

Execution of special geotechnical work — Ground anchors

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National foreword

This British Standard is the official English language version of EN 1537:1999. It supersedes those parts of BS 8081:1989 that deal with the construction ('execution') of ground anchorages; these parts will therefore be declared obsolescent by amendment.

The harmonized European design of ground anchorages will be dealt with by EN 1997-1. Until it is published, the design parts of BS 8081:1989 apply, whereafter BS 8081:1989 will be declared obsolescent on its entirety.

The UK participation in its preparation was entrusted to Technical Committee B/526, Geotechnics, which has the responsibility to:

- aid enquirers to understand the text;
- present to the responsible European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;
- monitor related international and European developments and promulgate them in the UK.

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

Cross-references

The British Standards which implement international or European publications referred to in this document may be found in the BSI Standards Catalogue under the section entitled "International Standards Correspondence Index", or by using the "Find" facility of the BSI Standards Electronic Catalogue.

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Summary of pages

This document comprises a front cover, an inside front cover, the EN title page, pages 2 to 61 and a back cover.

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Execution of special geotechnical work – Ground anchors

Exécution des travaux géotechniques spéciaux – Tirant
d'ancrage

Ausführung von besonderen geotechnischen Arbeiten
(Spezialtiefbau) - Verpreßanker

This European Standard was approved by CEN on 20 February 1998.

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 Central Secretariat or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Central Secretariat has the same status as the official versions.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
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Foreword

This European Standard 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 June 2000, and conflicting national standards shall be withdrawn at the latest by June 2000.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

The remit of CEN/TC 288 is the standardization of the execution procedures for geotechnical works (including testing and control methods) and of the required material properties. CEN/TC 288/WG 2 has been charged with the preparation of a standard in the subject area of ground anchors, which includes all anchors bonded to the ground by grout and are tensioned.

The document has been prepared to stand alongside ENV 1997-1-1 : Geotechnical Design, General Rules. Clause 7 "Design considerations" of this standard deals only with those matters which should be taken into account during the execution stage of ground anchor so that the design of the anchor system may be fulfilled. The standard, however, provides full coverage of the construction and supervision requirements. An informative Annex D provides a detailed treatment of ground anchor design.

The standard has been drafted by a working group comprising delegates from 10 countries and is based on the review of 10 national and international codes of practice.

1 Scope

This standard is applicable to the installation, testing and monitoring of permanent and temporary ground anchors where the load capacity is tested. An anchor consists of an anchor head, A free anchor length and a fixed anchor length which is bonded to the ground by grout. The term "ground" is taken to encompass both soil and rock.

The planning and design of ground anchors calls for experience and knowledge in this specialized field and although these topics are covered briefly in ENV 1997-1 Eurocode 7 : Geotechnical Design, Part 1 : General Rules a more detailed treatment of the design of ground anchors is included in an annex to this standard.

The installation and testing phases require skilled and qualified labour and supervision. This standard cannot replace the knowledge of specialist personnel and the expertise of experienced contractors required to apply the standard.

This standard does not address alternative systems of anchoring such as tension piles, screw anchors, mechanical anchors, soil nails, expander anchors or deadman anchors.

The standard establishes and defines principles with regard to anchor technology. Where anchor systems do not comply with the principles defined in the text, flexibility in the use of these systems is offered by written acceptance of the Client's Technical Representative.

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies.

Exceptionally the list of normative references contains European Pre-standards which are at the draft stage. If any of these documents becomes a European Standard the reference shall be checked.

