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Geotechnical investigation and testing — Laboratory testing of soil —

Part 4:
Determination of particle size distribution

Reconnaissance et essais géotechniques — Essais de sol au laboratoire —

Partie 4: Détermination de la granulométrie

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ISO/TS 17892-4:2004(E)

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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*

- *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 17892-4:2004) 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”.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to announce this Technical Specification: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

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- *Part 11: Determination of permeability by constant and falling head*
- *Part 12: Determination of the 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]).

1 Scope

This document describes methods for the determination of the particle size distribution of soil samples.

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. For soils with less than 10 % fines, the sieving method is applicable. Soils with more than 10 % fines can be analysed by a combination of sieving and sedimentation.

Sieving is the process whereby the soil is separated in particle size classes by the use of test sieves. Sedimentation is the process of the setting of soil particles in a liquid. The difference in settling rate enables the particle size classes to be separated. Two sedimentation methods are described; the hydrometer method and the pipette method.

The methods described are applicable to all non-cemented soils with particle sizes less than 125 mm.

Depending on the purpose for the determination of the particle size distribution, pretreatment or correction for calcium carbonate, dissolved salts and/or organic matter can be required. The use of these methods should be stated in the laboratory report.

Modern methods that incorporate detection systems using x-rays, laser beams, density measurements and particle counters are not covered by this document.

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.

CEN ISO/TS 17892-1, *Geotechnical investigation and testing — Laboratory testing of soil — Part 1: Determination of water content (ISO/TS 17892-1:2004).*

CEN ISO/TS 17892-3, *Geotechnical investigation and testing — Laboratory testing of soil — Part 3: Determination of particle density — Pycnometer method (ISO/TS 17892-3:2004).*

ISO 565, *Test sieves - Metal wire cloth, perforated metal plate and electroformed sheet - Nominal sizes of openings.*

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.*

3 Terms and definitions

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

3.1
particle size distribution
proportions by mass of the various particle size classes present in a specific soil

3.2
equivalent diameter
particle diameter calculated from sedimentation data using Stoke's law, and assuming spherical particles

3.3
coarse-grained cohesionless soils
soils comprising gravel and/or sand sizes particles with less than about 10 % of fines, and which are virtually non-cohesive

NOTE The fines content is measured only quantitatively, by difference after washing the material away.

3.4
fine-grained soils
soils comprising more than about 10 % of fines, sometimes with sand but with little or no gravel-sized particles. This category includes both non-cohesive and cohesive soils

3.5
mixed soils
soils comprising gravel, sand, and more than about 10 % of fines

NOTE These soils may or may not be cohesive, depending on the amount of clay present.

3.6
fines
particles passing the 0,063 mm sieve

3.7
D_{90}
the smallest sieve mesh aperture through which 90 % or more of the particles will pass

4 Equipment

4.1 General

4.1.1 Balances

Balances shall have an accuracy of 0,3 % of the total dry specimen mass and a readability of 0,1 % of total dry specimen mass.

4.1.2 Drying ovens

Drying ovens shall be capable of maintaining a temperature of 105 °C ± 5 °C and 50 °C ± 5 °C.

4.1.3 Desiccator

Desiccator shall contain anhydrous silica gel.

WARNING — Traditional blue self-indicating silica gel contains cobalt chloride which has been reclassified as potential carcinogen by inhalation by EU Directive 98/98/EC.

4.1.4 Evaporating dish

Evaporating dish shall be made of porcelain or non-corroding metal, having a minimum content of 100 ml.

4.1.5 Sieves

Sieves shall comprise a sieve of 0,063 mm, suitably reinforced for use as a washing sieve, with receiver, and one sieve of 2,0 mm.

4.2 Sieving

4.2.1 Test sieves

Test sieves of metal wire cloth or perforated metal plate in accordance with ISO 565 and ISO 3310, together with appropriate receivers shall be used.

The aperture of the test sieves should adequately cover the range for the particular soil tested, but it is recommended that within the full range of 125 mm to 0,063 mm not less than 12 sieves are used. The smallest test sieve should have an aperture of 0,063 mm. The number of sieves used shall be sufficient to ensure that any discontinuities in the grading curve are detected. The test sieves should be visually checked before every use.

4.2.2 Ancillary apparatus

The ancillary apparatus shall consist of

- corrosion resistant trays;
- large corrosion resistant or plastic tray or bucket;
- scoop;
- sieve brushes;
- rubber tubing;
- cylindrical beaker, 800 ml or more;
- riffle box (optional);
- mechanical sieve shaker (optional).

4.3 Hydrometer method

4.3.1 Hydrometer

The hydrometer shall be torpedo-shaped and made of glass as free as possible from visible defects. The glass shall be resistant to chemicals and well annealed. The hydrometer stem and bulb shall be circular in cross section and symmetrical around the main axis, without abrupt change in cross section. The hydrometer shall always float, at all points within its range, within the stem within 1,5° of the vertical. The scale and inscription shall be marked clearly and permanently, showing no apparent irregularities in spacing. The graduation lines shall be at intervals of 0,0005 g/ml and the range of the hydrometer shall be between 0,9950 g/ml and 1,0300 g/ml. The hydrometer shall be indelibly marked with a unique identification number.

4.3.2 Graduated glass cylinders

Graduated glass cylinders shall be provided with parallel sides and with constant cross sectional area across their length. The diameter shall be at least twice that of the hydrometer bulb and the length be sufficient to ensure that the hydrometer can float freely in 1000 ml of pure water.

4.3.3 Thermometers

Thermometer shall cover a temperature range of 0 °C to 50 °C and be accurate to 0,5 °C.

4.3.4 Water bath

The water bath shall be insulated and may have a temperature controller.

