsibility for all results of the FPC.

5.1.3 Other tasks

5.1.3.1 Control of the PT System components and materials

The characteristics of incoming materials which comply with a harmonized European technical specification are considered satisfactory and need, except in case of justified doubt, no further checking. All materials shall be in accordance with the requirements of the ETA and the specifications of the Manufacturer.

Where harmonised technical specifications are not available, materials according to specifications valid in the place of use may be adopted provided that their use is compatible with the results of approval tests. Otherwise, the specifications are given in this ETA.

5.1.3.2 Inspection and testing

The validity of the type and frequency of checks / testing conducted during production and on the final product has to be considered as a function of the production process. This includes verification conducted during production, on properties that cannot be inspected at a later stage and verification on the final product. These include:

- Definition of the number of samples taken by the Manufacturing Plant
- Material properties (tensile strength, hardness, surface finish, chemical composition, etc.)
- Determination of the dimensions of components
- Check correct assembly
- Documentation of tests and test results.

All tests are performed according to written procedures with suitable calibrated measuring devices. All test results are recorded in a consequent and systematic way.

The prescribed test plan relative to the PT System (see Annex 3) complies with the requirements of the Table 3 of EAD 160004-00-0301, including the minimum test frequencies to perform.

5.1.3.3 Control of non-conforming products

Products which are considered as non-conforming with the ETA are immediately marked and separated from the complying products. The prescribed test plan addresses control of non-conforming products.

5.1.3.4 Complaints

The quality management system of the Manufacturer includes provisions to keep records of all complaints about the PT System.

5.2 TASKS OF THE NOTIFIED BODY

5.2.1 General responsibilities of the Notified Body

The Notified Body (NB) shall perform the following tasks in accordance with the provisions laid down in the "Control Plan" relating to this European Technical Assessment:

- Initial type testing
- Initial inspection of factory and of factory production control
- Continuous surveillance, assessment and approval of factory production control
- Audit testing of samples taken at the factory

The Notified Body is responsible for the Assessment and Verification of the Constancy of Performances (AVCP) of the Manufacturer. The Notified Body shall issue an AVCP certificate of the product stating the conformity with the provisions of this European Technical Assessment.

In case the provisions of the European Technical Assessment and its “Control Plan” are no longer fulfilled the Notified Body shall withdraw the AVCP certificate and inform Cerema without delay.

The Notified Body may act with its own resources or subcontract inspection tasks and testing tasks to inspection bodies and testing laboratories.

5.2.1.1 Initial type testing

The results of the tests performed during the assessment procedure and then assessed by the Technical Assessment Body may be used by the Notified Body as initial type testing.

5.2.1.2 Initial assessment of factory and of factory production control

The Notified Body assesses both the factory capacities and the factory production control performed by the Manufacturing Plant in order to ensure that, in compliance with the prescribed test plan, the manufacturing resources and FPC are able to guarantee continuous and consistent manufacturing of PT System components in accordance with ETA specifications. These tasks shall comply with the prescribed test plan and with the conditions described under the “Initial inspection of the manufacturing plant and of the factory production control” part in Table 4 of EAD 160004-00-0301.

5.2.1.3 Continuous surveillance, assessment and approval of factory production control

The Notified Body shall perform surveillance inspections, Components Manufacturers inspections and sample extractions either in the plants or on the job sites for the purpose of conducting independent tests under its responsibility. These tasks shall comply with the prescribed test plan and with the conditions described under the "Continuous surveillance, assessment and evaluation of factory production control" part in Table 4 of EAD 160004-00-0301.

The Manufacturing Plant shall be audited at least once a year by the Notified Body. Each Component Manufacturer shall be checked at least once every five years by the notified body. At the issue of these audits, the Notified Body shall make available a written report.

The Notified Body shall provide to Cerema, upon request, the results of certification and continuous surveillance. In cases of serious non conformities, related to important aspects of the performances of the post-tensioning system, which cannot be corrected within the deadlines, the Notified Body shall withdraw the certification of AVCP and inform Cerema without delay.

5.2.1.4 Audit testing of samples taken at the factory

During surveillance inspection, the Notified Body shall take samples at the factory for independent testing of components of the PT system included in this European technical assessment. For the most important components the Annex 2 of this ETA., summarises the minimum procedures. These tasks shall comply with the "Audit-testing of samples taken by the notified product certification body at the manufacturing plant or at the manufacturer's storage facilities" part in Table 4 of EAD 160004-00-0301.

At least once a year specimens are taken by the Manufacturer from the Manufacturing Plant. One series of single tensile element tests shall be performed according to Annex 2 of this ETA (Annex C.7 of EAD 160004-00-0301) by the Notified Body with these specimens. The relevant reports include:

- Identification of the plant where the components have been taken
- Date of sampling
- Identification of the components (i. e. anchorage, strand, etc.)
- Place and date of testing
- Summary of the results including a test report
- Specific remarks as relevant
- Name and position of signatory
- Date of signature
- Signature

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By
Centre d'étude et d'expertise sur les risques, l'environnement, la mobilité et l'aménagement
Direction technique Infrastructures de transport et matériaux

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ANNEX 1 TECHNICAL DATA OF THE VSL AF SYSTEM

1 DEFINITION OF THE SYSTEM

1.1 PRINCIPLE OF THE VSL AF SYSTEM

The VSL AF anchorage is a dead end anchorage particularly suited for vertical or inclined tendons without access to the dead-end anchorage.

It consists of a cast iron anchorage which forms the dead end, and which transfers the tendon load over flanges and ribs by load bearing to the structural concrete, similarly to other traditional PT anchorages.

The prestressing strands are anchored inside the AF Anchorage by bond of the strand and direct bearing of the compression fittings which are extruded onto each individual strand end and encased before stressing into a high performance grout. The load is transferred from the high strength grout cone through geometrical interlocking inside the cast iron anchorage body. The interlocking is achieved by a draw-in of the grout cone into the anchorage

The constituting strands are those defined in the European standard "prEN 10138-3: Prestressing steels - Part 3: Strand". They refer to 7-wire strands with nominal diameters of ∅ 15.3 and ∅ 15.7 mm (f_{pk} = 1860 N/mm^2 or f_{pk} = 1770 N/mm^2), which are identical to those used with the VSL Multistrand system. As long as EN 10138 does not exist, 7-wire strands in accordance with national standards shall be used.

By varying both the strand diameter and number (and, if applicable, their specified characteristic tensile strength), it is possible to obtain a value for the characteristic tensile strength per tendon that varies between 1040 kN and 8649 kN.

The strands are stressed on the anchorage at the opposite (stressing) end. For more detail refer to the relevant chapter of the European Technical Assessment ETA 06/0006.

1.2 CHARACTERISTICS OF THE SYSTEM UNITS

On the basis of the strand characteristics defined in draft Standard "pr EN 10138-3: Prestressing steels - Part 3: Strand" and the values of tendon cross-sections A_p, the maximum forces recommended by EN 1992-1-1 are:

$$P_{max} = \min\{k_1.A_p.f_{pk};\ k_2.A_p.f_{p0.1k}\},\ \text{with}\ k_1 = 0.8,\ k_2 = 0.9$$
$$P_{m0,max} = \min\{k_7.A_p.f_{pk};\ k_8.A_p.f_{p0.1k}\},\ \text{with}\ k_7 = 0.75,\ k_8 = 0.85$$

Where P_{max} is the the maximum force applied to a tendon and $P_{m0,max}$ is the maximum value of the initial prestress force applied to the concrete immediately after tensioning and anchoring.
Taking , $f_{p0.1k} = 0.88\ f_{pk}$ the forces for the VSL PT system units are as follows:

