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Geotechnical investigation and testing — Testing of geotechnical structures —

Part 5: Testing of grouted anchors

Reconnaissance et essais géotechniques — Essais des structures géotechniques —

Partie 5: Essais de tirants d'ancrage

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 182, *Geotechnics*.

A list of all the parts in the ISO 22477 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document, together with EN 1997-1 and EN 1537, form the trinity in which:

— EN 1997-1 defines the design requirements for grouted anchors, including the limits of proof load and limiting criteria by testing of grouted anchors, which may be specified in the national annex (for EN 1997-1) or a similar national application document for ISO countries;

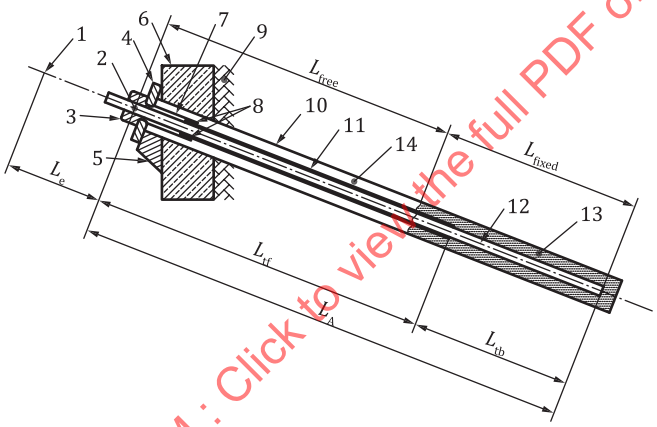
— EN 1537 defines the execution of grouted anchors;

— this document defines the testing of grouted anchors.

The document has been structured so that common items are given in Clauses 1 to 7. The different test specific loading procedures, measurements, checks and presentation of test results for the three test methods (Test Method 1, 2 and 3) have been placed in three separate clauses. The determination of the fundamental characteristics: creep rate, load loss, critical creep load and the apparent tendon free length are not test specific and for this reason these have been placed in Annexes A to D.

Yield stress and tensile strength for typical anchor steels appear in Annex E.

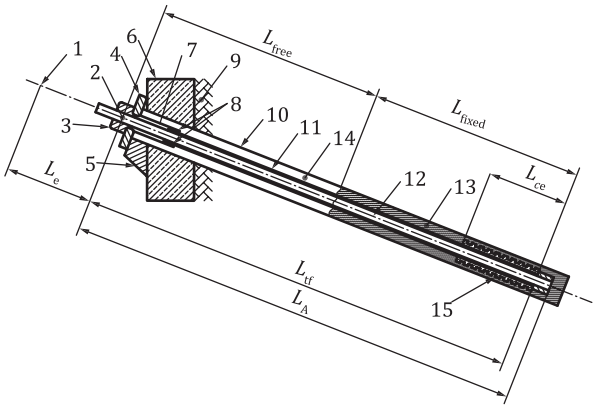
Figures 1 and 2 illustrate the two main types of grouted anchors considered in EN 1537.



Key

1 anchorage point at jack during stressing
2 anchorage point at anchor head in service
3 tensioning element at anchor head (nut or barrel and wedge)
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

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 (nut or barrel and wedge)
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

Geotechnical investigation and testing — Testing of geotechnical structures —

Part 5: Testing of grouted anchors

1 Scope

This document establishes specifications for the execution of tension tests to be carried out on an anchor grouted in the ground, as defined in EN 1997-1 and EN 1537. Three methods of testing are recognized by this document. Test Method 1 involves cyclic tension loading with measurement of displacement at the load stages; Test Method 2 involves cyclic tension loading with measurement of load loss at the load stages; and Test Method 3 involves step-loading with measurement of displacement under successive maintained tension loads.

This document provides specifications for the experimental devices, the measurement apparatus, the test procedures, the definition and presentation of the test results and the content of records.

NOTE This document does not provide specification for the size of the proof load and the limiting criteria. These aspects reside in EN 1997-1 or its national annex for CEN countries and in similar national application documents for this test standard for ISO countries.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 1537:2013, *Execution of special geotechnical works — Ground anchors*

EN 1997-1:2004+A1:2013, *Eurocode 7: Geotechnical design — Part 1: General rules*

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 1997-1 and EN 1537 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1.1
acceptance test
load test to confirm that an individual anchor conforms with its acceptance criteria

Note 1 to entry: Refer to EN 1997-1.

3.1.2
anchor tendon resistance
ultimate tensile resistance of the anchor tendon

3.1.3
critical creep load
load corresponding to the end of the first pseudo-linear part of the "α versus load diagram"

Note 1 to entry: Refer to Annex C for the determination of the critical creep load.

3.1.4
geotechnical ultimate limit state resistance
ultimate resistance of the ground-grout interface or pull-out resistance

Note 1 to entry: The ground-grout interface resistance is the load at which the creep rate α meets the limiting criterion in the form of a specific creep rate α_{ULS} or the vertical asymptote of the creep rate versus load curve, (that is an infinite creep rate).

Note 2 to entry: For Test Method 2 load loss is used as criterion instead of creep rate, refer to EN 1997-1.

3.1.5
serviceability limit state resistance
load at which the creep rate α meets the limiting criterion in the form of a specific creep rate α_{SLS}

Note 1 to entry: Also defined as the load corresponding to a characteristic point — the knee point — on the creep rate versus load curve, termed the critical creep load.

Note 2 to entry: Refer to EN 1997-1.

3.1.6
investigation test
load test to establish the geotechnical ultimate resistance of an anchor and to determine the characteristics of the anchor in the working load range

Note 1 to entry: Refer to EN 1997-1.

3.1.7
production anchor
anchor that forms part of the anchored structure

Note 1 to entry: Also referred to as a working anchor.

Note 2 to entry: Not suitable for investigation tests.

3.1.8
proof load
maximum test load to which an anchor is subjected in a particular load test

3.1.9
suitability test
load test to confirm that a particular anchor design will be adequate in particular ground conditions

Note 1 to entry: Refer to EN 1997-1.

3.1.10
test anchor
sacrificial anchor installed for testing purposes only

3.2 Symbols

A_t Cross-sectional area of anchor tendon

E_t elastic modulus of anchor tendon

f friction loss as a percentage of P_p

f_{tk} characteristic tensile strength, also referred to as f_{uk} in EN 1993 (all parts)

$f_{t0,1k}$ characteristic yield stress corresponding the 0,1 % yield strain = f_{yk}

$f_{t0,2k}$ characteristic yield stress corresponding the 0,2 % yield strain = f_{yk}

k_l load loss

$k_{l;ULS}$ permissible cumulative loss of load over specified time period, used to determine ultimate limit state resistance of an anchor

$k_{l;SLS}$ permissible cumulative loss of load over specified time period, used to determine serviceability limit state resistance of an anchor

L_{app} apparent tendon free length

L_{ce} length of compression element (refer to EN 1537)

L_e external length of tendon measured from the tendon anchorage in the anchor head to the anchorage point in the stressing jack (refer to EN 1537)

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_c critical creep load

P_o anchor lock-off load

P_p proof load

$R_{ULS:m}$ measured value of the geotechnical resistance of an anchor complying with the ultimate limit state criteria

$R_{SLS:m}$ measured value of the geotechnical resistance of an anchor complying with the serviceability limit state criteria

s tendon end displacement

t time

α slope of “creep displacement vs. decimal logarithm of time” plot, creep rate, creep displacement rate

α_{ULS} limit criterion of α in ULS

α_{SLS} limit criterion of α in SLS

α_1 limit of α by test method 1

α_3 limit of α by test method 3

ΔP difference between proof load and datum load

ΔP_f friction loss

Δs measured displacement of the tendon end produced by load increment ΔP

Δs_{el} measured displacement of the tendon end at proof load P_p minus displacement after de-loading to datum load P_a

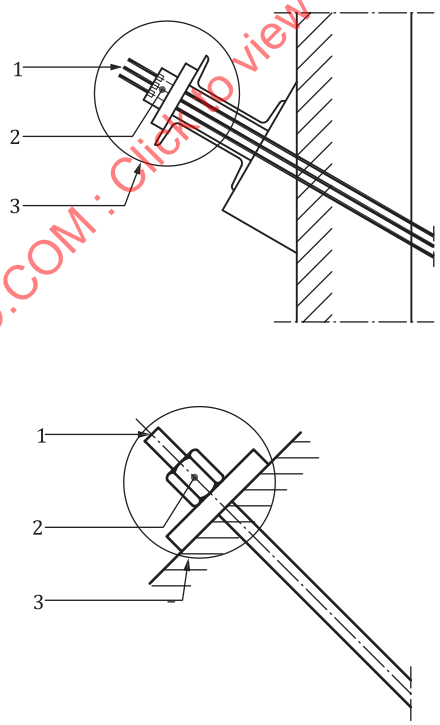
4 Equipment

4.1 Test loading set-up

The principal components of a test loading system are a stressing device, a reaction system and equipment for the measurement and recording of loads or pressures, displacement and time. Other equipment may include devices for the measurement and recording of ambient temperature.

The test loading system shall be designed to operate safely up to the proof load.

When using Test Method 2 or if an independent datum point is not available (at the tendon end, Figure 3) then the structural movement shall be monitored (see Figure 5, key 8).