4.3.5 Mechanical shaker or mixer

The mechanical shaker or mixer shall be capable of keeping the appropriate quantities of soil and water in continuous suspension.

4.3.6 Timer

The stop watch or stop clock shall be readable to 1 s.

4.3.7 Working bench

The working bench shall be free from vibrations.[1]

4.3.8 Centrifuge

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

4.4 Pipette method

4.4.1 Pipette

The pipette shall be calibrated. It shall have a volume of 20 ml and be mounted in a pipette configuration (Figure 1).

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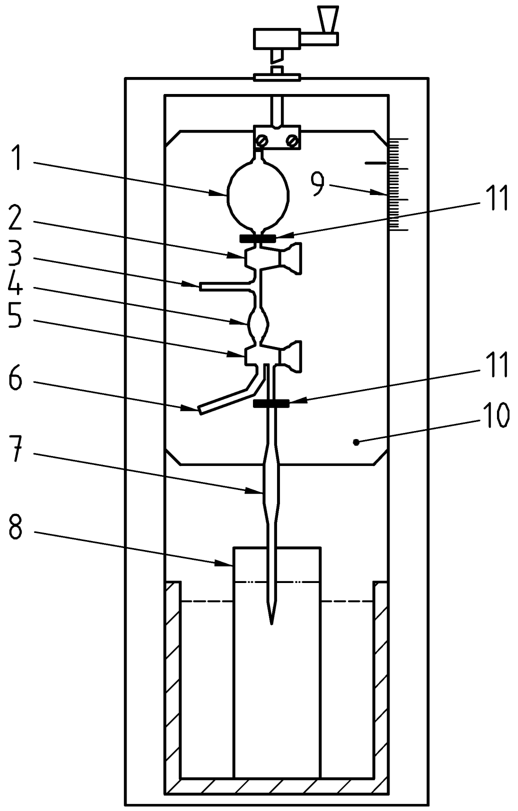
[1] Free from vibrations means no ripples can be seen on the surface of a suspension placed on the working bench.



Key

1	Bulb
2	Stop cock
3	Safety bulb suction inlet
4	Safety bulb
5	Three-way stop cock
6	Outlet tube
7	Sampling pipette
8	Sedimentation cylinder
9	Graduated scale
10	Sliding panel
11	Clamps

Figure 1 — Example of pipette configuration

4.4.2 Balance

The balance shall have an accuracy of 0,3 mg.

4.4.3 Thermometers

Thermometers shall cover a temperature range of 0 °C to 50 °C and be accurate to 0,5 °C.

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The water bath shall be insulated and may have a temperature controller.

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A stop watch or stop clock shall be readable to 1 s.

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The working bench shall be free from vibrations.[a]

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

4.5 Reagents

4.5.1 General

Reagents shall be of analysis quality.

4.5.2 Water

The water shall be distilled, de-ionised or demineralised.

4.5.3 Dispersing agent

The dispersing agent may be water. However, if flocculation occurs, this can be prevented by adding a dispersing agent. Options include but are not limited to:

- Sieving: sodium hexametaphosphate, approximately 2 g/l or sodium pyrophosphate, approximately 2 g/l;
- Sedimentation: sodium hexametaphosphate approximately 40 g/l (0,07 M) or sodium pyrophosphate, approximately 20 g/l (0,07 M).

Solutions shall be renewed monthly. Sodium carbonate shall not be added to the sodium hexametaphosphate.

4.5.4 Hydrogen peroxide

Hydrogen peroxide (20% V/V) may be used to remove organic material.

4.5.5 Hydrochlorid acid

Hydrochlorid acid (0,2 M (± 1 %)) may be used to remove carbonates (optional).

5 Test procedure

5.1 Selection of test method

The test method shall be selected as follows:

For mixed soils separate sieving and sedimentation shall be performed.

If 90 % or more of the particles are larger than 0,063 mm sieving shall be performed.

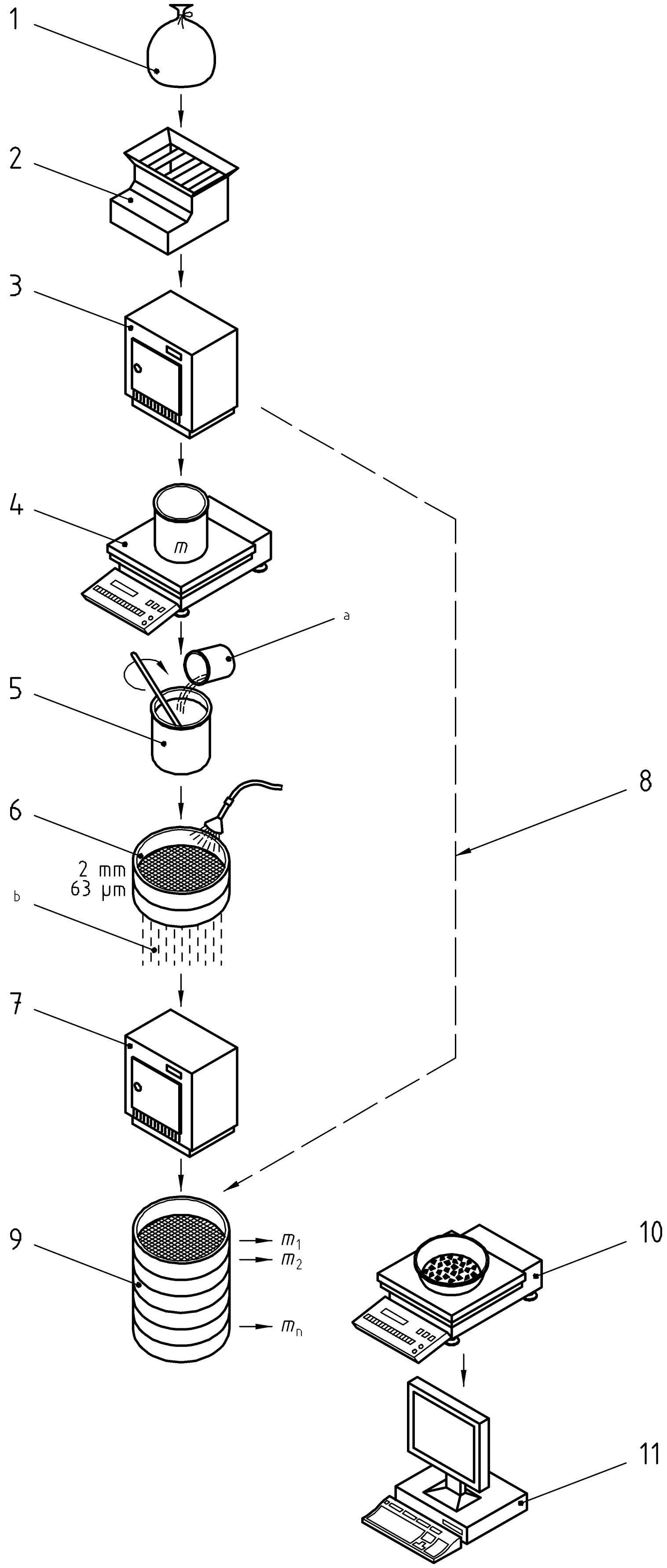
If more than 10 % of the particles are smaller than 0,063 mm sedimentation shall be performed.

