BS EN 1537:2013

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Execution of special geotechnical works — Ground anchors

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National foreword

This British Standard is the UK implementation of EN 1537:2013. It supersedes BS EN 1537:2000 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee B/526, Geotechnics.

A list of organizations represented on this committee can be obtained on request to its secretary.

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Execution of special geotechnical works - Ground anchors

Exécution des travaux géotechniques spéciaux - Tirants d'ancrage

Ausführung von Arbeiten im Spezialtiefbau - Verpressanker

This European Standard was approved by CEN on 8 May 2013.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CEN member.

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Foreword

This document (EN 1537:2013) has been prepared by Technical Committee CEN/TC 288 “Execution of special geotechnical works”, the secretariat of which is held by AFNOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by January 2014, and conflicting national standards shall be withdrawn at the latest by January 2014.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document supersedes EN 1537:1999.

The remit of CEN/TC 288 is the standardisation of the execution procedures for geotechnical works (including testing and control methods) and of the required material properties. CEN/TC 288/WG 14 has been charged with the revision of EN 1537:1999 in the subject area of ground anchors, which includes all anchors that are bonded to the ground by grout and are stressed and tested.

This standard has been prepared to stand alongside EN 1997-1, *Eurocode 7: Geotechnical design — Part 1: General rules*, and prEN ISO 22477-5, *Geotechnical investigation and testing — Testing of geotechnical structures — Part 5*. Design, safety aspects and testing, which were included as the informative Annexes D and E in the previous issue of this standard (EN 1537:1999), were consequently taken out of this present issue. Clause 7, “Considerations related to design” of this standard deals only with those design matters that should be taken into account during the execution stage of ground anchors so that the design of the anchor system may be fulfilled. In addition, this standard provides full coverage of the construction and supervision requirements.

The revision of this standard was effected by a working group comprising of delegates from ten countries and the comments of these countries have been taken into account. The main amendments are:

— definitions and terminology brought into accordance with the definitions and terminology of EN 1997-1:2004, *Eurocode 7*, in particular with Section 8;

— alignment of this European Standard with prEN ISO 22477-5;

— structural revisions to match the structure of this standard with that of other standards for special geotechnical works, e.g. EN 1536, *Execution of special geotechnical work — Bored piles* and EN 1538, *Execution of special geotechnical work — Diaphragm walls*;

— general revision in accordance with comments received during the CEN Enquiry, 2010;

— update of references.

As long as EN ISO 22477-5 is not available, national solutions should be implemented for the testing of anchors.

According to the CEN-CENELEC Internal Regulations, the national standards organisations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

1 Scope

1.1 This European Standard covers ground anchors grouted into the ground which are stressed and tested. They can be used for permanent or temporary applications.

NOTE For the purpose of this standard the term ‘anchor(s)’ refers to ‘ground anchor(s)’.

1.2 The anchors are designed in accordance with EN 1997-1 and are tested in accordance with prEN ISO 22477-5.

1.3 Typical bond and compression type anchors are shown in Figure 1 and Figure 2.

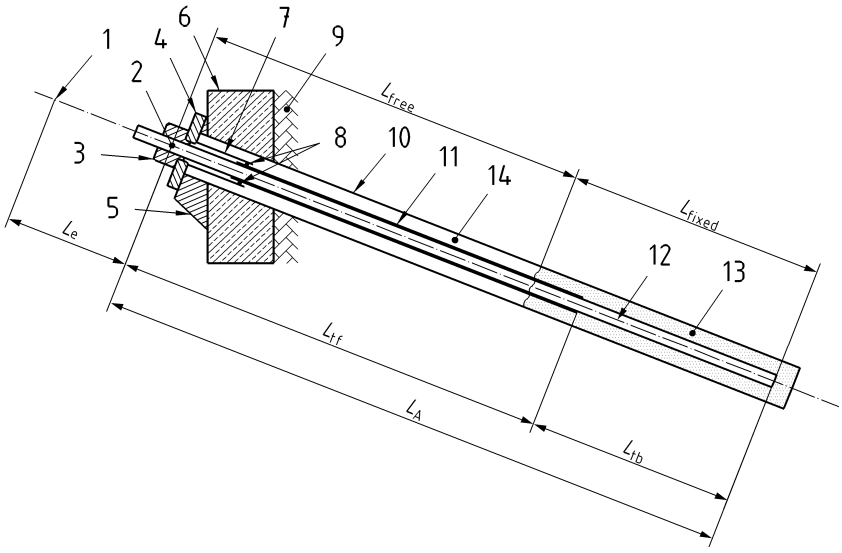
1.4 The term "ground" is taken to encompass soil, rock and fill already in place or existing prior to the execution of the construction work.

1.5 The planning and design of ground anchors calls for experience and knowledge in this specialised field.

1.6 The installation and testing phases require skilled, qualified labour and supervision.

1.7 This standard cannot replace the knowledge of specialist personnel and the expertise of experienced contractors required to apply this standard.

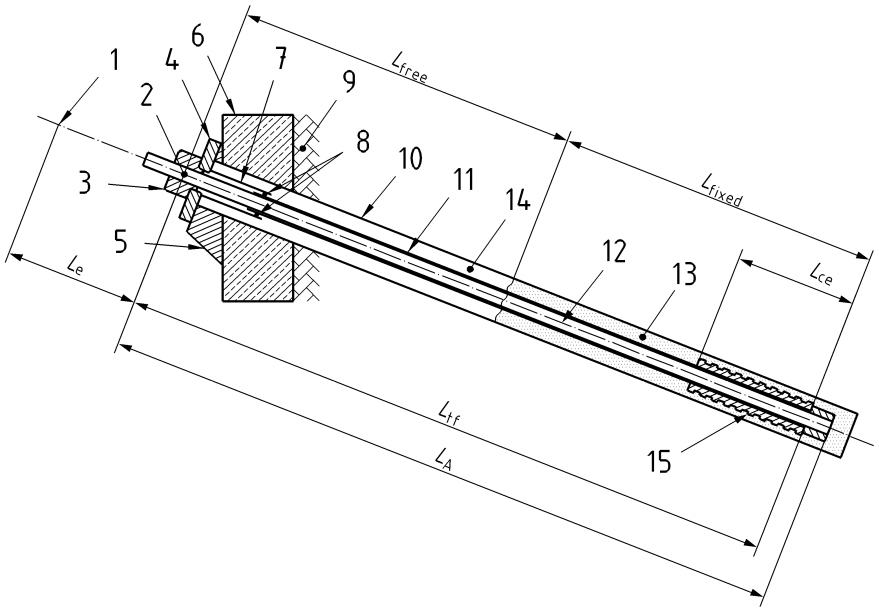
1.8 This standard does not address systems such as tension piles, screw anchors, mechanical anchors, soil nails, dead-man anchors or expander anchors as these do not fulfil the requirements of this standard.



Key

1	anchorage point at jack during stressing	8	O-Ring
2	anchorage point at anchor head in service	9	soil/rock
3	tensioning element at anchor head	10	borehole
4	bearing plate	11	debonding sleeve
5	load transfer block	12	tendon
6	structural element	13	fixed length grout body
7	trumpet or anchor head tube	14	free length filling where appropriate

Figure 1 — Sketch of a bond type ground anchor — Details of anchor head and head protection omitted



Key

1 anchorage point at jack during stressing
2 anchorage point at anchor head in service
3 tensioning element at anchor head
4 bearing plate
5 load transfer block
6 structural element
7 trumpet or anchor head tube
8 O - Ring
9 soil/rock
10 borehole
11 debonding sleeve
12 tendon
13 fixed length grout body
14 free length filling where appropriate
15 compression element

Figure 2 — Sketch of a compression type ground anchor — Details of anchor head and head protection omitted

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 206-1, *Concrete — Part 1: Specification, performance, production and conformity*

EN 447, *Grout for prestressing tendons — Basic requirements*

EN 934-2, *Admixtures for concrete, mortar and grout — Part 2: Concrete admixtures — Definitions, requirements, conformity, marking and labelling*

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

EN 1997-1:2004, *Eurocode 7: Geotechnical design — Part 1: General rules*

EN 1997-2, *Eurocode 7 — Geotechnical design — Part 2: Ground investigation and testing*

EN 10025 (all parts), *Hot-rolled products of structural steels*

EN 10080, *Steel for the reinforcement of concrete — Weldable reinforcing steel — General*

prEN 10138-1, *Prestressing steel — Part 1: General requirements*

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

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

EN 10219-2, *Cold formed welded structural hollow sections of non-alloy and fine grain steels — Part 2: Tolerances, dimensions and sectional properties*

EN ISO 12944-5, *Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Part 5: Protective paint systems (ISO 12944-5)*

prEN ISO 22477-5, *Geotechnical investigation and testing — Testing of geotechnical structures — Part 5: Testing of anchorages (ISO/DIS 22477-5)*[1)]

ETAG 013, *Post-tensioning kits for prestressing of structures*

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1.1
anchor head
fr: tête d'ancrage
de: Ankerkopf
element of a ground anchor which transmits the tensile load from the tendon to the bearing plate or the structure

1) In preparation.

3.1.2
anchor system
fr: système d'ancrage
de: Ankersystem
system comprising specific components and materials which collectively form the ground anchor

3.1.3
acceptance test
fr: essai de réception
de: Abnahmeprüfung
load test to confirm that each anchor conforms with the acceptance criteria

3.1.4
apparent tendon free length
fr: longueur libre équivalente de l'armature
de: Rechnerische freie Stahllänge
length of tendon which is estimated to be fully decoupled from the surrounding grout and is calculated from the load-elastic displacement data following testing

3.1.5
borehole diameter
fr: diamètre de forage
de: Bohrlochdurchmesser
diameter of a borehole as defined by the drill bit or casing diameter, excluding any enlargements

3.1.6
compression type anchor
fr: tirant à élément de compression
de: Druckrohranker
ground anchor, the load of which is transferred via a decoupled steel tendon down to the bottom of the borehole, and from there via a compression element and the borehole grout into the ground

3.1.7
compression element length
fr: longeur d'élément de compression
de: Druckrohrlänge
length of the compression element for load transfer of a compression type anchor

3.1.8
coupler
fr: coupleur
de: Koppelelement
device for joining the lengths of bar or strand which comprise an anchor tendon

3.1.9
critical creep load
fr: traction critique de fluage
de: Kritische Kriechkraft
anchor load corresponding to the end of the first linear part of a plot of anchor load against creep rate

3.1.10
datum load
fr: traction de référence
de: Vorbelastung
level of anchor load from which the anchor head displacement is measured during a stress test

3.1.11
encapsulation
fr: protection
de: Korrosionsschutzumhüllung
corrosion protection barrier which is typically a plastic or metallic tube applied to the tendon

3.1.12
fixed anchor length
fr: longueur de scellement du tirant
de: Krafteintragungslänge
designed length of an anchor over which the load is transmitted to the surrounding ground, through a grout body

3.1.13
free anchor length
fr: longueur libre du tirant
de: Freie Ankerlänge
distance between the proximal end of the fixed anchor length and the tendon anchorage point at the anchor head

3.1.14
ground anchor
fr: tirant d'ancrage
de: Verpressanker
structural element capable of transmitting an applied tensile load to a load-bearing stratum; it consists of an anchor head, a free anchor length and a fixed anchor length

3.1.15
grout
fr: coulis
de: Verpressgut
fluid mixture of a binding and/or setting agent (usually cement) and water that hardens after being placed in position

3.1.16
investigation test
fr: essai préalable
de: Untersuchungsprüfung
load test to establish the ultimate load resistance of an anchor at the ground/grout interface and to determine the characteristics of the anchor in the working load range

3.1.17
lock-off load
fr: traction de blocage
de: Festlegekraft
load transferred to an anchor head immediately on completion of a stressing operation

3.1.18
permanent anchor
fr: tirant d'ancrage permanent
de: Daueranker
anchor with a design life in excess of two years

3.1.19
proof load
fr: traction d'épreuve
de: Prüfkraft
maximum test load to which an anchor is subjected

3.1.20
suitability test
fr: essai de contrôle
de: Eignungsprüfung
load test to confirm that a particular anchor design will be adequate in particular ground conditions

3.1.21
temporary anchor
fr: tirant d'ancrage provisoire
de: Kurzzeitanker
anchor with a design life of two years or less

3.1.22
tendon
fr: armature
de: Zugglied
part of a ground anchor that is capable of transmitting the tensile load from the fixed anchor length to the anchor head

3.1.23
tendon bond length
fr: longueur de scellement de l'armature
de: Verankerungslänge des Zuggliedes
length of the tendon that is bonded directly to the grout and capable of transmitting the applied tensile load

3.1.24
tendon free length
fr: longueur libre de l'armature
de: Freie Stahllänge
length of tendon between the anchorage point at the anchor head and the proximal end of the tendon bond length

3.2 Symbols

A_t	Cross sectional area of anchor tendon
E_t	Elastic modulus of anchor tendon
f_{tk}	Characteristic tensile strength of a tendon
L_A	Anchor length
L_{app}	Apparent tendon free length
L_e	External length of tendon measured from the tendon anchorage in the anchor head to the anchorage point in the stressing jack
L_{ce}	Length of compression element
L_{fixed}	Fixed anchor length

L_{free} Free anchor length

L_{tb} Tendon bond length

L_{tf} Tendon free length

P_a Datum load

P_o Anchor lock-off load

P_p Proof load

4 Information needed for the execution of the work

4.1 General

4.1.1 Prior to the execution of the work, all necessary information shall be provided and shall include:

— any legal or statutory restrictions;

— execution specifications (see Note);

— the location of main grid lines for setting out;

— the conditions of structures, roads, services, etc. adjacent to the work, including any necessary surveys;

— a suitable quality management system, including supervision, monitoring and testing.

