Cerema

Direction technique
infrastructures de transport et matériaux

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Member of EOTA
www.eota.eu

Cerema ITM
110 rue de Paris
77 171 Sourdun
FRANCE

Mail: ete-dtecitm@cerema.fr
Tel: +33 160 523 131
web: www.cerema.fr

European Technical Assessment

ETA 13/0978 of 06/06/2018

Technical Assessment Body issuing the ETA:	Cerema Direction technique infrastructures de transport et matériaux
Trade name of the construction product	VSLab ® S 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	42 pages including 3 Annexes (30 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
This ETA replaces	ETA 13/0978 of 28/06/2013

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EUROPEAN TECHNICAL ASSESSMENT – VSL POST-TENSIONING SYSTEM

1 TECHNICAL DESCRIPTION OF THE PRODUCTS

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

VSLab® S System with 2, 3, 4 and 5 strands

The VSLab® S system (2 to 5 strands) or PT System, defined in Annex 1, is a system fo flat post-tensioning anchorages that is particularly suited for for use on thin construction elements for building or bridge decks, where the strands are protected.

The VSLab® S system comprises the following components:

- Anchorages which include the anchorage bodies for 2 to 5 strands, the wedges and the trumpets. The anchorages can be used at both side of the tendon:
  - Active side
  - Passive side
- Tendons made out of 2, 3, 4 or 5 strands (using 0.6" - 7 wire strand, Ø 15.3 or Ø 15.7, 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 greased and sheathed for the system without injection
- Ducting system:
  - Corrugated steel duct
  - Corrugated VSL PT-PLUS® plastic duct
- Grouting products (cement base injection mortar) for bonded tendons:
  - Grouts in accordance with EN 447
  - Products covered by an ETA
- Other components such as protective products. They are necessary to ensure either a permanent level of prestressing (during the entire life cycle of the structure) or a temporary one (over a limited period) for civil engineering structural elements, buildings or any other type of construction.

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

The VSLab® S System has been designed to introduce post-tensioning forces on structures or sections of structures made of concrete.

The VSLab® S Post-Tensioning System may be used for:

- New structural works
- Repair and strengthening of existing structures

The VSLab® S System may also be employed in structures made of other materials than concrete; such as masonry, steel, cast iron, wood or combinations of several materials.

The tendons assembled as part of the VSLab® S system may have the following basic use categories:

- Internal bonded tendon for concrete and composite structures
- Internal unbonded tendon for concrete and composite structures

The following optional use categories can also be used:

- Re-stressable tendon (internal)
- Exchangeable tendon (internal)

The tendons for ground and rock anchors, external cables with a layout positioned beyond the structural envelope or the structural component, and stay cables are not covered by the present ETA.

The tables presented in § 1.4 and § 3.1.4 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 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 and judged.

The 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).

Product type: Post–Tensioning Kit		**Intended use:** Prestressing of structures (all basic use categories)
Basic requirement for construction work	**Essential characteristic**	**Performance**
1 Mechanical resistance and stability	Resistance to static load	≥95% of Actual Ultimate Tensile Strength – AUTS (acceptance criteria given in clause 2.2.1 of EAD 160004-00-0301)
	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 clause 2.2.2 of EAD 160004-00-0301)
	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)
	Friction coefficient	See clause 2.6.1 (acceptance criteria given in clause 2.2.4 of EAD 160004-00-0301)
	Deviation/deflection (limits) for internal bonded and internal unbonded tendon	See clause 2.3.2 (acceptance criteria given in clause 2.2.5 of EAD 160004-00-0301)
	Assessment of assembly	Installation of strands, duct filling (acceptance criteria given in clause 2.2.7 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 VSLab® S 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 the Technical Assessment Body. 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+

This AVCP system is defined as follows:

System 1+: Declaration of the performance of the essential characteristics of the construction product by the manufacturer on the basis of the following items:

- (a) Tasks of the manufacturer
  - (1) Factory production control;
  - (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.

The methods for verifying, evaluating and assessing suitability and test procedures comply with those detailed in EAD 160004-00-0301 of post-tensioning kits for prestressing of structures.

[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 PROVIDED FOR 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 components manufacturers. This list shall be submitted to the Notified Body and the Technical Assessment Body.

Each Component Manufacturer has to be audited 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 components manufacturer
- Date of audit of components manufacturer
- Summary of the results and records of the FPC since last audit
- Summary of the complaint records
- Evaluation of the components 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 at least one job site. One series of single tensile element tests is performed according to Annex 2 of this ETA (Annex C.7 of EAD 160004-00-0301) by the Manufacturer with these specimens. One series of single tensile element tests are performed with components from only one site. The results of these test series are made available to the Certification Body. These reports include:

- Identification of the job site where the components have been taken
- Date of sampling
- Identification of the components (anchor head, wedges, 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 the European Technical Assessment.

The Factory Production Control is in accordance with the control plan of VSL named QM relating to this European Technical Assessment which is part of the technical documentation of this European technical assessment. The control plan is laid down in the context of the factory production control system operated by the manufacturer and deposited at Cerema.

The basic elements of the control plan comply with Table 3 of EAD 160004-00-0301. The results of the factory production control shall be recorded and evaluated in accordance with the provisions of the control plan.

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.

The FPC and the prescribed test plan are defined in Annex 2 of this ETA.

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 harmonized technical specifications are not available, materials according to specifications valid in the place of use may be used provided that their use is compatible with the results of assessment tests. Otherwise, the specifications are given in the 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 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 not 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 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 conformity 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 certificate of conformity 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 from tests performed during the assessment procedure and then evaluated 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 factories 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 producer 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

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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

Barthélémy PETIT, ETA manager

ANNEX 1 TECHNICAL DATA OF THE VSL « VSLab® S » SYSTEM

1 DEFINITION OF THE SYSTEM

1.1 PRINCIPLE OF THE "VSLAB® S" SYSTEM

The VSLab® S system (or more generally the PT system) is composed of a tendon or cable, made out of 2, 3, 4 or 5 steel strands, and the associated set of anchorages and accessories.

The VSLab® S system is mainly intended for use for "bonded" applications. In this case, the strands are located within a duct that constitutes a flat conduit. The void created is then filled with a grout according to EN 447 or EAD 160027-00-0301 for the purpose of bonding with the structure and inhibiting corrosion.

The constituting strands are those defined in the European standard "prEN 10138-3: Prestressing steels - Part 3: Strand". They are 7-wire strands with nominal diameters of ∅ 15.3 and ∅ 15.7 mm (f_{pk} = 1860 N/mm² or f_{pk} = 1770 N/mm²), 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 496 kN and 1395 kN.

Each strand of a tendon is individually stressed and becomes locked within a conical anchoring hole by means of wedges. The locking function is performed when the strand moves back (due to its elasticity) at the time of pressure release in the jack.