Key

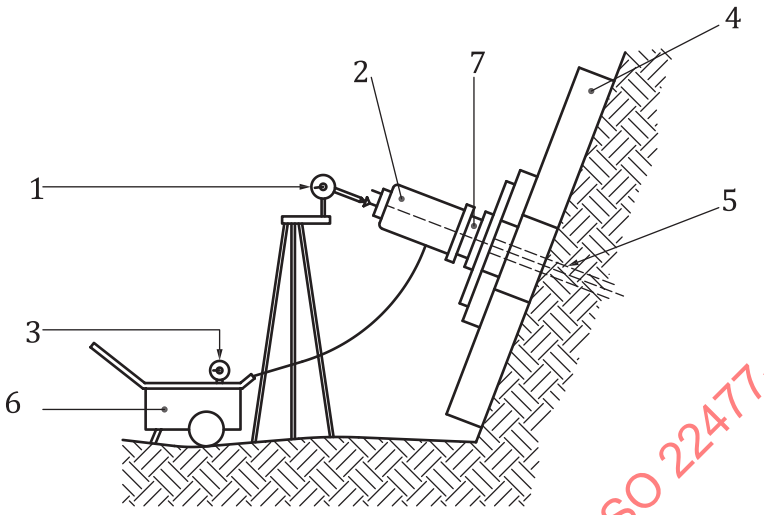
1 tendon end

2 anchorage point, provided by wedges on strand anchor or nut on bar anchor

3 anchor head

Figure 3 — Anchor head details for strand and bar anchors

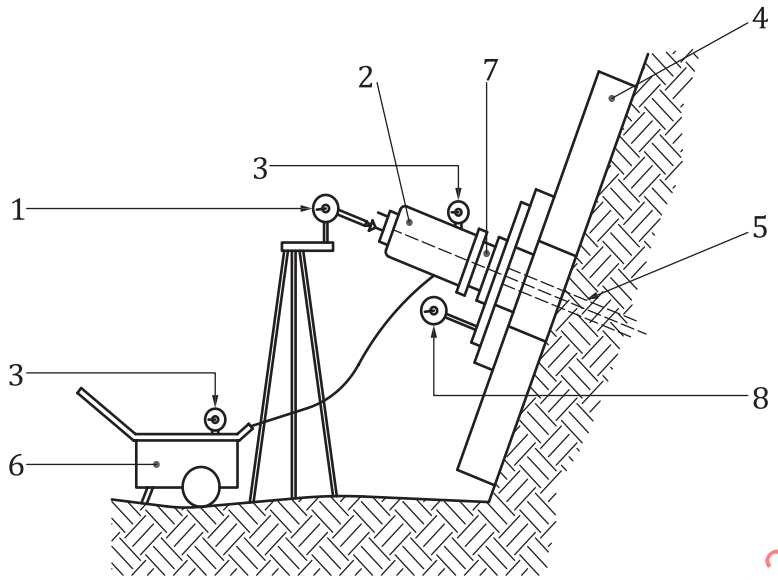
NOTE Schematic illustrations of loading systems are presented in Figures 4, 5 and 6. Where possible it is better to measure the load between the loading device and the bearing plate to avoid the determination of the friction in the jack.



Key

1 displacement monitoring of tendon end
2 stressing device
3 load monitoring system (pressure gauges)
4 reaction system/structure
5 tendon
6 hydraulic system (pump)
7 load cell (optional)

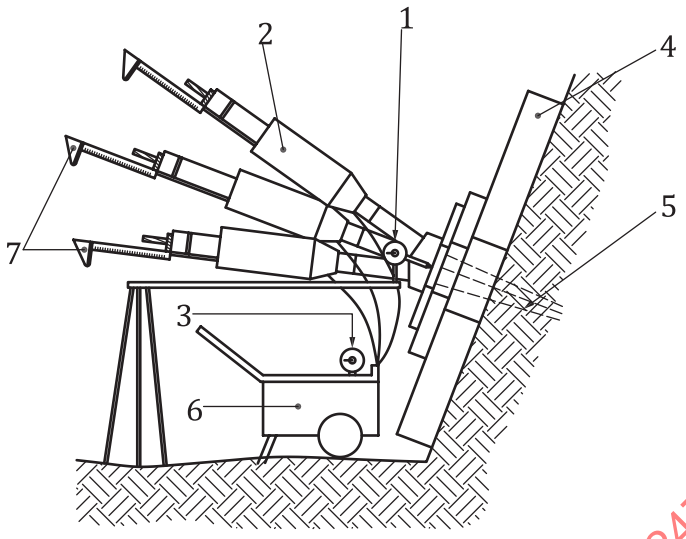
Figure 4 — Schematic illustration showing typical method of measuring tendon displacement from an independent datum



Key

1 displacement monitoring of the tendon end
2 stressing device
3 load monitoring system (pressure gauges)
4 reaction system/structure
5 tendon
6 hydraulic system (pump)
7 load cell to measure load loss
8 displacement monitoring of the reaction structure, mounted on separate tripod (not shown)

Figure 5 — Schematic illustration showing typical method of measuring tendon load loss using a pressure gauge, with reaction system deformation measurement from an independent datum



Key

1 independent displacement monitoring of structure (two dial gauges on centre axis, each side of bearing plate)
2 multiple jacks acting as stressing device for staggered anchors
3 load monitoring system (pressure gauge)
4 reaction system/structure
5 tendon
6 hydraulic system (pump)
7 displacement monitoring system, comprising long stroke digital Vernier gauge or similar

Figure 6 — Schematic illustration showing typical method of measuring tendon displacement on staggered free lengths, using long stroke Vernier gauge

4.2 Reaction system

The reaction system shall be designed to resist the proof load in accordance with the relevant European standards.

The reaction system should be designed not to impose excessive loads to the ground, which may cause detrimental deformation or settlement.

In the case of load loss measurement, monitoring of the reaction system shall be performed to determine the displacement of the reaction structure itself during testing.

4.3 Loading device

The loading device, normally a hydraulically operated jack, should have a capacity at least 10 % greater than the proof load.

The extension of the jack should be greater than the sum of the elongation of the tendon under the proof load, and the displacement of the reaction system. In cases where a single jack cannot provide the necessary extension, suitable equipment (e.g. multiple jacks placed in series) shall be used.

The equipment (hydraulic jack, pumping unit, etc.) shall be capable of safely tensioning the tendon smoothly and axially, in accordance with the test procedure. The load shall be applied or released in a controlled manner without any shocks.

With the exception of anchors with staggered free lengths, stressing equipment for bar and strand tendons shall tension the complete tendon as a single unit. The stressing equipment for anchors with staggered free lengths shall comply with EN 1537:2013, 8.4.5.

4.4 Load measurement

The load may be measured either indirectly (e.g. by means of a calibrated pressure gauge, monitoring the hydraulic pressure in the stressing device) or directly (e.g. by the use of a load cell).

The required minimum accuracy for the measured load shall be the larger of 1 % of the measured value or 10 kN.

Pressure gauges, load cells and jacks, used to measure the load, shall be calibrated within 12 months prior to the test. The calibration certificates shall be made available for inspection on site at all times.

4.5 Displacement measurement

The support for the displacement devices shall be remote from the stressing device and reaction system and be sufficiently rigid so as not to be influenced by background vibrations. The test installation should be protected against direct sunlight, and the measuring equipment from rain.

Tendon end displacement shall be recorded following the application of the datum load.

The precision of the measuring equipment shall be 0,5 mm or better for displacement measurements, and 0,01 mm for creep monitoring.

The displacement measuring devices shall be calibrated within 12 months prior to the test.

Displacement devices should be capable of monitoring the displacement of the tendon end, throughout the test, without the need for resetting.

Where displacement measurements exceed those practical by dial gauges, either cable actuated extension measuring devices (from an independent datum) or digital Vernier gauges, with a separate monitoring of the reaction system, may be used.

4.6 Time and temperature measurement

The accuracy of the measured time shall be 1 s.

The accuracy of the measured air temperature shall be ≤1 °C.

5 Test types

5.1 General

The standard provides specifications for three types of tension tests as defined in EN 1997-1 and EN 1537: investigation tests, suitability tests and acceptance tests.

Test Method 1, 2 or 3 shall be used consistently for all test types (investigation, suitability and acceptance).

5.2 Investigation test

The purpose of an investigation test is to:

— identify the pull out resistance;

— identify a possible proof load for the suitability test and acceptance test;

— document the apparent tendon free length;

— identify the critical creep load (Test Method 3).

5.3 Suitability test

The purpose of a suitability test is to:

— document the ability of the anchor to resist a proof load;

— assess the behaviour of the anchor system up to proof load in terms of creep rate or load loss;

— document the apparent tendon free length;

— document the lock-off load.

5.4 Acceptance test

The purpose of an acceptance test is to:

— document the ability to resist a proof load;

— document the apparent tendon free length;

— document the lock-off load.

6 Execution

6.1 Test location

The results of the site investigation shall be considered when selecting a test anchor location.

Ground conditions at the test location shall be representative for the ground conditions of production anchors. The test location shall be placed at the location with the least favourable results of the ground investigation for anchoring.

6.2 Test anchors

Investigation tests shall be carried out on test anchors which are not part of an actual structure and are installed prior to the installation of production anchors.

The method used for the installation of test anchors shall be fully documented, as prescribed in EN 1537.

Test anchors shall be installed using the same installation procedures as production anchors.

Test anchors shall have the same borehole diameter as the production anchors.

Test anchors should have the same inclination as production anchors. Where alternative installations have been used for test anchors, supplementary suitability tests shall be carried out with the same inclination as for production anchors.

Test anchors may have stronger tendons than production anchors.

Test anchors should have the same fixed length as production anchors. However, to ascertain the geotechnical ultimate resistance a shorter fixed length or stronger tendon may be employed in investigation tests, provided that supplementary suitability tests are carried out with the same fixed length as the production anchors.

6.3 Time period between installation and test

Between the installation of anchors and the beginning of the test, adequate time shall be allowed to ensure that the required strength of the anchor fixed length grout and the regeneration of ground strength are achieved.

6.4 Test preparation

Prior to commencement of the test, the preparation shall at least include:

a) installation of measurement devices and checking their normal and safe functioning;

b) establishment of a perimeter of safety around the anchor;

c) installation of the stressing system and checking its normal and safe functioning (e.g. it shall be checked that the stressing device is in the axis of the anchor to be tested).

The reference system shall be located in such a way that it is not affected by any displacement of the reaction system and it shall be protected against climatic effects.

