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Geotechnical investigation and testing — Testing of geotechnical structures —

Part 10:
Testing of piles: rapid load testing

Reconnaissance et essais géotechniques — Essais de structures géotechniques —

Partie 10: Essai des pieux: essai de charge rapide

ICS: 93.020

ISO/CEN PARALLEL PROCESSING

This draft has been developed within the European Committee for Standardization (CEN), and processed under the **CEN lead** mode of collaboration as defined in the Vienna Agreement.

This draft is hereby submitted to the ISO member bodies and to the CEN member bodies for a parallel five month enquiry.

Should this draft be accepted, a final draft, established on the basis of comments received, will be submitted to a parallel two-month approval vote in ISO and formal vote in CEN.

To expedite distribution, this document is circulated as received from the committee secretariat. ISO Central Secretariat work of editing and text composition will be undertaken at publication stage.

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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.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 22477-10 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 (in preparation)*

— *Part 5: Testing of pre-stressed ground anchors(in preparation)*

— *Part 6: Testing of soil nails (in preparation)*

— *Part 10: Testing of piles: rapid load testing (in preparation)*

Introduction

This international standard establishes the specifications for the execution of rapid load pile tests in which a single pile is subject to an axial load in compression to measure its load-displacement behaviour under rapid loading and to allow an assessment of its measured compressive resistance and corresponding load-displacement behaviour. This international standard outlines how a rapid load pile test is defined and specifies the equipment and testing procedures required. Informative non-prescriptive guidance is included on the analysis of rapid load pile test results required to determine mobilised or ultimate compressive resistance of a pile.

This international standard has been prepared as part of ISO 22476-series, Geotechnical investigation and testing — Field testing.

Geotechnical investigation and testing — Testing of geotechnical structures — Part 10: Testing of piles: rapid load testing

1 Scope

This international standard establishes the specifications for the execution of rapid load pile tests in which a single pile is subject to an axial load in compression to measure its load-displacement behaviour under rapid loading and to allow an assessment of its measured compressive resistance ($R_{c,m}$) and corresponding load-displacement behaviour.

The provisions of this international standard apply to piles loaded axially in compression.

All pile types mentioned in EN 1536, EN 12699 and EN 14199 are covered by this international standard.

The tests considered in this international standard are limited to rapid load pile tests only.

NOTE 1 ISO 22477-10 can be used in conjunction with EN 1997-1. Numerical values of partial factors for limit states from pile load tests to be taken into account in design are provided in EN 1997-1. For design to EN 1997-1 the results from rapid load pile testing will be considered equivalent to the measured compressive resistance $R_{c,m}$ after being subject to appropriate analysis.

NOTE 2 Guidance on analysis of the rapid load testing results to determine measured compressive resistance and corresponding load-displacement behaviour is given in the informative Annex A.

This international standard provides specifications for:

1) Investigation tests, whereby a sacrificial test pile is loaded up to ultimate limit state;

2) Control tests, whereby the pile is loaded up to a specified load in excess of the serviceability limit state.

NOTE 3 Generally, an investigation test focuses on general knowledge of a pile type; a control test focuses on one specific application of a pile.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 22476-series Geotechnical investigation and testing — Field testing

ISO 22477-1 Geotechnical investigation and testing – Testing of geotechnical structures – Part 1: Pile load test by static axially loaded compression (in preparation)

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

EN 1997-2 Eurocode 7: Geotechnical design —Part 2: General rules

3 Terms definitions and symbols

3.1 Terms and definitions

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

3.1.1
trial pile
pile installed before the commencement of the main piling works or a specific part of the works for the purpose of investigating the suitability of the chosen type of pile and for confirming its design, dimensions and bearing resistance

NOTE The trial pile might be sacrificed to achieve ultimate limit state.

3.1.2
working pile
pile that will form part of the foundation of the structure

3.1.3
test pile
pile to which loads are applied to determine the resistance deformation characteristics of the pile and the surrounding ground

NOTE A test pile can be a trial pile, or a working pile

3.1.4
Pile load
Axial compressive load (or force) applied to the head of the pile during the test

3.1.5
rapid load
A force applied to the pile in a continuously increasing and then decreasing manner of a suitable duration (typically less than 1 sec) relative to the natural period of the pile which causes the pile to compress over the full length and translate approximately as a unit during the full loading period

3.1.6
maximum compressive load
maximum axial compressive load (or force) applied to the pile during the test, generally defined prior to the test

3.1.7
rapid load test
pile loading test where a pile is subjected to chosen axial rapid load at the pile head for the analysis of its capacity

3.1.8
ultimate measured compressive resistance of a pile
corresponding state in which the pile foundation displaces significantly with negligible increase of resistance

NOTE 1 Where it is difficult to define an ultimate limit state from a load settlement plot showing a continuous slight increase, a settlement of the pile top equal to 10 % of the pile base diameter should be adopted as the “failure” criterion

NOTE 2 The ultimate compressive resistance is not measured directly during a rapid load test. The measured resistance obtained from rapid load testing must be analysed to remove the effects of inertia and soil dependent behavior before it can be considered equivalent to the ultimate measured compressive resistance.

3.1.9
design compressive static resistance of a pile
is the ultimate compressive static resistance of a pile that shall be determined prior to load testing to allow specification of appropriate magnitude rapid load test cycles

3.1.10
equivalent diameter
diameter of an equivalent circle of which the area equals the area of the relevant pile section

NOTE The equivalent diameter for a circular pile is the outer diameter of the pile, for a square pile the diameter which gives the same area as the square pile (as long as the longest side is smaller than 1,5 times the shortest side) is the equivalent diameter.

