

Methods of test for

Soils for civil engineering purposes —

Part 1: General requirements and sample preparation

Committees responsible for this British Standard

The preparation of this British Standard was entrusted by the Road Engineering Standards Policy Committee (RDB/-) to Technical Committee RDB/38, upon which the following bodies were represented:

- Association of Consulting Engineers
- British Civil Engineering Test Equipment Manufacturers Association
- County Surveyors' Society
- Department of the Environment (Property Services Agency)
- Department of the Environment (Building Research Establishment)
- Department of Transport
- Department of Transport (Transport and Road Research Laboratory)
- Co-opted members

This British Standard, having been prepared under the direction of the Road Engineering Standards Policy Committee, was published under the authority of the Board of BSI and comes into effect on 28 February 1990

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First published in 1948
First published in metric, 1975

The following BSI references relate to the work on this standard:
Committee reference RDB/38
Draft for comment 88/10674 DC

ISBN 0 580 17692 4

Amendments issued since publication

Amd. No.	Date of issue	Comments
8258	January 1995	Indicated by a sideline in the margin

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BS 1377:1975 which has now been withdrawn is replaced by the following Parts of BS 1377:1990: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

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

2.2.38**air voids line**

a line on a graph showing the dry density/moisture content relationship for soil containing a constant percentage of air voids. The line can be calculated from the equation:

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

where

ρ_d is the dry density of the soil (Mg/m³);

ρ_w is the density of water (Mg/m³);

V_a is the volume of air voids in the soil, expressed as a percentage of the total volume of the soil;

ρ_s is the particle density (Mg/m³);

w is the moisture content, expressed as a percentage of the mass of dry soil.

2.2.39**saturation line (zero air voids line)**

a line on a graph showing the dry density/moisture content relationship for soil containing no air voids. It is obtained by putting $V_a = 0$ in the equation given in definition 2.2.38

2.2.40**limiting densities**

the dry densities corresponding to the extreme states of packing (loosest and densest) at which the particles of a granular soil can be placed

2.2.41**maximum density ($\rho_{dmax.}$)**

the maximum dry density at the densest practicable state of packing of particles of a granular soil

2.2.42**minimum density ($\rho_{dmin.}$)**

the minimum dry density at the loosest state of packing of dry particles which can be sustained in a granular soil

2.2.43**maximum (minimum) porosity or voids ratio**

the porosity or voids ratio corresponding to the minimum (maximum) dry density as defined above

2.2.44**density index (I_D)**

the ratio of the difference between the maximum and actual voids ratio of a soil, to the difference between the maximum and minimum voids ratios:

$$I_D = \left(\frac{e_{max.} - e}{e_{max.} - e_{min.}} \right) = \left(\frac{\rho_d - \rho_{dmin.}}{\rho_{dmax.} - \rho_{dmin.}} \right) \left(\frac{\rho_{dmax.}}{\rho_d} \right)$$

2.2.45**California bearing ratio (CBR)**

the ratio (expressed as a percentage) of the force required to cause a circular piston of 1935 mm² cross-sectional area to penetrate the soil from the surface at a constant rate of 1 mm/min, to the force required for similar penetration into a standard sample of crushed rock. The ratio is determined at penetrations of 2.5 mm and 5.0 mm, and the higher value is used

2.2.46**penetration resistance**

the force required to maintain a constant rate of penetration of a probe, e.g. a CBR piston, into the soil

2.2.47**consolidation**

the process whereby soil particles are packed more closely together over a period of time by application of continued pressure. It is accompanied by drainage of water from the voids between solid particles

2.2.48**pore water pressure (u_w)**

the pressure of the water in the voids between solid particles

2.2.49**excess pore pressure**

the increase in pore water pressure due to the application of an external pressure or stress

2.2.50**degree of consolidation (U)**

a measure of consolidation at a given time, expressed as a percentage defined by the equation:

$$U = \frac{u_1 - u_w}{u_1 - u_0} 100 (\%)$$

where

u_w is the pore pressure at the time considered;

u_1 is the initial pore pressure;

u_0 is the final equilibrium pore pressure when consolidation is complete.

2.2.51**coefficient of volume compressibility (m_v)**

the change in volume per unit volume, per unit pressure change, as a result of consolidation due to that pressure change:

$$m_v = \left(\frac{1}{1+e} \right) \left(\frac{\delta_e}{\delta_p} \right)$$

where

δ_e is a change in voids ratio produced by a change in pressure;

δ_p is a change in pressure;

e is the voids ratio.

2.2.52**coefficient of consolidation (c_v)**

the parameter which relates the change in excess pore pressure with respect to time, to the amount of water draining out of the voids of a soil prism during that time, due to consolidation:

$$c_v = \frac{k}{m_v \rho_w g}$$

2.2.53**time factor (T_v)**

the dimensionless parameter which is related to time, t , the coefficient of consolidation, c_v , and the length of drainage path, H , used for defining the theoretical rate of consolidation curve:

$$T_v = \frac{c_v t}{H^2}$$

2.2.54**coefficient of secondary compression (C_{sec})**

the ratio of the change in height to the initial height of a consolidation test specimen over one log cycle of time during the secondary compression phase:

$$C_{sec} = \frac{(\delta H)_s}{H_o} \text{ over one } \log_{10} \text{ cycle of time}$$

2.2.55**normally consolidated soil**

a soil which has never been subjected to an effective pressure greater than the present effective overburden pressure

2.2.56**overconsolidated soil**

a soil which has been consolidated under effective pressures greater than that due to the present effective pressure

2.2.57**swelling**

the process opposite to consolidation, i.e. expansion of a soil on reduction of pressure due to water being drawn into the voids between particles

2.2.58**swelling pressure**

the pressure required to maintain constant volume, i.e. to prevent swelling, when a soil has access to water

2.2.59**permeability**

the ability of a material to allow the passage of a fluid (Also known as hydraulic conductivity.)

2.2.60**hydraulic gradient (i)**

the ratio of the difference in total head of water, δh , on either side of a layer of soil, to the thickness of the layer measured in the direction of flow, L :

$$i = \frac{\delta h}{L}$$

2.2.61**coefficient of permeability (k)**

the mean discharge velocity of flow of water in a soil under the action of a unit hydraulic gradient:

$$k = \frac{Q}{A i t}$$

where Q is the quantity of water discharged in time t through a cross-sectional area A normal to the direction of flow, under hydraulic gradient, i

2.2.62**piping**

movement of soil particles carried by water eroding channels through the soil, leading to sudden collapse of soil

2.2.63**erosion**

removal of soil particles by the movement of water

2.2.64**dispersive (erodible) clays**

clays from which individual colloidal particles readily go into suspension in practically still water

2.2.65**total stress (σ)**

the actual stress in a soil mass the application of a pressure or force

2.2.66**effective stress (σ')**

the difference between the total stress, σ , and the pore water pressure, u_w :

$$\sigma' = \sigma - u_w$$

2.2.67**shear resistance**

the resistance offered to deformation by a soil when it is subjected to stress

2.2.68 shear strength

the maximum shear resistance which a soil can offer under defined conditions of effective stress and drainage

2.3 Symbols and units

The following symbols are used in this standard. The symbols generally conform to international usage. The units are those generally used. An asterisk indicates that no unit is used.

Term	Symbol	Unit
Moisture content	w	%
Liquid limit	w_L	%
Plastic limit	w_P	%
Shrinkage limit	w_s	%
Plasticity index	I_P	%
Liquidity index	I_L	*
Shrinkage ratio	R_s	*
Bulk density	ρ	Mg/m ³
Dry density	ρ_d	Mg/m ³
Particle density	ρ_s	Mg/m ³
Density of water	ρ_w	Mg/m ³
Voids ratio	e	*
Porosity	n	%
Degree of saturation	S_r	%
Percentage air voids	V_a	%
Maximum dry density	$\rho_{dmax.}$	Mg/m ³
Minimum dry density	$\rho_{dmin.}$	Mg/m ³
Maximum voids ratio	$e_{max.}$	*
Minimum voids ratio	$e_{min.}$	*
Density index $\frac{e_{max.} - e}{e_{max.} - e_{min.}}$	I_D	*
California bearing ratio	CBR	%
Mean particle diameter	D	mm or μm
Percentage by mass finer than D	K	%
Elapsed time	t	minutes or seconds
Dynamic viscosity of water	η	mPa s
Hydraulic gradient	i	*
Coefficient of permeability	k	m/s
Degree of consolidation	U	%
Coefficient of volume compressibility (one dimensional)	m_v	m ² /MN
Coefficient of consolidation (one dimensional)	c_v	m ² /year
Theoretical time factor	T_v	*
Coefficient of secondary compression	C_{sec}	*
Coefficient of volume compressibility (isotropic)	m_{vi}	m ² /MN
Coefficient of consolidation (isotropic)	c_{vi}	m ² /year
Coefficient of consolidation (radial outward drainage)	c_{ro}	m ² /year
Coefficient of consolidation (radial inward drainage)	c_{ri}	m ² /year

Term	Symbol	Unit
Total major principal stress	σ_1	kPa
Total minor principal stress	σ_3	kPa
Normal stress	σ_n	kPa
Effective major principal stress	σ_1'	kPa
Effective minor principal stress	σ_3'	kPa
Principal stress difference	$(\sigma_1 - \sigma_3)$	kPa
Maximum principal stress difference	$(\sigma_1 - \sigma_3)_f$	kPa
Pore water pressure	u_w	kPa
Shear resistance	τ	kPa
Maximum shear resistance	τ_f	kPa
Undrained shear strength	c_u	kPa
Unconfined compressive strength	q_u	kPa
Cohesion intercept (effective stresses)	c'	kPa
Angle of shear resistance (effective stresses)	ϕ'	degrees
Residual cohesion intercept	c'_R	kPa
Residual angle of shear resistance	ϕ'_R	degrees
Strain	ϵ	%
Remoulded shear strength	c_r	kPa
Sensitivity	S_t	*
Stress path parameters: $\frac{1}{2} (\sigma_1' + \sigma_3')$	s'	kPa
$\frac{1}{2} (\sigma_1' - \sigma_3')$	t'	kPa
Theoretical 100 % consolidation	t_{100}	minutes
Calculated time to failure	t_f	minutes
Pore pressure coefficient $\frac{\delta u_w}{\delta \sigma_3}$ (when $\sigma_1 = \sigma_2 = \sigma_3$)	B	*
Pore pressure coefficient $\frac{\delta u_w}{\delta (\sigma_1 - \sigma_3)}$ (for the condition $B = 1$)	A	*
Cone resistance (static cone test CPT)	q_c	MPa
Local unit side friction resistance (CPT)	f_s	kPa
Friction ratio (CPT)	R_f	%
Penetration resistance (SPT): Test with drive shoe	N	*
Test with solid cone	$SPT(C)$	*
Ultimate bearing capacity	q_u	kPa
“Apparent” resistivity	r_s	Ωm
Redox potential	E_h	mV
Specific conductance of water	—	$\mu S/mm$
Incremental changes of ...	δ	
Cumulative changes of ...	Δ	

3 Classification of soils

3.1 Grouping of soils

For the purposes of the tests described in this standard, soils shall be grouped as *cohesive or cohesionless*, as defined in 2.1. Each of these types shall be grouped as follows.

