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POST-TENSIONING KITS FOR PRESTRESSING OF STRUCTURES

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1 SCOPE OF THE EAD

1.1 Description of the construction product

This EAD serves to obtain ETAs for post-tensioning kits for prestressing of structures. Post-tensioning kits are more commonly referred to by the industry as PT Systems. They will be called PT kits or PT systems in this document.

This Document considers post-tensioning kits for prestressing of structures or parts of structures.

The product is not covered by a harmonised European standard (hEN).

PT systems at least contain tensile elements, anchorages, ducts, and filling material. If required monostrands, couplings, deviators, bursting reinforcement and any other special accessories as needed are part of the PT system. Figure 1 shows a schematic representation of an installed PT system.

The document is only valid for PT kits containing anchorages meant to be placed on or embedded in concrete according to EN 1992-1-1 or EN206.

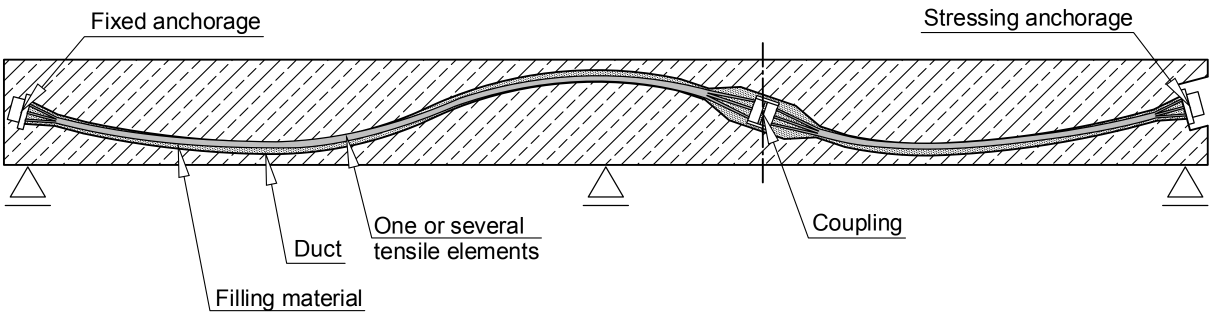

Figure 1 – Installed PT system / PT kit – Schematic example

The list below details the minimum specifications of all components suitable for the assessment of the PT kit according to the document:

- Only tensile elements (wires, strands, or bars), complying with the specifications of prEN 10138-2:2009 table 4, prEN 10138-3:2009 table 4 or prEN 10138-4:2009 table 2 in terms of geometry, and characteristic force or complying with the regulations in place of use, are covered by this EAD. No essential characteristics are assessed for tensile elements in this EAD.

- Monostrand is a single strand with its individual protection by grease and plastic sheathing (it is permanently unbonded from the structure).

  The base material for the sheathing is a high density polyethylene that complies with the essential characteristics detailed in Table 1. Recycled material is not covered unless it is from the same factory and production process.

  Tensile elements are prestressing steel strands as described above and filling materials are according to EAD 160027. Monostrands can be assessed through this document, but monostrands according to standards and regulations in force at the place of use are equivalently acceptable.

- Anchorages are devices used to anchor the tensile elements to a structure or a member. They are available in two basic forms as “stressing” and “fixed” anchorages. Stressing anchorages are mechanical devices that are made of different components such as anchor head, bearing plate, wedges, trumpet and sleeves as defined by the ETA applicant. Stressing anchorages for single strand tendons may be used as intermediate anchorages. Fixed anchorages may be mechanical devices or may be formed by bond of the tensile elements to concrete. Anchor heads are made of steel or ductile cast iron. Anchor plates are made of steel, cast iron, mortar or concrete. In the last two cases, attention has to be paid to the potentially brittle behaviour of such anchorages. Fatigue and creep behaviour have also to be checked. This EAD applies if non brittle behaviour of force transfer unit (FTU) is ensured through steel or cast iron or suitable confinement if the part in mortar or concrete is only submitted to compression. In any case, the material(s) used for FTU shall be standardized (steel, cast iron, mortar, concrete, …). Anchorages are assessed in this EAD.

Note 1: in the case of a kit containing anchor plate made of mortar or concrete, possible shrinkage or creep effects have to be considered when evaluate this kit.

Note 2: In the case of an intermediate anchorage (see definition in section 1.3), overlapping wedge bites on the strand and angular deviation of the strand before or behind the intermediate anchorage shall be avoided. The intermediate anchorage can only be used in structures where fatigue verification is not required for tendon (some guidance is provided in EN 1992-2 section 6.8 clause 102).

- Couplings are devices used to connect adjacent sections of tensile elements. Movable couplings connect adjacent sections of tensile elements that are intended to be stressed at the same time. Fixed couplings connect a first section of tensile elements installed and stressed initially, to a second section installed and stressed subsequently. They are made of different components as specified by the ETA applicant. Only coupling devices made of steel and ductile cast iron are covered. Couplings are assessed in this EAD.
- Ducts are used to isolate, guide, and protect the tensile elements. They can consist of :
    - Steel strip ducts. Only steel strip ducts complying with EN 523 (harmonised standard) are covered.
    - Smooth plastic pipe. Only smooth plastic pipe complying with Annex D.1 are covered.
    - Corrugated plastic ducts as per *fib* Bulletin 75. Assessed in this EAD.
- Filling materials are situated inside the anchorages and the ducts. They can be made of:
    - Cementitious grout complying with rules in the place of use and, if non-contradicting, as per EN 447 (non harmonised standard).
    - Cementitious grout, wax or grease as per EAD 160027.
- Pipes or special details provide a defined deviator for external tendons at designated locations in a structure. Such deviator pipes are often made of smooth steel pipe. Only components complying with EN 10210-1 (harmonised standard), EN 10216-1 (harmonised standard), EN 10217-1 (harmonised standard), EN 10219-1 (harmonised standard), EN 10255+A1 (harmonised standard), EN 10305-5 (non harmonised standard), or ISO 4200 are covered.
- A recess inside concrete elements or structural steel saddles may be used to form the tendon deviator. No essential characteristics for deviators are assessed in this EAD.
- Bursting reinforcement provides confinement to concrete elements that contain the tendon anchorages and/or tendon deviators for a safe introduction of the prestressing loads at anchorages or deviators into the concrete elements or structures. Bursting reinforcement according to EN 1992-1-1, EN 10025 (harmonised standard) or directly specified by the ETA are covered.

- Special accessories facilitate installation, stressing, filling of duct, detensioning, and replacement of the prestressing kit including duct vents and duct drains, specific tendon support devices, temporary or permanent caps at anchorages and couplings, connectors for duct lengths/sections or for ducts to anchorages, etc. Accessories are assessed in this EAD where relevant for practicability and durability.

Post-tensioning kits made of other components than those listed above are not considered.

Ground anchors, external tendons with the tendon path outside the envelope of the structure or member, and stay cables, are not covered by this EAD. (The envelope designates here the line or the contour connecting all the extreme points of the cross section).

This EAD covers components made of materials complying with harmonized European Technical specifications, and where these do not exist with non harmonized EN, ISO standards or if none of these exist with national specifications and standards or recommendations by *fib*.

The ETA applicant has to define which components listed above are included in the ETA and provide sufficient details to define each component (material specifications and geometry with fabrication tolerances)..

Copies of manufacturing drawings and specifications of the PT system and components in sufficient detail to define manufacturing (e.g. chemical composition of materials not defined in standards and fabrication tolerances) need to be deposited at the Technical Assessment Body (TAB) and Notified Body (NB). These documents are confidential and proprietary and shall not be given to other parties.

Concerning product packaging, transport, storage, maintenance, replacement and repair it is the responsibility of the manufacturer to undertake the appropriate measures and to advise his clients on the transport, storage, maintenance, replacement and repair of the product as he considers necessary.

Relevant manufacturer’s stipulations having influence on the performance of the product covered by this European Assessment Document shall be considered for the determination of the performance and detailed in the ETA.

1.2 Information on the intended use(s) of the construction product

1.2.1 Intended use(s)

The following basic intended uses are considered:

- Internal bonded tendon for concrete and composite structures (with anchors placed in concrete),
- Internal unbonded tendon for concrete and composite structures (with anchors placed in concrete),
- External tendon for concrete and composite (steel-concrete) structures with a tendon path situated outside the cross section of the structure or member but inside its envelope (with anchors placed in concrete). Included are ring tendons for e.g. tanks, placed circumferentially onto the outer surface of the structure.

Optional Use Categories that go beyond the above basic intended uses of tendons with its post-tensioning system can also be considered:

- Internal tendon for cryogenic applications with anchorage (coupling assembly) outside the possible cryogenic zone,
- Internal tendon for cryogenic applications with anchorage (coupling assembly) inside the possible cryogenic zone,
- Internal bonded tendon with corrugated plastic duct made of HDPE or PP,
- Encapsulated tendon,
- Electrically isolated tendon.

The ETA applicant has to choose at least one of the three basic uses. Optional use(s) can also be considered if requested by the manufacturer. Each use(s) needs to be assessed according to Chapter 2 and specified in the ETA. Options that combine different Use Categories, such as e.g. an encapsulated tendon for use in cryogenic applications, shall be verified for requirements of each Use Category, i.e. for use in encapsulated tendon and for cryogenic applications.

0 summarises the different types of PT kits and give details about the different use categories.

Post-tensioning kits are for use in:

- New construction,
- Repair and strengthening of existing structures.

Post-tensioning kits are intended to be used whenever structural Eurocodes or equivalent national codes refer to "prestressing for post-tensioned construction”.

Post-tensioning kits are primarily used in structures made of concrete. They can, however, be used with other structural materials such as steel, masonry, and timber. However, these applications are not covered by this document.

Post-tensioning kits can be used in any type of structure but are found most frequently in:

- Bridges (superstructures, piers, abutments, foundations),
- Buildings (floors, foundations, core walls, walls, lateral load resisting frames),
- Reservoirs (walls, floors, roofs),
- Silos (walls),
- Towers of wind turbines,
- Nuclear containment structures,
- Offshore structures (all parts),
- Barges and floating platforms (all parts),
- Retaining walls,
- Dams,
- Tunnels (longitudinal and transverse/hoop tendons),
- Large diameter pipe,
- Pavements and roads.

1.2.2 Working life/Durability

The assessment methods included or referred to in this EAD have been written based on the manufacturer's request to take into account a working life of the PT kit for the intended use of 100 years when installed in the works (provided that the PT kit is subject to appropriate installation (see 1.1)). These provisions are based upon the current state of the art and the available knowledge and experience.

When assessing the product, the intended use as foreseen by the manufacturer shall be taken into account. The real working life may be, in normal use conditions, considerably longer without major degradation affecting the basic requirements for works[2].

The indications given as to the working life of the construction product cannot be interpreted as a guarantee neither given by the product manufacturer or his representative nor by EOTA when drafting this EAD nor by the Technical Assessment Body issuing an ETA based on this EAD, but are regarded only as a means for expressing the expected economically reasonable working life of the product.

Note: this EAD also covers PT kits for temporary uses. In this case the kit has to be assessed in the same way but its properties in terms of durability will be different (for example corrosion protection). For temporary use, a working life of 2 years will be considered.

[2] The real working life of a product incorporated in a specific works depends on the environmental conditions to which that works is subject, as well as on the particular conditions of the design, execution, use and maintenance of that works. Therefore, it cannot be excluded that in certain cases the real working life of the product may also be shorter than the working life referred to above.

1.3 Specific terms used in this EAD (if necessary in addition to the definitions in CPR, Art 2)

Terminology

1.3.1 Accessories

Auxiliary components used in a PT system to facilitate installation, stressing and duct filling, such as duct vents, duct drains, specific tendon support devices, temporary or permanent caps at anchorages and couplings, and connectors for duct lengths/sections or for ducts to anchorages.

1.3.2 Anchor Head/Block

Part that holds one or several tensile elements by wedges/button heads/nuts and transfers the prestressing load to the bearing plate, or for small tendon sizes directly into the structure. The anchor head is sometimes called a “wedge plate”.

1.3.3 Anchorage

A mechanical device, usually comprising several components, designed to retain the force in the stressed tendon, and to transmit the force to the structure.

1.3.4 Anchorage Cap

A special cap made of steel or plastic to encapsulate the end of the tensile elements at the anchorage.

1.3.5 Anchorage Component

Part of the anchorage or coupling such as wedge/button head/nut, anchor head or bearing plate.

1.3.6 Bearing Plate

Part that supports the anchor head and transfers the prestressing load onto or into the structure. The bearing plate is sometimes called a “force transfer unit”.

1.3.7 Bursting Reinforcement

Reinforcement in the local anchorage zone, just adjacent to the anchorage, to confine the concrete, and to resist transverse tensile loads due to the introduction of the prestressing load. This reinforcement forms part of the kit.

1.3.8 Button Head

Part that holds an individual tensile element, typically a wire, and transfers the prestressing force to the anchor head, or for an individual tensile element directly to the bearing plate.

1.3.9 Coil

Delivery unit of strands, monostrand or wires, generally made of a cylindrical shape

1.3.10 Component Manufacturer

Company, which manufactures components of the PT kit that correspond to the specifications of the ETA holder.

1.3.11 Compression fitting

A cylindrical steel component that is extruded/cold deformed over the tensile element such as to provide a tight fit with the tensile element allowing to anchor the tensile element force.

1.3.12 Connector

Special element to join individual duct lengths/sections between each other or to join a duct segment to the anchorage or trumpet.

1.3.13 Coupling/Coupler

A device to join adjacent sections of tendons.

1.3.14 Deviator

A structural element where external tendons are deflected, and tendon forces are transmitted to the structure.

1.3.15 Drain

Tube or hose that permits water to drain from the duct at low points of the tendon profile.

1.3.16 Duct

An enclosure in which tensile elements are placed and that temporarily or permanently allows relative movement between the tensile elements and the surrounding concrete. The remaining void within the duct can subsequently be filled with filling material.

1.3.17 Duct Support

A device that supports and firmly holds a duct in position.

1.3.18 Encapsulated Tendon

A tendon that is provided with a leak tight envelope over the entire tendon length (duct, anchorage and cap). (Note: according to *fib* Bulletin 75 an Encapsulated Tendon provides tendon protection level PL2).

1.3.19 Electrically Isolated Tendon (EIT)

A tendon that is encapsulated in an electrically isolating envelope and thus is electrically isolated from the surrounding structure. (Note: according to *fib* Bulletin 75 an EIT provides tendon protection level PL3).

1.3.20 Filling Material

A material used to completely fill the space around the tensile elements inside a duct to provide corrosion protection and/or bond. A cementitious filling material is also called “grout”.

1.3.21 Force transfer unit (FTU)

See Bearing plate.

1.3.22 Fixed Anchorage

Anchorage that does not allow stressing, or anchorage formed by bond between tensile elements and concrete (bond anchorage).

1.3.23 Fixed Coupling

Coupling that allows joining of adjacent tendon sections stressed not at the same time.

1.3.24 Friction Coefficients

Coefficients used to calculate loss of tendon force during stressing due to friction between the tensile elements and the duct at intentional tendon curvature.

1.3.25 Friction Loss

Loss of prestressing force during stressing of the tensile elements due to friction between the tensile elements and the duct at intentional tendon deviations.

1.3.26 Grout

A cementitious filling material with characteristics according to EN 447 or EAD 160027. As EN 447 is a non harmonised standard, national regulations in place of use might apply, if grout according to EN 447 is considered.

1.3.27 Intermediate Anchorage (for single strand with mechanical anchorage only)

Can be used when structures are built in steps. The intermediate anchorage anchors temporarily one (single) strand in a first section before the second section is built and the whole strand is stressed from the other end of the second section. After stressing the whole strand from the second section, the anchorage remains in the structure without taking any forces. The anchorage can be used for internal bonded or internal unbonded tendons.

1.3.28 International Organisation

Organisations such as *fib*, ISO, ...

1.3.29 Mean Actual Tensile Strength

Mean value of the actually measured tensile strength of tensile elements determined from a minimum of 3 single tests.

1.3.30 Monostrand

A single strand with its individual protection by grease and HDPE sheathing. It is permanently unbonded from the structure.

1.3.31 Movable Coupling

Coupling that allows joining of adjacent tendon sections stressed at the same time.

1.3.32 Nut

Piece that holds an individual tensile element, typically a bar, and transfers the prestressing force to the anchor head, or for an individual tensile element directly to the bearing plate. Nuts can also be components of anchorages or couplers.

1.3.33 Pipe

A thick walled smooth duct made of plastic or steel.

1.3.34 Plastic Duct

See polymer duct.

1.3.35 Polymer Duct

A duct and duct system for bonded internal post-tensioning that is manufactured of polypropylene or polyethylene in accordance with *fib* Recommendations (*fib* Bulletin 75).

1.3.36 Post-Tensioning System

For ease of reference it is called “PT system” in the text.

1.3.37 PT Specialist Company

Company which carries out installation, stressing and filling of duct of the PT system.

1.3.38 PT Kit Component

Part of a PT kit such as tensile element, anchorage, coupling, duct, filling material, deviator, bursting reinforcement and special accessories.

1.3.39 Series

A specific model of an anchorage, coupling, duct, or tendon, etc., which typically is made in several sizes, using the same design concept, materials, corrosion protection system and similar geometrical shape for all sizes form a series.

1.3.40 Sheath

See Duct.

1.3.41 Sheathing

An enclosure encapsulating a single tensile element, usually separated by a thin layer of grease or wax from the tensile element. Typically monostrands are equipped with polymer sheathing.

1.3.42 Stressing Anchorage

Anchorage allowing stressing of the tendon, usually a mechanical anchorage.

1.3.43 Tendon

A single tensile element or a bundle of tensile elements used for the prestressing of a structure, including the required protection and anchorages.

1.3.44 Tensile Element

Individual element such as strand, wire or bar to impart prestressing.

1.3.45 Trumpet

Device used to join bearing plate to duct providing the necessary leak tightness and allowing a reduction of the bundle diameter in the case of multi tensile elements anchorage.

1.3.46 Vent

Tube or hose that permits air and water to escape the duct at high points and ends of the tendon profile.

1.3.47 Wedge

Part that holds an individual tensile element, typically a strand, and transfers the prestressing force to the anchor head, or, typically for a single tensile element but also feasible for several tensile elements, directly to the bearing plate.

1.3.48 Wobble

Unintentional angular deviation of a tendon due to placing tolerance of the duct that causes loss of prestressing load due to friction between tensile elements and duct at the deviations.

1.3.49 Notations

A_p Nominal cross-sectional area of tensile elements of tendon

A_{pm} Mean actual cross-sectional area of tensile elements of tendon

$(E\ I)_{eff}$ Effective duct stiffness

F_d, F_1 Lateral loads on duct

F_{bu} Test load for bond test of duct

F_{pk} Characteristic ultimate resisting force of tensile elements of tendon:
$F_{pk} = A_p \times f_{pk}$

F_{pm} Actual ultimate resisting force of tensile elements of tendon:
$F_{pm} = A_{pm} \times f_{pm}$

F_{pm0} Initial prestressing force of the tendon

$F_{p0.1k}$ Characteristic yield force of tensile elements of tendon:
$F_{p0.1k} = A_p \times f_{p0.1k}$

$F_{p0.1,\ cryo}$ Actual force at yield at cryogenic conditions of tensile elements of tendon

F_{pre} Longitudinal load on duct system

F_{Tu} Measured maximum force of tensile elements in tendon assembly

F_u Measured maximum force in load transfer test

max F Upper load in the fatigue test (dynamic load test) with tendon assembly

min F Lower load in the fatigue test (dynamic load test) with tendon assembly

ΔF Load range in the fatigue test (dynamic load test): ΔF = max F – min F

L Length of specimen of duct system

N Number of sizes to be tested

P_{max} Prestressing force at x = 0 m

R_{min} Minimum radius of curvature of a particular tendon specified by ETA holder

R, C, D Electrical resistance, capacitance, and loss factor of duct system

α Angular deviation of tendon at deviator

α_T Thermal expansion coefficient of duct

ε_{TU} Elongation of tensile elements on free length of tendon at maximum force F_{Tu}

ε_v Longitudinal strain on surface of load transfer test specimen

ε_t Transverse strain on surface of load transfer test specimen

μ Friction coefficient between duct or pipe and tendon

ϕ Nominal diameter of prestressing steel strand

θ Sum of the total angular deviation of the tendon between 0 and x

Δ Elongation of duct system

ΔP_μ Losses of prestressing force along the tendon path due to friction

$\Delta\sigma_p$ Stress range in the fatigue test (dynamic load test)

r, Δr Relative load – and time – dependent displacement between the individual components of the anchorage

s, Δs Relative load – and time – dependent displacement of the tensile elements with respect to the anchorage

Δt Deformations of the anchor head in circumferential direction

Δz Deflections of the anchor head relative to the supporting plate

a Reference dimension of cross section of load transfer test specimen specified by ETA-holder, measured in x-direction
Dimension of test specimen of assembly, stressing test

b Reference dimension of cross section of load transfer test specimen specified by ETA-holder, measured in y-direction
Dimension of test specimen of assembly, stressing test

c	Concrete cover of reinforcement Dimension of test specimen of assembly, stressing test
d_1, d_2	Diameters of duct
$d_{duct,i}$	Internal diameter of circular duct
d_{strand}	Diameter of strand
h	Height of load transfer test specimen Dimension of test specimen of assembly, stressing test
k	Wobble coefficient
l	Dimension of test specimen of assembly, stressing test
w	Crack width in load transfer test
max w	Maximum crack width measured in the load transfer test
n	Maximum number of tensile elements for tendon size used in fatigue test Number of cycles in load transfer test
n'	Reduced number of tensile elements in tendon installed for fatigue test
r_1	Number of rings of holes in the anchor head for smallest size of the series for anchorages/couplers
r_2	Number of rings of holes in the anchor head for largest size of the series for anchorages/couplers
t	Time
t_0	Time at which 80 % of the characteristic tensile strength of the tensile element is reached in the static load test
f_{ck}	Characteristic compressive strength of concrete at 28 days
$f_{cm,0}$	Mean compressive strength of concrete at which full prestressing is applied as given per ETA
$f_{cm,e}$	Mean compressive strength of concrete at time of failure in the load transfer test
f_{pk}	Characteristic tensile strength of tensile elements
f_{pm}	Mean actual tensile strength of tensile elements used for testing (mean of the results of a minimum of three tests)
$f_{p0.1k}$	Characteristic 0.1 %-proof stress of tensile elements
f_{yk}	Characteristic yield strength of reinforcement
$p_{R,\ max}$	Recommended maximum allowable pressure under critical strand in the absence of national regulations
A_c	Cross-sectional area of load transfer test specimen
x	Minimum centre distance of anchorage in the structure in x-direction, derived from reference dimensions a and b Or curvilinear abscissa along the tendon path for prestressing loss calculation

y Minimum centre distance of anchorage in the structure in y-direction, derived from reference dimensions a and b

e_x Edge distance in x-direction in the structure, derived from minimum centre distance x of anchorage in the structure

e_y Edge distance in y-direction in the structure, derived from minimum centre distance y of anchorage in the structure

2 ESSENTIAL CHARACTERISTICS AND RELEVANT ASSESSMENT METHODS AND CRITERIA

2.1 Essential characteristics of the product

Table 1 shows how the performance of PT kits is assessed in relation to the essential characteristics.

Table 1 Essential characteristics of the product and methods and criteria for assessing the performance of the product in relation to those essential characteristics

No	Essential characteristic	Assessment method	Type of expression of product performance *(level, class, description)*
Basic Works Requirement 1: Mechanical resistance and stability			
1	*Resistance to static load*	Static load test (Annex C.2.1) Clause 2.2.1	Level
2	*Resistance to fatigue*	Fatigue test (Annex C.3) Clause 2.2.2	Level
3	*Load transfer to structure*	Load transfer test (C.4) Clause 2.2.3	Level
4	*Friction coefficient*	(1) Tendon: - Assessment or - Assembly/ stressing test (Annex C.6.1) (2) Anchorage / coupling: - Assessment Clause 2.2.4	Level
5	*Deviation/ deflection (limits) for internal bonded and internal unbonded tendon*	- Assessment Clause 2.2.5	Description

No	Essential characteristic	Assessment method	Type of expression of product performance *(level, class, description)*
6	*Deviation/ deflection (limits) for external tendon*	- Assessment or - Deviator static load test (Annex C.5.1) and / or - Deviated tendon test (Annex C.5.2). Clause 2.2.6	Description
7	Assessment of assembly	- Assessment or - For PT kits without documented prior experience practicability / reliability of assembly test (Annex C.6.1 and C.6.2) Clause 2.2.7	Description
8	*Resistance to static load under cryogenic conditions for applications with anchorage/coupling outside the possible cryogenic zone*	- Cryogenic single tensile element test (Annex C.2.2) Clause 2.2.8	Level
9	*Resistance to static load under cryogenic conditions for applications with anchorage/coupling inside the possible cryogenic zone*	- Cryogenic single tensile element test (Annex C.2.2) - Cryogenic multiple tensile elements/ anchorage/ coupling assembly test (Annex C.2.3) Clause 2.2.9	Level
10	*Material properties, component performance, system performance of plastic duct*	Testing according to *fib* Bulletin 75 of: - Material HDPE and PP - Components PL1 - System PL1 Clause 2.2.10	Level
11	*Material properties, component performance, system performance of plastic duct to provide an encapsulated tendon.*	Testing according to *fib* Bulletin 75 of: - Material HDPE and PP - Components PL2 - System PL2 Clause 2.2.11	Level

No	Essential characteristic	Assessment method	Type of expression of product performance *(level, class, description)*
12	*Material properties, component performance, system performance of plastic duct to provide an electrically isolated tendon.*	Testing according to *fib* Bulletin 75 of: - Material HDPE and PP - Components PL3 - System PL3 Clause 2.2.12	Level
13	*Corrosion protection*	Clause 2.2.13.	Description
Monostrand, sheathing base material			
14	*Melt index*	Clause 2.2.14	Level
15	*Density*	Clause 2.2.15	Level
16	*Carbon black*	Clause 2.2.16	Level
17	*Tensile strength*	Clause 2.2.17	Level
18	*Elongation*	Clause 2.2.18	Level
19	*Thermal stability*	Clause 2.2.19	Level
Monostrand, manufactured sheathing			
20	*Tensile strength*	Clause 2.2.20	Level
21	*Elongation*	Clause 2.2.21	Level
22	*Surface of sheathing*	Clause 2.2.22	Description
23	*Environmental stress cracking*	Clause 2.2.23	Level
24	*Temperature resistance*	Clause 2.2.24	Level
25	*Resistance to externally applied agents*	Clause 2.2.25	Level
26	*Sheathing minimum thickness*	Clause 2.2.26	Level
Monostrand, manufactured monostrand			
27	*External diameter of sheathing*	Clause 2.2.27	Level

No	Essential characteristic	Assessment method	Type of expression of product performance *(level, class, description)*
28	*Mass of sheathing per metre*	Clause 2.2.28	Level
29	*Mass of filling material per metre*	Clause 2.2.29	Level
30	*Alteration of dropping point caused by monostrand manufacturing*	Clause 2.2.30	Level
31	*Alteration of oil separation caused by monostrand manufacturing*	Clause 2.2.31	Level
32	*Impact resistance*	Clause 2.2.32	Level
33	*Friction between sheathing and strand*	Clause 2.2.33	Level
34	*Leak tightness*	Clause 2.2.34	Description
Basic Works Requirement 2: Safety in case of fire			
35	*Reaction to fire*	Clause 2.2.35	Class
Basic Works Requirement 3: Hygiene, health and the environment			
36	*Content, emission and/or release of dangerous substances*	Clause 2.2.36	Description

Note 1: 0 contains the characteristics relevant for the different intended uses.