6.5 Proof load

The proof load shall be stated in EN 1997-1 or its national annex for CEN countries and in similar national application documents for this test standard for ISO countries.

The proof load P_p shall be defined prior to the test.

The tendon shall comply with the following limiting criteria, c.f. EN 1997-1:2004+A1:2013, 8.5.4 (2)P:

$$P_p \leq 0{,}80 \cdot P_{tk} = 0{,}80 \cdot f_{tk} \cdot A_t$$

$$P_p \leq 0{,}95 \cdot P_{t0,1k} = 0{,}95 \cdot f_{t0,1k} \cdot A_t \text{ or } 0{,}95 \cdot P_{t0,2k} = 0{,}95 \cdot f_{t0,2k} \cdot A_t, \text{ respectively}$$

where

f_{tk} = the tensile strength = f_{uk};

$f_{t0,1k}$ and $f_{t0,2k}$ are both yield stresses f_{yk} at 0,1 % and 0,2 % yield strain, respectively.

The smallest value is definitive.

The use of $P_{t0,1k}$ or $P_{t0,2k}$ depends on the applied steel quality. Values of $f_{t0,1k}$, $f_{t0,2k}$ and f_{tk} for typically steel types appear from Annex E.

6.6 Datum load

A datum load P_a shall be applied to minimise movement of the anchor test system on initial loading. This datum load can be equal to 10 % of P_p.

6.7 Group testing

Group testing shall comprise simultaneous suitability tests on three adjacent anchors.

The group test is an investigation of possible adverse effect on adjacent anchors and does not relate directly to overall stability.

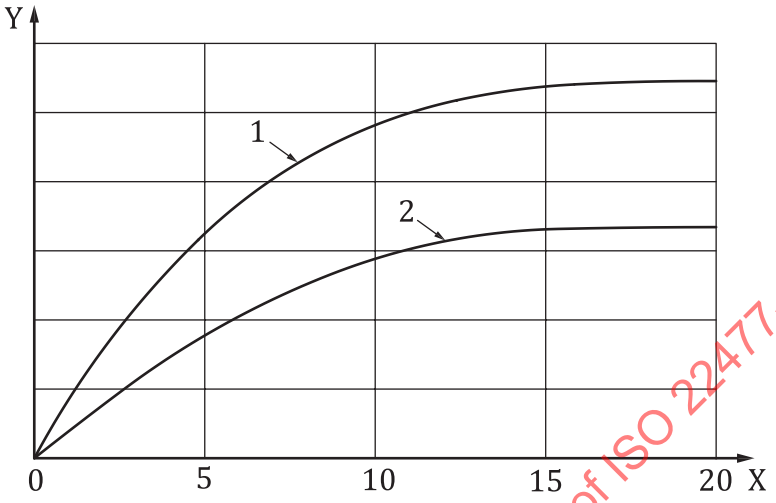
6.8 Alternating load testing

When grouted anchors are tested to alternating loads, the magnitude of the upper load and lower load shall be defined before the test.

During the test, the anchor shall be subjected 20 times to alternating load cycles between this upper and lower load. The tendon end displacements shall be measured during the test, at least after each fifth cycle. Subsequently, the anchor shall be unloaded to the datum load P_a and the plastic displacements resulting from the alternating load cycles shall be determined. The results of the alternating load test

shall be presented as shown in Figure 7. The increment of the displacement per load cycle shall reduce by increasing number of load cycles, as illustrated in Figure 7.

NOTE Tests with alternating loads can be applied if the bonded length is situated in uniform sands showing contractive behaviour.



Key

X load cycles *n*
Y displacement
1 upper load
2 lower load

Figure 7 — Displacement by alternating loading

7 Test report

7.1 Investigation and suitability tests

The test report should include:

a) Reference to all relevant standards;

b) The following specifications concerning the anchor (see Record sheet of EN 1537:2013, Annex D):

- Location, reference number and type of anchor;
- Date of installation;
- Observations related to the installation of the anchor, likely to have an influence on the test results;
- Geometrical data of the anchor and mechanical properties of the anchor material;
- Levels of the anchor head, the bottom of the fixed anchor length and the existing ground level;

c) The following factors concerning ground conditions:

- Reference to the site investigation report;
- Location of the closest geotechnical investigation profiles;
- Ground conditions encountered during anchor installation;

d) The following factors concerning the anchor test:

- Reference of the organisation which has carried out the test;
- Date of the test;
- Value of the prescribed proof load;
- Characteristics of the loading system;
- Description and identification (serial number) of all monitoring systems and their components;
- Sketch of the instrumentation of the anchor to be tested;
- Observations related to the execution of the test, likely to have an influence on the results (see EN 1537);
- Calibration data for the measuring equipment;

e) The relevant graphical plots derived from the adopted test method.

The lock-off load shall be documented, for suitability tests.

Tables of numerical values of the collected data shall be provided in the annexes of the test report.

7.2 Acceptance test

The test report should include:

a) Reference to all relevant standards;

b) The following specifications concerning the anchor (see Record sheet of EN 1537:2013, Annex D):

- Location, reference number and type of anchor;
- Date of installation;
- Observations related to the installation of the anchor, likely to have an influence on the test results;
- Geometrical data of the anchor and mechanical properties of the anchor material;
- Levels of the anchor head, the bottom of the fixed anchor length and the existing ground level;

c) The following factors concerning the anchor test:

- Reference of the organisation which has carried out the test;
- Date of the test;
- Value of the prescribed proof load;
- Calibration data for measuring equipment;

d) The relevant graphical plots from the adopted test method where the criteria for the minimum observation period is exceeded.

The lock-off load shall be documented.

Tables of numerical values of the collected data shall be provided in the annexes of the test report.

8 Test Method 1

8.1 General

The anchor is loaded stepwise by one or more load cycles increasing from the datum load to the proof load (see Figure 8). At each load step the displacement of the tendon end shall be measured during a fixed time period.

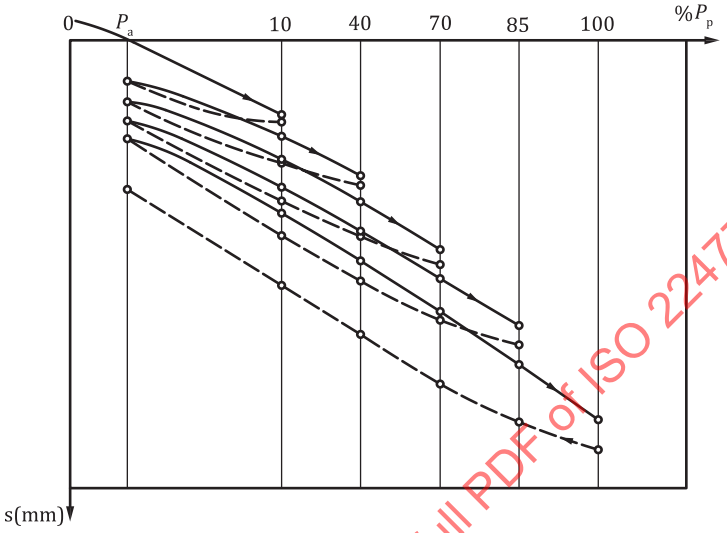


Figure 8 — Example of load-displacement curve for suitability test on a permanent anchor in coarse soil and rock

NOTE The creep behaviour of the anchor and the extension of the tendon by loading are used for evaluation of the behaviour of the anchor (see Annex A).

8.2 Investigation test

8.2.1 General

An investigation test according to Test Method 1 is a test in which an axial load is applied incrementally in cycles to a grouted anchor up to the proof load P_p, which is designed to reach failure of the ground-grout interface. The test should be based on six cycles. At the maximum load of each cycle the load is maintained constant for a specified period of time. The test involves measurement of tendon end displacement versus applied load and, at the maximum load of each cycle, measurement of tendon end displacement versus time.

If the anchor fails before the six cycles have been executed, the test is concluded.

NOTE The target of P_p is based on an estimate.

8.2.2 Loading procedure

The anchor should be loaded from the datum load P_a to the proof load P_p in a minimum of six cycles (Figure 9). The maximum load for each cycle is specified in Table 1. In each cycle, the maximum load shall be reached in stages. The maximum load for the cycles should be P_a – 40 % P_p – 55 % P_p – 70 % P_p – 80 % P_p – 90 % P_p and 100 % P_p, as shown in Figure 9. Load steps are to be held for at least 1 min. Maximum load in each cycle is to be maintained for at least the duration stated in Table 1.

Subsequently, the anchor shall be unloaded to the datum load P_a using the same loading steps. The observation times for unloading steps shall be not less than 1 min.

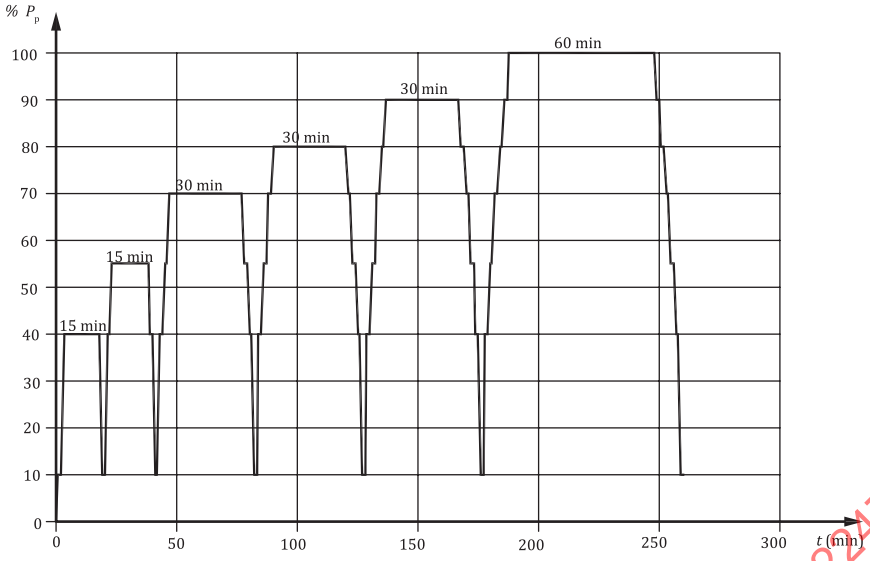


Figure 9 — Loading sequence for investigation test for coarse soil and rock

Table 1 — Loading sequence for investigation test

Cycle	Maximum load	Minimum observation period at maximum load for each cycle (min)	
		Coarse soil and rock	Fine soil
0	P_a	1	1
1	0,40 P_p	15	15
2	0,55 P_p	15	15
3	0,70 P_p	30	60
4	0,80 P_p	30	60
5	0,90 P_p	30	60
6	1,00 P_p	60	180

NOTE For the definition of coarse and fine soil refer to ISO 14688-1.

