

Please be aware that this PDF has been created from the original hardcopy document, which might not be in good condition and so the PDF might reflect this.

w/d S/S by April 1975 issue
+ 1 Amd

BRITISH STANDARD 1377 : 1967

UDC 624.131

**METHODS OF TESTING
SOILS
FOR CIVIL ENGINEERING
PURPOSES**



BRITISH STANDARDS INSTITUTION

PD 6412

Amendment No. 1, published 1 May, 1968

to BS 1377 : 1967

Methods of testing soils for civil engineering purposes

Revision

2.7.4.5.2.(2)a. Delete the 2nd paragraph (i.e. the last line on page 78 and the first two lines on page 79).

METHODS OF TESTING
SOILS
FOR CIVIL ENGINEERING
PURPOSES

BS 1377 : 1967

Price 60/- net

BRITISH STANDARDS INSTITUTION

INCORPORATED BY ROYAL CHARTER

BRITISH STANDARDS HOUSE, 2 PARK ST., LONDON, W.1

TELEGRAMS: STANDARDS LONDON W1

TELEPHONE: 01-629 9000

THIS BRITISH STANDARD, having been approved by the Road Engineering Industry Standards Committee and endorsed by the Chairman of the Engineering Divisional Council, was published under the authority of the General Council on 20th December, 1967.

First published, July, 1948.

First revision, July, 1961.

Second revision, December, 1967.

The Institution desires to call attention to the fact that this British Standard does not purport to include all the necessary provisions of a contract.

In order to keep abreast of progress in the industries concerned, British Standards are subject to periodical review. Suggestions for improvements will be recorded and in due course brought to the notice of the committees charged with the revision of the standards to which they refer.

A complete list of British Standards, numbering over 4000, fully indexed and with a note of the contents of each, will be found in the British Standards Yearbook, price 15s. The BS Yearbook may be consulted in many public libraries and similar institutions.

This standard makes reference to the following British Standards:

- BS 410. Test sieves.
- BS 593. Laboratory thermometers.
- BS 604. Graduated measuring cylinders.
- BS 718. Density hydrometers and specific gravity hydrometers.
- BS 733. Density bottles.
- BS 812. Methods for sampling and testing of mineral aggregates, sands and fillers.
- BS 846. Burettes and bulb burettes.
- BS 892. Glossary of highway engineering terms.
- BS 903. Methods of testing vulcanized rubber.
- BS 1154. Vulcanized natural rubber compounds.
- BS 1583. One-mark pipettes.
- BS 1610. Methods for the load verification of testing machines.

- BS 1739. Filter flasks.
- BS 1752. Laboratory sintered or fritted filters.
- BS 1780. Bourdon tube pressure and vacuum gauges.
- BS 1792. One-mark volumetric flasks.
- BS 1796. Methods for the use of British Standard fine-mesh test sieves.
- BS 1923. Glass filter funnels.
- BS 1924. Methods of test for stabilized soils.
- BS 1991. Letter symbols, signs and abbreviations.
- BS 2648. Performance requirements for electrically-heated laboratory drying ovens.
- BS 3423. Recommendations for the design of glass vacuum desiccators.
- BS 4019. Rotary core drilling equipment.
- CP 2001. Site investigations.

British Standards are revised, when necessary, by the issue either of amendment slips or of revised editions. It is important that users of British Standards should ascertain that they are in possession of the latest amendments or editions.

The following BSI references relate to the work on this standard:
Committee references RDE/9, RDE/9/7 and RDE/9/8
Drafts for comment D 65/7607 and D 65/10540

CONTENTS

Co-operating organizations	Page 7
Foreword	8

METHODS

1. GENERAL

1.1 Definitions and symbols	10
1.2 Apparatus	14
1.3 Grouping of soils	14
1.4 Preparation of disturbed samples for testing	15

2. SOIL CLASSIFICATION TESTS

2.1 Test 1. Determination of the moisture content	25
1(A). Standard method (oven-drying method)	25
1(B). Subsidiary method (sand-bath method)	28
1(C). Subsidiary method (alcohol method)	31
2.2 Test 2. Determination of the liquid limit	33
2(A). Standard method	33
2(B). Subsidiary method (one point method)	39
2.3 Test 3. Determination of the plastic limit	42
2.4 Test 4. Calculation of the plasticity index	44
2.5 Test 5. Determination of the linear shrinkage	45
2.6 Test 6. Determination of the specific gravity of soil particles	48
6(A). Method for fine-grained soils	48
6(B). Method for medium- and coarse-grained soils	52
2.7 Test 7. Determination of the particle size distribution	55
7(A). Standard method by wet sieving	55
7(B). Subsidiary method by dry sieving	58
7(C). Standard method for fine-grained soils (pipette method)	61
7(D). Subsidiary method for fine-grained soils (hydrometer method)	73

3. SOIL CHEMICAL TESTS

3.1 Test 8. Determination of the organic matter content	86
---	----

3.2 Test 9. Determination of the sulphate content of soil and the sulphate content of the ground-water	Page 90
9(A). Standard method (gravimetric method)	90
9(B). Subsidiary method (ion-exchange method)	95
3.3 Test 10. Determination of the pH value	101
10(A). Standard method (electrometric)	101
10(B). Subsidiary method (colorimetric)	103

4. SOIL COMPACTION TESTS

4.1 Test 11. Determination of the dry density/moisture content relation—5.5 lb (2.5 kg) rammer method	105
4.2 Test 12. Determination of the dry density/moisture content relation—10 lb (4.5 kg) rammer method	111
4.3 Test 13. Determination of the dry density/moisture content relation of granular soil-vibrating hammer method	117
4.4 Test 14. Determination of the dry density of soil on the site	122
14(A). Sand replacement method suitable for fine- and medium-grained soils: small pouring cylinder method	122
14(B). Sand replacement method suitable for fine-, medium- and coarse-grained soils: large pouring cylinder method	131
14(C). Sand replacement method suitable for fine-, medium- and coarse-grained soils: hand scoop method	138
14(D). Core-cutter method for fine-grained and chalk soils free from stones	142
14(E). Weight in water method	145
14(F). Water displacement method	150

5. SOIL STRENGTH TESTS

5.1 Test 15. Determination of the California Bearing Ratio	154
--	-----

	Page
5.2 Test 16. Determination of the one-dimensional consolidation properties	169
5.3 Test 17. Determination of shear strength in the field by the vane test	184
5.4 Test 18. Determination of the penetration resistance using the split-barrel sampler	189
5.5 Test 19. Determination of the unconfined compressive strength using portable apparatus	195
5.6 Test 20. Determination of the compressive strength of a specimen tested in undrained triaxial compression without the measurement of pore water pressure	199

APPENDICES

A. Maximum weight of material to be retained on each test sieve at the completion of sieving (from BS 812)	206
B. Typical data and calculation forms	207

CO-OPERATING ORGANIZATIONS

The Road Engineering Industry Standards Committee, under whose supervision this British Standard was prepared, consists of representatives from the following Government departments and scientific and industrial organizations:

- *Asphalt and Coated Macadam Association
- *Association of Consulting Engineers
- British Granite and Whinstone Federation
- *British Road Tar Association
- British Slag Federation
- British Tarpaviors' Federation
- *Cement and Concrete Association
- Concrete Society Ltd.
- Contractors' Plant Association
- *County Surveyors' Society
- *Federation of Civil Engineering Contractors
- Federation of Manufacturers of Construction Equipment
- *Institute of Petroleum
- *Institution of Civil Engineers
- *Institution of Highway Engineers
- *Institution of Municipal Engineers
- *Institution of Structural Engineers
- Limestone Federation
- *Ministry of Defence, Army Department
- *Ministry of Public Building and Works
- *Ministry of Transport
- *Ministry of Transport, Road Research Laboratory
- Sand and Gravel Association of Great Britain
- Society of Chemical Industry

The Government departments and scientific and industrial organizations marked with an asterisk in the above list, together with the following, were directly represented on the committee entrusted with the preparation of this British Standard:

Building Research Station—Ministry of Public Building and Works
 Greater London Council
 Imperial College of Science and Technology
 Road Emulsion Association Ltd.
 Rothamsted Experimental Station
 Individual manufacturers and user

BRITISH STANDARD METHODS OF TESTING SOILS FOR CIVIL ENGINEERING PURPOSES

FOREWORD

This British Standard was first published under the authority of the Road Engineering Industry Standards Committee in 1948 and revised in 1961. It has now been revised for the second time and is being published simultaneously with the related British Standard 1924, 'Methods of test for stabilized soils', which has also been revised. This has been done to ensure that where similar tests exist for natural and stabilized soils the same test procedures are specified in the respective standards, thus making it possible to compare results obtained with natural and stabilized soils.

No changes of principle have been made to the test procedures given in the second edition of the standard but the detail has been revised to take account of the increased knowledge that has been gained in the testing of soils. The opportunity has also been taken to include a number of new test procedures and to standardize test procedures which, although widely used, had not hitherto been standardized. The additional tests that have been included comprise:

- (1) The linear shrinkage test which provides indirect methods of assessing the plasticity index of soils having low clay contents.
- (2) An additional compaction test which utilizes a vibratory method of compaction and which has been found to give results that are closer to field conditions with granular materials.
- (3) An additional test for determining the dry density of soil on the site.
- (4) A subsidiary method for determining the sulphate content of soils by an ion-exchange procedure.
- (5) A new section containing a number of soil strength tests such as the California Bearing Ratio, shear strength and the one-dimensional consolidation of soil.

In several instances methods are termed 'standard method' and 'subsidiary method' respectively. The former are more accurate but may be unsatisfactory for use in the laboratory or the field owing to the time taken or the need for equipment which is not easily obtainable.

Typical forms are included for nearly all the test methods to illustrate how the results may conveniently be calculated and recorded. The layout of such forms is a matter of individual preference, but most of the typical layouts have been printed so that photographic reproduction and enlargement to about foolscap size will provide a usable standard form.

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

NOTE. The values stated in British units are to be regarded as the standard. Any metric equivalents are approximate. More accurate conversions should be based on the data in BS 350, 'Conversion factors and tables'.

METHODS

1. GENERAL

1.1 DEFINITIONS AND SYMBOLS

1.1.1 Definitions*. For the purposes of this British Standard the following definitions apply:

(1) *Liquid limit (LL)*. The moisture content at which a soil passes from the plastic to the liquid state as determined by the liquid limit test.

(2) *Plastic limit (PL)*. The moisture content at which a soil becomes too dry to be in a plastic condition as determined by the plastic limit test.

(3) *Plasticity index (PI)*. The numerical difference between the liquid limit and the plastic limit of a soil.

(4) *Non-plastic*. A soil with a plasticity index of zero or one on which the plastic limit cannot be determined.

(5) *Particle size distribution*. The percentages of the various grain sizes present in a soil as determined by sieving, sedimentation, elutriation or other means.

(6) *Cobbles*. Rounded or sub-angular stones of sizes between 200 mm (8 in) and 60 mm (2½ in).

(7) *Gravel fraction*. The fraction of a soil composed of particles between the sizes of 60 mm (2½ in) and 2 mm (0.08 in). The gravel fraction may be sub-divided as follows:

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

(8) *Sand fraction*. The fraction of a soil composed of particles between the sizes 2.0 mm and 0.06 mm. The sand fraction may be sub-divided as follows:

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

(9) *Silt fraction*. The fraction of a soil composed of particles between the sizes 0.06 mm and 0.002 mm. The silt fraction may be sub-divided as follows:

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

* See also BS 892, 'Glossary of highway engineering terms', and BS 1991, 'Letter symbols and abbreviations'.

(10) *Clay fraction*. The fraction of a soil composed of particles smaller in size than 0.002 mm.

(11) *Cohesive soil*. A soil which, by virtue of its clay content, will form a coherent mass.

(12) *Non-cohesive soil*. *Granular soil*. A soil which will not form a coherent mass.

(13) *Sampling*. The selection of a representative portion of a material.

(14) *Quartering*. The reduction in quantity of a large sample of material by dividing a circular heap into four approximately equal parts by diameters at right angles, removing two diagonally opposite quarters, and mixing the two remaining quarters intimately 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.

(15) *Riffing*. The reduction in quantity of a large sample of material by dividing the mass into two approximately equal halves by passing the sample through an appropriately sized riffle (or riffle box). The process is repeated until a sample of the required size is obtained.

(16) *Compaction*. The process of packing soil particles more closely together by rolling or other mechanical means, thus increasing the dry density of the soil.

(17) *Consolidation*. The process whereby soil particles are packed more closely together over a *period* of time by application of continued pressure.

(18) *Bulk density*. The weight of a material (including solid particles and any contained water) per unit volume including voids.

(19) *Dry density*. The weight of the dry material after drying to constant weight at 105°C (221°F) contained in unit volume of undried material.

(20) *Moisture content*. The quantity of water which can be removed from the soil, usually by heating at 105°C (221°F), expressed as a percentage of the dry weight.

(21) *Optimum moisture content*. The moisture content at which a specified amount of compaction will produce the maximum dry density (see Fig. 1).

(22) *Maximum dry density*. The dry density obtained using a specified amount of compaction at the optimum moisture content (see Fig. 1).

(23) *Relative compaction*. The percentage ratio of the dry density of the soil to the maximum dry density of that soil as determined by a specified laboratory compaction test.

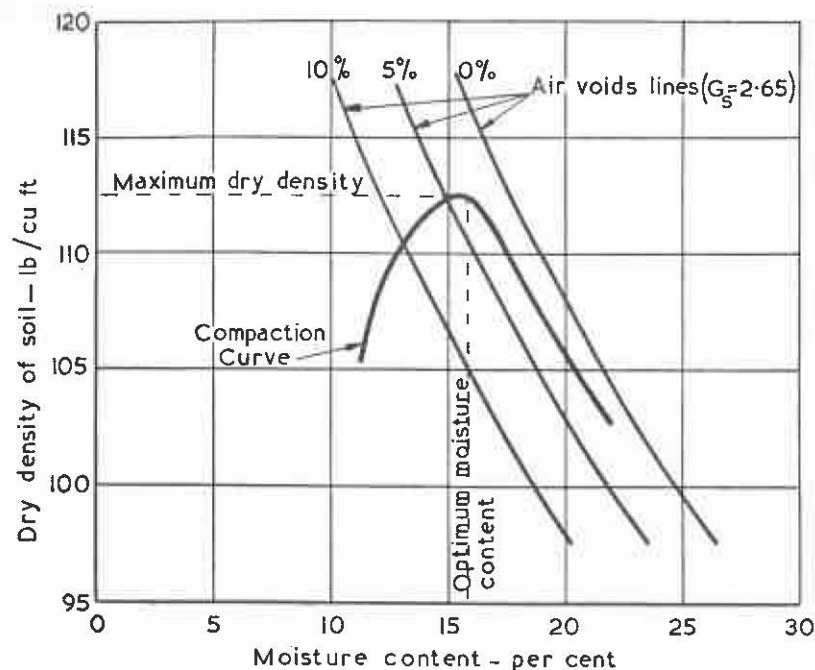


Fig. 1. Definition of terms used in compaction tests

(24) *Dry density/moisture content relationship.* The relation between dry density and moisture content of a soil when a given compactive effort is employed.

