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Geotechnical investigation and testing — Testing of geotechnical structures —

Part 1:
Testing of piles: static compression load testing

Reconnaissance et essais géotechniques — Essais des structures géotechniques —

Partie 1: Essais de pieux: essai de chargement statique en compression

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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 of 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 www.iso.org/iso/foreword.html.

This document was prepared by the European Committee for Standardization (CEN) Technical Commitee CEN/TC 341, *Geotechnical Investigation and Testing*, in collaboration with ISO Technical Committee ISO/TC 182, *Geotechnics*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

A list of all 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.

This corrected version of ISO 22477-1:2018 incorporates the following corrections:

— in Figure 1 a), added the ground surface level and corrected the "floating" reaction load;

— adjusted the scales for Figure 1 a) to e) to be consistent.

Geotechnical investigation and testing — Testing of geotechnical structures —

Part 1: Testing of piles: static compression load testing

1 Scope

This document establishes the specifications for the execution of static pile load tests in which a single pile is subjected to an axial static load in compression in order to define its load-displacement behaviour.

This document is applicable to vertical piles as well as raking piles.

All types of piles are covered by this document. The tests considered in this document are limited to maintained load tests. Pile load tests with constant penetration rate and cyclic load tests are not covered by this document.

NOTE This document is intended to be used in conjunction with EN 1997-1. EN 1997-1 provides numerical values of partial factors for limit states and of correlation factors to derive characteristic values from static pile load tests to be taken into account in design.

This document provides specifications for the execution of static axial pile load tests:

a) checking that a pile will behave as designed;

b) measuring the resistance of a pile.

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.

ISO 7500-1, *Metallic materials — Calibration and verification of static uniaxial testing machines — Part 1: Tension/compression testing machines — Calibration and verification of the force-measuring system*

EN 1990, *Eurocode 0: Basis of structural design*

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

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

3 Terms, definitions and symbols

For the purposes of this document, the terms and definitions given in EN 1990, EN 1997-1, EN 1997-2 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 Terms and definitions

3.1.1
pile load
F_c
load applied to the head of the pile during the test

Note 1 to entry: For tests with embedded jack, the load is applied at another level, see Annex B.

3.1.2
load increment
ΔF
increment of load added or removed during the test

3.1.3
pile diameter
equivalent pile diameter
D
diameter of the pile

Note 1 to entry: For a noncircular pile with cross section A, the equivalent pile diameter equals $\sqrt{\frac{4A}{\pi}}$.

3.1.4
working pile
pile for the foundation of a structure

3.1.5
test pile
pile to which loads are applied to determine the resistance-displacement characteristics of the pile and the surrounding ground

3.1.6
measured compressive resistance
$R_{c,m}$
measured value of the compressive resistance at the ultimate limit state, in one or several *pile load* (3.1.1) tests

Note 1 to entry: The recommended failure criterion is defined in EN 1997-1.

3.1.7
creep rate
α
ratio of the increase in pile head displacement and the decimal logarithm of time during a specified time interval

3.2 Symbols

A	pile cross section
D_b	equivalent pile base diameter
$F_{c,cr}$	critical creep load in compression
$F_{c,cr,m}$	measured value of $F_{c,cr}$ in one or several pile load tests
$F_{c,k}$	characteristic axial compression load
F_p	predefined maximum load applied during the test

N	axial force
q_s	unit shaft friction
$q_{s,m}$	measured value of q_s
$q_{s,mob}$	mobilised shaft friction
R_b	pile base resistance
$R_{b,m}$	measured value of R_b in one or several pile load tests
$R_{b,mob}$	mobilised base resistance
R_c	compressive resistance of the ground against a pile, at the ultimate limit state
R_s	pile shaft resistance
$R_{s,m}$	measured value of R_s in one or several pile load tests
$R_{s,mob}$	mobilised shaft resistance
s	axial displacement of pile at any depth z
s_b	axial displacement of pile base
s_h	axial displacement of pile head
t	time
z	depth

4 Equipment

4.1 General

The selection of the equipment shall take into account the aim of the test, the ground conditions and the expected displacement of the pile under the maximum test load.

4.2 Reaction device

The reaction device for pile compressive loads can be:

— dead load (kentledge);

— tension piles or anchors;

— an existing structure over the test pile.

NOTE The reaction device can be the test pile itself where the load is applied at depth by one or more hydraulic jacks which are cast into the pile for bi-directional pile loading (see Annex B).

Dead load should not be used for tests of raking piles, unless particular measures are carefully considered with respect to the stability and displacements of the kentledge system.

The influence of the reaction system on the test pile shall be minimized. Unless otherwise agreed, minimum required distances are shown in Figure 1 a) to e). For Figure 1 a) to d), the maximum value shall be applied. If the length of reaction piles is greater than the length of the test pile, provisions given in Figure 1 c) shall be applied.

