Construction Standard CS3:2013

Aggregates for Concrete

香港特別行政區政府
The Government of the Hong Kong Special Administrative Region

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Prepared by:

The Working Group on Drafting of CS3 under SCCT. The members of the Working Group are as follows:

Department	Post
Civil Engineering and Development Department	Senior Engineer Concrete/Lab (Chairman) Engineer 2/Lab 2 Chemist Principal Technical Officer/Lab 2
Architectural Services Department	Senior Structural Engineer/301
Buildings Department	Technical Secretary/Structural
Drainage Services Department	Senior Engineer/Quality Assurance
Highways Department	Senior Engineer/General (Urban) Engineer/General (NTW)
Housing Department	Senior Structural Engineer/18 Structural Engineer/Lab 7
Innovation and Technology Commission	Senior Accreditation Officer (3)/HK Accreditation Services
Water Supplies Department	Senior Engineer/Design (2)

Any comments on the contents of this Construction Standard could be addressed to:

The Secretary of the Standing Committee on Concrete Technology
Civil Engineering and Development Department,
101 Princess Margaret Road,
Homantin,
Kowloon.

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FOREWORD

Introduction

This Construction Standard has been prepared by the Working Group on Drafting of Construction Standard CS3 under the Standing Committee on Concrete Technology, Development Bureau, the Government of the Hong Kong Special Administrative Region. It provides a standard for aggregates obtained from natural sources for concrete production in Hong Kong. It also contains requirements for recycled aggregates which are suitable for production of some prescribed mix concrete and designed mix concrete.

The drafting of this Construction Standard has made reference to the following British Standards (BS), European Standards adopted as British Standards (BS EN), publication of BRE, National Standard of the People's Republic of China (GB), publication from International Union of Laboratories and Experts in Construction Materials, Systems and Structures (RILEM, from its French name, Réunion Internationale des Laboratoires et Experts des Materiaux, systèmes de construction et ouvrages) and ASTM International Standards, with modifications to suit local conditions and practices.

BS 812: Part 2:1995
BS 812: Part 100:1990
BS 812: Part 102:1989
BS 812: Section 103.1:1985
BS 812: Section 105.1:1989
BS 812: Section 105.2:1990
BS 812: Part 109:1990
BS 812: Part 111:1990
BS 812: Part 112:1990
BS 812: Part 117:1988
BS 812: Part 118:1988
BS 812: Part 120:1989
BS 812: Part 121:1989
BS 882:1992, incorporating Amendment no. 1
BS 1881: Part 124:1988
BS 7943:1999
BS EN 196-1:2005
BS EN 932-5:2000
BS EN 933-9:2009
BS EN 1015-4:1999
BS EN 1015-11:1999, incorporating amendment no. 1
BS EN 12620:2002+A1:2008, incorporating Corrigendum May 2004
BS EN 1744-1:2009
BRE Digest 433
GB/T 14684-2011
RILEM AAR-1
ASTM C131-06
ASTM C294-12
ASTM C295-08

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The contribution from the following organisations on the drafting of the Construction Standard is gratefully acknowledged:

The Concrete Producers Association of Hong Kong Ltd.
The Hong Kong Contract Quarry Association
The Institute of Quarrying (Hong Kong Branch)
The Import Aggregates Suppliers Association Ltd.
The Association of Construction Materials Laboratories Ltd.
The University of Hong Kong

The electronic files of this Construction Standard including amendments, if any, can be found on the website of the Civil Engineering and Development Department.

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SECTION 1

SCOPE

This Construction Standard (Standard) specifies the requirements of the properties of aggregates obtained by processing natural or recycled materials and mixtures of these aggregates for use in production of concrete. It also specifies the requirements of quality control and the methods for testing of aggregates. These requirements shall apply to both natural and recycled aggregates unless specified otherwise.

This Standard is limited to coarse and fine natural aggregates, and coarse recycled aggregate. It covers aggregates having an oven-dried particle density not less than 2,000 kg/m^3, and does not cover lightweight aggregates, heavyweight aggregates and all-in aggregates. Coarse recycled aggregate will only be used in concrete in accordance with relevant Works Bureau Technical Circular (WBTC) (e.g. WBTC No. 12/2002).

SECTION 2

TERMS AND DEFINITIONS

For the purpose of this Standard, the following terms and definitions shall apply.

2.1 AGGREGATE

Granular material used in construction, aggregate may be natural or recycled.

2.2 NATURAL AGGREGATE

Aggregate from mineral sources subjected to nothing more than mechanical processing.

2.3 RECYCLED AGGREGATE

Aggregate resulting from the processing of old concrete.

2.4 COARSE AGGREGATE

Aggregate mainly retained on a 5 mm test sieve and containing no more finer material than is permitted for the various sizes in this Standard.

2.5 FINE AGGREGATE

Aggregate mainly passing a 5 mm test sieve and containing no more coarser material than is permitted for the various sizes in this Standard.

2.6 FINES

Particle size fraction of an aggregate passing the 75 μm test sieve.

2.7 GRADING

Particle size distribution expressed as the percentages by mass passing a specified set of test sieves.

2.8 TEST SIEVE

Test sieve of metal wire cloth complying with ISO 3310-1:2000 or of square-hole perforated metal plate complying with ISO 3310-2:1999.

2.9 CONSTANT DRY MASS

A test portion or test specimen is regarded to have achieved constant dry mass after it has been heated in an oven at a temperature of 105 ± 5ºC for at least 24 h or its change in mass

is within 0.1% when weighed at an interval of 1 h after heating at 105 ± 5ºC for a minimum of 16 h.

SECTION 3

GEOMETRICAL REQUIREMENTS

3.1 GENERAL

The geometrical properties of aggregates shall be determined with consideration of the application conditions and origin of the aggregates, and in accordance with the test methods specified in this Standard.

3.2 GRADING

3.2.1 Coarse aggregate

The grading of coarse aggregates, determined in accordance with Section 10 of this Standard, shall be within the appropriate limits given in Table 3.1.

Table 3.1 - Grading of coarse aggregates

Sieve size (mm)	**Percentage by mass passing test sieves** (%)							
	Nominal size of graded aggregates (mm)			Nominal size of single-sized aggregate (mm)				
	40 to 5	20 to 5	14 to 5	40	20	14	10	5
50	100	-	-	100	-	-	-	-
37.5	90-100	100	-	85-100	100	-	-	-
20	35-70	90-100	100	0-25	85-100	100	-	-
14	25-55	40-80	90-100	-	0-70	85-100	100	-
10	10-40	30-60	50-85	0-5	0-25	0-50	85-100	100
5	0-5	0-10	0-10	-	0-5	0-10	0-25	45-100
2.36	-	-	-	-	-	-	0-5	0-30

NOTE: *For coarse recycled 20 mm and 10 mm single-sized aggregates, the percentage by mass passing 4 mm test sieve shall not exceed 5%.*

3.2.2 Fine aggregate

The grading (i.e. C, M or F) of fine aggregates, determined in accordance with Section 10 of this Standard, shall be declared and documented by the aggregate producer or supplier. This grading shall comply with both the overall limits and the limits for the declared grading given in Table 3.2. In addition, not more than one in ten consecutive samples shall have a grading outside the limits for the declared grading.

Table 3.2 - Grading of fine aggregates

Sieve size	Percentage by mass passing test sieves (%)			
	Overall limits	Limits for declared grading		
		C	M	F
10 mm	100	-	-	-
5 mm	89-100	-	-	-
2.36 mm	60-100	60-100	65-100	80-100
1.18 mm	30-100	30-90	45-100	70-100
600 µm	15-100	15-54	25-80	55-100
300 µm	5-70	5-40	5-48	5-70
150 µm	0-20	-	-	-

3.3 SHAPE OF COARSE AGGREGATE

3.3.1 Flakiness Index

The flakiness index of coarse natural and coarse recycled aggregates, determined in accordance with Section 11 of this Standard, shall not exceed 30 and 40 respectively.

3.3.2 Elongation Index

The elongation index of coarse natural aggregate, determined in accordance with Section 12 of this Standard, shall not exceed 35.

3.4 SHELL CONTENT

Coarse natural aggregate shall be free of shell.

3.5 FINES CONTENT

The amount of material passing the 75 µm test sieve, determined in accordance with Section 10 of this Standard, shall not exceed the quantities given in Table 3.3. The aggregate producer or supplier shall declare the class (i.e. Class I or II) of the fine natural aggregate.

Table 3.3 - Limits for fines content

Aggregate type		Maximum percentage by mass passing 75 µm test sieve (%)
Coarse aggregates		4
Fine natural aggregate	Class I	10
	Class II	>10 and ≤14

NOTE: 1. *For heavy duty floor finishes, Class I fine natural aggregate should be used.*
2. *For Class II fine natural aggregate, the methylene blue value, determined in accordance with Section 13 of this Standard, shall be ≤ 1.4.*

3.6 FOREIGN MATERIALS CONTENT IN COARSE RECYCLED AGGREGATE

The maximum content of foreign materials in coarse recycled aggregate, determined by manual sorting in accordance with BRE Digest 433, shall not exceed the quantities given in Table 3.4.

Table 3.4 - Limits for foreign materials in coarse recycled aggregate

Type of foreign materials	**Maximum percentage by mass** (%)
Wood and other material less dense than water	0.5
Other foreign materials (e.g. metals, plastics, clay lumps, asphalt and tar, glass etc.)	1.0

SECTION 4

PHYSICAL REQUIREMENTS

4.1 GENERAL

The physical properties of aggregates shall be determined with consideration of the application conditions and origin of the aggregates, and in accordance with the test methods specified in this Standard.

4.2 RESISTANCE TO FRAGMENTATION

4.2.1 Los Angeles value

The Los Angeles value of coarse natural aggregate, determined in accordance with Section 14 of this Standard, shall not exceed 30% loss.

4.2.2 Aggregate impact value

The aggregate impact value of coarse natural aggregate, when determined in accordance with Section 15 of this Standard, shall not exceed 30%.

4.2.3 Ten per cent fines value

The ten per cent fines value of coarse aggregates, determined in accordance with Section 16 of this Standard, shall not be less than 100 kN.

4.3 PARTICLE DENSITY AND WATER ABSORPTION

4.3.1 Particle density

The oven dried particle density of aggregates, determined in accordance with Section 17 of this Standard, shall not be less than 2,000 kg/m^3.

4.3.2 Water absorption

The water absorption of coarse natural aggregate and coarse recycled aggregate, determined in accordance with Section 17 of this Standard, shall not exceed 0.8% and 10% respectively.

4.4 DURABILITY

4.4.1 Soundness

The magnesium sulphate soundness value of coarse natural aggregate, determined in accordance with Section 19 of this Standard, shall not be less than 94%.

4.4.2 Drying shrinkage

The drying shrinkage of natural aggregates used in structural concrete, when determined in accordance with Section 20 of this Standard, shall not exceed 0.075%.

4.4.3 Alkali-silica reactivity

The potential alkali-reactivity of aggregates shall be determined based on the results of the ultra-accelerated mortar bar test specified in Section 22 of Construction Standard CS1:2010 (CS1) or the concrete prism test specified in Section 23 of CS1, and shall be assessed based on Table 10 or 13 of CS1 respectively.

Other test methods such as petrographic examination should be treated as secondary methods for providing supplementary information on potential alkali-reactivity.

SECTION 5

CHEMICAL REQUIREMENTS

5.1 GENERAL

The chemical properties of aggregates shall be determined with consideration of the application conditions and origin of the aggregates, and in accordance with the test methods specified in this Standard.

5.2 CHLORIDES

5.2.1 Water-soluble chloride ion content

The water-soluble chloride ion content of natural aggregates shall be determined in accordance with Cl. 21.3 of Section 21 of this Standard.

5.2.2 Acid-soluble chloride ion content

The acid-soluble chloride ion content of coarse recycled aggregate shall be determined in accordance with Cl. 21.4 of Section 21 of this Standard.

5.2.3 Chloride ion content

The chloride ion contents of the combined natural aggregates shall not exceed the limits given in Table 5.1 for four categories of concrete.

Table 5.1 - Limits for chloride ion content of natural aggregates

Type and use of concrete	**Chloride ion content expressed as percentage by mass of combined natural aggregates** (%)
Prestressed concrete and heat-cured concrete containing embedded metal	0.01
Concrete containing embedded metal and made with cement complying with BS 4027	0.03
Concrete containing embedded metal and made with cement complying with BS EN 197-1 or combinations with ground granulated blastfurnace slag (GGBS) or pulverized-fuel ash (PFA)	0.05
Other concrete	No limit

The chloride ion content of the natural aggregates and coarse recycled aggregate when combined in use shall not exceed 0.05% by mass.

5.3 SULPHUR CONTAINING COMPOUNDS

5.3.1 Acid-soluble sulphate content

The acid-soluble sulphate content of natural aggregates, when determined in accordance with Cl. 21.5 of Section 21 of this Standard, shall not exceed 0.8% by mass.

The acid-soluble sulphate content of coarse recycled aggregate, determined in accordance with Cl. 21.5 of Section 21 of this Standard, shall not exceed 1% by mass.

5.3.2 Total sulphur content

The total sulphur content of natural aggregates, when determined in accordance with Cl. 21.6 of Section 21 of this Standard, shall not exceed 1% by mass.

5.4 OTHER CONSTITUENTS

Aggregates shall be free of organic substances. The aggregate producer or supplier shall demonstrate that the supplied aggregate is free of organic substances or alternatively the presence of organic substances does not affect the stiffening or hardening of mortar.

The presence of organic substances in the form of humus shall be determined in accordance with Cl. 21.7 of Section 21 of this Standard. Where the test result under Cl. 21.7 is negative, the aggregate shall be considered to be free of organic substances. Otherwise the aggregate shall be further tested in accordance with Section 22 of this Standard to assess the effect of organic substances on the stiffening time and compressive strength of mortar. The organic substances shall be of such proportion that:

(a) the stiffening time of mortar test specimens does not increase by more than 120 minutes; and

(b) the 28-day compressive strength of mortar test specimens does not decrease by more than 20%.

SECTION 6

QUALITY CONTROL

6.1 GENERAL

The aggregate producer and supplier shall take responsibility for the quality of aggregates. They shall establish and maintain their documented quality system to monitor the production, supply and delivery of aggregates to ensure that required characteristics of the aggregate are achieved and maintained, and that the aggregate product is traceable throughout the process.

The producer and supplier shall undertake routine control and laboratory testing to ensure that the aggregate product conforms to this Standard. When requested, details of the quality system for the production, storage, delivery of aggregates and test results shall be submitted to the purchaser for perusal.

6.2 ROUTINE CONTROL

6.2.1 Quality assurance and traceability

6.2.1.1 Direct supply of aggregates from an aggregate producer

The aggregate producer shall establish and maintain a quality assurance system certified to the ISO 9001 standard by a certification body accredited by Hong Kong Accreditation Service (HKAS) or its Multilateral Recognition Arrangement (MLA) partner(s) for Quality Management System (QMS) certification. He shall produce and maintain a production control manual in his quality system setting out the procedures by which the requirements for quality assurance of the production and delivery of aggregates are satisfied. The requirements for quality assurance of the production and delivery of aggregates shall include, but not limited to, the following:

(a) The responsibility, authority and interrelation of all personnel who manage, perform and check work affecting quality in the production of aggregates shall be defined.

(b) There shall be documentation detailing the nature of the raw material, its source and where appropriate, one or more maps showing the location of the source of the raw materials.

(c) There shall be procedures to identify and control the aggregate products, including quantity, inspection, testing, details of transport and delivery, etc. Each aggregate product shall be traceable up to the point of sale as regards source and type.

(d) For the purpose of this Standard, the “source” means the place of origin of rocks (i.e. location of quarry, site formation and tunneling projects, etc.) for producing aggregates. Rock crushing plants are not normally considered as a source of producing aggregates unless a proper production control system is implemented to ensure the quality and traceability of the aggregate product complying with this Standard.

(e) For imported rocks, the aggregate producer shall keep detailed records and provide documentation to the purchaser detailing the origin of the rocks for each delivery of aggregates. Also, the aggregate producer shall comply with the quality assurance and traceability requirements and the testing for aggregates as specified in this Standard. Any imported rocks that have been found not complying with this Standard shall be discarded, and records for handling such non-conforming materials shall be kept as part

of the quality system records. For the purpose of this Standard, "imported rocks" are rocks that are brought to the crushing plant from sources other than the quarry of that plant.

(f) There shall be a control and record system to identify the extent of the aggregate producer's responsibility in relation to the storage and delivery of the aggregate products.

(g) A control and monitoring system shall be implemented for those documents and data that are relevant to the requirements of this Standard and shall cover purchasing, processing, inspection, sampling, testing, handling and storage of the aggregate products.

6.2.1.2 Supply of aggregates from a supplier

If aggregates are supplied by a supplier who is not an aggregate producer, the aggregate supplier shall ensure that the aggregate is purchased from an aggregate producer, or other aggregate suppliers, with quality assurance system certified to the ISO 9001 standard by a certification body accredited by HKAS or its MLA partner(s). He shall obtain from the aggregate producer/other suppliers the production and quality records of the aggregate products as specified in Cl. 6.2.1.1. The responsibility between the aggregate supplier and aggregate producer, including all other aggregate suppliers, in relation to the storage and delivery of the aggregate products shall also be defined. In addition, the aggregate supplier shall establish and maintain his own quality assurance system certified to the ISO 9001 standard by a certification body accredited by HKAS or its MLA partner(s) for QMS certification and undertake those quality requirements and responsibility not covered by the aggregate producer or other suppliers to ensure compliance with the quality and traceability requirements as specified in this Standard throughout the chain of supply.

6.2.2 Testing and test certificate

Aggregates shall be obtained from an approved source and comply with the requirements of this Standard. All tests shall be performed by a laboratory accredited by HKAS under the Hong Kong Laboratory Accreditation Scheme (HOKLAS) in accordance with the test methods specified in this Standard. All test results shall be presented in HOKLAS endorsed test reports. When requested, the aggregate producer or supplier shall provide the following data (including test results/certificates for the typical properties of the aggregate) as required:

(a) Source of supply

  (1) Name and location of quarry or pit (grid reference)

  (2) Country or region

  (3) Location of sampling

(b) Aggregate type

(c) Typical properties

  (1) Coarse natural aggregate

    (i) Grading
    (ii) Flakiness index
    (iii) Elongation index
    (iv) Fines content
    (v) Los Angeles value
    (vi) Ten per cent fines value

(vii) Oven-dried particle density
(viii) Water absorption
(ix) Magnesium sulphate soundness value
(x) Alkali-silica reactivity
(xi) Water-soluble chloride ion content
(xii) Presence of organic substances

(2) Fine natural aggregate

(i) Grading
(ii) Fines content
(iii) Oven-dried particle density
(iv) Alkali-silica reactivity
(v) Water-soluble chloride ion content
(vi) Presence of organic substances

(3) Coarse recycled aggregate

(i) Grading
(ii) Flakiness index
(iii) Fines content
(iv) Foreign materials content
(v) Ten per cent fines value
(vi) Oven-dried particle density
(vii) Water absorption
(viii) Alkali-silica reactivity
(ix) Acid-soluble chloride ion content
(x) Acid-soluble sulphate content
(xi) Presence of organic substances

and any other tests as requested by the purchaser.

NOTE 1: *Unless specified otherwise, data provided from test results for the above properties, except for grading of aggregates, shall not be more than six months old.*

NOTE 2: *Unless specified otherwise, data provided from test results for grading of aggregates shall not be more than three months old.*

NOTE 3: *All production/quality records and data/test results shall be kept for a period of at least 5 years and made available for inspection when requested.*

The above geometrical, physical and chemical properties of aggregates shall be determined in accordance with the relevant parts of this Standard. The purchaser shall assess and determine the appropriate aggregate properties required to be determined in his testing plan to suit the requirements and applications of the aggregate products.

The aggregate producer or supplier is to notify the purchaser of any changes in production likely to affect the validity of the information given.

6.3 CONTROL UNDER A THIRD PARTY PRODUCT CERTIFICATION SYSTEM

Alternatively, quality assurance of the aggregate production and supply may rely on a third party certification of product conformity based on testing and continuous product surveillance and on the quality assurance system of the aggregate producer and supplier. This requires the development of a product certification scheme for Hong Kong to cover the production, supply, testing, handling, storage, transportation, etc. of the aggregates. The product certification scheme shall be based on widely acceptable international/national

product standards and shall be acceptable to the relevant stakeholders including the end users. The certification scheme shall include, but not limited to, the following quality, technical and certification requirements:

(a) A quality management system for the aggregate production and supply, which complies with ISO 9001.

(b) Details of the administrative and technical requirements or regulations for the product certification.

(c) Details of the certification standards and requirements in accordance with product certification System 5 of ISO/IEC Guide 67 or its latest revision, including initial assessment of quality and production systems, initial plant/factory inspection and type testing, recertification assessment of aggregate producer's quality and production systems followed by periodic surveillance visits, etc.

(d) Detailed description of the way in which the certification body establishes the process or procedure required and the evaluation of conformity of product, including audit method, inspection protocol, test method, inspection instruction, initial type tests, production control tests and audit tests, etc.

(e) Other relevant requirements stipulated in this Standard, i.e. the traceability requirement throughout the production process and chain of supply, etc.

The certification scheme shall be reviewed by a certification body accredited for product certification to ensure that the quality, technical and certification requirements be properly included. HKAS will provide advice on the accreditation criteria of the proposed product certification scheme. The certification body operating the above product certification shall be accredited by HKAS or its MLA partner(s) for product certification.

SECTION 7

GENERAL REQUIREMENTS FOR COMMON EQUIPMENT AND CALIBRATION

7.1 SCOPE

This Section specifies general requirements for apparatus and methods of calibration to be used when testing aggregates for compliance purposes. Where specific requirements are given in other Sections for specific areas of testing or measurement, those requirements should take precedence.

7.2 ABBREVIATION FOR UNITS

Table 7.1 shows the meaning of the abbreviations for the units used in this Standard but is not intended to be exhaustive.

Table 7.1 - Abbreviations for the units

Abbreviation	Meaning	Abbreviation	Meaning
g	gram	N/m^2	Newton(s) per square metre
kg	kilogram	kPa	kiloPascal
L	litre	g/mL	gram(s) per millilitre
mL	millilitre	g/L	gram(s) per litre
m	metre	mol/L	mole(s) per litre
mm	millimetre	h	hour
μm	micrometre	min	minute
m^2	square metre	s	second
m^3	cubic metre	r/min	revolution(s) per minute
N	Newton	$^{\circ}C$	degrees Celsius
kN	kilo Newton	%	percentage

7.3 TOLERANCES

7.3.1 Manufacturing tolerances

(a) Linear dimensions

Where a dimension is specified with manufacturing tolerances or limits, it shall be an essential dimension of the apparatus.

NOTE: *Dimensions stated without tolerances or limits are given for guidance.*

(b) Mass

Where mass is used, the manufacturing tolerances shall be ± 1% of the specified mass unless otherwise stated.

7.3.2 Working tolerance

Working tolerances shall apply to apparatus after being subjected to wear and tear during use, and shall not be more than twice the manufacturing tolerances unless otherwise specified.

7.4 TEST APPARATUS

7.4.1 Measuring instruments

(a) Balances and weights

Balances and weights shall be checked and calibrated. Calibration and checking of balances shall comply with Cl. 7.6.4 (a). The balances (and weights if required) selected for a weighing shall enable the mass to be determined to the accuracy required by the test method. If calibration determines that the balance is not suitable for use across its full working range, it shall be labeled to show the upper and lower limits of usable capacity.

NOTE 1: *Examples of categories of balances are given in Table 7.2*

NOTE 2: *Balances can incorporate an analogue or a digital display.*

Table 7.2 - Examples of categories of balances

Capacity (g)	**Scale interval or digit** (g)	**Maximum error of weighing** (g)
200	0.001	0.005
1,200	0.01	0.05
2,000	0.1	0.3
5,000	0.5	1
10,000	1	3
25,000	5	10
50,000	10	20

(b) Thermometers

Thermometers shall be selected with the required accuracy of reading as shown in Table 7.3 to suit the requirement of the test method.

Table 7.3 - Accuracy and graduations of thermometers

Required accuracy of reading (°C)	**Graduation intervals or digit** (°C)
0.2	not greater than 0.1
0.5	not greater than 0.2
1.0	not greater than 0.5

For liquid-in-glass thermometers the form of graduations shall comply with ISO 386. The calibration of thermometers shall comply with Cl. 7.6.4 (b).

(c) Steel rule

When required, an engineer's steel rule with scale divisions every 0.5 mm shall be used and shall be checked in accordance with Cl. 7.6.4 (c).

(d) Vernier calipers

Vernier calipers for internal and external measurements shall be readable to 0.1 mm or better. Calibration shall be in accordance with Cl.7.6.4 (c).

(e) Micrometers

Micrometers shall be readable to 0.01 mm or 0.002 mm or better, depending upon the resolution specified in the test method. Micrometers shall be calibrated in accordance with Cl. 7.6.4 (c).

(f) Dial gauges

Dial gauges shall be readable to 0.01 mm or 0.002 mm or better depending upon the range of travel required by the test method. Calibration shall be in accordance with Cl. 7.6.4 (c).

(g) Timers

Stopwatches or stopclocks readable to 1 s are suitable timers. A suitably placed wall clock with seconds hand, and large enough to read from the workstation is an acceptable alternative. The calibration of timers shall comply with Cl. 7.6.4 (d).

(h) Volumetric glassware

Volumetric glassware shall comply with Class A or B of ISO 4788. Class B volumetric glassware shall be checked before initial use in accordance with Cl. 7.6.4 (e). Where certified volumetric glassware complying with Class A of ISO 4788 is specified, in-house calibration is not required.

7.4.2 General apparatus

(a) Ovens

Ovens used for drying aggregates shall incorporate a thermostatic temperature control device or system which can be set to maintain the specified working temperature to within ± 5°C.

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

Each oven shall have a temperature indicating device of the required range and accuracy. Ovens shall be checked and calibrated in accordance with Cl. 7.6.5 (a).

(b) Test sieves

Test sieves shall comply with Cl. 2.8 of this Standard. Square-hole perforated metal plate test sieves shall have aperture sizes of at least 4 mm. Metal wire cloth test sieves shall have aperture sizes less than 4 mm.

Each sieve shall be separately identified. The manufacturer's certificate issued with each sieve shall be retained throughout its working life.

The sieves shall be checked and calibrated in accordance with Cl. 7.6.5 (c).

(c) Sieve shakers

When mechanical sieve shakers are used, they shall hold securely a nest of sieves with their lid and receiver. Their design shall ensure that the test material on any given sieve progresses over the surface of the sieve when it is agitated.

(d) Sample dividers

Sample dividers shall be of a size appropriate to the largest size of aggregate particle contained in the sample to be divided. The specification of the sample divider is given in Cl. 8.4 (e).

(e) Desiccators

Desiccators shall be provided with a lid which can form an airtight seal. Desiccator cabinets shall be fitted with an airtight seal around the doors. Shelves shall permit free vertical circulation of air.

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

A vacuum desiccator shall be covered by a safety cage during evacuation, while under vacuum and during vacuum release.

(f) Bottle shakers and rollers

If a motorised unit is used for shaking and/or rotating, it shall be capable of rotating or agitating the containers continuously at the specified speed for periods up to 24 h.

Calibration shall be in accordance with Cl. 7.6.5 (e).

(g) Heaters

An electric hotplate shall be fitted with an adjustable control device to provide boiling and/or simmering at specified temperatures.

NOTE: *Alternatively, a Bunsen burner, with tripod and gauze, can be used as a controllable source of heat.*

7.5 LABORATORY REFERENCE STANDARDS FOR CALIBRATION

7.5.1 Reference standards for in-house calibration

For in-house calibration of test measuring instruments, the laboratory shall hold reference standards or instruments that are used solely for calibration purposes.

Reference standards or instruments shall be stored securely in a suitable environment separate from working standards or instruments when not in use. They shall be used only by personnel who are competent and trained in their use.

Reference standards and instruments shall be of an accuracy greater than that of the working standards and instruments so that the desired accuracy of test measurement is achieved.

Reference standards and instruments shall be calibrated and certified in accordance with Cl. 7.5.2 and 7.5.3.

Reference standards shall be re-calibrated at intervals not greater than those specified in Cl. 7.5.3 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 mishandled, repaired, dismantled, adjusted or overhauled, it shall be re-calibrated before further use.

7.5.2 Traceability of reference standards

Reference standards and instruments shall be calibrated regularly by an accredited calibration laboratory. The certification shall show the traceability to recognised standards of measurement.

7.5.3 Specifications for reference standards and instruments

(a) Reference weights

Calibrated and certificated reference weights used for calibrating balances and working weights shall be kept separate and stored in a secure place. Reference weights shall be calibrated when first brought into use and shall then be re-calibrated after 2 years and every 5 years thereafter.

