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**Soil quality — Determination of soil water content as a volume fraction on the basis of known dry bulk density — Gravimetric method**

*Qualité du sol — Détermination de la teneur en eau volumique du sol à partir de la masse volumique apparente sèche connue — Méthode gravimétrique*

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## Foreword

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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.

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ISO 16586 was prepared by Technical Committee ISO/TC 190, *Soil quality*, Subcommittee SC 5, *Physical methods*.

## Introduction

The determination of water content volume fraction using coring sleeves, which is described in ISO 11461, is the basic method for determination of the water content volume fraction. This International Standard provides a less precise method than that given in ISO 11461.

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# Soil quality — Determination of soil water content as a volume fraction on the basis of known dry bulk density — Gravimetric method

## 1 Scope

This International Standard specifies a method for the gravimetric determination of soil water content as a volume fraction on the basis of the ratio of measured water content mass to known dry bulk density.

This International Standard is applicable to all types of non-swelling or non-shrinking soils. It is used as a reference method (e.g. the calibration of indirect methods for determination of water content).

## 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 11465:1993, *Soil quality — Determination of dry matter and water content on a mass basis — Gravimetric method*

## 3 Terms and definitions

### 3.1

**water content**

**water content mass fraction**

**water content mass ratio**

ratio of the mass of water evaporating from the soil when dried to constant mass at 105 °C, to the dry mass of the soil sample

NOTE For soil with high content of organic matter, drying at a temperature below 70 °C is usual practice.

### 3.2

**dry bulk density**

mass of the solid particles divided by the undisturbed bulk volume of the soil

### 3.3

**water content volume fraction**

**volumetric water content**

ratio of the volume of water evaporating from the soil when dried to constant mass at 105 °C, to the original bulk volume of the soil

## 4 Symbols

- $s_x$  sample standard deviation of variation of variable  $x$ ;
- $w$  water content (mass fraction), expressed in kilograms per kilogram;
- $\Delta_x$  standard deviation of the errors in variable  $x$ ;
- $\varphi$  water content volume fraction, expressed in cubic metres per cubic metre;
- $\rho_b$  dry bulk density, expressed in kilograms per cubic metre;
- $\rho_w$  density of water, expressed in kilograms per cubic metre.

## 5 Principle

Soil samples are dried to constant mass at 105 °C. The difference in the mass of the soil sample, before and after the drying procedure, is taken as a measure of the water content. The water content (mass fraction) is converted to the water content (volume fraction) by using a known value for the dry bulk density. This method is inherently less accurate than ISO 11461, since the dry bulk density is not determined on the same sample.

NOTE The dry bulk density may be known from previous sampling. If the dry bulk density is not known, it can be determined in accordance with ISO 11272.

## 6 Apparatus

Equipment for determination of water content as a mass fraction shall be in accordance with ISO 11465.

## 7 Procedure

Sampling, transport and laboratory treatment of the samples shall be carried out in accordance with ISO 11465.

NOTE Usually larger samples are needed than those specified in ISO 11465. For structured soils, a sample including 20 structural elements is satisfactory for most investigations.

## 8 Expression of results

Calculate  $w$  in accordance with ISO 11465. Compute the water content volume fraction from:

$$\varphi = w \frac{\rho_b}{\rho_w}$$

where

- $w$  is the water content mass fraction;
- $\varphi$  is the water content volume fraction;
- $\rho_b$  is the dry bulk density of the sample, in kilograms per cubic metre;

$\rho_w$  is the density of water at soil temperature, in kilograms per cubic metre (usually an approximation of 1 000 kg m<sup>-3</sup> will be satisfactory for this method)

NOTE The water content (mass fraction) in accordance with ISO 11465 is expressed as a percentage. This number can be converted to a decimal fraction by dividing by 100.

## 9 Accuracy and precision

**9.1** Various error sources influence the accuracy of the calculated water content through errors in  $w$ ,  $\rho_b$  and  $\rho_w$ . The basic inaccuracies due to sampling, transport and laboratory handling have to be assessed within the procedures given in ISO 11465 ( $w$ ) and ISO 11272 ( $\rho_b$ ), as well as the final error in these variables. For convenience, a summary of the assessment of these errors is given in Annex A.

**9.2** Temperature differences between the field and laboratory introduce a deviation in  $\rho_w$ . If this systematic error occurs, a correction shall be established for it. The uncertainty in this correction shall then be applied as the final systematic error, hence: corr.  $\Delta\rho_w$ .

**9.3** After estimation of the standard deviation of the respective error sources in  $w$ ,  $\rho_b$  and  $\rho_w$ , their propagation in the water content can be estimated with the following formula:

$$s_\varphi = \sqrt{\left(\frac{\rho_b}{\rho_w}\right)^2 s_w^2 + \left(\frac{w}{\rho_w}\right)^2 s_{\rho_b}^2 + \left(\frac{\varphi}{\rho_w}\right)^2 s_{\rho_w}^2}$$

where  $s_\varphi$ ,  $s_w$ ,  $s_{\rho_b}$  and  $s_{\rho_w}$  are the standard deviations of  $\varphi$ ,  $w$ ,  $\rho_b$  and  $\rho_w$  respectively.

