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Geotechnical investigation and testing — Laboratory testing of soil —

Part 2: Determination of density of fine-grained soil

Reconnaissance et essais géotechniques — Essais de sol au laboratoire —

Partie 2: Détermination de la masse volumique d'un sol fin

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

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

— *Part 1: Determination of water content*

— *Part 2: Determination of density of fine-grained soil*

— *Part 3: Determination of particle density — Pycnometer method*

— *Part 4: Determination of particle size distribution*

— *Part 5: Incremental loading oedometer test*

— *Part 6: Fall cone test*

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

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Contents

Page

Figures

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Foreword

This document (CEN ISO/TS 17892-2:2004) 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 12: Determination of the Atterberg limits*

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Introduction

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

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1 Scope

This document specifies methods of test for the determination of the bulk and dry density of intact soil or rock within the scope of the geotechnical investigations according to prEN 1997-1 and prEN 1997-2.

The bulk density of a soil is useful in the determination of the in-situ overburden stresses at various depth (geostatic stresses). Furthermore, bulk and dry density can qualitatively describe the mechanical characteristics of a soil via empirical relationships which are to be found in the technical literature. Such relationships should be used only as guidelines and should be supplemented by direct measurements of the mechanical characteristics.

This document describes three methods:

a) linear measurements method;

b) immersion in water method;

c) fluid displacement method.

The linear measurement method is suitable for the determination of the density of a specimen of cohesive soil of regular shape, including specimens prepared for other tests. The specimens used are normally in the form of either rectangular prisms or straight cylinders.

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

The fluid displacement method covers the determination of the bulk density and dry density of a specimen of soil by measuring mass and displacement of water or other appropriate fluid after immersion. The method is employable whenever lumps of material of suitable size can be obtained.

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2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

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

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

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3 Terms and definitions

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

3.1
bulk density
ρ
mass of soil or rock per unit volume of the material, including any water or gas it contains

3.2
dry density
ρ_d
mass of oven-dried soil contained in a unit volume

NOTE The term unit weight, denoted by γ, is used when calculating the force exerted by a mass of soil, and is derived from the mass density by the equation $\gamma = \rho \cdot g$, where g is the acceleration due to gravity (in m/s²). The value of g varies between 9,82 m/s², and 9,79 m/s², depending upon latitude.

3.3
undisturbed sample
normally a sample of quality class 1, according to prEN 1997-2

4 Equipment

4.1 Linear measurement method

The following items are necessary for the linear measurement method:

— Cutting and trimming tools (e.g. a sharp knife, wire saw, spatula, scoop);

— steel straightedge and try-square;

— steel rule;

— vernier callipers;

— balance, accuracy 0,03 g;

— apparatus for water content determination according to CEN ISO/TS 17892-1.

4.2 Immersion in water method

The following items are necessary for the immersion measurement method:

— A watertight container of a suitable size;

— a balance, accuracy 0,3 g;

— a 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;

— equipment for melting paraffin wax;

— apparatus for water content determination according to CEN ISO/TS 17892-1;

— materials: plasticine or putty and paraffin wax.

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4.3 Fluid displacement method

The following items are necessary for the fluid displacement method:

— A cylindrical metal container with a siphon tube;

— a tight container to act as a receiver for the fluid siphoning over from the container;

— a balance, accuracy 0,3 g;

— equipment for melting paraffin wax;

— apparatus for water content determination according to CEN ISO/TS 17892-1;

— materials: plasticine or putty and paraffin wax;

— alternatively, the apparatus 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

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 undisturbed 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 be appropriate for that test, too.

5.1.2.2 The ends of the prism shall be made plane and parallel using the mitre box, or by careful trimming and checking with straightedge and try square on the glass plate. The test specimen may be either rectangular or cylindrical.

5.1.2.3 For a rectangular specimen the other four faces of the prism shall be trimmed so that they are mutually perpendicular and at right angles to the end faces. Flatness and squareness shall be accurate to within 0,5 % of each dimension.