EN 45014, *General criteria for declaration of conformity.*

ENV 206, *Concrete - Performance, production, placing and compliance criteria.*

ENV 1991-1-1, *Eurocode 1 : Basis of design and actions on structures - Part 1-1 : Basis of Design.*

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

ENV 1992-1-5, *Eurocode 2 : Design of concrete structures - Part 1-5 : Structures with unbonded and external prestressing tendons.*

ENV 1993-1-1, *Eurocode 3 : Design of steel structures - Part 1-1 : General Rules and rules for buildings.*

ENV 1994-1-1, *Eurocode 4 : Design of composite steel and concrete structures - Part 1-1 :- General rules and rules for buildings.*

ENV 1997-1:1994, *Eurocode 7 : Geotechnical design - Part 1 : General rules.*

prEN 445, *Grout for prestressing tendons - Test methods.*

prEN 446, *Grout for prestressing tendons - Grouting procedures.*

prEN 447, *Grout for prestressing tendons.*

prEN 10138, *Design of prestressing steel - Specification for common grout.*

3 Terms, definitions and symbols

3.1 Terms and definitions

The main terms are used in common with all Eurocodes. For the purposes of this standard the following definitions apply :

3.1.1

anchor

fr : tirant d'ancrage

de : Anker

an installation capable of transmitting an applied tensile load to a load bearing stratum

3.1.2

anchor head

fr : tête d'ancrage

de : Ankerkopf

the component of a ground anchor which transmits the tensile load from the tendon to bearing plate or structure

3.1.3

acceptance test

fr : essai de réception

de : Abnahmeprüfung

a load test to confirm that each anchor conforms with the acceptance criteria

3.1.4

apparent tendon free length

fr : longueur libre équivalente

de : Rechnerische freie Stahllänge

the length of tendon between the connection of the tendon to the stressing jack and a point along the tendon, deduced from load testing of an anchor

3.1.5

bleed

fr : ressuage

de : Absetzma

the separation of water from grout paste

3.1.6

borehole diameter

fr : diamètre de forage

de : Bohrlochdurchmesser

the diameter of a borehole as defined by the drill bit or casing diameter, excluding any enlargements

3.1.7

characteristic internal anchor resistance

fr : résistance interne

caractéristique du tirant

de : Charakteristischer Innerer

Ankerwiderstand

the characteristic load capacity of the anchor tendon

3.1.8

client's technical representative

fr : représentant technique du client

de : Technischer Bauherrnvertreter

represents the client and is fully acquainted with all aspects of the works related to the use of the anchors, including specialist knowledge of ground anchor technology

3.1.9

coupler

fr : coupleur

de : Koppelement

a device for joining lengths of bar or strand which comprise an anchor tendon

3.1.10

creep limit

fr : vitesse limite de fluage

de : Grenzkriechmaß

the maximum creep displacement rate permitted at a specific load level

3.1.11

critical creep load

fr : traction critique de fluage

de : Kritische Kriechkraft

the anchor load corresponding to the end of the first linear part of a plot of anchor load against creep rate

3.1.12

datum load

fr : traction de référence

de : Vorbelastung

the level of anchor load from which the anchor head displacement is measured during a stress test. In general, a value of 10 % proof load is adopted

3.1.13

encapsulation

fr : protection

de : Korrosionsschutzumhüllung

a corrosion protection applied at least to the tendon bond length

3.1.14

external anchor resistance

fr : résistance externe du tirant

de : Herauszieh Widerstand des Ankers

the load resistance of an anchor at the interface between ground and fixed anchor length

3.1.15

fixed anchor length

fr : longueur de scellement du tirant

de : Krafteintragungslänge

the designed length of an anchor over which the load is transmitted to the surrounding ground, through a grout body

3.1.16

free anchor length

fr : longueur libre du tirant

de : Freie Ankerlänge

the distance between the proximal end of the fixed anchor length and the tendon anchorage at the anchor head

3.1.17

grout

fr : coulis

de : Verpreßmörtel

a setting material which transfers load from the tendon to the ground over the fixed anchor length, and which may fill the rest of the borehole and/or contribute to corrosion protection

3.1.18

investigation test

fr : essai préalable

de : Untersuchungsprüfung

a load test to establish the ultimate load resistance of an anchor at the grout/ground interface and to determine the characteristics of the anchor in the working load range