Note 2: only monostrands with filling materials complying with EAD-160027 are covered.

2.2 Methods and criteria for assessing the performance of the product in relation to essential characteristics of the product

General considerations about tests described below:

Testing program according to the intended use or intended uses of the PT system shall be agreed between the manufacturer and the Technical Assessment Body (TAB) prior to its implementation. The testing program includes inter alia the series composing the PT system, sizes to be tested, interpolations, concrete strength of specimens, etc., as required.

Test results shall be assessed by the TAB for the anchorage/coupling or tendon sizes specified in this chapter if the method of verification is by testing. All tests need to pass the acceptance criteria. For each type of tests according to 2.2.1 to 2.2.9 it is acceptable if only one test within a series fails and two additional identical tests are performed and pass. Analysis is accepted for interpolation between tested tendon sizes out of a series of similar anchorage and coupling type designs. Stresses in the components of interpolated sizes of anchorages and couplings and bearing stresses on concrete shall however, not be larger than those of components verified by tests.

The number of tests specified below applies to a series of similar anchorage and coupling type designs. The definition for a series is given in 1.3.39.

If a PT system is specified for use with different strength grades of the same kind of tensile element, the specified assessment should be undertaken with the strength grade that produces the highest force applied to the PT system. However, testing of more than one strength grade may be required if the geometry of the interface between tensile element and anchorage is different for different strength grades.

Note: This rule applies e.g. in the case where one type/size of wedge is specified to be used with two or more different nominal diameters of strands, e.g. 15.3 mm and 15.7 mm.

If a change to a wedge or compression fitting that is part of an already issued ETA, is proposed, these new wedges or compression fittings have to be checked. TAB will have to assess whether testing is necessary or not depending on the actual changes made in terms of geometry, material or manufacturing process of the wedge or compression fittings. If testing is considered necessary, the number of tests and type of test (multi-strand tests or single strand tests) shall be specified with due consideration of the proposed tendon range and maximum tendon size. In this case, testing of a total of 10 wedges or compression fittings for each in static load and fatigue with the most severe angular deviation of tensile elements is considered an absolute minimum.

2.2.1 Resistance to static load

Assessment of resistance to static load shall be based on testing in accordance with Annex C.2.1.

In the case of a series of anchorage components with several different sizes, the number N of sizes to be tested and choice of these sizes shall be as follows:

- $F_{pk} \leq$ 10'500 kN: N = 3 covering largest, intermediate and small sizes. Largest size is always tested twice. Out of small and intermediate sizes, the one with higher stresses is tested twice, the other once.
- $F_{pk} >$ 10'500 kN: N = ($r_2 - r_1$ + 1), where r_1 is the number of full rings of holes in the anchor head of the smallest size of the series but $r_1 \geq 2$, and r_2 is the number of rings of holes in the anchor head for largest size of the series. Refer to Figure 2 for examples of rings and full rings of holes in anchor head. Largest size is always tested twice. Out of small and intermediate sizes, the one with highest stresses is tested twice, the others once.

  Notes: The above definition for the number of sizes to be tested in case of $F_{pk} >$ 10'500 kN applies strictly to strand PT systems. However, TAB should apply the concept similarly to wire and bar PT systems where applicable.
  For "monostrand" PT systems with one tensile element only, 5 tests shall be performed.
  If a series contains only one size with $F_{pk} \geq$ 1'500 kN then 2 tests with 2 anchorages each are required only.
  For series of sizes containing not more than 5 sizes, the small or medium size may be replaced by the medium or small size whichever has more severe stresses.
  Tendon sizes out of one PT kit with N sizes tested shall be interpreted as follows: "small" = most severe size in lowest (1/N)th of series; "intermediate" = most severe in intermediate (1/N)th of series.
  If the pattern of holes shown in Figure 2 is not regularly filled, e.g. if some intermediate rings are omitted and replaced with solid material, this space with solid material shall be considered filled with fictitious holes, and the number r_2 of rings considered to determine the number N of sizes to be tested, shall include these rings of fictitious holes.

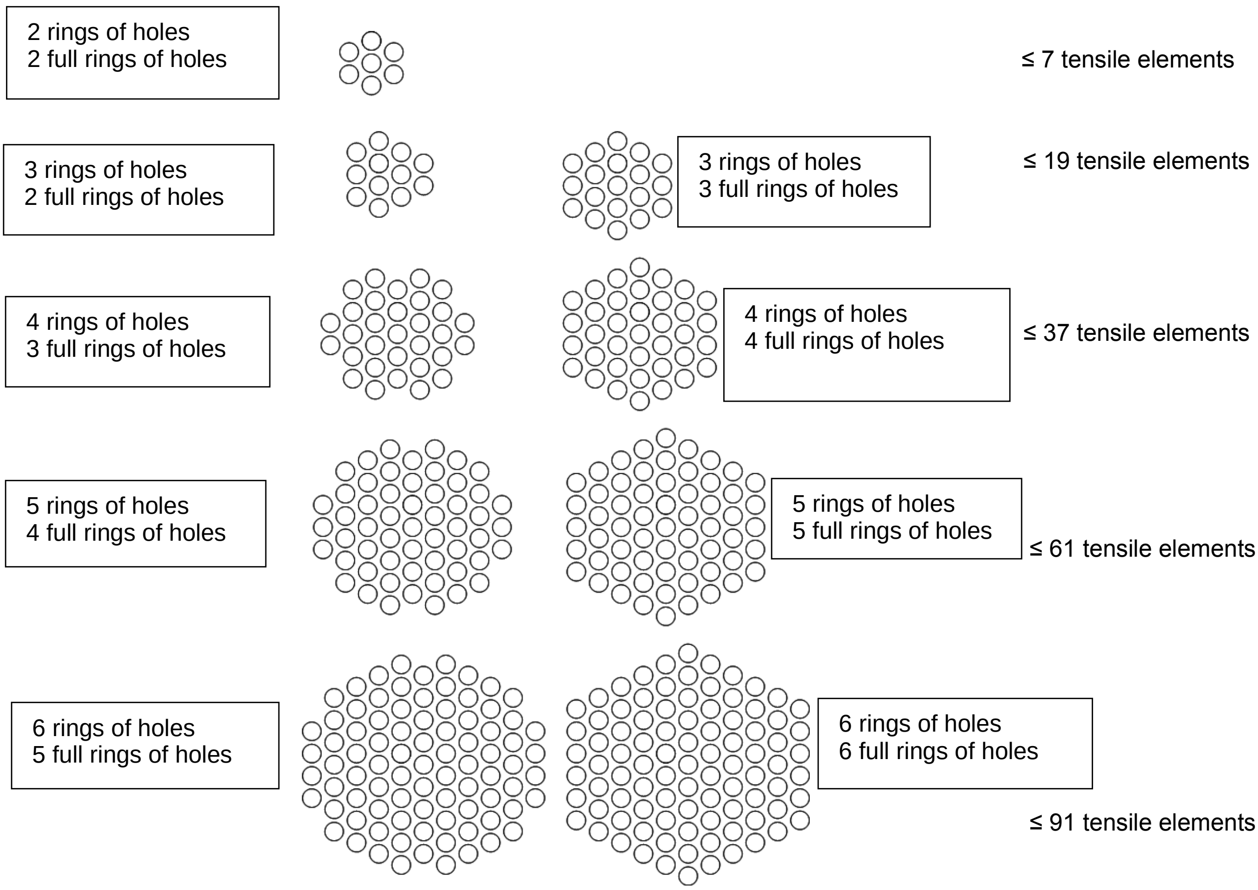

Figure 2 - Examples of rings of holes in an anchor head

The performances required for the resistance to static load test are:

- Measured maximum load shall not be less than 95% of the actual ultimate strength, A_{pm} f_{pm}, nor less than 95% of the specified characteristic strength, A_p f_{pk}, of the tensile elements
- Total elongation, ε_{Tu}, of tensile elements on the free length at measured maximum load shall be at least 2.0%
- Failure shall be by fracture of the tensile elements. Failure of the tendon shall not be induced by the failure of anchorage components (small longitudinal cracking or splitting of wedges shall not be considered as a failure of the anchorage)
- Residual deformations of anchorage components after testing shall confirm the reliability of the anchorage. Any unusual deformations should be stated in the ETA.
- With the load held at 80% of the tensile element characteristic strength the relative movements between anchorage components as well as between tensile elements and anchorage components shall stabilise within the first 30 minutes.
- Additionally for external tendons and internal unbonded tendons the deformations Δt and Δz, shall stabilise within the first 30 minutes. However this applies only in the case the corresponding measurement are feasible.

Note: these required performances originate in ETAG 013 (June 2002).

2.2.2 Resistance to fatigue

Assessment of resistance to fatigue shall be based on testing in accordance with Annex C.3.

In the case of a series of anchorage components with several different sizes, the number N of sizes to be tested and choice of these sizes shall be as follows:

N = 3 – largest, intermediate and small sizes. Largest size is always tested twice. Small and intermediate sizes are tested once each.

Notes: For “monostrand” PT systems with one tensile element only or for bar systems with only one size, 4 tests shall be performed.
If a series (strands or wires) contains only one size with F_{pk} ≥ 1’500 kN then 2 tests with 2 anchorages each are required only.
For series of sizes containing not more than 5 sizes, the small or medium size may be replaced by the medium or small size whichever has more severe stresses.
Tendon sizes out of one PT kit with 3 sizes tested shall be interpreted as follows: “small” = most severe size in lowest third of series; “intermediate” = most severe in middle third of series.

The performances required for the resistance to fatigue test are:

- No fatigue failure in anchorage components shall occur
- No more than 5% of tensile element cross section shall be lost during fatigue testing with 2 million cycles with a minimum stress range of $\Delta\sigma_p$=80 MPa at maximum stress of 65% of tensile element characteristic strength, f_{pk}
- The relative displacements between anchorage components as well as between tensile elements and anchorage components shall stabilise during the test.

Note: these required performances originate in ETAG 013 (June 2002).

2.2.3 Load transfer to structure

Assessment of load transfer to structure shall be based on testing in accordance with Annex C.4.

In the case of a series of anchorage components with several different sizes, the number N of sizes to be tested and choice of these sizes for the lowest mean concrete strength at the time of tensioning, f_{cm0}, defined by the ETA applicant shall be the same as specified for resistance to static load, see 2.2.1.
For the highest mean concrete strength at the time of tensioning, f_{cm0}, defined by the ETA applicant, one additional set of tests of the same sizes shall be performed. If there are more than two defined strengths, and the lowest and highest mean concrete strength at the time of tensioning, f_{cm0}, differ by more than 20 MPa one or more additional sets of tests with an intermediate mean concrete strength at the time of tensioning, f_{cm0}, are required. In any case, difference of concrete strength between two sets of tests shall not be higher than 20 MPa.

Notes: For PT systems with one anchorage size only, 3 tests shall be performed.
For series of sizes containing not more than 5 sizes, the small or medium size may be replaced by the medium or small size whichever has more severe stresses.
Tendon sizes out of one PT kit with N sizes tested shall be interpreted as follows: “small” = most severe size in lowest (1/N)th of series; “intermediate” = most severe in intermediate (1/N)th of series.
For interpolation between tested sizes and for assessment of what sizes have more severe stresses, suitable mechanical models are available and shall be employed. Theory of Gregor P. Wollmann may be considered (see reference in section 4).

The performances required for the load transfer to structure test are:

- Crack widths max w:
  - upon first attainment of upper load of 80% of tensile element characteristic strength not more than 0.15 mm
  - upon last attainment of lower load of 12% of tensile element characteristic strength not more than 0.15 mm

- upon last attainment of upper load of 80% of tensile element characteristic strength not more than 0.25 mm
- Readings of longitudinal and transverse strains shall stabilise during cyclic loading
- Readings of crack widths shall stabilise during cyclic loading
- Mechanical anchorages shall have a measured ultimate force of at least :

  $F_u \geq 1.1\ F_{pk}\ (f_{cm,e}/f_{cm,0})$
- Anchorages intended to be placed into concrete with brittle behaviour, like unreinforced concrete without any supplementary reinforcement other than the 50kg/m³ shall have a measured ultimate force of at least :

  $F_u \geq 1.3\ F_{pk}\ (f_{cm,e}/f_{cm,0})$
- Bond anchorages shall have a measured ultimate force of at least :

  $F_u \geq 1.1\ F_{pk}\ (f_{cm,e}/f_{cm,0})$
- Slip of bond anchorages shall stabilise during cyclic loading
- If a test specimen tested in accordance with clause C.4.2 (Bond Anchorages) satisfies the ultimate force and slip requirements but does not satisfy the requirements for crack widths and strains, a second test on an identical specimen may be performed, with maximum load level of $0.8F_{pk}$, but tested with a concrete strength $f_{cm,e} \leq f_{cm,0}$. The bond anchorage is considered to satisfy the requirements of this EAD if the crack widths and strains of this second test satisfy the acceptance criteria including the stabilisation criteria. There is no need to test the second specimen for ultimate force.

Note: these required performances originate in ETAG 013 (June 2002).

2.2.4 Friction coefficient

a) Friction losses along the tendon path:

As proposed by EN 1992-1-1, the loss due to friction ΔP_μ along a tendon path are estimated with the following formula :

$$\Delta P_\mu = P_{max} \cdot \left(1 - e^{-\mu \cdot (\theta + k \cdot x)}\right)$$

Where:

x is the curvilinear abscissa along the tendon path (with x = 0 where $P = P_{max}$)

θ is the sum of the total angular deviation of the tendon between abscissas 0 and x

μ is the friction coefficient between duct or pipe and tendon

k is the wobble coefficient (or also called unintentional angular displacement for internal tendons per unit length by EN 1992-1-1)

Friction and wobble coefficients μ and k between tensile elements and ducts or pipes are stated in the ETA. The TAB has to ensure that values come from standards or known behaviour of PT systems with components used successfully for years. Alternatively, if values indicated in standards are not applicable, and if known behaviour is not available, μ and k coefficients shall be determined by assembly/ stressing testing in accordance with Annex C.6.1.

If testing is applicable, the number of sizes to be tested shall be one medium size tendon.

The performance required for the assembly/ stressing test is:

- Friction and wobble coefficients shall be within the range of values typically given in standards, e.g *fib* Model Code 2010, or used successfully in the industry since some time for comparable tendon-duct combinations, or comply with the test results for the specified tendon-duct combination.

Note: this required performance come from ETAG 013 (June 2002).

b) Friction losses in anchorages:

Assessment of friction losses in anchorages may be based on well documented measurements from sites. Alternatively, if such measurements are not available, assessment shall be by suitable testing of friction losses in anchorages.

If testing is applicable, the number of anchorage sizes to be tested shall be one medium size.

The performance required for the friction losses in anchorages test is:

- Friction losses in anchorages specified by the ETA applicant shall be within the range of values documented from sites, or the range of values measured during testing.

Note: this required performance comes from ETAG 013 (June 2002).

2.2.5 Deviation/deflection (limits) for internal bonded and unbonded tendon

a) General:

- For determining the minimum radii of curvature for internal bonded tendon with steel duct and
- internal unbonded tendons

The following principle applies:

1 : refer to values proposed below (values to be stated in the ETA)

2 : Smaller value of radii of curvature shall be assessed based on testing.

Note: minimum radius of curvature for internal bonded tendons with polymer ducts shall be determined based on testing according to *fib* Bulletin 75 (wear resistance), see 2.2.10, 2.2.11 and 2.2.12.

b) Strands:

In case there is no national regulation for radii of curvature the following values are advised for internal bonded tendons with strands (grade Y1770S7 or Y1860S7 according to prEN 10138-3, cross-sectional area 139 to 150 mm²):

$$R_{\min} = \frac{2.F_{pm0}.d_{strand}}{p_{R,\max}.d_{duct,i}} \geq 2{,}5\ m$$

Where

R_{min}	minimum allowable radius of curvature
F_{pm0}	initial prestressing force of the tendon
d_{strand}	diameter of strands
$p_{R,max}$ = 130, 150 or 230 kN/m	recommended maximum allowable pressure under critical strand in the absence of national regulations
$d_{duct,i}$	internal diameter of circular duct

Note 1: For strands Y1770S7 or Y1860S7, cross-sectional area 93 or 100 mm², the maximum pressure under the strands of 130 or 200 kN/m is acceptable if 15 mm is applied in the equation as strand diameter, i.e.

$$R_{\min} = \frac{2.F_{pm0}.15\ mm}{p_{R,\max}.d_{duct,i}}$$

Note 2: For tendons with one single layer of tensile elements (such as e.g. tendons in flat ducts) direct calculation can be carried out to assess pressure on duct, but in this case, the limit of 2.5 m will become determinant.

The equation giving the minimum radii of curvature has to be written in the ETA with the three possible $p_{R,max}$ given above. The designer can choose among these three $p_{R,max}$ values, depending on the national regulations in place of use. Numerical values can be given as indicative values in the ETA and stated as such.

c) Bars:

In case there is no national regulation for radii of curvature the following values are advised for internal bonded and unbonded tendons with bars, using steel ducts:

Elastic bending

Extreme fibre stress resulting from bending and stressing shall be ≤ $f_{p0.1k}$ of prestressing steel.

Note: Elastic bending may require a reduced prestressing force.

Plastic bending

The radius of curvature may be less than the minimum elastic bending radius. Such smaller radii of curvature require to plastically bent the bar prior to installation. Pre-bending is also applicable for larger radii of curvature, if the bar is not adapting itself to the intended curvatures, e.g. for very short tendons or horizontal layout.

Essential items for pre-bending are

- Pre-bending is without heating the prestressing steel at ambient temperature, i.e. in cold condition
- Pre-bent bars are of even curvature and
- Free of damages like friction marks etc.
- For pre-bending specific equipment is to be employed.

2.2.6 Deviation/ deflection (limits) for external and internal unbonded tendon

For determining the minimum radii of external tendon curvature, the following principle applies:

1 : apply national regulations if they exist

2 : refer to values proposed below

3 : in the case a smaller value of radii of curvature is required, perform the corresponding test.

Where relevant, radii of curvature for external tendon as well as the system of deviation have to be recorded in the ETA.

a) Assessment of minimum radii of tendon curvature for external tendons may be based on analysis/ historical data/ and comparison with known successful behaviour or values specified in standards and international recommendations, and/or within the limits specified in Table 2.

Table 2 Radii of curvature for external tendons

Tendons with strands	Minimum radius of curvature at deviator
19 ϕ 13 mm or 12 ϕ 15 mm	2.5 m
31 ϕ 13 mm or 19 ϕ 15 mm	3.0 m
55 ϕ 13 mm or 37 ϕ 15 mm	4.0 m
61 ϕ 15 mm	5.5 m

Notes: Interpolation is allowed between sizes given in Table 2.

Tendons with wires should have the same minimum radius of curvature as tendons with strands of the same F_{pk}.

This table come from ETAG013 which made reference to ENV1992-1-5 (this part of the standard was not reintroduced in EN 1992-1-1).

Alternatively, if such historical data are not acceptable at the place of use, or if smaller radii of curvature than given in Table 2 are intended to be used, assessment shall be by deviator static load testing in accordance with Annex C.5.1.

If testing is applicable, the number of sizes to be tested shall be one largest size tendon.

The performances required for the deviation/ deflection (limits) are:

- Measured maximum load shall not be less than 95% of the actual ultimate strength, A_{pm} f_{pm}, nor less than 95 % of the specified characteristic strength, A_p f_{pk}, of the tensile elements
- Total elongation, ε_{Tu}, of the free length of the tendon at measured maximum load shall be at least 2.0 %
- Tendon failure shall be by fracture of the tensile elements. Failure of the tendon shall not be induced by the failure of deviator components.

Note: these required performances originate in ETAG 013 (June 2002).

The way of assessing minimum radii of curvature (test according to Annex C.5.1 or radii of curvature according to Table 2) shall be stated in the ETA.

b) Assessment of wear of external tendon with plastic pipe and tensile element sheathing of internal unbonded tendon based on historical data and comparison with known successful behaviour can be considered sufficient.
If such historical data does not exist, deviated tendon tests in accordance with Annex C.5.2 shall be performed.

If testing is applicable, the number of tests is one medium size tendon. However, forces and stresses between tensile elements and duct or sheathing in other sizes shall not be than in the tested size.

The performances required for the deviated tendon test are:

- The tensile element sheathing, if any, shall not be cut through or torn
- The tendon duct in contact with the tensile elements shall not be cut through by the tensile elements
- For tendons not subject to restressing, residual wall thickness of tendon duct shall be $\geq$ 50 % of initial wall thickness but not less than 0.8 mm. Initial wall thickness is the average of at least 6 wall thicknesses measured at a piece of duct adjacent to the duct of the deviated tendon test.

Note: these required performances originate in ETAG 013 (June 2002).

The way of assessing wear of external tendon or tensile element sheathing of internal unbonded tendon (test according to Annex C.5.2 or historical data) shall be stated in the ETA.

2.2.7 Assessment of assembly

Here, the feasibility that components of kit may be properly assembled (fit together as necessary for intended use and for durability) is assessed.

The assessment may be based on judgment and data for PT systems incorporating traditional components that together have proven to be adequate for years.

Such effects as the following may be considered:

- Assembly tolerances
- Sensitivity of PT system performance to staining/ dirt on site
- Easy and reliable placing and compacting of concrete around anchorages
- Sensitivity of particular activities or details to extreme environmental conditions (wet, dry, hot, cold, etc.)
- Allowance for stage stressing, load and elongation monitoring during stressing
- Allowance for simultaneous stressing of all tensile elements
- Detensioning of tendons (partial or complete) during stressing operations
- Likelihood of having reasonably uniform distribution of the prestressing force between tensile elements
- Practicability of filling of duct, in particular details such as vent size and location, and robustness against accidental damage during installation
- Filling ratio of ducts to allow reliable installation of tensile elements.

The performances required are:

- Procedures covering all assembly and filling activities anticipated for the PT kit shall be available with sufficient detail to assess their feasibility and their reliability. Values, assumptions, and methods specified shall be within the range of successful experience in the industry for comparable PT systems.
- Methods for connecting individual components of the PT system and sealing of anchorages, couplers and auxiliary components shall provide sufficient leak tightness such that installation of tensile elements and filling of duct are not compromised and that equivalent corrosion protection and durability as provided to the tendon in general is achieved.

Note: these required performances originate in ETAG 013 (June 2002).

Alternatively, if testing is found necessary, the assessment shall be by assembly/ stressing test in accordance with Annex C.6.1 followed by duct filling test in accordance with Annex C.6.2.

The number of sizes to be tested shall be one medium size tendon.

The performance required for the assembly/ stressing and filling test is:

- Procedures covering all assembly and filling activities anticipated for the PT kit shall be available with sufficient detail, and the test results shall prove the feasibility and reliability of the proposed procedures.

Note: this required performance comes from ETAG 013 (June 2002).

2.2.8 Resistance to static load under cryogenic conditions for applications with anchorage / coupling outside the possible cryogenic zone

Assessment shall be by resistance to static load testing in accordance with single tensile element test, Annex C.2.2.

The number of tests shall be three single tensile element tests.

The performances required for the single tensile element test are:

- With the load held at 80 % of the tensile element characteristic strength the displacements Δs and Δr shall stabilise within the first 30 minutes at room temperature
- Measured maximum load F_{Tu} shall not be less than 95 % of the actual ultimate strength, A_{pm} f_{pm}, nor less than 95 % of the specified characteristic strength, A_p f_{pk}, both determined at room temperature
- Total elongation, ε_{TU}, of tensile element of the free length at the measured maximum load F_{Tu} shall be at least 2.0 %. Note that the test may be stopped once 2.0 % elongation has been reached.

Note: these required performances originate in ETAG 013 (June 2002).

2.2.9 Resistance to static load under cryogenic conditions for applications with anchorage / coupling inside the possible cryogenic zone

Cryogenic testing with multiple tensile elements - anchorage/ coupling assembly is performed with either one or both end anchorages/couplings of tendon subject to cryogenic conditions. This configuration – one or both anchorages/couplings - is stated in the ETA.

a) Testing of tendon with one anchorage / coupling under cryogenic condition and the second anchorage at ambient temperature:

(1) Assessment shall be by resistance to static load testing in accordance with single tensile element test, Annex C.2.2.

The number of tests shall be three single tensile element tests.

The performances required for the single tensile element test are:

- With the load held at 80 % of the tensile element characteristic strength the displacements Δs and Δr shall stabilise within the first 30 minutes at room temperature
- Measured maximum load F_{Tu} shall not be less than 95 % of the actual ultimate strength, A_{pm} f_{pm}, nor less than 95 % of the specified characteristic strength, A_p f_{pk}, both determined at room temperature
- Total elongation, ε_{TU}, of tensile element of the free length at the measured maximum load F_{Tu} shall not be less than 2.0 %. Note that the test may be stopped once 2.0 % elongation has been reached.

Note: these required performances originate in ETAG 013 (June 2002).