(b) Reference thermometers

Liquid-in-glass thermometers used as reference thermometers for calibrating laboratory working thermometers shall be calibrated before first brought into use and re-calibrated or replaced at 5 year intervals.

Another appropriate single point check of reference thermometers (e.g. ice point) shall be carried out 6 months after first being brought in use, then annually in addition to the 5 year calibration interval requirement.

Calibrated reference thermocouples and platinum resistance thermometers shall be re-calibrated at least once a year.

(c) Dimensional standards

Gauge blocks shall comply with ISO 3650 and shall be re-calibrated at 5 year intervals.

7.6 CALIBRATION AND CHECKING OF TEST EQUIPMENT

7.6.1 Traceability

All measurements necessary for the performance of tests covered by this Standard shall be traceable to national or international standards of measurement through an unbroken chain

of calibrations. The number of links in the chain shall be no greater than necessary to achieve the required accuracy.

7.6.2 External and in-house calibration

(a) General requirements

Calibrations shall be carried out either by an external calibration laboratory, or in-house by the laboratory's own staff. Systems used shall comply with the principles and requirements given in Cl. 7.6.4 and under the relevant test method, where appropriate.

All calibrated test equipment shall be used only over the range for which it has been calibrated.

(b) External calibration

Wherever possible, all external calibrations shall be carried out by a recognized accredited calibration laboratory. When calibration is carried out under contract by an external calibration laboratory, traceability shall be established by the issue of a certificate of calibration for the relevant item. The certificate shall contain the following information, and shall be retained on file:

(1) the name of the calibrating organisation;

(2) for whom calibration was done and at what location;

(3) a description of the item calibrated, including identification number;

(4) the method of calibration;

(5) the equipment used, including reference devices;

(6) the calibration certificate number of the reference device against which the instrument was calibrated, and the traceability route, if the calibration is not performed by a recognised accredited calibration laboratory;

(7) the calibration temperature;

(8) the calibration data and results;

(9) the date of calibration;

(10) the signature of the person responsible for the calibration;

(11) a unique identifier of the certificate (such as a serial number);

(12) a statement of compliance with the relevant specification; and

(13) a statement of the uncertainty of measurement of the item.

(c) In-house calibration

In-house calibration shall be carried out only by suitably qualified and experienced staff in accordance with written procedures for each item. Reference instruments or standards against which working instruments are calibrated shall comply with, and shall be kept, used and maintained in accordance with Cl. 7.5.

Calibration records shall be retained on file and shall contain the following information:

(1) a description of the item calibrated, including identification number;

(2) the method of calibration;

(3) the equipment used, including reference device(s);

(4) the calibration certificate number of the reference device(s);

(5) the calibration temperature;

(6) the calibration data and results;

(7) the date of calibration;

(8) the date when the next calibration is due, if appropriate;

(9) the signature of person responsible for the calibration; and

(10) a statement of compliance with the relevant specification.

7.6.3 Frequency of calibration

Routine re-calibration of measuring instruments shall be carried out at intervals that are based on usage of the instruments and on the analysis of documented calibration data to ensure the required accuracy is not lost between calibrations.

NOTE: *The periods between re-calibrations specified in Cl. 7.6.4 are the maximum calibration intervals for each type of instrument.*

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

7.6.4 Calibration and checking of measuring instruments

(a) 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 weighing exceeding the values specified in Cl. 7.4.1 (a).

(b) Thermometers

Liquid-in-glass thermometers complying with ISO 386 shall be calibrated or replaced at intervals not exceeding 5 years. Other liquid-in-glass thermometers shall be calibrated against a reference standard before initial use and shall be re-calibrated or replaced at intervals not exceeding 5 years.

Another appropriate single point check of thermometers (e.g. ice point) shall be carried out 6 months after first being brought into use, then annually in addition to the 5 year calibration interval requirement.

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

(c) Dimensional measuring instruments

The following applies to dimensional measuring instruments.

(1) Steel rules shall be checked before use for readability and for wear at their ends at least once a year.

(2) Vernier calipers shall be checked regularly and calibrated at least once a year against reference gauge blocks.

(3) Micrometers shall be calibrated at least once a year against reference gauge blocks.

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

(d) Timers

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

(e) Volumetric glassware

Calibration of volumetric glassware shall be carried out in-house by weighing the amount of boiled or de-aired water that the vessel contains or delivers at a measured temperature. A calibrated balance and the temperature correction tables in ISO 4788 shall be used. Volumetric glassware shall be rechecked on a rolling programme at least once every 5 years.

(f) Load measuring devices (compressive forces)

Each load measuring device shall be checked regularly and calibrated at least once a year against a calibrated proving device having a range and sensitivity appropriate to that of the measuring device. Where a load measuring device is fitted with a dial gauge or displacement transducer this shall be considered to be an integral part of the device, identified as such and shall not be replaced without re-calibration of the device.

7.6.5 Calibration and checking of general apparatus

(a) Ovens

The temperature profile of an empty oven shall be checked before initial used and after any major repair or replacement of heater elements and/or thermostat. The set temperature at the mid-point of the usable oven space of an empty oven shall be verified by means of a calibrated temperature measuring device at least once a year.

NOTE: *The following procedure is a suitable method for verifying the temperature profile of an oven, but other procedures may be used provided that it can be demonstrated that suitably accurate data can be obtained.*

Eight calibrated temperature measuring devices should be used in conjunction with the mid-point device to measure the temperature profile in the usable oven space. Four should be located in the upper one-third of the oven space and four should be located in the lower one-third of the oven space. Each calibrated temperature devices should be located at least 75 mm from the sides of the oven chamber. The temperature recorded at each monitoring points should be within ± 5˚C of the set temperature as measured at the mid-point of the usable oven space.

(b) Constant temperature bath

Constant temperature water baths shall be checked once a year or at shorter intervals if necessary by using a calibrated immersion thermometer at several points within the working area of the bath and observing the temperature when it becomes stable.

NOTE: *For a given steady room temperature, the water temperature control setting can be calibrated against various water temperatures by repeating the procedure over a range of settings.*

(c) Test sieves

All test sieves shall be checked by the following methods:

(1) **Visual checks**. Test sieves shall be checked visually by a competent operator before each use. A detailed visual check shall be made of the condition of every test sieve at regular intervals depending on frequency of use. The visual checks shall identify any damage, scoring, or blinding which is likely to affect the performance of the test sieve. If any doubt exists, a performance or measurement check, as appropriate, shall be carried out before further use.

(2) **Measurement checks**. The apertures of perforated plate test sieves shall be measured according to ISO 3310-2 at least once a year.

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

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

(ii) **Master sieves**. Working test sieves shall be checked against a master set of test 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 test sieves consecutively for a controlled period and to compare the masses retained on each test sieve of each set. It will be necessary to use a different test portion with each test sieve size. A test sieve shall be considered as failing the performance check when the corresponding masses on individual sieves of the same mesh size differ by more than 5%.

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

NOTE: *Wear and tear on test sieves is very dependent on their manner of use and the abrasiveness of the material being tested. Until such time that the laboratory has sufficient records to indicate rates of wear and thus fix rational check periods, performance checks should be at intervals of not more than 3 months.*

(d) Moulds, etc.

Items of equipment such as moulds shall be checked by determining their essential dimensions and mass where applicable. These determinations shall be carried out on items before initial use and shall be repeated at intervals, depending on frequency of use, to allow for wear and tear. When the change due to wear and tear exceeds the permitted working tolerance, the item shall not be used.

(e) Bottle shakers and rollers

If a motorized unit is used for shaking or rolling bottles and gas jars, the speed of oscillation or rotation of such machines shall be calibrated at least once a year with the shaker or roller fully laden.

(f) Rotating or vibrating machinery

Where the speed of rotation (or the frequency of vibrating) of an item of machinery is critical to the test method, then the speed (or the frequency) of the item shall be checked at least once a year using a calibrated instrument. The machinery shall be normally loaded during the check procedure.

7.7 REAGENTS

7.7.1 Distilled water

Where distilled water is specified, it shall be produced either by the use of de-ionising or by distillation apparatus. De-ionised or distilled water shall comply with the following requirements:

(a) **Non-volatile residue**, not more than 5 mg/L of residue.

(b) **pH value**, not higher than 7.5 and not lower than 5.0.

(c) **Specific conductance**, not higher than 5.0 micro-Siemens per cm (μS/cm) at 25˚C.

7.7.2 Chemical reagents

Chemical reagents used shall be reagent grade unless otherwise stated in the test method.

SECTION 8

METHODS FOR SAMPLING

8.1 SCOPE

This Section describes the methods for obtaining samples of aggregates of the quantity required for carrying out testing in accordance with other Sections of this Standard. The methods for sampling and sample reduction, and the requirements for dispatch of samples and certificate of sampling are given.

NOTE: *This Section does not cover sampling at a potential quarry or rock supply site. Care should be taken in selecting test samples from rock cores or rock outcrops from the potential site. It is necessary to ensure that the test samples are representative of the bulk rock mass. Otherwise, the test results may not provide a reliable indication of the suitability of the site for production of aggregates for use in concrete.*

8.2 DEFINITIONS

Batch is a definite quantity of aggregates manufactured or produced under conditions which are presumed uniform.

NOTE 1: *The quantity produced under a continuous process during a specified period should be treated as a batch.*

Sampling increment is a quantity of aggregates taken at one time from a larger body of aggregates.

NOTE 2: *The material taken by a single operation of the scoop during the course of sampling aggregates should be treated as a sampling increment.*

Bulk sample is a combination of the sampling increments.

Laboratory sample is a sample intended for laboratory testing or inspection.

Test portion is the material used as a whole in laboratory testing or inspection.

Riffling is 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 (or riffle box). The process is repeated until a sample of the required size is obtained.

Quartering is the reduction in quantity of a large sample of material by dividing a conical heap, into four parts of around equal size, 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 representative sample of the required size is obtained.

NOTE 3: *When sampling a batch of aggregates, the combination of the sampling increments forms the bulk sample. If the bulk sample is of an appropriate size, it is sent as a laboratory sample to the laboratory, otherwise it is reduced by a sample reduction process as described in Cl. 8.6 to the laboratory sample. The laboratory sample is reduced at the laboratory by one or more sample reduction operations to the quantity required by a particular test method; the quantity of material produced at the final stage of sample reduction is referred to as the test portion. A particular test method may then require preparation of several specimens from a test portion.*

8.3 PRINCIPLE

The aim of sampling is to obtain a bulk sample of aggregate which is representative of the average properties of the batch.

8.4 APPARATUS

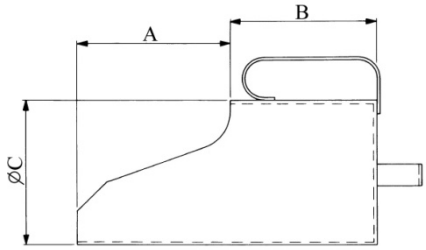
The following apparatus is required:

(a) A small sampling scoop

The small sampling scoop shall have a capacity of holding a volume of at least 1 L of aggregate (i.e. about 1.5 kg of aggregate of normal density) and shall be used for sampling aggregates of nominal sizes less than 5 mm (see Figure 8.1).

(b) A large sampling scoop

The large sampling scoop shall have a capacity of holding a volume of at least 2 L of aggregate (i.e. about 3 kg of aggregate of normal density) and shall be used for sampling aggregates of any grading, particularly aggregate of nominal sizes greater than 5 mm (see Figure 8.1)



	Small scoop	Large scoop
A	100 mm	125 mm
B	100 mm	125 mm
C	100 mm	125 mm

Not to scale

Figure 8.1 - Sampling scoop

(c) Sample increment containers

The sample increment containers shall be containers such as buckets for collecting the increments of a sample from the batch of aggregate and shall be clean and non-absorbent.

(d) Sample dispatch containers

The sample dispatch containers shall be containers such as bags made of plastics with a minimum thickness of 100 μm for sending samples to the laboratories and shall be clean and impervious.

(e) A sample divider

The sample divider shall be a device such as the riffle box as shown in Figure 8.2 capable of dividing a sample into two uniform portions and shall be of an appropriate size such that the width of the slots of the sample divider shall not be less than 1.5 times the diameter of the largest aggregate particle.

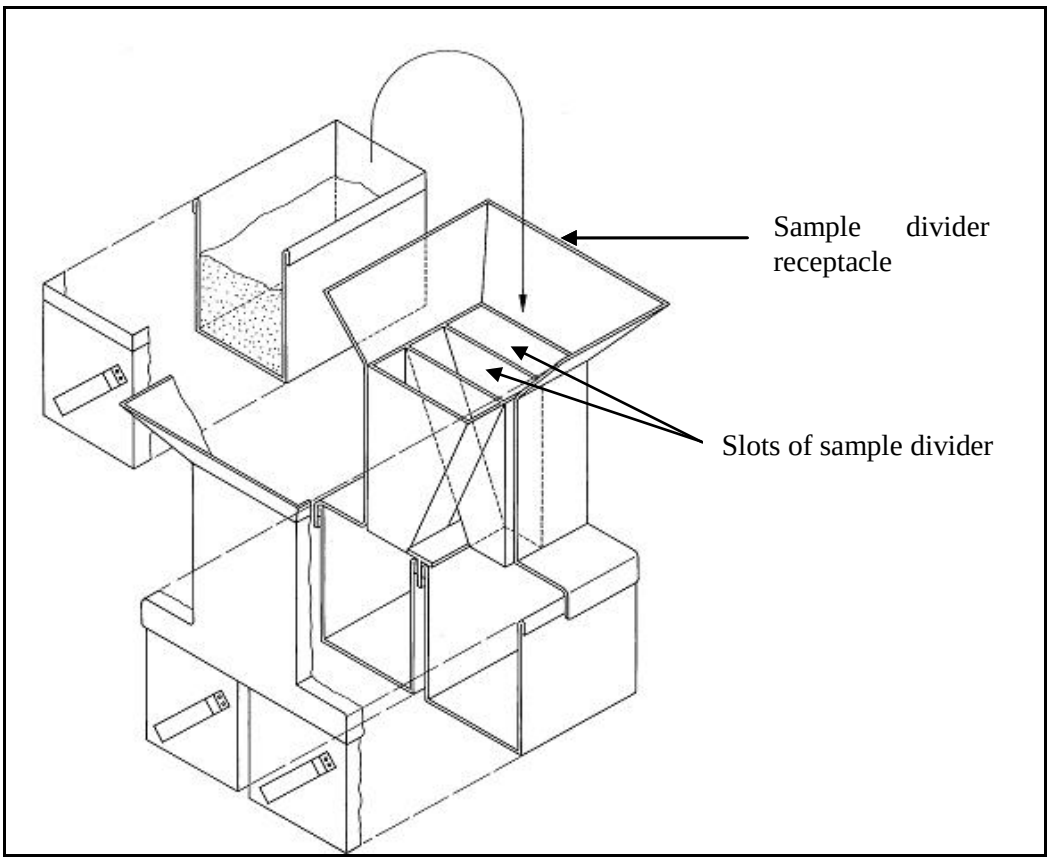


Figure 8.2 - Sample divider

(f) Quartering equipment

The quartering equipment shall comprise a flat shovel and a clean, flat and hard surface such as a metal tray for use in quartering.

NOTE 1: *All apparatus shall comply with the general requirements of Section 7 of this Standard.*

NOTE 2: *Other equipment may be required for sampling in special circumstances. For example, shovels, spades, picks, etc. may be required to reach the aggregate to be sampled.*

NOTE 3: *The equipment specified in this Section of the Standard is based on manual procedures. Other mechanical or automatic sampling equipment may be used, and shall be designed to enable every particle in a batch to have an equal probability of being included in the bulk sample.*

8.5 PROCEDURE FOR SAMPLING

The batch of aggregate to be represented by the bulk sample shall be clearly defined and a responsible and experienced person shall be engaged to carry out the sampling.

A bulk sample shall be obtained by using a sampling scoop of appropriate size and collecting, in a sample increment container, a sufficient number of increments (i.e. scoopfuls) to provide the required quantity of aggregate for all the tests to be made.

The sampling increments shall be taken from different parts of the batch in such a way as to represent the average quality. The number of sampling increments shall not be less than those given in Table 8.1.

Table 8.1 - Minimum number of sampling increments

Nominal size of aggregate	Minimum number of sampling increments		Approximate minimum mass (kg)
	Small scoop	Large scoop	
28 mm and larger	-	20	50
5 mm to 28 mm	-	10	25
5 mm and smaller	10	10 half scoops	10

When duplicate (or more) samples are required, each sample shall be taken as a separate and independent operation.

When sampling from heaps of aggregate, the required number of sampling increments shall be taken from positions evenly distributed over the whole surface of the heap. At the required spot for each increment, as much surface material as necessary shall be removed to expose aggregate at a depth of at least 150 mm from the surface. The sampling increments shall be taken by digging the scoop into the exposed aggregate.

NOTE 1: *Aggregates that are badly segregated present problems of variable quality and in many cases it is better to wait until they are moved.*

NOTE 2: *Sampling near ground surface should be carried out with care to avoid contamination with, for example, residues of previous materials.*

NOTE 3: *Sampling in segregated areas (extreme top or bottom) or from the surface should be avoided.*

When sampling from aggregate in motion, i.e. when it is being loaded or unloaded, the times for the batch of aggregate to pass the sampling point should be calculated to give the required number of sampling increments, ensuring that they are randomly distributed through the batch of aggregate.

NOTE 4: *A mechanical sampler, automatically or manually operated, used for sampling from a moving stream of aggregates may be considered to be in accordance with this Standard provided that each complete operation of the sampler produces an increment of at least 2 L of coarse aggregate or 1 L of fine aggregate.*

When sampling from a falling stream of aggregate, sampling increments shall be taken from the whole width of the stream.

When sampling from conveyor belts, the conveyor should be stopped at the appropriate time and a fixed length of aggregate across the width of the conveyor belt shall be taken as a sampling increment.

NOTE 5: *Sampling manually from a moving conveyor shall not be permitted.*

For all methods of sampling, all the sampling increments shall be combined to form the bulk sample.

On completion of the sampling process, the bulk sample and the batch of material in bulk shall be checked visually to see if the bulk sample is representative of the batch sampled.

8.6 PROCEDURE FOR SAMPLE REDUCTION

The mass of the bulk sample shall be reduced substantially in such a way to preserve at each stage a representative part of the bulk sample either by riffling or by quartering.

8.6.1 Procedures for riffling

(a) The bulk sample shall be poured into the sample divider (riffle-box) for dividing the sample into two portions. It should be poured from the long side of the sample divider receptacle down the centre line of the sample divider. In case the bulk sample is too large to go into the sample divider receptacle, it shall be divided into subsamples that are small enough. Each subsample shall be reduced by the same number of riffling stages and the reduced subsamples shall then be combined.

(b) In case the bulk sample contains material finer than 5 mm, it shall be surface-dried, mixed thoroughly and then passed through the sample divider.

(c) After dividing the original sample into two approximately equal halves by the sample divider, one of the two halves shall be retained and passed through the sample divider again. The sample reduction process shall be repeated as necessary to reduce the original bulk sample to the required mass for the laboratory sample.

8.6.2 Procedures for quartering

(a) The sample shall be mixed thoroughly by heaping it on to a clean, flat and hard surface to form a cone. The conical heap shall be formed 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 the centre of the cone is not displaced.

(b) The heap shall be turned over with a shovel to form a new cone, the operation being carried out three times.

(c) The third cone shall be flattened by repeated vertical insertion of the shovel across the apex of the cone and lifting of the shovel clear of the material after each insertion so that it is uniform in thickness and diameter.

(d) The flattened heap shall be quartered along two diameters intersecting at right angles.

(e) One pair of diagonally opposite quarters shall be discarded and the remaining quarters shall be shoveled into a heap.

(f) The process of mixing and reduction shall be repeated until the required mass for the laboratory sample is obtained.

8.6.3 Procedures for sample reduction to provide replicate laboratory samples

(a) The bulk sample shall be reduced by the procedure described in Cl. 8.6.1 or 8.6.2.

(b) All excess bulk samples rejected at the individual division stages shall be recombined, mixed thoroughly and reduced again to provide a second laboratory sample.

(c) The process is repeated as necessary to provide the required number of laboratory samples.

8.7 DISPATCH OF SAMPLE

The samples shall be transferred completely to sample dispatch containers, which shall then be sealed for dispatch. Where necessary, particularly where the aggregate contains crushed particles of the larger sizes, the sample dispatch containers shall be protected against damage in transit by casing in other suitable containers. The mass of each sample dispatch container containing the samples shall not exceed 30 kg.

Each sample dispatch container 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.

8.8 CERTIFICATE OF SAMPLING

Each sample, or group of samples of aggregates from a single source, shall be accompanied by a certificate of sampling, from the person responsible for taking the sample, certifying that sampling was carried out in accordance with this Standard.

The certificate shall include as much of the following information as appropriate:

(a) The date, time, place and method of sampling.

(b) The name and location of source.

(c) Sample identification mark (or marks).

(d) Nominal description of the aggregate sampled, including the following data:

(1) Type – One of the following terms shall be used:

(i) Crushed rock.

(ii) Sand or gravel (in this case, it is necessary to record if the aggregate is crushed or partially crushed and, when known, if it has been obtained by inland or marine working).

(iii) Recycled (in this case, it is necessary to record the type of hard inert construction and demolition materials such as broken rock and concrete).

(2) Nominal size.

(3) Other - References shall be made to the presence of any obvious extraneous pieces in the sample such as clay lumps, organic material, etc.

NOTE: *When a geological or petrological term is used to describe an aggregate in more detail or when it is necessary to describe the particle shape and surface texture characteristics, reference should be made to Section 9 of this Standard.*

(e) Description of the batch.

(f) Any other information likely to be helpful to the tester.

NOTE: *The procedure described in Cl. 8.5 is for obtaining a bulk sample representative of the average properties of the batch sampled. When sampling is carried out to assess variability within a batch, a number of sampling increments are taken from defined places in the batch and are not combined but tested separately. For such purpose, simplified procedures such as use of fewer sampling increments may be adopted. Such departure from the method described in this Standard should be recorded on the certificate of sampling.*

(g) Name and signature of sampler.

SECTION 9

METHOD FOR PETROGRAPHIC EXAMINATION OF AGGREGATES

9.1 SCOPE

This Section describes the method and procedures for the petrographic examination of materials intended for use as aggregates in concrete.

9.2 PRINCIPLE

Petrographic examination of a sample generally involves the identification and quantification of the types of rock and mineral constituents present in the aggregate. The examination should focus on the identification of any materials/mineral constituents whose properties may be expected to influence the behaviour of concrete in construction, such as alkali-aggregate reaction.

9.3 SAMPLING

This Standard applies to the following materials intended for use as aggregates in concrete:

(a) Rock sample/drilled core from undeveloped quarries.

(b) Natural aggregate.

(c) Crushed rock aggregate.

Sampling of the materials shall be carried out by a competent geologist who can identify suitable and representative materials for petrographic examination. The competent geologist shall have a degree pertaining to geology, earth sciences or equivalent; or shall have obtained good geological knowledge with at least 5 years relevant experience in local geology. Sampling of the materials can also be carried out by a qualified petrographer. The exact location from which samples are taken, the geology of the site and other data relevant to the examination shall be recorded. The minimum size of bulk samples is given in Table 9.1.

The laboratory sample shall be taken in accordance with the procedure described in Section 8 of this Standard.

Table 9.1 - Minimum size of bulk samples for petrographic examination

Sample type	**Nominal size of material** (mm)	**Minimum mass to be delivered to the laboratory** (kg)
Rock sample/drilled core from undeveloped quarries	-	100 mm dia. core through the entire depth of material expected to be exploited and not less than 2 kg from each distinctive stratum
Natural aggregate/ crushed rock aggregate	50 40 28 20 14 10 5 < 5	100 50 20 10 5 1 1 0.5

9.4 APPARATUS

The following apparatus are required:

(a) Test sieves (aperture sizes: 50 mm, 37.5 mm, 28 mm, 20 mm, 10 mm and 5 mm)

(b) Sample divider

(c) Balance (to an accuracy of 0.1 %)

(d) Apparatus and machinery suitable for making an aggregate thin section of minimum size 50 mm × 30 mm with thickness of 25 μm – 30 μm

(e) Hand lens (10×)

(f) Stereoscopic microscope (e.g. 6×, 10×, 80×)

(g) Petrographic microscope (minimum 500×)

(h) Point counting device

(i) Photomicrographic camera and accessories

NOTE: *All apparatus shall comply with the general requirements of Section 7 of this Standard.*

9.5 METHOD

Petrographic examination of aggregates shall be carried out by a qualified petrographer who is capable of operating the equipment used for the examination and with at least 5 years of relevant experience in materials used in concrete. The qualified petrographer shall have a degree pertaining to geology, mineralogy, petrography and optical mineralogy, or have obtained equivalent knowledge and experience through on-the-job training.

The examination shall be carried out through visual inspection of hand specimens with the aid of a hand lens or stereoscopic microscope, followed by the inspection of aggregate thin sections using a petrographic microscope, with point counting (if necessary). The purpose of point counting is to identify and quantify the rock and mineral constituents of an

aggregate sample, such that the relative proportion of materials/mineral constituents in that sample that are suspected to have deleterious effects in concrete can be determined.

For the investigation of particular problems or very fine-grained rocks, additional methods such as X-ray diffraction analysis, which depend on the purpose of the examination and the nature of the sample, shall be used.

Photomicrographic records of any features that are suspected to influence the behavior of concrete shall be taken and included in the report.

9.6 PREPARATION OF TEST PORTIONS

The laboratory sample (excluding rock sample and drilled core from undeveloped quarries) shall be reduced using sample reduction procedure described in Cl. 8.6 of Section 8 of this Standard to produce a test portion. The test portion shall first be dry sieved into different size fractions prior to examination. Test sieves of aperture sizes 50 mm, 37.5 mm, 28 mm, 20 mm, 10 mm and 5 mm shall be used to separate the samples into the following size fractions:

(a) < 5 mm

(b) 5 – < 10 mm

(c) 10 – < 20 mm

(d) 20 – < 28 mm

(e) 28 – < 37.5 mm

(f) 37.5 – < 50 mm

(g) ≧ 50 mm

9.7 PROCEDURE

9.7.1 General

The petrographic examination shall establish whether the sample contains the following materials/mineral constituents that may cause deleterious effects in concrete:

(a) Chemically unstable minerals (such as soluble sulphates and unstable sulphides).

(b) Volumetrically unstable materials (such as swelling clay).

(c) Alkali-silica reactive constituents (such as opal, chalcedony, cristobalite, tridymite, volcanic glass and highly strained/microcrystalline quartz).

(d) Alkali-carbonate reactive constituents (such as calcareous dolomites or dolomitic limestones with clayey insoluble residues).

(e) Contaminants (such as synthetic glass, cinders, clinker, coal ash, calcium/magnesium oxide, gypsum, soil, hydrocarbons and chemicals, animal excrement and plant remains).

Quantitative analysis by point counting, if necessary, shall be carried out in thin sections to determine the relative proportions of deleterious materials/mineral constituents present in the samples.

9.7.2 Visual inspection of hand specimen

The test portion shall be examined through visual inspection with the aid of a hand lens or stereoscopic microscope. A minimum of 150 particles of each size fraction (for natural aggregate and crushed rock aggregate) shall be examined and counted for reliable statistical results. For rock sample and drilled core from undeveloped quarries, at least two specimens for each distinctive lithology identified shall be examined. The following physical conditions of the sample shall be recorded:

(a) Colour.

(b) Texture (crystalline/granular/glassy, etc.).

(c) Fabric.

(d) Grain size.

(e) Lithology (rock type).

(f) Degree of weathering (fresh/moderately weathered/very weathered).

(g) Particle form (flat/elongate/equidmensional).

(h) Particle angularity (angular/subangular/subrounded/rounded).

(i) Porosity (dense/porous/friable).

(j) Type and condition of any exterior coatings (for natural aggregate).

Suggestions on the nomenclature of minerals and rocks are given in Table 9.2 and Table 9.3. Commonly used local names of aggregates may also be given in brackets.