NOTE The execution specification consists of documents covering all drawings, technical data and requirements necessary for the execution of a particular project. The execution specification is not one document but signifies the total sum of documents required for the execution of the work. It includes the project specification prepared in order to supplement and qualify the requirements of this European Standard as well as to refer to the national provisions relevant in the place of use.

4.1.2 The information regarding the site conditions shall cover, where relevant:

— the geometry of the site, including boundary conditions, topography, access, slopes, headroom restrictions;

— the existing underground structures, services and aerial photographs, known contaminations, and archaeological constraints;

— the environmental restrictions, including noise, vibration, pollution;

— the future or ongoing activities such as dewatering, tunnelling, deep excavations.

4.2 Special features

4.2.1 Anchor testing and the verification of design parameters are necessary elements in the construction procedure.

4.2.2 Activities required for the design, execution, testing and maintenance of the ground anchors and the interface between these activities shall be defined before the start of the work.

4.2.3 The following shall be provided prior to the initial supply and installation of the ground anchor system:

— details of the ground anchor project and the construction sequence and programme;

— a site investigation report incorporating a geotechnical classification and engineering properties of the ground in which the ground anchors are to be located;

— information on all other boundary conditions, including underground services, existing foundations and requirements relevant to the location and performance of the ground anchors;

— details of ownership of the ground into which the anchors are to be installed;

— details of any agreement required to gain access to ground into which the anchors are to be installed.

— details of requirements, where relevant, for destressing and/or removing anchors when they are no longer required.

4.2.4 Environmental issues, including the use of grout, removal of soil, water recycling, noise and vibration shall be considered in the design and planning of the work.

5 Geotechnical investigation

5.1 General

5.1.1 The geotechnical investigation shall fulfil the requirements of EN 1997-1.

5.1.2 The geotechnical investigation report shall be made available in enough time to allow for the reliable design and execution of the special geotechnical works.

5.1.3 The geotechnical investigation shall be checked to see whether it is sufficient for the design and execution of the special geotechnical works.

5.1.4 If the geotechnical investigations are not sufficient, a supplementary investigation shall be conducted.

5.2 Specific requirements

5.2.1 All geotechnical investigations shall be undertaken in accordance with the requirements and recommendations of EN 1997-1 and EN 1997-2.

5.2.2 This can be achieved through the execution of an appropriate ground investigation or by reference to pre-existing information of surrounding ground conditions.

5.2.3 Since inclined ground anchors are installed commonly as vertical anchors, lateral variations in ground properties should be investigated as thoroughly as the vertical variations.

5.2.4 Geotechnical investigations should be extended to site extremities and, where possible, extended to include ground formations outside the actual site if stresses induced by anchors extend beyond the site. This enables the strata profile to be interpolated between the investigation locations rather than extrapolated outside the area investigated.

5.2.5 Where appropriate, the effects of deleterious stray currents should be investigated in accordance with EN 50162.

5.2.6 Depths of the geotechnical investigation should be adequate to ensure that:

a) the anticipated geological formation affected by changes in stresses induced by tensioning the anchor, is confirmed;

b) no underlying stratum will affect design;

c) groundwater conditions are well defined.

5.2.7 From the geotechnical investigation, it should be possible to determine the likelihood of difficulties relating to:

— potential obstructions to drilling;

— the process of borehole drilling (drillability);

— borehole stability;

— flow of ground water in or out of the borehole;

— loss of grout from the borehole.

6 Materials and products

6.1 General

6.1.1 Anchor systems shall be used for which there are documented successful tests and/or experience with respect to performance.

6.1.2 All anchor systems shall have been subjected to relevant investigations to verify the competence of the anchor systems. The investigations shall be documented.

NOTE A relevant investigation of the anchor system includes the demonstration of the adequacy of the anchor system, or elements of the anchor system, acting individually or in combination with each other.

6.1.3 The documented investigation of the anchor system shall be evaluated in accordance with the principles stated in this European Standard.

NOTE The evaluation of the anchor system investigation is undertaken by a suitably qualified and experienced anchor specialist or authority and may be defined in a national document.

6.1.4 All materials used shall be mutually compatible.

NOTE This applies in particular to adjacent materials with a common interface.

6.1.5 Material properties shall not change during the designed service life of the ground anchor in such a way that the anchor loses its serviceability.

NOTE An exception is corrosion inhibiting compound on restressable anchors that can require replenishment in service.

6.2 Anchor components subject to corrosion protection

6.2.1 Tendon

6.2.1.1 All steel tendons shall comply with the following European Standards, where appropriate:

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

— EN 10219-1, *Cold formed welded structural hollow sections of non-alloy and fine grain steels: Technical delivery requirements*;

— EN 10219-2, *Cold formed welded structural hollow sections of non-alloy and fine grain steels: Tolerances, dimensions and section properties*;

— EN 10025 (all parts), *Hot-rolled products of structural steels*;

— EN 10080, *Steel for the reinforcement of concrete — Weldable reinforcing steel — General;*

— prEN 10138-1, *Prestressing steel Part 1 — General requirements*;

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

6.2.1.2 Other tendon materials may only be used if their suitability as anchor components has been proven.

6.2.2 Anchor head

6.2.2.1 The anchor head shall distribute the tendon load to the main structure or to the ground in accordance with the overall design of the structure through designed or tested components.

6.2.2.2 The anchor head shall allow the tendon to be stressed, proof loaded, locked-off and, if required, released, destressed and restressed.

6.2.2.3 The anchor head shall comply with the requirements of ETAG 013.

6.2.3 Coupler

6.2.3.1 Couplers shall comply with EN 1992-1-1.

6.2.3.2 The tendon should not be coupled inside the bond length.

6.2.3.3 The free extension of a steel tendon shall not be compromised by restraint of the coupler.

6.2.3.4 The corrosion protection of the coupler shall be compatible with the corrosion protection provided to the tendon.

6.2.4 Tendon bond length

6.2.4.1 In order to anchor the tendon in the bond length, profiled or ribbed bars, strands or compression tubes shall be used in this section.

6.2.4.2 As a guide, the following types of steel tendon may be anchored by bond action:

— cold-drawn wires profiled after drawing;

— quenched and tempered wires ribbed during hot rolling;

— ribbed bars;

— seven wire strands.

6.2.4.3 The relative area of the ribs of ribbed or profiled wires and bars shall be in accordance with EN 1992-1-1.

6.2.5 Components in the borehole

6.2.5.1 Any component installed and remaining in the borehole shall be spaced and located so that it does not reduce the bond capacity of the anchor.

6.2.5.2 Spacers and centralisers should be located such that minimum grout cover requirements and complete filling of open volume by grout are achieved, and that the tendon, the tendon components, the corrosion protection components and any other component in the borehole are correctly positioned.

6.2.5.3 Spacers and centralisers shall be fixed firmly so that they do not move within the borehole.

6.2.5.4 When used outside an encapsulation, in a permanent anchor, centralisers should be manufactured from corrosion resistant materials.

6.2.5.5 The design of centralisers shall take into account the shape of the hole, e.g. the presence of under-reamed bells, the weight of the tendon, and the susceptibility of the ground to disturbance during insertion of the tendon.

6.2.6 Compression element of a compression type anchor

6.2.6.1 A compression element transfers the anchor load from the distal end of the borehole in a compression type anchor into the grout body. It is loaded with compression only.

6.2.6.2 The compression element of a compression type anchor shall be able to transfer the proof load into the grout body and this shall be proven by a documented investigation in accordance with 6.1.2.

6.2.6.3 The compression element of a compression type anchor shall have a minimum grout cover of 10 mm.

6.2.6.4 The bond capacity of a compression element shall be verified by a documented investigation in accordance with 6.1.2.

6.3 Corrosion protection of steel tendon and stressed steel components

6.3.1 General

6.3.1.1 All steel components shall be protected against corrosion for their designed service life.

NOTE 1 There is no certain way of identifying corrosive circumstance with sufficient precision to predict corrosion rates of steel in the ground.

NOTE 2 The system of corrosion protection is classified by the anchor designed service life (see 3.1.18 and 3.1.21) and the aggressivity of the environment.

6.3.1.2 Corrosion protection elements shall be capable of transmitting tendon loads, where required.

6.3.1.3 All installed tendons and encapsulations shall be provided with a minimum of 10 mm grout cover within the fixed length.

6.3.2 Temporary ground anchor

6.3.2.1 The steel components of a temporary ground anchor shall be provided with protection which will inhibit or prevent corrosion over a minimum designed service life of two years.

Examples of corrosion protection, which may be considered to satisfy the above principles of protection to temporary anchors, are described in Annex C.

6.3.2.2 If the anchor is installed in ground conditions known to be aggressive then appropriate measures shall be taken to protect all parts of the anchor from corrosion.

6.3.2.3 If temporary ground anchors are subjected to unforeseen extended service life or if there are changes in the environmental conditions which can affect the aggressivity of the ground, then appropriate

periodic inspections and service behaviour monitoring should be implemented to assess satisfactory performance.

6.3.2.4 The use of the chosen system for enhanced corrosion protection for temporary ground anchors and its suitability for the project's requirements shall be evaluated in accordance with 6.1.2.

6.3.3 Permanent ground anchor

6.3.3.1 The minimum corrosion protection surrounding the tendon of the anchor shall be a single continuous layer of corrosion preventive material which does not degrade during the designed service life of the anchor.

6.3.3.2 The corrosion protection of the tendon of a permanent ground anchor shall be subjected to relevant investigations to verify the competence of the corrosion protection system.

The evaluation of the anchor corrosion protection investigation is undertaken by a suitably qualified and experienced anchor specialist or authority and may be defined in a national document.

The corrosion protection system shall comprise either:

a) a single protective barrier to corrosion, the integrity of which shall be proven by testing each anchor in situ unless otherwise specified; or

b) two protective barriers to corrosion such, that if one barrier is damaged during installation or anchor loading, the second barrier remains intact.

Examples of corrosion protection which may be considered to satisfy the above principles of protection to permanent anchors are described in Annex C.

6.4 Grouts for corrosion protection and load transfer

6.4.1 Cement grout for temporary anchors

6.4.1.1 When selecting the type of cement for grout placed in contact with the surrounding ground, account shall be taken of the presence of aggressive substances in the environment, e.g. carbonic acid, sulphates, the permeability of the ground and of the designed service life of the anchor.

6.4.1.2 The aggressivity of the environment shall be defined in accordance with EN 206-1.

6.4.1.3 Where cement grout is used for load transmission, water/cement ratios and grout strengths shall be chosen to suit the ground conditions and shall be sufficient for load transfer.

6.4.1.4 Cement grouts in contact with prestressing steel tendons within an encapsulation shall conform in general with EN 447.

6.4.1.5 Where there is conflict between the provisions of this European Standard and EN 447, the provisions of this European Standard shall be adopted.

6.4.1.6 Admixtures as defined in EN 934-2 may be used for improving workability or durability, for reducing bleed or shrinkage, or for increasing rate of strength development.

6.4.1.7 Admixtures shall be free from any constituent liable to damage prestressing steel or the grout itself.

6.4.1.8 No admixture that contains more than 0,1 % of chlorides, sulphides or nitrates shall be used.

6.4.1.9 Where appropriate, inert fillers (e.g. sand) may be incorporated within the grout mix to reduce leakage away from the borehole.

6.4.1.10 Laboratory and field tests shall be undertaken to verify the mixture, mixing efficiency, setting times and performance.

6.4.1.11 These tests should be undertaken in accordance with EN 445, where applicable.

6.4.1.12 Cement grout injected into boreholes is permitted as temporary corrosion protection in a non-aggressive environment, provided that the cover to the tendon is not less than 10 mm throughout its length.

6.4.2 Cement grout for permanent anchors inside encapsulations

6.4.2.1 Cement grouts used in the encapsulation shall conform to EN 447.

6.4.2.2 Admixtures shall be free from any product liable to damage prestressing steel or the grout itself.

6.4.2.3 No admixture that contains more than 0,1 % of chlorides, sulphides or nitrates shall be used.

6.4.2.4 Cement grout in accordance with EN 447 injected under factory (or equivalent) controlled conditions is permitted as one of the two permanent protection barriers, provided that the cover between the tendon and the outer barrier is not less than 5 mm.

6.4.2.5 In the case of tube-à-manchette type anchors, the steel or plastic corrugated duct should be at least 3 mm thick, surrounded by a minimum of 20 mm grout cover injected under a pressure of not less than 500 kPa.

6.4.2.6 The distribution of cracks and their widths can, in certain conditions, be controlled by the distribution of ribs on a bar tendon.

6.4.2.7 Quality control and volume checks shall be made during and after encapsulation grouting.

6.4.3 Cement grout for permanent anchors outside encapsulations

6.4.3.1 Water/cement ratios and grout strengths shall be chosen to suit the ground conditions and shall be sufficient for load transfer.

6.4.3.2 When selecting the type of cement for grout placed in contact with the surrounding ground, account shall be taken of the presence of aggressive substances in the environment, e.g. carbonic acid, sulphates, the permeability of the ground and of the designed service life of the anchor.

6.4.3.3 The aggressivity of the environment shall be defined in accordance with EN 206-1.

6.4.3.4 Admixtures, as defined in EN 934-2 may be used for improving workability or durability, for reducing bleed or shrinkage, or for increasing rate of strength development.

6.4.3.5 Where appropriate, inert fillers (e.g. sand) may be incorporated within the grout mix to reduce leakage away from the borehole.

