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British Standard

# Stabilized materials for civil engineering purposes

Part 1. General requirements, sampling, sample preparation and  
tests on materials before stabilization

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Matériaux stabilisés pour le génie civil

Partie 1. Caractéristiques générales, échantillonnage, préparation des échantillons et essais des matériaux avant stabilisation

Stabilisierte Baustoffe für den Tiefbau

Teil 1. Allgemeines, Probenahme und Probenvorbereitung, Prüfung vor der Stabilisierung

British Standards Institution

## Foreword

This Part of BS 1924 has been prepared under the direction of the Road Engineering Standards Policy Committee. It is Part 1 of a revision in two Parts of BS 1924 : 1975, which is now withdrawn.

The two Parts of BS 1924 are:

- Part 1. General requirements, sampling, sample preparation and tests on materials before stabilization;
- Part 2. Methods of test for cement-stabilized and lime-stabilized materials.

The tests for materials in the unstabilized state are given in Part 1 by reference to other British Standards. Except where they are seldom used or the test procedures are identical in all respects, the tests for materials in the stabilized condition included in Part 2 are given in full, although they may be similar to tests in other British Standards. This is to provide a complete and comprehensive document for use by testing laboratories, and because the tests themselves have to be modified to take account of the presence of the stabilizing agent. This particularly applies to sample preparation.

The title of the standard has been amended to reflect the wider scope of this revision, which is intended to cover, in addition to soils, materials which when stabilized with cement or lime may be used for civil engineering purposes. Although concerned principally with Portland cement, hydrated lime (calcium hydroxide) and quicklime (calcium oxide) it is also applicable to other cements and types of lime, including those in which pulverised fuel ash (pfa) or slag are the major components.

This revision includes all the tests, with minor exceptions, for materials stabilized with lime or cement that were included in the 1975 edition but does not include any tests for materials stabilized with bitumen. In deciding to exclude tests for bitumen-stabilized materials from the revision the Committee consulted extensively on the currency and use of the tests in the 1975 edition and on the existence of or need for other tests. Reader's comments are invited on the need for and contents of a further Part, (Part 3) of this British Standard for such tests\*.

Lime, and to a lesser extent cement, may also be used to modify rather than to stabilize a material. Modified materials are usually natural soils and probably fine-grained but may be by-products of industrial processes, e.g. colliery spoil. The object of the modification process is to improve the properties of the soil such as shear strength, durability, etc. but the modified material retains many of the properties of soil. The process may, for example, be used to render an unsuitable material suitable by modifying the plasticity characteristics. In these cases the tests in this standard may be suitable but equally the soil tests in BS 1377 referred to in the text may be considered to be applicable to measure the change in properties caused by modifying the soil or other material.

It has been assumed in the drafting of this standard that the execution of its provisions is entrusted to appropriately experienced people, for whose guidance it has been prepared.

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

\*Comments should be sent to the Secretary, Technical Committee RDB/9, BSI, 2 Park Street, London W1A 2BS.

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## Methods

### 1 Scope

This Part of BS 1924 deals with general requirements, sampling, sample preparation and preliminary tests carried out on materials in the unstabilized condition to assess their suitability for stabilization.

NOTE. The titles of the publications referred to in this standard are listed on page 13.

### 2 Definitions

For the purposes of this Part of BS 1924 the following definitions apply.

**2.1 particle size distribution.** The percentages of various grain sizes present in a material as determined by sieving and sedimentation.

**2.2 cobbles\*.** Rounded or sub-angular particles of sizes between 200 mm and 60 mm.

**2.3 gravel fraction\*.** The fraction composed of particles between the sizes of 60 mm and 2 mm. See note to 2.5.

**2.4 sand fraction\*.** The fraction composed of particles between the sizes of 2.0 mm and 0.06 mm. See note to 2.5.

**2.5 silt fraction\*.** The fraction composed of particles between the sizes 0.06 mm and 0.002 mm.

NOTE. The gravel, sand and silt fractions may be subdivided as in table 1.

**2.6 clay fraction\*.** The fraction composed of particles smaller in size than 0.002 mm.

**2.7 cohesive material.** All material which by virtue of its clay content will form a coherent mass.

**2.8 non-cohesive material (granular material).** A material which will not form a coherent mass.

**2.9 sampling.** The selection of a representative portion of material.

**2.10 representative sample.** A sample taken to represent a body of material in order to study its average properties.

**2.11 spot sample.** A sample taken from control tests carried out during construction work which represents only the material in that larger sample from which it was taken.

**2.12 batch (stockpile).** A definite quantity of material produced under conditions which are presumed uniform.

NOTE. With a continuous process such as is used in most work connected with cement and lime stabilization the quantity produced in a stated period should be treated as a batch.

**2.13 sampling increment.** A quantity of material taken at one time from a larger body of material.

NOTE. The material taken by a single operation of the scoop should be treated as a sampling increment.

**2.14 bulk sample.** An aggregation of the sampling increments.

**2.15 laboratory sample.** A sample intended for laboratory inspection or testing.

**2.16 test portion.** The material used as a whole in testing or inspection.

**2.17 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, then repeating the process until a representative sample of the appropriate size is obtained.

Table 1. Fraction particle size and test sieves

Fraction	Particle size	Sizes of test sieves to be used for separation†‡
	mm	
(a) Gravel fraction		
Coarse gravel	60 to 20	63 mm to 20 mm
Medium gravel	20 to 6	20 mm to 6.3 mm
Fine gravel	6 to 2	6.3 mm to 2.0 mm
(b) Sand fraction		
Coarse sand	2.0 to 0.6	2.0 mm to 600 µm
Medium sand	0.6 to 0.2	600 µm to 212 µm
Fine sand	0.2 to 0.06	212 µm to 63 µm
(c) Silt fraction		
Coarse silt	0.06 to 0.02	—
Medium silt	0.02 to 0.006	—
Fine silt	0.006 to 0.002	—

†These are the test sieve sizes nearest to the theoretical sizes. When the 2.0 mm and 63 µm sieves are not available the 2.36 mm and 75 µm test sieves may be used in most cases without seriously affecting the result.  
‡See 2.30.

**2.18 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 sample divider, e.g. a riffle box, then repeating the process until a sample of the required size is obtained.

**2.19 compaction.** The process of packing stabilized particles more closely together by rolling or mechanical means, thus increasing the dry density of the stabilized material.

NOTE. This term should not be confused with consolidation, which is the process whereby soil particles are packed more closely together over a period of time by application of continued pressure.

\*These classifications are based solely on particle size and give no indication of the mineralogy of the material.

**2.20 bulk density.** The mass of material (including solid particles, any contained water and any fluid stabilizer) per unit volume, including voids.

**2.21 dry density.** The mass of material after drying to constant mass at 105 °C, and after removal of any fluid stabilizers, contained in unit volume of undried material (see note to 2.28).

