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Soil quality — Determination of unsaturated hydraulic conductivity and water-retention characteristic — Wind's evaporation method

Qualité du sol — Détermination de la conductivité hydraulique en milieu non saturé et de la caractéristique de rétention en eau — Méthode par évaporation de Wind

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Contents

Page

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 11275 was prepared by Technical Committee ISO/TC 190, *Soil quality*, Subcommittee SC 5, *Physical methods*.

This corrected version of ISO 11275:2004 incorporates the following corrections of inadvertent omissions:

a) in Equation (5) a minus sign has been added to the numerator on the right-hand side of the equation;

b) in Equation (9) a fourth term, $\widehat{\varphi}_{i,j+1}$, has been added to the right-hand side of the equation.

Introduction

Soil water content and matric pressure are related to each other and determine the water-retention characteristics of a soil. Soil water, which is in equilibrium with free water, is at zero matric pressure (or suction) and either the soil is saturated or the gaseous phase occurs only as small bubbles. As a saturated soil dries, the matric pressure decreases (i.e. becomes more negative), and the largest pores empty of water. Progressive decreases in matric pressure will continue to empty finer pores until eventually water is held in only the finest pores. Not only is water removed from soil pores, but the films of water held around soil particles are reduced in thickness. Therefore, a decreasing matric pressure is associated with decreasing soil water content[8],[9]. Laboratory or field measurements of these two parameters can be made; and the relationship (which can be reported graphically, in tabular form, or possibly as an equation) is called the soil water-retention characteristic. The relationship extends from saturated soil to oven-dry soil (approximately 0 kPa to about -10^6 kPa matric pressure).

The soil water-retention characteristic is different for each soil type. The shape and position of the curve relative to the axes depend on soil properties such as texture, density and hysteresis associated with the wetting and drying history. Individual points on the water-retention characteristic curve may be defined for specific purposes.

The hydraulic conductivity is a measure of the rate at which liquid water can move through the soil under the influence of variations in matric pressure from point to point within the soil. The hydraulic conductivity of unsaturated soil depends on the same factors as does the soil water-retention characteristic, also showing hysteresis. As a saturated soil dries, the hydraulic conductivity decreases, and it is convenient to express the hydraulic conductivity corresponding to the soil water-retention characteristic as a function of the decreasing matrix pressure.

The results obtained using these methods can be used, for example:

- to provide an assessment of the equivalent pore-size distribution (e.g. identification of macro- and micro-pores);
- to determine indices of plant-available water in the soil and to classify soil accordingly (e.g. for irrigation purposes);
- to determine the drainable pore space (e.g. for drainage design, pollution risk assessments);
- to monitor changes in the structure of a soil (caused by e.g. tillage, compaction or addition of organic matter or synthetic soil conditioners);
- to ascertain the relationship between the negative matric pressure and other soil physical properties (e.g. hydraulic conductivity, thermal conductivity);
- to determine water content at specific negative matric pressures (e.g. for microbiological degradation studies);
- to estimate other soil physical properties.

Soil quality — Determination of unsaturated hydraulic conductivity and water-retention characteristic — Wind's evaporation method

1 Scope

This International Standard specifies a laboratory method for the simultaneous determination in soils of the unsaturated hydraulic conductivity and of the soil water-retention characteristic. It is applicable only to measurement of the drying or desorption curve. Application of the method is restricted to soil samples which are, as far as possible, homogeneous. The method is not applicable to soils which shrink in the range of matric head $h_{\text{m}} = 0$ cm to $h_{\text{m}} = -800$ cm.

The range of the determination of the conductivity depends on the soil type. It lies between matric heads of approximately $h_{\text{m}} = -50$ cm and $h_{\text{m}} = -700$ cm.

The range of the determination of the water-retention characteristic lies between matric heads of approximately $h_{\text{m}} = 0$ cm and $h_{\text{m}} = -800$ cm.

NOTE 1 An infiltrometer method can be used to determine hydraulic conductivities near saturation.

NOTE 2 ISO 11274 gives methods to determine the water-retention characteristic for matric heads between 0 cm and −15 000 cm.

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.

ISO 10381-1, *Soil quality — Sampling — Part 1: Guidance on the design of sampling programmes*

ISO 10381-4, *Soil quality — Sampling — Part 4: Guidance on the procedure for investigation of natural, near-natural and cultivated sites*

ISO 11274, *Soil quality — Determination of the water-retention characteristic — Laboratory methods*

ISO 11276, *Soil quality — Determination of pore water pressure — Tensiometer method*

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 definitions apply.

