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**Geotechnical investigation and testing —
Laboratory testing of soil —**

**Part 6:
Fall cone test**

*Reconnaissance et essais géotechniques — Essais de sol au
laboratoire —*

Partie 6: Essai au cône



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Throughout the text of this document, read "...this European pre-Standard..." to mean "...this Technical Specification...".

ISO 17892 consists of the following parts, under the general title *Geotechnical investigation and testing — Laboratory testing of soil*:

- *Part 1: Determination of water content*
- *Part 2: Determination of density of fine-grained soil*
- *Part 3: Determination of particle density — Pycnometer method*
- *Part 4: Determination of particle size distribution*
- *Part 5: Incremental loading oedometer test*
- *Part 6: Fall cone test*

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- *Part 7: Unconfined compression test on fine-grained soil*
- *Part 8: Unconsolidated undrained triaxial test*
- *Part 9: Consolidated triaxial compression tests on water-saturated soil*
- *Part 10: Direct shear tests*
- *Part 11: Determination of permeability by constant and falling head*
- *Part 12: Determination of the Atterberg limits*

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Foreword

This document (CEN ISO/TS 17892-6:2004) has been prepared by Technical Committee CEN/TC 341 “Geotechnical investigation and testing”, the secretariat of which is held by DIN, in collaboration with Technical Committee ISO/TC 182 “Geotechnics”.

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- *Part 10: Direct shear tests*
- *Part 11: Determination of permeability by constant and falling head*
- *Part 12: Determination of Atterberg limits*

Introduction

This document covers areas in the international field of geotechnical engineering never previously standardised. 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 [1]).

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1 Scope

This document specifies the laboratory determination of undrained shear strength of both undisturbed and remoulded specimen of saturated fine grained cohesive soils by use of a fall-cone.

This document specifies the fall-cone test, in which a cone is allowed to fall with its tip towards a soil specimen, whereupon the penetration of the cone into the soil is measured. Tests performed according to this test yield penetration values which can be used to estimate the undrained shear strength.

The test is applicable to both undisturbed and remoulded soil test specimen.

For undisturbed soil test specimen, the results of the test are dependent on the quality of the specimen. Because of possible effects of anisotropy, it can also differ depending on what undrained shear strength the relation refers to.

The evaluated value of the undrained shear strength of the 'undisturbed' soil refers to its state during the test in the laboratory. This value is not necessarily indicative of the undrained shear strength of the soil in its natural state in the field. Therefore, the test should be regarded as an index test.

NOTE 1 For non-homogeneous soil samples, this method yields values of the undrained shear strength which are less representative for the bulk shear strength of the sample than other tests involving a larger volume of soil.

NOTE 2 For disturbed soil samples and fissured soil samples this method normally yields higher strength values than tests involving a larger volume of soil.

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.

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

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

3 Terms and definitions

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

3.1

undrained shear strength

c_u

the shear strength of a saturated fine grained soil determined in such a way that the soil remains undrained during the shearing process

3.2

fall-cone undrained shear strength

c_{ufc}

the undrained shear strength determined using a fall-cone apparatus

3.3

undisturbed sample

normally a sample of quality class 1 according to prEN 1997-2

4 Equipment

4.1 Cone apparatus

4.1.1 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.

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

4.1.3 The cone apparatus shall be equipped with a scale or other read off unit with such grading and resolution that the depth of the cone penetration, which shall be within 5 mm to 20 mm, can be read off to a resolution of $\pm 0,1$ mm after the release of the cone.

4.2 Fall-cones

4.2.1 A set of cones with cone angles of 30° or 60° and masses covering the whole range of possible shear strengths shall be used. A typical set of four fall cones is given on Table 1. The 60 g/ 60° cone is shown in Figure 1 as a typical example of such a cone.

