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**GUIDELINE FOR EUROPEAN TECHNICAL
APPROVAL**

of

**POST-TENSIONING KITS FOR
PRESTRESSING OF STRUCTURES**

(These are commonly called Post-Tensioning Systems)

EOTA
Kunstlaan 40 Avenue des Arts
B-1040 Brussels

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FOREWORD

- Reference documents

Reference documents are referred to within the body of the ETAG and are subject to the specific conditions mentioned therein.

The **list of reference documents** (mentioning the year of issue) for this ETAG is given hereafter. When additional parts for this ETAG are written afterwards, they may comprise modifications to the list of reference documents applicable to that part.

Updating conditions

The edition of a reference document given in this list is that which has been adopted by EOTA for its specific use.

When a new edition becomes available, this supersedes the edition mentioned in the list only when EOTA has verified or re-established (possibly with appropriate linkage) its compatibility with the guideline.

EOTA Technical Reports go into detail in some aspects and as such are not part of the ETAG but express the common understanding of existing knowledge and experience of the EOTA-bodies at that moment. When knowledge and experience is developing, especially through approval work, these reports can be amended and supplemented.

EOTA Comprehension Documents permanently take on board all usefull information on the general understanding of this ETAG as developed when delivering ETA's in consensus by the EOTA members. Readers and users of this ETAG are advised to check the current status of these documents with an EOTA member.

EOTA may need to make alterations/corrections to the ETAG during its life. These changes will be incorporated into the official version on the EOTA website www.eota.be and the actions catalogued and dated in the associated **History File**.

Readers and users of this ETAG are advised to check the current status of the content of this document with that on the EOTA website. The front cover will indicate if and when amendment has taken place.

References

- EC/EOTA documents:

- [1] CPD: Directive relating to construction products. Council Directive of 21 December 1988 on the approximation of laws, regulations and administrative provisions of the Member States relating to construction products (89/106/EEC) taking account of the modified provisions (93/68/EEC).
- [2] ID No 1 (Mechanical Resistance and Stability): Council Directive 89/106/EEC, Construction Products Interpretative Documents, Brussels, 16-7-1993.
- [3] EC Guidance Paper A: The designation of approved bodies in the field of the construction products directive.
- [4] EC Guidance Paper B: The definition of factory production control in technical specifications for construction products.
- [5] EC Guidance Paper C: The treatment of kits and systems under the construction products directive.
- [6] EC Guidance Paper D: CE-marking under the construction products directive.
- [7] ETA-format: Commission decision of 22nd July 1997 on the general format of European Technical Approvals for construction products, 97/571/EC, O.J. No L 236/7 to 13, 27th August 1997.
- [8] EOTA Guidance Document 004 / Edition December 1999 "The provision of data for assessments leading to ETA".
- [9] EC Guidance Paper L: Application and Use of Eurocodes.

- European Standards:

- [10] ENV 1991 "Eurocode 1": Basis of design and actions on structures, (1994)
- [11] ENV 1992 "Eurocode 2": Design of concrete structures, (1994)
- [12] ENV 1993 "Eurocode 3": Design of steel structures, (1993)
- [13] ENV 1994 "Eurocode 4": Design of composite steel and concrete structures, (1994)
- [14] ENV 1995 "Eurocode 5": Design of timber structures, (1993)
- [15] ENV 1996 "Eurocode 6": Design of masonry structures, (1995)
- [16] Draft prEN 10138: "Prestressing steels", (1999)
- [17] prEN 10080 Parts 1 to 4: "Steel for the reinforcement of concrete – Weldable reinforcing steel – Part 1: General requirements; Part 2: Technical delivery conditions for class A; Part 3: Technical delivery conditions for class B; Part 4: Technical delivery conditions for class C", (1999)
- [18] EN 10025 "Hot rolled products for non-alloy structural steels – Technical delivery conditions (includes amendment A1: 1993), (1993)
- [19] EN 523 "Steel strip sheaths for prestressing tendons" - Terminology, requirements, quality control, (1997)
- [20] prEN 10255 "Non-alloy steel tubes suitable for welding or threading", (1996)
- [21] EN 524 – Parts 1 to 6: "Steel strip sheaths for prestressing tendons" - Test methods – Part 1: Determination of shape and dimensions; Part 2: Determination of flexural behaviour; Part 3: To and fro bending test; Part 4: Determination of lateral load resistance; Part 5: Determination of tensile load resistance; Part 6: Determination of leak tightness (Determination of water loss)", (1997)
- [22] EN 445 "Grout for prestressing tendons", Test methods; (1996)
- [23] EN 446 "Grout for prestressing tendons", Grouting procedures; (1996)
- [24] EN 447 "Grout for prestressing tendons", Specifications for common grout, (1996)
- [25] Draft prEN 934-4 "Admixtures for concrete, mortar and grout – Part 4: Admixtures for grout for prestressing tendons – Definitions, requirements and conformity", (1999)
- [26] EN 10204 "Metallic products; type of inspection documents", (1991)

- FIP Guides to Good Practice and Recommendations, and ISO Standards:

- [27] "Tensioning of tendons: Force-elongation relationship", (1986)
- [28] "Corrugated plastic ducts for internal bonded post-tensioning", (2000)

- [29] "Corrosion protection of prestressing steels", (1996)
- [30] ISO 4200 "Plain end steel tubes, welded and seamless; general tables of dimensions and masses per unit length", (1991)

- Standards referenced in Annex C:

- [31] EN ISO 527 - Part 1 and Part 2 "Plastics – Determination of tensile properties – Part 1: General principles; Part 2: Test conditions for moulding and extrusion plastics", (1996)
- [32] ISO 1183 "Plastics – Methods for determining the density and relative density of non-cellular plastics", (1987)
- [33] ISO 2137 "Petroleum products – Lubricating grease and petroleum – Determination of cone penetration", (1985)
- [34] ISO 2176 "Petroleum products – Lubricating grease – Determination of dropping point", (1995)
- [35] ISO 4437 "Buried polyethylene (PE) pipes for the supply of gaseous fuels – Metric series – Specifications", (1997)
- [36] ISO 6964 "Polyolefin pipes and fittings – Determination of carbon black content by calcination and pyrolysis – Test method and basic specification", (1986)
- [37] ISO/TR 10837 "Determination of the thermal stability of polyethylene (PE) for use in gas pipes and fittings", (1991)
- [38] ISO 2160 "Petroleum products – Corrosiveness to copper – copper strip test", (1998)
- [39] Draft prEN 12201 - Part 1 and 2 "Plastic piping systems for water supply – Polyethylene (PE) – Part 1: General; Part 2: Pipes", (1995)
- [40] EN 496 "Plastics piping systems; Plastics pipes and fittings; Measurements of dimensions and visual inspection of surfaces", (1991)
- [41] NF C32-060 (English) "Polyolefin insulation and sheath for communication cables", (original) "Polyoléfine pour enveloppes isolantes et gaines de câbles de communication", (1996)
- [42] NF M07-023 (English) "Liquid fuels. Determination of chlorides in crude petroleum and petroleum products", (original) "Méthode de dosage des chlorides in crude les pétroles bruts et produits pétroliers", (1969)
- [43] NF T51-029 (English) "Plastics. Determination of resistance to liquid chemical substances, including water", (original) "Plastiques – Détermination de l'action des agents chimiques liquides, y compris l'eau", (1982)
- [44] NF T60-128 (English) "Congelating point of petroleum waxes, including petrolatum", (original) "Produits pétroliers – Détermination du point de figeage des paraffines, des cires, des vaselines et des petrolata issus du pétrole", (1974)
- [45] NF T60-119 (English) "Petroleum products. Determination of cone penetrability of paraffinic products", (original) "Produits pétroliers – Détermination de la pénétrabilité au cône des produits paraffineux", (1970)
- [46] NF X41-002 (English) "Protection against physical, chemical and biological agents – Salt spray test", (1975)
- [47] DIN 51802 (English) "Testing lubricating greases for their corrosion inhibiting properties by SKF EMCOR method"; (original) "Prüfung von Schmierstoffen; Prüfung von Schmierfetten auf korrosionsverhindernde Eigenschaften; SFK-Emcor-Verfahren", (1990)
- [48] DIN 51808 (English) "Testing of lubricants; determination of oxidation stability of greases; oxygen method", (original) "Prüfung von Schmierstoffen; Bestimmung der Oxidationsbeständigkeit von Schmierstoffen; Sauerstoff-Verfahren", (1978)
- [49] DIN 51817 (English) "Determination of oil separation from lubricating grease under static conditions"; (original) "Prüfung von Schmierstoffen – Bestimmung der Ölabscheidung aus Schmierfetten unter statischen Bedingungen", (1998)
- [50] BS 2000: PT121 "Methods of test for petroleum and its products – Oil separation on storage of grease", (1982)
- [51] ASTM D942-90(1995)e1 "Standard test method for oxidation stability of lubricating greases by the oxygen bomb method", (1995)

- Standards referenced in Annex E:
 - [52] EN ISO 7500-1 “Metallic materials – Verification of static uniaxial testing machines – Part 1: Tension/Compression testing machines – Verification and calibration of the force-measuring system”, (1999)
 - [53] ISO 9513 “Metallic materials – Calibration of extensometers used in uniaxial testing”, (1999)
 - [54] prEN ISO 15630-3 “Steel for the reinforcement and prestressing of concrete – Test methods – Part 3: Prestressing steel”, (1999)
 - [55] ISO 6892 “Metallic materials – Tensile testing at ambient temperature”, (1998)

Section One : INTRODUCTION

1 PRELIMINARIES

1.1 LEGAL BASIS

This ETA guideline has been established in full compliance with the provisions of the Council Directive 89/106/EEC (CPD), [1], and taking into account the following steps :

- issuing of the final mandate by the EC : 16/04/98
- issuing of the final mandate by the EFTA : 16/04/98
- adoption of the guideline by EOTA (Executive Commission) : 22/10/2001
- opinion of the Standing Committee for Construction : 18-19/12/2001
- endorsement by the EC : 28/05/2002

This document is published by the Member States in their official language or languages according to Art. 11.3 of the CPD.

No existing ETA Guideline is superseded.

1.2 STATUS OF ETA GUIDELINES

a. An ETA is one of two types of technical specifications in the sense of the EC 89/106 Construction Products Directive. This means that Member States shall presume the approved products are fit for their intended use, e.g. that they enable works in which they are employed to satisfy the essential requirements during an economically reasonable working life, provided that:

- the works are properly designed and built;
- the conformity of the products with the ETA has been properly attested.

b. This ETA Guideline is a basis for ETA's, that is a basis for technical assessment of the fitness for use of a product for an intended use. An ETA Guideline is not itself a technical specification in the sense of the CPD.

This ETA Guideline expresses the common understanding of the Approval Bodies, acting together within EOTA, as to the provisions of the EC-Construction Products Directive 89/106 and of the Interpretative Documents, in relation to the products and uses concerned, and is written within the framework of a mandate given by the Commission and the EFTA Secretariat, after consulting the EC-Standing Committee for Construction.

c. When accepted by the European Commission after consultation with the Standing Committee for Construction this **ETAG is binding** for the issuing of ETAs for the Post-tensioning kits for prestressing of structures for the defined intended uses.

The application and satisfaction of the provisions of an ETAG (examinations, tests and evaluation methods) leads to an ETA and a presumption of fitness of a Post-tensioning kit for the defined use only through an evaluation and approval process and decision, followed by the corresponding attestation of conformity. This distinguishes an ETAG from a harmonized European standard which is the direct basis for attestation of conformity.

Where appropriate, Post-tensioning kits which are outside of the precise scope of this ETAG may be considered through the approval procedure without guidelines according to art. 9.2 of the CPD.

The requirements in this ETAG are set out in terms of objectives and of relevant actions to be taken into account. It specifies values and characteristics, the conformity with which gives the presumption

that the requirements set out are satisfied, wherever the state of art permits and after having been confirmed as appropriate for the particular product by the ETA.

2 SCOPE

2.1 SCOPE

- This ETAG serves to obtain ETA's for kits, and for certain products, as detailed later in this section.
- Post-tensioning kits are more commonly referred to by the industry as PT Systems.
- This Guideline considers post-tensioning systems for prestressing of structures or parts of structures.
- Post-tensioning kits typically comprise the components listed below. They may include all of these components or just some as needed, and as specified by the ETA applicant:
 - Tensile elements in the form of wires, strands, or bars made of prestressing steel.
 - 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 which are made of different components such as anchor head, bearing plate, wedges, trumpet, sleeves, etc. as defined by the ETA applicant. Fixed anchorages may be mechanical devices or may be formed by bond of the tensile elements to concrete.
 - Couplings are devices used to connect adjacent sections of tensile elements. Movable couplings connect adjacent sections of tensile elements which 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.
 - Ducts, used to isolate, guide, and protect the tensile elements. They can be made of steel strip and steel pipe, or of plastic for smooth pipe and for corrugated ducts.
 - Filling material inside the anchorages and the ducts such as cementitious grout, grease and wax.
 - Pipes or special details to provide a defined deviator for external tendons at designated locations in a structure. Such deviator pipes are often made of smooth steel pipe. Special details may include formed reservations inside concrete elements or structural steel saddles to form the tendon deviator.
 - Bursting reinforcement to provide confinement to concrete elements which 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.
 - Special accessories to 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.
- This ETAG considers post-tensioning kits which use the following components:
 - Tensile elements as per prEN 10138, [16]
 - Monostrand tensile elements, Annex C.1
 - Steel strip ducts as per EN 523, [19]
 - Steel pipes as per prEN 10255, [20], or ISO 4200, [30]
 - Smooth plastic pipe as per Annex C.2
 - Corrugated plastic ducts as per Annex C.3
 - Filling materials as per EN 447, [24]
 - Special filling materials as per Annex C.4
 - Bursting reinforcement as per prEN 10080, [17], and EN 10025, [18]

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

- Post-tensioning systems can be used for the following types of tendons:

- Internal bonded tendons
- Internal unbonded tendons
- External tendons with a tendon path situated outside the cross section of the structure or member but inside its envelope

Ground anchors, external tendons with the tendon path outside the envelope of the structure or member, and stay cables are not considered by this ETAG.

- ETA's can be obtained for:
 - a kit containing tensile elements, anchorages, couplings if specified, ducts, filling material, deviators if any, bursting reinforcement, and special accessories as needed
 - the following individual components: Special filling materials as specified in Annex C.4.
- 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 if these applications are declared as use categories in the ETA.
- 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)
 - 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

Unless noted otherwise in the ETA, post-tensioning kits are assumed to be applied to all above listed applications, and for permanent use.

- Furthermore, the ETA applicant shall provide, where necessary, the following documentation accompanying the post-tensioning kit to the issuing approval body :
 - Specifications and drawings of all the components
 - Specifications of specific equipment for installation, stressing, and duct filling
 - Procedures for consideration in the design of structures
 - Procedures for manufacturing of components
 - Procedures for transport and storage of components
 - Procedures for installation of components
 - Procedures for maintenance of systems

2.2 USE CATEGORIES

- Different types of tendons may need specific considerations. The ETA applicant shall therefore, specify the basic Use Category of his post-tensioning system in the form of the following tendon types:
 - Internal bonded tendon for concrete and composite structures
 - Internal unbonded tendon for concrete and composite structures
 - External tendon for concrete structures with a tendon path situated outside the cross section of the structure or member but inside its envelope
- The ETA applicant may choose to offer supplementary Optional Use Categories which go beyond above basic types of tendons with his post-tensioning system. Such options may include the following:
 - **(a)** Restressable tendon (internal or external)
 - **(b)** Exchangeable tendon (internal or external)
 - **(c)** Tendon for cryogenic applications
 - **(d)** Internal bonded tendon with plastic duct
 - **(e)** Encapsulated tendon
 - **(f)** Electrically isolated tendon
 - **(g)** Tendon for use in structural steel or composite construction as external tendon
 - **(h)** Tendon for use in structural masonry construction as internal and/or external tendon
 - **(i)** Tendon for use in structural timber construction as internal and/or external tendon

Any such option needs to be specified as Optional Use Category by the ETA applicant in the ETA. Options which combine different Use Categories such as e.g. tendon for use in structural steel construction as external tendon, shall be verified for requirements of each Use Category, i.e. for use in structural steel construction and for external tendon. Verification of these additional options is covered by Chapters 4, 5, and 6 as far as it has been foreseen at the time of writing this ETAG but may require additional considerations by the Approval Body to verify specified options not presently anticipated in the document.

2.3 ASSUMPTIONS

PT kits are assumed to be used in structures designed in accordance with Eurocodes [10, 11, 12, 13, 14, 15] or equivalent national regulations.

It is assumed that the PT kit is installed correctly in accordance with the ETA holders specifications. The quality of installation has a significant effect on the reliability and the durability of the PT system. Thus, it is up to the Member States to take measures concerning the supervision of planning, design and execution of the works, and concerning the qualifications of parties and persons involved.

Other basic assumptions implied with the use of this ETAG are listed in Chapter 7.

3 TERMINOLOGY

3.1 COMMON TERMINOLOGY AND ABBREVIATIONS (SEE ANNEX A)

3.2 PARTICULAR TERMINOLOGY AND ABBREVIATIONS

3.2.1 Terminology

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, connectors for duct lengths/sections or for ducts to anchorages, etc.

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

Anchor Head/Block: Part which 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 "wedge plate".

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

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

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

Anchorage Seating: Relative movement between tensile element and anchorage when transferring the prestressing load from the stressing equipment to the anchorage.

Bearing Plate: Part which supports the anchor head and transfers the prestressing load onto or into the structure. The bearing plate is sometimes called "force transfer unit".

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.

Button Head: see Wedge

Chartered Engineer: A competent civil or structural engineer.

Component Manufacturer: Company, which manufactures components of the PT kit according to the specifications of the ETA holder.

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

Coupling: A device to join adjacent sections of tendons.

Department: The term used in this ETAG representing the function and resources to carry out the defined tasks and procedures. It is not meant to represent an organisational structure.

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

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

Duct: An enclosure in which several tensile elements are placed and which 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.

Duct Support: A device which supports and firmly holds a duct in position.

Encapsulated Tendon: A tendon which is provided with a watertight envelope (duct and cap).

ETA Applicant: Company applying for an ETA.

ETA Holder: Company which has obtained an ETA. ETA holder is also used in cases where clauses apply to both the ETA applicant and the ETA holder.

European Technical Specification: Eurocodes, product standards, and European Technical Approvals, including officially published drafts of these documents.

Exchangeable Tendon: This is a tendon which can be exchanged at some time during the design working life of the structure, i.e. the existing tendon can be removed from the structure and a new tendon can be installed in its place.

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".

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

Fixed Coupling: Coupling which allows joining of adjacent tendon section stressed not at the same time.

Friction Coefficient: Coefficient used to calculate loss of tendon load during stressing due to friction between the tensile elements and the duct at intentional tendon curvature.

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

Grout: A cementitious filling material as per EN 447.

Innovative PT System: A PT system which is significantly different in design, and/or choice of materials, and/or choice of installation/stressing/ filling procedures of duct, to the PT systems traditionally used by the industry for some time.

Monostrand : A single strand with its individual protection by grease or wax and plastic sheathing. It is permanently unbonded to the structure.

Movable Coupling : Coupling which allows joining of adjacent tendon sections stressed at the same time.

Nut : see Wedge

Pipe: A thick walled smooth duct made of plastic or steel.

Post-Tensioning System : For ease of reference it is called "PT system" in the text.

PT Site Manager: An expert with a technical qualification or license and with special experience in managing large scale PT sites, and recognised by the ETA holder.

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

PT Supervisor: An expert with special experience in PT site activities, and recognised by the ETA holder.

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

International Organisation : Organisations such as fib, FIP, CEB, ISO.

Restressable Tendon: A tendon for which the stressing force can be modified at any time during the design working life of the structure.

Sheath : see Duct.

Sheathing : An enclosure encapsulating a single tensile element, usually separated with a layer of grease or wax from the tensile element.

Special Grout: A cementitious filling material having characteristics according annex C.4.3.

Stressing Anchorage: Anchorage allowing stressing of the tendon, also called mechanical anchorage.

Swage : see Wedge.

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

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

Type : 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.

Vent : Tube or hose which permits air to escape the duct at high points of the tendon profile.

Wedge/Button Head/Nut/Swage : Part which holds an individual tensile element and transfers the prestressing load to the anchor head, or for an individual tensile element directly to the bearing plate.

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

3.2.2 Abbreviations

AC-system: System of attestation of conformity.

CB : Certification body which meets the requirement of the CPD, [1], and the Guidance Paper A, [3].

CEB : Comité Européen/International du Béton.

EEA : European Economic Area.

fib : Fédération Internationale du Béton (created as merger of FIP and CEB).

FIP : Fédération Internationale de la Précontrainte.

OJ : Official Journal of the European communities.

ER : Essential requirement (see Annex A.2.3)

3.3 NOTATIONS

A_p	Nominal cross-sectional area of tensile elements of tendon
A_{pm}	Actual mean cross-sectional area of tensile elements of tendon
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: $F_{pm} = A_{pm} \times f_{pm}$
$F_{p0,1k}$	Characteristic yield force of tensile elements of tendon: $F_{p0,1k} = A_p \times f_{p0,1k}$
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): $\Delta F = \text{Max F} - \text{Min F}$
R_{min}	Minimum radius of curvature of a particular tendon specified by ETA holder
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
$\Delta\sigma_p$	Stress range in the fatigue test (dynamic load test)
a	Reference dimension of cross section of load transfer test specimen specified by ETA-holder, measured in x-direction
b	Reference dimension of cross section of load transfer test specimen specified by ETA-holder, measured in y-direction
c	Concrete cover of reinforcement
h	Height of load transfer test specimen
max w	Maximum crack width measured in the load transfer test
n	Maximum number of tensile elements for tendon size used in fatigue test
n'	Reduced number of tensile elements in tendon installed for fatigue test
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 permitted as per ETA
$f_{cm,e}$	Mean compressive strength of concrete at final test to failure in the load transfer test
f_{pk}	Characteristic tensile strength of tensile elements
f_{pm}	Actual mean 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
A_c	Cross-sectional area of load transfer test specimen
x	Minimum centre or twice the edge distance of anchorage in the structure in x-direction, derived from reference dimensions a and b
y	Minimum centre or twice the edge distance of anchorage in the structure in y-direction, derived from reference dimensions a and b
α	Angular deviation of tendon at deviator

Section Two :

GUIDANCE FOR THE ASSESSMENT OF THE FITNESS FOR USE

GENERAL NOTES

(a) Applicability of the ETAG

This ETAG provides guidance on the assessment of a family of PT kits and their intended uses. It is the ETA applicant who defines the PT kit for which he is seeking ETA and how it is to be used in the works, and consequently the scale of the assessment.

It is therefore possible that for some PT systems which are fairly conventional only some of the tests and corresponding criteria are sufficient to establish fitness for use (except for requirements in Clauses 4.1.1-I to 4.1.3-I for which test results have to be submitted in all cases). In other cases, e.g. special or innovative PT systems or materials, or where there is a range of uses, the whole package of tests and assessment may be applicable.

(b) General lay out of this section

The assessment of the fitness of PT systems with regard to their fitness for intended use in construction works is a process with the following main steps:

- **Chapter 4** clarifies the specific requirements for the works relevant to the PT systems and uses concerned, beginning with the Essential Requirements for works (CPD art. 11.2) and then listing the corresponding relevant characteristics of PT systems.
- **Chapter 5** extends the list in Chapter 4 into more precise definitions and the methods available to verify PT system characteristics and to indicate how the requirements and the relevant PT system characteristics are described. This is typically done by testing but may include methods of calculation, analysis, experience, and comparison with known behaviour. The test procedures for PT systems are presented in Annex B, and for non-standardised components in Annex C.
- **Chapter 6** provides guidance on the assessing and judging methods to confirm fitness for the intended use of the PT system. This includes in particular the listing of acceptance criteria.
- **Chapter 7**, assumptions and recommendations are only relevant in as far as they concern the basis upon which the assessment of the PT kit is made concerning fitness for the intended use.

(c) Levels or classes or minimum requirements related to the essential requirements and to the PT system performance (see ID, [2], Clause 1.2).

No levels or classes are defined for PT kits in the mandate.

(d) Working life (durability) and serviceability

The provisions, test and assessment methods in this ETAG have been written based upon the assumption that the estimated design working life (nominal design value of the intended life of a structure) of the PT system is the same as the one specified by the Eurocodes relevant for the structure in which they are intended to be used provided that the PT systems are subject to appropriate use and maintenance (see Chapter 7). Eurocode 1, [10], specifies 100 years design working life for bridges and other engineering structures. These provisions are based upon the current state of art and the available knowledge and experience.

The indication given on the design working life of a product cannot be interpreted as a guarantee given by the producer (or the Approval Body) but is regarded only as a means for choosing appropriate components and materials in relation to the expected economically reasonable design working life of the works, see ID paragraph 5.2.2.

Installation (e.g. filling of duct) by qualified personnel is particularly important to assure the durability of the PT system over the design working life.

(e) Fitness for the intended use

According to the CPD it has to be understood that within the terms of this ETAG, PT kits shall “have such characteristics that the works in which they are to be incorporated, assembled, applied or installed, can, if properly designed and built, satisfy the Essential Requirements”, see CPD article 2.1.

Hence, the PT kits shall be suitable for use in construction works which, as a whole and in their separate components, are fit for their intended use, account being taken of economy, and in order to satisfy the essential requirements. Such requirements shall, subject to normal maintenance, be satisfied for an economically reasonable working life. The requirements generally concern actions which are foreseeable, see CPD Annex 1, preamble.

4 REQUIREMENTS FOR WORKS, AND THEIR RELATIONSHIP TO THE CHARACTERISTICS OF THE PT SYSTEM

This chapter sets out the aspects of performance to be examined in order to satisfy the relevant Essential Requirements by:

- Expressing in more detail, within the scope of the ETAG, the relevant Essential Requirements of the CPD in the Interpretative Documents and in the mandate, for works or parts of the works, taking into account the actions to be considered, as well as the expected durability and serviceability of the works.
- Applying them to the scope of the ETAG (post-tensioning system and its constituents, components and intended uses) and providing a list of relevant characteristics and other relevant properties.

4.0 GENERAL

Successful application of prestressing is only obtained when approved PT systems are installed by qualified and experienced personnel. In view of the risks involved, provision of an ETA shall be restricted to companies which can demonstrate that they possess the knowledge and experience of design, manufacturing, and installation of PT kits that they put on the market. Chapters 4, 5 and 6 consider the PT systems aspects while Chapter 7 will address aspects of installation, and qualification of personnel and companies.

PT systems shall deliver accurate prestressing loads, correctly located, at the ends and along the tendons, during the construction and throughout the intended life of the structure. Equipment to stress the PT system shall be adapted to the intended use, and shall be accurate, and calibrated regularly.

The anchorage system shall retain the specified percentage of the strength of the tendon and the prestressing load transmitted to it throughout the intended life of the structure.

Materials used for components shall comply with European Technical Specifications (EN standards or ETAs). If such specifications do not exist, ISO standards shall be considered. If none of the above exists, national specifications and standards or recommendations by FIP, CEB, and fib may be considered acceptable. However, for individually greased and sheathed monostrands, for plastics pipes for external tendons, for plastic ducts for bonded internal tendons, and for special filling materials the component specifications provided in Annex C shall be used.

