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Soil quality — Determination of particle density

Qualité du sol — Détermination de la masse volumique des particules

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 190, *Soil quality*, Subcommittee SC 3, *Chemical methods and soil characteristics*.

This second edition cancels and replaces the first edition (ISO 11508:1998), which has been technically revised.

The main changes compared to the previous edition are as follows:

a) the terms and definitions have been updated;

b) a new subclause 4.3 "Unified reference temperature" was added;

c) a new subclause 4.4 "Calculation of mean particle density" was added;

d) Table 1, "Density of water…", was deleted under 4.1.4;

e) a new Annex A "Density of water at different temperatures" was added;

f) bibliographic references were added;

g) editorial changes were made.

Introduction

This document specifies the particle density (ρ_S) which is used together with the dry bulk density ($^b\rho_S$, see ISO 11272) for the calculation of the pore volume of a soil layer.

Soil quality — Determination of particle density

1 Scope

This document specifies two methods for the determination of particle density of soils calculated from the mass and the volume of soil particles.

The first method (4.1) is applicable to fine soil (<2 mm diameter) and the second method (4.2) is applicable to both porous and nonporous gravel and stones (>2 mm diameter).

The particle density can be used for the calculation of the proportion of solids and of the porosity of soil layers in combination with the procedure given in ISO 11272.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

ISO 11461, *Soil quality — Determination of soil water content as a volume fraction using coring sleeves — Gravimetric method*

3 Terms and definitions

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

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

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

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

3.1
particle density
ratio of the total mass of oven-dry solid particles, e.g. minerals or organic matter, to the volume of these particles

Note 1 to entry: The volume comprises internal pores of soil particles but pore spaces between particles are excluded.

Note 2 to entry: The preferred SI unit of measurement is kilograms per cubic metre ($kg \cdot m^{-3}$) but grams per cubic centimetre ($g \cdot cm^{-3}$) is also very common. Note that $x\ g \cdot cm^{-3} = 1\ 000 \cdot x\ kg \cdot m^{-3}$.

4 Procedure

4.1 Fine soil (<2 mm diameter)

4.1.1 Principle

The mass of a portion of soil is determined by weighing. The volume of the soil is calculated from the mass and the density of water displaced by the sample in a pycnometer.

4.1.2 Apparatus

4.1.2.1 Thermometer, capable of measuring to an accuracy of 0,1 °C.

4.1.2.2 Pycnometer, preferably with a volume of 20 cm^3 to 50 cm^3, regularly calibrated glass flask fitted with a ground-glass stopper, which is pierced lengthways by a capillary opening.

4.1.2.3 Vacuum desiccator, with self-indicating silica gel or anhydrous calcium sulfate.

4.1.2.4 Laboratory balance, capable of weighing to an accuracy of 0,1 mg.

4.1.2.5 Sieve, conforming to ISO 565, aperture size 2 mm.

4.1.3 Sampling

Take a disturbed representative sample from the soil, pass it through a sieve (4.1.2.5), and dry it at room temperature. Determine the reference water content, w, of the air-dried soil in a subsample in accordance with ISO 11461.

4.1.4 Density determination

Weigh a clean, dry and calibrated pycnometer in air (m_0). Add 10 g to 25 g of air-dried soil (4.1.3) and weigh the pycnometer with the soil (m_s). Add distilled water to the pycnometer to approximately the half-full mark.

Wet and then de-aerate the soil sample in the pycnometer in a vacuum desiccator until there is no further escape of air. Fill the pycnometer completely with distilled, boiled and cooled (de-aerated) water in a weighing room maintained at constant temperature, and insert the stopper so that no air bubbles remain under the stopper and the capillary tube in the stopper is completely filled with water (hold the pycnometer at the neck only during this operation). Then carefully dry the pycnometer without warming it, using filter paper, and weigh it (m_{sw}).

During the procedure, take care to ensure that the capillary tube remains filled with water, and that the temperature does not change.

After weighing, read the temperature of the water to the nearest 0,1 °C and determine its density (ρ_w) from Table A.1.

Finally, remove the soil sample from the pycnometer and refill with deionized and degassed water of the same temperature as before, insert the stopper, thoroughly dry the outside with filter paper, and weigh it (m_w), taking care that the temperature remains the same as before.