1.2 CHARACTERISTICS OF THE SYSTEM UNITS

On the basis of the strand characteristics defined in "prEN 10138-3: Prestressing steels - Part 3: Strand" and the nominal tendon cross-sections A_p, the maximum forces under anchorage upon tensioning 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		STRAND Y1770 S7-15.7 f_{pk} = 1 770 N/mm² F_{pk} = 266 kN; $F_{p0.1k}$ = 234 kN			STRAND Y1860 S7-15.3 f_{pk} = 1 860 N/mm² F_{pk} = 260 kN; $F_{p0.1k}$ = 229 kN			STRAND 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
VSLab ® S	6-2	300	420,6	397,2	280	412,5	389,6	300	441,9	417,4
	6-3	450	630,8	595,8	420	618,7	584,3	450	662,9	626,1
	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

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 PT 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 strands of the tendon are stressed individually. 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

Depending on their function, the anchorages of the VSLab® S system may be classified as follows:

1.3.1.1 Active anchorages

These anchorages (also known as live end anchorages) have been designed to anchor tendons at the end where stressing will be performed strand by strand. They are composed of a single-block anchorage drilled with conically-shaped holes (2 to 5) in which the strands are anchored by means of wedges.

1.3.1.2 Passive anchorages

These anchorages (also known as dead end anchorages) ensure the locking of tendons at the end on which no stressing force is being exerted by mean of the jack.
The wedges have been locked into the anchorage body and pushed in their cavities in order to prevent any slipping movement.

The continuity of protection and the waterproof sealing between the duct and the anchorage are provided by means of a plastic trumpet (sleeve).

More details are presented in § 3 Anchorages.
The stressing of tendons is only conducted by the mean of a VSL stressing jack. More details are presented in § 4 Stressing.

1.3.2 List of approved anchorages

The set of approved anchorages is as follows:

Qty. x ∅ of strand		Active anchorage	Passive anchorage
2x ∅15.3	2x ∅15.7	✓	✓
3x ∅15.3	3x ∅15.7	✓	✓
4x ∅15.3	4x ∅15.7	✓	✓
5x ∅15.3	5x ∅15.7	✓	✓

1.4 USE CATEGORIES, OPTIONS AND POSSIBILITIES

1.4.1 Use categories of the VSLab® S system

The VSLab® S system anchorages are entirely internal to the concrete structure.They may be:

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

The tendons assembled as part of the VSLab® S system may have the following basic use categories as per EAD 160004-00-0301:

- Internal bonded tendon for concrete and composite structures
- Internal unbonded tendon for concrete and composite structures

The following optional use categories can also be used:

- Re-stressable tendon (internal)
- Exchangeable tendon (internal)[2]
- Internal bonded tendon with plastic duct
- Encapsulated tendon

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

- For strands and ducts see § 2 Strands and ducts
- For anchorages see § 3 Anchorages
- For injection see § 5 Injection and sealing

1.4.2 Possibilities of the VSLab® S system

The VSLab® S system may be stressed in partial stages. At the beginning of each stage, the wedges are unclamped by action of the jack on the strand. Once the targeted force has been reached, pressure in the jack is released and the wedges are once again locked inside the anchorage. The same procedure applies for stressing a long cable, where the elongation may require several successive jack strokes.

The de-stressing of a strand(s) anchored by in a VSLab® S anchorage is possible using a special tooling assembly mounted on the stressing jack.De-stressing procedure is only possible if the required strand over-length has been conserved and that the strand remains independent of the structure (unbonded).

[2] The designer must check feasibility regarding geometrical tendon layout.

2 STRANDS AND DUCTS

2.1 STRAND

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

2.2 DUCTS

The VSLab® S system can use several types of flat duct. Duct type selection depends on the project, the final use designed for the structure and the post-tensioning units.

2.2.1 Unbonded system

Individually greased and sheathed strands are installed without duct. The cables composed by several individual parallel strands are placed on regularly-spaced supports to avoid twisting of strands and obtain the required layout.

The connection of the duct with the anchorage is made by a plastic sleeve that provides a watertight seal with the sheathing.

2.2.2 Bonded system

2.2.2.1 Type and dimensions of usable ducts

Depending on the specific application, various types of ducts may be employed. 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	Metal duct	Polymeric duct
	Flat[1)] corrugated steel strip	**Flat[1)] VSL PT-PLUS□ duct**
Standard	✓	✓
Encapsulated	X	✓[2)]
✓ = advised	X = unadvised or forbidden	
[1)] Flat ducts have an oblong section	[2)] This set-up corresponds to a fully protected tendon	

The height of the flat duct is considerably less than two strand diameters in order to ensure that the strands remain juxtaposed side by side, in the same position all along the tendon.

The flat ducts for the VSLab® S system are large enough to provide for easy tendon installation and adequate grouting.

The most common duct sizes are listed in § 6.5 Ducting.

2.2.2.2 Metal ducts

Tendons are most often isolated from the concrete by means of corrugated steel strip flat sheaths. Although not covered in Standard EN 523, these flat sheaths could fall within Category 1 (normal sheaths), since their characteristics are nearly the same as those of the cylindrical ducts contemplated in the standard.

Connections at the extremity of the duct segments are made by a coupler. The waterproof sealing at the joints is provided by adhesive tape or heat-shrinkable sleeves.

2.2.2.3 Polymeric ducts

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

The fittings between ducts segments are made by connectors that create a waterproof sealing. The VSL PT-PLUS® duct complies with EAD 160004-00-0301.

The VSL PT-PLUS® duct with its set of appropriate fittings is also employed in the case of encapsulated (waterproof) tendons. In this case rigid half-shells are installed between the duct and its supports at the deviation points of the cable to prevent damages on the duct during stressing.

2.2.2.4 Accessories for inlet, outlet and bleed vents

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 plastic shell	Plastic pipe
VSL PT-PLUS® duct	Special "clipped" collar	Plastic pipe

2.2.2.5 Connection to anchorage

The connection of the duct to the anchorage is performed by a component called trumpet. Its shape allows a smooth transition of the strands from the anchorage body hole pattern to the final strand lay-out in the duct.

The trumpets are fastened to the formwork during the installation stage (before concreting) by means of a recess former. After the concreting stage, the recess former is removed and an appropriate recess is thus created to allow the installation of the anchorage body.

The sealing between the ends of duct and trumpet is carried out using adhesive tape, heat-shrinkable sleeves or a duct connector (e.g. a VSL PT-PLUS® clip).

2.3 CABLE LAYOUT

The cable layout patterns are defined by the project.

2.3.1 Straight length behind the anchorages

The proper alignment of the tendon is obtained by the trumpet of the VSLab® S system. For both systems, bonded and unbonded, it is not necessary to provide an additional straight length behind this trumpet.