6.4.4 Resin Grout

6.4.4.1 Resins and resin mortars may be used in ground anchor construction as an alternative to cement grout if their applicability has been proven appropriate in accordance with 6.1.2.

6.4.4.2 Laboratory and field tests shall be undertaken to verify the mixture, mixing efficiency, setting times and performance.

6.4.4.3 Resin grouts injected or placed in a controlled manner with a minimum cover to the tendon of 5 mm are permitted as one permanent barrier providing they are contained, and when stressed do not crack.

NOTE The evaluation of resin grout performance is a specialist activity and requires specialist knowledge and expertise in resin grout technology.

6.5 Other components and materials for corrosion protection barriers

6.5.1 Plastic sheaths and ducts

6.5.1.1 Plastic sheaths and ducts shall conform with relevant European product standards and, in particular, are required to be continuous, impermeable to water, resistant to age brittleness and resistant to ultra-violet radiation damage during storage, transportation and installation.

6.5.1.2 Joints between plastic components shall be fully sealed against the ingress of water by use of appropriate sealants.

6.5.1.3 Where used, PVC shall be resistant to ageing and shall not produce free chlorides.

6.5.1.4 The minimum wall thickness of an external corrugated duct common to one or several tendon elements shall be:

— 1,0 mm for internal diameter ≤ 80 mm;

— 1,2 mm for internal diameter > 80 mm but ≤ 120 mm;

— 1,5 mm for internal diameter > 120 mm.

6.5.1.5 The minimum wall thickness of an external smooth common sheath or duct shall be 1 mm greater than that required for the corrugated ducts, or it shall be reinforced.

6.5.1.6 The minimum wall thickness of an internal sheath and an internal corrugated duct shall be 1,0 mm.

NOTE Where two plastic barriers are provided some protection to the inner barrier is provided during installation by the outer barrier.

6.5.1.7 When used for load transfer, plastic ducts shall be deformed or corrugated.

6.5.1.8 The amplitude and pitch of the deformations or corrugations shall be related to the wall thickness.

6.5.1.9 The amplitude and pitch of the deformations or corrugations shall be able to transfer load in a manner not susceptible to creep losses.

6.5.1.10 Where a corrugated duct, used for grout injection under pressure, is considered as a protective barrier, it should be demonstrated that the grout ports do not allow the ingress of water after grout injection.

6.5.1.11 Such a duct shall be not less than 3 mm thick and the pitch and amplitude of the corrugations shall be suitable for load transfer, as proven by appropriate investigations on relevant components (see 6.1.2).

6.5.1.12 The integrity of the protective barrier should also be demonstrated in the stressed state (see 6.1.2).

6.5.1.13 Where a single plastic duct forms the sole protective barrier of a permanent anchor, an in situ test shall be carried out to verify the integrity of the plastic duct throughout the length of the anchor.

6.5.2 Heat shrink sleeves

6.5.2.1 Heat shrink sleeves may be used to connect sheaths and ducts which encapsulate corrosion protection compounds covering the surface of a steel element.

6.5.2.2 The heat shall be applied during shrinkage in such a way that other elements of the corrosion protection system remain within the requirements of this standard, e.g. not deformed nor burnt by heat application or otherwise damaged to the impairment of serviceability.

6.5.2.3 The shrinkage ratio shall be such as to prevent any gaps from opening in the designed service life.

6.5.2.4 The wall thickness of the sleeve after shrinkage shall be not less than 1 mm. The minimum overlap shall not be less than 50 mm.

6.5.3 Seals

The seal shall prevent any leak of packing or any penetration of water from outside, whatever the subsequent relative movements between adjacent elements being sealed.

NOTE Mechanical joints are sealed with O-rings, gaskets or heat shrink sleeves.

6.5.4 Corrosion protection compounds based on petroleum, waxes or greases

NOTE 1 Corrosion protection compounds based on petroleum waxes and greases are commonly used.

NOTE 2 Guidelines for the acceptance criteria for viscous corrosion protection compounds and examples of test methods to measure properties of viscous corrosion protection compounds are given in Annex B.

6.5.4.1 The properties of corrosion protection compounds shall include stability against oxygen and resistance to bacterial and microbiological attack.

6.5.4.2 Corrosion protection compounds used for permanent corrosion barriers shall be contained within a robust moisture-proof sheath, duct or cap which itself shall be resistant to corrosion.

NOTE In these circumstances, such compounds also act as lubricants and void fillers that are able to exclude moist atmosphere and water.

6.5.4.3 Non-contained corrosion protection compounds may be used as temporary corrosion barriers when applied effectively as a coating.

6.5.4.4 Tape impregnated with corrosion protection compounds may only be used as temporary protection in a non-aggressive environment, since there is a tendency for it to deteriorate whilst exposed to air or water.

6.5.5 Sacrificial metallic coating

6.5.5.1 Sacrificial metallic coatings shall not be applied to tendons.

6.5.5.2 Sacrificial metallic coatings may be used on other steel components such as bearing plates, caps and sleeves.

6.5.5.3 No metallic coating shall be used which results in the formation of a galvanic element which might be detrimental to the tendons.

6.5.6 Other coatings on steel parts

6.5.6.1 Tar-epoxy, tar-polyurethane and fusion bonded epoxy coatings may be applied to steel surfaces that are sand blasted and free from any deleterious matter.

6.5.6.2 They may be used as corrosion protection to tendons of temporary anchors if they are factory applied.

6.5.6.3 Permanent anchors shall be protected with a coating applied under factory conditions in accordance with EN ISO 12944-5.

6.5.6.4 Coatings are only permitted in the bond length if the bond capacity and the integrity of the corrosion protection are verified by testing (see 6.6).

6.5.6.5 Bituminous paint is permitted for use on non-stressed elements of temporary anchors that are sand blasted and free from any deleterious matter.

6.5.7 Steel tubes and caps

6.5.7.1 Steel parts can provide permanent corrosion protection barriers where they are themselves externally protected.

6.5.7.2 Such protection may be provided by dense cement grout or concrete, by hot dip galvanising or by multiple application of coating materials.

6.5.7.3 Steel parts with coatings which become stressed during anchor loading are only permitted if the bond and integrity of the corrosion protection are verified by testing (see 6.6).

6.5.7.4 Where a duct used for grout injection is considered as a protective barrier, it should be demonstrated that the grout ports do not allow the ingress of water after grout injection.

6.5.7.5 The duct shall be not less than 3 mm thick, surrounded by a minimum of 20 mm grout cover.

6.5.7.6 The bond capacity and integrity of the corrosion protection shall be verified in accordance with 6.1.2.

6.5.7.7 Any potential degradation of the steel or coating shall be considered in the design of the anchor in the selection of element thickness and sizes.

6.6 Application of corrosion protection

6.6.1 General

6.6.1.1 The applied protective system shall not restrict any stressing or destressing operation nor be damaged by it.

6.6.1.2 In the tendon free length, a lubricated or bond free contact shall be present within either the individual sheaths or the common sheath to ensure free movement of the tendon during stressing.

6.6.1.3 Particular care shall be taken to seal transition points from one protection component to another and at end points.

6.6.2 Tendon free and bond lengths

6.6.2.1 Tendons shall be free of pitting corrosion prior to the application of a corrosion protection system.

6.6.2.2 Slight surface rust is permissible prior to the application of cement grout or corrosion protection compound.

6.6.2.3 Corrosion protection, shall be applied either under factory conditions off site or on site within specially constructed work areas where a suitable environment can be assured.

6.6.2.4 Environmental and working conditions shall be created such that the application of corrosion protection is undertaken in accordance with this standard.

6.6.2.5 Where corrosion protection of permanent anchors is applied in situ care shall be taken to ensure that all components are kept clean and free of corrosive materials during this operation.

6.6.2.6 Grouting of the encapsulation of permanent anchors shall be undertaken from the lower end of the duct and shall be continuous until completed.

6.6.2.7 The tendon shall not be exposed to deleterious stray currents.

6.6.3 Anchor head

6.6.3.1 Where the environment is aggressive, early protection of the anchor head shall be applied to both temporary and permanent anchors.

6.6.3.2 The purpose of the inner head protection is to provide an effective overlap with the free length protection, to protect the short exposed length of tendon below and passing through the bearing plate.

6.6.3.3 Where injection techniques are employed, a lower injection pipe and upper vent pipe should be used to ensure the complete filling of the void.

6.6.3.4 Where no access for injection of the inner head is provided, a pre-packed corrosion protection compound may be used.

6.6.3.5 Where restressability or load checking is not required, resins, grouts and other setting sealants may be used within the anchor cap.

NOTE There is a risk that the wedge gripping efficiency in strand anchors can be compromised.

6.6.3.6 Where restressability or load checking is required, the outer head protection including the anchor head cap and its contents shall be removable.

6.6.3.7 It shall be possible to refill the cap with corrosion protection compound.

6.6.3.8 A suitable seal and mechanical coupling shall be provided between the cap and the bearing plate.

6.6.3.9 Where applied to permanent anchors, the bearing plate and the other exposed steel components at the anchor head shall be protected in accordance with EN ISO 12944-5 for the coating of steel structures prior to being brought onto site.

6.6.3.10 Steel caps for permanent anchors shall have a minimum wall thickness of 3 mm.

6.6.3.11 Reinforced plastic caps shall have a minimum flange thickness of 10 mm and a minimum wall thickness of 5 mm.

6.6.3.12 The protection system applied to the inner and outer anchor head shall be subjected to appropriate investigations of the relevant components (see 6.1.2).

6.7 Corrosion protection system

6.7.1 All corrosion protection systems shall have been subjected to an investigation of the relevant components in accordance with 6.1.2.

6.7.2 The corrosion protection system shall continue to perform adequately after the anchor has been tested in accordance with prEN ISO 22477-5.

6.7.3 When testing the corrosion protection in the bond length, the confinement conditions should simulate those encountered in the ground.

Either in situ tests or simulated laboratory tests may be performed. Laboratory tests may include uniform stressing of encapsulated tendon as well as simulating the load transfer in the bond length.

6.7.4 Where an in situ test is undertaken, the installation procedure shall simulate the procedure used with production anchors.

6.7.5 After loading, test anchors shall be exposed with care in order to observe the effect of the stressed condition on the corrosion protection system.

6.7.6 The following properties of the corrosion protection system shall be assessed by inspection or measurement, where appropriate:

— wall thickness and integrity of plastic ducts;

— integrity of joints and seals;

— grout cover and performance of spacers and centralisers;

— location, width and spacing of cracks in the cement grout where it serves as a corrosion protection barrier;

— degree of filling of grout, resin and corrosion protection compound in ducts and volumes of containment;

— damage to coatings;

— degree of bond or debonding along interfaces;

— dislocation of components during installation and loading.

6.7.7 It should be noted that in certain systems the integrity of the inner protective barrier depends on the maintenance of the integrity of the outer barrier.

6.7.8 Where plastic duct(s) are used as a protection barrier in the bond length of a permanent anchor, investigations shall be carried out in accordance with 6.1.2 to demonstrate the integrity of the pre-grouted encapsulation.

6.7.9 The test should simulate the loading condition by preloading in a confined or unconfined condition in accordance with Annex A.

6.7.10 Where a single plastic duct protection is supplemented by a crack-controlled grout, an investigation in accordance with 6.1.2 should establish the acceptability of the crack spacing and crack width within the encapsulation.

6.7.11 Where a single 3 mm thick steel or corrugated plastic tube-à-manchette duct is supplemented by a crack-controlled grout and a minimum external grout cover of 20 mm, an investigation in accordance with 6.1.2 should establish the crack spacing and width within the encapsulation.

6.7.12 From the elastic properties of the tendon and the observed spacing of the cracks it should be shown that the crack width does not exceed 0,1 mm for presstressing steels and 0,2 mm for structural steels under service loading in the test undertaken.

6.7.13 A single documented test for a tendon arrangement in each particular duct size should be sufficient in the simulated load condition. An example of such a test is described in Annex A.

7 Considerations related to design

7.1 For the detailed design of a ground anchor system, reference should be made to EN 1997-1.

7.2 The following should be clearly shown on construction drawings, where appropriate:

— cross-sectional dimensions and material characteristics of all elements within the anchor system;

— dimensions of fixed and free anchor lengths;

— angle of inclination of boreholes to accommodate the type of anchors;

— tolerances on anchor dimensions, inclinations and anchor locations;

— corrosion protection type.

7.3 Where changes in the anchor locations, spacing or inclinations are proposed, appropriate studies or tests should be undertaken to demonstrate the suitability of such an arrangement.

7.4 Anchor inclinations between +10° and –10° to the horizontal should be avoided.

7.5 If this is not possible, it shall be confirmed that the fixed anchor length is able to be fully grouted.

7.6 The anchor design shall take into account the construction tolerances given in 8.1.2 and the execution conditions as set out in Clause 8.

8 Execution

8.1 Drilling of holes

8.1.1 Drilling Methods

8.1.1.1 The drilling method shall be chosen with due regard to the ground conditions to cause minimum adverse ground disturbance in order to maintain ground conditions most beneficial for the anchor performance and

— to prevent collapse of the borehole wall during drilling and tendon installation (where necessary a casing should be utilised),

— to minimise loosening of the surrounding ground in cohesionless soils,

— to minimise change of groundwater levels, and

— to minimise softening of the surface of the borehole wall in cohesive soils and degradable rocks.

8.1.1.2 The drilling fluid and possible additives shall have no adverse effect on the tendon, tendon protection, the grout or on the borehole walls especially in the tendon bond length.