In the final result one may distinguish between the (total) variable component in time and space  $s_\varphi(t,x)$  and the (total) systematic component  $s_\varphi$  (see Annex A).

General guidelines for the actual magnitude of specific error sources cannot be given, since they fully depend on sampling and laboratory practice. Apart from the error sources in  $\rho_b$  as elaborated in Annex A, the temporal and spatial variabilities in this variable shall be taken into account, due to differences in both sampling sites and sampling times between  $w$  and  $\rho_b$ .

## 10 Test report

The test report shall include following information:

- reference to this International Standard;
- an accurate description of the sampling location and depth;
- the date of field sampling;
- the mass of the soil sample used for the determination;
- the dry bulk density value(s) used, the method used to determine the dry bulk density, the time and sites used for the dry bulk density determination(s);
- the calculated water content (volume fraction);
- details of any operations not specified in this International Standard, or regarded as optional, as well as any other factors which may have affected the results.

## Annex A (informative)

### The accuracy of $w$ and $\rho_b$

#### A.1 General

At present ISO 11465 and ISO 11272 do not provide for procedures for estimation of the errors in  $w$  and  $\rho_b$ . In this Annex these errors are elaborated.

#### A.2 Symbols

The following new symbols are used in this Annex:

- $m_1$  mass of the field-moist soil sample, in kilograms;
- $m_2$  mass of the dried soil sample, in kilograms;
- $s_x$  sample standard deviation of variation of variable  $x$ ;
- $V$  volume of the soil sample, in cubic metres;
- $\Delta_x$  standard deviation of the errors in variable  $x$ .

#### A.3 Basic sources of $w$ error

In the course of the procedures followed for determination of  $w$ , the following main causes of error are present that can influence the calculated values.

##### a) Storage

Evaporation of water from moist soil samples or sorption of water from the air by relatively dry samples can occur due to poor closure of the transport bags and/or a too long period for transport or storage. The susceptibility of the sample to such changes in water content is influenced by its initial water content. If this systematic error occurs, a correction should be established for it. The uncertainty in this correction should then be applied as the final systematic error, hence: corr.  $\pm \Delta_{m_1}$ .

##### b) Laboratory analysis

- 1) poor precision of the weighing balance, which results in a variable error in weighings in both time and space ( $t, x$ ), hence:  $\Delta_{m_1}(t, x)$  and  $\Delta_{m_2}(t, x)$ ;
- 2) poor precision of the weighing balance, which results in a variable error in the weighing of the moisture box used for drying the soil. This error influences the calculation of  $m_2$ , hence:  $\Delta_{m_2}(t, x)$
- 3) volatilization of substances other than water. Also in this case one should establish a correction for this effect, hence: corr.  $\pm \Delta_{m_1}$

- 4) sorption of moist air due to a too long time gap between removing the sample from the desiccator and the second weighing. This also calls for a correction: corr.  $\pm \Delta_{m_2}$ .
- 5) variations in the time and temperature of drying.

#### A.4 Propagation of errors in $w$

After estimation of the standard deviation of all of the respective error sources in  $m_1$  and  $m_2$ , their propagation in  $w$  can be estimated with the following formula:

$$s_w = \sqrt{\left(\frac{1}{m_2}\right)^2 s_{m_1}^2 + \left(\frac{m_1}{m_2^2}\right)^2 s_{m_2}^2}$$

where

$s_{m_1}$  and  $s_{m_2}$  are the standard deviations of the errors influencing  $m_1$  and  $m_2$  respectively;

$s_w$  is the standard deviation of the determination of  $w$ .

The formula results in total errors irrespective of their behaviour in time and/or space. One may distinguish between the (total) variable component  $\Delta(t,x)$  and the (total) systematic component  $\Delta$ , according to A.3 b) 1) to A.3 b) 5).

#### A.5 Basic sources of $\rho_b$ error

In the course of the procedures followed for determination of  $\rho_b$ , the following main causes are present that can influence the calculated values:

##### a) Sampling

- 1) Compaction and/or disturbance of the sample.

Various factors, including the compressibility of the soil, the presence of stones and the sharpness of the cutting edge influence whether a sample is disturbed and/or compacted to some extent during sampling. These factors may cause variable and/or systematic errors in time and space. The variable (i.e. coincidental) error component occurs in time and space ( $t,x$ ) with respect to  $m_2$ :  $\Delta_{m_2}(t,x)$ . Systematic errors may occur and if possible, a correction should be established for these. The uncertainty in this correction should then be applied as the final systematic error, hence: corr.  $\pm \Delta_{m_2}$ .

- 2) Deviation in the sample volume due to imperfect cutting of the sample. This results in a variable error of the type  $\Delta_V(t,x)$ ;

- 3) Poor precision of the volume of the sample sleeve. One should establish a correction for this effect, hence: corr.  $\pm \Delta_V$ ;

##### b) Laboratory analysis

- 1) Poor precision of the weighing balance, which results in a variable error, hence:  $\Delta_{m_2}(t,x)$ .
- 2) Volatilization of substances other than water. Also in this case one should establish a correction for this effect, hence: corr.  $\pm \Delta_{m_2}$ .