2.3.2 Radius of curvature

For both metal and plastic ducts, a minimum radius of curvature (r_{min}) has to be respected:

- Plane: $r_{min} \geq 6.00$ m
- Elevation: $r_{min} \geq 2.50$ m

2.3.3 Spacing of the supports and tolerances

In order to allow the duct placement with the required level of precision, the supports underneath the cables or ducts are usually placed approximately every 1m for a large radius of curvature and every 50cm for a small radius of curvature.

The fastening fittings shall be sufficiently robust and close enough to maintain the position of the duct and not allow displacements or deformations in excess of the tolerances. Recommended spacing of tendon supports is 10 to 12 time duct diameter.

The duct supports are laid out as indicated in the design that also establishes the order in which the cables are to be installed to ensure installation without "intertwining" in the case of slabs with tendons in both directions.

The tolerances on cable positions in the concrete elements must comply with the requirements of the standard "EN 13670".

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. Special attention must be paid to to structural singularities, such as floor openings.

The VSLab® S system may be installed according to the so-called "free path" or "Freie Spanngliedlage" method:

- The method of “Freie Spanngliedlage” is applicable for slabs with a thickness of less than 450 mm
- Tendons placed with the method of “Freie Spanngliedlage” need only a limited number of tendon supports (usually at the low and high points of the tendon profile) that are spaced as follows:
    - The maximum spacing of tendon supports is:
        - A maximum of 1.5m between the tendon fixation to the top layers of reinforcement and an adjacent anchorage
        - A maximum of 3.0m between the tendon fixation to the bottom layers of reinforcement and an anchorage or a tendon fixation to the top layer of reinforcement
- At the low points and high points of the tendon profile, the tendons have to be fixed to the top and bottom layers of reinforcement, respectively, on at least two locations separated 0.3m to 1.0m. The fixation shall ensure a tight fit without damaging the tendon sheathing. The reinforcement layers have to be defined in accordance with the relevant standards.

2.3.4 Strand cut length

Since the anchorage has been 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. This overlength has been defined in § 6.4 Stressing equipment.

2.4 INSTALLATION OF DUCTS AND STRANDS

Depending on the size, the layout, the available space of the worksite and the schedule of works, one of the following solutions can be adopted:

- Cables (both tendons and ducts) fabricated in the plant and then delivered as needed on the worksite for installation into the passive reinforcement
- Strand bundle fabricated in a mobile workshop located adjacent to the worksite and then drawn before concreting into the ducts installed in the passive reinforcement;
- Installation of individual strands before concreting inside the ducts attached to in the passive reinforcement.

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 provide an adequate level of corrosion protection and present a good bond behaviour. This product shall not be removed before grouting of the tendon.

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).

The products used must not be a threat to the hygiene, health and the environment. In addition they must comply with the national provisions of requirements introduced by the Member States (such as national laws, regulations or administrative provisions).

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 [(1)] [rad^{-1}]	***K*** [rad/m]
Individually greased and sheathed strand	0.05	0.020 - 0.060
Cable with corrugated steel strip sheath	0.17 - 0.19	0.005 - 0.010
Cable with VSL PT-PLUS□ duct	0.12 - 0.14	0.005 - 0.010
[(1)] The interval limit values encompass both lubricated and non-lubricated strands.		

2.6.2 Basis for evaluating elongations

Taking the stress $f_{p0}(x) = \frac{F_{po}(x)}{\text{Nominal steel cross-section of the tendon}}$ 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 (see § 4.2.2 Force measurements for more details) 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 (if applicable):
  - in the case where the cable is terminated on its dead end by a fixed anchorage, whose wedges were manually pre-set, a value of g' = 3 mm shall be added

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).

2.6.3 Active anchorage settings

The values of the wedge draw-in are the same for all types of anchorages and wedges included in this ETA:

- 6 mm if they are stressed without the seating ram on the stressing jack.(see §4 Stressing)
- 5 mm if they are installed with a seating ram on the stressing jack. (see §4 Stressing)

Note: The VSLab® S system does not allow for any adjustment with shim.

3 ANCHORAGES

3.1 DESCRIPTION OF THE ANCHORAGE COMPONENTS

3.1.1 Active / Passive anchorages

The anchorages VSLab® S system anchorages comprise:

- Anchorage body VSLab® S. It is a cast iron component combining anchor head and bearing plate.The anchorage body is molded and cast with a spheroidal graphite cast iron in accordance with standard EN 1563.

- Trumpet VSLab® S. The plastic trumpet (or sleeve) is inserted into the concrete structure and allows the installation of the anchorage body after the concreting stage. Its shape is adapted to fit perfectly to the anchorage body and provide an adequate bearing surface. The trumpet also allows the connection of the ducting system and gives a smooth transition of the strands layout between the anchorage body and the final tendon layout in the duct.

- Grout cap VSLab® S. A provisional or permanent plastic cap provides a tight sealing of the tendon envelope at the anchorage end in order to perform the grouting.

- Wedges. The two-part wedges are made out of alloyed steel for cementation according to the standard EN 10084. The wedges are machined, cut in two parts and heat treated. They are submitted to rigorous quality controls and are available in two sizes:
  - Wedge W6N, to be used with a strand diameter of 15.3mm
  - Wedge W6S, to be is used with a strand diameter of 15.7mm

3.1.2 Delivery process of anchorages

The tendon components are delivered to the site with complete identification and adequate packaging. In the usual case of internal (concrete) post-tensioning of a new structure, the strands are installed after concreting and the sequence of deliveries to site is as follows:

1) Delivery of the VSLab® S trumpets, ducts, accessories and strands. These anchorage parts are fastened to the formwork.

Following concreting and curing of the concrete,

2) Delivery of the wedges and the VSLab® S anchorage body before stressing

3.2 ORGANIZATION OF SUPPLY QUALITY

The fabrication of the anchorage components of the VSLab® S 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 VSLAB® S ANCHORAGES

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

3.3.1 Type VSLab® S 6-2 to VSLab® S 6-5 – Active anchorages

The installation of this active anchorage is done as follows:

1) <u>At time of passive reinforcement installation:</u>

The VSLab® S trumpet and the VSLab® S recess former are attached to the stop-end formwork and connected to the duct (already aligned according to the tendon layout). The vent hoses, grouting inlet and outlet are put into place.

2) <u>After the concreting stage:</u>

The VSLab® S recess former is removed and the strands are threaded through the VSLab® S anchorage body which is then placed on the VSLab® S trumpet.

3) <u>Stressing stage:</u>

The wedges are placed immediately prior to the stressing operation to ensure that they are clean. Once the stressing procedure is finished and after that the stressing report has been approved, the strand overlength is cut and the VSLab® S grout cap is installed on the VSLab® S anchorage body.