STRAND GRADE		Y1770 S7-15.7 f_{pk} = 1 770 N/mm² F_{pk} = 266 kN; $F_{p0.1k}$ = 234 kN			Y1860 S7-15.3 f_{pk} = 1 860 N/mm² F_{pk} = 260 kN; $F_{p0.1k}$ = 229 kN			Y1860 S7-15.7 f_{pk} = 1 860 N/mm² F_{pk} = 279 kN; $F_{p0.1k}$ = 246 kN		
Anchorage Type	Tendon Unit	A_p	P_{max}	$P_{m0,max}$	A_p	P_{max}	$P_{m0,max}$	A_p	P_{max}	$P_{m0,max}$
		mm²	kN	kN	mm²	kN	kN	mm²	kN	kN
6-4	6- 4	600	841,1	794,4	560	824,9	779,1	600	883,9	834,8
	6- 5	750	1 051,4	993,0	700	1 031,2	973,9	750	1 104,8	1 043,5
	6- 6	900	1 261,7	1 191,6	840	1 237,4	1 168,7	900	1 325,8	1 252,2
6-7	6- 7	1 050	1 471,9	1 390,2	980	1 443,7	1 363,5	1050	1 546,8	1 460,8
	6- 8	1 200	1 682,2	1 588,8	1120	1 649,9	1 558,2	1200	1 767,7	1 669,5
	6- 9	1 350	1 892,5	1 787,3	1260	1 856,1	1 753,0	1350	1 988,7	1 878,2
	6-10	1 500	2 102,8	1 985,9	1400	2 062,4	1 947,8	1500	2 209,7	2 086,9
	6-11	1 650	2 313,0	2 184,5	1540	2 268,6	2 142,6	1650	2 430,6	2 295,6
6-12	6-12	1 800	2 523,3	2 383,1	1680	2 474,8	2 337,4	1800	2 651,6	2 504,3
	6-13	1 950	2 733,6	2 581,7	1820	2 681,1	2 532,1	1950	2 872,6	2 713,0
	6-14	2 100	2 943,9	2 780,3	1960	2 887,3	2 726,9	2100	3 093,6	2 921,7
6-15	6-15	2 250	3 154,1	2 978,9	2100	3 093,6	2 921,7	2250	3 314,5	3 130,4
	6-16	2 400	3 364,4	3 177,5	2240	3 299,8	3 116,5	2400	3 535,5	3 339,1
	6-17	2 550	3 574,7	3 376,1	2380	3 506,0	3 311,2	2550	3 756,5	3 547,8
	6-18	2 700	3 785,0	3 574,7	2520	3 712,3	3 506,0	2700	3 977,4	3 756,5
6-19	6-19	2 850	3 995,2	3 773,3	2660	3 918,5	3 700,8	2850	4 198,4	3 965,1
	6-20	3 000	4 205,5	3 971,9	2800	4 124,7	3 895,6	3000	4 419,4	4 173,8
	6-21	3 150	4 415,8	4 170,5	2940	4 331,0	4 090,4	3150	4 640,3	4 382,5
6-22	6-22	3 300	4 626,1	4 369,1	3080	4 537,2	4 285,1	3300	4 861,3	4 591,2
	6-23	3 450	4 836,3	4 567,7	3220	4 743,4	4 479,9	3450	5 082,3	4 799,9
	6-24	3 600	5 046,6	4 766,3	3360	4 949,7	4 674,7	3600,0	5 303,2	5 008,6
	6-25	3 750	5 256,9	4 964,9	3500	5 155,9	4 869,5	3750,0	5 524,2	5 217,3
	6-26	3 900	5 467,2	5 163,4	3640	5 362,2	5 064,3	3900,0	5 745,2	5 426,0
6-27	6-27	4 050	5 677,5	5 362,0	3780	5 568,4	5 259,0	4050,0	5 966,1	5 634,7
	6-28	4 200	5 887,7	5 560,6	3920	5 774,6	5 453,8	4200,0	6 187,1	5 843,4
	6-29	4 350	6 098,0	5 759,2	4060	5 980,9	5 648,6	4350,0	6 408,1	6 052,1
	6-30	4 500	6 308,3	5 957,8	4200	6 187,1	5 843,4	4500,0	6 629,0	6 260,8
6-31	6-31	4 650	6 518,6	6 156,4	4340	6 393,3	6 038,2	4650,0	6 850,0	6 469,5
Note: Prestressing force applied to structure must be in accordance with national regulations.										

Temporary overstressing is permitted in accordance with the requirements of EN 1992-1-1 to a maximum force of $k_3.A_p.f_{p0.1k}$, with $k_3 = 0.95$.

P_{max} and $P_{m0,max}$ can be increased in acc. with section 4 of EN 1992-1-1 if the actual values of the strand are $f_{p0.1k} / f_{pk} > 0.88$.

The system can be used with strands with lower characteristic tensile strength or diameter (i.e. with strands with f_{pk} = 1770 N/mm^2 or ∅15.2). The provisions for tendons with strands with a characteristic tensile strength f_{pk} = 1860 N/mm^2 also apply to tendons with strands with f_{pk} < 1860 N/mm^2.

The standard prEN 10138-3 gives the following nominal values for the other useful characteristics of prestressing strands composing the VSL AF system units:

- Elongation at maximal force: ≥ 3.5%
- Relaxation at 0.70 f_{pk} after 1 000 hours: ≤ 2.5%
- Relaxation at 0.80 f_{pk} after 1 000 hours: ≤ 4.5%
- Fatigue behaviour (0.70 f_{pk}; 190 N/mm^2): ≥ 2x10^6 cycles
- Maximum *D* value of deflected tensile test: ≤ 28%
- Modulus of elasticity E_p: 195 000 N/mm^2

The actual modulus of elasticity of the strand, measured by the supplier and communicated at the time of its supply, shall be taken into account for calculation of the cable elongations. Individually sheathed and protected strands have the same mechanical properties as listed above for bare strands.

1.3 ANCHORAGES

1.3.1 Presentation of the anchorages

1.3.1.1 Active anchorages

The active anchorages (also known as live-end anchorages) are used on the stressing end in combination with the AF passive anchorages and need to be compliant with ETA 06/0006. A more detailed description of the anchorages type E, E-WT, CS and GC can be found in the European Technical Assessment ETA 06/0006.

The stressing of tendons is conducted with VSL stressing jacks, which are presented in § 4 Stressing. Other models of jacks could be used if they are approved by VSL.

1.3.1.2 Passive anchorages

The AF anchorage is a passive mechanical anchorage that is used on the dead-end. It is described in chapter § 1.1 Principle of the VSL AF System.

More details are presented in § 3 Anchorages.

1.3.2 List of approved anchorages

The set of approved anchorages that allow creating all of the intermediate prestressing units is as follows:

Unit	Active end			Passive end
	E /E-WT	CS	GC	AF
6-4	✓		✓	✓
6-7	✓	✓	✓	✓
6-12	✓	✓	✓	✓
6-15	✓		✓	✓
6-19	✓	✓	✓	✓
6-22	✓	✓	✓	✓
6-27	✓	✓	✓	✓
6-31	✓	✓	✓	✓

Note: Refer to the European Technical Assessment ETA 06/0006 for details of the active end anchorages that are used in combination with the AF anchorages described in this European Technical Assessment

1.4 USE CATEGORIES, OPTIONS AND POSSIBILITIES

1.4.1 Uses categories of the AF system

The AF anchorages are entirely internal and fully embedded in the concrete structure. They can be used with two types of tendons:

- **Bonded**, i.e. with "bare" strands placed inside a duct filled with a permanent grout, providing bonding to the structure
- **Unbonded**, i.e. with sheathed and protected strands, unbonded to the structure

The tendons that include AF anchorages on their dead-end may have the following basic use categories as per EAD 160004-00-0301:

- Restressable tendon (internal or external)
- Cryogenic applications
- Internal bonded tendon with plastic duct
- Encapsulated tendon
- Tendon for use in structural steel or composite construction as external tendon
- Tendon for use in structural masonry construction as internal and/or external tendon
- Tendon for use in structural timber as internal and/or external tendon

The use categories above can be combined for particular applications, for instance as follows:

- External tendon with grouted duct
- External tendon with soft filler and duct
- External tendon using adherent protected and sheathed strands

Detail of unit or cable components can be found in the following chapters of this ETA:

- For strands and ducts see § 2 Strand and duct
- For anchorages see § 3 Anchorages
- For injection see § 5 Injection and Sealing

1.4.2 Possibilities of the AF system

The anchorages may be stressed in partial stages. Overstressing with shims or adjustment with ring nut are also possible. De-stressing procedure is only possible if the required strand over-length has been conserved on the stressing end and the strand remains independent of the structure (unbonded).