**2.22 moisture content.** The mass of free water which can be removed from a material, usually by heating at 105 °C, expressed as a percentage of the dry mass (see note to 2.28).

NOTE. Although the term moisture content has been used throughout this standard the term water content is also widely used and either may be employed.

**2.23 optimum moisture content.** The moisture content at which a specified amount of compaction will produce a maximum dry density (see note to 2.28).

**2.24 maximum dry density.** The dry density obtained using a specified amount of compaction at the optimum moisture content (see note to 2.28).

**2.25 relative compaction.** The percentage ratio of the dry density of the material to the maximum dry density of that material as determined by a specified laboratory compaction test.

**2.26 dry density/moisture content relationship.** The relation between dry density and moisture content of a material when a given compactive effort is employed (see note to 2.28).

**2.27 percentage air voids.** The volume of air voids in the material expressed as a percentage of the total volume of the material.

**2.28 air voids line.** A line showing the relation between the dry density and moisture content for a material containing a constant percentage of air voids.

NOTE. Figure 1 shows a method of deriving the optimum moisture content and maximum dry density from the dry density/moisture content relationship. The dry density/moisture content relationship does not always take the form shown in figure 1, particularly with coarse-grained materials where the relation may not be well defined.

Figure 1 also shows air voids lines. The line can be calculated from the equation:

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

where

$\rho_d$  = the dry density of the material (in Mg/m<sup>3</sup>);

$\rho_w$  = the density of water (in Mg/m<sup>3</sup>);

$V_a$  = the volume of air voids in the material (as a percentage of the total volume of the material);

$\rho_s$  = the particle density\*;

$w$  = the moisture content, expressed as a percentage of dry material.

**2.29 saturation line (zero air voids line).** A line showing the dry density/moisture content relation for a material containing no air voids.

NOTE. The saturation line is also shown in figure 1. It is obtained by putting  $V_a = 0$  in the equation given in definition 2.28.

**2.30 test sieve.** A sieve complying with BS 410.

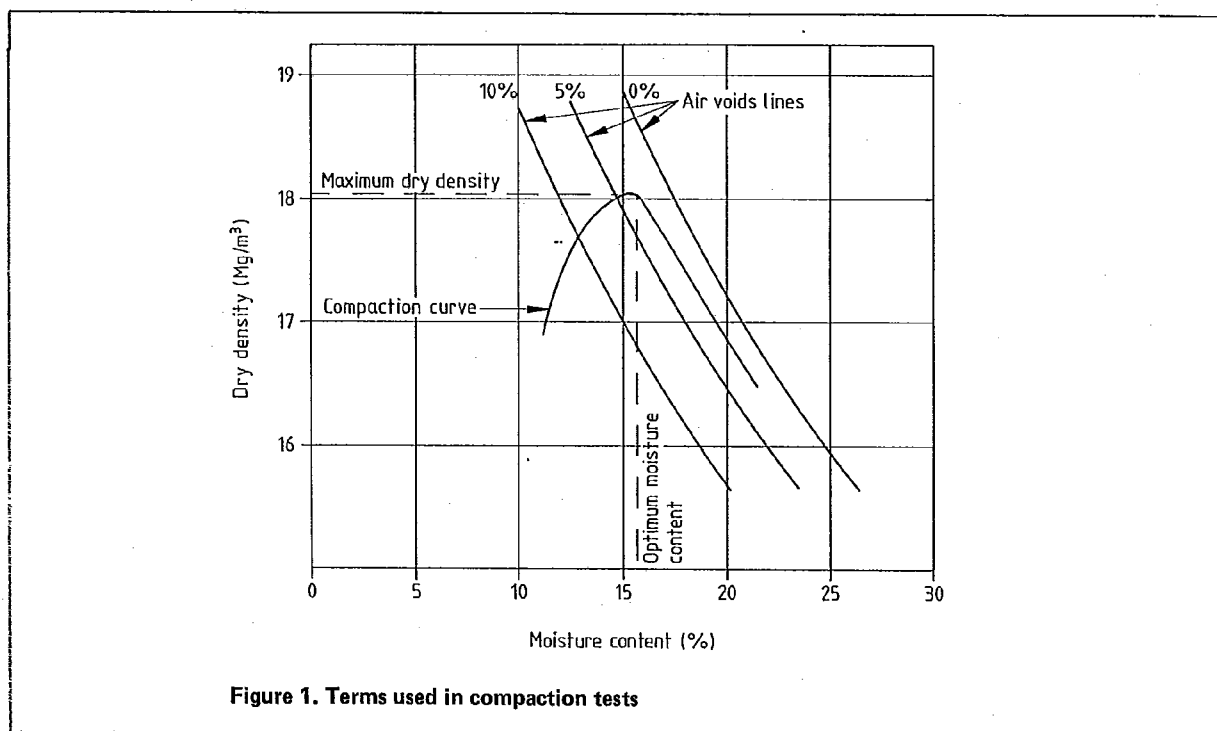


Figure 1. Terms used in compaction tests

\*The term 'particle density' has been chosen in preference to 'specific gravity' used in earlier editions of BS 1924 as the latter term is now deprecated.

### 3 Symbols and units

For the purposes of this standard, the following symbols and units are used.

Term	Symbol	Unit
Moisture content	$w$	%
Liquid Limit	$w_L$	%
Plastic Limit	$w_P$	%
Bulk density	$\rho$	Mg/m <sup>3</sup> *
Dry density	$\rho_d$	Mg/m <sup>3</sup> *
Particle density	$\rho_s$	Mg/m <sup>3</sup> *
Percentage air voids	$V_a$	%
California Bearing Ratio	CBR	%
Compressive strength	$p$	MPa†
Tensile strength	$\sigma_{ct}$	Pa

### 4 General

#### 4.1 Grouping of materials

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

- (a) *fine-grained*: materials containing less than 10 % retained on a 2 mm test sieve;
- (b) *medium-grained*: materials containing more than 10 % retained on a 2 mm test sieve but not more than 10 % retained on a 20 mm sieve;
- (c) *coarse-grained*: materials containing more than 10 % retained on a 20 mm test sieve but not more than 10 % retained on a 37.5 mm sieve.

Any material shall be regarded as belonging to the finest-grained group appropriate under the definitions given above.

NOTE. In those cases where the grouping of the material is not known in advance or is not self-evident a portion should be sieved following the procedure given in 5.3. Materials with a greater proportion than approximately 10 % retained on a 37.5 mm test sieve cannot usefully be examined by the majority of tests described in this British Standard.

#### 4.2 Apparatus

**4.2.1 General.** The apparatus required for each test method shall be as listed in the appropriate clause and Part of this standard.

NOTE. Specifications for items of general apparatus that are used in more than one test method are given in 4.2.4. Apparatus used only for one test method is specified in that method.