Corrosion protection of all components of a PT kit is a prime concern from production, to transport, storage, installation up to final/ permanent use in a structure, to assure retaining the specified characteristics throughout the intended life of the structure.

The connection between the tendon and the stressing equipment shall be safe under all conditions encountered on site both during stressing and during transfer of load from the stressing equipment to the anchorage. The concrete or other materials in the anchorage zone, and the associated reinforcement shall be capable of carrying the prestressing load safely.

Table 4.1 lists relevant Essential Requirements, the relevant paragraphs of the corresponding IDs, and the related requirements to PT system performances as a function of the Use Categories. Table 4.2 gives reference to component specifications in Annex C.

Table 4.1 : Relationship between ETAG paragraph on PT system performances, methods of verification, assessing and judging the fitness for use, and test procedure

ER	Corresponding ID paragraph for works	Corresponding ID paragraph for PT system performance	Application / Use Category	ETAG paragraph on PT system performance	Methods of verification	Assessing and judging the fitness for use	Test procedure
1	§ 4.2 Provisions concerning works	§ 4.3 Provisions concerning products + Appendix Clause 3 § on characteristics for – “Prestressing steel” – “Prestressing devices for post-tensioning” – “Ducts and sheaths” – “Grouts”	I. All systems	4.1.1-I Resistance to static load	5.1.1-I Resistance to static load	6.1.1-I Resistance to static load	B.1.1 Static load test
				4.1.2-I Resistance to fatigue	5.1.2-I Resistance to fatigue	6.1.2-I Resistance to fatigue	B.2.1 Fatigue test
				4.1.3-I Load transfer to structure	5.1.3-I Load transfer to structure	6.1.3-I Load transfer to structure	B.3.1 Load transfer test
				4.1.4-I Friction coefficient	5.1.4-I Friction coefficient	6.1.4-I Friction coefficient	By assessment, or by testing: B.4 Friction losses in anchorages, B.6.1 Assembly/ Installation/ Stressing test
				4.1.5-I Deviation / Deflection (limits)	5.1.5-I Deviation/ Deflection (limits)	6.1.5-I Deviation/ Deflection (limits)	By assessment, or by testing: B.5.1 Deviator static load test, B.5.2 Deviated tendon test
				4.1.6-I Practicability/ reliability of installation	5.1.6-I Practicability/ reliability of installation	6.1.6-I Practicability/ reliability of installation	By assessment of installation procedures, or by testing: B.6 Practicability / Reliability of installation

Table 4.1 (continued)

ER	Corresponding ID paragraph for works	Corresponding ID paragraph for PT system performance	Application / Use Category	ETAG paragraph on PT system performance	Methods of verification	Assessing and judging the fitness for use	Test procedure
			II. Systems with optional Use Categories, and Innovative Systems				
			Restressable tendon	4.1.6-II(a) Practicability/ reliability of installation	5.1.6-II(a) Practicability/ reliability of installation	6.1.6-II(a) Practicability/ reliability of installation	By assessment, or by testing: B.5.2 Deviated tendon test B.6.1 Assembly/ Installation/ Stressing test
			Exchangeable tendon	4.1.6-II(b) Practicability/ reliability of installation	5.1.6-II(b) Practicability/ reliability of installation	6.1.6-II(b) Practicability/ reliability of installation	By assessment, or by testing: B.6.3 Tendon replacement test
			Tendon for cryogenic applications	4.1.1-II(c) Resistance to static load	5.1.1-II(c) Resistance to static load	6.1.1-II(c) Resistance to static load	B.1.3 Cryogenic static load test
			Internal bonded tendon with plastic duct	4.1.6-II(d) Practicability/ reliability of installation	5.1.6-II(d) Practicability/ reliability of installation	6.1.6-II(d) Practicability/ reliability of installation	By assessment, or by testing: B.6.1 Assembly/ Installation / Stressing test, B.6.2 Duct filling test
			Encapsulated tendon	4.1.6-II(e) Practicability/ reliability of installation	5.1.6-II(e) Practicability/ reliability of installation	6.1.6-II(e) Practicability/ reliability of installation	By assessment, or by testing: B.6.4 Leak tightness test
			Electrically isolated tendon	4.1.6-II(f) Practicability/ reliability of installation	5.1.6-II(f) Practicability/ reliability of installation	6.1.6-II(f) Practicability/ reliability of installation	By assessment, or by testing: B.6.5 Electrical resistance test

Table 4.1 (concluded)

ER	Corresponding ID paragraph for works	Corresponding ID paragraph for PT system performance	Application / Use Category	ETAG paragraph on PT system performance	Methods of verification	Assessing and judging the fitness for use	Test procedure
			Tendon for use in structural steel or composite construction	4.1.3-II(g) Load transfer to structure	5.1.3-II(g) Load transfer to structure	6.1.3-II(g) Load transfer to structure	By design
			Tendon for use in structural masonry construction	4.1.3-II(h) Load transfer to structure	5.1.3-II(h) Load transfer to structure	6.1.3-II(h) Load transfer to structure	By design
			Tendon for use in structural timber construction	4.1.3-II(i) Load transfer to structure	5.1.3-II(i) Load transfer to structure	6.1.3-II(i) Load transfer to structure	By design
			Innovative systems	4.1.6-II(k) Practicability/ reliability of installation	5.1.6-II(k) Practicability/ reliability of installation	6.1.6-II(k) Practicability/ reliability of installation	By assessment, or by testing: B.6.1 Assembly/ Installation/ Stressing test B.6.2 Duct filling test
2			All systems	Not relevant	Not relevant	Not relevant	Not relevant
3			All systems	4.3 Hygiene, health and environment	5.3 Hygiene, health and environment	6.3 Hygiene, health and environment	By assessment
4,5,6			All systems	Not relevant	Not relevant	Not relevant	Not relevant
Related aspects of serviceability			All systems	4.7 Related aspects of serviceability	5.7 Related aspects of serviceability	6.7 Related aspects of serviceability	By assessment

Note: ER = Essential Requirement

Table 4.2: Reference to component requirements, methods of verification, and acceptance criteria

Component	ER	Reference Specification		Methods of verification		Acceptance Criteria	
		Standard	Annex	Materials	Components	Materials	Components
Tensile Elements	1	prEN 10138	none	prEN 10138	prEN 10138	prEN 10138	prEN 10138
Monostrand Tensile Elements	1	none	C.1	C.1.2	C.1.3	C.1.2	C.1.3
Steel Strip Duct	1	EN 523	none	EN 523	EN 524	EN 523	EN 523
Steel Pipe	1	prEN 10255 ISO 4200	none	prEN 10255 ISO 4200	prEN 10255 ISO 4200	prEN 10255 ISO 4200	prEN 10255 ISO 4200
Smooth Plastic Pipe	1	prEN 12201	C.2	prEN 12201 and C.2.2	prEN 12201 and C.2.3	prEN 12201 and C.2.2	prEN 12201 and C.2.3
Corrugated Plastic Ducts	1	none	C.3	C.3.2	C.3.3	C.3.2	C.3.3
Filling Materials	Related aspects of serviceability	EN 447	none	EN 445	EN 445	EN 447	EN 447
Grease	Related aspects of serviceability	none	C.4.1	C.4.1.2	none	C.4.1.2	none
Wax	Related aspects of serviceability	none	C.4.2	C.4.2.2	none	C.4.2.2	none
Special Grout	Related aspects of serviceability	none	C.4.3	C.4.3.2	C.4.3.3	C.4.3.2	C.4.3.3
Bursting Reinforcement	1	prEN 10080 EN 10025	none	prEN 10080 EN 10025	prEN 10080 EN 10025	prEN 10080 EN 10025	prEN 10080 EN 10025

ER = Essential Requirements

4.1 MECHANICAL RESISTANCE AND STABILITY OF SYSTEMS

Requirements in Clause 4.1 are grouped in Part I and Part II. Part I lists compulsory requirements which apply to all PT systems. Part II gives supplementary requirements which apply to PT systems for certain optional use categories which may be defined as options by the ETA applicant. Some of these supplementary requirements can also apply to new innovative PT systems which use non standardised components, including corrugated plastic ducts for bonded tendons specified in Annex C.3. Optional use categories which combine features of more than one use category need to satisfy requirements of each category (e.g. external tendon for use in structural steel construction needs to satisfy requirements of external tendons and of tendons for use in structural steel construction).

Part I: Compulsory Requirements for all PT Systems

4.1.1-I **Resistance to static load** (of the tensile element/ anchorage/ coupling assembly)

PT systems shall be able to develop a specified percentage of the tensile element ultimate strength with a minimum elongation, without premature failure of anchorage components, without undue deformations in the components, and without disproportionate relative movements between tensile elements and anchorage components.

4.1.2-I **Resistance to fatigue** (of the tensile element/ anchorage/ coupling assembly)

PT systems shall be able to withstand specified fatigue loads (dynamic strength) without exceeding a specified percentage loss of tensile element cross section.

4.1.3-I **Load transfer to the structure** (mechanical and bond anchorages)

PT systems shall be able to transfer a specified percentage of the tensile element ultimate strength from the anchorage into the concrete structure, of a defined strength class of concrete, without undue cracking of the structure, and at deformations which stabilise within a given time frame.

4.1.4-I **Friction coefficient**

PT systems shall allow application of accurate prestressing loads at anchorages, and allow reliable prediction of loads due to losses by friction and wobble effects along the tendon length, during construction and throughout the design working life of the structure. Loss of prestressing load due to anchorage seating, friction in anchorages, and along the tendon path need to be known (range and recommended friction and wobble coefficients shall be given, effect of filling ratio of ducts on values shall be known).

4.1.5-I **Deviation/ deflection (limits)**

Radii of tendon curvature need to be specified to limit stresses, applied by the tendon on the concrete, friction losses, wear of duct or sheathing, secondary stresses in tensile elements, etc., to acceptable values.

Unintentional deviations and deflections of tendons, or installation tolerances of components, shall not reduce the tendon ultimate strength as per 4.1.1 to 4.1.3, nor unduly affect the application of prestressing loads as per 4.1.4.

4.1.6-I **Practicability/ reliability of installation** (e.g. filling of duct)

PT systems shall allow safe and reliable handling, installation, stressing, and complete filling of duct and anchorages, in the works.

Part II: Supplementary Requirements for Optional Use Categories and for Innovative PT Systems

(a) Restressable tendon:

4.1.6-II(a) Practicability/ reliability of installation (e.g. filling of duct)

PT systems shall allow safe and reliable re-stressing of tendons at any time during the design working life of the structure without compromising the corrosion protection system of the tendon.

(b) Exchangeable tendon:

4.1.6-II(b) Practicability/ reliability of installation (e.g. filling of duct)

PT systems shall allow safe and reliable replacement in the works during the design working life while assuring a reliable permanent corrosion protection.

(c) Cryogenic applications:

4.1.1-II(c) Resistance to static load (of the tensile element/ anchorage/ coupling assembly)

Extreme temperatures for which the PT system is approved shall not unduly affect the resistance to static load, and the fracture toughness of materials.

(d) Internal bonded tendon with plastic duct:

4.1.6-II(d) Practicability/ reliability of installation (e.g. filling of duct)

PT systems shall allow reliable assembly, installation, stressing, and filling of duct.

(e) Encapsulated tendon:

4.1.6-II(e) Practicability/ reliability of installation (e.g. filling of duct)

PT systems shall be sufficiently leak tight to assure full encapsulation.

(f) Electrically isolated tendon:

4.1.6-II(f) Practicability/ reliability of installation (e.g. filling of duct)

PT systems shall demonstrate a sufficient electrical resistance between the tensile elements and the structure to be considered electrically isolated.

(g) Tendon for use in structural steel or composite construction as external tendon:

4.1.3-II(g) Load transfer to the structure

PT systems shall be able to safely transfer a specified percentage of the tensile element ultimate strength from the anchorage into the structural steel or composite structure.

(h) Tendon for use in structural masonry construction as internal bonded or unbonded and/or external tendon:

4.1.3-II(h) Load transfer to the structure

PT systems shall be able to safely transfer a specified percentage of the tensile element ultimate strength from the anchorage into the masonry structure.

(i) Tendon for use in structural timber construction as internal unbonded and/or external tendon:

4.1.3-II(i) Load transfer to the structure

PT systems shall be able to safely transfer a specified percentage of the tensile element ultimate strength from the anchorage into the timber structure.

(k) Innovative systems:

4.1.6-II(k) Practicability/ reliability of installation (e.g. filling of duct)

PT systems shall allow safe and reliable assembly, installation, stressing, and filling of duct.

4.2. SAFETY IN CASE OF FIRE

Not relevant

4.3. HYGIENE, HEALTH AND ENVIRONMENT

Release of dangerous substances :

The product/kit must be such that, when installed according to the appropriate provisions of the Member States, it allows for the satisfaction of the ER3 of the CPD as expressed by the national provisions of the Member States and in particular does not cause harmful emission of toxic gases, dangerous particles or radiation to the indoor environment nor contamination of the outdoor environment (air, soil or water).

4.4. SAFETY IN USE

Not relevant

4.5. PROTECTION AGAINST NOISE

Not relevant

4.6. ENERGY ECONOMY AND HEAT RETENTION

Not relevant

4.7. RELATED ASPECTS OF SERVICEABILITY

Not relevant except for aspects related to design working life (see paragraph 4.0) such as:

Protection of tensile elements, anchorage components, couplings, ducts, etc. during transport, storage, and construction to prevent corrosion and its adverse effects on friction, depending on time/duration of exposure, environment, etc.

Permanent corrosion protection shall be provided to tendons in all cases.

Locations where tendons 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.

The quality of filling material, and the quality of executing the filling of duct on site have a major effect on the quality of corrosion protection, and hence the durability, of the PT system

5 METHODS OF VERIFICATION

5.0 GENERAL

This chapter refers to the verification methods used to determine the various aspects of performance of the products in relation to the requirements for the works (calculations, tests, engineering knowledge, site experience, etc.) as set out in chapter 4.

EOTA Guidance Document No 004 “The provision of data for assessments leading to ETA”, [8], details the current basis for acceptance of test data.

Actual material characteristics of components to be used for testing (mechanical, chemical, metallurgical, geometrical, etc as relevant) shall be determined and documented (see “The provision of data for assessments leading to ETA”, [8]), and shall comply with the ETA applicant’s specification.

Test results shall be submitted by the ETA applicant for verification of compulsory requirements as listed in Clauses 4.1.1-I to 4.1.3-I. Tests carried out before this ETAG was issued are acceptable if the test procedures of such tests comply with this ETAG. Analysis and comparison with past successful experience is acceptable for verification of requirements listed in Part I, Clauses 4.1.4-I to 4.1.6-I, and in Part II, Clauses 4.1.3. to 4.1.6., except for innovative systems.

PT system testing shall be documented with a test report including the following information:

- A signed statement by the laboratory or body which has carried out or witnessed the tests that these tests have been carried out in accordance with this ETAG.
- 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 (or steel, masonry, or timber).
- Certificates of equipment and test machine calibration.
- Description and drawing of test specimen with actual dimensions.
- Description and drawing of test set-up and measuring equipment including calibration certificate.
- Description of detailed test procedure.
- Record of all measurements and observations.
- Photographs of test specimen prior, during, and after 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.

Where Eurocodes are quoted in this ETAG as the methods for the verification of certain product characteristics, their application in this ETAG as well as in the subsequent ETA’s issued according to this ETAG, shall be in accordance with the principles laid down in the EC Guidance Paper on the use of Eurocodes in harmonised European technical specifications, [9].

The listed methods of verification apply to the verification of an initial request for ETA. For renewal and extension of an ETA, the following applies:

In case of a renewal of an ETA no new verification is required. However, renewal shall be granted based on summary reports on the past experience (extent of use, problems, etc) submitted by the ETA holder, and by the CB, to the Approval Body, as well as other information collected by the Approval Body.

In case of an extension of an existing ETA, verification may be limited to the modifications made to the previous ETA and to the compatibility of these modifications with the existing ETA.

Table 5.1 lists the relationship between ETAG paragraph on PT system performance, PT system characteristics and ETAG paragraph on verification method as a function of the Use Category. Table 5.2 gives reference to component specifications in Annex C.

Table 5.1 : Relationship between ETAG paragraph on PT system performance, PT system characteristics and ETAG paragraph on verification method as a function of the Use Category.

ER	Application / Use Category	ETAG paragraph for PT system verification
1	I. All systems	5.1.1-I Resistance to static load
		5.1.2-I Resistance to fatigue
		5.1.3-I Load transfer to structure
		5.1.4-I Friction coefficient
		5.1.5-I Deviation / Deflection (limits)
		5.1.6-I Practicability/ reliability of installation
	II. Systems with optional Use Categories, and Innovative Systems	
	Restressable tendon	5.1.6-II(a) Practicability/ reliability of installation
	Exchangeable tendon	5.1.6-II(b) Practicability/ reliability of installation
	Tendon for cryogenic applications	5.1.1-II(c) Resistance to static load
	Internal bonded tendon with plastic duct	5.1.6-II(d) Practicability/ reliability of installation
	Encapsulated tendon	5.1.6-II(e) Practicability/ reliability of installation
	Electrically isolated tendon	5.1.6-II(f) Practicability/ reliability of installation
	Tendon for use in structural steel or composite construction	5.1.3-II(g) Load transfer to structure
Tendon for use in structural masonry construction	5.1.3-II(h) Load transfer to structure	
Tendon for use in structural timber construction	5.1.3-II(i) Load transfer to structure	
Innovative systems	5.1.6-II(k) Practicability/ reliability of installation	
2	All systems	Not relevant
3	All systems	5.3 Hygiene, health and environment
4,5,6	All systems	Not relevant
Related aspects of serviceability	All systems	5.7 Related aspects of serviceability

Note: ER = Essential Requirements

Table 5.2: Methods of verification for components

Component	ER	Methods of verification	
		Materials	Components
Tensile Elements	1	prEN 10138	prEN 10138
Monostrand Tensile Elements	1	C.1.2	C.1.3
Steel Strip Duct	1	EN 523	EN 524
Steel Pipe	1	prEN 10255 ISO 4200	prEN 10255 ISO 4200
Smooth Plastic Pipe	1	prEN 12201 and C.2.2	prEN 12201 and C.2.3
Corrugated Plastic Ducts	1	C.3.2	C.3.3
Filling Materials	Related aspects of serviceability	EN 445	EN 445
Grease	Related aspects of serviceability	C.4.1.2	none
Wax	Related aspects of serviceability	C.4.2.2	none
Special Grout	Related aspects of serviceability	C.4.3.2	C.4.3.3
Bursting Reinforcement	1	prEN 10080 EN 10025	prEN 10080 EN 10025

ER = Essential Requirements

5.1 MECHANICAL RESISTANCE AND STABILITY OF SYSTEMS

Clause 5.1 lists the methods of verification of the corresponding requirements for mechanical resistance and stability of PT systems given in Clause 4.1. Corresponding acceptance criteria are given in Clause 6.1.

Methods of verification in Clause 5.1 are grouped in Part I and Part II, with the same intent as stated in Clause 4.1. Methods of verification in Part II need only be applied if the corresponding aspect has been defined as optional use category by the ETA applicant.

Part I: Compulsory Methods of Verification for all PT Systems

The following verification methods/tests shall be done for each anchorage type and coupling type specified by the ETA applicant.

5.1.1-I **Resistance to static load** (of the tensile element/ anchorage/ coupling assembly)

Static Load test/ Anchorage Efficiency test → [Annex B.1.1]

5.1.2-I **Resistance to fatigue** (of the tensile element/ anchorage/ coupling assembly)

Fatigue/Dynamic test → [Annex B.2.1]

5.1.3-I **Load transfer to the structure** (mechanical and bond anchorages)

Load Transfer test → [Annex B.3.1]

5.1.4-I **Friction coefficient**

- Friction losses along the tendon path may be assessed by comparison with values given in standards, or based on known behaviour from past experience (e.g. stressing records, lift-off tests, etc). If such comparison is not possible, or if such experience does not exist, testing is required :
 - Assembly/ Installation/ Stressing test → [Annex B.6.1]
- Friction losses in anchorages shall be assessed and documented, either based on:
 - Experience from sites, see FIP Report “Tensioning of Tendons: Force-elongation relationship” [27], or
 - Testing of friction losses in anchorages → [Annex B.4]

The ETA applicant shall declare how these losses have been measured/determined, and shall state whether these losses are considered or not in the stressing equipment calibration.

5.1.5-I **Deviation/ deflection (limits)**

- Radii of curvature of internal bonded tendons shall be based on known behaviour from past experience, or values given in standards.
- Radii of curvature of external tendons at tendon deviators shall comply with ENV 1992-1-5. Smaller radii of curvature may be accepted if the tendon capacity has been assessed in the deviator static load test → [Annex B.5.1]
- Wear of duct, and in particular of sheathing of monostrand tensile elements for external tendons, shall be assessed based on known behaviour from past experience. Where such experience does not exist, or is not considered sufficient to confirm the performance and reliability of corrosion protection of the tendon in the deviator, a deviated tendon test shall be performed → [Annex B.5.2]

5.1.6-I **Practicability/ reliability of installation** (e.g. filling of duct)

Review of the installation procedures for the kit.

Such effects as the following shall be assessed:

- Completeness of the installation procedures to cover the anticipated activities
- Installation tolerances
- Sensitivity of PT system performance to staining / dirt on site
- Easy and reliable placing and compacting of concrete behind anchorages
- Sensitivity of particular activities to extreme environmental conditions (wet, dry, hot, cold, etc.)
- Allowance for stage stressing, load and elongation monitoring
- 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 load between tensile elements
- Practicality of filling of duct, in particular details such as vent size and location, and robustness against accidental damage during construction
- Filling ratio of ducts to allow reliable installation of tensile elements.

In general, the verification may be based on design/ judgement/ known experience/ reference. However, for type of kits without documented prior experience in use, verification shall be based on testing → [Annex B.6].

Part II: Supplementary Methods of Verification for Optional Use Categories and for Innovative PT Systems

These methods of verification need only be applied if the corresponding aspect has been defined as optional use category by the ETA applicant.

(a) Restressable tendon :

5.1.6-II(a) Practicability/ reliability of installation (e.g. filling of duct)

By design/ judgement/ known experience/ reference. If judgement is not considered sufficient, and if no experience/reference exists, the restressability of external tendons may be assessed with the deviated tendon test set-up, simulating restressing → [Annex B.5.2, Test A].

For internal restressable tendons, the assembly/installation/stressing test may be used for verification, simulating restressing → [Annex B.6.1].

The robustness of the corrosion protection system shall be verified where unintentional deviations cannot be excluded or in cases where small intentional deviations of not more than 1 degree are permitted without special deviation saddle details → [Annex B.5.2, Test B].

(b) Exchangeable tendon :

5.1.6-II(b) Practicability/ reliability of installation (e.g. filling of duct)

Tendon replacement test for external tendons, or of internal, unbonded tendons → [Annex B.6.3]
By design/ judgement/ known experience/ reference

(c) Cryogenic applications :

5.1.1-II(c) Resistance to static load (of the tensile element/ anchorage/ coupling assembly)

Cryogenic test → [Annex B.1.2]

(d) Internal bonded tendon with plastic duct :

5.1.6-II(d) Practicability/ reliability of installation (e.g. filling of duct)

Assembly / Installation / Stressing test → [Annex B.6.1]
Duct Filling test → [Annex B.6.2]
By design/ judgement/ known experience/ reference

(e) Encapsulated tendon :

5.1.6-II(e) Practicability/ reliability of installation (e.g. filling of duct)

Leak Tightness test → [Annex B.6.4]
By design/ judgement/ known experience/ reference

(f) Electrically isolated tendon :

5.1.6-II(f) Practicability/ reliability of installation (e.g. filling of duct)

Electrical Resistance test → [Annex B.6.5]
By design/ judgement/ known experience/ reference

(g) Tendon for use in structural steel or composite construction as external tendon :

5.1.3-II(g) Load transfer to the structure

By design of load introduction zone according to Eurocode 3 Design of Steel Structures, [12], and/or Eurocode 4 Design of Composite Steel and Concrete Structures, [13], or equivalent national regulations.

(h) Tendon for use in structural masonry construction as internal bonded or unbonded and/or external tendon :

5.1.3-II(h) Load transfer to the structure

By design of load introduction zone according to Eurocode 6 Design of Masonry Structures, [15], or equivalent national regulations.

(i) Tendon for use in structural timber construction as internal unbonded and/or external tendon:

5.1.3-II(i) Load transfer to the structure

By design of load introduction zone according to Eurocode 5 Design of Timber Structures, [14], or equivalent national regulations.

(k) Innovative systems:

5.1.6-II(k) Practicability/ reliability of installation (e.g. filling of duct)

Assembly / Installation / Stressing test → [Annex B.6.1]
Duct Filling test → [Annex B.6.2].

5.2. SAFETY IN CASE OF FIRE

Not relevant

5.3. HYGIENE, HEALTH AND ENVIRONMENT

Release of dangerous substances :

5.3.1. – Presence of dangerous substances in the product

The applicant shall submit a written declaration stating whether or not the product/kit contains dangerous substances according to European and national regulations, when and where relevant in the Member States of destination, and shall list these substances.

5.3.2. – Compliance with the applicable regulations

If the product/kit contains dangerous substances as declared above, the ETA will provide the method(s) which has been used for demonstrating compliance with the applicable regulations in the Member States of destination, according to the dated EU data-base (method(s) of content or release, as appropriate).

5.3.3.3 – Application of the precautionary principle

An EOTA member has the possibility to provide to the other members, through the Secretary General, warning about substances which, according to Health authorities of its country, are considered to be dangerous under sound scientific evidence, but are not yet regulated. Complete references about this evidence will be provided.

This information once agreed upon, will be kept in an EOTA data base, and will be transferred to the Commission services.

The information contained in this EOTA data base will also be communicated to any ETA applicant.

On the basis of this information, a protocol of assessment of the product, regarding this substance, could be established on request of a manufacturer with the participation of the Approval Body which raised the issue.

5.4. SAFETY IN USE

Not relevant

5.5 PROTECTION AGAINST NOISE

Not relevant

5.6 ENERGY ECONOMY AND HEAT RETENTION

Not relevant

5.7 RELATED ASPECTS OF SERVICEABILITY

Protection of tensile elements, anchorage components, couplings, ducts, etc. during transport, storage, and construction to prevent corrosion and its adverse effects on friction shall be assessed based on method statements in the ETA applicant's guide.

Permanent corrosion protection shall be assessed based on PT system assembly drawings and method statements with particular emphasis on sealing details at anchorages, connectors of ducts between themselves and to anchorages and couplings, and filling of duct on site.

Permanent corrosion protection of any exposed parts shall be assessed based on the specified surface treatment and maintenance provisions given in the ETA applicant's guide.

6 ASSESSING AND JUDGING THE FITNESS FOR USE

6.0 GENERAL

This chapter details the performance requirements to be met by PT systems (given in Chapter 4) into precise and measurable or qualitative terms, using the verification methods (given in Chapter 5). For the extent and detail of the verification, the Approval Body shall consider whether the assessment is for kits, components and materials which are known through long experience or whether it is for new and innovative PT systems, components and materials.