For more detail, refer to the relevant chapter of the European Technical Assessment ETA 06/0006 on partial stressing of stressing end anchorages.

2 STRANDS AND DUCTS

2.1 STRAND

The high-strength prestressing steel (strands) composing the tendons are labelled "Y1860S7 – No. 1.1366" and are defined in the standard "prEN 10138-3: Prestressing steels - Part 3: Strand ". Strands labelled "Y1770S7 – No. 1.1365" may also be employed. The main characteristics have been summarized in § 1.2 Characteristics of the system units.

Individually greased and sheathed monostrands can be used for unbonded tendons, either internal or external to concrete or other materials. They are compliant with EAD 160004-00-0301, which specifies the requirements, verification methods and acceptance criteria of both the grease and the sheathing. Adherent protected sheathed strands complying with XP-A35-037-3 can also be used for unbonded tendons, either internal or external to concrete or other materials.

2.2 DUCTS

2.2.1 Type and dimensions of usable ducts

The AF system can use several types of duct as mentioned in this section. Duct type selection depends on the specific project, the final use designed for the structure and the options selected for the post-tensioning units.

From a general standpoint, the ducts used must be mechanically resistant, have continuity in shape, ensure continuity of the seal over their entire length, as well as comply with the project's bond requirements without causing any chemical attack to the prestressing steel.

The ducts of the following table have frequently demonstrated their capacities in the uses and applications cited above:

APPLICATIONS \ DUCTS			Metal Ducts		Polymeric Ducts	
			Corrugated metal duct	**Smooth metal duct**	**VSL PT-PLUS® Duct**	**Smooth polymeric duct polyethylene, polypropylene**
Internal Cable, in the concrete	with bonded injection	standard	✓	NR	✓	NR
		cryogenic	✓	NR	✓	NR
		encapsulated	NA	NR	✓ (0)	NR
	with unbonded injection (2)	standard + encapsulated	NA	✓	NR	✓
		restressable	NA	✓	NR	✓
External Cable, out of the concrete (or other material)	with bonded injection	standard + encapsulated	NA	✓ (1)	NR	✓
	with unbonded injection (2)	standard + encapsulated	NA	✓ (1)	NR	✓
		restressable	NA	✓ (1)	NR	✓

For the other materials such as steel, masonry,timber, etc. adaptations may be necessary.

NOTES:

(0) This set-up corresponds to a fully-bonded cable.

(1) Smooth ducts in polyethylene or polypropylene are the most common.

(2) Strands are defined in chap. 2.1. They can be bare strands with unbonded injection of duct or sheathed and protected sliding monostrands with a bonded grout of the duct.

✓: Advised ~: Possible NR: not recommended NA: not allowed

Corrugated steel duct or VSL PT-PLUS® corrugated polymeric duct can be used. The wall thickness shall be chosen to comply with the construction method and the concrete pressure expected on site.

Duct diameters for the type AF anchorage are indicated in § 6.3 Anchorage AF – Main dimensions. Please note that the duct diameters are oversized to facilitate insertion of strands fitted with compression fittings.

2.2.2 Metal ducts

The tendons are most often separated from the concrete by means of corrugated steel strip sheaths. They comply with EN 523 and, according to this standard, they can be Category 1 (normal sheaths) or Category 2 (rigid sheaths).

Junctions between coils or straight segments are made by a connection piece that is threaded on the two extremities to be connected. The sealing at the joints is done by adhesive tape or heat-shrinkable sleeves.

In certain applications (e.g. nuclear, offshore), the tendons are encased in smooth steel ducts. The most frequently-employed tubes, whether welded or not, are thin (in compliance with the EN standards) and machine-bendable. The segments are connected usually by flaring one end and clamping the other. The seal is obtained by welding, heat-shrinkable sleeves or adhesive tape.

2.2.3 Polymeric ducts

In the case of stringent requirements for corrosion protection and fatigue performance, it is recommended to use the corrugated polymeric duct VSL PT-PLUS®. This duct may only be used inside the concrete and filled with grout to generate bond between the tendons and the structure. It is recommended for applications in particularly-aggressive environment or under strong fatigue loads.

The VSL PT-PLUS® duct complies with EAD 160004-00-0301 and is included in the European Technical Assessment ETA 06/0006.

2.2.4 Accessories for inlet, outlet and bleed vents

When the prestressed structure is made out of prefabricated elements, it is very important to ensure the continuity of ducts at the junction of two elements. Specially designed segmental couplers are used for that purpose.

In order to provide permanent protection of the tendons, the grout injection has to fill completely the ducts. For this purpose inlets, vents and outlets are installed on the ducts alongside the duct path. The position and design of these elements has to be carefully defined in the project. The following options are available:

Duct	**Duct connection accessory**	**Inlet, venting, bleeding or outlet accessory**
Corrugated steel strip sheath	Sealed strip/polymeric shell	Polymeric pipe
Smooth steel tube	Welded pipes	Steel tube or polymeric pipe
VSL PT-PLUS® duct	Special "clipped" collar / coupler	Polymeric pipe
Polymeric duct	Electro-weldable collar or welded pipes	Polymeric pipe

2.2.5 Connection to anchorage

The sealing between the ends of duct and trumpet is carried out using adhesive tape or a heat shrinkable sleeve.

2.3 CABLE LAYOUT

The cable layout is defined by the project.

2.3.1 Straight length behind the anchorages

The deviation of the strands is obtained inside the AF cast anchorage. It is not necessary to provide a straight length in order to obtain an adequate performance of the anchorage. For installation, however, it may be necessary, in some cases, to provide a smooth transitions behind the anchorage as agreed with VSL.

2.3.2 Radius of curvature

For minimum radius of curvature, refer to the relevant chapter of the European Technical Assessment ETA 06/0006.

2.3.3 Spacing of the supports and tolerances

The fastening fittings shall be sufficiently robust and spaced close enough such that the ducts with tendons cannot be displaced in excess of the allowed tolerances. The tolerances on cable positions in the concrete elements must comply with the requirements of the standard EN 13670.

Transverse fixation elements can be used to avoid undesired movements of external tendons.

The designer shall consider the deviation forces and define the local reinforcement accordingly, in particular whenever a cable deviates deviate in the vicinity of an edge of concrete leading to potential spalling of the concrete cover.

2.3.4 Strand cut length

Since the tendon is usually fastened to the post-tensioned structure, the strand cut length will be the length of the pre-stressed element plus the necessary overlength to install the stressing jack. Refer to the relevant chapter of ETA 06/0006 for more details.