5.1.2.4 For a cylindrical specimen the specimen shall be placed in a soil lathe and the excess soil cut 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 moved from the lathe. It shall be cut to the required length and the ends shall be made plane and normal to the specimen axis to within 0,5°. A split mould may be used as a jig for this operation if of sufficient accuracy.

5.1.3 Specimen directly extruded from sample tube

5.1.3.1 End caps and wax or other protective material shall be removed from each end.

5.1.3.2 Each end of the sample shall be trimmed to give a flat surface normal to the axis of the tube.

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5.1.3.3 The sample shall be extruded by using an appropriate mechanical sample extruder.

5.1.3.4 Surplus soil shall be cut off and the ends of the specimen shall be trimmed flat and perpendicular to the specimen axis. The specimen shall be protected from loss of moisture until the specimen is ready to be tested.

5.1.4 Cylindrical specimen of smaller diameter than the sampling tube.

5.1.4.1 A thin-walled tube shall be clamped firmly in the holding jig.

5.1.4.2 The tube shall be pushed steadily at constant speed into the soil until the tube is nearly full, maintaining alignment of the axis of the tube with the direction of motion.

5.1.4.3 The tube shall be rotated through 360° to shear the specimen and the tube shall be withdrawn.

5.1.4.4 The specimen shall be removed from the tube and trimmed, if necessary.

5.1.5 Measurements

5.1.5.1 The trimmed specimen shall be weighed to the nearest 0,01 g.

5.1.5.2 For a specimen consisting of a rectangular prism, the length of each face shall be measured and recorded along the edges and near the mid-face to the nearest 0,1 mm.

5.1.5.3 For a cylindrical specimen of stiff soil, the diameter shall be measured and recorded in two perpendicular directions, at each end and near the middle, to the nearest 0,1 mm. The length shall be measured along three lines spaced at about 120° around the curved surface, to the nearest 0,1 mm.

5.1.5.4 If the specimen is likely to deform on removal from the tube its volume should be determined by measuring to the nearest 0,1 mm the tube diameter and length, and the distance from each end of the tube to the trimmed ends of the specimen. In this case the mass of the specimen should be determined by weighing the tube before and after extrusion of the specimen.

5.2 The immersion in water method

5.2.1 Equipment preparation

5.2.1.1 The balance shall be supported with the scoop or 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.

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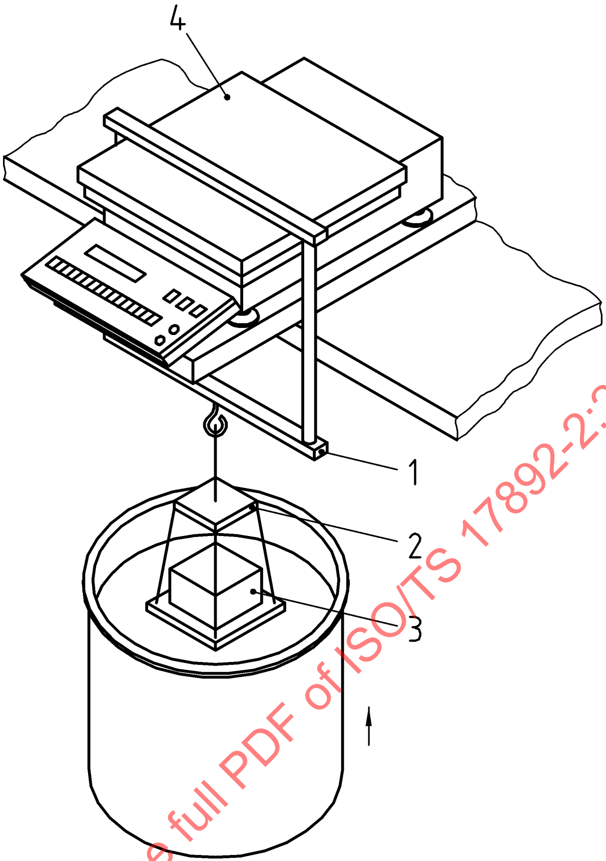