Assessing and judging compulsory requirements as listed in Part I, Clauses 4.1.1-I to 4.1.3-I, shall be based on suitable test results provided by the ETA applicant. However, analysis may be accepted for interpolation between tendon sizes out of a series of similar anchorage and coupling type designs. Interpolation between tendon sizes shall be based on analysis and shall verify that stresses in the components of anchorages and couplings including concrete are not greater than those verified by tests. See Clause 5.0 for acceptance of testing laboratories.

The number of tests to be submitted by the ETA applicant is given in Table 6.3. For large anchorage type series of many different sizes, typically three different sizes shall be tested for each compulsory test method 6.1.1-I to 6.1.3-I, i.e. a small, a medium, and the largest size. However, for smaller series of not more than five different anchorage or coupling sizes, at least two different sizes shall be tested. The medium size anchorage or coupling may then be replaced by an additional largest size anchorage or coupling test. All tests need to pass the acceptance criteria. If one test fails, two additional identical tests shall be performed and shall pass.

Table 6.1 lists the relationship between PT system performance to be assessed and expressions of Use Categories and declaration. Table 6.2 gives reference to acceptance criteria for components.

Table 6.1 : Relationship between PT system performance to be assessed and expressions of Use Categories and declaration.

ER	Application / Use Category	ETAG paragraph for assessing and judging the fitness for use of PT systems
1	I. All systems	6.1.1-I Resistance to static load
		6.1.2-I Resistance to fatigue
		6.1.3-I Load transfer to structure
		6.1.4-I Friction coefficient
		6.1.5-I Deviation / Deflection (limits)
		6.1.6-I Practicability/ reliability of installation
	II. Systems with optional Use Categories, and Innovative Systems	
	Restressable tendon	6.1.6-II(a) Practicability/ reliability of installation
	Exchangeable tendon	6.1.6-II(b) Practicability/ reliability of installation
	Tendon for cryogenic applications	6.1.1-II(c) Resistance to static load
	Internal bonded tendon with plastic duct	6.1.6-II(d) Practicability/ reliability of installation
	Encapsulated tendon	6.1.6-II(e) Practicability/ reliability of installation
	Electrically isolated tendon	6.1.6-II(f) Practicability/ reliability of installation
	Tendon for use in structural steel or composite construction	6.1.3-II(g) Load transfer to structure
Tendon for use in structural masonry construction	6.1.3-II(h) Load transfer to structure	
Tendon for use in structural timber construction	6.1.3-II(i) Load transfer to structure	
Innovative systems	6.1.6-II(k) Practicability/ reliability of installation	
2	All systems	Not relevant
3	All systems	6.3 Hygiene, health and environment
4,5,6	All systems	Not relevant
Related aspects of serviceability	All systems	6.7 Related aspects of serviceability

Note: ER = Essential Requirements

Table 6.2: Acceptance criteria for components

Component	ER	Acceptance criteria	
		Materials	Components
Tensile Elements	1	prEN 10138	prEN 10138
Monostrand Tensile Elements	1	C.1.2	C.1.3
Steel Strip Duct	1	EN 523	EN 523
Steel Pipe	1	prEN 10255 ISO 4200	prEN 10255 ISO 4200
Smooth Plastic Pipe	1	prEN 12201 and C.2.2	prEN 12201 and C.2.3
Corrugated Plastic Ducts	1	C.3.2	C.3.3
Filling Materials	Related aspects of serviceability	EN 447	EN 447
Grease	Related aspects of serviceability	C.4.1.2	none
Wax	Related aspects of serviceability	C.4.2.2	none
Special Grout	Related aspects of serviceability	C.4.3.2	C.4.3.3
Bursting Reinforcement	1	prEN 10080 EN 10025	prEN 10080 EN 10025

ER = Essential Requirements

6.1 MECHANICAL RESISTANCE AND STABILITY OF SYSTEMS

Clause 6.1 lists the acceptance criteria to be met in the verification methods to satisfy the requirements for mechanical resistance and stability of PT systems given in Clause 4.1.

Acceptance criteria in Clause 6.1 are grouped in Part I and Part II, with the same intent as stated in Clause 4.1.

Part I : Acceptance Criteria for Compulsory Requirements applicable to all PT Systems

6.1.1-I **Resistance to static load** (of the tensile element/ anchorage/ coupling assembly)

The number of tests is specified in Table 6.3. The test procedure is specified in Annex B.1.1.

Acceptance criteria are :

- Measured maximum load shall not be less than 95% of the actual ultimate strength, $A_{pm} f_{pm}$, i.e. achieve an anchorage efficiency of 95%, 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%
- Failure shall be by fracture of the tensile elements. Failure of the tendon shall not be induced by the failure of anchorage components
- Residual deformations of anchorage components after testing shall confirm the reliability of the anchorage
- Rate of the displacements between anchorage components as well as between tensile elements and anchorage components shall decrease with the increase of the tendon load up to 80% of the tensile element characteristic strength
- With the load held at 80% of the tensile element characteristic strength the relative movements mentioned in the preceding clause, and additionally for external tendons the deformations Δt and Δz , shall stabilise within the first 30 minutes.

6.1.2-I **Resistance to fatigue** (of the tensile element/ anchorage/ coupling assembly)

The number of tests is specified in Table 6.3. The test procedure is specified in Annex B.2.

For bond anchorages, the specimen shall be made of concrete with the lowest mean concrete strength at the time of tensioning, $f_{cm,0}$, declared by the ETA applicant.

Acceptance criteria 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 load of 65% of tensile element characteristic strength, f_{pk} .

6.1.3-I **Load transfer to the structure** (mechanical and bond anchorages)

The number of tests is specified in Table 6.3. Total number of load transfer tests per anchorage and coupling type for the lowest mean concrete strength at the time of tensioning, $f_{cm,0}$, declared by the ETA applicant, shall be four: One small, one medium, and two largest tendon sizes shall be tested. For the highest mean concrete strength at the time of tensioning, $f_{cm,0}$, declared by the ETA applicant, one additional set of tests shall be performed. If there are more than two declared strengths, and the lowest and the highest mean concrete strengths at the time of tensioning, $f_{cm,0}$, differ by more than 20 MPa one additional set of tests with an intermediate mean concrete strength at the time of tensioning,

$f_{cm,0}$, is required. Mean concrete strengths at the time of tensioning shall preferably be chosen from concrete strength classes listed in Eurocode 2, [11], or shall be related to these concrete strength classes, e.g. as a percentage of the characteristic strength f_{ck} . The test procedure is specified in Annex B.3.

Acceptance criteria are :

- Crack widths max w :
 - upon first attainment of upper load of 80% of tensile element characteristic strength not more than 0.15mm
 - upon last attainment of lower load of 12% of tensile element characteristic strength not more than 0.15mm
 - upon last attainment of upper load of 80% of tensile element characteristic strength not more than 0.25mm
- 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 :

$$F_u \geq 1.1 F_{pk} (f_{cm,e}/f_{cm,0})$$

- 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

6.1.4-I Friction coefficient

- Friction losses along tendon path :

Judgement based on comparison with values indicated in standards or known behaviour from past experience can be considered sufficient for systems which incorporate traditionally used components. If values indicated in standards are not applicable, and if experience is not available, assembly/ installation/ stressing tests shall be performed for the tendon-duct combination specified by the ETA applicant. The number of tests is specified in Table 6.3. The test procedure is specified in Annex B.6.1.

Acceptance criteria are:

Friction and wobble coefficients specified by the ETA applicant shall be within the range of values typically given in standards , e.g. [11], 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.

- Friction losses in anchorages:

Well documented experience from sites may be considered. If such experience is not available, tests for friction losses in anchorages shall be performed. The number of tests is specified in Table 6.3. The test procedure is specified in Annex B.4.

Acceptance criteria are:

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.

6.1.5-I Deviation/ deflection (limits)

- Judgement of minimum radii of curvature for internal bonded and unbonded tendons, and for external tendons, based on analysis/ experience/ and comparison with known successful behaviour or values specified in standards can be considered sufficient for PT systems which apply traditionally used components with a sufficiently long successful experience.

Acceptance criteria are:

Specified minimum radii of curvature shall be within past successfully used experience, and/or within limits specified in standards, e.g. ENV 1992-1-5.

- For external tendons with minimum radii of curvature not complying with ENV 1992-1-5, deviator static load tests shall be performed. The number of tests is specified in Table 6.3. The test procedure is specified in Annex B 5.1.

Acceptance criteria 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%
- Tendon failure shall be by fracture of the tensile elements. Failure of the tendon shall not be induced by the failure of deviator components

- Judgement of wear of external tendon duct or tensile element sheathing based on experience and comparison with known successful behaviour can be considered sufficient. If such experience does not exist, deviated tendon tests shall be performed. The number of tests is specified in Table 6.3. The test procedure is specified in Annex B 5.2.

Acceptance criteria are:

- The tensile element sheathing, if any, shall not be cut through or torn up
- The tendon duct in contact with the tensile elements shall not be cut through by the tensile elements
- In both cases, the residual minimum duct wall or sheathing thickness after testing shall not be less than 50% of the initial wall thickness nor less than 0.8 mm.

6.1.6-I Practicability/ reliability of installation (e.g. filling of duct)

Judgement and known experience shall be adequate for PT systems incorporating traditional components installed in accordance with conventional installation techniques that together have proven, by past experience, to be adequate.

Acceptance criteria are:

Installation procedures covering the installation activities anticipated for the kit shall be existing with sufficient detail to judge 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.

If testing is found necessary, the number of tests is specified in Table 6.3. The test procedure is specified in Annex B.6.

Acceptance criteria are:

The test results shall prove the feasibility and reliability of the proposed installation procedures.

Part II: Acceptance Criteria for Supplementary Requirements applicable to Optional Use Categories and to Innovative PT Systems

(a) Restressable tendon :

6.1.6-II(a) Practicability/ reliability of installation (e.g. filling of duct)

By judgement and known experience. If this is not considered sufficient, a deviated tendon test (for external tendon) as specified in Annex B.5.2 or an assembly/ installation/ stressing test (for internal tendon) as specified in Annex B.6.1 shall be carried out, simulating restressing. The number of tests is specified in Table 6.3.

Acceptance criteria :

Demonstrate the feasibility of the proposed method.

Tests according to Annex B.5.2 shall meet the following acceptance criteria:

- Sheathing of monostrands shall after the testing have a residual minimum wall thickness of not less than 50% of the initial wall thickness and not less than 1.0 mm
- The tendon duct shall after the testing have a residual minimum wall thickness of not less than 75% of the initial wall thickness and not less than 2.0 mm
- Grease shall not leak from the tendon duct
- The tensile elements shall not be damaged
- Other particularities of proprietary systems such as the acceptance of deformations for the corrosion protection shall be assessed individually.

Tests according to Annex B.6.1 shall meet acceptance criteria comparable to the above as far as applicable.

(b) Exchangeable tendon:

6.1.6-II(b) Practicability/ reliability of installation (e.g. filling of duct)

If judgement and known experience are not considered sufficient, then a tendon replacement test for external or internal, unbonded tendon shall be done as specified in Annex B.6.3. The number of tests is specified in Table 6.3.

Acceptance criteria are:

Demonstrate the feasibility of the proposed method in a consistent manner.

(c) Cryogenic applications:

6.1.6-II(c) Resistance to static load (of the tensile element/ anchorage/ coupling assembly)

The largest tendon size shall be tested as far as permitted by available testing facilities. The test procedure is specified in Annex B.1.2. The number of tests is specified in Table 6.3.

Acceptance criteria are :

- Measured maximum load shall not be less than 95% of the actual ultimate strength, $A_{pm} f_{pm}$, i.e. achieve an anchorage efficiency of 95%, nor less than 95% of the specified characteristic strength, $A_p f_{pk}$, at room temperature
- Total elongation, ε_{Tu} , of tensile elements on the free length at measured maximum load shall be declared

- Failure shall be by fracture of the tensile elements. Failure of the tendon shall not be induced by the failure of anchorage components
- Residual deformations of anchorage components after testing shall confirm the reliability of the anchorage
- Rate of the displacements between anchorage components as well as between tensile elements and anchorage components before temperature is decreased to cryogenic level shall decrease with the increase of the tendon load up to 80% of the tensile element characteristic strength.

(d) Internal bonded tendon with plastic duct:

6.1.6-II(d) Practicability/ reliability of installation (e.g. filling of duct)

If judgement and known experience are not considered sufficient, an assembly / installation / stressing test as specified in Annex B.6.1, and a duct filling test as specified in Annex B.6.2 shall be carried out. The number of tests is specified in Table 6.3.

Acceptance criteria are:

- Demonstrate that design values and assumptions such as friction coefficients are met in a consistent manner
- Demonstrate the feasibility of the proposed method of assembly, installation, and stressing in a consistent manner
- Filling of duct shall be complete with only localised voids of a cross sectional size not larger than 5% of the duct cross section, and a consistent quality of the filling material
- The residual wall thickness of the duct due to wear in the stressing test shall not be smaller than 1 mm.

(e) Encapsulated tendon:

6.1.6-II(e) Practicability/ reliability of installation (e.g. filling of duct)

If judgement and known experience are not considered sufficient, then a leak tightness test as specified in Annex B.6.4 shall be carried out. The number of tests is specified in Table 6.3.

Acceptance criteria are:

- Demonstrate that design values and assumptions are met in a consistent manner
- Demonstrate the feasibility of the proposed method in a consistent manner
- Pressure loss over the test period of 5 minutes shall not exceed 10% of the initial pressure.

(f) Electrically isolated tendon:

6.1.6-II(f) Practicability/ reliability of installation (e.g. filling of duct)

If judgement and known experience are not considered sufficient, then an electrical resistance test as specified in Annex B.6.5 shall be carried out. The number of tests is specified in Table 6.3.

Acceptance criteria:

- Demonstrate that design values and assumptions are met in a consistent manner
- Demonstrate the feasibility of the proposed method in a consistent manner
- The electrical resistance between tensile elements and structure (measured on the reinforcing steel cage) shall not be less than 1 kilo-Ohm.

(g) Tendon for use in structural steel or composite construction as external tendon:

6.1.3-II(g) Load transfer to the structure

Design of the steel components supporting the PT system anchorage according to Eurocode 3, [12], or equivalent national regulations.

Acceptance criteria are:

Stresses and deformations in the structural steel components supporting the PT system anchorage, at maximum specified stressing load, shall be within allowable limits as per Eurocode 3 Design of Steel Structures, [12]. The components supporting the PT system anchorage shall at least have a nominal strength of $1.1 F_{pk}$.

(h) Tendon for use in structural masonry construction as internal bonded or unbonded and/or external tendon :

6.1.3-II(h). Load transfer to the structure

Design of the masonry load introduction zone supporting the PT system anchorage according to Eurocode 6, [15], or equivalent national regulations.

Acceptance criteria are:

Stresses in the masonry load introduction zone, at maximum specified stressing load, shall be within allowable limits as per Eurocode 6 Design of Masonry Structures, [15]. The load introduction zone of the masonry shall at least have a nominal strength of $1.1 F_{pk}$.

(i) Tendon for use in structural timber construction as internal unbonded and/or external tendon:

6.1.3-II(i) Load transfer to the structure

Design of the timber load introduction zone supporting the PT system anchorage according to Eurocode 5, [14], or equivalent national regulations.

Acceptance criteria are:

Stresses in the timber load introduction zone, at maximum specified stressing load, shall be within allowable limits as per Eurocode 5 Design of Timber Structures, [14]. The load introduction zone of the timber shall at least have a nominal strength of $1.1 F_{pk}$.

(k) Innovative systems:

6.1.6-II(k) Practicability/ reliability of installation (e.g. filling of duct)

If judgement and known experience are not considered sufficient, then an Assembly / Installation / Stressing test as specified in Annex B.6.1, and a Duct Filling test as specified in Annex B.6.2 shall be carried out. The number of tests is specified in Table 6.3.

Acceptance criteria :

Demonstrate the feasibility of the proposed method in a consistent manner.

6.2 SAFETY IN CASE OF FIRE

Not relevant

6.3 HYGIENE, HEALTH AND ENVIRONMENT

Release of dangerous substances :

The product/kit shall comply with all relevant European and national provisions applicable for the uses for which it is brought to the market. The attention of the applicant should be drawn on the fact that for other uses or other Member States of destination there may be other requirements which would have to be respected. For dangerous substances contained in the product but not covered by the ETA, the NPD option (no performance determined) is applicable.

6.4 SAFETY IN USE

Not relevant

6.5 PROTECTION AGAINST NOISE

Not relevant

6.6 ENERGY ECONOMY AND HEAT RETENTION

Not relevant

6.7 RELATED ASPECTS OF SERVICEABILITY

Judgement and known successful experience can be considered sufficient for PT systems which use standardised components with details known to work in the industry for comparable PT systems.

Acceptance criteria are:

Proposed details and method statements shall comply with standard procedures successfully applied in the industry under comparable circumstances and exposure conditions for some time, see e.g. [29].

Table 6.3 : Number of tests

Test Method	Tendon Size			Total Number of Tests
	Small	Medium	Largest	
Part I: Compulsory tests for all systems				
6.1.1-I Resistance to static load (for each anchorage and coupling type)	2	1	2	5
6.1.2-I Resistance to fatigue (for each anchorage and coupling type)	1	1	2	4
6.1.3-I Load transfer to the structure (for each anchorage and coupling type), see also 6.1.3-I:				
- for the lowest declared concrete strength	1	1	2	4
- for the highest, and intermediate, if any, declared concrete strengths	1	1	2	4
6.1.4-I Friction coefficient (for each tendon, anchorage and coupling type):				
- Friction losses along tendon path	0	(1)	0	(1)
- Friction losses in anchorages	0	(1)	0	(1)
6.1.5-I Deviation/ deflection (limits) (for each tendon type):				
- Deviator static load test	0	0	(1)	(1)
- Deviated tendon test	0	(1)	0	(1)
6.1.6-I Practicability/ reliability of installation (e.g. filling of duct)				
- Assembly/ Installation/ Stressing test	0	(1)	0	(1)
- Duct filling test	0	(1)	0	(1)
Part II: Supplementary tests for optionally specified Use Categories and for Innovative Systems				
(a) Restressable tendon :				
6.1.6-II(a) Deviated tendon test simulating restressing for external tendon (for each tendon type)	0	0	(1)	(1)
6.1.6-II(a) Assembly/ Installation/ Stressing test simulating restressing for internal tendon (for each tendon type)	0	0	(1)	(1)
(b) Exchangeable tendons:				
6.1.6-II(b) Tendon replacement test (for each external or internal, unbonded exchangeable tendon type)	0	0	(1)	(1)
(c) Cryogenic applications:				
6.1.1-II(c) Cryogenic test (for each anchorage and coupling type):	0	0	1 **	1 **
(d) Internal bonded tendon with plastic duct:				
6.1.6-II(d) Assembly/ Stressing / Friction test (for each duct type if needed)	0	(1)	0	(1)
6.1.6-II(d) Duct filling test (for each duct type if needed)	0	(1)	0	(1)
(e) Encapsulated tendon:				
6.1.6-II(e) Leak tightness test (for each duct type if needed)	0	(1)	0	(1)
(f) Electrically isolated tendon:				
6.1.6-II(f) Electrical resistance test (for each electrically isolated system)	0	(1)	0	(1)
(k) Innovative systems:				
6.1.6-II(k) Assembly/ Installation/ Stressing test (for each innovative system)	0	(1)	0	(1)
6.1.6-II(k) Duct filling test (for each innovative system)	0	(1)	0	(1)

- Notes: -- Number of tests applies per kit
 -- Tendon sizes out of a series of sizes of one PT kit shall be interpreted as follows:
- "Small": The largest in the lower third of sizes in one series
 - "Medium": In middle third of sizes in one series

- "Largest": The largest size in one series

N.B. For "monostrand" PT systems with one tensile element only, the same total number of tests applies as for a multistrand PT system with different tendon sizes, e.g. for Part A, Test 5.1.1.: 5 tests).

N.B. For series of sizes which are small, i.e. not more than 5 sizes, the medium size may be replaced by an additional largest size test.

-- If a PT system is specified for use with different grades of tensile element strength, above tests shall be done with the highest specified grade and/or load capacity.

-- Values in brackets (1) indicate required number of tests if judgement based on experience, etc. is not considered sufficient.

-- ** The largest tendon size as permitted by available testing facilities shall be tested.

7 ASSUMPTIONS AND RECOMMENDATIONS UNDER WHICH THE FITNESS FOR USE OF A PT SYSTEM IS ASSESSED

7.0 GENERAL

This chapter sets out the assumptions and recommendations for design, manufacturing, packaging, transport and storage, installation, maintenance and repair under which the assessment of the fitness for use according to the ETAG can be made (only when necessary and in so far as they have a bearing on the assessment or on the products).

7.1 DESIGN OF THE WORKS

The basis for the quality of a prestressed structure lies in its design which results from a good co-operation between the parties involved. In this regard, the most important role is that of the designer who has, initially to prepare a preliminary design, as general as possible and suitable for any PT system and secondly, when the other parties are known (in practice when the contract is signed), to adapt it to the construction methods and in particular the possible resources of the PT specialist companies which can be made available to the general contractor in charge of the execution of the work. A correct design gives due consideration to detailing. This is very much related to the technologies to be implemented by the PT specialist companies. Such companies consist of qualified personnel who are thoroughly familiar with the possibilities and limits of the PT system and who install it with suitable well maintained equipment. Since it is fundamental that a close technical consultation is set up between these major participants before design completion, the ETA applicant shall be able to advise and propose appropriate PT design and detailing.

The quality of a prestressed structure is also bound to the quality of the work performance. With consideration to the high technology involved in the use of the prestressing technique, as well as to the safety implications, it is assumed that the kit is installed by such PT specialist companies.

The ETA holder shall have the procedures and be organised and structured to ensure a constant quality of the components of the kit and of the specialised equipment, and shall have the resources to give users (consultants, general contractors and third parties) skilled advice concerning the use of the kit.

The PT specialist companies are assumed to be able to:

- prepare and execute the work on sites with consistent quality,
- quickly react to unforeseen problems by demonstrating the ability to propose and perform appropriate and safe solutions adapted to the site,
- train and qualify skilled specialists.

The design and execution of the works and the requirements on the qualification of installers is an area regulated by the national provisions of the Member States. Nevertheless it is recommended that the national provisions take into account the recommendations contained in Annex D.

7.2 PACKAGING, TRANSPORTATION, STORAGE AND HANDLING

The ETA holder shall have instructions related to:

- Temporary protection of prestressing steels and components in order to prevent corrosion during transportation from the production site to the job site.
- Transportation, storage and handling of the tensile elements and of other components in order to avoid any mechanical, chemical or electrochemical changes.
- Protection of tensile elements and other components from moisture.

- Segregation of tensile elements from zones where welding operations are performed.

7.3 STRESSING EQUIPMENT

The ETA holder shall have instructions on the calibration of the jacks and their load measuring system.

The requirements on this calibration are regulated by the national provisions of the Member States. Nevertheless it is recommended that the national provisions take into account the following recommendations :

- The jacks and their load measuring system should have an appropriate calibration not older than 6 months.
- A calibration certificate should be provided by a qualified laboratory and should include a calibration curve establishing a correlation between the values given by the measuring system (manometer, load transducer or others) and the loads applied by the jacks.
- A statement should be done on the uncertainty of the measured values for the whole calibrated range. The uncertainty should not be greater than 2% of the corresponding applied loads.
- The calibration may relate to the whole equipment, or the jack and the measuring system separately. In the second case, the uncertainties of the different calibrations should be stated in the corresponding reports, and be combined to assess the overall uncertainty of the measurements.
- If the measuring system is a manometer, and a separate calibration is used, a minimum of two manometers should be available on site, with a calibration certificate which is not older than 6 months. They should be verified with a standard manometer every 100 stressing operations.

7.4 INSTALLATION, STRESSING, AND FILLING OF DUCT

It is assumed that PT specialist companies install the PT system, stress the tensile elements, and carry out filling operations of duct, if applicable, in accordance with the defined procedures.

Section Three: **ATTESTATION AND EVALUATION OF CONFORMITY (AC)**

8 ATTESTATION AND EVALUATION OF CONFORMITY

8.1 EC DECISION

The system of attestation of conformity specified by the European Commission in mandate 98/456/EC is system 1+, with audit testing of samples, described in Council Directive (89/106/EEC) Annex III and is detailed as follows ¹⁾ :

a) tasks for the manufacturer ²⁾, see Clause 8.2.1:

(1) Factory production control

(2) Further testing of samples taken at the factory by the manufacturer in accordance with a prescribed test plan

(b) tasks for the Approved Body, see Clause 8.2.2:

(1) Initial type testing of the product

(2) Initial inspection of factory and of factory production control (FPC)

(3) Continuous surveillance, assessment and approval of factory production control (FPC)

(4) Audit testing of samples

Notes: ¹⁾ Corrigendum (for German issue of the OJ only) OJ L 313, 21.11.1998, page 29.

²⁾ Manufacturer is the person who puts the kit on the market, called kit manufacturer in the following.

8.2 RESPONSIBILITIES

8.2.1 Tasks for the kit manufacturer

8.2.1.1 General responsibilities of the kit manufacturer

The kit manufacturer shall keep available an updated list of all components manufacturers. Copies of this list shall be made available to the CB and may be made available to the Approval Body for information.

At least once a year, each components manufacturer shall be audited by the kit manufacturer. Each audit shall be made available to the CB. These audit reports shall typically include:

- Identification of the components manufacturer
- Date of audit of components manufacturer
- Summary of the results and records of the FPC since last audit
- Summary of the complaint records
- Evaluation of the components manufacturer concerning FPC
- Specific remarks as relevant
- Clear and unique statement whether the requirement of the ETA are met
- Name and position of signatory
- Date of signature
- Signature

At least once a year specimens shall be taken by the kit manufacturer from at least one job site. One series of single tensile element tests shall be performed according to Annex E.3 by the kit manufacturer with these specimens. One series of single tensile element tests shall be performed with components

from only one site. The results of these test series shall be made available to the CB. These reports shall include:

- Identification of the job site where the components have been taken
- Date of sampling
- Identification of the components (i.e. wedge plate, wedges, strand, ...)
- Place and date of testing
- Summary of the results including a test report according to Annex E.3
- Specific remarks as relevant
- Name and position of signatory
- Date of signature
- Signature

The kit manufacturer shall make available for at least 10 years all records of relevant results concerning the ETA and the audit reports concerning the components manufacturers.

8.2.1.2 Factory production control (FPC)

8.2.1.2.1 General

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. This control system shall ensure that the PT system is in conformity with the European Technical Approval (ETA).

FPC and the prescribed test plan (see Annex E.1) shall address the following aspects:

- manufacturing
- distribution and delivery to job site

FPC systems which comply with EN ISO 9001 : 2000 and which address the requirements of the ETA, are recognised as satisfying the FPC requirements of the Directive.

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. A testing laboratory which meets the requirements of the CPD and the Guidance Paper "A" [3] and which addresses the requirements of the corresponding ETA will be acceptable.