(25) *Percentage air voids.* The volume of air voids in the soil expressed as a percentage of the volume of undried material.

(26) *Air voids line.* A line showing the dry density/moisture content relation for soil containing a constant percentage of air voids. (Air voids lines are shown in Fig. 1.) The line can be calculated from the formula:

$$\gamma_d = \gamma_w \frac{\left(1 - \frac{V_a}{100}\right)}{\frac{1}{G_s} + \frac{m}{100}}$$

where γ_d = dry density of the soil (lb/ft³).

γ_w = density of water (lb/ft³).

V_a = volume of air voids in the soil, expressed as a percentage of the total volume of the soil.

G_s = specific gravity of the soil particles.

m = moisture content, expressed as a percentage of the weight of dry soil.

(27) *Saturation line (zero air voids line).* A line showing the dry density/moisture content relation for soil containing no air voids. The saturation line is also shown on Fig. 1. It is obtained by putting $V_a = 0$ in the formula above.

1.1.2 Symbols*. For the purposes of this British Standard the following symbols are used:

(1) Moisture content	m	(12) Secondary compression ratio	r_s
(2) Liquid limit	LL	(13) Vane shear strength	S
(3) Plastic limit	PL	(14) Penetration resistance	N
(4) Plasticity index	PI	(15) Unconfined compression strength	σ_f
(5) Non-plastic	NP	(16) Maximum principal stress difference	$(\sigma_1 - \sigma_3)_f$
(6) Linear shrinkage	LS	(17) Specific gravity of soil	G_s
(7) California Bearing Ratio	CBR	(18) Bulk density of soil	γ
(8) Coefficient of compressibility (one-dimensional)	m_v	(19) Dry density of soil	γ_d
(9) Coefficient of consolidation	c_v	(20) Percentage air voids	V_a
(10) Initial compression ratio	r_o		
(11) Primary compression ratio	r_p		

* See also BS 1991, 'Letter symbols, signs and abbreviations'.

1.2 APPARATUS

Apparatus shall where possible comply with British Standards, e.g.:

- BS 410, 'Test sieves'.
- BS 593, 'Laboratory thermometers'.
- BS 604, 'Graduated measuring cylinders'.
- BS 718, 'Density hydrometers and specific gravity hydrometers'.
- BS 733, 'Density bottles'.
- BS 846, 'Burettes and bulb burettes'.
- BS 1583, 'One-mark pipettes'.
- BS 1739, 'Filter flasks'.
- BS 1752, 'Laboratory sintered or fritted filters'.
- BS 1792, 'One-mark volumetric flasks'.
- BS 1923, 'Glass filter funnels'.
- BS 2648, 'Performance requirements for electrically-heated laboratory drying ovens'.
- BS 3423, 'Recommendations for the design of glass vacuum desiccators'.

NOTE 1. The following range of balances covers the requirements of all the tests in this standard:

Capacity	100 g	250 g	1 kg	5 kg	10 kg	25 kg
Accuracy	0.001 g	0.01 g	0.1 g	0.5 g	1 g	5 g

NOTE 2. The following palette knives cover the requirements of all the tests in this standard:

Length	4 in (10 cm)	8 in (20 cm)
Breadth	$\frac{3}{4}$ in (2 cm)	$1\frac{1}{4}$ in (3 cm)

NOTE 3. The essential details of the equipment illustrated in this specification have been underlined in the drawings.

The manufacturing tolerances on these essential dimensions shall be as shown below unless other tolerances are shown in the drawing.

- (1) $\pm \frac{1}{2}$ in (0.8 mm) on dimensions greater than 12 in (300 mm), and shown as fractions.
- (2) $\pm \frac{1}{64}$ in (0.4 mm) on dimensions up to and including 12 in (300 mm) and shown as fractions.
- (3) ± 0.005 in (0.13 mm) on dimensions shown as decimals.

Where weight is an essential requirement the tolerance on the weight is shown in the drawing.

1.3 GROUPING OF SOILS

For the purposes of the tests described in this British Standard, soils shall be grouped as follows:

- (1) *Fine-grained soils*. Soils containing not less than 90% passing a No. 7 (2.40 mm) BS test sieve*.

* BS 410, 'Test sieves'.

- (2) *Medium-grained soils*. Soils containing not less than 90% passing a $\frac{3}{4}$ in (20 mm) BS test sieve.
- (3) *Coarse-grained soils*. Soils containing not less than 90% passing a $1\frac{1}{2}$ in (40 mm) BS test sieve.

The grouping of a soil thus depends on the result of a sieve analysis. Any soil shall be regarded as belonging to the finest-grained group appropriate under the definitions given above.

Soils with a greater proportion of material than about 10% retained on a $1\frac{1}{2}$ in (40 mm) BS test sieve cannot usefully be examined by any of the tests in this British Standard except the sieve analysis and the plasticity tests. They would, of necessity, fall into the range of materials classed as aggregates which are covered by BS 812*.

1.4 PREPARATION OF DISTURBED SAMPLES FOR TESTING

1.4.1 *Scope*. This section covers the preparation of soil samples as received from the field and their allocation for subsequent tests (see Note 1).

1.4.2 Apparatus

- (1) A balance readable and accurate to 0.1 g.
- (2) A balance readable and accurate to 1 g.
- (3) A means of breaking up aggregations of soil without reducing the size of the individual particles, e.g. a mortar and a rubber pestle similar to the one illustrated in Fig. 2, or a suitable mechanical device.
- (4) British Standard test sieves† of the following sizes: No. 36 (420 microns), No. 7 (2.40 mm), $\frac{3}{16}$ in (5 mm), $\frac{3}{4}$ in (20 mm), $1\frac{1}{2}$ in (40 mm).
- (5) A thermostatically controlled drying oven capable of maintaining a temperature of 45–50°C (113–122°F) and of 105–110°C (221–230°F).
- (6) Sample dividers, e.g. of the multiple-slot type (riffle box) similar to those shown in Fig. 3.

1.4.3 General preparation of sample (see Note 1)

(1) An assessment should be made of whether the soil is to be classified as a fine-grained, medium-grained or coarse-grained soil (see 1.3, Grouping of soils). In many cases this will be known or self-evident but, in doubtful cases or where confirmation is required, a portion of the sample should be sieved through the appropriate sieve or sieves, using generally the procedure given under Test 7(A) or 7(B). The size of sample used for this shall be in accordance with the following table:

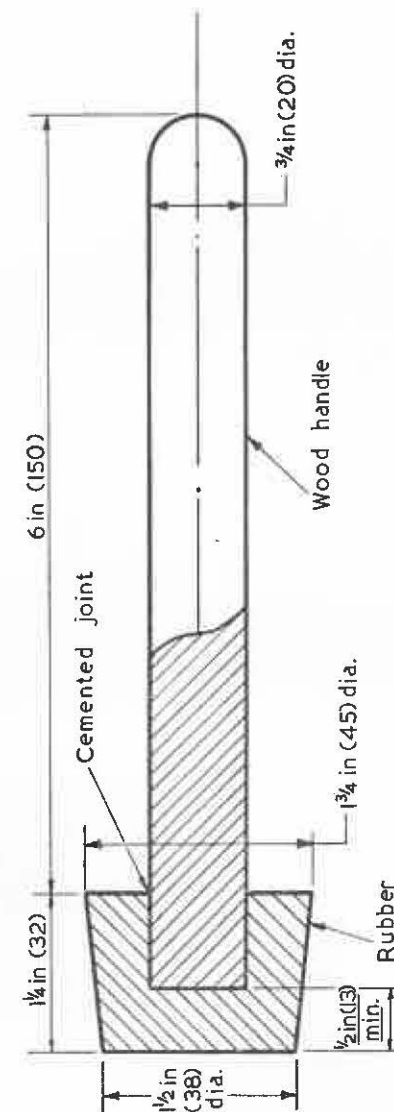
* BS 812, 'Sampling and testing of mineral aggregates, sands and fillers'.

† BS 410, 'Test sieves'.

Maximum size of material present in substantial proportion (more than 10%)	Minimum weight of sample to be taken for sieving	
	kg	lb
Larger than ¾ in (20 mm)	15	33
¾ in (20 mm)	2	4.5
Passing No. 7 (2.40 mm) BS test sieve	0.1	0.2

(2) The total weight of sample required depends on the soil group and the tests to be carried out but, to ensure a representative sample, the total weight should not, in general, be less than the following minimum weights:

Fine-grained soils	500 g
Medium-grained soils	5 kg
Coarse-grained soils	30 kg



This design has been found satisfactory, but alternative designs may be employed provided that the essential requirements are fulfilled. Millimetre dimensions in brackets.

Fig. 2. Rubber pestle

This design has been found satisfactory, but alternative designs may be employed provided that the essential requirements are fulfilled.

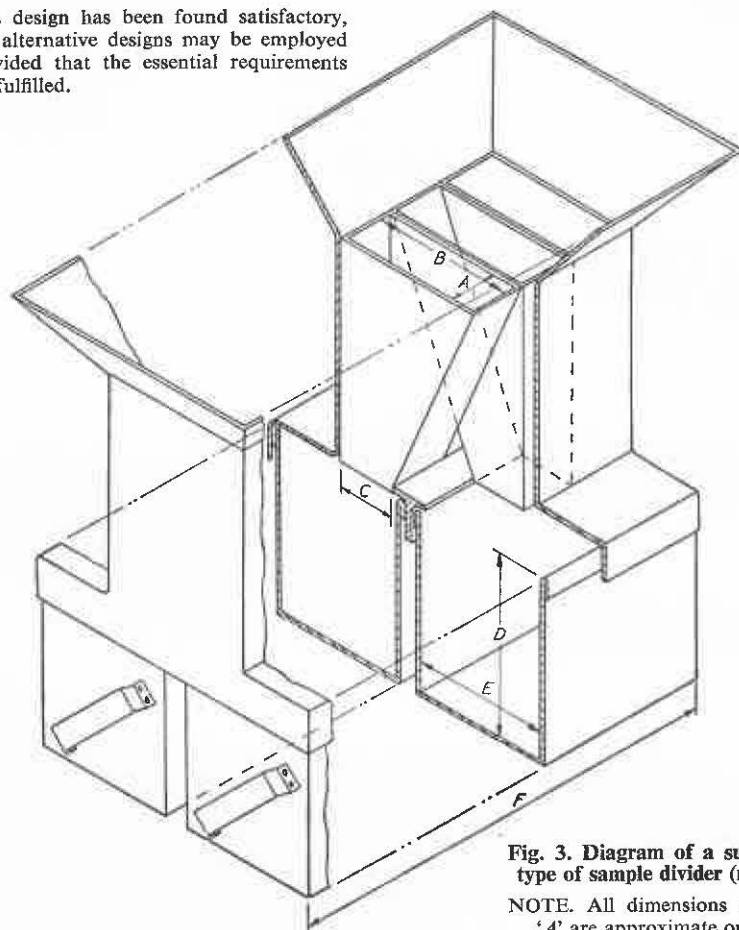


Fig. 3. Diagram of a suitable type of sample divider (rifle)

NOTE. All dimensions except 'A' are approximate only.

Maximum size of sample		Number of slots	Internal dimensions						Internal dimensions of the boxes (3 required)					
			A		B		C		D		E		F	
in	mm		in	cm	in	cm	in	cm	in	cm	in	cm	in	cm
1½	40	8	1¾	4.5	6	15	2½	6.5	9	23	6	15	15	38
¾	20	10	1	2.5	5	12.5	1½	3.8	6	15	4	10	11½	30
⅜	10	12	½	1.3	3	7.5	1⅛	2.9	4½	11.5	3½	9	6½	16.5
⅜	5	12	¼	0.7	1½	1.8	½	1.3	2	5	2	5	3½	9

The actual weight of sample required can be assessed by multiplying the weight given in the table below (which includes some allowance for drying, wastage and rejection of stones where required) by the maximum number of tests envisaged. Where the total weight of sample so calculated is less than the minimum weight given above for the appropriate soil group then that minimum weight shall be taken.

Type of test		Soil group		
		Fine-grained	Medium-grained	Coarse-grained
Moisture content	Test 1(A)	50 g	350 g	4 kg
Moisture content	Test 1(B)	50 g	350 g	3 kg
Moisture content	Test 1(C)	50 g	350 g	—
Liquid limit	Test 2(A)	500 g	1 kg	2 kg
Liquid limit	Test 2(B)	150 g	250 g	500 g
Plastic limit	Test 3	50 g	100 g	200 g
Linear shrinkage	Test 5	500 g	800 g	1.5 kg
Specific gravity	Test 6(A)	100 g	100 g	100 g
Specific gravity	Test 6(B)	600 g	600 g	600 g
Particle-size distribution	Test 7(A)	150 g	2.5 kg	17 kg
Particle-size distribution	Test 7(B)	150 g	2.5 kg	17 kg
Particle-size distribution	Test 7(C)	100 g	100 g	100 g
Particle-size distribution	Test 7(D)	250 g	250 g	250 g
Organic matter content	Test 8	150 g	600 g	3.5 kg
Sulphate content	Test 9(A)	150 g	600 g	3.5 kg
Sulphate content	Test 9(B)	150 g	600 g	3.5 kg
pH value	Test 10(A)	150 g	600 g	3.5 kg
pH value	Test 10(B)	150 g	600 g	3.5 kg
Compaction test*	Test 11	(10 kg) 25 kg	(10 kg) 25 kg	(10 kg) 25 kg
Compaction test*	Test 12	(10 kg) 25 kg	(10 kg) 25 kg	(10 kg) 25 kg
Compaction test*	Test 13	(50 kg) 80 kg	(50 kg) 80 kg	(50 kg) 80 kg
California Bearing Ratio	Test 15	6 kg	6 kg	12 kg

* The weight given in brackets applies only when the soil is not susceptible to crushing during compaction (see Note 2).

Tests not covered in this table are those in which undisturbed samples are used or where tests are made on the soil in situ.

(3) If the moisture content of the natural soil, as received, is required,

representative samples of the following minimum weights shall be obtained by riffling or quartering:

	Test 1(A)	Test 1(B)	Test 1(C)
For fine-grained soils	30 g	30 g	30 g
For medium-grained soils	300 g	300 g	300 g
For coarse-grained soils	3 kg	2 kg	—

Where samples are being taken for moisture content determination the use of shallow trays for storing or carrying should be avoided as these expose the samples unnecessarily to evaporation or rainfall. Such samples should be kept covered over, if not sealed up, except when material is actually being extracted.

(4) If the California Bearing Ratio is to be determined (Test 15) the appropriate quantity of material shall be removed from the main sample and sealed up in a container so as to prevent loss of moisture until such time as the tests are carried out.

(5) The soil sample (or the remainder if procedures (3) or (4) are carried out) shall be brought to a state in which it may be crumbled, if necessary by drying it in air or in the oven. This shall be done at a temperature not exceeding 50°C (122°F). Oven drying at 105–110°C (221–230°F) may be employed, provided this does not affect the results of the tests to be carried out subsequently (see Note 3).

1.4.4 Preparation for classification and chemical tests (Tests 1–10)

1.4.4.1 The aggregations of particles in the sample obtained in 1.4.3(5) shall be broken up in such a way as to avoid crushing the individual particles. Care shall be taken that no particles are crushed in this operation but that all aggregations of particles are broken down so that if the sample were sieved on a No. 7 (2.40 mm) BS test sieve* only individual particles would be retained.

