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

**Part 2:
Determination of bulk density**

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

Partie 2: Détermination de la masse volumique



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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. 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. 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 WTO principles in the Technical Barriers to Trade (TBT), see the following URL: [Foreword - Supplementary information](#)

ISO 17892-2 was prepared by the European Committee for Standardization (CEN) Technical Committee CEN/TC 341, *Geotechnical investigation and testing*, in collaboration with Technical Committee ISO/TC 182, *Geotechnics*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This first edition of ISO 17892-2 cancels and replaces ISO/TS 17892-2:2004, which has been technically revised. It also incorporates the Technical Corrigendum ISO/TS 17892-2:2004/Cor 1:2006.

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 bulk density*
- *Part 3: Determination of particle density*
- *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 soils*
- *Part 8: Unconsolidated undrained triaxial test*
- *Part 9: Consolidated triaxial compression tests on water-saturated soils*
- *Part 10: Direct shear tests*
- *Part 11: Determination of permeability by constant and falling head*
- *Part 12: Determination of Atterberg limits*

Introduction

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

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Geotechnical investigation and testing — Laboratory testing of soil —

Part 2: Determination of bulk density

1 Scope

This International Standard specifies three methods for the determination of the bulk density of soils, comprising:

- a) linear measurement method;
- b) immersion in fluid method;
- c) fluid displacement method.

This International Standard is applicable to the laboratory determination of the bulk density of soil within the scope of geotechnical investigations.

The linear measurement method is suitable for the determination of the bulk density of a specimen of soil of regular shape, including specimens prepared for other tests. The specimens used are either rectangular prisms or cylinders with circular cross sections.

The immersion in fluid method covers the determination of the bulk density of a specimen of natural or compacted soil by measuring its mass in air and its apparent mass when suspended in fluid. The method may be used when lumps of material of suitable size can be obtained.

The fluid displacement method covers the determination of the bulk density of a specimen of soil by measuring its mass in air and the mass of fluid displaced by immersion. The method may be used when lumps of material of suitable size can be obtained.

If the immersion in fluid method or fluid displacement method is used, and if the fluid is likely to penetrate into the specimen (eg water) the specimen should be coated before testing to prevent fluid penetration.

The bulk density of a soil is useful in the determination of the *in situ* overburden stress as a function of depth.

If required, the dry density of a specimen may be calculated from the bulk density and the water content, if known.

NOTE This International Standard fulfils the requirements of the determination of the bulk density of soils for geotechnical investigation and testing in accordance with EN 1997-1 and 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 17892-1, *Geotechnical investigation and testing — Laboratory testing of soil — Part 1: Determination of water content*

ISO 14688-1, *Geotechnical investigation and testing — Identification and classification of soil — Part 1: Identification and description*

3 Terms and definitions

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

3.1 bulk density

ρ
mass of soil per unit volume of the material, including any water or gas it contains

3.2 dry density

ρ_d
mass of oven-dried soil per unit volume of the material

4 Equipment

4.1 Linear measurement method

The following items are necessary for the linear measurement method:

- 4.1.1 **Cutting and trimming tools** (e.g. a sharp knife, wire saw, spatula, cutting ring, soil lathe).
- 4.1.2 **Steel straight edge**, with a maximum deviation from straight of 0,1 % of its length.
- 4.1.3 **Try-square or a jig** (e.g. a mitre box) or **split mould** to ensure that flatness shall be accurate to within 0,5 % of each dimension and that right-angles are within 0,5° of true.
- 4.1.4 **Callipers**, either analogue or digital, readable to 0,1 mm or 0,1 % of the measured length, whichever value is the greater.
- 4.1.5 **Balance**, accurate to 0,01 g or 0,1 % of the weighed mass, whichever value is the greater.

4.2 Immersion in fluid method

The following items are necessary for the immersion measurement method:

- 4.2.1 **Container of a suitable size**.
- 4.2.2 **Balance**, accurate to 0,01 g or 0,1 % of the weighed mass, whichever is the greater.
- 4.2.3 **Thermometer or temperature measuring device**, accurate to 1°C.
- 4.2.4 **Cradle and supporting frame**, similar in principle to that shown in [Figure 1](#) which, with the frame attached to the scoop or platform of the balance, can support the cradle below the balance.
- 4.2.5 **Materials: modelling clay or putty and a suitable coating**, to prevent fluid penetration (if used, e.g. paraffin wax).
- 4.2.6 **Equipment for melting wax** (if used), preferably electrically heated and thermostatically controlled.

