
**Geotechnical investigation and
testing — Laboratory testing of soil —
Part 4:
Determination of particle size
distribution**

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

*Partie 4: Détermination de la distribution granulométrique des
particules*



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Contents

	Page
Foreword	iv
Introduction	v
1 Scope	1
2 Normative references	1
3 Terms and definitions	1
4 Apparatus	2
4.1 General.....	2
4.2 Sieving method.....	3
4.3 Hydrometer method.....	4
4.4 Pipette method.....	4
4.5 Reagents.....	6
5 Test procedure	6
5.1 Selection of test method.....	6
5.2 Sieving method.....	7
5.2.1 General.....	7
5.2.2 Specimen preparation.....	9
5.2.3 Test execution.....	10
5.3 Hydrometer method.....	12
5.3.1 General.....	12
5.3.2 Specimen preparation.....	14
5.3.3 Test execution.....	15
5.4 Pipette method.....	15
5.4.1 General.....	15
5.4.2 Specimen preparation.....	16
5.4.3 Test execution.....	16
5.5 Combined tests.....	16
6 Test results	18
6.1 Sieving.....	18
6.1.1 Fraction passing each sieve.....	18
6.2 Hydrometer.....	18
6.2.1 Total dry mass.....	18
6.2.2 Fraction passing each sieve.....	19
6.2.3 True hydrometer reading.....	19
6.2.4 Effective depth.....	19
6.2.5 Equivalent particle diameter.....	19
6.2.6 Modified hydrometer reading.....	20
6.2.7 Fraction smaller than equivalent particle diameter.....	20
6.2.8 Correction for material larger than 2 mm.....	21
6.3 Pipette.....	21
6.3.1 Total dry mass.....	21
6.3.2 Fraction passing each sieve.....	21
6.3.3 Equivalent particle diameter.....	21
6.3.4 Fraction smaller than equivalent particle diameter.....	22
6.3.5 Correction for material larger than 2 mm.....	22
7 Test report	22
Annex A (normative) Calibration, maintenance and checks	24
Annex B (informative) Pre-treatment of samples	30
Bibliography	31

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.

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).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation on 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 17892-4 was prepared by the European Committee for Standardization (CEN) Technical Committee CEN/TC 341, *Geotechnical investigation and testing*, in collaboration with ISO Technical Committee TC 182, *Geotechnics*, in accordance with the agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This first edition cancels and replaces the first edition (ISO/TS 17892-4:2004), which has been technically revised.

It also incorporates the Technical Corrigendum ISO/TS 17892-4:2004/Cor 1:2006.

A full list of parts in the ISO 17892 series, published under the general title *Geotechnical investigation and testing — Laboratory testing of soil*, can be found on the ISO website.

Introduction

This part of ISO 17892 covers areas in the international field of geotechnical engineering never previously standardized. It is intended that this part of ISO 17892 presents broad good practice throughout the world and significant differences with national documents is not anticipated. It is based on international practice (see Reference [2]).

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Geotechnical investigation and testing — Laboratory testing of soil —

Part 4: Determination of particle size distribution

1 Scope

This part of ISO 17892 specifies a method of determining the particle size distribution of soils.

This part of ISO 17892 is applicable to the laboratory determination of the particle size distribution of a soil test specimen by sieving, or sedimentation, or a combination of both within the scope of geotechnical investigations.

The particle size distribution is one of the most important physical characteristics of soil. Classification of soils is mainly based on the particle size distribution. Many geotechnical and geohydrological properties of soil are related to the particle size distribution.

The particle size distribution provides a description of soil based on a subdivision in discrete classes of particle sizes. The size of each class can be determined by sieving and/or sedimentation. Coarse soils are usually tested by sieving, but fine and mixed soils are usually tested by a combination of sieving and sedimentation, depending on the composition of the soil.

The sieving method described is applicable to all non-cemented soils with particle sizes less than 125 mm. Two sedimentation methods are described: the hydrometer method and the pipette method.

NOTE This part of ISO 17892 fulfils the requirements of the particle size distribution testing in accordance with EN 1997-2.

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 3310-1, *Test sieves — Technical requirements and testing — Part 1: Test sieves of metal wire cloth*

ISO 3310-2, *Test sieves — Technical requirements and testing — Part 2: Test sieves of perforated metal plate*

ISO 4788, *Laboratory glassware — Graduated measuring cylinders*

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*

ISO 17892-3, *Geotechnical investigation and testing — Laboratory testing of soil — Part 3: Determination of particle density*

3 Terms and definitions

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

**3.1
sieving**

process of separating soil particles into size classes by the use of test sieves consisting of a wire mesh or slotted metal plate that permits particles smaller than the mesh size to pass through

**3.2
sedimentation**

process of separating soil particles into size classes by the gravitational settling of soil particles in a liquid, where different size classes settle at different rates

**3.3
particle size distribution**

proportions by mass of the various particle size classes present in a soil

**3.4
dispersion**

mechanical or chemical treatment of the soil to separate any aggregations into single particles

**3.5
coagulation**

process of aggregation of soil particles in suspension

**3.6
equivalent particle diameter**

particle diameter calculated from *sedimentation* (3.2) data using Stokes' law, assuming spherical particles

Note 1 to entry: Stokes' law establishes the relationship between the terminal velocity of a sphere falling through a column of fluid, the sphere's diameter, the density and dynamic viscosity of the fluid and the density of the sphere.

4 Apparatus

4.1 General

See [Annex A](#) for calibration, maintenance and checks on the following apparatus.

4.1.1 Balances

The balance for sieve test and hydrometer test shall have an accuracy of 0,01 g or 0,1 % of the weighed mass, whichever value is greater. The balance for pipette test shall have an accuracy of 0,001 g or 0,1 % of the weighed mass, whichever is greater.

4.1.2 Drying ovens

The drying oven should be of the forced-draught type and shall be capable of maintaining a uniform temperature throughout the drying chamber. Any air circulation shall not be so strong that any transport of particles can take place.

4.1.3 Timing devices

The watch or clock shall be readable to 1 s.

4.1.4 Temperature measuring devices

Temperature measuring devices, such as thermometers and thermocouples, shall cover the temperature range of that part of the test and be readable to 0,1 °C.

4.1.5 Desiccator

A desiccator, if used, shall be of suitable size and contain dry, self-indicating desiccant such as silica gel. It is not required if test specimen containers with close-fitting lids are used.

4.1.6 Test specimen containers

Test specimen containers shall be made of a material that does not change mass as a result of repeated drying cycles. Glass, porcelain and corrosion-resistant metals have been found to be suitable.

Containers shall have a capacity large enough to hold the mass of sample to be dried without spillage, but should not be so large that the mass of the empty container is significantly in excess of that of the specimen.

4.1.7 Sample separation following pre-treatment

If pre-treatment is required, a centrifuge or vacuum filter and ancillaries or other apparatus used shall be suitable for separating out the soil particles from the reagent without altering the particle size distribution.

4.2 Sieving method

4.2.1 Test sieves

Test sieves conforming to ISO 3310-1 and ISO 3310-2, together with appropriate receivers, shall be used.

