

Methods of test for

Soils for civil engineering purposes —

Part 1: General requirements and sample preparation

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Committees responsible for this British Standard

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- British Civil Engineering Test Equipment Manufacturers Association
- County Surveyors' Society
- Department of the Environment (Property Services Agency)
- Department of the Environment (Building Research Establishment)
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Foreword

This Part of BS 1377 has been prepared under the direction of the Road Engineering Standards Policy Committee. It is a revision of clause 1 of BS 1377:1975 which is deleted by amendment. BS 1377 was first published in 1948 and first appeared in metric form in 1975.

BS 1377:1975 which has now been withdrawn is replaced by the following Parts of BS 1377:1990:

- *Part 1: General requirements and sample preparation;*
- *Part 2: Classification tests;*
- *Part 3: Chemical and electro-chemical 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.*

Part 1 covers general requirements, Parts 2 to 8 relate to laboratory tests on soils, and Part 9 covers in-situ tests. The distinction between laboratory and in-situ tests is that the former are carried out on soil samples removed from the ground whether the testing takes place in a central laboratory, in a site laboratory, or in the field, whereas the latter are performed on the soil in-situ.

Descriptions of test methods have been broken down into smaller procedural stages than were used previously. Where more than one test procedure is given for a particular determination, the one termed the definitive method should normally be used. If an alternative method is used the reason should be stated in the test report and the relevant facts included. Examples of forms are included in an appendix to each Part on which to prepare the test report.

In each of the methods the measurement of only one value of the quantity concerned is described. It is recognized that in many practical applications it is necessary to make a number of tests in order to obtain a representative value and an indication of its reliability. Guidance on the number of measurements required and the treatment of the results obtained is beyond the scope of the present standard.

A new clause has been included on calibration.

The term “specific gravity” has been replaced by “particle density” with dimensions of density in accordance with current ISO usage.

For general information on site investigation procedures, especially with regard to safety precautions, reference should be made to BS 5930:1981.

It has been assumed in the drafting of this British Standard that the execution of its provisions is entrusted to appropriately qualified and experienced people.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to vi, pages 1 to 28, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

0 Introduction

This British Standard consists of nine Parts. Part 1 contains general information relevant to all the other Parts. Parts 2 to 8 describe methods of test on soils for civil engineering purposes for which samples need to be taken for testing in a laboratory. The laboratory test procedures are grouped under the following headings.

- *Part 2: Classification tests;*
- *Part 3: Chemical and electro-chemical 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 specifies methods of test which are carried out directly on the soil in-situ.

Part 1: General requirements and sample preparation. Part 1 of this standard contains general information relating to the tests, common calibration and specification requirements and general requirements for testing laboratories and field work. It also includes details of procedures for the preparation of disturbed and undisturbed samples, where these are common to more than one type of test.

Part 2: Classification tests. Part 2 describes tests for the classification of soils according to moisture content, Atterberg limits, density, particle density and particle size distribution. No changes in principle have been made in the test procedures, but some additional tests are included. In the preparation of cohesive soils for testing, the requirement of using the soil in its natural state, without drying, has been introduced. The main additions and amendments are as follows.

- a) *Moisture content.* Determination of the saturation moisture content of chalk has been added. The alcohol method and the sand bath method have been deleted.
- b) *Liquid limits.* A one-point cone penetration test has been added.
- c) *Shrinkage limit.* This is an addition, and two procedures are given.
- d) *Bulk density.* Determination by direct measurement has been added.
- e) *Particle density (previously specific gravity).* The pycnometer jar method has been reintroduced as a site test.

f) *Particle size distribution (sedimentation).*

Procedures have been rationalized and amended where necessary. Pretreatment is not now a requirement.

Part 3: Chemical and electro-chemical tests. Part 3 describes chemical tests on soils and on water. Existing test procedures have been retained, with some modification, and additional tests have been included for the determination of the following.

- a) Loss on ignition.
- b) Carbonate content.
- c) Chloride content.
- d) Total dissolved solids.

Tests have also been included for the assessment of the corrosivity of soils; these are the determination of the electrical resistivity and of the redox potential. In-situ methods of these two tests are given in Part 9.

Part 4: Compaction-related tests. Part 4 describes those tests that refer in some way to the compaction of soils. These include existing procedures for determining compaction parameters; additional tests for measurement of the limiting densities of non-cohesive soils; and tests which are related to the control and behaviour of soil placed in-situ as fill, comprising the CBR test and two procedures which have been added. These are the moisture condition test, and the chalk crushing value test, both of which require use of the same apparatus. Attention has been given to several methods of sample preparation appropriate to different soil types prior to compaction tests and the compaction of samples for the CBR test.