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

A piece of apparatus referred to as a calibrated item shall have been calibrated in accordance with its specification and as described in 4.2.7 where appropriate.

General items of test apparatus shall comply with the relevant British Standards.

\*kg/m<sup>3</sup> may also be used: 1000 kg/m<sup>3</sup> = 1 Mg/m<sup>3</sup>.

†MPa = 1 N/mm<sup>2</sup> = 1MN/m<sup>2</sup>.

#### 4.2.2 Tolerances

##### 4.2.2.1 Manufacturing tolerances

**4.2.2.1.1 Linear dimensions.** Drawings indicating the specified requirements of apparatus used for the tests described in this British Standard include essential dimensions, marked \*, for which manufacturing tolerances or limits are given. All other dimensions are given for guidance.

**4.2.2.1.2 Mass.** Where mass is specified, the manufacturing tolerance on the mass shall be within  $\pm 1$  % unless otherwise stated.

**4.2.2.1.3 Working tolerances.** Working tolerances which apply to apparatus after being subjected to wear in use, shall not exceed twice the manufacturing tolerance unless otherwise specified.

##### 4.2.3 Specification for test apparatus

###### 4.2.3.1 Measuring instruments

**4.2.3.1.1 Balances and weights.** The categories of balance given in table 2 are examples of those which cover the requirements of the tests in this standard. Balances may incorporate an analogue or digital display. Each set of ancillary weights shall be calibrated in accordance with 4.2.6.3.1.

The balance selected for weighing shall enable the mass to be determined to the accuracy required for the purpose of the test. Calibration of balances shall comply with 4.2.7.4.1. Balances shall be labelled showing limitations of use with regard to the lower end of their range as determined by calibration.

Table 2. Categories of balance

Capacity not less than	Scale interval or digit	Maximum error of weighing
	g	g
200 g	0.001	0.005
1200 g	0.01	0.05
2 kg	0.1	0.3
5 kg	0.5	1
10 kg	1	3
25 kg	5	10
50 kg	20	25

**4.2.3.1.2 Thermometers.** Thermometers having the graduations given in table 3 are suitable and shall be selected as appropriate to the requirements of the test.

For mercury-in-glass thermometers the form of the graduations shall comply with clause 8 of BS 593 : 1974. The calibration of thermometers shall comply with 4.2.7.4.2.

###### 4.2.3.1.3 Length measurement instruments

**4.2.3.1.3.1 Engineer's steel rule,** with scale divisions every 0.5 mm and calibrated in accordance with 4.2.7.4.3.

**Table 3. Accuracy and graduation requirements of thermometers**

Accuracy of reading	Graduation intervals
°C	°C
0.2	not greater than 0.1
0.5	not greater than 0.2
1	not greater than 0.5

**4.2.3.1.3.2 Vernier callipers**, for internal and external measurements, readable to 0.1 mm or better and calibrated in accordance with 4.2.7.4.3.

**4.2.3.1.3.3 Try-square**

NOTE. An engineer's steel try-square is suitable.

**4.2.3.1.3.4 Micrometers**, readable to 0.01 mm or 0.002 mm or better, depending on the resolution specified in the test method. Calibration shall be in accordance with 4.2.7.4.3.

**4.2.3.1.3.5 Dial gauges**, readable to 0.01 mm or 0.002 mm or better, depending on the range of travel required by the test method and calibrated in accordance with 4.2.7.4.3.

**4.2.3.1.4 Timers**. Timers shall be calibrated in accordance with 4.2.7.4.4.

NOTE. Stopwatches or stopclocks readable to 1 s are suitable. A suitably placed wall clock with seconds hand, and large enough to read to 1 s from the work station, is an acceptable alternative.

**4.2.3.1.5 Volumetric glassware**. Glassware shall be calibrated in accordance with 4.2.7.4.5.

NOTE. Volumetric glassware complying with class B of BS 5898 is adequate.

**4.2.4 General apparatus**

**4.2.4.1 Ovens**. Ovens used for drying material shall incorporate a temperature control which can be set to maintain a selected temperature within the range 45 °C to 110 ± 5 °C. Each oven shall have provision for inserting a calibrated temperature indicating device of the required range of accuracy.

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

Ovens shall be calibrated in accordance with 4.2.7.5.1.

**4.2.4.2 Test sieves**. Test sieves shall comply with BS 410. Sieves with aperture sizes of 5 mm and above shall be perforated plate square hole test sieves. Sieves with aperture sizes of less than 5 mm shall be woven wire test sieves.

Each sieve shall be separately identified and the certificates issued with each sieve by the manufacturer shall be retained throughout its working life.

Calibration checks on sieves shall be carried out in accordance with 4.2.7.5.2.

**4.2.4.3 Moulds for the preparation of strength test specimens**. The moulds shall be manufactured from ferrous metal. The material shall have a hardness value of at least 95 HRB when determined in accordance with BS 891 or of at least 197 Brinell when determined in accordance with BS 240. All parts of the moulds shall be robust enough to prevent distortion in use.

**4.2.4.4 Heaters**. An electric hotplate shall be fitted with an adjustable temperature control to provide boiling and simmering temperatures.

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

**4.2.4.5 Wax bath**. An electrically heated wax bath shall be fitted with an adjustable temperature control to enable the wax to be maintained at a temperature just above its melting point. Excessive heating of wax shall be avoided.

**4.2.4.6 Sample dividers**. When sample dividers are used they shall be of a size appropriate to the largest particle contained in the sample to be divided.

**4.2.5 Special apparatus**. Apparatus required only for a particular test or series of related tests is specified under the relevant test method. Calibration of such apparatus shall comply with the general requirements of 4.2.7 and as specified in the relevant test procedure.

**4.2.6 Laboratory reference standards**

**4.2.6.1 Reference standards for in-house calibration**

Where calibration of test measuring instruments is carried out in-house the laboratory shall hold reference standards or instruments that are used solely for calibration purposes as required by BS 5781. Reference standards or instruments shall be retained securely in a suitable environment separate from working standards or instruments when not in use.

Reference standards and instruments suitable for use for the purposes of this standard shall be calibrated and certified as specified in 4.2.6.2 and 4.2.6.3. They shall be of at least one order of accuracy better than working items so that the desired accuracy of the test measurement is achieved. Recalibration of reference standards shall be at intervals not greater than those specified in 4.2.6.3 for each type of instrument. Notwithstanding these intervals, whenever a change in accuracy of a reference instrument is suspected, or when a reference instrument has been repaired, dismantled, adjusted or overhauled, it shall be recalibrated before further use.

**4.2.6.2 Traceability of reference standards**. Reference standards and instruments shall have official certification provided by the competent national body, e.g. National Physical Laboratory (NPL), National Weights and Measures Laboratory (NWML), or by a laboratory currently recognized for that purpose within the National Measurement system e.g. a National Measurement Accreditation Service (NAMAS) accredited calibration laboratory,

or by an acceptable international body. The certificate shall show traceability to national standards.