The number of sieves used and their aperture sizes shall be sufficient to ensure that any discontinuities in the grading curve are detected.

The inclusion of sieves 63 mm, 20 mm, 6,3 mm, 2,0 mm, 0,63 mm, 0,20 mm and 0,063 mm is recommended as these represent the boundary sizes for coarse materials as defined in ISO 14688-1. These facilitate sample description and classification.

4.2.2 Mechanical sieve shaker (optional)

A mechanical sieve shaker, if used, shall hold a nest of sieves with their lid and receiver securely. The design of the shaker shall ensure that the test material on any given sieve progresses over the surface of the sieve when it is agitated.

4.2.3 Ancillary apparatus

The ancillary apparatus shall consist of the following:

- corrosion resistant trays;
- large corrosion resistant or plastic tray or bucket;
- scoop;
- sieve brushes;
- rubber tubing;
- laboratory glassware (e.g. beakers and flasks);
- riffle box (optional).

4.3 Hydrometer method

4.3.1 Hydrometer

The hydrometer shall be torpedo-shaped, made of glass, as free as possible from visible defects and preferably manufactured to a national standard. The hydrometer stem and bulb shall be circular in cross section and symmetrical around the main axis, without abrupt change in cross section.

The scale and inscription shall be marked clearly and permanently, showing no apparent irregularities in spacing as shown in [Figure A.1](#). The range of the hydrometer shall be at least between 0,995 0 g/ml and 1,030 0 g/ml with graduation lines at intervals of 0,000 5 g/ml or less. The markings may be directly in g/ml or may be the difference from 1,000 0 g/ml, expressed in mg/ml. The hydrometer shall be indelibly marked with a unique identification number.

NOTE Some hydrometers measure the specific gravity of the solution (i.e. the density of the solution relative to that of pure water) rather than the absolute density of the solution. Use of a hydrometer measuring specific gravity will introduce a small error in the measurements.

4.3.2 Sedimentation cylinders

Sedimentation cylinders marked at 1 000 ml shall have constant cross-sectional area throughout their length and be transparent to facilitate reading. The diameter shall be at least twice that of the hydrometer bulb and the length shall be sufficient to ensure that the hydrometer can float freely in 1 000 ml of pure water. Larger cylinders of the same specification may be used provided the quantities of the contents are scaled up equally to ensure that the concentration of the suspension is maintained.

4.3.3 Water bath (optional)

The temperature in the cylinders shall not vary by more than 3 °C during the test. Unless this is achieved within a temperature controlled room, a water bath fitted with a temperature controller shall be used. If using a water bath, the water level in the bath shall be maintained at least as high as the suspension in the sedimentation cylinder throughout the test.

NOTE Temperature control minimizes the formation of convection currents within the suspension which may affect the results.

4.3.4 Mechanical shaker or mixer

The mechanical shaker or mixer shall be capable of keeping the appropriate quantities of soil and water in continuous suspension, but not so vigorously that soil particles are fractured or lost.

4.4 Pipette method

4.4.1 Pipette

The pipette shall have a nominal volume of 2 % of the volume of the soil suspension and shall be mounted in a pipette configuration ([Figure 1](#)).

4.4.2 Sedimentation cylinders

Sedimentation cylinders (marked at specified volume) shall be of constant cross-sectional area throughout their length and transparent to facilitate reading. Cylinders should have a minimum volume of 500 ml.

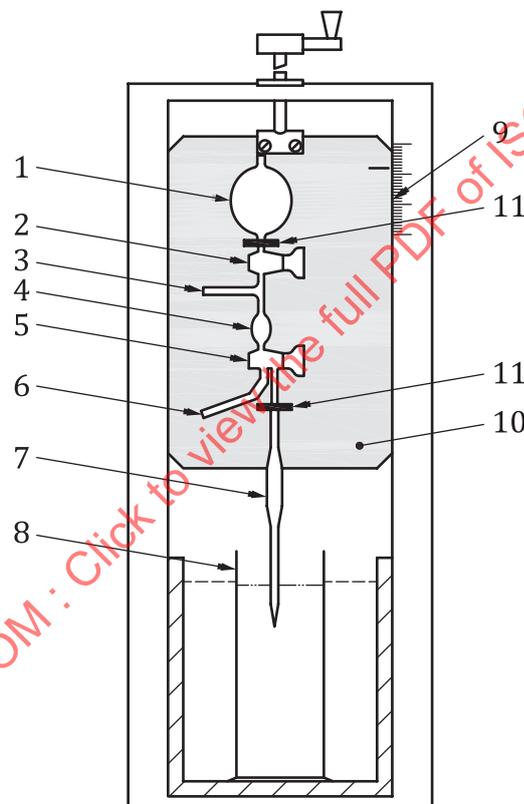
4.4.3 Pipette specimen containers

Containers, e.g. glass bottles with ground glass stoppers or evaporating dishes, shall be suitable for the drying of aliquots removed from the sedimentation suspension by the pipette. Glass bottles about 25 mm in diameter and about 50 mm tall have been found to be suitable for a 10 ml sampling pipette.

4.4.4 Water bath (optional)

The temperature in the cylinders shall not vary by more than 3 °C during the test. Unless this is achieved within a temperature controlled room, a water bath fitted with a temperature controller shall be used. If using a water bath, the water level in the bath shall be maintained at least as high as the suspension in the sedimentation cylinder throughout the test.

NOTE Temperature control minimizes the formation of convection currents within the suspension which may affect the results.



Key

- | | | | |
|---|---------------------------|----|------------------------|
| 1 | rubber suction bulb | 7 | sampling pipette |
| 2 | tap | 8 | sedimentation cylinder |
| 3 | safety bulb suction inlet | 9 | graduated scale |
| 4 | safety bulb | 10 | sliding panel |
| 5 | three-way tap | 11 | clamps |
| 6 | outlet tube | | |

Figure 1 — Example of pipette configuration

4.4.5 Mechanical shaker or mixer

The mechanical shaker or mixer shall be capable of keeping the appropriate quantities of soil and water in continuous suspension, but not so vigorously that soil particles are fractured or lost.

4.4.6 Centrifuge (optional)

The centrifuge or vacuum filter and ancillaries or any other apparatus shall be suitable for separating out the soil particles following pre-treatment for the removal of salts, organic and/or calcareous matter.

4.5 Reagents

4.5.1 General

Other than water, the following reagents shall be of recognized analytical reagent quality.

4.5.2 Water

The water shall be distilled, de-ionized or demineralized. Where distilled is referred to in this part of ISO 17892, the terms are interchangeable.

4.5.3 Dispersing agent

Where a dispersing agent is required by the test procedure, options include but are not limited to the following:

- sieving: hexa-sodium hexametaphosphate or tetra-sodium diphosphate, approximately 2 g/l dissolved in water;
- sedimentation: hexa-sodium hexametaphosphate, approximately 40 g/l, or tetra-sodium diphosphate, approximately 20 g/l, dissolved in water.