8.2.3 Measurements and checks

Tendon end displacement shall be measured immediately upon application of every load and unload stage and at the end of the minute hold period. At the maximum load of the cycle, where the test load is held constant, the displacement shall be measured over the observation period, at time intervals such as:

1→2→3→4→5→7→10→15→20→30→45→60→90→120→150→180 (min)

NOTE 1 The periodicity of the measurements can be adapted to conditions of the test.

At the highest load of each cycle, the value of α shall be checked. The results shall be shown on a semi-logarithmic diagram (Figure A.1). The observation times for loading stages reached for the first time shall be extended if the creep rate α cannot be clearly determined.

NOTE 2 Guidance on the determination of α is given in Annex A.

A recommended value of the limiting criterion of α (termed α_1 in Test Method 1) identifying the pull-out resistance $R_{ULS,m}$ is stated in EN 1997-1. α_1 may be set in the national annex to EN 1997-1.

8.2.4 Test results

Measurements taken during the test shall be presented graphically in the following plots:

— plot of the creep rate α versus anchor load (Figure 10);

— plot of tendon end displacement versus anchor load (Figure 12);

— plot of tendon end displacement versus log time at the highest load of each cycle (Figure 13).

Based on the collected data, the following parameters shall be determined:

— measured anchor pull-out resistance $R_{ULS;m}$ to be derived from Figure 10. The measured pull out resistance $R_{ULS;m}$ of an anchor is reached when the creep rate α exceeds the limiting value given in EN 1997-1 (that is α_1 in Test Method 1);

— calculated apparent tendon free length L_{app} (Annex D).

In cases where α does not exceed the given limiting value in EN 1997-1 during the test, the measured pull out resistance $R_{ULS;m}$ shall be defined as the maximum test load.

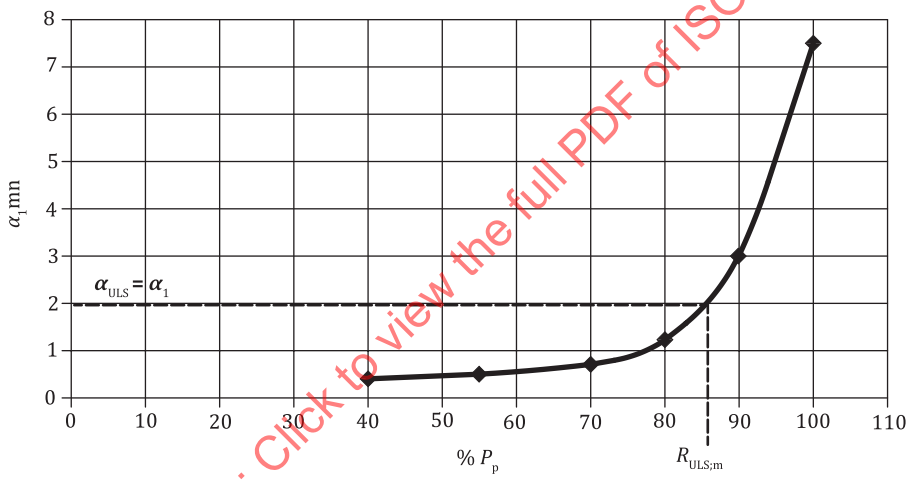


Figure 10 — Plot of α versus anchor load, example investigation test (pull out resistance was reached before target value of P_p)

8.3 Suitability test

8.3.1 General

A suitability test according to Test Method 1 is a test in which an axial load is applied incrementally in at least five cycles to a ground anchor up to a proof load P_p to confirm that a particular anchor design will be adequate in particular ground conditions. At the maximum load of each cycle the load is maintained constant for a specified period of time. The test involves measurement of tendon end displacement versus applied load and, at the maximum load of each cycle, measurement of tendon end displacement versus time.

8.3.2 Loading procedure

The anchor shall be loaded from the datum load P_a to the proof load P_p in a minimum of five cycles (Figure 11). The maximum load for each cycle is specified in Table 2. In each cycle, the maximum load shall be reached in stages. The maximum load for the cycles shall be P_a – 40 % P_p – 55 % P_p – 70 % P_p – 85 % P_p and 100 % P_p, as shown in Figure 11. Incremental loads are to be held for at least 1 min. Maximum loads in each cycle are to be maintained for at least the duration stated in Table 2.

Subsequently, the anchor shall be unloaded to the datum load P_a using the same loading stages. The observation times for unloading stages shall be not less than 1 min.

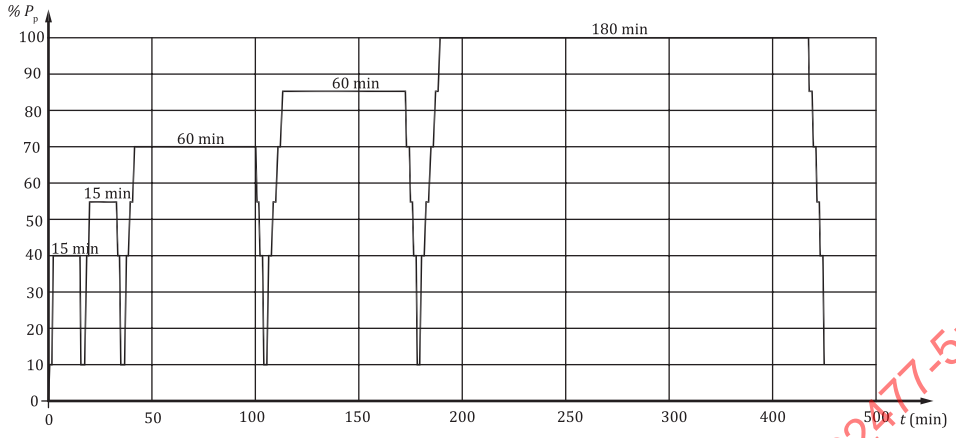


Figure 11 — Loading sequence for suitability test of a permanent anchor in fine soil

Table 2 — Loading sequence for suitability test

Cycle	Maximum load	Minimum observation period at maximum load for each cycle (min)			
		Temporary anchor		Permanent anchor	
		Coarse soil and rock	Fine soil	Coarse soil and rock	Fine soil
0	P_a	1	1	1	1
1	0,40 P_p	1	1	15	15
2	0,55 P_p	1	1	15	15
3	0,70 P_p	5	10	30	60
4	0,85 P_p	5	10	30	60
5	1,00 P_p	30	60	60	180

NOTE For the definition of coarse and fine soil refer to ISO 14688-1.

8.3.3 Measurements and checks

The displacement of the tendon end shall be measured at every loading and unloading stage. Tendon end displacement shall be measured immediately upon application of incremental loads. At the maximum load of the cycle, when the test load is constant, the displacement shall be measured over the observation period, at time intervals such as:

1→2→3→4→5→7→10→15→20→30→45→60→90→120→150→180 (min)

At the highest load of each cycle, the value of α shall be checked. The results shall be shown on a semi-logarithmic diagram as Figure 13.

NOTE 1 Guidance on the determination of α is given in Annex A.

The observation periods stated in Table 2 shall be extended if the displacement limit for the minimum observation period given in Table 3 is exceeded:

Table 3 — Minimum and extended observation periods at P_p for suitability tests

	Temporary anchors		Permanent anchors	
	Coarse soil and rock	Fine soil	Coarse soil and rock	Fine soil
Proof load (see national annex to EN 1997-1)	P_p	P_p	P_p	P_p
Test with minimum observation period by complying with the criterion:				
t_a in minutes	10	20	20	60
t_b in minutes	30	60	60	180
Displacement $\Delta s = s_b - s_a$ in mm	≤0,5	≤0,5	≤0,5	≤0,5
Test with extended observation period: t_a in minutes				
t_b in minutes	≥60	≥120	≥120	≥720
Creep rate[a], α, in mm	≤α_1	≤α_1	≤α_1	≤α_1

[a] α is determined by recording t_a from the linear part of the time displacement curve, see Figure A.1.

NOTE 2 For the definition of coarse and fine soil refer to ISO 14688-1.

Tendon end displacement shall be recorded during the extended observation period at intervals of 10 min. Tests with extended observation periods shall be continued until the creep rate α has stabilized.

The measured pull-out resistance $R_{ULS;m}$ of an anchor is reached by a suitability test when the creep rate α exceeds the value (α_1) given in EN 1997-1. If the criterion α_1 is exceeded before reaching the proof load P_p during the suitability test of an anchor, the design anchor load for all anchors covered by the test shall be determined on the basis of the (lower) test load, by which the creep rate complies with the requirement.

The elastic displacement measured referring to apparent tendon free length L_{app} shall be between the boundary lines at the load level ≥0,7 P_p; see Figure 12.

