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Methods of test for soils for civil engineering purposes –

Part 3: Chemical and electrochemical tests

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Contents

Summary of pages
This document comprises a front cover, and inside front cover, pages i to iv, pages 1 to 98, an inside back cover and a back cover.

Foreword

Publishing information

This part of BS 1377 is published by BSI Standards Limited, under licence from The British Standards Institution, and came into effect on 31 July 2018. It was prepared by Subcommitee B/526/3, *Site investigation and ground testing*, under the authority of Technical Committee B/526, *Geotechnics*. A list of organizations represented on these committees can be obtained on request to their secretary.

Supersession

This part of BS 1377 supersedes BS 1377-3:1990, which is withdrawn.

Relationship with other publications

BS 1377-3 is published in the following parts:

- Part 1: *General requirements and sample preparation*;
- Part 2: *Classification tests*;
- Part 3: *Chemical and electrochemical tests*;
- Part 4: *Compaction-related tests*;
- Part 5: *Compressibility, permeability and durability tests*;
- Part 6: *Consolidation and permeability tests in hydraulic cells and with pore pressure measurement*;
- Part 7: *Shear strength tests (total stress*);
- Part 8: *Shear strength tests (effective stress)*;
- Part 9: *In-situ tests*.

Information about this document

This part of BS 1377 is intended to be read in conjunction with BS 1377-1.

In this part of BS 1377, the tests described in the 1990 edition have been retained. Additional tests have been added to include the recommendations of BRE Special Digest 1 [SD1] (BRE 2005) [1]. Also, analytical methods of chemical analysis have been included, i.e. total carbon analyzer, ion chromatography and inductively coupled plasma atomic emission spectroscopy. The two point resistivity method has been removed and additional four point tests included.

This is a full revision of the standard, and introduces the following principal changes:

- determination of total organic carbon;
- determination of total sulfur content;
- determination of total sulfide (reduced sulfur) content;
- determination of acid-soluble sulfide content (monosulfide sulfur); and
- determination of water soluble magnesium.

Hazard warnings

WARNING. Persons using this British Standard are expected be familiar with normal laboratory practice. This British Standard calls for the use of substances and/or procedures that can be injurious to health if adequate precautions are not taken. It refers only to technical suitability and does not absolve the user from legal obligations relating to health and safety at any stage. These include the use of fume cupboards or similar apparatus when using acids and other toxic chemicals. This standard does not purport to address the safety problems, if any, associated with its use. It is the responsibility of the user to establish appropriate safety and health practices and to ensure compliance with any national regulatory conditions.

It is expected that tests conducted in accordance with this British Standard will be carried out by suitably trained and experienced staff.

WARNING. It is dangerous to add water to concentrated acid.

Use of this document

It has been assumed in the preparation of this part of BS 1377 that the execution of its provisions will be entrusted to appropriately qualified and experienced people, for whose use it has been produced.

Presentational conventions

The provisions of this standard are presented in roman (i.e. upright) type. Its methods are expressed as a set of instructions, a description, or in sentences in which the principal auxiliary verb is “shall”.

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

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1 Scope

This part of BS 1377 describes test methods for determining the amount of chemical substances in samples of soil and extremely weak and very weak rocks, as defined by BS 5930, and groundwater.

NOTE 1 Chemical tests in this part of BS 1377 may be used on other rocks if required.

It also describes test methods for the determination of some electrochemical and resistivity properties of solid samples.

NOTE 2 These tests provide data to assess the potential of the ground and solutes to damage construction materials, including cementitious materials and metals in the ground. They can also be used in assessment of the potential for volume change of the ground due to chemical reaction. Resistivity test results can also be used to assess in-situ resistivity results.

This British Standard is not written for testing samples from contaminated land or for soil quality assessment.

Procedures described in this part of BS 1377 are for the determination of the following:

a) organic matter content in the material (Clause **4**);

b) total organic carbon (TOC) content in the material (Clause **5**);

c) loss on ignition of the material (Clause **6**);

d) sulfur compounds (Clause **7**):

   1) water-soluble sulfate content of the material by 2:1 extraction;

   2) sulfate content in groundwater;

   3) acid-soluble sulfate content of the material;

   4) total sulfur content of the material;

   5) total sulfide content (total reduced sulfur) content of the material;

   6) acid-soluble sulfide (monosulfides sulfur) content of the material;

e) carbonate content of the material (Clause **8**);

f) chloride content (Clause **9**):

   1) water-soluble chloride content of the material;

   2) acid-soluble chloride content of the material.

g) water-soluble magnesium content of the material (Clause **10**);

h) total dissolved solids of the groundwater (Clause **11**);

i) pH value (Clause **12**);

j) electrical resistivity of the material (Clause **13**); and

k) redox potential of the material (Clause **14**).