3.1.19

load loss limit

fr : pert de tension admissible

de : Grenzkraftabfall

the permitted cumulative loss of load at the end of a specified time period

3.1.20

lock-off load

fr : traction de blocage

de : Festlegekraft

the load transferred to an anchor head immediately on completion of a stressing operation

3.1.21

permanent anchor

fr : tirant d'ancrage permanent

de : Daueranker

an anchor with a design life which is in excess of two years

3.1.22

proof load

fr : traction d'épreuve

de : Prüfkraft

the maximum test load to which an anchor is subjected

3.1.23

suitability test

fr : essai de contrôle

de : Eignungsprüfung

a load test to confirm that a particular anchor design will be adequate in particular ground conditions

3.1.24

system test

fr : essai de système

de : Systemprüfung

a test which is carried out on an anchor system to verify its competence to perform as required

3.25

temporary anchor

fr : tirant d'ancrage provisoire

de : Kurzzeitanker

an anchor with a design life of less than two years

3.1.26

tendon

fr : armature

de : Zugglied

the part of a ground anchor that is capable of transmitting the tensile load from the fixed anchor length to the anchor head

3.1.27

tendon bond length

fr : longueur de scellement de l'armature

de : Verankerungslänge des Zuggliedes

the length of the tendon that is bonded directly to the grout and capable of transmitting the applied tensile load

3.1.28

tendon free length

fr : longueur libre de l'armature

de : Freie Stahllänge

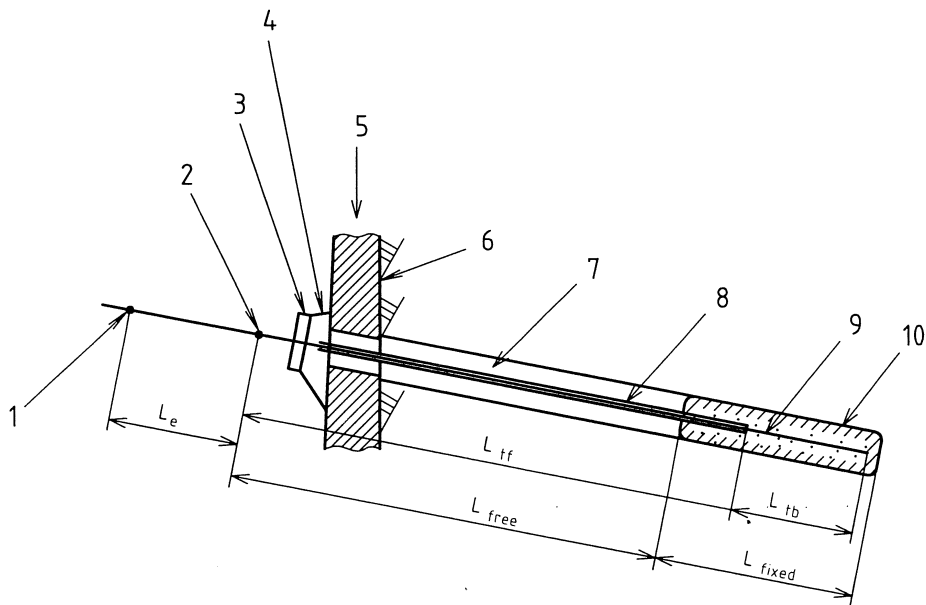
the length of tendon between the anchor head and the proximal end of the tendon bond length

A typical anchor is shown in Figure 1.

