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**Soil quality — Determination of hydraulic  
conductivity of saturated porous  
materials using a flexible wall  
permeameter**

*Qualité du sol — Détermination de la conductivité hydraulique de  
matériaux poreux saturés à l'aide d'un perméamètre à paroi flexible*

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Case postale 56 • CH-1211 Geneva 20  
Tel. + 41 22 749 01 11  
Fax + 41 22 749 09 47  
E-mail [copyright@iso.org](mailto:copyright@iso.org)  
Web [www.iso.org](http://www.iso.org)

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 17313 was prepared by Technical Committee ISO/TC 190, *Soil quality*, Subcommittee SC 5, *Physical methods*.

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## Introduction

The rate of water flow through the soil is of considerable importance in many aspects of agricultural and urban life. The entry of water into soil, the movement of water to plant roots, the flow of water to drains and wells, and the evaporation of water from the soil surface are but a few of the obvious situations in which the rate of water flow plays an important role. Also in cases of soil pollution and polluted groundwater, prediction of the rate of movement of soil water is of great importance in obtaining information about the spreading of pollutants.

The soil properties that determine the behaviour of soil water flow systems are the hydraulic conductivity and water retention characteristics. The hydraulic conductivity of soil is a measure of its ability to transmit water. The water retention characteristics are an expression of its ability to store water. These properties determine the response of a soil water system to imposed boundary conditions.

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# Soil quality — Determination of hydraulic conductivity of saturated porous materials using a flexible wall permeameter

## 1 Scope

This International Standard specifies a test method for laboratory measurement of the hydraulic conductivity of water-saturated porous materials using a flexible wall permeameter.

This International Standard is applicable to undisturbed or compacted specimens that have a hydraulic conductivity between  $1 \times 10^{-5}$  m/s ( $1 \times 10^{-3}$  cm/s) and  $1 \times 10^{-11}$  m/s ( $1 \times 10^{-9}$  cm/s). Typical soil types falling in this category are clay, clay and sand tills, silt, peat, mud, etc.

## 2 Terms and definitions

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

### 2.1 hydraulic conductivity

*k*

rate of discharge of water under laminar flow conditions through a unit cross-sectional area of a porous medium under a unit hydraulic gradient and standard temperature conditions (usually 20 °C)

### 2.2

#### pore volume of flow

cumulative quantity of flow into a test specimen divided by the volume of voids in the specimen

### 2.3

#### hydraulic gradient

change in total hydraulic head of water per unit distance of flow

## 3 Significance and use

This test method applies to the one-dimensional, laminar flow of water from bottom to top within porous materials such as soil and rock.

The hydraulic conductivity of porous materials generally decreases with an increasing amount of air in the pores of the material. This test method applies to water-saturated porous materials containing almost no air.

This test method applies to permeation of porous materials with water. Permeation with other liquids, such as chemical wastes, can be accomplished using procedures similar to those described in this test method. However, this test method is only intended for use when water is the permeant liquid.

It is assumed that Darcy's law is valid and that the hydraulic conductivity is essentially unaffected by hydraulic gradient. The validity of Darcy's law can be evaluated by measuring the hydraulic conductivity of the specimen at three hydraulic gradients; if all measured values are similar (within about 25 %), then Darcy's law may be taken as valid. However, when the hydraulic gradient acting on a test specimen is changed, the state of stress will also change, and, if the specimen is compressible, the volume of the specimen will change. Thus, some

change in hydraulic conductivity can occur when the hydraulic gradient is altered, even in cases where Darcy's law is valid.

Normally, hydraulic conductivity measured by laboratory testing is different from large-scale field-test results. The reason is that samples of the size described in this International Standard are representative for homogeneous soil, but seldom for stratified, fissured or other non-homogeneous soil. In order to obtain results representing the hydraulic conductivity in the field in these cases, large-scale samples or field-testing shall be considered.

## 4 Reagents

### 4.1 Permeant water, as specified by the requester.

If no specification is made, tap water shall be used for the permeant liquid. The type of water utilized shall be indicated in the test report.

### 4.2 De-aerated water.

To avoid introducing air, and to aid in removing as much air from the test specimen as possible, de-aerated water shall be used. To prevent dissolution of air back into the water, de-aerated water shall not be exposed to air for prolonged periods.

## 5 Apparatus

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### 5.1 Hydraulic system

Constant head (Method A), falling head (Methods B and C), or constant rate of flow (Method D) systems may be utilized provided they meet the criteria outlined as follows.

#### a) Constant head (Method A)

The system shall be capable of maintaining constant hydraulic pressure. Pressures shall be measured by a pressure gauge, electronic pressure transducer or any other device of suitable accuracy.

#### b) Falling head

The system shall allow for measurement of the loss of applied head. The head loss shall be measured with a pressure gauge, electronic pressure transducer, engineer's scale, graduated pipette, or any other device of suitable accuracy. Falling head tests may be performed with either a constant tail water elevation (Method B) or a rising tail water elevation (Method C).