8.3.4 Test results

Measurements taken during the test shall be presented graphically in the following plots:

— plot of tendon end displacement versus anchor load at the end of each cycle (Figure 12);

— plot of tendon end displacement versus log time at the highest load of each cycle (Figure 13);

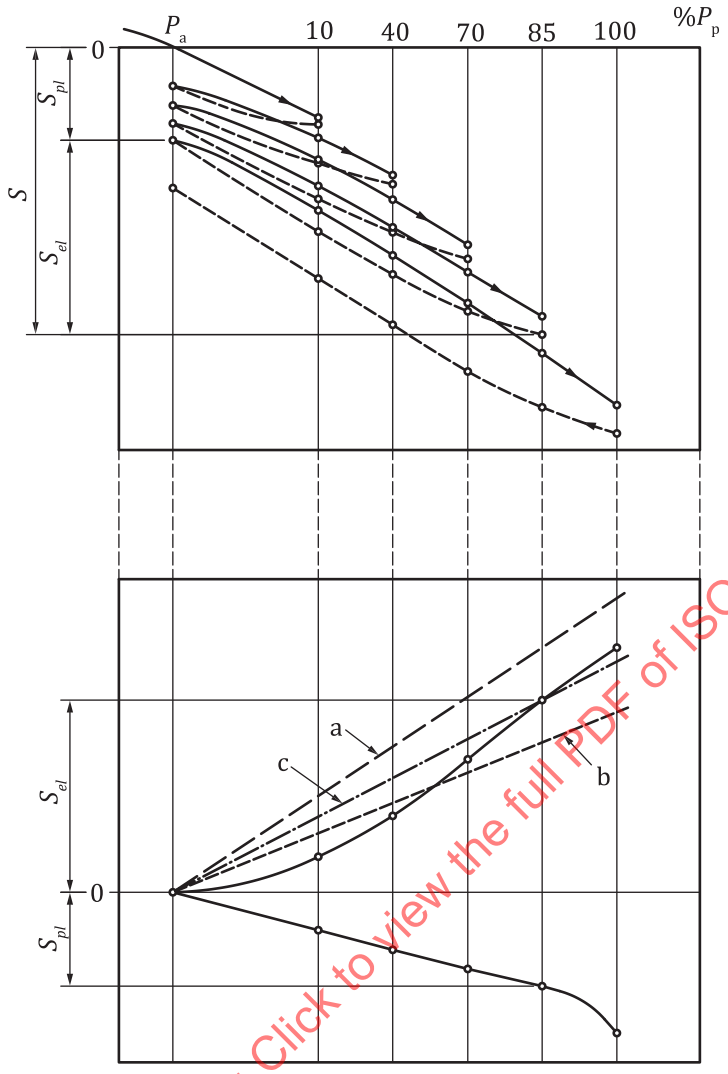
— plot of the creep rate α versus anchor load (Figure 14).

Based on the collected data, the following parameters shall be determined:

— α value at the proof load P_p, (Figure 13 and Annex A);

— calculated apparent tendon free length L_{app} (Annex D);

— If reached: the measured anchor pull-out resistance $R_{ULS;m}$.



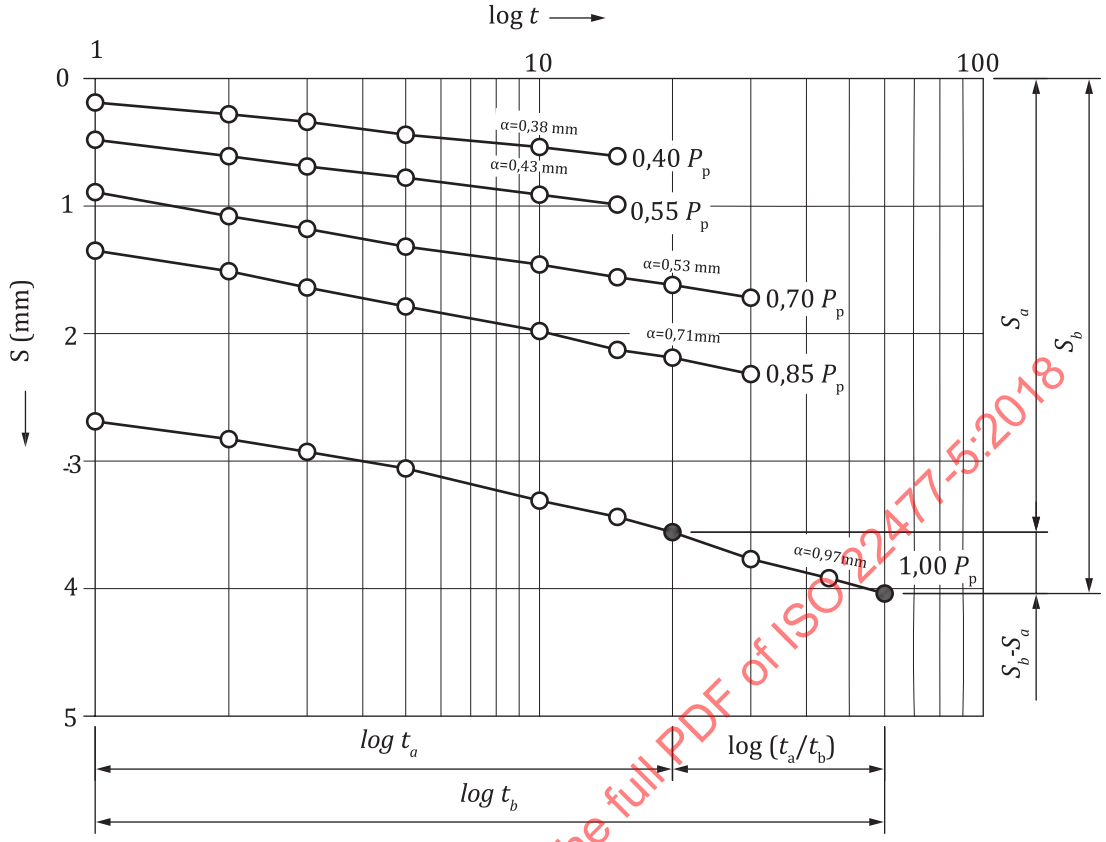
Top: load-displacement curve

Bottom: elastic and plastic displacement and boundary lines a and b of displacement

The boundary lines a and b represent the upper and lower value of elastic displacement behaviour corresponding to upper and lower limit of L_{app} according to EN 1537.

Line c represents the elastic elongation of the anticipated tendon free length incl. the external length, $L_{tf} + L_e$.

Figure 12 — Plot of tendon end displacement versus anchor load at the end of each cycle for suitability test in coarse soil or rock



Key

1 time in minutes, log scale

2 displacement in mm, linear scale

Figure 13 — Plot of tendon end displacement versus log time, example suitability test in coarse soil or rock

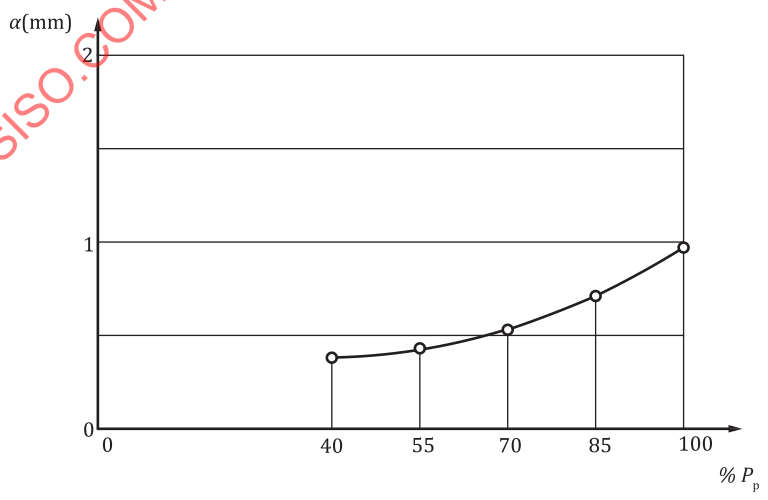


Figure 14 — Plot of α versus anchor load, example suitability test

8.4 Acceptance test

8.4.1 General

An acceptance test according to Test Method 1 is a test in which an axial load is applied incrementally in at least five steps to a grouted anchor up to a proof load P_p to confirm that a particular anchor meets the design requirements. At the proof load P_p, the load is maintained constant for a specified period of time. The test involves measurement of tendon end displacement versus applied load for each load step, and at the proof load P_p, measurement of tendon end displacement versus time.

NOTE Where appropriate an initial load cycle, up to the proof load before the test starts, can be applied to reduce friction in the free length. Displacement would be recorded at each increment.

8.4.2 Loading procedure

The anchor should be loaded from the datum load Pa to the proof load Pp in a minimum of five load steps (Figure 15). The loading stages shall be P_a – 40 % P_p – 55 % P_p – 70 % P_p – 85 % P_p and 100 % P_p, as shown in Figure 15 and stated in Table 4. The load stages are to be held for at least 1 min. The proof load is to be maintained for at least the duration stated in Table 4.

Subsequently, the anchor shall be unloaded to the datum load P_a using the same loading steps. The observation times for unloading steps shall be not less than 1 min. After this, the anchor shall be stressed up to the lock-off load P_0 and the anchor shall be locked off.

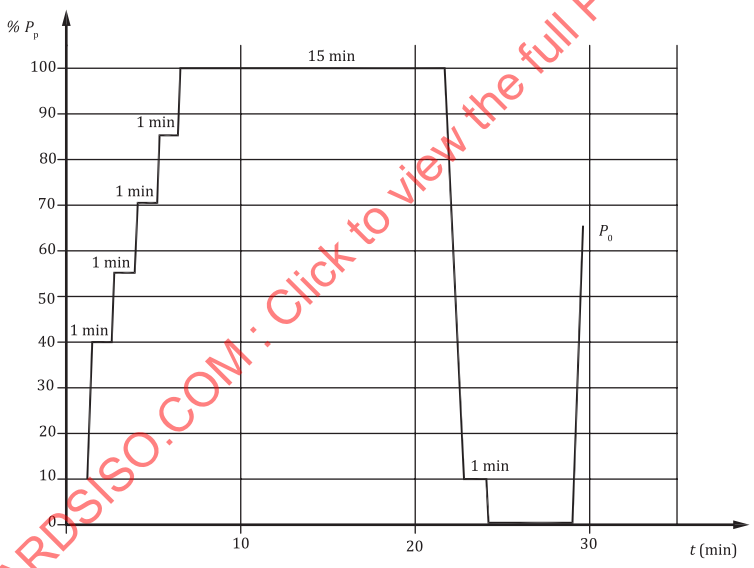


Figure 15 — Example loading sequence for acceptance test in fine soil

Table 4 — Loading sequence for acceptance test

Load step	Maximum load	Minimum duration of observation period (min)	
		Coarse soil and rock	Fine soil
0	P_a	1	1
1	0,40 P_p	1	1
2	0,55 P_p	1	1
3	0,70 P_p	1	1
4	0,85 P_p	1	1
5	1,00 P_p	5	15

NOTE For the definition of coarse and fine soil refer to ISO 14688-1.