NOTE The relationship between area of inlet of the drilling fluid, the annular area of flush return, the particle size and density of the drill spoil and the density of the drilling fluid are critical to the efficiency of the drilling system.

8.1.1.3 The use of air flush can be hazardous and should be used with caution.

8.1.1.4 Special care should be taken when drilling through ground under artesian water pressure.

8.1.1.5 Techniques to counteract the water pressure and to prevent any blow-out, hole collapse and erosion during drilling, installation and grouting operations shall be identified in advance and implemented as and when required.

NOTE 1 Clays, marls and marly rock can be liable to swelling or softening if exposed to water flush for unnecessarily lengthy periods.

NOTE 2 Sands can be loosened and destabilised by prolonged air flushing or adverse hydraulic gradients in the soil surrounding the borehole.

8.1.1.6 In high water table situations it can be necessary to use heavy drilling fluids.

NOTE Examples of preventative measures include:

— the use of special auxiliary drilling equipment such as seals or packers;

— the lowering of the water table, after the risks of general settlement of the ground have been assessed;

— pre-grouting of the ground.

8.1.1.7 Drilling operations should be conducted in such a way that any major variation in ground characteristics, from those on which the ground anchor design has been based, can be detected immediately.

8.1.1.8 An indicative drilling log should be established using simple practical identification data (e.g. class of ground, colour of flushing returns or loss of drilling fluid downhole), which can be easily recognised by the operator.

8.1.1.9 Any major deviation from the indicative drilling log shall be reported immediately.

8.1.1.10 During execution, the borehole diameter can be increased due to the necessary use of casing, etc.

NOTE Changes in the diameter of the fixed anchor length affect the mobilised resistance of the anchor.

8.1.1.11 The hole diameter shall provide for the specified grout cover to the tendon along the fixed anchor length.

NOTE Where there is significant delay prior to tendon placement, it can become necessary to redrill or ream and water test the borehole to ensure that it is acceptable for tendon installation and grouting.

8.1.2 Tolerances

8.1.2.1 Holes for anchors shall be drilled to the tolerances specified.

8.1.2.2 Allowance for extra drilling depth should be added to the specified depth when detritus cannot be removed from the bottom of the hole.

8.1.2.3 Unless otherwise specified, the choice and the set-up of the drilling equipment should satisfy the following conditions:

— the borehole collar axis at the anchor head should be positioned within a radial tolerance of 75 mm;

— the initial alignment when setting up the drilling rig should not deviate by more than 2° from the specified axis of the borehole.

8.1.2.4 The alignment should be checked after the borehole has been advanced 2 m.

8.1.2.5 During drilling, the overall borehole deviation tolerance should be limited to 1/30 of the anchor length.

NOTE On occasion, ground conditions can dictate the need for a relaxation of the tolerances given above.

8.1.2.6 The drilling rig assembly and any working platform shall be kept rigid to achieve the desired borehole alignment.

8.1.2.7 In case of doubt, the positioning should be rechecked during drilling.

NOTE 1 Compliance with the angular tolerance is important in relation to the interaction between the fixed anchor lengths.

NOTE 2 If fixed, anchor length interference is possible in the case of longer anchors, either smaller angular tolerances or a minimum distance between two successive fixed lengths is considered.

NOTE 3 Compliance with the alignment and deviation tolerances is important in relation to the interaction between the fixed anchor lengths.

NOTE 4 Borehole deviation can be minimised by using rigid and large diameter drill rods and associated casing.

NOTE 5 Deviation of rigid systems usually results from obstructions or inclined bedding planes.

8.2 Manufacturing, transport, handling and installation of tendons

8.2.1 Manufacture

8.2.1.1 During manufacture and storage, the tendons and their components shall be kept clean and free from corrosion, mechanical damage and weld splash.

8.2.1.2 The tendons shall not be coiled to radii less than any minimum specified by the manufacturer.

8.2.1.3 Where tendons comprise pre-coated greased strand or wire, exposed elements in the tendon bond length shall be cleaned and degreased thoroughly using steam or solvents.

8.2.1.4 When solvents are used to degrease the tendons, care shall be taken to ensure that the solvents are not aggressive to any of the anchor components and that after application the grout/tendon bond is able to transfer the design tensile loads without unacceptable creep.

8.2.1.5 Centralisers capable of ensuring the required cover to the tendon should be firmly attached to the tendon.

NOTE The spacing of centralisers will primarily depend on the stiffness and weight per unit length of the tendon.

8.2.2 Transport, handling and installation

8.2.2.1 During loading, transporting, handling and installation of the tendon or any part of it, care shall be taken not to damage the corrosion protection system nor kink the tendon to cause damage to its components and corrosion protection elements.

8.2.2.2 Prior to tendon installation, the borehole should be checked for obstructions and cleanliness in addition to length.

8.2.2.3 Tendon installation should be carried out in a controlled manner with care being taken to avoid relative displacement of the components.

8.2.2.4 In upward inclined ground anchors, the installed tendon should be securely fixed to prevent movement during grouting.

8.2.2.5 The time intervals between the different operations required for the construction of an anchor should be kept as short as possible.

8.2.2.6 Where there is a risk of ground swelling or softening, installation and grouting of the tendon should follow immediately after the drilling of the borehole.

8.2.2.7 Tendon installation and grouting should be carried out on the same day as drilling of the fixed anchor length.

8.2.2.8 If a delay cannot be avoided, each hole should be plugged to prevent the entry of deleterious material.

8.3 Grouting

8.3.1 General

8.3.1.1 Grouting shall meet one or more of the following functions:

a) to form the fixed anchor length in order that the applied load can be transferred from the tendon to the surrounding ground;

b) to protect the tendon against corrosion;

c) to strengthen the ground immediately adjacent to the fixed anchor in order to enhance ground anchor capacity;

d) to seal the ground immediately adjacent to the fixed anchor length in order to limit the loss of grout.

8.3.1.2 If an injected grout volume is in excess of three times the borehole volume at pressures not exceeding total overburden pressure, then general void filling which is beyond routine anchor construction is indicated.

NOTE 1 In such cases, general void filling can be necessary before grouting the anchor.

NOTE 2 For functions c) and d) above, only nominal grout consumptions can be expected.

NOTE 3 In order to form the fixed anchor length without an uncontrolled loss of grout over this length, a combination of the following operations can be considered:

— borehole testing;

— pre-grouting;

— anchor grouting.

8.3.2 Borehole testing

On completion of the borehole or during the grouting of the anchor measures shall be taken to ensure that the fixed length is fully grouted after the grout has set.

NOTE This can be done for example, by water testing, falling head grout tests or by pressure grouting.

Water Testing - The likelihood of cement grout loss can be assessed in rock from an analysis of a water injection test. Routinely a falling head test is applied to the borehole or the fixed anchor length via a packer. Pre-grouting is not usually

required if leakage or water loss in the hole or fixed anchor length is less than 5 l/min at an excess head of 0,1 MPa measured over a period of 10 min.

Falling Head Grout Test - When pressure grouting of the fixed anchor length is not carried out as part of the routine anchor construction, the borehole can be pre-filled with grout and the grout level observed until it becomes steady. If the level continues to fall it is topped up and after sufficient stiffening of the grout the borehole is redrilled and retested. The test can be applied to the entire borehole or restricted to the fixed anchor length by packer or casing over the free anchor length.

Pressure Grouting - For anchor types where grouting of the fixed anchor length is done under pressure, this activity is generally isolated during controlled withdrawal of the casing or by the use of a packer or tube-á-manchette system. During injection, a controlled flow rate at a measured pressure indicates a satisfactory grouting operation. On completion of grouting of the fixed anchor length, the efficiency of this phase can be checked by monitoring the response of the ground to further grout injection when the back pressure should be quickly restored.

8.3.3 Pre-grouting

8.3.3.1 General

8.3.3.1.1 Pre-grouting should be carried out by filling the borehole with cement based grout, either under pressure or without pressure.

NOTE Sand/cement grout can be employed in rock and very stiff to hard cohesive ground with partially filled or open fissures and in permeable cohesionless soils to reduce grout consumption.

8.3.3.1.2 On completion of pre-grouting and redrilling, the borehole should be retested. If necessary, pre-grouting, with or without pressure, should be repeated.

8.3.3.1.3 If chemical grouting is employed, it should be demonstrated that the chemical will have no deleterious effect on the anchor or on the environment (i.e. contamination of ground and groundwater).

8.3.3.2 Pre-grouting of rock

In soft rocks, the time of redrilling in relation to grout strength gain is critical to avoid problems of drilling alignment.

NOTE Typically, redrilling takes place between 6 h and 24 h after pre-grouting.

8.3.3.3 Pre-grouting of soil

8.3.3.3.1 Where borehole testing has identified that the soil is highly permeable or that the grout can be injected at a high flow rate without generating back pressure, pre-grouting is sometimes necessary.

NOTE This is often not a routine procedure but a prudent precautionary measure if the above soil conditions are suspected to prevail.

8.3.3.3.2 In exceptional circumstances it can be necessary to carry out general void filling for overall ground strengthening.

8.3.3.3.3 In this case such work should not be considered part of routine ground anchor construction.

8.3.4 Anchor grouting

8.3.4.1 Placement of grout should be carried out as soon as possible after the completion of drilling.

8.3.4.2 When grouting by the tremie method, the end of the tremie pipe shall remain submerged in the grout within the fixed anchor length and grouting shall continue until the consistency of the grout emerging is the same as that of the injected grout.

8.3.4.3 The grouting process should start at the lower end of the section to be grouted.

8.3.4.4 For horizontal and upward inclined holes, a seal or packer shall be used to prevent loss of grout from either the fixed anchor length or the entire hole.

8.3.4.5 Air and water shall be able to escape to permit complete grout filling.

8.3.4.6 De-airing of ascending boreholes can be achieved by means of a hose beginning at the highest point and exiting at the borehole opening.

8.3.4.7 When installing nearly horizontal anchors, special measures, such as multi-stage pressure grouting, should be used to prevent any voids being left in the section to be grouted.

8.3.4.8 When multi-sequence grouting along the fixed anchor length or re-grouting is envisaged, one or more sleeved port pipes or a tube à manchette should be incorporated in the anchor assembly.

8.3.4.9 In certain ground conditions load can be transferred from the fixed length through the free length where the grout column is adequately confined and onto the back of the structure. This is to be avoided.

8.3.4.10 Where appropriate, one or more of the following actions may be taken to prevent this:

— flush the grout out from behind the structure;

— replace the free length grout with a non-load transferring material;

— locate a packer at the proximal end of the fixed length.

8.3.4.11 High pressure multi-stage grouting, before or after tendon installation, may be used to increase anchor resistance by introducing further grout into the ground and raising the normal stresses at the ground/grout interface.

8.3.4.12 After grouting any seepage of water from the borehole shall be counteracted.

8.3.5 Post-grouting

8.3.5.1 In certain types of ground and where drilling and flushing techniques tend to weaken the ground surrounding the borehole, post-grouting over the fixed length may be adopted to enhance the in situ strength of the ground adjacent to the fixed length.

NOTE 1 There is a possibility that a single grouting procedure will not be sufficient if the anchor is installed in ground with weak mechanical properties, mainly cohesive soils or weak fissured rock.

NOTE 2 Post-grouting is achieved through one or several pipes installed in the grout body and fitted with post-grouting valves.

8.3.5.2 Depending on the ground condition found, the post-grouting procedure can be carried out at the earliest about 8 h to 10 h after the primary grouting.

8.3.5.3 Post-grouting should be undertaken within 24 h after primary grouting.

8.3.5.4 Further post-grouting may follow in 10 hour intervals thereafter.

NOTE The increase in anchor bond capacity can be related to the degree of post-grouting control (i.e. the applied pressure, time of application, maintained pressure, volume and rate of grout consumption).

8.4 Stressing

8.4.1 General

8.4.1.1 Stressing is required to fulfil the following two functions:

— to ascertain and record the load displacement-time behaviour of the anchor up to proof load;

— to tension the tendon and to anchor it at its lock-off load.

8.4.1.2 Stressing and recording shall be carried out by experienced personnel under the control of a suitably qualified supervisor, preferably someone provided by a specialist anchor contractor or stressing equipment supplier.

8.4.2 Equipment

8.4.2.1 Calibration of stressing equipment and load cells in regular use shall not have taken place more than 12 months prior to use, and the calibration certificate shall be made available for inspection on the site at all times.

8.4.2.2 Stressing equipment for bar, wire and strand tendons should tension the complete tendon as a single unit.

8.4.2.3 The equipment should be capable of safely tensioning the tendon to the specified proof load within the rated pressure capacity of the pumping unit.

8.4.3 Stressing procedure

8.4.3.1 If the loading on the structure is required to control the sequence or the phase loading of the anchors, this shall be specified at the design stage.

8.4.3.2 The anchored structure shall be designed to provide a reaction to allow load testing of the ground anchors in accordance with Clause 9.

8.4.3.3 The methods of stressing and load recording to be used in each testing or stressing operation should be detailed prior to any tensioning work.

8.4.3.4 The equipment should be used strictly in accordance with the manufacturer's operating instructions.

8.4.3.5 Stressing or testing should not be carried out until sufficient hardening of the grout in the fixed length has been achieved, which normally requires seven days.

8.4.3.6 In sensitive cohesive soils, it can be appropriate to stipulate a minimum time period for soil recovery after completion of the ground anchor installation and prior to stressing.

8.4.3.7 Where a loss of prestress over a short period of time is observed due to the disturbance of sensitive cohesive soils, a series of regular, e.g. weekly, re-loads can be employed to investigate if stable conditions can be attained, thereby avoiding rejection or de-rating of the anchor.