Dispersing agent solutions shall not be used more than 1 month after their preparation.

NOTE Different dispersing agents, and different concentrations of the agents, can cause differences in the effectiveness of dispersion, as can differences in the pH of the solution. There is no single universally agreed optimal dispersing agent for all soils.

4.5.4 Hydrogen peroxide (optional)

Hydrogen peroxide (20 % V/V) may be used to remove organic material. See [Annex B](#).

4.5.5 Hydrochloric acid (optional)

Hydrochloric acid (0,2 M ± 0,02 M) may be used to remove carbonate. See [Annex B](#).

5 Test procedure

5.1 Selection of test method

The test method or combination of methods should be specified prior to testing or be selected on the following basis.

- If a sample has less than about 10 % of particles smaller than 0,063 mm, sedimentation test is not normally required.
- If all of the sample is smaller than 2 mm and has less than about 10 % of particles larger than 0,063 mm, a full sieve test is not normally required.
- For all other samples, a combination of sieve test and sedimentation should be performed in order to determine the full particle size distribution.

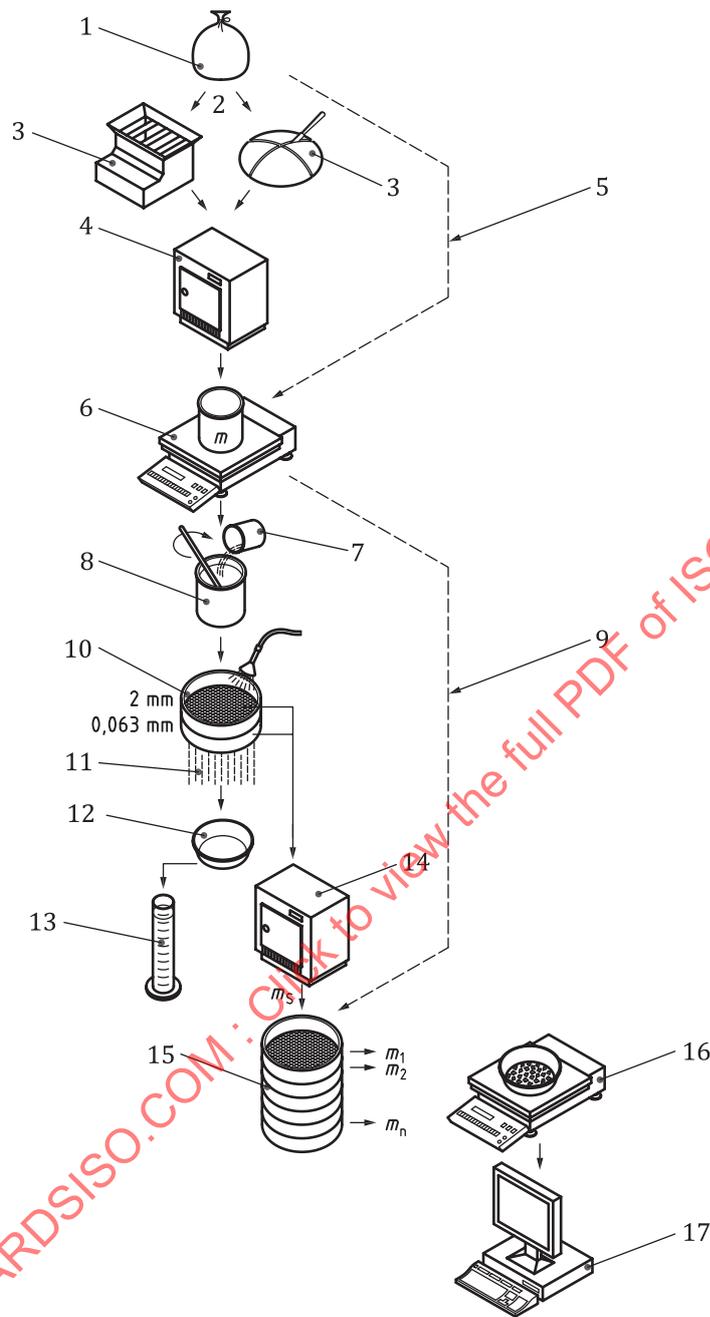
5.2 Sieving method

5.2.1 General

5.2.1.1 The general procedure for sieving is outlined schematically in [Figure 2](#). Either a moist or a dry sample may be tested.

5.2.1.2 Although the starting sample may be moist, and although washing a sample through a sieve may be used during sample preparation as described below, the sieve test to determine the masses of material retained on each sieve is always performed on a dried specimen.

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Key

- | | | |
|--------------------------|--|------------------------------------|
| 1 sample | 7 dispersing agent | 13 sedimentation test (optional) |
| 2 dry sample method | 8 soaking and stirring | 14 drying retained material |
| 3 riffling or quartering | 9 dry separation (alternative method) | 15 sieving |
| 4 drying | 10 separating and washing | 16 weighing material on each sieve |
| 5 moist sample method | 11 washings | 17 test results calculations |
| 6 weighing | 12 collect material <0,063 mm (optional) | |

Figure 2 — General sieving procedure

5.2.2 Specimen preparation

5.2.2.1 Wet preparation is preferred for soils with particles smaller than 0,063 mm, as use of the dry preparation method may introduce significant errors.

5.2.2.2 Prepare a representative test specimen by riffing or quartering the sample. The required initial wet mass of the test specimen is dependent upon the maximum particle diameter (D_{\max}) present and the soil water content. The dry mass of test specimens should be as given in [Table 1](#) or as defined in [5.2.2.3](#) for other values of D_{\max} .

Table 1 — Recommended minimum masses for sieving

Particle diameter D_{\max}^a mm	Recommended minimum masses ^b g
<2,0	100
2,0	100
6,3	300
10	500
20	2 000
37,5	14 000
63	40 000

^a Maximum diameter of soil particles, excluding any discrete coarser particles present.

^b Using a test specimen smaller than the recommended minimum mass indicated requires discretion, although it may be adequate for the purpose of the test.

5.2.2.3 For values of D_{\max} smaller than 20 mm, the minimum mass should be estimated by interpolation of the values in [Table 1](#). For values of D_{\max} greater than 20 mm, the recommended minimum mass (m_{\min} , kg) should be evaluated from [Formula \(1\)](#):

$$m_{\min} = \left[\frac{D_{\max}}{10} \right]^2 \quad (1)$$

NOTE The particle sizes above are based on the boundaries between and within sand, gravel and cobbles as defined in ISO 14688-1.

5.2.2.4 Soils may be pre-treated prior to sieving to remove dissolved salts, organic and/or calcareous matter if required. The method shall be stated on the test report, together with the amount of material removed. A suggested method for pre-treatment for organic or carbonate material is included in [Annex B](#).

5.2.2.5 If a dry sample is used, determine the mass of the specimen (m) to the nearest 0,1 g or 0,1 % of the mass, whichever is greater.

5.2.2.6 If a moist sample is used, determine the wet mass of the sample (m_w) to the nearest 0,1 g or 0,1 % of the mass, whichever is greater, and its water content by drying a separate specimen of the whole sample in accordance with ISO 17892-1.

