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Geotechnical investigation and testing — Laboratory testing of soil —

Part 6: Fall cone test

Reconnaissance et essais géotechniques — Essais de laboratoire sur les sols —

Partie 6: Essai de pénétration de cône

Reference number
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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.

ISO 17892-6 was prepared by the European Committee for Standardization (CEN) Technical Committee 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).

This first edition cancels and replaces ISO/TS 17892-6:2004, which has been technically revised. It also incorporates the Technical Corrigendum ISO/TS 17892-6:2004/Cor 1:2006.

A list of all parts in the ISO 17892 series can be found on the ISO website.

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Introduction

This document covers areas in the field of geotechnical engineering never previously standardized internationally. It is intended that this document presents broad good practice throughout the world and significant differences with national documents is not anticipated. It is based on international practice (see Reference [1]).

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Geotechnical investigation and testing — Laboratory testing of soil —

Part 6: Fall cone test

1 Scope

This document specifies a method of undrained strength index testing of both undisturbed and remoulded specimens of fine grained soils by the fall cone method.

This document is applicable to the laboratory estimation of undrained shear strength of a soil test specimen within the scope of geotechnical investigations.

In the fall cone test, a cone is allowed to fall with its tip towards a soil specimen, and the resulting penetration of the cone into the soil is measured. The penetration values are used to estimate the undrained shear strength. The fall cone test produces a complex shear in the test specimen, and does not represent either a vertical triaxial compression or a horizontal shear test. However, this index test may be correlated to some estimate of undrained shear strength determined in the laboratory by other test methods.

As the test is performed on a small laboratory specimen, the result may not agree with laboratory tests on larger specimens. In addition, the test specimen may not be fully representative of the soil in its natural state in the field; for example, the test specimen may not have fissures present *in situ* at a larger spacing than the specimen size.

Therefore, for the above reasons, the test can be regarded as an estimation of undrained shear strength, rather than a true measurement of it.

The ratio of the remoulded shear strength to the undisturbed shear strength may be used to estimate the sensitivity of a soil specimen. Time-dependent measurement of the shear strength may be used to assess the thixotropic regain of strength of a remoulded soil specimen.

NOTE This document fulfils the requirements of the strength index testing of soils for geotechnical investigation and testing in accordance with EN 1997–1 and EN 1997–2.

2 Normative references

The following documents are referred to in 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 14688-1, *Geotechnical investigation and testing — Identification and classification of soil — Part 1: Identification and description*

ISO 17892-1, *Geotechnical investigation and testing — Laboratory testing of soil — Part 1: Determination of water content*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

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

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

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

3.1
fall cone undrained shear strength of undisturbed soil
c_{ufc}
undrained shear strength of an undisturbed fine grained soil specimen estimated by the fall cone method

3.2
fall cone undrained shear strength of remoulded soil
c_{urfc}
undrained shear strength of a remoulded fine grained soil specimen estimated by the fall cone method

4 Equipment

See Annex A for calibration requirements for the equipment in this clause.

4.1 Cone apparatus

The apparatus shall permit the cone to be held firmly initially and to be released instantaneously to fall freely in the vertical direction into the soil specimen.

The apparatus shall have a mechanism which allows the cone to be raised or lowered and adjusted so that the tip of the cone just touches the surface of the specimen before the cone is released.

The cone apparatus shall be equipped with a method of measuring the penetration across the range of at least 4 mm to 20 mm penetration. Methods include a linear scale alongside the shaft, or a circular dial with a pointer needle or an electronic transducer, in both cases bearing on the upper end of the shaft. If the scale is designed for manual reading, it shall be marked in increments of 1 mm or better.

4.2 Fall cones

A set of cones with cone angles of 30° or 60° and masses (i.e. mass of cone plus shaft) covering a range of possible shear strengths shall be used. Typical examples of suitable fall cones are given on Table 1. There is limited experience or validation of cones of alternative configuration, for example, heavier than 400 g. Alternate cones should be used with caution.