8.4.3.8 During the testing or stressing of production anchors, no indents resulting from tendon gripping shall be formed in the tendon below the anchor head.

8.4.3.9 No damage shall be allowed to the corrosion protection measures used on the production anchor.

8.4.4 Lock off of anchor

8.4.4.1 Anchors are normally prestressed after the acceptance test and are locked off at a load in accordance with EN 1997-1.

8.4.4.2 The lock-off load shall not affect the ability of the anchor head to transfer the load in accordance with 6.2.2.

8.4.4.3 If the anchor load is subsequently changed, the suitability of the anchor elements (e.g. wedges, nuts) shall be considered.

8.4.5 Stressing of anchors with staggered free lengths

8.4.5.1 For anchors in these cases, special consideration shall be given to the stressing operation to avoid the overstressing of each individual tendon element.

NOTE This is especially important for those tendon elements with shorter free lengths.

8.4.5.2 The stressing procedure shall be undertaken in a manner such that the loads in all tendon elements are equal at the anchor proof load.

NOTE After locking the anchor and under service conditions, the stresses in the individual tendon elements can vary slightly.

9 Supervision, testing and monitoring

9.1 General

9.1.1 Three types of anchor testing are recognised:

— investigation test;

— suitability test;

— acceptance test.

9.1.2 Investigation tests establish, in advance of the installation of the working anchors:

a) the resistance R_a of the anchor at the ground/grout interface;

b) the critical creep load of the anchor system; or

c) the creep characteristics of the anchor system at loads up to failure; or

d) the load loss characteristics of the anchor system at the serviceability limit state P_0;

e) an apparent tendon free length L_{app}.

9.1.3 Suitability tests confirm, for a particular design situation:

a) the ability to sustain a proof load P_p;

b) the creep or load loss characteristics of the anchor system up to proof load;

c) an apparent tendon free length L_{app}.

9.1.4 Acceptance tests confirm, for each individual anchor:

a) the ability of the anchor to sustain a proof load;

b) the creep or load loss characteristics at the serviceability limit state, when necessary;

c) the apparent tendon free length L_{app};

d) to ensure that the lock-off load is at the design load level, excluding friction.

9.1.5 The supervision and assessment of all anchor tests shall be undertaken by a competent person experienced in anchor technology.

NOTE The test methods for investigation, suitability and acceptance tests specified in prEN ISO 22477-5 apply to both temporary and permanent anchors.

9.1.6 On each project where encapsulations are grouted in the borehole, a test involving the complete filling of the encapsulation with a quality grout in accordance with 6.4.2 shall be undertaken by simulated operations under similar geometrical conditions prior to production anchor grouting.

9.2 Measurement requirements

Requirements for measurement of load, displacement, time and temperature are prescribed in prEN ISO 22477-5.

9.3 Datum load

A datum load, P_a, shall be applied to minimise movement of the anchor test set-up upon initial loading. Datum load requirements are prescribed in prEN ISO 22477-5.

9.4 Test methods

Three test methods applicable to each test class are prescribed in prEN ISO 22477-5. These are:

a) **Test Method 1:** The anchor is loaded incrementally in cycles from a datum load to a proof load. The test involves measurement of anchorage point displacement versus applied load and, at the peak of each cycle, measurement of anchorage point displacement versus time.

b) **Test Method 2:** The anchor is loaded incrementally in cycles from a datum load to a proof load. The loss of load at the anchor head is measured over a period of time at the maximum load in each cycle.

c) **Test Method 3:** The anchor is loaded in incremental steps from a datum load to a maximum load. The displacement of the anchorage point is measured under maintained load at each loading step.

9.5 Investigation test

9.5.1 Investigation tests can be required to establish for the designer, in advance of the installation of the working ground anchors, the ultimate load resistance in relation to the ground conditions and materials used, to prove the competence of the contractor and/or to prove a new type of ground anchor by inducing a failure at the ground/grout interface.

9.5.2 Investigation tests should be carried out where anchors are used in ground conditions not yet tested by previous investigation tests or for higher working loads than those already adopted in similar ground conditions.

9.5.3 The number of investigation tests should be specified in the design.

9.5.4 Anchors subjected to investigation tests shall not be used in the permanent works.

9.5.5 The diameter of the borehole and dimensions of other components, apart from the tendon, should be the same as the working anchor.

9.5.6 Where an increase in capacity of the tendon is not possible, a shorter fixed length may be tested in order to induce a ground/grout interface failure.

9.5.7 Where failure of a test anchor with a reduced fixed anchor length is attained, an increase in load resistance directly proportional to the increase in fixed length should not be applicable for anchors of longer fixed lengths.

9.5.8 If the diameter of the borehole is increased, the behaviour of an anchor in an investigation test shall not be compared directly to the behaviour of working anchors.

9.6 Suitability test

9.6.1 Prior to the execution of suitability tests, full consideration of the benefits of investigation tests should be made and the results from any such tests should be assessed.

9.6.2 Permanent and temporary anchors should be subject to suitability tests in order to achieve the objectives set out in 9.1.3.

9.6.3 Where undertaken, suitability tests shall be carried out on the site where the permanent and temporary anchors are to be executed.

9.6.4 The number of suitability tests is defined in EN 1997-1.

9.7 Acceptance test

Each working anchor shall be subjected to an acceptance test.

9.8 Evaluation of the apparent tendon free length

9.8.1 Guidance for the evaluation of apparent tendon free length is given in prEN ISO 22477-5.

9.8.2 The limits of L_{app} are:

— Upper limit for bond anchors:

$L_{app} = L_{tf} + L_e + 0{,}5\ L_{tb}$

— Upper limit for compression type anchors:

$L_{app} = 1{,}1\ L_{tf} + L_e$

— Lower limit for both bond and compression type anchors:

$L_{app} = 0{,}8\ L_{tf} + L_e$

9.8.3 Where the apparent tendon free length lies outside the limits, the anchor may be subjected to repeated load cycles to P_p.

9.8.4 If the anchor demonstrates repeatability of load/displacement behaviour, the anchor can be accepted, provided it satisfies the design criteria.

9.8.5 If an anchor does not demonstrate repeatability of load/displacement behaviour, the effect on the design of the structure as a whole should be evaluated and if necessary appropriate action should be taken to meet the design requirements.

9.9 Supervision of construction and testing

9.9.1 The installation and testing of all anchors shall be supervised and records shall be made at the site (see Clause 10).

9.9.2 If inspection reveals uncertainties with respect to the quality of installed anchors, additional investigations shall be carried out to determine the as-built conditions of the anchors.

9.10 Monitoring

9.10.1 Ground anchors can be installed with a monitoring facility.

9.10.2 Where a structure is sensitive to changes in load or ground movement, use can be made of this facility to monitor the behaviour throughout its design life.

9.10.3 The necessity for monitoring, the number of anchors to be monitored and the intervals between measurements shall be specified in the design.

9.10.4 The monitoring should include the inspection of corrosion protection of the accessible parts of the anchor head and the anchor head itself.

9.10.5 Where monitoring is carried out, a minimum of 5 % of the anchors should be monitored on a regular basis during their design life.

9.10.6 Where an anchor is equipped with a device for long term load monitoring, two other anchors, of the same type and working load, in close proximity should be equipped to permit residual load checking by restressing, as a reference for the monitoring device, if required.

10 Records

10.1 An anchor installation plan containing the technical specification related to the anchor system to be used shall be prepared and shall be available on site.

NOTE An anchor installation plan can contain the following information, as appropriate:

— the anchor type with designation;

— anchor number;

— the location and orientation of each anchor and tolerances in position;

— free anchor length and fixed anchor length;

— required proof load and lock-off load;

— installation technique (drilling, placing, grouting and stressing);

— known obstructions;

— any other constraints on anchoring activities.

10.2 Records of anchor construction shall be compiled in accordance with EN 1997-1 and shall cover, where relevant:

a) anchor number and location;

b) details of deliveries of all cementitious materials, resins and hardeners, cement and resin grouts;

c) existing soil conditions;

d) drilling equipment and technique;

e) installation and geometry of anchor elements;

f) date and time of installation of each anchor;

g) weather conditions;

h) grout composition, pressure, grouted volume, grouting length, grouting time; pre-grouting and post-grouting;

i) installation of the chosen corrosion protection;

j) anchor testing requirement including calibration certificates;

k) stressing, including final lock-off load;

l) monitoring equipment;

m) anchor construction company;

n) driller/stressing operative/foreman/engineer's name.

10.3 A signed record shall be kept for each anchor installation and this record shall include any special features of construction.

10.4 All installation and testing records shall be kept after the completion of the works.

10.5 As-built plans shall be compiled after completion of the anchors and kept with the construction records.

10.6 Any acceptance certificates issued by regulatory authorities for materials used in the anchor installation shall be kept with the construction records.

10.7 Copies of all records described in this clause should be deposited such that they can be consulted by interested parties in the future.

NOTE An example of a record sheet is given in Annex D.

11 Special requirements

11.1 When executing anchor works, the following list shall be complied with:

— security of the site;

— environmental protection;

— safety of the working procedures;

— operational safety of drilling and auxiliary equipment and tools.

11.2 Where European Standards are not available, respective national standards, specifications or statutory requirements regarding execution of anchor works shall be observed.

11.3 Particular attention shall be drawn to all processes requiring personnel operating alongside heavy equipment and heavy tools.

11.4 Nuisance and/or environmental damage that can be caused by the anchor work shall be kept to a minimum.

NOTE Such nuisance and/or environmental damage can be caused by:

— noise;

— ground vibration;

— ground pollution;

— surface water pollution;

— groundwater pollution;

— air pollution.

11.5 During stressing, adherence to safety precautions is essential and shall include:

— Operatives and observers to position themselves to one side of the tensioning equipment and never pass behind the equipment during stressing.

— Notices to be displayed stating 'DANGER - Tensioning in Progress' or similar wording.

Annex A
(informative)

Examples of testing corrosion protection

This annex describes testing methods for establishing the integrity of the corrosion protection of a prefabricated anchor encapsulation in a loaded or post-loaded condition. These tests are undertaken in a test frame. Figure A.1 shows the general arrangement of the test apparatus.

TEST A

This method involves the loading of an encapsulated tendon with the encapsulation unconfined.

The tendon, the encapsulation grout and the surrounding plastic duct(s) are subjected to loading procedures identical to those on a working anchor.

The anchor is loaded to the maximum load it will be subjected to during testing in situ.

The flexibility and crack resistance of the duct is observed externally during the loading of the anchor.

The tendon is subsequently unloaded to zero load.

A section of the outer plastic covering is removed and the tendon reloaded to the lock-off load in order to inspect the condition of the inner duct and to check the crack distribution and crack widths in the encapsulation grout.

TEST B

This method involves the loading of an encapsulated tendon in a confined and bonded state within a grouted split gunbarrel.

The loading condition simulates that applied to a service anchor.

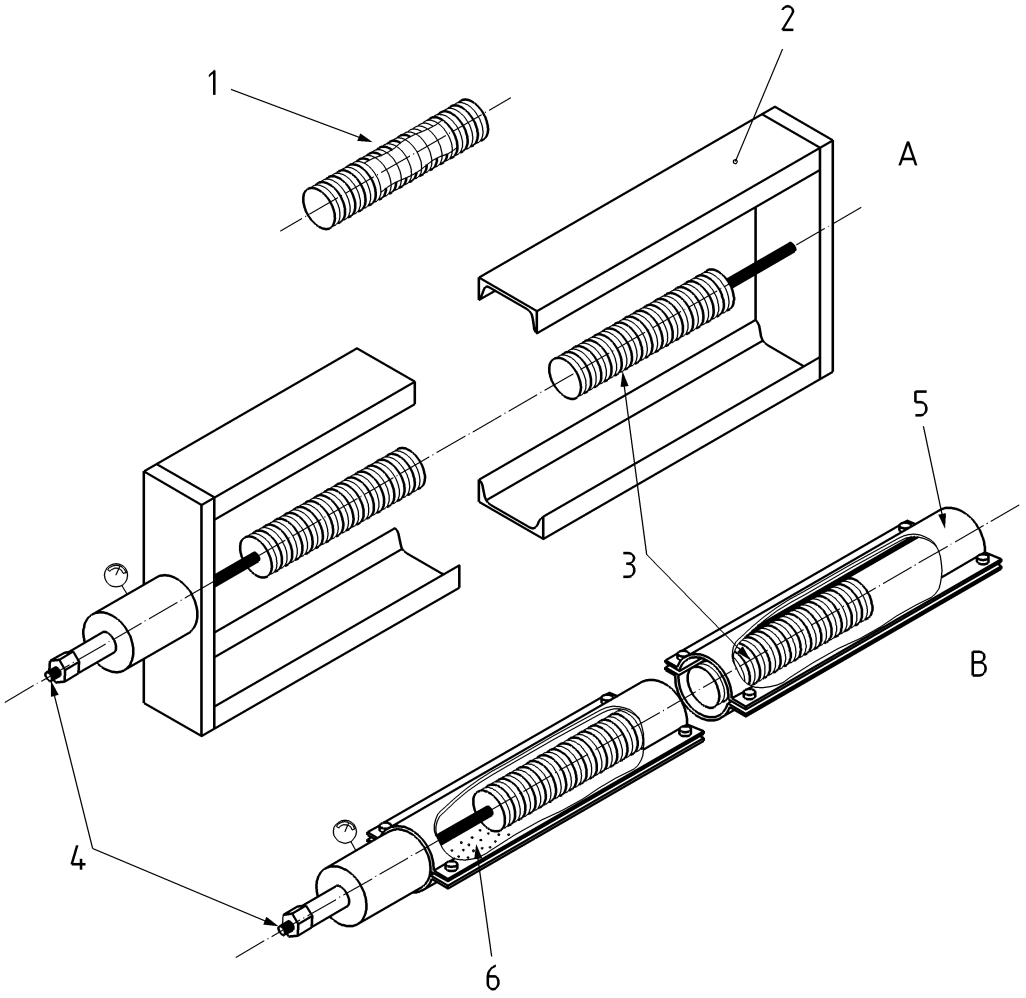
The anchor is loaded to the maximum load it will be subjected to during testing in situ.