5.2.2.7 For specimens with coarse gravel or boulders, an initial separation on a suitable sieve may be necessary to avoid overloading smaller subsequent sieves. A 20 mm sieve is recommended for this initial separation as this is the boundary between medium and coarse gravel, but other sieves may be used.

5.2.2.8 If the sample has been reduced in [5.2.2.7](#), a water content determination shall be carried out, in accordance with ISO 17892-1, on a representative specimen of the material passing the separation sieve.

5.2.2.9 Clean the material retained on the separation sieve by washing or lightly brushing to remove any adhering fine material. The retained material shall be dried and weighed (m_r) to 0,1 g or 0,1 % of the total mass (m), whichever is greater.

5.2.2.10 Add any material removed by cleaning in [5.2.2.9](#) and which is smaller than the separation sieve size used in [5.2.2.7](#) to the original material passing the separation sieve in [5.2.2.7](#) and mix. Determine the resulting mass of material (m_s) to 0,1 g or 0,1 % of the total mass (m), whichever is greater.

5.2.2.11 The mass of material at [5.2.2.10](#) may be reduced by riffing or other means, providing the resulting smaller specimen meets the minimum masses given in [Table 1](#).

5.2.2.12 Place the material finer than the separation sieve in a tray or bucket and cover with water. Allow it to stand for a minimum of 1 h and stir frequently. It may be necessary to add dispersing agent to the water in order to disperse interstitial clay.

5.2.2.13 Wash the specimen through a 2 mm sieve nested in a 0,063 mm sieve until the water runs virtually clear. In mixed soils, it may be beneficial to only sieve the suspended material first, washing until the water passing through the 0,063 mm sieve starts to run clear and only then adding the settled coarser material. Ensure that neither sieve becomes overloaded. Material passing the 0,063 mm sieve does not need to be retained.

5.2.2.14 Combine the material retained on the 2 mm and 0,063 mm sieves and oven-dry it to constant mass, and then weigh to the nearest 0,1 g or 0,1 % of the total dry mass of the specimen (m_s), whichever is greater.

5.2.3 Test execution

5.2.3.1 At any point in the sieve test, the sample quantity may be further reduced by riffing, or similar, in order to avoid excessive overloading of smaller mesh-size sieves.

5.2.3.2 If a separation sieve has been used, sieve the dried material at [5.2.2.9](#) through a series of test sieves of increasingly smaller mesh size down to the separation sieve size, weighing the soil retained on each test sieve ($m_{ss1}, m_{ss2}, \dots, m_{ssn}$). The masses retained on each sieve shall not exceed the values listed in [Table 2](#).

5.2.3.3 Sieve the dried material at [5.2.2.14](#) through a series of sieves of increasingly smaller mesh size to 0,063 mm, weighing the soil retained on each test sieve ($m_{s1}, m_{s2}, \dots, m_{sn}$) and weighing any material passing the 0,063 mm sieve (m_p). The masses retained on each sieve shall not exceed the values listed in [Table 2](#).

Table 2 — Maximum mass of soil retained on each sieve

Nominal sieve aperture size	Maximum mass of soil on sieve of diameter		
	450 mm	300 mm	200 mm
mm	kg	kg	g
0,063			40
0,20			70
0,63			125
2,0			220
6,3	2,0	0,8	
10,0	2,5	1,1	
20,0	3,5	1,5	
37,5	4,8	2,1	
63,0	6,3	2,8	

The maximum mass on sieve sizes not included above should be derived from [Formula \(2\)](#):

$$M = \frac{A \times \sqrt{d}}{200} \quad (2)$$

where

M is the maximum mass of soil retained on sieve (g);

A is the cross-sectional area of the sieve (mm²);

d is the aperture size of the sieve (mm).

5.2.3.4 The effectiveness of mechanical sieving is influenced by the soil type, the sieving time, the loading on the sieve and the parameters of the shaking movement, such as amplitude and frequency. In most soils, if a mechanical sieve shaker is used, the specimen should be shaken for at least 10 min. If hand sieving is used, each sieve should be shaken for at least 2 min.

5.2.3.5 Sieving shall be considered complete when additional sieving for 1 min does not lead to a change of mass of the retained material on any sieve by more than 1 % by mass.

5.2.3.6 If the maximum permitted mass is exceeded on any sieve, the soil on that sieve shall be split into two or more smaller portions which are then sieved separately. The total mass on each sieve is calculated from the sum of masses retained from each portion.

5.2.3.7 For each test, the total mass retained on all the sieves, and the fraction passing the 0,063 mm sieve shall be totalled. If the specimen mass has been reduced by riffing, the masses after the riffle stage shall be scaled up by the ratio of masses before and after riffing.

5.2.3.8 If the total in [5.2.3.7](#) differs from the mass (m) at the start of sieving by more than 1 %, the test shall be repeated.

5.3 Hydrometer method

5.3.1 General

5.3.1.1 The general procedure is outlined schematically in [Figure 3](#).

5.3.1.2 The test requires the fraction of each sample passing 0,063 mm to be tested. No material greater than 2 mm shall be taken into the sedimentation cylinder for the test.

NOTE Sand-sized particles will settle rapidly during the early stages of sedimentation and the presence of small quantities of sand is not thought to adversely affect the sedimentation process.

5.3.1.3 For tests carried out in a temperature-conditioned room, a calibrated temperature measuring device shall be placed permanently in the room to record the maximum and minimum temperatures in the proximity of the test.

5.3.1.4 If a water bath is used, care shall be taken that its circulation system does not introduce vibrations in the specimen suspension.

5.3.1.5 All readings of the hydrometer should be recorded as the decimal part of the reading, multiplied by 1 000, e.g. 1,030 0 becomes 30,0. This convention should be applied to all test readings, calculations and calibrations.