Key
1 Supporting frame
2 Cradle
3 Waxed specimen
4 Balance

Figure 1 — Method of determining density by immersion in water

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5.2.1.2 The container shall be filled with water almost to the top. The cradle and supporting frame shall be adjusted, so that the cradle is suspended in the water without touching either the bottom or the sides of the container. The largest specimen to be tested shall be immersed completely when on the cradle.

5.2.1.3 The counter-mass shall be placed on the scale plan to bring the reading on the balance back to zero if a two-plan balance is used, or the tare device shall be used to set the balance reading to zero.

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 0,1 g (m).

5.2.2.3 All the surface voids of the specimen shall be filled with a material which is insoluble in water e.g. plasticine or putty (see 5.2.2.7) and the specimen (m_f) shall be weighed.

5.2.2.4 When necessary, the specimen shall be coated completely by repeating dipping in molten paraffin wax (see 5.2.2.8 and 5.2.2.9). The waxed specimen shall cool and shall be weighed to the nearest 0,1 g (m_w).

5.2.2.5 The waxed specimen shall be placed in the cradle and the cradle shall be suspended from the supporting frame attached to the scoop or platform of the balance. The buoyant mass of the specimen shall be measured while suspended in water to the nearest 0,1 g (m_g) (see 5.2.2.10).

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5.2.2.6 The specimen shall be removed from the cradle, allowed to surface dry and broken up. A portion of the soil shall be taken which is completely free from paraffin wax, plasticine or putty and its water content w shall be determined.

5.2.2.7 Care should be taken to fill only air voids and not the holes resulting from loss of stone during collection and preparation of the specimen. In filling the voids the material used should be trimmed level with the surface of the specimen.

5.2.2.8 Waxing of the specimen should be carried out very carefully. Surface depressions, including cavities left by stones, should be first coated with molten wax applied by brush, and allowed to set before dipping. Ensure that air bubbles are not formed under the wax.

5.2.2.9 To avoid shrinking and cracking of the wax-coating the wax should be only just molten when applied. In the absence of a thermostatically controlled wax-pot, use of a carpenter's glue pot helps to avoid overheating of the wax.

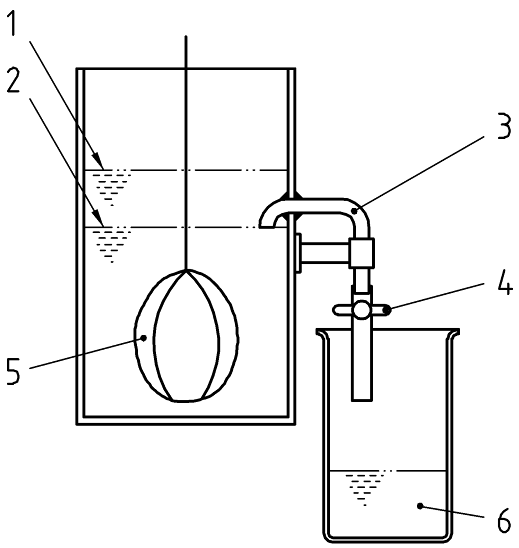
5.2.2.10 When the specimen is placed in the water, supported by the cradle, care should be taken to see that no air bubbles are trapped underneath the specimen. Also, while measuring the apparent mass when suspended in water ensure that the specimen is immersed completely. If this is not the case either the level of the water in the container should be raised or the supporting frame should be adjusted until the specimen is immersed completely. The specimen should then be removed from the cradle and the apparatus readjusted. Some parts of the cradle may be submerged to different degrees during weighing. The volume of these parts should be negligible compared to the volume of the specimen.