(2) Assessment shall further include resistance to static load testing in accordance with multiple tensile elements/ anchorage/ coupling assembly test (Annex C.2.3).

The number of sizes to be tested shall be one medium size tendon where medium shall be interpreted to be a tendon with at least 60 % of the specified characteristic strength of the largest tendon size of the series.

The performances required for the multiple tensile elements/ anchorage/ coupling assembly test are:

- With the load held at 80 % of the characteristic tensile strength of the tensile element the displacements Δs and Δr shall stabilize within the first 30 minutes at room temperature
- Measured maximum load F_{Tu} shall not be less than 95 % of the actual ultimate strength, A_{pm} f_{pm}, nor less than 95 % of the specified characteristic strength, A_p f_{pk}, both determined at room temperature if one anchorage at tendon ends is under cryogenic conditions
- Total elongation, ε_{TU} , of tensile element of the free length at the measured maximum load F_{Tu} shall not be less than 2.0% if one anchorage is tested at cryogenic condition. Note that the test may be stopped once 2.0 % elongation has been reached.

Note: these required performances come from ETAG 013 (June 2002).

b) Testing of tendon with both anchorages / coupling under cryogenic condition:

(1) Assessment shall be by resistance to static load testing in accordance with single tensile element test, Annex C.2.2.

The number of tests shall be three single tensile element tests.

Yield strength under cryogenic condition, $F_{p0.1, cryo}$, is determined with these tests.

The performances required for the single tensile element test are:

- With the load held at 80 % of the tensile element characteristic strength the displacements Δs and Δr shall stabilise within the first 30 minutes at room temperature
- Measured maximum load F_{Tu} shall not be less than 95 % of the actual ultimate strength, A_{pm} f_{pm}, nor less than 95 % of the specified characteristic strength, A_p f_{pk}, both determined at room temperature
- Total elongation, ε_{TU}, of tensile element of the free length at the measured maximum load F_{Tu} shall not be less than 2.0 %. Note that the test may be stopped once 2.0 % elongation has been reached.

Note: these required performances come from ETAG013 (June 2002).

(2) Assessment shall further include resistance to static load testing in accordance with multiple tensile elements/ anchorage/ coupling assembly test (Annex C.2.3).

The number of sizes to be tested shall be one medium size tendon where medium shall be interpreted to be a tendon with at least 60 % of the specified characteristic strength of the largest tendon size of the series.

The performances required for the multiple tensile elements/ anchorage/ coupling assembly test are:

- With the load held at 80 % of the characteristic tensile strength of the tensile element the displacements Δs and Δr shall stabilize within the first 30 minutes at room temperature
- Measured maximum load F_{Tu} shall not be less than force at yield strength for cryogenic condition $F_{p0.1, cryo}$.
- Note that the test may be terminated when force at yield strength for cryogenic condition $F_{p0.1, cryo}$ is attained.

Total elongation at maximum load shall be stated in the ETA.

Note: these required performances originate in ETAG 013 (June 2002).

2.2.10 Material properties, component performance, system performance of plastic duct (PL1)

Polymer duct material PP and HDPE are assessed according to *fib* recommendations (Bulletin 75), Chapter 5, Tables 5.1 and 5.2, respectively. Material of duct shall be tested for:

- Oxidation Induction Time (OIT) at 200 °C tested according to EN ISO 11357-6: ≥ 25 minutes
- Environmental Stress Cracking Resistance (ESCR) (Condition C) tested according to ASTM D 1693: ≥ 600 hours
- Notched impact tested according to EN ISO 179-1/1eA at 23 °C: ≥ 22 kJ/m^2, and at 0 °C: ≥ 4 kJ/m^2
- Hydrostatic Design Basis (HDB) for HDPE only tested according to ISO TR 9080: ≥ 8.0 MPa.

In addition, the following properties shall be stated in the ETA:

- Melt Flow Rate (MFR) according to EN ISO 1133 at 230 °C and at 190 °C for PP and PE, respectively
- Density according to EN ISO 1183-1
- Flexural Modulus according to EN ISO 178
- Tensile Yield Strength according to EN ISO 6259-3
- Elongation at yield and at break according to EN ISO 6259-3
- Thermal expansion coefficient according to ASTM D696.

Polymer duct components are assessed according to *fib* recommendations (Bulletin 75), Chapter 6, Section 8.5 and Annex A as applicable for PL1.

- Dimensional requirements – assessed in accordance with *fib* Bulletin 75, Annex A.1 with 3 tests per size performed on all sizes of duct and connector tested at 23 °C ± 5 °C. The required performances are:
  - Actually measured dimensions or, where applicable, average dimensions of ducts and connectors shall be within the dimensions and tolerances specified in the manufacturer's drawings or specifications;
  - average value of internal and external diameters, d_1 and d_2, respectively, shall be within ± 1% or ± 1 mm, whichever is greater;
  - average value of wall thickness shall be within -0 / +0.5 mm.
- Stiffness of duct – assessed in accordance with *fib* Bulletin 75, Annex A.2 with 1 test per size performed on all duct sizes tested at 23 °C ± 5 °C and at 45 °C. The required performances are:
  - Effective duct stiffness $(E * I)_{eff}$ as determined in test.
- Longitudinal load resistance of duct system – assessed in accordance with *fib* Bulletin 75, Annex A.3 with 1 test per size performed on all duct sizes with each connector tested at 23 °C ± 5 °C. The required performances are:
  - Maintain specified longitudinal load F_{pre} for at least 10 minutes for ducts intended to be used with prefabricated tendons supplied on coils.
- Lateral load resistance of duct – assessed in accordance with *fib* Bulletin 75, Annex A.4 with 1 test per size performed on all duct sizes tested at 23 °C ± 5 °C and at 45 °C. The required performances are:
  - No deformations exceeding 35% of duct internal diameter immediately when reaching the specified lateral load F_d;
  - no deformations exceeding 35% of duct internal diameter or 5 mm whichever is smaller two minutes after release of load F_1;
  - no visual damage of test specimen.
- Flexibility of duct system – assessed in accordance with *fib* Bulletin 75, Annex A.5 with 1 test per size performed on all duct sizes with each connector tested at 23 °C ± 5 °C, at -15 °C, and at 45 °C. The required performances are:
  - No deformations exceeding 5% of duct internal diameter while test specimen is in final bent position – confirmed by easy passage of plunger;
  - no visual damage of test specimen.
- Leak tightness of duct system – assessed in accordance with *fib* Bulletin 75, Annex A.6 with 1 test per size performed on all duct sizes with each connector tested at 23 °C ± 5 °C. The required performances are:

  - Less than 1.5% loss of water.
- Concrete pressure test on duct – assessed in accordance with *fib* Bulletin 75, Annex A.7 with 1 test per size performed on all duct sizes tested at 23 °C ± 5 °C. The required performance is:
  - No changes in geometry/ duct diameter of more than 10% in plane of template and at right angle to plane; (2) no collapse of duct.
- Wear resistance of duct – assessed in accordance with *fib* Bulletin 75, Annex A.8 with 1 test per size performed on all duct sizes tested at 23 °C ± 5 °C and at 45 °C. The required performance is:
  - Minimum residual wall thickness after testing is 1.0 mm at all sections.
- Wear resistance of duct under sustained load – assessed in accordance with *fib* Bulletin 75, Annex A.9 with 1 test per size performed on all duct sizes tested at 23 °C ± 5 °C and at 45 °C. The required performance is:
  - Minimum residual wall thickness after testing is 0.5 mm at all sections.
- Bond behaviour of duct – assessed in accordance with *fib* Bulletin 75, Annex A.10 with 1 test per size performed on 3 duct sizes, i.e. small, medium and largest, tested at 23 °C ± 5 °C. The required performances are:
  - Maintain full test load F_{bu} for at least two minutes duration without excessive strand slippage, grout column to duct failure, or duct to concrete failure (all defined as movements greater than 5 mm);
  - the relative movement of tendon and grout versus concrete shall stabilize within the 2 minutes (if it does not, the full test load F_{bu} shall be maintained until relative movement has stabilized).
- Precast segmental duct coupler system where applicable – assessed in accordance with *fib* Bulletin 75, Annex A.11 with 1 test per size performed on all segmental duct coupler sizes, tested at 23 °C ± 5 °C. The required performances are:
  - Precast segmental duct coupler assembly must sustain a 1.50 bar internal test pressure for a minimum of five minutes with no more than a 0.15 bar reduction in pressure;
  - precast segmental duct coupler assembly (with duct and connectors) shall be intact, free of epoxy infiltration into the inside of the encapsulation, and properly attached without crushing, tearing or other signs of failure.

Polymer duct systems are assessed according to *fib* recommendations (Bulletin 75), Chapter 7, Section 8.5 and Annex B as applicable for PL1.

- Leak tightness of anchorage-duct assembly – assessed in accordance with *fib* Bulletin 75, Annex B.1 with 1 test per size performed on 1 medium representative duct size at 23 °C ± 5 °C. The required performances are:
  - Less than 1.5% loss of water.

Note: These required performances originate in ETAG 013 (June 2002).

2.2.11 Material properties, component performance, system performance of plastic duct to provide an encapsulated tendon (PL2)

Polymer duct material PP and HDPE are assessed according to *fib* recommendations (Bulletin 75), Chapter 5, Tables 5.1 and 5.2, respectively. Material of duct shall be tested for:

- Oxidation Induction Time (OIT) at 200 °C tested according to EN ISO 11357-6: ≥ 25 minutes
- Environmental Stress Cracking Resistance (ESCR) (Condition C) tested according to ASTM D 1693: ≥ 600 hours
- Notched impact tested according to EN ISO 179-1/1eA at 23 °C: ≥ 22 kJ/m², and at 0 °C: ≥ 4 kJ/m²

- Hydrostatic Design Basis (HDB) for HDPE only tested according to ISO TR 9080: ≥ 8.0 MPa.

In addition, the following properties shall be stated in the ETA:

- Melt Flow Rate (MFR) according to EN ISO 1133 at 230 °C and at 190 °C for PP and PE, respectively
- Density according to EN ISO 1183-1
- Flexural Modulus according to EN ISO 178
- Tensile Yield Strength according to EN ISO 6259-3
- Elongation at yield and at break according to EN ISO 6259-3
- Thermal expansion coefficient according to ASTM D696.

Polymer duct components are assessed according to *fib* recommendations (Bulletin 75), Chapter 6, Section 8.5 and Annex A as applicable for PL2.

- Dimensional requirements – assessed in accordance with *fib* Bulletin 75, Annex A.1 with 3 tests per size performed on all sizes of duct and connector tested at 23 °C ± 5 °C. The required performances are:
  - Actually measured dimensions or, where applicable, average dimensions of ducts and connectors shall be within the dimensions and tolerances specified in the manufacturer's drawings or specifications;
  - average value of internal and external diameters, d_1 and d_2, respectively, shall be within ± 1% or ± 1 mm, whichever is greater;
  - average value of wall thickness shall be within -0 / +0.5 mm.
- Stiffness of duct – assessed in accordance with *fib* Bulletin 75, Annex A.2 with 1 test per size performed on all duct sizes tested at 23 °C ± 5 °C and at 45 °C. The required performances are:
  - Effective duct stiffness $(E * I)_{eff}$ as determined in test.
- Longitudinal load resistance of duct system – assessed in accordance with *fib* Bulletin 75, Annex A.3 with 1 test per size performed on all duct sizes with each connector tested at 23 °C ± 5 °C. The required performances are:
  - Maintain required elongation $\Delta = 40 * \alpha_T * L$ of the duct length for at least 10 minutes for ducts for all tendon applications;
  - maintain specified longitudinal load F_1 for at least 10 minutes for ducts intended to be used with prefabricated tendons supplied on coils;
  - no visual slippage of connector and no unusual observations that would indicate failure of duct system.
- Lateral load resistance of duct – assessed in accordance with *fib* Bulletin 75, Annex A.4 with 1 test per size performed on all duct sizes tested at 23 °C ± 5 °C and at 45 °C. The required performances are:
  - No deformations exceeding 35% of duct internal diameter immediately when reaching the specified lateral load F_d;
  - no deformations exceeding 35% of duct internal diameter or 5 mm whichever is smaller two minutes after release of load F_1;
  - no visual damage of test specimen.
- Flexibility of duct system – assessed in accordance with *fib* Bulletin 75, Annex A.5 with 1 test per size performed on all duct sizes with each connector tested at 23 °C ± 5 °C, at -15 °C, and at 45 °C. The required performances are:
  - No deformations exceeding 5% of duct internal diameter while test specimen is in final bent position – confirmed by easy passage of plunger;
  - no visual damage of test specimen.
- Leak tightness of duct system – assessed in accordance with *fib* Bulletin 75, Annex A.6 with 1 test per size performed on all duct sizes with each connector tested at 23 °C ± 5 °C. The required performances are:

- No visibly detectable leaks with positive and with negative pressure applied for 5 minutes duration.

- Concrete pressure test on duct – assessed in accordance with *fib* Bulletin 75, Annex A.7 with 1 test per size performed on all duct sizes tested at 23 °C ± 5 °C. The required performances are:
  - No changes in geometry/ duct diameter of more than 10% in plane of template and at right angle to plane;
  - no collapse of duct.
- Wear resistance of duct – assessed in accordance with *fib* Bulletin 75, Annex A.8 with 1 test per size performed on all duct sizes tested at 23 °C ± 5 °C and at 45 °C. The required performance is:
  - Minimum residual wall thickness after testing is 1.5 mm at all sections.
- Wear resistance of duct under sustained load – assessed in accordance with *fib* Bulletin 75, Annex A.9 with 1 test per size performed on all duct sizes tested at 23 °C ± 5 °C and at 45 °C. The required performance is:
  - Minimum residual wall thickness after testing is 1.0 mm at all sections.
- Bond behaviour of duct – assessed in accordance with *fib* Bulletin 75, Annex A.10 with 1 test per size performed on 3 duct sizes, i.e. small, medium and largest, tested at 23 °C ± 5 °C. The required performances are:
  - Maintain full test load F_{bu} for at least two minutes duration without excessive strand slippage, grout column to duct failure, or duct to concrete failure (all defined as movements greater than 5 mm);
  - the relative movement of tendon and grout versus concrete shall stabilize within the 2 minutes (if it does not, the full test load F_{bu} shall be maintained until relative movement has stabilized).
- Precast segmental duct coupler system where applicable – assessed in accordance with *fib* Bulletin 75, Annex A.11 with 1 test per size performed on all segmental duct coupler sizes, tested at 23 °C ± 5 °C. The required performances are:
  - Precast segmental duct coupler assembly must sustain a 3.50 bar internal test pressure for a minimum of five minutes with no more than a 0.35 bar reduction in pressure;
  - precast segmental duct coupler assembly (with duct and connectors) shall be intact, free of epoxy infiltration into the inside of the encapsulation, and properly attached without crushing, tearing or other signs of failure.
- Fracture resistance of duct system (optional test) – assessed in accordance with *fib* Bulletin 75, Annex A.12 with 1 test per size performed on 3 duct sizes, i.e. small, medium and largest, tested at 23 °C ± 5 °C. The required performance is:
  - After two million cycles of crack opening between 0.2 mm and 0.5 mm, there shall be no cracks, perforations or excessive wear in the polymer duct.

Polymer duct systems are assessed according to *fib* recommendations (Bulletin 75), Chapter 7, Section 8.5 and Annex B as applicable for PL2.

- Leak tightness of anchorage-duct assembly – assessed in accordance with *fib* Bulletin 75, Annex B.1 with 1 test per size performed on 1 medium representative duct size at 23 °C ± 5 °C. The required performance is:
  - No visibly detectable leaks with positive and with negative pressure applied for 5 minutes duration.
- Full scale duct system assembly – assessed in accordance with *fib* Bulletin 75, Annex B.4 with 1 test per size performed on 1 medium representative duct size at ambient temperature (typically 23 °C ± 5 °C would be considered suitable). The required performances are:
  - All components can be installed as specified in the method statement;
  - duct profile complies with the specified profile within specified tolerances as per method statement;

  - no apparent tendon profile kinks or discontinuities or loose connections;
  - no excessive duct deformations on the duct support or duct deflections between the supports.
- Leak tightness of assembled duct system – assessed in accordance with *fib* Bulletin 75, Annex B.5 with 1 test per size performed on 1 medium representative duct size at ambient temperature (typically 23 °C ± 5 °C would be considered suitable). The required performance is:
  - Pressure loss after test duration of 5 minutes shall not exceed 10% of initial pressure, i.e. 0.05 bar.

The ETA shall state whether the performance for fracture resistance of duct system (optional test) has been assessed or not.

Note that successful testing to PL2 will ensure compliance with PL1.

Note: These required performances originate in ETAG 013 (June 2002).

2.2.12 Material properties, component performance, system performance of plastic duct to provide an electrically isolated tendon (PL3)

Polymer duct material PP and HDPE are assessed according to *fib* recommendations (Bulletin 75), Chapter 5, Tables 5.1 and 5.2, respectively. Material of duct shall be tested for:

- Oxidation Induction Time (OIT) at 200 °C tested according to EN ISO 11357-6: ≥ 25 minutes
- Environmental Stress Cracking Resistance (ESCR) (Condition C) tested according to ASTM D 1693: ≥ 600 hours
- Notched impact tested according to EN ISO 179-1/1eA at 23 °C: ≥ 22 kJ/m^2, and at 0 °C: ≥ 4 kJ/m^2
- Hydrostatic Design Basis (HDB) for HDPE only tested according to ISO TR 9080: ≥ 8.0 MPa.

In addition, the following properties shall be stated in the ETA:

- Melt Flow Rate (MFR) according to EN ISO 1133 at 230 °C and at 190 °C for PP and PE, respectively
- Density according to EN ISO 1183-1
- Flexural Modulus according to EN ISO 178
- Tensile Yield Strength according to EN ISO 6259-3
- Elongation at yield and at break according to EN ISO 6259-3
- Thermal expansion coefficient according to ASTM D696.

Polymer duct components are assessed according to *fib* recommendations (Bulletin 75), Chapter 6, Section 8.5 and Annex A as applicable for PL3.

- Dimensional requirements – assessed in accordance with *fib* Bulletin 75, Annex A.1 with 3 tests per size performed on all sizes of duct and connector tested at 23 °C ± 5 °C. The required performances are:
  - Actually measured dimensions or, where applicable, average dimensions of ducts and connectors shall be within the dimensions and tolerances specified in the manufacturer's drawings or specifications;
  - average value of internal and external diameters, d_1 and d_2, respectively, shall be within ± 1% or ± 1 mm, whichever is greater;
  - average value of wall thickness shall be within -0 / +0.5 mm.
- Stiffness of duct – assessed in accordance with *fib* Bulletin 75, Annex A.2 with 1 test per size performed on all duct sizes tested at 23 °C ± 5 °C and at 45 °C. The required performance is:
  - Effective duct stiffness $(E * I)_{eff}$ as determined in test.

- Longitudinal load resistance of duct system – assessed in accordance with *fib* Bulletin 75, Annex A.3 with 1 test per size performed on all duct sizes with each connector tested at 23 °C ± 5 °C. The required performances are:
  - Maintain required elongation $\Delta = 40 * \alpha_T * L$ of the duct length for at least 10 minutes for ducts for all tendon applications;
  - maintain specified longitudinal load F_1 for at least 10 minutes for ducts intended to be used with prefabricated tendons supplied on coils;
  - no visual slippage of connector and no unusual observations that would indicate failure of duct system.
- Lateral load resistance of duct – assessed in accordance with *fib* Bulletin 75, Annex A.4 with 1 test per size performed on all duct sizes tested at 23 °C ± 5 °C and at 45 °C. The required performances are:
  - No deformations exceeding 35% of duct internal diameter immediately when reaching the specified lateral load F_d;
  - no deformations exceeding 35% of duct internal diameter or 5 mm whichever is smaller two minutes after release of load F_1;
  - no visual damage of test specimen.
- Flexibility of duct system – assessed in accordance with *fib* Bulletin 75, Annex A.5 with 1 test per size performed on all duct sizes with each connector tested at 23 °C ± 5 °C, at -15 °C, and at 45 °C. The required performances are:
  - No deformations exceeding 5% of duct internal diameter while test specimen is in final bent position – confirmed by easy passage of plunger;
  - no visual damage of test specimen.
- Leak tightness of duct system – assessed in accordance with *fib* Bulletin 75, Annex A.6 with 1 test per size performed on all duct sizes with each connector tested at 23 °C ± 5 °C. The required performance is:
  - No visibly detectable leaks with positive and with negative pressure applied for 30 minutes duration.
- Concrete pressure test on duct – assessed in accordance with *fib* Bulletin 75, Annex A.7 with 1 test per size performed on all duct sizes tested at 23 °C ± 5 °C. The required performances are:
  - No changes in geometry/ duct diameter of more than 10% in plane of template and at right angle to plane;
  - no collapse of duct.
- Wear resistance of duct – assessed in accordance with *fib* Bulletin 75, Annex A.8 with 1 test per size performed on all duct sizes tested at 23 °C ± 5 °C and at 45 °C. The required performance is:
  - Minimum residual wall thickness after testing is 1.5 mm at all sections.
- Wear resistance of duct under sustained load – assessed in accordance with *fib* Bulletin 75, Annex A.9 with 1 test per size performed on all duct sizes tested at 23 °C ± 5 °C and at 45 °C. The required performance is:
  - Minimum residual wall thickness after testing is 1.0 mm at all sections.
- Bond behaviour of duct – assessed in accordance with *fib* Bulletin 75, Annex A.10 with 1 test per size performed on 3 duct sizes, i.e. small, medium and largest, tested at 23 °C ± 5 °C. The required performances are:
  - Maintain full test load F_{bu} for at least two minutes duration without excessive strand slippage, grout column to duct failure, or duct to concrete failure (all defined as movements greater than 5 mm);
  - the relative movement of tendon and grout versus concrete shall stabilize within the 2 minutes (if it does not, the full test load F_{bu} shall be maintained until relative movement has stabilized).

- Precast segmental duct coupler system where applicable – assessed in accordance with *fib* Bulletin 75, Annex A.11 with 1 test per size performed on all segmental duct coupler sizes, tested at 23 °C ± 5 °C. The required performances are:
  - Precast segmental duct coupler assembly must sustain a 3.50 bar internal test pressure for a minimum of five minutes with no more than a 0.35 bar reduction in pressure;
  - precast segmental duct coupler assembly (with duct and connectors) shall be intact, free of epoxy infiltration into the inside of the encapsulation, and properly attached without crushing, tearing or other signs of failure.
- Fracture resistance of duct system (optional test) – assessed in accordance with *fib* Bulletin 75, Annex A.12 with 1 test per size performed on 3 duct sizes, i.e. small, medium and largest, tested at 23 °C ± 5 °C. The required performance is:
  - After two million cycles of crack opening between 0.2 mm and 0.5 mm, there shall be no cracks, perforations or excessive wear in the polymer duct.

Polymer duct systems are assessed according to *fib* recommendations (Bulletin 75), Chapter 7, Section 8.5 and Annex B as applicable for PL3.

- Leak tightness of anchorage-duct assembly – assessed in accordance with *fib* Bulletin 75, Annex B.1 with 1 test per size performed on 1 medium representative duct size at 23 °C ± 5 °C. The required performance is:
  - No visibly detectable leaks with positive and with negative pressure applied for 30 minutes duration.
- EIT performance of the duct system – assessed in accordance with *fib* Bulletin 75, Annex B.2 with 1 test per size performed on all duct sizes with each connector and vent tested at 23 °C ± 5 °C. The required performances are:
  - All three specimens (i.e. duct, duct with connector, duct with connector and vent) shall reach an electrical AC resistance of R ≥ 2000 kOhm;
  - the capacitance C and loss factor D for all test specimens shall be stated in the ETA and shall be consistent with the material and duct diameter.
- EIT performance of anchorage-duct assembly – assessed in accordance with *fib* Bulletin 75, Annex B.3 with 1 test per size performed on 1 medium representative duct size at 23 °C ± 5 °C. The required performances are:
  - Electrical resistance of at least 15 kOhm over entire duration of test;
  - eventual coatings on metallic anchorage surfaces remain visually intact.
- Full scale duct system assembly – assessed in accordance with *fib* Bulletin 75, Annex B.4 with 1 test per size performed on 1 medium representative duct size at ambient temperature (typically 23 °C ± 5 °C would be considered suitable). The required performances are:
  - All components can be installed as specified in the method statement;
  - duct profile complies with the specified profile within specified tolerances as per method statement;
  - no apparent tendon profile kinks or discontinuities or loose connections;
  - no excessive duct deformations on the duct support or duct deflections between the supports.
- Leak tightness of assembled duct system – assessed in accordance with *fib* Bulletin 75, Annex B.5 with 1 test per size performed on 1 medium representative duct size at ambient temperature (typically 23 °C ± 5 °C would be considered suitable). The required performance is:
  - Pressure loss after test duration of 5 minutes shall not exceed 10% of initial pressure, i.e. 0.05 bar.

The ETA shall state whether the performance for fracture resistance of duct system (optional test) has been assessed or not.

Note that successful testing to PL3 will ensure compliance with PL2 and PL1.

Note: These required performances originate in ETAG 013 (June 2002).

2.2.13 Corrosion protection

Corrosion protection of all components of a PT system is a prime concern to assure the specified characteristics are retained throughout the intended life of the structure. It is recommended that the ETA gives instructions on required protection measures and materials for tensile elements, anchorage components, couplings, ducts, etc. to prevent corrosion and its adverse effects on friction or strength.

Corrosion protection shall be provided to tendons in all cases and be appropriate for the intended use and expected environment and exposure. Corrosion protection of internal tendons is primarily achieved by adequate concrete cover, by suitable choice of duct type and filling material. Corrosion protection of external tendons is primarily achieved by careful detailing and locating external tendons in the structure, suitable choice of duct (material and thickness) and filling material. The quality of filling material, and the quality of executing the filling of ducts on site have a major effect on the quality of corrosion protection, and hence the durability of the PT system both for internal and external tendons.

Locations where PT system components are exposed to the environment such as at anchorages, at vents and drains, etc. shall be provided with details such as to effectively seal and protect the tensile elements and anchorage components. This also applies to connections between duct sections and to anchorages if they are exposed.

Metallic surfaces that are exposed to the environment such as at anchorages should be protected effectively against corrosion. Guidance may be found in EN ISO 12944.