8.2.1.2.2 Control of the PT kit components and materials

The characteristics of incoming material which comply with a harmonised European technical specification, having met the corresponding AC-procedure shall be considered satisfactory and need, except in case of justified doubt, no further checking. All materials shall be in accordance with the requirements of the ETA or the corresponding specifications of the kit manufacturer.

Where harmonised technical specifications are not available materials according to specifications valid in the place of use shall be used provided that their use is compatible with the results of the approval tests.

Otherwise the specifications shall be given in the ETA.

8.2.1.2.3 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 consequent and systematic way.

Annex E.1 includes minimum test frequencies which shall be performed under the prescribed test plan.

8.2.1.2.4 Control of non-conforming products

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

8.2.1.2.5 Complaints

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

8.2.2 Tasks for the CB

8.2.2.1 General

The CB may act with its own resources or subcontract inspection tasks and testing tasks to inspection bodies and testing laboratories which meet the requirements of the Guidance Paper "A" [3].

8.2.2.2 Initial type-testing

Approval tests will have been conducted by the Approval Body or under its responsibility which may include a proportion conducted by an indicated laboratory or by the manufacturer, witnessed by the Approval Body in accordance with Chapter 5 of this ETAG. The Approval Body will have assessed the results in accordance with Chapter 6 of this ETAG, as part of the ETA issuing procedure.

These tests shall be used for the purpose of Initial Type Testing and shall be validated by the CB for Certification of Conformity purposes.

Note: Initial Type Testing falls within the responsibility of the CB, whereas approval testing falls under the responsibility of the Approval Body.

8.2.2.3 Audit testing

Audit testing is detailed in Fig. 8.1, Item {8}, under the heading of "continuous surveillance".

8.2.2.4 Certification

Assessment of the FPC is the responsibility of the CB. An assessment shall be carried out to demonstrate that the FPC is in conformity with the ETA. At the end of the certification process with success, the CB shall issue a certificate of product conformity.

Fig. 8.1 shows the flow chart of a typical certification procedure.

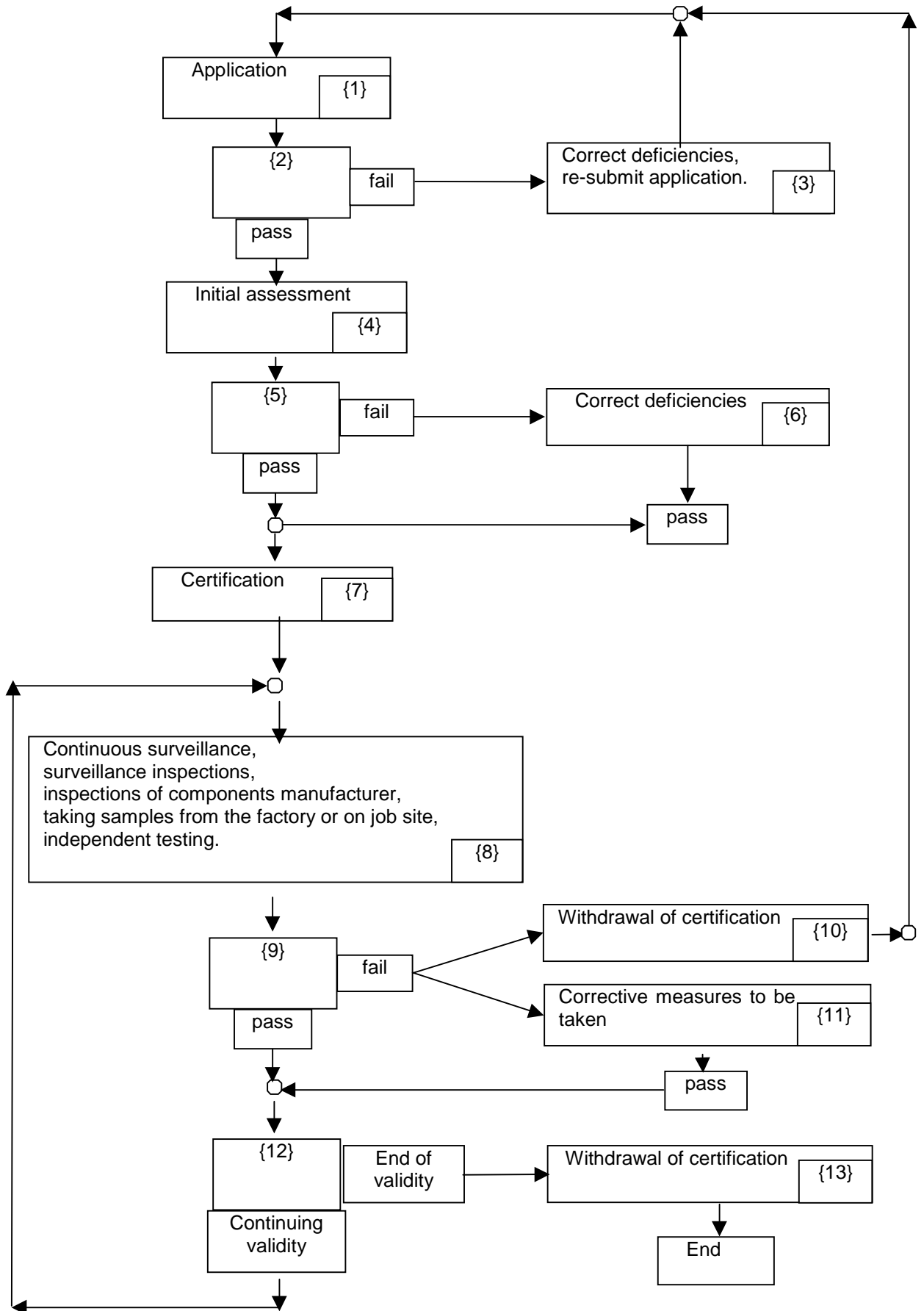


Figure 8.1: Flow chart of a typical certification procedure

Legend to Fig. 8.1:

{1} Application

The kit manufacturer submits a copy of the ETA and the necessary technical documentation to the CB – see paragraphs 8.3 (1) to (3).

{2} Decision by the CB

The CB examines the technical documentation and decides about their completeness and plausibility.

{3} Correct deficiencies.

Re-submit application.

If the technical documentation does not satisfy the CB, the application is rejected and corrected by the applicant.

{4} Initial assessment.

The CB assesses the factory production control of the kit manufacturer. The results of the tests, performed during the approval procedure, shall be taken as initial type tests.

{5} Decision by the CB

The CB verifies the results of the initial assessment and decides on the conformity with the ETA.

{6} Correct deficiencies

The kit manufacturer corrects all deficiencies, as requested by the CB.

{7} Certification

When the results of the initial assessment fulfil the requirements of the ETA, the CB issues the Certificate of Conformity and informs the Approval Body.

{8} Continuous surveillance.

Surveillance inspections, inspections of components manufacturer, and taking samples from the factory or the job site for independent testing under the responsibility of the CB.

Minimum Frequencies:

Surveillance inspection, including independent testing :

The kit manufacturer shall be inspected at least once a year. Its FPC will be checked and according to Annex E.2, samples are taken for independent testing.

Each component manufacturer shall be inspected at least once during the period of validity of the ETA, that is at least once in five years.

{9} Decision by the CB

The CB verifies the results of the inspections, the audit tests and the results of the factory production control and establishes conformity with the ETA.

{10} Withdrawal of Certification

In case of severe non-conformities which relate to important performance aspects of the PT system and which cannot be corrected in due time, the CB withdraws the Certificate of Conformity.

The CB shall inform the Approval Body about the withdrawal of certification and report to him about the reasons.

{11} Corrective measures to be taken

Corrective measures shall be taken by the kit manufacturer if deficiencies are detected. These measures include:

- Action against a warning from the CB
- Higher inspection and test frequency
- Implementation of changes

{12} Period of validity

Depending on the period of validity of the ETA, a CB continues surveillance. Changes of any aspect of the specification of the PT system or of any component during the validity of the ETA, shall only be permitted after approval by the CB and the AB.

As a basis of renewal of the ETA, the CB shall prepare a summary report and send it to the kit manufacturer and the Approval Body. This report shall include the experiences of the CB

concerning the PT kit. Also a summary of the complaint records and other relevant information (e.g. major problems and their solutions) shall be included in the summary report.

{13} Withdrawal of certification

The CB shall inform the Approval Body about the withdrawal.

8.3 DOCUMENTATION

In order to assist the CB in performing the evaluation of conformity, the Approval Body issuing the ETA shall supply all the information detailed below, which will generally form the basis for assessing the FPC. This information shall initially be prepared or collected by the Approval Body and where appropriate shall be agreed with the kit manufacturer. Parts of this information may be of confidential nature.

- The ETA
- Prescribed test plan
- Other relevant information

The following gives guidance on the type of information required:

(1) The ETA

The nature of any additional (possibly confidential) information shall be declared in the ETA.

(2) Prescribed test plan

The kit manufacturer and the Approval Body issuing the ETA shall agree on a prescribed test plan. This prescribed test plan is necessary to ensure that the product corresponds to the ETA and its characteristics remain unchanged.

Provisions concerning the prescribed test plan for a PT system are given in Chapters 7 and 8 as well as in Annexes D.1, D.3, E.1, and E.2.

(3) Other relevant information

Any other relevant information needed by the CB.

8.4 EC-CONFORMITY MARKING AND INFORMATION

8.4.1 CE-Marking

CE-marking shall be in accordance with the CPD and the Guidance Paper "D" [GP "D"] [6] on CE-marking.

The delivery note, associated with the components of the PT system, shall contain the CE conformity marking which shall consist of the CE-symbol and:

1. The name or identifying mark of the kit manufacturer.
2. The last two digits of the year in which the marking was affixed.
3. The number of the Certificate of Conformity
4. The ETA-number
5. The use category(ies).
6. The number of the CB.

All other information shall be clearly separated from the CE-marking and the accompanying information.

Section Four : ETA CONTENT

9 THE ETA CONTENT

All the technical data necessary for design and execution shall be submitted by the applicant with the application and will be used by the Approval Body to create the ETA and to define the additional information.

Clauses 9.1 and 9.2 distinguish between information

- given in the ETA
- available additional information given to anyone concerned in design and execution as design engineers, contractors, clients, authorities, etc. as needed.

In general both sets of information shall not contain any confidential information. Confidential information may be dimensional tolerances, manufacturing processes, composition of components, etc.

9.1 THE ETA CONTENT

9.1.1 Model ETA

The format of the ETA shall be based on the Commission Decision (97/571/EC) (ETA-format) of 22. 07. 1997, EC Official Journal L236 of 1997-08-27.

9.1.2 Checklist for the Approval Body

The technical part of the ETA shall contain information on the following items, in the order and with reference to the relevant two Essential Requirements (ER 1 and 3). For each of the listed items, the ETA shall either give the mentioned indication / classification / statement / description or state that the verification / assessment of this item has not been carried out (no performance determined). The items are here given with reference to the relevant paragraphs of this ETAG, whereas specific use categories may require additional items:

- Definition of the kit for which an ETA is issued. This shall include a listing of all components of the kit, or of the individual components as defined in Clause 2.1 for which the ETA is issued.
- Design and execution aspects of the PT system
 - * Anchorage and tendon
 - range of anchorages
 - designation of anchorages and tendon
 - all types of anchorage to be used (active, passive, embedded, couplings, ...)
 - characteristic performance of tendon (paragraphs 6.1.1-I and 6.1.2-I)
 - number of tensile elements
 - information on incompletely filled anchorage
 - nominal sectional area of tendon
 - nominal mass per meter run of tendon
 - characteristic ultimate resisting force of tendon F_{pk}
 - specific conditions for passive anchoring of tensile elements
 - friction (paragraph 6.1.4-I)
 - friction coefficient (paragraph 6.1.4-I)
 - wobble coefficient (paragraph 6.1.4-I)

- friction in anchorage (paragraph 6.1.4-I)
- supports (paragraph 6.1.4-I)
 - spacing
 - requirements on materials
- corrective terms to assess the elongation of the tensile elements on site
 - anchorage seating at passive anchorage, couplers, ...
 - anchorage seating at active anchorage
- ducts
 - type
 - specification
 - dimensions
 - minimum radii of curvature of tendon (paragraph 6.1.5-I)
- etc., as relevant

Above information shall preferably be presented in a standard format, see Annex F.

- * Design and execution of load transfer to concrete structure (paragraph 6.1.3-I)
 - outline drawings at final stage
 - outline drawings of installed components for each type of anchorage
 - edge distance of anchorage depending on concrete strength at time of stressing
 - spacing of anchorage depending on concrete strength at time of stressing
 - minimum straight length of tendon behind the anchorages
 - local reinforcement (bursting reinforcement) depending on f_{yk} and concrete strength at time of stressing
 - recommended maximum load at tensioning
 - lowest, highest, and intermediate, if any, minimum concrete strength at the time of tensioning, declared by the ETA holder
 - etc., as relevant
- Use categories (Clause 2.2)
 - * Use categories according to the material of the structure
 - concrete
 - steel
 - composite
 - masonry
 - timber
 - * Use categories according to the type of tendon
 - Internal bonded tendon
 - Internal unbonded tendon
 - External tendon
 - Restressable tendon
 - Exchangeable tendon
 - Tendon for cryogenic applications
 - Internal bonded tendon with plastic ducts
 - Encapsulated/watertight tendon
 - Electrically isolated tendon
- Component's description

A description of the components of the PT kit:

 - * Tensile elements (paragraph 6.1.1-I)

Specifications of the tensile elements compatible with the PT system according to prEN 10138 [16], and Annex C.1

These specifications shall include as relevant:

 - type (wire, 7-wire strand, bar, threaded bar ...)
 - diameter
 - mass per meter run

- surface
- thread
- strength $f_{p0.1k}$ and f_{pk}
- fatigue
- relaxation
- minimum curvature during transport and installation
- ..., etc. as relevant

N.B. Normally, a reference to the applicable standard is sufficient.

* Specific components of the PT system kit

List all components of all types of anchorage (active, passive, embedded, ...), couplers (fixed, movable), deviators, etc.. These components are e.g. anchor head, bearing plate, wedge, nut, ...

- designation of each component
- materials by referring to standards, trade names, specific requirements, as relevant
- outline drawings for all components. Dimensions as required especially for:
 - identification of the component
 - design of the works, especially critical dimensions relevant to the installation of the system, minimum length of thread engagement, etc. as relevant
- Statements concerning welding:
 - Welding is generally not permitted on PT system components, except on specified points.
- etc. as relevant

* Bursting and additional (auxiliary) reinforcement

- material's specification of reinforcement by reference to prEN 10080-series, [17], or EN 10025 (paragraph 6.1.3-l), [18]
- dimensions
- etc. as relevant

* Ducts

- types of duct
 - steel strip
 - steel pipe
 - plastic duct or pipe
- specification of duct according to EN 523, [19], Annex C.2 or Annex C.3
- ..., etc. as relevant

* Filling material

Description/ list of filling materials specified by ETA holder.

- Temporary and permanent corrosion protection system
- Dangerous substances (Clause 6.3)

The ETA shall include the following note:

“In addition to the specific clauses relating to dangerous substances contained in this European Technical Approval, there may be other requirements applicable to the products falling within its scope (e.g. transposed European legislation and national laws, regulations and administrative provisions). In order to meet the provisions of the EU Construction Products Directive, these requirements need also to be complied with, when and where they apply.”

- Attestation of conformity (Chapter 8)
 - A reference, that the AC procedures have to be performed according to this ETAG.

- The tables of Annex E.1 and Annex E.2, adapted and eventually completed by information about additional important components shall be included in the ETA.

9.2 ADDITIONAL INFORMATION

It shall be stated in the ETA, that the ETA holder is responsible to inform anyone concerned about the use of the PT system. Additional information as listed below shall be held available at the ETA holder and shall be distributed as needed, except if noted otherwise.

- List of manufacturers
- Component's description

A description of components of the PT system other than listed in Clause 9.1.

- * Vents

Specifications of vents including material and dimensions

- * Drains

Specifications of drains including material and dimensions

- * Temporary and permanent sealing caps

- Equipment

- * Stressing equipment

- jacks
- type and designation
- user's manual including safety instructions
- stroke
- maximum force
- maximum pressure
- dimensions and weight
- calibration
- elongation of the extra length between clamping in the jack and anchorage
- clearance behind the anchorage to allow stressing
- etc. as relevant

- * Pumps

- type and designation
- user's manual including safety instructions
- capacity
- dimensions and weight
- power supply, energy source
- power/fuel consumption
- etc. as relevant

- * Equipment for filling of duct

- type and designation
- user's manual including safety instructions
- capacity
- dimensions and weight
- power supply, energy source
- power/fuel consumption
- etc. as relevant

- * Special equipment

- purpose

- type and designation
- user's manual including safety instructions
- dimensions and weight
- etc. as relevant

It shall be stated in the ETA, that additional (possibly confidential) information shall be supplied to the CB for the evaluation of conformity, see Clause 8.3 of this ETAG.

9.3 CONFIDENTIAL INFORMATION

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) need to be deposited at the Approval Body and CB. These documents are confidential and proprietary and shall not be given to other parties.

9.4 INSTALLATION REQUIREMENTS

Additional execution aspects other than those listed in Clause 9.1 may need to be provided.

- anchorage and tendon assembly drawings at state of installation in the formwork
- cutting lengths of tendons
- quantity of filling material needed
- etc. as relevant.

ANNEX A

COMMON TERMINOLOGY AND ABBREVIATIONS

A.1. WORKS AND PRODUCTS

A.1.1. **Construction works** (and parts of works) (often simply referred to as “works”) (ID1.3.1)

Everything that is constructed or results from construction operations and is fixed to the ground. (This covers both building and civil engineering works, and both structural and non structural elements).

A.1.2 **Construction products** (often simply referred to as “products”) (ID 1.3.2)

Products which are produced for incorporation in a permanent manner in the works and placed as such on the market. (The term includes materials, elements, components of prefabricated systems or installations.)

A.1.3 **Incorporation** (of products in works) (ID 1.3.1)

Incorporation of a product in a permanent manner in the works means that: its removal reduces the performance capabilities of the works, and that the dismantling or the replacement of the product are operations which involve construction activities.

A.1.4 **Intended use** (ID 1.3.4)

Role(s) that the product is intended to play in the fulfilment of the essential requirements.

A.1.5 **Execution** (ETAG-format)

Used in this document to cover all types of incorporation techniques such as installation, assembling, incorporation, etc...

A.1.6 **System** (EOTA/TB guidance)

Part of the works realised by particular combination of a set of defined products, and particular design methods for the system, and/or particular execution procedures.

A.2 Performances

A.2.1 **Fitness for intended use** (of products) (CPD 2.1)

Products have such characteristics that the works in which they are intended to be incorporated, assembled, applied or installed, can, if properly designed and built, satisfy the essential requirements.

A.2.2 **Serviceability** (of works)

Ability of the works to fulfil their intended use and in particular the essential requirements relevant for this use.

The products must be suitable for construction works which (as a whole and in their separate parts) are fit for their intended use, subject to normal maintenance, be satisfied for an economically reasonable working life. The requirements generally concern foreseeable actions (CPD Annex I, Preamble).

A.2.3 **Essential requirements** (for works)

Requirements applicable to works, which may influence the technical characteristics of a product, and are set out in terms of objectives in the CPD, Annex I (CPD, art. 3.1).

A.2.4 **Performance** (of works, parts of works or products) (ID 1.3.7)

The quantitative expression (value, grade, class or level) of the behaviour of the works, parts of works or of the products, for an action to which it is subject or which it generates under the intended service conditions (works or parts of works) or intended use conditions (products).

A.2.5 **Actions** (on works or parts of the works) (ID 1.3.6)

Service conditions of the works which may affect the compliance of the works with the essential requirements of the Directive and which are brought about by agents (mechanical, chemical, biological, thermal or electro-magnetic) acting on the works or parts of the works.

A.2.6 **Classes or levels** (for essential requirements and for related product performances (ID 1.2.1)

A classification of product performance(s) expressed as a range of requirement levels of the works, determined in the ID's or according to the procedure provided for in art. 20.2a of the CPD.

A.3 ETAG-format

A.3.1 **Requirements** (for works) (ETAG-format 4)

Expression and application, in more detail and in terms applicable to the scope of the guideline, of the relevant requirements of the CPD (given concrete form in the ID's and further specified in the mandate, for works or parts of the works, taking into account the durability and serviceability of the works.

A.3.2 **Methods of verification** (for products) (ETAG-format 5)

Verification methods used to determine the performance of the products in relation to the requirements for the works (calculations, tests, engineering knowledge, evaluation of site experience, etc.)

A.3.3 **Specifications** (for products) (ETAG-format 6)

Transposition of the requirements into precise and measurable (as far as possible and proportional to the importance of the risk) or qualitative terms, related to the products and their intended use.

A.4 Working life

A.4.1 **Working life** (of works or parts of the works) (ID 1.3.5(1))

The period of time during which the performance will be maintained at a level compatible with the fulfilment of the essential requirements.

A.4.2 **Working life** (of products)

Period of time during which the performances of the product are maintained - under the corresponding service conditions - at a level compatible with the intended use conditions.

A.4.3 **Economically reasonable working life** (ID 1.3.5(2))

Working life which takes into account all relevant aspects, such as costs of design, construction and use, costs arising from hindrance of use, risks and consequences of failure of the works during its working life and cost of insurance covering these risks, planned partial renewal, costs of inspections, maintenance, care and repair, costs of operation and administration, of disposal and environmental aspects.

A.4.4 **Maintenance** (of works) (ID 1.3.3(1))

A set of preventive and other measures which are applied to the works in order to enable the works to fulfil all its functions during its working life. These measures include cleaning, servicing, repainting, repairing, replacing parts of the works where needed, etc.

A.4.5 **Normal maintenance** (of works) (ID 1.3.3(2))

Maintenance, normally including inspections, which occurs at a time when the cost of the intervention which has to be made is not disproportionate to the value of the part of the work concerned, consequential costs (e.g. exploitation) being taken into account.

A.4.6 **Durability** (of products)

Ability of the product to contribute to the working life of the work by maintaining its performances, under the corresponding service conditions, at a level compatible with the fulfilment of the essential requirements by the works.

A.5 Conformity

A.5.1 **Attestation of conformity** (of products)

Provisions and procedures as laid down in the CPD and fixed according to the directive, aiming to ensure that, with acceptable probability, the specified performance of the product is achieved by the ongoing production.

A.5.2 **Identification** (of a product)

Product characteristics and methods for their verification, allowing to compare a given product with the one that is described in the technical specification.

A.6 Approval and approved bodies

A.6.1. **Approval Body**

Body notified in accordance with Article 10 of the CPD, by an EU Member State or by an EFTA State (contracting party to the EEA Agreement), to issue European Technical Approvals in (a) specific construction product area(s). All such bodies are required to be members of the European Organisation for Technical Approvals (EOTA), set up in accordance with Annex II.2 of the CPD.

A.6.2. **Approved Body(*)**

Body nominated in accordance with Article 18 of the CPD, by an EU Member State or by an EFTA State (contracting party to the EEA Agreement) , to perform specific tasks in the framework of the Attestation of Conformity decision for specific construction products (certification, inspection or testing). All such bodies are automatically members of the Group of Notified Bodies.

(*) *Also known as Notified Body*

A.7 Abbreviations

A.7.1 Abbreviations concerning the Construction products directive

AC	: Attestation of conformity
CEC	: Commission of the European Communities
CEN	: Comité européen de normalisation – European Committee for Standardisation
CPD	: Construction products directive
EC	: European communities

EFTA : European free trade association
EN : European Standards
FPC : Factory production control
ID : Interpretative documents of the CPD
ISO : International standardisation organisation
SCC : Standing committee for construction of the EC.

A.7.2 Abbreviations concerning approval

EOTA : European organisation for technical approvals
ETA : European technical approval
ETAG : European technical approval guideline
TB : EOTA-Technical board
UEAtc : Union Européenne pour l'Agrément Technique dans la construction – European Union of Agreement

A.7.3 General abbreviations

WG : Working group.

Annex B

B TESTING OF PT SYSTEMS

Contents

- B.1 RESISTANCE TO STATIC LOAD
 - B.1.1 Static load test
 - B.1.2 Cryogenic static load test
- B.2 RESISTANCE TO FATIGUE
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 - B.2.1 Fatigue test: II – Bond anchorage
- B.3 LOAD TRANSFER TO THE STRUCTURE
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 - B.3.1 Load transfer test: II – Bond anchorage
- B.4 TEST FOR FRICTION LOSSES IN ANCHORAGES
- B.5 DEVIATION / DEFLECTION (LIMITS)
 - B.5.1 Deviator static load test
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- B.6 PRACTICABILITY / RELIABILITY OF INSTALLATION
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 - B.6.2 Duct filling test
 - B.6.3 Tendon replacement test
 - B.6.4 Leak tightness test
 - B.6.5 Electrical resistance test

B.1 RESISTANCE TO STATIC LOAD

B.1.1 STATIC LOAD TEST

B.1.1.1 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-section 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 more than one grade of tensile elements of the same type is to be used with the same type of anchorage, the tests shall be performed using the grade with the highest characteristic tensile strength, and/or load capacity.

B.1.1.2 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 and two hours for internal and external tendons, respectively. 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 $\pm 1\%$. Loads shall be maintained with a maximum tolerance of $\pm 2\%$. 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.

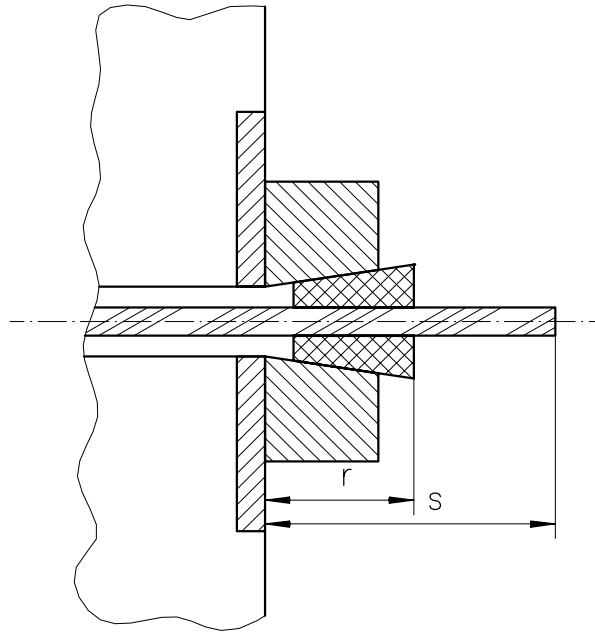
B.1.1.3 Measurements and observations

The following measurements and observations shall be made and recorded :

- Compliance checking of the components with ETA specifications (materials, machining, geometry, hardness, etc).
- Relative load -and time- dependent displacement Δs of the tensile elements with respect to the anchorage on at least two elements (Fig. B.1.1.1).
- Relative load -and time- dependent displacement Δr between the individual components of the anchorage on at least two components, e.g. wedges (Fig. B.1.1.1), or as applicable for other methods of anchoring the tensile elements.
- 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 Fig. B 1.1.2, 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.