- a) *Fine-grained soils*. Soils containing not more than 10 % retained on a 2 mm test sieve;
- b) *Medium-grained soils*. Soils containing more than 10 % retained on a 2 mm test sieve but not more than 10 % retained on a 20 mm test sieve;
- c) *Coarse-grained soils*. Soils containing more than 10 % retained on a 20 mm test sieve but not more than 10 % retained on a 37.5 mm test sieve.

NOTE Soils with more than 10 % of material retained on a 37.5 mm test sieve cannot usefully be examined by the laboratory tests of this standard except for the particle size analysis (sieving), and the moisture content and plasticity tests on the fine fraction if present. Some of these materials would be classed as aggregates, which are covered by BS 812. Very coarse materials such as rockfill are not covered by this standard.

A soil shall be regarded as belonging to the finest-grained group as appropriate under the above definitions.

3.2 Description of soils

The visual description of soils shall comply with BS 5930.

3.3 Classification system

Soils shall be classified in accordance with the British Soil Classification System for Engineering Purposes (BSCS), as described in clause 42 of BS 5930:1981. This shall be supplemented by the laboratory classification procedure (clause 43 of BS 5930:1981) when test results are known.

4 Apparatus

4.1 General

4.1.1 Specification for apparatus. The apparatus required for each test method shall be as listed in the appropriate clause of Parts 2 to 9 of this standard.

Items of general apparatus that appear in more than one Part of this standard shall be as specified in 4.2.

Apparatus used only for one purpose is specified in the appropriate Part of this standard.

Each item of apparatus shall be checked before use to ensure that it complies with its specification, calibration requirements and the relevant general requirements given in this clause.

A piece of apparatus referred to as a calibrated item shall have been calibrated in accordance with its specification and as described in 4.4, where appropriate.

4.1.2 Relevant British Standards. Test apparatus and equipment shall comply with the relevant British Standards.

4.1.3 Tolerances

4.1.3.1 Manufacturing tolerances

Linear dimensions. The manufacturing tolerances or limits on the essential dimensions, marked *, of apparatus used for the tests shall be in accordance with those given in the drawings featured in the Parts of this standard.

NOTE All other dimensions are given for guidance.

4.1.3.1.1 Mass. Where mass is specified, the manufacturing tolerance on the mass shall be within ± 1 % unless stated otherwise.

4.1.3.1.2 Working tolerances. Working tolerances shall not exceed twice the manufacturing tolerance unless other requirements are specified.

NOTE Working tolerances apply to apparatus after being subjected to wear in use.

4.2 Specification for general test apparatus

4.2.1 Measuring instruments

4.2.1.1 Balances and weights. The categories of balance listed in Table 1 are examples of those which cover the requirements of the tests in this British Standard.

NOTE Balances may incorporate an analogue or a digital display.

Each set of ancillary weights shall be calibrated in accordance with 4.3.3.1.

Table 1 — Categories of balances

Capacity	Scale interval or digit	Maximum error of reading
g	g	g
200	0.001	0.005
1 200	0.01	0.05
kg		
2	0.1	0.3
5	0.5	1
10	1	3
25	5	10
50	10	20

The balance selected for a weighing shall enable the mass to be determined to the accuracy required for the purpose of the test, which shall normally be within 0.1 % of the mass being determined.

Calibration of balances shall comply with 4.4.4.1. Balances shall be labelled showing limitations of use with respect to the lower end of their range as determined by calibration.

4.2.1.2 Thermometers. Thermometers covering the required working range and having the following graduations are suitable:

Required accuracy of reading	Graduation intervals or digit
0.2 °C	≤ 0.1 °C
0.5 °C	≤ 0.2 °C
1 °C	≤ 0.5 °C

For mercury-in-glass thermometers the graduations shall comply with clause 8 of BS 593:1974. Calibration of thermometers shall comply with 4.4.4.2.

4.2.1.3 Length measurement instruments

4.2.1.3.1 Steel rule. An engineer's steel rule with scale divisions every 0.5 mm is suitable.

4.2.1.3.2 Try-square. An engineer's steel try-square is suitable.

4.2.1.3.3 Vernier calipers. Vernier calipers for internal and external measurements shall be readable to 0.1 mm or better and shall be calibrated in accordance with 4.4.4.3.

4.2.1.3.4 Micrometers. Micrometer measuring devices shall be readable to 0.01 mm or 0.002 mm or better, depending on the resolution specified in the test method. Calibration shall be in accordance with 4.4.4.3.

4.2.1.3.5 Dial gauges. Dial gauges shall be readable to 0.01 mm or 0.002 mm or better, depending on the range of travel specified in the test method. Calibration shall be in accordance with 4.4.4.3.

4.2.1.3.6 Displacement transducers. Electrical transducers used for measuring displacement shall have a range of travel, readability and accuracy at least as good as that specified for the equivalent dial gauges and shall be calibrated in accordance with 4.4.4.3.

4.2.1.4 Timers. Stopwatches and stopclocks readable to 1 s shall be used, or a suitably placed wall clock with seconds hand, and large enough to read to 1 s from the work station. Timers shall be calibrated in accordance with 4.4.4.4.

4.2.1.5 Volumetric glassware. For the purpose of this standard, volumetric glassware complying with class B of BS 5898 is adequate. Glassware shall be calibrated in accordance with 4.4.4.5.

4.2.1.6 Force measurement. A suitable calibrated force-measuring device shall be mounted in a reaction frame fitted with a means of generating forces on the specimen under test. The frame shall be rigid enough not to impair the required accuracy of the force measurement in the test method.

The force-measuring device selected for a test procedure described in this standard shall be of a range and sensitivity appropriate to the strength properties of the material being tested under the conditions of the test. Readings of applied force used for establishing soil parameters shall lie within the calibration range.

Force-measuring devices shall be calibrated in accordance with 4.4.4.6.

4.2.1.7 Pressure gauges. Bourdon tube pressure gauges used as part of the instrumentation for the tests covered by this standard shall be of "test" grade as defined in BS 1780. Alternatively, electrical pressure transducers may be used. The working range of either type of instrument shall be appropriate to the requirements of the test apparatus, and they shall be readable to within 0.5 % of the full-scale reading for pressures exceeding 10 % of that reading.

NOTE 1 Manufacturers of Bourdon tube pressure gauges recommend that they should not be subjected to steady continuous pressures exceeding about 75 % of the full-scale reading.

NOTE 2 For measurement of pressures below 50 kPa a mercury manometer, or a pressure transducer of the specified accuracy, or a pressure gauge having a scale range from 0 to about 100 kPa, should be used.

Connections and couplings shall comply with BS 1780.

Pressure gauges shall be calibrated in accordance with 4.4.4.7.

4.2.1.8 Volume-change indicators. A volume-change indicator, e.g. burette or transducer type, shall be capable of measuring the volume of water draining into or out of a specimen, at pressures up to the maximum working pressure, to the following readability:

capacity up to 50 cm ³	: to within 0.1 mL;
capacity exceeding 50 cm ³	: to within 0.2 mL.

NOTE The direction of flow within the indicator may be reversible to accommodate volume changes in excess of its full-scale capacity, provided that suitable allowance is made for backlash errors which occur on reversal.

Volume-change indicators shall be calibrated in accordance with 4.4.4.8.

4.2.2 General apparatus

4.2.2.1 Drying ovens. Ovens used for drying soil shall incorporate a temperature control which can be set to maintain a selected temperature within the range 45 °C to 110 °C. Ovens shall be capable of maintaining the temperature required for the test to within ± 2.5 °C as measured at a point in the middle of the working space. Each oven shall have provision for inserting a calibrated temperature-indicating device.

Drying ovens shall be calibrated in accordance with 4.4.5.1.

NOTE A circulation fan may be fitted as an aid to uniform temperature distribution.

4.2.2.2 Constant temperature bath. A constant temperature water bath shall be deep enough to enable the test vessel to be immersed to the specified depth. It shall be fitted with a temperature control unit, assisted by forced circulation if necessary, to provide a temperature within the specified limits at any point within the bath. Calibration shall be in accordance with 4.4.5.2.

4.2.2.3 Test sieves. Test sieves shall comply with BS 410. For the type of materials covered by this standard, full tolerance sieves as defined by BS 410 are adequate. Sieves with aperture sizes of 5 mm and above shall be perforated plate square hole test sieves. Below that size they shall be woven wire test sieves.

Certificates issued with sieves by the manufacturer shall be retained throughout the working lives of the sieves.

Sieves used for particle size analysis shall be marked with a set reference and used only as a constituent of that set. When a new sieve is incorporated into a set it shall receive the set reference mark.

Calibration checks on sieves shall be carried out in accordance with 4.4.5.3.

4.2.2.4 Sieve shakers. Mechanical sieve shakers shall hold securely a nest of test sieves with their lid and receiver. Their design shall ensure that the test material progresses over the surface of the sieve while it is agitated.

4.2.2.5 Sample dividers. When sample dividers are used the width of slot shall be not less than 1.5 times the largest size of particle contained in the sample to be divided.

The size of riffle box used shall be appropriate to the largest size of particle contained in the sample to be divided.

4.2.2.6 Hanger weights. Hanger weights used for applying a force vertically to a test specimen shall normally be of the slotted cast-iron type. They shall be capable of being stacked in a stable condition on the hanger. Each weight shall be clearly marked with its mass.

Hanger weights shall be calibrated in accordance with 4.4.5.4.

4.2.2.7 Sample moulds and tubes. Containers for holding or preparing soil samples, such as moulds, sampling tubes and specimen-retaining rings, shall be corrosion-resistant and capable of resisting distortion in normal operational use.

Sampling tubes and rings that are pushed into undisturbed soil for obtaining a sample shall have an area ratio (as defined in note 2 to 8.2.3.2) as low as possible consistent with robustness, and not in excess of 20 % unless stated otherwise in the individual test.

The internal dimensions and the mass of sample moulds and tubes shall be checked in accordance with 4.4.5.5.