2.4 INSTALLATION OF ANCHORAGES, DUCTS AND STRANDS

The method for tendon installation shall be adapted to the project. It includes usually the following main steps:

- First, the dead-end anchorage type AF is placed inside the formwork and secured (see § 3.3 Installation of the AF anchorages for details.
- A duct is connected to the anchorage. This duct will be extended according to the progress of construction.
- At the other tendon end, a stressing anchorage type GC, E, E-WT or GC is placed without its anchor head.
- The lower extremity of each strand is prepared and fitted with an AF compression fitting. They are marked with paint to ensure equal positioning after threading
- The strands can then be installed by pushing strands individually from the stressing anchorage, through the duct, into the dead-end.
- The anchor head of the anchorage is threaded over the strand ends at the active anchorage and the wedges are inserted.
- Once all the strands are installed and their position is confirmed, the AF anchorage can be filled with the high performance AF anchorage grout. The volume of the AF anchorage grout, the injection process and the compressive strength are carefully monitored.
- Once the required strength of the AF anchorage grout is achieved, the tendon can be stressed to the specified load and anchored at the stressing end. When tendon force and elongation are approved by the engineer, the tendon tails can be cut and the tendon can be grouted over the entire length as for other anchorage/tendon types

2.5 PROVISIONAL PROTECTION AND LUBRICATION

In the **bonded** system, oiling or greasing of tendons shall be done exclusively with approved products in order to provide:

- Provisional protection against corrosion until the tendons are grouted
- Additional lubrication to diminish the friction losses during stressing

In these cases, this will be achieved by a factory applied product that provides an adequate level of corrosion protection and present a good bond behaviour. The strands shall be cleaned inside the AF anchorage to obtain bond with the high performance AF grout. However, the product shall not be removed on the free length of the tendon before cement grouting.

With this same objective, other products serving to reduce friction may be used, as long as they are recognized as non-dangerous, can be easily applied and remain inert in the presence of permanent protection (and the eventual rigid bond to the structure).

2.6 CALCULATION ELEMENTS

2.6.1 Friction losses

The friction of strands in their ducts creates a loss of force along the cable path. The force at a distance x of the anchorage is given by:

$$F_{p0}(x) = F_{p0}(0) \cdot e^{-\mu(\theta + k\,x)}$$

Where:

x	distance to the stressing end
$F_{p0}(0)$	prestressing force on the stressing end (x=0)
$F_{p0}(x)$	tension in the cable at the abscissa x
μ	coefficient of friction (over the curve) between the strands and the duct
θ	the sum of the angular deviations of the cable over the distance x
k	the unintentional angular deviation (wobble coefficient) affecting the cable path

It is recommended to adopt the numerical values of μ and *k* prescribed in *Eurocode 2* which can be summarized as follows:

Application	**μ (rad^{-1}) (1)**		***k* (rad/m) (2)**	
	Range	**Recommended value**	**Range**	**Recommended value**
Internal bonded tendon with corrugated steel strip sheath (bare strand)	0.16-0.22	0.18	0.004-0.008	0.005
Internal bonded tendon with smooth steel tube	0.16-0.24	0.20	0.005-0.010	0.007
Internal bonded tendon with VSL PT-PLUS duct (bare strand)	0.10-0.15	0.12	0.004-0.010	0.005
External tendon with smooth steel tube	0.16-0.24	0.20	0	0
External tendon with polymeric duct	0.10-0.14	0.12	0	0
Internal unbonded tendon with individually greased and sheathed strands	0.04-0.07	0.05	0.004–0.006	0.005
External tendon with individually greased and sheathed strands	0.04-0.07	0.05	0	0
External tendon with individually sheathed and protected adherent strands	0.05-0.10	0.08	0	0

(1) The interval limit values encompass both lubricated and non-lubricated strands.
(2) The values of *k* are zero for cables outside the concrete.

2.6.2 Basis for evaluating elongations

Taking the stress $f_{p0}(x) = \frac{F_{p0}(x)}{\text{Nominal steel cross-section of the tendon}}$ the elongation is calculated as follows:

$$\Delta l = \underbrace{\int_{-Lj}^{o} \frac{f_{po}(x)}{E_p} dx}_{\text{Elongation in the stressing jack}} + \underbrace{\int_{o}^{La} \frac{f_{po}(x)}{E_p} dx}_{\text{Elongation in the prestressed element}} + \underbrace{\int_{o}^{La} \frac{f_b(x)}{E_b} dx}_{\text{Concrete shortening of the prestressed element}} + \underbrace{g'}_{\text{Eventual displacement of the dead end of the tendon}}$$

The total elongation of the tendon is the sum of four terms:

- Elongation in the stressing jack, where:
  - L_j: length of the strands in the stressing jack.
  - $f_{po}(x) \sim (1 + k_a).\ f_{po,o}$ = constant
    - $f_{po,o}$: stress in the strands upon stressing at x = 0,
    - k_a: friction loss in the anchorage, which may be neglected for this purpose
- Elongation in the prestressed element:
  - L_a: length of the tendon or the prestressed element
- Concrete shortening of the prestressed element:
  - negligible in the majority of cases (except if stresses in the concrete resulting from prestressing are high)
- Movement of dead-end of the tendon:
  - in the case where the cable is terminated on its dead end by an AF anchorage, the value of the draw-in of the cone of high performance AF grout depends on various factors. Usual values are in the range of 3 to 5 mm. For calculation, VSL recommends to consider a characteristic value of g' = 4 mm.

Defining $f_{po,m}$ as the average stress in the concerned strand length, we have the following simplified expression:

$$\Delta l = \frac{f_{po,o}}{E_p} Lj + \frac{f_{po,m}}{E_p} La + g'$$

On the worksite during stressing, elongation due to tendon slack should be eliminated from the reported value with appropriate procedures (e.g. taking into account elongations only once the tendon has been stiffened inside its duct).

For more details about friction losses (k_a) and wedge draw-in at the anchorages of the stressing end, refer to the relevant chapter of the European Technical Assessment ETA 06/0006.

3 ANCHORAGES

3.1 DESCRIPTION OF THE ANCHORAGE COMPONENTS

VSL Multistrand System anchorages make use of a set of standard elements, to be categorized as follows:

3.1.1 Live end anchorages

The AF anchorages can be used in combination with the E, E-WT, GC and CS stressing-end anchorages. For more details refer to the relevant chapters of the European Technical Assessment ETA 06/0006.

3.1.2 Dead end anchorages

The AF anchorages are formed by the following components:

- Casting AF. The anchorage body is made out of cast iron according to EN1563
- Cover AF. The lower end of the anchorage body is closed by a cover made out of structural steel according to standard EN10025
- Compression fittings AF. The AF compression fittings are composed of a hard steel wire coil wound in a spiral and a fitting sleeve made out of unalloyed steel according to EN10083-2. The coil is threaded on the strand and then the fitting sleeve is swaged on the assembled unit.
- High performance AF anchorage grout

3.1.3 Delivery process of anchorages

The tendon components are delivered to the site with complete identification and adequate packaging. In the usual case, the strands are installed after the construction of the structure to be stressed and the sequence of deliveries to site is as follows:

1) Delivery of the AF anchorages, the ducts and the accessories for placement within the passive reinforcement. These anchorage parts are fastened to the formwork

Following concreting and curing of the concrete,

2) Delivery of strands, compression fittings, high performance AF grout and active anchorages for the stressing end.

3.2 ORGANIZATION OF SUPPLY QUALITY

The fabrication of anchorage components of the AF system is conducted in compliance with the specifications, production and control procedures laid out in the present ETA document and all associated documents.

The control procedures implemented by the Manufacturer and the PT Specialist Company, serve to ensure the traceability of the components until they are delivered and installed on the site.

3.3 INSTALLATION OF THE AF ANCHORAGES

The installation of AF anchorages must be assigned to competent staff members within the PT Specialist Company or to well-trained PT Supervisors.

A special attention has to be taken during the anchorage installation since they will be not be accessible after the concreting stage.

The installation of the AF anchorages is done as described below. The most usual case (installation of strands inside the AF anchorage after concreting) is presented:

1) At time of passive reinforcement installation:

The AF anchorage (cast trumpet and sealed cover) is attached to the rebar, then positioned inside the formwork and connected to the duct (already aligned according to the tendon layout). The vent hoses, grouting inlet and inspection port are put into place.

2) After the concreting stage:

The strands are measured and cut to length. The compression fittings are extruded on the lower extremity of the strand. Then the strands are threaded in the vertical duct with the compression fittings positioned inside the AF anchorage. The position of the compression fittings inside the AF anchorage is carefully checked to ensure that they have reached their intended position. Once all strands have been installed, the anchorage is filled with the high performance AF grout. The correct filling of the anchorage is confirmed visually (by endoscope) at the inspection port.