If the complete curve of the grain size distribution is required, sieving and sedimentation test shall be carried out.

5.2 Sieving

5.2.1 General

5.2.1.1 The general procedure for sieving is outlined in Figure 2.



Key

1 Sample
2 Riffling or quartering
3 Drying
4 Weighing
5 Stirring
6 Separating
7 Drying
8 Dry separation (alternative method)
9 Sieving
10 Weighing
11 Computation
a Dispersing agent
b Clear water

Figure 2 — Sieving procedure

5.2.1.2 Sieves shall be regularly checked for compliance with ISO 3310-1 and ISO 3310-2.

5.2.1.3 The oven temperature shall be verified at least every two years by means of a calibrated temperature measuring device.

5.2.1.4 Oven-drying shall be done at 105 °C ± 5 °C, unless the soil is susceptible to heating. Susceptible soils shall be dried at 50 °C.

NOTE Soils susceptible to heating include organic soils, gypsum and laterite.

5.2.2 Specimen preparation

5.2.2.1 Wet preparation should be used.

For soils containing more than 10 % fines, use of the dry preparation method may introduce significant errors.

5.2.2.6 to 5.2.2.8 is only applicable to wet preparation.

5.2.2.2 A representative specimen shall be prepared by riffling or quartering, and oven-drying. Minimum masses for dried specimens required for testing are given in Table 1. If it is found that the amount of soil is not sufficient to comply this fact shall be reported.

Table 1 — Minimum mass required for sieving as a function of particle diameter D_{90}

Particle diameter D_{90} mm	Minimum mass required for sieving g
0,5	50
1,0	100
4,0	150
6,0	350
8,0	600
16,0	2500
22,4	5000
31,5	10000
45,0	20000
63,0	40000
75,0	56000

5.2.2.3 If sedimentation is also required, this shall be done using a separate specimen, which is not oven-dried.

5.2.2.4 Soils may be pretreated 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 pretreatment for organic and carbonate material is included in annex B.

5.2.2.5 The dry specimen shall be weighed to the nearest 0,1 % of the total dry mass (m).

5.2.2.6 The specimen shall be placed in a tray or bucket and covered with water. It shall stand for a minimum of 1 hour and be stirred frequently.

For specimens with particles with diameter above 5 mm, it may be necessary to split the sample on a suitable sieve, and treat the coarse fraction separately. If necessary the mass of the fraction passing the sieve shall be reduced by riffling.

It may be necessary to soak the specimen in dispersing agent to remove interstitial clay.

5.2.2.7 The specimen shall be washed through a 2 mm sieve nested in a 0,063 mm sieve until the water runs virtually clear. Ensure that neither sieve becomes overloaded. Material passing the sieves can be collected if required.

5.2.2.8 All material retained on the sieves shall be transferred, oven-dried, and weighed to the nearest 0,1 % of the total dry mass of the specimen.

5.2.3 Test execution

5.2.3.1 The dried material shall be sieved down to 0,063 mm, weighing the soil retained on each test sieve, and any material passing the 0,063 mm sieve. The masses retained on each sieve shall not exceed the values listed in Table 2.

When a sieving machine is used, sieving should be continued for at least 10 min. When hand sieving is used, the sieve should be shaken for at least 2 min, and then until no more material passes.

When the maximum mass listed in Table 2 is exceeded, the sieving shall be performed in stages. The soil on the first sieve exceeding the maximum amount is split in smaller portions which are then sieved separately. The total mass on each sieve is calculated from the sum of masses retained from each portion.

5.2.3.2 For each sieving sequence, the cumulative mass retained on each sieve and the fraction passing the last sieve shall be calculated. If this differs from the mass at the start of sieving by more than 1 %, the sieving shall be repeated.