The tendon is unloaded to zero load.

The gunbarrel is split open and the gunbarrel grout removed from the outer plastic duct. The integrity of the outer plastic duct is then proved by inspection.

On removal of the outer duct, either the inner duct is inspected or, in the absence of an inner duct, the distribution of the cracks and crack widths in the encapsulated grout is measured.

It is necessary to establish the maximum crack spacing within the encapsulation, so that the maximum crack width can be calculated knowing the strain in the tendon at proof load.



Key

1 inspection of inner duct or grout crack distribution/crack width observed/measured in a loaded (Test “A”) or unloaded (Test “B”) condition at various locations
2 test frame
3 tendon encapsulation
4 bar, multi-strand or multi-wire tendon system
5 split gunbarrel
6 grout
A test “A” unconfined condition
B test “B” confined condition

Figure A.1 — Testing of corrosion protection

Annex B
(informative)

Guidelines for acceptance criteria for viscous corrosion protection compounds and examples of standards for the testing of material properties

Table B.1 — Acceptance criteria for viscous corrosion protection compounds

Property	Units	Acceptance values
Content of free sulphur, sulphates and sulphides	$1x10^{-3}$ mgm/gm	≤50
Content of ionic chlorides, nitrites, nitrates, rhodanites	$1x10^{-3}$ mgm/gm	≤ 50
Spec. resistivity	Ω*cm	≥ 10^9
Water absorption c(KOH) = 0,1 mol/l after 30 days	%	≤ 2
Saponification (acidity)	mg KOH/gm	≤ 5
Deoiling on filter paper at 50 °C, 24 h: increase in diameter of oil spot.	mm	≤ 5
Penetration depth in deoiling test on hardened cement grout 5 mm thick at 50 °C after 7 days	mm	≤ 2
Thermal stability, 24 h No oil droplet at sieve for temperature increase of 10 °C every 2 h.	°C Occurrence of oil droplets	≥ 40
Drop point	°C	≥ 60
Protection against rust - Marine fog: 5 % NaCl - 168 h at 35 °C	-	Visual inspection: zero corrosion
Bleeding at 40 °C	%	≤ 5

Examples of standards for the testing of materials are:

— EN ISO 9227, *Corrosion tests in artificial atmospheres — Salt spray tests (ISO 9227)*

— DIN 51576, *Testing of mineral oil hydrocarbons — Determination of salt content (Prüfung von Mineralöl-Kohlenwasserstoffen — Bestimmung des Salzgehaltes)*

— DIN 53483 (all parts), *Testing of insulating materials; Determination of the dielectric properties (Prüfung von Isolierstoffen; Bestimmung der elektrischen Eigenschaften)*

— ASTM D130-12, *Standard test method for corrosiveness to copper from petroleum products by copper strip test*

— ASTM D94-07, *Standard test methods for saponification number of petroleum products*

— ASTM D512-12, *Standard test methods for chloride ion in water*

Annex C
(informative)

Corrosion protection systems for temporary and permanent anchors and typical details for permanent anchor heads

Table C.1 — Examples of corrosion protection systems for temporary anchors

1. Tendon bond length
All installed tendons should be provided with a minimum 10 mm cement grout cover to the borehole wall. Where aggressive ground conditions are known to exist, it may be appropriate to enhance the protection, for example by the use of a single corrugated duct around the tendon.
2. Tendon free length
The protection system should have low frictional properties and allow movement of the tendon within the borehole. This can be achieved by the provision of one of the following: a) plastic sheath surrounding each individual tendon element, end sealed against ingress of water; b) plastic sheath surrounding each individual tendon element, completely filled with corrosion protection compound; c) plastic or steel sheath or duct common to all tendon elements, end sealed against ingress of water; d) plastic or steel sheath or duct common to all tendon elements completely filled with corrosion protection compound; b) or d) are appropriate for use in aggressive conditions.
3. Transition between anchor head and free length (inner anchor head)
The free length sheath or duct can be sealed to the bearing plate/anchor head, or a metal sleeve or plastic duct can be sealed or welded to the bearing plate. It should overlap the free length sheath or duct and in aggressive conditions be filled with corrosion protection compound, cement or resin which is contained at the lower end.
4. Anchor head
Where the anchor head is accessible for inspection and possible re-coating, the following protection should be acceptable: a) a coating of non-fluid corrosion protection compound; or b) a combination of corrosion protection compound and tape which is impregnated with corrosion protection compound. Where the anchor head is not accessible a metal or plastic cap should be fitted and filled with corrosion protection compound for extended use. Where aggressive conditions are known to exist, a metal or plastic cap should be filled with corrosion protection compound.

Table C.2 — Examples of corrosion protection systems for permanent anchors

Verification of protection offered

All corrosion protection systems are subjected to test(s) to verify the competence of the system. The results from these tests are documented and made available for inspection.

A single corrosion protection system implies that one physical barrier against corrosion is provided for the tendon. A double corrosion protection system implies the supply of two barriers where the purpose of the outer second barrier is to protect the inner barrier against the possibility of damage during tendon handling and installation.

Where only a single protective barrier is provided in the tendon bond length, the integrity of this barrier can be checked by an in situ test such as a falling head water test.

1. Tendon bond length The encapsulation can consist of one of the following:	**Protective barriers offered in situ**
a) a single corrugated plastic duct containing the tendon and cement grout;	a) one plastic duct;
b) two concentric corrugated plastic ducts containing the tendon, fully pre-grouted (with cement or resin) within the core and the annulus between the ducts prior to installation;	b) two plastic ducts;
c) a single corrugated plastic duct containing a bar tendon or multi-element tendon and pre-grouted with cement grout. A minimum cover of 5 mm is provided between the duct and bar. The bar tendon has a continuous ribbed outer surface. The crack width of the cement grout between the duct and the bar does not exceed 0,1 mm under service loading;	c) internal cement grout and surrounding plastic duct;
d) a single steel or corrugated plastic tube-a-manchette duct not less than 3 mm thick, surrounded by a minimum of 20 mm grout cover injected under a pressure of not less than 500 kPa at intervals along the tube-a-manchette no greater than 1 metre. A minimum cover of 5 mm is provided between the duct and the tendon elements. The crack width of this cement grout does not exceed 0,2 mm under service loading;	d) internal cement grout and surrounding steel or plastic duct;
e) a single corrugated steel duct (compression tube) closely surrounding a greased steel tendon. The duct and plastic cap at the restraining nut are protected by the surrounding cement grout having a thickness of not less than 10 mm, and where the crack widths do not exceed 0,1 mm under service loading.	e) steel duct and surrounding cement grout.

2. Tendon free length

The protection system allows free movement of the tendon within the borehole. This can be achieved by one of the following:

— a plastic sheath to individual tendon elements filled completely with flexible corrosion protection compound plus the inclusion of A, B, C or D below;

— a plastic sheath to individual tendon elements filled completely with cement grout plus A or B below;

— a common plastic sheath for multiple tendon elements filled completely with cement grout plus B.

A. common plastic sheath or duct filled with flexible corrosion protection compound

B. common plastic sheath or duct sealed at the ends against ingress of water

C. common plastic sheath or duct filled with cement grout

D. common steel duct filled with dense cement grout

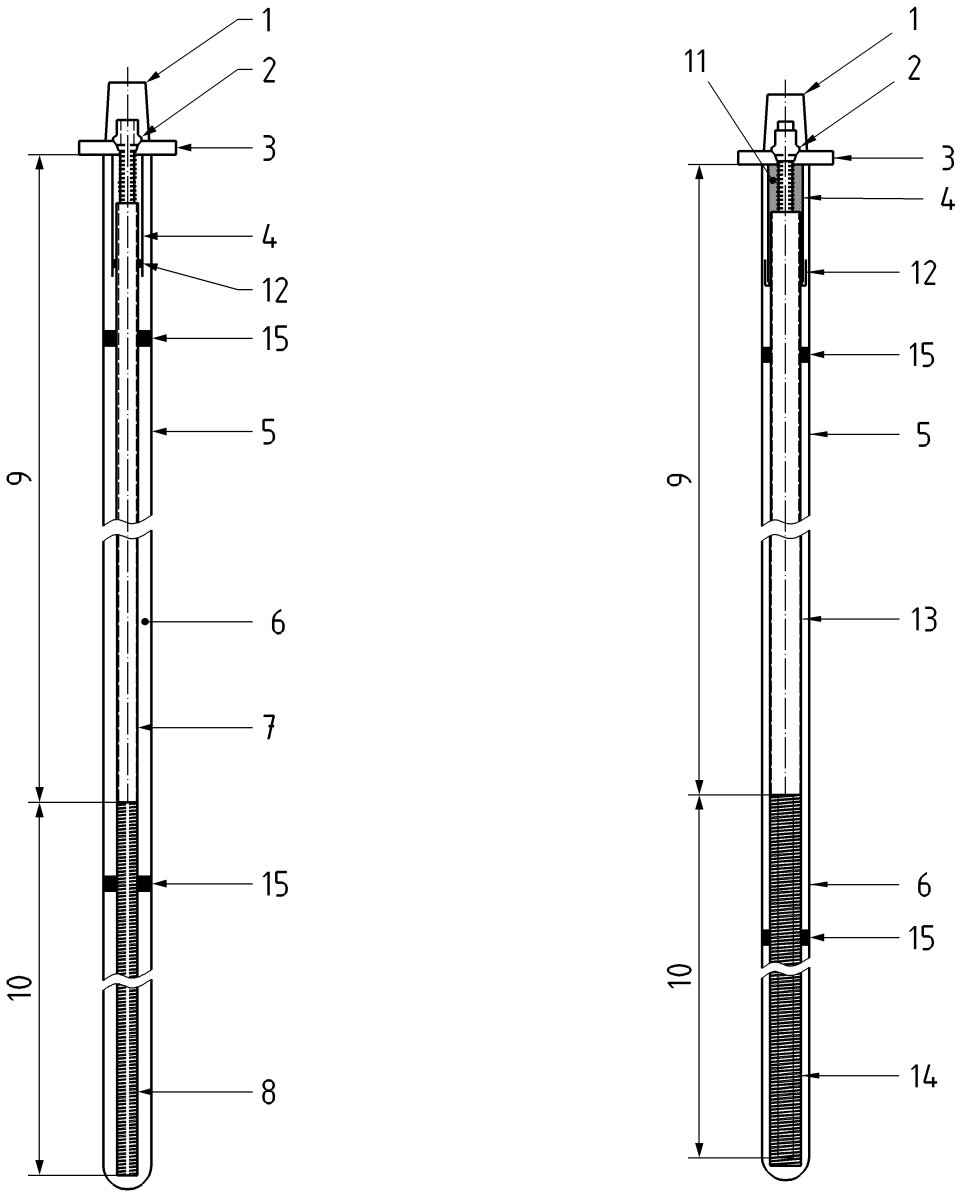
A lubricant or bond free contact is present within either the individual sheaths or the common sheath to ensure free movement of the tendon(s) during stressing.

3. Transition between anchor head and free length

A coated, grouted or cast-in metal sleeve or fixed plastic duct is sealed or welded to the anchor head. It is then sealed to the free length sheath or duct and filled with corrosion protection compound, cement or resin.

4. Anchor head

A coated and/or galvanised metal cap with a minimum 3 mm wall thickness or a rigid plastic cap with a minimum 5 mm wall and 10 mm flange thickness is connected to the bearing plate and, if removable, it is filled with a flexible corrosion protection compound and sealed with a gasket. If non-removable it can be filled with cement or resin.