4.1.5 Calculation

a) Calculate the air-dried mass of soil (m_d) from Formula (1):

$$m_d = \frac{m_s - m_0}{1 + w_s} \quad (1)$$

where

m_s is the mass of pycnometer plus air-dried soil sample, in g;

m_0 is the mass of the empty pycnometer (pycnometer filled with air), in g;

w_s is the water content of the air-dried soil sample.

b) Calculate the soil particle density, ρ_s, in g/cm^3, using Formula (2):

$$\rho_s = \frac{m}{V} = \frac{\rho_w \cdot m_d}{(m_{sw} - m_w)} = \frac{\rho_w \cdot m_d}{m_d + m_w - m_{sw}} \quad (2)$$

where

m is the mass, in g;

V is the volume, in cm^3;

m_d is the oven-dried mass of the soil sample, in g;

ρ_w is the density of water at the temperature observed, in g/cm^3 (see Table A.1);

m_{sw} is the mass of pycnometer filled with soil and water, in g;

m_w is the mass of pycnometer filled with water at the temperature observed, in g.

NOTE The standard deviation of particle density of fine soil usually varies between 0,02 g/cm^3 to 0,03 g/cm^3 for different personnel or different laboratories, respectively.

4.2 Gravel and stones (>2 mm diameter)

4.2.1 Apparatus

4.2.1.1 Laboratory balance, with thin wire attached to the weighing beam, from which a light frame can be suspended. The frame serves as a platform for a weighing dish with a small container so that both frame and dish can be immersed in a large container of water during weighing (see Figure 1).

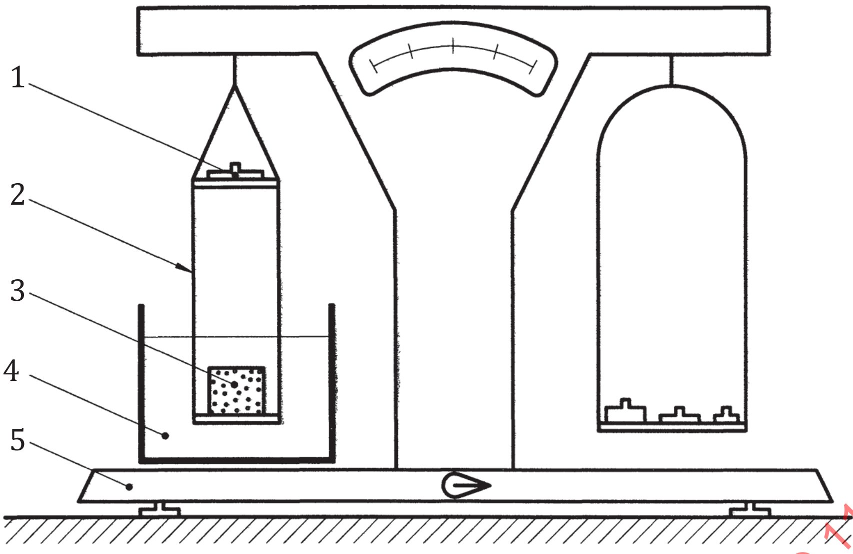
4.2.1.2 Vacuum desiccator, with self-indicating desiccant.

4.2.1.3 Thermometer, capable of measuring to an accuracy of 0,1 °C.

4.2.2 Density determination

Weigh the weighing dish of the balance (m_0). Clean the gravel and stones (for example by shaking them with sodium hexametaphosphate solution), wash in water, and dry them at (105 ± 2) °C.

Place the gravel and stones in the small container of the dish and weigh both together (m_s). Then fill the small container with distilled, boiled and cooled water. Put this container in a vacuum desiccator and de-aerate twice for 10 min, allowing air to enter the desiccator between evacuations. Then put this container on the weighing dish and submerge dish with the container in a large container containing distilled, boiled and cooled water and carefully reweigh while the stones and gravel are suspended in the water (m_{sw}). Remove and discard the sample, clean the weighing dish with its container, and weigh it while it is submerged in water (m_w). Measure the temperature of the water and from Table A.1 determine its density (ρ_w).



Key

1 compensating weights

2 thin wire

3 small container

4 large container filled with water

5 balance

Figure 1 — Schematic layout of a laboratory balance to determine the volume of gravel and stones by weighing in air and water

4.2.3 Calculation

Calculate the density of the soil composed of large particles, ρ_p, using Formula (3):

$$\rho_p = \frac{m}{V} = \frac{\dfrac{m_s - m_0}{(m_s - m_0) - (m_{sw} - m_w)}}{\rho_w} = \frac{\rho_w (m_s - m_0)}{m_s + m_w - m_{sw} - m_0} \qquad (3)$$

where

m is the mass, in g;

V is the volume, in cm^3;

ρ_w is the density of water, in g/cm^3;

m_s is the oven-dry mass of the gravel and stones with container and weighing dish, in g;

m_0 is the mass of container and weighing dish, in g;

m_{sw} is the mass of large particles and dish submerged in water, in g;

m_w is the mass of container and dish alone, submerged in water, in g.

NOTE The standard deviation of particle density of gravel and stones is approximately 0,01 g/cm^3 for both different personnel or different laboratories.