(1)



(2)

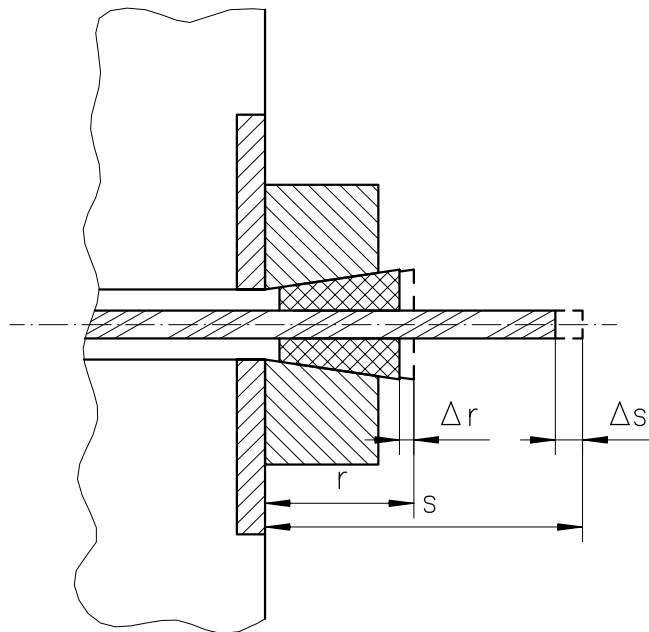
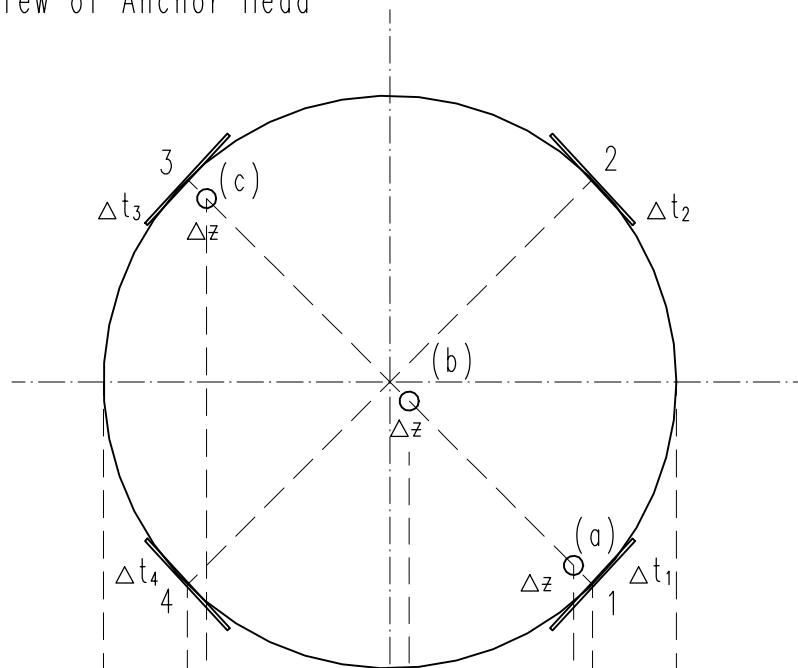


Figure B.1.1.1 : Displacements during testing : (1) before locking; (2) after locking
(Shown for wedge anchorage, other methods of anchoring the tensile elements as applicable)

(1) Plan View of Anchor Head



(2) Elevation

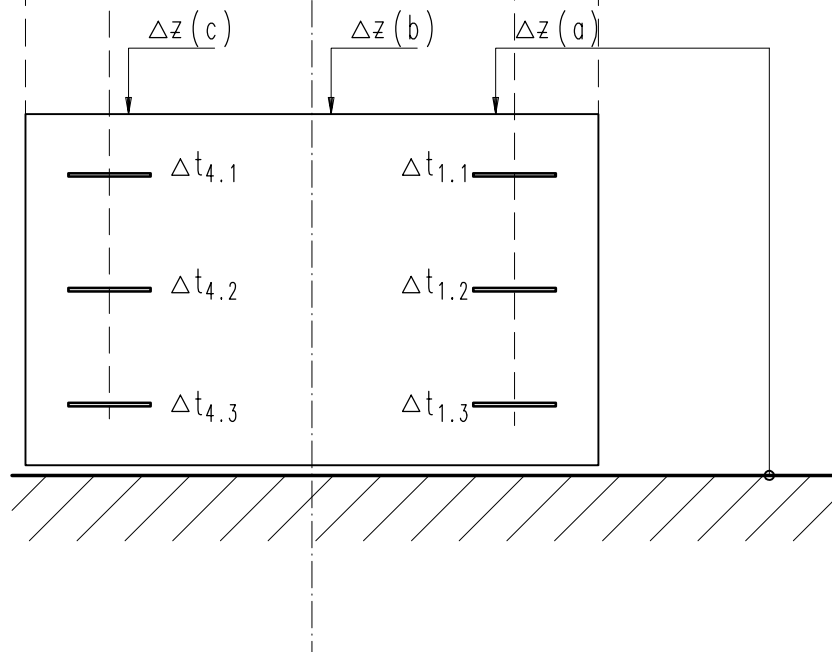


Figure B.1.1.2 : Deformation readings on anchor head of external tendon

B.1.2 CRYOGENIC STATIC LOAD TEST

B.1.2.1 Test specimen

Same as given in B.1.1 "Static load test"

B.1.2.2 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 80% level, the load is held constant for one hour.

Subsequently, the temperature is decreased to the specified cryogenic temperature of $-196\pm 5^{\circ}\text{C}$, while the load in the tendon is maintained constant.

Subsequently, 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 80% level are executed, see Fig. B.1.2.1.

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

B.1.2.3 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).
- Complete load and tendon elongation diagram based on measuring jack load and stroke.
- Relative load – and time – dependent displacement Δs of the tensile element with respect to the anchorage on at least two elements (Fig. B.1.1.1) before temperature is decreased to cryogenic level.
- Relative load – and time – dependent displacement Δr between the individual components, e.g. wedges (Fig. B.1.1.1), or as applicable for other methods of anchoring the tensile elements, before temperature is decreased to cryogenic level.
- Elongation of the tensile elements ε_{Tu} on free length at measured maximum force F_{Tu} .
- Measured maximum force F_{Tu} .
- Deformations of the anchorage components after the test to failure.
- Location and mode of failure.
- Examination of components after dismantling, photographic documentation, comments.

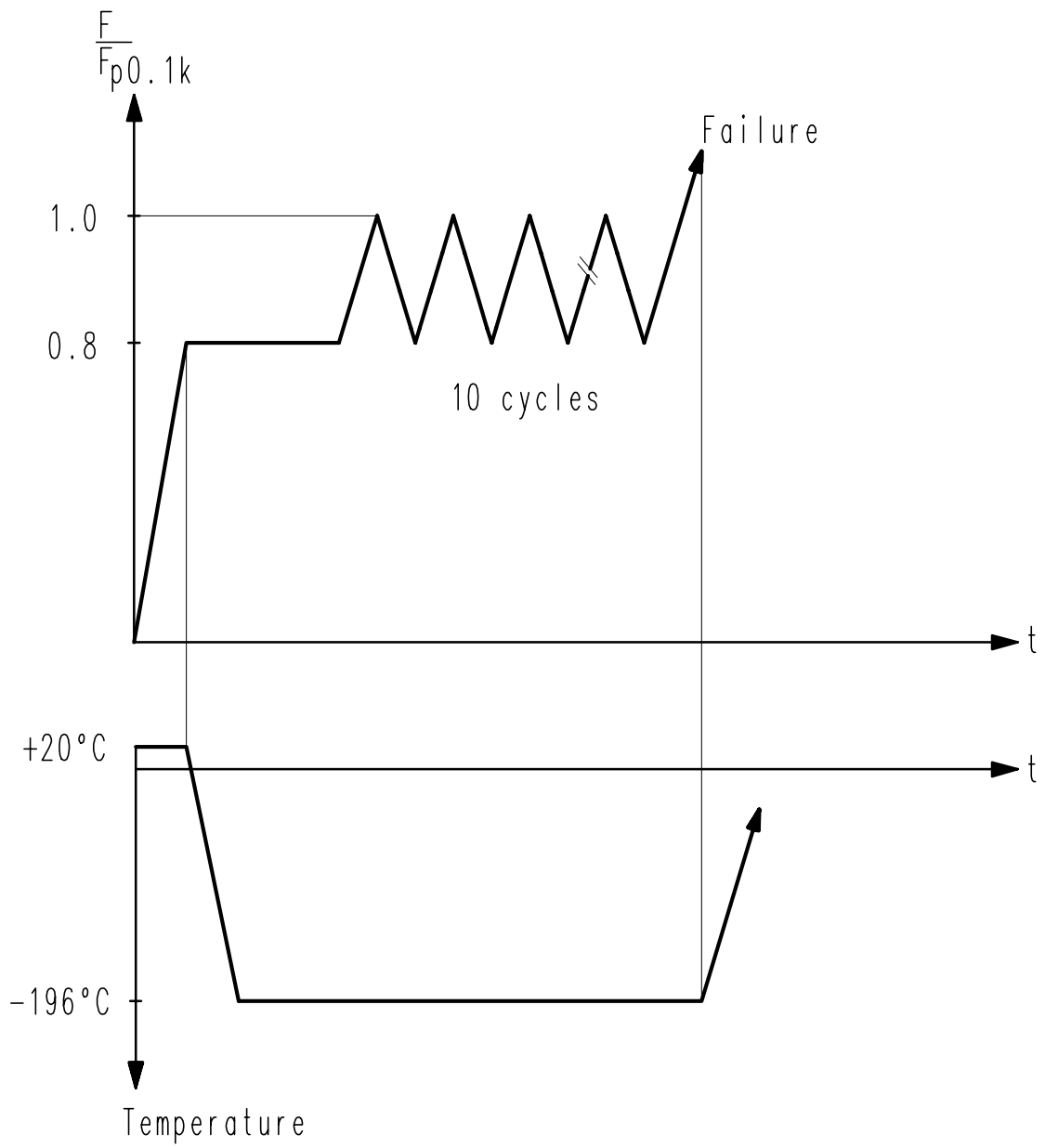


Figure B.1.2.1 : Test procedure for cryogenic load test

B.2 RESISTANCE TO FATIGUE

B.2.1 FATIGUE TEST

I - Mechanical Anchorage

B.2.1.1 Test specimen

The type of specimen corresponds to Annex B.1.1, Clause 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 more than one grade of tensile elements of the same type is to be used with the same type of anchorage, the tests shall be performed with tensile elements using the grade with the highest characteristic tensile strength, and/or largest load capacity.

Where possible the tendon shall be tested with the complete number of tensile elements installed. However, 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 $n \leq 12$: $n' \geq n/2$
- if $n \geq 12$: $n' \geq 6 + (n - 12)/3$

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

B.2.1.2 Test procedure

The test shall be performed in a tensile testing machine with the pulsator at a constant load frequency of not more than 10 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 levels corresponding to 80 MPa stress amplitude in the 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.

B.2.1.3 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).
- 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 (Fig. B.1.1.1).
- 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 which have failed by fatigue, as a function of the number of load cycles.
- Examination of components after dismantling, photographic documentation, comments.

II - Bond anchorage

B.2.1.1 Test specimen

As described in Annex B.2.1, Clause B.2.1.1 – I, see also Fig. B.3.1.4. The concrete strength at the start of the fatigue test shall not exceed $f_{cm,0}$.

B.2.1.2 Test procedure

As described in Annex B.2.1, Clause B.2.1.2 – I.

B.2.1.3 Measurements and observations

As described in Annex B.2.1, Clause B.2.1.3 – I above. In addition the slip of ends of the tensile elements relative to the concrete shall be measured.

B.3 LOAD TRANSFER TO THE STRUCTURE

B.3.1 LOAD TRANSFER TEST

I - Mechanical anchorage

B.3.1.1 Test specimen

The test specimen is schematically shown in Fig. B.3.1.1. The specimen shall contain those anchorage components and bursting reinforcement which 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.

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 permitted 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:

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

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

$$\begin{aligned} x &\geq 0.85 a \\ y &\leq 1.15 b \end{aligned}$$

with: 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, and/or twice the specified edge distance of the tendon, whichever is smaller; $x \leq y$

The height h of specimen shall be at least twice the longer of the two side lengths a or b , see Fig. B.3.1.1. 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 technical approval if the following conditions are met :

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

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} . 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 10mm. For tests done with larger concrete cover, the acceptance criteria for maximum crack width in Clause 6.1.3-I may be modified according to the rules in Eurocode 2, [11], for consideration of concrete cover.

B.3.1.2 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 which 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 $0.8 F_{pk}$ (Fig. B.3.1.2). 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 B.3.1.3. Fig. B.3.1.2 shows the sequence of loading and measurements.

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

$$f_{cm,e} \leq f_{cm,0}$$

B.3.1.3 Stabilisation criteria

- Crack widths can be considered to have stabilised if their width under upper load complies with:
 $w_n - w_{n-4} \leq 1/3 (w_{n-4} - w_0)$, $n \geq 10$
- 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 Fig. B.3.1.5 for details on how to assess stabilisation criteria.

B.3.1.4 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).
- 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.
- 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.
- Location and mode of failure.
- Measured ultimate force F_u .
- Examination of components and specimen after testing, photographic documentation, comments.

Fig. B.3.1.3 schematically shows the arrangement of the gauge points for the strain measurement on each side of the specimen, etc.

II - Bond anchorage

B.3.1.1 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. The cross-section and side lengths, a and b of the specimen, should correspond to the values defined in Annex B.3.1, Clause B.3.1.1 – I.

The test specimen is shown schematically in Fig. B.3.1.4. 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 which 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 B.3.1, Clause B.3.1.1 - I 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.

B.3.1.2 Test procedure

The test procedure corresponds to Annex B.3.1, Clause B.3.1.2 - I and Fig. B.3.1.2. At the final test to failure the mean compressive strength of concrete in the specimen should be :

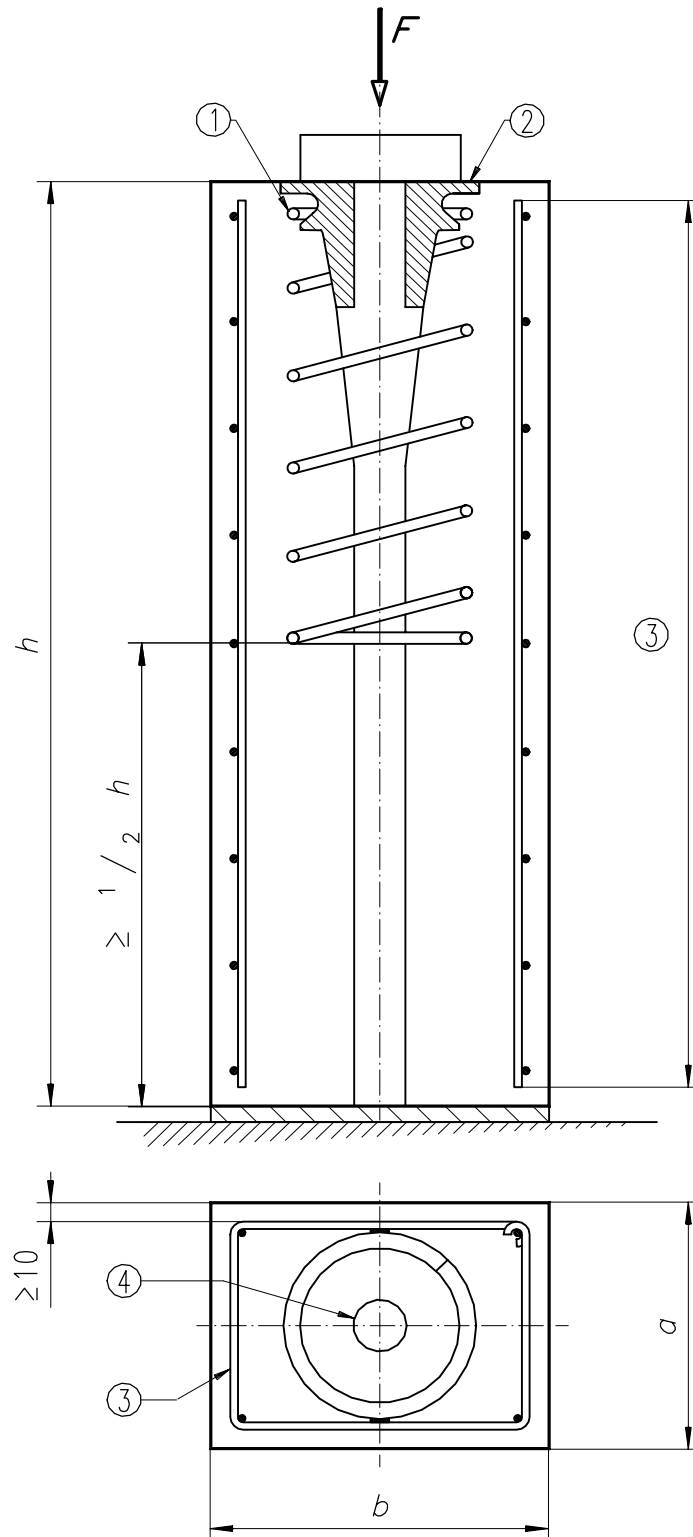
$$f_{cm,e} \leq 0.80 f_{cm,0}$$

B.3.1.3 Stabilisation criteria

Same as in Annex B.3.1, Clause B.3.1.3 - I.

B.3.1.4 Measurements and observations

These shall correspond to Annex B.3.1, Clause B.3.1.4 - I above. In addition the slip of ends of the tensile elements relative to the concrete shall be measured.



- ① Bursting reinforcement
- ② Anchorage components
- ③ Auxiliary reinforcement
- ④ Empty duct

Figure B.3.1.1: Test specimen for load transfer test

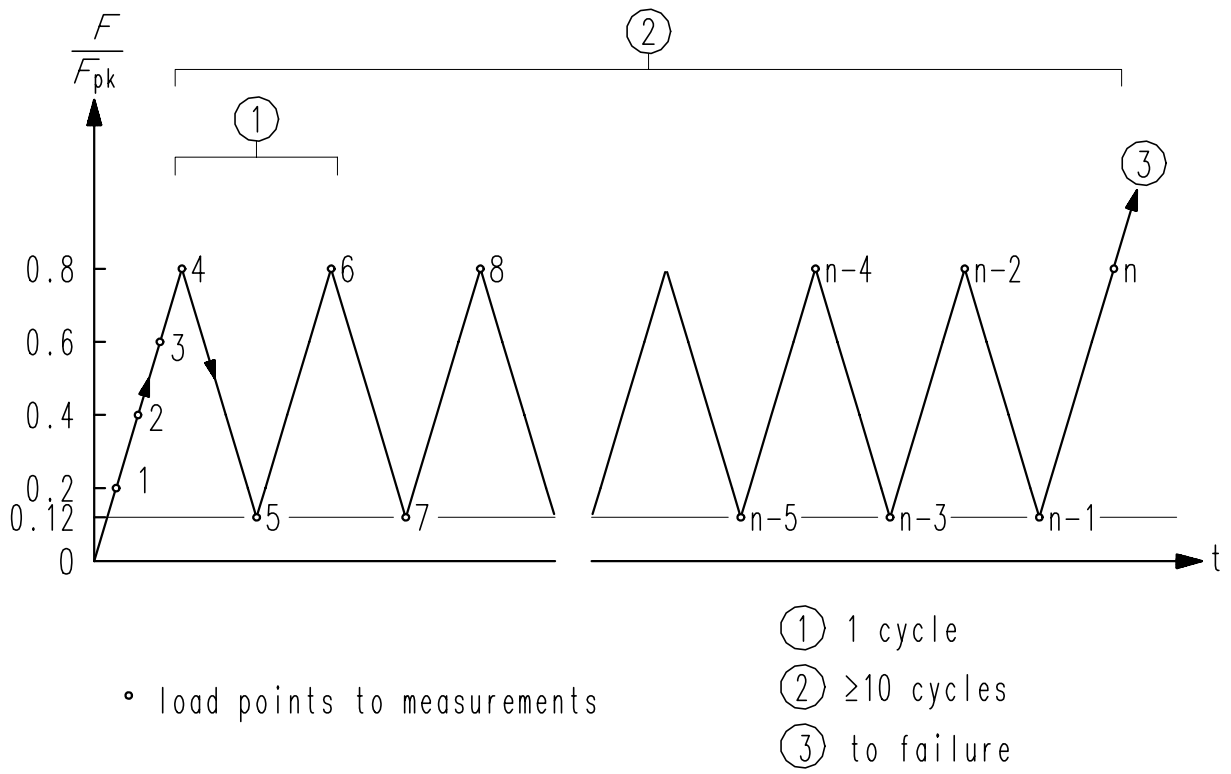
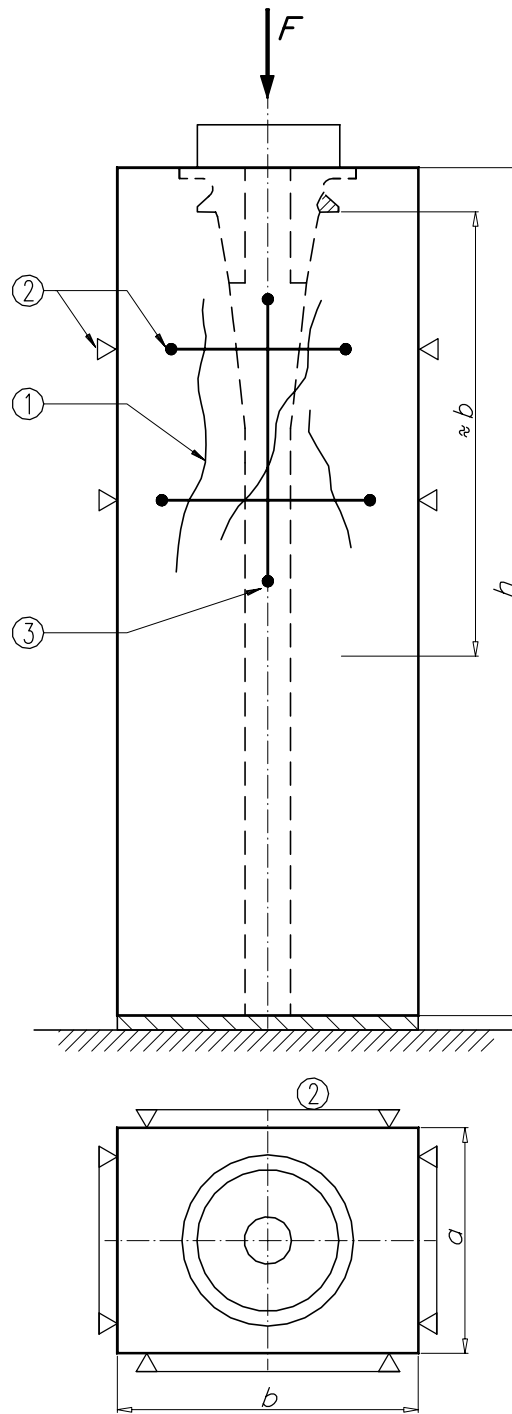
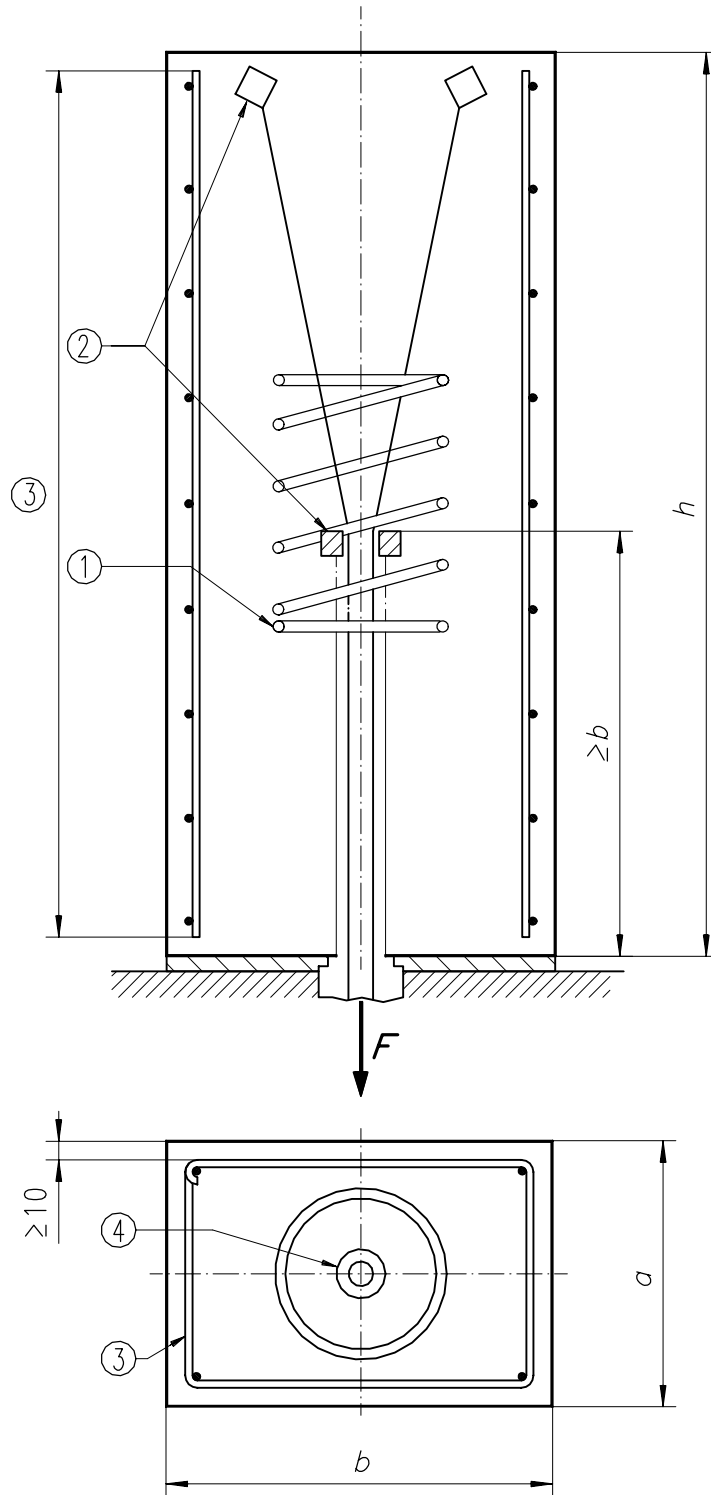


Figure B.3.1.2: Procedure of load transfer test



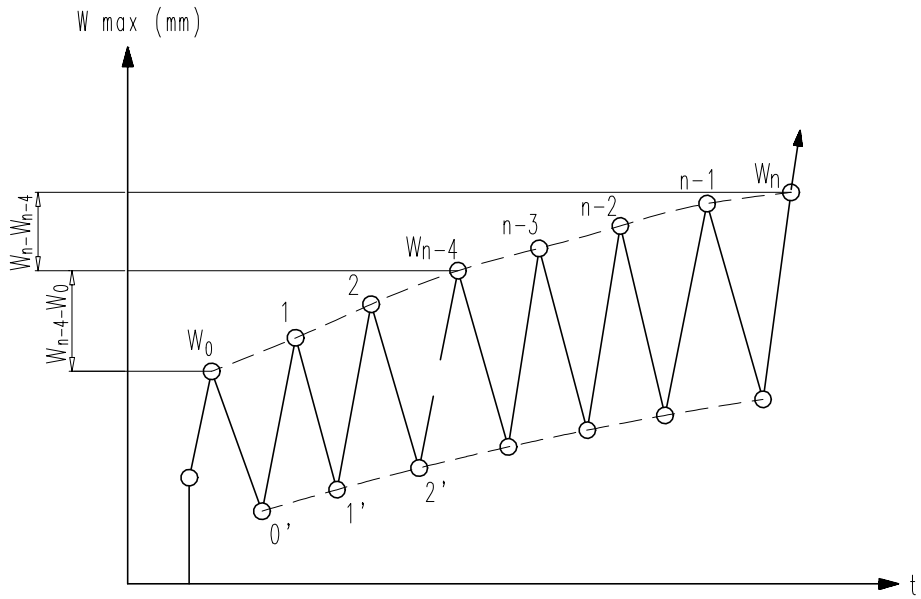
- ① cracks
 - ② for ϵ_t
 - ③ for ϵ_v
- ϵ_t transverse strain
 ϵ_v vertical strain gauge length
 ≈ 0.6 up to $0.8 b$

Figure B.3.1.3: Measuring set-up for load transfer test

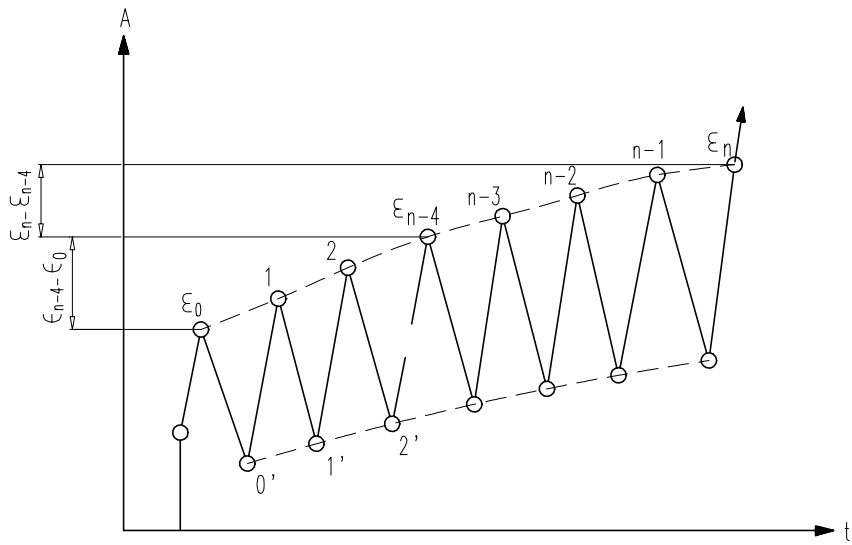


- ① Bursting reinforcement
- ② Actual anchorage components
- ③ Auxiliary reinforcement
- ④ Duct

Figure B.3.1.4: Test specimen for load transfer test with bond anchorage



(a) Crack widths



(b) Strains

Note:
 $A = \max \epsilon_v$ and $\max \epsilon_t$ /resp.