4) <u>Grouting stage (bonded tendon):</u>

The grouting of the duct is performed according to the VSL procedure. If applicable, the anchorage recess is filled according to the site specifications.

3.3.2 Type VSLab® S 6-2 to VSLab® S 6-5 – Passive anchorages

The installation of this passive anchorage is done as described in § 3.3.1 Type VSLab® S 6-2 to VSLab® S 6-5 – Active anchorages.

The wedges are pre-locked using a wedge tool. The anchorage then remains accessible throughout the stressing phase for observation.

The only difference is that the strand overlength is shortened since no stressing operation is performed on this anchorage.

3.3.3 Type VSLab® SF 6-2 to VSLab® SF 6-5 – Passive anchorages (embedded)

The installation of this embedded passive anchorage is done as follows:

1) <u>At time of passive reinforcement installation:</u>

The VSLab® S trumpet is connected to the duct (already aligned according to the tendon layout). The vent hoses, grouting inlet and outlet are put into place.

The VSLab® SF anchorage body is assembled on the strands then the wedges are pushed in their cavities by the mean of a special equipment, and checked. The anchorage body is then locked to its final position in the trumpet.

The whole assembly is then fixed to the stop-end formwork.

The rest of the operation is done at the active anchorage as per described in § 3.3.1 Type VSLab® S 6-2 to VSLab® S 6-5 – Active anchorages.

<u>Note:</u>

A special attention has to be taken during the installation because the anchorages will be not be accessible after the concreting stage.

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

In order to facilitate jack placement and simplify the stressing procedure, a free space must be allocated behind the anchorage. These dimensions are given in § 6.4 Stressing equipment.

For the use of destressing equipment or overstressing equipment, these dimensions must be increased.

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 diffusion 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 VSLab® S system has been designed for a concrete strength at time of stressing ($F_{(0,0)} = F_{max}$):

$$f_{cm0} \geq 20 / 25 \text{ N/mm}^2 \text{ (cyl. / cube)}$$

The dimensions of the anchorage, the anchorage spacing and the layout of the local reinforcement (applicable for $P_{(0,0)} = P_{max}$) are given in the chapter § 6.3.2 Concrete reinforcement of the anchorage local zone @ $f_{cm0} \geq 20/25$ MPa.

Two options for the layout of the steel reinforcement are presented in this chapter:

- Transverse stirrups
- Rectangular spiral

The anchorage blocks presented in this ETA are prismatic and have rectangular cross section with dimensions X⋅Y (length by width). The anchorages are centered in the block, which has two axes of symmetry.

It is however possible to adopt a modified block with dimensions A x B, by diminishing one of the two dimensions (either length A or width B) until 0.85 times the original value. In this case, the other dimension 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⋅Y).

In addition A and B have to be bigger than the minimum values X_{min} and Y_{min}. The **minimum slab thickness** has to be respected as per data sheet in § 6.3.2 Concrete reinforcement of the anchorage local zone.

For each of the two possibilities of rebar (transverse stirrups and rectangular stirrups), the two extreme configurations are presented in chapter § 6.3.2 Concrete reinforcement of the anchorage local zone @ f_{cm0} ≥ 20/25 MPa:

- Layout of reinforcement with minimum slab thickness
- Layout of reinforcement with minimum anchorage spacing

When two anchorages are located in the same cross section, their anchorage blocks should not overlap.In addition, they should remain inside the concrete.

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 compensate the concentrated post-tensioning force.

In all cases, the general anchorage zone must contain reinforcement for equilibrium designed by the project designer in accordance with the applicable design rules (refer to § 6.3.2 Concrete reinforcement of the anchorage local zone).

As foreseen by this ETA, 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

4.1 STRESSING EQUIPMENT

The VSL equipment used for stressing is primarily composed of stressing jacks, hydraulic power packs (commonly called pumps) and the associated set of measurement instruments or systems.

4.1.1 Stressing jacks

The strands are individually stressed by means of VSL stressing jacks, which are available according to two types:

- A double acting front-gripping hollow piston jack,
- A twin ram double acting jack, with two parallel pistons laid out on both sides of the strand.

This equipment enables stressing the strand in one or several stages and then, if needed, to de-stress the strand.

These jacks are composed of:

- 1 nose (chair ring) at the front resting upon the anchorage body and connected to a seating ram (depending on the model)
- 1 body or cylinder, composed of one or two jacks and resting upon the chair ring
- 1 auxiliary anchorage driven by the piston(s) and laid out as close as possible to the anchorage installed in place in order to limit the over length of the strands. The un-gripping of the jack anchorage is performed automatically.

List of VSL jacks:

Designation		DKP 6	ZPE 23 FJ
Type		**2 parallel pistons**	**1 hollow piston**
Cross section	mm^2	240 x 165	∅ 116
Length	mm	615	790
Weight	kg	30	23
Stroke	mm	200	200
Ram area	mm^2	4 926	4 710
Maximum pressure	bar	467	488
Maximum force	kN	230	230
Presence of seating ram	-	No	Yes

The drawings in § 6.4 Stressing equipment, indicates the clearances to be introduced around the anchorages at the extremities of the post-tensioned structures in order to allow anchorage installation and stressing.

4.1.2 Hydraulic pumps

The VSL hydraulic pumps are typically driven by electric motors that are connected to distributors, nozzles and safety valves. They and have been designed for normal stressing speeds and include safety elements for each specific application.

4.1.3 Instruments and measuring systems

The VSL force and elongation measurement instruments or systems serve to control with precision the stressing operation and display the results obtained.

4.2 PROCESSES OF STRESSING AND CONTROL PROCEDURE

Before stressing a tendon, the following conditions must be met:

- All pertinent safety measures must be implemented
- The target forces and elongations (as well as the tolerances) must be known by the PT Supervisor, who will eventually make the necessary adjustments to account for parameters specific to the equipment
- The order in which the prestressing cables (and strands in the cable) are to be stressed must be specified,
- The stressing equipment (including measurement instruments) must comply with the guidelines of this ETA
- The concrete below the anchorage and in the prestressed structure has to be homogeneus and must have achieved the required strength.
- The structure is free to move and the loads are compatible with stressing.
- The overlengths of the strands to be stressed are clean

All safety rules must be respected during stressing. In particular, it is strictly forbidden to be positioned behind the jack or within its immediate vicinity. The same precautions must be taken for the area in the back of the accessible dead-end anchorages.

Even though the VSL PT System does not require mechanical locking, the wedges may be set in order to reduce the losses due to wedge draw-in.

4.2.1 Elongation measurements

In order to obtain the elongation, a reference mark can be made on the strands. It is also possible to measure the elongation at each stressing stage by measuring the movement of the jack piston and making the necessary corrections. In particular, the measurement obtained during the first stressing operation has to be corrected to take into account the slack of the tendons.