4.2.2.8 Desiccators. Glass desiccators shall be provided with a lid which can form an airtight seal. Desiccator cabinets shall be fitted with an airtight seal around the doors. Shelves shall be such as to allow air to circulate.

The desiccant shall be of self-indicating silica gel crystals.

A vacuum desiccator shall be covered by a safety cage when in use.

4.2.2.9 Bottle shakers. A motorized device to which bottles or gas jars can be securely attached, giving an end-over-end rotary motion, can be used for shaking a suspension of soil in water. The motor shall be capable of rotating the containers continuously at the specified speed for periods up to 24 h.

A protective guard shall be provided if appropriate. Rotary bottle shakers shall be calibrated in accordance with 4.4.5.6.

4.2.2.10 Centrifuges. Centrifuges shall comply with the safety requirements of BS 4402.

4.2.2.11 Vacuum system. A vacuum source shall be capable of producing a vacuum of 15 mm of mercury or lower in the system. The system shall be fitted with a calibrated vacuum indicator readable to 20 mm of mercury or the equivalent, or better.

4.2.2.12 Hotplate. An electric hotplate shall be fitted with an adjustable control to provide boiling or simmering temperatures.

NOTE A bunsen burner, with tripod and gauze, may be used as an alternative controlled source of heat.

4.2.2.13 Wax bath. An electrically heated wax bath shall be fitted with an adjustable control to enable the wax to be maintained at a temperature just above its melting point.

NOTE Excessive heating of wax should be avoided.

4.2.3 Special apparatus. Apparatus required only for a particular laboratory or in-situ test shall be as specified under the relevant test method. Calibration of these items shall comply with the general requirements of 4.4.6.

4.3 Laboratory reference standards

4.3.1 Reference standards for in-house calibration. Where calibration of test measuring instruments is carried out in-house the laboratory shall hold reference standards or instruments that are used solely for calibration purposes as required by BS 5781. Reference standards or instruments shall be retained securely in a suitable environment when not in use. Reference standards and instruments shall be of an accuracy greater than that of the working device so that the desired accuracy of test measurement is achieved.

Recalibration of reference standards shall be at intervals not greater than those specified in 4.3.3.1 to 4.3.3.5 for each type of instrument. Notwithstanding these intervals, whenever a change in accuracy of a reference instrument is suspected, or when a reference instrument has been repaired, dismantled, adjusted or overhauled, it shall be recalibrated before further use.

Instruments used as reference standards for calibration for the purposes of this standard shall be as summarized in Table 2. They shall be calibrated and certificated as specified in 4.3.2 and 4.3.3.

4.3.2 Traceability of reference standards. Reference standards and instruments shall have certification provided by the competent national body, e.g. NPL¹⁾, NWML²⁾, or by a laboratory currently recognized for that purpose within the National Measurement System, e.g. a NAMAS³⁾ accredited calibration laboratory. The certification shall show traceability to national standards.

4.3.3 Specifications for reference standards and instruments

4.3.3.1 Reference weights. Reference weights used for calibrating balances shall be appropriate to the category of balance, and shall be of an accuracy at least five times better than the required readability of the balance in the appropriate range.

Table 2 — Instruments used as reference standards for calibration

Measured quantity	Instruments	BS reference
Mass	Reference weights	BS 593
Temperature	Mercury-in-glass thermometers	
	Thermocouples	
Length	Platinum-resistance thermometers	BS 4311
	Gauge blocks	
Force	Proving rings	BS 1610
	Electrical force transducers	
	Hydraulic press using dead-weights	
Pressure	Test pressure gauge	BS 1780
	Dead-weight tester	

¹⁾ National Physical Laboratory, Teddington, Middlesex TW11 0LW.
²⁾ National Weights and Measures Laboratory, National Physical Laboratory, Teddington, Middlesex TW11 0LW.
³⁾ National Measurement Accreditation Service. NAMAS Executive, National Physical Laboratory, Teddington, Middlesex TW11 0LW.

Reference weights shall be recalibrated at intervals not exceeding those specified in Table 3.

Table 3 — Reference weights

Range	Maximum calibration interval
≤ 200 g	First calibration after 2 years, then every 5 years
> 200 g	5 years

4.3.3.2 Reference thermometers. Mercury-in-glass thermometers used as reference thermometers for calibrating laboratory working thermometers shall comply with BS 593. Reference thermometers shall be calibrated initially and then recalibrated after 2 years and thereafter at intervals not exceeding 5 years.

Calibrated thermocouples and platinum-resistance thermometers used as reference instruments shall be recalibrated at least once every 2 years.

4.3.3.3 Linear measuring standards. Gauge blocks shall comply with grade 1 or better of BS 4311 and shall be recalibrated at least once every 5 years.

4.3.3.4 Proving devices for force measurement. Proving rings or calibrated electrical force transducers used for calibrating laboratory working force-measuring devices shall be of grade 1.0 when calibrated in accordance with BS 1610-2. A range of proving devices shall be available so that each force-measuring device can be calibrated against a proving device of appropriate range and sensitivity.

4.3.3.5 Reference pressure gauges. A reference gauge used for calibrating working pressure gauges or transducers shall be of test grade and shall have a resolution at least as good as that of the working gauges. It shall be calibrated at least once a year.

A dead-weight testing device shall be recalibrated at least once every 5 years.

4.4 Calibration and checking of test equipment

4.4.1 Traceability. All measurements necessary for the performance of tests covered by this standard shall be traceable, where this concept is applicable, to UK national standards of measurement through an unbroken chain of calibrations. The number of links in the chain shall be no greater than necessary to achieve the required accuracy.

4.4.2 External and in-house calibration

4.4.2.1 General requirements. Calibrations shall be carried out either by an external organization, or in-house by the laboratory's own staff. In either case traceability to UK national standards shall be achieved. Systems used shall comply with BS 5781, as well as the requirements given in 4.4.4 and under the relevant test method, where appropriate.

All calibrated equipment shall be used only over the range for which it has been calibrated. For tests where temperature control is specified calibrations shall be carried out within the range of temperature specified.

4.4.2.2 External calibration. When calibration is carried out under contract by an external organization, traceability shall be established by the issue of a certificate of calibration for the relevant item. The certificate shall include the following information, and shall be retained on file:

- a) name of calibrating organization;
- b) for whom calibrated, and location;
- c) description of the instrument calibrated, including identification number;
- d) method of calibration;
- e) equipment used;
- f) calibration certificate number of the reference device against which the instrument was calibrated, and the traceability route if the calibration was not performed by a laboratory of the National Measurement System;
- g) calibration temperature;
- h) calibration data and results;
- i) date of calibration;
- j) signature of person responsible for the calibration.

4.4.2.3 In-house calibration. Calibration shall be carried out in-house only by suitably qualified and experienced staff, in accordance with written procedures for each item. Reference instruments or standards against which working instruments are calibrated shall comply with, and shall be kept, used and maintained in accordance with, 4.3.

Calibration records shall include the following, and shall be retained on file:

- a) description of the instrument calibrated, including identification number;
- b) method of calibration;
- c) equipment used;
- d) calibration certificate number of the reference device against which the instrument was calibrated, and the traceability route if the calibration was not performed by a laboratory of the National Measurement System;
- e) calibration temperature;
- f) calibration data and results;
- g) date of calibration;
- h) date when the next calibration is due, if appropriate;
- i) signature of person responsible for the calibration.

4.4.3 Frequency of calibration. Routine recalibration of measuring instruments shall be carried out at intervals that are based on usage and on the analysis of documented calibration data so as to ensure that the required accuracy is not lost between calibrations. The periods between recalibrations specified in 4.4.4 and in Part 9 of this standard shall be the maximum periods for each type of instrument.

Whenever a change in accuracy of an instrument is suspected, or when an instrument has been repaired, dismantled, adjusted or overhauled, it shall be recalibrated before further use.

4.4.4 Calibration of measuring instruments

4.4.4.1 Balances. Balances shall be checked, adjusted and calibrated over their working range, using reference weights, at least twice a year, or at shorter intervals if necessary to prevent the maximum error of readings exceeding the values given in Table 1.

4.4.4.2 Thermometers. Mercury-in-glass thermometers shall be calibrated against a reference standard before first use. They shall be recalibrated at intervals not exceeding 5 years.

If other temperature-measuring devices are used they shall be calibrated against a reference thermocouple, platinum-resistance thermometer or reference mercury-in-glass thermometer at least once every 6 months.

4.4.4.3 Linear measurement instruments

4.4.4.3.1 Vernier calipers and micrometers shall be calibrated at least once a year against reference gauge blocks.

4.4.4.3.2 Dial gauges and electrical displacement transducers shall be calibrated against a calibrated micrometer device, or in a comparator frame using gauge blocks or length bars. Dial gauges shall be calibrated at least once a year. Electrical devices shall be calibrated at least once a year, together with the same read-out unit as is used for tests.

4.4.4.4 Timers. Timing devices such as stopclocks and stopwatches shall be calibrated at least once a year to within 1 s in 5 min.

4.4.4.5 Volumetric glassware. In-house calibration of volumetric glassware may be carried out by weighing the amount of distilled water that the vessel contains or delivers at a measured temperature. A calibrated balance shall be used, and the temperature correction tables in BS 1797 shall be applied.

4.4.4.6 Force-measuring devices (compressive forces)

4.4.4.6.1 Each force-measuring device shall be calibrated at least once a year against a calibrated proving device having a range and sensitivity appropriate to that of the measuring device. Where it is not practicable to calibrate each force-measuring device in the load frame in which it is to be used it shall be calibrated in a dedicated load frame. The load frame used shall be identified in the calibration records.

Where a device is fitted with a dial gauge or displacement transducer this shall be considered to be an integral part of the device and shall be marked as such. It shall not be replaced without recalibration of the device.

The calibration apparatus shall be used only over the range for which it has been calibrated.

4.4.4.6.2 The method of calibrating a force-measuring device for the purposes of this standard shall be as follows.

- a) Mount the force-measuring device and the proving device in the calibration apparatus so that the forces are applied to the device along the loading axis of the frame.
 - b) Record the temperature of the equipment when stabilized.
 - c) Exercise the two devices three times up to the maximum calibration load and down to zero load.
 - d) Reset to zero the dial indicator or displacement transducer on the force-measuring device being calibrated and, if necessary, reset the indicator of the proving device.
 - e) Operate the calibration apparatus to apply a series of at least five more or less equispaced known forces (as determined by the proving device) upwards from 20 % of the maximum scale reading of the force-measuring device, or the lower limit of verification as defined in BS 1610-1, whichever is greater. Apply the series of forces in ascending order. Record each reading of the dial indicator on the force-measuring device.
- NOTE Where calibration for use below 20 % of the maximum scale reading is required, then this should be done in accordance with BS 1610-1.
- f) Repeat e) to give three series of the same forces. After each series remove the force completely and record the zero reading of the force-measuring device.
 - g) Average the force-measuring device dial indicator readings (divisions or digits) for each force, obtained from the three sets of applied forces.

h) Calculate the spread of each set of three readings, and the repeatability, as described in BS 1610-1.

i) Divide the applied force by the average reading to obtain the calibration factor (force/division or force/digit) for each calibration force.