#### **4.2.6.3 Specifications for reference standards and instruments**

**4.2.6.3.1 Reference weights.** Calibrated and certified reference weights used for calibrating balances and working weights shall be kept separate from working weights in a secure place and in a suitable environment. Reference weights shall be initially recalibrated after 2 years and every 5 years thereafter.

**4.2.6.3.2 Reference thermometers.** Mercury-in-glass thermometers used as reference thermometers for calibrating laboratory working thermometer shall be calibrated before first use. They shall be recalibrated or replaced at five year intervals.

NOTE. Thermometers complying with BS 593 are suitable for use as reference thermometers if calibrated.

Calibrated thermocouples and platinum-resistance thermometers used as reference instruments shall be recalibrated at least once a year.

**4.2.6.3.3 Dimensional measuring standards.** Gauge blocks shall comply with BS 4311 and shall be recalibrated at 5 year intervals.

**4.2.6.3.4 Proving devices for force measurement.** Proving rings or calibrated electrical force transducers used for calibrating laboratory working load measuring devices shall be of grade 1.0 when calibrated in accordance with BS 1610 : Part 2. Each load measuring device shall be calibrated against a proving device of appropriate range and sensitivity.

NOTE. Care should be taken when calibrating load measuring devices against proving devices, to eliminate potential hazards due to incorrect alignment of ball or plate seatings when loads are applied.

#### **4.2.7 Calibration and checking of test equipment**

**4.2.7.1 Traceability.** All measurements necessary for the performance of tests covered by this standard shall be traceable as applicable, to UK national standards of measurements through an unbroken chain of calibrations. The number of links in the chain shall be no larger than necessary to achieve the required accuracy.

##### **4.2.7.2 External and in-house calibration**

**4.2.7.2.1 General requirements.** Calibrations shall be carried out either by an external organization, or in-house by the laboratory's own staff. In either case traceability to UK national standards shall be achieved. Systems used shall comply with the principles given in BS 5781, as well as the requirements given in 4.2.7.4 and under the relevant test method, where appropriate. All calibrated equipment shall be used only over the range for which it has been calibrated.

**4.2.7.2.2 External calibration.** When calibration is carried out under contract by an external organization, traceability shall be established by the use of a certificate of calibration

for the relevant item. The certificate shall include the following information and shall be retained:

- (a) name of calibrating organization;
- (b) for whom calibrated, and location;
- (c) description of the item calibrated, including identification number;
- (d) method of calibration;
- (e) equipment used, including reference devices;
- (f) calibration certificate reference of the reference device against which the instrument was calibrated, and the traceability route;
- (g) calibration temperature;
- (h) calibration data and results;
- (i) date of calibration;
- (j) date when next calibration is due, if appropriate;
- (k) signature of person responsible for the calibration.

**4.2.7.2.3 In-house calibration.** Calibration shall be carried out in-house only by suitably qualified and experienced staff, and in accordance with written procedures for each type of item. Reference instruments or standards against which working instruments are calibrated shall comply with, and shall be kept, used and maintained in accordance with the requirements of 4.2.6.

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

- (a) description of the instrument calibrated, including identification number;
- (b) method of calibration;
- (c) equipment used, including reference devices;
- (d) calibration certificate reference of the reference device(s);
- (e) calibration temperature;
- (f) calibration data and results;
- (g) date of calibration;
- (h) date when next calibration is due, if appropriate;
- (i) signature of person responsible for the calibration.

**4.2.7.3 Frequency of calibration.** Routine recalibration of measuring instruments shall be carried out at intervals that are based on usage and on the analysis of documented calibration data so as to ensure the required accuracy is not lost between calibrations. The periods specified in 4.2.7.4 are the maximum periods for each type of instrument.

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

##### **4.2.7.4 Calibration of measuring instruments**

**4.2.7.4.1 Balances.** Balances shall be checked, adjusted and calibrated over their working range, using certified reference weights, at least once a year, or at shorter intervals if necessary to prevent the maximum error of readings exceeding the values specified in 4.2.3.1.1.



**4.2.7.4.2 Thermometers.** Mercury-in-glass thermometers complying with BS 593 shall be calibrated or replaced after not more than 5 years and at intervals not exceeding 5 years thereafter. Other mercury-in-glass thermometers shall be calibrated against a reference standard before first use and shall be recalibrated or replaced at intervals not exceeding 5 years.

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

**4.2.7.4.3 Dimensional measuring instruments.** Steel rules shall be checked before first use and examined for readability and for wear at their ends at least once a year.

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

Micrometers shall be calibrated at least once a year in accordance with BS 870.

Dial gauges shall be calibrated at least once a year against a calibrated micrometer device, or in a comparator frame using gauge blocks or length bars.

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

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

#### **4.2.7.5 Calibration and checking of general apparatus**

**4.2.7.5.1 Ovens.** The temperature at the midpoint of the useable oven space of an empty oven shall be verified at least once a year by means of a calibrated temperature measuring device.

**4.2.7.5.2 Test sieves.** All test sieves shall be checked as follows:

(a) *Visual checks.* Sieves shall be checked visually by the operator before each use. A detailed visual check shall be made of the condition of every sieve at regular intervals depending on use.

(b) *Measurement checks.* The apertures of perforated plate test sieves shall be measured in accordance with appendix F of BS 410 : 1986 at least once a year.

(c) *Performance checks.* The apertures of woven wire cloth test sieves shall be checked at regular intervals depending on use, by either of the following methods.

(1) *Reference sample.* Reference samples, consisting preferably of rounded or sub-rounded particles, of known particle size distribution, and having approximately 50 % retained on the sieve being checked, shall be used to check each working test sieve.

(2) *Master sieves.* Working test sieves shall be checked against a master set of sieves retained exclusively for that purpose. The check procedure shall be to dry-sieve a test portion, which gives approximately 50 % retained on the test sieve being checked, on both sets of sieves consecutively for a controlled period and to compare the masses retained on each sieve of each set. It will be necessary to use a different test portion with each sieve size.

A sieve shall fail the performance check when the corresponding masses on individual sieves of the same mesh size differ by more than 5 percent.

Test sieves which fail measurement or performance checks shall be clearly marked and either discarded or used as protection sieves where appropriate.

NOTE. Wear and tear on sieves is very dependent on their manner of use and the abrasiveness of the material being used. Until the laboratory therefore has sufficient records to indicate rates of wear and thus fix meaningful check periods, performance checks should be at intervals of not more than three months.

**4.2.7.5.3 Moulds and other items.** Items of equipment such as moulds shall be checked by determining their internal measurements and mass. These determinations shall be carried out on new items and shall be repeated at intervals, depending on frequency of use, to allow for wear. When the change due to wear exceeds the permitted working tolerance the item shall be discarded.