Assessment is to be based on past successful use in practice regarding duct type, filling material, sealing of anchorages and tendons, and protection of exposed steel surfaces. In the case of an innovative system with no past successful use, assessment can be done through suitable test (depending on the nature of the innovation).

2.2.14 Monostrand, sheathing base material, melt index

Melt index is determined according to EN ISO 1133, 10 minutes with 2.16 kg.

Melt index shall be ≤ 0.25 g

Note: The required performance originates from ETAG 013, June 2002.

2.2.15 Monostrand, sheathing base material, density

Density is determined according to EN ISO 1183-1.

Density shall be ≥ 0.94 g/cm^3

Note: The required performance originates from ETAG 013, June 2002.

2.2.16 Monostrand, sheathing base material, carbon black

Content of carbon black is determined according to ISO 6964.

Content of carbon black shall be 2.3 ± 0.3 %.

Dispersion of carbon black is determined according to ISO 4437.

Dispersion of carbon black shall have an index of maximum 3.

Distribution of carbon black is determined according to ISO 4437.

Distribution of carbon black shall have an index of maximum C2.

Note: The required performances originate from ETAG 013, June 2002.

2.2.17 Monostrand, sheathing base material, tensile strength

Tensile strength is determined according to EN ISO 527-2.
Test conditions are

– Specimen 1A according to EN ISO 527-2
– Loading speed 100 mm/minute
– Temperature 23 °C

Tensile strength shall be ≥ 22 MPa
Note: The required performance originates from ETAG 013, June 2002.

2.2.18 Monostrand, sheathing base material, elongation

Elongation is determined according to EN ISO 527-2
Test conditions are

– Specimen 1A according to EN ISO 527-2
– Loading speed 100 mm/minute
– Temperature 23 °C
– Temperature -20 °C

At a temperature of 23 °C elongation shall be ≥ 600 %
At a temperature of -20 °C elongation shall be ≥ 350 %
Note: The required performances originate from ETAG 013, June 2002.

2.2.19 Monostrand, sheathing base material, thermal stability

Thermal stability is determined according to EN ISO 11357-6 at 210 °C.
Time without degradation – oxygen induction time – shall be ≥ 20 minutes
Note: The required performance originates from ETAG 013, June 2002.

2.2.20 Monostrand, manufactured sheathing, tensile strength

Tensile strength is determined according to EN ISO 527-2.
Test conditions are

– Specimen 1B according to EN ISO 527-2
– Loading speed 100 mm/minute
– Temperature 23 °C

Tensile strength shall be ≥ 18 MPa
Note: The required performance originates from ETAG 013, June 2002.

2.2.21 Monostrand, manufactured sheathing, elongation

Elongation is determined according to EN ISO 527-2.
Test conditions are

– Specimen 1B according to EN ISO 527-2
– Loading speed 100 mm/minute
– Temperature 23 °C
– Temperature -20 °C

At a temperature of 23 °C elongation shall be ≥ 450 %
At a temperature of -20 °C elongation shall be ≥ 250 %
Note: The required performances originate from ETAG 013, June 2002.

2.2.22 Monostrand, manufactured sheathing, surface of sheathing

Surface of sheathing is visually inspected for damages and other distinctive features.

There shall be

- No visual damage
- No bubbles
- No traces of filling material visible

Note: The required performances originate from ETAG 013, June 2002.

2.2.23 Monostrand, manufactured sheathing, environmental stress cracking

Environmental stress cracking is determined according to EN 60811-4-1.

No cracking after 72 hours in a tensio-active liquid at 50 °C

Note: The required performance originates from ETAG 013, June 2002.

2.2.24 Monostrand, manufactured sheathing, temperature resistance

Temperature resistance is determined as alteration of tensile strength and elongation after conditioning for 3 days at 100 °C.

Tensile strength and elongation are determined according to EN ISO 527-2

Test conditions are

- Specimen 1B according to EN ISO 527-2
- Loading speed 100 mm/minute
- Temperature 23 °C

Alteration of tensile strength shall be ≤ 25 %.

Alteration of elongation shall be ≤ 25 %.

Note: The required performances originate from ETAG 013, June 2002.

2.2.25 Monostrand, manufactured sheathing, resistance to externally applied agents

Resistance to externally applied agents

Testing is performed according to EN ISO 175 with 16 weeks test duration at 23 °C.

Exposure to	Test agent	
Mineral oil	Oil No 3 according to ISO 1817	Alteration of tensile strength ≤ 25 % Alteration of elongation ≤ 25 % Alteration of volume ≤ 5 %
Acid	10 % sulphuric acid	Alteration of tensile strength ≤ 25 % Alteration of elongation ≤ 25 % Alteration of volume ≤ 5 %
Base	Saturated calcium hydroxide 40 % sodium hydroxide	Alteration of tensile strength ≤ 25 % Alteration of elongation ≤ 25 % Alteration of volume ≤ 5 %
Solvents	Blend of acetone : ethanol : n-heptane : toluol, 1 : 1 : 1 : 1 by mass	Alteration of tensile strength ≤ 25 % Alteration of elongation ≤ 25 % Alteration of volume ≤ 10 %
Salt water	Saturated solution of demineralised tab water and NaCl	Alteration of tensile strength ≤ 25 % Alteration of elongation ≤ 25 % Alteration of volume ≤ 5 %

Tensile strength and elongation are determined according to EN ISO 527-2.

Test conditions are

- Specimen 1B according to EN ISO 527-2
- Loading speed 100 mm/minute
- Temperature 23 °C

Note: The required performances originate from ETAG 013, June 2002.

2.2.26 Monostrand, manufactured sheathing, sheathing minimum thickness

Sheathing minimum thickness is determined according to EN ISO 3126. 1 mm is required as a minimum value.

Note: The required performance originates from ETAG 013, June 2002.

2.2.27 Monostrand, manufactured monostrand, external diameter of sheathing

External diameter of sheathing is determined according to EN ISO 3126.

2.2.28 Monostrand, manufactured monostrand, mass of sheathing per metre

Mass of sheathing per metre is determined by weighing the sheathing of a length of monostrand after removal of prestressing steel strand and filling material and thoroughly cleaning. The mass of the piece is divided by its length, resulting in the mass of sheathing per metre.

2.2.29 Monostrand, manufactured monostrand, mass of filling material per metre

Mass of filling material per metre is determined by weighing

- A length of the monostrand,
- Sheathing and
- Prestressing steel strand of that length of the monostrand.

Sheathing and individual wires of prestressing steel strand shall after removal from the monostrand be thoroughly cleaned before weighing. Cleaned components of the monostrand shall be dry before weighing.The mass of the length of monostrand minus mass of sheathing and minus mass of prestressing steel is divided by its length, resulting in the mass of filling material per metre.

2.2.30 Monostrand, manufactured monostrand, alteration of dropping point caused by monostrand manufacturing

Dropping point of filling material before and after monostrand manufacturing is determined according to ISO 2176.

Alteration of dropping point shall be $\leq$ 10 %.

Note: The required performance originates from ETAG 013, June 2002.

2.2.31 Monostrand, manufactured monostrand, alteration of oil separation caused by monostrand manufacturing

Oil separation of filling material before and after monostrand manufacturing is determined according to BS 2000-121.

Alteration of oil separation shall be

- at 72 hours $\leq$ 3 %
- at 7 days $\leq$ 5 %.

Note: The required performances originate from ETAG 013, June 2002.

2.2.32 Monostrand, manufactured monostrand, impact resistance

The test specimen is a monostrand of a minimum length of 2.5 times the lay of the strand.

The test specimen is fixed onto a steel plate to prevent its rotation during the test. A steel block of 1 kg mass is dropped from 500 mm height, 10 times at different locations along the specimen onto it. The test is performed at 23 ± 2 °C. The impact device is shown in Figure 3.

Any visually detectable tear or penetration of the sheathing shall be recorded.

No tear or penetration of sheathing shall occur.

Note: The required performance originates from ETAG 013, June 2002.

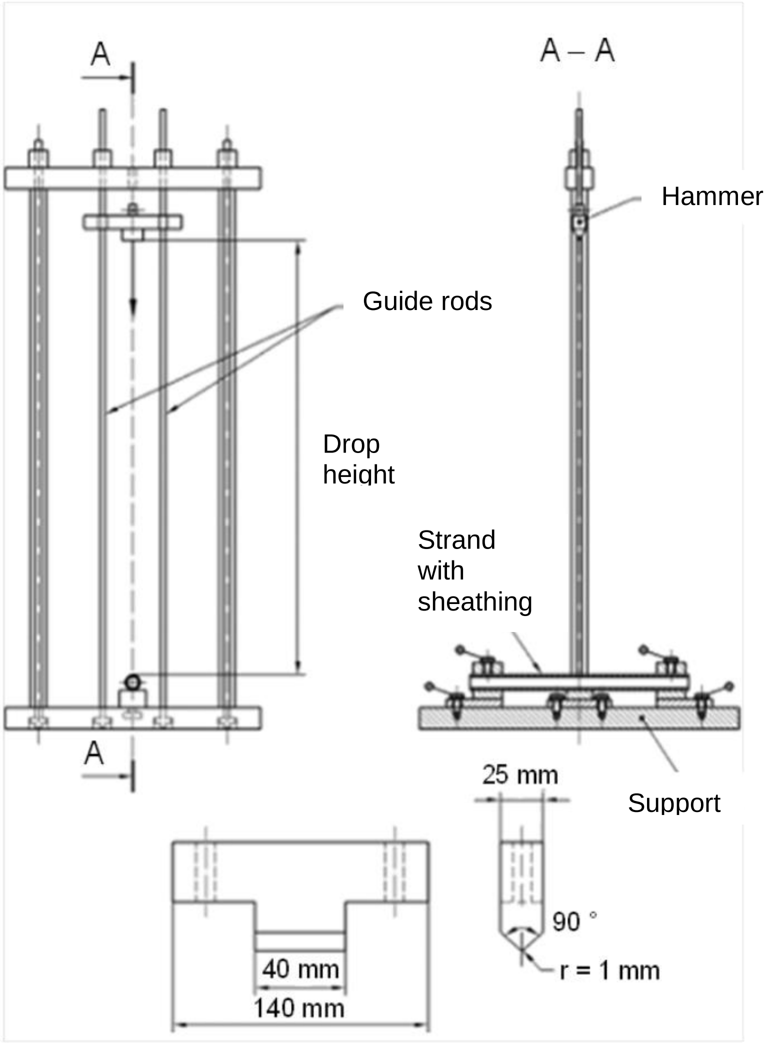

Figure 3 – Monostrand – Test for impact resistance

2.2.33 Monostrand, manufactured monostrand, friction between sheathing and strand

Friction between sheathing and strand

The specimen is a monostrand sufficiently long to permit measurement of friction over a length of 1 m.

The sheathing is removed at one end of the monostrand to permit proper anchorage of the tensile element. At the other end of the monostrand a dynamometer or any other equivalent equipment is fixed onto the sheathing. The distance between the fixing and the end of the sheathing is 1 m. A force is then applied with the dynamometer and gradually increased until the sheathing is moving over the tensile element, at a temperature of 23 ± 2 °C.

The force and the sheathing movement relative to the tensile element shall be continuously recorded.

Friction between sheathing and strand shall be ≤ 60 N/m.

Note: The required performance originates from ETAG 013, June 2002.

2.2.34 Monostrand, manufactured monostrand, leak tightness

A monostrand of 1 m length is used for the test.

The specimen is straightened and placed horizontally on a flat table. At one end of the specimen a water reservoir is attached with a constant water head of 1 m, over a period of 24 hours at a temperature of 23 ± 2 °C.

Quantity of water collected at the end of the sheathing opposite of the water reservoir that leaks through the monostrand.

No water shall leak through the specimen.

Note: The required performance originates from ETAG 013, June 2002.

2.2.35 Reaction to fire

Components made of steel, cast iron, stainless steel, cement or mortar containing mineral binders are considered to satisfy the requirements for performance class A1 of the characteristic reaction to fire, in accordance with the provisions of Decision 96/603/EC (as amended), without the need for testing on the basis of it fulfilling the conditions set out in that Decision and its intended use being covered by that Decision.

Therefore the performance of these components is class A1.

Other components may need to be tested according to EN 13501-1, depending on the class the manufacturer wants to declare.

2.2.36 Content, emission and/or release of dangerous substances

The performance of the PT kit related to the emissions and/or release and, where appropriate, the content of dangerous substances will be assessed on the basis of the information provided by the manufacturer[3] after identifying the release scenarios (in accordance with EOTA TR 034) taking into account the intended use of the product and the Member States where the manufacturer intends his product to be made available on the market.

The identified intended release scenarios for this product and intended use with respect to dangerous substances are:

IA1: Product with direct contact to indoor air.

IA2: Product with indirect contact to indoor air (e.g. covered products) but possible impact on indoor air.

S/W1: Product with direct contact to soil, ground- and surface water.

S/W2: Product with indirect contact to soil, ground- and surface water.

2.2.36.1 SVOC and VOC

For the intended use covered by the release scenario IA1 and IA2 semi-volatile organic compounds (SVOC) and volatile organic compounds (VOC) are to be determined in accordance with EN 16516. The loading factor to be used for emission testing is 0,007 m^2/m^3.

The PT kit to be tested shall be assembled according to the envisaged application, using all components necessary, including tensile elements, anchorages, ducts and filling material. If required monostrands, couplings, deviators, bursting reinforcement and any other special accessories as needed should be part of the test specimen. The installation should be in accordance with the manufacturer's product installation instructions or (in absence of such instructions) the usual practice of installation.

Once the test specimen has been produced, as described above, it should immediately be placed in the emission test chamber. This time is considered the starting time of the emission test.

The test results have to be reported for the relevant parameters (e.g. chamber size, temperature and relative humidity, air exchange rate, loading factor, size of test specimen, conditioning, production date, arrival date, test period, test result) after 3 and 28 days testing.

The relevant test results shall be expressed in [mg/m^3] and stated in the ETA.

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3 The manufacturer may be asked to provide to the TAB the REACH related information which he must accompany the DoP with (cf. Article 6(5) of Regulation (EU) No 305/2011).
The manufacturer is not obliged:
- to provide the chemical constitution and composition of the product (or of constituents of the product) to the TAB, or
- to provide a written declaration to the TAB stating whether the product (or constituents of the product) contain(s) substances which are classified as dangerous according to Directive 67/548/EEC and Regulation (EC) No 1272/2008 and listed in the "Indicative list on dangerous substances" of the SGDS.

Any information provided by the manufacturer regarding the chemical composition of the products may not be distributed to EOTA or to TABs.

2.2.36.2 Leachable substances

For the intended use covered by the release scenario S/W1 the performance of the PT kit concerning leachable substances has to be assessed. A leaching test with subsequent eluate analysis must take place, each in duplicate. Leaching tests of the PT kit are conducted according to CEN/TS 16637-2:2014. The leachant shall be pH-neutral demineralised water and the ratio of liquid volume to surface area must be (80 ± 10) l/m².

The PT kit to be tested shall be assembled according to the envisaged application, using all components necessary, including tensile elements, anchorages, ducts and filling material. The installation should be in accordance with the manufacturer's product installation instructions or (in absence of such instructions) the usual practice of installation.

In eluates of "6 hours" and "64 days", the following biological tests shall be conducted:

- Acute toxicity test with Daphnia magna Straus according to EN ISO 6341
- Toxicity test with algae according to ISO 15799
- Luminescent bacteria test according to EN ISO 11348-1, EN ISO 11348-2 or EN ISO 11348-3

For each biological test, EC20-values shall be determined for dilution ratios 1:2, 1:4, 1:6, 1:8 and 1:16.

If the parameter TOC is higher than 10 mg/l, the following biological tests shall be conducted with the eluates of "6 hours" and "64 days" eluates:

- Biological degradation according to OECD Test Guideline 301 part A, B or E.

Determined toxicity in biological tests must be expressed as EC20-values for each dilution ratio. Maximum determined biological degradability must be expressed as "…% within …hours/days". The respective test methods for analysis must be specified.

3 ASSESSMENT AND VERIFICATION OF CONSTANCY OF PERFORMANCE

3.1 System(s) of assessment and verification of constancy of performance to be applied

For the products covered by this EAD the applicable European legal act is: Decision 98/456/EC

98/456/EC: Commission Decision 98/456/EC of 3 July 1998 on the procedure for attesting the conformity of construction products pursuant to Article 20(2) of Council Directive 89/106/EEC as regards post-tensioning kits for the prestressing of structures, Official Journal of the European Communities L 201 from 17 July 1998, page 112.

The system is: 1+

3.2 Tasks of the manufacturer

The cornerstones of the actions to be undertaken by the manufacturer of the product in the procedure of assessment and verification of constancy of performance are laid down in Table 3.

Table 3 Control plan for the manufacturer; cornerstones

No	Subject/type of control *(product, raw/constituent material, component - indicating characteristic concerned)*	Test or control method	Criteria, if any	Minimum number of samples	Minimum frequency of control
Factory production control (FPC) including testing of samples taken at the factory in accordance with a prescribed test plan					
1	Simple Bearing plate material	Checking of relevant certificate[1)]		100%	continuous
	Other than simple bearing plate and other force transfer units, material	Checking of relevant certificate[3)]		100%	continuous
	Bearing plate and other force transfer units, detailed dimensions	Testing		3% with a minimum of 2 specimens	continuous
	Bearing plate and other force transfer units, visual inspection[4)]	Testing		100%	continuous
	Bearing plate traceability	bulk			
2	Anchor head material	Checking of relevant certificate[3)]		100%	continuous
	Anchor head, detailed dimensions	Testing		5% with a minimum of 2 specimens	continuous
	Anchor head, visual inspection[4)]	Checking		100%	continuous
	Anchor head, traceability	full			
3	Wedge, nut, … material	Checking of relevant certificate[3)]	conform to compo-nent specif.	100%	continuous
	Wedge, nut, … treatment, hardness	Testing	conform to compo-nent specif.	0.5% with a minimum of 2 specimens	continuous

No	Subject/type of control *(product, raw/constituent material, component - indicating characteristic concerned)*	Test or control method	Criteria, if any	Minimum number of samples	Minimum frequency of control
	Wedge, nut, … detailed dimensions	Testing	conform to compo-nent specif.	5% with a minimum of 2 specimens	continuous
	Wedge, nut, … visual inspection[4)]	Checking	conform to compo-nent specif.	100%	continuous
	Wedge, nut, …traceability	full			
4	Tensile element, material	Checking	[2) 8)]	100%	continuous
	Tensile element, diameter	Testing	[2) 8)]	1 sample	each coil or every 7 tons[7)]
	Tensile element, visual inspection	Checking	[2) 8)]	1 sample	each coil or every 7 tons[7)]
5	Steel strip duct material	Checking of relevant certificate (CE)	[2)]	100%	continuous
	Steel strip duct dimension	Testing	[2)]	3% with a minimum of 2 specimens	continuous
	Steel strip duct traceability	full			
6	Corrugated plastic/polymer duct	According to *fib* Bulletin 75, Chapter 9	[2)]	According to *fib* Bulletin 75, Chapter 9	According to *fib* Bulletin 75, Chapter 9
7	Plastic pipe, material	Checking of relevant certificate (CE)		100%	continuous
	Plastic pipe, traceability	full			
8	Helix other than reinforcing steel, material	Checking of relevant certificate (CE)	[2)]	100%	continuous
	Helix other than reinforcing steel, visual inspection	Checking	[2)]	100 %	continuous

No	Subject/type of control *(product, raw/constituent material, component - indicating characteristic concerned)*	Test or control method	Criteria, if any	Minimum number of samples	Minimum frequency of control
	Helix other than reinforcing steel, traceability	full			
9	Constituent of filling materials as per EN 447 [6)]	Checking of relevant certificate [5)]	[2)]	all	100%
10	Cement of filling materials as per EN 447	Checking of relevant certificate [5)]	[2)]	100%	continuous
	Admixtures, additions of filling materials as per EN 447	Checking of relevant certificate [5)]	[2)]	100%	continuous
	Filling material traceability	full			
11	Other important components as relevant	To be added by the TAB as relevant			
12	Monostrand External diameter of monostrand sheathing	Test EN ISO 3126	[2)]	1 sample	each coil or every 7 tonnes[7)]
	Monostrand Wall thickness	Test EN ISO 3126	[2)]	1 sample	each coil or every 7 tonnes[7)]
	Monostrand Mass of sheathing per linear metre	Test 2.2.28	[2)]	1 sample	each coil or every 7 tonnes[7)]
	Monostrand Mass of filling material per linear metre	Test 2.2.29	[2)]	1 sample	each coil or every 7 tonnes[7)]
	Monostrand Impact resistance	Test 2.2.32	2.2.32	1 sample	each 50 tonnes
	Monostrand Friction between sheathing and strand	Test 2.2.33	2.2.33	3 samples	each 50 tonnes
	Monostrand Leak tightness	Test 2.2.34	2.2.34	1 sample	each 50 tonnes
	Monostrand Material (HDPE and grease)	Checking of relevant certificate [3)]	[2)]	100 %	each delivery
13	Static load test at cryogenic condition	2.2.8	2.2.8	2.2.8	Initially at start of production of every specific project.
14	Other important components as relevant	To be added by the TAB as relevant			

Key
1) The certificate is at least a test report 2.2 according to EN 10204.
2) Conformity with the specifications of the components
3) The certificate is an inspection report 3.1 according to EN 10204

4) Successful visual inspection does not need to be documented.
5) CE marking and declaration of performance or, if basis for CE marking is not available, certificate of supplier
6) For grout additional regulations in place of use might apply
7) Maximum between a coil and 7 tons has to be taken into account
8) While the basis of "CE"-marking is not available, the prescribed test plan has to include appropriate measures, only for the time until the harmonised technical specification is available.

Traceability
full : Full traceability of each component to its raw material.
bulk : Traceability of each delivery of components to a defined point.
Material: Defined according to technical specification deposited by the supplier
Detailed dimension: Measuring of all the dimensions and angles according to the specification given in the test plan
Visual inspection: Main dimensions, correct marking and labelling, surface, corrosion, coating, etc.
Treatment, hardness: surface hardness, core hardness and treatment depth

3.2.1 General

The kit manufacturer shall perform permanent control of the factory production control (FPC).

The manufacturer has to provide manufacturing drawings that give the material characteristics and manufacturing tolerances of the different components, to the TAB.

3.2.2 Permanent control of the factory production control (FPC)

The kit manufacturer shall exercise permanent internal control of the production. All the elements, requirements and provisions adopted by the kit manufacturer shall be documented in a systematic manner in the form of written policies and procedures. FPC and the prescribed test plan concern manufacturing.
FPC systems that comply with EN ISO 9001 and which address the requirements of the ETA will be acceptable. Parts of the FPC may be transferred to an independent test laboratory. Nevertheless, the kit manufacturer has the full responsibility for all results of the FPC.

Control of the incoming materials
Manufacturer has to check the incoming materials to comply with its specifications. For components covered by a harmonized EN or by an ETA, the verification of the performance of the said components (by the manufacturer or by the notified body) will be limited to the verification of the Declaration of Performance of the component manufacturer to ensure that the component has the performance required by the kit manufacturer. The same will apply for all components of the kit which will be gradually covered by harmonised ENs (e.g. tensile elements) or ETAs.

Inspection and testing
The validity of the type and frequency of checks/tests conducted during production and on the final product shall be considered as a function of the production process. This will include the checks conducted during manufacture on properties that cannot be inspected at a later stage and for checks on the final product. These will normally include:

- Definition of the number of samples taken by the kit manufacturer
- Material properties e.g. tensile strength, hardness, surface finish, chemical composition, …
- Determination of the dimensions of components
- Check correct assembly
- Documentation of tests and test results.

All tests shall be performed according to written procedures with suitable calibrated measuring devices. All test results shall be recorded in a consistent and systematic way. The kit manufacturer and the TAB issuing the ETA shall agree on a prescribed test plan. Table 3 gives the minimum procedures that have to be performed for the most important components, to be adapted by the TAB. For all other components of the PT kit, not reported in Table 3, the FPC has to include appropriate measures. In this sense, the TAB has to adapt Table 3 according to the importance of the components for the performance of the PT system.

Control of non-conforming products

Products, which are considered as not conforming to the prescribed test plan shall be immediately marked and separated from such products that comply. The prescribed test plan has to address control of non-conforming products.

Complaints

The prescribed test plan shall include provisions to keep records of all complaints about the kit.

3.3 Tasks of the notified body

The cornerstones of the actions to be undertaken by the notified body (NB) in the procedure of assessment and verification of constancy of performance for the PT kits are laid down in Table 4.