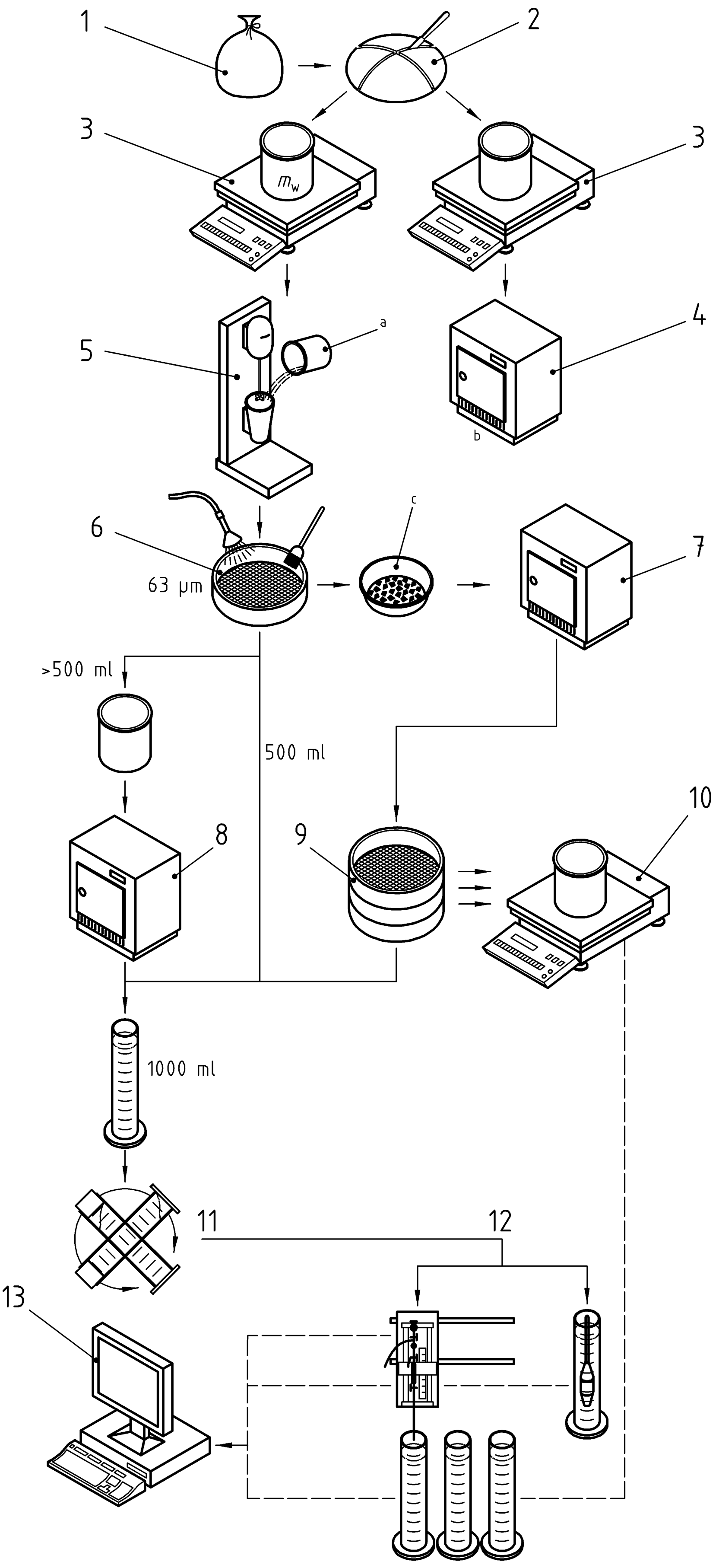
Table 2 — Maximum mass of soil retained on each sieve

Nominal opening	Maximum mass on sieve of diameter		Nominal mesh size	Maximum mass on sieve of diameter
	450 mm	300 mm		200 mm
mm	mass kg	mass kg	mm	mass g
5,0	1	0,50	0,038	20
5,6	1	0,50	0,063	25
6,3	1,5	0,75	0,125	35
8,0	1,7	0,9	0,150	40
10,0	2,0	1,0	0,212	50
11,2	2,2	1,2	0,250	50
14,0	3,0	1,5	0,300	50
16,0	3,5	1,7	0,355	60
20,0	4,0	2,0	0,425	75
22,4	4,5	2,2	0,500	70
28,0	6,0	2,5	0,600	75
31,5	6,5	3,0	0,710	80
37,5	8,0	3,5	1,18	100
45,0	9,0	4,0	1,4	125
50,0	10,0	4,5	2,0	200
63,0	11,0	5,0	3,35	300
			4,0	300

5.3 Hydrometer analysis

5.3.1 General

5.3.1.1 The general procedure for hydrometer analysis is outlined in Figure 3.



Key

1	sample
2	quartering
3	weighing
4	drying
5	stirring
6	separating
7	drying
8	evaporation and decantation
9	sieving
10	weighing
11	agitation
12	sedimentation
13	computation
a	dispersant
b	water content
c	evaporating dish

Figure 3 — General procedure for sedimentation

5.3.1.2 The oven temperature shall be verified at least every two years by means of a calibrated temperature measuring device.

5.3.1.3 The temperature shall be kept constant for the duration of the test. The test may be performed in a temperature-conditioned room, in an insulated water bath or in a constant temperature bath. The temperature fluctuation during the test should not exceeded 0,5 °C, the temperature itself falling within the range of 15 °C to 25 °C.

5.3.1.4 Oven-drying shall be done at 105 °C ± 5°C, unless the soil is susceptible to heating. Susceptible soils shall be dried at 50 °C.

5.3.1.5 For test carried in a temperature-conditioned room, a calibrated temperature measuring device shall be placed permanently in the room to provide a continuous temperature record.

5.3.1.6 If a constant temperature bath is used, care shall be taken that its agitator does not introduce vibrations in the specimen.

5.3.1.7 Calibration of the hydrometer shall be performed prior to its first use. Corrections may be applied individually or combined, but the following points should always be taken into account:

- volume and geometry;
- scale calibration;
- meniscus correction;
- temperature correction, if necessary;
- dispersing agent correction.

A method for determining these corrections is described in annex A.