All the stressing data (type of jack, target force and elongation, values of pressure-elongation, etc.) are recorded in a stressing data sheet.

For details, refer to § 2.6.2 Basis for evaluating elongations.

4.2.2 Force measurements

The force in the cable (and the corresponding value of pressure on the stressing jack) are generally the controlling parameters for stressing.

The pressure inside the jack chamber is indicated by the manometer installed on the pump or, if required, on the jack. The manometers used (Accuracy 1%) are regularly calibrated and have a guaranteed precision of 1% of their maximum pressure, which is usually in the range of 490 bars. These instruments have therefore a precision of 6 bars over the entire manometer scale.

The actual force applied to the structure is calculated taking into account the losses inside the jack and the friction losses inside the anchorage.

Losses inside the jacks are measured during the calibration. They can be estimated by a bilinear function with a fixed term and a linear term proportional to the pressure. For the usual cases, when the jacks reach the stressing pressure, the losses inside jacks are:

- DKP 6 jack: 3.5%
- ZPE 23 FJ jack: 1.5%

The losses in active anchorages, named k_a, are due to friction of the strands deviated on the component parts and, depending on the specific anchorage, exhibit the following values:

	VSLab® S 6-2	VSLab® S 6-3	VSLab® S 6-4	VSLab® S 6-5
General	2%	2%	1%	1%
Outer strands	2%	2%	1%	1%

5 INJECTION AND SEALING

5.1 INJECTION

5.1.1 General information:

The nature and composition of injection products for the permanent protection of tendons and anchorages and for their bonding to the structure are defined by the project.

The products used must not be a threat to the hygiene, health and the environment. In addition they must comply with the national provisions of requirements introduced by the Member States (such as national laws, regulations or administrative provisions).

The products used for the permanent protection of post-tensioning tendons and anchorages may be categorized as follows:

- Hydraulic cement-based injection grouts. These products are the most commonly employed. They can be common grouts as defined in the standard EN 447 or special grouts that make use of performance-enhancing admixtures. Unfavourable climatic conditions may impose the application of special grouts according to EAD 160027-00-0301.
- Injection products covered by an ETA.

Completion of the tendon envelope in the anchorage zone is provided at the time of injection by means of either temporary or permanent grouting caps.

5.1.2 Injection equipment:

The set of injection equipment has been adapted to the products to be injected.

For the cement-based grout, the VSL injection equipment is composed for the most part of mixers and pumps integrated into a single set of equipment that enables preparing the grout and performing the injection. This equipment allows to dose the grout components accurately and to obtain a perfectly-homogeneous mix. The pump with which the equipment is fitted has been designed for continuous injection at a suitable speed.

5.1.3 Injection procedures:

Before proceeding with the injection of a permanent cable protection, a certain number of conditions must be fulfilled and in particular:

- The injection product must comply with the terms of the present ETA.
- The injection equipment must comply with indications laid out in the present ETA.
- The waterproof sealing of the tendon and anchorage envelopes (ducts, fittings, pipes and caps) must be verified.
- The climatic conditions and temperature of the structure must satisfy the use conditions of the injection product.

The main controls conducted during injection consist of verifying the adequate filling of the duct by means of inlets, bleed vents and outlets along the cable path and checking that the product flowing out of the vents has the required properties.

Grouting procedures and grouting surveillance shall be carried out according to EN 446. All the relevant data for grouting shall be recorded on the injection data sheets.

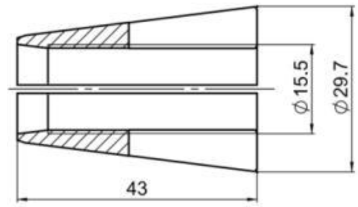
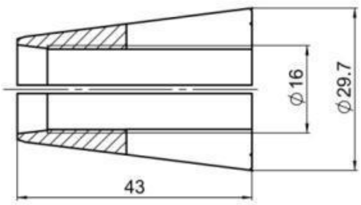
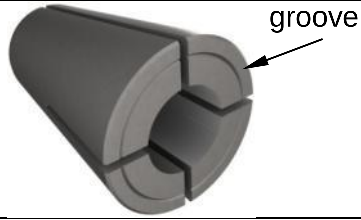
5.2 SEALING

The continuity of protection against all types of aggressions must be ensured all along the cable including the anchorages.

The protection measures introduced for the anchorage zone, which is located at the end of the slab and frequently protected from external aggressions, is most often limited in this case to the patching of the block-out with mortar or concrete. In the case of end zones exposed to aggressive environment additional protection measures may be necessary (permanent cap or waterproof lining).

6 SCHEMATIC DRAWINGS

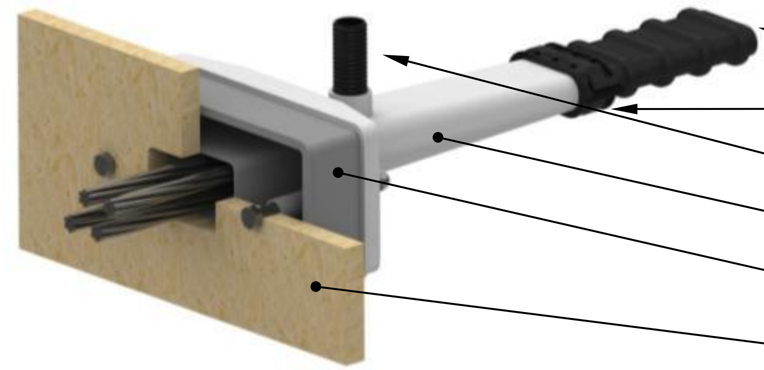
6.1 STANDARD COMPONENTS

Designation	Option	Main dimensions
Wedge **W6N**	Used with a strand diameter of 15.3 mm	 
Wedge **W6S**	Used with a strand diameter of 15.7 mm	 

all dimensions in [mm]

6.2 VSLAB® S 6-2 TO 6-5 – PRINCIPLE

6.2.1 Before concreting (placing devices)



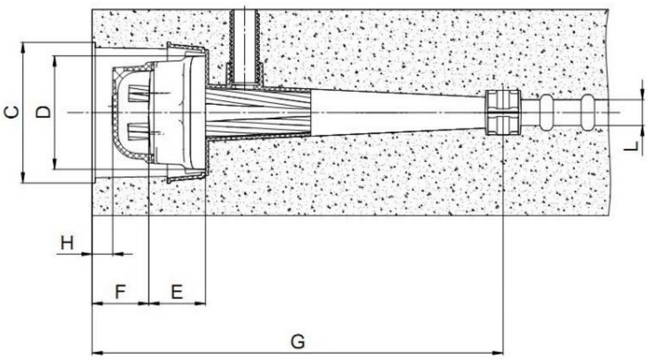
VSLab® system principle before concreting
(concrete steel reinforcement not shown)

