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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

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FOR CIVIL ENGINEERING

PURPOSES

BS 1377 : 1967

Price 60/- net

BRITISH STANDARDS INSTITUTION

INCORPORATED BY ROYAL CHARTER

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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

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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) *Riffling*. 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.

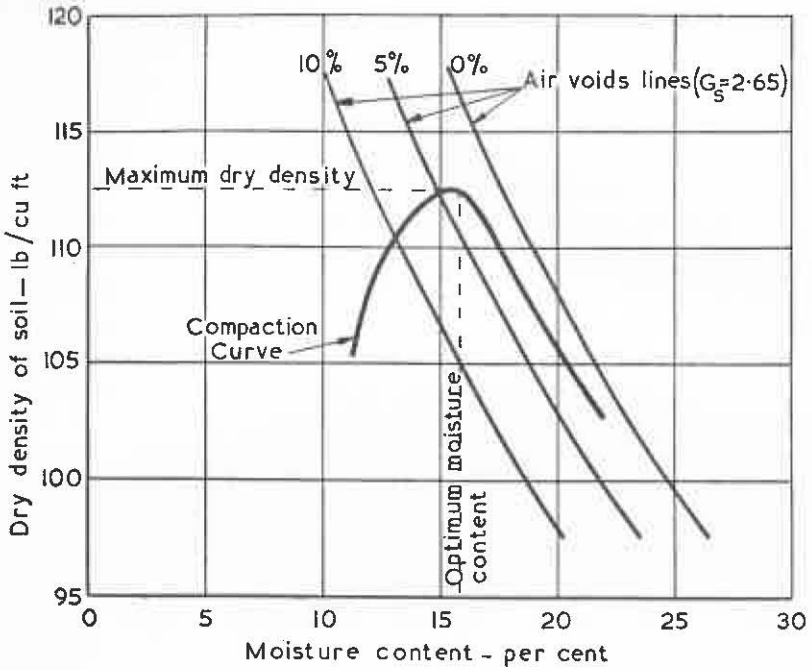

Fig. 1. Definition of terms used in compaction tests

(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 '.