5.3.2 Specimen preparation

5.3.2.1 A specimen of non-dried soil shall be selected in accordance with Table 3.

Table 3 — Dry mass of soil specimen for sedimentation test

Soil type	Dry mass of soil g
Soil containing sand	up to 75
Cohesive soils, with little or no sand	30 to 50
Very plastic to plastic clays	10 to 30

5.3.2.2 The water content of the soil shall be determined on a separate specimen according to CEN ISO/TS 17892-1 .

5.3.2.3 The density of solid particles, when required, shall be determined on a separate specimen in accordance with CEN ISO/TS 17892-3.

NOTE The density of solid particles is needed for the calculation of equivalent particle diameters and corresponding fractions.

5.3.2.4 When required, the soil samples shall be pretreated to remove organic and/or carbonate material. Suggested methods are given in annex B.

NOTE Pretreatment is recommended if organic material and/or carbonate compounds are present in significant quantities, unless geotechnical classification of carbonate soil is required.

5.3.2.5 The soil specimen shall be placed in a conical flask. If the specimen has been pretreated and a centrifuge is used, the pretreated soil should remain in the centrifuge bottle.

5.3.2.6 100 ml of the dispersant solution shall be added to the soil specimen. The mixture shall be thoroughly shaken until all the soil is in suspension.

The dispersion shall be complete because otherwise the particles could form aggregates.

NOTE An indication of incomplete dispersion is the formation of layers in the suspension when allowed to stand.

5.3.2.7 The suspension shall be agitated by 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. For other methods, such as a high-speed stirrer or a vibration stirrer, a 20 minutes agitation is usually sufficient. A reduced period should be adopted for soil which might be broken down by the agitation process. The agitation period may also be reduced if experience shows that the soil is readily dispersed.

5.3.2.8 The prepared soil suspension shall be transferred to the 0,063 mm sieve placed on the receiver, and the fine particles shall be washed through the sieve using a jet of water, the amount of which shall not exceed 800 ml.

In some cases, double separation may be needed, e.g. both on a 2 mm and 0,063 mm sieve. Separation on the 2 mm sieve may be helped by brushing.

When accidently the total volume of the suspension passing the sieve exceeds 1000 ml, the excess water shall be removed by evaporation. Only if the suspension does not contain any dispersing agent, is decanting allowed.

5.3.2.9 The suspension passing the sieve shall be transferred to the measuring cylinder and made up to the 1 l graduation mark with water.

5.3.2.10 The material retained on the sieve shall be transferred to an evaporating dish, and dried in an oven.

5.3.2.11 The material shall be allowed to cool and the soil retained on the sieves shall be sieved down to the smallest mesh size as described in 5.2.3.

5.3.2.12 Any material passing the smallest mesh size shall be added to the sedimentation cylinder.

The suspension shall rest for at least 12 h. When a water bath is used, the sedimentation cylinder shall be placed in the water bath and the temperature of the cylinder shall become equal to the temperature of the water bath.

The water level in the water bath should be at least as high as the level in the sedimentation cylinder.

5.3.2.13 A sedimentation cylinder shall be prepared with a reference solution consisting of 100 ml dispersant solution and 900 ml of water. This cylinder shall be treated identically to the cylinder containing the soil suspension.

5.3.3 Test execution

5.3.3.1 The suspension shall be agitated vigorously until full suspension is obtained, e.g. by turning the sedimentation cylinder end-over-end about 60 times in 2 min.

5.3.3.2 The cylinder shall be placed back and the timer shall be started. The hydrometer shall be immersed in the suspension so that it is allowed to float freely.

5.3.3.3 Hydrometer readings R'_h shall be taken at the upper rim of the meniscus after short periods of time (e.g. 0,5 min, 1 min and 2 min), to the nearest 0,001 g/ml. The hydrometer shall be removed slowly and rinsed.

5.3.3.4 The hydrometer shall be placed in the reference solution, the hydrometer shall be read and this value shall be recorded as the reference value R_0 to the nearest 0,001 g/ml.

5.3.3.5 The hydrometer shall be re-inserted slowly in the soil suspension at suitable intervals, about 15 s before a reading is due. The hydrometer shall be read to the nearest 0,001 g/ml.

NOTE 1 A suitable interval would be readings at 4, 8, 30, 60, 120, 480 min, and 24 h, calculated from the beginning of the sedimentation period. The number of readings can be more or less, however with a minimum of 3, suitably distributed over the sedimentation curve.

NOTE 2 It is not essential to keep rigidly to the schedule provided that the actual time of the reading is recorded.

5.3.3.6 The temperature of the suspension shall be recorded once in the first 15 min, and then after every hydrometer reading, to the nearest 0,5 °C.

5.3.3.7 If the temperature at any reading differs more than 1 °C from the previous reading, an additional reading in the reference solution shall be taken.

It is also allowed to apply a correction for the temperature as described in annex A.

5.4 Pipette method

5.4.1 General

5.4.1.1 The general procedure is outlined in Figure 3.

5.4.1.2 The oven temperature shall be verified at least every two years by means of a calibrated temperature measuring device.

5.4.1.3 Oven-drying shall be done at 105 °C ± 5°C, unless the soil is susceptible to heating. Susceptible soils shall be dried at 50 °C.

5.4.2 Specimen preparation

5.4.2.1 The soil specimen shall be prepared as described for the hydrometer method (5.3.2). The dry mass shall be approximately 50 g for sandy soils, and 20 g for silty or clayey soils.

5.4.3 Test execution

5.4.3.1 A number of evaporating dishes shall be dried at 105 °C, and the mass of each dish shall be determined to the nearest 0,1 mg ($m_{1,\mathrm{i}}$).

5.4.3.2 The suspension shall be agitated vigorously by turning the sedimentation cylinder end-over-end about 60 times in 2 min.