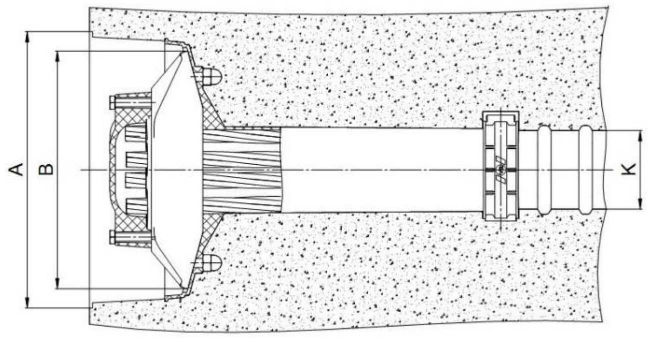
6.2.2 After post-tensioning

VSLab® S system principle after post-tensioning
(concrete steel reinforcement not shown)

6.3 VSLAB® S SYSTEM 6-2 TO 6-5 – MAIN DIMENSIONS

6.3.1 Anchorage body and trumpet



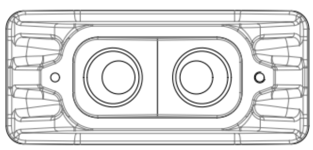


Unit	A	B	C	D	E	F	G	H	K [1)]		L [1)]	
									Out	In	Out	In
6-2	175	170	80	75	55	60	315	20	51	37	35	21
6-3	215	210	95	90	55	60	460	20	68	54	35	21
6-4	235	230	115	110	60	60	440	20	86	72	35	21
6-5	265	260	130	125	60	60	440	20	104	90	35	21

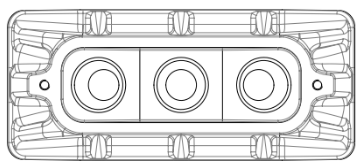
1) Flat duct with PT-PLUS® ducting system

all dimensions in [mm]

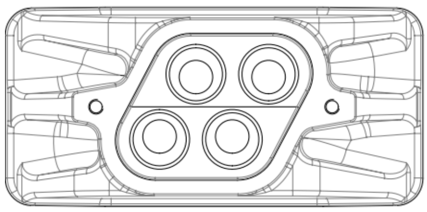
VSLab® S 6-2 Anchorage Body



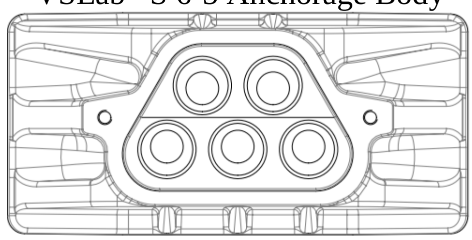
VSLab® S 6-3 Anchorage Body



VSLab® S 6-4 Anchorage Body



VSLab® S 6-5 Anchorage Body

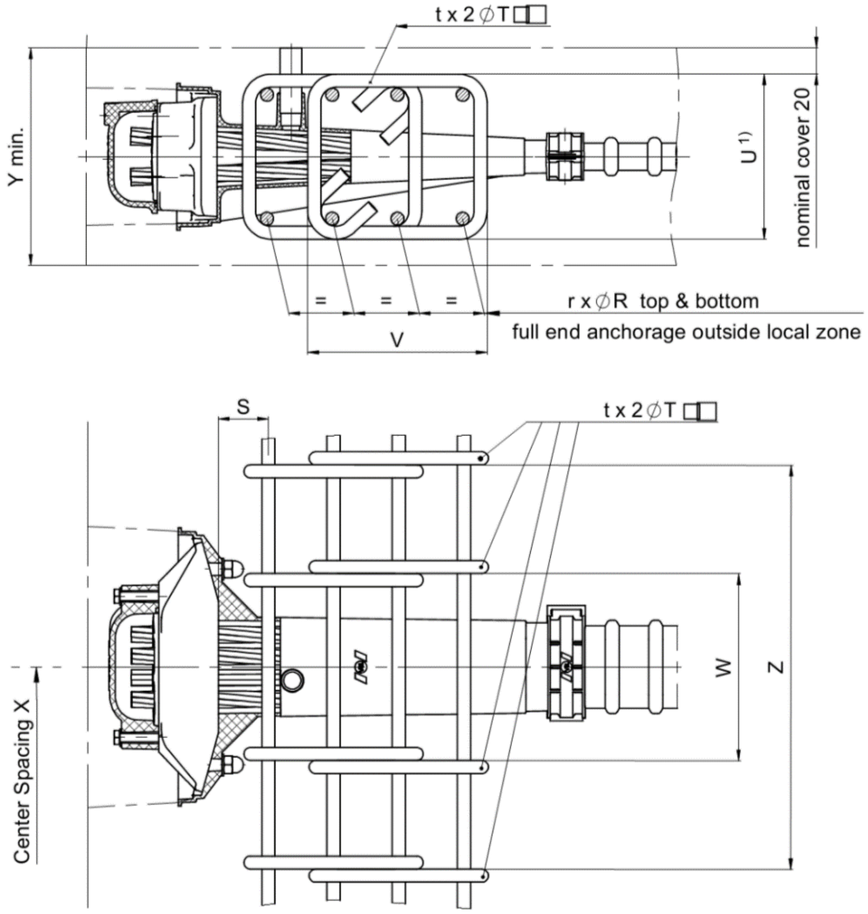


6.3.2 Concrete reinforcement of the anchorage local zone @ f_{cm0} ≥ 20/25 MPa

Local zone reinforcement is based on 110% GUTS of tendon unit and is optimized for minimal dimensions of the local load introduction zone.

Reinforcement fy ≥ 500N/mm² bent in accordance with Eurocode 2
Strand type Y1860 S7-15.7 (A_p=150.0mm²; f_{pk}=1'860N/mm² (GUTS); F_{pk}=279kN)
Max. stressing force 80% GUTS.