Table 9.2 - Classification of minerals

Mineral Group	Mineral(s) potentially reactive in concrete
Silica minerals	● Chalcedony (reactive with the alkalies in concrete) ● Cristobalite (reactive with the alkalies in concrete) ● Opal (reactive with the alkalies in concrete) ● Strained/highly fractured/microcrystalline/cryptocrystalline quartz (reactive with the alkalies in concrete) ● Tridymite (reactive with the alkalies in concrete) ● Devitrified volcanic glass (reactive with the alkalies in concrete)
Feldspars	● Highly altered or exceptionally weathered feldspars (may release additional alkalies in concrete)
Ferromagnesian minerals	-
Micaceous minerals	-
Clay minerals	● Swelling clays (subject to large volume change with wetting and drying)
Zeolites	● Heulandite (may release alkalies in concrete through cation exchange) ● Laumontite (subject to large volume change with wetting and drying) ● Natrolite (may release alkalies in concrete through cation exchange)
Carbonate minerals	● Calcite (effervescence in cold dilute hydrochloric acid)
Sulphate minerals	● Anhydrite (may contribute to sulphate attack in concrete) ● Gypsum (may contribute to sulphate attack in concrete)
Iron sulphide minerals	● Marcasite and some forms of pyrite and pyrrhotite (may oxidise to form iron oxide and sulphuric acid to cause brown staining and popouts in concrete)
Iron oxide minerals	● Large amount of soft iron oxide minerals (may colour concrete shades of yellow or brown)

Table 9.3 - Nomenclature of rocks

Rock Group	Rock Name
Igneous (Intrusive)	Diorite Dolerite Dunite Foidolite Gabbro Granite Granodiorite Monzonite Norite Pegmatite Peridotite Pyroxenite Syenite Tonalite
Igneous (Extrusive)	Andesite Basalt Dacite Foidite Latite Lava Obsidian Phonolite Pumice Rhyolite Tephrite Trachyte Tuff
Sedimentary	Argillite Arkose Chalk Chert Conglomerate Dolomite Graywacke Limestone Mudstone Quartzite Sandstone Siltstone
Metamorphic	Amphibolite Gneiss Hornfels Marble Quartzite Phyllite Schist Slate Serpentinite

9.7.3 Examination of rock/aggregate thin section

For each size fraction (for natural aggregate and crushed rock aggregate), a minimum of two aggregate thin sections (minimum size of 50 mm × 30 mm with thickness between 25 μm and 30 μm) shall be made and examined using a petrographic microscope. For rock sample and drilled core from undeveloped quarries, a minimum of two rock thin sections for each distinctive lithology identified shall be prepared for petrographic examination.

NOTE: *This Standard does not attempt to describe the details of aggregate thin-section making. The aggregate thin sections can be prepared by the petrographer or a commercial thin-section making laboratory.*

Impregnation of the thin sections with epoxy resin containing a fluorescent dye may be necessary if the samples are friable or the internal porosity of the aggregate constituents needs to be characterised.

The following items shall be recorded:

(a) Mineral constituents of the rock/aggregate sample.

(b) Presence of materials/mineral constituents in the sample that may cause deleterious effects in concrete.

9.7.4 Point counting

If deleterious materials/mineral constituents are identified, point counting shall be carried out further in thin sections with a view to quantifying their relative proportions in the samples. The point counting analysis shall be carried out by traversing in regular increments over the whole thin section in the form of a grid pattern. A minimum of 1,000 points shall be counted in each rock/aggregate thin section.

Subject to the point counting results, the sample shall be further classified into the following three categories in terms of its potential alkali-reactivity:

(a) Non-reactive.

(b) Potentially reactive.

(c) Reactive.

Where the point counting results show that the sample is potentially reactive or reactive, the potential alkali-reactivity of the sample shall be confirmed by the tests specified in Cl. 4.4.3.

9.8 TEST REPORT

The report shall affirm that the petrographic examination was carried out in accordance with this Standard, and whether or not a certificate of sampling is available. If available, the certificate of sample shall be provided. The report shall include a detailed description of all essential physical properties of the sample as revealed by the examination. The findings shall be easily understandable by persons who may not have knowledge/experience in petrographic examination or whose job is to determine the suitability of a material for use as aggregate in concrete. Samples found to contain materials/mineral constituents that may have deleterious effects in concrete, shall be described both qualitatively and quantitatively and the suspected unfavorable effects in concrete, such as alkali-aggregate reaction, shall be mentioned in the report. The report shall contain the following information:

(a) Details of the petrographer (including qualification and experience).

(b) Date of the report.

(c) Basic information of the samples (date received, sampling locality, sample type/size/quantity).

(d) Results of visual inspection of hand specimen.

(e) Results of examination of rock/aggregate thin section.

(f) Quantitative assessment by point counting to show the relative proportions of any materials/mineral constituents in the sample that are suspected to have deleterious effects in concrete.

(g) Classification of sample (non-reactive, potentially reactive or reactive) in terms of its potential alkali-reactivity.

(h) Photomicrographic records of any features that are expected to influence the behavior of concrete.

(i) Recommendations for additional petrographic investigation such as X-ray diffraction analysis and/or additional confirmation test for potential alkali-reactivity, if considered necessary.

SECTION 10

METHODS FOR DETERMINATION OF PARTICLE SIZE DISTRIBUTION – SIEVE TESTS

10.1 SCOPE

This Section describes two methods for determining the particle size distribution of samples of aggregates by sieving.

10.2 PRINCIPLE

10.2.1 Washing and sieving

This is the preferred method (see Cl. 10.6.2) for aggregates which may contain clay or other materials likely to cause agglomeration of particles. It involves preliminary separation by washing through a fine sieve before the determination of the particle size distribution by dry sieving.

10.2.2 Dry sieving

This is an alternative method (see Cl. 10.6.3) which may be used for coarse and fine aggregates free from particles causing agglomeration.

NOTE 1: *Dry sieving is quicker and less laborious to carry out than washing and sieving but gives inaccurate results for aggregates containing clay.*

NOTE 2: *It is not possible to specify accurately the amount of clay or other materials which will make dry sieving inappropriate and unless it can be demonstrated (e.g. by previous experience) that dry sieving gives accurate results, it is recommended that washing and sieving should always be used. Because of this, some materials specifications may call for washing and sieving to be followed at all times.*

10.3 SAMPLING

The laboratory sample shall be taken in accordance with the procedures described in Section 8 of this Standard.

10.4 APPARATUS

The following apparatus is required:

(a) Sample divider

(b) Ventilated oven

The ventilated oven shall be capable of being thermostatically controlled to maintain a temperature of 105 ± 5ºC.

(c) Balance(s)

The balance(s) shall be of suitable capacity accurate to 0.1% of the mass of the test portion.

(d) Test sieves and nesting guard sieve

A set of sieves of the sizes and apertures given in Table 10.1 will cover most applications of the method.

Table 10.1 - Particulars of sieves for sieve analysis

Nominal aperture sizes		
Square-hole perforated metal plate, 450 mm or 300 mm diameter	Metal wire cloth, 300 mm or 200 mm diameter	
(mm)	(mm)	(μm)
75 63 50 37.5 28 20 14 10 6.3 5	3.35 2.36 1.7 1.18	850 600 425 300 212 150 75 #
# For some applications, 63 μm is appropriate.		

(a) Mechanical sieve shaker (optional)

(b) Trays

The trays shall be of suitable size, which can be heated in the ventilated oven without damage or change in mass.

(c) Test portion containers

The containers shall be of size sufficient to contain the test portion plus five times its volume of water (for washing and sieving method only).

NOTE: *All apparatus shall comply with the general requirements of Section 7 of this Standard.*

10.5 PREPARATION OF TEST PORTION

The laboratory sample shall be reduced in accordance with the procedures described in Cl. 8.6 of Section 8 of this Standard to produce the required number of test portions each of which complies with the minimum mass given in Table 10.2. Each test portion shall be heated in the oven to achieve constant dry mass. It shall be allowed to cool to the room temperature and shall then be weighed to obtain a mass (M_1) of the test portion.

Table 10.2 - Minimum mass of test portion for sieve analysis

Nominal size of material (mm)	**Minimum mass of test portion** (kg)
63	50
50	35
40	15
28	5
20	2
14	1
10	0.5
6	0.2
5	0.2
3	0.2
< 3	0.1

10.6 PROCEDURE

10.6.1 General

For some materials, the particle size distribution may result in excess mass on one or more test sieves particularly on the finer sizes. Therefore, if it is not possible to include extra test sieves of appropriate intermediate size to reduce the loading, one of the following procedures shall be adopted.

(a) The test portion shall be subdivided into two or more sub-portions. The particle size distribution for each portion shall be determined and the results for the sub-portions shall be combined for the purpose of reporting.

(b) The test portion shall be separated on an appropriate test sieve, e.g. 20 mm or 5 mm. The fractions of the test portion retained and passing the test sieve shall be weighed separately to determine the proportion of each fraction. The particle size distribution of each fraction shall be determined separately, reducing the sample where necessary using the sample reduction procedure as described in Cl. 8.6 of Section 8 of this Standard. The particle size distribution of the original sample shall be calculated by combining the results for each fraction in the proportions present.

Before and after each use, the sieving medium and the frame shall be cleaned and inspected and degreased if necessary. The cleaning of the test sieve shall be carried out with great care so that the sieving medium is not damaged.

NOTE: *A useful method for the removal of entrapped material in the test sieve, particularly from finer apertures, is immersed in a bath of water agitated by an ultrasonic transducer.*

10.6.2 Washing and sieving method

10.6.2.1 Preliminary separation

Both sides of a 75 μm test sieve (see Cl. 10.4 (d)), which is reserved for use in this test only, shall be wetted. A nesting guard sieve (e.g. 1.18 mm) shall then be fitted on top of the test sieve. The two sieves shall be mounted in such a way that the suspension passing the test sieve can be run to waste or, when required, collected in a suitable vessel.

The weighed oven-dried test portion (see Cl. 10.5) shall be placed in a test portion container (see Cl. 10.4 (g)) and sufficient water shall be added to half fill the container. The contents shall be agitated so that particles smaller than 75 μm are completely separated from coarser particles.

NOTE 1: *To achieve complete separation, soaking or continued agitation or, in the case of large particles, brushing may be required.*

The suspension of fine solids shall be poured onto the guarded 75 μm test sieve.

NOTE 2: *Unless it is required for other purposes, the suspension passing the test sieve may be run to waste.*

Washing the coarse residue shall be carried out continuously until the water passing the test sieve is clear (see note 2) and then all the residues shall be washed from the container and sieve(s) into the tray (see Cl. 10.4 (f)). Excess free water shall be removed by careful decantation through the test sieve, avoiding transfer of solids (see note 2) and the residue shall be heated in the oven (see Cl. 10.4 (b)) to achieve constant dry mass. The residue shall be cooled and shall then be weighed to obtain its mass (M_2).

NOTE 3: *Excess water flows which may damage or flood the sieves shall be avoided.*

NOTE 4: *If some transfer of solids does occur, they shall be washed back into the tray and the operation shall be repeated.*

NOTE 5: *As fine sieves are fragile, the integrity of the mesh should be checked frequently.*

The mass of material passing the test sieve shall be determined as $M_1 - M_2$.

10.6.2.2 Sieving the dried residue

The clean and dry test sieves shall be nested on a fitting receiver in order of increasing aperture size from bottom to top. The dried residue shall be placed on the top coarsest test sieve and covered with a fitting lid. The test sieves shall be shaken for a sufficient time either by hand or using a mechanical sieve shaker (see Cl. 10.4 (e)) to separate the test sample into the size fractions determined by the sieve apertures used.

NOTE 1: *Experience has shown that the preliminary separation (see Cl. 10.6.2.1) does not necessarily remove all the particles smaller than 75 μm due to capillary action of water on particle surfaces. It is therefore necessary to include a 75 μm test sieve in the series of test sieves used to sieve the dried residue.*

When the mechanical sieve shaker is used, after sieving, complete separation between particles shall be checked by hand sieving. When sieving is done by hand alone, it shall be carried out starting with the coarsest test sieve. Each test sieve shall be shaken separately over a clean tray or receiver for a period of not less than 2 min until not more than a trace passes through the test sieve. Shaking shall be done with a varied motion, backwards and forwards, left to right, circular, clockwise and anti-clockwise, and with frequent jarring so that the material is kept moving over the test sieve surface in frequently changing directions. Materials shall not be forced through the test sieve by hand pressure but placing of particles is permitted. Lumps of agglomerated materials which consist of particles representative of the bulk shall be broken by gentle pressure with the fingers against the side of the test sieve.

Any extraneous material not representative of the bulk that will not readily break down into individual particles, such as clay lumps, shall be recorded and removed from the test sieve for separate weighing.

Pressure shall not be applied to the surface of the test sieve to force particles through the mesh. Light brushing with a soft brush on the underside of the test sieve may be used to clear sieve openings. Light brushing with a fine camel-hair brush may be used on the 150

μm and 75 μm test sieves to prevent agglomeration of the powder and blinding of the apertures. Stiff or worn-down brushes shall not be used for this purpose.

The mass of aggregate retained on the test sieve at the completion of sieving shall be checked to ensure that it does not exceed the value for that test sieve shown in Table 10.3 in order to prevent blinding of the sieve apertures by overloading.

Table 10.3 - Maximum mass to be retained at the completion of sieving

Test sieve nominal aperture size	**Maximum mass**		**Test sieve nominal aperture size**		**Maximum mass**	
	450 mm diameter sieves	300 mm diameter sieves			300 mm diameter sieves	200 mm diameter sieves
(mm)	(kg)	(kg)	(mm)	(μm)	(g)	(g)
50	14	5	5		750	350
37.5	10	4	3.35		550	250
			2.36		450	200
28	8	3	1.7		375	150
20	6	2.5	1.18		300	125
14	4	2				
10	3	1.5		850	260	115
				600	225	100
				425	180	80
6.3	2	1		300	150	65
5	1.5	0.75		212	130	60
3.35	1	0.55		150	110	50
				75	75	30

NOTE 2: *Additional operations, as described in Cl. 10.6.1, will thus be required on some test sieves for some sample masses.*

NOTE 3: *In some cases it may be possible to reduce sufficiently the load on a test sieve by incorporating an intermediate sieve into the test series.*

The material retained on each test sieve together with any material cleaned from the mesh, shall be weighed on completion of sieving on that test sieve.

NOTE 4: *To prevent loss, samples containing dust should be sieved into a receiver.*

The aggregate passing the test sieve shall be added to the next test sieve in the series before commencing the operation on that test sieve.

10.6.3 Dry sieving method

The procedure described in Cl. 10.6.2.2 shall be used.

10.7 CALCULATION AND EXPRESSION OF RESULTS

The mass retained on each test sieve shall be calculated as a percentage of the original dry mass (M_1). For the mass of material passing the finest test sieve, it shall include the mass of the material passing during washing ($M_1 - M_2$) and the mass retained on the receiver during the dry sieving. The mass passing each test sieve shall be calculated as a cumulative percentage of the total sample mass.

10.8 TEST REPORT

The report shall affirm that the particle size distribution was determined in accordance with this Section of the Standard and whether or not a copy of the certificate of sampling is available. If available, a copy of the sampling certificate shall be provided. The test report shall contain the following additional information:

(a) Sample identification.

(b) Either the cumulative percentage of the mass of the total sample passing each of the test sieves, to the nearest whole number; or the percentage of the mass of the total sample passing one test sieve and retained on the next smaller test sieve, to the nearest whole number.

NOTE: *A specimen chart which may be used for illustrating the results graphically is shown in Figure 10.1.*

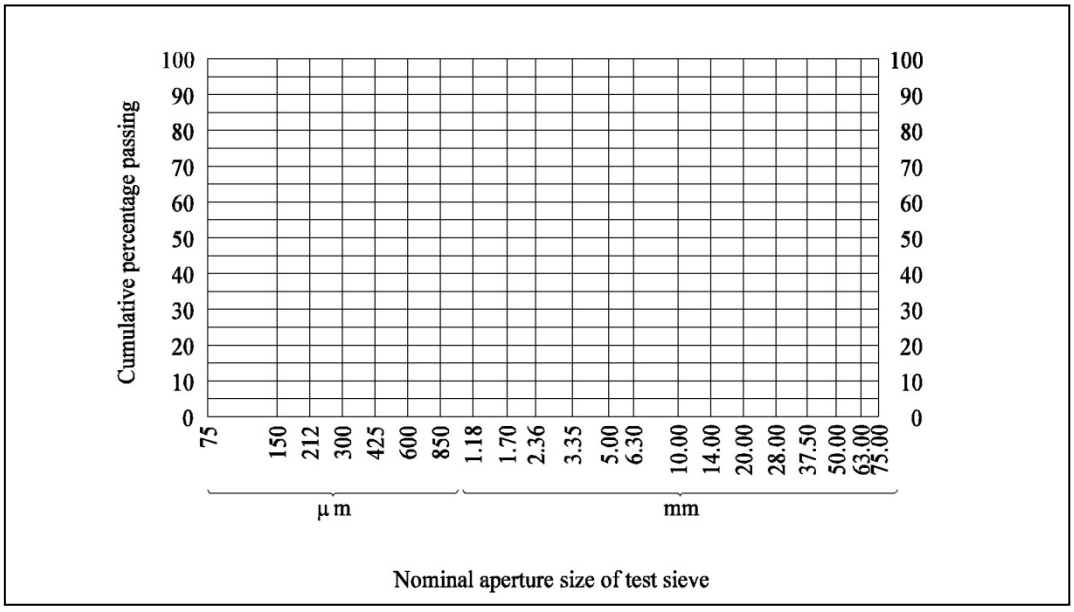


Figure 10.1 - Chart for recording sieve analysis results

(c) The method used by reference to either Cl. 10.6.2 or Cl. 10.6.3 of this Section.

(d) Whether or not lumps of material not representative of the bulk, such as clay lumps, were found to be present and the test sieve sizes on which they were retained, together with the total amount present expressed as an overall percentage by mass of the total sample.

SECTION 11

METHOD FOR DETERMINATION OF FLAKINESS INDEX

11.1 SCOPE

This Section describes the method for determining the flakiness index of coarse aggregates.

11.2 PRINCIPLE

Aggregate particles are classified as flaky when they have a thickness (smallest dimension) of less than 0.6 of their mean test sieve size, this size being taken as the mean of the limiting sieve apertures used for determining the size fraction in which the particles occur. The flakiness index of an aggregate sample is determined by separating the flaky particles and expressing their mass as a percentage of the mass of the sample tested. The test is inapplicable to material passing a 6.3 mm test sieve or retained on a 63 mm test sieve.

11.3 SAMPLING

The laboratory sample shall be taken in accordance with the procedure described in Section 8 of this Standard.

11.4 APPARATUS

The following apparatus is required:

(a) Sample divider

(b) Ventilated oven

The ventilated oven shall be capable of being thermostatically controlled to maintain a temperature of 105 ± 5ºC.

(c) Balance(s)

The balance(s) shall be of suitable capacity accurate to 0.1% of the mass of the test portion.

(d) Test sieves

(e) Mechanical sieve shaker (optional)

(f) Trays

The trays shall be of suitable size, which can be heated in the ventilated oven without damage or change in mass.

(g) Metal thickness gauge

The gauge shall be of the pattern shown in Figure 11.1 or similar, or special sieves having elongated apertures. Special sieves for each aggregate size fraction shall have elongated apertures of the dimensions shown in Figure 11.1 for the relevant size fraction. The width and length of the apertures in the thickness gauge and in the sieves

shall be within the tolerances given in Table 11.2. The gauge shall be made from 1.5 mm thick sheet steel.

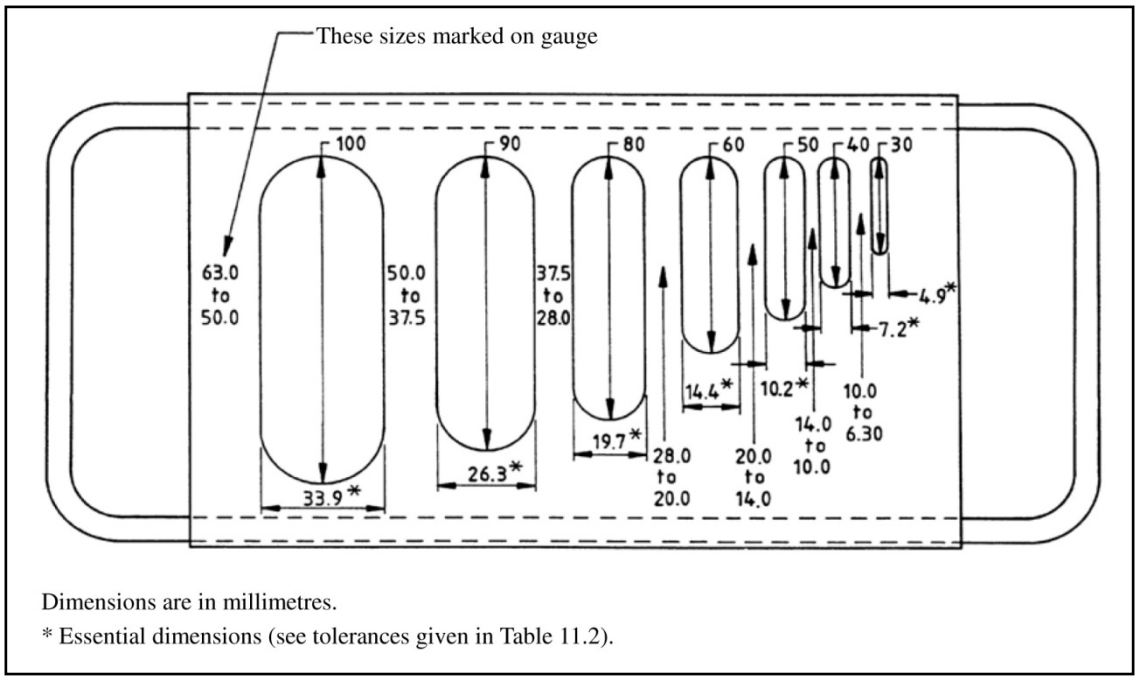


Figure 11.1 - Thickness gauge

NOTE: *All apparatus shall comply with the general requirements of Section 7 of this Standard.*

11.5 PREPARATION OF TEST PORTION

The laboratory sample shall be reduced by the procedure described in Cl. 8.6 of Section 8 of this Standard to produce a test portion that complies with Table 11.1 with due allowance for the later rejection of particles retained on a 63 mm test sieve and particles passing a 6.3 mm test sieve. The test portion shall be heated in the oven to achieve constant dry mass. It shall be allowed to cool to the room temperature and shall then be weighed.

Table 11.1 - Minimum mass of test portion for determination of flakiness index

Nominal size of material (mm)	**Minimum mass of test portion after rejection of oversize and undersize particles** (kg)
50	35
40	15
28	5
20	2
14	1
10	0.5

11.6 PROCEDURE

A sieve analysis shall be carried out in accordance with Cl. 10.6.3 of Section 10 of this Standard using the test sieves given in Table 11.2. All aggregates retained on the 63 mm test sieve and all aggregates passing the 6.3 mm test sieve shall be discarded.

NOTE 1: *For aggregates which may contain clay or other materials likely to cause agglomeration of particles, a sieve analysis in accordance with Cl. 10.6.2 of Section 10 of this Standard should be used.*

Table 11.2 - Data for determination of flakiness index

Aggregate size-fraction		**Width of slot in thickness gauge or special sieve**	**Minimum mass for subdivision**
Test sieve nominal aperture size			
100% passing (mm)	100% retained (mm)	(mm)	(kg)
63	50	33.9 ± 0.3	50
50	37.5	26.3 ± 0.3	35
37.5	28	19.7 ± 0.3	15
28	20	14.4 ± 0.15	5
20	14	10.2 ± 0.15	2
14	10	7.2 ± 0.1	1
10	6.3	4.9 ± 0.1	0.5

Each of the individual size fractions retained on the test sieves, other than the 63 mm test sieve, shall be weighed, and they shall be stored in separate trays with their size marked on the trays.

NOTE 2: *Where the mass of any size fraction exceeds the minimum mass given in Table 11.2, the fraction may be subdivided by the methods described in Section 8 of this Standard, provided that the mass of the subdivided fraction is not less than half of the minimum mass given in Table 11.2. Under such circumstances, the rest of the procedure should be suitably modified and the appropriate correction factor applied to determine the mass of flaky particles that would have been obtained had the whole of the original size fraction been gauged.*

From the sums of the masses of the size fractions in the trays (M_1), the individual percentages of the size fractions retained on each of the various test sieves shall be calculated. Any size fraction whose mass is 5% or less of mass (M_1) shall be discarded. The mass remaining (M_2) shall be recorded.

Each size fraction shall be gauged by using either of the following procedures:

(a) In using the special sieves, the special sieve (see Cl. 11.4 (g)) appropriate to the size fraction under test shall be selected. The whole of the size fraction shall be placed into the sieve and the sieve shall be shaken until the majority of the flaky particles have passed through the slots. Then the particles retained shall be gauged by hand.

(b) In using the gauge, the thickness gauge (see Cl. 11.4 (g)) appropriate to the size fraction under test shall be selected and each particle of that size fraction shall be gauged separately by hand.

All the particles passing each of the gauges shall be combined and weighed to obtain a total mass (M_3).

NOTE 3: *If required, a flakiness index may be determined separately for individual size fractions by recording separately the masses of the individual size fractions and the masses of each size fraction passing the appropriate gauges.*

11.7 CALCULATION AND EXPRESSION OF RESULTS

The flakiness index shall be calculated to the nearest whole number from the following equation:

$$Flakiness\ \ index = \frac{M_3}{M_2} \times 100$$

where

M_2 is the sum of the masses of size fractions that have a mass greater than 5% of the total mass; and

M_3 is the mass of all the flaky particles.

NOTE: *When the flakiness index has been determined for individual size fractions (see note 3 to Cl. 11.6), the overall flakiness index of the aggregate is calculated by summing the appropriate masses or as the weighted average of the individual size fractions.*

11.8 TEST REPORT

The report shall affirm that the flakiness index was determined in accordance with this Section of the Standard and whether or not a copy of the certificate of sampling is available. If available, a copy of the sampling certificate shall be provided. The test report shall contain the following additional information:

(a) Sample identification.

(b) Flakiness index.

(c) Sieve analysis obtained from this test.

SECTION 12

METHOD FOR DETERMINATION OF ELONGATION INDEX

12.1 SCOPE

This Section describes the method for determining the elongation index of coarse aggregates.

12.2 PRINCIPLE

Aggregate particles are classified as elongated when they have a length (greatest dimension) of more than 1.8 of their mean test sieve size, this size being taken as the mean of the limiting sieve apertures used for determining the size fraction in which the particles occur. The elongation index is determined by separating the elongated particles and expressing their mass as a percentage of the mass of sample tested. The test is inapplicable to material passing a 6.3 mm test sieve or retained on a 50 mm test sieve.

12.3 SAMPLING

The laboratory sample shall be taken in accordance with the procedures described in Section 8 of this Standard.

12.4 APPARATUS

The following apparatus is required:

(a) Sample divider

(b) Ventilated oven

The ventilated oven shall be capable of being thermostatically controlled to maintain a temperature of 105 ± 5ºC.

(c) Balance(s)

The balance(s) shall be of suitable capacity accurate to 0.1% of the mass of the test portion.

(d) Test sieves

(e) Mechanical sieve shaker (optional)

(f) Trays

The trays shall be of suitable size, which can be heated in the ventilated oven without damage or change in mass.

(g) Metal length gauge

The gauge shall be of the pattern shown in Figure 12.1.

NOTE: *It is not mandatory to incorporate a hardwood base; other durable materials may be used to form a stable base for the metal length gauge.*

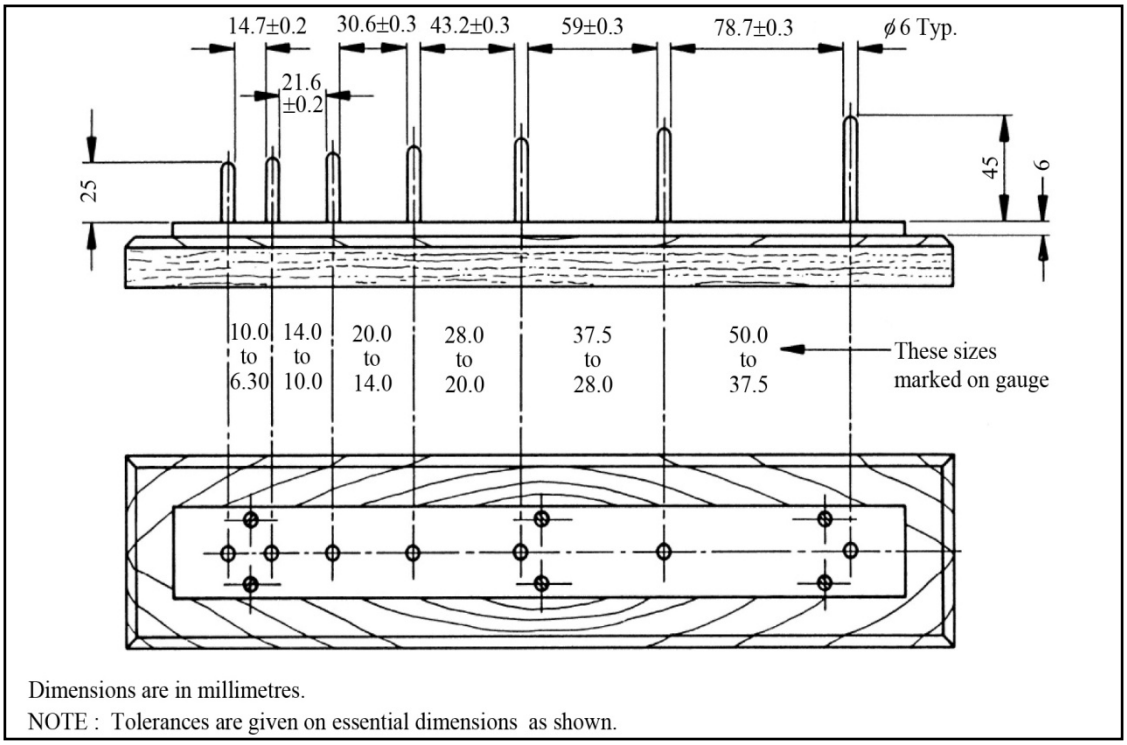


Figure 12.1 - Metal length gauge

NOTE: *All apparatus shall comply with the general requirements of Section 7 of this Standard.*

12.5 PREPARATION OF TEST PORTIONS

The laboratory sample shall be reduced by the procedures described in Cl. 8.6 of Section 8 of this Standard to produce a test portion that complies with Table 12.1 with due allowance for the later rejection of particles retained on a 50 mm test sieve and particles passing a 6.3 mm test sieve. The test portion shall be heated in the oven to achieve constant dry mass. It shall be allowed to cool to room temperature and shall then be weighed.