4.3 Fluid displacement method

The following items are necessary for the fluid displacement method:

4.3.1 Rigid container with a siphon tube. The container shall be large enough to accommodate the specimen.

4.3.2 Container, to collect the fluid siphoning over from the specimen container.

4.3.3 Balance, accurate to 0,01 g or 0,1 % of the weighed mass, whichever value is the greater.

4.3.4 Thermometer or temperature measuring device, accurate to 1°C.

4.3.5 Materials: modelling clay or putty and a suitable coating, to prevent fluid penetration (if used, e.g. paraffin wax).

4.3.6 Equipment for melting wax (if used), preferably electrically heated and thermostatically controlled.

Alternatively, the equipment described in [4.2](#) can be used. In such case, a correction for the uplift for the cradle shall be included in the calculations.

5 Test procedure

Test specimens should be at least 50 cm³ in volume, and preferably significantly larger.

NOTE If smaller specimens are tested they may be less representative of the material as a whole and the result may not be as accurate as suggested by the reported value.

5.1 Linear measurement method

5.1.1 General

The principle of the method is to weigh a specimen of known volume. Three procedures are specified for preparing the specimen. Other methods are also accepted if they provide representative specimens of regular shape.

5.1.2 Specimen from block sample

5.1.2.1 At least 10 mm from the outside face of the block sample shall be cut away and an approximately rectangular prism of soil slightly larger than the final dimensions of the specimen shall be formed. If the specimen is to be used for some other test, its shape and dimensions shall also be appropriate for that test.

5.1.2.2 For a rectangular prism specimen the faces shall be made plane and parallel by careful trimming and checking with a straight edge and try-square or other jig. The other four faces of the prism shall be trimmed so that they are mutually perpendicular and at right angles to the end faces.

5.1.2.3 For a cylindrical specimen the specimen shall be placed in a soil lathe and the excess soil removed with vertical cuts in thin layers. The specimen shall be rotated between each cut until a cylindrical specimen is produced. The specimen shall not be trimmed while it is being rotated. After trimming, the specimen shall be removed from the lathe. It shall be cut to the required length and the ends shall be made plane and normal to the specimen axis.

5.1.3 Specimen from sample tube

5.1.3.1 If the specimen is likely to deform on removal from the tube, its volume should be determined by measurement according to [5.1.5.4](#).

5.1.3.2 For samples that are extruded from a sample tube, measurements can be made directly on the sample. Remove the caps, wax or other sealing material from each end of the sample tube. Extrude the sample and trim surplus soil from the ends of the specimen until flat and perpendicular to the specimen axis. The measurements should then be made as soon as possible on the extruded sample.

5.1.4 Cylindrical specimen of smaller diameter than the sample tube

Either the sample may be extruded from the sample tube through a cylindrical cutter or a cylindrical cutter may be pushed into the sample. The sample tube or specimen cutter shall be pushed steadily at constant speed into the soil. The specimen shall be trimmed further to make the ends flat and perpendicular to the specimen axis, as necessary.

5.1.5 Measurements

5.1.5.1 The trimmed specimen shall be weighed to the nearest 0,01 g or 0,1 % of the total mass, whichever is the greater (m).

5.1.5.2 For a rectangular prism specimen, the lengths of the specimen shall be measured in at least three positions in each dimension to the nearest 0,1 mm or 0,1 % of the dimension being measured, whichever is the greater.

5.1.5.3 For a cylindrical specimen, the diameter shall be measured in two perpendicular directions, at each end and near the middle, to the nearest 0,1 mm or 0,1 % of the dimension being measured, whichever is the greater. The length shall be measured along three lines spaced at about 120° around the circumference, to the nearest 0,1 mm or 0,1 % of the dimension being measured, whichever is the greater.