Table 1 — Set of fall cones - typical total masses and tip angles

Mass	g	10	60	80	100	400
Tip angle β	°	60	60	30	30	30

A 60 g/60° cone is shown in Figure 1 as a typical example of such a cone.

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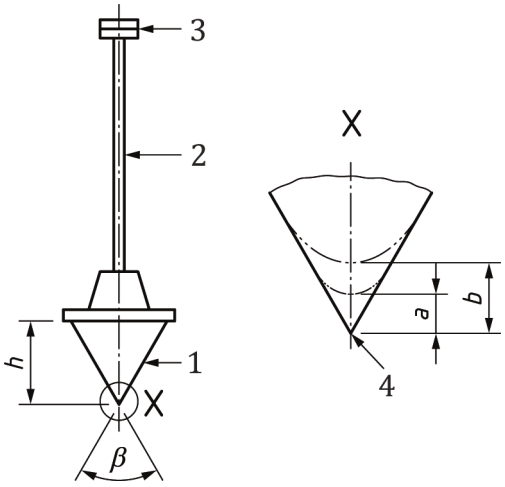

Key

1	cone	*a*	deviation from the geometrical tip at manufacturing
2	shaft	*b*	maximum wear
3	index mark	*h*	height of the conical tip
4	cone tip	*β*	tip angle

Figure 1 — Example of a fall cone

When penetration readings are taken from a linear scale alongside the shaft, there shall be a distinct index mark for reference near the top of each shaft which shall be clearly visible when viewing the scale.

The cones shall be made of or be coated with a corrosion-resistant material such as stainless steel or chromium, and should have smooth polished surfaces with an average roughness, R_a, of less than 0,8 µm. Cones with significant wear or scratches shall be replaced.

The masses of the cones, together with their shafts, shall be within 1 % of the nominal mass and the tip angles shall be within 0,2° of the nominal angles.

The deviation from the geometrical tip at manufacturing, *a*, shall be less than 0,1 mm. The maximum wear, *b*, shall be less than 0,3 mm (see Figure 1).

The height of the conical tip, *h*, shall be greater than the maximum penetration used in the measurement.

4.3 Ancillary apparatus

— sample extruder;

— wire cutter;

— glass plate and tools to trim undisturbed specimens with flat and parallel ends;

— tools to prepare a remoulded soil specimen such as a spatula and straight edge;

— suitable cup to hold remoulded specimens for testing, shall be made of a rigid non-corrodible material, with a base parallel to the rim and at least 50 mm in diameter and 25 mm in depth;

— equipment as necessary to determine water content.

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5 Test procedure

5.1 Test specimen preparation

5.1.1 General

5.1.1.1 For the estimation of the undrained shear strength of undisturbed soil, the samples shall be taken with a sampling method that yields undisturbed samples. However, useful index data can be derived from fall cone tests on other samples providing that the moisture content is representative of field conditions and post sampling disturbance is minimized. Regardless, the undisturbed laboratory fall cone estimation corresponds to the current state of an intact soil specimen.

5.1.1.2 The time for storage of the soil samples and their storage conditions can affect the test result due to changes in the sample, for example drying, oxidation or biological processes, unless precautions are taken to minimize this.

5.1.2 Undisturbed specimen in sample tube

5.1.2.1 The test shall be performed on a soil specimen which is representative of the sampling depth and from that part of the sample, which according to experience of the particular sampling method is least disturbed.

5.1.2.2 Any disturbed material at the top of the sample tube shall be extruded and carefully cut off with the wire cutter in order to leave a clean, fresh and flat surface for fall cone testing. The required amount of sample to be cut off mainly depends on the type of sampler used.

5.1.3 Extruded and/or trimmed undisturbed test specimen

5.1.3.1 A test specimen of the sample shall be prepared with a diameter of at least 50 mm and with plane and parallel ends. The height of the test specimen shall be at least 25 mm.