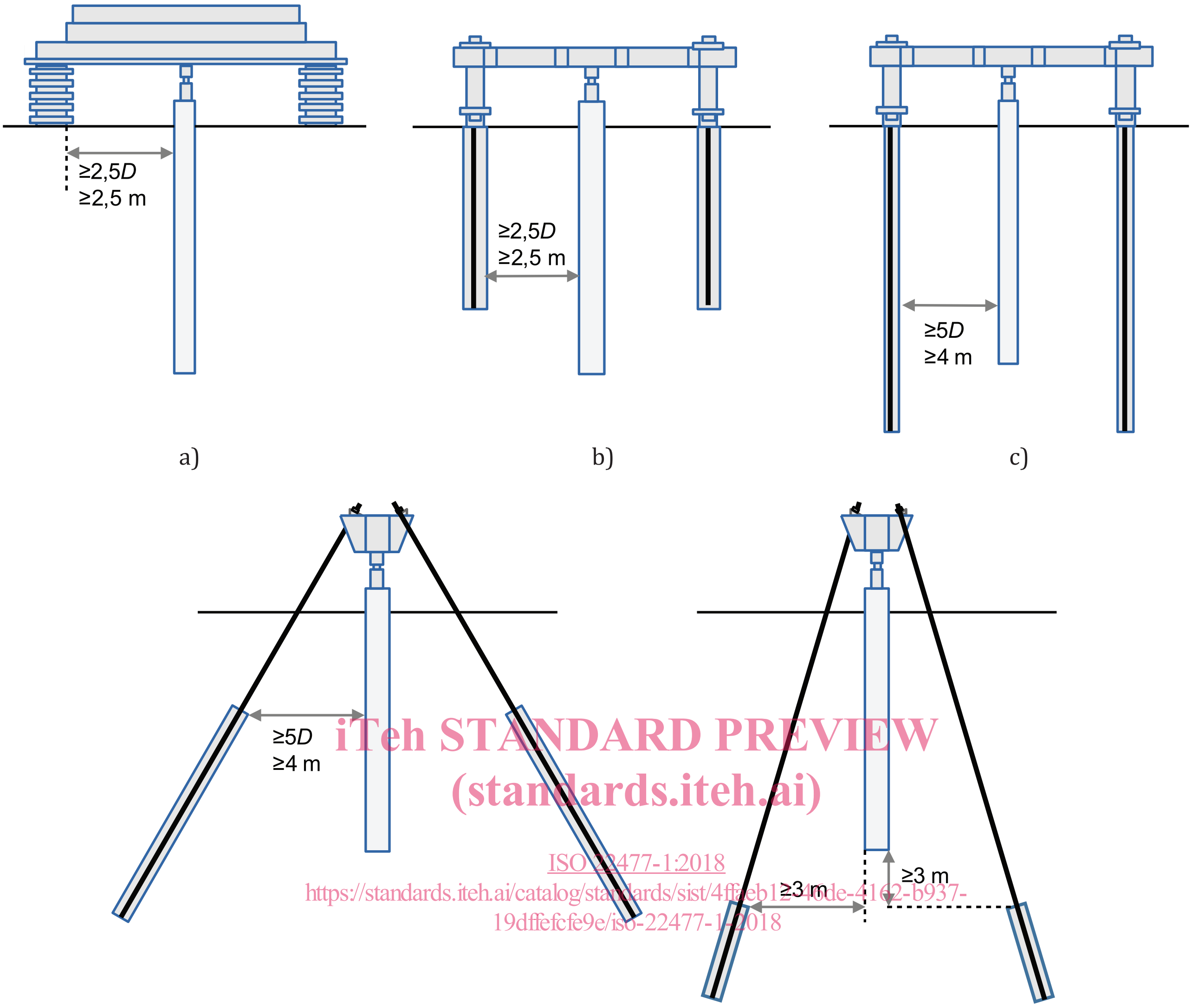


Figure 1 — Reaction system

For static pile load tests on micropiles, these distances may be reduced. However, the minimum clear distance shall be 1,5 m.

The reaction system shall be designed to resist the maximum test load F_p in accordance with the relevant standards.

To avoid uplift or instability of the kentledge, the dead load should be centred and in excess of the maximum test load F_p by at least 10 %.

Working piles may be used as reaction piles, provided that their structural resistance is sufficient and there is no detrimental effect on their ability to perform as part of the structure. The uplift of the working piles shall be monitored during the test.

Reaction piles and anchors should be arranged symmetrically around the test pile. In cases of non-symmetrical reaction systems measures shall be taken to avoid detrimental rotation and/or translation of the reaction system.

4.3 Force input

4.3.1 General

One or more hydraulic jacks should be used to apply the load on the test pile.