3) Stressing stage and final protection:

Installation of active anchorages on the opposite stressing end. Stressing can be carried out when the high performance AF grout achieves the required minimum strength $f_{c,cube}$ = 100 MPa (provided that the structure has also achieved the required strength). In some particular projects, heating may be required to ensure or accelerate strength gain. The rest of the operations (stressing operation, cutting of the excess lengths and grouting for the permanent protection of both cables and anchorages) are described in the relevant chapters of the European Technical Assessment ETA 06/0006.

3.4 GEOMETRICAL AND MECHANICAL USE CONDITIONS

For the correct installation of anchorages, certain construction-related conditions must be verified.

3.4.1 Clearances behind anchorages

The requirements for clearance are not applicable to the AF anchorages, which are not stressed,. For details about stressing jacks and clearance requirements on the stressing-end, refer to the relevant chapter in ETA 06/0006.

3.4.2 Concrete cover and anchorage spacing

Post-tensioning introduces concentrated forces that are transferred to the structures by the anchorages. The high stress values encountered underneath the anchorages necessitate certain construction-related measures:

- The anchorages must be laid out at a sufficient distance from the nearest edge of the concrete (cover) and respect a spacing between anchorages (centre to centre) that is specified in this ETA.
- The concrete in the vicinity of the anchorages must be especially homogeneous and achieve, at the time of stressing, an adequate level of strength.

- A general distribution zone must be designed and prepared behind the anchorages, thereby reducing the concentrated forces and distributing them over the concrete cross-section, in compliance with the design rules.

The maximum prestressing force is usually achieved on the live end at the time of stressing (before load transfer to the anchorages). The value of this force $P_{(0,0)}$ has to be smaller than the values given in the chapter § 1.2 Characteristics of the system units.

The AF system has been designed for a concrete strength at time of stressing ($F_{(0,0)} = F_{max}$):

$f_{cm0} \geq$ 32 / 40 N/mm^2 (cyl. / cube)

The dimensions of the anchorage, the anchorage spacing and the layout of the local reinforcement are given in the chapter § 6.4 AF Anchorage – Local zone reinforcement @ 32/40 MPa. The values are applicable for $P_{(0,0)} = P_{max}$

The anchorage blocks presented in this ETA are square and its side is equal to the anchorage spacing X.

It is however possible to diminish one of the two dimensions (either length A or width B) until 0.85 times the original value. In this case, the other dimensions shall be increased so that the total area (length by width) is equivalent to or bigger than the area of the reference anchorage block (that is A B ≥ X^2).

The value of the concrete cover for the tests is usually 10 mm. If the required concrete cover is bigger, then the distance to the edges has to be increased in the two directions:

0.5 A + cover-10 mm and 0.5 B+cover – 10 mm

Note:
During cable stressing, the concrete in front of the anchorages must have reached an adequate strength level. A 100% stressing of $F_{(0,0)} = P_{max}$ is not permitted if $f_{cm}(t) < f_{cm0}$.

It remains possible however to partially tension the tendon in accordance with EN 1992 1-1 (chapter 5.10.2.2 point (4)): "*If prestress in an individual tendon is applied in steps, the required concrete strength may be reduced. The minimum strength fcm(t) at the time t should be k_4 [%] of the required concrete strength for full prestressing given in the European Technical Approval. Between the minimum strength and the required concrete strength for full prestressing, the prestress may be interpolated between k_5 [%] and 100% of the full prestressing.*
Note: The values of k_4 and k_5 for use in a country may be found in its National Annex. The recommended value for k_4 is 50 and for k_5 is 30."

For example, in the case of stressing to 50% of the maximum value at the anchorage for example, the characteristic strength f_{cm0} may be reduced to approximately 2/3 of the value indicated above.

3.5 BURSTING REINFORCEMENT

A bursting reinforcement is required in the local anchorage zone due to application of the concentrated post-tensioning force.

The anchorage zone must also contain reinforcement for general balance in accordance with the applicable design rules (refer to § 6.4 AF Anchorage – Local zone reinforcement @ 32/40 MPa).

The local zone reinforcement specified in this ETA and confirmed in the load transfer tests, may be modified for a specific project design if required. In that case, it shall comply with national design codes and be approved by the the local authority and the ETA holder to provide equivalent performance.

The contractor responsible for concreting must ensure that the density and configuration of reinforcement within the diffusion zone allow for adequate and homogeneous concreting of the entire zone.

4 STRESSING

Multistrand jacks shall be used to stress all tendons with AF anchorages. Stressing strand by strand is possible however on tendons without any deviation with special procedures.

For details about stressing equipment, operating methods and control procedures, refer to the relevant chapter in ETA 06/0006.

5 INJECTION AND SEALING

The AF anchorages are embedded in concrete and protected by the concrete cover.

According to the specifications of the project it may be necessary to inject the free length of the tendon and seal the stressing-end anchorages in order to ensure their permanent protection.

For details of injection products, equipment, injection procedures and sealing refer to the relevant chapter of ETA 06/0006 for detailed information.

6 SCHEMATIC DRAWINGS

6.1 STANDARD COMPONENTS

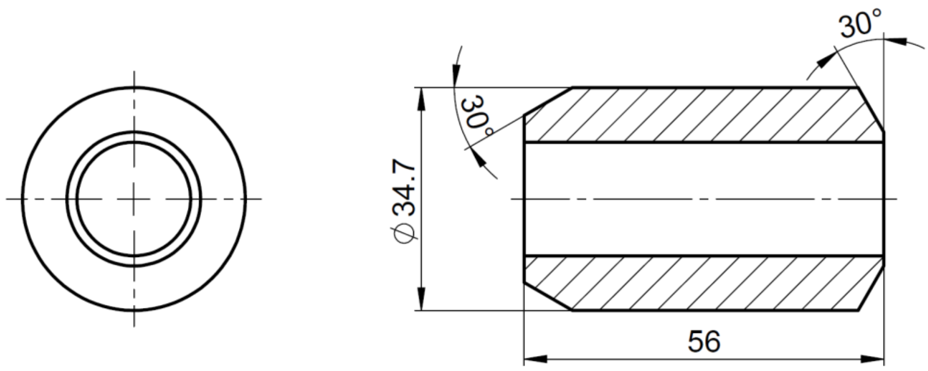

Figure 1 Compression fitting AF6

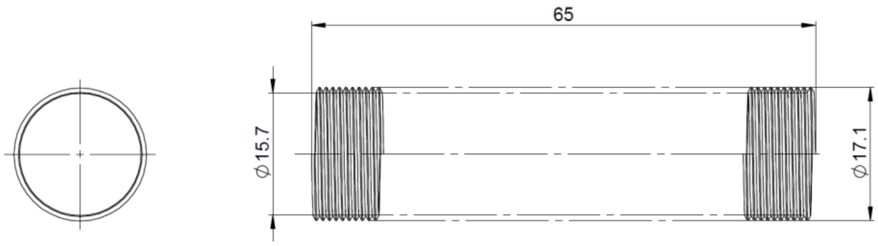

Figure 2 Insert CF6
(Used with strand ϕ15.7 mm)

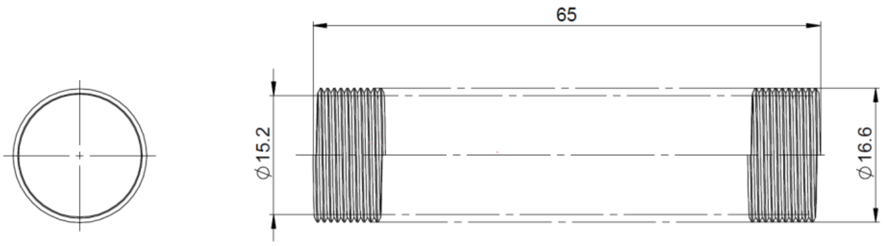

Figure 3 Insert CF6N
(Used with strand ϕ15.2 or ϕ15.3 mm)