Brief guidance on the detrimental effects of sulfur compounds on engineering works and alternative methods of identifying the specific minerals is given in Annex A.

NOTE 3 Good practice in chemical testing requires duplicate specimens to be tested. In each of the test methods the measurement of only one value of the overall result is described. It is recognized that it is necessary in many practical applications to make a number of tests in order to obtain a representative value and an indication of the reliability of the results. Guidance on the number of measurements required and the treatment of the results obtained are not provided in this standard.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes provisions 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.

BS 89, *Specification for direct acting indicating electrical measuring instruments and their accessories*

BS 1377-1:2016, *Methods of test for soils for civil engineering purposes — Part 1: General requirements and sample preparation*

BS 1881-124:2015, *Testing concrete — Part 124: Methods for analysis of hardened concrete*

BS 5930, *Code of practice for ground investigations*

BS EN ISO 3696:1995, *Water for analytical laboratory use — Specification and test methods*

BS EN ISO 17034, *General requirements for the competence of reference material producers*

BS EN ISO 17892-1, *Geotechnical investigation and testing — Laboratory testing of soil — Part 1: Determination of water content*

BS EN ISO 22475-1:2016, *Geotechnical investigation and testing — Sampling methods and groundwater measurements — Part 1: Technical principles for execution*

3 Terms and definitions

For the purposes of this part of BS 1377, the terms and definitions given in BS 1377-1 and the following apply.

3.1 titration

addition of a solution from a graduated burette to a known volume of a second solution, until the chemical reaction between the two is completed

NOTE If the strength of one of the solutions is known, that of the other can be calculated from the volume of liquid added.

3.2 indicator

substance which is capable of giving a clear visual indication of the completion of a chemical reaction in a solution being titrated, usually by means of a change in colour

3.3 pH value

logarithm to base 10 of the reciprocal of the concentration of hydrogen ions in an aqueous solution

NOTE It provides a measure of the acidity or alkalinity of the solution on a scale reading from 0 to 14, on which 7 represents neutrality.

3.4 resistivity (of soil)

electrical resistance, in Ω (ohms) per unit length, of a column of soil of unit area of cross-section

NOTE In this part of BS 1377, resistivity is expressed in Ωm (ohm metres).

3.5 redox potential (reduction/oxidation potential)

relative measure, expressed in millivolts, of the reducing or oxidising capacity of soil, usually increasing with increasing oxygen content

3.6 calibration blank sample

extract solution used to make solutions

NOTE 1 For example, water or acid used for the preparation of extractions prior to analysis.

NOTE 2 The primary purpose of a blank is to trace sources of artificially introduced contamination and used to facilitate correction of the final test sample result.

3.7 stock solution

solution with accurately known analyte concentration(s) prepared with an appropriate purity

NOTE Stock solutions are reference materials within the meaning of PD ISO Guide 30.

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4 Determination of the organic matter content

4.1 Principle

This procedure covers the determination of the percentage by dry mass of oxidisable organic matter present in a soil.

NOTE The method, which uses dichromate oxidation, is known as Walkley and Black's method.

Soils containing sulfides or chlorides have been found to give high results by this procedure.

Methods for checking for the presence of these compounds, and procedures for their removal before testing if they are present, are included.

The requirements of BS 1377-1, where appropriate, shall apply to this test method.

4.2 Reagents

4.2.1 All reagents shall be of recognized analytical reagent quality.

NOTE Where accurately standardized solutions are required it might be more convenient to obtain them already standardized in concentrated form and to dilute them as necessary in accordance with the manufacturer's instructions.

4.2.2 *Potassium dichromate solution*, [$c(K_2Cr_2O_7) = 0.167$ mol/l]. Dissolve 49.035 g of potassium dichromate in distilled/de-ionized water (BS 1377-1:2016, **6.1**) to make 1 l of solution.

4.2.3 *Ferrous sulfate solution*. Dissolve approximately 140 g of ferrous sulfate in sulfuric acid solution [$c(H_2SO_4) = 0.25$ mol/l] to make 1 l of solution. Add 14 ml of concentrated sulfuric acid to distilled/de-ionized water (BS 1377-1:2016, **6.1**) to make 1 l of sulfuric acid solution [$c(H_2SO_4) = 0.25$ mol/l]. Record the date the solution is made on the bottle. This solution is unstable in air. Keep it tightly stoppered and standardize against the potassium dichromate solution at least once a week.