1.4.4.2 The sample obtained in 1.4.4.1 shall be thoroughly mixed and then sub-divided either by quartering, by riffling, or by other suitable means until representative sub-samples of the minimum weights given, after suitable further preparation where necessary, are obtained for the appropriate tests.

(1) Tests 1(A), 1(B) and 1(C). (*Determinations of the moisture content of the prepared samples.*)

	Test 1(A)	Test 1(B)	Test 1(C)
For fine-grained soils	30 g	30 g	30 g
For medium-grained soils	300 g	300 g	300 g
For coarse-grained soils	3 kg	2 kg	—

(2) Tests 2(A), 2(B), 3, 4 and 5. (*Determinations of liquid limit, plastic limit, plasticity index and linear shrinkage.*) Sufficient of the material obtained in

* BS 410, 'Test sieves'.

1.4.4.1 shall be taken so that when sieved through a No. 36 (420 microns) BS test sieve* the following quantities of material passing the test sieve are obtained (see Note 4):

Test 2(A)	200 g
Test 2(B)	50 g
Test 3	20 g
Test 4	No additional sample required
Test 5	150 g

Care shall be taken that no particles are crushed but that all aggregations of particles are broken down so that only individual particles are left on the sieve (see Notes 5 and 6). The proportion of material passing the No. 36 (420 microns) BS test sieve* shall be recorded (see Note 7).

(3) Test 6(A). (*Determination of specific gravity.*) A 50 g sample shall be taken from the material prepared in 1.4.4.1 and, if necessary, ground to pass a No. 7 (2.40 mm) BS test sieve*. A representative 5–10 g sub-sample shall be obtained and oven-dried at 105–110°C (221–230°F) (see Note 8).

(4) Test 6(B). (*Determination of specific gravity.*) A 400–500 g sample of the material prepared in 1.4.4.1 shall be taken and stones larger than 1½ in (40 mm) diameter shall be broken down below this size. The sample shall be oven-dried at 105–110°C (221–230°F) (see Note 8).

(5) Tests 7(A) and 7(B). (*Determination of particle-size distribution.*) Sufficient material as prepared in 1.4.4.1 shall be taken and oven-dried at 105–110°C (221–230°F) to give the minimum weight in accordance with the following table:

Maximum size of material present in substantial proportion (more than 10%)		Minimum weight of sample to be taken for sieving	
in	mm	kg	lb
2½	64	50	110
2	50	35	77
1½	40	15	33
1	25	5	11
¾	20	2	4.5
½	12.5	1	2.2
⅜	10	0.5	1
¼ or ⅜	6.3 or 5	0.2	0.4
Passing No. 7, 25, 52 or 200 BS test sieves*	2.40 mm, 600 microns, 300 microns or 75 microns)	0.1	0.2

* BS 410, 'Test sieves'.

(6) *Tests 7(C) and 7(D). (Determination of particle-size distribution.)* (Applicable only to soils with more than 10% passing the No. 200 (75 microns) BS test sieve*.)

The following quantities of material as prepared in 1.4.4.1 are required:

Test 7(C)	60 g
Test 7(D)	200 g

(7) *Tests 8, 9(A), 9(B), 10(A) and 10(B). (Determination of organic content, sulphate content and pH value.)* The preparation of the samples for these tests are fairly involved and are given, therefore, under the respective test procedures. The following quantities of material prepared as in 1.4.4.1 are required for each test:

For fine-grained soils	100 g
For medium-grained soils	500 g
For coarse-grained soils	3 kg

1.4.5 Preparation for compaction tests and strength tests (Tests 11–17)

(1) *Tests 11 and 12. (Compaction tests using a rammer.)* A portion of the material, prepared as in 1.4.3(5) large enough to provide about 6 kg of material passing a $\frac{3}{4}$ in (20 mm) BS test sieve* (for soils not susceptible to crushing during compaction) or 15 kg of material passing a $\frac{3}{4}$ in (20 mm) BS test sieve (for soils susceptible to crushing during compaction) shall be taken (see Note 2). This shall be sieved on a $\frac{3}{4}$ in (20 mm) BS test sieve and the coarse fraction rejected after its proportion of the total sample has been recorded.

Aggregations of particles shall be broken down so that, if the sample were sieved on a $\frac{3}{16}$ in (5 mm) BS test sieve, only individual particles would be retained.

(2) *Test 13. (Compaction test using a vibrating hammer.)* A portion of the material, prepared as in 1.4.3(5) large enough to provide about 30 kg of material passing a $1\frac{1}{2}$ in (40 mm) BS test sieve (for soils not susceptible to crushing during compaction) or 50 kg of material passing a $1\frac{1}{2}$ in (40 mm) BS test sieve (for soils susceptible to crushing during compaction) shall be taken (see Note 2). This shall be sieved on a $1\frac{1}{2}$ in (40 mm) BS test sieve and the coarse fraction rejected after its proportion of the total sample has been recorded.

Aggregations of particles shall be broken down so that, if the sample were sieved on a $\frac{3}{16}$ in (5 mm) BS test sieve, only individual particles would be retained.

(3) *Tests 14(A), 14(B), 14(C), 14(D), 14(E) and 14(F). (Dry density determinations.)* These are site tests for which no sample preparation is required.

(4) *Test 15. (Determination of the California Bearing Ratio.)* This test is generally carried out on soil at its natural moisture content. A portion of the

* BS 410, 'Test sieves'.

material obtained in 1.4.3(4) large enough to provide for each test about 6 kg of material passing a $\frac{3}{4}$ in (20 mm) BS test sieve, shall be taken. This shall be rubbed through a $\frac{3}{4}$ in (20 mm) BS test sieve and the coarse fraction rejected after its proportion of the total sample has been noted (see Note 9).

Where the test is to be carried out at moisture contents other than the natural moisture content details of the sample preparation are given under the test procedure.

(5) *Test 16. (Determination of one-dimensional consolidation), Test 19 (Determination of the unconfined compressive strength using portable apparatus) and Test 20 (Determination of the compressive strength, etc.).* These tests are carried out on undisturbed samples of soil. The preparation of these samples is given under the relevant test procedures.

(6) *Test 17. (Shear strength determination by field vane) and Test 18 (Determination of the penetration resistance using the split barrel sampler.)* These are site tests for which no sample preparation is required. Reference should be made to CP 2001, 'Site investigations', for details of the methods.

NOTES

NOTE 1. Procedure for sampling is not described in this standard. Reference should be made to CP 2001, 'Site investigations', for details of the methods.

NOTE 2. 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, etc., which is reduced in size by the action of the rammer or vibrating hammer.

NOTE 3. Air drying has been specified in the preparation of soil samples for testing since with some soils irreversible changes take place in the soil when it is oven dried at 105–110°C (221–230°F). With many soils, however, this effect is of negligible practical significance. Samples to be used for plasticity or pH tests shall not be oven-dried at above 50°C. Certain tropical soils are even affected by air-drying and should be used in their natural state.

In the United Kingdom samples may be air-dried by leaving them spread out on trays in the laboratory with free access to air for three or four days. Some silts and clays without large particle sizes may be used in their natural state for certain tests instead of being air-dried.

NOTE 4. The testing of samples of natural soil. When no stones are present in the soil and it practically all passes the No. 36 (420 microns) BS test sieve* it is often convenient to carry out plasticity tests on samples without previously preparing them as described in 1.4.4.2(2). When soils are tested in the natural condition the results will usually differ from those obtained with air-dried samples. The test record shall state that the soil in the natural condition was used.

NOTE 5. Care should be taken to see that test sieves are not overloaded (see Appendix A).

NOTE 6. With granular soils containing a small proportion of cohesive material it may be necessary to wet sieve through the No. 36 (420 microns) BS test sieve to obtain the fraction required. If wet sieving is carried out the material and water passing the test sieve shall be collected and allowed to stand. When the water has become substantially clear it shall be decanted and the remaining sample air-dried as in 1.4.3(5).

NOTE 7. It should be remembered that the recorded proportion passing the No. 36 (420

* BS 410, 'Test sieves'.

microns) BS test sieve* will be only approximate as the determination is made with air-dried soil.

NOTE 8. Oven-drying of the soil has been specified for convenience. If there is any reason to believe that this will change the specific gravity due to loss of water of hydration the soil should be tested in its natural condition and the weight of soil used determined by oven-drying at the end of the test.

NOTE 9. If the test is to be made on samples containing larger particles than $\frac{3}{4}$ in (20 mm) the fraction retained on the $\frac{3}{4}$ in (20 mm) BS test sieve should be removed. If this does not exceed 25% of the whole it is unnecessary to make any correction. If the percentage retained on the $\frac{3}{4}$ in (20 mm) BS test sieve is greater than this, it should be replaced with a similar fraction of $\frac{3}{4}$ – $\frac{3}{16}$ in (20–5 mm) material from the main sample.

* BS 410, 'Test sieves'.

2. SOIL CLASSIFICATION TESTS

2.1 TEST 1. DETERMINATION OF THE MOISTURE CONTENT

2.1.1 Test 1(A). Standard method (Oven-drying method)

2.1.1.1 Scope. This method covers the determination of the moisture content of soil as a percentage of its dry weight.

2.1.1.2 Apparatus. A thermostatically controlled drying oven capable of maintaining a temperature of 105–110°C (221–230°F) and:

For fine-grained soils:

(1) A glass weighing bottle fitted with a ground glass stopper or cap, or a suitable airtight non-corrodible metal container (a convenient size is 2 in (5 cm) diameter and 1 in (2.5 cm) high.

(2) A balance readable and accurate to 0.01 g.

(3) A desiccator (a convenient size is 8–10 in (20–25 cm) diameter) containing anhydrous silical gel (see Note 1).

For medium-grained soils:

(1) An airtight non-corrodible container of about 1 lb (450 g) capacity.

(2) A balance readable and accurate to 0.1 g.

(3) A scoop (a convenient size is one about 8 in (20 cm) long and 4½ in (11 cm) wide).

For coarse-grained soils:

(1) An airtight non-corrodible container of about 6 lb (3 kg) capacity.

(2) A balance readable and accurate to 1 g.

(3) A scoop (a convenient size is one about 8 in (20 cm) long and 4½ in (11 cm) wide).

2.1.1.3 Procedure

For fine-grained soils:

(1) The weighing bottle or container shall be cleaned, dried, and weighed to 0.01 g (W_1). A sample of at least 30 g of soil shall be crumbled and placed loosely in the container or the weighing bottle, and the lid or stopper shall be replaced. The container or bottle and contents shall then be weighed to 0.01 g (W_2).

(2) The lid or stopper shall then be removed, and the container or bottle with its lid and contents shall be placed in the oven and dried at 105–110°C (221–230°F) (see Note 2). The period required for drying will vary with the type of soil and the size of sample. The sample shall be deemed to be dry when the differences in successive weighings of the cooled sample (see (3) and (4)) at intervals of 4 hours, do not exceed 0.1% of the original weight of the sample

(see Note 3). The lid or stopper shall not be replaced whilst the sample is in the oven.

(3) After drying, the container or bottle and contents shall be removed from the oven and the whole placed in the desiccator to cool (see Note 4).

(4) The lid shall be replaced and the container or bottle and contents shall then be weighed to 0.01 g (W_3).

For medium-grained soils:

(1) The container shall be cleaned, dried and weighed to 0.1 g (W_1). A sample of at least 300 g of soil shall be crumbled and placed loosely in the container, and the lid shall be replaced. The container and contents shall then be weighed to 0.1 g (W_2).

(2) The lid shall then be removed and the container and contents shall be placed in the oven and dried at 105–110°C (221–230°F)* (see Note 3). The period required for drying will vary with the type of soil and the size of sample. The sample shall be deemed to be dry when the differences in successive weighings of the cooled sample (see (3) and (4)) at intervals of 4 hours do not exceed about 0.1 % of the original weight of the soil (see Note 3). The lid shall not be replaced whilst the sample is in the oven.

(3) After drying, the lid shall be replaced and the whole allowed to cool.

(4) The container and contents shall then be weighed to 0.1 g (W_3).

For coarse-grained soils:

(1) The container shall be cleaned, dried, and weighed to the nearest 1 g (W_1). A sample of at least 3 kg of soil shall be crumbled and placed loosely in the container and the lid replaced. The container and contents shall then be weighed to the nearest 1 g (W_2).

(2) The lid shall be removed and the container and contents shall be placed in the oven and dried at 105–110°C (221–230°F) (see Note 3). The period required for drying will vary with the type of soil and the size of sample. The sample shall be deemed to be dry when the differences in successive weighings of the cooled sample (see (3) and (4)) at intervals of 4 hours do not exceed about 0.1 % of the original weight of the soil (see Note 4). The lid shall not be replaced whilst the sample is in the oven.

(3) After drying, the lid shall be replaced and the whole allowed to cool.

(4) The container and contents shall then be weighed to the nearest 1 g (W_3).

2.1.1.4 Calculations*. The moisture content of the soil (m) shall be calculated, as a percentage of the dry soil weight, from the formula:

$$m = \frac{W_2 - W_3}{W_3 - W_1} \times 100 \text{ (per cent)}$$

* See Form A, Appendix B.

where W_1 = weight of container

W_2 = weight of container and wet soil

W_3 = weight of container and dry soil.

2.1.1.5 Reporting of results. The moisture content of the soil (m) for values up to 10 % shall be reported to two significant figures. For moisture contents above 10 % the result shall be reported to the nearest whole number (see Note 2). The method used to obtain the results shall be stated.

NOTES ON TEST 1(A)

NOTE 1. It is preferable to use self-indicating silica gel as the desiccant. Calcium chloride should not be used as it is known that many clays when oven dry are capable of absorbing water from it.

NOTE 2. *Soils containing gypsum.* Certain soils contain gypsum which on heating loses its water of crystallization. The moisture content determined by this method will be affected by approximately 0.2 % for each 1 % of gypsum. If it is suspected that gypsum is present in the soil the moisture content samples should be dried at not more than 80°C (176°F) and possibly for a longer time. This fact shall be reported.

NOTE 3. *Drying time of soils.* 16–24 hours is usually a sufficient length of time for drying most soils, but certain soil types and large or very wet samples will require longer. The drying time will also depend on the amount of material in the oven.

NOTE 4. If the lids of the containers fit well and it is unlikely that the samples are to be left for a considerable time before weighing, the samples need not be placed in the desiccator to cool, unless glass weighing bottles with ground-in glass stoppers have been used.

2.1.2 Test 1(B). Subsidiary method (Sand-bath method)

2.1.2.1 Scope. This method covers the determination of the moisture content of a soil as a percentage of its dry weight. It is intended as a rapid alternative to Test 1(A) but is less accurate and is more suitable as a site test. The method shall not be used if it is suspected that the soil contains a large proportion of gypsum, calcareous matter or organic matter.

2.1.2.2 Apparatus

For fine-grained soils:

- (1) A suitable airtight, non-corrodible metal container, approximately 2 in (5 cm) in diameter and 1 in (2.5 cm) deep.
- (2) A balance readable and accurate to 0.1 g.
- (3) A sand bath approximately 7 in (18 cm) diameter and containing clean sand to a depth of at least 1 in (2.5 cm). A larger bath may be used to heat several samples at once.
- (4) Equipment for heating the sand bath, e.g. a bottled gas or paraffin pressure stove.
- (5) A palette knife (a convenient size is one having a blade 4 in (10 cm) long and $\frac{3}{4}$ in (2 cm) wide).