Figure B.3.1.5: Assessment of crack width and strain stabilisation

B.4 TEST FOR FRICTION LOSSES IN ANCHORAGES

As the friction losses are different when the stress increases or decreases, when the loading devices work actively or passively, four different linear regression shall be determined.

B.4.1 Test specimen

The test specimen shall consist of a prismatic concrete beam (or another device) including the tensile elements, anchorage components including bearing plate, anchor head, wedges or as applicable for other methods of anchoring the tensile elements, etc as well as the jacks and manometers.

B.4.2 Test procedure

The test specimen is assembled in the rig machine according to the envisaged application, as specified in the ETA, using the components necessary for anchoring the tendon.

At least three successive loading and unloading cycles will be done, with the jack in its open/middle/closed position, respectively.

B.4.3 Measurements and observations

The linear regression shall be determined from the 20% load level to the maximum load.

B.5 DEVIATOR / DEFLECTION (LIMITS)

B.5.1 DEVIATOR STATIC LOAD TEST

B.5.1.1 Test specimen

A typical test specimen is schematically shown in Fig. B.5.1.1. The specimen shall contain those deviator components which 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.

The test specimen shall be a concrete prism sufficiently large to contain the tendon deviator for a tendon deviation $\alpha = 10^\circ$ 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 which may be used are indicated in Fig. B.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.

If more than one grade of tensile element of the same type is to be used with the same type of deviator, the tests shall be performed using the grade with the highest characteristic tensile strength, and/or the largest load capacity.

B.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 movement shall be not less than 800mm. 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.

B.5.1.3 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).
- 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.

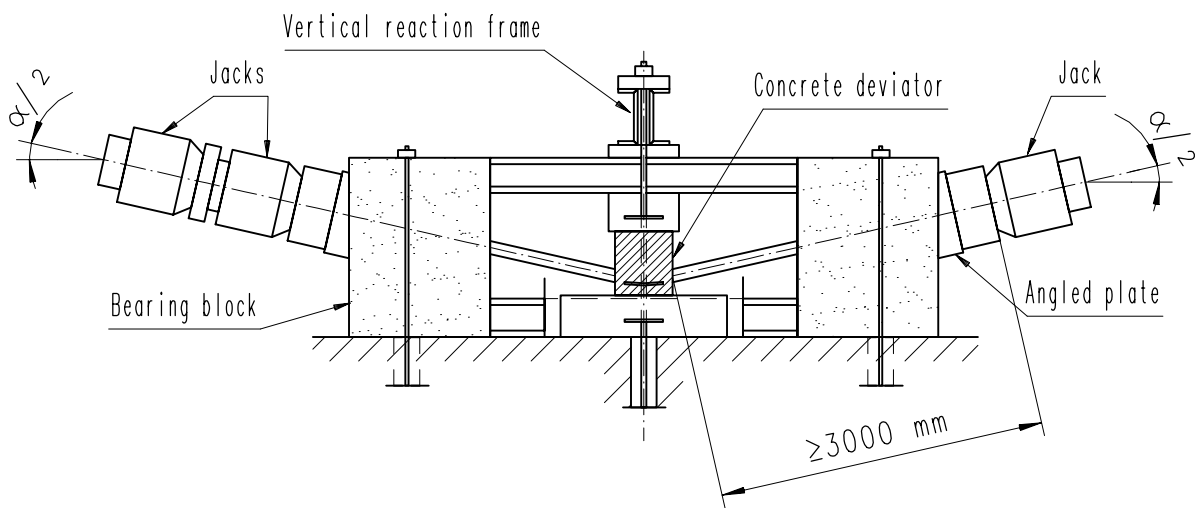


Figure B.5.1.1: Typical test set-up for deviator static load test

B.5.2 DEVIATED TENDON TEST

B.5.2.1 Test specimen

The test specimen shall be as per Clause B.5.1.1. However, the tendon deviation shall be $\alpha = 14^\circ$.

B.5.2.2 Test procedure

Test A: Large deviation

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

- If filling of duct is specified in the ETA to be done before complete stressing, it 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 length 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.

Test B: Small deviation

The tendon shall be deviated over sharp edges on a horizontal saddle of 700 mm length by 2° at each saddle end. The sharp edge shall be formed by a steel section providing a radius at the deviation of 5 mm. The test procedure shall otherwise follow Test A.

B.5.2.3 Measurements and observations

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

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

B.6 PRACTICABILITY / RELIABILITY OF INSTALLATION

B 6.1 ASSEMBLY / INSTALLATION / STRESSING TEST

B.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 Eurocode 2 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 Fig. B.6.1.1.

The specimen shall include tendon components in accordance with the ETA applicants guide for installation, 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 such as to allow installation of 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 Fig. B.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 B.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.

B.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.

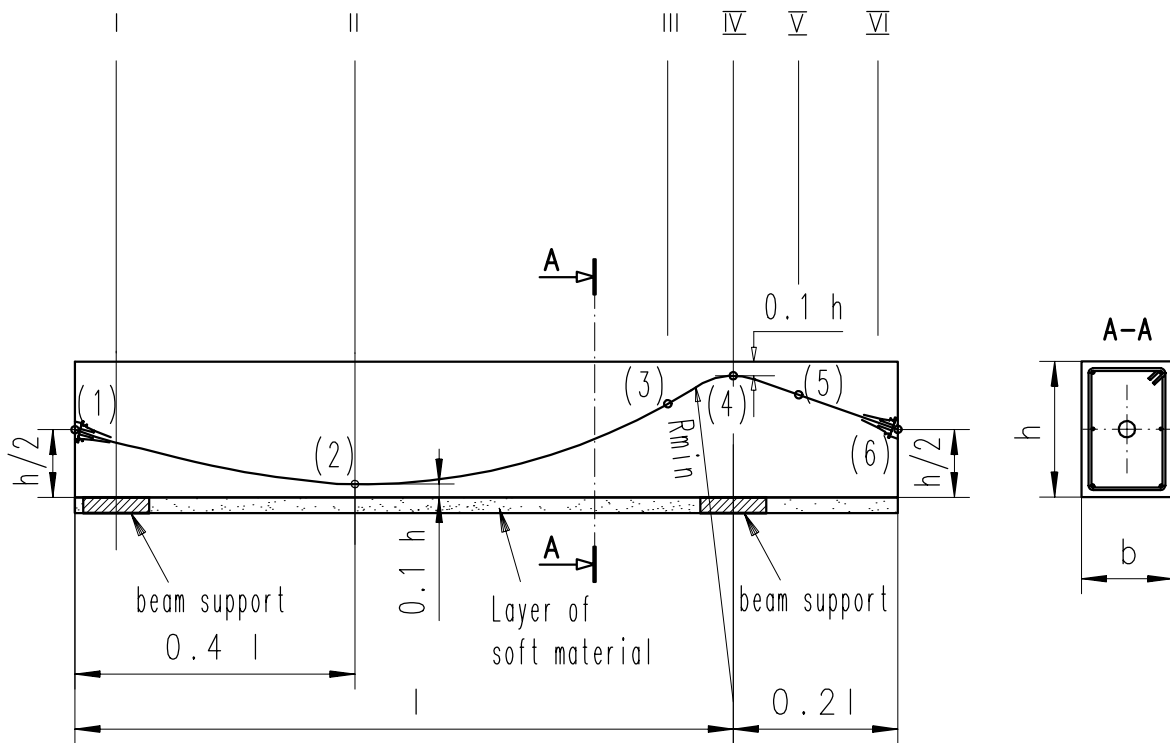
Once, the concrete is sufficiently hardened and the tensile elements installed, the tendon shall be stressed in steps to the maximum load in accordance with the ETA applicants guide. Jacks shall be used at both tendon ends, but only one is used actively to stress the tendon while the other is used to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

Subsequently, the tendon shall be completely detensioned, 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.

B.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, detensioning, 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.



- (1) End anchorage
- (2) Low point
- (3) Transition point of parabola
- (4) High point
- (5) Transition point of parabola
- (6) End coupler or anchorage

Dimensions :

$l \geq 25m$

$h \geq 1.5m$

$b = \text{twice the specified minimum}$

edge distance of anchorage, $\geq 0.5m$

Figure B.6.1.1: Test specimen of Assembly / Installation / Stressing test for internal tendon

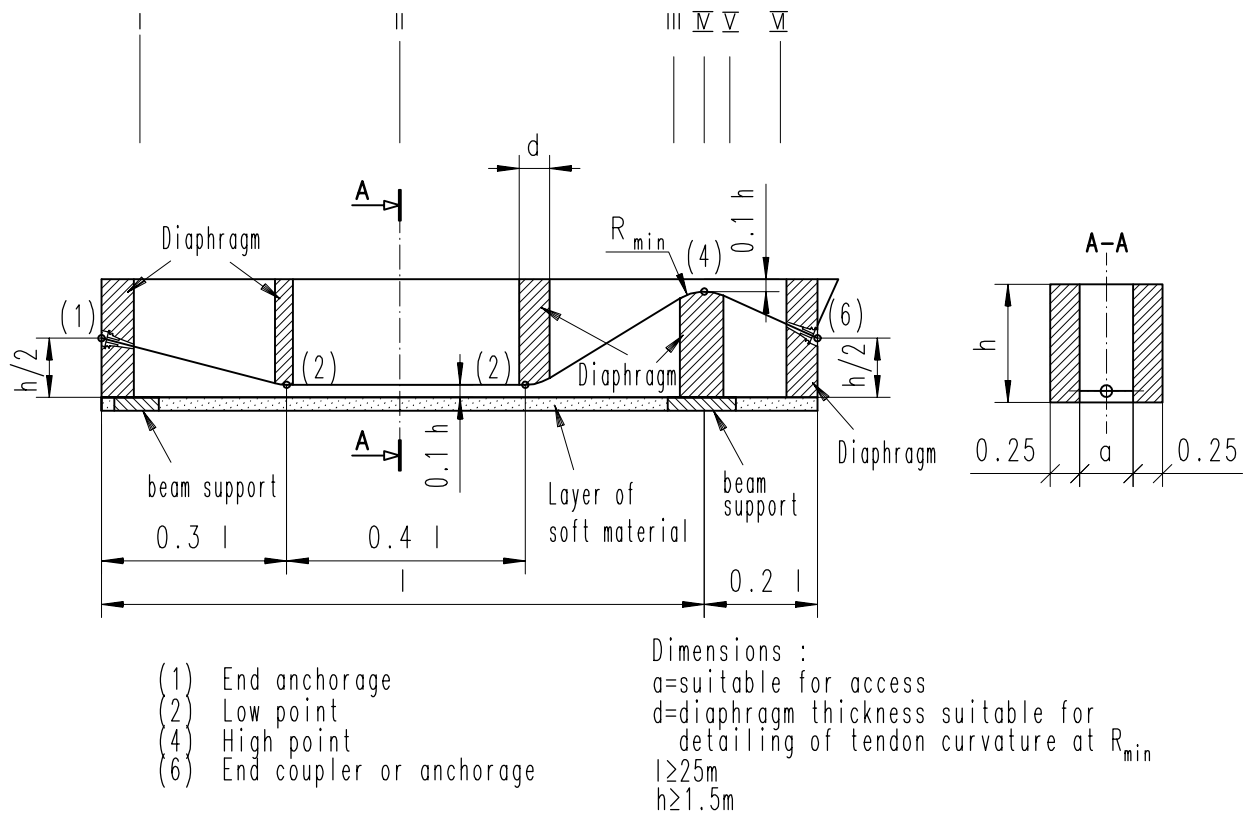


Figure B.6.1.2: Typical test specimen of Assembly / Installation / Stressing test for external tendon

B.6.2 DUCT FILLING TEST

B.6.2.1 Test specimen

The finally stressed specimen used in Annex B 6.1 for the “ Assembly / Installation / Stressing test ” shall be used for the “Duct filling test”.

B.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 Fig. B.6.1.1 and Fig. B.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.

B.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.

B.6.3 TENDON REPLACEMENT TEST

B.6.3.1 Test specimen

External tendons:

The tendon is installed in a concrete prism which includes two Load Transfer Test specimens at either ends. The Load Transfer Test specimens shall have the dimensions specified in Annex B 3.1 but shall not be less than 1.0 m long. The tendon-anchorage assembly shall include all details specified in the ETA applicants guide for the intended application. Components used for testing shall be randomly selected.

The distance between front surfaces of anchorages shall exceed 4.0 m. A possible set-up for external tendon testing is shown in Fig. B.6.3.1.

Between the two Load Transfer Test specimens, the duct encapsulating the tensile elements away from the anchorages shall be accessible to enable cutting of the tensile elements, see "Window" in Fig. B.6.3.1.

Except for above requirements, the specimen may be designed to suit the particular testing facility.

Internal tendons

The test specimen shall be similar to the one described in the above clause. However, the tendon shall include in the middle part of the specimens, outside the Load Transfer Test specimens, a section with at least one double curvature, corresponding to a total deviation angle of 45°, at minimum radius of curvature, R_{min} , specified in the ETA for this application. Tendon installation and concrete casting sequence shall be adapted to the intended use. A possible set-up for internal tendon testing is shown in Fig. B.6.3.2.

B.6.3.2 Test procedure

After installation of the complete tendon, the load in the tensile elements shall be increased in steps to 80% F_{pk} according to the ETA applicants guide. The tendon is then injected with filling material, if applicable, with a pressure according to the ETA applicant's guide. After a minimum period of 7 days, the tensile elements of external tendons shall be cut at the "Window", and the tendon shall be removed from the specimen. Exchangeable internal tendons shall be replaced as described in the ETA.

B.6.3.3 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).
- Chronological order of installation, stressing, filling of duct, if applicable, cutting and removal of tendon
- Pressure for filling of duct, if applicable
- Means used to extract tendon from specimen
- Difficulties encountered during removal, if any
- Results of visual examination of the tendon components after removal, photographic documentation, comments.

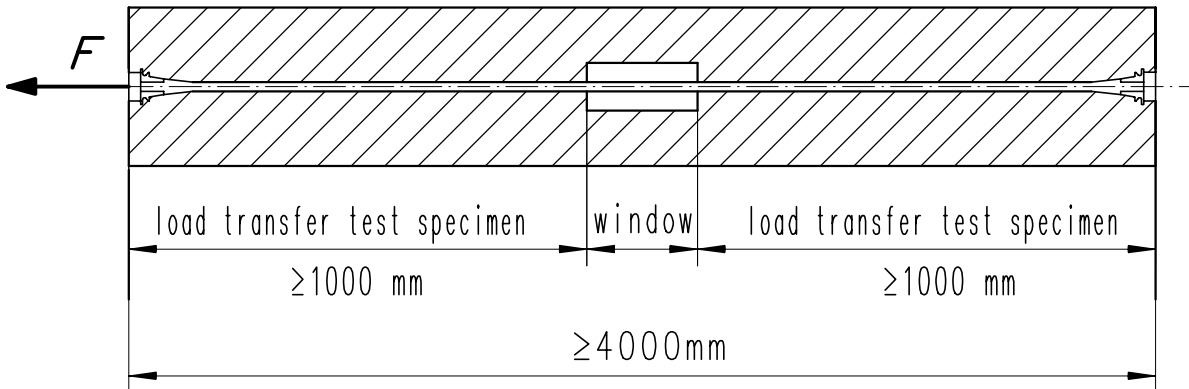


Figure B.6.3.1: Test set-up for tendon replacement test for external tendon

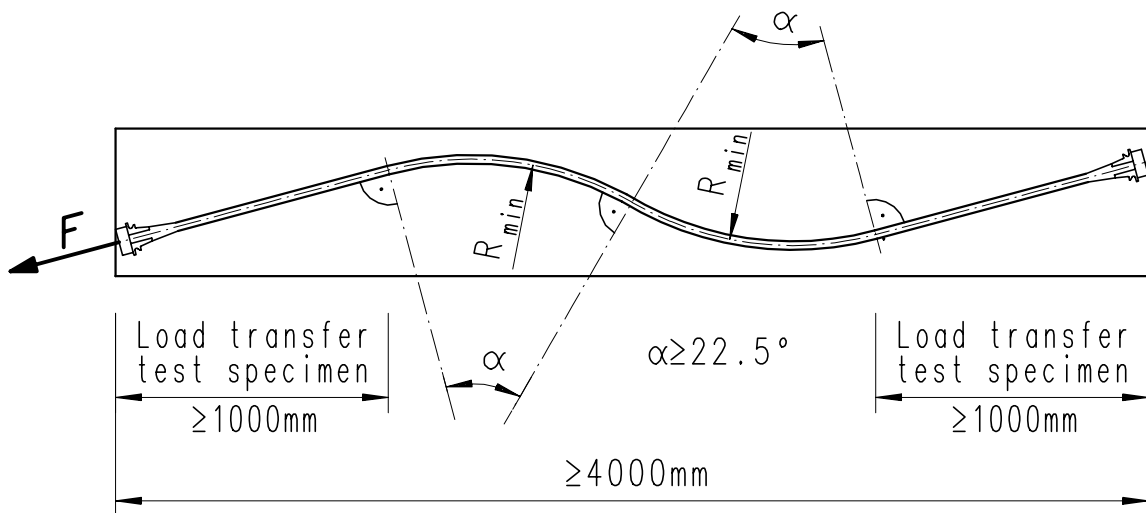


Figure B.6.3.2: Test set-up for tendon replacement test for internal tendon

B.6.4 LEAK TIGHTNESS TEST

B.6.4.1 Test specimen

The assembled specimen used in Annex B 6.1 for the “ Assembly / Installation / Stressing test, Internal Tendons ” shall be used for the “Leak tightness test”, but without the tensile elements being installed, and before the concrete being poured. Anchorage sealing details such as caps shall be installed.

B.6.4.2 Test procedure

The assembled system shall be subjected to an initial air pressure of 0.1 bar, from the inside of the duct. This pressure shall be held for 5 minutes to accommodate any initial movements in the system. Subsequently, the valve of the air supply shall be closed. The loss of air pressure in the duct system after closing the valve shall be measured over a period of 5 minutes.

B.6.4.3 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 leak tightness test.
- Loss of air pressure, over the period of 5 minutes after closing the valve.
- Examination of assembled system and eventual leakage points, photographic documentation, comments.

B.6.5 ELECTRICAL RESISTANCE TEST

B.6.5.1 Test specimen

The fully grouted specimen used in Annex B 6.2 for the “ Grouting test, Internal Tendons ”, but before opening the specimen, shall be used for the “Electrical resistance test”. A electrical measuring cable is connected to the tendon anchorage, preferably at the anchor head, with suitable clean connection details which assure consistent electrical readings (e.g. fixation by bolt). A similar electrical connection is provided to the reinforcing steel cage, located on one reinforcing bar, preferably near the anchorage. All electrical cables shall be provided with a robust, electrically isolating, and water tight encapsulation. The electrical measuring cable shall have a copper core of not less than 1 mm² cross sectional area.

B.6.5.2 Test procedure

The electrical measuring cables attached to the tendon anchorage and the reinforcing steel cage shall be connected into an electrical resistance measurement device, such as used for measuring electrical earth. This device shall have the following characteristics:

- a measuring frequency of approximately 100 Hz, alternating current
- supply with 20/40 V alternating electrical power,
- a digital display with a measuring range of electrical resistance between 0.1 Ohm and 300 kOhm, and a resolution of 0.1 Ohm.

The electrical resistance between the tensile elements and the structure (reinforcing steel cage) shall be measured with the above specified measuring device. The measurement shall be repeated a second independent time to assure consistency of the measurement. If any inconsistencies occur between the readings, the connection details of the electrical measuring cable shall be verified and cleaned, and the measurements repeated.

B.6.5.3 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).
- Details of duct connections, vent location and details.
- Data sheet of electrical resistance measurement device.
- Weather conditions, air temperature during the electrical resistance test.
- Length and electrical resistance of electrical measuring cables.
- Layout and connection details of electrical measuring cables.
- Measured electrical resistance between the tensile elements and the reinforcing steel of the structure (all measured values to be recorded).
- Examination of electrical connections to tensile elements and reinforcing steel, photographic documentation, comments.

Annex C

C REFERENCE SPECIFICATIONS

Contents

C.1 INDIVIDUALLY GREASED AND SHEATHED MONOSTRANDS

C.2 PLASTIC PIPES FOR EXTERNAL TENDONS

C.3 PLASTIC DUCTS FOR BONDED, INTERNAL TENDONS

C.4 SPECIAL FILLING MATERIALS

C.4.1 Grease

C.4.2 Wax

C.4.3 Special grout

C.1 INDIVIDUALLY GREASED AND SHEATHED MONOSTRANDS

C.1.1 Scope

This clause covers individually greased and sheathed single monostrands used in post-tensioning systems for prestressing of structures.

C.1.2 Materials: Requirements, methods of verification, and acceptance criteria

C.1.2.1 Tensile elements

These are 7-wire strands which shall comply with prEN 10138 – Part 3 “Strand”.

C.1.2.2 Grease

Grease materials shall comply with Annex C.4.1.

Additionally, grease properties shall not change beyond the values indicated in Table C.1.1 during monostrand manufacturing:

Table C.1.1: Grease properties after monostrand manufacturing

Characteristics	Test method / Standard	Acceptance criteria
Dropping point - variation during monostrand manufacturing	ISO 2176	≤ 10%
Oil separation - variation during monostrand manufacturing	DIN 51808	At 72 hours: ≤ 3% At 7 days: ≤ 5%

C.1.2.3 Sheathing base material

The base material for the sheathing is a high density polyethylene which complies with the following specification, see Table C.1.2. Only new base material shall be used except that material of the same factory and production process for the same product may be recycled.

Table C.1.2: Sheathing base material specification

Characteristics	Test method / Standard	Acceptance criteria
Melt index	ISO 1133 (10 minutes at 2.16kg)	≤ 0.25 g
Density	DIN 53479	≥ 0.95 g/cm ³
Carbon black: - Content - Dispersion - Distribution	ISO 6964 ISO 4437 ISO 4437	2.3 +/- 0.3 % Index max: C2 Index max: 3
Tensile strength (23 °C)	EN ISO 527-2	≥ 22 MPa (1)
Elongation - at 23 °C: - at -20 °C:	EN ISO 527-2 EN ISO 527-2	> 600 % (1) > 350 % (1)
Thermal stability	ISO/TR 10837	≥ 20 minutes at 210 °C in O ₂ without degradation (oxygen induction time)

Note (1): Standardised specimen according to ISO 1 BA, loading speed 100mm/minute

The origin and the composition of the sheathing material shall be declared by the supplier. Other materials such as polypropylene may be considered if they satisfy similar performance criteria and do not have other characteristics which make them less desirable.

C.1.2.4 Manufactured sheathing

The manufactured sheathing shall have the characteristics given in Table C.1.3:

Table C.1.3: Manufactured sheathing specification

Characteristics	Test method / Standard	Acceptance criteria
Tensile strength at 23 °C	EN ISO 527-2	≥ 18 MPa (1)
Elongation: - at 23 °C - at -20°C	EN ISO 527-2 EN ISO 527-2	≥ 450% (1) ≥ 250 % (1)
Surface of sheathing		No visual damage No bubbles No traces of filling material visible
Environmental stress cracking	NF C 32-060	No cracking after 72 hours in a tensio-active liquid at 50 °C
Temperature resistance - variation of tensile strength at 23 °C after conditioning for 3 days at 100 °C - variation of elongation at 23 °C after conditioning for 3 days at 100 °C	EN ISO 527-2 EN ISO 527-2	≤ 25 % ≤ 25 %
Resistance to externally applied agents: - Mineral oil - Acids - Bases - Solvents - Salt spray	EN ISO 175	Variation of tensile strength ≤ 25 % Variation of elongation ≤ 25 % Variation of volume ≤ 5 %
Sheathing minimum thickness	EN 496	≥ 1.0 mm (2)

Note (1): Standardised specimen according to ISO 1 BA, loading speed 100mm/minute

(2): The actual value shall be declared by the ETA applicant such as to satisfy application parameters, see Clause 6.1.6-II(a).

