SLOVENSKI STANDARD
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Izvedba posebnih geotehničnih del - Geotehnična sidra

Execution of special geotechnical work - Ground anchors

Ausführung von besonderen geotechnischen Arbeiten (Spezialtiefbau) - Verpreßanker

Exécution des travaux géotechniques spéciaux - Tirant d'ancrage

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Execution of special geotechnical work - Ground anchors

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Ausführung von besonderen geotechnischen Arbeiten (Spezialtiefbau) - Verpreßanker

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

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Contents

Foreword 4

1 Scope 5

2 Normative references 5

3 Terms, definitions and symbols 6
3.1 Terms and definitions 6
3.2 Symbols 9

4 Specific needs 10
4.1 General 10
4.2 Planning of anchor works 11

5 Site investigation 12

6 Materials and products 13
6.1 General 13
6.2 Tendon 13
6.3 Anchor head 13
6.4 Coupler 14
6.5 Tendon bond length 14
6.6 Spacer and other components in the borehole 14
6.7 Cement grout and admixtures 15
6.8 Resin grout 15
6.9 Corrosion protection of steel tendon and stressed steel components 15
6.10 Commonly used components and materials for corrosion protection barriers 17
6.11 Application of corrosion protection 20
6.12 Corrosion protection testing for permanent anchors with system tests 22

7 Design considerations 23

8 Execution 24
8.1 Drilling of holes 24
8.2 Manufacturing, transport, handling and installation of tendons 25
8.3 Grouting 26
8.4 Stressing 28

9 Testing, supervision and monitoring 29
9.1 General 29
9.2 Measurement accuracy 30
9.3 Datum Load 30
9.4 Test methods 31
9.5 Investigation test 31
9.6 Suitability test 31
9.7 Acceptance test 32
9.8 Maximum lock-off load 32
9.9 Evaluation of the apparent tendon free length 32
9.10 Supervision of construction and testing 33
9.11 Monitoring 33

10 Records 34

11 Special requirements 35

Annex A (informative) Electrical testing of corrosion protection 36

Annex B (informative) Investigation testing of corrosion protection 40

Annex C (informative) Guidelines for acceptance criteria for viscous corrosion protection compounds and examples of standards for the testing of material properties 42

Annex D (informative) Design of ground anchors 43

Annex E (informative) **Examples of anchor testing methods** **49**

Annex F (informative) **Examples of record sheets** **60**

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 standardisation 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 specialised 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 Prestandards 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 : Koppelelement
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 : Grenzkriechmaβ
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 : Herausziehwiderstand 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 : Verpreβmörtel
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

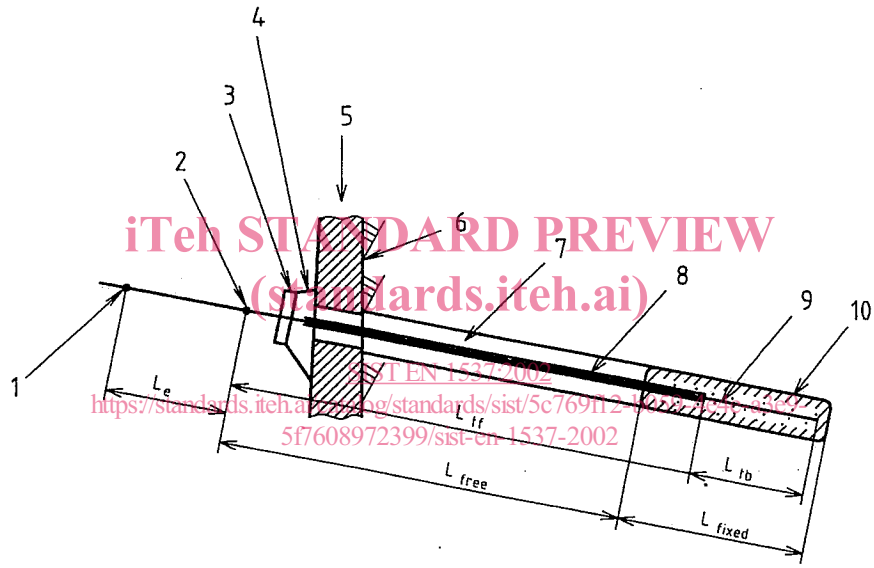
3.1.28
tendon free length
fr : longueur libre de l'armature
de : Freie Stahllänge
the length of tendon between the anchor head and the proximal end of the tendon bond length

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_1	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 Lold transfer black
5 Structural element
6 Soll/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.

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

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 have 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 % P_{tk}.