3.2 Symbols

A_t	Cross sectional area of anchor tendon
E_d	Design value of the effect of an action
$E_{d,dst}$	Design value of the effect of destabilising action
$E_{d,stb}$	Design value of the effect of stabilising action
E_t	Elastic modulus of anchor tendon
f	Friction loss as a percent of P_p
f_{tk}	Characteristic tensile strength of a tendon
$f_{t0,1k}$	Characteristic tensile stress at which there is a permanent strain of 0,1%
f_r	Relative area of ribs of ribbed or profiled wire or bar
k_s	Creep displacement rate
k_l	Load loss
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_{fixed}	Fixed anchor length
L_{free}	Free anchor length
L_{tb}	Tendon bond length
L_{tf}	Tendon free length
P	Anchor tendon load
P_a	Datum load
P_c	Critical creep load
P_c'	Approximation to critical creep load
P_o	Anchor lock-off load
P_p	Proof load
P_{tk}	Characteristic load capacity of tendon
$P_{t0,1k}$	Characteristic tensile load at which there is a permanent strain of 0,1 %
R_a	External anchor resistance
R_{ak}	Characteristic external anchor resistance
R_{ik}	Characteristic internal anchor resistance

R_d	Design resistance of an anchor
R_k	Lower of characteristic internal and external resistances
s	Anchor head displacement
t	Time from application of load increment or load lock-off
α	Slope of creep displacement/log time plot
ΔP	Difference between proof load and anchor datum load
Δs	Measured extension of anchor tendon under load increment ΔP
γ_q	Variation factor for anchor load
γ_R	Partial factor on anchor resistance



Key	
1	Anchorage point at jack during stressing
2	Anchorage point at anchor head in service
3	Bearing plate
4	Load transfer block
5	Structural element
6	Soil/rock
7	Borehole
8	Debonding sleeve
9	Tendon
10	Grout body

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

4 Specific needs

4.1 General

Ground anchors can only be designed efficiently on the basis of a sound knowledge of the construction project, of the structural requirements of the anchor and of the geotechnical properties of the ground. Anchor testing and the verification of design parameters are necessary elements in the construction procedure for economical installation of effective ground anchors.

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The responsibilities of all parties involved in the design, execution, testing and maintenance of the ground anchors shall be defined. Table 1 shows, as a guide, an appropriate separation of design and execution activities.

Table 1 — Design and execution activities

Overall design activities	Specialist execution activities
1. Provision of site investigation data for construction of ground anchors 2. Decision to use ground anchors, required trials and testing and provision of a specification 3. Acquisition of legal authorisation and entitlement to encroach on third party property 4. Overall design of anchored structure, calculations of anchor force required. Definition of safety factors to be employed. 5. Definition of ground anchor life (permanent/temporary) and requirement for corrosion protection. 6. Specification of anchor spacing and orientation, anchor loads and overall stability requirements. 7. Specification of minimum distance from the structure to mid fixed length to ensure stability of the structure. 8. Specification of load transfer mechanism from the anchor to the structure. 9. Specification of any sequence of anchor loading required of the structure and the appropriate load levels. 10. Specification of systems for monitoring ground anchor behaviour and for interpretation of results. 11. Supervision of the works. 12. Specification of maintenance for ground anchors. 13. Instruction to all parties involved of key items in the design philosophy to which special attention should be directed.	1. Assessment of site investigation data with respect to design assumptions. 2. Selection of ground anchor components and details. 3. Determination of fixed anchor dimensions. 4. Detailing of the corrosion protection system for the ground anchor. 5. Supply and installation of the ground anchor system. 6. Supply and installation of the ground anchor monitoring system. 7. Quality control of works. 8. Execution and assessment of anchor tests. 9. Evaluation of on-site anchor tests. 10. Maintenance of ground anchor as directed.

Sufficient information to assist in the design and installation of ground anchors should be provided prior to, and updated during, the execution of the works.

NOTE The whole design or some parts of the design may be performed by the client, the main contractor, a specialist contractor or by a consultant.

4.2 Planning of anchor works

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 ;

The amount of investigative and design work depends upon the type and size of the project, the complexity of the ground and the degree of risk involved.

5 Site investigation

The ground is a vital element of the ground anchor system, therefore a good quality geotechnical investigation is essential. A common cause of individual anchor failure at the acceptance testing stage is the lack of accurate information on the ground conditions local to the anchor.