Table 12.1 - Minimum mass of test portion for determination of elongation index

Nominal size of material (mm)	**Minimum mass of test portion after rejection of oversized and undersized particles** (kg)
40	15
28	5
20	2
14	1
10	0.5

12.6 PROCEDURE

A sieve analysis shall be carried out in accordance with Cl. 10.6 of Section 10 of this Standard using the test sieves given in Table 12.2. All aggregate retained on the 50 mm test sieve and all the aggregate passing the 6.3 mm test sieve shall be discarded.

Each of the individual size fractions retained on the test sieves, other than the 50 mm test sieve, shall be weighed and they shall be stored in separate trays with their size marked on the trays.

NOTE 1: *Where the mass of any size fraction exceeds the minimum mass given in Table 12.2, the fraction may be subdivided by the methods described in Section 8 of this Standard, provided that the mass of the subdivided fraction is not less than half of the minimum mass given in Table 12.2. Under such circumstances, the rest of the procedure should be suitably modified and the appropriate correction factor applied to determine the mass of elongated particles that would have been obtained had the whole of the original size fraction been gauged.*

The individual percentage retained on each of the various test sieves shall be calculated from the sums of the masses of the size fractions in the trays (M_1). Any size fraction whose mass is 5% or less of mass (M_1) shall be discarded. The mass remaining (M_2) shall be recorded.

Each size fraction shall be gauged as follows. The length gauge appropriate to the size fraction under test (see Table 12.2) shall be selected and each particle shall be gauged separately by hand. Elongated particles are those whose greatest dimension prevents them from passing through the gauge, and these particles are placed to one side.

All the elongated particles shall be combined and weighed to give a total mass (M_3).

NOTE 2: *If required, an elongation index may be determined separately for individual size fractions by reporting separately the masses of each of the individual size fractions and the masses of elongated particles in each size fraction.*

Table 12.2 - Data for determination of elongation index

Aggregate size fraction		**Gap between pins of length gauge***	**Minimum mass for subdivision**
Test sieve			
100% passing (mm)	100% retained (mm)	(mm)	(kg)
50	37.5	78.7 ± 0.3	35
37.5	28	59.0 ± 0.3	15
28	20	43.2 ± 0.3	5
20	14	30.6 ± 0.3	2
14	10	21.6 ± 0.2	1
10	6.3	14.7 ± 0.2	0.5
* This dimension is equal to 1.8 times the mean test sieve size.			

12.7 CALCULATION AND EXPRESSION OF RESULTS

The value of the elongation index shall be calculated to the nearest whole number from the following equation:

$$Elongation\ \ index = \frac{M_3}{M_2} \times 100$$

where

M_2 is the sum of the masses of size fractions that have a mass greater than 5% of the total mass; and

M_3 is the mass of all the elongated particles.

12.8 TEST REPORT

The test report shall affirm that the elongation index was determined in accordance with this Section of the Standard and whether or not a copy of the certificate of sampling is available. If available, a copy of the sampling certificate shall be provided. The test report shall contain the following additional information:

(a) Sample identification.

(b) Elongation index.

(c) Sieve analysis obtained from this test.

SECTION 13

METHOD FOR DETERMINATION OF METHYLENE BLUE VALUE

13.1 SCOPE

This Section describes the method for determining the methylene blue value for fine natural aggregate.

13.2 PRINCIPLE

Increments of a dye solution of methylene blue are added successively to a suspension of the test portion of fine aggregate in water. The adsorption of dye solution by the test portion is checked after each addition of the dye solution by conducting a stain test on filter paper to detect the presence of free dye.

When the presence of free dye is confirmed, the methylene blue value is calculated and expressed as grams of dye adsorbed per kilogram of the fine aggregate tested.

13.3 REAGENTS

The following reagents are required:

(a) Dye solution is a solution of standard or technical quality methylene blue, 10.0 ± 0.1 g/L (see Cl. 13.7.1). The maximum period of use of the solution shall be 28 days and the solution shall be stored away from light.

(b) Distilled water.

13.4 SAMPLING

The laboratory sample shall be taken in accordance with the procedures described in Section 8 of this Standard.

13.5 APPARATUS

The following apparatus is required:

(a) Burette

The burette shall have a capacity of either 100 mL or 50 mL and graduation of either 1/10 mL or 1/5 mL, or one 5 mL and one 2 mL micro-pipette.

(b) Filter paper

The filer paper shall be quantitative and ash-free (< 0.01 %), 95 g/m^2, thickness 0.2 mm, filtration speed Herzberg 340 s and pore size 8 µm.

(c) Glass rod

The glass rod shall be 300 mm in length and 8 mm in diameter.

(d) Impeller agitator

The impeller agitator shall be capable of providing controlled variable rates up to 600 ± 60 r/min with three or four impeller blades of 75 ± 10 mm diameter.

(e) Balance

The balance shall be readable to 0.1 % of the mass to be weighed.

(f) Stopwatch or stopclock

The stopwatch or stopclock shall be readable to 1 s.

(g) Test sieve

A metal wire cloth test sieve of aperture size of 2.36 mm shall be provided.

(h) Beaker, glass or plastic

The beaker, glass or plastic, shall be of capacity about 1 L.

(i) Flask or glass

The flask or glass shall be of capacity 1 L.

(j) Ventilated oven

The over shall be thermostatically controlled to maintain a temperature of 100 ± 5ºC or 105 ± 5ºC depending on the requirement.

(k) Thermometer

The thermometer shall be readable to 1ºC.

(l) Spatula

(m) Desiccator

NOTE: All *apparatus shall comply with the general requirements of Section 7 of this Standard.*

13.6 PREPARATION OF TEST PORTION

The laboratory sample shall be reduced using sample reduction procedure described in Cl. 8.6 of Section 8 of this Standard to produce a sub-sample with about 400 g. The sub-sample shall be sieved through a 2.36 mm test sieve and the particles passing the 2.36 mm test sieve shall then be heated in an oven to achieve constant dry mass. The test portion obtained from this dried sub-sample shall have a dry mass (M_1) of 200 ± 0.1 g.

13.7 PROCEDURE

13.7.1 Preparation of 10 g/L methylene blue solution

(a) Methylene blue ($C_{16}H_{18}ClN_3S \cdot 3H_2O$ purity ≥ 95 %) shall be used.

(b) The water content (W) of the methylene blue powder shall be determined as follows:

(1) Approximately 5 g of methylene blue powder shall be weighed and the mass (M_h) shall be recorded to the nearest 0.01 g.

(2) The powder shall be heated in an oven at 100 ± 5ºC to achieve constant dry mass, cooled in the desiccator, and weighed immediately after taking out of the desiccator. The dry mass (M_g) shall be recorded to the nearest 0.01 g.

NOTE: *Methylene blue powder can be modified at temperature above 105ºC.*

(3) The water content (W) shall be calculated as a percentage to the first decimal point from the following equation:

$$W = \frac{M_h - M_g}{M_g} \times 100$$

where

M_h is the mass of the methylene blue powder (in g); and
M_g is the mass of the dried methylene blue powder (in g).

(4) The water content shall be determined for preparation of every new batch of dye solution.

(c) A mass of methylene blue powder of ((100 + W)/10) ± 0.01 g (equivalent to 10 g of dry powder) shall be taken.

(d) 600 mL of distilled water in a beaker shall be warmed to a temperature of 35ºC to 40ºC.

(e) The contents of the beaker shall be agitated whilst slowly pouring the methylene blue powder into the warm water. The agitation shall continue for 40 min until complete dissolution of the powder, and the contents of the beaker shall then be allowed to cool to 20ºC.

(f) The contents of the beaker shall be poured into a flask of capacity 1 L and the beaker shall be rinsed with distilled water to ensure complete transfer of all dye into the flask. Check shall be made to ensure that the flask and the water are at a temperature of 20 ± 1ºC to conform with the calibration of the flask. More distilled water shall be added to the flask to the 1 L graduation mark.

(g) The flask shall be shaken to ensure complete dissolution of the powder and the contents of the flask shall be poured into a conservation bottle in tinted glass.

(h) The following details shall be marked on the conservation bottle:

(1) 10 g/L methylene blue solution;

(2) date of preparation; and

(3) limit date of use.

(i) Methylene blue solution shall not be used more than 28 days after preparation and the stock of methylene blue solution shall be stored in a dark place.

13.7.2 Preparation of suspension

(a) 500 ± 5 mL of distilled water shall be placed in the beaker and the dried test portion shall then be added to the beaker, stirring well with the spatula.

(b) The dye solution (see Cl. 13.3 (a)) shall be stirred thoroughly. The burette shall be filled with the dye solution and the stock of the dye solution shall be returned to a dark place.

(c) The agitator shall be set to a speed of 600 r/min and the impeller shall be positioned about 10 mm above the base of the beaker.

(d) The agitator shall be switched on together with the stopwatch started. The contents of the beaker shall be agitated for 5 min at 600 ± 60 r/min and agitation shall continue at 400 ± 40 r/min for the remainder of the test.

13.7.3 Stain test

(a) The dye solution shall be added to the beaker containing the suspension of the test portion by using the burette. A drop of the suspension of the test portion shall be taken by means of the glass rod and shall be deposited on the filter paper. This will result in stain in the filter paper, comprising of a central deposit of material (with a generally solid blue colour) surrounded by a colourless wet zone.

(b) The amount of drop of the suspension taken shall be such that the diameter of the central deposit is between 8 mm and 12 mm.

(c) The test is deemed to be positive if a halo consisting of a persistent light blue ring with a width of about 1 mm is formed in the wet zone around the central deposit.

NOTE: *As the end-point for the reaction is approached, the halo will appear, but can then disappear again, because the clay minerals can take some time to complete their adsorption of the dye solution. For this reason the end-point should be confirmed by repeating the stain test at 1 min intervals for 5 min without adding more dye solution.*

13.7.4 Determination of the quantity of dye adsorbed

(a) The filter paper shall be placed on top of an empty beaker, or some other suitable support, so that most of its surface is not in contact with any solid or liquid.

(b) After agitating for 5 min. at 600 ± 60 r/min, a dose of 5 mL of dye solution (see Cl. 13.3 (a)) shall be injected into the beaker; which shall then be agitated at 400 ± 40 r/min for at least 1 min. A stain test (see Cl. 13.7.3) shall be carried out on the filter paper. If after the addition of this 5 mL of dye solution the halo does not appear, a further 5 mL of dye solution shall be added with agitation continued for 1 min. Another stain test shall then be carried out. If a halo still does not appear, agitation shall continue in conjunction with the additions of dye and performing further stain tests until a halo is observed. When this stage is reached, agitation shall continue and without further additions of dye solution, stain tests shall be performed at 1 min intervals.

(c) If the halo disappears during the first 4 min, a further 5 mL of dye solution shall be added. If the halo disappears during the fifth minute, only 2 mL of dye solution shall be added. In either case, agitation and performing stain tests shall continue until a halo persists for 5 min.

(d) The total volume of dye solution (V_1) added to produce a halo that persists for 5 min shall be recorded to the nearest 1 mL.

NOTE: *Containers shall be cleansed thoroughly with water as soon as the tests are completed. Traces of any detergents used shall be removed by thoroughly rinsing. It is recommended to reserve containers used in methylene blue tests specifically for that test.*

13.8 CALCULATION AND EXPRESSION OF RESULTS

The methylene blue value (*MBV*) shall be expressed in grams of dye per kilogram of the fine aggregate to the first decimal place and shall be calculated from the following equation:

$$MBV = \frac{V_1}{M_1} \times 10$$

where

M_1 is the mass of the test portion (in g);
V_1 is the total volume of dye solution added (in mL); and
10 is the density factor for converting the volume of the dye solution used to the mass of dye adsorbed per kilogram of the fine aggregate tested.

13.9 TEST REPORT

The report shall affirm that the methylene blue value for fine aggregates was determined in accordance with this Section of the Standard and whether or not a copy of the certificate of sampling is available. If available, a copy of the sampling certificate shall be provided. The test report shall contain the following additional information:

(a) Sample identification.

(b) Description of the material tested.

(c) Date on receipt of sample.

(d) The methylene blue value of the tested sample.

(e) Date of test.

SECTION 14

METHOD FOR DETERMINATION OF LOS ANGELES VALUE

14.1 SCOPE

This Section describes the method for determining the Los Angeles value of coarse natural aggregate which gives a relative measure of the resistance to degradation of the aggregate by abrasion, impact and grinding in the Los Angeles machine.

The method applies to the coarse natural aggregate having a nominal maximum size smaller than 37.5 mm.

NOTE: *This test method has been widely used as an indicator of the relative quality or competence of various sources of aggregate having similar mineral compositions. The results do not automatically permit valid comparisons to be made between sources distinctly different in origin, structure, or composition. Specification limits based on this test method should be assigned with extreme care in consideration of available aggregate types and their performance history in specific end uses.*

14.2 PRINCIPLE

This test method is a measure of degradation of mineral aggregates of standard gradings resulting from a combination of actions including abrasion or attrition, impact, and grinding in a rotating steel drum containing a specified number of steel spheres, the number depending upon the grading of the test sample. As the drum rotates, a shelf plate picks up the test sample and the steel spheres, carrying them around until they are dropped to the opposite side of the drum, creating an impact-crushing effect. The contents then roll within the drum with an abrading and grinding action until the shelf plate picks up the test sample and the steel spheres, and the cycle is repeated. After the prescribed number of revolutions, the contents are removed from the drum and the test portion is sieved to measure the degradation as percent loss.

14.3 SAMPLING

The laboratory sample shall be taken in accordance with the procedure described in Section 8 of this Standard.

14.4 APPARATUS

The following apparatus is required:

(a) Los Angeles machine

The Los Angeles machine shall be of the general form as shown in Figure 14.1. The machine shall be so counterbalanced and so driven as to maintain a substantially uniform peripheral speed. If an angle is used as the shelf, the direction of rotation shall be such that the steel spheres are caught on the outside surface of the angle.

NOTE: *Back-lash or slip in the driving mechanism is very likely to provide test results which are not duplicated by other Los Angeles machines producing constant peripheral speed.*

The machine shall comprise the parts described as follows:

(1) **A hollow steel cylinder**, with a wall thickness of not less than 12.4 mm closed at both ends, shall have an inside diameter of 711 ± 5 mm, and an inside length of 508 ± 5 mm. The interior surface of the cylinder shall be free from protrusions disrupting the path of the test sample and steel spheres except for the shelf described below. The cylinder shall be mounted on stub shafts attached to the ends of the cylinder but not entering it. The cylinder shall be mounted in such a manner that it rotates with the axis in a horizontal position within a tolerance in slope of 1 in 100. An opening in the cylinder shall be provided for the insertion of the test sample.

(2) **A dust-tight cover** shall be provided for the opening with means for bolting the cover in place. The cover shall be so designed as to maintain the cylindrical contour of the interior surface unless the shelf is so located that the steel spheres will not fall on the cover, or come in contact with it during the test.

(3) **A removable steel shelf** shall extend the full length of the cylinder and shall project inward 89 ± 2 mm. The shelf shall be mounted on the interior cylindrical surface of the cylinder, in such a way that a plane centered between the large faces coincides with an axial plane. The shelf shall be of such thickness and so mounted, by bolts or other suitable means, as to be rigid and firm. The position of the shelf shall be such that the test sample and the steel spheres shall not impact on or near the opening and its cover, and that the distance from the shelf to the opening, measured along the outside circumference of the cylinder in the direction of rotation, shall be not less than 1,270 mm. The shelf shall be inspected periodically to determine that it is not bent either lengthwise or from its normal radial position with respect to the cylinder. If either condition is found, replace or repair the shelf before further tests are conducted.

NOTE: *The use of a shelf of rectangular in cross section, wear-resistant steel and mounted independently of the cover, is preferred. However, a shelf consisting of a section of rolled angle, properly mounted on the inside of the cover plate, may be used provided the direction of rotation is such that the steel spheres will be caught on the outside face of the angle.*

(b) Steel spheres

Steel spheres shall be averaging approximately 46.8 mm in diameter and each having a mass of between 390 g and 445 g.

(c) Test sieves

(d) Balance

The balance shall have a capacity of not less than 6,000 g and shall be readable to 0.1 g.

(e) Ventilated oven

The ventilated oven shall be capable of being thermostatically controlled to maintain a temperature of 105 ± 5ºC.

(f) Soft brush

Brush shall have fine-haired of about 3 mm diameter.

NOTE: *All apparatus shall comply with the general requirements of Section 7 of this Standard.*

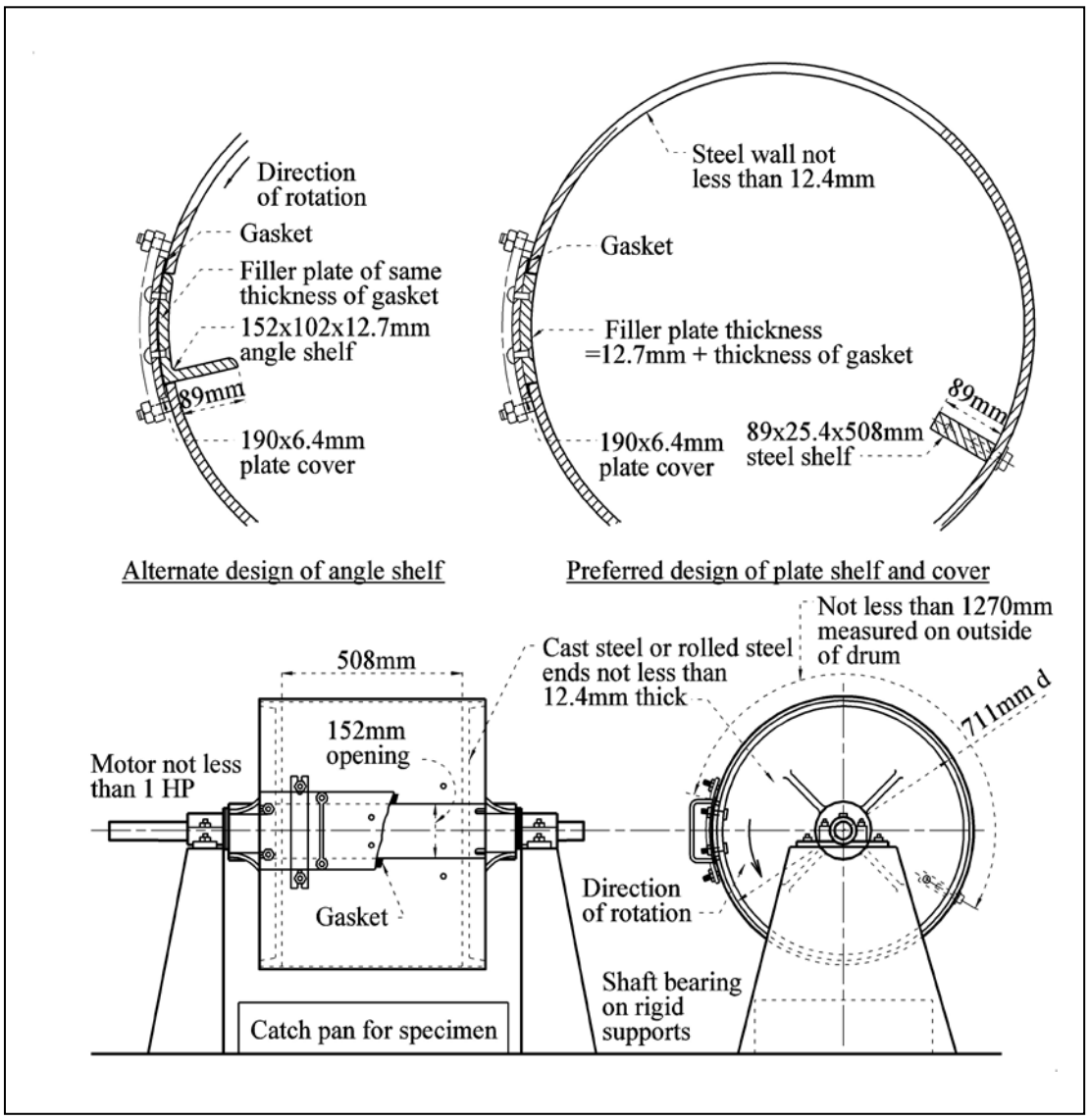


Figure 14.1 - Los Angeles machine

14.5 PREPARATION OF TEST PORTIONS AND SPECIMENS

14.5.1 Test portions

The laboratory sample shall be reduced using sample reduction procedure described in Cl. 8.6 of Section 8 of this Standard to produce a test portion of sufficient mass for one test specimen complying to one of the grading designation in Table 14.1.

The test portion shall be washed to remove surface dust and heated in an oven to achieve constant dry mass, and then cooled to room temperature. The test portion shall then be sieved into individual size fractions, and recombined to form a test specimen to the grading designation of Table 14.1 most nearly corresponding to the range of aggregate sizes in the sample.

14.5.2 Test specimens

The mass of the test specimen shall be adjusted until its total mass is 5,000 ± 10 g. The specimen shall be weighted and recorded to the nearest 1 g prior to test.

Table 14.1 - Grading designation of test specimen for determination of Los Angeles value

Sieve size (mm)		**Mass of indicated sizes** (g)			
Passing	Retained on	Grading designation			
		A	B	C	D
37.5	28	1,250 ± 25	-	-	-
28	20	1,250 ± 25	-	-	-
20	14	1,250 ± 10	2,500 ± 10	-	-
14	10	1,250 ± 10	2,500 ± 10	-	-
10	6.3	-	-	2,500 ± 10	-
6.3	5	-	-	2,500 ± 10	-
5	2.36	-	-	-	5,000 ± 10
	Total	5,000 ± 10	5,000 ± 10	5,000 ± 10	5,000 ±10

14.6 PROCEDURE

Depending upon the grading designation of the specimen, the appropriate numbers of steel spheres shall be selected from Table 14.2.

Table 14.2 - Steel spheres for determination of Los Angeles value

Grading designation	**Number of spheres**	**Mass of spheres** (g)
A	12	5,000 ± 25
B	11	4,584 ± 25
C	8	3,330 ± 20
D	6	2,500 ± 15

NOTE 1: *Steel ball bearings 46.0 mm and 47.6 mm in diameter, having a mass of approximately 400 and 440 g each, respectively, are readily available. Steel spheres 46.8 mm in diameter having a mass of approximately 420 g may also be obtainable. The steel spheres may consist of a mixture of these sizes conforming to the mass tolerances of Cl. 14.4 (b) and Table 14.2.*

The test specimen and the steel spheres shall be placed in the Los Angeles testing machine and the machine shall be rotated at a speed of 30 to 33 r/min for 500 revolutions.

After the prescribed number of revolutions, the material shall be discharged from the machine and a preliminary separation of the sample shall be made on a 2.36 mm sieve. The finer portion shall be sieved on a 1.7 mm sieve.

The material coarser than the 1.7 mm shall be washed and oven-dried at 105 ± 5°C to substantially constant mass and the material shall be weighed and recorded to the nearest 1 g.

NOTE 2: *If the aggregate is essentially free of adherent dust and coatings, the requirement for washing after the test is optional. However, in the case of dispute, the washing procedure shall be performed.*

14.7 CALCULATIONS AND EXPRESSION OF RESULTS

The Los Angeles value (*LAV*) shall be calculated as a percentage loss to the nearest whole number from the following equation:

$$LAV = \frac{m_1 - m_2}{m_1} \times 100$$

where

m_1 is the original mass of the test specimen (in g); and
m_2 is the mass of the material retained on 1.7 mm test sieve (in g).

14.8 TEST REPORT

The report shall affirm that the Los Angeles value of the aggregate was determined in accordance with this Section of the Standard and whether or not a certificate of sampling is available. If available, a copy of the sampling certificate shall be provided. The test report shall contain the following additional information:

(a) Sample identification and sample description.

(b) The grading designation from Table 14.1 used for the test.

(c) The Los Angeles value of the aggregate.

SECTION 15

METHODS FOR DETERMINATION OF AGGREGATE IMPACT VALUE

15.1 SCOPE

This Section describes methods for determining the aggregate impact value of coarse natural aggregate which gives a relative measure of the resistance of the aggregate to sudden shock or impact.

Two procedures are covered, one in which the aggregate is tested in a dry condition, and the other in a soaked condition.

The methods are applicable to aggregates passing a 14 mm test sieve and retained on a 10 mm test sieve. For smaller size fractions, a recommended method is described in Cl. 15.9. Aggregate sizes larger than 14 mm are inappropriate to the aggregate impact value test.

15.2 PRINCIPLE

A test specimen is compacted into an open steel cup in a standardized manner and is then subject to a number of standard impacts from a dropping weight. This action breaks the aggregate to a degree which depends on the impact resistance of the material. The degree of breaking is assessed by a sieving test on the impacted specimen and is taken as the aggregate impact value.

15.3 SAMPLING

The laboratory sample shall be taken in accordance with the procedure described in Section 8 of this Standard.

15.4 APPARATUS

The following apparatus is required:

(a) Impact testing machine

The machine shall be of the general form as shown in Figure 15.1, have a total mass of between 45 kg and 60 kg and shall comprise the following parts:

(1) Circular metal base

The metal base shall have a mass of between 22 kg and 30 kg, with a plane lower surface of not less than 300 mm diameter and shall be supported on a level and plane concrete or stone block floor at least 450 mm thick. The machine shall be prevented from rocking either by supporting it on a level and plane metal plate cast into the surface of the block or floor, or by fixing it to the block or floor.

(2) Cylinder steel cup

The steel cup shall have an internal diameter of 102 ± 0.5 mm and an internal depth of 50 ± 0.25 mm. The walls of the cup shall be not less than 6 mm thick and

the inner surfaces shall be case hardened. The cup shall be rigidly fastened at the centre of the base and shall be easily removed for emptying.

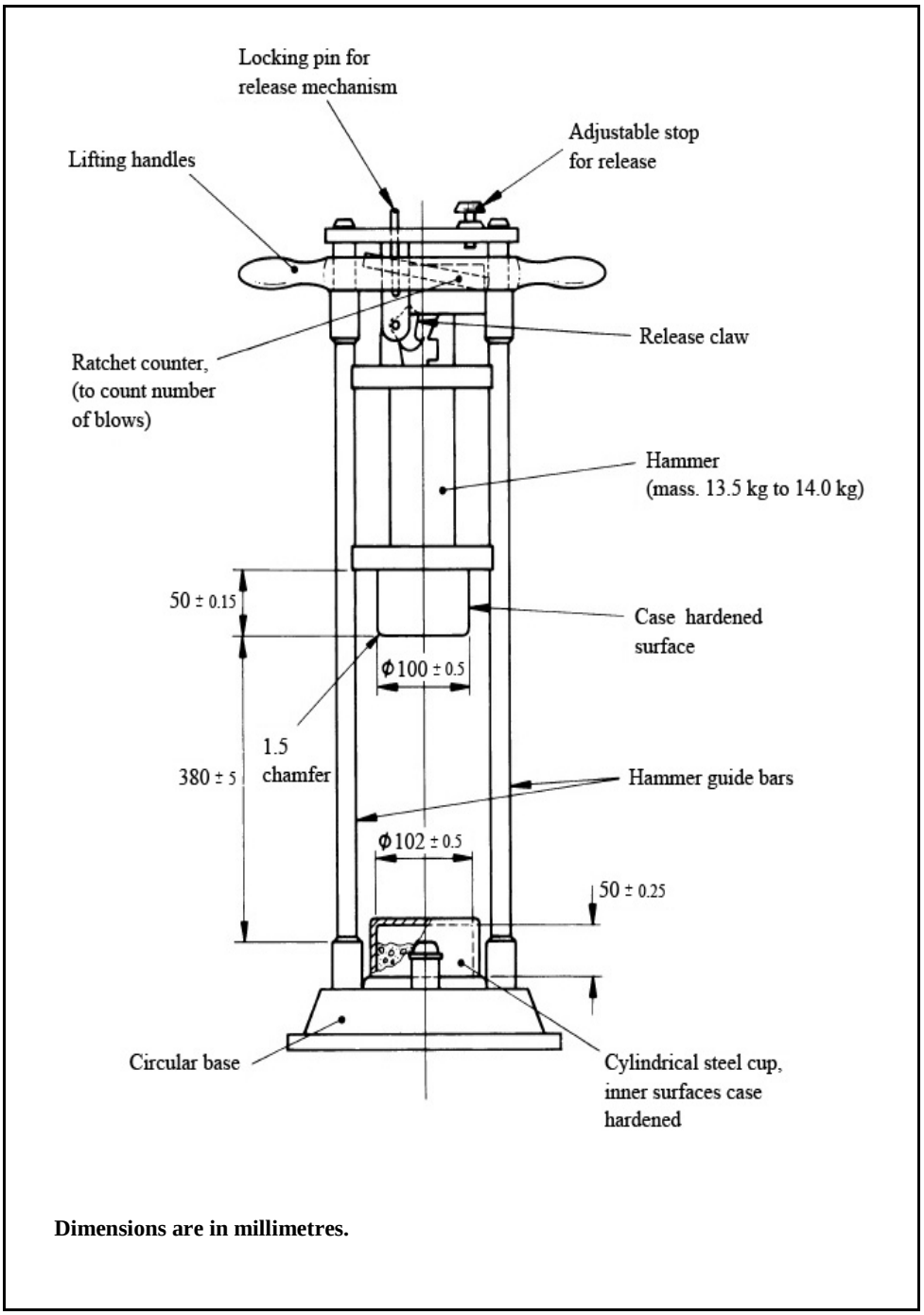


Figure 15.1 - Aggregate impact test machine

(3) Metal hammer

The metal hammer shall have a mass of between 13.5 kg and 14.0 kg, the lower end of which shall be cylindrical in shape, 100.0 ± 0.5 mm diameter and 50 ± 0.15 mm long, with a 1.5 mm chamfer at the lower edge, and case hardened. The hammer shall slide freely between the vertical guides so arranged that the lower (cylindrical) part of the hammer is above and concentric with the cup.