Table 4 Control plan for the notified body; cornerstones

No	Subject/type of control *(product, raw/constituent material, component - indicating characteristic concerned)*	Test or control method	Criteria, if any	Minimum number of samples 1)	Minimum frequency of control
Initial inspection of the manufacturing plant and of factory production control					
1	FPC documentation system: procedures and technical forms	documents	check	all	-
2	Records of the FPC documentation system	records	check	1 for type	-
3	Factory organisation: qualifications, tasks and responsibilities of the technical and management staff	documents and records (3)	check	all	-
4	Production flow	documents	check	all	-
5	Order management: offer, order and accompanying documentation	documents	check	1	-
6	Preparation of the Register of Manufacturer and the Declaration of Performance	documents	check	all	-
7	Criteria, methods and records of materials internal controls and checks of the acceptance controls	documents and records	check	1 for type	-
8	Production management (frequency, number and location of samples of finished products or components, periodic tests; identification systems products and their components; certifications of materials)	documents and records	check	1 for type	-
9	Records of tests performed by the Manufacturer	records	check	all	-
10	Inspection of production plants and warehouses	visual	check	all	-
11	Manufacturer testing lab: check of critical equipment for the purpose of experimental measurements and / or controls; assurance metrological traceability of measurement and control equipment	visual, documents and records	check	all	-
12	Treatment of non-conforming products, criteria for declassification and segregation	visual	check	1	-
13	Traceability of products, from raw materials to the job site and vice versa	visual and records	check	1	-
Continuous surveillance, assessment and evaluation of factory production control					

1	FPC documentation system: procedures and technical forms	documents	check	modifications only	1/year
2	Records of the FPC documentation system	records	check	1 for type	1/year
3	Factory organisation: qualifications, tasks and responsibilities of the technical and management staff	documents and records	check	modifications only	1/year
4	Production flow	documents	check	modifications only	1/year
5	Register of Manufacturers	records	check	all	1/year
6	Records of audits of component manufacturers	records	check	all	1/year
7	Declaration of Performance	records	check	1	1/year
8	Order management: offer, order and accompanying documentation	records	check	1	1/year
9	Criteria, methods and records of materials internal controls and checks of the acceptance controls	records	check	1	1/year
10	Production management (frequency, number and location of samples of finished products or components, periodic tests; identification systems products and their components; certifications of materials)	records	check	1 for type	1/year
11	Records of tests performed by the Manufacturer	records	check	1	1/year
12	Inspection of production plants and warehouses	visual	check	all	1/year
13	Manufacturer testing lab: check of critical equipment for the purpose of experimental measurements and / or controls; assurance metrological traceability of measurement and control equipment	visual and records	check	all	1/year
14	Treatment of non-conforming products, criteria for declassification and segregation	visual and records	check	1	1/year
15	Traceability of products, from raw materials to the job site and vice versa	visual and records	check	1	1/year
Audit-testing of samples taken by the notified product certification body at the manufacturing plant or at the manufacturer's storage facilities					
1	Bearing plate and other force transfer units, material	Checking and testing (hardness and chemical)	[2)]	1	1/year
	Bearing plate and other force transfer units, detailed dimensions	testing	[2)]	1	1/year
	Bearing plate and other force transfer units, visual inspection	checking	[2)]	1	1/year
2	Anchor head, material	Checking and testing (hardness and chemical)	[2)]	1	1/year
	Anchor head, detailed dimensions	testing	[2)]	1	1/year
	Anchor head, visual inspection	checking	[2)]	1	1/year

3	Wedge, nut, … material	Checking and testing (mechanical and chemical)	2)	2	1/year
	Wedge, nut, … treatment, hardness	Checking and testing (hardness profile)	2)	2	1/year
	Wedge, nut, … detailed dimensions	Testing	2)	1	1/year
	Wedge, nut, …, main dimensions, surface hardness	Testing	2)	5	1/year
	Wedge, nut, … visual inspection	checking	2)	5	1/year
4	Corrugated plastic/polymer ducts	According to *fib* Bulletin 75, Chapter 9	2)	1 for material; 2 duct sizes and 2 components	1/year
5	Single tensile element test	Annex C.7	Annex C.7	9	1/year
6	Monostrand External diameter of monostrand sheathing	EN ISO 3126	2)	1 sample	1/year
	Monostrand Wall thickness	EN ISO 3126	2)	1 sample	1/year
	Monostrand Mass of sheathing per linear metre	Test 2.2.28	2)	1 sample	1/year
	Monostrand Mass of filling material per linear metre	Test 2.2.29	2)	1 sample	1/year
	Monostrand, sheathing Melt index	Test 2.2.14	2)	1 sample	1/year
	Monostrand, sheathing Density	Test 2.2.15	2)	1 sample	1/year
	Monostrand, sheathing Black carbon content	Test 2.2.16	2)	1 sample	1/year

Key

1) If the kit comprises different types of anchor heads e.g. with different materials, different shape, different wedges, etc., then the number of samples are understood as per type.

2) Conformity with the specifications of the components

3) Requirements and points to check are the following :

- Technical staff: qualified staff that passed at least an internal training for the tasks
- Laboratory staff for FPC with passed internal and external qualifications
- Clear and reasonable system of tasking and supervising, documented; recognizable responsibilities

Material: Defined according to technical specification deposited by the ETA holder at the Notified Body
Detailed dimension: Measuring of all the dimensions and angles according to the specification given in the test plan
Treatment, hardness: Surface hardness, core hardness and treatment depth
Visual inspection: Main dimensions, correct marking and labelling, surface, corrosion, coating, etc.

Note : subject to the agreement between TAB and the manufacturer, the control plan can include the audit of component manufacturers every 5 years as was required by ETAG013. In the same way, the control plan can include the fact to take samples for audit tests directly from job sites.

3.3.1 General

The NB shall perform the:

- Initial inspection of the factory and FPC;
- Continuing surveillance, assessment and evaluation of FPC;
- Audit-testing of samples taken by the notified product certification body at the manufacturing plant or at the manufacturer storage facility.

3.3.2 Initial inspection of the factory and FPC

The NB shall establish that, in accordance with the prescribed test plan, the manufacturing plant, in particular personnel and equipment, and the factory production control are suitable to ensure a continuous manufacturing of the PT system according to the given technical specifications. The activities shall be conducted by the NB or under its responsibility, which may include a proportion included by an external inspection body, witnessed by the NB. For the most important activities, Table 4 summarizes the minimum procedure. The TAB has to adapt Table 4 according to the specific case.

3.3.3 Continuing surveillance, assessment and evaluation of FPC

The activities shall be conducted by the NB or under its responsibility, which may include a proportion included by an external inspection body, witnessed by the NB.
The activities shall include surveillance inspections. The kit manufacturer shall be inspected at least once a year. The FPC is checked and samples are taken for independent single tensile element test;
For the most important activities, Table 4 summarizes the minimum procedure. The TAB has to adapt Table 4 according to the specific case.
It shall be verified that the system of factory production control and the specified manufacturing process are maintained taking account of the control plan and as well as at least the control items given in Table 4, in its part relative to “continuous surveillance, assessment and evaluation of factory production control”.

3.3.4 Audit-testing of samples taken at the manufacturing plant or at the manufacturer storage facility

During surveillance inspection, the NB shall take samples of components of the PT system for independent testing. Audit-testing is conducted at least once a year by the NB or under its responsibility that may include a proportion conducted by an indicated laboratory or by the manufacturer, witnessed by the NB or inspection bodies. For the most important components, Table 4 summarizes the minimum procedures. The TAB has to adapt Table 4 according to the specific case. In particular, in additions to the tests carried out by the kit manufacturer, the NB will also carry out, at least once a year, one single tensile element test series according to Annex C.7 with specimens taken from the manufacturing plant or at the manufacturer storage facility. The NB can choose the strand from those strand suppliers used by the kit manufacturer. If the kit manufacturer uses several strand suppliers or several wedge or anchorage device suppliers, then different combinations have to be tested every year. If the kit comprises several anchorages or coupling sizes then the tested sizes shall vary year by year (it shall be avoided to test always the same size). If the kit comprises different types of anchor heads e.g. with different materials, a test series has to be done for each type.

3.3.5 Decision of the NB

In case of severe non-conformities that relate to important performance aspects of the PT system and that cannot be corrected in due time, the NB withdraws the Certificate. If minor deficiencies are detected, corrective measures shall be taken by the kit manufacturer. These can include:

- Action against warning from the NB
- Higher inspection and test frequency
- Implementation of changes.

4 REFERENCE DOCUMENTS

As far as no edition date is given in the list of standards thereafter, the standard in its current version at the time of issuing the European Technical Assessment, is of relevance.

- EC/EOTA documents:

CPR, Construction Products Regulation. Regulation (EU) no 305/2011 of the European Parliament and of the Council of 9 March 2011 laying down harmonised conditions for the marketing of construction and repealing Council Directive 89/106/EEC

Regulation (EC) No 1272/2008 of the European Parliament and of the Council of 16 December 2008 on classification, labelling and packaging of substances and mixtures, amending and repealing Directives 67/548/EEC and 1999/45/EC, and amending Regulation (EC) No 1907/2006

EOTA Technical Report 034, "General BWR 3 Checklist for EADs/ETAs "

ETAG 013, Edition of June 2002, Guideline for European Technical Approval of post-tensioning kits for prestressing of structures

EAD 160027, Special filling products for post-tensioning kits

- European Standards:

EN 206, Concrete - Specification, performance, production and conformity

EN 447, Grout for prestressing tendons – Basic requirements

EN 523, Steel strip sheaths for prestressing tendons – Terminology, requirements, quality control

EN 1563, Founding - Spheroidal graphite cast irons

EN 1564, Founding - Ausferritic spheroidal graphite cast irons

EN 1992-1-1, Eurocode 2: Design of concrete structures - Part 1-1 : General rules and rules for buildings

ENV 1992-1-5, Eurocode 2 : design of concrete structures - Part 1-5 : general rules - Structures with unbonded and external prestressing tendons (cancelled and replaced by EN 1992-1-1 in 2010)

EN 1992-2, Eurocode 2: Design of concrete structures - Part 2 : Concrete bridges - Design and detailing rules

EN 10025, Hot rolled product of structural steels

EN 10083-2, Steels for quenching and tempering - Part 2 : Technical delivery conditions for non alloy steels

EN 10138, Prestressing steels (while EN does not exist, valid pr EN or regulations in place of use apply)

prEN 10138-2, Prestressing steels – Part 2 : Wire

prEN 10138-3, Prestressing steels – Part 3 : Strand

prEN 10138-4, Prestressing steels – Part 4 : Bar

EN 10204, Metallic products - Types of inspection documents

EN 10210-1, Hot finished structural hollow sections of non-alloy and fine grain steels – Part 1: Technical delivery conditions

EN 10216-1, Seamless steel tubes for pressure purposes – Technical delivery conditions – Part 1: Non-alloy steel tubes with specified room temperature properties

EN 10217-1, Welded steel tubes for pressure purposes – Technical delivery conditions – Part 1: Non-alloy steel tubes with specified room temperature properties

EN 10219-1, Cold formed welded structural hollow sections of non-alloy and fine grain steels – Part 1: Technical delivery conditions

EN 10255, Non-alloy steel tubes suitable for welding and threading – Technical delivery conditions

EN 10305-5, Steel tubes for precision applications – Technical delivery conditions – Part 5: Welded cold sized square and rectangular tubes

EN 12201-1, Plastics piping systems for water supply, and for drainage and sewage under pressure - Polyethylene (PE) - Part 1: General

EN 12201-2, Plastics piping systems for water supply, and for drainage and sewage under pressure - Polyethylene (PE) - Part 2: Pipes

EN 13501-1, Fire classification of construction products and building elements - Part 1 : classification using data from reaction to fire tests

EN 13670, Execution of concrete structures

EN 60811-4-1, Insulating and sheathing materials of electric and optical cables - Common test methods - Part 4-1: Methods specific to polyethylene and polypropylene compounds - Resistance to environmental stress cracking - Measurement of the melt flow index - Carbon black and/or mineral filler content measurement in polyethylene by direct combustion - Measurement of carbon black content by thermogravimetric analysis (TGA) - Assessment of carbon black dispersion in polyethylene using a microscope

- EN ISO and ISO standards:

EN ISO 175, Plastics - Methods of test for the determination of the effects of immersion in liquid chemicals

EN ISO 178, Plastics - Determination of flexural properties

EN ISO 179-1, Plastics – Determination of Charpy impact properties – Part 1: Non-instrumented impact test

EN ISO 527-2, Plastics - Determination of tensile properties - Part 2 : test conditions for moulding and extrusion plastics

EN ISO 1133, Plastics – Determination of the melt mass-flow rate (MFR) and melt volume-flow rate (MVR) of thermoplastics

EN ISO 1183-1, Plastics - Methods for determining the density of non-cellular plastics - Part 1: Immersion method, liquid pyknometer method and titration method

EN ISO 3126, Plastics piping systems - Plastics components - Measurement of dimensions

EN ISO 6259-3, Thermoplastics pipes - Determination of tensile properties - Part 3: polyolefin pipes

EN ISO 6892-1, Metallic materials, Tensile testing – Part 1: Method of test at room temperature

EN ISO 9001, Quality management systems – Requirements.

EN ISO 11357-6, Plastics – Differential scanning calorimetry (DSC) – Part 6: Determination of oxidation induction time (isothermal OIT) and oxidation induction temperature (dynamic OIT)

EN ISO 12944, Paints and varnishes – Corrosion protection of steel structures by protective paint systems

EN ISO 15630-1, Steel for the reinforcement and prestressing of concrete – Test methods – Part 1: Reinforcing bars, wire rod and wire

EN ISO 15630-3, Steel for the reinforcement and prestressing of concrete – Test methods – Part 3: Prestressing steel

EN IEC ISO 17025 : General requirements for the competence of testing and calibration laboratories

ISO 1817, Rubber, vulcanized or thermoplastic - Determination of the effect of liquids

ISO 2176, Petroleum products - Lubricating grease - Determination of dropping point

ISO 4200, Plain end steel tubes, welded and seamless - General tables of dimensions and masses per unit length

ISO 4437, Plastics piping systems for the supply of gaseous fuels - Polyethylene (PE)

ISO 6964, Polyolefin pipes and fittings – Determination of carbon black content by calcination and pyrolysis – Test method and basic specification

ISO/TR 9080, Thermoplastics pipes for the transport of fluids – Methods of extrapolation of hydrostatic stress rupture data to determine the long-term hydrostatic strength of thermoplastics pipe materials

- *fib* Guides to Good Practice and Recommendations:

fib Model Code 2010, 2012
fib Bulletin 75, polymer duct systems for internal bonded post-tensioning, 2014

- Other documents:

Post-tensioning manual, sixth edition, Anchorage zone design, Gregor P. Wollmann, Post-Tensioning Institute

ASTM D696, Standard test method for coefficient of linear thermal expansion of plastics between -30°C and 30°C with a vitreous silica dilatometer

ASTM D1693, Standard Test Method for Environmental Stress-Cracking of Ethylene Plastics

BS 2000-121, Methods of test for petroleum and its products. Determination of oil separation from lubricating grease. Pressure filtration method

ANNEX A. CHARACTERISTICS RELEVANT FOR THE DIFFERENT INTENDED USES

Following table summarises use categories and optional use categories of post-tensioning kits for prestressing of structures that may be provided by manufacturers. For each use category the individual components and essential characteristics are identified.

Item	Intended use	Tensile element	Anchorage / coupling	Duct / pipe	Filling material	Accessories	Deviator	Relevant essential characteristic
1	Internal bonded tendon	Bare strand, wire or bar	One or several series of stressing anchorages, optional series of fixed anchorages and couplings	Steel strip duct or steel pipe	Grout	Vents, tendon support devices, temporary grout caps, connectors for ducts and pipes	None	(1) for each series of anchorage and coupling series: - Resistance to static load - Resistance to fatigue - Load transfer to structure (for lowest concrete strength, for highest, and intermediate, if any, concrete strengths) - Friction coefficients (in anchorages) (2) for each combination of tensile element and duct series of kit: - Friction coefficients (along tendon path) - Deviation/ deflection limits - Assessment of assembly (3) Description of temporary corrosion protection where needed and of permanent corrosion protection for all components
2	Internal unbonded tendon	Individually greased and sheathed strand	One or several series of stressing anchorages, optional series of fixed anchorages and couplings	None	Grease	Tendon support devices, temporary and/or permanent caps, connector to anchorage	None	As per Item 1 above
3	Internal unbonded tendon with assessed monostrand	Individually greased and sheathed strand	One or several series of stressing anchorages, optional series of fixed anchorages	None	Grease	Tendon support devices, temporary and/or permanent	None	As per Item 1, plus Sheathing base material – Melt index – Density – Carbon black

			and couplings			caps, connector to anchorage		– Tensile strength – Elongation – Thermal stability Finishes sheathing – Tensile strength – Elongation – Surface of sheathing – Environmental stress cracking – Temperature resistance – Resistance to externally applied agents – Sheathing minimum thickness Finishes monostrand – External diameter of sheathing – Mass per metre of sheathing – Mass per metre of filling material – Alteration of dropping point caused by monostrand manufacturing – Alteration of oil separation caused by monostrand manufacturing – Impact resistance – Friction between sheathing and strand – Leak tightness
4	Internal unbonded tendon	Bare strand, wire or bar	One or several series of stressing anchorages, optional series of fixed anchorages and couplings	PE pipe or steel pipe	Grease or wax	Vents, tendon support devices, temporary and/or permanent caps, connector for pipes and to anchorage	None	As per Item 1 above
5	External tendon	Bare strand, wire or bar	One or several series of stressing anchorages, optional series of fixed anchorages	PE pipe or steel pipe	Grout or grease or wax	Vents, tendon support devices, permanent caps, connector for pipes and to	Steel or PE pipe through recess in concrete deviation member or directly	As per Item 1 above

						anchorage	through recess in concrete deviation member	
6	External tendon	Individually greased and sheathed strand	One or several series of stressing anchorages, optional series of fixed anchorages	PE pipe or steel pipe	Grout	Vents, tendon support devices, temporary and/or permanent caps, connector for pipes and to anchorage	Steel or PE pipe through recess in concrete deviation member or directly through recess in concrete deviation member	As per Item 1 above
7	External tendon with assessed monostrand	Individually greased and sheathed strand	One or several series of stressing anchorages, optional series of fixed anchorages	PE pipe or steel pipe	Grout	Vents, tendon support devices, temporary and/or permanent caps, connector for pipes and to anchorage	Steel or PE pipe through recess in concrete deviation member or directly through recess in concrete deviation member	As per Item 1 above Sheathing base material – Melt index – Density – Carbon black – Tensile strength – Elongation – Thermal stability Finishes sheathing – Tensile strength – Elongation – Surface of sheathing – Environmental stress cracking – Temperature resistance – Resistance to externally applied agents – Sheathing minimum thickness Finishes monostrand – External diameter of sheathing – Mass per metre of sheathing – Mass per metre of filling material

								– Alteration of dropping point caused by monostrand manufacturing – Alteration of oil separation caused by monostrand manufacturing – Impact resistance – Friction between sheathing and strand Leak tightness
8	Optional Use Category: Internal tendon – Cryogenic applications with anchorage / coupling outside the possible cryogenic zone	Bare strand, wire or bar or monostrand (individually greased strand)	One or several series of stressing anchorages, optional series of fixed anchorages and couplings	Steel strip duct or steel pipe	Grout	Vents, tendon support devices, temporary grout caps, connectors for ducts and pipes	None	As per Item 1 above, plus: - Resistance to static load under cryogenic conditions with single tensile element
9	Optional Use Category: Internal tendon – Cryogenic applications with anchorage / coupling outside the possible cryogenic zone	Bare strand, wire or straight bar	One or several series of stressing anchorages, optional series of fixed anchorages and couplings	Plastic duct (polymer duct) with PL1, PL2 or PL3	Grout	Vents, tendon support devices, temporary grout caps, connectors for ducts and pipes	None	As per Item 1 above, plus: - Resistance to static load under cryogenic conditions with single tensile element - Polymer material: ● Oxidation Induction Time (OIT) at 200 °C ● Environmental Stress Cracking Resistance (ESCR) (Condition C) ● Notched impact ● Hydrostatic Design Basis (HDB) for PE only. ● Melt Flow Rate (MFR) at 230 °C and at 190 °C for PP and PE, respectively ● Density ● Flexural Modulus ● Tensile Yield Strength

								• Elongation at yield and at break • Thermal expansion coefficient. - Duct components : • Dimensional requirements • Stiffness of duct • Longitudinal load resistance of duct system • Lateral load resistance of duct • Flexibility of duct system • Leak tightness of duct system • Concrete pressure test on duct • Wear resistance of duct • Wear resistance of duct under sustained load • Bond behaviour of duct • Precast segmental duct coupler system where applicable for PL2 and PL3 only • Fracture resistance of duct system (optional test) for PL2 and PL3 only. - Duct system: • Leak tightness of anchorage-duct assembly for PL1, PL2 and PL3 • Leak tightness of assembled duct system for PL2 and PL 3 only • EIT performance of the duct system for PL3 only • EIT performance of anchorage-duct assembly for PL3 only • Full scale duct assembly for PL2 and PL3 only.
10	Optional Use Category: Internal tendon – Cryogenic	Bare strand, wire or bar or monostrand (individually	One or several series of stressing anchorages, optional series of fixed anchorages	Steel strip duct or steel pipe	Grout	Vents, tendon support devices, temporary grout caps,	None	As per Item 1 above, plus: - Resistance to static load under cryogenic conditions with single tensile element - Resistance to static load under cryogenic

	applications with anchorage / coupling inside the possible cryogenic zone	greased strand)	and couplings			connectors for ducts and pipes		conditions with multiple tensile elements/ anchorage/ coupling assembly
11	Optional Use Category: Internal tendon – Cryogenic applications with anchorage / coupling inside the possible cryogenic zone	Bare strand, wire or straight bar	One or several series of stressing anchorages, optional series of fixed anchorages and couplings	Plastic duct (polymer duct) with PL1, PL2 or PL3	Grout	Vents, tendon support devices, temporary grout caps, connectors for ducts and pipes	None	As per Item 1 above, plus: - Resistance to static load under cryogenic conditions with single tensile element - Resistance to static load under cryogenic conditions with multiple tensile elements/ anchorage/ coupling assembly - Polymer material: • Oxidation Induction Time (OIT) at 200 °C • Environmental Stress Cracking Resistance (ESCR) (Condition C) • Notched impact • Hydrostatic Design Basis (HDB) for PE only. • Melt Flow Rate (MFR) at 230 °C and at 190 °C for PP and PE, respectively • Density • Flexural Modulus • Tensile Yield Strength • Elongation at yield and at break • Thermal expansion coefficient. - Duct components : • Dimensional requirements • Stiffness of duct • Longitudinal load resistance of duct system • Lateral load resistance of duct

								• Flexibility of duct system • Leak tightness of duct system • Concrete pressure test on duct • Wear resistance of duct • Wear resistance of duct under sustained load • Bond behaviour of duct • Precast segmental duct coupler system where applicable for PL2 and PL3 only • Fracture resistance of duct system (optional test) for PL2 and PL3 only. - Duct system : • Leak tightness of anchorage-duct assembly for PL1, PL2 and PL3 • Leak tightness of assembled duct system for PL2 and PL 3 only • EIT performance of the duct system for PL3 only • EIT performance of anchorage-duct assembly for PL3 only • F ull scale duct assembly for PL2 and PL3 only.
12	Optional Use Category: Internal bonded tendon with plastic (polymer) duct	Bare strand, wire or straight bar	One or several series of stressing anchorages, optional series of fixed anchorages and couplings	Plastic duct (polymer duct) PL1	Grout	Vents, tendon support devices, temporary grout caps, connectors for ducts and to anchorage	None	As per Item 1 above, plus: - Polymer material: • Oxidation Induction Time (OIT) at 200 °C • Environmental Stress Cracking Resistance (ESCR) (Condition C) • Notched impact • Hydrostatic Design Basis (HDB) for PE only. • Melt Flow Rate (MFR) at 230 °C and at 190 °C for PP and PE, respectively

								• Density • Flexural Modulus • Tensile Yield Strength • Elongation at yield and at break • Thermal expansion coefficient. - Duct components for PL1: • Dimensional requirements • Stiffness of duct • Longitudinal load resistance of duct system • Lateral load resistance of duct • Flexibility of duct system • Leak tightness of duct system • Concrete pressure test on duct • Wear resistance of duct • Wear resistance of duct under sustained load • Bond behaviour of duct. - Duct system for PL1: : • Leak tightness of anchorage-duct assembly.
13	Optional Use Category: Encapsulated (bonded) tendon	Bare strand, wire or straight bar	One or several series of stressing anchorages, optional series of fixed anchorages and couplings	Plastic duct (polymer duct) PL2	Grout	Vents, tendon support devices, temporary and permanent grout caps, connectors for ducts and to anchorage	None	As per Item 1 above, plus: - Polymer material: • Oxidation Induction Time (OIT) at 200 °C • Environmental Stress Cracking Resistance (ESCR) (Condition C) • Notched impact • Hydrostatic Design Basis (HDB) for PE only. • Melt Flow Rate (MFR) at 230 °C and at 190 °C for PP and PE, respectively • Density • Flexural Modulus • Tensile Yield Strength

								• Elongation at yield and at break • Thermal expansion coefficient. - Duct components for PL2: • Dimensional requirements • Stiffness of duct • Longitudinal load resistance of duct system • Lateral load resistance of duct • Flexibility of duct system • Leak tightness of duct system • Concrete pressure test on duct • Wear resistance of duct • Wear resistance of duct under sustained load • Bond behaviour of duct • Precast segmental duct coupler system where applicable • Fracture resistance of duct system (optional test). - Duct system for PL2: • Leak tightness of anchorage-duct assembly • Full scale duct assembly • Leak tightness of assembled duct system.
14	Optional Use Category: Electrically isolated (bonded) tendon	Bare strand, wire or straight bar	One or several series of stressing anchorages, optional series of fixed anchorages and couplings	Plastic duct (polymer duct) PL3	Grout	Vents, tendon support devices, temporary and permanent grout caps, connectors for ducts and to anchorage, electrical isolation details	None	As per Item 1 above, plus: - Polymer material: • Oxidation Induction Time (OIT) at 200 °C • Environmental Stress Cracking Resistance (ESCR) (Condition C) • Notched impact • Hydrostatic Design Basis (HDB) for PE only. • Melt Flow Rate (MFR) at 230 °C

						for anchorage		and at 190 °C for PP and PE, respectively • Density • Flexural Modulus • Tensile Yield Strength • Elongation at yield and at break • Thermal expansion coefficient. - Duct components for PL3: • Dimensional requirements • Stiffness of duct • Longitudinal load resistance of duct system • Lateral load resistance of duct • Flexibility of duct system • Leak tightness of duct system • Concrete pressure test on duct • Wear resistance of duct • Wear resistance of duct under sustained load • Bond behaviour of duct • Precast segmental duct coupler system where applicable • Fracture resistance of duct system (optional test). - Duct system for PL3: • Leak tightness of anchorage-duct assembly • EIT performance of the duct system • EIT performance of anchorage-duct assembly • Full scale duct assembly • Leak tightness of assembled duct system.

ANNEX B. TEST REPORT CONTENT

PT system testing shall be documented with a test report that should be prepared in accordance with the general principles of EN IEC ISO 17025 and include at least the following specific information:

- Name and address of the test laboratory
- Test report number or unique identification
- Name and address of the client who has contracted the laboratory
- A signed statement by the laboratory or body that has carried out or witnessed the tests that these tests have been carried out in accordance with this EAD.
- Identification of all PT system components.
- Certificates of all relevant materials to confirm compliance with relevant specifications. Actual characteristics of components (mechanical, chemical, metallurgical, geometrical, etc as relevant) at time of testing, and source of manufacture. These include in particular tensile elements, anchorage components, ducts, filling material, reinforcement, and also concrete, see Table 5.
- Certificates of equipment and test machine calibration.
- Description and drawing of test specimen with actual dimensions.
- Description and drawing of test setup and measuring equipment including calibration certificate.
- Description of detailed test procedure.
- Actual ambient temperature, where relevant.
- Record of all measurements and observations.
- Photographs of test specimen prior, during, and after testing.
- Any other information specified in the test procedures of Annex C such as e.g. actual composition of concrete used for test samples.
- Statement of any unexpected or unusual behaviour / observation of anchorage components during testing.
- Date and place of testing.
- Name and signature of person responsible for testing.