#### c) Constant rate of flow (Method D)

The system shall be capable of maintaining a constant rate of flow through the specimen to within  $\pm 5\%$  or better. Flow measurement shall be by calibrated syringe, graduated pipette, or other device of suitable accuracy.

The hydraulic system shall be designed to facilitate rapid and complete removal of free air bubbles from flow lines.

The hydraulic system shall have the capability to apply back-pressure to the specimen to facilitate saturation. The back-pressure may be provided by a compressed gas supply, a deadweight acting on a piston, or any other method capable of applying and controlling the back-pressure to the tolerance required.

The above-mentioned test methods are considered equivalent. The accuracy of the test results depends on the instruments used.



## 5.2 Flow measurement system.

Both inflow and outflow volumes shall be measured, unless the lack of leakage, continuity of flow and cessation of consolidation or swelling can be verified by other means. Flow volumes shall be measured by a graduated accumulator, graduated pipette or vertical standpipe in conjunction with an electronic pressure transducer or other column-measuring device of suitable accuracy.

Head losses in the tubes, valves, porous end pieces, and filter paper may lead to error, and shall be less than 10 % of the head loss of the sample.

## 5.3 System for pressurizing the permeameter cell.

The pressurizing system may consist of a reservoir connected to the permeameter cell and partially filled with de-aerated water, with the upper part of the reservoir connected to a compressed gas supply or other source of pressure. The gas pressure shall be controlled by a pressure regulator and measured by a pressure gauge, electronic pressure transducer or any other device capable of measuring to the tolerance required. A hydraulic system pressurized by deadweight acting on a piston or any other pressure device capable of applying and controlling the permeameter cell pressure to the tolerance required may be used.

**5.4 Permeameter cell**, in which the specimen and porous end pieces, enclosed by a membrane sealed to the cap and base, are subjected to controlled fluid pressures.

A cell (5) in a typical permeameter system is shown in Figure 1. The permeameter cell may allow for observation of changes in height ( $l_0$ ) of the soil sample.

In order to facilitate gas removal, and thus saturation of the hydraulic system, drainage lines lead to the test specimen, to the base and top cap. The drainage lines shall be controlled by no-volume-change valves, such as ball valves, and shall be designed to minimize dead space in the lines.

**5.5 Top cap and base**, impermeable and rigid, to support the specimen and provide for transmission of permeant liquid to and from the specimen.

**5.6 Flexible membrane**, used to encase the specimen and provide reliable protection against leakage.

The membrane shall be carefully inspected prior to use, and if any flaws or pinholes are evident, the membrane shall be discarded. To minimize restraint of the specimen, the diameter or width of the unstretched membrane shall be between 90 % and 95 % that of the specimen. The membrane shall be sealed to the specimen base and cap by rubber O-rings for which the unstressed, inside diameter is less than 90 % of the diameter of the base and cap, or by any other method that will produce an adequate seal.

**5.7 Porous end pieces**, of silicon carbide, aluminium oxide, or other material that is not attacked by the specimen or permeant liquid.

The end pieces shall have plane and smooth surfaces and be free of cracks, chips and non-uniformities. They shall be checked regularly to ensure that they are not clogged. The hydraulic conductivity of the porous end pieces shall be significantly greater than that of the specimen to be tested.