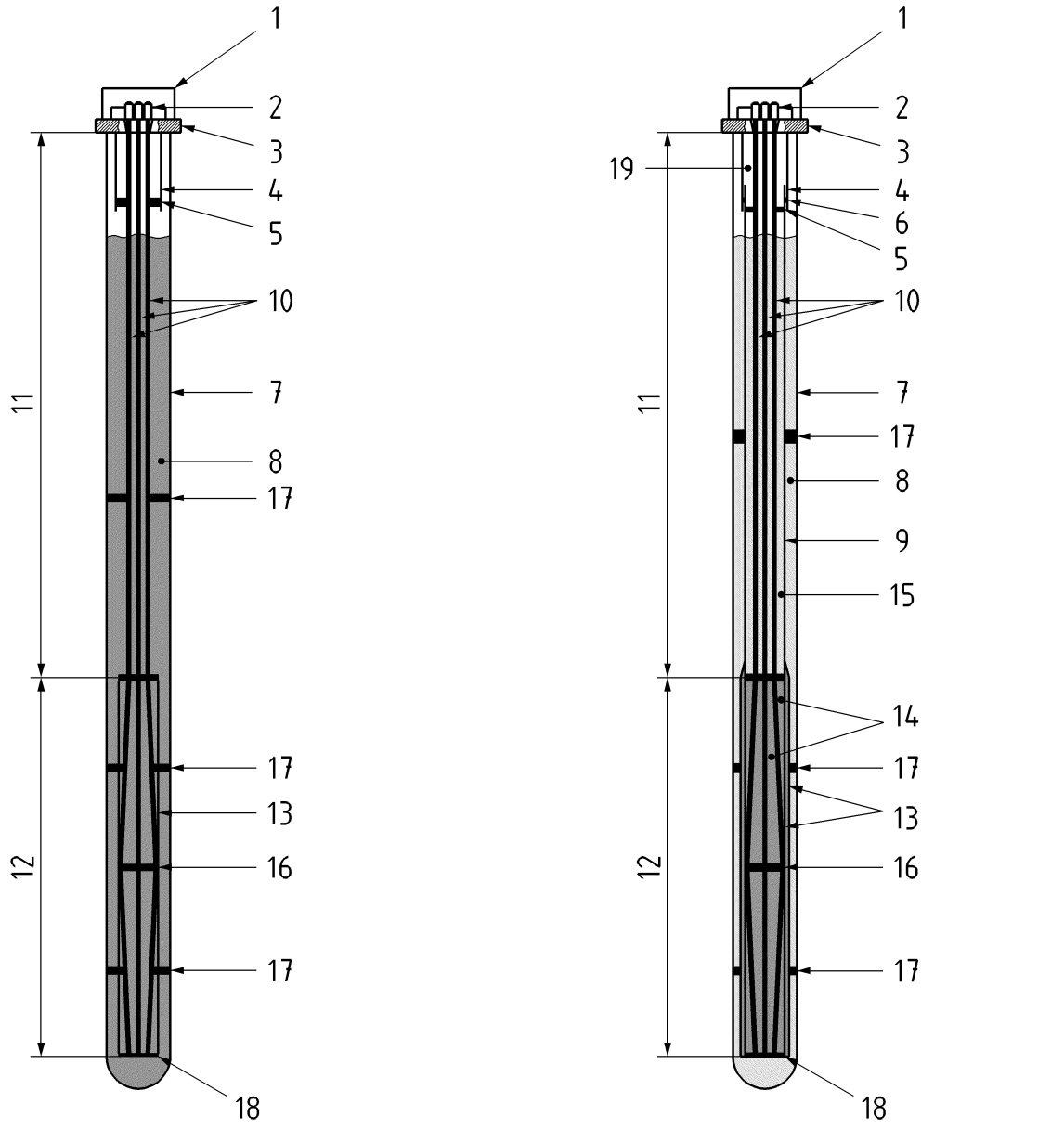
a) Bar anchor single corrosion protection

b) Bar anchor double corrosion protection

Key

1 protection cap filled with anti-corrosion compound
2 conic bolt
3 bearing plate
4 steel tube
5 drilling hole
6 grout
7 smooth plastic sheathing
8 ribbed bar
9 free length
10 fixed length
11 corrosion protection compound
12 sealing O-ring
13 smooth plastic sheathing around ribbed plastic sheath
14 ribbed plastic sheathing pre-filled with grout
15 centraliser

Figure C.1 – Examples of single and double corrosion protection for a ribbed bar anchor

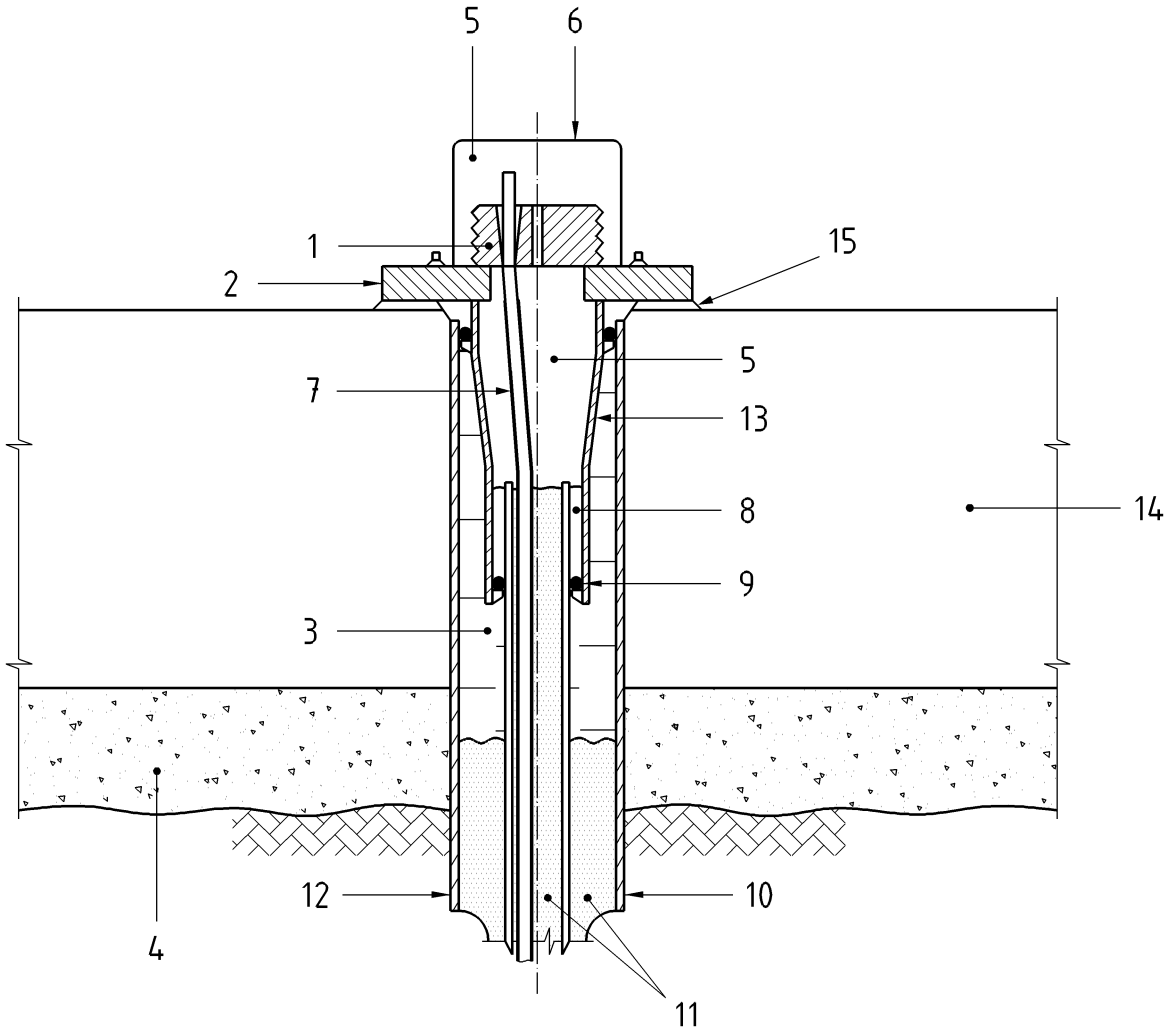


a) Strand anchor single corrosion protection **b) Strand anchor double corrosion protection**

Key

1 protection cap filled with anti-corrosion compound
2 3 part wedge
3 bearing plate
4 steel tube
5 packer
6 O-Ring
7 borehole
8 borehole grout
9 smooth plastic sheathing in free length only
10 greased and sheathed strand in free length only
11 free length
12 fixed length
13 ribbed plastic sheathing
14 factory injected grout
15 secondary grout or anti-corrosion compound applied in situ
16 spacer
17 centraliser
18 seal and end cap

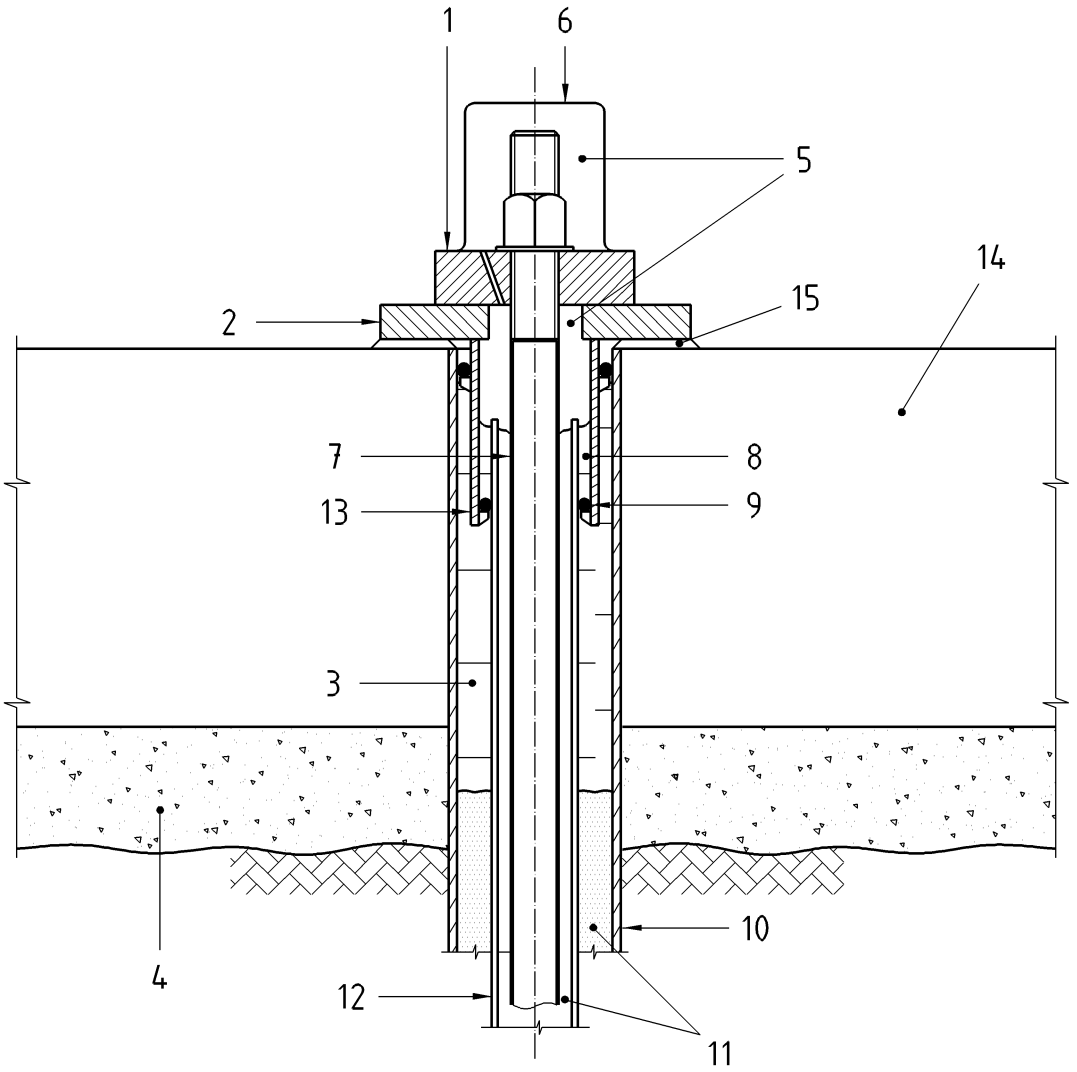
Figure C.2 — Examples of single and double corrosion protection for a strand anchor



Key

1 restressable anchor head
2 steel bearing plate and trumpet painted with epoxy paint
3 corrosion protection compound injected before bedding bearing plate and trumpet
4 blinding concrete
5 corrosion protection compound in-fill injected after stressing
6 plastic coated steel removable cap with gasket and clips
7 protected strand tendon
8 epoxy resin plug
9 rubber seal
10 mild steel flanged tube set in blinding concrete and cast into reinforced concrete slab
11 cement/Bentonite grout
12 hard plastic tube over free length
13 mild steel trumpet
14 load transfer block
15 epoxy resin bedding

Figure C.3 – Example of double corrosion protection detail for a strand anchor at the head



Key

1 distribution plate
2 steel bearing plate and trumpet painted with epoxy paint
3 corrosion protection compound injected before bedding bearing plate and trumpet
4 blinding concrete
5 corrosion protection compound in-fill injected after stressing
6 plastic coated steel removable cap with gasket and clips
7 protected mono-bar steel tendon
8 epoxy resin plug
9 rubber seal
10 mild steel flanged tube set in blinding concrete and cast into reinforced concrete slab
11 cement/Bentonite grout
12 hard plastic tube over free length
13 mild steel trumpet
14 load transfer block
15 epoxy resin bedding

Figure C.4 – Example of double corrosion protection detail for a bar anchor at the head

Annex D
(informative)

Example of record sheet

	RECORD SHEET FOR ANCHORS ____				Doc.	
01) Contract 02) Location						
03) Anchor Type/DWG						
04) Anchor No.						
Drilling	101) Entry position *X/Y*	m				
	102) Entry Level *Z*	m				
	103) Direction N/E	°				
	104) Inclination (Horiz)	°				
	105) Drill method					
	106) Hole diameter	mm				
	107) Overall length	m				
	108) Cased from/to	m				
	109) Flushing medium					
	110) Groundwater level	m				
	111) Ground characteristics					
	112) Pre-grouting (if any)					
	113) Testing					
	114) Drill Date					
Tendon	201) Tendon types					
	202) No./D	/mm				
	203) Tendon area A_t	mm^2				
	204) Yield stress f_y	N/mm^2				
	205) Characteristic tensile strength of the tendon f_{tk}	N/mm^2				
	206) Elastic Modulus E_t	N/mm^2				
	207) Tendon bond length L_{tb}	m				
	208) Tendon free length L_{tf}	m				
	209) External length of tendon L_e	m				
	210) Overall length L_A	m				
	211) Protection along the bond length					
	212) Protection along the free length					

	213) Spacers along the bond length					
	214) Spacers along the free length					
	215) Centralisers along the bond length					
	215) Centraliser along the free length					
	217) Grouting ducts					
Grouting	301) Cement type					
	302) Admixtures					
	303) W/C					
	304) Cement consumption	kg				
	305) Grouting pressure	MPa				
	306) Post-grouting (if any)					
	NOTES					
	Operators:					

Annex E
(informative)

Obligation of the provisions

The provisions are marked corresponding to their obligation:

— *(RQ)* : Requirement;

— *(RC)* : Recommendation;

— *(PE)* : Permission;

— *(PO)* : Possibility and eventuality;

— *(ST) :* Statement.