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

All geotechnical investigation shall be undertaken in accordance with the requirements and recommendations of ENV 1997-1-1 Eurocode 7, Part 1.

Geotechnical investigation should be extended to site extremities so that the strata profile may be interpolated between the investigation locations rather than extrapolated outside the area investigated. Where possible it should be extended to include ground formations outside the actual site if stresses induced by anchors are extended there.

Depths of geotechnical investigation should be adequate to ensure that :

- a) a known geological formation is proved ; or
- b) no underlying stratum will affect design ; and
- c) groundwater conditions are well defined.

In addition to the lithology and structure of the ground in accordance with ENV 1997-1 Eurocode 7, Part 1, the following shall also be known, where applicable :

a) for soils :

- soil description and classification (grading, moisture content, unit weight, relative density, Atterberg limits) ;
- shear strength, compressibility and radial stiffness ;
- permeability ;
- ground water conditions ;
- corrosion potential of soil and ground water ;
- existence of stray electric currents ;

b) for rocks :

- classification (geometry of discontinuities, unit weight, degree of weathering, index tests) ;
- rock stratification ;
- unconfined compression strength of intact rock ;
- shear strength and deformability of rock mass ;
- permeability ;
- ground water conditions ;

- corrosion potential of rock and ground water ;
- existence of stray electric currents.

From this information, 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 into the borehole ;
- loss of grout from the borehole.

6 Materials and products

6.1 General

Anchor systems shall be used for which successful experience with respect to performance and durability has been documented.

All anchor systems shall have been subjected to at least one system test to verify the competence of the system. The results of all tests shall be documented in detail.

The documented system test shall be approved by the Client's Technical Representative in accordance with principles stated in this standard.

All materials used shall be mutually compatible. This applies in particular to adjacent materials with a common interface. Material properties shall not change during the design life of the ground anchor in such a way that the anchor loses its serviceability.

Anchors involving the use of newly developed materials or methods of execution are permitted subject to the performance of the anchor and durability of the materials used being proven by system tests and approved by the Client's Technical Representative to ensure that the serviceability of the anchor system is maintained for the design life of the anchored structure.

6.2 Tendon

All steel tendons shall comply with the following European Standards :

Construction steel	- ENV 1993-1 : Eurocode 3 : Design of steel structures - Part 1 : General rules ;
Steel reinforcement	- ENV 1992-1-1 : Eurocode 2 : Design of concrete structures - Part 1 : General rules ;
Prestressing steel	- prEN 10138: Design of prestressing steel ; - prENV 1992-1-5 : Eurocode 2 Part 1- 5: The use of unbonded and external prestressing tendons.

Other tendon materials may only be used if their suitability as anchor components has been proven and they are approved by the Client's Technical Representative.

6.3 Anchor head

The anchor head shall allow the tendon to be stressed, proof loaded and locked-off and, if required, released, destressed and restressed. It shall be able to carry the characteristic tensile load of the tendon of 100 % F_{yk}.

The anchor head shall comply with ENV 1992-1 : Eurocode 2 unless the required deviation is justified. The anchor head shall be designed to tolerate angular deviations of the tendon from the direction normal to the head, up to a maximum of 3° at 97 % P_{tk} of the tendon.

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.

The anchor head (i.e. the connection between the anchor tendon and the structure) shall be able to adjust to deformations which may be expected during the design life of the structure.

6.4 Coupler

Couplers shall comply with ENV 1992-1-1 : Eurocode 2, and shall not compromise the required tensile strength of the tendon.

The tendon should not be coupled inside the bond length.

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

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

6.5 Tendon bond length

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

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.

The relative area, f_r , of the ribs of ribbed or profiled wires and bars shall be in accordance with ENV 1992-1: Eurocode 2.

Prestressing steels with a smooth surface with or without special proven anchoring devices may only be used with temporary anchors when approved by the Client's Technical Representative.