### **4.3 Materials**

**4.3.1 Distilled water.** Where distilled water is specified it shall be produced either by distillation or by the use of de-ionizing apparatus. The latter shall incorporate a device for measuring the electrical conductivity of the water which includes a means of indicating when an acceptable upper limit is reached.

Distilled water whether produced by distillation or de-ionization shall comply with the following requirements.

(a) The non-volatile residue shall be not more than 5 mg per litre when tested in accordance with appendix A of BS 3978 : 1987.

(b) The pH value shall be not lower than 5.0 or higher than 7.5.

**4.3.2 Chemical reagents.** Chemical reagents used in carrying out the tests given in this standard shall be of recognized analytical quality. The date of preparation of all chemical solutions shall be recorded on their containers.

NOTE. The shelf life of all solutions needs to be taken into account and fresh solutions prepared as necessary.

**4.3.3 Storage containers.** Containers into which samples of stabilized material are placed shall be of glass or plastics or corrosion-resistant metal.

NOTE. Aluminium and zinc-galvanized containers are not suitable for storing cement or lime-stabilized materials.

Containers for samples from which the moisture content is to be determined shall be capable of being sealed to prevent loss or gain of moisture.

**4.3.4 Paraffin wax.** Paraffin wax used for sealing or coating samples shall be of microcrystalline grade, which has low shrinkage and a low melting point. Wax shall not be heated more than is necessary to cause it to melt, and whenever possible a temperature-controlled wax pot shall be used.

#### 4.4 Environmental requirements

**4.4.1 Temperature control.** When laboratory temperature control is specified the system shall be capable of maintaining a constant ambient temperature to within  $\pm 2^\circ\text{C}$  of that specified day and night, throughout the year. The system shall be capable of restoring changes of temperature in the locality of the test, e.g. due to opening and closing of doors, to comply with these limits within a period not exceeding 10 min.

**4.4.2 Temperature records.** Daily readings of maximum and minimum air temperatures in testing areas shall be recorded.

## 5 Sampling

NOTE. This clause describes the methods for obtaining samples of material, both in an unstabilized condition, and in a stabilized condition, of the quantity required for testing in accordance with the test procedures described in this British Standard. For recommendations for sampling see appendix A.

A hierarchy of sampling terms is used; these are defined in Clause 2.

### 5.1 Principle

For most testing of stabilized materials the principle will be to obtain a test portion that is representative of the average property of a batch, i.e. a representative sample as defined in 2.10. The methods of sampling and sample reduction given in 5.3 and 5.4 are designed to achieve this aim.

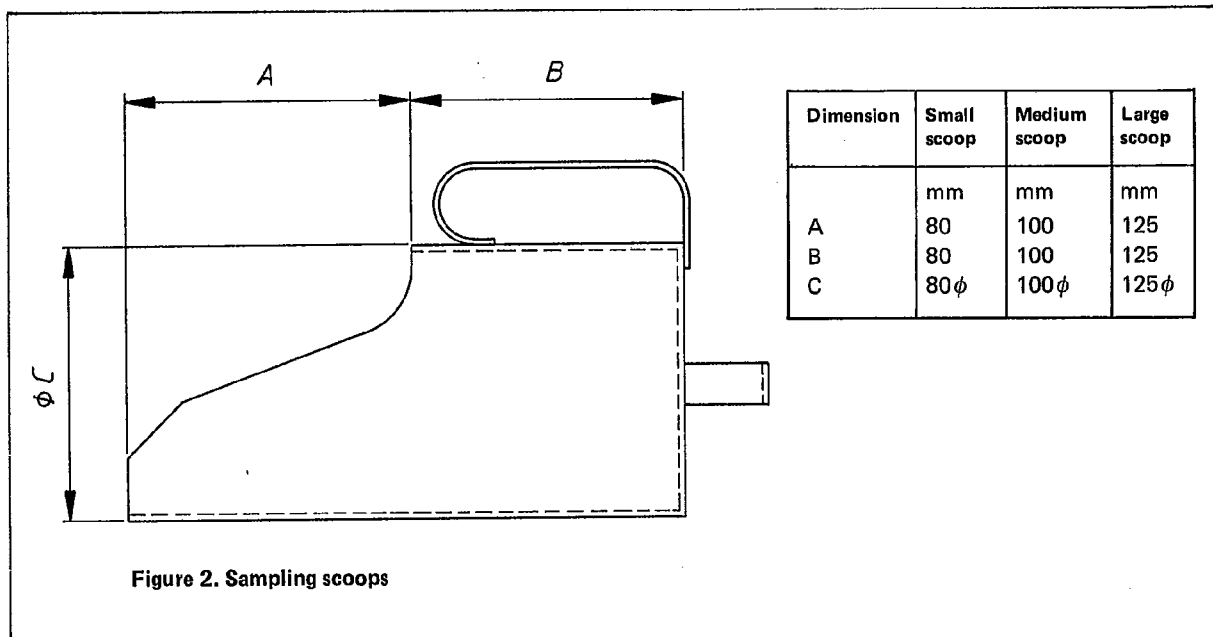
These methods may not, however, be applicable where it is intended to take spot samples to find the variability of the material within a batch. Here the sampling increments will be taken from a smaller volume of material resulting in a smaller bulk sample and less sample reduction. Nevertheless, the same general principles apply in that the test portion on which the test is carried out should be representative of the original volume of material taken as the spot sample.

### 5.2 Apparatus

**5.2.1 A small scoop** (see figure 2) to hold a volume of about 0.5 L, i.e. about 750 g of material of normal density, for sampling fine-grained materials.

**5.2.2 A medium scoop** (see figure 2) to hold a volume of about 1 L, i.e. about 1.5 kg of material of normal density, for sampling medium-grained materials.

**5.2.3 A large scoop** (see figure 2) to hold a volume of about 2 L, i.e. about 3 kg of material of normal density, for sampling coarse-grained materials.



**5.2.4 Containers**, clean and non-absorbent, such as buckets, for collecting increments of a sample.

**5.2.5 Containers with airtight lids**, or impervious bags capable of being sealed, e.g. bags made of plastics at least 100 µm thick, for storing samples of various sizes up to 100 kg in mass.

**5.2.6 Materials for sealing and marking the containers**, e.g. string, labels, adhesive tape etc.

**5.2.7 A sample divider**, appropriate to the grading of the material to be handled.

NOTE. Alternatively, a flat shovel and a clean flat and hard surface, e.g. a metal tray, may be used for quartering.

For sampling in special circumstances other apparatus may be needed, e.g. shovels, spades, picks, etc. may be needed to reach the material to be sampled.

### 5.3 Sampling procedure

The quantity of material to be represented by the bulk sample shall be clearly defined.

Obtain a bulk sample by collecting, in the clean containers, a sufficient number of increments to provide the required quantity of material for all subsequent tests. The number of increments shall be not less than those given in table 4.