5.3 Fluid displacement method

5.3.1 Equipment preparation

5.3.1.1 The metal container shall be stood on a level base and fluid shall be poured into the container until the level of the liquid is well above the siphon tube. Excess fluid should be able to run to waste (see Figure 2).

5.3.1.2 The container shall be weighed for receiving the fluid to the nearest 0,1 g (m_1), and it shall then be placed below the siphon outlet.



Key

1 Displaced water level
2 Final water level
3 Siphon tube
4 Clip
5 Waxed specimen suspended by wire
6 Displaced water

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.

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5.3.2.2 The specimen shall be weighed to the nearest 0,1 g (m).

5.3.2.3 All the surface air voids of the specimen shall be filled with a material which is insoluble in the fluid (see 5.3.2.7). Cavities left by removal of stones shall not be filled. The specimen shall be weighed to the nearest 0,1 g (m_f).

5.3.2.4 When necessary, the specimen shall be coated completely by repeated dipping in molten paraffin wax (see 5.3.2.8 and 5.3.2.9) The specimen shall be cooled and then weighed to the nearest 0,1 (m_w).

5.3.2.5 The specimen shall be lowered carefully into the container so that no portion of the specimen is projecting above the level of the siphon. The clip shall be released on the siphon outlet tube, allowing the displaced fluid to siphon over into the receiver (see 5.3.2.10). The receiver and fluid shall be weighed to the nearest 0,1 g (m_2).

5.3.2.6 The specimen shall be removed from the container, allowed to surface dry and broken up. A representative part of the specimen shall be taken, completely free from paraffin wax, plasticine or putty and water content w shall be determined.

5.3.2.7 Care should be taken to fill only air voids and not the holes resulting from loss of stone during collection and preparation of the specimen. In filling the voids the material used should be trimmed level with the surface of the specimen.

5.3.2.8 To avoid shrinking and cracking of the wax-coating the wax should be only just molten when applied. Cavities considered to be parts of existing voids, e. g. in compacted soils, due to poor compaction, should be made up with filler before waxing.

5.3.2.9 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.

6 Test results

6.1 Linear measurement method

6.1.1 Bulk density

The bulk density ρ shall be calculated from the equation (1):

$$\rho = \frac{m}{V} \text{ (in Mg/m}^3\text{)} \tag{1}$$

where

m is the specimen mass (g);

V is the volume of the specimen (cm³).

6.1.2 Dry density

If the water content w of the soil is known, the dry density of the specimen ρ_d shall be calculated from the equation (2):

$$\rho_d = \frac{\rho}{1+w} \text{ (in Mg/m}^3\text{)} \tag{2}$$

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where

w is the water content, expressed as decimal fraction of dry mass.

6.2 Immersion in water method

6.2.1 Volume

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

$$V = \frac{(m_w - m_g)}{\rho_w} - \frac{(m_w - m_f)}{\rho_p} \text{ (in cm}^3\text{)} \quad (3)$$

where

m_w is the mass of specimen and wax coating (g);

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

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

ρ_p is the density of paraffin wax (Mg/m³);

ρ_w is the density of the water (Mg/m³).

6.2.2 Bulk density

The bulk density of the specimen ρ shall be calculated from the equation (4):

$$\rho = \frac{m}{V} \text{ (in Mg/m}^3\text{)} \quad (4)$$

where

m is the mass of the soil specimen (g).

6.2.3 Dry density

The dry density of the specimen ρ_d shall be calculated from the equation (5):

$$\rho_d = \frac{\rho}{1 + w} \text{ (in Mg/m}^3\text{)} \quad (5)$$

where

w is the water content of the soil, expressed as a decimal fraction of dry mass.

6.3 Fluid displacement method

6.3.1 Volume

The volume of the test specimen V shall be calculated from the equation (6):

$$V = \frac{(m_2 - m_1)}{\rho_f} - \frac{(m_w - m_f)}{\rho_p} \text{ (in cm}^3\text{)} \quad (6)$$

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