a) With transverse stirrups



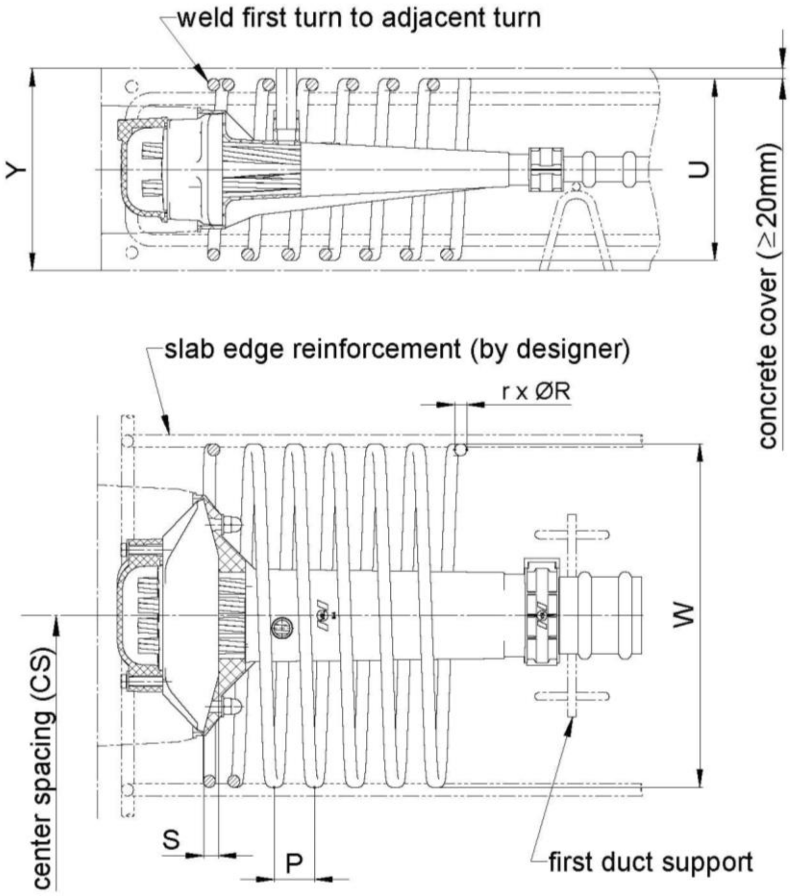
Unit	r	ØR	S	t	ØT	U_{min}	U_{max}	V	W	Z	X[2)]	Y_{min}
6-2	4	10	20	2	10	110	120	130	210	-	240	160
6-3	4	14	30	2	14	130	150	150	300	-	310	180
6-4	4	14	35	4	14	150	180	150	180	290	360	200
6-5	4	14	35	4	14	170	200	170	200	330	400	220

all dimensions in [mm]

r = number of transverse bars
t = number of pairs of links
Y_{min} = minimum allowable slab thickness

Notes:
1) Depending on slab thickness and required concrete cover $U_{min} \leq U \leq U_{max}$
2) Min. edge distance: X/2 + ØT + concrete cover

b) With rectangular spiral



					Values for minimum slab thickness				Values for minimum anchorage spacing			
Unit	**P**	**r**	**ØR**	**S**	U_{mst}	W_{mst}	Y_{mst}	CS_{mst}	U_{mas}	W_{mas}	Y_{mas}	CS_{mas}
6-2	35	6	12	10	120	255	160	275	145	220	185	240
6-3	40	6	12	0	140	330	180	350	180	260	220	280
6-4	40	7	12	10	160	380	200	400	220	280	260	300
6-5	35	8	12	15	180	420	220	440	250	310	290	330

all dimensions in [mm]

r = number of turns
S=distance from base of anchorage to first transverse bar
U, W= outer dimensions of rectangular stirrup
Y=slab thickness with minimum concrete cover of 20 mm
CS= center spacing between anchorages

Notes:
1) Values are minimum for a concrete cover of 20 mm
2) Min. edge distance: W/2 + concrete cover

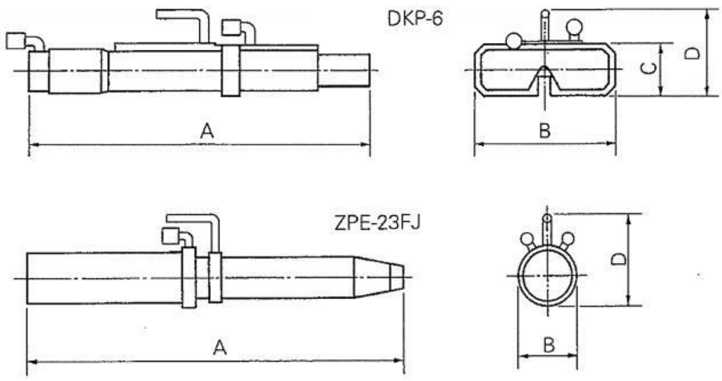
6.4 STRESSING EQUIPMENT

Stressing jack type DKP-6

This twin-ram jack is optimized for short clearance spaces (block-outs) and may also be used for intermediate anchorages. It must be equipped with the chair appropriate for the particular operation.

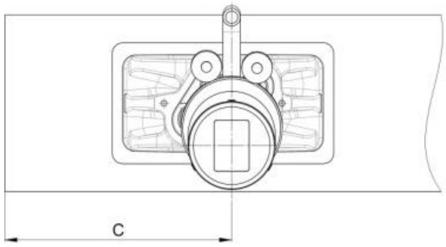
Stressing jack type ZPE-23 FJ

This is a front-gripping hollow piston jack with seating ram. It is not suitable for intermediate anchorages. Different chairs allow the use for many different anchorages.

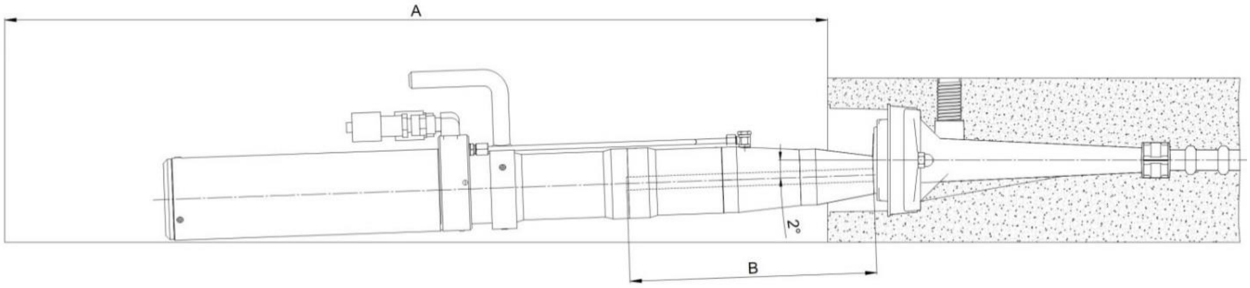


Jack type		DKP-6	ZPE-23 FJ
A	[mm]	580	865
B	[mm]	240	116
C	[mm]	84	-
D	[mm]	165	195
Stroke	[mm]	200	200
Piston area	[cm^2]	49.26	47.1
Capacity	[kN]	230	230
	[bar]	467	488
Weight	[kg]	30	23