For medium-grained soils:

- (1) A balance readable and accurate to 0.5 g.
- (2) A heat-resistant tray about 50 in² (325 cm²) in area and about 2 in (5 cm) deep.
- (3) A sand bath containing clean sand to a depth of at least 1 in (2.5 cm) and large enough to take the tray. A larger bath may be used to heat several samples at once.
- (4) Equipment for heating the sand bath, e.g. a bottled gas or paraffin pressure stove.
- (5) A palette knife (a convenient size is one having a blade 4 in (10 cm) long and $\frac{3}{4}$ in (2 cm) wide).
- (6) A scoop (a convenient size is one about 8 in (20 cm) long and 4½ in (11 cm) wide).

For coarse-grained soils:

- (1) A balance readable and accurate to 1 g.
- (2) A heat-resistant tray about 100 in² (650 cm²) in area and 2–3 in (5–7 cm) deep.
- (3) A sand bath, containing sand to a depth of at least 1 in (2.5 cm) and large enough to take the tray.
- (4) Equipment for heating the sand bath, e.g. a bottled gas or paraffin pressure stove.

(5) A palette knife (a convenient size is one having a blade 8 in (20 cm) long and 1¼ in (3 cm) wide).

(6) A scoop (a convenient size is one about 8 in (20 cm) long and 4½ in (11 cm) wide).

2.1.2.3 Procedure

For fine-grained soils:

(1) The container shall be cleaned, dried and weighed to 0.1 g (W_1) (see Note 1). A sample of at least 30 g of soil shall be crumbled and placed loosely in the container, and the lid shall be replaced. The container and contents shall then be weighed to 0.1 g (W_2).

(2) After the lid has been removed, the container and contents shall be placed on the sand bath, which shall be heated by means of the stove. Care shall be taken not to get the sand bath too hot (see Note 2). During heating the sample shall be disturbed frequently and thoroughly with the palette knife to assist the evaporation of moisture.

(3) When the container and contents have been heated for a period sufficient to dry out the sample (usually one hour is sufficient, see Note 3), they shall be removed from the sand bath, the lid replaced and the whole allowed to cool.

(4) The container and contents shall then be weighed to 0.1 g (W_3).

For medium- and coarse-grained soils:

(1) The tray shall be cleaned, dried and weighed to 0.5 g (W_1). A sample of at least 300 g for medium-grained and 2 kg for coarse-grained soils shall be crumbled and spread out evenly in the tray and the tray and contents weighed to the nearest 0.5 g (W_2), for medium-grained soils and to the nearest 5 g (W_2) for coarse-grained soils.

(2) The tray shall be placed on the sand-bath which shall be heated by means of the stove (care shall be taken not to get the sand bath too hot) (see Note 2). During heating the sample shall be disturbed frequently and thoroughly with the palette knife to assist the evaporation of moisture.

(3) When the tray has been heated for a period sufficient to dry out the sample (usually one hour is sufficient, see Note 3) it shall be removed from the sand bath and allowed to cool.

(4) Immediately the tray is cool enough to handle the tray and contents shall be weighed to the nearest 0.5 g for medium-grained soils and to the nearest 5 g for coarse-grained soils (W_3).

2.1.2.4 Calculations*. The moisture content of the soil (m) shall be calculated, as a percentage of the dry soil weight, from the formula:

$$m = \frac{W_2 - W_3}{W_3 - W_1} \times 100 \text{ (per cent)}$$

* See Form A, Appendix B.

where W_1 = weight of container (or tray)
 W_2 = weight of container (or tray) and wet soil
 W_3 = weight of container (or tray) and dry soil.

2.1.2.5 Reporting of results. The moisture content of the soil (m), for values up to 10%, shall be reported to two significant figures. For moisture contents above 10%, the result shall be reported to the nearest whole number. The method used to obtain the result shall be stated.

NOTES ON TEST 1(B)

NOTE 1. It is convenient when many containers are in use to bring them to a standard weight, e.g. 30.00 g, by the addition of solder to the inside of the lid.

NOTE 2. *Avoidance of overheating.* A convenient method of detecting overheating of the soil is by the use of small pieces of white paper mixed with the soil. Overheating is indicated if the paper turns brown.

NOTE 3. *Period of drying.* The drying period will vary with the type of soil, the size of sample and field conditions and it is suggested that when a large number of moisture determinations are to be made with one soil several measurements should be made using different periods of drying to determine the minimum period required to effect adequate drying. The material shall be deemed to be dry if the additional loss of weight when it is heated for a further period of 15 minutes does not exceed 0.1 g for fine-grained soils, 0.5 g for medium-grained soils and 5 g for coarse-grained soils.

2.1.3 Test 1(C). Subsidiary method (Alcohol method)

2.1.3.1 Scope. This method covers the determination of the moisture content of a soil as a percentage of its dry weight. It is intended as a rapid alternative to Test 1(A) but is less accurate and is more suitable as a site test. Because of the large quantity of methylated spirit required and the consequent risk of fire, this method is not advised for use with coarse-grained soils. The method shall not be used if the soil contains a large proportion of clay, gypsum, calcareous matter or organic matter.

2.1.3.2 Apparatus

(1) An evaporating dish (a convenient size is one about 4 in (10 cm) diameter for fine-grained soils and about 6 in (15 cm) diameter for medium-grained soils).

(2) A palette knife (a convenient size is one having a blade 4 in (10 cm) long and $\frac{3}{4}$ in (2 cm) wide).

(3) A length of about 8 in–10 in (20 cm–25 cm) of wire about $\frac{1}{8}$ in (3 mm) diameter (see Note).

(4) A balance readable and accurate to 0.1 g for fine-grained soils and 0.5 g for medium-grained soils.

(5) A quantity of methylated spirit.

2.1.3.3 Procedure

(1) The evaporating dish shall be cleaned, dried and weighed to 0.1 g for fine-grained soils and 0.5 g for medium-grained soils (W_1).

(2) A sample of soil of about 30 g for fine-grained soils and 300 g for medium-grained soils shall be placed in the evaporating dish, and the evaporating dish and its contents weighed to 0.1 g or 0.5 g respectively (W_2).

(3) A quantity of methylated spirit, about 30 ml for fine-grained soils and 300 ml for medium-grained soils shall be poured over the soil so that it is well covered. The methylated spirit shall be well worked into the soil with the palette knife and any large lumps of soil broken-up.

(4) The evaporating dish shall be placed on a surface unlikely to be affected by heat and the methylated spirit ignited.

(5) The soil shall be stirred constantly with the piece of iron wire, care being taken to see that none of the soil is lost.

(6) The dish of soil shall be allowed to cool after the methylated spirit has burnt away completely and when cool enough to be handled the dish and contents shall be weighed to 0.1 g for fine-grained and 0.5 g for medium-grained soils (W_3).

2.1.3.4 Calculations*. The moisture content of the soil (m) shall be calculated as a percentage of the dry sample weight, from the formula:

$$m = \frac{W_2 - W_3}{W_3 - W_1} \times 100 \text{ (per cent)}$$

where W_1 = weight of dish
 W_2 = weight of dish and wet soil
 W_3 = weight of dish and dry soil.

2.1.3.5 Reporting of results. The moisture content of the soil (m) for values up to 10% shall be reported to two significant figures. For moisture content above 10% the result shall be reported to the nearest whole number. The method used to obtain the result shall be stated.

NOTE. A piece of wire has been found to be the most useful means of stirring as the heat generated will soften a palette knife blade and crack a glass rod.

* See Form A, Appendix B.

2.2 TEST 2. DETERMINATION OF THE LIQUID LIMIT

2.2.1 Test 2(A). Standard method

2.2.1.1 Scope. This method covers the determination of the liquid limit of the air-dried soil, i.e. the moisture content at which a soil passes from the plastic to the liquid state, as determined in accordance with the following procedure. The method may also be used on a sample of soil in its natural state (see Note 1).

2.2.1.2 Apparatus

- (1) A flat glass plate $\frac{3}{8}$ in (9 mm) thick and 18 in (46 cm) square or larger.
- (2) Two palette knives (a convenient size is one having a blade 8 in (20 cm) long and $1\frac{1}{4}$ (3 cm) wide).
- (3) A mechanical device similar in the essential details to that illustrated in Fig. 4 (see Note 2).
- (4) A grooving tool and gauge similar in the essential details to those illustrated in Fig. 5.
- (5) An evaporating dish (a convenient size is one about 15 cm (6 in) diameter) or a damp cloth.
- (6) Apparatus for moisture content determination as described in Method 1(A).
- (7) A wash bottle, preferably plastic, or a beaker, containing distilled water.
- (8) A non-corrodible airtight container.

2.2.1.3 Adjustment of apparatus

- (1) The liquid limit device shall be inspected to determine that the device is clean, dry and in good working order that the cup falls freely and that it does not have too much side play at its hinge. The grooving tool shall also be inspected to determine that it is clean, dry and that the critical dimensions are as shown in Fig. 5 (see Note 3).
- (2) The height to which the cup of the liquid limit device is lifted shall be adjusted so that when the cup is raised to its maximum height the 1 cm gauge will just pass between it and the base.

2.2.1.4 Procedure

- (1) A sample weighing at least 200 g shall be taken from the material passing the No. 36 (420 microns) BS test sieve* which has been obtained in accordance with the procedure for the preparation of disturbed soil samples for testing (see 1.4) the proportion of material passing the No. 36 (420 microns) BS test sieve being recorded. This sample shall be placed on the flat glass plate and thoroughly mixed with distilled water, using the palette knives until the mass

* BS 410, 'Test sieves'.

becomes a thick homogeneous paste. This paste shall then be allowed to stand in the airtight container for about 24 hours to allow the water to permeate throughout the soil mass (see Note 4).

(2) The sample shall then be removed from the container and remixed for at least 10 minutes (see Note 5).

A portion of the soil-water mixture shall be placed in the cup (the cup resting on the base) levelled off parallel to the base, and divided by drawing the grooving tool along the diameter through the centre of the hinge at the same time holding it normal to the surface of the cup with the chamfered edge facing in the direction of movement (see Note 6). By turning the crank at the rate of two per second, the cup shall be lifted and dropped until the two parts of the soil come into contact at the bottom of the groove along a distance of $\frac{1}{2}$ in (13 mm). This length shall be measured with the end of the grooving tool or a ruler. The number of blows at which this occurs shall be recorded.

(3) A little extra of the soil mixture shall be added to the cup and mixed with the soil in the cup.

(4) (2) and (3) shall be repeated until two consecutive runs give the same number of blows for closure (see Notes 7 and 8).

(5) A quantity of soil (about 10 g) from the portions of the sample that have just flowed together shall be removed with a spatula and placed in a suitable container, and the moisture content otherwise determined by Test 1(A).

(6) Operations (2) to (5) shall be carried out at least four times using the same sample to which further increments of distilled water have been added. The moisture contents chosen or the amount of water added shall be such that when the moisture contents are plotted they are evenly distributed over a range between 50 and 10 blows. The test shall always proceed from the drier to the wetter condition of the soil. Each time, the soil is removed from the cup for the addition of more water the cup and the grooving tool shall be washed and dried.

(7) If at any time during the above procedure the soil has to be left for a while on the glass plate it shall be covered with the evaporating dish or damp cloth to prevent it drying out too rapidly.

2.2.1.5 Calculations*. The relation between moisture content and corresponding number of blows shall be plotted on a semi-logarithmic chart with the percentage moisture contents as ordinates on the linear scale and the number of blows as abscissae on the logarithmic scale. The best straight line fitting the plotted points shall be drawn through them.

2.2.1.6 Reporting of results. The moisture content corresponding to the intersection of the 'flow curve' with the 25 blows abscissa shall be taken as the liquid limit (LL) of the soil and shall be expressed to the nearest whole number.

* See Form B, Appendix B.

DIMENSIONS

Letter	<u>A</u>	<u>B</u>	<u>C</u>	<u>D</u>	<u>E</u>	<u>F</u>	<u>G</u>
mm	54 ± 0.25	2 ± 0.25	27 ± 0.25	12.5 ± 0.25	56 ± 0.5	25 ± 0.5	10 ± 0.25
in	$2\frac{1}{8}$	$\frac{5}{64}$	$1\frac{1}{16}$	$\frac{1}{2}$	$2\frac{7}{32}$	1	$\frac{25}{64}$

Letter	<u>H</u>	<u>I</u>	<u>K</u>	<u>L</u>	<u>M</u>	<u>N</u>	<u>P</u>	<u>Q</u>	<u>R</u>	<u>S</u>	<u>T</u>
mm	16 ± 0.25	60 ± 1	51 ± 1	152 ± 1	127 ± 1	27	28	6	22	19	45
in	$\frac{5}{8}$	$2\frac{3}{8}$	2	6	5	$1\frac{1}{16}$	$1\frac{3}{32}$	$\frac{1}{4}$	$\frac{55}{64}$	$\frac{47}{64}$	$1\frac{3}{4}$

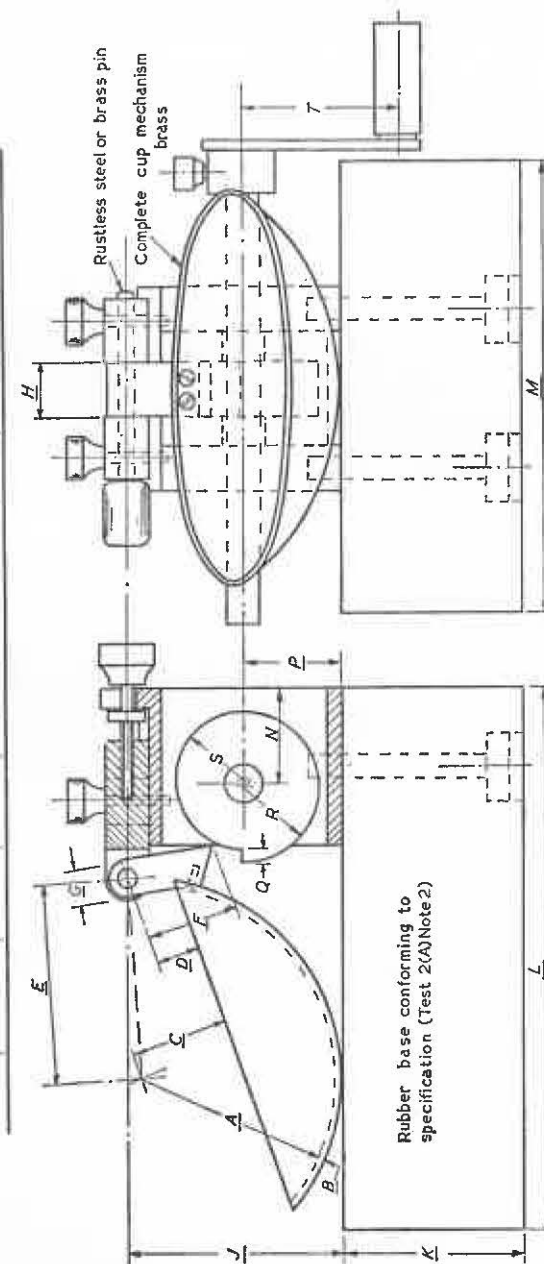
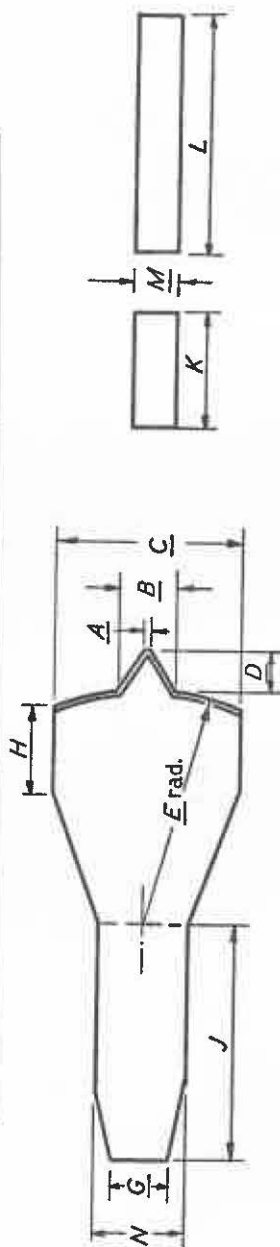