All tests out of a series performed to obtain an ETA shall be recorded in the test report whether successful or not.

ANNEX C. TESTING OF PT SYSTEMS

C.1 DETERMINATION OF ACTUAL MATERIAL CHARACTERISTICS

Characterisation of products to be assessed shall be done in accordance with available specifications, notably the actual material characteristics of components to be used for testing (mechanical, chemical, metallurgical, geometrical, etc. as relevant) shall be determined and documented, and shall comply with the ETA applicant's specification. In particular, specifications of tensile elements used in tests (e.g. version of prEN 10138) shall be stated in the ETA.

For the determination of the actual material characteristics of the tensile elements, anchorage and coupling components at the time of testing, at least the tests according to are necessary (carried out by an indicated laboratory for the assessment tests or any other independent testing laboratory after confirmation by the TAB). For the tests, specimens from the same charge/unit of manufacture as for the assessment tests shall be taken.

Table 5 Minimum number of tests for the determination of the actual material properties at the time of testing

Anchorage component	**Item**	**Number of tests/specimens** **for every charge/unit of manufacture used for the assessment tests**
Prestressing steel	Yield strength and tensile strength (stress-strain diagram)	3 tensile tests according to EN ISO 15630-3
Wedge, nut, compression fitting	Core hardness [1)] Surface hardness [1)] Hardness distribution (hardness across the section) [1)] Surface-roughness [2)]	2 components
Anchor head/ coupling or bearing plate made of steel [5)]	Yield strength and tensile strength (stress-strain diagram) Surface hardness Surface-roughness of the bore holes (only for anchor head/coupling) of the wedges	1 tensile test according to EN ISO 6892-1 [3)] 1 test on the specimen used for the tensile test and 1 test on every tested anchor head/coupling/bearing plate (for confirmation/comparison of the material properties) 1 test
Anchor head/ coupling or bearing plate made of cast-iron [6)]	Yield strength and tensile strength (stress-strain diagram) Surface hardness Surface-roughness of the bore holes (only for anchor head/coupling) of the wedges	1 tensile test according to EN ISO 6892-1 [4)] 1 test on the specimen used for the tensile test and 1 test on every tested anchor head/coupling/bearing plate (for confirmation/comparison of the material properties 1 test
Bursting reinforcement	Yield strength and tensile strength	1 tensile test according to EN ISO 15630-1

1) The determination of the hardness shall be carried out according to the same standard/provisions as is provided by the ETA applicant/component manufacturer and according to the certificate.

2) Only for wedges.

3) The specimen is to be taken out of the anchor head/coupling/bearing plate in the direction of the load. In cases where the ETA applicant wants to take the specimen out of the primary material and not out of a component from the same charge/ unit of manufacture this is to be assessed by the TAB prior to testing.

4) A sketch of the location and dimensions of the specimen for the tensile test is necessary. The specimen may be taken out of an anchor head/coupling/bearing plate from the same charge or may be cast separately.

5) Steel according to EN 10083-2 with a grade equal or higher to C45 if quenched and tempered or normalized. For other types of steels, the type and number of tests may have to be adapted by the TAB.

6) Ductile cast iron according to EN 1563 (spheroidal) or EN 1564 (ausferritic ductile cast iron). For other types of cast iron, the type and number of tests may have to be adapted by the TAB.

C.2 RESISTANCE TO STATIC LOAD

C.2.1 STATIC LOAD TEST

C.2.1.1 Test specimen

The tendon to be tested shall be assembled according to the envisaged application, using all components necessary for anchoring the tendon. Components for testing shall be randomly selected. The geometrical configuration of the individual tensile elements in the specimen shall be identical to that of the specified tendon assembly given in the ETA applicant's guide. The following data of the tensile elements shall be established:

- the main mechanical and geometrical properties of the tensile elements, including the actual ultimate strength
- calculated actual ultimate force F_{pm}
- mean total cross-sectional area of tensile elements A_{pm}
- surface characteristics of tensile elements.

Relevant geometrical and mechanical properties of anchorage components shall also be determined. The free length of the tensile elements in the tendon specimen to be tested shall be not less than 3.0m, except for bar tendons with a minimum length of 1.0 m. If an anchorage or coupling device is specified for use with different strength grades of the same type of tensile element, the test should be done with the strength grade that produces the highest load applied to the anchorage or coupling device. However, testing of more than one strength grade may be required if the geometry of the interface between tensile element and anchorage or coupling device is different for different strength grades.

Note: This rule applies e.g. in the case where one type/size of wedge is specified to be used with two or more different nominal diameters of strands, e.g. 15.3 mm and 15.7 mm.

Anchor heads that do not feature a flat contact surface to place on a steel plate may be tested embedded in a concrete body. A concrete body similar to the specimen for load transfer test, see Figure C.4.1-1, has been proven suitable for that purpose. The dimensions shall be at least same in cross section and additional reinforcement, but height may be reduced to the upper reinforced part. Concrete strength should be not more than 20 % above $f_{cm,0}$. Different suitable concrete bodies are acceptable as well.

C.2.1.2 Test procedure

The tendon specimen is mounted in the test rig or testing machine, observing the same geometrical configuration of the individual tensile elements in the specimen to that specified in the ETA applicant's guide.

The tendon is stressed at one end with representative equipment comparable to the one used on construction site, and specified in the ETA applicant's guide, in steps corresponding to 20%, 40%, 60% and 80% of the characteristic tensile strength of the tensile elements. The load is increased at a constant rate corresponding to about 100 MPa per minute. At 80% level, the load is transferred from the equipment to the anchorage and test rig. It is then held constant at 80% level for one hour for internal bonded tendons and two hours for external tendons. For external tendons, the load is then reduced to 20% level. Subsequently, the load is gradually increased for both tendon types with the test rig to failure at a maximum strain rate of 0.002 per minute.

The uncertainty of values measured with the measuring equipment shall be within ±1%. Loads shall be maintained with a maximum tolerance of ±2%. The load measured in the jack shall be adjusted for estimated friction losses in the anchorages to assure that the specified load has been applied to the anchor head used for measurement.

Tests on anchorages for use with internal unbonded tendons are performed with the same procedure, measurements, and observations as specified for external tendons.

It is highly recommended to follow the procedures specific to anchorages for external tendons also for anchorages for internal bonded tendon.

C.2.1.3 Measurements and observations

The following measurements and observations shall be made and recorded:

- Determination of actual material characteristics of tested components according to Annex C.1.
- Compliance checking of the components with ETA specifications (materials, machining, geometry, hardness, etc).
- Relative load -and time-dependent displacement Δs of the tensile elements with respect to the anchorage on at least two elements (Figure C.2.1-1). The measurement of the relative displacement Δs shall in general be done on two tensile elements. If the tensile elements are strands, the measurement shall be done on the king wire and one external wire each.
- Relative load – and time – dependent displacement Δr between the individual components of the anchorage on at least two components, e.g. wedges (Figure C.2.1-1), or as applicable for other methods of anchoring the tensile elements. Δr shall be measured on the same component of the two tensile elements as used for Δs.
- For external tendons only, deformations of one anchor head in circumferential direction Δt, and deflections of the head relative to the supporting plate Δz, see Figure C.2.1-2, in seven measurement series as follows :

    1. At 20% level
    2. At 40% level
    3. At 80% level between time t_0 and t_0 + 10 minutes, where t_0 is time when 80% level was reached
    4. At 80% level between time t_0 + 30 minutes and t_0 + 40 minutes
    5. At 80% level between time t_0 + 60 minutes and t_0 + 70 minutes
    6. At 80% level between time t_0 + 120 minutes and t_0 + 130 minutes
    7. At 20% level

- Complete load-elongation diagram, continuously recorded during the test.
- Elongation of the tensile elements ε_{Tu} on free length at measured maximum force F_{Tu}.
- Measured maximum force F_{Tu}.
- Location and mode of failure.
- Examination of components after dismantling, photographic documentation, comments, including residual deformations of the anchor head. Any unusual deformations of anchor head after the end of the test should be reported (if measurements of deformations are made, they shall have resolution lower or equal than 10 µm).

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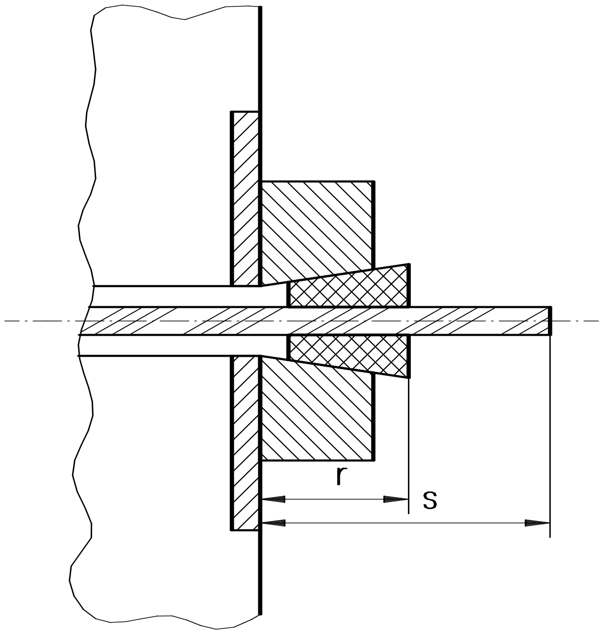
Note: For small anchor heads, Δt and Δz measurement may be replaced by alternative techniques (strain gauges, deformation measurement by image correlation analysis, …), or omitted completely, if measurement is physically not possible e.g. if there is no access and the number of levels on which the measurement is performed may possibly be reduced to less than the three, which are indicated in Figure C.2.1-2. In any case, the measurements details shall be agreed by the TAB prior to testing.

(1)



(2)

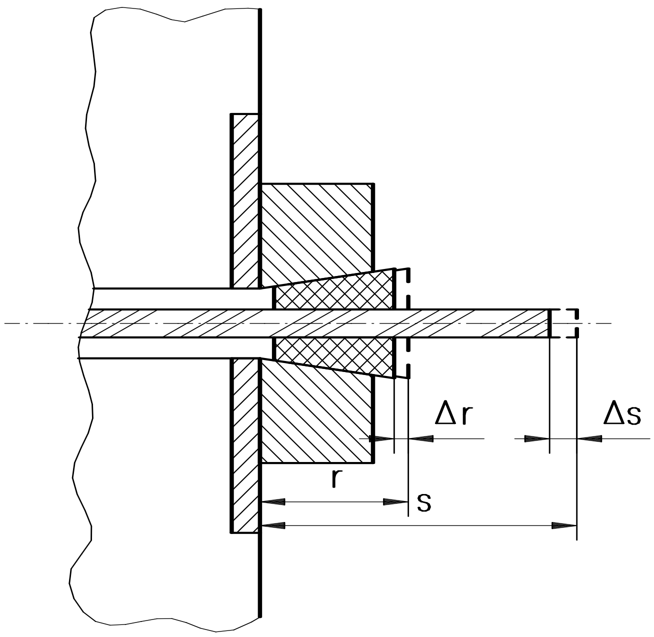


Figure C.2.1-1 - Displacements during testing: (1) before locking; (2) after locking (shown for wedge anchorage; to be adapted for other methods of anchoring the tensile elements)

(1) Plan View of Anchor Head

(2) Elevation

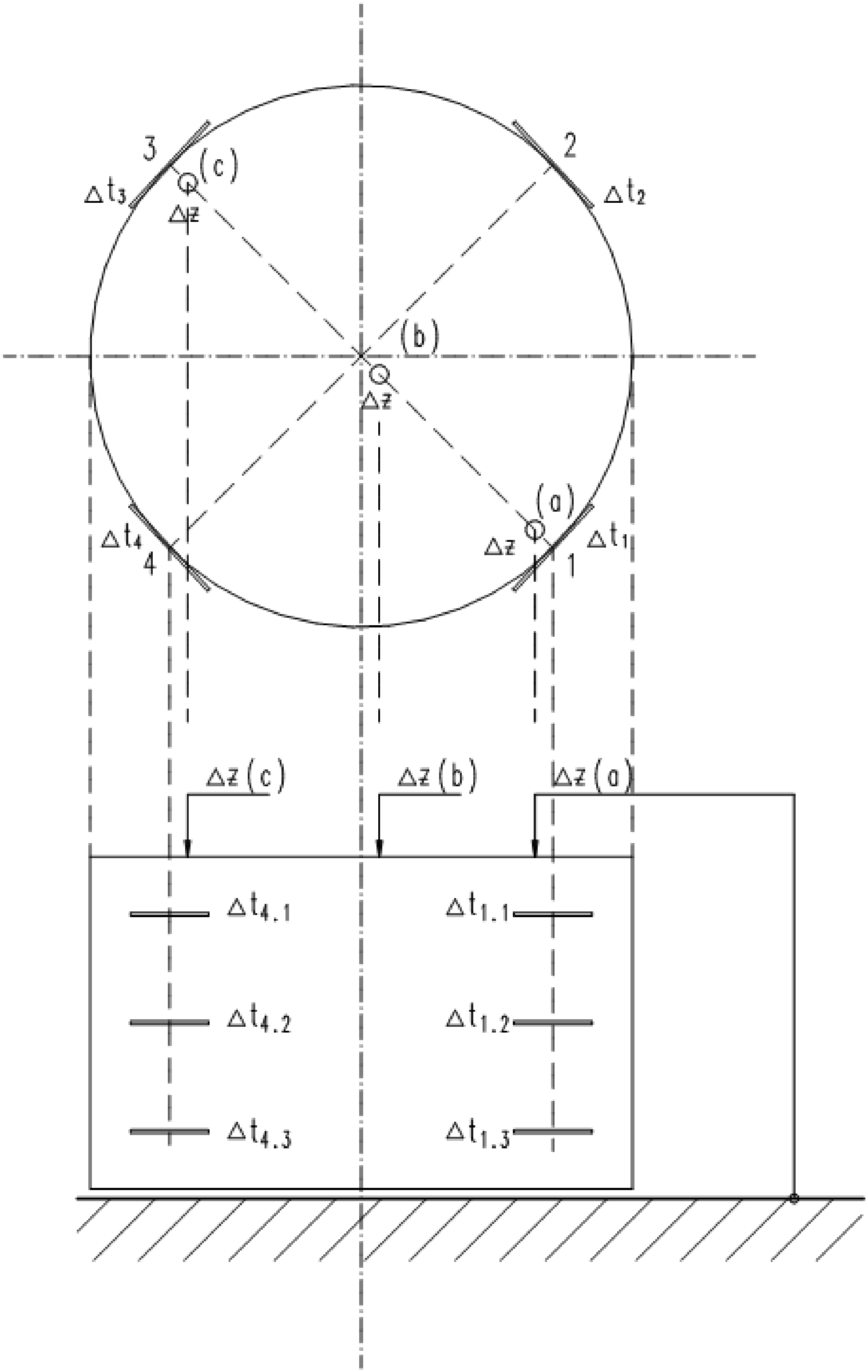


Figure C.2.1-2 - Deformation readings on anchor head of external tendon

C.2.2 CRYOGENIC STATIC LOAD TEST – SINGLE TENSILE ELEMENT

C.2.2.1 Test specimen

A single tensile element with a free length of at least 1 m shall be anchored at both ends with mechanical anchorages (e.g. barrel of relevant mechanical characteristics) and anchoring element (wedge, button head, nut) of the same type as intended to be used for the same kit in the ETA for cryogenic conditions. If the test shall be carried out for internal bonded tendon for cryogenic applications with anchorage inside the possible cryogenic zone (section 2.2.9), then the most severe tensile element deviation has to be tested. The deviations can be taken into account by introduction of a supporting wedge-shaped plate at the maximum angle α (see Annex C.7).

If an anchorage or coupling device is specified for use with different strength grades of the same type of tensile element, the test should be done with the strength grade that produces the highest load applied to the anchorage or coupling device. However, testing of more than one strength grade may be required if the geometry of the interface between tensile element and anchorage or coupling device is different for different strength grades.

Note: This rule applies e.g. in the case where one type/size of wedge is specified to be used with two or more different nominal diameters of strands, e.g. 15.3 mm and 15.7 mm.

C.2.2.2 Test procedure

The tendon specimen is mounted in a calibrated test rig or testing machine. The tendon is stressed in steps corresponding to 20 %, 40 %, 60 % and 80 % of the characteristic tensile strength of the tensile elements f_{pk}. The load is increased at a constant rate corresponding to about 100 MPa per minute. At the 80 % level, the load is held constant for one hour.

Subsequently, the whole single tensile element with mechanical anchorage assemblies at both ends is immersed into liquid nitrogen of specified cryogenic temperature of -196 ± 5 °C, while the load in the tensile element is maintained constant.

Once the temperature of the assembly has stabilized at cryogenic conditions (no temperature variation higher than 5 °C), to simulate the possible increase in stress in tensile elements due to self-stressing effects and to model the stress variation due to several depletions with complete warming-up of the cryogenic containment, ten load cycles between the characteristic yield force $F_{p0.1k}$ of the tensile element at room temperature and 0.9 $F_{p0.1k}$ are executed, see Figure C.2.2-1.

Finally, the tendon load is increased gradually to failure at a maximum strain rate of 0.002 per minute.

C.2.2.3 Measurements and observations

The following measurements and observations shall be made and recorded:

- Determination of actual material characteristics of tested components according to Annex C.1.
- Compliance checking of the components with ETA specifications (materials, machining, geometry, hardness, etc.),
- Complete load and tendon elongation diagram based on measuring jack load and stroke. The total elongation, ε_{Tu}, of the tensile element of the free length at the measured maximum load shall be calculated from the relevant jack stroke,
- Measured temperature on the outside surface of one anchorage over the duration of the test,
- Load, and time, dependent displacement Δs of the tensile element with respect to the anchorage of the element (Figure C.2.1-1), before temperature is decreased to cryogenic level. The measurement of the relative displacement Δs shall in general be done on two tensile elements. If the tensile elements are strands, the measurement shall be done on the king wire and one external wire each,
- Load, and time, dependent displacement Δr of the individual components, e.g. wedges (Figure C.2.1-1), or as applicable for other methods of anchoring the tensile elements, before temperature is decreased to cryogenic level. Δr shall be measured on the same component of the two tensile elements as used for Δs.
- Measured maximum force F_{Tu},
- Location and mode of failure,

– Examination of components after dismantling, photographic documentation, comments.

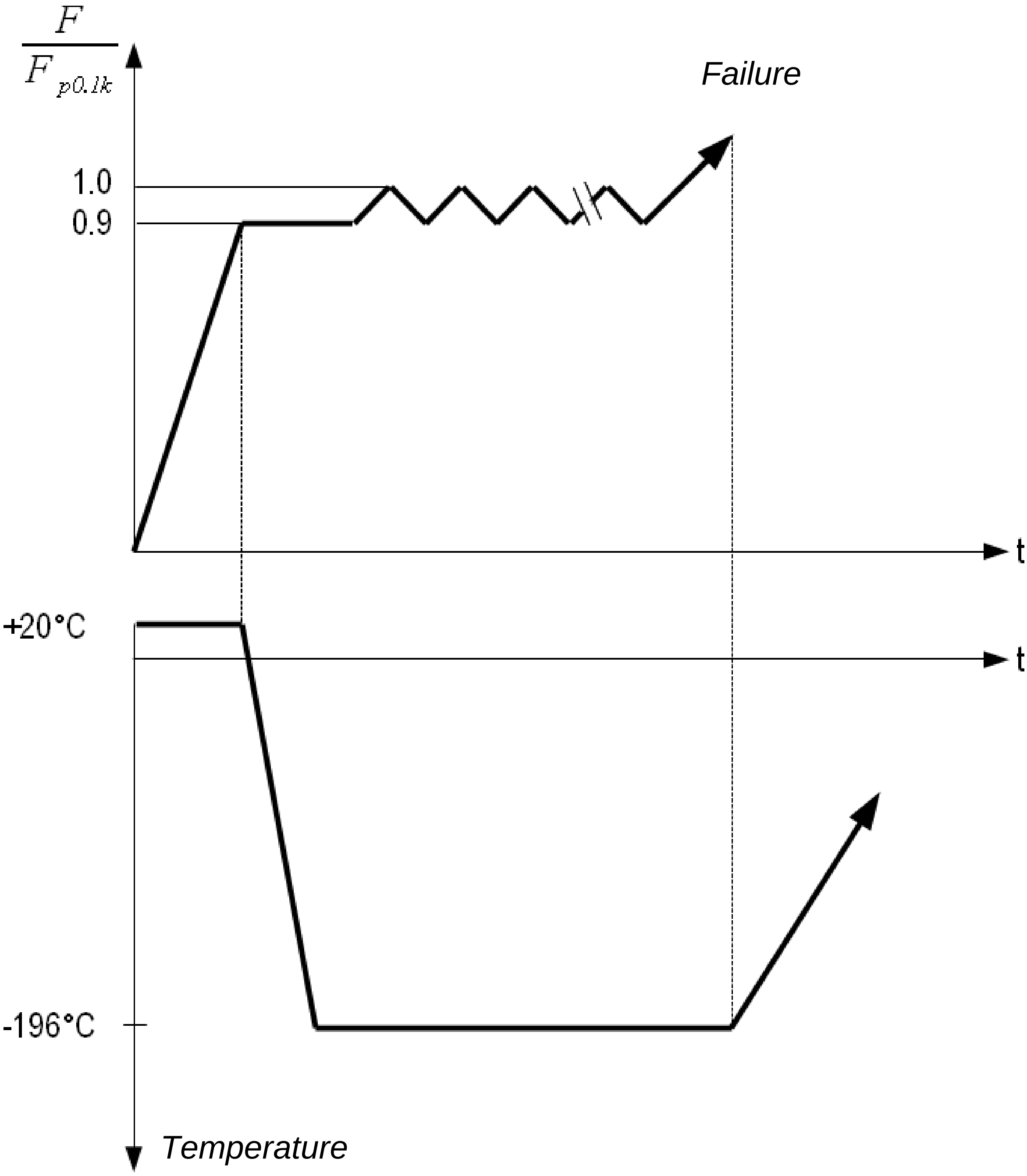


Figure C.2.2-1 - Test procedure for cryogenic load test

C.2.3 CRYOGENIC STATIC LOAD TEST - MULTIPLE TENSILE ELEMENTS/ ANCHORAGE/ COUPLING ASSEMBLY TEST

C.2.3.1 Test specimen

Same as given in C.2.1 “Static load test” with mechanical anchorages of the same type as the ones specified for the kit in the ETA. If an anchorage or coupling device is specified for use with different strength grades of the same type of tensile element, the test should be done with the strength grade that produces the highest load applied to the anchorage or coupling device. However, testing of more than one strength grade may be required if the geometry of the interface between tensile element and anchorage or coupling device is different for different strength grades.

Note: this rule applies e.g. in the case where one type/size of wedge is specified to be used with two or more different nominal diameters of strands, e.g. 15.3 mm and 15.7 mm.

C.2.3.2 Test procedure

The tendon specimen is mounted in a calibrated test rig or testing machine. The tendon is stressed in steps corresponding to 20 %, 40 %, 60 % and 80 % of the characteristic tensile strength of the tensile elements f_{pk} at room temperature. The load is increased at a constant rate corresponding to about 100 MPa per minute. At the 80 % level, the load is held constant for one hour. The load is then adjusted to 0.9 $F_{p0.1k}$.

Subsequently, the multi tensile element with one anchorage (coupling, if applicable) assembly including the region where the tensile elements are deviated is immersed into liquid nitrogen of specified cryogenic temperature of -196 ± 5 °C, while the load in the tensile elements is maintained constant. Alternatively, the entire tendon with both anchorage assemblies may be immersed into liquid nitrogen.

Once the temperature of the cooled assembly has stabilized at cryogenic conditions (no temperature variation higher than 5 °C) to simulate the possible increase in stress in tensile elements due to self-stressing effects and to model the stress variation due to several depletions with complete warming-up of the cryogenic containment, ten load cycles between the characteristic yield force $F_{p0.1k}$ of the tensile element at room temperature and 0.9 $F_{p0.1k}$ are executed, see Figure C.2.2-1.

Finally, the tendon load is increased gradually to failure (or at least until the criteria are met) at a maximum strain rate of 0.002 per minute.

C.2.3.3 Measurements and observations

The following measurements and observations shall be made and recorded:

- Determination of actual material characteristics of tested components according to Annex C.1.
- Compliance checking of the components with ETA specifications (materials, machining, geometry, hardness, etc.),
- Load, and time, dependent displacement Δs of the tensile elements with respect to the anchorage on at least two elements (Figure C.2.1-1), in the case of strands at least the king wire and one external wire of two strands shall be measured before the temperature is decreased to cryogenic level,
- Load, and time, dependent displacement Δr of the individual components of the anchorage on at least two components, e.g. wedges (Figure C.2.1-1), or as applicable for other methods of anchoring the tensile elements before the temperature is decreased to cryogenic level,
- Measured temperature on the outside surface of one anchorage or both anchorages if both are immersed into liquid nitrogen over the duration of the test,
- Measured maximum force F_{Tu},
- Location and mode of failure (if applicable),
- Examination of components after dismantling, photographic documentation, comments.
- Complete load and tendon elongation diagram based on measuring jack load and stroke.

The total elongation, ε_{TU}, of the tensile element of the free length at the measured maximum load shall be calculated from the relevant jack stroke

C.3 RESISTANCE TO FATIGUE

C.3.1 FATIGUE TEST – MECHANICAL ANCHORAGE

C.3.1.1 Test specimen

The type of specimen corresponds to Annex C.2.1.1. At least at one tendon end the anchorage with all components, which deviate the tensile elements in the anchorage and at the entrance into the duct shall be provided identical to the assembly specified in the ETA applicant's guide, with no change to their geometry, their material, and their machining. These components, which deviate the tensile elements shall be kept at a fixed distance from the anchorage to duplicate the actual deviation and the relative movements to the tensile elements. If both tendon ends have such anchorage details as specified above, the specimen shall count as two tests.