8.4.3 Measurements and checks

The displacement of the tendon end shall be measured at every load and unload stage. Tendon end displacement shall be measured immediately upon application of incremental loads. At the proof load when the test load is constant, the displacement shall be measured over the observation period, at time intervals such as:

1→2→3→4→5→7→10→15 (min)

The minimum observation periods stated in Table 4 shall be extended if the displacement limit for minimum observation period given in Table 5 is exceeded. Tests with extended observation periods shall be continued until the creep rate α has stabilized.

Table 5 — Minimum and extended observation periods at P_p for acceptance tests

	Permanent and temporary anchors	
	Coarse soil and rock	**Fine soil**
Proof load (see national annex to EN 1997-1)	P_p	P_p
Test with minimum observation period by complying with the criterion: t_a in minutes t_b in minutes Displacement: $\Delta s = sb - sa$ in mm	 2 5 ≤0,2	 5 15 ≤0,25
Test with extended observation period: t_a in minutes t_b in minutes Creep rate[a], α, in mm	 ≥15 $\leq\alpha_1$	 ≥30 $\leq\alpha_1$
a α is determined by recording t_a from the linear part of the time displacement curve, see Figure A.1.		

NOTE 1 For the definition of coarse and fine soil refer to ISO 14688-1.

NOTE 2 Guidance on the determination of α is given in Annex A.

Tendon end displacement shall be recorded during the extended observation period at intervals of 5 min.

Following a satisfactory acceptance test, the anchor should be stressed to P_0, then locked off.

8.4.4 Test results

The following measurements taken during the test shall be presented in numbers:

— tendon end displacement at the end of each load step versus anchor load;

— tendon end displacement versus time over the duration that P_p is applied.

Based on the collected data, the following parameters shall be determined:

— the value of α at the proof load P_p (only necessary when the requirements for minimum observation times given in Table 5 are not fulfilled in the test);

— calculated apparent tendon free length L_{app} (Annex D).

9 Test Method 2

9.1 General

The anchor is loaded stepwise by load cycles increasing from a datum load to the proof load. At each load step the load loss in the anchor shall be measured during a fixed time period.

NOTE 1 Movement of the anchored structure will affect the load loss.

NOTE 2 Load loss is dependent on the free anchor length.

9.2 Investigation test

9.2.1 General

An investigation test according to Test Method 2 is a test in which an axial load is applied incrementally in cycles to a grouted anchor up to a maximum test load P_p which should not exceed the limits specified in EN 1997-1:2004+A1:2013, 8.5.4(2)P. The test should be based on six cycles. P_p is determined to check the resistance of the ground-grout interface. At the maximum load of each cycle, the tendon end displacement relative to the structure is held constant and load loss measured during a specified period. The anchor head is fixed against a load cell or an inactive jack to facilitate the measurement of load loss.

NOTE The target of P_p is based on best estimate and for this reason, six cycles might not be achieved.

If the anchor fails before the six cycles have been executed, the test is concluded.

9.2.2 Loading procedure

The loading procedure shown in Figure 16 and Table 6 should be followed for conducting investigation tests. Where appropriate, the final load cycle should be repeated to provide a measured check on load displacement behaviour and reproducibility.

If the cumulative load loss at P_p, after 50 min observation period, after allowance for temperature, structural movements and relaxation of the tendon, exceeds the limits specified in the national annex to EN 1997-1:2004+A1:2013, the test is completed.

9.2.3 Measurements and checks

Prior to commencement of the test, it shall be ensured that external sources do not disturb the normal functioning of the measurement equipment.

The following measurement procedure shall be followed for performing investigation tests:

a) During the stressing stage, at the highest load of each cycle, the value of the load loss k_l at the anchor head shall at least be recorded at the following times, depending on the duration of the load application:

$$0 \rightarrow 5 \rightarrow 15 \rightarrow 50 \rightarrow 150 \rightarrow 1\,500 \text{ (min)};$$

b) The displacement of the reaction system shall be recorded at the beginning and at the end of each load step.

At the highest load of each cycle, the value of k_l shall be checked.

At the load step, the stressing and reaction devices shall be visually inspected in order to detect any degradation.

At each load step, the stability of the installation shall be ensured.

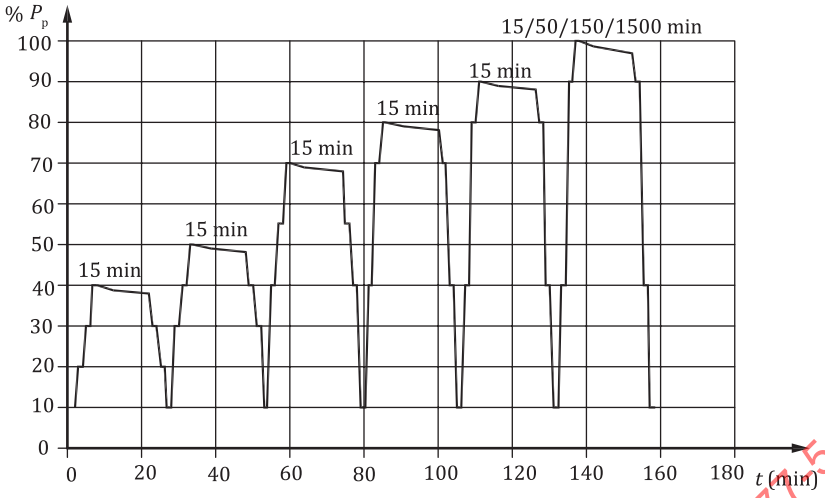


Figure 16 — Loading sequence for investigation test

Table 6 — Loading sequence for investigation test

Load levels (% P_p)						Minimum period of observation (min)
Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5	Cycle 6	
10	10	10	10	10	10	1
20	30	40	40	40	40	1
30	40	55	70	80	90	1
40	50	70	80	90	100	15, 50,150 or 1 500
30	40	55	70	80	90	1
20	30	40	40	40	40	1
10	10	10	10	10	10	1
NOTE It is recommended that load-displacement results should be plotted as the test proceeds. In this way it should be possible to observe trends and, in particular, the yield of the fixed anchor as failure approaches.						

9.2.4 Test results

Measurements taken during the test shall be presented graphically in the following plots:

— load loss versus time at the end of each load step;

— load loss versus log time at the highest load of each cycle;

— load loss versus anchor load;

— load versus displacement.

Based on the collected data, the following parameters shall be determined:

— anchor pull-out resistance $R_{ULS;m}$;

— the apparent tendon free length L_{app} by unloading from P_p to P_a (Annex D).

9.3 Suitability test

9.3.1 General

A suitability test according to Test Method 2 is a test in which an axial load is applied incrementally in at least three cycles to a grouted anchor up to a proof load P_p to confirm that a particular anchor design

will be adequate in particular ground conditions. At the highest load of cycles 2 and 3, the tendon end displacement relative to the structure is held constant. The test involves measurement of load loss, after lock-off, during a specified period.

9.3.2 Loading procedure

The loading procedure shown in Figure 17 and Table 7 should be followed for conducting suitability tests.

Each load step in the second and third cycles should be held for 1 min and the displacement recorded at the beginning and end of each period. At proof loads, this period is extended to at least 15 min with an intermediate reading at 5 min. On completion of the third cycle, reload in one operation to P_0 and lock-off. Reread the load immediately after lock-off to establish the lock-off load. This moment represents zero time for monitoring load loss -time behaviour.

If the proof load has been reduced by more than limits specified in the national annex to EN 1997-1:2004+A1:2013 during the 15 min, after allowing for any temperature changes and movements of the anchored structure, then the anchor should be subjected to two further proof load cycles and the behaviour recorded. If the limit specified in the national annex to EN 1997-1:2004+A1:2013 is exceeded in either cycle, then the proof load should be reduced to a value at which compliance with this clause may be achieved.

If, at the lock-off load, the rate of load loss is greater than limits specified in the national annex to EN 1997-1:2004+A1:2013 per log cycle of time interval, after allowing for temperature, structural movements and relaxation of the tendon, the test should be extended by monitoring up to 1 500 min or until the rate of load loss, in accordance with EN 1997-1:2004+A1:2013, becomes acceptable.

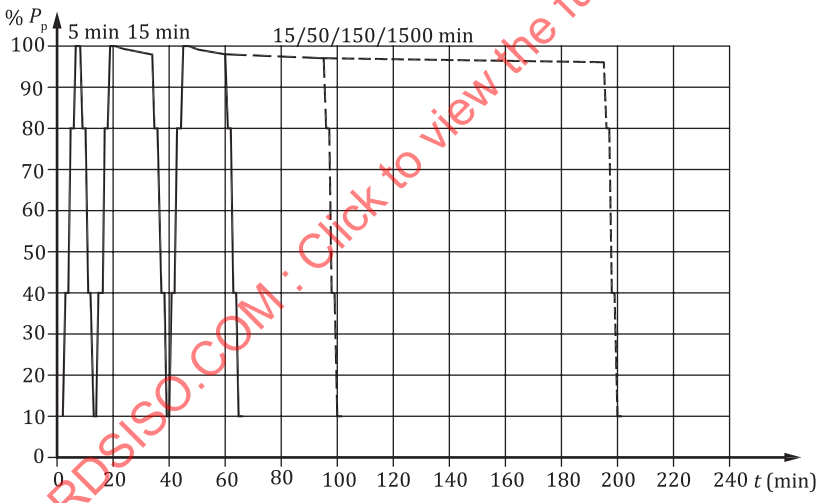


Figure 17 — Loading sequence for suitability test

Table 7 — Loading sequence for suitability test

Load levels (% P_p)		Minimum period of observation (min)
Cycle 1[a]	Cycles 2 and 3	
10	10	1
40	40	1
80	80	1
100	100	15

[a] For this load cycle, there is no pause other than necessary for the recording of displacement data.

