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Geotechnical investigation and testing — Testing of geotechnical structures —

Part 1:
Pile load test by static axially loaded compression

Reconnaissance et essais géotechniques — Essais de structures géotechniques —

Partie 1: Essai de charge statique axiale en compression

ICS 93.020

ISO/CEN PARALLEL ENQUIRY

This draft International Standard is a draft standard developed within the European Committee for Standardization (CEN) and processed under the CEN-lead mode of collaboration as defined in the Vienna Agreement. The document has been transmitted by CEN to ISO for circulation for ISO member body voting in parallel with CEN enquiry. Comments received from ISO member bodies, including those from non-CEN members, will be considered by the appropriate CEN technical body. Should this DIS be accepted, a final draft, established on the basis of comments received, will be submitted to a parallel two-month FDIS vote in ISO and formal vote in CEN.

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

ISO 22477-1 was prepared by Technical Committee ISO/TC 182, *Geotechnics*, Subcommittee SC 1, and by Technical Committee CEN/TC 341, *Geotechnical investigation and testing* in collaboration.

ISO 22477 consists of the following parts, under the general title *Geotechnical investigation and testing — Testing of geotechnical structures*:

— *Part 1: Pile load test by static axially loaded compression*

— *Part 2: Pile load test by static axially loaded tension* (in preparation)

— *Part 3: Pile load test by static transversally loaded tension* (in preparation)

— *Part 4: Pile load test by dynamic axially loaded compression test* (in preparation)

— *Part 5: Testing of anchorages*

— *Part 6: Testing of nailing* (in preparation)

— *Part 7: Testing of reinforced fill* (in preparation)

Geotechnical investigation and testing — Testing of geotechnical structures — Part 1: Pile load test by static axially loaded compression

1 Scope

This Standard 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.

The provisions of EN 22477-1 apply to vertical piles as well as raking piles.

All types of piles are covered by this standard.

The tests considered in this Standard are limited to maintained load tests.

EN 22477-1 shall be used in conjunction with EN 1997-1. 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 are provided in EN 1997-1. Guidance on analysis of the load testing results is given in the informative Annex D.

This Standard provides specifications for:

a) Investigation tests, whereby the pile is loaded up to failure or close to failure ;

b) Control tests, whereby the pile is loaded up to a specified load in excess of the SLS design action.

2 Normative references

The following referenced documents are indispensable for the application 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 1990:2002, *Eurocode 0 : Basis of structural design*

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

EN 1536:1999, *Execution of special geotechnical work - Bored piles*

EN 10002-2, *Metallic materials – Tensile testing – Part 2 : Verification of the force measuring system of the tensile testing machines*

EN 12699:2000, *Execution of special geotechnical work - Displacement piles*

prEN 14199:2001, *Execution of special geotechnical work – Micropiles*

3 Terms, definitions and symbols

For the purposes of this document, the terms and definitions given in EN 1990 and the following apply.

Terms, definitions and symbols specific for EN 22477-1-1 are given hereunder.

3.1
Q : pile load
the load applied to the head of the pile during the test

3.2
ΔQ : load increment
an increment of load added or removed during the course of the test

3.3
Q_{max}
the predefined maximum load to be applied for the test

3.4
$R_{c;u}$
ultimate total pile (bearing) resistance in compression : the load per pile required to produce a condition of failure in the ground or in the pile

NOTE Following 7.6.1.1 of EN 1997-1, the compressive resistance failure corresponds to the state in which the pile foundation displaces significantly with negligible increase of resistance. In case that it is difficult to define an ultimate limit state from a load settlement plot showing a continuous curvature, a settlement of the pile top equal to 10 % of the pile base diameter should be adopted as the “failure” criterion.

3.5
$R_{b;u}$
ultimate pile base resistance

3.6
$R_{s;u}$
ultimate pile shaft resistance

3.7
$q_{s;u}$
ultimate unit shaft resistance

3.8
$Q_{b;u}$
ultimate unit base resistance

3.9
R_y
yield resistance:

a) a critical experimental load beyond which the rate of axial displacement takes place with a notably increased increment

b) the load at which the rate of settlement increases without any significant increase in load

3.10
α_y : yield factor
the ratio of the increase in pile head displacement and the log of time during a specified time interval (usually the last 30 min of a load step)

3.11
s_h, s_b : settlement
the axial displacement of pile head or pile base respectively

3.12
D_b : equivalent pile base diameter
for noncircular pile sections with A being the area of the relevant pile base, the equivalent diameter equals $\sqrt{(4/\pi).A}$

3.13
preliminary pile
a pile installed before the commencement of the main piling works or a specific part of the works for the purpose of establishing the suitability of the chosen type of pile and for confirming its design, dimensions and bearing resistance (EN 1536:1999)

3.14
trial pile
pile installed to assess the practicability and suitability of the construction method for a particular application (EN 1536:1999)

3.15
working pile
pile for the foundation of a structure (EN 1536:1999)

3.16
test pile
pile to which loads are applied to determine the resistance deformation characteristics of the pile and the surrounding ground (EN 1536:1999)

NOTE The test pile can be a preliminary pile, a trial pile or a working pile.

3.17
static pile load test
loading test where a pile is subjected to chosen axial and/or lateral forces at the pile had for the analysis of its capacity

3.18
maintained pile load test
static loading test in which a test pile has loads applied in incremental stages, each of which is held constant for a certain period or until pile motion has virtually ceased or has reached a prescribed limit (ML-test) (EN 1536:1999)

4 Equipment

4.1 General

For guidance, the most relevant specifications related to the equipment, as detailed hereunder, are summarised in Table A.1.