Take the increments from different parts of the batch in such a way as to represent the average quality.

When more than one sample of whatever size is required take each sample as a separate and independent operation.

When sampling from heaps of material, take the required number of increments from the positions evenly distributed over the whole surface of the heap. At the required spot for each increment remove as much surface material as necessary to expose material at least 150 mm in from the surface of the heap. Take the increment by digging the scoop into this exposed material.

NOTE 1. Large stockpiles of materials which are badly segregated present problems and in many cases it is better to wait until they are stockpiled on site and ready for use.

NOTE 2. Sampling near ground level should be done with care to avoid contamination.

When sampling from material in motion, i.e. when it is being loaded or unloaded, ensure that the sampling increments are randomly distributed through the batch.

When sampling from a falling stream, take increments from the whole width of the stream.

NOTE 3. Mechanical samplers, manually or automatically operated, used for sampling from moving streams may be taken as being in accordance with this standard provided that each complete operation of the sampler produces an increment of at least 2 L of coarse-grained material, 1 L of medium-grained material or 0.5 L of fine-grained material. When sampling from conveyor belts, the conveyor should be stopped at the appropriate time and all the material taken from a fixed length of conveyor.

**Caution.** For reasons of personal safety samples should under no circumstances ever be taken from a moving conveyor.

For all methods of sampling, combine all the increments and either despatch the bulk sample or reduce it to a smaller representative sample, acceptable to the tester, by the procedure described in 5.4 and then despatch to the laboratory as the laboratory sample.

On completion of the sampling process, always make a visual check of the relation of the sample to the material in bulk and record these details.

NOTE 4. Whether the bulk is uniform or not, the sample should be seen to contain a similar range of sizes including the maximum and minimum.

NOTE 5. The procedure described in this clause is for obtaining a bulk sample representative of the batch sampled. When a selected sample is required to assess variability within the batch, one or more increments should be taken from defined places in the batch, they should not be combined but tested separately. For routine testing quality control, simplified procedures may be used. Fewer increments may prove to be satisfactory for this purpose. Where it is necessary to determine the presence and quantity of an occasional contaminant, special measures may be necessary and reference should be made to the appropriate Part of this standard. These and other departures from the specified procedure should be recorded on the certificate of sampling.

### 5.4 Sample reduction

**5.4.1 General.** It is usually necessary to reduce the mass of the bulk sample to obtain a laboratory sample which is in turn reduced to obtain a test portion of mass appropriate to the test in hand. The sample reduction shall be done in such a way as to preserve at each stage a representative part of the bulk sample. The method using a sample divider as described in 5.4.2 is recommended but the alternative of quartering given in 5.4.3 may be more appropriate for very coarse or very large quantities of material.

**5.4.2 Using a sample divider.** The width of the channels of the divider shall be appropriate to the grading of the material and in general not less than 1.5 times the size of

Table 4. Composition of bulk sample

Grouping of material	Minimum number of sampling increments			Approx. mass of sample
	Small scoop	Medium scoop	Large scoop	
Fine-grained	20	—	—	kg
Medium-grained	40	20	—	12.5
Coarse-grained	—	40	20	25
				50

the largest particle. If the material is wet it shall be dried to a condition in which it will flow freely through the sample divider.

Thoroughly mix the sample and then pass it through the sample divider. Retain one portion; pass it through again and repeat the process as often as necessary to reduce the original sample to the required mass.

**5.4.3 Quartering.** Thoroughly mix the sample by heaping it on to a clean, flat and hard surface to form a cone, and turning this over with the shovel to form a new cone, the operation being carried out three times. Form each conical heap by depositing each shovelful of the material on the apex of the cone so that the portions which slide down the sides are distributed as evenly as possible, and so that the centre of the cone is not displaced.

Flatten the third cone by repeated vertical insertion of the shovel across the apex of the cone, lifting the shovel clear of the material after each insertion. Quarter the flattened heap, which shall be uniform in thickness and diameter, until the required mass of sample is obtained.

**5.4.4 Sample reduction to provide multiple samples.** When two or more laboratory samples are required from a bulk sample first reduce the bulk sample by the procedure described in 5.4.2 or 5.4.3. Recombine all the excess bulk sample rejected at the individual division stages, mix thoroughly and reduce again to provide a second laboratory sample. Repeat as necessary to provide the required number of laboratory samples.

NOTE. This procedure should also be used to provide replicate test portions from a laboratory sample.

## 5.5 Despatch of samples

NOTE. These requirements refer primarily to samples which are being despatched to a laboratory remote from the site where the bulk sample was obtained. For site laboratories a simplified procedure may be sufficient.

**5.5.1 Packing samples.** The samples shall be transferred completely to containers (see 5.2.5) which shall then be sealed for despatch. When necessary the bags shall be protected against damage in transit by casing in suitable containers.

**5.5.2 Information to be sent with the samples.** Each package shall contain a card, suitably protected from damage by moisture and abrasion, giving the name and address of the sender and his description of the material.

When several samples are taken from a single source, each individual sample shall be separately identified.

## 5.6 Certificate of sampling (See note to 5.5.)

Each sample, or group of samples from a single source, shall be accompanied by a certificate from the person responsible for taking the sample, certifying that sampling was carried out in accordance with BS 1924. The certificate shall include as much as is appropriate of the following information:

- (a) the date, time, place and method of sampling;
- (b) the name and location of source;
- (c) sample identification mark (or marks);

(d) description of the batch;

(e) any other information likely to be helpful to the tester;

(f) name and signature of the sampler.

## 6 Preparation of samples for testing

NOTE. The methods to be used for preparing samples (obtained as described in 5.3) for test are described under each test procedure. This clause deals only with the preparation of samples for testing materials mixed with cement or lime in the laboratory in order to establish the properties of stabilized material prior to its being used in practice.

### 6.1 Apparatus

**6.1.1 Metal trays,** non-corrodible of sizes ranging from 0.05 m<sup>2</sup> to 1 m<sup>2</sup>.

**6.1.2 Test sieves,** as follows: 37.5 mm, 20 mm, 10 mm, 5 mm, 2 mm.

**6.1.3 A means of breaking down large aggregations,** e.g. a 150 mm cast-iron mortar and/or a 80 mm porcelain mortar, each with a suitable pestle.

**6.1.4 A rubber-ended pestle.**

**6.1.5 Balances,** capable of weighing to 10 kg and 25 kg readable to 1 g and 5 g respectively.

**6.1.6 A temperature-controlled oven,** capable of maintaining a temperature of 45 ± 5 °C and of 105 ± 5 °C.

NOTE. It will often be found to be convenient to have one about 0.2 m<sup>3</sup> to 0.3 m<sup>3</sup> capacity. Microwave ovens may be used for drying provided care is taken to ensure that the temperature of the material does not rise above 105 ± 5 °C (see also note to 1.3.5 of BS 1924 : Part 2 : 1990).