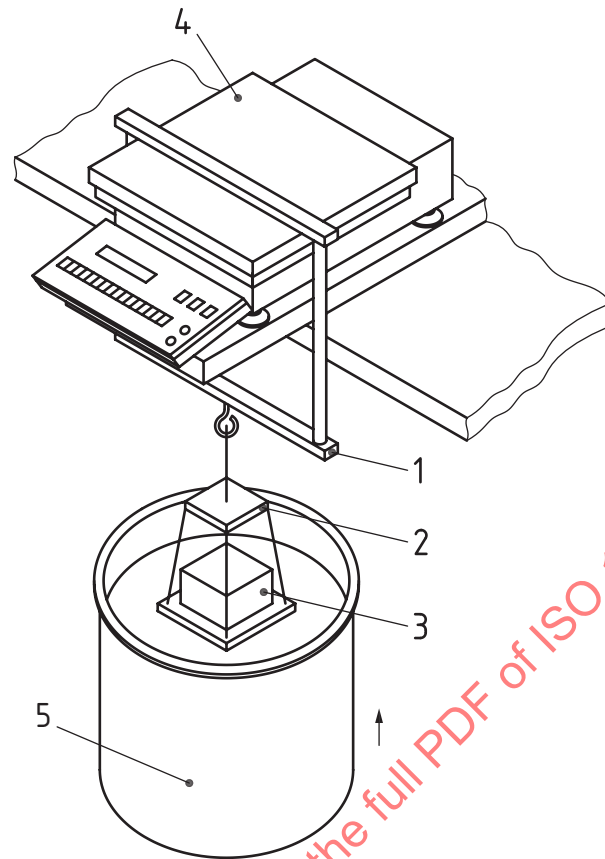
5.1.5.4 If the specimen is likely to deform on removal from the tube its volume should be determined by measuring the inside diameter and the length of the sample tube. If the tube is not full, allowance should be made for any missing sample. Each length shall be measured to the nearest 0,1 mm or 0,1 % of the dimension being measured, whichever is the greater. The mass of the specimen should then be determined by difference, by weighing the tube with the specimen and the clean tube after extrusion of the specimen.

5.1.5.5 If the dry density is required, the water content of a representative portion of the sample shall be determined in accordance with ISO 17892-1.

5.2 Immersion in fluid method

5.2.1 Equipment preparation

5.2.1.1 The balance shall be supported with the platform over the container and with sufficient clear space between the underside of the supports and the top of the container. A suitable arrangement is shown in [Figure 1](#).



Key

- 1 supporting frame
- 2 cradle
- 3 specimen (with coating if used)
- 4 balance
- 5 fluid container

Figure 1 — Method of determining density by immersion in fluid

5.2.1.2 The cradle, supporting frame and fluid container shall be adjusted so that the cradle is suspended in the fluid without touching either the bottom or the sides of the container. The container shall be filled with fluid to a depth so that the specimen to be tested shall be completely submerged when on the cradle.

5.2.1.3 Set the balance reading to zero or otherwise record the indicated reading.

5.2.2 Specimen preparation and measurements

5.2.2.1 The soil specimen shall be trimmed if necessary.

5.2.2.2 The specimen shall be weighed to the nearest 0,01 g or 0,1 % of the mass whichever is the greater (m).

5.2.2.3 All the surface voids of the specimen shall be filled with a material which is insoluble in the fluid and the specimen shall be re-weighed to the nearest 0,01 g or 0,1 % of the mass, whichever is the greater (m_f). Care should be taken to fill only natural air voids present in the sample before sampling (generally with wax or putty) and not the cavities resulting from loss of coarse particles during collection

and preparation of the specimen. In filling the voids the material used should be trimmed level with the surface of the specimen.

5.2.2.4 The specimen shall be coated completely if the chosen fluid can penetrate into the specimen. For example, if coating with wax the specimen should be repeatedly dipped into molten wax, allowing each layer of wax to solidify before further dipping. To avoid shrinking and cracking of the wax, it should be only just molten when applied.

5.2.2.5 Coating of the specimen should be carried out very carefully ensuring, for example, that air bubbles are not formed under the coating.

5.2.2.6 Once completely coated, the specimen shall be allowed to cool, if necessary, and shall be re-weighed to the nearest 0,01 g or 0,1 % of the mass, whichever is the greater (m_c).

5.2.2.7 The specimen shall be placed in the cradle suspended from the supporting frame attached to the balance. The specimen shall be placed in the fluid taking care that no air bubbles are trapped underneath the specimen. Adjust the fluid level so that the specimen is completely submerged and so that the cradle is at about the same depth in the fluid as in [5.2.1.2](#).