Fig. 4. Liquid limit apparatus

DIMENSIONS

Letter	<u>A</u>	<u>B</u>	<u>C</u>	<u>D</u>	<u>E</u>	<u>F</u>
mm	2 ± 0.25	11 ± 0.25	40 ± 0.5	8 ± 0.25	51 ± 0.5	1.6 ± 0.1
in	$\frac{5}{64}$	$\frac{7}{16}$	$1\frac{1}{16}$	$\frac{5}{16}$	2	0.064

Letter	<u>G</u>	<u>H</u>	<u>J</u>	<u>K</u>	<u>L</u>	<u>M</u>	<u>N</u>
mm	12.5 ± 0.5	19	51	25	51	10 ± 0.25	19
in	$\frac{1}{2}$	$\frac{3}{4}$	2	1	2	$2\frac{5}{16}$	$\frac{3}{4}$



36

This design has been found satisfactory, but alternative designs may be employed provided that the essential requirements are fulfilled. (Essential dimensions underlined.)

Fig. 5. Grooving tool and height gauge
(Brass or stainless steel)

The percentage of material passing the No. 36 (420 microns) BS test sieve* shall be noted. The history of the sample shall also be noted, i.e. natural state, air dried, oven dried or unknown. The method used to obtain the result shall also be stated, i.e. 'standard method'.

NOTES ON TEST 2(A)

NOTE 1. *The testing of samples of natural soil.* When no stones are present in the soil and it practically all passes the No. 36 (420 microns) BS test sieve* it is often convenient to test samples without previously preparing them as described in 1.4. When soils are tested in the natural condition the results will usually differ from those obtained with air-dried samples. The test record shall state that the soil in the natural condition was used.

If stones are present, only the material passing the No. 36 (420 microns) BS test sieve should be used for the test; this can be obtained by rubbing the wet soil through the sieve until a sufficient quantity of the size passing the No. 36 (420 microns) BS test sieve is obtained. The test sieve used for this part of this process should not be one of a set used for particle size analysis as the rubbing of wet soil through a test sieve results in rapid wear of the sieve. This wear, however, will not have any appreciable effect on the liquid limit obtained for the sample under test.

NOTE 2. *Specification of the base.* The base of the liquid limit apparatus shall be made of four vulcanized rubber laminations $\frac{3}{16}$ in (13 mm) thick, 6 in (152 mm) long and 5 in (127 mm) wide. The hardness of each rubber lamination measured on the full thickness, but otherwise as in BS 903, Part A7 (1957) shall be 84-94° at $20 \pm 2^\circ\text{C}$ and the resilience measured with a Lupke pendulum as in BS 903†, Part A22 (1963) shall be 20-35% at $20 \pm 2^\circ\text{C}$. The laminations shall be adequately bonded together and shall be made basically as in BS 1154‡, compound number Z16, with the necessary variations to give the required physical characteristics.

NOTE 3. *Wear on the grooving tool.* When the tip of the grooving tool has worn to a width of 3 mm ($\frac{1}{8}$ in) the tool shall be withdrawn from use and reshaped to the proper dimensions, 2 mm ($\frac{5}{64}$ in). It may be found useful to have a standard check gauge of the correct dimensions against which the tool can be checked.

NOTE 4. A curing period of 24 hours is recommended for most soils, but for soils of low clay content it may not be necessary to cure for this length of time and the test can be made immediately after mixing.

NOTE 5. Certain soils may require as much as 40 minutes continuous mixing immediately before testing to obtain reliable results.

NOTE 6. With soils having low plasticity indices it is sometimes difficult to cut a smooth groove in the soil with the grooving tool specified. Hitherto an alternative tool (the 'A.S.T.M. type' tool) has been recommended for use with such soils but it is considered that its action in cutting the groove is not correct. The usual action of the tool is that of the insertion of a wedge into the pat of soil causing the two halves of the pat to slide at the cup-soil face. During the test the tendency is then for the soil to slide back again on this same face instead of flowing as it should do.

It does not necessarily follow that because a smooth groove cannot be obtained, the soil is non-plastic and it should be recorded that the liquid limit could not be obtained. If a measure of the plasticity index of such a soil is required, this can be obtained by the use of the linear shrinkage test (Test 5).

* BS 410, 'Test sieves'.

† BS 903, 'Methods of testing vulcanized rubber'. Part A7, 'Determination of hardness', Part A22, 'Determination of apparent hardness on curved surfaces'.

‡ BS 1154, 'Vulcanized rubber compounds'.

37

NOTE 7. Some soils tend to slide on the surface of the cup instead of the soil flowing. If this occurs the result should be discarded and the test repeated until flowing does occur. If, after additional increments of water, sliding still occurs, the test is not applicable, and a note should be made that the liquid limit could not be obtained.

NOTE 8. Care should be taken to see that the sample does not dry out too rapidly between repeat tests as the number of blows for closure will increase gradually as the sample dries out.

2.2.2 Test 2(B). Subsidiary method (One point method)

2.2.2.1 Scope. This method covers the determination of the liquid limit of the soil, i.e. the moisture content at which a soil passes from the plastic to the liquid state, as determined by the following procedure. The advantage of the method is speed, since it involves taking one measurement of the moisture content only.

2.2.2.2 Apparatus

- (1) A flat glass plate $\frac{3}{8}$ in (9 mm) thick and 18 in (46 cm) square or larger.
- (2) Two palette knives (a convenient size is one having a blade 8 in (20 cm) long and $1\frac{1}{4}$ in (3 cm) wide).
- (3) A mechanical device similar in the essential details to that illustrated in Fig. 4.
- (4) A grooving tool and a guage similar in the essential details to those illustrated in Fig. 5.
- (5) A non-corrodible airtight container large enough to take about 200–250 g of wet soil.
- (6) Apparatus for moisture content determination as described in Method 1(A).
- (7) A wash bottle, preferably plastics, or a beaker containing distilled water.

2.2.2.3 Adjustment of apparatus

- (1) The liquid limit device shall be inspected to determine that it is in good working order, that the cup falls freely and that it does not have too much side play at its hinge. The grooving tool shall be inspected to determine that the critical dimensions are as shown in Fig. 5 (see Note 1).
- (2) The height to which the cup of the liquid limit device is lifted shall be adjusted so that when the cup is raised to its maximum height the 1 cm gauge will just pass between it and the base.

2.2.2.4 Procedure

- (1) A sample which has been obtained in accordance with the procedure for the preparation of disturbed samples for testing (1.4) weighing at least 50 g, shall be taken from the material passing the No. 36 (420 microns) BS test sieve* (see Notes 2 and 3). The proportion passing the No. 36 (420 microns) BS test sieve shall be recorded. This sample shall be placed on the flat glass plate and thoroughly mixed with distilled water using the spatula until the mass becomes a homogeneous thick paste at a moisture content as near as possible to that corresponding to the 25 blows value (see Notes 4 and 5). This may be checked with the liquid limit machine until experience with the soils under test renders this step unnecessary. The mixing shall be carried out for at least 10 minutes.

* BS 410, 'Test sieves'.

(2) The sample shall then be placed in the airtight container and stored for at least 24 hours at normal room temperature (see Note 6).

(3) Immediately before testing the soil shall be removed from the airtight container, and remixed for at least 1 minute.

(4) A portion of the soil-water mixture shall be placed in the cup (the cup resting on the base, levelled off parallel to the base, and divided by drawing the grooving tool along the diameter through the centre of the hinge, at the same time holding it normal to the surface of the cup with the chamfered edge facing in the direction of movement (see Note 7). By turning the crank at the rate of two revolutions per second, the cup shall be lifted and dropped until the two parts of the soil come into contact at the bottom of the groove along a distance of $\frac{1}{2}$ in (13 mm) (see Note 8). This length shall be measured with the end of the grooving tool or a ruler. The number of blows at which this occurs shall be recorded. The number shall be between 15 and 35.

(5) A little extra of the soil mixture shall be added to the cup and mixed with the soil in the cup.

(6) (4) and (5) shall be repeated until two consecutive runs give the same number of blows for closure (see Note 9).

(7) The soil shall then be removed from the cup, placed in a suitable container and the moisture content determined as in Test 1(A).

2.2.2.5 Calculations. The liquid limit shall be calculated by multiplying the moisture content obtained by the factor corresponding to the number of blows obtained in the test. The factors are given in the table below:

No. of blows	Factor	No. of blows	Factor	No. of blows	Factor	No. of blows	Factor
15	0.95	21	0.98	26	1.00	31	1.02
16	0.96	22	0.99	27	1.01	32	1.02
17	0.96	23	0.99	28	1.01	33	1.02
18	0.97	24	0.99	29	1.01	34	1.03
19	0.97	25	1.00	30	1.02	35	1.03
20	0.98						

2.2.2.6 Reporting of results. The liquid limit calculated as above shall be expressed to the nearest whole number. The percentage of material passing the No. 36 (420 microns) BS test sieve* shall be noted.

The history of the sample shall also be noted, i.e. natural state, air dried, oven dried or unknown. The method used to obtain the result shall also be stated, i.e. 'one point method'.

* BS 410, 'Test sieves'.

NOTES ON TEST 2(B)

NOTE 1. Wear on grooving tool. When the tip of the grooving tool has worn to a width of 3 mm ($\frac{1}{8}$ in) the tool shall be withdrawn from use and reground to the proper dimension 2 mm ($\frac{5}{64}$ in). It may be found useful to have a standard check gauge of the correct dimensions against which the tool can be checked.

NOTE 2. If it is suspected that the liquid limit is above about 120% the standard procedure (Test 2(A)) should be carried out using a 200 g sample.

NOTE 3. When no stones are present in the soil and it practically all passes the No. 36 (420 microns) BS test sieve it is often convenient to test samples without previously preparing them as described in 1.4. When soils are tested in the natural condition, the results will usually differ from those obtained with air-dried samples. The test record shall state that soil in the natural condition was used.

If stones are present, only the material passing the No. 36 (420 microns) BS test sieve should be used for the test; this can be obtained by rubbing the wet soil through the sieve until a sufficient quantity of the size passing the No. 36 (420 microns) BS test sieve is obtained. The sieve used for this part of this process should not be one of a set used for particle size analysis as the rubbing of the wet soil through a sieve results in rapid wear of the sieve. This wear, however, will not have any appreciable effect on the liquid limit obtained for the sample under test.

NOTE 4. As can be seen from the table of correction factors, the nearer the moisture content is to that at 25 blows the less the error due to the variation of the slope of the flow line from the slope of the calculated line which is obtained from the formula:

$$LL = m \left(\frac{n}{25} \right) \tan B$$

where LL = liquid limit (per cent)

m = moisture content (per cent) corresponding to n blows

$\tan B$ = 0.092 (the slope of the calculated flow line for British soils).

NOTE 5. The amount of distilled water added should be such that the number of blows is less rather than more than 25 as during storage some moisture tends to evaporate on to the sides of the container causing the soil to be drier when actually tested.

NOTE 6. A curing period of 24 hours is recommended for most soils, but for soils of low clay content it may not be necessary to cure for this length of time and the test can be made immediately after mixing.

NOTE 7. With soils having low plasticity indices it is sometimes difficult to cut a smooth groove in the soil with the grooving tool specified. Hitherto an alternative tool ('A.S.T.M. type' tool) has been recommended for use with such soils but it is considered that its action in cutting the groove is not correct. The usual action of the tool is that of the insertion of a wedge into the pat of soil causing the two halves of the pat to slide at the cup-soil face. During the test the tendency is then for the soil to slide back again on this same face instead of flowing as it should do.

It does not necessarily follow that because a smooth groove cannot be obtained, the soil is non-plastic and it should be recorded that the liquid limit could not be obtained. If a measure of the plasticity index of such a soil is required this can be obtained by the use of the linear shrinkage test (Test 5).

NOTE 8. Some soils tend to slide on the surface of the cup instead of the soil flowing. If this occurs the result should be discarded and the test repeated until the flowing does occur. If after additional increments of water sliding still occurs the test is not applicable, and a note should be made that the liquid limit could not be obtained.

NOTE 9. Care should be taken to see that the sample does not dry out too rapidly between the repeat tests as the number of blows for closure will increase gradually as the sample dries out.

2.3 TEST 3. DETERMINATION OF THE PLASTIC LIMIT

2.3.1 Scope. This method covers the determination of the lowest moisture content at which the soil is plastic, as determined in accordance with the following procedure (see Note 1).

2.3.2 Apparatus

- (1) A flat glass plate $\frac{3}{8}$ in (9 mm) thick and 18 in (46 cm) square, or larger.
- (2) Two palette knives (a convenient size is one having a blade 8 in (20 cm) long and $1\frac{1}{4}$ in (3 cm) wide).
- (3) Apparatus for moisture content determination as described in 2.1.1.2.
- (4) (Optional.) A length of metal rod $\frac{1}{8}$ in (3 mm) in diameter and about 4 in (10 cm) long.
- (5) A non-corrodible airtight container.

2.3.3 Procedure

(1) A sample weighing about 20 g shall be taken from the material passing the No. 36 (420 microns) BS test sieve*, which has been obtained in accordance with the procedure for the preparation of disturbed soil samples for testing 1.4. The proportion of material passing the No. 36 (420 microns) BS test sieve shall be recorded. The air-dried soil shall be thoroughly mixed with distilled water on the glass plate until it becomes homogeneous and plastic enough to be shaped into a ball (see Note 2).

(2) The ball of soil shall be rolled between the hand and the glass plate with just sufficient pressure to form the soil mass into a thread. When the diameter of the resulting thread becomes $\frac{1}{8}$ in (3 mm) the soil shall be kneaded together and rolled out again. This process shall be continued until crumbling of the thread occurs when it is $\frac{1}{8}$ in (3 mm) in diameter (Fig. 6); the metal rod may be used for comparison as a guide to the correct diameter.