5.4.3.3 The cylinder shall be placed back and the timer shall be started.

5.4.3.4 The temperature of the suspension shall be determined and the insertion depth and insertion time for the relevant fraction shall be read from Table 4.

Table 4 — Insertion depth of pipette

Temperature of the suspension °C	Upper limit particle fraction µm						
	38	25	20	16	8	4	2
	Settling time						
	90 s	320 s	6 min	15 min	20 min	1 h	4 h
	Insertion depth of pipette mm						
15,0	99	153	110	176	59	44	44
15,5	100	155	112	179	60	45	44
16,0	102	157	113	181	60	45	45
16,5	103	159	115	183	61	46	46
17,0	104	161	116	186	62	46	46
15,5	106	163	118	188	63	47	47
18,0	107	166	119	191	64	48	47
18,5	108	168	121	193	64	48	48
19,0	110	170	122	196	65	49	49
19,5	111	172	124	198	66	50	49
20,0	112	174	125	201	67	50	50
20,5	114	176	127	203	68	51	50
21,0	115	178	128	205	68	51	51
21,5	117	180	130	208	69	52	52
22,0	118	183	132	210	70	53	52
22,5	119	185	133	213	71	53	53
23,0	121	187	135	215	72	54	54
23,5	122	189	136	218	73	54	54
24,0	124	191	138	221	74	55	55
24,5	125	194	139	223	74	56	55
25,0	127	196	141	226	75	56	56

5.4.3.5 The pipette shall be inserted carefully in the suspension to the required depth. The pipette shall be filled gradually, and it shall be emptied into an oven-dry evaporating dish. The pipette shall be rinsed with water, and the washings shall be added to the same evaporating dish.

5.4.3.6 The evaporating dish shall be dried with the soil fraction in a drying oven until a constant mass is obtained, and the dry mass ($m_{2,i}$) shall be determined to the nearest 0,1 mg.

5.4.3.7 A sample shall also be taken by the pipette from the reference solution, and this shall be put into an oven-dry dish. The pipette shall be flushed, the washings shall be added to the dish. The evaporating dish shall be dried in an oven until a constant mass is obtained, and the dry mass (m_b) shall be determined to the nearest 0,1 mg.

5.4.3.8 5.4.3.4 to 5.4.3.7 shall be repeated for all required particle sizes.

A minimum of 3 fractions should be taken, distributed evenly over the particle size distribution curve.

6 Test results

6.1 Sieving

6.1.1 Fraction passing each sieve

The fraction of the soil passing each sieve shall be calculated by equation (1):

$$f_n = \frac{m_1 + m_2 + .. + m_n}{m} \times 100\% \tag{1}$$

where

f_n	is fraction passing the sieve (%);
m_1	is mass of soil passing the smallest mesh size (g);
m_2, m_n	is mass of soil passing the consecutive sieves, up to the sieve considered (g);
m	is total dry mass of the specimen (g).

NOTE 1 If the soil has been pretreated, the dry mass after pretreatment replaces m in above equation.

NOTE 2 It can sometimes be appropriate to exclude particles > 2 mm from the calculation if they are insignificant, e.g. mainly sandy, silty or clayey soil samples containing a few stones, stone fragments, shells, etc. If this is done then the amount of material excluded should be stated in the report, expressed as a percentage of the total mass. This is recommended for mixed soils.

6.2 Hydrometer

6.2.1 Total dry mass

The total dry mass of the specimen shall be calculated by equation (2):

$$m = m_w \times \frac{100}{100 + w} \tag{2}$$

where

m	is total dry mass (g);

m_w is wet mass of soil (g);

w is water content (%).

When the specimen was pretreated, the dry mass after pretreatment shall be calculated as above. This dry mass replaces m in all following calculations.

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

The true hydrometer reading shall be calculated from

$$R_h = R'_h + C_m \qquad (3)$$

where

R_h is true hydrometer reading;

R'_h is observed hydrometer reading;

C_m is meniscus correction.

6.2.4 Effective depth

The effective depth H_r shall be calculated from the true hydrometer reading using the hydrometer scale calibration (see annex A).

6.2.5 Equivalent particle diameter

The equivalent particle diameter corresponding to reading R_h shall be calculated using Stoke's law, by equation (4):

$$d_i = 0{,}005531\sqrt{\frac{\eta \times H_r}{(\rho_s - 1) \times t}} \qquad (4)$$

where

d_i is equivalent particle diameter (mm);

η is dynamic viscosity of water (see Table 5);

H_r is effective depth of hydrometer (mm);

ρ_s is particle density (Mg/m^3);

t is time (s).

Table 5 — 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 Intermediate values can be calculated by interpolation.	

6.2.6 Modified hydrometer reading

The modified hydrometer reading R_d shall be calculated by the equation (5):

$$R_d = R'_h - R'_0 \tag{5}$$

where

R_d is modified hydrometer reading;

R'_h is observed hydrometer reading;

R'_0 is observed hydrometer reading in reference solution.

R'_h and R'_0 should consist only of the decimal part of the reading, multiplied by 1000.

6.2.7 Fraction smaller than equivalent diameter

The fraction smaller than the corresponding equivalent diameter shall be calculated by the equation (6):

$$K = \frac{100 \times \rho_s}{m(\rho_s - 1)} R_d \tag{6}$$

K is fraction smaller than equivalent diameter (%);

ρ_s is particle density (Mg/m^3);

m is dry mass of specimen (g);

R_d is modified hydrometer reading.

6.3 Pipette method

6.3.1 Total dry mass

The total dry mass of the specimen shall be calculated by equation (7):

$$m = m_w \times \frac{100}{100 + w} \tag{7}$$

where

m is total dry mass (g);

m_w is wet mass of soil (g);

w is water content (%).