5.2.2.8 Record the temperature of the immersion fluid.

5.2.2.9 The buoyant mass of the specimen shall be measured while suspended in fluid to the nearest 0,01 g or 0,1 % of the mass, whichever is the greater (m_g).

5.2.2.10 If the dry density is required, the specimen shall be removed from the cradle, allowed to surface dry or otherwise have excess surface fluid removed, and then be broken open. A portion of the specimen shall be taken which is completely free from coating, wax, modelling clay or putty and its water content shall be determined in accordance with ISO 17892-1.

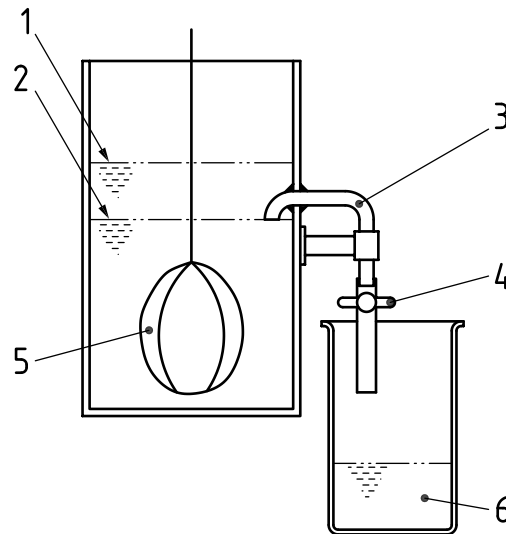
5.3 Fluid displacement method

5.3.1 Equipment preparation

5.3.1.1 The general arrangement of the equipment is shown in [Figure 2](#).

5.3.1.2 Stand the specimen container on a level base and fill with fluid until the level of the liquid is well above the siphon tube. Allow excess fluid to siphon to waste.

5.3.1.3 The receiving container shall be weighed to the nearest 0,01 g or 0,1 % of the mass, whichever is the greater (m_1) and it shall then be placed below the siphon outlet.

**Key**

- 1 displaced fluid level
- 2 final fluid level
- 3 siphon tube
- 4 tap or clip
- 5 specimen (with coating if used)
- 6 displaced fluid

Figure 2 — Method of determining density by fluid displacement

5.3.2 Specimen preparation and measurements

5.3.2.1 The soil specimen shall be trimmed if necessary.

5.3.2.2 The specimen shall be weighed to the nearest 0,01 g or 0,1 % of the mass, whichever is the greater (m).

5.3.2.3 All the surface voids of the specimen shall be filled with a material which is insoluble in the fluid and the specimen shall be re-weighed to the nearest 0,01 g or 0,1 % of the mass, whichever is the greater (m_f). Care should be taken to fill only natural air voids present in the sample before sampling (generally with wax or putty) and not the cavities resulting from loss of coarse particles during collection and preparation of the specimen. In filling the voids the material used should be trimmed level with the surface of the specimen.

5.3.2.4 The specimen shall be coated completely if the chosen fluid can penetrate into the specimen. For example, if coating with wax, the specimen shall be coated completely by repeating dipping in molten wax, allowing each layer of wax to solidify before further dipping. To avoid shrinking and cracking of the wax, it should be only just molten when applied.

5.3.2.5 Coating of the specimen should be carried out very carefully ensuring, for example, that air bubbles are not formed under the coating.

5.3.2.6 Once completely coated, the specimen shall be allowed to cool, if necessary, and shall be re-weighed to the nearest 0,01 g or 0,1 % of the mass, whichever is the greater (m_c).

5.3.2.7 The specimen shall be lowered carefully into the container so that the whole specimen is submerged below the inlet to the siphon. When the specimen is placed in the fluid in the container care should be taken to see that no air bubbles are trapped underneath the specimen.

5.3.2.8 Record the temperature of the fluid that the sample is placed into.

5.3.2.9 The tap or clip on the siphon outlet tube shall be opened, allowing the displaced fluid to siphon over into the receiving container. The receiving container and fluid shall be weighed to the nearest 0,01 g or 0,1 % of the mass, whichever is the greater (m_2).

5.3.2.10 If the dry density is required, the specimen shall be removed from the cradle, allowed to surface dry or otherwise have excess surface fluid removed, and then be broken open. A portion of the specimen shall be taken which is completely free from coating, wax, modelling clay or putty and its water content shall be determined in accordance with ISO 17892-1.