(4) Means for raising hammer

The device shall allow the hammer to fall freely between the vertical guides from a height of 380 ± 5 mm on to the test sample in the cup, and means for adjusting the height of fall within 5 mm.

(5) Means for supporting the hammer

The device shall provide facility to support the hammer, whilst fastening or removing the cup.

NOTE: *It is desirable to have some means for automatically recording the number of blows.*

(b) Test sieves

Square-hole perforated metal plate test sieves of aperture sizes 14 mm and 10 mm, and a metal wire cloth test sieve of aperture size 2.36 mm shall be provided.

(c) Cylindrical metal measure

The device shall be sufficiently rigid to retain its form under rough usage and shall have an internal diameter of 75 ± 1 mm and an internal depth of 50 ± 1 mm.

(d) Tamping rod

The rod shall be made out of straight iron or steel bar of circular cross section, 16 ± 1 mm diameter and 600 ± 5 mm long, with both ends hemispherical.

(e) Balance

The balance shall have capacity not less than 500 g and shall be readable to 0.1 g.

(f) Ventilated oven

The ventilated oven shall be capable of being thermostatically controlled to maintain a temperature of 105 ± 5ºC.

(g) Metal tray

Metal tray shall be large enough to contain 1 kg of aggregate.

(h) Brush

Brush shall have stiff bristles.

(i) Rubber mallet

The following additional apparatus for testing aggregate in a soaked condition is required:

(j) Drying cloths or absorbent paper

The drying cloths or absorbent paper shall be suitable for the surface-drying of the aggregate after it has been soaked in water, e.g. two hand-towels of a size not less than 750 mm × 450 mm or rolls of absorbent paper of suitable size and absorbency.

(k) Wire-mesh basket

One or more wire-mesh baskets shall have apertures not larger than 6.5 mm or a perforated container of convenient size with hangers for lifting purposes.

(l) Stout watertight container

The size of container shall be large enough to hold the basket(s) immersed in water.

(m) Clean water

The water shall be of drinking quality.

NOTE: *All apparatus shall comply with the general requirements of Section 7 of this Standard.*

15.5 PREPARATION OF TEST PORTIONS AND SPECIMENS

15.5.1 Test portions

The laboratory sample shall be reduced using sample reduction procedure described in Cl. 8.6 of Section 8 of this Standard to produce a test portion of sufficient mass for three test specimens of 14 mm to 10 mm size fraction.

NOTE: *A single test specimen is that quantity of material required to fill the cup (see the 1st para. of Cl. 15.6.1 and Table 15.1).*

Table 15.1 - Minimum mass of test portion for determination of aggregate impact value

Grade of the aggregate (mm)	**Minimum mass of the test portion** (kg)
Graded aggregate 40 to 5	12
Graded aggregate 20 to 5	8
Graded aggregate 14 to 5	5

15.5.2 Test specimens in a dry condition

The dried test portion shall be sieved thoroughly on the 14 mm and 10 mm test sieves to remove the oversize and undersize fractions. The resulting 14 mm to 10 mm size fractions shall be divided to produce three test specimens each of sufficient mass to fill the measure (see Cl. 15.4 (c)) when it is filled by the procedure described in the 3rd para. of this clause.

NOTE: *Mechanical sieving shall only be used for aggregates which do not degrade under its action.*

The test specimens shall be heated in an oven to achieve constant dry mass and then cooled to room temperature before testing.

The measure shall be filled to overflow with the aggregate comprising the test specimen by means of a scoop. The aggregate shall be tamped 25 blows with the rounded end of the tamping rod, each blow being given by allowing the tamping rod to fall freely from a height of about 50 mm above the surface of the aggregate and the blows being evenly distributed over the surface. Surplus aggregate shall be removed by rolling the tamping rod across, and in contact with, the top of the container. Any aggregate which impedes its progress shall be removed by hand and any obvious depressions shall be filled with added aggregate. The net mass of aggregate in the measure shall be weighed and the same mass shall be used for the second test specimen.

15.5.3 Test specimens in a soaked condition

The test specimens shall be prepared using the procedure described in Cl. 15.5.2 except that the test portion is tested in the as-received condition and not oven-dried. Each test specimen

(see note of Cl. 15.6.2) shall be placed in the wire basket and immersed in the water in the container with a cover of at least 50 mm of water above the top of the basket. Immediately after immersion, the basket shall be lifted 25 mm above the base of the container and dropped 25 times at a rate of about once a second in order to remove the entrapped air from the specimen. The basket and aggregate shall be kept completely immersed during the operation and for a subsequent period of 24 ± 2 h and the water temperature shall be maintained at 20 ± 5ºC.

After soaking, the specimen of aggregate shall be removed from the basket and the free water on the aggregate surface shall be blotted with absorbent cloths. The test procedure as described in Cl. 15.6.2 shall be carried out immediately after this operation.

15.6 PROCEDURE

15.6.1 Aggregate in a dry condition

The impact machine shall be rested, without wedging or packing, upon the level plate, block or floor, so that it is rigid and the hammer guide columns are vertical. Before fixing the cup to the impact machine, the whole of the test specimen in the cup shall be compacted by 25 strokes of the tamping rod (see the 3rd para. of Cl. 15.5.2). With the minimum of disturbance to the test specimen, the cup shall be firmly fixed in position on the base of the machine. The height of the hammer shall be adjusted so that its lower face is 380 ± 5 mm above the upper surface of the aggregate in the cup and it is then allowed to fall freely on to the aggregate. The test specimen shall be subjected to a total of 15 such blows, each being delivered at an interval of not less than 1 s.

NOTE 1: *No adjustment for hammer height after the first blow is required.*

The crushed aggregate shall be removed by holding the cup over a clean tray and hammering on the outside with the rubber mallet until the particles are sufficiently disturbed to enable the mass of the specimen to fall freely on to the tray.

NOTE 2: *If this fails to remove the compacted aggregate, other methods shall be used but take care not to cause further crushing of the particles.*

NOTE 3: *Mechanical sieving shall only be used for aggregates which do not degrade under its action.*

Fine particles adhering to the side of the cup and the underside of the hammer shall be transferred to the tray by means of the stiff bristle brush. The tray and the aggregate shall be weighed and the mass of aggregate used (M_1) shall be recorded to the nearest 0.1 g.

The whole of the specimen in the tray shall be sieved on the 2.36 mm test sieve until no further significant amount passes during a further period of 1 min. The fractions passing and retained on the sieve shall be weighed and recorded to the nearest 0.1 g (M_2 and M_3 respectively), and if the total mass ($M_2 + M_3$) differs from the initial mass (M_1) by more than 1 g, the result shall be discarded and a further specimen shall be tested.

The procedure as described in the 1st to 3rd para. of this clause shall be repeated inclusively using a second specimen of the same mass as the first specimen.

15.6.2 Aggregate in a soaked condition

The test procedure as described in Cl. 15.6.1 shall be followed except that the number of blows of the hammer to which the aggregate is subjected, is the number of blows which will yield between 5% and 20% of fines when this value is calculated by the procedure given in Cl. 15.7.

NOTE: *The number of blows will usually be less than 15, but the actual number has to be ascertained by a process of trial and error. For this reason, more than two test specimens will almost invariably be required and due allowance should be made for this when preparing the specimen by the procedure given in Cl. 15.5.3. Once the number of blows required had been determined, the procedure is repeated on a second test specimen which is subjected to the same number of blows.*

The crushed specimen shall be removed from the cup and heated in an oven to achieve constant dry mass. The dried material shall be cooled to room temperature and weighed to the nearest gram (M_1). The procedure as described in the 2nd para. of Cl. 15.6.1 starting at the stage where the specimen is sieved on the 2.36 mm test sieve shall be completed.

15.7 CALCULATIONS AND EXPRESSION OF RESULTS

15.7.1 Aggregate in the dry condition

The aggregate impact value (*AIV*) shall be calculated as a percentage to the first decimal place from the following equation:

$$AIV = \frac{M_2}{M_1} \times 100$$

where

M_1 is the mass of the test specimen (in g); and
M_2 is the mass of the material passing the 2.36 mm test sieve (in g).

15.7.2 Aggregate in the soaked condition

The mass of fines (*m*) shall be calculated as a percentage from the following equation:

$$m = \frac{M_2}{M_1} \times 100$$

where

M_1 is the mass of oven-dried test specimen (in g); and
M_2 is the mass of oven-dried material passing the 2.36 mm test sieve (in g).

The aggregate impact value (*AIV*) shall be calculated as a percentage to the first decimal place from the following equation:

$$AIV = \frac{15m}{n}$$

Where

n is the number of hammer blows to which the specimen is subjected.

15.7.3 Results

The mean of the two values determined in Cl. 15.7.1 or 15.7.2 shall be calculated to the nearest whole number. The mean shall be reported as the aggregate impact value, unless the individual results differ by more than 0.15 times the mean value. In this case, the test shall

be repeated on two further specimens, the median of the four results shall be calculated to the nearest whole number, and the median shall be reported as the aggregate impact value.

In the case of tests on aggregate in the soaked condition, the number of hammer blows shall be reported.

NOTE: *The median of the four results is calculated by excluding the highest and the lowest results and calculating the mean of the two middle results.*

15.8 TEST REPORT

The report shall affirm that the aggregate impact value of the dry aggregate and /or soaked aggregate was determined in accordance with this Section of the Standard and whether or not a certificate of sampling is available. If available, a copy of the sampling certificate shall be provided. The test report shall include the following additional information:

(a) Sample identification and sample description.

(b) The condition (dry or soaked) in which the aggregate was tested.

(c) The aggregate impact value of the dry aggregate.

(d) The aggregate impact value of the soaked aggregate and the number of blows of the hammer that was used in the determination.

(e) If the aggregate impact value is greater than 30 %, a statement that the results obtained should be treated with caution.

15.9 RECOMMENDED METHOD FOR DETERMINING THE AGGREGATE IMPACT VALUE FOR OTHER SIZE FRACTIONS OF COARSE NATURAL AGGREGATE

15.9.1 Method

When required, or if the definitive size fraction passing the 14 mm test sieve and retained on a 10 mm test sieve is not available, tests may be made on aggregates of other sizes passing a 14 mm test sieve and retained on 2.36 mm test sieve. Because of the lack of experience of testing sizes other than the definitive size fraction, it has not been possible to provide any positive indication as to how the result obtained on non-standard sizes would compare with those obtained by the standard test procedures. In general, the smaller sizes of aggregate will give a lower value, but the relationship between the values obtained with different sizes may vary from one aggregate to another.

15.9.2 Apparatus

The apparatus shall be as described in Cl. 15.4 together with such additional test sieves that may be necessary to prepare the test portions (see Table 15.2).

Table 15.2 - Particulars of test sieves for testing other size fractions of aggregates

Size fraction	Nominal aperture size of test sieve			
	For preparation of test specimens		For separating fines	
	Passing (mm)	Retained (mm)	(mm)	(μm)
Larger than 14 mm	NA[a]	NA[a]	NA[a]	NA[a]
Standard	14	10	2.36	-
Smaller than standard	10 6.3 5 3.35	6.3 5 3.35 2.36	1.7 1.18 - -	- - 850 600
[a] The test is not applicable (NA).				

15.9.3 Preparation of test portions and specimens

The procedure described in Cl. 15.5, using the appropriate sieves as described in Table 15.2, according to the size of the fraction under test, shall be followed. For a grading of test portions of less than 10 mm maximum size, a minimum mass of 1 kg is needed.

15.9.4 Procedure

The procedure described in Cl. 15.6 using the appropriate separating test sieve given in Table 15.2 shall be followed.

15.9.5 Calculation and expression of results

The general procedure described in Cl. 15.7 shall be followed.

15.9.6 Test report

The test report shall include the information specified in Cl. 15.8, with additionally the size of aggregate tested.

SECTION 16

METHODS FOR DETERMINATION OF TEN PER CENT FINES VALUE

16.1 SCOPE

This Section describes methods for determining the ten per cent fines value of coarse aggregates which gives a relative measure of the resistance of the aggregate to crushing under a gradually applied compressive load.

Two procedures are covered, one in which the aggregate is tested in a dry condition, and the other in a soaked condition.

The methods are applicable to both strong and weak aggregates passing a 14 mm test sieve and retained on a 10 mm test sieve. For other size fractions, a recommended method is described in Cl. 16.9.

16.2 PRINCIPLE

A test specimen is compacted into a steel cylinder fitted with a freely moving plunger in a standardized manner and is then subjected to a load applied through the plunger. This action crushes the aggregate to a degree which depends on the crushing resistance of the material. The degree of crushing is assessed by a sieving test on the crushed specimen and the procedure is repeated with various loads to determine the maximum force which generates a given sieve analysis. This force is taken as the ten per cent fines value.

16.3 SAMPLING

The laboratory sample shall be taken in accordance with the procedure described in Section 8 of this Standard.

16.4 APPARATUS

The following apparatus is required:

(a) Open-ended steel cylinder

Open-ended steel cylinder shall be equipped with a plunger and a baseplate and shall be of the general form and dimensions shown in Table 16.1 and Figure 16.1. It shall have a nominal internal diameter of 150 mm. The surfaces in contact with the aggregate shall be machined and case hardened, or otherwise treated, so as to have a hardness value of not less than 650 HV, in accordance with BS EN ISO 6507-1, and shall be maintained in a smooth condition.

Table 16.1 - Outline form of open-ended steel cylinder (with plunger & baseplate)

Letter symbol	Dimensions for component	Nominal 150 mm internal diameter (mm)	Nominal 75 mm internal diameter (mm)
	Cylinder		
A	Internal diameter	154 ± 0.5	78.0 ± 0.5
B	Internal depth	125 to 140	70.0 to 85.0
C	Minimum wall thickness	16.0	8.0
	Plunger		
D	Diameter of piston	152 ± 0.5	76.0 ± 0.5
E	Diameter of stem	> 95 to ≤ D	> 45.0 to ≤ D
F	Overall length of piston plus stem	100 to 115	60.0 to 80.0
G	Minimum depth of piston	not less than 25.0	not less than 19.0
H	Diameter (nominal) of hole	20.0 ± 0.1	10.0 ± 0.1
	Baseplate		
I	Minimum thickness	10	10
J	Length of each side of square	200 to 230	110 to 115

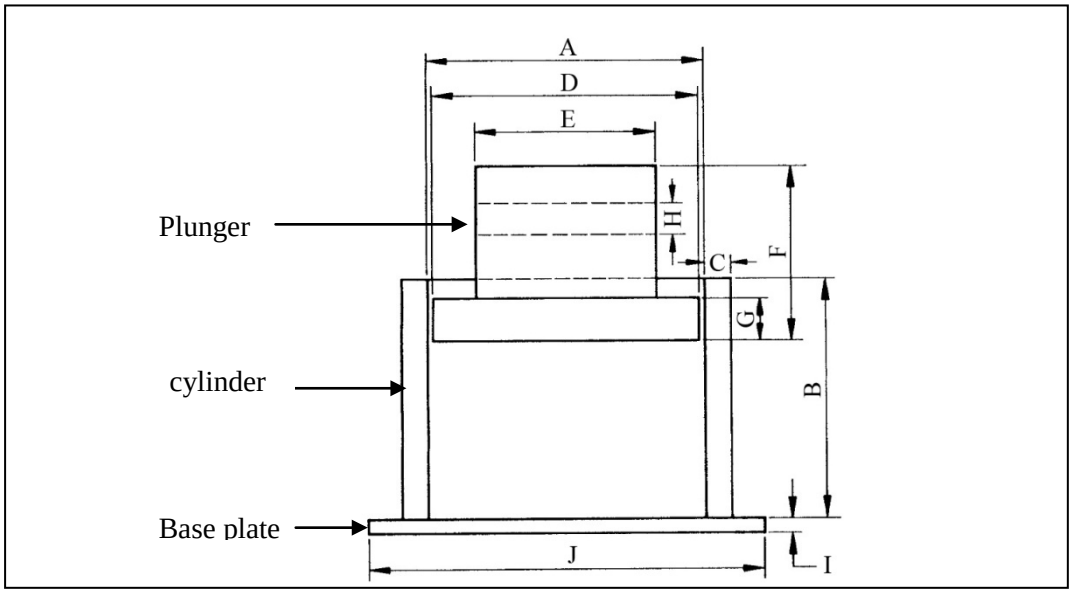


Figure 16.1 - Outline form of open-ended cylinder (with plunger & baseplate)
(see Table 16.1.)

(b) Tamping rod

The rod shall be made out of straight iron or steel bar of circular cross section, 16 ± 1 mm diameter and 600 ± 5 mm long, with both ends hemispherical.

(c) Balance

The balance shall have a capacity of not less than 3 kg and shall be readable to 1g.

(d) Test sieves

Square-hole perforated metal plate test sieves of aperture sizes 14 mm and 10 mm, and a metal wire cloth test sieve of aperture size 2.36 mm shall be provided.

(e) Compression testing machine

The machine shall be capable of applying a compressive force up to 500 kN and shall be capable of being operated to give a uniform rate of loading so that this force is reached in 10 min (see the 3rd para. of Cl. 16.6.1). The machine shall comply with the requirements of CS1 for a class 1 or class 2 machine. The machine may be operated with or without a spherical seating.

(f) Cylindrical metal measure

The device shall be sufficiently rigid to retain its form under rough usage and shall have an internal diameter of 115 ± 1 mm and an internal depth of 180 ± 1 mm.

(g) Ventilated oven

The ventilated oven shall be capable of being thermostatically controlled to maintain a temperature of 105 ± 5ºC.

(h) Rubber mallet

(i) Metal tray

Metal tray shall be large enough to contain 3 kg of aggregate.

(j) Brush

Brush shall have stiff bristles.

(k) Stopwatch

The stopwatch shall be accurate to 1 s in 5 min.

(l) Dial Gauge

The dial gauge shall accurate to 0.5 mm and readable to 0.01 mm.

The following additional apparatus for testing aggregate in a soaked condition is required:

(m) Drying cloths or absorbent paper

The drying cloths or absorbent paper shall be suitable for the surface-drying of the aggregate after it has been soaked in water, e.g. two hand-towels of a size not less than 750 mm × 450 mm or rolls of absorbent paper of suitable size and absorbency.

(n) Wire-mesh basket

One or more wire-mesh baskets shall have apertures not larger than 6.5 mm or a perforated container of convenient size with hangers for lifting purposes.

(o) Stout watertight container

The size of the container shall be large enough to hold the basket(s) immersed in water.

(p) Clean water

The water shall be of drinking quality.

NOTE: *All apparatus shall comply with the general requirements of Section 7 of this Standard.*

16.5 PREPARATION OF TEST PORTIONS AND SPECIMENS

16.5.1 Test portions

The laboratory sample shall be reduced using sample reduction procedure described in Cl. 8.6 of Section 8 of this Standard to produce a test portion of sufficient mass for three test specimens of 14 mm to 10 mm size fraction.

NOTE: *A single test specimen is that quantity of material required to fill the cylinder (see the 1st para. of Cl. 16.6.1 and Table 16.2).*

Table 16.2 - Minimum mass of test portion for determination of ten per cent fines value

Grade of the aggregate (mm)	**Minimum mass of the test portion** (kg)
Graded aggregate 40 to 5	40
Graded aggregate 20 to 5	25
Graded aggregate 14 to 5	15

16.5.2 Test specimens in a dry condition

The entire surface dry test portion shall be sieved thoroughly on the 14 mm and 10 mm test sieves to remove the oversize and undersize fractions. The resulting 14 mm to 10 mm size fractions shall be divided to produce three test specimens with the mass of each specimen such that the depth of the material in the cylinder shall be approximately 100 mm after tamping as described in Cl. 16.6.1.

NOTE 1: *The appropriate quantity of aggregate may be found conveniently by filling the cylindrical measure in three layers of approximately equal depth and each layer shall be tamped 25 times, from a height of approximately 50 mm above the surface of the aggregate, with the rounded end of the tamping rod. The surface of aggregate shall be levelled off using the tamping rod as a straightedge.*

NOTE 2: *Mechanical sieving shall only be used for aggregates which do not degrade under its action.*

The test specimens shall be heated in an oven to achieve constant dry mass and then cooled to room temperature before testing. The mass of material comprising the test specimens shall be recorded.

16.5.3 Test specimens in a soaked condition

The test specimens shall be prepared using the procedure described in the 1st para. of Cl. 16.5.2 except that the test portion is tested in the as-received condition and not oven-dried. Each test specimen shall be placed in the wire basket and immersed in the water in the container with a cover of at least 50 mm of water above the top of the basket. Immediately after immersion, the basket shall be lifted 25 mm above the base of the container and then dropped 25 times at a rate of about once a second in order to remove any air entrapped from the specimen. The basket and aggregate shall be kept completely immersed during the operation and for a subsequent period of 24 ± 2 h and the water temperature shall be maintained at 20 ± 5ºC.

NOTE: *The appropriate quantity of aggregate to use may be found as described in Cl. 16.5.2.*

After soaking, the specimen of aggregate shall be removed from the basket and the free water on the aggregate surface shall be blotted with absorbent cloths. The test procedure as described in Cl. 16.6.2 shall be carried out immediately after this operation.

16.6 PROCEDURE

16.6.1 Aggregate in a dry condition

The cylinder of the test apparatus shall be placed in position on the baseplate and the test specimen shall be added in thirds, each third being subjected to 25 strokes from the tamping rod distributed evenly over the surface of the layer and dropping from a height approximately 50 mm above the surface of the aggregate.

NOTE 1: *The particles of some aggregates may break down when they were tamped in this way. If this occurs, it shall be reported.*

The surface of the aggregate shall be carefully levelled. The plunger shall be inserted so that it rests horizontally on this surface. Care should be taken to ensure that the plunger does not jam in the cylinder.

The apparatus with the test specimen and plunger shall be placed in position, between the platens of the testing machine. Force shall be applied at a rate as uniform as possible so as to cause a total penetration of the plunger in 10 min ± 30 s of approximately:

(a) 15 mm for rounded or partially rounded aggregates, e.g. uncrushed gravels.

(b) 20 mm for normal crushed aggregates.

(c) 24 mm for vesicular (honeycombed) aggregates e.g. some slags.

NOTE 2: *When, during the early stages of the test, there is a significant deformation, it may be impossible to maintain the required loading rate and variations in the loading rate may occur especially at the beginning of the test. These variations shall be kept to a minimum with the principal object of completing the test in the overall time of 10 min ± 30 s.*

NOTE 3: *These figures may be varied in accordance with the extent of the rounding or honeycombing.*

NOTE 4: *When an aggregate impact value (AIV) as determined by the procedure given in Section 15 of this Standard is available, the force required (in kN) for the first ten per cent fines test can be estimated by means of the following equation more conveniently than by the use of the dial gauge.*

$$Required \quad force = \frac{4000}{AIV}$$

This value of force will nearly always provide a percentage of fines within the required range of 7.5% to 12.5 %.

The maximum force (f) applied to produce the required penetration shall be recorded. The crushed aggregate shall be removed by holding the cylinder over a clean tray of known mass and hammering on the outside with the rubber mallet until the particles are sufficiently disturbed to enable the mass of the specimen to fall freely onto the tray. Any particles adhering to the inside of the cylinder, the baseplate and the underside of the plunger shall be transferred to the tray by means of a stiff bristle brush. The tray and the aggregate shall be weighed to the nearest gram to obtain the mass of aggregate used (M_1).

NOTE 5: *If this fails to remove the compacted aggregate, other methods shall be used but care must be taken not to cause further crushing of the particles.*

The whole of the specimen in the tray shall be sieved on the 2.36 mm test sieve until no further significant amount passes during a further period of 1 min. The fractions passing and retained on the sieve shall be weighed and recorded to the nearest gram (M_2 + M_3 respectively). If the total mass (M_2 + M_3) differs from the initial mass (M_1) by more than 10 g, the result shall be discarded and a further specimen shall be tested.

If the percentage of material (*m*) passing the test sieve, calculated from the following equation does not fall within the range 7.5% to 12.5%, a further specimen shall be tested, using an adjusted maximum test loading to bring the percentage of fines within the range and the value of m obtained shall be recorded.

$$m = \frac{M_2}{M_1} \times 100$$

NOTE 6: *The formula given in Cl. 16.7 may be used for calculating the force required.*

NOTE 7: *In the operations described in the 4th and 5th para. of this clause, care shall be taken to avoid loss of fines.*

NOTE 8: *Mechanical sieving shall only be used for aggregates which do not degrade under its action.*

The complete test procedure shall be repeated with the same mass of aggregate at the same force that gave a percentage fines value within the range 7.5% to 12.5%.

16.6.2 Aggregate in a soaked condition

The procedure described in Cl. 16.6.1 shall be followed except that after the crushed specimen has been removed from the cylinder (see the 4th para. of Cl. 16.6.1), it shall be heated in the oven to achieve constant dry mass. The dried material shall be allowed to cool to room temperature and shall then be weighed to the nearest gram (M_1). The procedure as described in the 5th to 7th para. of Cl. 16.6.1 shall be completed.

NOTE: *The use of the aggregate impact value to estimate the required force as described in the note 4 of Cl. 16.6.1 is inapplicable to the determination of the ten per cent fines value for soaked aggregates.*

16.7 CALCULATIONS AND EXPRESSION OF RESULTS

The force (*F*) (in kN) required to produce 10% of fines for each test specimen, with the percentage of material passing in the range 7.5% to 12.5%, shall be calculated to the nearest whole number from the following equation:

$$F = \frac{14f}{m+4}$$

where

f is the maximum force (in kN); and
m is the percentage of material passing the 2.36 mm test sieve at the maximum force.

The mean of the two results shall be calculated to the nearest 10 kN for forces of 100 kN or more, or to the nearest 5 kN for forces of less than 100 kN. The mean shall be reported as the ten per cent fines value, unless the individual results differ by more than 10 kN and by more than 0.1 times the mean value. In this case, the test shall be repeated on two further specimens, the median of the four results shall be calculated to the nearest 10 kN for forces of 100 kN or more, or to the nearest 5 kN for forces of less than 100 kN, and the median shall be reported as the ten per cent fines value.

NOTE: *The median of four results is calculated by excluding the highest result and the lowest results and calculating the mean of the two middle results.*

16.8 TEST REPORT

The report shall affirm that the ten per cent fines value of the dry aggregate and/or soaked aggregate was determined in accordance with this Section of the Standard and whether or not a certificate of sampling is available. If available, a copy of the sampling certificate shall be provided. The test report shall include the following additional information:

(a) Sample identification and sample description.

(b) The condition (dry or soaked) in which the aggregate was tested.

(c) The ten per cent fines value of the dry aggregate.

(d) The ten per cent fines value of the soaked aggregate.