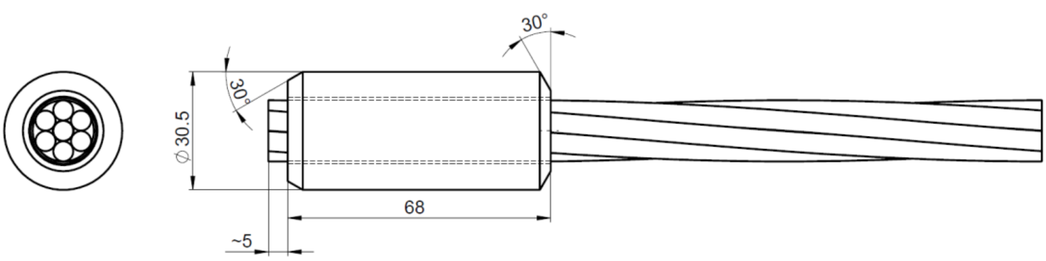

Figure 4 Assembly

6.2 AF ANCHORAGE – PRINCIPLE

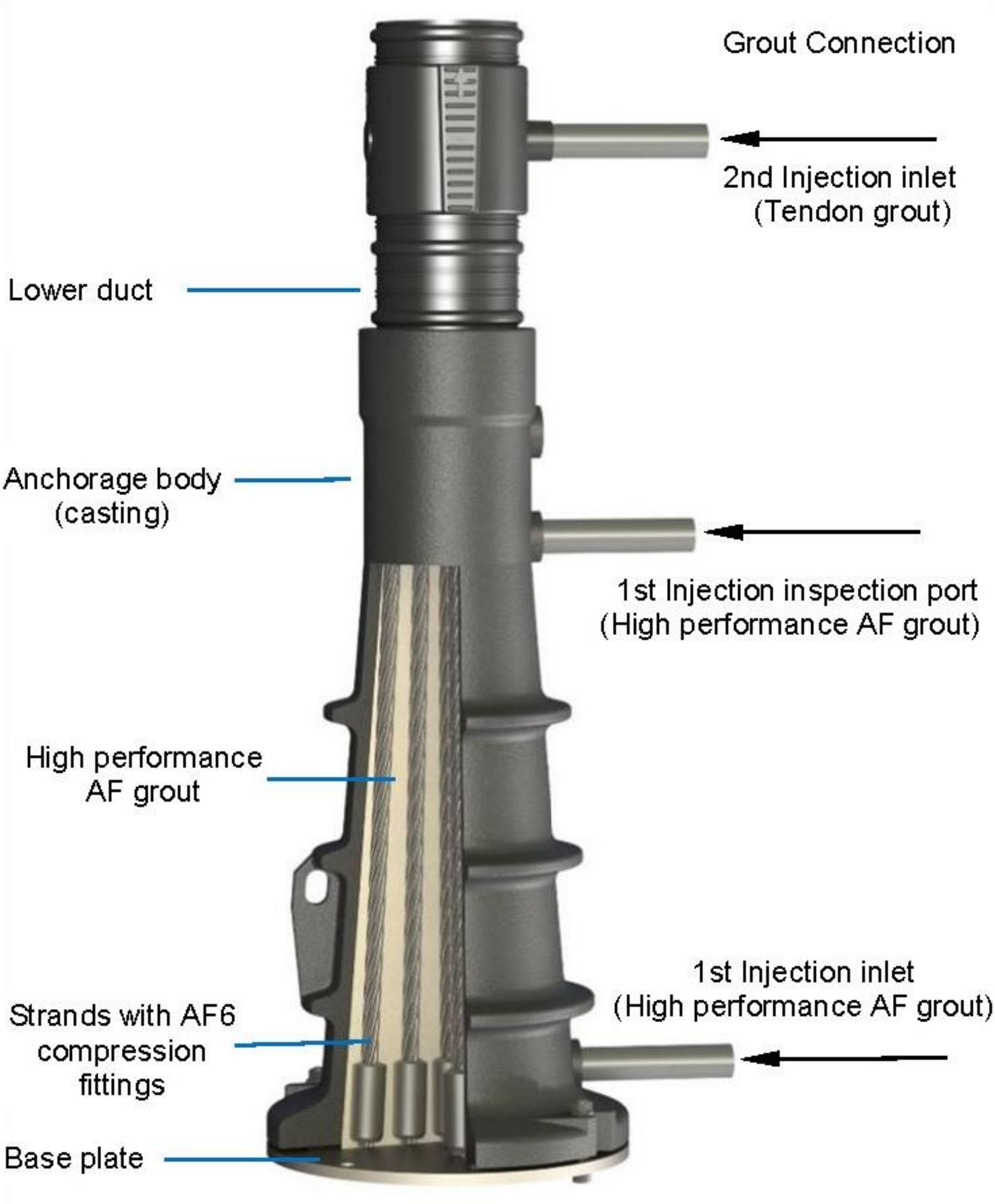

Figure 5 Principle of the AF anchorage and main parts (example with PT-Plus® duct)