Part 5: Compressibility, permeability and durability tests. Part 5 describes test procedures in which the presence or drainage or flow of water within the pore spaces of the soil is the significant factor, but without requiring the measurement of pore water pressure. These include the one-dimensional oedometer consolidation test, which incorporates some additional requirements. Tests for determining the swelling and collapsing characteristics have been added. Further additional test procedures are as follows.

- a) Determination of soil permeability (constant-head method).
- b) Determination of erodibility and dispersive characteristics of fine-grained soils.
- c) Determination of potential frost heave for which reference is made to BS 812-124.

Part 6: Consolidation and permeability tests in hydraulic cells and with pore pressure measurement.

Part 6 is a major addition to this standard. It describes tests for the determination of consolidation and permeability parameters using equipment in which the measurement of pore water pressure is an essential feature. These comprise the following.

- a) Determination of consolidation properties in a hydraulic consolidation cell. For samples of large diameter, either vertical or horizontal (radial) drainage can be used.
- b) Determination of consolidation properties in a triaxial cell under isotropic conditions.

Part 7: Shear strength tests (total stress). Part 7 describes methods for the determination of the shear strength of soils in terms of total stress, or (in the case of drained direct shear tests) in terms of effective stress when equal to total stress. A test for determining unconfined compressive strength using standard laboratory apparatus has been added. For very soft soils the laboratory vane test has been added. Direct shear tests using the shear box and the ring shear apparatus have been added, and include the determination of drained and drained-residual shear strength parameters. The triaxial compression test procedure has been augmented by the addition of a multi-stage method which is appropriate under certain conditions.

Part 8: Shear strength tests (effective stress). Part 8 is a major addition to this standard, namely the determination of effective stress shear strength parameters in the consolidated-drained and consolidated-undrained triaxial compression tests.

Part 9: In-situ tests. The methods described in this Part include major additions and have been formed into groups, according to either the purpose of the test or the mode of execution. These groups are as follows:

In-situ density tests. The hand-scoop method has been deleted and substituted by a new test for coarse-grained soils based on a water-replacement method. Determination of in-situ density of fine-grained, medium-grained, and coarse-grained soils by attenuation of gamma rays has been added which includes moisture content determination.

In-situ penetration tests. The split-barrel sampler method has been revised to conform more closely to international practice. Two other test methods have been added as follows.

- a) Determination of the penetration resistance using fixed 60° cone and friction sleeve (the static cone test CPT).

- b) Determination of the dynamic probing resistance using a 90° cone (dynamic probing, DP).

In-situ vertical deformation and strength tests.

Three test methods have been added as follows.

- a) Determination of the vertical deformation and strength characteristics of soil by the plate loading test.
- b) Determination of the settlement characteristics of soil for lightly loaded foundations by the shallow pad maintained-load test.
- c) Determination of the in-situ California Bearing Ratio (CBR).

In-situ corrosivity tests. Two test methods are given as follows.

- a) Determination of the in-situ apparent resistivity of soil.
- b) Determination of the in-situ redox potential of the soil.

1 Scope

This Part of BS 1377 specifies general requirements for the testing of soils for civil engineering purposes and describes methods for the calibration of equipment and the preparation of test samples.

NOTE The titles of the publications referred to in this standard are listed on the inside back cover.

2 Terminology, definitions, symbols and units

2.1 Terminology

For the purposes of this British Standard the following terminology applies.

2.1.1 soil. An assemblage of discrete particles in the form of a deposit, usually of mineral composition but sometimes of organic origin, which can be separated by gentle mechanical means and which includes variable amounts of water and air (and sometimes other gases). A soil commonly consists of a naturally occurring deposit forming part of the earth's crust, but the term is also applied to made ground consisting of replaced natural soil or man-made materials exhibiting similar behaviour, e.g. crushed rock, crushed blast-furnace slag, fly-ash.

2.1.2 cohesive soil. Soil which because of its fine-grained content will form a coherent mass at suitable moisture contents.

2.1.3 cohesionless soil. Granular soil consisting of particles which can be identified individually by the naked eye or with the aid of a hand lens, e.g. gravel, sand.

2.2 Definitions

For the purposes of this British Standard the following definitions apply.

2.2.1

sample

a portion of soil taken as being representative of a particular deposit or stratum

2.2.2

specimen

a portion of a sample on which a test is carried out

2.2.3

sampling

the selection of a representative portion of a material

2.2.4

quartering

the reduction in quantity of a large sample of material by dividing a circular heap, by diameters at right angles, into four more or less equal parts, removing two diagonally opposite quarters, and thoroughly mixing the two remaining quarters together so as to obtain a truly representative half of the original mass. The process is repeated until a sample of the required size is obtained

2.2.5

riffling

the reduction in quantity of a large sample of material by dividing the mass into two approximately equal portions by passing the sample through an appropriately sized sample divider. The process is repeated until a sample of the required size is obtained