C.1.3 Monostrands: Requirements, methods of verification, and acceptance criteria

C.1.3.1 Specification

The monostrand shall comply with Table C.1.4:

Table C.1.4: Monostrand specification

Characteristics	Test method / Standard	Acceptance criteria
Impact resistance	Clause C.1.3.2.1	No tear or penetration of sheathing
Friction between sheathing and strand	Clause C.1.3.2.2	≤ 60 N/m
Squeezing: - transverse deformation under load: - residual transverse deformation after removal of load:	Clause C.1.3.2.3	$\leq 3\%$ $\leq 2.5\%$
Leak tightness	Clause C.1.3.2.4	No water leaking through specimen

The manufacturer or supplier of the monostrands defines the product with the following characteristics in terms of absolute values and tolerance with a material certificate, and declares these values:

- External diameter of the sheathing.
- Mass of the sheathing per linear meter.
- Mass of the filling material per linear meter.

C.1.3.2 Test procedures

C.1.3.2.1 Impact resistance test

C.1.3.2.1.1 Specimen

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

C.1.3.2.1.2 Procedure

The test specimen is fixed onto a steel plate to prevent its rotation during the test. A steel block of 1 kg weight is dropped from 500 mm height, 10 times at different locations along the specimen onto it. The steel block has an edge with a radius of curvature of 0.5 mm and an angle of 40° at the location of the impact on the monostrand. The test is performed at 23±2 °C.

C.1.3.2.1.3 Measurements

The following measurements and observations shall be made and recorded:

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

C.1.3.2.2 Friction test

C.1.3.2.2.1 Specimen

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

C.1.3.2.2.2 Procedure

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 fixation 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 $23\pm 2^{\circ}\text{C}$.

C.1.3.2.2.3 Measurements

The following measurements and observations shall be made and recorded:

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

C.1.3.2.3 Squeezing resistance test

C.1.3.2.3.1 Specimen

The specimen is a monostrand of minimum 500 mm length.

C.1.3.2.3.2 Procedure

The specimen is supported on a flat steel surface of 200 mm length. A steel weight of 50 kg distributed over 100 mm of the specimen length is placed on the specimen at the centre of the supported length, for a duration of 10 minutes, at a temperature of $23\pm 2^{\circ}\text{C}$. Subsequently, the weight is removed.

C.1.3.2.3.3 Measurements

The following measurements and observations shall be made and recorded:

- Diameter of the monostrand at the location of the support before application of the weight
- Transverse deformation of the specimen under the weight
- Residual transverse deformation of the specimen after removal of the weight
- Observation of tear or damage to the sheathing.

C.1.3.2.4 Leak tightness test

C.1.3.2.4.1 Specimen

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

C.1.3.2.4.2 Procedure

The specimen is straight 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 $23\pm 2^{\circ}\text{C}$.

C.1.3.2.4.3 Measurements

The following measurements and observations shall be made and recorded:

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

C.1.4 Evaluation of conformity

A control on the following characteristics is performed for each coil of monostrands produced:

- External diameter of the sheathing on the monostrand
- Wall thickness

- Mass of sheathing per linear meter
- Mass of filling material per linear meter

In addition the following characteristics shall be determined for each lot of 50 tonnes of production to the same specification, or for each new specification:

- Impact resistance
- Friction between sheathing and strand
- Leak tightness

The squeezing resistance is determined at the begin of each production to a particular specification with specific constituents.

Acceptance of monostrands shall be based on documentation specified in Annex E.1.

C.2 PLASTIC PIPES FOR EXTERNAL TENDONS

C.2.1 Scope

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

C.2.2 Material: Requirements, methods of verification, and acceptance criteria

Materials for plastic ducts for external tendons shall comply with prEN 12201 – Plastics piping systems for water supply – Polyethylene (PE), Part 1 “General” and Part 2 “Pipes”, 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 $C = 1.25$.
- PE 80 and PE 100 are considered suitable for this scope only.

C.2.3 Plastic pipe: Requirements, methods of verification, and acceptance criteria

C.2.3.1 Plastic pipes

Plastic pipes for external tendons shall comply with prEN 12201 – Plastics piping systems for water supply – Polyethylene (PE), Part 1 “General” and Part 2 “Pipes”, 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 = $0.009 d_n$ (d_n = nominal outside diameter) with a maximum value of 1.0 mm.
- Ducts for external tendons shall be supplied in straight lengths only, but not coiled.
- Characteristics for effects on water quality can be disregarded.

C.2.3.2 Connections

The ETA applicant shall have procedures and details available to join the pipes into a continuous duct such as to assure proper installation, stressing, and in particular filling of the duct.

C.2.4 Evaluation of conformity

Acceptance of plastic pipes shall be based on documentation specified in Annex E.1.

C.3 PLASTIC DUCTS FOR BONDED, INTERNAL TENDONS

C.3.1 Scope

This annex covers corrugated plastic ducts made of HDPE and PP for use in PT systems for prestressing of structures as ducts for bonded internal tendons.

C.3.2 Material: Requirements, methods of verification, and acceptance criteria

The requirements, methods of verification and acceptance criteria for the materials used to manufacture plastic ducts for bonded, internal tendons shall comply with fib Report “Corrugated Plastic Ducts for Internal, Bonded Post-Tensioning”, [28], Chapter 3 “Material”.

C.3.3 Plastic ducts: Requirements, methods of verification, and acceptance criteria

C.3.3.1 Requirements

Plastic ducts for bonded, internal tendons shall comply with fib Report “Corrugated Plastic Ducts for Internal, Bonded Post-Tensioning”, [28], Clause 4.1 “Components Testing”.

Chapter 1 “Introduction”, Chapter 2 “Use”, Chapter 5 “Design Considerations”, and Chapter 6.2 “Standards considered to be equivalent” do not apply for this ETAG. However, they may be considered for additional guidance.

C.3.3.2 Methods of verification

Test procedures and acceptance criteria for plastic duct components shall comply with fib Report “Corrugated Plastic Ducts for Internal, Bonded Post-Tensioning”, [28], Annexes A 1 to A 8.

C.3.4 Evaluation of conformity

Acceptance of plastic ducts shall be based on documentation specified in Annex E.1.

C.4 SPECIAL FILLING MATERIALS

C.4.1 Grease

C.4.1.1 Scope

This clause covers mineral oil-based grease used as filling material for PT systems for prestressing of structures for ducts for external tendons, and as filling material for monostrands. For monostrands this material usually permits to achieve performance levels as specified for the fabricated monostrands after the production process, see Annex C.1.

C.4.1.2 Material: Requirements, methods of verification, and acceptance criteria

Grease for filling material is typically of metallic basis such as lithium. Potash and sodium alkaline soaps are not suitable for filling materials.

Grease for filling material shall comply with Table C.4.1.1:

Table C.4.1.1: Grease specification

Characteristics	Test method / Standard	Acceptance criteria
Cone penetration, 60 strokes (1/10mm)	ISO 2137	250 - 300
Dropping point	ISO 2176	≥ 150°C
Oil separation at 40°C	DIN 51 817	At 72 hours: ≤ 2.5 % At 7 days: ≤ 4.5 %
Oxidation stability	DIN 51 808	100 hours at 100°C: ≤ 0.06 MPa 1000 hours at 100°C: ≤ 0.2 MPa
Corrosion protection 168 hours at 35 °C 168 hours at 35 °C	NFX 41-002 (salt spray) (1) NFX 41-002 (distilled water spray) (1)	Pass No corrosion
Corrosion test	DIN 51 802	Grade: 0
Content of aggressive elements: Cl ⁻ , S ²⁻ , NO ₃ ⁻ : SO ₄ ²⁻ :	NFM 07-023 (2) NFM 07-023 (2)	≤ 50ppm (0.005%), ≤ 100ppm (0.010%),

Note (1): Test sample consists of a structural steel plate Fe 510 with a surface roughness comparable to prestressing wire and strand. The plate is covered with a layer of grease of a maximum thickness corresponding of the declared mass of filling material per linear meter of monostrand divided by the nominal strand surface per linear meter (based on nominal strand diameter).

(2): Applied accordingly to grease.

The origin and the composition of the grease shall be declared by the supplier. Other properties to be declared by the supplier shall include the Flash Point, Water Content, and Soak Test result. Suitable reference can be found in [29].

In the absence of suitable testing methods for the content of any potentially aggressive elements, reference to passed successful experience and applications can be considered acceptable.

C.4.1.3 Component: Requirements, methods of verification, and acceptance criteria

There are no additional component requirements.

C.4.1.4 Evaluation of conformity

Acceptance of grease on site and in the factory shall be based on compliance of characteristics declared by the supplier on certificates with the characteristics specified in Clause C.4.1.2, and on documentation specified in Annex E.1.

Injection of grease on site shall follow the procedures specified in the ETA, including the recommendations of the supplier.

Use of grease in the factory for monostrand shall follow the procedures specified by the manufacturer and the recommendations by the supplier.

C.4.2 Wax

C.4.2.1 Scope

This clause covers bitumastic petroleum-based wax suitable for filling material for PT systems for prestressing of structures, for ducts for external tendons.

C.4.2.2 Material: Requirements, methods of verification, and acceptance criteria

Wax for filling materials shall comply with Table C.4.2.1:

Table C.4.2.1: Wax specification

Characteristics	Test method / Standard	Acceptance criteria
Congealing point	NFT 60-128	≥ 65 °C
Penetration (1/10mm) at -20 °C	NFT 60-119	No cracking
Bleeding at 40 °C	BS 2000: PT121 (1982) modified	≤ 0.5 %
Resistance to oxidation 100 hours at 100 °C	ASTM D942.70	≤ 0.03 MPa
Copper-strip corrosion 100 hours at 100 °C	ISO 2160	Class: 1a
Corrosion protection 168 hours at 35 °C 168 hours at 35 °C	NFX 41-002 (Salt spray) (1) NFX 41-002 (Distilled water spray) (1)	Pass No corrosion
Content of aggressive elements: Cl^- , S^{2-} , NO_3^- : SO_4^{2-} :	NFM 07-023 NFM 07-023	≤ 50 ppm (0.005%), ≤ 100 ppm (0.010%),

Note (1): Test sample consists of a structural steel plate Fe 510 with a surface roughness comparable to prestressing wire and strand. The plate is covered with a layer of grease of a maximum thickness corresponding of the declared mass of filling material per linear meter of monostrand divided by the nominal strand surface per linear meter (based on nominal strand diameter).

The origin and the composition of the wax shall be declared by the supplier.

C.4.2.3 Component: Requirements, methods of verification, and acceptance criteria

There are no additional component requirements.

C.4.2.4 Evaluation of conformity

Acceptance of wax on site shall be based on compliance of characteristics declared by the supplier on certificates with the characteristics specified in Clause C.4.2.2, and on documentation specified in Annex E.1.

Injection of wax on site shall follow the procedures specified in the ETA, and shall comply with the manufacturer's recommendations.

C.4.3 Special grout

C.4.3.1 Scope

This clause covers special grouts which are cementitious filling materials having characteristics not in accordance with EN 447.

Dry components of special grouts can be mixed on site or can be supplied to site as ready mix / pre-bagged mix. Water and eventual liquid admixtures are added on site.

C.4.3.2 Materials: Requirements, methods of verification, and acceptance criteria

C.4.3.2.1 Cement

Special grout shall only use such cements for which complete data on their origin and chemical and physical characteristics are known. This data shall include in particular the following:

- Origin, supplier of cement
- Date of production of cement
- Chemical analysis, mineral content, density, Blaine value, strength, setting time (absolute values and tolerance where applicable).

If such data is not available e.g. for ready mix grout, the performance of each special grout supply shall be confirmed with tests as per Clause C.4.3.3, and certified by the supplier, see Clause C.4.3.4.

C.4.3.2.2 Water

Water shall comply with EN 1008.

C.4.3.2.3 Admixtures

Admixtures shall comply with EN 934-4.

C.4.3.3 Special grout: Requirements, methods of verification, and acceptance criteria

C.4.3.3.1 Specification

Special grout properties shall comply with EN 447 except for additional or modified requirements as listed in Table C.4.3.1:

Table C.4.3.1: Special grout specification

Characteristics	Test method / Standard	Acceptance criteria
Bleed in Inclined Tube test	Clause C.4.3.3.2.1	$\leq 0.3\%$
Air void in Inclined Tube test	Clause C.4.3.3.2.1	$\leq 0.3\%$
Cracking of grout in Inclined Tube test	Clause C.4.3.3.2.1	No significant cracking visible to the naked eye
Sedimentation expressed as variation of density, R	Clause C.4.3.3.2.2	$\leq 10\%$
Wick-induced bleed	Clause C.4.3.3.2.3	$\leq 0.3\%$
Chloride content of special grout	Chemical analysis	$\leq 0.1\%$

The following supplementary characteristics of special grout shall be declared by the ETA applicant:

- Water/Cement ratio
- Flow time according to EN 445 (or measurement of viscosity with vane shear tester for thixotropic grout)
- Volume change according to EN 445
- Strength according to EN 445
- Time of start and end of setting of grout according to EN 196-3.

Flow time and start of setting of special grout shall be verified to be compatible with the particular application and the temperature range for which it is intended to be used on site.

Testing shall be done using grouting equipment specified by the ETA applicant for use on site, and mixing procedures in accordance with the ETA applicant's specification.

Testing of special grout shall be done for each special grout mix, i.e. each set of constituents from a particular source, and with specific characteristics.

The test reports shall contain all data of materials used, test procedures, equipment, mix proportions with sequence and duration of mixing, and test results.

The ETA applicant has two options for the verification of special grout:

(1): Materials for testing are specified in terms of the characteristics listed in Clause C.4.3.2 including acceptable tolerance of characteristics. The characteristics are documented as indicated in Annex E.1. In this case, testing will be considered as approval testing also valid for all future applications on site, i.e. tests do not need to be repeated for each site.

(2): Not all the characteristics as listed in C.4.3.2 including acceptable tolerances are known and documented as indicated in Annex E.1. In this case, testing will not be considered as approval testing, i.e. it is not valid for a future application on site, and will need to be repeated for each particular site.

C.4.3.3.2 Test procedures

Testing of special grout shall follow EN 445 except for the tests specified in Clauses C.4.3.3.2.1, C.4.3.3.2.2, and C.4.3.3.2.3.

C.4.3.3.2.1 Inclined Tube test

C.4.3.3.2.1.1 Objective

This test serves to determine the bleed properties and stability of a special grout, at full scale and including the filtering effect of strands. It also allows to confirm the proposed grouting procedures, in particular the effect of time between ending an initial grouting and starting of re-grouting on site, if specified, and equipment used on site. The intent of the test is to confirm that a duct on site can be completely filled with the proposed special grout, equipment and procedure without unacceptable bleed and segregation of the grout.

C.4.3.3.2.1.2 Test method

In a first test phase, the bleed water and air accumulated on top of a tube filled with special grout shall be determined. The special grout is injected under pressure and is setting such that water losses due to evaporation are prevented. In a second phase, the effect of re-grouting of a tube on bleed water and air accumulated shall be determined, if such a procedure is envisaged by the ETA applicant in the grouting method statement.

C.4.3.3.2.1.3 Test equipment and set-up

- Two transparent PVC tubes, of approximately 80 mm internal diameter and 5 m long, equipped with caps at each end including grout inlet at the lower end, and grout vent at the top. The tubes shall be able to sustain a grout pressure of at least 1 MPa.
- 12 prestressing strands \varnothing 0.6" per tube, i.e. a total of 24.
- Grouting equipment as per the grouting method statement.
- A thermometer with automatic recording.

C.4.3.3.2.1.4 Test procedure

- The two tubes are fixed on their supports such as to avoid noticeable deflections, at an inclination of $30^\circ \pm 2^\circ$ against a horizontal reference line. 12 strands shall be installed in each tube. The caps are subsequently installed on the tube ends (fixed with glue), see Fig. C.4.3.1.
- The special grout is prepared as per the grouting method statement. Specimens shall be taken from the grout mix to confirm flow time per EN 445. In case of a thixotropic grout, other methods shall be used, see C.4.3.3.1.

- Grouting of first tube :

Grout is injected into the first tube (Tube 1) from the bottom end. When the grout exits from the vent at the top with the same consistency as it enters at the bottom, the valve shall be closed, and the grout pressure shall be maintained for the duration specified in the method statement. Subsequently, the valve at the bottom is closed, and grouting of Tube 1 is considered complete.

The level of air, water, and any other eventual liquid on top of the grout shall be measured, see Fig. C.4.3.1. Such eventual liquid on top of the grout can be distinguished from the grout by its whitish to yellowish colour, usually clearer than the grout. A minimum of 4 measurements of levels shall be taken between 0 and 24 hours after completion of grouting, with one measurement just before re-grouting of Tube 2 is started. The following 4 measuring intervals are suggested : 30 minutes, 1 hour, 2 hours, and 24 hours after grouting.

- Grouting of second tube :

Grouting of Tube 2 shall follow the same procedure as used for Tube 1, and shall be done quasi simultaneously with Tube 1. At a time specified in the method statement for re-grouting, the mixing of grout in the equipment is started again, and the flow time of the grout is determined again.

Subsequently, the valves of inlet and vent of Tube 2 are opened again, and grouting is started again. This will allow any liquid accumulated on top to be replaced by grout. When grout exits from the vent on top, the valve is closed, and the grout pressure is maintained for the duration specified in the method statement. Subsequently, the valve at the bottom is closed, and re-grouting of Tube 2 is considered complete.

The time between initial grouting and re-grouting, and the duration for the second mixing activity, shall comply with the grouting method statement. Typically, this time will be between 30 minutes and 2 hours.

Similar to Tube 1, the measurement of levels are done between 0 and 24 hours after completion of the initial grouting. One of the measurements shall be taken just prior of re-grouting of Tube 2, followed by measurements 30 minutes, 1 hour, and 2 hours after completion of re-grouting.

C.4.3.3.2.1.5 Measurements and observations

The following measurements and observations shall be made and recorded:

- description of test set-up
- special grout mix design, origin and certificates of all grout constituents
- mixing procedure of grout
- flow time of grout mix before initial grouting, and before re-grouting (or viscosity of a thixotropic grout)
- method statement for grouting specified by ETA applicant
- measurements of level of air, water, and eventual liquid on top of the grout

- any observations and comments on the formation of bleed or liquid, or on difficulties encountered during the test
- any observations and comments on cracking of the grout, with location, orientation, and approximate widths of cracks
- development of air temperature during the entire test period
- photos illustrating test set-up, and details of top end of tube with air, water, and eventual liquid.

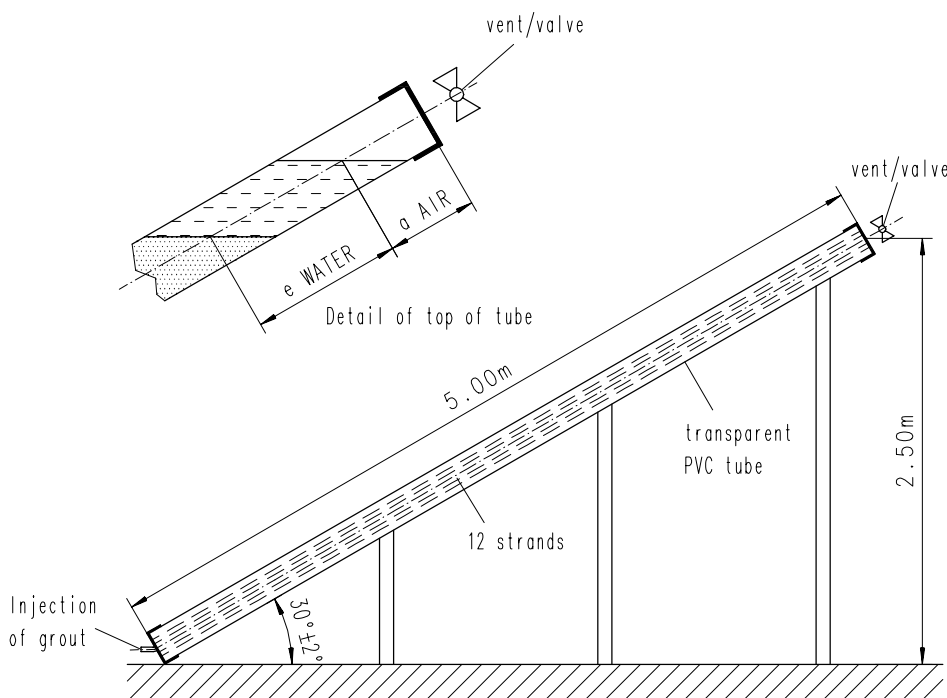


Figure C.4.3.1: Inclined Tube test set-up

C.4.3.3.2.2 Sedimentation test

C.4.3.3.2.2.1 Objective

This test serves to determine the sedimentation properties of a special grout. It is considered as a measurement of the homogeneity of the grout mixed in the equipment intended to be used on site.

C.4.3.3.2.2.2 Test method

Sedimentation is measured as a percentage difference in density of the grout between the samples taken from the top and bottom of the test specimen.

C.4.3.3.2.2.3 Test equipment

- Two transparent PVC tubes, of approximately 60 to 80 mm internal diameter, and 1 m long, equipped with caps at each end.
- Grouting equipment as per the grouting method statement.
- A thermometer with automatic recording.

C.4.3.3.2.4 Test procedure

The special grout mix specified by the ETA applicant is prepared in the grout mixer intended to be used on site. The transparent tubes are placed and held vertically on a surface free from shocks or vibrations. The tubes are filled with special grout to the top and sealed to prevent evaporation. At least 24 hours after filling, but after setting of the grout, the grout columns shall be removed gently from the tubes. The grout columns shall be marked and subsequently cut into equal slices of 50 mm each over the entire height. The relative position of each slice in the column shall be recorded. The density of each slice shall be measured by an approved method.

C.4.3.3.2.5 Measurements and observations

The following measurements and observations shall be made and recorded:

- Record temperature of grout constituents before testing, and air temperature during test period
- Record the density of each slice of both grout columns
- Determine the segregation ratio, R , of each of the grout columns as the variation of grout density between the bottom, D_{Bot} , to the top, D_{Top} , of the column as follows:

$$R = 1 - (D_{Top} / D_{Bot})$$

- Report any particular observation such as eventual bleed water on top of the grout column at the time of removing the grout column (presence of water and quantity), or discoloration of grout columns.
- Photographic documentation, and comments.

C.4.3.3.2.3 Wick-induced test

C.4.3.3.2.3.1 Objective

This test serves to determine the bleed properties of a special grout. It is considered to be more representative than the bleed test as per EN 445, and shall be done for approval and on site.

C.4.3.3.2.3.2 Test method

Bleed is expressed as the percentage of the bleed water depth on top of the grout column divided by the original grout column height, at 3 hours and after 24 hours.

C.4.3.3.2.3.3 Test equipment

- One transparent PVC tube, of approximately 60 to 80 mm internal diameter, and 1 m long, equipped with caps at each end, as used in the sedimentation test.
- One 7-wire strand of one metre length such as to fit inside the tube (if the type of tensile element with which the grout will be approved is specified, the 7-wire strand may be replaced with the actual type of tensile element specified for use. This may either be a prestressing bar of minimum 16 mm diameter, or a number of prestressing wires such as to provide an ultimate tendon capacity of the tensile elements of not less than 265 kN).
- Grouting equipment as per the grouting method statement.
- A thermometer with automatic recording.

C.4.3.3.2.3.4 Test procedure

The special grout mix specified by the ETA applicant is prepared in the grout mixer intended to be used on site. The transparent tube is placed and held vertically on a surface free from shocks or vibrations. The tensile elements are placed standing inside the tube and held concentrically. The tube

is filled with special grout to the top and sealed to prevent evaporation. After 3 hours and after 24 hours the bleed water depth on top of the grout column is measured.

C.4.3.3.2.3.5 Measurements and observations

The following measurements and observations shall be made and recorded:

- Record temperature of grout constituents before testing, and air temperature during test period
- Record type, size, and number of tensile elements installed in column
- Record the original grout column height
- Record bleed water depth at the top of the grout column after 3 hours and after 24 hours
- Determine the bleed ratio of the grout column as the depth of bleed water divided by the original height of the grout column
- Photographic documentation, and comments (not required for testing on site).

C.4.3.4 Evaluation of conformity

The two options listed in Clause C.4.3.3 apply:

(1) Special grout shall be produced according to a QA plan which assures use of materials which comply in all aspects with the specification and properties listed in C.4.3.2, and used for testing as specified in Clause C.4.3.3. In such a case, the testing as per Clause C.4.3.3 shall be considered as approval testing for the particular special grout mix, and does not need to be repeated for each site.

On site, only materials which comply with the specification and tolerance used for testing as per Clause C.4.3.3 shall be used. Acceptance of materials may be based on certificates from the suppliers, see Annex E.1 for documentation. However, suppliers shall declare the control of their production. Alternatively, material reception tests can be done to confirm the properties of the materials.

(2) If data as per Clause C.4.3.2 is not available e.g. for ready mix grout, the performance as per Clause C.4.3.3 of each special grout supply to a particular site shall be confirmed with the tests specified in Clause C.4.3.3, and certified by the supplier, see Annex E.1.

In addition to the above Items (1) and (2), on site suitability and confirmation testing of all special grout shall be performed as specified in EN 446 for common grout. However, instead of each bleed test according to EN 445, one "Wick-induced" test according to C.4.3.3.2.3 shall be done on site. Such tests shall be performed before start of grouting to confirm the special grout properties achieved in testing as per Clause C.4.3.3, and shall additionally be performed during grouting to confirm the consistency of the achieved results. All the test results shall be kept available for the record.

Annex D

D ANNEXES RELEVANT FOR ETAG CHAPTER 7

Contents

- D.1 RECOMMENDATIONS ON THE ORGANISATION OF THE ETA HOLDER AND PT SPECIALIST COMPANIES
- D.2 ITEMS RECOMMENDED TO BE VERIFIED AS COMPATIBLE WITH THE GENERAL DESIGN AND DETAILING OF POST-TENSIONED STRUCTURES
- D.3 RECOMMENDED MINIMUM CONTENTS OF A QUALITY PLAN FOR A JOB SITE

D.1 RECOMMENDATIONS ON THE ORGANISATION OF THE ETA HOLDER AND PT SPECIALIST COMPANIES

D.1.1 General

D.1.1.1 ETA holder

The ETA holder and PT specialist companies should have the resources to perform and/or take responsibility for the tasks detailed in Fig. D.1.1.

D.1.1.2 PT specialist company

The PT specialist companies should have at least the resources to perform and/or take responsibility for the tasks detailed in Fig. D.1.1 under logistics and site operations.

D.1.2 Technical

D.1.2.1 Responsibilities

The ETA holder should have the resources to take responsibility for the tasks detailed in Fig. D.1.1 under technical.

In so far as the ETA holder is involved in the detailing of a structure, the technical staff should have the responsibility to check that the PT system and installation methods are compatible with the general design prepared by the consultant and the construction methods proposed by the general contractor. If discrepancies occur, the technical staff should be able to suggest improvements to the other parties so as to ensure this compatibility.

A list of items recommended to be verified as compatible with the general design and detailing of post-tensioned structures is given in Annex D.2.