16.9 RECOMMENDED METHOD FOR DETERMINING THE TEN PER CENT FINES VALUE FOR OTHER SIZE FRACTIONS OF COARSE AGGREGATE

16.9.1 Method

When required, or if the definitive size fraction passing the 14 mm test sieve and retained on a 10 mm test sieve is not available, tests may be made on aggregates of other sizes passing a 28 mm test sieve and retained on a 2.36 mm test sieve. Because of the lack of experience of testing sizes other than the definitive size fraction, it has not been possible to provide any positive indication as to how the results obtained on non-standard sizes would compare with those obtained by the standard test procedures.

16.9.2 Apparatus

The apparatus shall be as described in Cl. 16.4, or for testing aggregate smaller than 10 mm in particle size, as described in the 2nd to 7th para. of this clause.

A steel cylinder shall be open-ended with plunger and baseplate with a nominal internal diameter of 75 mm, generally as described in Cl. 16.4 (a). The general form of dimensions of the cylinder and of the plunger are shown in Figure 16.1 and given in Table 16.1.

A tamping rod shall be made out of straight steel of circular cross section with 8 mm diameter and 300 mm long. One end shall be rounded.

A balance shall have a capacity of at least 500 g and shall be readable to 0.2 g.

Test sieves shall be of appropriate sizes as given in Table 16.3.

Table 16.3 - Particulars of test sieves for testing other size fractions of aggregates

Size fraction	Nominal aperture size of test sieve			
	For preparation of test specimens		For separating fines	
	Passing (mm)	Retained (mm)	(mm)	(μm)
Larger than standard	28	20	5	---
	20	14	3.35	---
Standard	14	10	2.36	---
Smaller than standard	10	6.3	1.7	---
	6.3	5	1.18	---
	5	3.35	---	850
	3.35	2.36	---	600

A compression testing machine shall be generally as described in Cl. 16.4 (e) except that it shall be capable of applying any force of up to 100 kN, and of being operated to give a uniform rate of loading so that this force is reached in 10 min (see note 2 of Cl. 16.6.1).

A cylindrical metal measure shall be generally as described in Cl. 16.4 (f) except that it shall have an internal diameter of 57 ± 1 mm and an internal depth of 90 ± 1 mm.

16.9.3 Preparation of test portions and specimens

The procedure described in Cl. 16.5 shall be followed, using the appropriate sieves as described in Table 16.3, according to the size of the fraction under test. For a grading of test portions of less than 10 mm maximum size, a minimum mass of 1 kg is required.

16.9.4 Procedure

The procedure described in Cl. 16.6 shall be followed, using the appropriate separating sieve given in Table 16.3.

NOTE: *The penetration of the plunger may not accord with the values given in Cl 16.6.*

16.9.5 Calculation and expression of results

The general procedure described in Cl. 16.7 shall be followed.

16.9.6 Test report

The test report shall include the information specified in Cl. 16.8, with additionally the size of aggregate tested.

SECTION 17

METHODS FOR DETERMINATION OF PARTICLE DENSITY AND WATER ABSORPTION

17.1 SCOPE

This Section describes methods for determining the water absorption and the following particle densities of aggregates:

(a) Oven-dried particle density.

(b) Saturated and surface-dried particle density.

(c) Apparent particle density.

17.2 PRINCIPLE

Particle density is the ratio of mass to volume. The mass is determined by weighing the test portion in the saturated surface-dry condition and again in the oven-dried condition. Volume is determined from the mass of the water displaced, either by mass reduction in the wire basket method or by weighing in the gas jar or pyknometer method.

Water absorption is the increase in mass of a sample of oven-dried aggregate due to the penetration of water into accessible voids in the aggregate. The increase in mass is determined by weighing the test portion in the saturated surface-dry condition and in the oven-dried condition.

NOTE 1: *Different sizes of the same aggregate may have different values of particle density and water absorption. When comparing different aggregates, it is therefore essential that the test be made on samples sensibly of the same grading.*

NOTE 2: *The wire basket method for aggregates larger than 10 mm is not appropriate for testing friable aggregates which may break down during the test, and therefore the gas jar method for aggregates between 40 mm and 5 mm should be employed for such material.*

17.3 SAMPLING

The laboratory sample shall be taken in accordance with the procedures described in Section 8 of this Standard.

17.4 METHOD FOR AGGREGATES ALL LARGER THAN 10 mm (WIRE BASKET METHOD)

17.4.1 Apparatus

The following apparatus is required:

(a) Balance

The balance shall be of capacity not less than 3 kg, accurate to 0.5 g, and of such a type and size as to permit the basket containing the sample to be suspended from the beam and weighed in water.

(b) Ventilated oven

The ventilated oven shall be capable of being thermostatically controlled to maintain a temperature of 105 ± 5ºC.

(c) Wire-mesh basket

The wire-mesh basket or perforated container preferably chromium plated and polished shall be of appropriate size and have apertures not larger than 6.5 mm. It shall be suspended from the balance by wire hangers (not thicker than 1 mm).

(d) Stout watertight container

The container shall be of an appropriate size to allow the basket to be freely suspended.

(e) Two dry soft absorbent cloths

Each of the absorbent cloths shall have a size of not less than 750 mm × 450 mm.

(f) Shallow tray

The shallow tray shall have an area of not less than 0.065 m^2.

(g) Airtight container

The airtight container shall have a capacity similar to the basket.

(h) 10 mm test sieve

(i) Supply of water

The supply of water shall be free from impurity (e.g. dissolved air) that may significantly affect its density. If distilled or deionised water is not available, tap water freshly boiled and cooled to room temperature may be used.

NOTE: *All apparatus shall comply with the general requirements of Section 7 of this Standard.*

17.4.2 Preparation of test portion

The laboratory sample shall be reduced in accordance with the procedures described in Cl. 8.6 of Section 8 of this Standard to produce two test portions each of which shall not be less than 2 kg. Aggregates which have been artificially heated shall not normally be used for the test. If such material is used, it shall be stated in the report. Two tests shall be performed. Each test portion shall be thoroughly washed to remove finer particles on the 10 mm test sieve and then drained.

17.4.3 Procedure

The prepared test portion shall be placed in the wire basket and shall be immersed in water at a temperature of 20 ± 5ºC with a cover of water at least 50 mm above the top of the basket. The entrapped air shall be removed from the test portion immediately after immersion by lifting the basket 25 mm above the base of the tank and allowing it to drop 25 times at a rate of about one per second. The basket and aggregate shall be completely immersed during this operation and for a period of 24 ± 0.5 h.

The basket and test portion shall again be jolted and shall then be weighed in water at a temperature of 20 ± 5ºC. If they need to be transferred to a different tank for weighing, they shall be jolted 25 times as mentioned above in the new tank before weighing to give a mass (*B*). The basket and aggregate shall then be removed from the water and shall be allowed to drain for a few minutes, after which the aggregate shall be emptied gently from the basket

on to one of the dry cloths. The empty basket shall be returned to the water and shall be jolted for 25 times before weighing in water to give a mass (*C*). The weighing operations described in this paragraph may be omitted if the water absorption only is required.

The aggregate shall be gently surface-dried with the first dry cloth. When no further moisture will be removed from the cloth, it shall be transferred to a second dry cloth. It shall then be spread out not more than one stone deep on the second cloth, and shall be exposed to the atmosphere away from direct sunlight or any other source of heat until all visible films of water disappear, but the aggregate still has a damp appearance. The aggregate shall be weighed to a mass (*A*). The operations described in this paragraph may be omitted if the apparent particle density only is required.

The aggregate shall be placed in the shallow tray and heated in the oven to achieve constant dry mass. It shall then be cooled in the airtight container and weighed to a mass (*D*). The operations described in this paragraph may be omitted if the particle density in a saturated and surface-dried basis only is required.

17.4.4 Calculations and expression of results

The particle density on an oven-dried basis (in Mg/m^3) shall be calculated from the formula:

$$\frac{D}{A-(B-C)}$$

The particle density on a saturated and surface-dried basis (in Mg/m^3) shall be calculated from the formula:

$$\frac{A}{A-(B-C)}$$

The apparent particle density (in Mg/m^3) shall be calculated from the formula:

$$\frac{D}{D-(B-C)}$$

The water absorption (as % of dry mass) shall be calculated from the formula:

$$\frac{100\,(A-D)}{D}$$

where

A is the mass of the saturated surface-dry aggregate in air (in g);
B is the apparent mass in water of the basket containing the test portion of saturated aggregate (in g);
C is the apparent mass in water of the empty basket (in g); and
D is the mass of the oven-dried aggregate in air (in g).

The values of particle density and water absorption shall be reported to the nearest 0.01 Mg/m^3 and 0.1% respectively.

17.5 METHOD FOR AGGREGATES BETWEEN 40 mm AND 5 mm (GAS JAR METHOD)

17.5.1 Apparatus

The following apparatus is required:

(a) Balance

The balance shall be of capacity not less than 3 kg, accurate to 0.5 g and of such a type as to permit weighing of the vessel containing the aggregate and water.

(b) Ventilated oven

The ventilated oven shall be capable of being thermostatically controlled to maintain a temperature of 105 ± 5ºC.

(c) Wide-mouthed glass vessel

The wide-mouthed glass vessel, such as gas jar, shall be of capacity 1.0 L to 1.5 L, with a flat ground lip and a plane-ground disc of plate glass to cover it, giving a watertight fit.

(d) Two dry soft absorbent cloths

Each of the absorbent cloths shall have a size of not less than 750 mm × 450 mm.

(e) Shallow tray

The shallow tray shall have an area of not less than 0.03 m^2.

(f) Airtight container

The airtight container shall be large enough to take the sample.

(g) 5 mm test sieve

(h) Supply of water

The supply of water shall be free from impurity (e.g. dissolved air) that would significantly affect its density. If distilled or deionised water is not available, tap water freshly boiled and cooled to room temperature may be used.

NOTE: *All apparatus shall comply with the general requirements of Section 7 of this Standard.*

17.5.2 Preparation of test portion

The laboratory sample shall be reduced in accordance with the procedures described in Cl. 8.6 of Section 8 of this Standard to produce two test portions each of which shall be about 1 kg. Aggregates which have been artificially heated shall not normally be used for the test. If such material is used, it shall be stated in the report. Two tests shall be performed. Each test portion shall be thoroughly washed to remove finer particles on the test sieve and then drained.

17.5.3 Procedure

The prepared test portion shall be immersed in water in the glass vessel at a temperature of 20 ± 5ºC for 24 ± 0.5 h. Air entrapped in and bubbles on the surface of the aggregate shall be removed by gentle agitation soon after immersion and again at the end of the soaking period. This may be done by rapid clockwise and anti-clockwise rotation of the vessel between the operator's hands.

The vessel shall be overfilled by adding water gently and the plane-ground glass disc shall be placed by sliding over the mouth so that no air is trapped in the vessel. The vessel shall then be dried on the outside and shall be weighed to a mass (*B*). The vessel shall be emptied

and the aggregate shall be allowed to drain. The vessel shall then be refilled fully with water and the glass disc shall be placed by sliding into position as before. The vessel shall then be dried on the outside and shall be weighed to a mass (*C*). The temperature difference of the water in the vessel during the first and second weighings shall not exceed 2ºC. The weighing operations described in this paragraph may be omitted if the water absorption only is required.

The aggregate shall be placed on the first dry cloth and shall be surface-dried with the cloth. When no further moisture will be removed from the cloth, it shall be transferred to a second dry cloth. It shall then be spread out not more than one stone deep on the second cloth, and shall be exposed to the atmosphere away from direct sunlight or any other source of heat until all visible films of water disappear, but the aggregate still has a damp appearance. The aggregate shall be weighed to a mass (*A*). The operations described in this paragraph may be omitted if the apparent particle density only is required.

The aggregate shall be placed in the shallow tray and heated in the oven to achieve constant dry mass. It shall then be cooled in the airtight container, and weighed to a mass (*D*). The operations described in this paragraph may be omitted if the particle density on a saturated and surface-dried basis only is required.

17.5.4 Calculations and expression of results

The particle density on an oven-dried basis (in Mg/m^3) shall be calculated from the formula:

$$\frac{D}{A-(B-C)}$$

The particle density on a saturated and surface-dried basis (in Mg/m^3) shall be calculated from the formula:

$$\frac{A}{A-(B-C)}$$

The apparent particle density (in Mg/m^3) shall be calculated from the formula:

$$\frac{D}{D-(B-C)}$$

The water absorption (as % of dry mass) shall be calculated from the following formula:

$$\frac{100\,(A-D)}{D}$$

where

A is the mass of the saturated surface-dry test portion in air (in g);
B is the mass of vessel containing test portion and filled with water (in g);
C is the mass of vessel filled with water only (in g); and
D is the mass of the oven-dry test portion in air (in g).

The values of particle density and water absorption shall be reported to the nearest 0.01 Mg/m^3 and 0.1% respectively.

17.6 METHOD FOR AGGREGATES 10 mm NOMINAL SIZE AND SMALLER (PYKNOMETER OR GAS JAR METHOD)

17.6.1 Apparatus

The following apparatus is required:

(a) Balance

The balance shall be of capacity not less than 3 kg, accurate to 0.5 g and of such a type as to permit weighing of the vessel containing the aggregate and water.

(b) Ventilated oven

The ventilated oven shall be capable of being thermostatically controlled to maintain a temperature of 105 ± 5ºC.

(c) Vessel

The vessel shall be capable of holding 0.5 kg to 1.0 kg of aggregate up to 10 mm nominal size and capable of being filled with water to a constant volume with an accuracy of ± 0.5 mL. The following vessels are suitable:

(1) Glass vessel

The glass vessel, referred to later as a pyknometer, shall be of about 1 L capacity, having a metal conical screw top with an approximately 6 mm diameter hole at its apex. The screw top shall be watertight when it is screwed onto the jar. If necessary, a rubber or fibre washer shall be inserted in the joint. If such a washer is used, 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 every time so as to fix the volume contained by the jar is constant throughout the test. A suitable vessel can be made from a 1 kg fruit preserving jar in which the glass lid normally used is replaced by a sheet metal cone as shown in Figure 17.1

(2) Wide-mouthed glass vessel

The wide-mouthed glass vessel, such as gas jar, shall be capacity of 1.0 L to 1.5 L, with a flat-ground lip and a plane-ground disc of plate glass to cover it, giving a watertight fit.

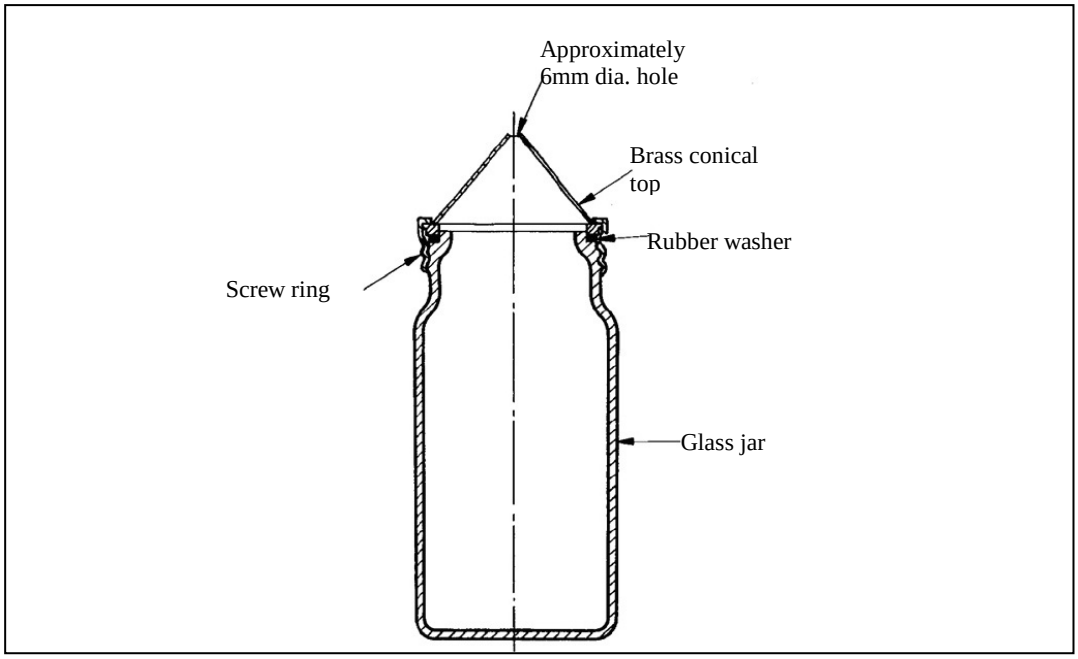


Figure 17.1 - Section of pyknometer made from a preserving jar

(d) Hair-dryer

It shall be of suitable capacity for supplying a current of warm air.

(e) Watertight tray

The watertight tray shall have an area of not less than 0.03 m^2.

(f) Airtight container

The airtight container shall be large enough to take the sample.

(g) Container

The container shall be of sufficient size to contain the sample covered with water and to permit vigorous agitation without loss of any part of the sample or water.

(h) 75 μm test sieve and nesting sieve

The nesting sieve, e.g. 1.18 mm sieve, shall be used to protect the 75 μm test sieve.

(i) Supply of water

The supply of water shall be free from impurity (e.g. dissolved air) that would significantly affect its density. If distilled or deionized water is not available, tap water freshly boiled and cooled to room temperature of tap water may be used.

(j) Metal mould (optional)

The metal mould shall be in the form of a frustum of a cone 40 mm diameter at the top, 90 mm at the bottom and 75 mm high. The minimum thickness of the metal mould shall be of 900 μm.

(k) Metal tamper

The weight of the metal tamper shall be of 340 ± 15 g and having a flat circular tamping face 25 ± 3 mm in diameter.

(l) Plain glass funnel (optional)

NOTE: *All apparatus shall comply with the general requirements of Section 7 of this Standard.*

17.6.2 Preparation of test portion

The laboratory sample shall be reduced in accordance with the procedures described in Cl. 8.6 of Section 8 of this Standard to produce two test portions each of which shall be about 1 kg for material having a nominal size from 10 mm to 5 mm inclusive, or about 500 g if finer than 5 mm. Aggregates which have been artificially heated shall not normally be used for the test. If such material is used, it shall be stated in the report. Two tests shall be performed. Each test portion shall be thoroughly washed to remove all material finer than the 75 μm test sieve using the following procedure.

The test portion shall be placed in the container and shall be covered by adding enough water. The contents of the container shall be agitated vigorously and the wash water shall be poured immediately over the test sieves, which have previously been wetted on both sides and arranged with the coarser test sieve on top and 75 μm test sieve at the bottom. The agitation shall be sufficiently vigorous so that all particles finer than the 75 μm test sieve can be separated completely from the coarse particles and the fine material shall be bought into suspension in order that it will be removed by decantation of the wash water. Decantation of the coarse particles of the test portion should be avoided as far as possible. The operation shall be repeated until the wash water is clean. All material retained on the test sieves shall be returned to the washed test portion.

17.6.3 Procedure

The test procedure shall be as described in Cl. 17.6.3.1 or Cl. 17.6.3.2.

17.6.3.1 Using the pyknometer

The washed aggregate shall be transferred to the tray and water shall be further added to ensure that the test portion is completely immersed. Soon after immersion, bubbles of entrapped air shall be removed by gentle agitation with a rod.

The test portion shall be kept immersed in water for 24 ± 0.5 h, the water temperature being maintained at 20 ± 5ºC for at least the last 20 h of immersion.

The water shall then be drained carefully from the test portion by decantation through a 75 μm test sieve covered by the protective coarser test sieve. Any material retained on the test sieves shall be returned to the test portion. The aggregate shall then be exposed to a gentle current of warm air to evaporate surface moisture and shall be stirred at frequent intervals to ensure uniform drying until no free surface moisture can be seen. For aggregate finer than 5 mm, it just attains a `free-running' condition (see note 1). The saturated and surface-dry test portion shall then be weighed to a mass (*A*).

The draining and drying operations described above may be omitted if the apparent particle density only is required, although for aggregate finer than 5 mm some surface drying may be desirable to facilitate handling.

The aggregate shall then be placed in the pyknometer and shall be filled with water. The cone shall be screwed into place and any trapped air shall be eliminated by rotating the pyknometer on its side, with the hole in the apex of the cone being covered with a finger. The pyknometer shall be topped up with water to remove any froth from the surface in order that the surface of the water in the hole is flat. The pyknometer shall then be dried on the outside and shall be weighed to a mass (*B*). The contents of the pyknometer shall be emptied into the tray with care to ensure that all the aggregate is transferred. The

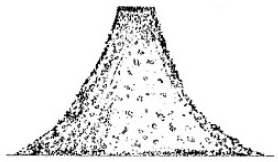
pyknometer shall be refilled with water (see note 2) to the same level as before. It shall then be dried on the outside and shall be weighed to a mass (*C*). The temperature difference of the water in the pyknometer during the first and second weighings shall not exceed 2ºC. The operations described in this paragraph may be omitted if the water absorption only is required.

The water shall be drained carefully from the test portion by decantation through a 75 μm test sieve and any material shall be retained shall be returned to the test portion. The test portion shall then be placed in the tray and heated in the oven to achieve constant dry mass, during which period it shall be stirred occasionally to facilitate drying. It shall then be cooled in the airtight container and shall be weighed to a mass (*D*). Two tests shall be performed. The operations described in this paragraph may be omitted if the particle density on a saturated and surface-dried basis only is required.

NOTE 1: *The `free-running' or `saturated surface-dry' condition of the fine aggregate (finer than 5 mm) is sometimes difficult to identify and, in order to help in identification, two alternative methods are suggested as possible aids.*

Method 1 *The following test procedure shall be adopted, making use of the conical mould and tamper referred to in Cl.17.6.1(j) and Cl.17.6.1(k).*

After drying the test portion with a current of warm air, it shall be allowed to cool to room temperature whilst thoroughly stirring it. The mould with its larger diameter face shall be held downwards on a smooth non-absorbent level surface. The mould shall be filled loosely with part of the test portion and shall be lightly tamped for 25 times through the hole at the top of the mould with the prescribed tamper. The space left after tamping shall not be refilled. The mould shall be lifted gently clear of the aggregate and the moulded shape shall be compared with Figure 17.2 (a) to Figure 17.2 (d). If the shape resembles Figure 17.2 (a) or Figure 17.2 (b), then there is still surface moisture present, the test portion shall be further dried and the test shall be repeated. If the shape resembles Figure 17.2 (c), then a condition close to the saturated surface-dry condition has been achieved. If the shape resembles Figure 17.2 (d), the aggregate has dried beyond the saturated surface-dry condition and is close to the oven-dry condition. In this case, the test portion shall be either rejected and the tests shall be repeated on a fresh test portion or the same test portion shall be re-soaked in water for a further 24 h and the tests shall be restarted as from the beginning of the 2nd para. of Cl. 17.6.3.1. It is recommended that at least one of the drying stages, as shown in Figure 17.2 (a) or Figure 17.2 (b), should have been observed before the aggregate reaches the stage represented by Figure 17.2 (c).



(a) Aggregate moist; almost retains complete shape of metal mould

(b) Aggregate slightly moist; appreciable slump observed

(c) Aggregate saturated surface-dry; almost complete collapse but definite peak still visible and slopes are angular

(d) Aggregate nearly oven dry; no distinct peak, surface outline close to being curvilinear

NOTE: *These sketches are not to scale and are for reference purposes only.*

Figure 17.2 - Estimation of free-running condition of fine aggregate

Method 2 *As an alternative to method 1, a dry glass funnel may be employed to help determine the `free-running' condition of aggregate finer than 5 mm. With the funnel inverted over the test portion tray, some of the test portion shall be poured over the sloping sides by means of a small scoop. Particles of the aggregate will adhere to the sides of the funnel if the test portion is still damp. Then drying shall be continued until subsequent pouring shows no sign of particles sticking to the glass.*

NOTE 2: *The glass and metal threads (and the washer if used) of the pyknometer shall be thoroughly dried before using a second time.*

17.6.3.2 Using the wide-mouthed glass vessel

The procedure shall be the same as in Cl. 17.6.3.1 except that the jar shall be filled with water just to overflowing and the glass plate shall be placed by sliding over it to exclude any air bubbles.

17.6.3.3 Calculations and expression of results

The particle density on an oven-dried basis (in Mg/m^3) shall be calculated from the formula:

$$\frac{D}{A-(B-C)}$$

The particle density on a saturated and surface-dried basis (in Mg/m^3) shall be calculated from the formula:

$$\frac{A}{A-(B-C)}$$

The apparent particle density (in Mg/m^3) shall be calculated from the formula:

$$\frac{D}{D-(B-C)}$$

The water absorption (as % of dry mass) shall be calculated from the formula:

$$\frac{100\,(A-D)}{D}$$

where

A is the mass of saturated surface-dry test portion in air (in g);
B is the mass of pyknometer or wide-mouthed glass vessel containing test portion and filled with water (in g);
C is the mass of pyknometer or wide-mouthed glass vessel filled with water only (in g); and
D is the mass of oven-dried test portion in air (in g).

The values of particle density and water absorption shall be reported to the nearest 0.01 Mg/m^3 and 0.1% respectively.

17.7 TEST REPORT

The test report shall affirm that the tests were done in accordance with this Section of the Standard and whether or not a copy of the certificate of sampling is available. If available, a copy of the sampling certificate shall be provided. The test report shall include the following additional information:

(a) Sample identification.

(b) Particle density and/or water absorption.

(c) The method used for the determination of the particle density reported.

The mean result shall be reported for each form of particle density determined and the title of which shall be quoted in full. The shortened title `particle density' shall not be used in relation to any values quoted. The size of aggregate tested, and whether it was artificially heated before the start of the test shall be stated in the report.

SECTION 18

METHODS FOR DETERMINATION OF MOISTURE CONTENT

18.1 SCOPE

This Section describes the following three methods for determining the moisture content of aggregates:

(a) Oven-drying method.

(b) High temperature method.

(c) Microwave-oven method for fine aggregate only.

18.2 PRINCIPLE

The oven-drying method is to measure the total water present in a sample of aggregate and is the definitive procedure. The method comprises placing a test portion in a container and heating it in an oven until it reaches constant dry mass. Moisture content is then determined by the difference in mass and expressed as a percentage of the dry mass.

NOTE: *The other two methods are based on the use of rapid drying methods and are basically variants of the oven-drying method but certain problems may arise with their use which can lead to erroneous results being obtained. They cannot be regarded as definitive methods, but in certain circumstances can give adequate results for quality control purposes in a fraction of the time taken by the oven-drying method.*

18.3 SAMPLING

The laboratory sample used for the test shall be taken in accordance with the procedures described in Section 8 of this Standard.

18.4 PREPARATION OF TEST PORTION

The laboratory sample shall be reduced by the procedures described in Cl. 8.6 of Section 8 of this Standard to produce a test portion of mass not less than the mass given in Table 18.1 appropriate to the nominal size of the aggregate.

Table 18.1 - Minimum mass of test portion for determination of moisture content

Nominal size of aggregate (mm)	**Minimum mass of test portion** (kg)
63	15
50	10
40 to 20	5
20 to 10	2
10 to 5	1
Less than 5	0.5
NOTE: *Some loss of water by evaporation is inevitable during sampling and sample reduction. Precautions should be taken to minimize evaporation losses by carrying out all operations as quickly as possible and by storing the samples in airtight containers at all intermediate stages.*	

18.5 OVEN-DRYING METHOD

18.5.1 Apparatus

The following apparatus is required:

(a) Balance(s)

The balance(s) shall be of suitable capacity accurate to 0.1% of the mass of the test portion.

(b) Container(s)

The container(s) shall be airtight, non-corrodible, of size sufficient to contain the test portion.

NOTE: *If it is more convenient, an open top container may be used to cool the test portion using an air-tight cabinet.*

(c) Ventilated oven

The ventilated oven shall be capable of being thermostatically controlled to maintain a temperature of 105 ± 5ºC.

(d) Scoop

A convenient size is about 120 mm wide and 200 mm long.

(e) Sample divider

(f) Thermometer

In addition, the thermometer shall cover the range from 100ºC to 110ºC.

NOTE: *All apparatus shall comply with the general requirements of Section 7 of this Standard.*

18.5.2 Procedure

The container, with its lid if fitted, shall be cleaned and dried, and shall then be weighed (M_1). The test portion prepared as described in Cl. 18.4 shall be placed in the container by means of the scoop. The lid shall be replaced and the whole shall then be re-weighed (M_2).

The lid shall be removed, and the container, lid, and test portion shall then be placed in the oven and heated to achieve constant dry mass.

The container and test portion shall be removed from the oven and then either the lid shall be replaced or it shall be placed in an air-tight cabinet and the whole shall be allowed to cool for 0.5 h to 1 h, after which the whole with the lid shall be weighed again (M_3).

All weighings shall be carried out and recorded to an accuracy of 0.1% of the mass of the test portion.

18.5.3 Calculation and expression of results

The moisture content shall be calculated as a percentage of the dry mass from the following equation:

$$Moisture\ \ content = \frac{(M_2 - M_3)}{(M_3 - M_1)} \times 100$$

where

M_1 is the mass of dry container and its lid (in g);
M_2 is the mass of the container, lid, and wet test portion (in g); and
M_3 is the mass of the container, lid, and dry test portion (in g).