2.2.6

dry soil

soil that has been dried to constant mass at a temperature of 105 °C to 110 °C, unless specified otherwise

2.2.7

moisture content (w)

the mass of water which can be removed from the soil, usually by heating at 105 °C, expressed as a percentage of the dry mass. The term water content is also widely used

2.2.8

liquid limit (w_L)

the moisture content at which a soil passes from the liquid to the plastic state, as determined by the liquid limit test

2.2.9

plastic limit (w_P)

the moisture content at which a soil becomes too dry to be in a plastic condition, as determined by the plastic limit test

2.2.10

plasticity index (I_P)

the numerical difference between the liquid limit and the plastic limit of a soil:

$$I_P = w_L - w_P$$

2.2.11

non-plastic

a soil with a plasticity index of zero or one on which the plastic limit cannot be determined

2.2.12

liquidity index (I_L)

the ratio of the difference between moisture content and plastic limit of a soil, to the plasticity index:

$$I_L = \frac{w - w_P}{I_P}$$

2.2.13

shrinkage limit

the moisture content at which a soil on being dried ceases to shrink

2.2.14

shrinkage ratio (R_s)

the ratio of the change in volume to the corresponding change in moisture content above the shrinkage limit

2.2.15

linear shrinkage

the change in length of a bar sample of soil when dried from about its liquid limit, expressed as a percentage of the initial length

2.2.16

bulk density (ρ)

the mass of material (including solid particles and any contained water) per unit volume including voids

2.2.17

dry density (ρ_d)

the mass of the dry soil contained in unit volume of undried material:

$$\rho_d = \frac{100\rho}{100 + w}$$

2.2.18

particle density (ρ_s)

the average mass per unit volume of the solid particles in a sample of soil, where the volume includes any sealed voids contained within the solid particles

2.2.19

particle size distribution

the percentages of the various grain sizes present in a soil as determined by sieving and sedimentation

2.2.10**test sieve**

a sieve complying with BS 410

2.2.21**cobble fraction**

solid particles of sizes between 200 mm and 60 mm

2.2.22**gravel fraction**

the fraction of a soil composed of particles between the sizes of 60 mm and 2 mm. The gravel fraction is subdivided as follows:

Coarse gravel	60 mm to 20 mm
Medium gravel	20 mm to 6 mm
Fine gravel	6 mm to 2 mm

2.2.23**sand fraction**

the fraction of a soil composed of particles between the sizes of 2.0 mm and 0.06 mm. The sand fraction is subdivided as follows:

Coarse sand	2.0 mm to 0.6 mm
Medium sand	0.6 mm to 0.2 mm
Fine sand	0.2 mm to 0.06 mm

2.2.24**silt fraction**

the fraction of a soil composed of particles between the sizes of 0.06 mm and 0.002 mm. The silt fraction is subdivided as follows:

Coarse silt	0.06 mm to 0.02 mm
Medium silt	0.02 mm to 0.006 mm
Fine silt	0.006 mm to 0.002 mm

2.2.25**clay fraction**

the fraction of a soil composed of particles smaller in size than 0.002 mm

2.2.26**finer fraction**

the fraction of a soil composed of particles passing a 63 µm test sieve

2.2.27**voids**

the spaces between solid particles of soil

2.2.28**voids ratio (e)**

the ratio between the volume of voids (air and water) and the volume of solid particles in a mass of soil:

$$e = \frac{\rho_s}{\rho_d} - 1$$

2.2.29**porosity (n)**

the volume of voids (air and water) expressed as a percentage of the total volume of a mass of soil:

$$n = \frac{e}{1+e} \times 100 (\%)$$

2.2.30**saturation**

the condition in which all the voids in a soil are completely filled with water

2.2.31**degree of saturation (S_r)**

the volume of water contained in the void spaces between soil particles, expressed as a percentage of the total voids:

$$S_r = \frac{w\rho_s}{e} (\%)$$

2.2.32**compaction**

the process of packing soil particles more closely together by rolling or other mechanical means, thus increasing the dry density of the soil

2.2.33**optimum moisture content**

the moisture content at which a specified amount of compaction will produce the maximum dry density

2.2.34**maximum compacted dry density**

the dry density obtained using a specified amount of compaction at the optimum moisture content

2.2.35**relative compaction**

the percentage ratio of the dry density of the soil to the maximum compacted dry density of a soil when a specified amount of compaction is used

2.2.36**dry density/moisture content relationship**

the relationship between dry density and moisture content of a soil when a specified amount of compaction is employed

2.2.37**percentage air voids (V_a)**

the volume of air voids in the soil expressed as a percentage of the total volume of the soil:

$$V_a = \left[1 - \frac{\rho_d}{\rho_w} \left(\frac{\rho_w}{\rho_s} + \frac{w}{100} \right) \right] 100 (\%)$$