5.1.3.2 The test specimen shall be placed with one of the plane ends on a flat surface, e.g. the glass plate.

5.1.4 Remoulded specimen

5.1.4.1 The possible existence of seams or layers (e.g. sand layers) or lenses of coarser soil shall be noted. If these have been removed before test, this shall also be noted.

5.1.4.2 Gravel size particles, shells, etc. should be removed, and if removed, shall be noted and reported.

5.1.4.3 The soil shall be thoroughly remoulded in order to break down the structure of the soil. Remoulding should be carried out by hand, using a glass-plate or a cup and spatula, taking care to avoid air bubbles being mixed into the sample. Changes to the water content of the specimen being remoulded shall be minimized. Continue the remoulding process until the consistency of the sample ceases to change, which may be checked by the test results.

NOTE The rate of breakdown of the initial soil structure depends on the remoulding effort, on the type of soil, on the natural water content of the test specimen (the rate of breakdown increases with increasing water content) and on the electrolytic content of the pore fluid.

5.1.4.4 The cup shall be filled with soil without entrapping air, and the soil surface shall be levelled flush with the brim of the cup using the spatula or a straight edge. Any surplus material shall be carefully preserved to minimize any loss of water content.

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5.1.4.5 The remoulded test specimen should be tested directly after remoulding and levelling of the surface. However if the thixotropic properties are to be assessed, a series of test specimens should be tested, each at a discrete time interval after remoulding.

NOTE After remoulding, a thixotropic strength increase generally takes place. The thixotropic strength increase has a considerable significance on the shear strength measured in the test, particularly for montmorillonite and sensitive clays.

5.2 Test points

5.2.1 For multiple tests on an undisturbed specimen, the test points shall be distributed across the sample surface so that the results are unaffected by other test points and the proximity to the perimeter of the sample. No part of the cone which penetrates into the soil shall be closer to the perimeter than 7 mm. The distance between the outer boundaries of the cone penetration in two test points shall be at least 14 mm.

5.2.2 If tests are performed at multiple depths on an undisturbed sample still in its sampling tube, a length of the sample corresponding to at least 1,5 times the cone penetration shall be extruded and the protruding part cut off with a wire cutter after each test.

5.2.3 For additional fall cone measurements on remoulded test specimens, the test specimen shall be re-mixed and levelled again after each test, adding some of the preserved spare material if necessary.

5.3 Determination of fall cone penetration

5.3.1 The specimen or cup shall be placed with its smooth and level surface below the cone.

5.3.2 With the cone locked in the raised position, the supporting assembly shall be lowered so that the tip of the cone just touches the surface of the soil and so that slight lateral movement of the cup just marks the surface of the soil (see Figure 2).

5.3.3 The initial zero penetration reading of the device shall be recorded.

5.3.4 The cone shall be released promptly. If the apparatus is not fitted with an automatic release and locking device, care shall be taken not to jerk the apparatus during this operation.

5.3.5 The penetration of the cone shall be determined at the moment the initial fall off the cone stops, and in any case not more than 2 s after the cone release, and shall be recorded to the nearest 0,25 mm or better. Careful observation of the fall of the cone is essential for the most accurate results.

NOTE The fall usually consists of two components, an initial rapid fall under the influence of gravity, which is often complete in the first few seconds, followed by a slower fall due to flow of soil around the cone or dilatancy bringing water to, and hence lubricating the soil-cone interface.