(3) The portions of the crumbled soil thread shall then be gathered together and placed in a container and the moisture content of the soil otherwise determined as in Test 1(A). Sufficient material shall be used to ensure that each wet moisture content sample weighs at least 5 g (see Form B†).

(4) Two completely separate determinations shall be made as described in (2) and (3) above.

2.3.4 Reporting of results. The average of the moisture contents determined in 2.3.3 above shall be taken as the plastic limit (PL) of the soil and shall be expressed to the nearest whole number. The percentage of material passing the No. 36 (420 microns) BS test sieve shall be noted. The history of the sample shall also be noted (i.e. natural state, air-dried, oven-dried, or unknown).

* BS 410, 'Test sieves'.

† Form B, Appendix B.



Fig. 6. The determination of the plastic limit

[To face page 42]

NOTES ON TEST 3

NOTE 1. When no stones are present in the soil and it practically all passes the No. 36 (420 microns) BS test sieve it is often convenient to test samples without previously preparing them as described in 1.4. When soils are tested in the natural condition the results will usually differ from those obtained with air-dried samples. The test record shall state that soil in the natural condition was used.

If stones are present, only the material passing the No. 36 (420 microns) BS test sieve should be used for the test; this can be obtained by rubbing the wet soil through the sieve until a sufficient quantity of the size passing the No. 36 (420 microns) BS test sieve is obtained. The sieve used for this part of this process should not be one of a set used for particle size analysis as the rubbing of wet soil through a sieve results in rapid wear of the sieve. This wear, however, will not have any appreciable effect on the liquid limit obtained for the sample under test.

NOTE 2. When the liquid limit test is carried out on a soil in the natural state it is convenient to put aside a little of the thoroughly mixed material for the determination of the plastic limit. This soil shall be used as in 2.3.3 (1)–(3) except that in cases where it is initially too wet it shall be allowed to dry in air until the required consistency is obtained.

2.4 TEST 4. CALCULATION OF THE PLASTICITY INDEX

2.4.1 Scope. This method covers the calculation of the plasticity index of a soil.

2.4.2 Procedure. The liquid limit (LL) and plastic limit (PL) shall be determined by the procedures given in 2.2 and 2.3 respectively.

2.4.3 Calculations. The plasticity index (PI) shall be calculated from the formula:

$$PI = LL - PL$$

2.4.4 Reporting of results. The numerical difference calculated shall be reported as the plasticity index (PI) except under the following conditions:

(1) When the plastic limit cannot be determined or when the plastic limit is equal to or greater than the liquid limit, the material shall be reported as non-plastic (NP).

(2) For some soils the liquid limit cannot be determined although a value can be obtained for the plastic limit. In such cases if a measure of the plasticity index is required it can be obtained by the use of the linear shrinkage test (Test 5).

2.5 TEST 5. DETERMINATION OF THE LINEAR SHRINKAGE

2.5.1 Scope. This method covers the determination of the linear shrinkage of soils. The test is of value in indicating the plastic properties of soils having low clay contents (see Note 1).

2.5.2 Apparatus

(1) Two palette knives (a convenient size is one having a blade about 4 in (10 cm) long and $\frac{3}{4}$ in (1.9 cm) wide).

(2) A flat glass plate approximately $\frac{3}{8}$ in (9 mm) thick and approximately 18 in (44 cm) square, or an evaporating dish approximately 14 cm diameter.

(3) A mould made of brass, or other suitable material, of the type illustrated in Fig. 7 (see Note 2).

(4) Silicone grease.

(5) An oven capable of maintaining constant temperatures of 60–65°C (140–149°F) and 105–110°C (221–230°F).

(6) A means of measuring a length of up to 6 in (15 cm) to within 0.02 in (0.5 mm).

2.5.3 Procedure

(1) The mould shall be thoroughly cleaned and a thin film of silicone grease shall then be applied to its inner walls in order to prevent the soil from adhering to the mould.

(2) A soil sample weighing about 150 g shall be taken from the material passing the No. 36 (420 microns) BS test sieve* which has been obtained in accordance with the procedure for the preparation of disturbed soil samples for testing (1.4). The proportion of material passing the No. 36 BS test sieve expressed as a percentage of the total weight of dry soil shall be recorded. The sample shall be placed on the flat glass plate and thoroughly mixed with distilled water, using the palette knives, until the mass becomes a smooth homogeneous paste, with a moisture content approximating to the liquid limit of the soil (see Note 3).

(3) Soil-water mixture shall be placed in the mould such that it is slightly proud of the sides of the mould, the mould shall then be gently jarred to remove any air-pockets in the mixture. The soil shall then be levelled off along the top of the mould with the palette knife. All soil adhering to the rim of the mould shall be removed by wiping with a damp cloth.

(4) The mould shall be placed so that the soil-water mixture can air-dry slowly in a position free from draughts until the soil has shrunk away from the walls of the mould, drying can then be completed first at a temperature of 60–65°C (140–149°F) until shrinkage has largely ceased and then at 105–110°C (221–230°F) to complete the drying.

(5) The mould and soil shall then be cooled and the mean length of the soil

* BS 410, 'Test sieves'.

bar measured. If the specimen has become curved during drying it shall be carefully removed from the mould and the lengths of the top and bottom surfaces measured. The mean of these two lengths shall be taken as the length of the oven dry specimen (see Note 4).

2.5.4 Calculations*. The linear shrinkage of the soil shall be calculated as a percentage of the original length of the specimen from the formula:

$$\text{Linear shrinkage} = \left(1 - \frac{\text{Length of oven dry specimen}}{\text{initial length of specimen}} \right) \times 100 \text{ (per cent)}$$

2.5.5 Reporting of results. The linear shrinkage of the soil shall be reported to the nearest whole number together with the proportion of soil that passes the No. 36 (420 microns) BS test sieve†.

NOTES ON TEST 5

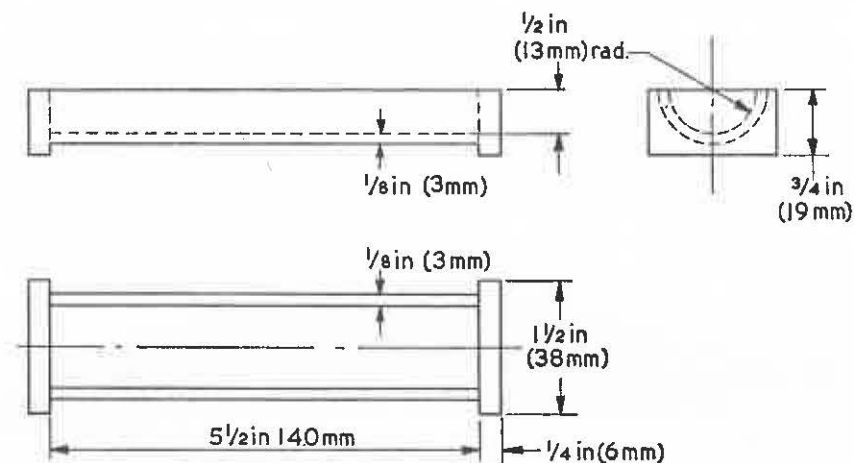
NOTE 1. It is often difficult to determine the liquid and plastic limits of soils having low clay contents and an approximate indication of the plasticity index (PI) can be obtained from the formula:

$$PI = 2.13 LS$$

NOTE 2. The mould may conveniently be made from $\frac{1}{8}$ in (3 mm) thick brass tube of 1 in (25.4 mm) internal diameter, cut in half to form a semi-cylindrical trough. The ends of $\frac{1}{4}$ in (6 mm) flat brass are brazed on.

NOTE 3. This moisture content is not critical to within a few per cent.

NOTE 4. Should a specimen crack badly, or break, such that measurement is difficult, the test should be repeated at a slower drying rate.



Material: non-ferrous.

This design has been found satisfactory, but alternative designs may be employed provided that the essential requirements are fulfilled.
Millimetre dimensions in brackets.

Fig. 7. Mould

* See Form C, Appendix B.

† BS 410, 'Test sieves'.

2.6 TEST 6. DETERMINATION OF THE SPECIFIC GRAVITY OF SOIL PARTICLES

2.6.1 Test 6(A). Method for fine-grained soils

2.6.1.1 Scope. This method covers the determination of the specific gravity of soil particles of fine-grained soils. The method may also be used for medium- and coarse-grained soils if the coarse particles are ground to pass, say, a No. 7 (2.40 mm) BS test sieve* before using.

2.6.1.2 Apparatus

- (1) Two density bottles (pycnometers) of approximately 50 ml capacity.
- (2) A water bath maintained at a constant temperature to within $\pm 0.2^\circ\text{C}$ ($\pm 0.5^\circ\text{F}$). (If standard density bottles are used this constant temperature is 20°C (68°F).)
- (3) A vacuum desiccator (a convenient size is one about 8–10 in (20–25 cm) in diameter).
- (4) A desiccator (a convenient size is one about 8–10 in (20–25 cm) in diameter) containing anhydrous silica gel.
- (5) A thermostatically controlled drying oven, capable of maintaining a temperature of $105\text{--}110^\circ\text{C}$ ($221\text{--}230^\circ\text{F}$).
- (6) A balance readable and accurate to 0.001 g.
- (7) A source of vacuum, e.g. a good filter pump or a vacuum pump.
- (8) A Chattaway spatula (a convenient size is one having a blade 5 in (13 cm) long and $\frac{1}{8}$ in (3 mm) wide; the blade must be small enough to go through the neck of the density bottle), or a piece of glass rod about 5 in (13 cm) long and $\frac{1}{8}$ in (3 mm) diameter.
- (9) A wash bottle, preferably plastics, containing air-free distilled water (see Note 1).
- (10) A sample divider of the multiple slot type (riffle box) with $\frac{1}{4}$ in (6 mm) width of opening.
- (11) A length of rubber tubing to fit vacuum pump and desiccator.

2.6.1.3 Procedure

- (1) The complete density bottle shall be dried at $105\text{--}110^\circ\text{C}$ ($221\text{--}230^\circ\text{F}$), cooled in the desiccator and weighed to the nearest 0.001 g (W_1) (see Note 2).
- (2) The 50 g sample obtained as described in the procedure for the preparation of disturbed samples for testing (1.4) shall if necessary be ground to pass a No. 7 (2.40 mm) BS test sieve. A 5–10 g sub-sample shall be obtained by riffing and oven-dried at $105\text{--}110^\circ\text{C}$ ($221\text{--}230^\circ\text{F}$) (see Note 3). This sample shall be transferred to the density bottle direct from the desiccator in which it has been cooled. The bottle and contents together with the stopper shall be weighed to the nearest 0.001 g (W_2).

* BS 410, 'Test sieves'.

- (3) Sufficient air-free distilled water (see Note 4) shall be added so that the soil in the bottle is just covered. The bottle containing the soil and liquid, but without the stopper, shall be placed in the vacuum desiccator, which shall then gradually be evacuated. The pressure shall be reduced to about 2 cm of mercury.

Care must be taken during this operation to see that the air trapped in the soil does not bubble too violently, in case small drops of the suspension are lost through the mouth of the bottle. The bottle shall be allowed to remain in the desiccator until no further air is released from the soil.

- (4) The vacuum shall be released and the lid of the desiccator removed. The soil in the bottle shall be stirred carefully with the Chattaway spatula or the bottle vibrated. Before removing the spatula from the bottle the particles of soil adhering to the blade shall be washed off with a few drops of air-free liquid. The lid of the desiccator shall then be replaced and the desiccator evacuated again.

- (5) The procedure in (3) and (4) shall be repeated until no more air is evolved from the soil.

- (6) The bottle and contents shall then be removed from the desiccator and further air-free liquid added until the bottle is full. The stopper shall then be inserted. The stoppered bottle shall be immersed up to the neck in the constant-temperature bath for approximately 1 hour, or until it has attained the constant temperature of the bath (see Note 5).

If there is an apparent decrease in volume of the liquid the stopper shall be removed and further liquid added to fill the bottle and the stopper replaced. The bottle shall then be returned to the bath and sufficient time shall be allowed to elapse after this operation to ensure that the bottle and its contents again attain the constant temperature of the bath. If the bottle is still not completely full this process shall be repeated.

- (7) The stoppered bottle shall then be taken out of the bath, wiped dry and the whole weighed to the nearest 0.001 g (W_3).

- (8) The bottle shall then be cleaned out and completely filled with air-free liquid, the stopper inserted and then the whole immersed in the constant temperature bath for 1 hour or until it has attained the constant temperature of the bath. If there is an apparent decrease in the volume of the liquid, the stopper shall be removed and further liquid added to fill the bottle and the stopper replaced. The bottle shall then be returned to the bath and sufficient time shall be allowed to elapse after this operation to ensure that the bottle and its contents again attain the constant temperature. If the bottle is still not completely full this process shall be repeated. The bottle shall then be taken out of the bath, wiped dry and the whole weighed to the nearest 0.001 g (W_4) (see Note 6).

- (9) Two determinations of the specific gravity of the same soil sample shall be made (see Notes 7 and 8).

2.6.1.4 Calculations*. The specific gravity of the soil particles (G_s) shall be calculated from the following formula if water is used (see Note 4):

$$G_s = \frac{W_2 - W_1}{(W_4 - W_1) - (W_3 - W_2)}$$

where W_1 = weight of density bottle

W_2 = weight of bottle and dry soil

W_3 = weight of bottle, soil and water

W_4 = weight of bottle when full of water only.

2.6.1.5 Reporting of results. The average of the values obtained shall be taken as the specific gravity of the soil particles and shall be reported to the nearest 0.01. If the two results differ by more than 0.03 the tests shall be repeated.

NOTES ON TEST 6(A)

NOTE 1. Air-free distilled water shall be obtained by boiling a quantity of distilled water for at least 30 minutes in a container that can be sealed from the atmosphere during cooling. Care shall be taken to see that the container is strong enough to resist the reduction in pressure inside it during cooling.

NOTE 2. *Standard density bottles.* If a density bottle conforming to BS 733† is used then in order to avoid distortion it should not be dried by placing it in an oven. It may be dried by rinsing with acetone or an alcohol-ether mixture and then blowing warm air through it.

NOTE 3. Oven drying of the soil has been specified for convenience. If there is any reason to believe that this will change the specific gravity due to loss of water of hydration the soil should be tested in its natural condition and the weight of the soil used determined by oven-drying at the end of the test. To obtain the true specific gravity of the soil, the weight of oven-dried soil should then be corrected to allow for any chemically-held water that has been removed by oven-drying. However, if the specific gravity is required for the calculation of air contents for the compaction tests the weight of oven-dried material does not need to be corrected.

NOTE 4. *Alternative liquids for specific gravity determination.* With certain soils, e.g. those containing soluble salts, kerosine (paraffin oil) or white spirit may be preferred. If one of these is used, the fact shall be recorded, and a separate experiment carried out to determine the specific gravity of the liquid at the temperature of the test. The formula for the specific gravity of the soil particles given in 2.6.1.4 then becomes:

$$G_s = \frac{G_L(W_2 - W_1)}{(W_4 - W_1) - (W_3 - W_2)}$$

where G_L = specific gravity of the liquid used, at the constant temperature

W_1 = weight of density bottle

W_2 = weight of bottle and dry soil

W_3 = weight of bottle, soil and liquid

W_4 = weight of bottle when full of liquid only.