If an anchorage or coupling device is specified for use with different strength grades of the same type of tensile element, the test should be done with the strength grade that produces the highest load applied to the anchorage or coupling device. However, testing of more than one strength grade may be required if the geometry of the interface between tensile element and anchorage or coupling device is different for different strength grades. *Note: This rule applies e.g. in the case where one type/size of wedge is specified to be used with two or more different nominal diameters of strands, e.g. 15.3 mm and 15.7 mm.*

The number of tensile elements in the tendon-anchorage assembly to be tested may be reduced as follows. For a tendon of n tensile elements, the reduced number n' of tensile elements installed for the test shall comply with**:**

- if $n \leq 12$: no reduction is allowed
- if $n \geq 12$: $n' \geq \max(12; 6 + (n - 12)/3)$

The tensile elements with the most severe angular deviation from the tendon axis shall be included.

C.3.1.2 Test procedure

The test shall be performed in a testing machine with at a constant load frequency of not more than 30 Hz, and with a constant upper load of 65% of the characteristic strength of the tensile elements. Range of loads $\Delta F = \max F - \min F$ shall be maintained constant throughout the testing, at a level corresponding to 80 MPa stress amplitude in the nominal cross section of tensile elements for 2 million cycles. On its free length the specimen is without duct and filling material.

The specimen shall be tested in such a way that secondary oscillations are precluded. When assembling the specimen and fitting it in the testing machine, special care should be taken to ensure that the load is evenly distributed to all the tensile elements of the tendon.

C.3.1.3 Measurements and observations

The following measurements and observations shall be made and recorded :

- Determination of actual material characteristics of tested components according to Annex C.1.

- Compliance checking of the components with ETA specifications (materials, machining, geometry, hardness, etc).

- Relative displacement between tensile elements and individual anchorage components as well as between the anchorage components, dependent on load and on number of load cycles on at least two tensile elements (Figure C.2.1-1). The measurement of the relative displacement Δs shall in general be done on two tensile elements. If the tensile elements are strands, the measurement shall be done on the king wire and one external wire each. Δr shall be measured on the same component of the two tensile elements as used for Δs.

- Examination of anchorage components and tensile elements after test with respect to fatigue damage and deformation.

- Record of fracture location and number of tensile elements that have failed by fatigue, as a function of the number of load cycles.

- Examination of components after dismantling, photographic documentation, comments.

C.3.2 FATIGUE TEST- BOND ANCHORAGE

C.3.2.1 Test specimen

As described in Annex C.4.2.1, see also Figure C.4.2-1. Concrete strength shall not exceed

- at the start of the fatigue test $f_{cm,0}$ and
- at the end of the fatigue test the greater of $f_{cm,0}$ +10 MPa or 1.2 · $f_{cm,0}$.

C.3.2.2 Test procedure

As described in Annex C.3.1.2.

C.3.2.3 Measurements and observations

As described in Annex C.3.1.3 above. In addition the slip of ends of the tensile elements relative to the concrete shall be measured.

C.4 LOAD TRANSFER TO THE STRUCTURE

C.4.1 LOAD TRANSFER TEST – MECHANICAL ANCHORAGE

C.4.1.1 Test specimen

The test specimen is schematically shown in Figure C.4.1-1. The specimen shall contain those anchorage components and bursting reinforcement that will be embedded in the structural concrete, and their arrangement has to comply with the intended application and with the specification as per the ETA applicant's guide. Components shall be randomly selected.

If an anchorage or coupling device is specified for use with different strength grades of the same type of tensile element, the test should be done with the strength grade that produces the highest load applied to the anchorage or coupling device.

The test specimen shall be a concrete prism tested in axial compression. Its concrete cross section $A_c = a \cdot b$ shall correspond to the minimum cross-section in axial compression for the particular tendon and concrete strength class in the structure defined by the ETA applicant's guide. The dimensions a and b of the concrete prism shall be specified in the ETA as reference dimensions**.**

From these reference dimensions a and b, minimum anchorage centre spacing in the structure in x- and y-directions, x and y, and minimum edge distances, shall be derived according to scientifically justified rules defined by the ETA applicant. Without specific testing, the following rule may be applied:

$$A_c = x \cdot y \geq a \cdot b$$

The actual spacing / centre distance and edge distance in the structure shall comply with:

$$x \geq 0.85\ a$$

$$y \geq 0.85\ b$$

Where a, b : side lengths of test specimen (reference dimensions given in ETA)
x, y : minimum specified centre spacing of the particular tendon in the structure, whichever is smaller; $x \leq y$

Edge distances in the structure are calculated with centre spacing in x- and y-direction by

$$e_x = \frac{x}{2} - 10\ \text{mm} + c$$

$$e_y = \frac{y}{2} - 10\ \text{mm} + c$$

Where e_x, e_y: Edge distance in x- and y-direction respectively
c: Concrete cover of reinforcement in the structure as required at the place of use

The height h of specimen shall be at least twice the longer of the two side lengths a or b, see Figure C.4.1-1. The height of the lower, nominally reinforced part of the specimen shall be at least 0.5h long.

The part of the specimen containing the anchorage components shall be provided with bursting reinforcement of the same magnitude and configuration as specified for the particular system and tendon in the ETA applicant's guide. For the assembly of the bursting reinforcement, auxiliary reinforcement may be used. It will not be part of the European Technical Assessment if the following conditions are met :

- longitudinal bars with a total cross-sectional area of $\leq 0.003\ A_c$
- stirrups, uniformly distributed along the height of specimen, with ≤ 50 kg steel/m^3 concrete.

The 50 kg/m^3 stirrups, uniformly distributed along the height of specimen, can be placed over the entire height of the specimen. They can also be combined with the local anchorage zone reinforcement. However, only the reinforcement beyond the 50 kg/m^3 needs to be given in the ETA.

The concrete of the test specimen shall correspond to normal concrete used for prestressed concrete structures with respect to materials, composition, compaction and its characteristic strength f_{ck}. The concrete mix design shall be submitted to the TAB for acceptance prior to testing. The composition of the concrete used for the load transfer test specimen shall be given in the test report. The test specimen should be concreted normally in a horizontal position. After casting the specimen shall be de-moulded after one day and then moist-cured until testing. The test cylinders or cubes cast for the determination of the compressive strength of concrete shall be cured in the same manner.

The concrete cover to the reinforcement shall typically be 10 mm.

C.4.1.2 Test procedure

The specimen shall be mounted in a calibrated test rig or testing machine. The load shall be applied to the specimen on an area that simulates the loading condition in a complete anchorage.

The load is increased in steps: 0.2 F_{pk}, 0.4 F_{pk}, 0.6 F_{pk}, and 0.8 F_{pk} (Figure C.4.1-2). After reaching the load 0.8 F_{pk} at least ten slow load cycles are to be performed, with 0.8 F_{pk} and 0.12 F_{pk} being the upper and the lower load limits, respectively. The necessary number of load cycles depends upon stabilisation of strain readings and crack widths as described below. Following cyclic loading, the specimen shall be loaded continuously to failure.

During cyclic loading measurements shall be taken at the upper and lower loads of several cycles in order to decide whether satisfactory stabilisation of strains and widths of cracks is being attained. Cyclic loading shall be continued to n cycles until stabilisation is satisfactory, see Clause C.4.1.3. Figure C.4.1-2 shows the sequence of loading and measurements. Figure C.4.1-3 schematically shows the arrangement of the gauge points for the strain measurement on each side of the specimen, etc.

At the final test to failure the mean compressive strength of concrete of specimen shall be :

$f_{cm.e} \leq f_{cm.0} + 3$ MPa

C.4.1.3 Stabilisation criteria

- Crack widths can be considered to have stabilised if their width under upper load complies with:
$w_n - w_{n-4} \leq 1/3\ (w_{n-4} - w_0)$, $n \geq 10$

The stabilisation criterion for the crack widths shall, however, only apply for crack widths larger than 0.1 mm.

- Longitudinal and transverse strains can be considered to have stabilised if the increase of strain under the upper load complies with :
$\varepsilon_n - \varepsilon_{n-4} \leq 1/3\ (\varepsilon_{n-4} - \varepsilon_0)$, $n \geq 10$

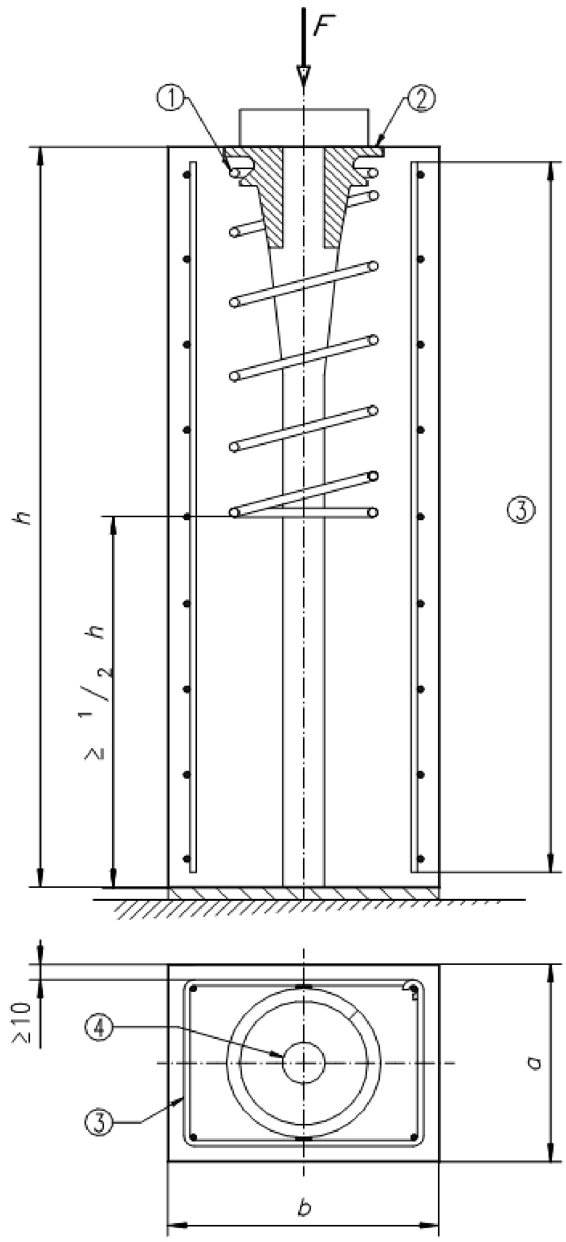
See Figure C.4.1-4 for details on how to assess stabilisation criteria.

C.4.1.4 Measurements and observations

The following measurements and observations shall be made and recorded :

- Determination of actual material characteristics of tested components according to Annex C.1.
- Compliance checking of the components with ETA specifications (materials, machining, geometry, hardness, etc).
- Longitudinal and transverse concrete strains on at least two side faces of the specimen in the region of maximum bursting effect under the upper and lower load, dependent on number of load cycles. Longitudinal and transverse concrete strains and crack width and propagation shall also be recorded at measuring points 1, 2, 3 indicated in Figure C.4.1-2.
- Formation, width and propagation of cracks on the side faces of the specimen, as mentioned above.
- Visual inspection and/or measurement of deformation of anchorage components in contact with concrete. Any unusual or excessive deformation, such as large permanent deformations, shall be reported in the test report, and such actual deformation may be measured.

- Location and mode of failure.
- Measured ultimate force F_u.
- Examination of components and specimen after testing, photographic documentation, comments.



Key:

1: Bursting reinforcement

2: Anchorage components

3: Auxiliary reinforcement

4: Empty duct

Figure C.4.1-1 - Test specimen for load transfer test

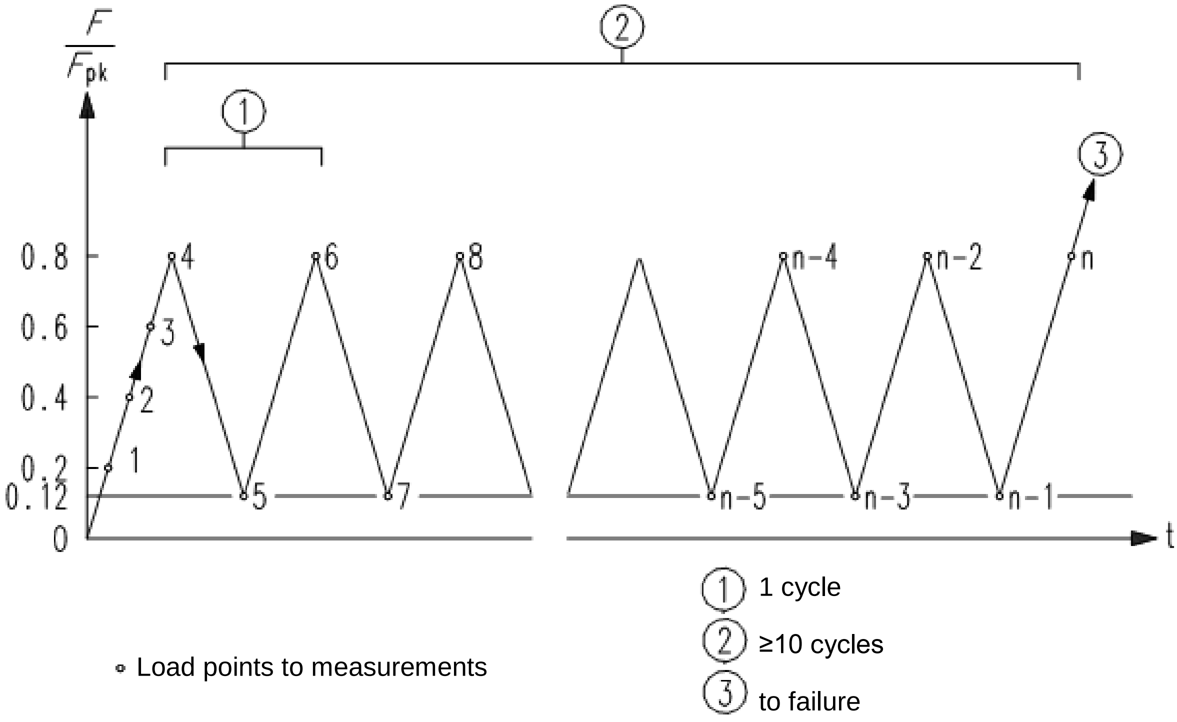
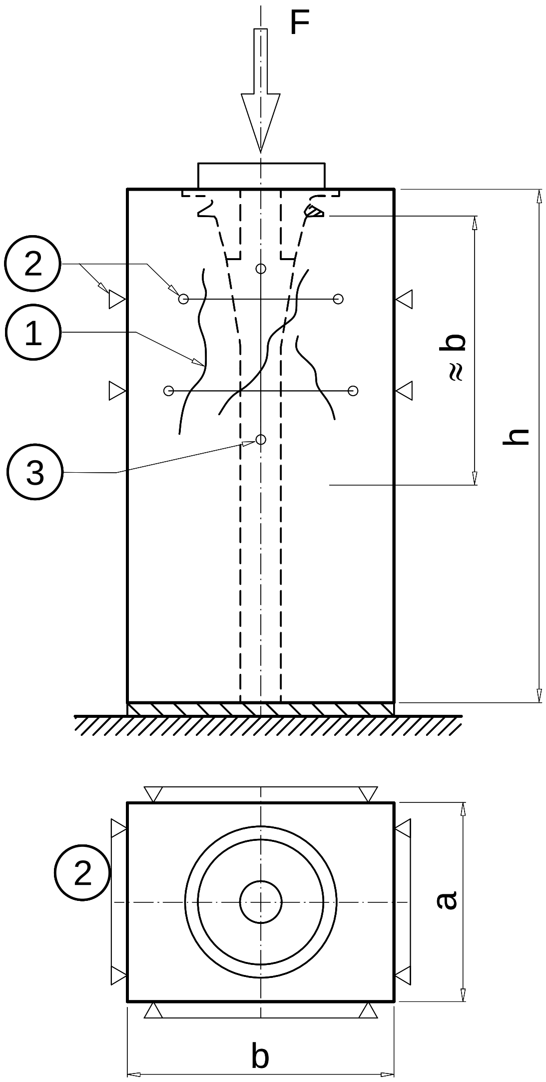


Figure C.4.1-2 – Procedure of load transfer test



Key:

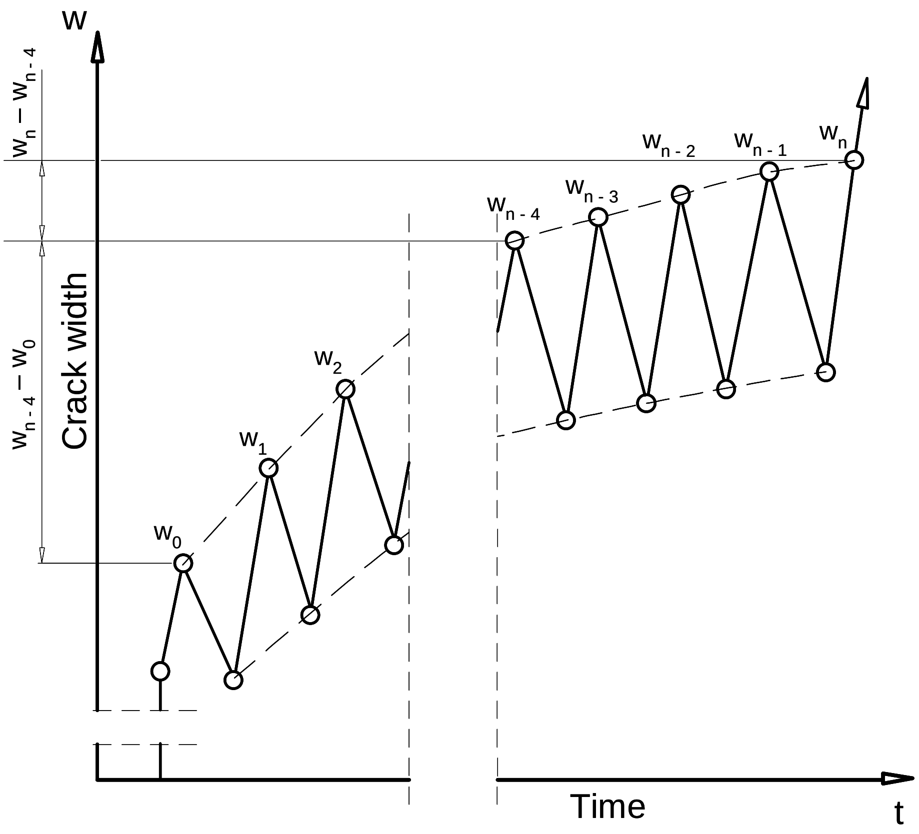
1: cracks

2: for ε_t (transversal strain)

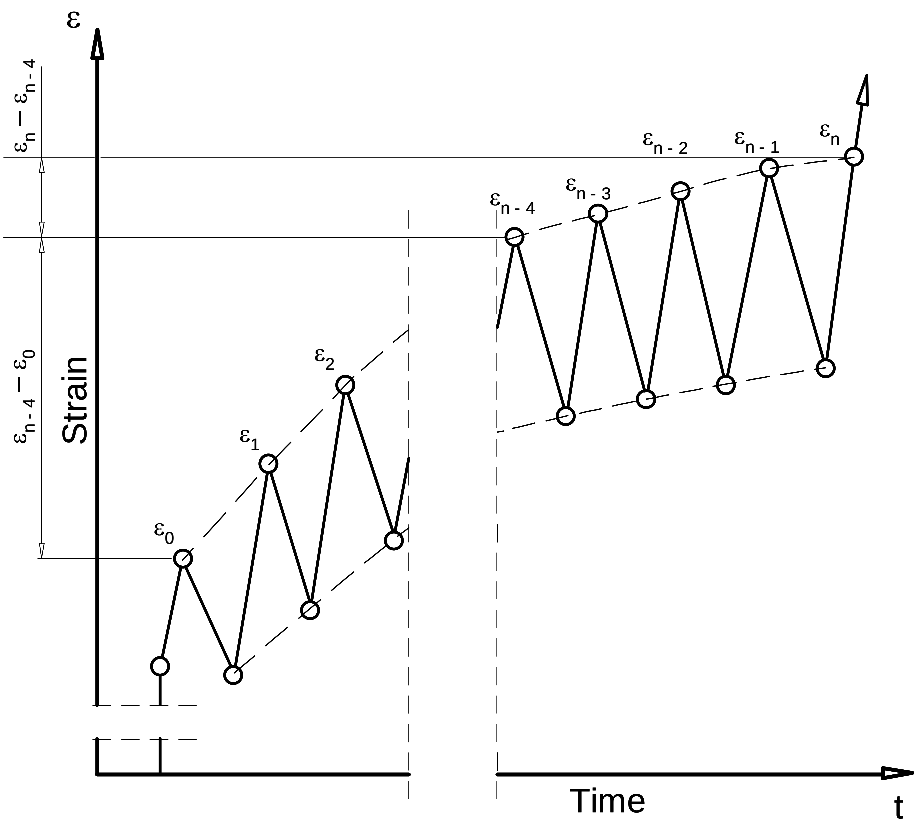
3: for ε_v (vertical strain)

gauge length ≈ 0,6 up to 0,8 b

Figure C.4.1-3 - Measuring set-up for load transfer test to be placed on at least 2 side faces



(a) Crack widths



(b) Strains

Note:

$\varepsilon = \varepsilon_v$ or ε_t respectively

Figure C.4.1-4 - Assessment of crack width and strain stabilisation

C.4.2 LOAD TRANSFER TEST – BOND ANCHORAGE

C.4.2.1 Test specimen

The bond anchorage and tendon shall be cast into a concrete block. The arrangement of the tensile elements, their geometrical shape, anchorage components, etc. shall comply with the ETA applicant's guide. Components used for testing shall be randomly selected.

If a bond anchorage is specified for use with different strength grades of the same type of tensile element, the test should be done with the strength grade that produces the highest load applied to the anchorage or coupling device.

The cross-section and side lengths, a and b of the specimen, should follow the same concept as defined in Annex C.4.1.1. However, the test specimen for bond anchorages may have a larger cross section than the mechanical anchorages to compensate for the fact that the test is carried out at $\leq$ 80% $f_{cm,0}$ compared with $\leq f_{cm,0}$ in C.4.1.2.

The test specimen is shown schematically in Figure C.4.2-1. The specimen consists of two regions. One region contains the embedded bond anchorage, all the anchorage components and the bursting reinforcement. The other region contains the straight tendon with the duct that is not injected with filling material. The straight tendon length shall exceed the length of the longer side of the specimen.

The specimen shall be cast in a horizontal position. To allow for the detrimental effect due to setting of fresh concrete on bond, an additional concrete block of a height of about 500 mm below the specimen shall be cast integrally with the specimen. This additional block shall be removed before testing.

Identical requirements to Annex C.4.1.1 apply to the bursting reinforcement and the concrete regarding strength, de-moulding and curing, etc. All details of the tendon need to comply with the ETA applicant's guide.

C.4.2.2 Test procedure

The test procedure corresponds to Annex C.4.1.2 and Figure C.4.1-2. At the final test to failure the mean compressive strength of concrete in the specimen should be :

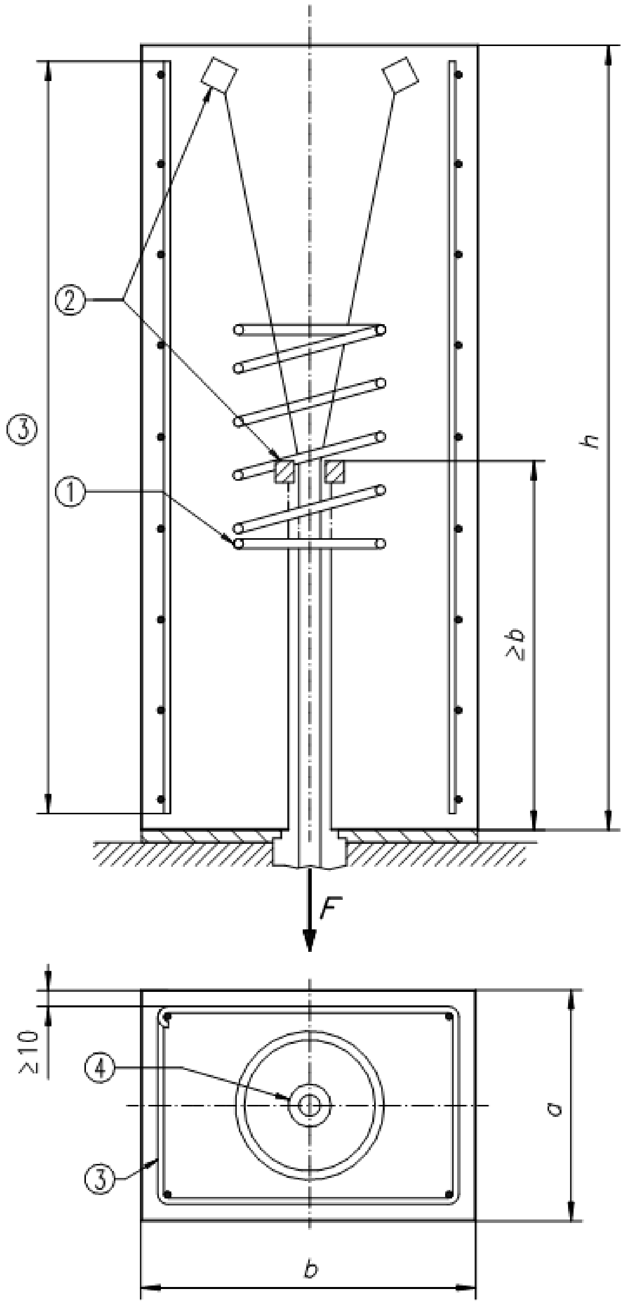
$f_{cm.e} \leq 0.80\ f_{cm.0}$

C.4.2.3 Stabilisation criteria

Same as in Annex C.4.1.3.

C.4.2.4 Measurements and observations

These shall correspond to Annex C.4.1.4 above. In addition the slip of ends of the tensile elements relative to the concrete shall be measured.