Plot each calibration factor as ordinate against the average reading (divisions or digits) as abscissa. Join the points with a straight line or a smooth curve as appropriate.

j) Draw a horizontal line representing the calibration factor for the mid-scale force (or closest for which readings have been obtained).

k) Calculate values of calibration factors that are 2 % higher and 2 % lower than the mid-scale factor.

l) The mid-range calibration factor may be used in a test to calculate the force in a test where the calibration curve lies within the ± 2 % limits established in k). Where the calibration factor lies outside these limits the calibration factor shall be obtained from the graph.

m) The calibration data obtained in i) are acceptable over the range within which the repeatability does not exceed 2 %.

4.4.4.7 Pressure gauges

4.4.4.7.1 Pressure gauges, whether of the Bourdon tube type or electrical transducers, shall be calibrated at least once every 6 months against a calibrated dead-weight tester or a calibrated master reference gauge. The principle given in clause 7.1 of BS 1780:1985 shall be used. When two gauges are used for comparing differences of pressure they shall be calibrated simultaneously against the same reference pressure source. Small pressure differences shall be measured with a differential pressure gauge or with a mercury manometer designed to provide measurements of the required accuracy over the required range and to withstand the applied pressures.

4.4.4.7.2 A method of applying the calibration readings for the purposes of this standard shall be as follows.

a) Plot the error (positive and negative in opposite directions) corresponding to each reading as ordinate, against the reading of the working gauge as abscissa. The error shall be plotted on a suitably exaggerated scale.

b) Join successive points with a straight line, or fit a smooth curve through the points if convenient. The graph gives the amount by which the gauge reading shall be increased or decreased to obtain the corrected pressure.

c) Alternatively tabulate the errors against gauge readings and obtain intermediate values by interpolation.

d) Display the calibration graph or table alongside the gauge to which it relates.

4.4.4.8 *Volume-change indicators.* Volume-change indicators shall be calibrated as specified in 4.4.4.5 for volumetric glassware. Burette type indicators shall be calibrated at least once every 2 years. Indicators fitted with transducers and their associated read-out units shall be calibrated at least once a year.

4.4.5 Calibration and checking of general test equipment

4.4.5.1 *Drying ovens.* The temperature at the mid-point of the usable oven space inside an empty oven shall be verified periodically by means of a calibrated temperature-measuring device.

4.4.5.2 *Constant temperature bath.* Constant temperature water baths shall be checked by using a calibrated immersion thermometer at several points within the working area of the bath and observing the temperature when it becomes steady.

NOTE For a given steady room temperature the water temperature control setting may be calibrated against various water temperatures by repeating the above procedure over the range of settings used for tests in this standard.

4.4.5.3 *Test sieves.* All test sieves shall be checked by the following method.

a) *Visual checks.* Check sieves visually for defects before each use. Make also a detailed visual check of the condition of every sieve, by designated personnel, at regular intervals, depending on use. Use the method described in b) or c) as appropriate to check and replace sieves suspected of being defective, if necessary.

b) *Measurement checks.* Measure the apertures of perforated plate test sieves in accordance with appendix F of BS 410:1986 at least twice a year.

c) *Performance checks.* Check the aperture of woven wire cloth test sieves at regular intervals depending on use, by either of the following methods.

i) *Use of reference sample.* Use reference samples, consisting preferably of rounded or sub-rounded particles, of known particle size distribution, and having approximately 50 % retained on the sieve being checked, to check each working test sieve.

ii) *Use of master sieves.* Check working test sieves against a master set of sieves retained exclusively for that purpose. Do this by dry-sieving a test portion of dry quartz sand, preferably of rounded or sub-rounded particles, which gives approximately 50 % retained on the test sieve being checked, on both sets of sieves consecutively for a controlled period. Compare the masses retained on each sieve of each set. It will be necessary to use a different test portion with each sieve size.

For either method a sieve shall be considered as failing the performance check when the corresponding masses on individual sieves of the same mesh size differ by more than 5 %.

NOTE Wear and tear on sieves is also dependent on their manner of use and the abrasiveness of the material being used. Until a laboratory has sufficient records to indicate rates of wear and thus fix meaningful check periods, performance checks should be frequent.

d) *Failure.* Clearly mark test sieves which fail measurement or performance checks. Either discard or use as protection sieves where appropriate.

4.4.5.4 *Hanger weights.* Hanger weights used for applying force to test specimens in consolidation and direct shear tests, e.g. slotted hanger weights, shall be calibrated at least once every 2 years. Calibration shall be to within 0.1 % of the mass being measured.

4.4.5.5 *Specimen formers.* Items of equipment such as moulds, and specimen rings, shall be checked at least once a year by determining their internal measurements and mass. These determinations shall be carried out on new items and shall be repeated at intervals, depending on frequency of use, to allow for wear. When the change due to wear exceeds the permitted working tolerance, the item shall be discarded.

4.4.5.6 *Rotary bottle shakers.* The speed of rotation of machines used for shaking bottles and gas jars shall be calibrated at least once a year with the shaker fully laden.

4.4.6 *Calibration and checking of special test equipment.* The type of check needed on certain items of special apparatus, either to determine their performance during a test, or to ensure that they meet the specified requirements, as detailed for each case, shall be carried out at regular intervals related to frequency of use.

In addition, pretest checks and adjustments shall be carried out where necessary, as described in the relevant procedures.

5 Materials

5.1 Distilled water

Where distilled water is specified in test materials, it shall be produced either by distillation or by the use of deionizing apparatus. The latter shall incorporate a device for indicating when an unacceptable upper limit of conductance is reached.

Distilled or deionized water shall comply with the following requirements:

- a) *Non-volatile residue.* Not more than 5 mg of total dissolved solids per litre of water when tested in accordance with clause 8 of BS 1377-3:1990.
- b) *pH value.* Not lower than 5.0 and not higher than 7.5.

5.2 De-aerated water

Unless otherwise specified in test methods, de-aerated water shall consist of mains tap water from which dissolved air has been removed, e.g. by boiling or agitation under vacuum.

NOTE De-aerated tap water is normally satisfactory, but for some purposes the use of de-aerated natural ground water may be desirable for saturation of soil specimens. De-aerated distilled or deionized water should not be used because of its possible corrosive effects.

5.3 Chemicals and mercury

5.3.1 *Chemical reagents.* Chemical reagents used in performing the tests given in this standard shall be of recognized analytical reagent quality.

5.3.2 *Mercury.* Mercury used in test procedures shall be clean.

WARNING. Mercury is a hazardous substance, and appropriate precautionary measures should be taken when using it. Reference should be made to current Government regulations and to Guidance Note MS 12, Health and Safety Executive: Mercury — medical surveillance (HMSO, June 1979). Operations involving the use of mercury should be carried out in a fume cupboard or in the vicinity of an air-extractor fan so that any mercury vapour can be removed immediately.

5.4 Soil containers and sealants

5.4.1 *Containers.* Containers into which soil samples are placed shall be of glass or plastics or corrosion-resistant metal.

NOTE The potential corrosivity of some naturally occurring ground water should be taken into account.

Containers for undisturbed samples, and for samples from which natural moisture contents are to be determined, shall be capable of being sealed to prevent loss or gain of moisture.

5.4.2 Paraffin wax. Paraffin wax used for sealing or coating samples shall be of micro-crystalline grade, which has low shrinkage and a low melting point. Wax shall not be heated more than is necessary to cause it to melt, and wherever possible a temperature-controlled wax pot shall be used. A coating of wax shall be built up in several thin layers, the first two or three of which shall be applied by brush.

6 Environmental requirements

6.1 Temperature control

Where laboratory temperature control is specified the temperature control system shall be capable of maintaining a constant ambient laboratory temperature during the test to within the limits specified. The system shall be capable of restoring changes of temperature in the locality of the test, e.g. due to opening and closing of doors, to comply with these limits within a period not exceeding 10 min. A method of continual recording of the temperature shall be adopted to ensure compliance with these limits.

NOTE The following test methods in this standard require environmental temperature control:

Part 5: Determination of the one dimensional consolidation properties

Determination of swelling and collapse characteristics

Part 6: Determination of consolidation properties using a hydraulic cell

Determination of permeability in a hydraulic consolidation cell

Determination of isotropic consolidation properties using a triaxial cell

Determination of permeability in a triaxial cell

Part 7: Determination of shear strength by direct shear using the large and small shear box

Determination of residual strength using the small ring shear apparatus

Part 8: Consolidated undrained triaxial compression test
Consolidated drained triaxial compression test

6.2 Temperature records

Daily readings of maximum and minimum air temperatures in testing areas shall be recorded.

7 Preparation of disturbed samples for testing

7.1 General

This section covers the preparation of disturbed samples of soil from the samples received from the field, and their allocation for subsequent tests. The preparation of test specimens of compacted soil for strength, compressibility and permeability tests is also included.

Recommended procedures for obtaining samples from the ground in-situ are described in BS 5930, to which reference should be made.

7.2 Apparatus

7.2.1 Processing. The apparatus shall be as described in 7.2.1.1 to 7.2.1.12 for initial processing of disturbed samples, including drying, disaggregation and subdivision for testing as described in 7.3 to 7.7.

7.2.1.1 A balance, of 2 kg capacity, readable to 0.1 g.

7.2.1.2 A balance, of 10 kg capacity, readable to 1 g.

7.2.1.3 A balance, e.g. platform scales, of 25 kg capacity, readable to 5 g.

7.2.1.4 A means of breaking up aggregations of soil without reducing the size of the individual particles, e.g. a mortar and a rubber-headed pestle or a suitable mechanical device which has an action no more severe than that of a rubber-headed pestle.