Table 7 *(continued)*

Load levels (% P_p)		Minimum period of observation (min)
Cycle 1[a]	Cycles 2 and 3	
80	80	1
40	40	1
10	10	10

[a] For this load cycle, there is no pause other than necessary for the recording of displacement data.

9.3.3 Measurements and checks

Prior to commencement of the test, it shall be ensured that external sources do not disturb the normal functioning of the measurement equipment.

The following measurements procedure shall be followed for performing suitability tests:

a) During the stressing stage, the displacement should be recorded at the beginning and end of each period;

b) At the highest load of each cycle, if necessary, and after lock-off, the value of the load loss k_l at the anchor head shall at least be recorded at the following times, depending on the duration of the load application:

$$0 \rightarrow 5 \rightarrow 15 \rightarrow 50 \rightarrow 150 \rightarrow 1\,500 \text{ (min)}.$$

Where relevant, the displacement of the reaction system shall be recorded at least at the end of each load step.

At the highest load of each cycle, the value of k_l shall be checked.

NOTE Guidance on the permissible cumulative loss of load k_l is given in the national annex to EN 1997-1:2004+A1:2013.

At each load step, the stressing and reaction devices shall be visually inspected in order to detect any degradation.

At each load step, the stability of the installation shall be ensured.

9.3.4 Test results

Measurements taken during the test shall be presented in numbers:

— load loss at the end of each load step versus time;

— load loss versus time over the duration that P_p is applied;

— load versus displacement.

Based on the collected data, the following parameters shall be determined:

— the apparent tendon free length L_{app} by unloading from P_p to P_a (Annex D).

9.4 Acceptance test

9.4.1 General

An acceptance test according to Test Method 2 is a test in which an axial load is applied incrementally in two cycles to a grouted anchor up to a proof load P_p to confirm that a particular anchor meets the design requirements. At the highest load of cycle 2, the tendon end displacement relative to the structure is

held constant. The test involves measurement of load loss at the maximum load of cycle 2 and after lock-off, during a specified period.

9.4.2 Loading procedure

The loading procedure shown in Figure 18 and Table 8 should be followed for conducting acceptance test.

Each load step in the second cycle should be held for 1 min and the displacement recorded at the beginning and end of each period. At proof loads, this period is extended to at least 15 min with an intermediate reading at 5 min. On completion of the second cycle, reload in one operation to the lock-off load P_0 and lock-off. Reread the load immediately after the lock-off to confirm the load level. This moment represents zero time for monitoring load loss versus time behaviour.

If the proof load has been reduced by more than the limit specified in the national annex to EN 1997-1:2004+A1:2013 during the 15 min, after allowing for any temperature changes and movements of the anchored structure, then the anchor should be subjected to two further proof load cycles and the behaviour recorded. If the limit specified in the national annex to EN 1997-1:2004+A1:2013 is exceeded in either cycle, then the proof load should be reduced to a value at which compliance with this clause may be achieved.

If, at the lock-off load, the rate of load loss is greater than the limit specified in the national annex to EN 1997-1:2004+A1:2013 per log cycle of time interval, after allowing for temperature, structural movements and relaxation of the tendon, the test should be extended by monitoring to 50 min or until the rate of load loss, in accordance with EN 1997-1:2004+A1:2013, becomes acceptable.

Where there is significant friction in the tendon free length, a partial cycle may be performed to determine the no-friction curve, to be able to calculate the apparent tendon free length more accurately (see Annex D).

Restressing or constant load methods may be used to monitor the displacement at the initial residual load.

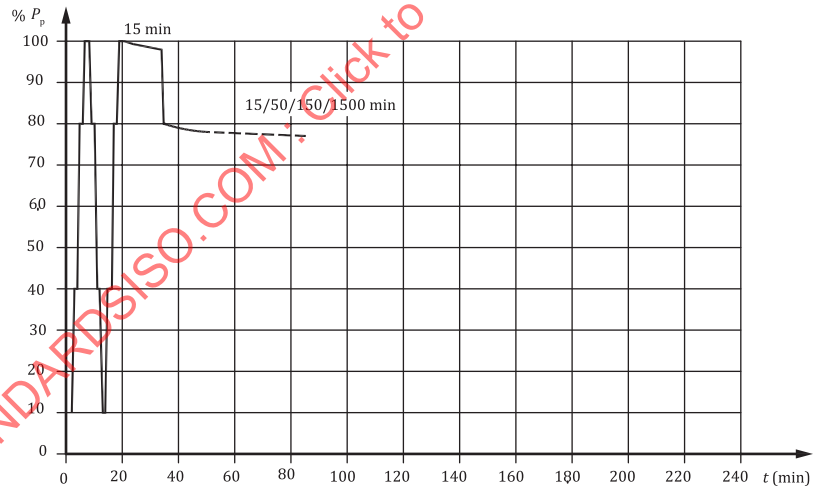


Figure 18 — Loading sequence for acceptance test

NOTE To determine apparent free length record displacement from proof load to datum as outlined in 4.5.

Table 8 — Loading sequence for acceptance test

Load levels (% P_p)		Minimum period of observation (min)
Cycle 1[a]	Cycle 2	
10	10	1
40	40	1
80	80	1
100	100	15
80	80	1
40	40	1
10	10	10

[a] For this load cycle, there is no pause other than necessary for the recording of displacement data.

9.4.3 Measurements and checks

Prior to commencement of the test, it shall be ensured that external sources do not disturb the normal functioning of the measurement equipment.

The following measurement procedure shall be followed for performing acceptance tests:

a) During the stressing stage, at the highest load of cycle 2 and after lock-off, the value of the load loss k_l at the anchor head shall at least be recorded at the following times:

$$0 \rightarrow 5 \rightarrow 15 \text{ (min)};$$

b) Where relevant, the displacement of the reaction system shall be recorded at least at the end of each load step.

At the highest load of cycle 2, the value of k_l shall be checked.

NOTE Guidance on the permissible cumulative loss of load k_l is given in EN 1997-1:2004+A1:2013. A limit of k_l can be set in the national annex.

At each load step, the stressing and reaction devices shall be visually inspected in order to detect any degradation.

At each load step, the stability of the installation shall be ensured.

9.4.4 Test results

Measurements taken during the test shall be presented in numbers:

— load loss at the end of each load step versus time;

— load loss versus time over the duration that P_p is applied.

Based on the collected data, the following parameters shall be determined:

— the apparent tendon free length L_{app} by unloading from P_p to P_a (Annex D).

10 Test Method 3

10.1 General

The anchor is loaded in incremental steps from a datum load to a maximum load. The displacement of the tendon end is measured under maintained load at each loading step.

10.2 Investigation test

10.2.1 General

An investigation test according to Test Method 3 is a test in which an axial load is applied by step to a grouted anchor up to a maximum test load P_p, which is designed to reach failure at the ground-grout interface. Each load is maintained constant during a specified period of time. The test involves measurement of tendon end displacement versus applied load and, for each load stage, measurement of tendon end displacement versus time.

10.2.2 Loading procedure

The loading procedure shown in Figure 19 and Table 9 should be followed for conducting investigation tests.

A loading stage may be stopped at 30 min if the tendon end displacement is less than or equal to 0,03 mm between measurements at 15 min and 30 min, which corresponds to a value of α equal to 0,1 mm.

NOTE Guidance on the determination of α is given in Annex A.

A loading stage may be stopped when the value of α reaches α_3 c.f. EN 1997-1:2004+A1:2013, Table A21. The national annex for EN 1997-1 may state a value of α_3. Additionally, a loading stage may be stopped when the tendon end displacement reaches the following value:

$$\frac{0{,}9 f_{yk}}{E_t}\left(L_{fixed} + L_{free} + L_e\right) + 0{,}01\,[m]$$

The final unloading will be done step by step with 0,25 P_p decrements. At each step, the load will be maintained constant for the time necessary to make all readings.

It is useful to know the total friction on the anchor to determine the effective load at the top of the fixed anchor length. This can be achieved by adding one cycle, starting at 70 % P_p down to 10 % of P_p and back to 70 % P_p with unloading and reloading steps of 10 % of P_p.

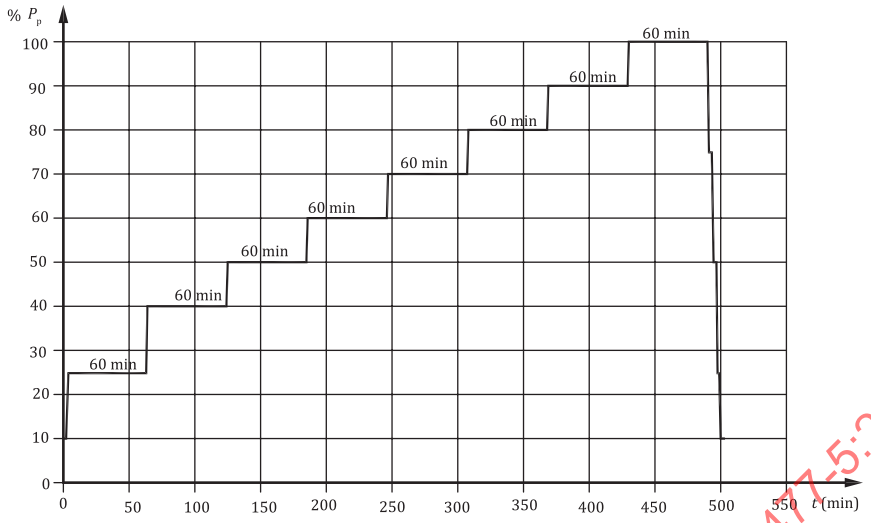


Figure 19 — Loading sequence for investigation test

Table 9 — Loading sequence for investigation test

Load increments									
Loading step	**Datum**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Applied load (%P_p)	P_a	25	40	50	60	70	80	90	100
Period of observation (min)	0	60	60	60	60	60	60	60	60

10.2.3 Measurements and checks

Prior to commencement of the test, it shall be ensured that external sources do not disturb the normal functioning of the measurement equipment.