4.2.4 *Sulfuric acid*, concentrated. Density 1.84 g/ml.

4.2.5 *Orthophosphoric acid*, 85% (v/v) solution. Density 1.70 g/ml to 1.75 g/ml.

4.2.6 *Indicator solution*. Dissolve 0.25 g of sodium diphenylamine sulfonate in 100 ml of distilled/de-ionized water (BS 1377-1:2016, **6.1**) water.

4.2.7 *Hydrochloric acid*, 25% (v/v) solution. Add 250 ml of concentrated hydrochloric acid (density 1.18 g/ml) to 500 ml of distilled/de-ionized water (BS 1377-1:2016, **6.1**), then make up to 1 l with distilled/de-ionized water (BS 1377-1:2016, **6.1**).

4.2.8 *Lead acetate paper*. Filter paper that has been dipped in a 10% solution of lead acetate.

4.2.9 *Sulfuric acid, [$c(H_2SO_4)$ = approximately1 mol/l]*. Add 53 ml of concentrated sulfuric acid to about 500 ml of distilled/de-ionized water (BS 1377-1:2016, **6.1**) water, then make up to 1 l with distilled/de-ionized water (BS 1377-1:2016, **6.1**).

4.3 Apparatus

4.3.1 *Drying oven*, capable of maintaining a temperature of (50 ±2.5) °C.

4.3.2 *Balance*, readable to 1 g.

4.3.3 *Balance*, readable to 0.001 g.

4.3.4 *1 l volumetric flask.*

4.3.5 *Two 25 ml burettes*, graduated to 0.1 ml.

4.3.6 *10 ml pipette and a 1 ml pipette*, each fitted with a rubber teat.

4.3.7 *Two conical flasks* of 500 ml capacity.

4.3.8 *200 ml and 20 ml graduated measuring cylinders.*

4.3.9 *Desiccator*, (a convenient size is about 200 mm to 250 mm in diameter) containing anhydrous silica gel.

4.3.10 *Glass weighing bottle*, approximately 25 mm in diameter, 50 mm high and fitted with a ground glass stopper.

4.3.11 *Test sieves,* 2 mm and 0.425 mm aperture sizes, with receiver.

4.3.12 *Sample dividers of multiple-slot type (riffle boxes),* having widths of opening of 7 mm and 15 mm.

4.3.13 *Pestle and mortar*, or a suitable mechanical crusher.

4.3.14 *Wash bottle*, preferably made of plastics, containing distilled/de-ionized water (BS 1377-1:2016, **6.1**).

4.3.15 *Glass boiling tube.*

4.3.16 *Filter funnel*, of approximately 100 mm diameter.

4.3.17 *Filter papers*, of a diameter appropriate to the size of the funnel: medium grade (e.g. Whatman No. 40 ®[1]) and fine grade (e.g. Whatman No. 42 ®[1]).

4.3.18 *Blue litmus paper*.

4.4 Preparation of test specimen

4.4.1 Each test specimen shall be prepared for analysis from the laboratory sample as given in **4.4.2** to **4.4.11**.

4.4.2 An initial sample shall be obtained as described in BS 1377-1:2016, **8.3**, and of the approximate size as specified in BS 1377-1:2016, **8.5**.

4.4.3 The sample shall be dried in the oven to constant mass at (50 ±2.5) °C, and cooled to room temperature in the desiccator.

4.4.4 The sample shall be weighed to the nearest 0.1% and the mass m_1 (in g) recorded.

4.4.5 The sample shall be sieved on a 2 mm test sieve (if appropriate, guarded by a test sieve of larger aperture) and crush retained particles other than stones to pass the 2 mm sieve.

NOTE It is assumed that any material retained on the 2 mm test sieve will not contain organic matter. If this is seen not to be true, the pieces of organic matter should be removed by hand, crushed to pass a 2 mm test sieve and incorporated in the fraction passing the sieve.

4.4.6 The stones shall be rejected, ensuring that no fine material adheres to them, e.g. by brushing. Record the mass of sample passing the 2 mm test sieve (in g) to the nearest 0.1% (m_2). Throughout these and subsequent operations take care to ensure that there is no loss of fines.

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[1] Whatman is a trademark of GE Healthcare. This information is given for the convenience of users of this document and does not constitute an endorsement by the British Standards Institution of the named product. Equivalent products may be used if they can be shown to lead to the same results.