If several hydraulic jacks are used to apply the test load, they shall be arranged symmetrically, of the same model and be supplied by a common supply from one hydraulic unit. Each hydraulic jack shall be provided with a shut-off valve and an additional pressure gauge.

A spherical seating shall be incorporated above the hydraulic jack.

If a single jack is used, it shall be arranged centrally on the pile cap in order to ensure the pile is loaded axially without eccentricity.

A rigid plate shall be placed on the pile head or cap to distribute the load.

4.3.2 Specifications of force input

The achievable force of the jack(s) shall exceed F_p. The stroke of the jack(s) shall exceed the expected deformations (pile head displacement and those of the reaction system under load).

It shall be possible to decrease or increase the load smoothly without any shocks or vibrations and to maintain the load at any required value.

To satisfy the required accuracies, an automatic and continuous electric or hydraulic control and regulation of the jack force may be used. Alternatively, a hand pump with accurate measurement of pressure or load and permanent regulation may be considered.

The accuracy of the force regulator shall be better than 0,5 % of F_p or 10 kN, whichever is greater.

4.4 Measurement of pile head displacements

The displacements of the pile head shall be measured either by dial gauges or transducers, supported from reference beams.

Reference beams should be supported independently from the test pile.

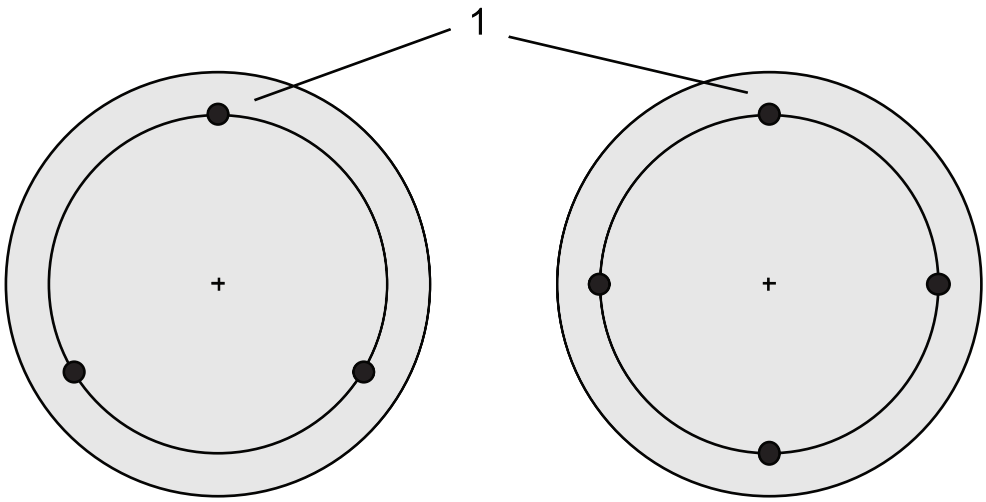
The clear distance between the supporting ends of the reference beams and the test pile and reaction piles or the nearest edge of the kentledge support should be at least 2,5 m or 2,5D, whichever is greater.

One end of each reference beam should be free to slide.

The position of the reference beams shall be checked by a secondary control measuring system, such as levelling methods or other measurement methods. The position of the pile head should be also checked by this secondary control system.

The axial pile head displacement shall be measured with at least three displacement transducers or dial gauges. They shall be arranged symmetrically (see Figure 2) and parallel to the axis of the pile. The friction between the pile head and the sensors should be minimized by using suitable devices such as glass plates fixed beneath the sensors.

NOTE If the pile diameter is too small, the installation of a wider plate enables the use of three transducers.



Key

1 displacement transducers or dial gauges

Figure 2 — Location of displacement transducers or dial gauges

The overall accuracy of the measured pile head displacement shall be better than 0,1 mm or 0,2 % of the measured value, whichever is greater. Therefore, dial gauges or transducers shall enable readings to be made to a resolution of at least 0,01 mm and any optical system of 0,1 mm.

The dial gauges or transducers should also have a sufficient measuring range, in order to avoid readjustment during testing.

Unless otherwise agreed, the secondary control measuring system shall enable readings to an accuracy of at least 0,1 mm.

Any optical levelling measurements shall be controlled by reference to one or more fixed reference points.

The transversal displacement of the test pile under axial load should be checked by two dial gauges or transducers with the same accuracy as above, positioned in orthogonal directions and fixed on reference beams. Alternatively, the secondary control system may be used. These measurements shall be made during load tests on raking or slender piles.

To safeguard against failure of the supports, the corner points of a kentledge, reaction piles or anchor heads should be included in the levelling checks.

4.5 Measurement of pile load

The load shall be measured at the head of the pile. Load measurement shall be obtained from a load cell (load cells) or from the pressure of the jack or jack system, by means of suitable calibrated pressure gauges.