3.1.11
minimum reference separation distance
distance which separates a stationary reference point from a point that will be significantly displaced by the testing method

NOTE Only stationary points can be used for reference of displacement measurement devices. Displacement measuring systems can be placed on the soil outside the reference distance without isolating (displacement compensating) measures.

3.1.12
displacement
axial displacement of the pile head measured during testing

3.2 Symbols

For the purposes of this document, the following symbols apply.

a	pile acceleration
c_p	velocity of the stress wave in the test pile
c_s	velocity of the shear wave in the ground
D	diameter or equivalent diameter of the test pile
F_c	pile load in compression
$F_{c,max}$	maximum compressive load
g	acceleration due to gravity
L	total length of the test pile
$R_{c,m}$	measured ultimate resistance of the ground in the test, or measured geotechnical resistance of the pile
r_{ref}	minimum reference separation distance
t	time
t_f	duration of the rapid load application
t_g	duration of the falling of the mass for a falling mass equipment
w	pile displacement

4 Testing equipment

4.1 General

The equipment should generate a rapid load at the pile head where the duration of the load fulfils equation (3.1).

$$10 < \frac{\left(t_f \times c_p\right)}{L} \leq 1000 \qquad (4.1)$$

If information on the ultimate compressive resistance of the pile is one of the aims of the test, the equipment shall have enough capacity to reach the ultimate compressive resistance under rapid loading.

NOTE 1 The force applied to the pile head during a rapid load test for measuring the ultimate compressive resistance might exceed the design compressive static resistance of a pile by a factor of two to three due to soil specific rate effects. The need to apply such high loads shall be considered when specifying equipment and pile materials.

If for a rapid load test, one or more of the requirements mentioned in this international standard is not met; it should be proven that this shortcoming has no influence on the achievement of the objectives of the test, before the results can be interpreted as a rapid load test.

NOTE 2 For long piles where the criteria in equation (4.1) is exceeded or where rock sockets result in non-uniform strains within the pile embedded pile instrumentation and specialised analysis will be required. Additional instrumentation should conform to 4.3.

Rapid load testing systems rely on a mass to apply load to a pile. This is either through launching a mass upwards, referred to as a launched mass system or by dropping a mass, referred to as a drop mass system. In both cases the upward or the downward movement of the mass is controlled to produce the required load duration in 4.1. To avoid eccentric loading of piles and additional safety considerations the movement of the mass should be guided during launched mass testing and drop mass testing.

4.2 Loading

The selection of the loading equipment shall take into account:

— the aim of the test;

— the ground conditions;

— the maximum pile load ($F_{c,max}$);

— the strength of the pile (material);

— the execution of the test;

— safety considerations.

The loading equipment shall generate a force which fulfils the requirements in 4.1 and is able to apply the required maximum compressive force to mobilise a specified compressive resistance or the ultimate compressive resistance of a pile.

If a test pile is tested by several cycles beginning with a low magnitude force cycle, the maximum force of each proceeding cycle should be larger than the maximum force of the preceding cycle. Where cycles of loading are applied this should be undertaken in a manner that removes the potential for uncontrolled reloading of the pile. This will require the device to have a mass catching mechanism.

The equipment shall load the pile accurately along the direction of the pile axis. The eccentricity of the load shall be less than 10 % of the equivalent diameter. The deviation or eccentricity of the alignment of the force to the axis of the pile shall be less than 20 mm/m. Eccentric loading of the pile is allowed where this has been specifically allowed for during pile design and it has been verified that this will not unduly effect the performance of the testing equipment.

The stress in the pile under the maximum applied load shall not exceed the permissible stress of the pile material.

4.3 Measurements

Prior to a rapid load test two variables shall be directly measured where the reaction mass comes into contact with the pile head prior to testing (not required for all equipment types):

— the force applied to the pile head;

— the displacement of the pile head;

During a rapid load test a minimum of three variables shall be directly measured relative to time (t):

— the force applied to the pile head (F_c);

— the displacement of the pile head (w);

— the acceleration of the pile head (a).

The transducers and signal processing shall satisfy the requirements from Table 1 to Table 4. Sampling shall commence a minimum of 50 ms before loading commences and continue for a minimum duration of 500 ms. Where duration of the loading event means that the duration of sampling exceeds 500 ms the duration of sampling shall be increased to capture the entire event and allow for the required post event sampling. All transducer sampling shall be synchronised. The transducers shall have sufficient measuring range, in order to avoid re-adjustment during testing. All instrumentation must be able to withstand pile installation and testing procedures

Table 1 — Rapid load test transducer and signal processing general requirements

Parameter	Requirement
Sampling rate	≥ 4 000 samples per second
Duration of pre-event sampling	≥ 50 ms
Duration of post-event sampling	≥ 300 ms
Cut off frequency low pass filter	≥ 1 kHz

Table 2 — Rapid load test load transducer and signal processing load requirements

Parameter	Requirement
Maximum load	> maximum test load
Linearity	< 2 % of maximum value reached
Hysteresis	< 2 % of maximum value reached
Response time	< 0,1 ms

Table 3 — Rapid load test acceleration transducer and signal processing requirements

Parameter	Requirement
number of transducers	≥ 1
resonant frequency	> 5 kHz
linearity	up to 50 *g*