When the specimen was pretreated, the dry mass after pretreatment shall be calculated. This dry mass replaces m in all following calculation.

6.3.2 Fraction passing each sieve

The fraction passing each sieve shall be calculated according to 6.1.1.

6.3.3 Fraction smaller than equivalent diameter

The fraction smaller than the equivalent diameter determined from Table 4 shall be calculated by equation (8):

$$K = \frac{(m_{2,i} - m_{1,\mathrm{i}} - m_\mathrm{b}) \times V_1}{V_2 \times m} \times 100\,\% \tag{8}$$

where

K is mass percentage of fraction (%);

$m_{1,\mathrm{i}}$ is mass of the empty evaporating dish (g);

$m_{2,\mathrm{i}}$ is mass of evaporating dish with dried fraction (g);

m_b is mass of oven-dried remains of reference liquid (g);

V_1 is the volume of the suspension in the sedimentation cylinder (ml);

V_2 is volume of the pipette (ml).

7 Test report

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

a) the method(s) of test used;

b) identification of the sample being tested, e. g. by boring number, sample number, test number, etc.;

c) the test results, presented on a semi-logarithmic plot (see Figure 4). When results have been obtained by sieving and sedimentation, these should be combined in one graph. If there is a discontinuity between the sieving and sedimentation curves, priority shall be given to the sieving data and the two curves shall be joined together to give a smooth continuous curve. Alternatively, test results may be tabulated, rounded to the nearest 1 %;

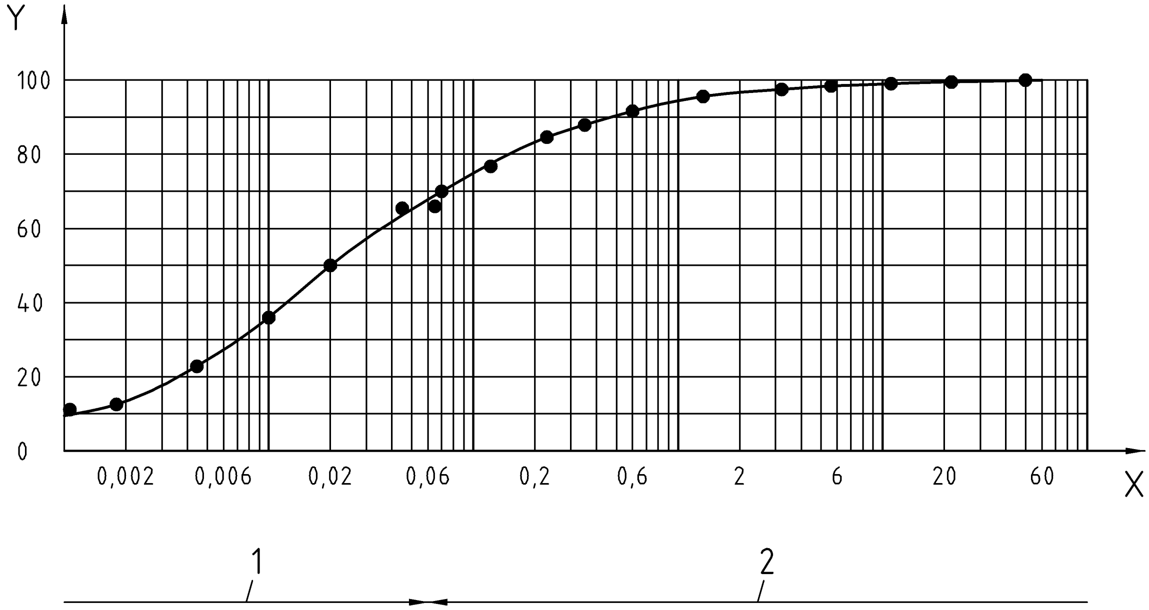
d) the value for the density of solid particles, used in the calculations, and whether this value was determined or assumed;

e) method of pretreatment, when applied;

f) the name of the test organisation;

g) any deviation from the specified procedure, and particulars that could be important for interpreting the test results.

When 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

2 Sieving

x Particle size (mm)

y Percentage passing

Figure 4 — Example of a particle size distribution result

Annex A
(informative)

Calibration of hydrometer

A.1 Volume calibration

The hydrometer should be weighed to the nearest 0,1 g and the mass should be recorded as the volume of the hydrometer in ml (V_h).

A.2 Scale calibration

The distance should be measured from the 100 ml scale mark to the 1000 ml scale mark on the sedimentation cylinder to the nearest mm (L) (see Figure A.1).

The distance of the lowest calibration mark should be measured on the hydrometer stem to each of the other major calibration marks R_h (d_i).

The distance should be measured from the neck of the bulb to the lowest calibration mark (N).

The distance H, corresponding to any reading R_h, should be calculated as the sum of the distances measured above ($N + d_1$, N + d_2, etc.).

The distance should be measured from the neck of the bulb to the bottom of the bulb (h)

NOTE It is assumed that a symmetrical bulb is used with a volume centre at ½ h under the neck of the bulb. If an asymmetrical bulb is used, the volume centre should be determined. In this case, h should be replaced by twice the distance from the neck to the volume centre of the bulb.