The value of moisture content shall be expressed to the nearest 0.1% of the dry mass of the test portion.

NOTE: *The percentage by wet mass may also be calculated from the following equation if specifically required.*

$$\underset{\text{(Percentage by wet mass)}}{\text{Moisture content}} = \frac{(M_2 - M_3)}{(M_2 - M_1)} \times 100$$

18.6 MODIFIED DRYING METHODS

18.6.1 General

When rapid results are required for quality control or other purposes, any method of drying which drives off water without affecting the aggregate may be used. However it is essential that temperature in excess of 500ºC shall be avoided. Flint and slag aggregates may spall at high temperatures.

NOTE: *The tester should be experienced in the interpretation of the test results when modified methods are used for quality control purposes. The test results may differ from those obtained by the oven-drying method.*

18.6.2 High temperature method

18.6.2.1 Apparatus

The following apparatus is required:

(a) Balance(s) for high temperature method

The balance(s) shall be of adequate capacity and accuracy and of such a type as to permit weighing of the test portion and/or the tray.

(b) Radiant heater or hotplate

Radiant heater or hotplate shall be suitable for heating the test portion.

(c) Shallow tray

The shallow tray shall be suitable for the mass of aggregate being heated.

(d) Spatula

Spatula or other implements for stirring the test portion during drying.

NOTE: *All apparatus shall comply with the general requirements of Section 7 of this Standard.*

18.6.2.2 Procedure

The mass of the test portion of aggregate to be tested shall be selected according to the purpose for which the result is required and the consequent need for the test portion to be representative of a bulk quantity. The test portion in accordance with Cl. 18.4 shall be prepared.

NOTE 1: *Normally, a mass of approximately 1 kg for coarse aggregates and 0.5 kg for fine aggregates is suitable.*

The test portion (M_1) shall be weighed, and then placed in the tray. It shall then be heated with due care to ensure that the aggregate does not reach a temperature where spitting or decomposition could occur.

NOTE 2: *The use of small pieces of white paper mixed with the aggregate is a convenient method of detecting overheating of the aggregate. Overheating is indicated if the paper turns brown.*

During heating, the test portion shall be stirred frequently with the spatula to ensure even exposure of the aggregate to the air and the source of heat. The spatula shall be kept in the tray until the test portion is dry to avoid loss of solid material.

When the test portion is considered to be dry, it shall be cooled and weighed, and the mass shall be recorded. It shall then be returned to the tray and heated again for a further 5 min. It shall be re-weighed. When the difference between consecutive weighings does not exceed 0.1% of the last recorded mass, the test portion shall be regarded as dry. The cycles of heating and weighing shall be continued until this condition is achieved and the final mass shall be recorded as (M_2).

18.6.2.3 Calculation and expression of results

The moisture content shall be calculated as a percentage of the dry mass from the following equation:

$$Moisture\ \ content = \frac{M_1 - M_2}{M_2} \times 100$$

where

M_1 is the mass of the wet test portion (in g); and
M_2 is the mass of the dry test portion (in g).

The value of moisture content shall be expressed to the nearest 0.1% of the dry mass of the aggregate.

NOTE: *If specifically requested, the percentage by wet mass may also be calculated from this method.*

18.6.3 Microwave oven method (normally limited to fine aggregates)

NOTE: *This method is inapplicable to some materials (see note 2 of Cl. 18.6.3.2).*

18.6.3.1 Apparatus

The apparatus shall be as described in Cl. 18.5.1 except that a ventilated microwave oven and non-metal containers of sufficient capacity to hold the mass of the test portion shall be used to replace the oven and airtight non-corrodible containers.

NOTE: *Metal containers would reflect microwaves and cannot be used. Materials such as porcelain and borosilicate glass which will be heated up under the influence of microwaves and not just by conduction from the aggregate are preferable; this reduces the possibility of water vapour condensing on the cooler walls of the container before being carried away by air circulation.*

18.6.3.2 Procedure

Preliminary trials to ascertain the time required to dry the test portions and to establish whether or not the aggregate under test is adversely affected by microwave radiation such as becoming excessively hot shall be carried out.

The procedure described in Cl. 18.5.2 shall be followed except that, as microwave drying is used, the period of drying will vary from that in Cl. 18.5.2.

NOTE 1: *The manufacturer's instructions should be followed in using the microwave oven.*

NOTE 2: *Most siliceous and calcareous aggregates can be dried satisfactorily in a microwave oven but flints, slag and some calcareous aggregates having a tendency to shatter cannot be tested by the microwave oven method. Materials such as pulverized fuel ash, colliery spoil or aggregates derived from them are unsuitable as any carbonaceous matter remaining in them will ignite in the microwave oven.*

18.6.3.3 Calculation and expression of results

The moisture content shall be calculated as described in Cl. 18.5.3 and the value shall be expressed to the nearest 0.1% of the dry mass of the aggregate.

18.7 TEST REPORT

The test report shall affirm that the moisture content was determined in accordance with this Section of the Standard and whether or not a copy of the certificate of sampling is available. If available, a copy of the sampling certificate shall be provided. The test report shall contain the following additional information:

(a) Sample identification.

(b) The moisture content of the test portion as a percentage of the dry mass.

(c) The method used for the determination of the moisture content i.e. the definitive oven-drying method or whichever of the subsidiary methods was used.

NOTE: *Normally, the subsidiary methods shall only be used for site control purposes.*

SECTION 19

METHOD FOR DETERMINATION OF SOUNDNESS

19.1 SCOPE

This Section describes the method for determining the soundness of coarse natural aggregate by subjecting the aggregate to cycles of immersion in a saturated solution of magnesium sulphate followed by oven-drying. The method is applicable to aggregate passing at 14 mm test sieve and retained on a 10 mm test sieve.

NOTE: *The majority of aggregates can be tested for soundness by this method. The test may not be suitable for all rock types and reservations have been made in respect of some carbonate aggregates and some aggregates having a high proportion of magnesium bearing minerals or of cryptocrystalline quartz.*

For other size fractions, a recommended method is described in Cl. 19.10.

19.2 PRINCIPLE

A sample of aggregate in the size range from 10 mm to 14 mm is subjected to five cycles of immersion in a saturated solution of magnesium sulphate, followed by oven-drying at 105ºC to 110ºC. This subjects the aggregate sample to the disruptive effects of the repeated crystallization and rehydration of magnesium sulphate within the pores of the aggregate. The extent of the disruption depends on the soundness of the aggregate. The degree of degradation arising from the disruptive effects is determined by the extent to which material finer than 10 mm in particle size is produced.

19.3 SAMPLING

The laboratory sample shall be taken in accordance with the procedure described in Section 8 of this Standard.

19.4 APPARATUS

The following apparatus is required:

(a) Test sieves

Square-hole perforated metal plate test sieves of aperture sizes 14 mm, 10 mm and 6.3 mm, and a metal wire cloth test sieve of aperture size 3.35 mm shall be provided.

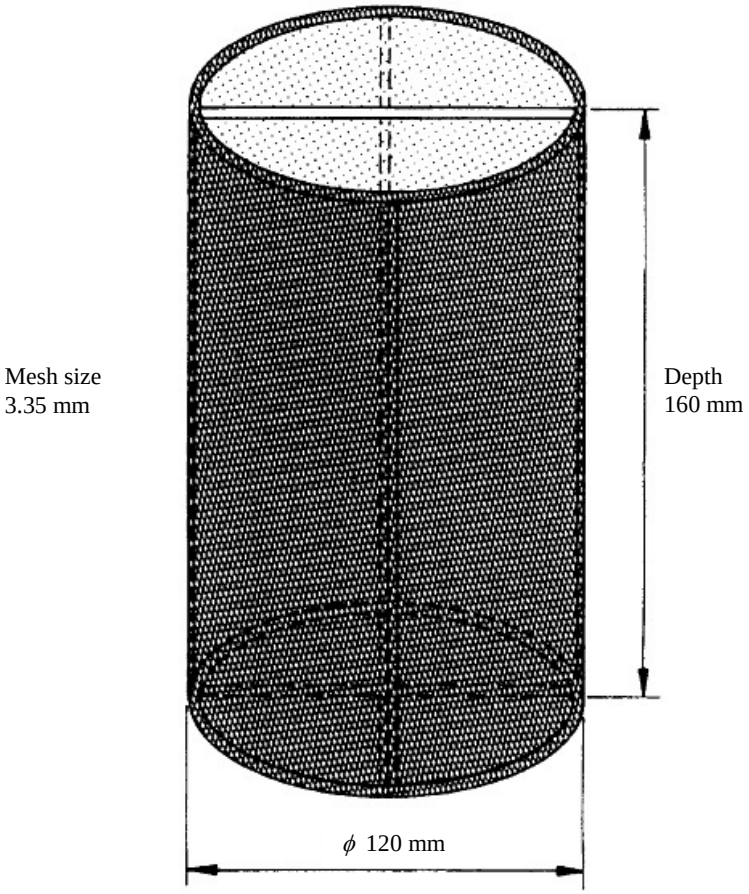
(b) Balance(s)

The balance shall be of suitable capacity accurate to 0.1% of the mass of the test portion.

NOTE: *In general, two balances, one of approximately 5 kg capacity accurate to 1 g and the other of approximately 500 g capacity accurate to 0.1 g, will suffice. If aggregate of larger than 28 mm nominal size is to be tested, a balance of 50 kg capacity accurate to 10 g will also be required.*

(c) Baskets

The baskets shall be brass or stainless steel mesh baskets for immersing aggregate specimens in the solution which permit free access to the solution and drainage of the solution from the aggregate under test. In general, at least two baskets are required. A suitable design of the basket is shown in Figure 19.1.



NOTE: *The dimensions given are not critical and are intended only as a guide. The main requirements are that the baskets should be large enough to allow the specimens to be totally immersed and to permit free circulation of the magnesium sulphate solution. The mesh should be strong enough to hold the aggregate but not so coarse that particles can pass through at the start of the test.*

Figure 19.1 - Basket for magnesium sulphate soundness testing

(d) Containers

The containers shall have a diameter such that the baskets listed in item (c) can be readily placed in and out, and shall have a volume at least five times the volume of the immersed aggregate.

NOTE: *Polypropylene beakers of 2 L capacity would make suitable containers.*

(e) Temperature control device

The temperature control device shall be capable of maintaining the temperature of the solution inside the containers at 20 ± 2ºC.

NOTE: *A tank of the type used for curing concrete cubes would be suitable.*

(f) Oven

The oven shall be thermostatically controlled and capable of maintaining a temperature within the range 105ºC to 110ºC, with fan-assisted air circulation, and ventilation by convection. The oven shall be capable of being heated continuously at 105ºC to 110ºC, and the rate of evaporation at this temperature range shall be at least 100 g over 4 h, during which time the doors of the oven shall be kept closed. This evaporation rate shall be determined by the loss of water from 1 L squat beakers (Griffin low-form type), each initially containing 500 g of distilled water, at a temperature of 20 ± 2ºC, placed at each corner and at the centre of each shelf of the oven. The requirement of evaporation is to apply to each test location with the oven empty except for beakers of water.

NOTE: *The oven should not be used for any other purposes while in use for this test unless it has been shown previously that the above performance requirement has also been achieved with the oven loaded in a similar manner to that proposed.*

(g) Density hydrometer

The density hydrometer shall comply with BS 718:1979 type M50 and shall be capable of measuring densities in the range from 1.284 g/mL to 1.300 g/mL to an accuracy of 0.001 g/mL. It shall be graduated at 20ºC for medium surface tension 55 mN/m.

NOTE: *A satisfactory method to use the hydrometer is to decant the solution under test into a gas jar, measure the density, and then return the solution to its original container.*

(h) Desiccator

The desiccator shall be large enough to contain at least two of the baskets listed in item (c).

NOTE: *All apparatus shall comply with the general requirements of Section 7 of this Standard.*

19.5 REAGENTS

The following reagents are required:

(a) A supply of deionized water or distilled water

(b) Barium chloride, 5% solution

5 g of barium chloride shall be dissolved in 100 mL of deionized or distilled water.

(c) Saturated solution of magnesium sulphate

NOTE 1: *A minimum quantity of 3 L is required for each of the tests.*

For the preparation of this solution, crystalline magnesium sulphate heptahydrate ($MgSO_4.7H_2O$) general purpose reagent grade shall be used.

NOTE 2: *Magnesium sulphate B.P. (Epsom salts), which is obtainable from pharmaceutical chemists, is suitable.*

The solution shall be prepared by slowly adding 1,500 g of the crystalline salt to each litre of water. During preparation, the water shall be stirred thoroughly during the addition of the crystals and the temperature shall be maintained at between 25ºC and 30ºC. After preparation, the water temperature shall be lowered to 20 ± 2ºC and this temperature shall be maintained for at least 48 h before use.

NOTE 3: *In accordance with published data on the solubility of magnesium sulphate, a saturated solution at 20ºC contains a 25.2% concentration of $MgSO_4$ (m/m) which has a relative density (20/4) of 1.290. The theoretical minimum mass of crystalline $MgSO_4.7H_2O$ required to produce the above degree of saturation, in 1 L of ion-free water at 20ºC, is 1,092 g. The mass of 1,500 g is intended to ensure that excess crystals are present in the solution during the preparation and all subsequent stages of the tests, but further quantities should be added if necessary.*

Prior to use, the density of the solution shall be checked by using the density hydrometer to ensure that it falls within 1.292 ± 0.008 g/mL. If not, the solution shall be rejected and the steps above shall be repeated by using fresh crystals.

NOTE 4: *All reagents shall comply with the general requirements of Section 7 of this Standard.*

19.6 PREPARATION OF TEST PORTIONS AND SPECIMENS

The laboratory sample shall be reduced using sample reduction procedure described in Cl. 8.6 of Section 8 of this Standard to produce two test portions of sufficient mass such that each will produce a minimum mass of 500 g of the 10 mm to 14 mm size range when processed as described in the 3rd para. of this clause.

Each test portion shall be dried in the oven at 105ºC to 110ºC to constant mass and shall be allowed to cool in the desiccator to laboratory temperature.

Each dried test portion shall be sieved using the 14 mm and 10 mm test sieves to obtain two test specimens of material, of 500 g approximate mass, in the size range 10 mm to 14 mm.

The test specimens shall be washed with distilled water until they are seen to be free from dust. This shall be followed by draining and heating in an oven to achieve constant dry mass. The test specimens shall then be removed from the oven and shall be allowed to cool in the desiccator to room temperature.

The sieving of each specimen shall be repeated using the 14 mm and 10 mm sieves to ensure that only material in this size range is used.

Each test specimen shall be weighed to the nearest 0.1 g such that the mass of each test specimen (M_1) falls between 420 g and 430 g. The specimens shall be transferred to two labeled mesh baskets.

NOTE: *In order to reduce to a minimum any loss by abrasion, care shall be taken to avoid shaking the specimens in their baskets at all subsequent stages.*

The procedure described in Cl. 19.7 shall be followed for each specimen.

19.7 PROCEDURE

The basket containing the specimen under test shall be immersed in a container holding the saturated solution of magnesium sulphate so that the aggregate is completely immersed for a period of 17 h ± 30 min. Each basket shall be suspended so that there is a minimum of 20 mm of solution above the specimen and 20 mm separation from any salt cake accumulation

or from any other basket. Particular care shall be taken during the process of immersion to ensure that no whole piece of aggregate is lost from the basket. The container holding the solution and the test specimen shall be covered to reduce evaporation and to prevent ingress of foreign matter.

NOTE 1: *Clock glasses would be suitable covers.*

At the end of the immersion period, the basket shall be removed from the solution and the container shall be covered. The basket shall be left to drain for a period of 2 h ± 15 min and placed in the oven maintained at a temperature of 105ºC to 110ºC for at least 24 h. It shall then be removed from the oven and left to cool to laboratory temperature for 5 h ± 15 min.

Prior to the next immersion, any salt cake which may have accumulated at the bottom of the container shall be broken up. The solution shall then be stirred thoroughly with a glass rod and shall be allowed to settle for 30 min. The density of the solution in the container shall be checked to confirm whether it is still in the required range. If it is not in the required range, the solution shall be replaced with unused saturated solution of magnesium sulphate.

NOTE 2: *In cases where severe disintegration of the aggregate occurs during the test, the relative density recorded may not accurately reflect the degree of saturation of the solution, because of the suspended fines or ion-exchange effects. Where the density falls outside the range 1.284 g/mL to 1.300 g/mL, the test procedure calls for replacement with a fresh solution of magnesium sulphate.*

The basket shall be immersed in the saturated solution of magnesium sulphate and the process of immersion, drainage, oven-drying, cooling and agitation shall be repeated described in the 1st to 3rd para. of this clause until five cycles have been completed, each cycle taking 48 ± 2 h. When scheduling the tests, a nominal value of 24 h is used for the oven-drying period.

When the specimen has cooled after the last cycle of the test, the aggregate in the basket shall be washed with water until it is free of magnesium sulphate. This shall be checked by adding a few drops of the barium chloride solution to a 10 mL aliquot of the washings and comparing the turbidity of the washings with the turbidity of an equal volume of fresh tap water.

The specimen shall be heated in an oven to achieve constant dry mass and shall be allowed to cool in the desiccator to laboratory temperature. The specimen shall be hand sieved on a 10 mm test sieve and the mass (M_2) of material retained on the sieve shall be recorded to the nearest 0.1 g.

19.8 CALCULATION AND EXPRESSION OF TEST RESULTS

The soundness value (S) of each specimen shall be calculated as a percentage to the first decimal place from the following equation:

$$S = \frac{M_2}{M_1} \times 100$$

where

M_1 is the initial mass of the test specimen (in g); and
M_2 is the mass of material retained on the 10 mm test sieve at the end of the test (in g).

The mean of the two results obtained shall be calculated to the nearest whole number to give the magnesium sulphate soundness value.

19.9 TEST REPORT

The test report shall affirm that the soundness, as measured by the magnesium sulphate soundness value, was determined in accordance with this Section of the Standard and whether or not a certificate of sampling is available. If available, a copy of the sampling certificate shall be provided. The test report shall contain the following additional information:

(a) Sample identification and sample decription including rock type and aggregate size.

(b) Aggregate size fraction.

(c) The individual soundness values of the two specimens and the magnesium sulphate soundness value.

19.10 RECOMMENDED PROCEDURE FOR DETERMINING THE MAGNESIUM SULPHATE SOUNDNESS VALUE FOR OTHER SIZE FRACTIONS OF COARSE NATURAL AGGREGATE

19.10.1 General

When required, or if the definitive size fraction passing the 14 mm test sieve and retained on a 10 mm sieve is not available, tests may be made on aggregates of other sizes passing a 28 mm test sieve and retained on a 300 μm test sieve.

Because of lack of experience of testing sizes other than the definitive size fraction, it has not been possible to give any positive indication as to how the results obtained on other sizes would compare with those obtained by the standard test procedures.

19.10.2 Apparatus and reagents

The apparatus and reagents are as described in Cl. 19.4 and 19.5 with the additional apparatus as follows:

(a) Test sieves, of appropriate sizes, as shown in Table 19.1.

(b) Wire mesh baskets, of appropriate size, as shown in Table 19.1.

Table 19.1 - Recommended test sieves, mesh baskets and mass of specimens for testing aggregates outside the size range 10 mm to 14 mm

Size fraction	Mass of test Specimen (g)	Test sieve		Mesh baskets		
		Passing (mm)	Retained (mm)	Mesh size (mm)	Height (mm)	Diameter (mm)
Larger than 14 mm	800-830	28	20	3.35	160	120
	600-630	20	14	3.35	160	120
10 mm to 14 mm	400-420	14	10	3.35	160	120
Smaller than 10 mm	300-310	10	6.3	1.18	120	95
	200-210	6.3	5	1.18	120	95
	200-210	5	3.35	0.6	120	95
	200-210	3.35	2.36	0.6	120	95
	100-110	2.36	1.18	0.15	80	65
	100-110	1.18	0.6	0.15	80	65
	100-110	0.6	0.3	0.15	80	65

19.10.3 Preparation of test portions and specimens

The procedure described in Cl. 19.6 shall be followed, using the appropriate mass of test specimen, sieves and mesh baskets as described in Table 19.1, according to the size of aggregate under test.

19.10.4 Procedure

The procedure described in Cl. 19.7 shall be followed and the specimen shall be hand sieved on the appropriate sieve at the end of the procedure.

19.10.5 Calculation and expression of results

The general procedure given in Cl. 19.8 shall be followed.

19.10.6 Test report

The test report shall contain the information specified in Cl. 19.9.

SECTION 20

METHOD FOR DETERMINATION OF DRYING SHRINKAGE

20.1 SCOPE

This Section describes the method for determining the drying shrinkage of natural aggregates for use in concrete. It applies to aggregate combinations where the coarse natural aggregate nominal maximum size does not exceed 20 mm and uses concrete prisms made with the coarse natural and/or fine natural aggregates for the test.

20.2 PRINCIPLE

Some aggregates change volume considerably from the wet state to the dry state and this may affect the concrete in which they are incorporated. The drying shrinkage of a concrete containing this aggregate can be as much as four times greater than that of concrete made with non-shrinkable aggregate. To determine the drying shrinkage of the aggregate under test, it is mixed with cement and water and cast into prisms of specified dimensions. The prisms are subjected to wetting followed by drying at 105 ± 5°C and the change in length from the wet state to the dry state determined. The drying shrinkage of the aggregate is calculated as the average change in length of the prisms as a percentage of their final dry lengths.

20.3 SAMPLING

The laboratory sample shall be taken in accordance with the procedure described in Section 8 of this Standard.

20.4 APPARATUS

The following apparatus is required:

(a) Sample divider

(b) Sieves

(c) Balance

(d) Ventilated oven

The ventilated oven shall be capable of being thermostatically controlled to maintain a temperature of 105 ± 5ºC.

(e) Thermometer

(f) Desiccators

(g) Gang mould

The gang mould shall be suitable for casting three concrete prisms of dimensions 200 ± 2 mm × 50 ± 2 mm × 50 ± 2 mm with a hemispherical button 8 mm diameter securely fixed to the centre of the inside faces of the 50 mm × 50 mm ends of mould.

NOTE: *It is permissible for reference pieces (inserts) to be used as an alternative to cementing steel balls (see Cl. 20.5 (c)) in the prisms. If inserts are used, the seatings of the measuring apparatus are required to be hemispherical, 6mm in diameter, and the ends of the invar rod (see Cl. 20.4 (i)) to be the same shape as that of the inserts.*

(h) Vibrating table

The vibrating table shall be suitable for compacting concrete in the manner as specified in Cl. 20.7.2.

(i) Measuring apparatus

The measuring apparatus shall incorporate a dial gauge with scale divisions of 0.002 mm having a maximum error of ± 0.002 mm in any half revolution. This dial gauge shall be rigidly mounted in a measuring frame and shall have a recessed end which can be located upon 6 mm diameter stainless steel balls cemented in the prisms (see Cl. 20.7.3). The other end of the frame shall have a similar recessed seating which can be located upon balls in the opposite end of the prisms. An invar steel rod which is 205 ± 1 mm long and with 6 mm hemispherical ends shall be used as a standard of length against which the readings of the gauge can be tested, thus enabling corrections to be made for any changes in the dimensions of the apparatus between successive measurements of the prisms. The invar steel rod shall be marked so that during the measurement the same end can be kept uppermost.

NOTE: *It is permissible for alternative measuring devices to be used in place of the dial gauge, e.g. linear variable differential transducers, provided that they are of at least equal performance and fitted with seatings compatible with the stainless steel balls or inserts.*

(j) Trays

Trays can be heated in the ventilated oven without damage or change in mass.

NOTE: *All apparatus shall comply with the general requirements of Section 7 of this Standard.*

20.5 MATERIALS

The following materials are required:

(a) Ordinary Portland cement complying with the requirements of BS EN 197-1.

(b) Drinkable water.

(c) 6 mm diameter stainless steel balls or inserts (see note to Cl. 20.4 (g)).

20.6 PREPARATION OF TEST PORTIONS

The laboratory sample shall be reduced using sample reduction procedure described in Cl. 8.6 of Section 8 of this Standard to produce test portions that can be sieved after oven drying to give approximately 1,600 g of 20 mm to 10 mm size fraction, 800 g of 10 mm to 5 mm size fraction and 1,300 g of fine aggregate.

The test portions shall be spread on shallow trays and dried for at least 16 h in the oven set at a temperature of 50 ± 5°C.

All oversize and undersize from the coarse aggregate to give fractions all passing the 20 mm sieve and retained on the 10 mm sieve, and all passing the 10 mm sieve and retained on the

5 mm sieve shall be rejected. All aggregate retained on the 5 mm sieve from the fine aggregate shall be rejected.

20.7 PREPARATION OF TEST SPECIMENS

20.7.1 Proportioning

Three test prisms shall be cast using the following amount of cement, aggregates and water:

(a)	Ordinary Portland cement	550 ± 5 g
(b)	Coarse aggregate (10 mm to 20 mm)	1,466 ± 5 g
(c)	Coarse aggregate (5 mm to 10 mm)	734 ± 5 g
(d)	Fine aggregate (5 mm)	1,100 ± 5 g
(e)	Water	330 ± 5 g

20.7.2 Mixing

The concrete for the three prisms shall be mixed on a non-porous surface which has been wiped over with a damp cloth. The cement and fine aggregate shall be mixed dry for 1 min with two trowels, and the coarse aggregate shall then be added and mixed dry until the mixture is uniform. The water shall be added to the mixture and the whole shall be mixed for 3 min with two trowels.

The concrete shall be transferred to the gang mould and a vibrating table shall be used to compact the concrete in the mould in two approximately equal layers, for sufficient time to achieve full compaction. Vibration shall cease as soon as the surface of the concrete becomes relatively smooth and air bubbles cease to appear. After the top layer has been compacted, it shall be levelled to the top of the mould with a steel float.

On completion of the compaction of the concrete, the surfaces of the prisms shall be smoothed with a trowel.

20.7.3 Storage of prisms

Immediately after completion of compaction, the prisms shall be covered with a flat impervious sheet (e.g. thin rubber, polyethylene or steel) making contact with the upper edges of the moulds. The prisms shall be left in this condition for 24 ± 2 h at an ambient temperature of 20 ± 5°C.

After 24 ± 2 h, the prisms shall be numbered for identification and one end of each shall be designated as the top, this end always being uppermost during subsequent measurements.

The prisms shall be demoulded. Where inserts are not used, stainless steel balls 6 mm in diameter shall be cemented into the indentations at the ends of the prisms.

NOTE: *It has been found satisfactory to use a cement/water grout for cementing balls in place and more than half of each ball should be embedded in the grout to aid retention.*

The prisms shall be covered with a damp Hessian and then a polyethylene sheet on top for a further 24 ± 2 h at an ambient temperature of 20 ± 5°C after which, the surface of the balls shall be wiped clean, or where inserts have been used, the ends of the inserts shall be wiped clean.

20.8 PROCEDURE

All measurements shall be carried out at a temperature of 20 ± 2°C. Each prism shall be measured by placing the prism uppermost (previously marked) in the frame and obtaining a minimum reading to the nearest division while slowly rotating the prism. Before and after each measurement, the length of the measuring apparatus shall be checked against the invar rod and if the difference in these readings is greater than 0.002 mm, the prisms shall be re-measured. The measured difference in length between the prism and the invar rod shall be recorded to the nearest 0.002 mm.

Within 48 ± 2 h of completion of compaction of the prisms, the prisms shall be immersed in water at a temperature of 20 ± 2°C for 5 days ± 4 h. The prisms shall then be removed from the water, the balls or inserts shall be wiped with a clean dry cloth and the length (w) of each prism shall be measured before placing them in an oven at a temperature of 105 ± 5°C. Free access of air to all sides of the prisms shall be ensured.

After 72 ± 4 h, the prisms shall be removed from the oven and cooled until they have reached a temperature of 20 ± 2°C in the desiccator. The length (*d*) of each prism shall be measured.

NOTE: *The cooling is likely to take most of a working day.*

After the dry measurement has been taken, the length of the prisms adjacent to the balls or inserts shall be measured to the nearest millimetre and shall be taken as the dry length (*I*).

20.9 CALCULATION AND EXPRESSION OF RESULTS

The drying shrinkage (*S*) of each prism shall be calculated as a percentage from the following equation:

$$S = \frac{w - d}{I} \times 100$$

where

w is the initial wet measurement (in mm);
d is the dry measurement (in mm); and
I is the dry length of the prism (in mm).

The drying shrinkage of the aggregate shall be expressed as the average of the three determinations to the nearest 0.001%.

If the range between the shrinkage values of individual prisms exceeds the greater of 0.010 mm or 12% of the average drying shrinkage, the test shall be considered to be unsatisfactory and a further test shall be carried out using fresh prisms.