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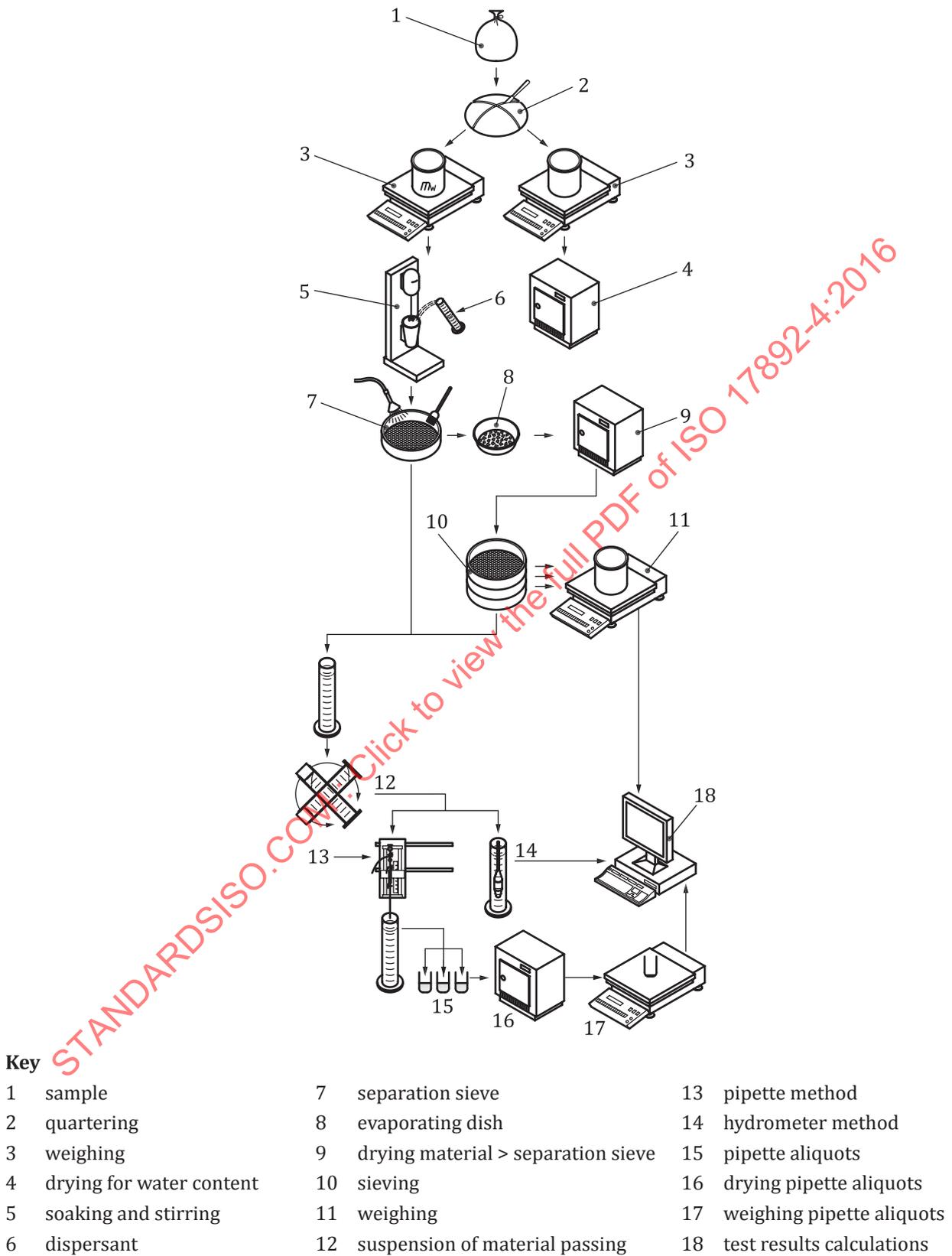


Figure 3 — General sedimentation procedure

5.3.2 Specimen preparation

5.3.2.1 The required initial wet mass of the soil specimen is dependent upon the particle size distribution present and the water content. The initial soil specimen, prior to preparation, should be large enough to give 20 g to 30 g of material smaller than 0,063 mm.

NOTE A suspension concentration of around 25 g of sediment smaller than 0,063 mm per litre of solution is regarded as ideal. Significantly higher suspension concentrations cause disturbance to the sedimentation process and significantly lower suspension concentrations reduce the precision of the results.

5.3.2.2 Determine the water content of the soil on a separate specimen according to ISO 17892-1.

5.3.2.3 Determine the particle density, if required, on a separate specimen according to ISO 17892-3.

5.3.2.4 Pre-treatment is recommended if organic material and/or carbonate compounds are present in significant quantities, unless geotechnical classification of carbonate soil is required. Suggested methods are given in [Annex B](#).

5.3.2.5 Weigh the soil specimen (m_w) to 0,1 g or 0,1 % of its mass, whichever is greater. If the soil specimen contains particles larger than 2 mm, these should then be removed.

5.3.2.6 Place the soil specimen in a suitable container, e.g. a flask. Add dispersing agent, equivalent to 10 % of the final volume of suspension if using the suggested solutions in [4.5.3](#), to the soil specimen. If the dispersing agent concentration differs from [4.5.3](#), alternative volumes may be required.

5.3.2.7 Agitate the suspension using a mechanical shaker or stirrer for a period long enough to achieve full dispersion of the soil particles. For gentle mixing, such as end-over-end shaking, a period of 4 h is appropriate. A shorter time period may be sufficient for more vigorous mixing methods, although care should be taken to avoid the fracture of discrete soil particles.

5.3.2.8 When only the fine fraction of soil is to be tested, transfer the prepared soil suspension to a 0,063 mm sieve placed over a suitable clean container. Wash the fine particles through the sieve using a stream of distilled water. The amount of water used should not exceed 80 % of the final volume of suspension.

5.3.2.9 If the total volume of the suspension passing the sieve inadvertently exceeds the final volume of suspension, the excess water shall be removed by evaporation.

5.3.2.10 Transfer the suspension passing the sieve to the sedimentation cylinder and make up to the specified test graduation mark with distilled water.

5.3.2.11 Transfer the material retained on the sieve to a suitable container and dry in an oven. After cooling, weigh it to 0,1 % or 0,01 g of its mass (m_s), whichever is greater.

5.3.2.12 If a separate sieve test has been performed on a larger sample, the material at [5.3.2.11](#) may be discarded. If not, sieve the material retained at [5.3.2.11](#) as described in [5.2.3](#). Any material passing the 0,063 mm sieve shall be added to the sedimentation cylinder.

5.3.2.13 If the sedimentation test is performed at a different temperature to that at which it was prepared, sufficient time shall be allowed for the temperature in the cylinder to equalize with the test temperature.

5.3.2.14 Prepare a sedimentation cylinder with a reference solution consisting of the same volume of dispersing agent solution as the test and made up to the specified graduation mark with distilled water. This reference cylinder shall be treated identically to the cylinder containing the soil suspension.

5.3.2.15 The solution in the reference cylinder may be tested at the same time as the samples, or may be performed earlier, in which case, it shall be tested every time a new batch of reagent solution is prepared and a temperature correction factor shall be applied.

5.3.3 Test execution

5.3.3.1 Place the hydrometer in the reference solution ensuring it floats freely. Take the hydrometer reading (R'_0) at the upper rim of the meniscus to the nearest 0,000 5 g/ml (nearest 0,5 reading; see [5.3.1.5](#)). Remove the hydrometer and rinse it with distilled water.

5.3.3.2 Agitate the soil suspension vigorously until full suspension is obtained, e.g. by turning the sedimentation cylinder end-over-end about 60 times in 2 min.

5.3.3.3 Start the timer at the instant the agitation is complete.

5.3.3.4 Promptly place the cylinder in its test position without further agitation of the suspension.

5.3.3.5 Place the hydrometer in the suspension without delay, ensuring it floats freely.

5.3.3.6 Take hydrometer readings (R'_h) at the upper rim of the meniscus after short periods of time. Take at least three readings during the first 5 min. Readings at 0,5 min, 1 min and 2 min are often found to be suitable. Record readings to the nearest 0,000 5 g/ml (nearest 0,5 reading; see [5.3.1.5](#)).