7.2.1.5 Test sieves, with aperture sizes 425 µm, 2 mm, 5 mm, 20 mm, 37.5 mm, and a receiver.

7.2.1.6 Drying ovens, capable of maintaining temperatures of 45 °C to 50 °C and 105 °C to 110 °C.

7.2.1.7 Sample dividers, e.g. of the multiple-slot type (riffle box).

7.2.1.8 A tray made of corrosion-resistant metal, large enough for mixing the initial soil sample.

7.2.1.9 A metal scoop.

7.2.1.10 A palette knife.

7.2.1.11 Watertight corrosion-resistant containers or strong polyethylene bags.

7.2.1.12 An implement for shredding stiff cohesive soil.

7.2.2 Compaction to form test specimens. Additional apparatus for the preparation of test specimens of compacted soil as described in 7.6 shall be selected from 7.2.2.1 to 7.2.2.7, depending on the specimen size and method used.

7.2.2.1 A cylindrical metal mould, internal volume 1 000 cm³ (the one-litre compaction mould) with detachable baseplate and extension, as specified in 3.3.2.1 of BS 1377-4:1990.

7.2.2.2 A 2.5 kg metal rammer, as specified in 3.3.2.2 of BS 1377-4:1990.

7.2.2.3 A 4.5 kg metal rammer, as specified in 3.5.2.2 of BS 1377-4:1990.

7.2.2.4 A cylindrical metal mould of internal diameter 152 mm (the CBR mould), with detachable baseplate and extension, as specified in 7.2.2.2 of BS 1377-4:1990.

7.2.2.5 Cylindrical split moulds, fitted with a clamping device capable of holding the component parts securely together and maintaining the cylindrical shape when the soil is subjected to compaction.

7.2.2.6 A source of vacuum with a connecting length of vacuum tubing.

7.2.2.7 Tamping rod, or spring-loaded tamping device, with a flat circular end of a diameter between one-third and half of the specimen diameter.

7.3 Initial preparation

7.3.1 Assessment of soil grouping. An assessment shall be made as to whether the soil is to be classified as cohesive or cohesionless, and as fine-grained, medium-grained or coarse-grained, as defined in clause 3. In doubtful cases or where confirmation is required, a portion of the sample shall be sieved through the appropriate sieve or sieves, using the procedure described in 9.2 or 9.3 of BS 1377-2:1990. The size of sample used for this shall comply with Table 4.

Table 4 — Size of particle and mass of sample required for assessment sieving

Largest size of particle present in substantial proportion, i.e. more than 10 %	Minimum mass of sample to be taken for assessment sieving
mm	kg
< 75 but > 20	15
< 20 but > 2	2
< 2	0.1

7.3.2 Mass of soil required for testing. The total mass of sample required for testing after assessment sieving depends on the soil group and the tests to be carried out but to ensure a representative sample the total mass shall be not less than the following minimum masses:

- fine-grained soils 500 g;
- medium-grained soils 5 kg;
- coarse-grained soils 30 kg.

The actual mass of sample required shall be assessed by multiplying the mass given in Table 5 (which includes some allowance for drying, wastage and rejection of stones where required) by the number of test determinations to be carried out. Where the total mass of sample so calculated is less than the minimum mass given above for the appropriate soil group then that minimum mass may be taken.

7.3.3 Moisture content determination. If the moisture content of the natural soil, as received, is required, representative samples of the minimum masses given in 7.4.2 shall be obtained by riffing or quartering.

Where samples are taken on site for moisture content determination the use of shallow trays for storing or carrying shall be avoided. The samples shall be kept covered or, preferably, sealed except when material is actually being extracted.

7.3.4 Drying of soil. Soil shall be dried by one or other of the following two methods:

- a) *Oven drying.* Drying to constant mass in an oven maintained at a temperature of 105 °C to 110 °C.
- b) *Air drying.* Partial drying at a temperature not exceeding 50 °C. in this method it shall be permissible for the drying methods to range from exposure to air at room temperature, to partial drying in a fan-assisted oven maintained at a temperature up to 50 °C.

NOTE 1 The soil should be turned over from time to time to avoid local drying out.

When it is necessary to reduce the moisture content to a level suitable for processing, the soil shall be partially dried at a temperature not exceeding 50 °C, unless drying at a higher temperature is specified. No part of the soil shall be allowed to dry out completely.

NOTE 2 Many definitive procedures require that the soil should not be allowed to become dry before testing. Wherever possible, soil should be used in its natural state. With some soils, irreversible changes take place when dried at 105 °C to 110 °C, or in some instances, e.g. organic soils or certain tropical soils, even when air-dried.

For most purposes the soil should be partially dried no more than is necessary to enable it to be crumbled, or to bring it to a suitable state for a test.

Exposure to direct sunlight or to infra-red lamps, and the use of a micro-wave oven, shall be avoided for soils containing clay or organic matter. When reducing the water content to a desired level, check weighings shall be made periodically.

When it is not practicable to use the soil in its natural state the reason shall be stated and the method of drying shall be reported.

7.3.5 Mechanical processing

7.3.5.1 Breaking down of aggregations. After partial drying (if necessary) in accordance with 7.3.4, aggregations of particles shall be broken down in such a way as to avoid crushing the individual particles. Use an action that is no more severe than that applied by a rubber pestle. All aggregations of particles shall be broken down so that when the sample is sieved on the specified test sieve only individual particles shall be retained.

NOTE The soil should be considered susceptible to crushing during compaction if the sample contains granular material of a soft nature, e.g. soft limestone, sandstone, which is reduced in size by the action of the pestle.

Table 5 — Mass of sample required for each test on disturbed samples

Type of test	Laboratory test specification		Soil group		
	BS 1377: Part number	Sub-clause no.	Fine-grained	Medium-grained	Coarse-grained
Moisture content	2	3.2	50 g	350 g	4 kg
Saturation moisture content of chalk		3.3	lump, 300 mL to 500 mL		
Liquid limit		4.3	500 g	1 kg	2 kg
Liquid limit		4.4	100 g	200 g	400 g
Liquid limit		4.5	500 g	1 kg	2 kg
Liquid limit		4.6	550 g	250 g	500 g
Plastic limit		5.3	50 g	100 g	200 g
Volumetric shrinkage		6.3	500 g	1 kg	2 kg
Volumetric shrinkage		6.4	100 g	200 g	400 g
Linear shrinkage		6.5	500 g	800 g	1.5 kg
Particle density		8.2	300 g	600 g	600 g
Particle density		8.3	100 g	100 g	100 g
Particle density		8.4	1.5 kg	2 kg	4 kg
Particle size distribution (sieving)		9.2	150 g	2.5 kg	17 kg
Particle size distribution (sieving)		9.3	130 g	2.5 kg	17 kg
Particle size distribution (sedimentation)		9.4	100 g	250 g ^b	250 g ^b
Particle size distribution (sedimentation)		9.5	250 g	100 g ^b	100 g ^b
Organic matter content	3	3.4	150 g	600 g	3.5 kg
Loss on ignition		4.3	150 g	600 g	3.5 kg
Sulphate content		5.5	150 g	600 g	3.5 kg
Sulphate content		5.6	150 g	600 g	3.5 kg
Carbonate content		6.3	50 g	200 g	1.5 kg
Chloride content		7.2	750 g	1.5 kg	3.5 kg
Chloride content		7.3	50 g	200 g	3.5 kg
Total dissolved solids		8.3	[about 500 mL (water)]		
pH value		9.3	150 g	600 g	3.5 kg
Electrical resistivity		10.2	12 kg	15 kg	20 kg
Electrical resistivity		10.3	12 kg	15 kg	20 kg
Electrical resistivity		10.4	8 kg	10 kg	15 kg
Compaction test ^a	4	3.3	25 kg (10 kg)	25 kg (10 kg)	25 kg (10 kg)
Compaction test ^a		3.4	80 kg (50 kg)	80 kg (50 kg)	80 kg (50 kg)
Compaction test ^a		3.5	25 kg (10 kg)	25 kg (10 kg)	25 kg (10 kg)
Compaction test ^a		3.6	80 kg (50 kg)	80 kg (50 kg)	80 kg (50 kg)
Compaction test ^a		3.7	80 kg (50 kg)	80 kg (50 kg)	80 kg (50 kg)
Maximum density		4.2	6 kg	—	—
Maximum density		4.3	16 kg	16 kg	30 kg
Minimum density		4.4	2 kg	—	—
Minimum density		4.5	16 kg	16 kg	30 kg
Moisture condition value (MCV)		5.4	3 kg	3 kg	6 kg
MCV/moisture content		5.5	6 kg	6 kg	12 kg
MCV rapid assessment		5.6	3 kg	3 kg	6 kg
Chalk crushing value		6.4	—	2 kg	4 kg
California bearing ratio		7.4	6 kg	6 kg	12 kg
Permeability	5	5.5	75 mm diameter cell 3.5 kg 100 mm diameter cell 8 kg		
Pinhole erodibility		6.2	300 g	^b	^b
Crumb dispersion		6.3	50 g	^b	^b
Hydrometer dispersion		6.4	500 g	^b	^b
Frost heave ^a		7.3	80 kg (50 kg)	80 kg (50 kg)	80 kg (50 kg)

NOTE Tests not covered in this table are those in which undisturbed samples are used.

^a The masses given in brackets apply only when the soil is not susceptible to crushing during compaction (see note to 7.3.5.1).^b Sufficient to give the stated mass of fine-grained material.

7.3.5.2 Subdividing. Mix the broken-down sample thoroughly and subdivide it by quartering, by riffing or by other suitable means until representative subsamples of the specified minimum masses (after suitable further preparation where necessary) are obtained.

7.4 Preparation of samples for classification tests

7.4.1 General

7.4.1.1 These procedures shall apply to the tests other than moisture content determination described in Part 2 of this standard.

7.4.1.2 For many classification tests it is first necessary to break the soil down to its constituent particles. When drying and mechanical disaggregation are acceptable, prepare the sample as described in **7.3.4** and **7.3.5**. Break down aggregations of particles in such a way as to avoid crushing the individual particles so that if the sample is sieved on a 2 mm test sieve, only individual particles are retained.

7.4.1.3 For tests which require the use of soil in its natural state, disaggregation shall be achieved by soaking in distilled water.

7.4.1.4 Mix the broken-down sample thoroughly and subdivide it as described in **7.3.5.2** until representative subsamples of the minimum masses specified in **7.4.2** to **7.4.5** are obtained.

7.4.2 Moisture content tests. The minimum masses of each category of soil shall be as follows.

	Reference in BS 1377-2:1990	Fine-grained	Medium-grained	Coarse-grained
3.2	Oven drying method	30 g	300 g	3 kg
3.3	Saturation moisture content of chalk		Lump of 1 kg	

7.4.3 Plasticity and shrinkage tests. The minimum masses of soil (by dry mass) passing a 425 µm test sieve shall be as follows. If coarser particles are present in the initial sample they shall be removed by hand or by washing on a 425 µm test sieve. The mixture of water and soil passing the test sieve shall be collected, decanted and partially air dried to bring it to the desired consistency.