Key:

1: Bursting reinforcement

2: Actual anchorage components

3: Auxiliary reinforcement

4: Duct

Figure C.4.2-1 - Test specimen for load transfer test with bond anchorage

C.5 DEVIATION / DEFLECTION (LIMITS)

C.5.1 DEVIATOR STATIC LOAD TEST

C.5.1.1 Test specimen

A typical test specimen is schematically shown in Figure C.5.1-1. The specimen shall contain those deviator components that will be embedded in the structure, and those tendon components specified in the ETA applicants guide placed at a tendon deviator. Deviator and tendon components used for testing shall be randomly selected. Their arrangement has to comply with the intended application and with the specification. The deviator shall be placed such as to provide an intended angular misalignment corresponding to the maximum tolerance specified in European Technical Specifications and/or the ETA applicant's guide.

If a deviator is specified for use with different strength grades of the same type of tensile element, the test should be done with the strength grade that produces the highest load applied to the deviator.

The test specimen shall be a concrete prism sufficiently large to contain the tendon deviator for a tendon deviation $\alpha = 10°$ and specified minimum radius of tendon curvature at the deviator. The concrete prism shall be reinforced such as to limit cracking and to avoid premature failure of the prism during deviator test. The concrete strength shall be chosen such as to avoid premature concrete crushing during deviator testing.

Other auxiliary parts of the test set-up that may be used are indicated in Figure C.5.1-1, and may be chosen such as to suit the testing laboratory. The free length of the tendon from the deviator face to the anchorage point shall be not less than 3.0m.

C.5.1.2 Test procedure

The tendon specimen is mounted in a calibrated test rig. The tensile elements of the tendon are each slightly tensioned to remove the slack and to limit the possible differences in tension between individual elements resulting from the differences in length across the deviator. The tendon is then stressed in steps corresponding to 20%, 40%, 60% and 80% of the characteristic tensile strength of the tensile elements f_{pk}. The load is increased at a constant rate corresponding to about 100 MPa per minute. At each load step the tensile elements shall be moved relative to the deviator to stimulate the movements due to tensile elements elongation. The total accumulated movement at 80% load level shall be not less than 800 mm. At 80% level, the load is held constant for one hour. Subsequently, the load is reduced to 70% level and the tendon is injected with filling material in the deviator region according to the ETA applicants guide.

When the filling material has attained its specified minimum strength, the tendon load is increased gradually to failure at a maximum strain rate of 0.002 per minute.

C.5.1.3 Measurements and observations

The following measurements and observations shall be made and recorded **:**

- Determination of actual material characteristics of tested components according to Annex C.1.
- Compliance checking of the components with ETA specifications (materials, machining, geometry, hardness, etc.)
- Tendon load and elongation at both ends
- Measured maximum force F_{Tu}
- Location and mode of failure
- Damage to deviator pipe or tendon inside the deviator upon dissecting the deviator
- Examination of the deviator, photographic documentation, comments.

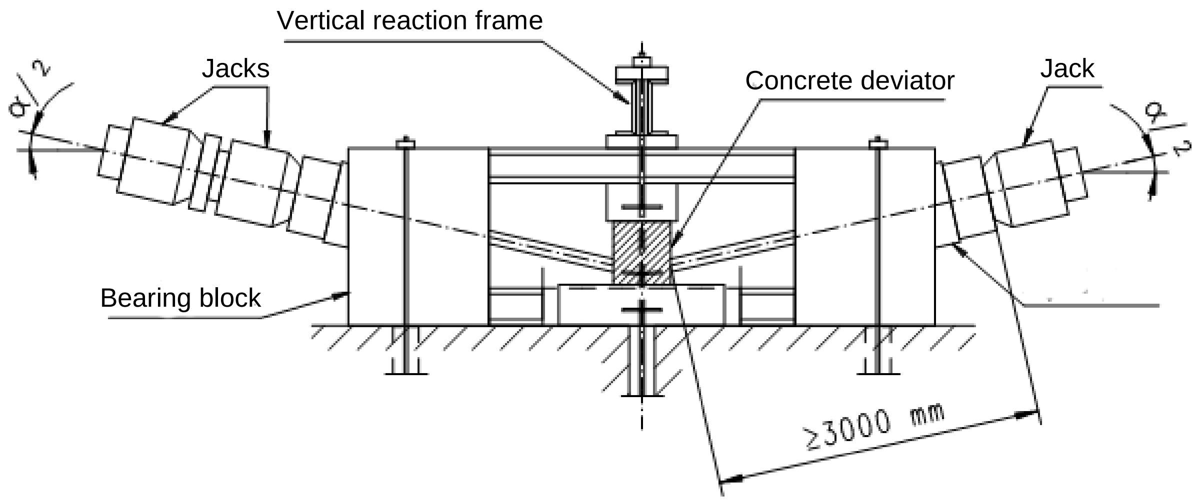


Figure C.5.1-1 - Typical test set-up for deviator static load test

C.5.2 DEVIATED TENDON TEST

C.5.2.1 Test specimen

The test specimen shall be as per Clause C.5.1.1 However, the tendon deviation shall be α = 14°.

If the deviator is specified for use with different strength grades of the same type of tensile element, the test should be done with the strength grade that produces the highest load applied to the anchorage or coupling device.

C.5.2.2 Test procedure

The test procedure described in Clause C.5.1.2 shall be applied with the following modifications:

- The tendon and deviator region is not filled with filling material, in general, in this test, unless filling of the duct is specified in the ETA to be done before complete stressing, in that case, filling shall also be carried out at the specified load in the test
- The maximum stressing load for the test shall be 70% level
- After achieving the maximum load, the tendon shall be moved under this load over the saddle over a distance of at least 800 mm
- After achieving the total movement, the load shall be held for 21 days
- Subsequently, the tendon is de-tensioned and dissected near the deviator over a length at least equal to the applied tendon movement. A test up to failure is not included.

C.5.2.3 Measurements and observations

The measurements and observations of Clause C.5.1.3 apply with the following modifications:

- Determination of actual material characteristics of tested components according to Annex C.1.
- Measured maximum force F_{Tu} and failure mode are not recorded
- Damage such as wear or cuts to the duct and sheathing of the tensile elements shall be measured and recorded
- Measurement and recording of minimum remaining thickness of duct and tensile element sheathing
- Observation and recording of relative movements between tendon components, i.e. tensile element and duct, and tensile element and sheathing.

NB : in the design of the deviator, kinks of the tendon at the exit of the deviator shall be absolutely avoided. If it happens unintentionally on a specific project, the obtained detail should be tested and the test could follow the procedure described above (with the actual angle and the actual deviation condition). Alternatively, a method or arrangement to smoothen the kink and avoiding tendon to steel deviator contact may be considered (introduction of a plastic sheet, …).

C.6 ASSESSMENT OF ASSEMBLY

C.6.1 ASSEMBLY / STRESSING TEST

C.6.1.1 Test specimen

Internal tendons:

The test specimen shall consist of a prismatic beam of minimum 30 m long and 1.5 m high. This beam and the associated tendon profile should represent an end span in a continuous beam including a portion of the first interior span. The tendon axis is defined by two second order parabolas through the anchorage (1) in the end span, the low point in the end point (2), the transition point of the parabolas (3), and the high point at the fictitious support (4). The connection of the second transition point (5) to the end coupler or anchorage (6) may be straight. At the high point (4), the tendon shall be curved at specified minimum radius of curvature in accordance with the ETA applicants guide. The tendon profile shall include intentional misalignment at tendon supports within limits specified in European Technical Specifications such as EN 13670 and/or the ETA applicant's guide (include at low point and high point on consecutive tendon supports the following intended misalignment : 0, - maximum tolerance, + maximum tolerance, 0). The beam and tendon profile are schematically shown in Figure C.6.1-1.

The specimen shall include tendon components in accordance with the ETA applicants guide for assembly, stressing and filling of duct. Components shall be randomly selected.

The specimen shall be reinforced in accordance with the Eurocodes or national codes, and shall contain anchorage bursting reinforcement in accordance with the ETA applicants guide.

External tendons:

The above specified test specimen shall be modified for external tendons. This can e.g. be achieved by splitting the above specified specimen into two halves, spaced apart, and installing an external tendon in the centre space between the halves, see Figure C.6.1-2. Alternatively, two identical external tendons may be installed on the two outside surfaces of the solid specimen specified for internal tendons. In both cases tendon deviators need to be provided either between the two halves, or on the outside surfaces of the specimen.

The tendon axis is defined by a trapezoidal path through the anchorage in the end span (1), two low points in the end span at one and two thirds of the span (2), the high point at the fictitious support (4), and an end anchorage (6). Each tendon deviation point is formed by a tendon deviator as specified in the ETA, at minimum specified radius of tendon curvature (deviators are preferably formed by half shells to allow easy inspection in the Duct Filling test, see C.6.2). The tendon deviators shall include intentional misalignment within limits specified in European Technical Specifications such as Eurocode 2 and/or the ETA applicant's guide.

C.6.1.2 Test procedure

The ETA applicant shall install all tendon components in accordance with the ETA guide into the reinforcing steel cage. The tensile elements shall be installed into the duct as provided in the ETA applicants guide. For internal tendons this may be before or after concreting of the beam, or both.

Pouring of concrete of the specimen shall then be done in accordance with standard practice.

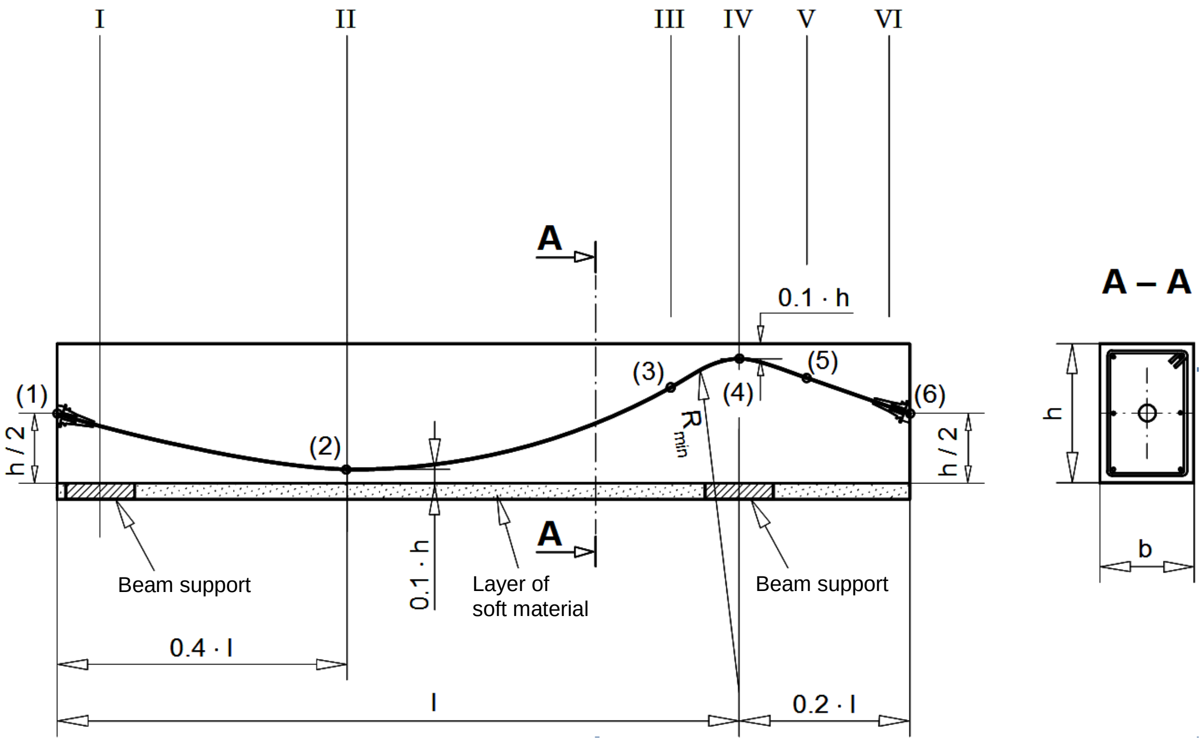
Once, the concrete is sufficiently hardened and the tensile elements installed, the tendon shall be stressed in steps to the maximum load in accordance with the ETA applicants guide. Jacks shall be used at both tendon ends, but only one is used actively to stress the tendon while the other is used to measure load.

Subsequently, the tendon shall be completely de-tensioned, and then stressed again in steps in accordance with the ETA applicants guide from the opposite end than done for the first stressing. Only one jack will be used and the tendon shall be finally anchored in accordance with the ETA applicants guide.

C.6.1.3 Measurements and observations

The following measurements and observations shall be made and recorded :

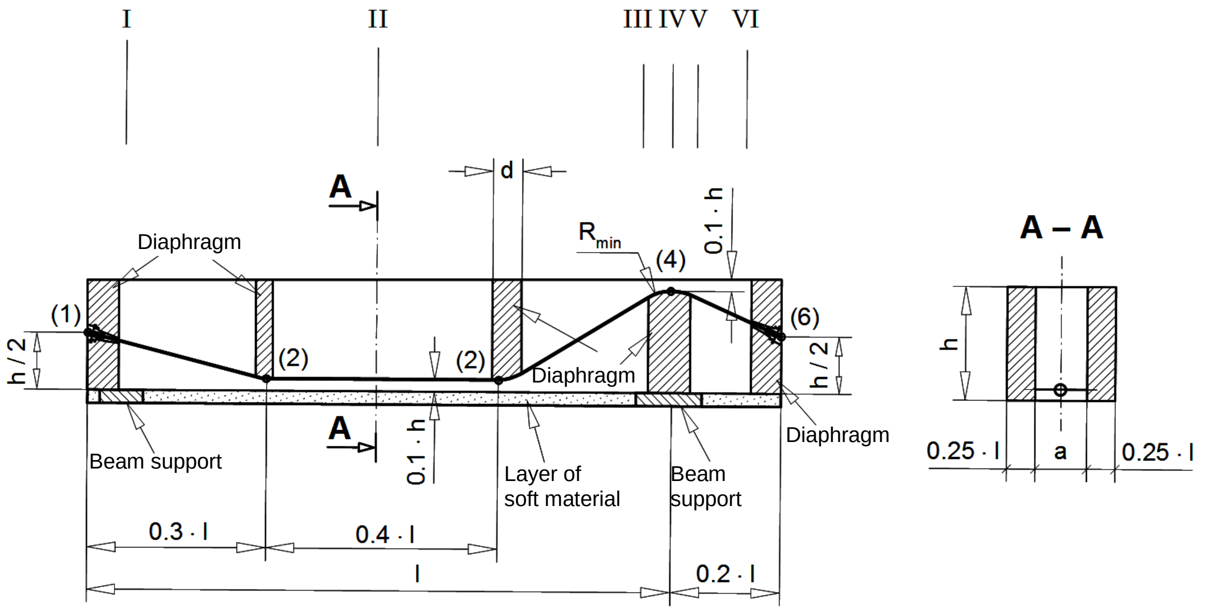
- Compliance checking of the components with ETA specifications (materials, machining, geometry, hardness, etc.).
- As built drawings of specimen, tendon profile and tendon details
- Tendon installation, stressing, de-tensioning, and re-stressing records
- Loads, tendon elongation and jack strokes at each load steps
- Weather conditions and air temperature
- Record timing of each step
- Appearance of anchorage components and tendon tails after final completion of test procedure
- Photographic documentation, comments.



Key:
(1) End anchorage
(2) Low point
(3) Transition point of parabola
(4) High point
(5) Transition point of parabola
(6) End anchorage

Dimensions:
l ≥ 25 m
h ≥ 1.5 m
b = twice the specified minimum edge distance of anchorage, ≥ 0.5 m

Figure C.6.1-1 - Test specimen of Assembly/Stressing test for internal tendon



Key:
(1) End anchorage
(2) Low point
(4) High point
(6) End anchorage

Dimensions:
a = suitable for access
d = diaphragm thickness suitable for detailing of tendon curvature at R_{min}
l ≥ 25 m
h ≥ 1.5 m

Figure C.6.1-2 - Typical test specimen of Assembly/Stressing test for external tendon

C.6.2 DUCT FILLING TEST

C.6.2.1 Test specimen

The finally stressed specimen used in Annex C.6.1 for the " Assembly / Stressing test " shall be used for the "Duct filling test".

C.6.2.2 Test procedure

The tendon shall be injected with filling material in accordance with the ETA applicants guide.

After the filling material has attained the specified minimum strength, the specimen shall be opened at the six locations I to VI indicated in Figure C.6.1-1 and Figure C.6.1-2. For internal tendons, cores sufficiently large to contain the entire duct can be taken at these sections. For external tendons, the duct shall be opened for inspection of the filling material.

C.6.2.3 Measurements and observations

The following measurements and observations shall be made and recorded :

- Compliance checking of the components with ETA specifications (materials, machining, geometry, hardness, etc).
- Weather conditions, air temperature during filling of duct and during curing.
- Position and orientation of tensile elements at each section.
- Locations and dimensions of any voids in the filling material.
- Observation of consistency and colour of filling material at each section.
- Examination of cores or filling material samples, photographic documentation, comments.

C.7 SINGLE TENSILE ELEMENT TEST FOR THE VERIFICATION OF CONSTANCY OF PERFORMANCE

C.7.1 GENERAL

This section specifies a test method for determining the strength of an anchorage of a single tensile element, strand, wire or bar in an anchor head. (e.g. strand, wedges and wedge plate or bar, nut and anchor head, etc.) Furthermore a method and requirements are given to evaluate the results of the tests.

C.7.2 TESTING EQUIPMENT

The tensile testing machine shall be of class 1 or better while the extensometer shall be of class 2 or better. The distance of cross head should be equal to at least 1.0 m. Supporting plate shall be used, if required, to adjust the angle α between the tensile element and the anchor head (see C.7.3 for explanation of angle α). A goniometer or gauges with a resolution of 0.5° shall be used to measure the inclination.

C.7.3 TEST SPECIMEN

Tests shall only be performed in test series. One test series consists of 9 to 12 (wire and strand) or 3 to 4 (bar) individual single tensile element tensile tests. The individual tests shall be performed with 9 to 12 (wire and strand) or 3 to 4 (bar) installed each in different holes of the anchor head, which, if enough holes are available, can be of one anchor head. Individual components of the PT system, representing a complete anchorage are sampled at random. It includes tensile element (strand, wire or bar) and anchorage elements (wedges, nut and anchor head), and possibly other components. The specimen, consisting of a single tensile element anchored in an anchor head, shall be prepared and assembled exactly as given in the ETA. The wedges are firstly driven with a tube in order to have the same driving of all elements. The locations of the tensile elements in the anchor head for the individual tests shall be in different rings of the anchor head. In case of deviations induced by the trumpet, individual tests with maximum deviations shall be part of the test series. The deviations can be taken into account by introduction of a supporting plate at this angle α. Tests are performed without or with the adjacent holes filled (bolted), depending on the ETA prescription, whether incomplete anchorage is permitted or not. The free length of the tensile element shall be not less than 1.0 m, or according to the needs given in the ETA. Before performing the tests, the following data shall be determined and documented in a systematically and traceable way:

- Geometrical and mechanical properties of tensile element shall determined according to prEN 10138-2, -3 or -4.
- Geometrical and mechanical properties of anchorage components.

C.7.4 TEST PROCEDURE

The specimen is placed and centred in the testing machine. One end of the tensile element is anchored in the anchor head, eventually inclined at an angle α using a supporting plate. On the other end, the tensile element is suitable gripped in such a way, that the load is applied as axially as possible. Figure C.7.4-1 shows the principle of the test set up. Then the angle α of inclination, if any, shall be measured. The elongation at maximum load shall be determined according to ISO/CD 15630-3 using a gauge length according to prEN 10138-3. The specimen is stressed by the tensile machine up to between 20% and 30% of F_{pm}; then released to approximately 5% of F_{pm}. The specimen is then stressed gradually to failure with an increase of load at a speed not more than 15 MPa/s). The following measurements and observations shall be made and recorded:
Position in the anchorage, with note of bolts if any in adjacent wedge holes not used in test, and including note of already tested parts.

- Measured inclination α in case of deviations;
- Elongation of the tensile element in the free length at measured maximum force;
- Measured maximum force;
- Location and mode of failure;
- Possibly deformation of the anchorage components, e.g. ovality of adjacent holes, etc.

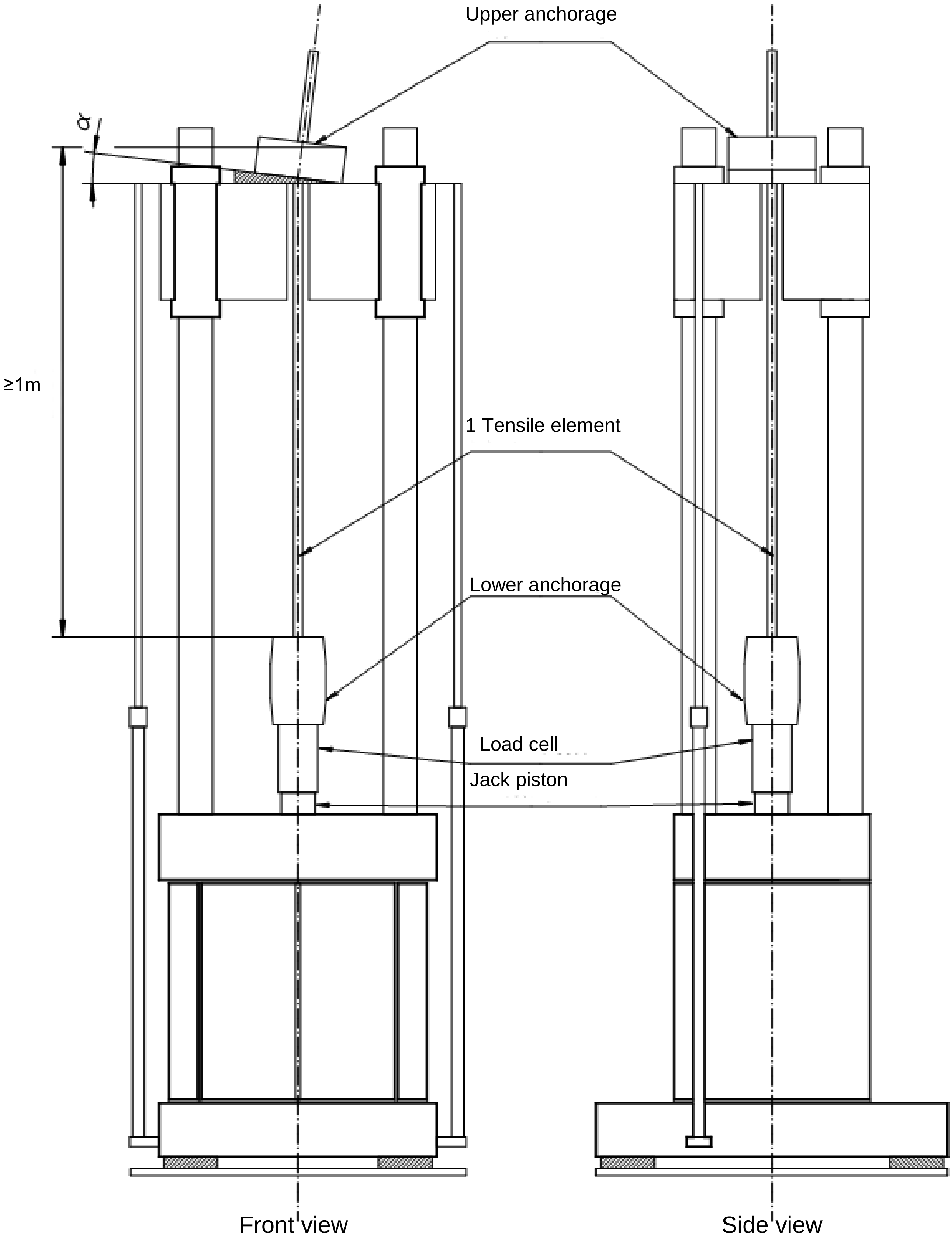


Figure C.7.4-1 Schematic view of the single tensile element test

C.7.5 EVALUATION AND REQUIREMENTS

Required performances for the individual tests are:

- The specimen fails by fracture of the tensile element. Consequently, failure of the specimen shall not be induced by the failure of anchorage components;
- The measured maximum force of all individual tests is ≥ 95 % of the actual resisting force of the tensile element (F_{pm});
- Total elongation in free length of the tensile element at measured maximum force is ≥ 2.0 %.

If failure of the tensile element occurs in the grip of the testing machine, and all the requirements are fulfilled, the individual test is considered as valid. If failure occurs in the grip of the testing machine and at least one of the requirements are not fulfilled, the individual test shall be considered as invalid and shall be repeated. In case of the first 9 individual tests are satisfactory according to the above requirements, the test series is deemed to be satisfactory. In the case of non-conforming result of one out of nine individual tests, three additional individual tests shall be performed. All of these three additional individual tests shall comply. If the test series fails, careful analysis shall be carried out and the kit manufacturer shall submit a detailed report to the NB explaining the reason for the failure, and proposing eventual corrective measures. After consideration of the report, the NB will decide on any eventual actions to be implemented or taken.

ANNEX D. COMPLEMENTS ABOUT CERTAIN PRODUCTS

D.1 PLASTIC PIPE FOR EXTERNAL TENDON

This clause covers plastic ducts (pipes) made of HDPE for use in PT systems for prestressing of structures for external tendons.

D.1.1 MATERIAL

Materials for plastic ducts for external tendons shall comply with EN 12201-1 and EN 12201-2, with the exceptions and modifications listed below:

- If other than black material is used, the durability of that material shall be appropriate for the intended use,
- Characteristics for effect on water quality can be disregarded,
- Classification and designation are applicable with an overall service (design) coefficient of C = 1.25,
- Only PE 80 and PE 100 are considered suitable for this scope.

D.1.2 PLASTIC PIPE

Plastic pipes for external tendons shall comply with EN 12201-1 and EN 12201-2, with the exceptions and modifications listed below:

- Maximum Operating Pressure (MOP) shall be 1 MPa unless specified otherwise by the ETA applicant,
- Tolerances for outside diameter shall be Grade A = 0.009 dn (dn = nominal outside diameter) with a maximum value of 1.0 mm,
- Ducts for external tendons shall be supplied in straight lengths only, i.e. not coiled in general. However, in the case of prefabricated tendons, coils shall have a minimum diameter as specified in the ETA.
- Characteristics for effects on water quality can be disregarded.