**6.1.7 Mechanical mixers,** of suitable capacities or suitable tools for hand mixing, e.g. a spatula, a trowel and a shovel.

**6.1.8 Graduated measuring cylinders** of 100 mL and 1 L capacity.

**6.1.9 Apparatus for the determination of moisture content** in accordance with 1.3 of BS 1924 : Part 2 : 1990.

### 6.2 Initial preparation of unstabilized materials

**6.2.1** The masses of the test portions required for the test procedures shall be as specified under the respective test procedures. To obtain the mass of the laboratory sample that is needed for any particular test, multiply the mass of the test portion by the maximum number of tests envisaged.

**6.2.2** Spread out the test portion of the unstabilized material obtained as described in 5.3 and 5.4 in a suitable size of metal tray, place in the oven and dry at 105 ± 5 °C until the material is in a condition where any aggregations may be readily broken down by the procedure given in 6.2.3.

NOTE. The material does not have to be completely dry at this stage. If it is suspected that oven-drying will alter its properties it should be allowed to dry in air until it reaches the required condition.

**6.2.3** Break down any aggregations of particles using a method that is not more liable to break down individual particles than is the method of mixing envisaged.

NOTE. In general the use of a hand-roller or the gentle use of a normal pestle and mortar will be acceptable but in some cases the use of a rubber-ended pestle with the mortar may be needed.

**6.2.4** Dry the material at  $105 \pm 5^\circ\text{C}$  (see note 1) to constant weight and allow to cool to room temperature (see note 2). Proceed to the next stage as soon as possible after cooling.

NOTE 1. Oven-drying has been specified because it is more convenient than air-drying and the majority of materials used in cement and lime stabilization are unlikely to be affected by heating at  $105^\circ\text{C}$ . However, some materials may change their properties when dried at this temperature and if in doubt the test portion should be air-dried and its air-dry moisture content determined. The amount of water present should then be allowed for when adding water to bring the test portion to the required moisture content. 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 3 to 4 days. Some materials without large particles may be used in their natural state for certain tests instead of being dried.

NOTE 2. Ideally the material should be dried to constant mass and allowed to cool in a desiccator. In practice, except for small masses of fine-grained materials, this is impracticable because of the mass of the material and the size of the tray. Most coarse-grained and medium-grained materials will be dry after 16 h at  $105^\circ\text{C}$  and will not absorb any significant amounts of water from the atmosphere whilst cooling.

### 6.3 Blending materials with water and stabilizer

**6.3.1** *Mixing two or more unstabilized materials.* Where a blend of two or more materials is to be stabilized, mix the blend before proceeding with the addition of cement or lime. Blend the materials by mixing appropriate masses (with due allowance for moisture content) either in the mechanical mixer or by hand using a spatula or trowel. Once mixed treat the blend as if it were a single material and follow the instructions for the addition of water and cement or lime given in 6.3.2 and 6.3.3 respectively.

**6.3.2** *Mixing with water and cement.* Place a known mass of the test portion of the material in the mechanical mixer or, if it is to be hand mixed, on a flat dry surface. Add the required volume of water, less an amount equal to 3 % of the mass of dried material, and mix thoroughly to bring the material to a uniform consistency. Take care to minimise the loss of water by evaporation. If the material is of a cohesive or absorbent nature place the moist material in an airtight container for at least 24 h before adding the cement. With all other materials proceed at once with the addition of the cement.

Add the required mass of cement to the material and mix to a uniform condition either by mixing in a mechanical mixer or by hand for 2 min. Add the remainder of the water and continue mixing for a further 8 min.

Start testing immediately after the material is removed from the mixer. All testing or preparation of specimens of materials stabilized with cement shall be completed within 2 h of the addition of the cement and any stabilized material remaining after that shall be discarded.

**6.3.3** *Mixing with water and lime.* Add water and lime to the material in the same manner as described for cement in 6.3.2. After mixing allow the material to stand for 24 to 48 hours before proceeding further and then mix for an additional 5 min.

NOTE. The 'curing' period is to allow initial reactions between the lime and the clay and/or water to occur. This is particularly important if quicklime is being used as the stabilizer. In this case due allowance needs to be made for the loss of water caused by the hydration of the quicklime and evaporation of water caused by the heat of hydration.

## 7 Tests on materials before stabilization

NOTE. This clause contains an outline of the test procedures to be used to determine those properties which are often identified in stabilization work and which are carried out on the material before any stabilizer is added. The full test procedures are either fully described in other standards or in BS 1924 : Part 2. This clause describes only the applicability of the test procedures to cement and lime-stabilized materials.

### 7.1 Determination of moisture content

The moisture content of the unstabilized material shall be determined in accordance with BS 1924 : Part 2.

### 7.2 Determination of particle-size distribution

The particle-size distribution of the material shall be determined as described in the following standards:

- (a) fine and medium-grained naturally occurring materials: BS 1377 : Part 2;
- (b) medium and coarse-grained naturally occurring materials and slags: BS 812 : Part 103;
- (c) waste materials and industrial by-products: BS 6543.

NOTE 1. The methods given apply only to the material in the unstabilized condition. They are not applicable to stabilized materials, even if they are freshly mixed, because the allowances for the moisture content and stabilizer content which have to be applied can lead to large errors.

NOTE 2. The methods given in these standards are broadly similar and for most materials will give results that are not significantly different.

### 7.3 Determination of plasticity properties

**7.3.1** *Determination of liquid limit.* The liquid limit shall be determined in accordance with BS 1924 : Part 2.

**7.3.2** *Determination of plastic limit.* The plastic limit shall be determined in accordance with BS 1924 : Part 2.

### 7.4 Determination of ten percent fines value (TFV)

NOTE. The ten percent fines value gives a measure of the mechanical strength of the individual particles of material and the test can be carried out only on medium and coarse-grained materials. It is used in specifications of stabilized materials to ascertain whether the material itself loses strength on being soaked in water.

When required the test shall be carried out in accordance with BS 812 : Part 111.

### 7.5 Determination of sulphate content

NOTE. Sulphates present in materials stabilized with cement or lime may affect the long-term durability of the cement or lime-stabilized material. The effect on the durability may be assessed by the test described in BS 1924 : Part 2 for determining the effect of immersion in water on the compressive strength of stabilized materials. However, some specifications limit the amount of sulphates that are allowed to be present in the material to be stabilized. In the case of materials to be stabilized with cement and/or lime these limits are generally in terms of the acid-soluble content as it is the total sulphate content rather than the water-soluble sulphate content which is important.

When required the sulphate content of the material shall be measured by the appropriate methods given in the following standards:

- (a) for soils: BS 1377 : Part 3;
- (b) for aggregates: BS 812 : Part 118;
- (c) for slags: BS 1047;
- (d) for pulverized fuel ash : BS 3892 : Part 1.