4.3 Unified reference temperature

If required, particle densities measured at different temperatures may be calculated to a reference temperature of 20 °C according to Formula (4).

$$\rho_{20°C} = \rho_{x°C} \times KF_{x°C} \quad (4)$$

where

$\rho_{20\,°C}$ is the particle density at 20 °C, in g/cm^3;

$\rho_{x\,°C}$ is the particle density at measured temperature, in g/cm^3;

$KF_{x\,°C}$ is the coefficient at measured temperature according to Table A.1.

4.4 Calculation of mean particle density

For soils with relevant content of stones the mean particle density at reference temperature is calculated from the densities of fine and coarse particles (gravel and stones) according to Formula (5).

$$\rho_{mean20\,°C} = \frac{\rho_{fine20\,°C} \cdot w_{fine} + \rho_{coarse20\,°C} \cdot w_{coarse}}{100} \quad (5)$$

where

$\rho_{mean20\,°C}$ is the particle density of total soil at 20 °C, in g/cm^3;

$\rho_{fine20\,°C}$ is the particle density of fine particles at 20 °C, in g/cm^3;

$\rho_{coarse20\,°C}$ is the particle density of gravel and stones at 20 °C, in g/cm^3;

w_{fine} is the mass fraction of fine particles in relation to air-dried soil, in %;

w_{coarse} is the mass fraction of gravel and stones in relation to air-dried soil, in %.

5 Test report

The test report shall contain at least the following information:

a) a reference to this document, i.e ISO 11508;

b) complete identification of the sample;

c) a reference to the method used (4.1 or 4.2 or both);

d) the results of the determination;

e) any details not specified in this document or which are optional, as well as any factor which may have affected the results.

Annex A
(informative)

Density of water at different temperatures

Table A.1 shows the density of water at different temperatures according to Reference [2].

Table A.1 — Density of water at different temperatures

Temperature °C	Density of water g/cm³	Coefficient KF	Temperature °C	Density of water g/cm³	Coefficient KF
15,0	0,999 10	1,000 90	23,0	0,997 54	0,999 33
15,1	0,999 09	1,000 88	23,1	0,997 52	0,999 31
15,2	0,999 07	1,000 87	23,2	0,997 49	0,999 29
15,3	0,999 06	1,000 85	23,3	0,997 47	0,999 26
15,4	0,999 04	1,000 84	23,4	0,997 45	0,999 24
15,5	0,999 02	1,000 82	23,5	0,997 42	0,999 21
15,6	0,999 01	1,000 80	23,6	0,997 40	0,999 19
15,7	0,998 99	1,000 79	23,7	0,997 37	0,999 17
15,8	0,998 98	1,000 77	23,8	0,997 35	0,999 14
15,9	0,998 96	1,000 76	23,9	0,997 32	0,999 12
16,0	0,998 95	1,000 74	24,0	0,997 30	0,999 09
16,1	0,998 93	1,000 72	24,1	0,997 27	0,999 07
16,2	0,998 91	1,000 71	24,2	0,997 25	0,999 04
16,3	0,998 90	1,000 69	24,3	0,997 23	0,999 02
16,4	0,998 88	1,000 67	24,4	0,997 20	0,998 99
16,5	0,998 86	1,000 66	24,5	0,997 17	0,998 97
16,6	0,998 85	1,000 64	24,6	0,997 15	0,998 94
16,7	0,998 83	1,000 62	24,7	0,997 12	0,998 92
16,8	0,998 81	1,000 61	24,8	0,997 10	0,998 89
16,9	0,998 79	1,000 59	24,9	0,997 07	0,998 87
17,0	0,998 78	1,000 57	25,0	0,997 05	0,998 84
17,1	0,998 76	1,000 55	25,1	0,997 02	0,998 81
17,2	0,998 74	1,000 54	25,2	0,997 00	0,998 79
17,3	0,998 72	1,000 52	25,3	0,996 97	0,998 76
17,4	0,998 71	1,000 50	25,4	0,996 94	0,998 74
17,5	0,998 69	1,000 48	25,5	0,996 92	0,998 71
17,6	0,998 67	1,000 47	25,6	0,996 89	0,998 68
17,7	0,998 65	1,000 45	25,7	0,996 87	0,998 66
17,8	0,998 63	1,000 43	25,8	0,996 84	0,998 63
17,9	0,998 62	1,000 41	25,9	0,996 81	0,998 60
18,0	0,998 60	1,000 39	26,0	0,996 79	0,998 58
18,1	0,998 58	1,000 37	26,1	0,996 76	0,998 55
18,2	0,998 56	1,000 35	26,2	0,996 73	0,998 52
18,3	0,998 54	1,000 34	26,3	0,996 71	0,998 50