3.1
hydraulic conductivity
K
factor of proportionality between the soil water flux density, v, and the hydraulic gradient ∇h_{h} in Darcy's equation, assuming isotropic conditions, i.e.

$$v = -K \nabla h_{\mathrm{h}}$$

NOTE For the purposes of this document, conductivity is used synonymously for unsaturated hydraulic conductivity.

3.2
soil water-retention characteristic
retention characteristic
relation between soil water content and soil matric head of a given soil (sample)

3.3
gravitational head
amount of work that must be done in order to transport reversibly and isothermally an infinitesimal quantity of water, identical in composition to the soil water, from a pool at a specified elevation and at atmospheric pressure, to a similar pool at the elevation of the point under consideration, divided by the mass of water transported

3.4
matric head
amount of work that must be done in order to transport reversibly and isothermally an infinitesimal quantity of water, identical in composition to the soil water, from a pool at the elevation and the external gas pressure of the point under consideration, to the soil water at the point under consideration, divided by the mass of water transported

3.5
pneumatic head
amount of work that must be done in order to transport reversibly and isothermally an infinitesimal quantity of water, identical in composition to the soil water, from a pool at atmospheric pressure and at the elevation of the point under consideration, to a similar pool at the external gas pressure of the point under consideration, divided by the mass of water transported

3.6
pressure head
tensiometer head
sum of the matric and pneumatic heads

NOTE The pneumatic head is assumed to be zero for the purposes of this method. On this basis, the pressure head equals the matric head.

3.7
hydraulic head
sum of the matric, pneumatic and gravitational heads

4 Symbols

a height, in centimetres;

h_{a} pneumatic head, in centimetres;

h_{h} hydraulic head $= h_{\mathrm{a}} + h_{\mathrm{g}} + h_{\mathrm{m}}$, in centimetres;

h_{g} gravitational head, in centimetres;

h_{m} matric head, in centimetres;

h_p pressure head = tensiometer head $h_a + h_m$, in centimetres;

i compartment and tensiometer index;

j time and measurement interval index;

k compartment index;

K unsaturated hydraulic conductivity, in centimetres per day ($cm \cdot d^{-1}$);

m mass, in kilograms;

m_e mass of soil sample at the end of the test, in kilograms;

t time, in days (d)

v soil water volume flux density, in centimetres per day ($cm \cdot d^{-1}$);

V volume, in cubic metres;

z vertical coordinate, in centimetres;

φ water content as volume fraction;

ρ_w density of water, in kilograms per cubic metre.

5 Principle

Undisturbed samples of soil are taken from the field in accordance with ISO 10381-1. Each soil sample is first wetted to near saturation in the laboratory. Then the sample is allowed to dry by evaporation from the top surface; at known times during this period, pressure heads are measured at different depths in the sample using tensiometers, and the mass of the sample is measured. These measurements are continued until air enters any of the tensiometers. This can take a few days to two weeks depending on the type of soil. At the end of the test, after completing these measurements, the sample is dried and weighed, and its water content is calculated for each of the measurement times.

The sample is considered as two or more compartments (sub-samples), one for each tensiometer. For each of the measurement times, the water content of each compartment is calculated from the water content of the whole sample and the tensiometer readings. The soil water-retention characteristic and the unsaturated hydraulic conductivity are calculated from these data using an adaptation[1] of Wind's evaporation method[2]. The method treats the soil sample as being homogeneous in its hydraulic properties and assumes one-dimensional flow.

6 Apparatus

6.1 Equipment for sampling undisturbed soil.

Usually metal or plastic sleeves of known dimensions are used, together with equipment to push the sleeves into the soil. Usually the sampling sleeves are used to retain the sample throughout the test, and therefore it is necessary to pre-drill holes for the tensiometers. The dimensions of the soil samples are dependent on the soil type and the purpose of the investigation. The height of a sample shall be less than or equal to its diameter, to prevent the acquisition of redundant data. In most cases a height of 8 cm and a diameter of 10 cm are suitable for stone-free soils.

The height shall be large enough to accommodate 2 to 4 tensiometers. However, larger heights delay the drying of the lower compartments unduly, so that the determination may take too long, and may require an increase in the number of measurement times. The ratio of the diameter to the height should be just above unity, e.g. 10:8, to provide reasonably uniform conditions across the sample without requiring too broad a sample.