NOTE 5. If a constant temperature room or cabinet is available then this procedure need not be carried out in a water bath.

* See Form D, Appendix B.

† BS 733, 'Density bottles'.

NOTE 6. If 2.6.1.3(8) is used to find the volume of the density bottle then the test may be carried out at any temperature provided it is constant throughout the test.

NOTE 7. Many soils have a substantial proportion of heavier or lighter particles. Such soils will give erratic values for the specific gravity even with the greatest care in testing and a number of repeat tests may be needed to obtain a good average value.

NOTE 8. Clean quartz and flint sands generally have a specific gravity close to 2.65; low values would suggest the presence of organic matter.

2.6.2 Test 6(B). Method for medium- and coarse-grained soils

2.6.2.1 Scope. This method covers the determination of the specific gravity of the soil particles of medium- and coarse-grained soils.

2.6.2.2 Apparatus

- (1) A pycnometer of the type illustrated in Fig. 8.
- (2) A thermostatically controlled drying oven, capable of maintaining a temperature of 105–110°C (221–230°F).
- (3) A balance readable and accurate to 0.5 g.
- (4) A desiccator (a convenient size is one about 8–10 in (20–25 cm) in diameter) containing anhydrous silica gel.
- (5) A glass rod about 12 in (30 cm) long and ¼ in (6 mm) diameter.
- (6) A thermometer, to cover the range 0–50°C (32–122°F) readable and accurate to 1 degC (2 degF).

2.6.2.3 Procedure

(1) The sample obtained as described in the procedure for the preparation of disturbed samples for testing (1.4) shall, if necessary, be divided by quartering or riffing until a sub-sample weighing 400–500 g is obtained. Stones larger than 1½ in diameter shall be broken down below this size and the sample shall be oven-dried at 105–110°C (221–230°F) (see Note 1).

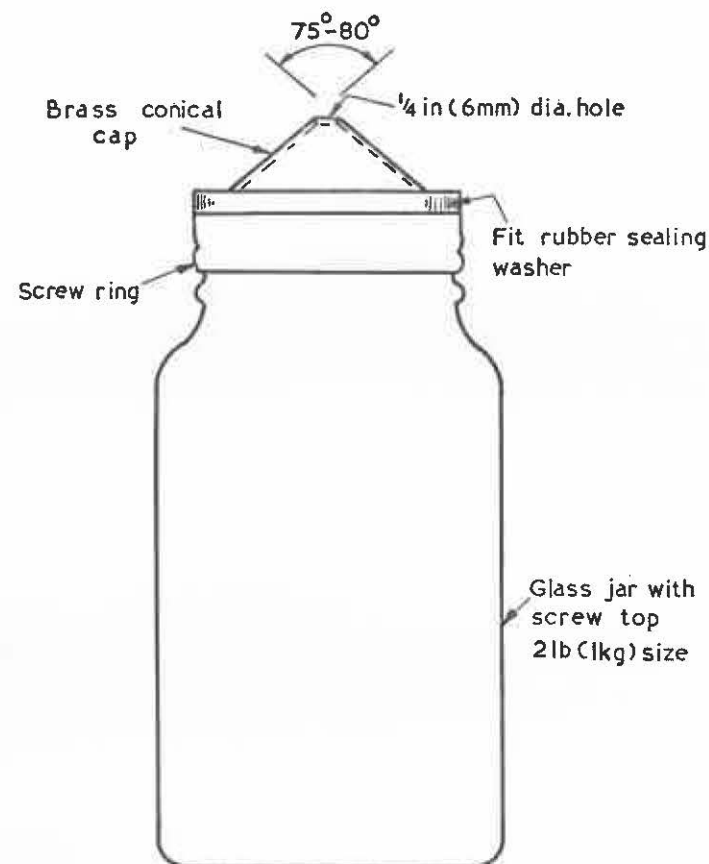
(2) The pycnometer shall be dried and weighed to the nearest 0.5 g (W_1).

(3) After removing the screw top, about 400–500 g of the soil (see Notes 2 and 3) shall be introduced into the pycnometer direct from the desiccator in which it has been cooled. The bottle, screw top and contents shall then be weighed to the nearest 0.5 g (W_2).

(4) Water, at a temperature within ± 2 degC (± 4 degF) of the average room temperature during the test (see Note 4) shall be added to the soil until the jar is approximately half-full, and the mixture shall be stirred thoroughly with the glass rod to remove air trapped in the soil. The screw top shall then be replaced (see Note 5) and the pycnometer shall be filled with water. Any remaining air shall be removed by shaking the pycnometer, holding one finger over the screw top (see Note 6). The pycnometer shall then be topped up with water, care being taken to avoid froth being caught underneath the conical top. The pycnometer shall then be thoroughly dried on the outside, and weighed to the nearest 0.5 g (W_3).

(5) The pycnometer shall be emptied, thoroughly washed out, and completely filled with water at room temperature until the surface of the water is flush with the hole in the screw top (see Note 5). The pycnometer shall be dried on the outside and weighed to the nearest 0.5 g (W_4).

(6) (1), (2), (3) and (4) shall be repeated on a second sample of the same soil and two values of the specific gravity obtained.



This design has been found satisfactory, but alternative designs may be employed provided that the essential requirements are fulfilled.

Fig. 8. Pycnometer for the determination of the specific gravity of medium- and coarse-grained soil

2.6.2.4 Calculations*. The specific gravity of the soil particles (G_s) shall be calculated from the formula:

$$G_s = \frac{W_2 - W_1}{(W_4 - W_1) - (W_3 - W_2)}$$

where W_1 = weight of pycnometer

W_2 = weight of pycnometer and soil

W_3 = weight of pycnometer, soil and water

W_4 = weight of pycnometer full of water only.

2.6.2.5 Reporting of results. The specific gravity of the soil particles shall be reported to the nearest 0.05. If the two results differ by more than 0.05 the tests shall be repeated (see Note 7).

NOTES ON TEST 6(B)

NOTE 1. Oven drying of the soil has been specified for convenience. If there is any reason to believe that this will change the specific gravity due to loss of water of hydration the soil should be tested in its natural condition and the weight of soil used determined by oven-drying at the end of the test. To obtain the true specific gravity of the soil the weight of oven-dried soil should then be corrected to allow for any chemically-held water that has been removed by oven-drying. However, if the specific gravity is required for the calculation of air contents for the compaction tests the weight of oven-dried material does not need to be corrected.

NOTE 2. With certain very porous materials it will be found helpful in removing the trapped air to grind the soil well in a pestle and mortar.

NOTE 3. *Size of samples.* About 400 g of soil has been specified for the average size of sample, since with smaller samples the results of the test are inaccurate, and with larger samples the complete removal of trapped air becomes difficult. The size of sample will vary to some extent with the type of soil tested. Larger samples may be used in the case of sands and gravels, and smaller samples when dealing with the finer grained soils. The method should not be used for clays.

NOTE 4. *Water temperature.* If there is a large difference between the air temperature and water temperature sufficient water should be drawn for the required number of tests and allowed to stand in the room in which the tests are being done until its temperature is within the given range.

NOTE 5. *Adjustment of screw top.* A rubber or fibre washer shall be inserted in the joint, and the screw top shall be water-tight when screwed on to the jar. A mark shall be made on the jar to correspond with a mark on the screw top, so that the screw is tightened to the same position each time, and the volume of the pycnometer is constant throughout the test.

NOTE 6. The air may also be removed by applying suction from an efficient filter pump to the hole in the cap of the pycnometer.

NOTE 7. If it is intended to use this result for air voids calculations, the material should be left immersed in the water for 24 hours.

* See Form E, Appendix B.

2.7 TEST 7. DETERMINATION OF THE PARTICLE SIZE DISTRIBUTION

2.7.1 Test 7(A). Standard method by wet sieving

2.7.1.1 Scope. This method covers the quantitative determination of the particle size distribution in a soil down to the fine sand size. The combined clay and silt fraction can be obtained by differences with this method. An exact procedure is given for this test but identical results will be obtained using other procedures provided no material other than the silt and clay fraction is lost in washing.

2.7.1.2 Apparatus

(1) British Standard test sieves* as follows:

3 in (75 mm), 2½ in (65 mm), 2 in (50 mm), 1½ in (40 mm), 1 in (25 mm), ¾ in (20 mm), ½ in (12.5 mm), ⅜ in (10 mm), ¼ in (6 mm), ⅓ in (5 mm), Nos. 7 (2.4 mm), 14 (1.2 mm), 25 (600 microns), 36 (420 microns), 52 (300 microns), 72 (210 microns), 100 (150 microns) and 200 (75 microns) (see Note 1).

(2) A balance readable and accurate to 0.5 g.

(3) A balance readable and accurate to 0.01 g.

(4) Sample dividers, e.g. the multiple slot type (riffle boxes) similar to those shown in Fig. 3.

(5) A thermostatically controlled drying oven capable of maintaining a temperature of 105–110°C (221–230°F).

(6) At least six evaporating dishes (a convenient size is about 15 cm (6 in) diameter).

(7) At least six metal trays (a convenient size is about 12 in (30 cm) diameter and 1½ in (4 cm) deep).

(8) Two or more large metal or plastics watertight trays, or a bucket about 12 in (30 cm) diameter and 12 in (30 cm) deep. (Convenient sizes for the trays are in the range 18 in (45 cm) to 36 in (90 cm) square and 3 in (8 cm) to 6 in (15 cm) deep.)

(9) A scoop (a convenient size is one about 8 in (20 cm) long and 4½ in (11 cm) wide) or a beaker (about 500 ml).

(10) Sieve brushes, and a wire brush or similar stiff brush.

(11) Sodium hexametaphosphate (commercial grade is suitable).

(12) A quantity of rubber tubing about ¼ in (6 mm) bore.

(13) (Optional.) A mechanical sieve shaker.

2.7.1.3 Procedure

(1) The over-dried sub-sample obtained as described in the procedure for the preparation of disturbed samples for testing (1.4) shall be weighed to 0.1 % of its total weight (see Note 3).

* BS 410, 'Test sieves'.

(2) The sub-sample shall then be placed on the $\frac{3}{4}$ in (20 mm) BS test sieve (see Appendix A) and any particles too coarse to pass through the test sieve shall be brushed with a wire brush or similar stiff brush until the individual particles are clean of any finer material. Care shall be taken when dealing with soft materials to ensure that the brushing is not removing parts of the large particles (see Note 4).

(3) The fraction of the oven-dry material passing the $\frac{3}{4}$ in (20 mm) BS test sieve shall then be riffled so that a fraction of convenient weight is obtained. This shall be about 2 kg (4.5 lb) if a substantial proportion of the material only just passes the $\frac{3}{4}$ in (20 mm) BS test sieve or less if the largest size is smaller. The fraction shall be weighed to 0.1% of its total weight and the weight recorded.

(4) The riffled fraction shall then be spread out in the large tray or placed in the bucket and covered with water.

(5) Sodium hexametaphosphate shall then be added at the rate of 2 g per litre of water and the whole well stirred to wet the soil. The soil shall then be allowed to stand for at least 1 hour in this solution and shall be stirred frequently.

(6) The sample shall then be washed through a suitable sized sieve, e.g. the $\frac{3}{16}$ in (5 mm) BS test sieve, into a large tray. If the sample is not too large it shall be washed in a No. 7 (2.40 mm) or No. 14 (1.20 mm) BS test sieve nested in a No. 200 (75 microns) BS test sieve, the material passing the No. 200 BS test sieve being allowed to run to waste. Care shall be taken to see that neither test sieve is overloaded in the process (see Appendix A). The maximum amount of material initially on the No. 200 (420 microns) BS test sieve shall not exceed 150 g.

The sample in the tray shall also be washed so that only the material passing the No. 200 (75 microns) BS test sieve is allowed to run to waste.

(7) Washing shall be continued until the water passing the No. 200 (75 microns) BS test sieve is virtually clear.

(8) All the material retained on the sieves shall be tipped into separate trays or evaporating dishes and dried in the oven at 105–110°C (221–230°F) (see Note 5).

(9) When dry the fractions, including any material retained on the $\frac{3}{4}$ in (20 mm) BS test sieve, shall be dry sieved through the appropriate sieves as in Method 7(B). The amounts retained on each sieve shall be weighed and the weights recorded.

(10) The amount of material passing the No. 200 (75 microns) BS test sieve shall be obtained by adding the weights of the material retained on each of the sieves used and subtracting the total from the total weight recorded in (3).

2.7.1.4 Calculations*

(1) The percentage by weight of material retained on each test sieve shall be calculated as well as the percentage passing the No. 200 (75 microns) BS test sieve. Care shall be taken to make due allowance in the calculation for any sub-division of the original sample.

(2) The cumulative percentages by weight of the sample passing each of the sieves shall be calculated.

2.7.1.5 Reporting of results

(1) The results obtained shall be reported on a semi-logarithmic chart of the type shown in Fig. 9.

(2) Alternatively, the results shall be reported in the form of a table showing to the nearest 1 per cent, the percentage by weight passing each of the sieves used.

NOTES ON TEST 7(A)

NOTE 1. *Choice of sizes of test sieves.* The sizes of the test sieves used for the test should adequately cover the range for the particular soil used, but it will not generally be necessary to use every size for every test.

NOTE 2. Where large numbers of tests are to be carried out it may be advantageous to have two sets of test sieves, one for the wet sieving and one for the dry sieving processes.

NOTE 3. If separation of the silt and clay fractions is required then a second riffled sample shall be retained and a fine analysis carried out as in Test 8(C) or 8(D).

NOTE 4. Certain soils (e.g. laterites) have large amounts of the clay fraction in the interstices of the larger particles. These soils should be treated as described in this method but the large particles retained on the $\frac{3}{4}$ in (20 mm) BS test sieve should then be washed in sodium hexametaphosphate solution; the amount of clay removed shall be estimated and allowed for in the final calculations.

NOTE 5. The material retained on each sieve shall not be dried on the sieve as it is detrimental to sieves to heat them.

* See Form F, Appendix B.

2.7.2 Test 7(B). Subsidiary method by dry sieving

2.7.2.1 Scope. This method covers the quantitative determination of the particle size distribution in a soil down to the fine sand size. This method shall not be used unless it has been shown that for the type of material under test it gives the same results as the method of analysis by wet sieving. In cases of doubt the method shall not be used.

2.7.2.2 Apparatus

(1) British Standard test sieves as follows:

3 in (75 mm), 2½ in (65 mm), 2 in (50 mm), 1½ in (40 mm), 1 in (25 mm), ¾ in (20 mm), ½ in (12.5 mm), ⅜ in (10 mm), ¼ in (6 mm), ⅓ in (5 mm), Nos. 7 (2.4 mm), 14 (1.2 mm), 25 (600 microns), 36 (420 microns), 52 (300 microns), 72 (210 microns), 100 (150 microns) and 200 (75 microns) (see Note 1).

(2) A balance readable and accurate to 0.5 g.

(3) A balance readable and accurate to 0.01 g.

(4) Sample dividers, e.g. the multiple slot type (riffle boxes) similar to those shown in Fig. 3.

(5) A thermostatically controlled drying oven, capable of maintaining a temperature of 105–110°C (221–230°F).

(6) Sieve brushes.

(7) At least six metal trays (a convenient size is about 12 in (30 cm) diameter and 1½ in (4 cm) deep).