6 Test results

6.1 Volume

6.1.1 Linear Method

Calculate the average of the measurements of each dimension of the sample (in millimetres).

For rectangular prisms calculate the volume of the test specimen V from Formula (1):

$$V = L \times W \times H \times 10^{-9} \text{ m}^3 \quad (1)$$

where

L is the average of the measurements of the length of one dimension (mm);

W is the average of the measurements of the length of the second dimension (mm);

H is the average of the measurements of the length of the remaining dimension (mm).

For cylindrical specimens, calculate the volume V from Formula (2):

$$V = \left[\pi \times \frac{d^2}{4} \times L \right] \times 10^{-9} \text{ m}^3 \quad (2)$$

where

d is the average of the six measurements of the diameter of the specimen (mm);

L is the average of the three measurements of the length of the specimen (mm).

6.1.2 Immersion in fluid method

The volume of the test specimen V shall be calculated from Formula (3):

$$V = \left[\frac{(m_c - m_g)}{\rho_{fl}} - \frac{(m_c - m_f)}{\rho_p} \right] \times 10^{-6} \text{ m}^3 \quad (3)$$

where

m_c is the mass of the immersed specimen (including the mass of coating if used) (g);

m_g is the apparent mass of specimen (and coating if used) when suspended in the fluid (g);

m_f is the mass of specimen after making up surface voids with filler (excluding coating) (g);

ρ_{fl} is the density of the immersion fluid at the test temperature (Mg/m³);

ρ_p is the density of the coating (Mg/m³).

NOTE The quoted unit of Mg/m³ for the density of the coating and of the immersion fluid has the same numerical value as the density expressed in g/cm³.

6.1.3 Fluid displacement method

The volume of the test specimen V shall be calculated from Formula (4):

$$V = \left[\frac{(m_2 - m_1)}{\rho_{fl}} - \frac{(m_c - m_f)}{\rho_p} \right] \times 10^{-6} \text{ m}^3 \quad (4)$$

where

m_1 is the mass of the fluid container (g);

m_2 is the mass of the fluid container and fluid siphoned into it (g);

m_c is the mass of specimen after coating (g);

m_f is the mass of specimen after filling surface voids (g);

ρ_{fl} is the density of fluid at the test temperature (Mg/m³);

ρ_p is the density of coating material (Mg/m³).

6.2 Bulk density

The bulk density, ρ , shall be calculated from Formula (5):

$$\rho = \frac{m}{V} \times 10^{-6} \text{ Mg/m}^3 \quad (5)$$

where

m is the specimen mass (g);

V is the volume of the specimen (m³).

6.3 Dry density

If required, the dry density of the specimen ρ_d shall be calculated from Formula (6):

$$\rho_d = \frac{\rho}{1 + (w / 100)} \text{ Mg/m}^3 \quad (6)$$

where w is the water content of the soil, expressed as a percentage of dry mass.

NOTE The term unit weight is often used and is calculated by multiplying the density by the acceleration due to gravity.

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) method of test used;
- b) identification of the specimen tested, e.g. by borehole number, sample number and sample depth and any other relevant details required, e.g. depth of specimen within a sample, method of sample selection if relevant;
- c) a visual description of the specimen including any observed features noted after testing, following the principles in ISO 14688-1;
- d) bulk density expressed to two decimal places;
- e) if required, the dry density expressed to two decimal places and the water content of the soil reported in accordance with ISO 17892-1;
- f) specimen size if less than 50 cm³ and any deviation from this specified procedure.

Annex A

(normative)

Calibration, maintenance and checks

A.1 General requirements

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

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

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

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

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

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

A.2 Environmental conditions

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

A.3 Equipment

A.3.1 Balances

Balances shall be calibrated over their working range, using certified reference weights, at least once a year. Reference weights shall be appropriate to the category of balance being calibrated, and shall have a tolerance (maximum permissible error) better than the resolution of the balance to be calibrated. Reference weights shall be calibrated when first brought into use and thereafter at least every two years.

Balances shall be checked on each day of use to confirm the zero point and to confirm the mass of a test item of known mass. The test item should not corrode or otherwise change mass with time, and should have a mass within the range 50 % to 80 % of the working range of the balance. The results of these checks shall be recorded. If the balance cannot be zeroed or the mass of the test weight is found to be outside the tolerance specified in 4.3, the balance shall be taken out of service until remedial action is complete.