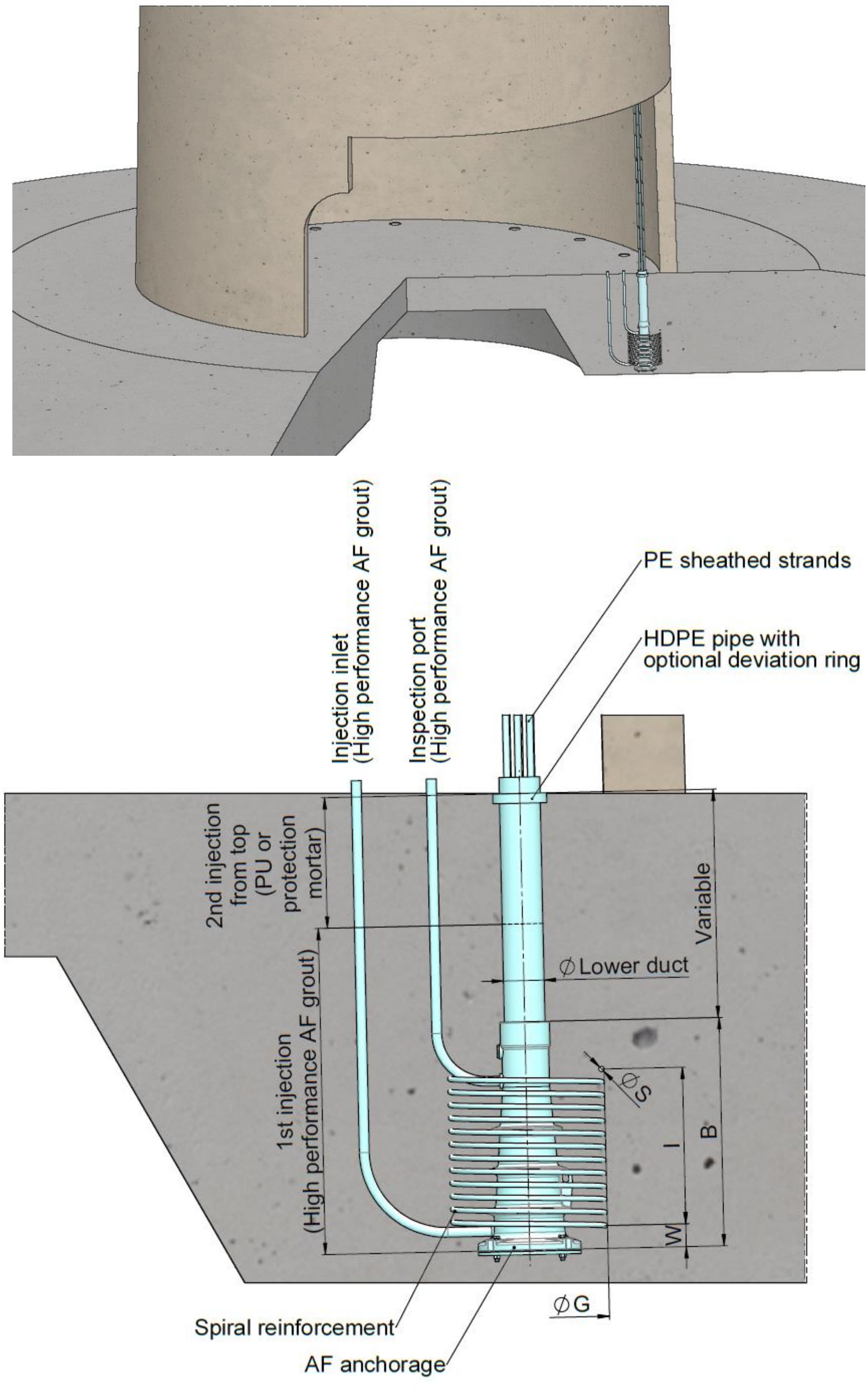

Figure 6 Example of installation on a structure. General view and detail

6.3 AF ANCHORAGE – MAIN DIMENSIONS

Unit	ØA	B	C	D	E	F_{min}
6-4	240	700	60	460	300	2000
6-7	250	700	60	460	300	2000
6-12	265	700	60	460	300	2000
6-15	285	700	60	460	300	2000
6-19	315	700	60	460	300	3000
6-22	333	750	60	510	350	3000
6-27	353	800	60	550	350	3000
6-31	380	900	60	660	350	3000

Unit	Ø Lower Duct			Ø Upper Duct	
	Corrugated steel duct	Smooth steel pipe	PT-PLUS®	Corrugated steel duct	PT-PLUS®
6-4	65/72	70.3/76.1	65	60/67	65
6-7	75/82	76.1/82.5	76	65/72	65
6-12	95/102	94.4/101.6	100	80/87	76
6-15	110/117	113.0/121.0	115	85/92	85
6-19	120/127	125.0/133.0	115	100/107	100
6-22	130/137	131.4/139.7	130	110/117	100
6-27	140/147	137.0/146.0	130	120/127	115
6-31	150/157	150.0/159.0	150	130/137	130

Notes

All dimensions in [mm]

System applicable to strands with A_p = 140 mm² or A_p = 150 mm²

Minimum strength of the AF anchorage grout at time of stressing $f_{c,\,cube}$ = 100 MPa

Depending on the project requirements, the system can be used with smooth steel pipes, corrugated steel duct or PT-PLUS® duct.

In case of reduction dof duct diameter of PT-PLUS® duct or corrugated duct, the minimum dimension F shall be respected.

Dimensions correspond to most common steel ducts and pipes. Contact VSL for other options.

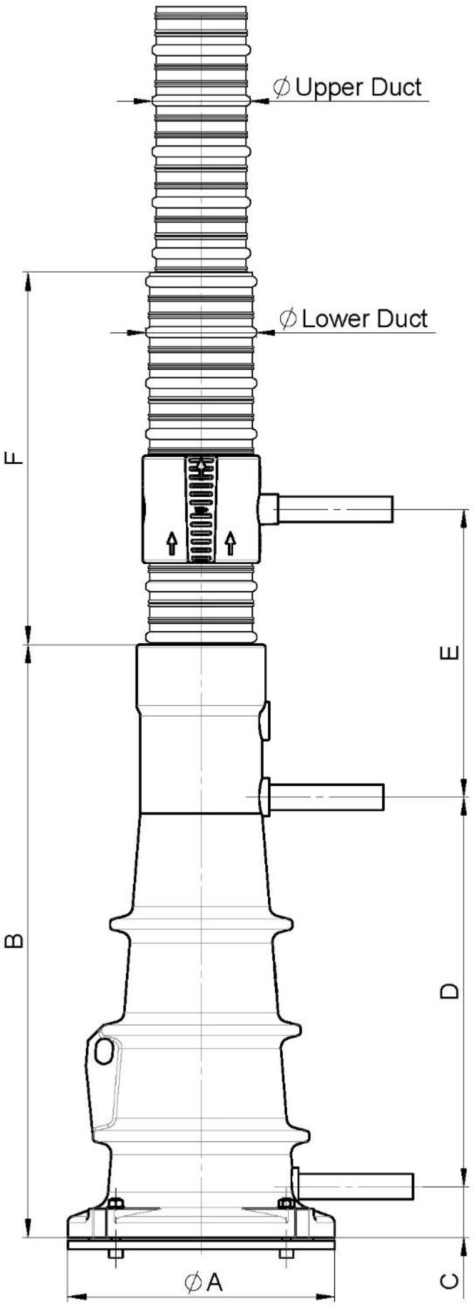

Figure 7 Anchorage AF – Main dimensions

6.4 AF ANCHORAGE – LOCAL ZONE REINFORCEMENT @ 32/40 MPA

OPTION A – SPIRAL REINFORCEMENT

OPTION B- STIRRUP REINFORCEMENT

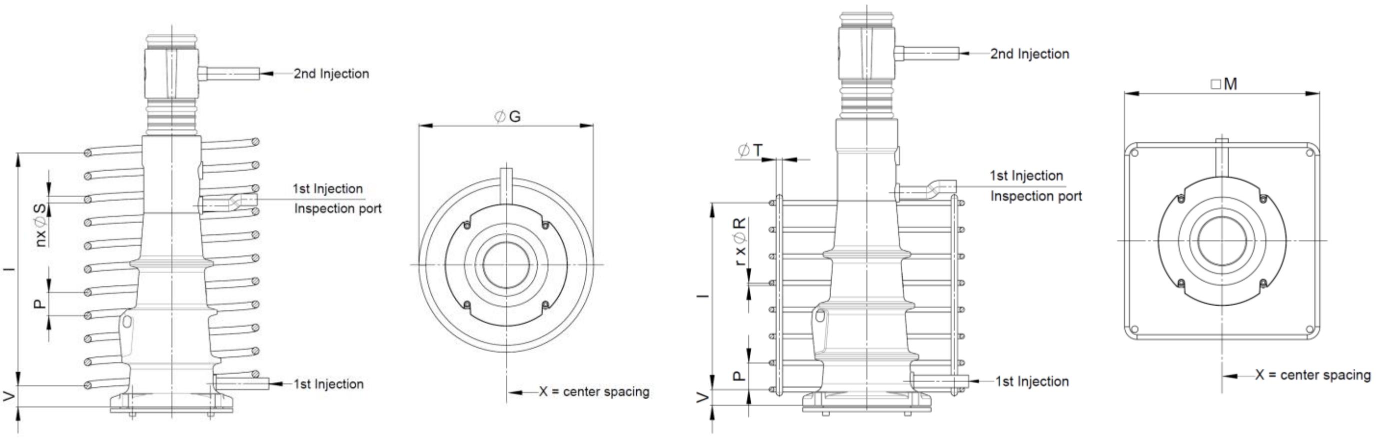

Figure 8 Local anchorage zone reinforcement type AF @ 32/40 MPa

Reinforcement for concrete with **$f_{c,min(t)}$ ≥ 32/40 N/mm^2** (cylinder/cube) at time of stressing

Unit	A-SPIRAL REINFORCEMENT							B – STIRRUP REINFORCEMENT						
	V	I	P	ØS	ØG	n [1]	X [3]	V	I	P	ØR	M	r [2]	X [3]
6-4	60	450	50	12	240	10	260	45	400	50	12	240	9	260
6-7	60	420	70	16	305	7	325	45	400	50	16	305	9	325
6-12	60	440	40	16	390	12	410	45	400	50	20	390	9	410
6-15	60	440	55	20	435	9	455	45	455	65	25	435	8	455
6-19	60	500	50	20	485	11	505	45	480	60	25	485	9	505
6-22	70	500	50	20	520	11	540	45	495	55	25	520	10	540
6-27	70	540	45	20	575	13	595	45	550	50	25	575	12	595
6-31	70	660	55	20	615	13	635	45	605	55	25	615	12	635

(1) n Number of turns including first and last turn required for anchorage of spiral
(2) r Number of reinforcement layers
(3) X Minimum centre spacing between anchorages (for square blocks). It is possible to reduce the centre spacing in one of the directions under some circumstances, as agreed with VSL

The distance from the centre of the anchorage to the concrete edge is 0.5 X + cover -10 mm.