### 7.6 Determination of chloride content

When required the chloride content shall be measured by the appropriate methods given in the following standards:

- (a) for soils: BS 1377 : Part 3;
- (b) for slags and aggregates: BS 812 : Part 117.

### 7.7 Determination of total organic content

NOTE 1. Determination of the total organic content gives only a poor indication of the presence of deleterious organic compounds which can interfere with the hydration processes of cement and lime-stabilized materials. This is because it is the type of organic compound present rather than the total amount of organic matter which is the crucial factor. Nevertheless, some specifications require an upper limit for the total organic content.

When required the total organic content shall be determined in accordance with BS 1377 : Part 3. This method, which is applicable only to natural soils, shall not be used to determine the organic contents of other materials.

NOTE 2. The previous edition of BS 1924 included a method for detecting the presence of organic matter able to interfere with the hydration of Portland cements. Experience has shown that, with the higher alkali contents of most present-day cements compared to the cements in use when the test was developed in 1960, it is almost impossible to find a cement that is suitable for the test. The test has therefore been omitted from this edition and no suitable alternative is available. A colorimetric test based on the extraction of the organic matter with sodium hydroxide is widely used to determine the presence of deleterious organic matter in concreting aggregates; this test is based on the assumption that only harmful organic materials will impart a dark coloration to the sodium hydroxide. This assumption is not valid for the majority of materials covered by this standard and the test should not be used.

## Appendix

### Appendix A. Recommendations for sampling

Sampling will vary widely according to the material being sampled, site conditions, the facilities available, the size of the sample required and its purpose. Nevertheless certain general principles should be followed.

It is important to remember that in the case of materials stabilized with cement, hydration of the cement begins as soon as it comes into contact with water and the properties of cement-bound materials are continually changing as hydration proceeds. All operations of sampling and subsequent testing should therefore be conducted with the utmost speed and the aim should be to complete the operations within 2 h from the time that the cement was added to the material.

The hardening process in materials mixed with lime takes place at a much slower rate so that the time factor is less critical. However, it is important to recognize that the properties of a lime-stabilized material do change with time; the elapsed time between mixing the lime and testing should therefore always be recorded and stated.

All the stages of sampling leading to the production of proper test portions require skill and care. Problems of several kinds arise, among which are the following.

- (a) Sampling may expose the operator to difficulty and possible danger. Due consideration should be given to the safety of the operator at all times. Sampling within the body of a vehicle or under chutes poses particular difficulties.
- (b) Often it is not easy to discern a batch, and thus specifications that rely on this British Standard should

state the maximum quantity that a bulk sample should represent.

(c) Materials often segregate by size; ideally, they should be sampled from large quantities during loading or unloading, but this is often impracticable.

The general principles of BS 5309 : Part 1 and Part 4 should be followed in drawing up a sampling programme. The method set out in clause 5 of BS 5309 : Part 4 : 1976 should be used as the basis for tests for compliance with specifications for the materials covered by this standard.

Fine, powdered materials such as pulverized fuel ash should be sampled in accordance with BS 3892 using procedures appropriate to the type of delivery, to produce a laboratory sample having a mass of at least 7 kg. The definitions of the several stages in the production of the test portions are given in 2.9 to 2.18.

In some cases the bulk sample is too large to send for testing and has to be reduced; otherwise it becomes the laboratory sample. At the laboratory, the laboratory sample is reduced in size to the mass of test portions required. A particular test method may then require several specimens to be made from a test portion. If adequate facilities exist at the point of taking the bulk sample, all necessary reduction to the stage of producing the test portions may be done before despatch to the laboratory. If several kinds of tests are to be done, an intermediate stage of reduction is necessary. In other cases, the test portion is reduced directly from the laboratory sample. It is again emphasized that care has to be taken to ensure that the test portions are representative of the bulk sample.

#### Publications referred to

BS 240	Method for Brinell hardness test and for verification of Brinell hardness testing machines
BS 410	Specification for test sieves
BS 593	Specification for laboratory thermometers
BS 812	Testing aggregates
	Part 103 Method for determination of particle size distribution
	Part 111 Methods for determination of ten percent fines value (TFV)
	Part 117 Method for determination of water-soluble chloride salts
	Part 118 Methods for determination of sulphate content
BS 870	Specification for external micrometers
BS 891	Methods for hardness test (Rockwell method) and for verification of hardness testing machines (Rockwell method)
BS 1047	Specification for air-cooled blastfurnace slag aggregate for use in construction
BS 1377	Methods of test for soils for civil engineering purposes
	Part 2 Classification tests
	Part 3 Chemical and electro-chemical tests
BS 1610	Materials testing machines and force verification equipment
	Part 2 Specification for the grading of equipment used for the verification of the forces applied by materials testing machines
BS 1797	Schedule for tables for use in the calibration of volumetric glassware
BS 1924	Stabilized materials for civil engineering purposes
	Part 2 Methods of test for cement-stabilized and lime-stabilized materials
BS 3892	Pulverized-fuel ash
	Part 1 Specification for pulverized-fuel ash for use as a cementitious component in structural concrete
BS 3978	Specification for water for laboratory use
BS 4311	Specification for metric gauge blocks
BS 5309	Methods for sampling chemical products
	Part 1 Introduction and general principles
	Part 4 Sampling of solids
BS 5781	Measurement and calibration systems
BS 5898	Specification for principles of design and construction of volumetric glassware for laboratory use
BS 6543	Guide to industrial by-products and waste materials in building and civil engineering

## BS 1924 : Part 1 : 1990

This British Standard, having been prepared under the direction of the Road Engineering Standards Policy Committee, was published under the authority of the Board of BSI and comes into effect on 31 October 1990

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First published as BS 1924 June 1953

Second edition February 1957

Third edition December 1967

Fourth edition April 1975

Fifth edition published as BS 1924 : Part 1 October 1990

ISBN 0 580 18497 8

The following BSI references relate to the work on this standard:  
Committee reference RDB/9 Draft for comment 88/14799 DC

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The preparation of this British Standard was entrusted by the Road Engineering Standards Policy Committee (RDB/-) to Technical Committee RDB/9, upon which the following bodies were represented:

British Aggregate Construction Materials Industries  
British Cement Association  
British Civil Engineering Test Equipment Manufacturers' Association  
British Coal Corporation  
County Surveyors' Society  
Department of the Environment (Property Services Agency)  
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Department of Transport

Federation of Civil Engineering Contractors  
Institution of Civil Engineers  
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Institution of Structural Engineers  
Rothamsted Experimental Station  
Society of Chemical Industry

The following bodies were also represented in the drafting of the standard, through subcommittees and panels:  
Association of Consulting Engineers  
Refined Bitumen Association Ltd.  
Co-opted members

### Amendments issued since publication

Amd. No.	Date of issue	Text affected

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