5.3.3.7 After these initial readings, remove the hydrometer slowly and rinse it with distilled water.

5.3.3.8 At least three additional readings are required. Readings at approximately 4 min, 8 min, 30 min and 1 h, 2 h, 6 h and 24 h are often found to be suitable provided that the actual time is noted. Insert the hydrometer slowly into the soil suspension about 15 s before a reading is due. Read the hydrometer to the nearest 0,000 5 g/ml (nearest 0,5 reading; see [5.3.1.5](#)).

5.3.3.9 The test may be stopped when the proportion finer than 0,002 mm has been determined.

5.3.3.10 Record the temperature of the suspension once in the first 15 min, and then after every hydrometer reading, to the nearest 0,1 °C.

5.4 Pipette method

5.4.1 General

5.4.1.1 The general procedure is outlined schematically in [Figure 3](#).

5.4.1.2 The test requires the fraction of each sample passing 0,063 mm to be tested. No material greater than 2 mm shall be taken into the sedimentation cylinder for the test.

NOTE Sand-sized particles will settle rapidly during the early stages of sedimentation and the presence of small quantities of sand is not thought to adversely affect the sedimentation process.

5.4.2 Specimen preparation

The soil specimen shall be prepared as described for the hydrometer method (see [5.3.2](#)).

5.4.3 Test execution

5.4.3.1 Dry sufficient containers described in [4.4.3](#) at 105 °C to 110 °C and determine the mass of each to the nearest 0,001 g ($m_{1,i}$).

5.4.3.2 Agitate the soil suspension vigorously until full suspension is obtained, e.g. by turning the sedimentation cylinder end-over-end about 60 times in 2 min.

5.4.3.3 Start the timer at the instant the agitation is complete.

5.4.3.4 Promptly place the cylinder in its test position without further agitation of the suspension.

5.4.3.5 The sampling times can be derived by introducing known parameters into [Formula \(12\)](#) so that at least three readings are taken corresponding to particle sizes between 0,063 mm and 0,002 mm. Particle sizes of 0,02 mm, 0,006 3 mm and 0,002 mm are recommended as a minimum, as these provide data for silt and clay fractions consistent with ISO 14688-1. At least one sampling time should be designed to produce a particle size of 0,002 mm or less to allow interpretation of the clay fraction.

5.4.3.6 The depth of insertion of the pipette (H_p) may be varied but it is usually practical to maintain a single depth (100 mm has been found to be satisfactory in a 500 ml suspension).

5.4.3.7 At each chosen time point, insert the pipette into the suspension to the required depth. Fill and then remove the pipette slowly and carefully in order to avoid stirring the suspension in the sedimentation cylinder. The total process at each time point should take about 30 s and should start about 15 s before the chosen time point. Insertion, filling and removal should each take about 10 s.

5.4.3.8 Empty the pipette into one of the containers. Rinse the pipette internally with water and add the washings to the same container.

5.4.3.9 Record the temperature to the nearest 0,1 °C immediately before or after taking the pipette specimen.

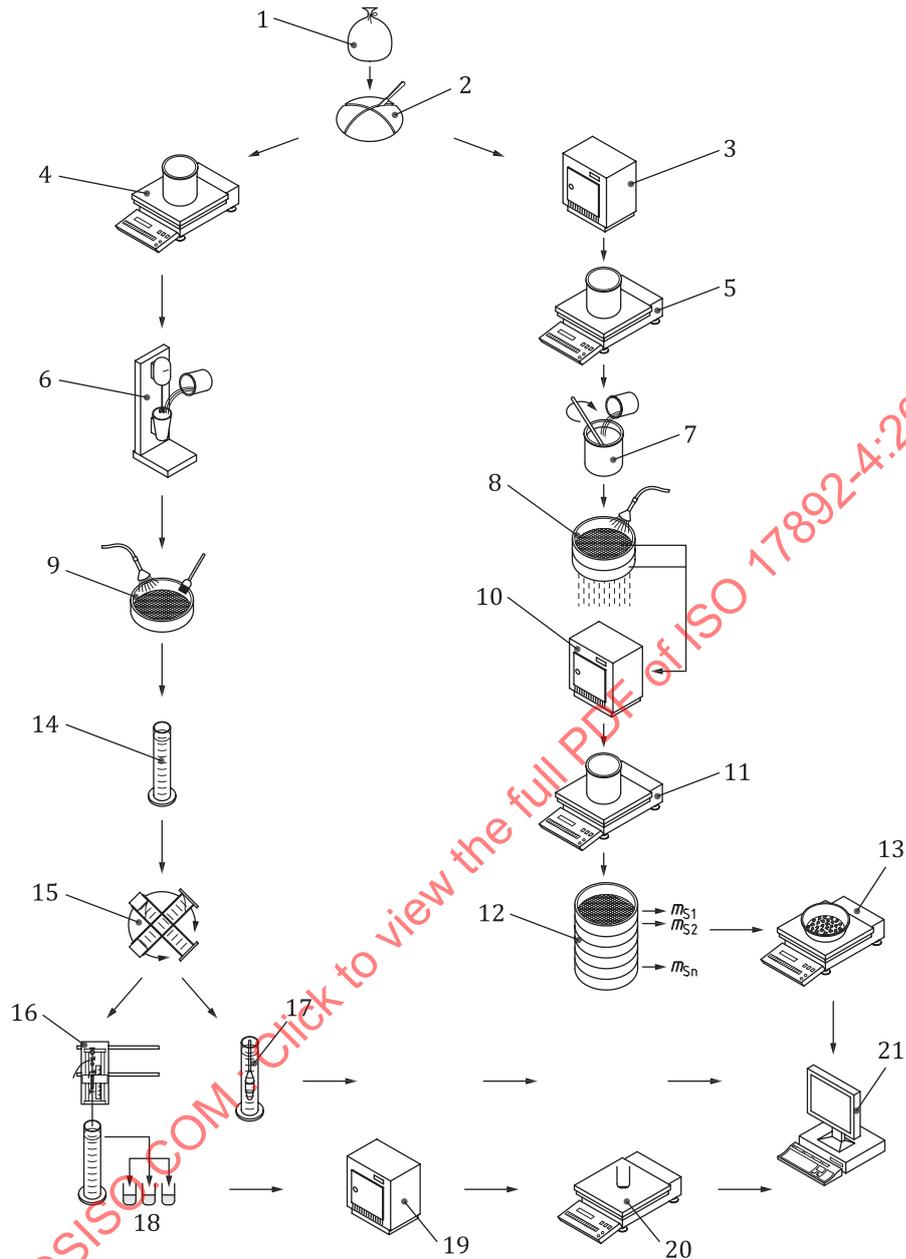
5.4.3.10 Dry the pipette contents and washings in a drying oven until a constant mass is obtained and determine the dry mass ($m_{2,i}$) to the nearest 0,001 g.

5.4.3.11 Take a sample by the pipette from the reference solution and put this into a container. Rinse the pipette with water and add the washings to the container. Dry the pipette contents and washings in an oven until a constant mass is obtained and the dry mass (m_b) shall be determined to the nearest 0,001 g. This reference specimen is only required once for each prepared batch of dispersant.