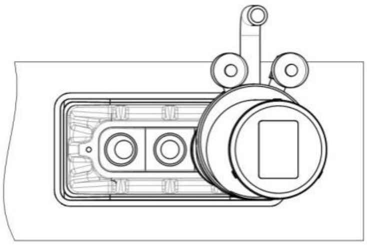
Front view with VSLab® S 6-4



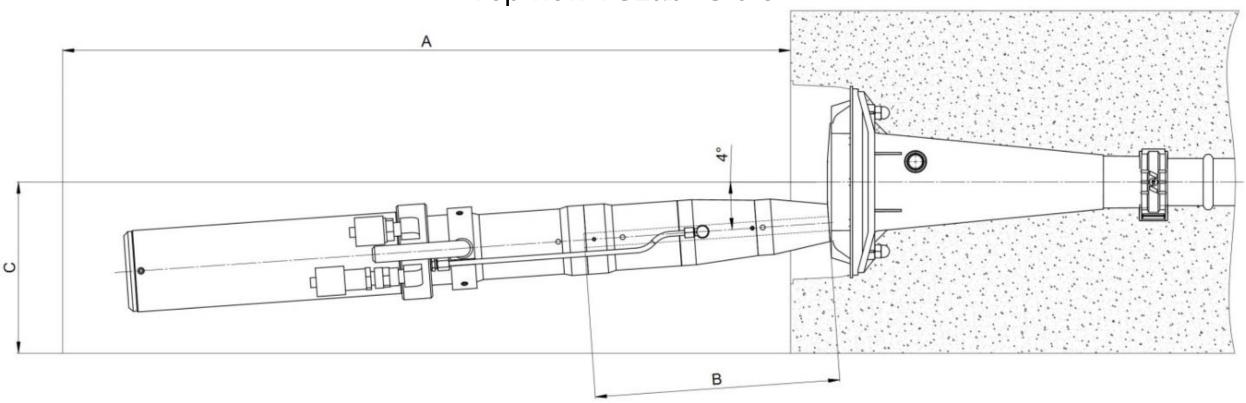
Side view VSLab® S 6-4



Front view VSLab® S 6-3



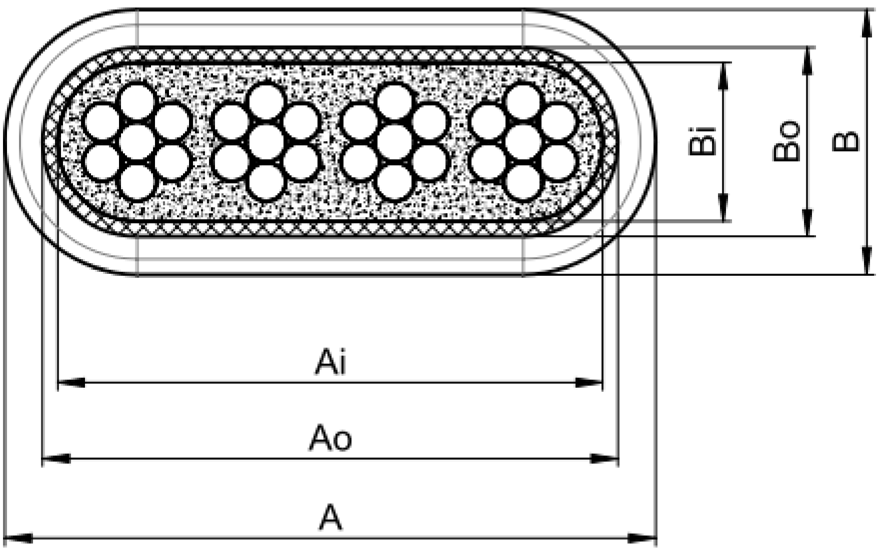
Top view VSLab® S 6-3



Jack type	A	B (strand overlength)	C
DKP 6	1'000	400	300
ZPE-23 FJ	1'100	300	300

all dimensions in [mm]

6.5 DUCTING



Dim.	Corrugated flat steel strip sheath				Corrugated flat plastic duct VSL PT-PLUS®			
	VSLab® S unit				VSLab® S unit / Nominal size of VSL Plus® duct			
	6-2	6-3	6-4	6-5	6-2	6-3	6-4	6-5
					37/21	54/21	72/21	90/21
A	40	57	75	93	51	68	86	104
B	-	-	-	-	35	35	35	35
Ai	37	54	72	90	37	54	72	90
Bi	18	18	18	18	21	21	21	21
Ao	-	-	-	-	41	58	76	94
Bo	21	21	21	21	25	25	25	25

all dimensions in [mm]

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**	**Documentation**
Anchorage zone components					
Anchor head[9]	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
Wedges	Material[6]	Check	full	100% [8]	"3.1"[1]
	Treatment, hardness	Test		0.5% [8] ≥ 2 elements	Yes
	Detailed dimensions[5]	Test		5% [8] ≥ 2 elements	Yes
	Visual inspection[3]	Check		100% [8]	No
Current zone components					
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	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/labeling, 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.

9 The inner and outer condition of cast iron components shall be tested for every batch/unit of manufacture and documented with inspection certificate “3.1” according to EN 10204:

- Outer condition: ≤ severity level SM2, LM2, AM2 according to EN 1369:1997 (magnetic particle inspection) and ≤ severity level determined for the components at the time of assessment testing (see Table 5.0),
- Inner condition: ≤ severity level 2 according to EN 12680-3 (ultrasonic testing) and ≤ severity level determined for the components at the time of assessment testing (see Table 5.0).

Inner condition shall be tested either with ultrasonic testing according to EN 12680-3 or with destructive testing.
Outer condition shall be tested with magnetic particle inspection according to EN 1369.

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
Anchor head	Material according to specification	Check, test	1
	Detailed dimensions	Test	
	Visual inspection [10]	Check	
Wedges	Material according to specification	Check, test	2
	Treatment	Test	2
	Detailed dimensions	Test	1
	Main dimensions, surface hardness	Test	5
	Visual inspection [10]	Check	5
Corrugated plastic/polymer duct	According to fib Bulletin 75, Chapter 9		1 for material; 2 duct sizes and 2 components
Single tensile element test	Single tensile element test according to Annex C.7 of EAD -160004-00-0301	Test	1 series
Inclined Tube test	Inclined Tube test as per EN 445 [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/labeling, 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 and this ETA.

ANNEX 3 REFERENCE STANDARDS AND GUIDELINES

1 MATERIAL AND REFERENCE STANDARDS

Component	Material	Standard
Cast iron anchor head	Cast iron	EN 1563
Wedges	Case hardening or free-cutting steel	EN 10084, EN 10087, GB/T 3077, GB/T 5216
Corrugated sheaths	Metal strip	EN 523
Polymeric duct	Polymeric material	Fib bulletin 75
Grout	Cement, additives	EN 447
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 10084:2010	“Case hardening steel – Technical delivery conditions
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”
GB/T 3077-1999	“Alloy structure steels”
GB/T 5216-2004	“Structural steels subject to end-quench hardenability requirements”