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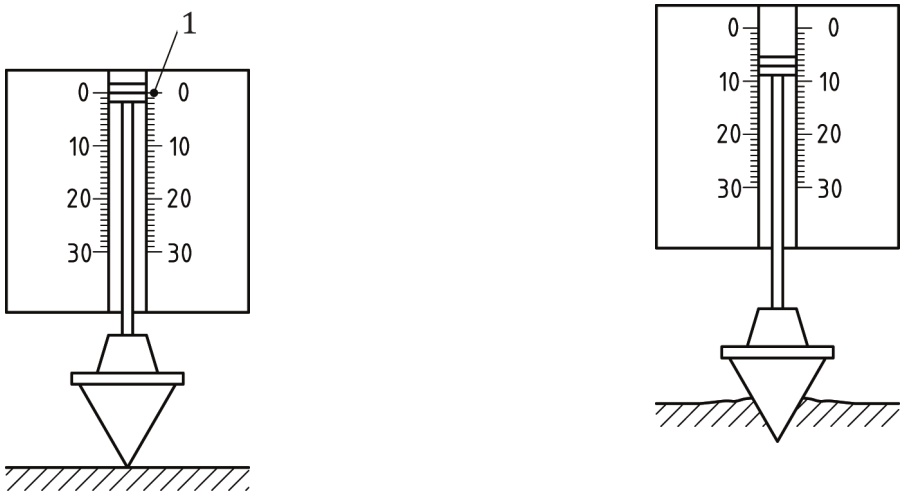

a) Position of cone prior to fall **b) Typical position of cone after fall**

Key

1 measurement scale, in mm

Figure 2 — Fall cone test on soil

5.3.6 Record the type of cone used.

5.3.7 The cone holder shall be raised so that the cone is lifted out of the soil test specimen and the cone shall be cleaned carefully.

5.3.8 A lighter or greater tip angle cone shall be selected if the cone penetration is more than 20 mm. A heavier or smaller tip angle cone shall be selected if the penetration is less than 4 mm. If two different cones are used for measurements on the same soil specimen, they should be treated as independent estimations with separate shear strength results.

5.3.9 A new test point shall be selected in accordance with 5.2, and the procedure from 5.3.1 to 5.3.8 shall be repeated.

5.3.10 For undisturbed samples, at least three test points should be measured with the same cone. If any value deviates more than 0,5 mm from the average, and if sufficient undisturbed sample surface is available to meet the requirements of 5.2, an additional test point should be measured and the most deviating value shall be disregarded.

If the undisturbed sample is heterogeneous, it may not be possible to obtain consistent measurements.

5.3.11 For remoulded specimens, at least two test points should be measured with the same cone. If these differ by more than 0,5 mm, the result shall be disregarded and the sample shall be remoulded further and tested again. The remoulding and measurement procedure shall continue until two successive pairs of test points give average penetrations within 0,5 mm of each other.

5.3.12 The water content of a representative specimen of soil shall be determined according to ISO 17892-1.

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6 Test results

6.1 Average penetration

The average penetration, *i*, shall be calculated for tests on undisturbed specimens. For remoulded test specimens, *i* equals the lower average value from two successive pairs of test points with penetrations within 0,5 mm of each other.

6.2 Estimated undrained fall cone shear strength

The undrained shear strength of the soil test specimen in its current state during the test is estimated according to Formula (1):

$$c_{ufc} \text{ (or } c_{urfc}) = c \cdot g \cdot \frac{m}{i^2} \quad (1)$$

where

c_{ufc} is the undrained shear strength of the undisturbed soil specimen in its tested state (kPa);

c_{urfc} is the undrained shear strength of remoulded soil (kPa);

c is a constant, dependent on the tip angle of the cone, where

c = 0,80 for cones with 30° tip;

c = 0,27 for cones with 60° tip;

g is the acceleration due to gravity at free fall, usually taken as a value of 9,81 (m/s^2);

m is the mass of the cone (g);

i is the average cone penetration (mm).

6.3 Additional estimate of undrained fall cone shear strength

The undrained shear strength may additionally be estimated by other correlations to shear strength based on local experience for specific soil types.