5.5 Combined tests

5.5.1 The general procedure for a combined sieve and sedimentation test is outlined schematically in [Figure 4](#).

5.5.2 A sieve test and a sedimentation test are required on separate specimens from the same sample. The procedure for each separate test shall be followed except that duplicate sieve analyses on the sedimentation specimen are not required.



Key

- | | | | |
|----|---------------------------------|----|---------------------------------|
| 1 | sample | 12 | sieving |
| 2 | quartering | 13 | weighing material on each sieve |
| 3 | drying | 14 | sedimentation (either method) |
| 4 | weighing sedimentation specimen | 15 | sedimentation mixing |
| 5 | weighing sieve specimen | 16 | pipette method |
| 6 | stirring and dispersing | 17 | hydrometer method |
| 7 | soaking and dispersing | 18 | pipette aliquots |
| 8 | separating and washing | 19 | drying pipette aliquots |
| 9 | separating and washing | 20 | weighing pipette aliquots |
| 10 | drying | 21 | test results calculations |
| 11 | weighing | | |

Figure 4 — General combined procedure

6 Test results

6.1 Sieving

6.1.1 Fraction passing each sieve

6.1.1.1 If the specimen mass has been reduced by riffing, scale up the masses after the riffle stage (m_{sn}) by the ratio of masses before and after riffing to obtain the adjusted retained masses (m'_{sn}).

6.1.1.2 For specimens where an initial separation sieve has been used, calculate the fraction of the soil passing a given sieve size, n , above the separation sieve from [Formula \(3\)](#) for sieve sizes greater than or equal to the separation sieve size:

$$f_n = 100\% - \left[\frac{m'_{ss1} + m'_{ss2} + \dots + m'_{ssn}}{m} \times 100\% \right] \quad (3)$$

6.1.1.3 For sieve sizes smaller than the separation sieve or for specimens which did not have an initial separation stage, the fraction of the soil passing a given sieve size, n , shall be calculated from [Formula \(4\)](#):

$$f_n = 100\% - \left[\frac{m'_{ss1} + m'_{ss2} + \dots + m'_{ssn} + m'_{s1} + m'_{s2} + \dots + m'_{sn}}{m} \times 100\% \right] \quad (4)$$

where

- f_n is the fraction passing the given sieve size, n (%);
- m'_{ss1}, m'_{ss2} are the masses of soil retained on each sieve for sieves sizes greater than the separation sieve (if used) after scaling for each riffle stage (g);
- m'_{ssn} is the mass of soil retained on sieve size, n , for sieve sizes greater than or equal to the separation sieve size (if used) after scaling for each riffle stage (g);
- m'_{s1}, m'_{s2} are the masses of soil retained on each sieve larger than sieve size, n , for sieve sizes smaller than the separation sieve after scaling for each riffle stage (g);
- m'_{sn} is the mass of soil retained on sieve size, n , for sieve sizes smaller than the separation sieve size after scaling for each riffle stage (g);
- m is the total dry mass of the initial soil specimen (g).

6.2 Hydrometer

6.2.1 Total dry mass

Calculate the total dry mass of the specimen from [Formula \(5\)](#):

$$m = m_w \times \frac{100}{100 + w} \quad (5)$$

where

- m is the total dry mass (g);
- m_w is the wet mass of soil (g);
- w is the water content (%).

If the soil was pre-treated, the dry mass after pre-treatment replaces m in [Formula \(5\)](#).

6.2.2 Fraction passing each sieve

The fraction passing each sieve shall be calculated according to [6.1.1](#).

6.2.3 True hydrometer reading

Correct the hydrometer reading for the meniscus effect from [Formula \(6\)](#):

$$R_h = R'_h + C_m \quad (6)$$

where

- R_h is the true hydrometer reading;
- R'_h is the observed hydrometer reading;
- C_m is the meniscus correction (see [Annex A](#)).

6.2.4 Effective depth

Calculate the effective depth, H_r , from the true hydrometer reading using the hydrometer scale calibration (see [Annex A](#)).

6.2.5 Equivalent particle diameter

Calculate the equivalent particle diameter corresponding to reading, R_h , using Stokes' law from [Formula \(7\)](#):

$$d_i = 0,005\,531 \sqrt{\frac{\eta \times H_r}{(\rho_s - \rho_w) \times t}} \quad (7)$$

where

- d_i is the equivalent particle diameter (mm);
- η is the dynamic viscosity of water mPa·s at the temperature of the test (see [Table 3](#));
- H_r is the effective depth of hydrometer (mm);
- ρ_s is the particle density (Mg/m³);
- ρ_w is the density of the sedimentation fluid at the temperature of the test (Mg/m³);
- t is the time elapsed from the start of sedimentation (min).

The density of pure water can be assumed to be 1,00 Mg/m³ since the variation with temperature is negligible within the likely test range and reporting accuracy required.

Table 3 — Dynamic viscosity of water

Temperature °C	Viscosity, η mPa·s
10	1,304
15	1,137
20	1,002
25	0,891
30	0,798

NOTE 1 Intermediate values can be estimated by interpolation. Alternatively, the dynamic viscosity may be calculated using the approximation:
 $\eta = 0,02414 \times 10^{(247,8 / (T+133))}$
 where T = test temperature, °C, in the above range.

NOTE 2 It is assumed that the viscosity of the dispersing agent solution is the same as that of water.

6.2.6 Modified hydrometer reading

Correct the hydrometer reading for the reference solution from [Formula \(8\)](#):

$$R_d = R_h - R_0 \quad (8)$$

where

R_d is the modified hydrometer reading;

R_h is the true hydrometer reading;

R_0 is the observed hydrometer reading in reference solution R'_0 corrected for meniscus.

R_h and R_0 should consist only of the decimal part of the reading, multiplied by 1 000, e.g. 1,030 0 becomes 30,0.

6.2.7 Fraction smaller than equivalent particle diameter

Calculate the fraction smaller than the corresponding equivalent particle diameter from [Formula \(9\)](#):

$$K = \frac{100 \times \rho_s}{m(\rho_s - 1)} R_d \quad (9)$$

where

K is the fraction smaller than equivalent particle diameter (%);

ρ_s is the particle density of the soil (Mg/m³);

m is the dry mass of specimen (g);

R_d is the modified hydrometer reading.

6.2.8 Correction for material larger than 2 mm

If the original sample contained material larger than 2 mm which was not included in the test, adjust the value of K calculated at [6.2.7](#) for the amount of material larger than 2 mm following [Formula \(10\)](#):

$$K_c = \frac{K \times f_{2,00}}{100} \quad (10)$$

where

$f_{2,00}$ is the fraction passing the 2 mm sieve (%) from the sieve test.

NOTE This adjustment allows the combined sieving and sedimentation to be reported as a single particle size distribution.

6.3 Pipette

6.3.1 Total dry mass

Calculate the total dry mass of the specimen using [Formula \(11\)](#):

$$m = m_w \times \frac{100}{100 + w} \quad (11)$$

where

m is the total dry mass (g);

m_w is the wet mass of soil (g);

w is the water content (%).