6.6 Spacer and other components in the borehole

All installed tendons and encapsulations shall be provided with a minimum of 10 mm grout cover to the borehole wall. This may be achieved by the use of spacers or centralizers.

Any component installed and remaining in the borehole should be spaced and located so that it does not reduce the bond capacity of the anchor. To ensure correct positioning of the tendon(s), the tendon components, the corrosion protection components and any other component in the borehole, spacers should be located such that minimum grout cover requirements and complete filling of open volume by grout are provided.

Spacers and centralizers shall not impede grout flow.

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

The design of centralizers shall take into account the shape of the hole, e.g. the presence of underreamed bells, the weight of the tendon and the susceptibility of the ground to disturbance during insertion of the tendon.

6.7 Cement grout and admixtures

Cement grouts used in the encapsulation and in contact with prestressing steel tendons shall conform in general with prEN 445, prEN 446 and prEN 447. Where there is conflict between the provisions of this standard and prEN 445, prEN 446 and prEN 447, the provisions of this standard shall be adopted.

For cement grout used to encase a tendon within an encapsulation or to protect steel tubes, the properties should be controlled to prevent bleed and shrinkage. Water/cement ratios for anchor grouts outside the encapsulation but within the borehole should be chosen appropriate to the ground conditions.

High sulphide content cements shall not be used in contact with prestressing steel.

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 and sulphates, of the permeability of the ground and of the design life of the anchor. The aggressivity of the environment shall be defined in accordance with ENV 206.

Admixtures may be used for improving workability or durability, for reducing bleed or shrinkage, or for increasing rate of strength development. The use of admixtures with prestressing steel shall be approved by the Client's Technical Representative. Admixtures shall be free from any product liable to damage prestressing steel or the grout itself. No admixture that contains more than 0,1 % (by mass) of chlorides, sulphides or nitrates shall be used.

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

Laboratory and field tests should be undertaken to verify mixture, mixing efficiency, setting times and performance. These tests should be undertaken in accordance with prEN 445 where applicable.

6.8 Resin grout

Resins and resin mortars may be used in ground anchor construction as an alternative to cement grout if their applicability has been proven by a system test appropriate to their application.

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

6.9 Corrosion protection of steel tendon and stressed steel components

6.9.1 General

There is no certain way of identifying corrosive circumstance with sufficient precision to predict corrosion rates of steel in the ground. All steel components which are stressed shall be protected against corrosion for their design life. Corrosion protection elements shall be capable of transmitting tendon loads, where required.

The standard of corrosion protection is classified by the anchor design life :

- temporary ground anchors are defined as those which are required to be in service no longer than two years ;
- permanent ground anchors are defined as those which are to have a design life of more than two years.

Table 2 — Examples of corrosion protection systems for temporary anchors

1. Tendon bond length All installed tendons shall 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(s).
2. Tendon free length The protection system shall have low frictional properties and allow movement of the tendon within the borehole. This may be achieved by the provision of one of the following : a) plastic sheath surrounding each individual tendon, end sealed against ingress of water ; b) plastic sheath surrounding each individual tendon, completely filled with corrosion protection compound ; c) plastic or steel sheath or duct common to all tendons, end sealed against ingress of water ; d) plastic or steel sheath or duct common to all tendons completely filled with corrosion protection compound ; b) or d) is appropriate for extended temporary use or in aggressive conditions.
3. Transition between anchor head and free length (inner anchor head) The free length sheath or duct may be sealed to the bearing plate/anchor head, or a metal sleeve or plastic duct may be sealed or welded to the bearing plate. It shall overlap the free length sheath or duct and for extended temporary use 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 is 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 shall be fitted and filled with corrosion protection compound for extended use. Where aggressive conditions are known to exist, a metal or plastic cap shall be filled with corrosion protection compound.