7 Test report

7.1 Mandatory reporting

The test report shall affirm that the test was carried out in accordance with this document, and shall include at least the following information:

a) identification of the specimen tested, e.g. by borehole number, sample number and sample depth and any other relevant details required, e.g. depth of specimen within a sample, method of sample selection if relevant, observed inhomogeneities, and whether the test is on an undisturbed or a remoulded specimen;

b) visual description of the specimen tested including any observed features noted after testing, following the principles in ISO 14688-1;

c) mass and the tip angle of the cone used in the testing;

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d) average penetration of the cone if no values differ by more than 0,5 mm from the average, or for tests where inconsistent results were obtained, the individual penetration results as well as the average in which case the test shall also be reported as a non-conforming test;

e) estimated undrained fall cone shear strength of the undisturbed or remoulded soil test specimen determined by Formula (1), the result of which shall be reported in kPa up to two significant digits or to the nearest 0,1 kPa below 1 kPa;

f) water content of the sample tested and a statement that it has been based on the specimen trimmings if appropriate;

g) any deviations from this procedure.

7.2 Optional reporting

The following additional information may be reported:

— undrained fall cone shear strength of the undisturbed or remoulded soil test specimen estimated by additional correlations based on local practice, the result of which shall be reported in kPa up to two significant digits or to the nearest 0,1 kPa below 1 kPa.

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Annex A
(normative)

Calibration, maintenance and checks

A.1 General requirements

All measurement equipment used in this document shall be calibrated periodically, its performance shall be checked where required at intervals, and it shall be operated in a controlled environment, if so specified. This annex defines these requirements for this method.

If calibration of measurement equipment is carried out by a third party, it shall be carried out by an accredited calibration laboratory. The certification shall show traceability to recognized national or international standards of measurement.

Where calibration of test measuring equipment is carried out in-house, the laboratory shall hold appropriate reference standards or instruments that are used solely for calibration purposes. These should be calibrated by an accredited calibration laboratory with certification requirements as above. When not in use, reference measurement equipment should be retained securely in a suitable environment separate from working standards or instruments. Reference standards and instruments shall be at least as accurate as the working device so that the desired accuracy of test measurement is achieved.

In-house calibration procedures shall be documented and performed by approved persons. Records of such calibrations and of performance checks shall be retained on file.

Notwithstanding the required calibration or check intervals in this annex, whenever any item of reference equipment or test measurement equipment has been mishandled, repaired, dismantled, adjusted or overhauled, it shall be recalibrated before further use.

All calibrated equipment shall be used only within the range for which it has been calibrated.

A.2 Environmental conditions

There are no specific environmental conditions applicable to the execution of this test method.

A.3 Cone sharpness and mass checks

The sharpness of the cone tip and the surface finish of the cones should be checked before first use on each day of use as follows:

— To ensure that the point remains sufficiently sharp for the purposes of the test, the cone should be replaced if the point can no longer be felt when brushed lightly with the tip of the finger when the tip is pushed through a hole (1,50 ± 0,02) mm in diameter, drilled through a metal plate (2,50 ± 0,02) mm thick for a 30° cone or a (1,00 ± 0,02) mm thick metal plate for a 60° cone. Other gauge dimensions may be used providing the ratios of its thickness to the diameters of the holes are maintained. The maximum permitted degree of wear of the cone tip (see 4.2) corresponds with the worn tip being flush with the bottom of the metal plate.

— The surface finish of the cones shall be checked visually to ensure no significant scratches or corrosion is visible.

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The cone surface roughness, masses, dimensions and total tip wear should be checked at least annually to ensure the requirements in 4.2 are met. Cones failing this test may be refurbished or should be replaced.

If the cone surface roughness is manufactured to meet the requirements in 4.2, a visual check for scratches and wear is sufficient as an annual check to maintain good results.

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Bibliography

[1] DIN. ISSMGE (Eds.), *Recommendations of the ISSMGE for geotechnical laboratory testing*; (in English, German and French); published by Beuth Verlag, Berlin

[2] EN 1997-1, *Eurocode 7 — Geotechnical design — Part 1: general rules published by CEN, Brussels*

[3] EN 1997-2, *Eurocode 7 — Geotechnical Design — Part 2: Ground investigation and testing, published by CEN, Brussels*

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