	Reference in BS 1377-2:1990	Minimum soil mass
4.3	Liquid limit cone penetrometer method	300 g
4.4	Liquid limit one-point cone method	150 g
4.5	Liquid limit Casagrande method	200 g
4.6	Liquid limit one-point Casagrande method	100 g

5.3	Plastic limit	20 g
6.3	Volumetric shrinkage (definitive method)	300 g
6.4	Volumetric shrinkage (subsidiary method)	50 g
6.5	Linear shrinkage	150 g

No particles shall be crushed. All aggregations of particles shall be broken down so that only individual particles are left on the 425 µm test sieve (see note 1). The approximate proportion by mass of material passing the 425 µm test sieve shall be determined (see note 2).

NOTE 1 Care should be taken to ensure that the test sieve is not overloaded. Refer to Table 4 of BS 1377-2:1990.
NOTE 2 This proportion by mass of material passing will be only approximate because the determination is not made with dried soil. A separate moisture content determination will enable the dry mass to be calculated.

7.4.4 Particle density tests. The minimum masses of dry soil shall be as follows. Any particles larger than the stated size shall be broken down to pass the test sieve of that size. The sample shall be oven-dried at 105 °C to 110 °C.

NOTE Oven drying is specified here for convenience. If there is reason to believe that this will change the particle density due to loss of water of hydration the soil should be tested in its natural condition and the mass of soil used determined by oven drying at the end of the test.

	Reference in BS 1377-2:1990	Minimum mass	Break down to pass test sieve of size
8.2	Gas-jar method	1 kg	37.5 mm
8.3	Small pyknometer method	100 g	2 mm
8.4	Large pyknometer method	1.5 kg	20 mm

7.4.5 Particle size tests. For sieving tests on cohesionless soils (see **9.2** and **9.3** of BS 1377-2:1990), the soil prepared as described in **7.3.4** and **7.3.5** shall be oven dried at 105 °C to 110 °C and subdivided to give the minimum masses specified in Table 3 of BS 1377-2:1990.
For sedimentation tests, the soil shall wherever possible be used in its natural state. If partial air drying is necessary the method used shall be reported.

The minimum masses of soil (expressed as dry mass) shall be as follows.

Reference in BS 1377-2:1990	Minimum soil mass
9.4 Sedimentation — hydrometer method	200 g (Applicable only to soils with more than 10 % passing the 63 µm test sieve)
9.5 Sedimentation — pipette method	60 g

7.5 Preparation of soil for chemical and electro-chemical tests

7.5.1 General. These procedures apply to the tests described in BS 1377-3:1990. Detailed preparation procedures are given under the respective test methods; some procedures specify oven drying at temperatures lower than 105 °C.

7.5.2 For preparing samples for chemical tests the minimum masses of soil, prepared as described in 7.3.5, shall be as follows.

Fine-grained soils	100 g
Medium-grained soils	500 g
Coarse-grained soils	3 kg
Soil corrosivity tests	The quantity of soil required depends on the size of the container used, and is typically about 5 kg.

7.6 Preparation of samples for compaction-related tests

7.6.1 General

7.6.1.1 These procedures apply to the tests described in BS 1377-4:1990.

7.6.1.2 Cohesive soil shall not become dry before testing. Where the removal of some water is essential the soil shall be air dried to provide the lowest moisture content required for compaction.

7.6.2 Compaction tests in one-litre compaction mould

7.6.2.1 Soil required for tests described in 3.3 and 3.5 of BS 1377-4:1990 shall be prepared as follows.

7.6.2.2 Prepare the soil as described in 7.3, using a portion large enough to provide about 6 kg of material passing through a 20 mm test sieve for soils not susceptible to crushing during compaction, or about 15 kg of material passing a 20 mm test sieve for soils susceptible to crushing during compaction.

NOTE The soil should be considered susceptible to crushing during compaction if the sample contains granular materials of a soft nature, e.g. soft limestone or sandstone etc., which would be reduced in size by the action of the rammer or vibrating hammer.

7.6.2.3 Break down aggregations of particles so that, if the sample is sieved on a 5 mm test sieve, only individual particles are retained. For cohesive soils suggested methods are to shred the soil that it can pass through a 5 mm test sieve, or to chop it into pieces to pass a 20 mm test sieve; the method used shall be recorded.

7.6.3 Compaction tests in CBR mould

7.6.3.1 Soil required for tests described in 3.4, 3.6 and 3.7 of BS 1377-4:1990 shall be prepared as follows.

7.6.3.2 Prepare the soil as described in 7.3, using a portion large enough to provide about 15 kg of material passing a 37.5 mm test sieve for soils not susceptible to crushing during compaction, or about 40 kg of material passing a 37.5 mm test sieve for soils susceptible to crushing during compaction (see note to 7.6.2.2).

Break down aggregations of particles so that, if the sample is sieved on a 20 mm test sieve, only individual particles are retained. Cohesive soil shall be shredded or chopped so that it passes the same sieve.

7.6.4 Limiting density tests. For these tests, which are carried out only on cohesionless soil, the sample shall be oven dried at 105 °C to 110 °C and subdivided by riffing to give the minimum mass listed below.

Reference to BS 1377-4:1990	Minimum mass
4.2 Maximum density of sands	6 kg
4.3 Maximum density of gravelly soils	16 kg
4.4 Minimum density of sands	2 kg
4.5 Minimum density of gravelly soils	10 kg

7.6.5 California bearing ratio test

7.6.5.1 The appropriate quantity of soil required for testing in accordance with clause 7 of BS 1377-4:1990 shall be removed from the main sample as received from site and sealed in a container to prevent loss of moisture until required for testing.

7.6.5.2 Take a portion of this material large enough to provide about 6 kg of material passing a 20 mm test sieve for each test. Rub this portion through a 20 mm test sieve, weigh the retained material and determine its proportion of the total sample.

7.6.5.3 If the test is to be performed on samples prepared from soil containing particles larger than 20 mm, remove the fraction retained on the 20 mm test sieve if it does not exceed 25 %. If the fraction is greater than 25 %, the test is not applicable.

7.7 Preparation of test specimens of compacted soil

7.7.1 General. The following procedure is for the preparation of soil which is to be used for making up test specimens when the strength, compressibility and permeability tests described in Parts 5, 6, 7 and 8 of this standard are to be carried out on compacted soil.

Specimen preparation procedures which relate only to one particular test shall be as described elsewhere as part of the appropriate test procedure.

7.7.2 Soil preparation

7.7.2.1 Prepare the initial sample as described in 7.3. If it is necessary to remove some of the moisture in order to break down the soil, partially air dry it as described in 7.3.4. Avoid reducing the moisture content below the highest value at which this can be achieved.

7.7.2.2 Remove any particles larger than the maximum size specified in 7.7.2.7, if necessary, by passing the soil through the test sieve of the appropriate aperture size.

7.7.2.3 Subdivide the soil by riffing to provide enough material for compacting the desired test specimens and for moisture content determination.

7.7.2.4 Bring the soil to the desired moisture content by thoroughly mixing with the appropriate amount of water, or by partial air drying as described in 7.3.4.

7.7.2.5 Take at least two representative specimens for determination of the moisture content, and calculate the average value.

7.7.2.6 Place the prepared soil in a sealed container and store for at least 24 h before use.

7.7.2.7 Particles larger than the sizes stated below shall be removed from the soil before preparing specimens for test.

Type of test	Maximum size of particle
Direct shear (shearbox)	H/10
Consolidation	H/5
Compressive strength (cylinder, H/D = about 2)	D/5
Permeability where H = height of specimen D = diameter of specimen	D/12

7.7.3 Compaction criteria. The degree of compaction can be related to either of two criteria.

a) *Compactive effort.* The soil is compacted at a specified moisture content into a mould under the application of a specified compactive effort.

NOTE The compactive effort applied is usually equivalent to that used in one of the compaction tests described in 3.3 and 3.5 of BS 1377-4:1990.

b) *Dry density.* The soil is compacted or compressed at a specified moisture content into a mould to achieve a specified dry density.

Either method can be used for preparing compacted samples of one of the following types:

a) a sample which is larger than the required test specimen, from which one or more test specimens of smaller size are to be taken (see 7.7.4).

b) the test specimen itself, when of a fairly large diameter, e.g. 100 mm (see 7.7.5).

The degree of compaction to be applied to the soil and the method of forming the test specimens shall be specified.

7.7.4 Compacted sample larger than test specimens

7.7.4.1 General. The prepared soil is compacted into a one-litre cylindrical mould, from which test specimens can be prepared.

After compaction and curing the specimens are prepared in the same way as from an undisturbed sample as described in 8.4 or 8.6.

7.7.4.2 Compaction

7.7.4.2.1 Compaction at specified effort. Compact the prepared soil into the mould in layers, as described in 3.3 or 3.5 of BS 1377-4:1990 depending on the required degree of compaction. Lightly scarify the top of each layer before adding the next.

7.7.4.2.2 Compaction to specified density. The compaction procedure shall be such that the mass of soil to achieve the required density just fills the mould when uniformly compacted. The requisite compactive effort and number of blows per layer shall be determined by trial.

Weigh out a mass of prepared soil which will give the required bulk density when it just fills the mould.

Compact the soil into the mould in layers as described in 7.7.4.2.1 except that the number of blows for each layer shall be such that the weighed soil just fills the mould. Any small cavities shall be filled by pressing in additional soil at the same moisture content.

If the excess or deficiency of the compacted sample is more than 2 % of the volume of the mould, the soil shall be removed from the mould, broken up, mixed with additional soil if necessary and recompactd without loss of moisture.

7.7.5 Compacted specimens of large diameter

7.7.5.1 General. This procedure is for the preparation of a specimen of the same diameter as a one-litre compaction mould or CBR mould, using a split mould of a height equal to twice the diameter.

7.7.5.2 Compaction

7.7.5.2.1 Compaction at specified effort. Compact the prepared soil into the assembled mould in layers, using the procedure described in 3.3 or 3.5 of BS 1377-4:1990, depending on the required degree of compaction, but modified as follows. The number of layers, and the number of blows to be applied to each layer, shall comply with Table 6, depending on the sample size and degree of compaction.

Trim the ends of the specimen flat and normal to the axis of the mould. Patch up any cavities by pressing similar soil well in.