Table 1 — Set of fall-cones - typical masses and dimensions

Mass	g	10	60	80	100	400
Tip angle β	$^\circ$	60	60	30	30	30

Key

- 1 index line
- 2 cone tip
- a is the deviation from the geometrical tip at manufacturing
- b is the maximum wear
- h is the height of the conical tip
- β is the tip angle

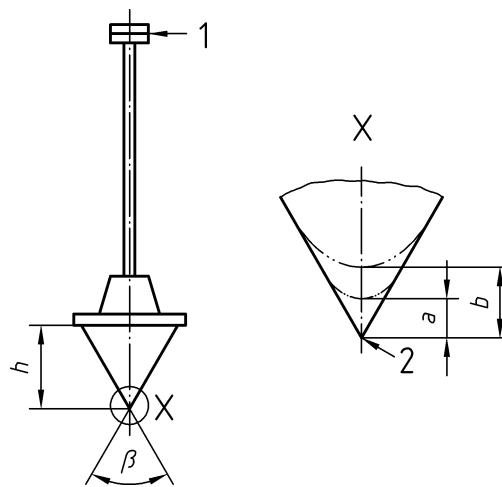


Figure 1 — Example of a fall-cone

4.2.2 When readings are taken manually, there shall be a distinct index line at the top of each shaft which shall be clearly visible in the reading scale.

4.2.3 The cones shall be made of stainless material and have smooth polished surfaces with an average roughness R_a of less than $0,8 \mu\text{m}$. Cones with obvious wear or scratches shall be replaced.

4.2.4 The masses of the cones, together with their shafts, shall be within 1 % of the nominal mass and the tip angles shall be within $0,2^\circ$ of the nominal angles.

4.2.5 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.

4.2.6 The height of the conical tip h shall be greater than 20 mm. 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 $(1,50 \pm 0,02)$ mm in diameter, drilled through a metal plate $(1,75 \pm 0,1)$ mm thick for a 30° cone or a $(1,0 \pm 0,1)$ mm thick metal plate for a 60° cone.

4.3 Ancillary apparatus

The ancillary apparatus consists of the following:

- a) Sample tube for undisturbed soil specimen or plane for extruded and/or trimmed test specimen;
- b) mixing cup; for remoulded specimen, a mixing cup shall be used with the rim parallel to the base. The cup shall be made of steel, porcelain or plastic, of cylindrical or semi-spherical shape, with a diameter greater than of 55 mm and depth of at least 30 mm;
- c) spatula;
- d) sample extruder;
- e) wire cutter.

5 Test procedure

5.1 Test specimen preparation

5.1.1 General

5.1.1.1 For determination of undrained shear strength of undisturbed soil, the samples shall be taken with a sampling method yielding undisturbed samples.

5.1.1.2 When the soil contains shells, coarser particles, fissures, channels etc. fall-cone tests may yield erroneous results.

5.1.1.3 The time for storage of the soil samples and their handling can affect the test result.

5.1.2 Undisturbed specimen in sample tube

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

5.1.2.2 Disturbed materials shall be extruded at the top of the sample from the tube by use of the sample extruder. The protruding part shall be cut off with the wire cutter in such a way that the soil surface is as even as possible.

NOTE The required amount of sample to be cut off mainly depends on the used type of sampler.