6.9.2 Temporary ground anchor

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

If there is a possibility that the design life of a temporary ground anchor is to be extended on a temporary basis or if the anchor is installed in ground conditions known to be corrosive then measures, approved by the Client's Technical Representative, shall be taken to protect all parts of the anchor from corrosion.

Examples of corrosion protection which may be considered to satisfy the above principles of protection to temporary anchors are described in Table 2.

6.9.3 Permanent ground anchor

The minimum corrosion protection surrounding the tendon(s) of the anchor shall be a single continuous layer of corrosion preventive material which does not degrade during the design life of the anchor.

The tendon(s) of a permanent ground anchor shall be provided with either :

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

- b) a single protective barrier to corrosion, the integrity of which shall be proven by testing each anchor insitu (see annex A) ;
- c) a corrosion protection system provided by a steel duct tube-a-manchette type anchor (see 6.10.4 and 6.10.9) ;
- d) a corrosion protection system provided by a corrugated plastic duct tube-a-manchette type anchor (see 6.10.4 and 6.10.9);
- e) a corrosion protection system provided by a steel duct compression tube type anchor (see 6.10.4 and 6.10.6).

Examples of corrosion protection which may be considered to satisfy the above principles of protection to permanent anchors are described in Table 3.

6.10 Commonly used components and materials for corrosion protection barriers

6.10.1 Plastic sheaths and ducts

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. Joints between plastic components shall be fully sealed against ingress of water by direct contact or by sealants. Where used, PVC shall be resistant to ageing and shall not produce free chlorides.

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

- 1,0 mm for internal diameter ≤ 80 mm ;
- 1,5 mm for internal diameter > 80 mm but ≤ 120 mm ;
- 2,0 mm for internal diameter > 120 mm.

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.

The minimum wall thickness of an internal sheath shall be 1,0 mm and an internal corrugated duct shall be 0,8 mm.

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

Where used for load transfer, plastic ducts shall be deformed or corrugated. The amplitude and pitch of the deformations or corrugations shall be related to the wall thickness and shall be able to transfer load in a manner not susceptible to creep losses.

Table 3 — Examples of corrosion protection systems for permanent anchors

Verification of protection offered a) All corrosion protection systems shall have been subjected to test(s) to verify the competence of the system. The results of all tests shall be well documented ; b) the Client's Technical Representative will carry out a technical assessment of the results of the corrosion protection system tests in order to verify that the protection offered by each barrier in the system is achieved. It should be noted that in certain systems the integrity of the inner protective barrier itself depends on the maintenance of the integrity of the outer barrier ; c) where only a single protective barrier is provided in the tendon bond length the integrity of this barrier may be checked by an insitu test such as an electrical resistivity test.	
1. Tendon bond length The encapsulation may consist of one of the following : a) a single corrugated plastic duct containing the tendon(s) and cement grout ; b) two concentric corrugated plastic ducts containing the tendon(s), fully pregrouted (with cement or resin) within the core and the annulus between the ducts prior to installation ; c) a single corrugated plastic duct containing a bar tendon or tendons and pregrouted with cement grout. A minimum cover of 5 mm is provided between the duct and bar. The bar tendon(s) have 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 ; 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 tendons. The crack width of this cement grout does not exceed 0,2 mm under service loading ; 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 10mm, and where the crack widths do not exceed 0,1 mm under service loading.	Protective barriers Offered insitu a) one plastic duct b) two plastic ducts c) internal cement grout and surrounding plastic duct ; d) internal cement grout and surrounding steel or plastic duct ; e) steel duct and surrounding cement grout
2. Tendon free length The protection system allows free movement of the tendon within the borehole. This may be achieved by one of the following : a) a plastic sheath to individual tendon(s) filled completely with flexible corrosion protection compound plus the inclusion of A, B, C or D below ; b) a plastic sheath to individual tendon(s) filled completely with cement grout plus A or B below ; c) a common plastic sheath for multiple tendon(s) 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 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 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 may be filled with cement or resin.	