Table 6 — Compaction of large specimens for triaxial tests

Specimen size diameter × length	Degree of compaction			
	2.5 kg rammer (see 3.3 of BS 1377-4:1990)		4.5 kg rammer (see 3.5 of BS 1377-4:1990)	
	No. of layers	Blows per layer	No. of layers	Blows per layer
mm				
100 × 200	5	25	8	27
105 × 210	5	29	8	31
150 × 300	8	54	13	54

7.7.5.2.2 Compaction to specified density. The procedure shall be as described in 7.7.4.2.2 but using the number of layers shown in Table 6.

7.7.6 Sealing and trimming. After compaction, samples of cohesive soils shall be sealed and stored for at least 24 h, to allow for dissipation of excess pore water pressures.

Final trimming of specimens shall be as described for undisturbed samples in clause 8.

8 Preparation of undisturbed samples for testing

8.1 General

8.1.1 Procedures. This clause covers the preparation of test specimens from undisturbed samples of soil received from the field, where the procedure is common to more than one type of test. Procedures that relate specifically to the preparation of samples for one type of test shall be as given in the relevant clauses of the appropriate Part of this standard.

Five procedures are described which depend on the type of undisturbed sample and the purpose of the test specimen, as follows:

- cylindrical specimen of the same diameter as the sample tube (see 8.3);
- cylindrical specimen, or set of specimens, of smaller diameter than the sampling tube (see 8.4);
- cylindrical specimen from a block sample (see 8.5);
- disc or square specimen from a sample in a sampling tube (see 8.6);
- disc or square section from a block sample (see 8.7).

These procedures shall also apply to the preparation of specimens from samples of compacted soil made up as described in clause 7.

8.1.2 Preservation of samples. Loss of moisture from undisturbed samples shall be prevented during transportation, preparation and storage.

NOTE In the short term this may be achieved by wrapping samples in thin clinging plastics film, followed by aluminium foil.

Tests shall be carried out as soon as possible after sampling, but if longer-term storage is necessary, samples shall be well sealed and stored in a room that is frost-free and not subjected to vibration.

During transportation, undisturbed samples shall be packed and stowed so as to be frost free and cushioned against jolting and vibration.

NOTE Ideally, undisturbed samples should be prepared for test, and stored, in an area maintained at a high relative humidity.

8.2 Apparatus

8.2.1 Apparatus common to all procedures

8.2.1.1 A sharp thin-bladed trimming knife.

8.2.1.2 A scalpel.

8.2.1.3 A spatula.

8.2.1.4 Two wire-saws, one of piano wire about 0.4 mm in diameter and the other a spiral wire-saw.

8.2.1.5 A saw, medium to coarse teeth.

8.2.1.6 A *metal straight-edge trimmer*, such as a steel strip about 300 mm long, 25 mm wide and 3 mm thick, with one bevelled edge.

8.2.1.7 A *straight-edge* such as an engineer's steel rule in good condition, graduated to 0.5 mm.

8.2.1.8 A *steel try-square*.

8.2.1.9 *Vernier calipers*, readable to 0.1 mm.

8.2.1.10 A *flat glass plate*, about 300 mm square and 10 mm thick.

8.2.2 Additional apparatus for 8.3

8.2.2.1 An *extruder* to suit the sample tube, and to which it can be securely attached during extrusion.

8.2.2.2 *Suitable supports*, needed for some soils, to prevent distortion of the sample as it is extruded.

NOTE Plastics guttering of the same nominal diameter as the specimen has been found to be suitable for this purpose, provided that it can be properly aligned and supported.

8.2.2.3 A *split mould assembly*.

8.2.3 Additional apparatus for 8.4

8.2.3.1 An *extruder*, as in 8.2.2.1.

8.2.3.2 *Thin-walled tube(s)* for cutting the test specimen(s). The tubes shall be smooth inside and out and turned at one end to form a cutting edge at the inner surface of the tube. The area ratio shall be kept as low as possible consistent with the strength requirements of the specimen tube, and its value shall not exceed 20 %. The length of the tube shall be about 50 % greater than the required length of the specimen.

NOTE The area ratio, A , is defined as the volume of soil displaced by the sampler in proportion to the volume of the sample and is given by the equation:

$$A = \frac{D_0^2 - D_1^2}{D_1^2} 100 \%$$

where

D_0 is the outside diameter of tube;

D_1 is the inside diameter of the cutting edge.

8.2.3.3 A *jig* for holding the specimen tube or tubes securely on the sample tube while the sample is being extruded. The axis of each tube shall be maintained in visual alignment with the direction of extrusion.

8.2.3.4 An *extruder* to suit the specimen tube, and to which it can be securely attached during extrusion.

NOTE The same extruder as used with the sample tubes can usually be fitted with an adaptor to hold the specimen tube or tubes.

8.2.4 Additional apparatus for 8.5

8.2.4.1 *Thin-walled tubes* as described in 8.2.3 (for specimens to be formed in a tube).

8.2.4.2 A *jig* for firmly holding the thin-walled specimen tube in alignment with its direction of movement as it is pushed into the block sample (for specimens to be formed in a tube).

8.2.4.3 A *soil lathe* (for specimens to be hand trimmed).

8.2.4.4 A *mitre box*.

8.2.5 Additional apparatus for 8.6

8.2.5.1 A *metal cutter* for holding or forming the test specimen, provided with a cutting edge. The cutter shall be circular or square in plan, depending on the type of test. Detailed requirements are given in the appropriate clause of this standard.

NOTE The ring normally provided for containing a consolidation test specimen also serves as the cutting ring.

8.2.5.2 A *jack and frame* suitable for extruding the soil vertically from the sampling tube.

8.2.5.3 A *jig* for holding the circular or square cutter just above the top of the sampling tube. The jig shall be designed to allow the sample to pass through and project above the cutter. Alternatively a separate driving ring may be used for the same purpose.

8.2.6 *Additional apparatus for 8.7*. A jig for firmly holding the plane of the cutter at right angles to its direction of movement as it is pushed into the block sample.

8.3 Preparation of cylindrical specimen direct from sampling tube

8.3.1 *General*. When a specimen is to be prepared from an undisturbed sample contained in a tube of the same internal diameter as the test specimen the procedure shall be as follows. The sample shall normally be pushed out of the tube in the same direction as it entered. Remove the protective wax and any loose or disturbed material.

8.3.2 Procedure

8.3.2.1 If the end of the protective coating, e.g. of wax, at the lower end of the sampling tube is reasonably flat and perpendicular to the axis of the tube, no initial preparation is necessary. Otherwise remove the protective coating and trim the end of the sample to achieve that condition.

8.3.2.2 Place an oiled paper disc next to the sample, or lightly oil the face of the extruder ram, to prevent adhesion between the soil and the extruder.

8.3.2.3 Fit the sampling tube on to the extruder and attach the split mould assembly.

8.3.2.4 Extrude enough of the sample out of the tube to enable any loose and disturbed material to be cut away.

8.3.2.5 Extrude the sample until the length required for testing is contained within the split mould.

NOTE The least disturbed portion of the sample will normally be at the bottom end of the tube, i.e. the end nearest to the cutting shoe when the sample was taken.

8.3.2.6 Cut off the surplus soil and trim the ends of the test specimen flat and flush with the ends of the split mould. Protect the ends from loss of moisture until the specimen is ready to be set up for the test.

8.3.2.7 Wrap and seal the surplus extruded soil. Either extrude, wrap and seal any soil remaining in the sampling tube, or reseal it inside the tube.

8.4 Preparation of cylindrical specimen of smaller diameter than sampling tube

8.4.1 General. This procedure applies to fine-grained cohesive soil which can be extruded into tubes with negligible disturbance.

The procedure shall be used when a specimen, or a set of (usually three) specimens, is to be obtained from an undisturbed sample of larger diameter than the test specimens. The method enables a set of specimens to be taken from one depth.

8.4.2 Procedure

8.4.2.1 Fit the sampling tube on to the extruder. Extrude enough of the sample from the tube to enable any loose and disturbed material to be cut off, leaving the end of the remaining sample flat and flush with the end of the tube.

8.4.2.2 Clamp the thin-walled specimen tube or tubes securely in the jig attached to the extruder with their cutting edges about 10 mm away from the end of the sample tube. The axis of the tubes shall be in alignment with the direction of extrusion.

8.4.2.3 Extrude the sample directly into tubes, maintaining a uniform speed. As extrusion proceeds cut away excess soil from outside the tubes so that it does not impede the extrusion.

8.4.2.4 Cut off the extruded soil, remove the specimen tubes from the jig and extrude the specimen from each tube as described in 8.3.

8.5 Preparation of cylindrical specimen from undisturbed block sample

8.5.1 Initial preparation

NOTE 1 This procedure can also be used for trimming specimens from a cylindrical sample of larger diameter than the specimen.

NOTE 2 When a set of similar specimens of small diameter is required the specimens should all be taken from the same geological horizon wherever possible. The location and orientation of each specimen within the block sample should be recorded.

8.5.1.1 Cut away about 10 mm from the outside of the block sample, and cut out an approximately rectangular prism of soil slightly larger than the final dimensions of the specimen. The orientation of the axis of the prism shall be appropriate for the test to be carried out, when necessary, and shall be recorded.

8.5.1.2 Make the ends of the prism plane and parallel using the mitre box, or by carefully trimming and checking with a straight-edge and try-square on the glass plate.

8.5.1.3 If a soil lathe is to be used, proceed as described in 8.5.2. If the specimen is to be formed in a tube with a cutting edge, proceed as described in 8.5.3 or 8.5.4.

8.5.2 Use of soil lathe

8.5.2.1 Place the specimen in a soil lathe and cut off the excess soil in thin layers. Rotate the specimen between each cut until a cylindrical specimen is produced. Take care to avoid disturbance due to torsional effects.

8.5.2.2 Remove the specimen from the soil lathe. Cut to the required length and make the ends plane and normal to the specimen axis to within $\frac{1}{2}^\circ$.

8.5.3 Use of tube with cutting edge

8.5.3.1 Clamp the thin-walled tube firmly in a holding jig.

8.5.3.2 Push the tube steadily into the soil, carefully trimming away most of the excess soil for a short distance in advance of the cutting edge. Ensure that the cutting edge itself always pares away the final silver of excess material so that voids are not formed inside the tube. Maintain alignment of the axis of the tube with the direction of motion during this operation.

8.5.3.3 When the tube contains a length of specimen slightly in excess of the required trimmed length, undercut the specimen so that the tube can be extracted.

8.5.3.4 Remove the specimen from the tube and trim as described in 8.3.

8.5.4 Encapsulation

8.5.4.1 General. With brittle soils for which the preceding methods are not practicable, the following method may be satisfactory. It can be used for an irregular lump of material as well as for a cylindrical or rectangular shape.