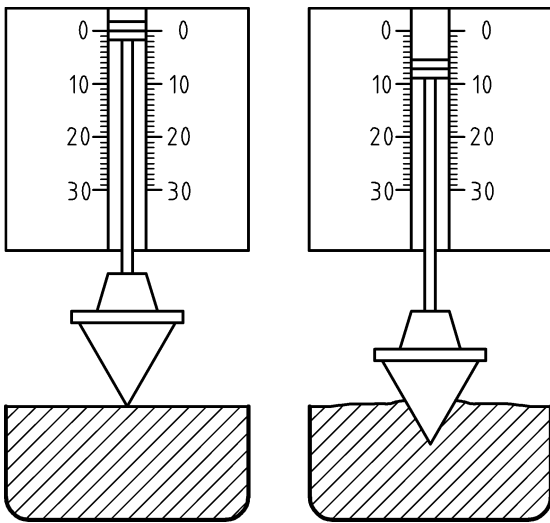


Figure 2 — Fall-cone test on remoulded soil

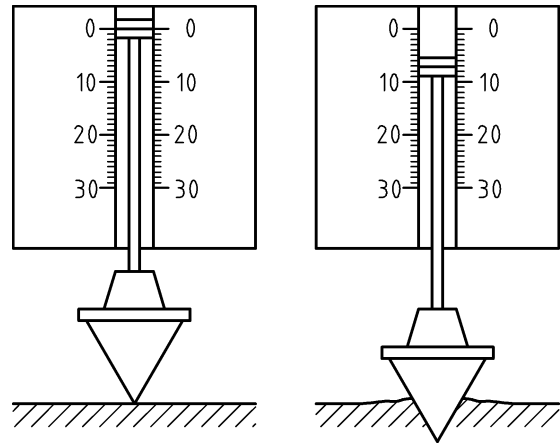


Figure 3 — Fall-cone test on undisturbed soil

5.1.3 Extruded and/or trimmed undisturbed test specimen

5.1.3.1 A test specimen of the sample shall be prepared in such way that it obtains a diameter of at least 50 mm, with plane and parallel ends.

5.1.3.2 The height of the test specimen shall be at least 5 mm more than the maximum expected cone penetration.

5.1.3.3 The test specimen shall be placed with one of the plane ends on plane 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 and if these have been removed.

5.1.4.2 If possible, all gravel size particles, shells etc. shall be removed and this shall be noted.

5.1.4.3 The soil shall be thoroughly remoulded in such a way as to avoid air bubbles being mixed into the sample.

5.1.4.4 The mixing cup shall be filled with soil without entrapping air, and the soil surface shall be levelled flush with the brim of the mixing cup using the spatula or a straight edge. The surplus material shall be placed in an empty cup.

5.1.4.5 Testing of the remoulded test specimen shall be performed directly after remoulding and levelling of the surface.

NOTE 1 When remoulding a soft, originally natural test specimen, a breakdown of the structure of the soil skeleton takes place. The rate of breakdown depends on the remoulding effort, on the type of soil, on the natural water content of the test specimen (the breakdown increases with increasing water content) and on the electrolytic content of the pore fluid. The remoulding is normally carried out by hand using a spatula and will be continued until the consistency of the sample ceases to change, which is checked by the test results.

NOTE 2 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 quick clays. Determination of the remoulded shear strength should therefore be made directly after remoulding.

5.2 Test points

5.2.1 For undisturbed specimens, the test points shall be distributed in such way that the results are unaffected by the other tests and the proximity to the perimeter. The part of the cone, which penetrates into the soil shall not in any point 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 After each test on test specimen remaining in the sampling tubes, a length of the sample corresponding to 1.5 times the cone penetration is extruded and the protruding part is cut off with a wire cutter.

5.2.3 For extruded and/or trimmed test specimen, a new test specimen with sufficient height in excess of the expected penetration of the cone shall be prepared.

5.2.4 For remoulded test specimens, the test specimen shall be mixed and levelled again after each test.

5.3 Determination of fall-cone penetration

5.3.1 The cone shall be locked in position. The zero setting shall be checked or, if required by the particular apparatus, the initial zero reading to the nearest 0,1 mm shall be recorded.

5.3.2 The specimen shall be placed with its smooth and level surface below the cone.

5.3.3 With the cone locked in the raised position, the supporting assembly shall be lowered so that the cone just touches the surface of the soil.

NOTE The adjustment can be aided and controlled by using the shadow of the cone when this is lit up from the side. When the cone is in the right position for a test on remoulded soil in a cup, a slight movement of the cup will result in just a marking of the soil surface.