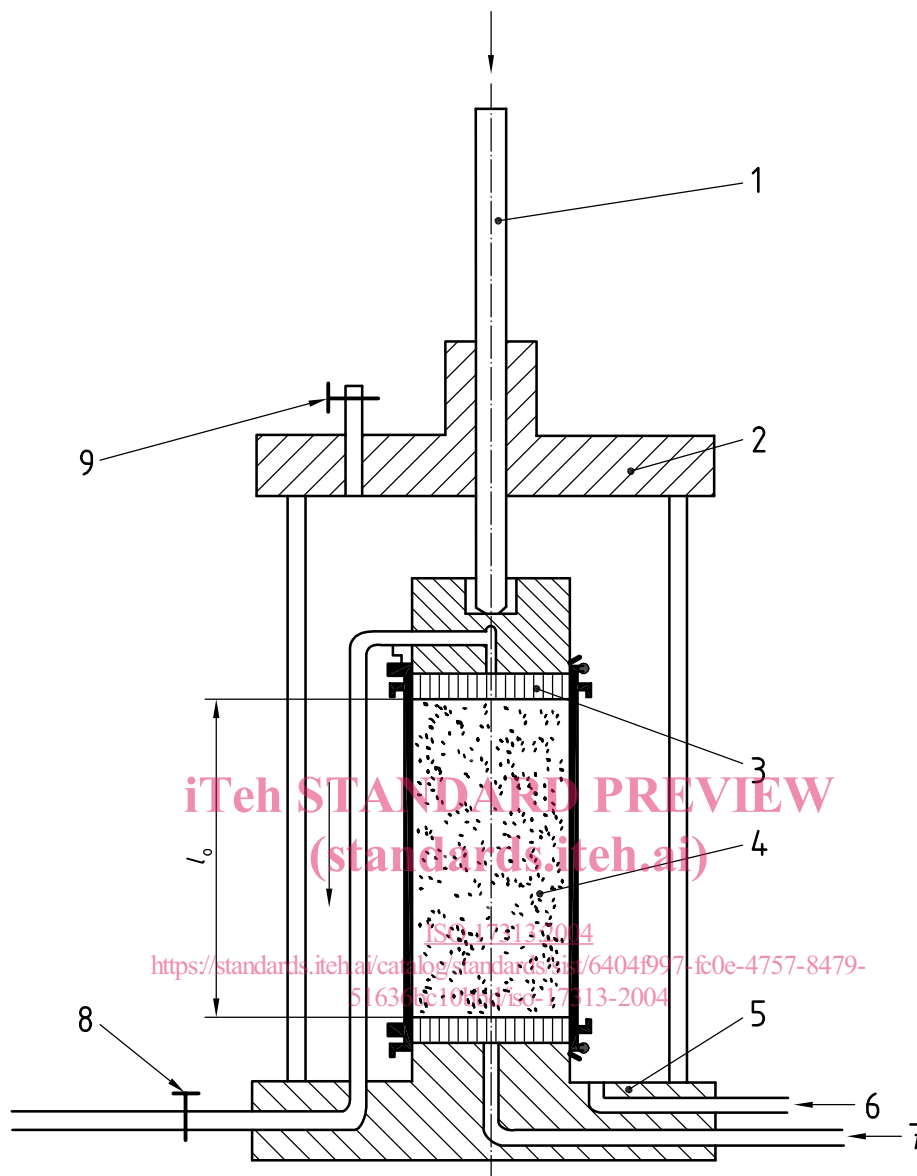
**5.8 Filter paper** (optional), to prevent intrusion of material into the pores of the porous end pieces.

If necessary, one or more sheets of filter paper shall be placed between the top and bottom porous end pieces and the specimen. The paper shall have a negligibly small hydraulic resistance.

**5.9 Equipment** (including compactor and mould) suitable **for compacting a specimen** by the method of compaction specified by the requester.

## 5.10 Sample extruder.

When the material being tested is a soil core, the soil core shall usually be removed from the sampler with an extruder.



**Key**

- 1 observation of changes of height
- 2 cell
- 3 porous end piece
- 4 soil test specimen
- 5 cell
- 6 cell pressure line
- 7 inlet line
- 8 outlet line
- 9 vent

**Figure 1 — Schematic diagram of a typical permeameter system**

### 5.11 Equipment for trimming the specimen to the desired dimensions.

This equipment will vary depending on the quality and characteristics of the sample. The following items may be used:

- a) lathe,
- b) wire saw with a wire about 0,3 mm in diameter,
- c) spatulas,
- d) knives,
- e) steel rasp for very hard clay specimens,
- f) cradle or split mould for trimming specimen ends,
- g) steel straight edge for final trimming of specimen ends.

**5.12 Equipment for mounting the specimen** in the permeameter cell, including a membrane stretcher or cylinder, and ring for expanding and placing O-rings on the base and top cap to seal the membrane.

### 5.13 Temperature-maintaining device.

The temperature of the permeameter, test specimen and reservoir of permeant liquid shall not vary more than  $\pm 3$  °C. Normally, this is accomplished by performing the test in a room with a relatively constant temperature. If such a room is not available, the apparatus shall be placed in a water bath, insulated chamber, or other device that maintains a constant temperature. The temperature shall be periodically measured and recorded.

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## 6 Test specimen

### 6.1 Specimen dimensions

Specimens shall have a minimum diameter of 70 mm and a minimum height of 25 mm. The diameter and height of the specimen shall each be at least six times greater than the largest particle size within the specimen. If, after completion of a test, it is found based on visual observation that oversized particles are present, that information shall be indicated in the test report.

### 6.2 Undisturbed specimen

Specimens obtained by tube sampling or coring may be tested without trimming, except for cutting the end surfaces plane and perpendicular to the longitudinal axis of the specimen, provided soil characteristics are such that no significant disturbance results from sampling. If the sampling operation has caused disturbance of the soil, the disturbed material shall be trimmed. If removal of pebbles or crumbling resulting from trimming causes voids in the surface of the specimen, the voids shall be filled with remoulded material obtained from the trimmings. The ends of the test specimen shall be cut and not trowelled (trowelling can seal off cracks, slicken sides or other secondary features that might conduct water flow). Specimens shall be trimmed whenever possible in an environment where changes in moisture content are minimized. A controlled high-humidity room is usually used for this purpose. The mass and dimensions of the test specimens shall be determined. The test specimens shall be mounted immediately in the permeameter. The water content of the trimmings shall be determined.

### 6.3 Laboratory-compacted specimen

The material to be tested shall be prepared and compacted inside a mould in a manner specified by the requester. Neither hard clods nor individual particles of the material shall exceed 1/6 of either the height or the diameter of the specimen. After compaction, the test specimen shall be removed from the mould, the ends