(8) At least six evaporating dishes (a convenient size is about 15 cm (6 in) in diameter).

(9) A light hammer and/or a mortar and a rubber pestle (see Fig. 2).

(10) A scoop (a convenient size is one about 8 in (20 cm) long and 4½ in (11 cm) wide).

(11) A mechanical sieve shaker (optional).

2.7.2.3 Procedure

(1) The oven-dried sub-sample obtained as described in the procedure for the preparation of disturbed samples for testing (1.4) shall be weighed to 0.1 % of its total weight.

(2) The largest size test sieve shall be fitted with the receiver and the sub-sample placed on the sieve (see Note 2 and BS 1796*).

(3) The test sieve shall be agitated so that the sample rolls in irregular motion over the test sieve. Any particles may be tested to see if they will fall through but they shall not be pushed through. The material from the test sieve shall be rubbed with the rubber pestle in the mortar and resieved to make sure

* BS 1796, 'Methods for the use of British Standard fine-mesh sieves'.

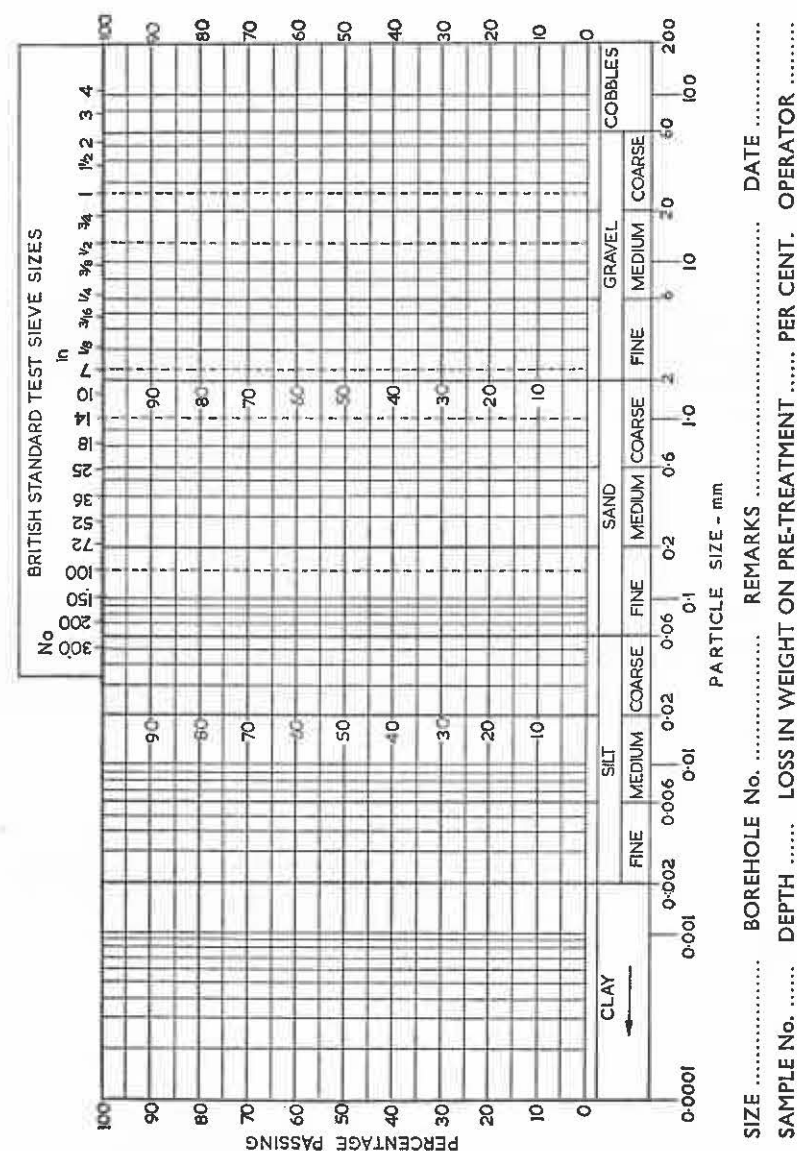


Fig. 9. Chart for recording particle-size distribution

that only individual particles are retained. The amount retained on the test sieve shall be weighed.

(4) The material retained in the receiver shall be transferred to a steel tray and the receiver fitted to the next largest sized test sieve. The contents of the steel tray shall then be placed on the sieve and (3) repeated.

(5) Operations (3) and (4) shall be repeated through all the test sieve sizes used. Note that if a mechanical shaker is available these steps can be performed in one operation provided the test sieves are all of the same diameter. Care shall be taken to ensure that sieving is complete. A minimum of 10 minutes shaking shall be used.

(6) If any test sieve becomes overloaded the material on the test sieve shall be sieved in parts, the parts not to exceed the weights given in the table (see Appendix A).

2.7.2.4 Calculations*

(1) The percentage by weight of material retained on each test sieve shall be calculated. The percentage passing the No. 200 (75 microns) BS test sieve shall be obtained by difference, and checked by weighing the amount in the receiver.

(2) The cumulative percentages (by weight of the total sample) passing each of the sieves shall be calculated.

2.7.2.5 Reporting of results

(1) The results obtained shall be reported on a semi-logarithmic chart of the type shown in Fig. 12. Alternatively, the results shall be reported as a table showing to the nearest 1% the percentage by weight passing each of the sieves used.

(2) It shall be reported that dry sieving only was used.

NOTES ON TEST 7(B)

NOTE 1. *Choice of test sieve sizes.* The sizes of test sieves used for the test should adequately cover the range for the particular soil used, but it will not generally be necessary to use every size for every test.

NOTE 2. If the assembly is not too heavy to handle, several sieves (in order of size) may be fitted together and used at the same time.

* See Form F, Appendix B.

2.7.3 Test 7(C). Standard method for fine-grained soils (pipette method)

2.7.3.1 Scope. This method covers the quantitative determination of the particle size distribution in a soil from the coarse sand size down (see Note 1). The test as described is not applicable if less than 10% of the material passes the No. 200 (75 microns) BS test sieve* as measured in Test 8(A).

2.7.3.2 Apparatus

(1) A sampling pipette of the type illustrated in Fig. 10 fitted with a pressure and suction inlet, and having a capacity of approximately 10 ml. The pipette shall be so arranged that it can be inserted to a fixed depth into a sedimentation tube (see below) when the latter is immersed in a constant temperature bath (Fig. 11).

(2) Two glass sedimentation tubes, 5 cm (2 in) diameter and approximately 34 cm (13 in) long graduated at 500 ml volume with rubber bungs to fit.

(3) Nine glass weighing bottles, approximately 25 mm (1 in) in diameter and 50 mm (2 in) high fitted with ground stoppers. The weights of the bottles shall be known to the nearest 0.001 g.

(4) A constant temperature bath capable of being maintained at 25°C (77°F), to an accuracy of ± 0.1 degC (± 0.2 degF) into which the sedimentation tube can be immersed up to the 500 ml mark. The bath shall not vibrate the sample.

(5) A suitable mechanical mixer, e.g. an electrically driven mixer as in Fig. 12 and a cup to fit equipped with a wire baffle of the type illustrated in Fig. 13, or its equivalent. The container and baffle shall be of such material as will not be attacked by the reagents placed in the container. The motion of the soil suspension shall be sufficient to mix the contents thoroughly but it shall not be so vigorous that the particles will be crushed or lost through splashing neither shall it be so sluggish as to leave unmixed material in the bottom of the container. (Different types of paddles or agitators operate best at different speeds, so no speed is specified. In order to reduce degradation of the particles as far as possible a low peripheral speed of the tips of the rotor is desirable, so long as it is compatible with thorough mixing.)

(6) British Standard test sieves No. 7 (2.4 mm), 25 (600 microns), 72 (210 microns) and 200 (75 microns) and a receiver.

(7) A sample divider of the multiple slot type (riffle box) similar to the $\frac{1}{4}$ in wide slot type shown in Fig. 3.

(8) A balance readable and accurate to 0.001 g.

(9) A thermostatically controlled drying oven, capable of maintaining a temperature of 105–110°C (221–230°F).

(10) A stop clock or stop watch.

* BS 410, 'Test sieves'.

- (11) A desiccator (a convenient size is one 8–10 in (20–25 cm) in diameter) containing anhydrous silica gel.
- (12) A boro-silicate glass evaporating dish 9 cm (3½ in) diameter and 5 cm (2 in) high.
- (13) A 650 ml or 1 litre conical beaker and a cover glass to fit and a smaller beaker.
- (14) A Büchner or Hirsch funnel about 7 cm (2.75 in) diameter.
- (15) A filter flask to take the funnel (about 500 ml).
- (16) A 100 ml measuring cylinder.
- (17) A 25 ml pipette.
- (18) A glass filter funnel about 4 in (10 cm) in diameter.
- (19) A wash bottle preferably plastics containing distilled water.
- (20) Filter papers* to fit the Büchner or Hirsch funnels.
- (21) pH indicator paper to cover range pH 2–pH 8.
- (22) A length of glass rod about 6–8 in (15–20 cm) long and ⅜ in (4–5 mm) in diameter fitted at one end with a rubber policeman.
- (23) A source of vacuum, e.g. an efficient filter pump.
- (24) A length of rubber tubing to fit vacuum pump and filter flask.

2.7.3.3 Reagents. The reagents used shall be of recognized analytical reagent quality:

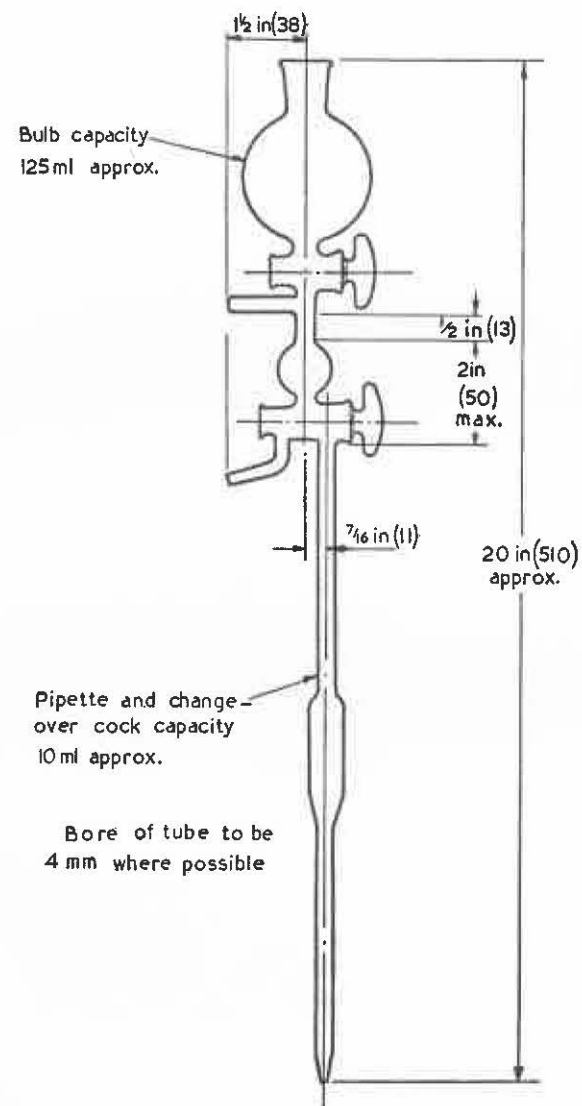
- (1) *Hydrogen peroxide.* A 20 volume solution.
- (2) *Hydrochloric acid, approximately N solution.* Dilute 89 ml of concentrated hydrochloric acid (s.g. 1.18) with distilled water to make 1 litre of solution.
- (3) *Sodium hexametaphosphate solution.* Dissolve 33 g of sodium hexametaphosphate and 7 g of sodium carbonate in distilled water to make one litre of solution. (*Note:* this solution is unstable and shall be freshly prepared approximately once a month. The date of preparation shall be recorded on the bottle.) (See Note 2.)

2.7.3.4 Procedure

2.7.3.4.1 Calibration of sampling pipette

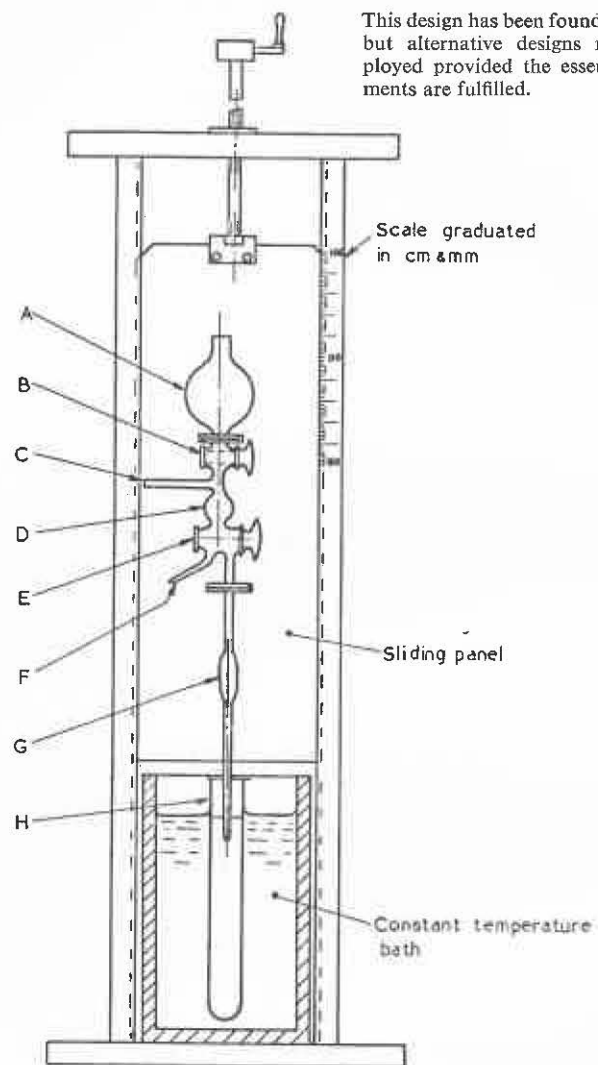
- (1) The sampling pipette shall be thoroughly cleaned and dried and the nozzle shall be immersed in distilled water. The tap B shall be closed and the tap E opened (Fig. 11).
- (2) By means of a rubber tube attached to C, water shall be sucked up into the pipette until it rises above E. The tap E shall be closed, and the pipette removed from the water. Surplus water drawn up into the cavity above E shall be poured off through F into the small beaker.

* Whatman No. 50 or Barcham Green No. 975 is suitable.



This design has been found satisfactory, but alternative designs may be employed provided that the essential requirements are fulfilled. Bore of tubing to be 4 mm where possible. Millimetre dimensions in brackets.

Fig. 10. Sampling pipette for sedimentation apparatus



- A & B. 125 ml bulb funnel with stopcock.
 C. Safety bulb suction inlet tube.
 D. Safety bulb.
 F. Outlet tube.
 G. Sampling pipette.
 H. Sedimentation tube.
 D, F & G are joined to three-way stopcock E.

Fig. 11. Diagram showing an arrangement for lowering the sampling pipette into the soil suspension



Fig. 12. Two types of stirrer suitable for use in the fine particle size analysis