The selection of the equipment shall take into account the aim of the test, the ground conditions and the execution of the test.

4.2 Reaction device

The reaction device for pile compressive loads can be :

- dead load (kentledge);
- ground anchorages either by tension piles or ground anchors;
- a structure over the test pile (e. g. for jacked underpinning piles);
- 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.

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.

For all these reaction systems the clear distance between the test pile and the nearest edge of the kentledge support or the anchorage shall be at least 2,5 m or 3 D_b, whichever is the greatest. These requirements might be more severe for test piles that act predominantly through skin friction or when using ground anchors as a reaction device.

The reaction system shall be designed for the maximum test load Q_{max} in accordance with the relevant European standards.

To avoid uplift or instability of the kentledge, the dead load should be in excess of the maximum test load Q_{max} 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

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 excessive rotation and/or translation of the reaction system.

4.3 Force input

Unless otherwise required by the design, one or more hydraulic jacks shall be used to apply the load on the test pile.

NOTE 1 For top-down loading the hydraulic jack is seated on top of the pile between the reaction assembly and the pile head.

NOTE 2 For bi-directional loading the hydraulic jack is cast into the pile to apply an axial load in two opposite directions.

The jacking force and stroke of the jack shall be matched to Q_{max} and to the expected deformations (pile head displacement and those of the reaction system under load). A minimum stroke of 150 mm and 15 % D_b is recommended.

It shall be possible to decrease or increase the load fluently without any shocks or vibrations and to maintain the load at any required value. For investigation tests an automatic and continuous electric or hydraulic control and regulation of the jack force should be used. For control tests a hand pump control and regulation may be used.

To safeguard the test, it should be possible to repair the equipment without excessive loss of load on the pile.

The accuracy of the force regulation shall by in accordance to the test purpose. It should allow the load Q to be applied and maintained during each load step within the following relative variation:

— For investigation tests : ± 0,5 % of Q_{max} and ± 1,0 % of Q

— For control tests : ± 3 % of Q

NOTE More severe requirements may be required for time dependent analysis of the test results.

4.4 Reference frame and points

The displacements of the pile head can be measured either by dial gauges or transducers, supported from reference beams or alternatively, the displacements may be measured independently from reference beams by advanced levelling methods such as electronic optical devices.

It is recommended to use reference beams supported independently from the test pile. Alternatively, beams may be fixed on the pile head. In this case the displacements of the pile head or the beams should be measured from independent reference marks.

The clear distance between the supporting ends of the reference beams (or alternatively the reference marks) and the test pile and reaction piles or the nearest edge of the kentledge support shall be at least 2,5 m or 3 × *D*, whichever is the greatest.

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

4.5 Measurements

4.5.1 Measurement of pile head displacements

The pile head displacements shall be measured with at least three displacement transducers or dial gauges supported from reference beams.

The overall accuracy of the measured pile head displacement shall be of MAX (0,1 mm; 0,2 % of the read out value) or better. Therefore dial gauges or transducers shall enable readings to be made to an accuracy of at least 0,01 mm.

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

The pile head displacements may be measured by alternative techniques (e.g. optical levelling) which are independent from the reference beam.

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

When relevant, complementary optical levelling of at least one point fixed to the test pile head shall be provided, as a control of the transducers or dial gauges measurements.

The potential 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, horizontal pile head displacements can be obtained from horizontal survey.

The displacements of the reference beams should be checked by optical levelling at least at the end of each load step.

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

4.5.2 Measurement of pile load

Load measurement can 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.

The load measurement devices shall be calibrated in accordance with EN 10002–2 by a certified institute.

For investigation tests, the accuracy of the load measurement should be 1 % or less.

For control tests, the accuracy of the load measurement should be 3 % or less.

When a load cell is used, it shall have been calibrated within a period of 12 months before the test.

When the load is measured from the jack pressure, the calibration of the entire jack system (jack + pump + pressure gauges) shall be executed within a period of 1 month before the test.

4.5.3 Pile instrumentation

The load distribution along the pile shaft may be determined by means of direct or indirect measurement of the force at cross sections of the pile at various depths.

The following measurement devices may be used:

— removable extensometer;

— telltales;

— strain gauges or strain gauge devices;

— vibrating wire strain gauge;

— load cell at the pile base or within the pile shaft;

— hydraulic jacks at the base of the pile or built-in in the shaft of the pile.

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

Removable extensometers should be installed in the centre of smaller diameter piles (shaft diameter < 0,5 m), or in diametrically opposed pairs for larger diameter piles (shaft diameter > 0,5 m), and this for each depth to be measured.

Strain gauges or strain gauge devices should be fixed to the reinforcement bars rods or embedded in the concrete of concrete piles or attached to the walls of steel piles at least in diametrically opposed pairs for each depth to be measured.

The cross section A and the deformation properties of the pile material (modulus of elasticity) shall be determined.

For reinforced concrete piles, a composite composed deformation modulus shall be applied comprising the concrete, the reinforcement and embedded parts. The effective deformation modulus of the pile shaft should be determined directly by :

— laboratory testing on a piece of pile made and conserved under the same conditions as the tested pile;

— in situ measurement of the pile deformation on the free upper part of the pile at a level below the pile head where uniform stress distribution can be presumed.

For steel piles, the manufacturer’s information or common methods may be used to determine the deformation modulus.