D.1.2.2 Personnel qualification

The technical side should be headed by a chartered engineer or equivalent with a minimum of 5 years experience in PT systems.

Key technical staff should have had 3 years experience in their field of expertise.

All technical staff should receive regular training to keep up to date with the technology in design, procedures, regulations and standards. The training programme should be available.

D.1.2.3 Procedures

The ETA holder should have documented procedure covering the key elements listed below :

- structure of the technical department
- responsibilities of each of its members
- system of communication with the consultant and the client
- organisation of the internal control
- system documentation and filing
- method statements for each phase of construction.

D.1.3 Logistics

D.1.3.1 Responsibilities

The ETA holder and PT specialist companies should have the resources to take responsibility for the tasks detailed in Fig. D.1.1 under logistics.

The responsibilities include the procurement and/or or manufacturing of all materials, components and equipment necessary to execute the PT works in accordance with the technical specifications of the ETA holder and the terms of the ETA.

D.1.3.2 Personnel qualification

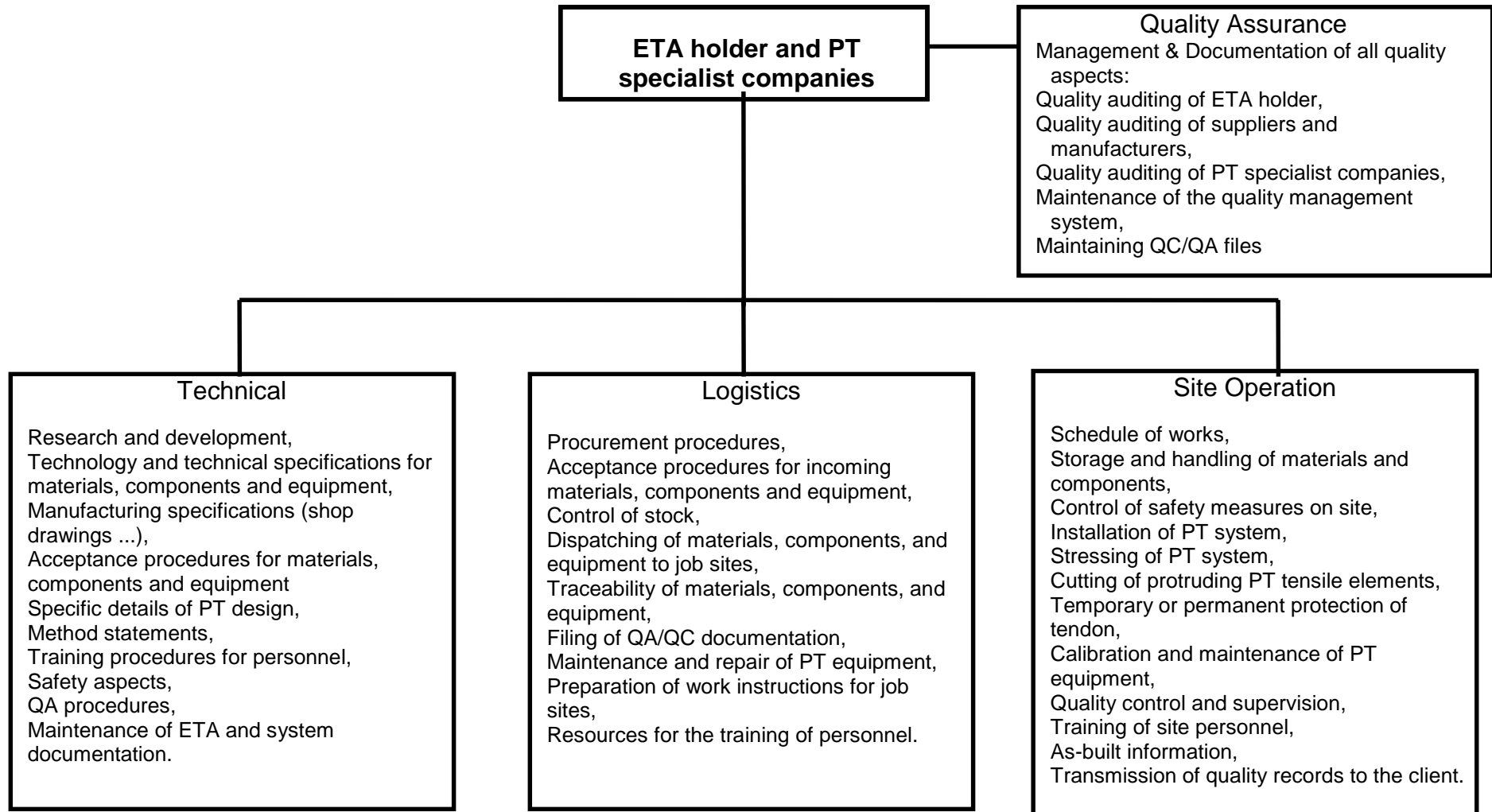
Suitable staff should be in place for procurement, packaging, dispatch, storage and traceability of materials, components and equipment. Logistics personnel should be knowledgeable in safety aspects of the system. CV's of personnel and training records should be available.

D.1.3.3 Procedures

The ETA holder and PT specialist companies should prepare the procedures for procurement and control in full conformity with the technical specifications, the safety regulations and the ETA.

The ETA holder and PT specialist companies should collect quality documentation to ensure the full traceability as per the quality assurance procedures defined by the ETA holder. It should provide certificates of conformity for materials, components and equipment supplied to the operational site.

Figure D.1.1: Recommended resources of the ETA holder and PT specialist companies



D.1.4 Site operations

D.1.4.1 Responsibilities

The ETA holder and the PT specialist companies should have the resources to take responsibility for the tasks detailed in Fig. D.1.1 under site operations. These responsibilities also include:

- ensuring that the PT system is prepared and installed in accordance with the ETA with consistent quality;
- dealing with unforeseen problems on site;
- training and maintaining training records for PT specialist personnel;
- accumulating and recording as-built information
- maintaining and following the relevant method statements for each phase of construction.

D.1.4.2 Personnel

Depending on the complexity and the importance of the job, the site should be headed by a PT site manager or a PT supervisor. Therefore the PT specialist company should include one or several PT site managers and one or several PT supervisors.

The PT site manager should have a minimum of 5 years site experience in PT activities, with a minimum of 12 months experience with the specific PT system of the ETA holder.

The PT supervisor should have a minimum of 2 years site experience in PT activities, with a minimum of 6 months experience with the specific PT system of the ETA holder.

Both should be familiar with matters relating to:

- materials, components and equipment for the PT system
- storage, handling, and installation of components and PT system
- safety conditions for personnel
- stressing
- temporary and/or permanent protection procedures, e.g. filling of duct.

All site staff should be given regular training to keep up to date with the technology, design, procedures, regulations and standards. The training programme should be available.

D.1.4.3 Procedures

The PT specialist company should prepare:

(a) General procedures covering each construction stage. Such procedures should be based on those issued by the technical department of the ETA holder, and be in a form that is easily understandable by the site staff and operators.

(b) A model quality assurance plan including as a minimum the following aspects:

- Materials, components traceability and delivery acceptance,
- Storage and handling of materials and components,
- Control of safety measures on site, personal protective equipment,
- Installation of PT system,
- Stressing of PT system
- Cutting of protruding tensile elements,
- Filling of duct or alternative permanent protection
- Calibration and maintenance of equipment
- Quality control and supervision,
- Training of site personnel,
- As-built information.

- (c) A site specific PT quality assurance plan based on the model with relevant procedures adapted to the specific site, prepared in conjunction with the main contractor, as required by the project specification.

Annex D.3 provides more detail of the typical minimum content of a site specific quality assurance plan.

D.2 ITEMS RECOMMENDED TO BE VERIFIED AS COMPATIBLE WITH THE GENERAL DESIGN AND DETAILING OF POST-TENSIONED STRUCTURES

Selection of appropriate prestressing units within the constraints imposed by the design prepared by the consulting engineer. The units should fit the dimensions of the members and the general arrangement of the construction.

Selection of suitable types and models of anchorages (a type is defined by a function to fulfil: active anchorage, dead anchorage, mobile coupler; fixed coupler, etc. Within each type there may be several models in the PT system).

Selection of adequate type of ducts, according to the type of tendon (internal or external) and to the mode of installation of the tendons (prefabricated tendons or tendons threaded in situ into ducts before or after concreting).

Selection of appropriate protection systems, compatible with the environmental conditions and with the intended abilities of the tendon (e.g. replaceability).

Improvement of the tendon layout, checking:

- the position of the anchorages, they should comply with the requirements for edge distance and spacing stipulated in the ETA, present the necessary clearance for the placing and operating the jacks, and avoid areas where accumulation of water may be detrimental to the structure,
- the radii of curvature of the ducts,
- the grouping of ducts into bundles,
- the suitability of the duct spacing,
- the compatibility of their arrangement with the reinforcing steels specified by the consulting engineer,
- the adequacy of the reinforcement in the anchorage zone (bursting reinforcement and general stability reinforcement).

Verification of the assumptions on the friction and wobble coefficients and on the concrete strength required prior to stressing of tensile elements.

Additional transverse tensile loads caused by the distribution of the prestressing load over the cross section of a member or structure should be determined by the engineer responsible for the design of the structure, and should be covered by reinforcement shown on the construction drawings. This reinforcement does not form part of the PT system approval. This verification does apply to all systems but is of particular importance for external tendons anchored in blisters. In certain cases the bursting reinforcement defined in the ETA may need to be adapted to suit the design of the structure. Such adaptation should be agreed with the ETA holder and approved by the designer.

D.3 RECOMMENDED MINIMUM CONTENTS OF A QUALITY PLAN FOR A JOB SITE

The quality plan should cover general operations and specific site requirements. They should include at least:

- (1) definition of organisational responsibilities and authorities, particularly those pertaining to quality control,
- (2) procedures for communication between on-site and off-site activities of the management / design team,
- (3) method statements for all on-site activities, including procedures for dealing with work instructions, quality control procedures, inspection and possible test arrangements, control of safety measures on site,
- (4) procedures to ensure raw materials and sub-contracted services comply with the specification, (traceability of raw materials/components will be as required in the project specification),
- (5) procedures for packaging, storage, transportation and handling of materials and components,
- (6) procedures for installation,
- (7) procedures for stressing,
- (8) procedures for filling of duct / application of alternative permanent protection,
- (9) procedures for cutting protruding tensile elements and for sealing,
- (10) procedures to check site staff are suitably trained and qualified,
- (11) procedures for work review, quality audits and filing of quality records including as-built information.

Each phase of the construction process should be dealt with. Typically this would include:

- (a) general information:
 - list of equipment used on the site,
 - definition of reference documents relating to design parameters e.g. required concrete strength prior to stressing tendons, possible tendon stressing order, routine compliance tests,
- (b) identification of materials:
 - origin of incorporated materials, including full traceability when required in the project specification
 - certification documentation relating to materials and components,
 - packaging, handling, transportation and storage procedures.
- (c) Ducts and vents installation and testing:
 - procedure for the installation of the duct system including ducts, duct connectors, connections for filling of duct, vents, vent connections, drains and transitions to anchorages and couplers caps.
 - If specified in the project specification the procedure for testing the tightness of the duct system (e.g. leak tightness test as specified in Annex B.6.4).
- (d) Tendons and anchorages installation and stressing:
 - procedure for temporary protection during installation,

- procedure in accordance with EC2, [11], and the contract specification including the measurement of tendon load and elongation for verification,
 - special procedure for short length tendons,
 - special procedure for assessing friction coefficient and verifying that intended initial stressing load is reached,
 - procedure for cutting of over-length of tensile elements and protection against corrosion and mechanical damage.
 - procedure for dealing with non-conformity or incidents.
- (e) Filling of duct and/or permanent corrosion protection:
- reference documents defining composition and acceptable variation in the composition of the filling material,
 - procedure for assigning batch numbers, ensuring compliance and maintaining records,
 - preparation of the duct
 - procedure for mixing and filling of duct including maximum rates of filling of duct and minimum volume of filling material at the outlet,
 - procedure for operating in cold or hot weather,
 - procedure for tests before and during filling of duct,
 - procedure in the event of a breakdown of equipment for filling of duct,
 - procedure for sealing of duct and vents after filling of duct.

Annex E

E ANNEXES RELEVANT FOR ETAG CHAPTER 8

Contents

E.1 BASIC ELEMENTS OF PRESCRIBED TEST PLAN

E.2 BASIC ELEMENTS OF AUDIT TESTING

E.3 SINGLE TENSILE ELEMENT TEST

E.1 BASIC ELEMENTS OF PRESCRIBED TEST PLAN

The kit manufacturer has to ensure, that all components of the PT kit or the individual components for which the ETA has been issued comply with the specifications given in the ETA. For the most important components, the Table E.1 given below summarises the minimum procedures which have to be performed. For all other components of the PT kit, not mentioned in the table below, the FPC has to include appropriate measures. The Approval Body has to adapt this table according to the importance of the components for the performance of the PT system. The information, given in the table below, represents the reference for this adaptation.

In any case, this possibly adapted table has to be included as part of the ETA, preferably in an Annex.

Table E.1: Minimum content of the Prescribed Test Plan

Prescribed Test Plan– Minimum procedures to be performed					
1	2	3	4	5	6
Component	Item	Test/Check	Traceability ⁴	Minimum frequency	Documentation
The Approval Body has to adapt the following according to the needs of the PT system covered by the ETA. This adaptation may include changes of the information given in the table as well as additional components and procedures. In any case, deviations of the information given below have to be justified.					
Bearing plate	material ⁷	check	bulk ⁶	100 %	"2.2" ^{1,6}
	detailed dimensions ⁵	test		3 % ≥ 2 specimen	yes
	visual inspection ³	check		100 %	no
Anchor head/block	material ⁷	check	full	100 %	"3.1.B" ¹
	detailed dimensions ⁵	test		5 % ≥ 2 specimen	yes
	visual inspection ³	check		100 %	no
Wedge, nut, ...	material ⁷	check	full	100 %	"3.1.B" ¹
	treatment, hardness	test		0,5 % ≥ 2 specimen	yes
	detailed dimensions ⁵	test		5 % ≥ 2 specimen	yes
	visual inspection ³	check		100 %	no

Prescribed Test Plan– Minimum procedures to be performed - continued -					
1	2	3	4	5	6
Component	Item	Test/Check	Traceability ⁴	Minimum frequency	Documentation
Duct	material ⁷	check	"CE" ²	100 %	"CE" ²
	visual inspection ³	check		100 %	no
Tensile element (strand, bar, wire)	material ⁷	check	"CE" ²	100 %	"CE" ²
	diameter	test		each coil/bundle	no
	visual inspection ³	check		each coil/bundle	no
Constituents of filling material as per EN 447	cement ⁷	check	full	100 %	"CE" ²
	admixtures, additions, ... ⁷	check	bulk	100 %	"CE" ²
Monostrands, Annex C.1	material ⁷	check	full	100 %	"CE" ⁸
Plastic pipes, Annex C.2	material ⁷	check	full	100 %	"CE" ²
Plastic ducts, Annex C.3	material ⁷	check	full	100 %	"CE" ⁸
Grease, Annex C.4.1	material ⁷	check	full	100 %	"CE" ⁸
Wax, Annex C.4.2	material ⁷	check	full	100 %	"CE" ⁸
Special grout, Annex C.4.3	material ⁷	check	full	100 %	"CE" ⁸
Other important components, as relevant	To be added by the Approval Body, as relevant				

All samples shall be randomly selected and clearly identified.

Details on sampling procedures including methods of recording as well as test methods shall be agreed between the Approval Body and the kit manufacturer as part of the prescribed test plan. Preferably standardised sampling and test methods shall be used. Generally all results shall be reported in the test reports in such a way to enable direct comparison with the specification's data in the ETA or subsidiary documentation.

- 1 "2.2" : Test report type "2.2" according to EN 10204 (this applies to simple steel bearing plates only)
- 2 "3.1.B" : Inspection certificate type "3.1.B" according to EN 10204
If 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.
- 3 Visual inspections means e.g.: Main dimensions, gauge testing, correct marking or labelling, appropriate performance, surface, fins, kinks, smoothness, corrosion, coating, etc., as given in the prescribed test plan

- 4 full : Full traceability of each component to its raw material.
bulk : Traceability of each delivery of components to a defined point.
- 5 Detailed dimensions mean measuring of all dimensions and angles according to the specification as given in the prescribed test plan
- 6 Only if the force transfer unit is a "simple" plate. Otherwise appropriate procedures have to be introduced.
- 7 Material checks are included for information only as these are not part of the prescribed test plan.
- 8 If the basis of "CE"-marking is not available, the prescribed test plan has to include appropriate measures. The certificate shall be based on specific testing on the fabrication lot from which the supply has been produced, to confirm specified properties, and shall be prepared by a department of the supplier which is independent of the production department.

E.2 BASIC ELEMENTS OF AUDIT TESTING

During surveillance inspections, the CB has to take samples of components of the PT kit or the individual components for which the ETA has been granted for independent testing. For the most important components, the Table E.2 given below summarises the minimum procedures which have to be performed by the CB. The Approval Body has to adapt this table according to the importance of the components for the performance of the PT system. The information, given in the Table E.2 below, represents the reference for this adaptation.

In any case, this possibly adapted table has to be included as part of the ETA, preferably in an Annex.

Table E.2: Audit testing

Audit Testing – Minimum Procedures to be Performed			
1	2	3	4
The Approval Body has to adapt the following according to the needs of the PT system covered by the ETA. This adaptation may include changes of the information given in the table as well as additional components and procedures. In any case, deviations of the information given below have to be justified.			
Component	Item	Test/Check	Sampling - Number of components per visit
Anchor head/block	material according to specification	check, test	1
	detailed dimensions	test	
	visual inspection ¹	check	
Wedge, nut, ...	material according to specification	check, test	2
	treatment	test	2
	detailed dimensions	test	1
	main dimensions, surface hardness	test	5
	visual inspection ¹	check	5

¹ Visual inspections means e.g.: Main dimensions, gauge testing, correct marking or labelling, appropriate performance, surface, fins, kinks, smoothness, corrosion, coating, etc.

Audit Testing – Minimum Procedures to be Performed			
- continued -			
1	2	3	4
Single tensile element test.	single tensile element tensile test according to Annex E.3	test	1 series
Inclined Tube test	Inclined Tube test as per Clause C.4.3.3.2.1	test	1 test
Other important components, as relevant	To be added by the Approval Body, as relevant		

All samples shall be randomly selected and clearly identified.

Details on sampling procedures including methods of recording as well as test methods shall be agreed between the Approval Body and the kit manufacturer as part of the prescribed test plan. Preferably standardised sampling and test methods shall be used. Generally all results shall be reported in the test reports in such a way to enable direct comparison with the specification's data in the ETA or subsidiary documentation.

If bearing plates are not of "simple plate type" they shall be included into the Audit Testing.

E.3 SINGLE TENSILE ELEMENT TEST

E.3.1 Scope

This Annex 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.

E.3.2 Apparatus

E.3.2.1 Tensile testing machine

The tensile testing machine shall be verified in accordance with ISO 7500-1 and shall be of class 1 or better.

E.3.2.2 Extensometer

The extensometer shall be of class 2 or better according to ISO 9513.

E.3.2.3 Distance of cross heads

An instrument with a resolution of 1 mm or better shall be used.

E.3.2.4 Supporting plate

If required supporting plates to adjust the angle between tensile element and anchor head are needed.

E.3.2.5 Inclination

A goniometer or gauges, suitable to determine the inclination with a resolution of 0,5° or better shall be used.

E.3.3 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) different holes of the anchor head, which, if enough holes are available, can be of one anchor head.

Individual components of an approved 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 a anchor head, shall be assembled exactly as given in the ETA. Preparation of the anchorage (grease, ...) are allowed only according to ETA prescription. 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.
Note: It is recommended to take a sample, large enough to perform additional tests if necessary.
- Geometrical and mechanical properties of anchorage components.

E.3.4 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. Fig. E.3.1 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 Fpm; then released to approximately 5% of Fpm.

The specimen is then stressed gradually to failure with an increase of load at a speed not more than 15 N/(mm² · s) or according to Clause 10.1.2 of ISO 6892.

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..

E.3.5 Evaluation and requirements

Requirements R for the individual tests:

R(1) The specimen shall fail by fracture of the tensile element. Consequently, failure of the specimen shall not be induced by the failure of anchorage components.

R(2) The measured maximum force of all individual tests shall be $\geq 95\%$ of the actual resisting force of the tensile element.

R(3) Total elongation in free length of the tensile element at measured maximum force shall be $\geq 2\%$.

If failure of the tensile element occurs in the anchorage or in the grip of the testing machine, and the requirements R(1) to R(3) 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 R(1) to R(3) 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 requirements R(1) to R(3), 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 CB explaining the reason for the failure, and proposing eventual corrective measures. After consideration of the report, the CB will decide on any eventual actions to be implemented or taken.

E.3.6 Test report

For each test series an individual test report shall be prepared.

The test report shall include the following information:

- Reference to this Annex and this ETAG.
- Identification of the components used.
- Properties of tensile element and anchorage components according to E.3.3.
- Identification of tensile testing machine used.
- Method used to determine elongation at measured maximum force.
- Configuration of the individual specimens of the individual tests, including possibly invalid tests.
- Measurements and observations of each individual test according to E.3.4, including possibly invalid tests.
- Comparison of the results of the individual tests with the requirements of E.3.5.
- Statement whether the test series has passed or failed.
- Name and position held by the person empowered to sign the test report.
- Date.
- Signature.

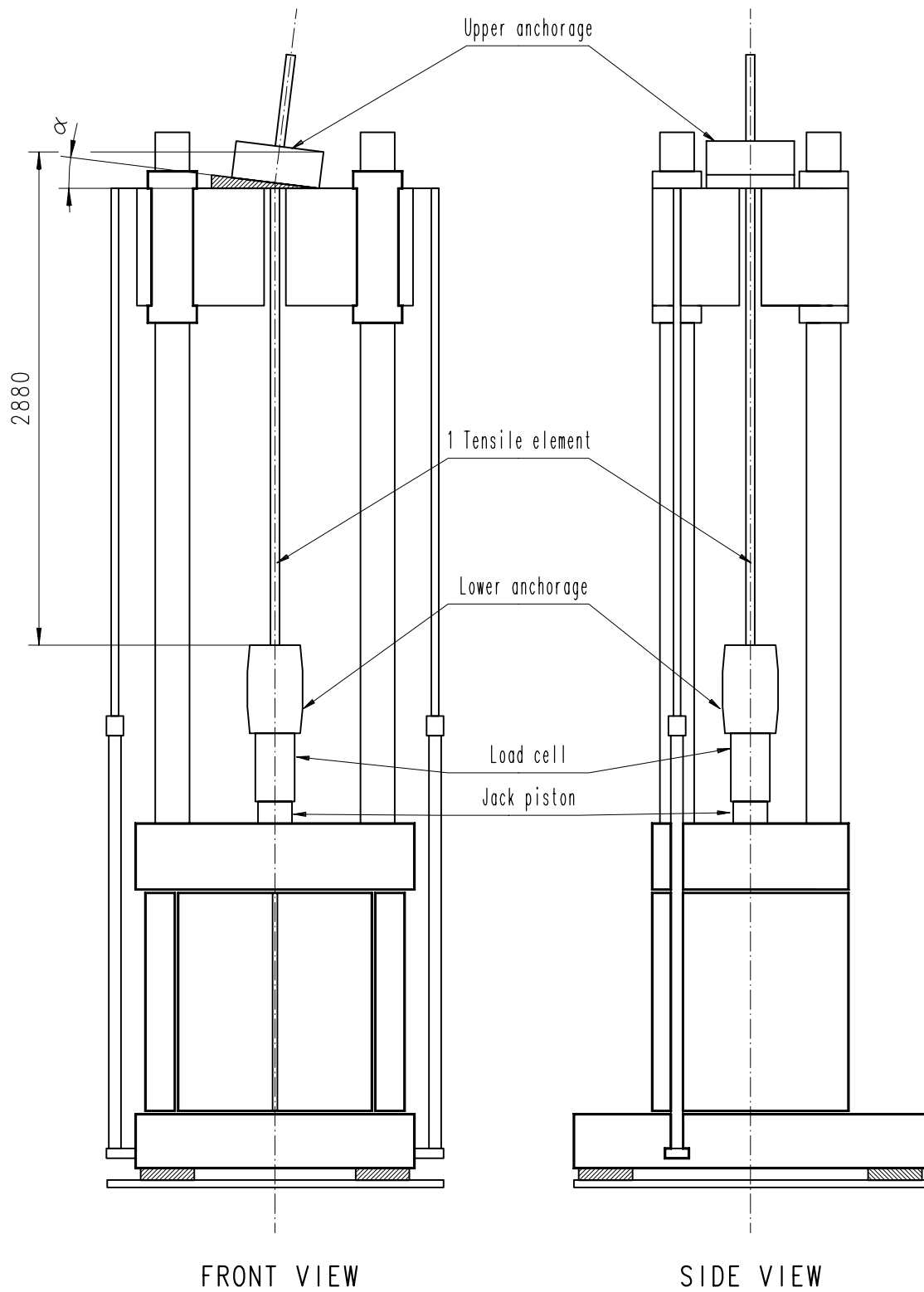


Figure E.3.1 : Single tensile element test - principle of test set up

Annex F

F PROPOSED STANDARD FORMAT FOR PT SYSTEM DATA SHEET

Designation of tendon:

Prestressing steel:

- | | | | | |
|--|---|----------|-------|--------------------|
| - Type | wire strand bar
(mark relevant type) | | | |
| - Strength | | f_{pk} | ..... | (MPa) |
| - Nominal cross section | | A_p | ..... | (mm ²) |
| - Relaxation at 0.70 f_{pk} after 1000 hours |  |  | ..... | (%) |
| - Modulus of elasticity | | E_p | ..... | (MPa) |

Tendon:

- | | | | | |
|---|---|-------------------------|-------|-----------------------|
| - Type | bonded unbonded internal external
(mark and / or specify relevant type) | | | use category (a to i) |
| - Corrosion protection | grout greased and sheathed
(mark and / or specify) | | | other |
| - Weight of tendon
(kg/m) | | | g_p | |
| - Force at 1.00 f_{pk} | | F_{pk} | ..... | (kN) |
| - Friction coefficient | | μ | ..... | - |
| - Unintentional deviation / Wobble coefficient | | k | ..... | (rad/m) |
| - Minimum radius of curvature | | R_{min} | ..... | (m) |
| - Duct outside and inside diameter, and thickness | | d_{out} d_{int} t | ..... | (mm) |
| - Maximum spacing of duct supports | | s_{max} | ..... | (m) |

Anchorage:

- | | | | | |
|--|--|------------|-------|-------|
| - Type | stressing fixed coupler
(mark and / or specify) | | | |
| - Minimum centre spacing
For mean concrete strength | | a_c, b_c | | (mm) |
| | | $f_{cm,0}$ | ..... | (MPa) |
| - Minimum edge distance
For mean concrete strength | | a_e, b_e | | (mm) |
| | | $f_{cm,0}$ | ..... | (MPa) |
| - Anchorage seating |  |  | ..... | (mm) |