The following measurement procedure shall be followed for performing investigation tests:

a) At each step, the time origin is taken immediately when the expected load is reached;

b) During the stressing stage, at each load step, if necessary, the load and the tendon end-displacement shall at least be recorded at the successive monitoring times, as indicated below:

0→1→2→3→4→5→7→10→15→20→30→45→60 (min);

NOTE Where relevant, the control of the load and of the tendon end-displacement is performed with a periodicity less than the successive monitoring times indicated above.

c) During the de-stressing stage, the load and the tendon end-displacement shall be recorded at least at the end of each step and 5 min after the total de-stressing;

d) Where relevant, the displacement of the reaction system shall be recorded at least at the end of each load step.

At each load step, the value of α shall be checked.

At each load step, the stressing and reaction devices shall be visually inspected in order to detect any degradation.

During the test, the stability of the installation shall be ensured.

10.2.4 Test results

Measurements taken during the test shall be presented graphically in the following plots:

— plot of "tendon end displacement versus anchor load" at the beginning and at the end of each load step;

— plot of "tendon end displacement versus time" for each load step;

— plot of "α versus anchor load".

Based on the collected data, the following parameters shall be determined:

— critical creep load P_c;

— anchor pull-out resistance $R_{ULS;m}$;

— calculated apparent tendon free length L_{app} (Annex D).

NOTE Guidance on the determination of P_c is given in Annex C.

The anchor pull-out resistance $R_{ULS,m}$ is the load corresponding to the vertical asymptote of α versus anchor load plot. If the asymptote cannot be easily determined, $R_{ULS,m}$ shall be determined in accordance with EN 1997-1+A1:2013 (Figure 20).

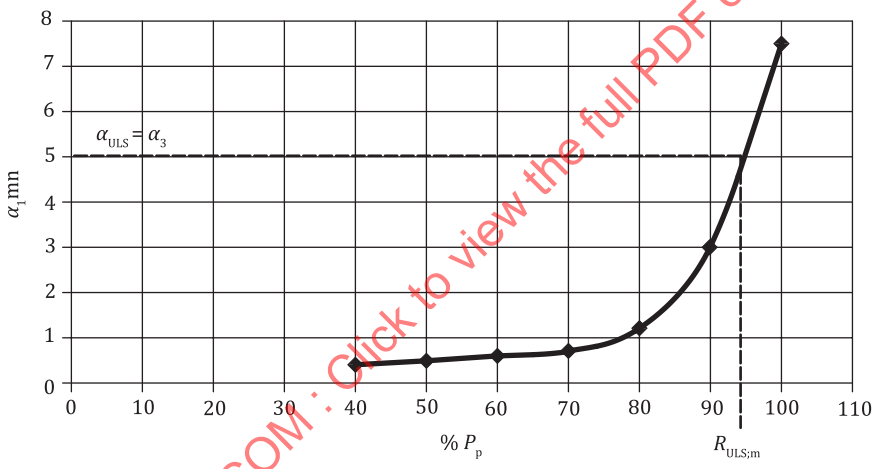


Figure 20 — Determination of the anchor pull-out resistance (Investigation test)

10.3 Suitability test

10.3.1 General

A suitability test according to Test Method 3 is a test in which an axial load is applied by step to a grouted anchor up to a proof load P_p to confirm that a particular anchor design will be adequate in particular ground conditions. Each load is maintained constant during a specified period. The test involves measurement of tendon end displacement versus applied load and, for each load step, measurement of tendon end displacement versus time.

10.3.2 Loading procedure

The loading procedure shown in Figure 21 and Table 10 should be followed for conducting suitability test.

A loading stage may be stopped at 30 min if the value of α is less than 0,1 mm.

NOTE Guidance on the determination of α is given in Annex A.

During the final de-stressing, the load shall be maintained constant at least at 75 % P_p, 50 % P_p, 25 % P_p and 10 % P_p during the time necessary to make all readings at each step.

The total friction on the anchor, which determines the effective load at the top of the tendon bond length, may be obtained by adding one cycle starting from 70 % P_p, down to 10 % P_p and back to 70 % P_p, with unloading and reloading steps of 15 % P_p or less.

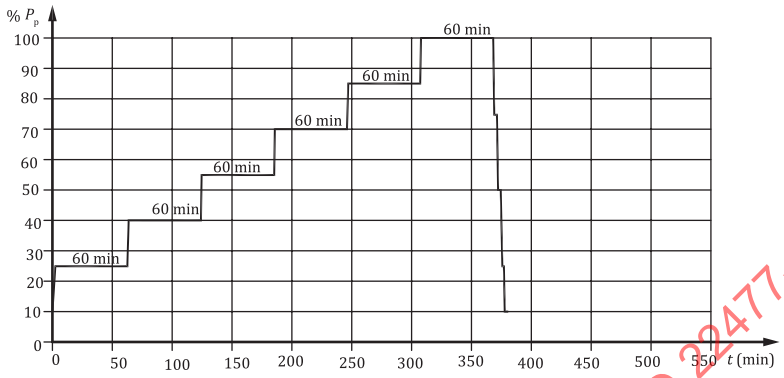


Figure 21 — Loading sequence for suitability test

Table 10 — Loading sequence for suitability test

Load increments							
Loading step	**Datum**	**1**	**2**	**3**	**4**	**5**	**6**
Applied load (%P_p)	P_a	25	40	55	70	85	100
Period of observation (min)	0	60	60	60	60	60	60

10.3.3 Measurements and checks

Prior to commencement of the test, it shall be ensured that external sources do not disturb the equipment.

The following measurement procedure shall be followed for performing suitability tests:

a) At each step, the time origin is taken immediately when the expected load is reached;

b) During the stressing stage, at each load step, if necessary, the load and the tendon end displacement shall at least be recorded at the successive monitoring times, as indicated below:

0→1→2→3→4→5→7→10→15→20→30→45→60 (min);

NOTE Where relevant, the control of the load and of the tendon end displacement is performed with a periodicity less than the successive monitoring times indicated above.

c) During the de-stressing stage, the load and the tendon end-displacement shall be recorded at least at the end of each step and 5 min after the total de-stressing;

d) Where relevant, the displacement of the reaction system shall be recorded at least at the end of each load step.

At each load step, the value of α shall be checked.

At each load step, the stressing and reaction devices shall be visually inspected in order to detect any degradation.

At each load step, the stability of the installation shall be ensured.

10.3.4 Test results

Measurements taken during the test shall be presented graphically in the following plots:

— plot of "tendon end displacement versus anchor load" at the beginning and at the end of each load step;

— plot of "tendon end displacement versus time" for each load step;

— plot of "α versus anchor load" when possible.

Based on the collected data, the following parameters shall be determined:

— α value at the proof load;

— calculated apparent tendon free length L_{app} (Annex D).

10.4 Acceptance test

10.4.1 General

An acceptance test according to Test Method 3 is a test in which an axial load is applied by step to a grouted anchor up to a proof load P_p to confirm that a particular anchor meets the design requirements. Each load is maintained constant only during the necessary time to perform the measurement (extension of the tendon end and corresponding load). At the proof load the measurement of the extension of the tendon end versus time during a specified time is recorded.

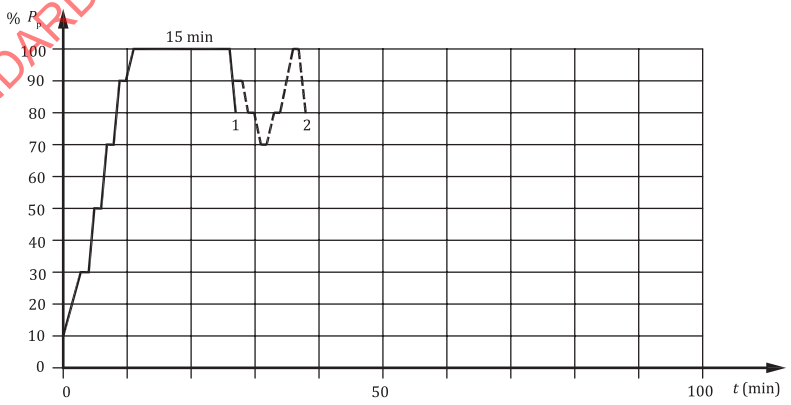
10.4.2 Loading procedure

The loading procedure shown in Figure 22 and Tables 11 and 12 should be followed for conducting acceptance test.

At proof load, the value of α shall be checked.

If α is larger than the limit value, the load and of the tendon end-displacement should be measured during a longer period than indicated above, for example during 1 h with measurements at 25 min, 30 min, 45 min, and 60 min, in order to check again the α value at the end of the observation time.

An unloading-reloading cycle may be performed to determine the no-friction curve, which enables calculation of the apparent tendon free length more accurately (see also Annex D) and also the existing load at lock-off at the top of the fixed length. This cycle may be partial (down to 70 % P_p) or completely (down to P_a).



Key

1 lock-off load after acceptance test without cycle

2 lock-off load after acceptance test with cycle

Figure 22 — Loading sequence for acceptance test