1 Scope

1.1 – 1.8	*(ST)*

2 Normative references

	(ST)

3 Terms, definitions and symbols

3.1 Terms and conditions

3.1	*(ST)*
3.1.1-3.1.24	*(ST)*

3.2 Symbols

	(ST)

4 Information needed for the execution of the work

4.1 General

4.1.1	*(RQ)*
4.1.2	*(RQ)*

4.2 Special features

4.2.1	*(ST)*
4.2.2	*(RQ)*
4.2.3	*(RQ)*
4.2.4	*(RQ)*

5 Geotechnical Investigation

5.1 General

5.1.1	*(RQ)*
5.1.2	*(RQ)*
5.1.3	*(RQ)*
5.1.4	*(RQ)*

5.2 Specific requirements

5.2.1	*(RQ)*
5.2.2	*(PO)*
5.2.3	*(RC)*
5.2.4	*(RC)*
5.2.5	*(RC)*
5.2.6	*(RC)*
5.2.7	*(RC)*

6 Materials and products

6.1 General

6.1.1	*(RQ)*
6.1.2	*(RQ)*
6.1.3	*(RQ)*
6.1.4	*(RQ)*
6.1.5	*(RQ)*

6.2 Anchor components subject to corrosion protection

6.2.1 Tendon

6.2.1.1	*(RQ)*
6.2.1.2	*(PE)*

6.2.2 Anchor head

6.2.2.1	*(RQ)*
6.2.2.2	*(RQ)*
6.2.2.3	*(RQ)*

6.2.3 Coupler

6.2.3.1	*(RQ)*
6.2.3.2	*(RC)*
6.2.3.3	*(RQ)*
6.2.3.4	*(RQ)*

6.2.4 Tendon bond length

6.2.4.1	*(RQ)*
6.2.4.2	*(PE)*
6.2.4.3	*(RQ)*

6.2.5 Components in the borehole

6.2.5.1	*(RQ)*
6.2.5.2	*(RC)*
6.2.5.3	*(RQ)*
6.2.5.4	*(RC)*
6.2.5.5	*(RQ)*

6.2.6 Compression element of a compression type anchor

6.2.6.1	*(ST)*
6.2.6.2	*(RQ)*
6.2.6.3	*(RQ)*
6.2.6.4	*(RQ)*

6.3 Corrosion protection of steel tendon and stressed steel components

6.3.1 General

6.3.1.1	*(RQ)*
6.3.1.2	*(RQ)*
6.3.1.3	*(RQ)*

6.3.2 Temporary ground anchor

6.3.2.1	*(RQ)*
6.3.2.2	*(RQ)*
6.3.2.3	*(RC)*
6.3.2.4	*(RQ)*

6.3.3 Permanent ground anchor

6.3.3.1	*(RQ)*
6.3.3.2	*(RQ)*

6.4 Grouts for corrosion protection and load transfer

6.4.1 Cement grout for temporary anchors

6.4.1.1	*(RQ)*
6.4.1.2	*(RQ)*
6.4.1.3	*(RQ)*
6.4.1.4	*(RQ)*
6.4.1.5	*(RQ)*
6.4.1.6	*(PE)*
6.4.1.7	*(RQ)*
6.4.1.8	*(RQ)*
6.4.1.9	*(PE)*
6.4.1.10	*(RQ)*
6.4.1.11	*(RC)*
6.4.1.12	*(PE)*

6.4.2 Cement grout for permanent anchors inside encapsulations

6.4.2.1	*(RQ)*
6.4.2.2	*(RQ)*
6.4.2.3	*(RQ)*
6.4.2.4	*(PE)*
6.4.2.5	*(RC)*
6.4.2.6	*PO)*
6.4.2.7	*RQ)*

6.4.3 Cement grout for permanent anchors outside encapsulations

6.4.3.1	*(RQ)*
6.4.3.2	*(RQ)*
6.4.3.3	*(RQ)*
6.4.3.4	*(PE)*
6.4.3.5	*(PE)*

6.4.4 Resin grout

6.4.4.1	*(PE)*
6.4.4.2	*(RQ)*
6.4.4.3	*(PE)*

6.5 Other components and materials for corrosion protection barriers

6.5.1 Plastic sheathes and ducts

6.5.1.1	*(RQ)*
6.5.1.2	*(RQ)*
6.5.1.3	*(RQ)*
6.5.1.4	*(RQ)*
6.5.1.5	*(RQ)*
6.5.1.6	*(RQ)*
6.5.1.7	*(RQ)*
6.5.1.8	*(RQ)*
6.5.1.9	*(RQ)*
6.5.1.10	*(RC)*
6.5.1.11	*(RQ)*
6.5.1.12	*(RC)*
6.5.1.13	*(RQ)*

6.5.2 Heat shrink sleeves

6.5.2.1	*(PE)*
6.5.2.2	*(RQ)*
6.5.2.3	*(RQ)*
6.5.2.4	*(RQ)*

6.5.3 Seals

	(RQ)

6.5.4 Corrosion protection compounds based on petroleum, waxes or greases

6.5.4.1	*(RQ)*
6.5.4.2	*(RQ)*
6.5.4.3	*(PE)*
6.5.4.4	*(PE)*

6.5.5 Sacrificial metallic coating

6.5.5.1	*(RQ)*
6.5.5.2	*(PE)*
6.5.5.3	*(RQ)*

6.5.6 Other coatings on steel parts

6.5.6.1	*(PE)*
6.5.6.2	*(PE)*
6.5.6.3	*(RQ)*
6.5.6.4	*(PE)*
6.5.6.5	*(PE)*

6.5.7 Steel tubes and caps

6.5.7.1	*(PO)*
6.5.7.2	*(PE)*
6.5.7.3	*(PE)*
6.5.7.4	*(RC)*
6.5.7.5	*(RQ)*
6.5.7.6	*(RQ)*
6.5.7.7	*(RQ)*

6.6 Application of corrosion protection

6.6.1 General

6.6.1.1	*(RQ)*
6.6.1.2	*(RQ)*
6.6.1.3	*(RQ)*

6.6.2 Tendon free and bond lengths

6.6.2.1	*(RQ)*
6.6.2.2	*(PE)*
6.6.2.3	*(RQ)*
6.6.2.4	*(RQ)*
6.6.2.5	*(RQ)*
6.6.2.6	*(RQ)*
6.6.2.7	*(RQ)*

6.6.3 Anchor head

6.6.3.1	*(RQ)*
6.6.3.2	*(ST)*
6.6.3.3	*(RC)*
6.6.3.4	*(PE)*
6.6.3.5	*(PE)*
6.6.3.6	*(RQ)*
6.6.3.7	*(RQ)*
6.6.3.8	*(RQ)*
6.6.3.9	*(RQ)*
6.6.3.10	*(RQ)*
6.6.3.11	*(RQ)*
6.6.3.12	*(RQ)*

6.7 Corrosion protection system

6.7.1	*(RQ)*
6.7.2	*(RQ)*
6.7.3	*(RC)*
6.7.4	*(RQ)*
6.7.5	*(RQ)*
6.7.6	*(RQ)*
6.7.7	*(RC)*
6.7.8	*(RQ)*
6.7.9	*(RC)*
6.7.10	*(RC)*
6.7.11	*(RC)*
6.7.12	*(RC)*
6.7.13	*(RC)*

7 Considerations related to design

7.1	*(RC)*
7.2	*(RC)*
7.3	*(RC)*
7.4	*(RC)*
7.5	*(RQ)*
7.6	*(RQ)*

8 Execution

8.1 Drilling of holes

8.1.1 Drilling methods

8.1.1.1	*(RQ)*
8.1.1.2	*(RQ)*
8.1.1.3	*(RC)*
8.1.1.4	*(RC)*
8.1.1.5	*(RQ)*
8.1.1.6	*(PO)*
8.1.1.7	*(RC)*
8.1.1.8	*(RC)*
8.1.1.9	*(RQ)*
8.1.1.10	*(PO)*
8.1.1.11	*(RQ)*

8.1.2 Tolerances

8.1.2.1	*(RQ)*
8.1.2.2	*(RC)*
8.1.2.3	*(RC)*
8.1.2.4	*(RC)*
8.1.2.5	*(RC)*
8.1.2.6	*(RQ)*
8.1.2.7	*(RC)*

8.2 Manufacturing, transport, handling and installation of tendons

8.2.1 Manufacture

8.2.1.1	*(RQ)*
8.2.1.2	*(RQ)*
8.2.1.3	*(RQ)*
8.2.1.4	*(RQ)*
8.2.1.5	*(RC)*

8.2.2 Transport, handling and installation

8.2.2.1	*(RQ)*
8.2.2.2	*(RC)*
8.2.2.3	*(RC)*
8.2.2.4	*(RC)*
8.2.2.5	*(RC)*
8.2.2.6	*(RC)*
8.2.2.7	*(RC)*
8.2.2.8	*(RC)*

8.3 Grouting

8.3.1 General

8.3.1.1	*(RQ)*
8.3.1.2	*(ST)*

8.3.2 Borehole testing

8.3.2	*(RQ)*

8.3.3 Pre-grouting

8.3.3.1 General

8.3.3.1.1	*(RC)*

8.3.3.1.2	*(RC)*
8.3.3.1.3	*(RC)*

8.3.3.2 Pre-grouting of rock

8.3.3.2	*(ST)*

8.3.3.3 Pre-grouting of soil

8.3.3.3.1	*(ST)*
8.3.3.3.2	*(PO)*
8.3.3.3.3	*(RC)*

8.3.4 Anchor grouting

8.3.4.1	*(RC)*
8.3.4.2	*(RQ)*
8.3.4.3	*(RC)*
8.3.4.4	*(RQ)*
8.3.4.5	*(RQ)*
8.3.4.6	*(PO)*
8.3.4.7	*(RC)*
8.3.4.8	*(RC)*
8.3.4.9	*(RQ)*
8.3.4.10	*(PE)*
8.3.4.11	*(PE)*
8.3.4.12	*(RQ)*

8.3.5 Post-grouting

8.3.5.1	*(PE)*
8.3.5.2	*(PO)*
8.3.5.3	*(RC)*
8.3.5.4	*(PE)*

8.4 Stressing

8.4.1 General

8.4.1.1	*(RQ)*
8.4.1.2	*(RQ)*

8.4.2 Equipment

8.4.2.1	*(RQ)*
8.4.2.2	*(RC)*
8.4.2.3	*(RC)*

8.4.3 Stressing procedure

8.4.3.1	*(RQ)*
8.4.3.2	*(RQ)*
8.4.3.3	*(RC)*
8.4.3.4	*(RC)*
8.4.3.5	*(RC)*
8.4.3.6	*(PO)*
8.4.3.7	*(PO)*
8.4.3.8	*(RQ)*
8.4.3.9	*(RQ)*

8.4.4 Lock off of anchor

8.4.4.1	*(ST)*
8.4.4.2	*(RQ)*
8.4.4.3	*(RQ)*

8.4.5 Stressing of anchors with staggered free lengths

8.4.5.1	*(RQ)*
8.4.5.2	*(RQ)*

9 Supervision, testing and monitoring

9.1 General

9.1.1	*(ST)*
9.1.2	*(ST)*
9.1.3	*(ST)*
9.1.4	*(ST)*
9.1.5	*(RQ)*
9.1.6	*(RQ)*

9.2 Measurement requirements

9.2	*(ST)*

9.3 Datum load

9.3	*(RQ)*

9.4 Test methods

9.4	*(ST)*

9.5 Investigation test

9.5.1	*(PO)*
9.5.2	*(RC)*
9.5.3	*(RC)*
9.5.4	*(RQ)*
9.5.5	*(RC)*
9.5.6	*(PE)*
9.5.7	*(RC)*
9.5.8	*(RQ)*

9.6 Suitability test

9.6.1	*(RC)*
9.6.2	*(RC)*
9.6.3	*(RQ)*
9.6.4	*(ST)*

9.7 Acceptance test

9.7	*(RQ)*

9.8 Evaluation of the apparent tendon free length

9.8.1	*(ST)*
9.8.2	*(ST)*
9.8.3	*(PE)*
9.8.4	*(PO)*
9.8.5	*(RC)*

9.9 Supervision of construction and testing

9.9.1	*(RQ)*
9.9.2	*(RQ)*

9.10 Monitoring

9.10.1	*(PO)*
9.10.2	*(PO)*
9.10.3	*(RQ)*
9.10.4	*(RC)*
9.10.5	*(RC)*
9.10.6	*(RC)*

10 Records

10.1	*(RQ)*

10.2	*(RQ)*
10.3	*(RQ)*
10.4	*(RQ)*
10.5	*(RQ)*
10.6	*(RQ)*
10.7	*(RC)*

11 Special requirements

11.1	*(RQ)*
11.2	*(RQ)*
11.3	*(RQ)*
11.4	*(RQ)*
11.5	*(RQ)*

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