The effective depth H_r should be calculated for each of the major calibration marks as follows:

$$H_r = H + 0{,}5\left(h - \frac{V_h}{900} L\right) \text{ (in mm)} \tag{A.1}$$

where

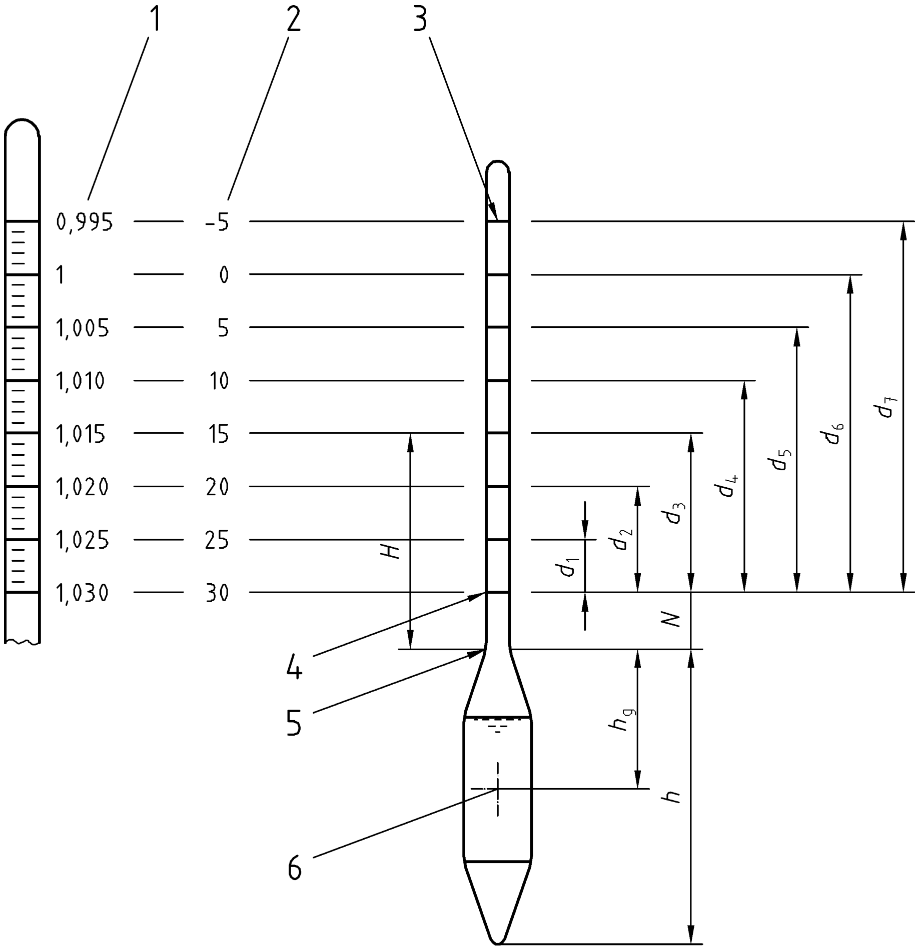
H is length from neck of bulb to graduation R_h (mm);

h is length of bulb (mm);

V_h is volume of bulb (ml);

L is distance between 100 ml and 1000 ml scale marking on sedimentation cylinder (mm).

The relationship $H_r = f(R_h)$ should be determined.



Key

1 Hydrometer relative density markings
2 Equivalent R_h
3 Main calibration marks
4 Lowest calibration mark
5 Neck of bulb
6 Centre of volume of bulb

Figure A.1 — Example of calibration of hydrometer scale

A.3 Meniscus correction

The hydrometer should be inserted in a sedimentation cylinder, containing about 800 ml of water.

Starting below the plane of the surface of the liquid, the eye should be raised until the surface seen as an ellipse becomes a straight line, and then the point where the plane intersects the hydrometer scale should be determined.

Starting above the plane of the surface of the liquid, the point where the upper limit of the meniscus intersects the hydrometer scale should be determined.

The difference between the readings is the meniscus correction C_m.

A.4 Temperature correction

When the density of the dispersant solution is not measured before every reading in the soil suspension, a temperature correction as shown in Table A.1 should be applied to R'_0, such that:

$$R'_0 \text{ (corrected)} = R'_0 + \text{CT} \tag{A.2}$$

Table A.1 — Temperature correction

T °C	CT	*T* °C	CT
7	–0,0013000	20	+0,0000
8	–0,0013	21	+0,0002
9	–0,0013	22	+0,0004
10	–0,0013	23	+0,0006
11	–0,0012	24	+0,0008
12	–0,0012	25	+0,0010
13	–0,0011	26	+0,0013
14	–0,0009	27	+0,0015
15	–0,0008	28	+0,0018
16	–0,0006	29	+0,0020
17	–0,0005	30	+0,0023
18	–0,0003	31	+0,0026
19	–0,0002	32	+0,0030

A.5 Dispersant correction

A correction for the dispersant is included in the calculations.

A.6 Sedimentation cylinder

Each distance L between the 100 ml and 10000 ml mark should be such that:

$$0{,}99\, L_r < L < 1{,}01\, L_r \tag{A.3}$$

where

L_r is an average distance L, corresponding for example to a reference volume of liquid in the graduated cylinder.

Annex B
(informative)

Calibration of hydrometer

B.1 Pretreatment for organic material

The specimen should be weighed and the water content should be determined as in 5.3.2.

The specimen should be placed in a conical flask, and 150 ml hydrogen peroxide should be added in portions of maximum 20 ml. The mixture should be stirred, covered, and left overnight.

It should then be heated gently, stirred occasionally, and then reduced to 50 ml by boiling.

If the specimen is highly organic, additional hydrogen peroxide can be required.

The soil should be separated using a suitable apparatus.

B.2 Pretreatment for carbonate material

Pretreatment for carbonate material can be carried in a similar fashion as for organic material, using hydrochoric acid instead of hydrogen peroxide.

Proper safety precautions should be taken.

B.3 Final pretreatment stage

B.3.1 Sieving

The soil should be dried in an oven at 105 °C, or (50 °C ± 5 °C) for susceptible soils. It should be allowed to cool in a desiccator, then it is recommended to continue with the particle size analysis.

B.3.2 Sedimentation

A portion of the recovered soil should be used to determine the water content.

The remaining pretreated soil should be used for the particle size analysis.

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.

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