NOTE 1 For tests with embedded jack, the load is measured at another level (see Annex B).

NOTE 2 Additional guidance could be found in the national foreword to this document.

The load measurement devices shall be calibrated against a suitable master device following ISO 7500-1, giving full traceability to National Standard.

The accuracy of the load measurement should be 1 % of F_c.

When the load is measured using the jack pressure, the calibration shall be done within a period of 6 months before the test. Otherwise, a period of 12 months shall be applied.

In some circumstances, for example shock or eccentric loading or deviations of electronic load cells, change of components or presumed damage, additional calibration is recommended.

4.6 Pile instrumentation

The pile instrumentation depends on the aim of the static pile load test:

— determine the overall resistance;

— determine the pile base resistance and the shaft resistance;

— determine the pile base resistance and the distribution of the shaft friction along the length of the pile.

To determine only the overall pile resistance, no pile instrumentation is needed.

The pile base resistance can be measured directly with a load cell at the pile base or indirectly using strain measurements at the pile base.

The distribution of the shaft resistance can be determined by measurement of the strain at cross sections of the pile at various depths. This can be achieved for example by:

— built-in or removable extensometers;

— strain-measuring devices (such as vibrating wires strain gauges, optical fibre sensors, etc.) fixed to the reinforcement or embedded in the concrete of precast concrete piles or attached to the walls of steel piles.

The pile base settlement can be measured by an extensometer (from head to base).

The depth, the number of measuring levels and the number of devices at each level shall take into account the ground conditions, the type and the size of the test pile and the aim of the test.

Removable extensometers shall be installed in diametrically opposed pairs for large diameter piles (shaft diameter > 0,6 m) and for each depth to be measured. For smaller piles (shaft diameter ≤ 0,6 m), one removable extensometer can be installed in the centre, if this does not conflict with execution codes.

If instrumentation is installed before pile installation, like strain measuring devices, there should be at least four symmetrically arranged pieces for each depth to be measured to achieve redundancy.

Strain measurements using continuous fibre optics shall be arranged with at least two loops symmetrically arranged.

To determine load from strain, the cross section A and the pile material modulus of elasticity shall be assessed. All the materials present in the pile shall be considered.

5 Test procedure

5.1 Test preparation

5.1.1 Protections

Throughout the test period all necessary precautions shall be taken to prevent external conditions (such as weather, vibrations, etc.) to interfere with the test results.

Techniques to fulfil this requirement can include:

— covering the entire testing set-up by a tent or similar;

— protective covers;

— adequate choice of materials for reference beams and conception of these beams;

— use of temperature compensated measuring devices;

— reference beams painted white.

All components, cables and measuring devices embedded in or arranged outside the pile shall be protected against damage during all stages of construction and testing. This includes in particular adequate insulation of electric gauges and cables against water as well as mechanical protection against damage during the execution of the pile (for example concreting, trimming or driving), the preparation of the pile head and the setting up of the test installation and devices of the test.

Any other site activities that may influence the measurements, for example vibrations caused by ongoing construction activities, should be suspended for the duration of the test.

The air temperature shall be recorded regularly during the course of the test to identify any temperature effects on the test results.

5.1.2 Construction of a test pile

Test piles should be constructed in a similar manner as working piles (same installation method, machinery and materials).

Test piles should be of the same diameter as the working piles. Load tests on smaller diameter test piles may be considered following the specifications and restrictions specified in EN 1997-1.

Test piles shall be designed to resist the maximum test load, so extra reinforcement and concrete of increased strength are permitted. However, their possible influence on the pile's behaviour shall be considered.

The influence of pile instrumentation on the pile construction and integrity shall be minimized.

Particular care should be given to the supervision and the monitoring of the installation of the test piles and the production of piling records. Guidance on the various items to be monitored and recorded is given in the respective piling execution standards.

5.1.3 Test date

Between the installation and testing of a pile, time periods given in Table 1 are recommended.

Table 1 — Recommended time periods between the installation and testing of a pile

Soil type	Pile type	Minimum time (days)
Coarse soils	All	7
Fine soils	Bored	21
	Displacement	28

NOTE 1 Alternative time periods can be specified with appropriate justification.

NOTE 2 In sensitive soils sometimes longer times periods are necessary.

In rock, a site-specific time assessment shall be made and agreed.

Load testing on cast-in-place concrete piles and grouted micropiles shall only begin when the material has reached the strength to accept the test load.

5.1.4 Preparation of the pile cap

The pile cap shall be designed and constructed such that the load can be applied uniformly and centrally without damage to the head of the pile. The top surface shall be flat, smooth and normal to the pile axis.

There shall be no load transfer between the pile cap and the ground.