If the soil was pre-treated, the dry mass after pre-treatment replaces m in [Formula \(11\)](#).

6.3.2 Fraction passing each sieve

The fraction passing each sieve shall be calculated according to [6.1.1](#).

6.3.3 Equivalent particle diameter

Calculate the equivalent particle diameter corresponding to each sampling point using Stokes' law from [Formula \(12\)](#):

$$d_i = 0,005\,531 \sqrt{\frac{\eta \times H_p}{(\rho_s - \rho_w) \times t}} \quad (12)$$

where

d_i is the equivalent particle diameter (mm);

η is the dynamic viscosity of water (mPa·s) (see [5.4.3.5](#) and [Table 3](#));

H_p is the depth of insertion of the pipette (mm);

- ρ_s is the mean particle density (Mg/m³) whether assumed or measured;
- ρ_w is the density of the sedimentation fluid at the temperature of the test (Mg/m³);
- t is the time elapsed from the start of sedimentation (min).

The density of pure water can be assumed to be 1,00 Mg/m³ since the variation with temperature is negligible within the likely test range and reporting accuracy required.

6.3.4 Fraction smaller than equivalent particle diameter

Calculate the fraction smaller than the equivalent particle diameter determined above for each test specimen using [Formula \(13\)](#):

$$K = \frac{(m_{2,i} - m_{1,i} - m_b) \times V_1}{V_2 \times m} \times 100\% \quad (13)$$

where

- K is the mass percentage of fraction smaller than the equivalent particle diameter (%);
- $m_{1,i}$ is the mass of the empty container (g);
- $m_{2,i}$ is the mass of container with dried fraction (g);
- m_b is the mass of oven-dried remains of reference solution (g);
- V_1 is the volume of the suspension in the sedimentation cylinder (ml);
- V_2 is the calibrated volume of the pipette (ml).

6.3.5 Correction for material larger than 2 mm

If the original sample contained material larger than 2 mm which was not included in the test, adjust the above percentage for the amount of material larger than 2 mm using [Formula \(14\)](#):

$$K_c = \frac{K \times f_{2,00}}{100} \quad (14)$$

where

$f_{2,00}$ is the fraction passing the 2 mm sieve (%) from the sieve test.

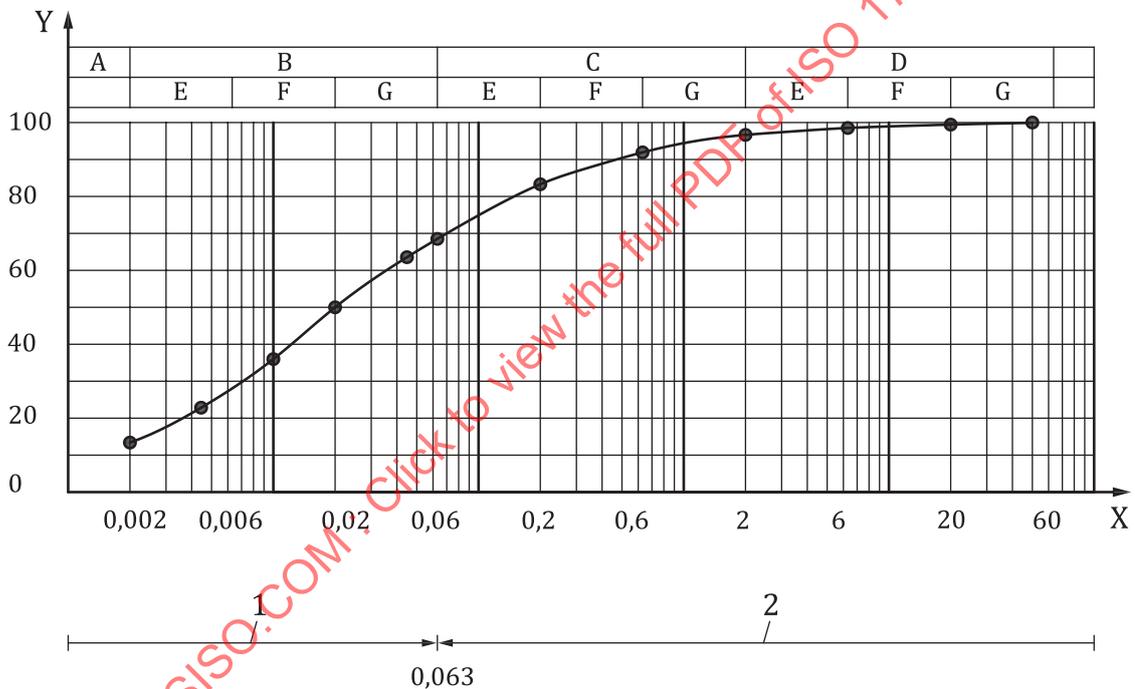
NOTE This adjustment allows the combined sieving and sedimentation to be reported as a single particle size distribution.

7 Test report

The test report shall affirm that the test was carried out in accordance with this part of ISO 17892 and shall include the following information:

- a) the method(s) of test used;
- b) a visual description of the specimen including any observed features noted after testing, following the principles in ISO 14688-1;
- c) an identification of the sample being tested, e.g. by boring number, sample number, test number, etc.;

- d) the test results, presented on a semi-logarithmic plot (see [Figure 5](#)). When results have been obtained by sieving and sedimentation, these should be combined in one graph to give a smooth continuous curve. Additionally, test results may be tabulated as particle size and percentage passing rounded to the nearest 1 %;
- e) the value for the density of solid particles, used in the calculations and whether this value was determined or assumed;
- f) the method of pre-treatment, when applied;
- g) any deviation from the specified procedure and particulars that could be important for interpreting the test results;
- h) if the amount of soil is not sufficient to comply with the recommended minimum mass, this fact shall be reported;
- i) if the size of the fractions is not expressed as percentage of total dry mass, this shall be stated, together with the nature and amount of fractions excluded.



Key

- | | |
|-----------------|-----------------------|
| 1 sedimentation | E fine |
| 2 sieving | F medium |
| A clay | G coarse |
| B silt | X particle size (mm) |
| C sand | Y percent passing (%) |
| D gravel | |

Figure 5 — Example of a particle size distribution result

Annex A (normative)

Calibration, maintenance and checks

A.1 General requirements

All measurement equipment used in this part of ISO 17892 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 specifies 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 shall only be 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 the sieve test.

The temperature of the suspension during sedimentation tests shall not vary by more than 3 °C during the test. This can be achieved either by controlling the temperature of the enclosure or room or water bath if used.

The sedimentation cylinders shall be free from vibrations and mechanical disturbance. Free from vibrations means no ripples can be seen on the surface of a suspension.

The apparatus shall be protected against sunlight, local sources of heat and draughts.

A.3 Apparatus

A.3.1 Ovens

The set temperature close to the centre of the usable oven space of an empty oven shall be checked by means of a calibrated temperature measuring device at least once a year.