All dimensions in [mm]. Two options (either spiral OR stirrup) are presented for reinforcement. Combinations of spiral and stirrups with equivalent performance (to be approved by VSL) are also possible.

Reinforcement steel f_{yk} ≥ 500 N/mm².
Strand A_p = 150mm^2, f_{pk} = 1860 N/mm^2 (GUTS), F_{pk} = 279kN
(Other types of strand or reinforcement steel to be agreed with VSL)

ANNEX 2 – PRESCRIBED TEST PLAN AND AUDIT TESTING

1 PRESCRIBED TEST PLAN

1	2	3	4	5	6
Component	**Item**	**Test / Check**	**Traceability[4]**	**Minimum frequency**	**Documen-tation**
Casting AF	Material[6]	Check	bulk[6]	100% [8]	"3.1"[1]
	Detailed dimensions[5]	Test		5% [8] ≥ 2 elements	Yes
	Visual inspection[3]	Check		100% [8]	No
Compression fittings	Material[6]	Check	full	100% [8]	"3.1"[1]
	Detailed dimensions[5]	Test		5% [8] ≥ 2 elements	Yes
	Visual inspection[3]	Check		100% [8]	No
Duct	Material[6]	Check	"CE"[2]	100%	"CE"[2]
	Visual inspection[3]	Check		100%	No
Strand	Material[6]	Check	National Certification till "CE"[2]	100 %	"CE"[2]
	Diameter	Test		Each coil	No
	Visual inspection[3]	Check		Each coil	No
Constituents of filling material as per EN 447 / AF grout	Cement[6]	Check	full	100%	"CE"[2]
	Admixtures, additions, ...[6]	Check	bulk	100%	"CE"[2]
Monostrand	Material[6]	Check	National Certification till "CE"[2]	100%	"CE"[7]
Corrugated plastic / polymer duct	Material[6]	According to fib Bulletin 75, Chapter 9	full	According to fib Bulletin 75, Chapter 9	"CE"[7]
Plastic pipe	Material[6]	Check	full	100%	"CE"[2]
	Visual inspection [3]	Check	full	100%	"CE"[2]

All samples are to be extracted at random and clearly identified.

Details on sampling procedures including methods of recording as well as test methods have been agreed between the Technical Assessment Body and the Manufacturer as part of the prescribed test plan. Preferably standardized sampling and test methods are used. Generally all results are reported in the test reports in such a way to enable direct comparison with the specification data in the ETA or subsidiary documentation.

1 "3.1": Inspection certificate type "3.1" according to EN 10 204.

2 If the basis of "CE"-marking is not available, the prescribed test plan has to include appropriate measures, only for the time until the harmonized technical specification is available.

3 Visual inspection of general aspects such as main dimensions, external aspect, correct marking/labelling, regularity of surface, absence of visual defaults, smoothness, absence of corrosion, coating, etc. unless covered in other items already of the prescribed test plan. The objective of this inspection is to ensure that the component corresponds to its description and to detect any non-conformity that is visible to an inspector who is knowledgeable in the particular component.

4 full: Full traceability of each component to its raw material.
bulk: Traceability of each delivery of components to a defined point.

5 Detailed dimensions mean measuring of all dimensions and angles according to the specifications as given in the prescribed test plan.

6 Material checks are included for information only as these are not part of the prescribed test plan.

7 If the basis of "CE"-marking is not available, the prescribed test plan has to include appropriate measures. The certificate shall be based on specific testing on the fabrication batch from which the supply has been produced, to confirm specified properties, and shall be prepared by a department of the supplier which is independent of the production department.

8 Procedure according to VSL Final Control Specifications.

Note: Generally speaking, all tests, inspections, etc. are aimed at verifying that the information contained in the manufacturing drawings and in the relevant specifications has actually been applied to the components.

2 AUDIT TESTING

During surveillance inspections, the Notified Body has to take samples of components of the PT System or the relative individual components for which the ETA has been granted for independent testing. For the most important components, the table given below summarises the minimum procedures which are performed by the Notified Body.

1	2	3	4
Component	Item	Test / Check	Sampling Number of components per visit
Casting AF	Material according to specification	Check, test	1
	Detailed dimensions	Test	
	Visual inspection [10]	Check	
Compression fitting	Material according to specification	Check, test	2
	Detailed dimensions	Test	1
	Visual inspection [10]	Check	5
Single tensile element test	Single tensile element test according to Annex E.3	Test	1 series
Inclined Tube test	Inclined Tube test as per Clause C.4.3.3.2.1 [11]	Test	1 test

All samples are to be randomly selected and clearly identified.

Details on sampling procedures including methods of recording as well as test methods have been agreed between the Technical Assessment Body and the Manufacturer as part of the prescribed test plan. Preferably standardized sampling and test methods are used. Generally all results are reported in the test reports in such a way to enable direct comparison with the specification's data in the ETA or subsidiary documentation.

[10] Visual inspections means e.g. : main dimensions, gauge testing, correct marking or labelling, appropriate performance, surface, fins, kinks, smoothness, corrosion, coating, etc. Visual inspection of general aspects such as main dimensions, external aspect, correct marking/labelling, regularity of surface, absence of visual defaults, smoothness, absence of corrosion, coating, etc. unless covered in other items already of the prescribed test plan. The objective of this inspection is to ensure that the component corresponds to its description and to detect any non-conformity that is visible to an inspector who is knowledgeable in the particular component.

[11] Applied to special grout specified within the EAD 160027-00-0301 in C.4.3 and this ETA.

ANNEX 3 – REFERENCE STANDARDS AND GUIDELINES

1 MATERIAL AND REFERENCE STANDARDS

Component	Material	Standard
Casting AF	Cast iron	EN 1563
Compression fittings	Unalloyed steel	EN 10083-2
Corrugated sheaths	Metal strip	EN 523
Polymeric duct	Polymeric material	Fib bulletin 7
Grout	Cement, additives	EN 447
High performance AF grout	UHP Concrete	-
Strand	Steel strand	prEN 10138-3

NB: Exact materials and properties are deposited at Cerema

2 GUIDELINES AND RECOMMENDATIONS

European Assessment Document

EAD 160004-00-0301 edition September 2016 of “Post-tensioning kits for prestressing of structures”

EAD 160027-00-0301 edition September 2016 of “Special filling products for post-tensioning kits”

CEN Workshop Agreement

CWA 14646:2003: “Requirements for the installation of post-tensioning kits for prestressing of structures and qualification of the specialist company and its personnel.”

3 STANDARDS AND NORMS

EN 445:2007	“Grout for prestressing of tendons – Test methods”
EN 446:2007	“Grout for prestressing of tendons – Grouting procedures”
EN 447:2007	“Grout for prestressing of tendons – Specification for common grout”
EN 523:2005	“Steel strip sheaths for prestressing tendons – Terminology, requirements, quality control”
EN 1563:2012	“Founding – Spheroidal graphite cast irons”
EN 1992-1-1:2004	“Eurocode 2: Design of concrete structures. Part 1-1: General rules and rules for buildings”
EN ISO 9001:2008	“Quality management systems-Requirements”
EN 10025-2:2006	“Hot rolled products of structural steel”
EN 10083-2:2006	“Quenched and tempered steel – Part 2: Technical delivery conditions for unalloyed quality steels”
prEN 10138-3:2006	“Prestressing steel – Part 3: strands”
EN 10204:2006	“Metallic products – Types of inspection documents”
EN 13391:2005	“Mechanical tests for Post-tensioning systems”
EN 13670:2013	“Execution of concrete structures”