8.5.4.2 Method

8.5.4.2.1 Cover the piece of soil with paraffin wax, or wrap with thin clinging film, to provide a waterproof coating.

8.5.4.2.2 Place the sample in a container, e.g. a one-litre compaction mould, and surround it with a suitable plaster, e.g. cellulose filler, mixed with water to a workable paste, so that the sample is completely encapsulated. Alternatively, pack damp sand around the sample.

8.5.4.2.3 Allow the plaster to set, but not to harden.

8.5.4.2.4 Jack a sampling tube with a sharp cutting edge into the encapsulated sample with a continuous steady movement.

8.5.4.2.5 Remove the sample from the tube and trim it as described in 8.3.

8.6 Preparation of disc or square specimen from sampling tube

8.6.1 General. This procedure is used for preparing either a squat cylindrical specimen for a consolidation test or swelling test in an oedometer (see clause 3 or 4 of BS 1377-5:1990), or a square specimen for a direct shear test in the small shearbox apparatus (see clause 6 of Part 7 of this standard). The mould with a cutting edge into which the specimen is intruded is referred to as the cutting ring, whether it is circular or square.

8.6.2 Procedure

8.6.2.1 Fit the sampling tube onto the extruder. Extrude enough of the sample from the tube to enable any loose and disturbed material to be cut off, leaving the end of the remaining sample flat and flush with the end of the tube.

8.6.2.2 Extrude a further short length, e.g. 20 mm to 30 mm, of the soil sample from the tube for examination, after removing the protective covering.

8.6.2.3 Cut off and remove the extruded length of sample. Trim the end of the remaining sample flat and flush with the end of the tube.

8.6.2.4 Secure the cutting ring rigidly in the jig and mount the assembly on the sample tube so that the cutting edge of the ring is 3 mm to 6 mm above the top of the tube.

8.6.2.5 Extrude the sample steadily directly into the cutting ring until the top surface projects slightly above the ring. During this operation trim away the soil from the outside of the ring to reduce friction and to prevent obstruction.

8.6.2.6 Cut off the sample in its ring a little below the cutting edge of the ring and remove the ring from the jig. With very soft soils take care to ensure that the specimen does not slide in, or fall out of, the ring.

8.6.2.7 Cut off the soil projecting above the upper end of the ring and trim the surface flat and flush with the ring, checking with the reference straight-edge. Avoid excessive remoulding of the surface.

8.6.2.8 Place the trimmed surface on the flat glass plate and trim the other surface flush with the cutting edge as described in 8.6.2.6. Ensure that no soil is left adhering to the outside of the ring.

8.6.2.9 If during the above operation a small inclusion interferes with extrusion and trimming, remove it and fill the cavity with fine material from the parings.

8.7 Preparation of disc or square specimen from block sample

8.7.1 General. This procedure is used for preparing a test specimen from an undisturbed sample received in the form of an excavated block, and may also be used for a sample that has been extruded from a sampling tube. The mould with a cutting edge into which the specimen is intruded is referred to as the cutting ring, whether it is circular or square.

8.7.2 Procedure using a holding jig

8.7.2.1 Clamp the cutting ring firmly in the holding jig.

8.7.2.2 Push the ring steadily into the soil, carefully trimming away most of the excess soil for a short distance in advance of the cutting edge. Ensure that the cutting edge itself always pares away the last sliver of excess soil so that voids are not formed inside the ring. Maintain the plane of the ring at right angles to the direction of motion during this operation.

8.7.2.3 When the top surface of the specimen protrudes slightly above the ring, sever the soil slightly below the cutting edge so that the soil contained in the ring can be removed intact.

8.7.2.4 Trim the specimen as described in 8.6.2.7 and 8.6.2.8.

8.7.2.5 If during the above operation a small inclusion interferes with extrusion and trimming, remove it and fill the cavity with fine material from the parings.

8.7.3 Procedure using a driving ring

8.7.3.1 Cut a roughly circular or square portion of soil from the sample of dimensions somewhat larger than the test specimen.

8.7.3.2 Prepare two plane faces on the portion so that they are flat and parallel to each other and orientated in the direction required for the test.

8.7.3.3 Place one prepared surface of the sample on the glass plate. Use the ring, placed on the exposed face, as a template while carefully trimming the edges of the sample. Push the ring down slowly and evenly without tilting, using a driving ring placed on top, allowing the cutting edge to pare away the last fraction of soil. Ensure that the specimen is a close fit in the ring with no voids against the inner surface. Push the ring down until the top surface of the specimen projects slightly above it.

8.7.3.4 Remove the driving ring and trim the top and bottom surface of the specimen flat and flush with the ring as described in **8.6.2.7** and **8.6.2.8**.

8.7.3.5 If a small inclusion interferes with the above trimming operations, remove it and fill the cavity with fine material from the parings.

9 Reports

9.1 Laboratory tests

Reports giving laboratory test data and results as specified for each test procedure shall include the following general information:

- a) sample identification reference or number, and location;
- b) type of sample;
- c) method of preparation of test specimen;
- d) location and orientation of test specimens within the original sample;
- e) visual description of soil, including soil fabric and any unusual features;
- f) comments on observed or inferred sample disturbance, including possible loss of moisture;
- g) unavoidable variations from specified procedure, with reasons;
- h) name of organization carrying out the test.

Data recorded in the laboratory report forms, such as those set out in an appendix to each Part of this standard, shall be available for inspection if required.

9.2 In-situ tests

Reports giving in-situ test data and results as specified for each test procedure shall include the following general information:

- a) test location, test number and borehole or pit number where appropriate;
- b) date of test;
- c) description of the soil tested if accessible, including reference to the factors relevant to the test method;
- d) where possible, information on the groundwater level;
- e) test level with respect to ground level and the reduced level of the test, where known;
- f) name of organization which made the test;
- g) weather and environmental conditions of time of test, e.g. if wet, sunny, frosty.

Data recorded in the test report forms, such as those set out in appendix A of Part 9 of this standard, shall be available for inspection if required.

Appendix A List of British Standards

The British Standards referred to in Parts 1 to 9 inclusive of BS 1377 are shown in the following list:

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

BS 410, *Specification for test sieves.*

BS 593, *Specification for laboratory thermometers.*

BS 604, *Specification for graduated glass measuring cylinders.*

BS 718, *Specification for density hydrometers.*

BS 733, *Pyknometers.*

BS 733-1, *Specification.*

BS 733-2, *Methods for calibration and use of pyknometers.*

BS 812, *Testing aggregates.*

BS 812-124, *Method for determination of frost heave.*

BS 846, *Specification for burettes.*

BS 870, *Specification for external micrometers.*

BS 903, *Methods of testing vulcanized rubber.*

BS 907, *Specification for dial gauges for linear measurement.*

BS 939, *Specification for engineers' squares (including cylindrical and block squares).*

BS 1154, *Specification for natural rubber compounds.*

BS 1377, *Methods of test for soils for civil engineering purposes.*

BS 1377-2, *Classification tests.*

BS 1377-3, *Chemical and electro-chemical tests.*

BS 1377-4, *Compaction-related tests.*

BS 1377-5, *Compressibility, permeability and durability tests.*

BS 1377-6, *Consolidation and permeability tests in hydraulic cells and with pore pressure measurement.*

BS 1377-7, *Shear strength tests (total stress).*

BS 1377-8, *Shear strength tests (effective stress).*

BS 1377-9, *In-situ tests.*

BS 1583, *Specification for one-mark pipettes.*

BS 1610, *Materials testing machines and force verification equipment.*

BS 1610-1, *Specification for the grading of the forces applied by materials testing machines.*

BS 1610-2, *Specification for the grading of equipment used for the verification of the forces applied by materials testing machines.*

BS 1739, *Specification for filter flasks.*

BS 1752, *Specification for laboratory sintered or fritted filters.*

BS 1780, *Specification for bourdon tube pressure and vacuum gauges.*

BS 1792, *Specification for one-mark volumetric flasks.*

BS 1797, *Schedule for tables for use in the calibration of volumetric glassware.*

BS 2000, *Methods of test for petroleum and its products.*

BS 2000-49, *Penetration of bituminous materials.*

BS 3423, *Recommendations for design of glass vacuum vessels (including desiccators for laboratory use).*

BS 3978, *Specification for water for laboratory use.*

BS 4019, *Specification for rotary core drilling equipment.*

BS 4019-1, *Basic equipment.*

BS 4311, *Specification for metric gauge blocks.*

BS 4372, *Specification for engineers' steel measuring rules.*

BS 4402, *Specification for safety requirements for laboratory centrifuges.*

BS 5573, *Code of practice for safety precautions in the construction of large diameter boreholes for piling and other purposes (formerly CP 2011).*

BS 5781, *Measurement and calibration systems.*

BS 5898, *Specification for principles of design and construction of volumetric glassware for laboratory use.*

BS 5930, *Code of practice for site investigations.*

BS 6231, *Specification for PVC-insulated cables for switchgear and controlgear wiring.*

BS 6376, *Reagents for chemical analysis.*

Publications referred to

- BS 410, *Specification for test sieves*.
BS 593, *Specification for laboratory thermometers*.
BS 812, *Testing aggregates*.
BS 812-124, *Method for determination of frost heave*.
BS 1377, *Methods of test for soils for civil engineering purposes*.
BS 1377-2, *Classification tests*.
BS 1377-3, *Chemical and electro-chemical tests*.
BS 1377-4, *Compaction-related tests*.
BS 1377-5, *Compressibility, permeability and durability tests*.
BS 1377-6, *Consolidation and permeability tests in hydraulic cells and with pore pressure measurement*.
BS 1377-7, *Shear strength tests (total stress)*.
BS 1377-8, *Shear strength tests (effective stress)*.
BS 1377-9, *In-situ tests*.
BS 1610, *Materials testing machines and force verification equipment*.
BS 1610-1, *Specification for the grading of the forces applied by materials testing machines*.
BS 1610-2, *Specification for the grading of equipment used for the verification of the forces applied by materials testing machines*.
BS 1780, *Specification for bourdon tube pressure and vacuum gauges*.
BS 1797, *Schedule for tables for use in the calibration of volumetric glassware*.
BS 3978, *Specification for water for laboratory use*.
BS 4311, *Specification for metric gauge blocks*.
BS 4402, *Specification for safety requirements for laboratory centrifuges*.
BS 5781, *Measurement and calibration systems*.
BS 5898, *Specification for principles of design and construction of volumetric glassware for laboratory use*.
BS 5930, *Code of practice for site investigations*.
Guidance Note MS 12, Health and Safety Executive: Mercury — Medical surveillance⁴⁾.

⁴⁾ Available from HMSO publications Centre, PO Box 276, London SW8 5DT.

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