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 In tests on remoulded test specimens, the penetration shall be read off or, if required by the particular apparatus, the cone shall be locked in position after (5 ± 1) s.

5.3.6 The penetration of the cone to the nearest 0,1 mm shall be read off and recorded. Also the type of cone used shall be recorded.

NOTE Especially in cone tests on remoulded silty soils, a post sinking of the cone takes place due to the influence of dilatancy and water migration in the specimen. After a certain penetration, the cone momentarily stops, and then continues to sink until it gradually stops definitely.

If post sinking occurs, this should be observed and noted in the record.

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

5.3.8 A lighter or blunter cone shall be selected if the cone penetration is more than 20 mm. A heavier or sharper cone shall be selected if the penetration is less than 5 mm.

5.3.9 A new test point shall be prepared 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 tests shall be performed. If any value deviates more than 10 % from the average, an additional test shall be performed, and the most deviating value shall be excluded from the calculation of the average. If only one or two tests have been performed because of lack of undisturbed materials, this shall be noted and pointed out in the report.

5.3.11 For remoulded specimens the tests shall be repeated until two successive tests yield identical values of cone penetration.

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 common value from two successive tests.

6.2 Undrained shear strength

The undrained shear strength of the soil test specimen in its current state during the test is calculated with the following equation:

$$c_u \text{ (or } c_{ur}) = cg \frac{m}{i^2} \quad (1)$$

where

- c_u is the undrained shear strength of the undisturbed soil specimen in its tested state, in kPa;
- c_{ur} is the undrained shear strength of remoulded soil, in kPa;
- c is the constant, dependent on the state of the soil and the tip angle of the cone:
 - $c = 0,80$ for cones with 30° tip;
 - $c = 0,27$ for cones with 60° tip;
- g is the acceleration at free fall, in m/s^2 ;
- m is the mass of the cone, in g;
- i is the cone penetration, in mm.

Any estimation of the in-situ undrained shear strength from the results of the index test should be based on local experience of the particular type of soil, and sampling and testing technique.

$$c_u = cg \frac{m}{i^2}$$

but using $c = 1,0$ for undisturbed soil and cones with 30° tip angle.

The thus derived undisturbed undrained shear strength is normally in good agreement with the corresponding strength values obtained in field vane tests.

The calculation value of the undrained shear strength of undisturbed soil is normally corrected with respect to empirical experience in the same way as the field vane test by:

$$c_{u(\text{corr})} = c_u \times \mu$$

where

$c_{u(\text{corr})}$ is the corrected shear strength

$$\mu = \left(\frac{0,43}{w_L} \right)^{0,45} \text{ and } 1,2 \geq \mu \geq 0,5$$

w_L is the liquid limit of the soil determined by the fall cone method, expressed as fraction.

7 Test report

The test report shall contain the following information:

- a) identification of the sample (material) being tested;
- b) method of sampling ;
- c) mass and the tip angle of the cone used in the testing of undisturbed soil;
- d) cone penetration values obtained for undisturbed soil, and the calculation average penetration;
- e) calculated undrained shear strength of the undisturbed soil test specimen in kPa, to two significant d
- f) mass and the tip angle of the cone used in the testing of remoulded soil;
- g) value of penetration in remoulded soil which is common for two successive tests;
- h) calculated undrained shear strength for remoulded soil in kPa, to two significant digits.

Bibliography

- [1] DIN, ISSMGE (Eds.) (1998): Recommendations of the ISSMGE for geotechnical laboratory testing; (in English, German and French); Berlin, Wien, Zürich (Beuth Verlag).
- [2] ISO (1995), Guide to the expression of uncertainty in measurement; Geneva.
- [3] prEN ISO 22475-1, *Geotechnical investigation and testing - Sampling by drilling and excavation methods and groundwater measurements - Part 1: Technical principles for execution (ISO/DIS 22475-1:2004)*.

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