20.10 TEST REPORT

The test report shall affirm that the drying shrinkage was determined in accordance with this Section of the Standard and whether or not a certificate of sampling is available. If available, a copy of the sampling certificate shall be provided. The test report shall contain the following additional information:

(a) The source, type and sizes of aggregate submitted for test.

(b) The source, type and sizes of aggregate used, if any, as the other component(s).

SECTION 21

METHODS FOR DETEMINATION OF CHEMICAL PROPERTIES

21.1 SCOPE

This Section describes the procedure for the preparation of test portion, sample treatment and testing methods for determining the water-soluble chloride ion content of natural aggregates, acid-soluble chloride ion content of recycled coarse aggregate, acid-soluble sulphate content of aggregates, total sulphur content of natural aggregates, and the presence of humus in aggregates.

21.2 GENERAL

21.2.1 Sampling

The laboratory sample shall be taken in accordance with the procedure described in Section 8 of this Standard.

21.2.2 Reagents

All reagents shall be of analytical reagent quality, and water shall be distilled or deionised. Solutions of solid reagents shall be filtered if the solution is not clear.

Proprietary reagents of equal quality to those described in the Standard may be used as alternatives.

21.2.3 Apparatus

A laboratory shall be fully equipped with common apparatus such as digital balances, beakers, volumetric flasks, pipettes, burettes, filtering units, magnetic stirrer, etc. Only those apparatus which are vital for conducting the chemical testing of aggregates shall be stated in this Section. Digital balances shall have a readability of at least 0.1 mg.

For gravimetric analysis involving ignition, an appropriate heating device (such as a muffle furnace) shall be required. The filter papers used shall be ashless.

The following apparatus for preparation of test portions is required:

(a) Crushing equipment e.g. jaw crusher.

(b) Oven at 105 ± 5ºC.

(c) Airtight bottles.

NOTE: *All apparatus shall comply with the general requirements of Section 7 of this Standard*

21.3 METHOD FOR DETERMINATION OF WATER-SOLUBLE CHLORIDE ION CONTENT

21.3.1 Principle

The water-soluble chloride ions are extracted from a sample of dried natural aggregates by using water. An excess of silver nitrate solution is added to the extract and the unreacted

silver nitrate is back-titrated with a standardised solution of thiocyanate, using ammonium iron (III) sulphate solution as an indicator.

21.3.2 Reagents

The following reagents are required:

(a) **Iron (III) indicator solution**

50 g of ammonium iron (III) sulphate shall be dissolved in 60 mL of water with warming, followed by addition of 10 mL of 6 mol/L nitric acid.

(b) **Nitric acid**, approximately 6 mol/L

100 mL of nitric acid (70% HNO_3, 1.42 g/mL) shall be diluted with water to 250 mL. The diluted acid shall be boiled until it is colorless.

(c) **Potassium thiocyanate standard solution**, approximately 0.1 mol/L

7.6 g of ammonium thiocyanate or 9.7 g of potassium thiocyanate shall be dissolved in water and diluted to 1 L. The solution shall be standardised against the silver nitrate standard solution using iron III indicator at weekly intervals or before use, whichever is sooner.

(d) **Silver nitrate standard solution**, approximately 0.1 mol/L

Powdered silver nitrate shall be dried at 150°C for two hours and cooled in a desiccator. A quantity of 16.989 g shall be dissolved in water and diluted to 1 L. The solution shall be stored in an opaque glass bottle and protected from prolonged exposure to light. The solution shall be standardised against sodium chloride (certified reference materials of purity min. 99.9%), using 5% w/v potassium chromate indicator solution.

(e) **3,5,5-Trimethylhexan-1-ol**

21.3.3 Preparation of test portion

The laboratory sample shall be thoroughly mixed. An appropriate portion of the sample shall be dried in an oven at a temperature 105 ± 5°C overnight and cooled. This portion of sample shall be reduced using the procedure described in Cl. 8.6 of Section 8 of this Standard to produce a sub-sample with a minimum mass of 5 kg for 20 mm, 10 mm and fine aggregates. The sub-sample shall be sieved through a 20 mm sieve. Any oversize particle shall be crushed using the jaw crusher so as to pass the sieve to avoid excessive grinding. The sieved portions shall be combined and mixed thoroughly, and shall be reduced using the sample reduction procedure described in Cl. 8.6 of Section 8 of this Standard to produce two test portions each of 2 kg mass for coarse aggregates or of 500 g mass for fine aggregates. The test portions shall be dried in an oven at a temperature of 105 ± 5°C to achieve constant dry mass.

21.3.4 Procedure

For coarse aggregates, 2 ± 0.1 kg of the test portion (see Cl. 21.3.3) shall be weighed, to the nearest 5 g, accurately into a wide-mouth, screw-capped plastic bottle of 5 L capacity. For fine aggregates, about 500 g of fine aggregate shall be weighed accurately into a wide-mouth, screw-capped bottle of 2 L capacity. A mass of water equal to the mass of the test portion shall be added to each bottle. The bottle shall be screwed water-tight. The contents shall be mixed by occasional shaking/rolling for at least 24 hours. The extracts shall be filtered through a dry, medium grade filter paper. A 100 mL portion of the filtrate shall be transferred, with a pipette, to a 500 mL conical flask. 5 mL of nitric acid shall be added to

the flask. A measured excess of silver nitrate standard solution shall be added until all the chloride have been precipitated. The total volume of the silver nitrate standardised solution added shall be recorded.

NOTE: *When aggregates containing sulphide (e.g. slags) are being analysed, the solution shall be boiled in a fume cupboard after adding the nitric acid but before adding the silver nitrate solution. A white precipitate of sulphur may form, but it is not necessary to filter this off. The solution shall be cooled and the silver nitrate solution shall then be added.*

2 mL of 3,5,5-trimethylhexan-1-ol shall be added into the capped flask. The solution shall be shaken vigorously to coagulate the precipitate. 5 mL of the iron (III) indicator solution shall be added. The content shall be titrated against the thiocyanate standard solution until the first permanent colour change from white opalescence to pale pinkish-brown is observed.

This procedure shall be repeated with a duplicate test portion.

21.3.5 Calculation and expression of results

The water-soluble chloride ion (Cl^-) content shall be calculated as a percentage from the following equation:

$$Cl^- \ content = \frac{3.545(V_1 N_1 - V_2 N_2)}{m}$$

where

V_1 is the total volume of silver nitrate standard solution added (in mL);
V_2 is the volume of thiocyanate standard solution used (in mL);
N_1 is the mean concentration of silver nitrate standard solution added (in mol/L);
N_2 is the mean concentration of thiocyanate standard solution used (in mol/L); and
m is the mass of dried aggregate sample (in g).

NOTE: *Other concentrations of silver nitrate solution and thiocyanate solution may be used and the equation modified accordingly.*

The water-soluble chloride ion content shall be reported to the nearest 0.01%.

21.3.6 Test report

The test report shall affirm that the water-soluble chloride ion content was determined in accordance with this Section of the Standard and whether or not a certificate of sampling is available. If available, a copy of the sampling certificate shall be provided. The test report shall contain the following additional information:

(a) Sample identification.

(b) The water-soluble chloride ion content.

21.4 METHOD FOR DETERMINATION OF ACID-SOLUBLE CHLORIDE ION CONTENT

21.4.1 Principle

The acid-soluble chloride ions are extracted from a sample of dried coarse recycled aggregates by using diluted nitric acid. An excess of silver nitrate solution is added to the

extract and the unreacted silver nitrate is back-titrated with a standardised solution of thiocyanate, using ammonium iron (III) sulphate solution as an indicator.

21.4.2 Reagents

The following reagents are required:

(a) **Iron III indicator solution**

50 g of ammonium ferric sulphate shall be dissolved in 60 mL of water with warming, followed by addition of 10 mL of 6 mol/L

(b) **Nitric acid**, approximately 6 mol/L

(c) **Potassium thiocyanate standard solution**, approximately 0.1 mol/L

7.6 g of ammonium thiocyanate or 9.7 g of potassium thiocyanate shall be dissolved in water and diluted to 1 L. The solution shall be standardised against the silver nitrate standard solution using iron III indicator at weekly intervals or before use, whichever is sooner.

(d) **Silver nitrate standard solution**, approximately 0.1 mol/L.

Powdered silver nitrate shall be dried at 150 ± 5°C for two hours and cooled to room temperature in a desiccator. A quantity of 16.989 g shall be dissolved in water and diluted to 1 L. The solution shall be stored in an opaque glass bottle and protected from prolonged exposure to light. The solution shall be standardised against sodium chloride (certified reference materials of purity min. 99.9%), using 5% w/v potassium chromate indicator solution.

(e) **3,5,5-Trimethylhexan-1-ol**

21.4.3 Preparation of test portion

The laboratory sample shall be thoroughly mixed. An appropriate portion of sample shall be dried in an oven at a temperature 105 ± 5°C overnight and cooled. This portion of the sample shall be reduced using the sample reduction procedure described in Cl. 8.6 of Section 8 of this Standard to produce a sub-sample with a minimum mass of 5 kg for 20 mm and 10 mm aggregates. The sub-sample shall be sieved through a 20 mm sieve. Any oversize particle shall be crushed using the jaw crusher so as to pass the sieve to avoid excessive grinding. The sieved portions shall be combined and mixed thoroughly, and shall be reduced using the sample reduction procedure described in Cl. 8.6 of Section 8 of this Standard to produce two test portions each of 2 kg mass. The test portions shall be dried in an oven at a temperature of 105 ± 5°C to achieve constant dry mass.

21.4.4 Procedure

5 ± 0.005 g of the test portion (see Cl. 21.4.3) shall be weighed accurately into a 500 mL conical flask. The sample shall be dispersed with 50 mL of water, followed by addition of 10 mL of nitric acid. 50 mL of hot water shall then be added and the mixture boiled for 4 to 5 minutes and kept warm for 10 to 15 minutes. (If the supernatant liquid is turbid, it shall be filtered through a fast hardened ashless filter paper and washed with hot water.) The filtrate/solution shall be cooled to room temperature and a measured excess of silver nitrate standard solution shall be added. The total volume of the silver nitrate added shall be recorded. 2 to 3 mL of 3,5,5-trimethylhexan-1-ol shall be added to the capped flask and the latter shall be shaken vigorously to coagulate the precipitate. 5 mL of iron III indicator solution shall be added. The content shall be titrated against the thiocyanate standard

solution with vigorous shaking until the first permanent colour change from white opalescence to pale pinkish-brown is observed.

This procedure shall be repeated with a duplicate test portion.

21.4.5 Calculation and expression of results

The acid-soluble chloride ion (Cl^-) content shall be calculated as a percentage from the following equation:

$$Cl^- \ content = \frac{3.545(V_1 N_1 - V_2 N_2)}{m}$$

where

V_1 is the total volume of silver nitrate standard solution added (in mL);
V_2 is the volume of thiocyanate standard solution used (in mL);
N_1 is the mean concentration of silver nitrate standard solution added (in mol/L);
N_2 is the mean concentration of thiocyanate standard solution used (in mol/L); and
m is the mass of dried aggregate sample (in g).

NOTE: *Other concentrations of silver nitrate solution and thiocyanate solution may be used and the equation modified accordingly.*

The acid-soluble chloride ion content shall be reported to the nearest 0.01%.

21.4.6 Test report

The test report shall affirm that the acid-soluble chloride ion content was determined in accordance with this Section of the Standard and whether or not a certificate of sampling is available. If available, a copy of the sampling certificate shall be provided. The test report shall contain the following additional information:

(a) Sample identification.

(b) The acid-soluble chloride ion content.

21.5 METHOD FOR DETERMINATION OF ACID-SOLUBLE SULPHATE CONTENT

21.5.1 Principle

The acid-soluble sulphate ions are extracted from a sample of dried aggregates by using diluted hydrochloric acid. Barium chloride is added and the barium sulphate precipitate is collected, heated to 800°C and weighed.

21.5.2 Reagents

The following reagents are required:

(a) **Barium chloride**, 5% solution.

50 g of barium chloride shall be dissolved in 1 L of water and filtered before use if necessary.

(b) **Diluted hydrochloric acid**

100 mL of concentrated hydrochloric acid (relative density 1.18) shall be diluted to 1 L with water.

(c) **Silver nitrate solution**

0.5 g of silver nitrate shall be dissolved in 100 mL of water and stored in an amber-coloured glass reagent bottle.

21.5.3 Preparation of test portion

The laboratory sample shall be dried at a temperature of 105 ± 5°C. Then it shall be reduced using the sample reduction procedure described in Cl. 8.6 of Section 8 of this Standard to produce a sub-sample with an amount not less than the mass given in Table 21.1.

Table 21.1 - Minimum mass of sub-sample for determination of acid-soluble sulphate content

Nominal maximum size of aggregate (mm)	**Minimum mass of sub-sample** (kg)
63	50
50	35
40	15
28	5
20	2
14	1
10	0.5
5 or less	0.2

The sub-sample shall be sieved through a 20 mm sieve and any oversize aggregate shall be crushed to pass the sieve to avoid excessive grinding. The sieved portions shall be combined and mixed thoroughly, and shall be reduced using the sample reduction procedure described in Cl. 8.6 of Section 8 of this Standard to produce two portions, each of about 2 kg, of the sub-sample. Each portion of the sub-sample shall be dried in an oven at a temperature of 105 ± 5°C to achieve constant dry mass. All the aggregate shall be crushed to pass a 5 mm sieve, mixed and reduced using the sample reduction procedure described in Cl. 8.6 of Section 8 of this Standard to not less than 200 g. After passing a 1 mm sieve to produce a sample of approximately 100 g, the latter shall be ground until it passes through a 150 μm sieve to produce the test portion.

NOTE: *With suitable mechanical grinding equipment it is possible to by-pass some of these stages. For example, a jaw-crusher could be used to crush all the sub-samples to pass a 5 mm sieve without the preliminary sieving and crushing at the 20 mm size. Similarly the 200 g sub-sample portion passing the 5 mm sieve could be crushed to pass a 150 μm sieve, by-passing the 1 mm size operation, in, for example, a disc mill. The intention is to produce a test portion which is fully representative of the laboratory sample.*

21.5.4 Procedure

About 3 ± 0.001 g of the test portion (see Cl. 21.5.3) shall be weighed into a beaker and 100 mL of diluted hydrochloric acid shall be added and stirred.

NOTE 1: *Aggregates containing significant amounts of carbonates will froth at this stage. In these cases, the acid shall be added slowly while the mixture is continuously stirred.*

NOTE 2: *Aggregates containing sulphide will release H_2S on acidification and this will be noticeable by its smell. In these cases there is a danger that this procedure will overestimate the sulphate content because of sulphide oxidation. If the aggregate contains sulphide, 100 mL of the diluted hydrochloric acid shall be added and heated to boiling point. The source of heat shall be removed*

and, while the acid solution is continuously stirred, the weighed analytical portion of about 3 g mass shall be sprinkled onto the acid.

The solution shall be heated to boiling and simmered gently for 15 min in a fume cupboard. Then it shall be filtered through a medium filter paper or re-filtered with a fine filter paper until the filtrate is clear. The filter paper shall be washed thoroughly with hot water and the filtrate and washings collected and diluted to 300 mL with water.

The solution shall be boiled and 10 mL barium chloride solution (see Cl. 21.5.2 (a)) added dropwise with constant stirring. Boiling shall be continued until the precipitate is properly formed. The solution shall be kept at just below boiling point for at least 30 min then left to cool for 24 h or overnight.

The precipitate of barium sulphate shall be transferred with extreme care to a previously ignited and weighed sintered silica filter crucible using suction. Alternatively the precipitate may be transferred to a suitable filter paper in a glass funnel and filtered. In either case the precipitate shall be washed with hot water until the washings are free from chloride, as indicated by the absence of turbidity when tested with silver nitrate. The sintered silica filter crucible containing the precipitate shall then be dried at 105 ± 5°C at first for 30 min and then gradually to 800°C in a muffle furnace. After ignition, the crucible and the residue shall be cooled to room temperature in a dessicator. The weight of the crucible and the residue shall be recorded to nearest 0.001g. The ignition shall be repeated until constant mass is achieved at the end of two successive 4-h ignitions.

If the precipitate is filtered through a filter paper, the filter paper and precipitate shall be transferred to a previously ignited and weighed crucible. The crucible and its contents shall be placed in a muffle furnace at room temperature and the temperature gradually raised to 800°C. If a burner is used, the filter paper and its contents shall first be dried and ignited over a small flame taking care to char the filter paper slowly so as not to lose the precipitate and then the temperature gradually raised to red heat. The ignition shall be repeated until constant mass is achieved by weighing the mass at 4-h ignition intervals as described above.

The procedure shall be repeated with a second duplicate 3 g of test portion.

21.5.5 Calculation and expression of results

The acid soluble sulphate (SO_3) content shall be calculated as a percentage from the following equation:

$$SO_3 \ content = \frac{m_2}{m_1} \times 34.3$$

where

m_1 is the mass of test portion (in g); and
m_2 is the mass of the precipitate obtained from ignition (in g).

The acid-soluble sulphate content shall be reported to the nearest 0.1%.

21.5.6 Test report

The test report shall affirm that the acid soluble sulphate content was determined in accordance with this Section of the Standard and whether or not a certificate of sampling is available. If available, a copy of the sampling certificate shall be provided. The test report shall contain the following additional information:

(a) Sample identification.

(b) The acid soluble sulphate content.

21.6 METHOD FOR DETERMINATION OF TOTAL SULPHUR CONTENT

21.6.1 Principle

The sulphur compounds are converted to sulphates and extracted from a sample of dried natural aggregates by using hydrogen peroxide and hydrochloric acid. Barium chloride is added and the barium sulphate precipitate is collected, heated to 925°C and weighed.

21.6.2 Reagents

The following reagents are required:

(a) **Hydrogen peroxide**, 30% concentration

(b) **Hydrochloric acid**, relative density 1.18 to 1.19

(c) **Diluted Hydrochloric acid (1+1)**

One volume of concentrated hydrochloric acid (relative density 1.18) shall be diluted with one volume of water.

(d) **Ammonium hydroxide**, relative density 0.88 to 0.91

(e) **Barium chloride**

100 g of barium chloride ($BaCl_2.2H_2O$) shall be dissolved in 1 L of water. The solution shall be filtered through a medium grade filter paper before use.

(f) **Methyl red indicator**

20 mg of methyl red powder shall be dissolved in 50 mL of ethanol, followed by addition of 50 mL of water.

21.6.3 Preparation of test portion

The laboratory sample shall be reduced using the sample reduction procedure described in Cl. 8.6 of Section 8 of this Standard to produce a sub-sample with a mass of not less than the mass given in Table 21.2. If necessary, the sub-sample shall be dried at a temperature not exceeding 105 ± 5°C to avoid the oxidation of sulphides. The sub-sample shall be crushed and reduced stepwise to a mass of approximately 20 g. The latter shall be ground until it passes through a 125 μm sieve to produce the test portion.

Table 21.2 - Minimum mass of sub-sample for determination of total sulphur content

Nominal maximum particle size of aggregate (mm)	**Minimum mass of sub-sample** (kg)
63	50
45	35
31.5	15
22.4 or less	5

21.6.4 Procedure

1 g of the analytical sample (see Cl. 21.6.3) shall be weighed accurately, to the nearest 0.1 mg, and transferred into a beaker. 20 mL of water shall be added to the sample, followed by 10 mL of hydrogen perioxide and the mixture shall be warmed for 30 min below boiling point. After the dissolution, 20 mL of diluted hydrochloric acid (1+1) shall be added and the beaker shall be left in a warm water bath for 30 min.

The mixture shall then be heated to below boiling and made alkaline to pH paper (or to methyl red indicator) with ammonium hydroxide. The mixture shall be allowed to simmer for 30 s and then filtered under gentle suction through a medium porosity filter paper. It shall be washed once with a little hot water and the filtrates reserved.

The filter paper with its contents shall be transferred to a beaker and dissolved in 5 mL hydrochloric acid to which has been added 70 mL hot water. The treatment stated above (boiling, precipitating, filtering and washing) shall be repeated and the resulting precipitate shall be rejected. The combined filtrates and washings (about 220 mL in all) shall be acidified with 1 mL hydrochloric acid. The solution shall be boiled for 5 ± 0.5 min. While the solution is heated at boiling point, 10 mL of barium chloride solution, heated to just below boiling, shall be added dropwise with vigorous stirring to precipitate the sulphate. (It is necessary to continue the boiling for 15 min so that the precipitate is properly formed.) The solution shall be kept just below boiling for 30 min and left in a warm place overnight. It shall be filtered through a fine filter paper which shall be washed several times with hot water until the washings are free from chloride. The filter paper containing the precipitate shall finally be transferred to a previously ignited and weighed ignition crucible. The crucible and its contents shall be ignited at a gradually increasing temperature in a furnace until it reaches 925 ± 25°C for 15 min. After ignition, the crucible and the residue shall be cooled to room temperature in a dessicator. The weight of the crucible and the residue shall be recorded to nearest 0.001 g. The ignition shall be repeated until constant mass is achieved at the end of two successive ignitions at 4-h intervals.

The procedure shall be repeated with a second duplicate test portion.

21.6.5 Calculation and expression of results

The total sulphur (*S*) content shall be calculated as a percentage from the following equation:

$$S\ content = \frac{m_5}{m_4} \times 13.74$$

where

m_5 is the mass of precipitate after ignition (in g); and
m_4 is the mass of the test portion (in g).

The total sulphur content shall be reported to the nearest 0.1%.

21.6.6 Test report

The test report shall affirm that the total sulphur content was determined in accordance with this Section of the Standard and whether or not a certificate of sampling is available. If available, a copy of the sampling certificate shall be provided. The test report shall contain the following additional information:

(a) Sample identification.

(b) The total sulphur content.

21.7 METHOD FOR DETERMINATION OF PRESENCE OF HUMUS

21.7.1 Principle

Humus is the organic substance formed by the decomposition of animal and plant residue. The humus is extracted from an aggregate sample with a solution of sodium hydroxide and the colour of the resulting solution is compared with that of a standard colour solution to determine the presence of humus.

21.7.2 Reagents

The following reagents are required:

(a) **Sodium hydroxide**, 3% solution

30 g of sodium hydroxide pellets shall be dissolved in water. The solution, cooled to room temperature, shall be diluted to 1 L with water in a volumetric flask.

(b) **Standard colour solution**

45.0 g of ferric chloride ($FeCl_3.6H_2O$) and 5.50 g of cobalt chloride ($CoCl_2.6H_2O$) shall be dissolved in 279.5 g of water with 1 mL of concentrated hydrochloric acid (relative density 1.18).

21.7.3 Preparation of test portion

The laboratory sample shall be reduced using the sample reduction procedure described in Cl. 8.6 of Section 8 of this Standard to produce a sub-sample with a mass of not less than the mass given in Table 21.2. The sub-sample shall be dried at a temperature of 40 ± 5°C and shall be sieved through a 4 mm test sieve to obtain the test portions.

21.7.4 Procedure

The sodium hydroxide shall be poured into a bottle to a height of about 80 mm. A test portion shall be added until the height of the aggregate and sodium hydroxide is 120 mm. The bottle shall then be stoppered and shaken vigorously for 1 min and shall be left to stand for 24 h. The colour of the resulting solution shall be compared to the colour of the standard colour solution, contained in a similar bottle, and the result (whether lighter or darker than the standard colour) shall be recorded.

This procedure shall be repeated with a duplicate test portion.

21.7.5 Expression of results

If the colour of the test solution is lighter than the standard colour, the test result shall be stated as Negative. If the colour of the test solution is darker than the standard colour, the test result shall be stated as Positive.

21.7.6 Test report

The test report shall affirm that the presence of humus was determined in accordance with this Section of the Standard and whether or not a certificate of sampling is available. If available, a copy of the sampling certificate shall be provided. The test report shall contain the following additional information:

(a) Sample identification.

(b) The positive or negative result of the test.

SECTION 22

METHOD FOR DETERMINATION OF EFFECT OF ORGANIC SUBSTANCES BY MORTAR METHOD

22.1 SCOPE

This Section describes the method for determining the effect of organic substances in aggregates by the mortar method.

22.2 PRINCIPLE

The mortar method is intended to quantify the effect of organic substances in aggregates on the stiffening and hardening of mortar. Two identical mortar samples are prepared and tested for stiffening rate and compressive strength. One mortar sample contains the test aggregate while the other mortar sample is prepared from a duplicate test portion of aggregate, which has been sufficiently heated to destroy any organic matter in the aggregate. The heated aggregate acts as a control for comparison with the test aggregate. The stiffening test is used to assess the acceleration or retardation of the setting of the mortar, while the 28-day compressive strength test is used to show any longer term effect.

22.3 SAMPLING

The laboratory sample shall be taken in accordance with the procedures described in Section 8 of this Standard, and shall have a mass of at least 15 kg.

22.4 APPARATUS

The following apparatus is required:

(a) Sample divider

(b) Furnace

The furnace shall have a capacity of keeping at least 2 kg of aggregates in one time and shall be able to maintain a temperature of 480 ± 25°C for 4 h.

(c) Balance(s)

The balance(s) shall be of suitable capacity accurate to 0.1% of the mass of the test portion.

(d) Test sieves

(e) Mechanical sieve shaker (optional)

(f) Trays

The trays shall be of suitable size, which can be heated in the ventilated oven without damage or change in mass.

(g) Test portion containers

The containers shall be of size sufficient to contain the test portion.

(h) Mixer

The mixer shall consist of the following parts:

(1) A stainless steel bowl with a capacity of about 5 L of the typical shape and size as shown in Figure 22.1, provided with some means by which it can be fixed securely to the mixer frame during mixing and by which the height of the bowl in relation to the blade and the gap between blade and bowl can be finely adjusted and fixed.

(2) A stainless steel blade of the typical shape, size and tolerances as shown in Figure 22.1, revolving about its own axis as it is driven in a planetary movement around the axis of the bowl at controlled speeds by an electric motor. The directions of rotation about its own axis and planetary movement around the axis of the bowl shall be opposite.

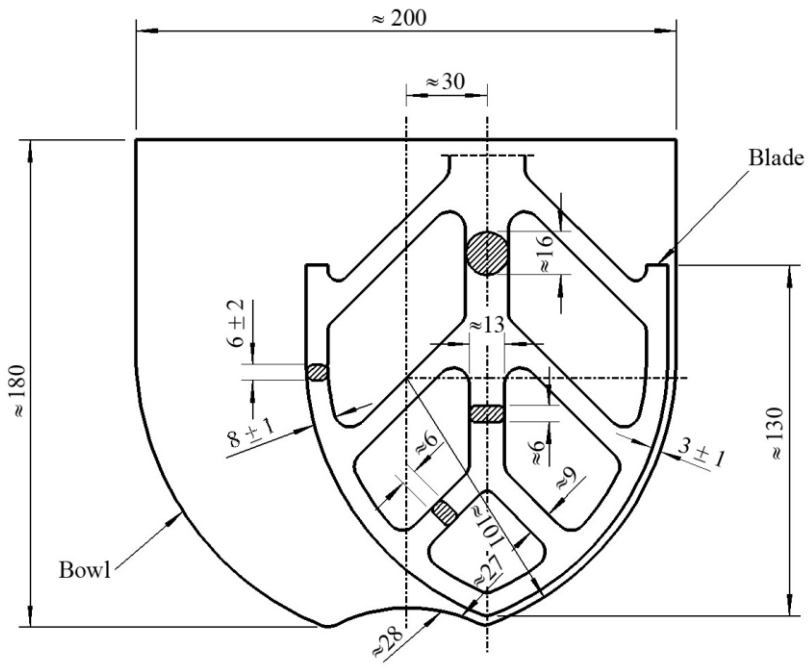
The gap between the blade and bowl as shown in Figure 22.1 shall be checked regularly. The gap of 3 ± 1 mm refers to the situation when the blade in the empty bowl is brought as close as possible to the wall. Feeler gauges are useful where direct measurement is difficult.

NOTE: *The dimensions marked on Figure 22.1 are approximate only and should only be used for the guidance of manufacturers.*

The mixer shall operate at the speeds given in Table 22.1 when mixing the mortar.

Table 22.1 - Speeds of mixer blade

Speed	Rotation per minute	Planetary movement per minute
Low speed	140 ± 5	62 ± 5
High Speed	285 ± 10	125 ± 10



Dimensions are in millimetres.

Figure 22.1 - Typical mixer bowl and blade

(i) Plunger test apparatus

The plunger test apparatus shall conform to the typical requirements as shown in Figure 22.2 and shall consist of the following parts:

(1) Plunger stand

The plunger stand shall consist of a base plate, frame, clamp with guide bushes and fixing screw.

(2) Cylindrical vessel

The cylindrical vessel shall be secured centrally in a positioning recess.

(3) Penetration rod

The penetration rod shall consist of an upper scale and a plastics plunger of circular cross-section at the base and with a hemispherical lower end of the same diameter. The total mass of the plunger and penetration rod is 90 ± 2 g. The penetration rod is fixed in an initial position 100 mm above the mortar surface, measured from the lower hemispherical end of the plunger.

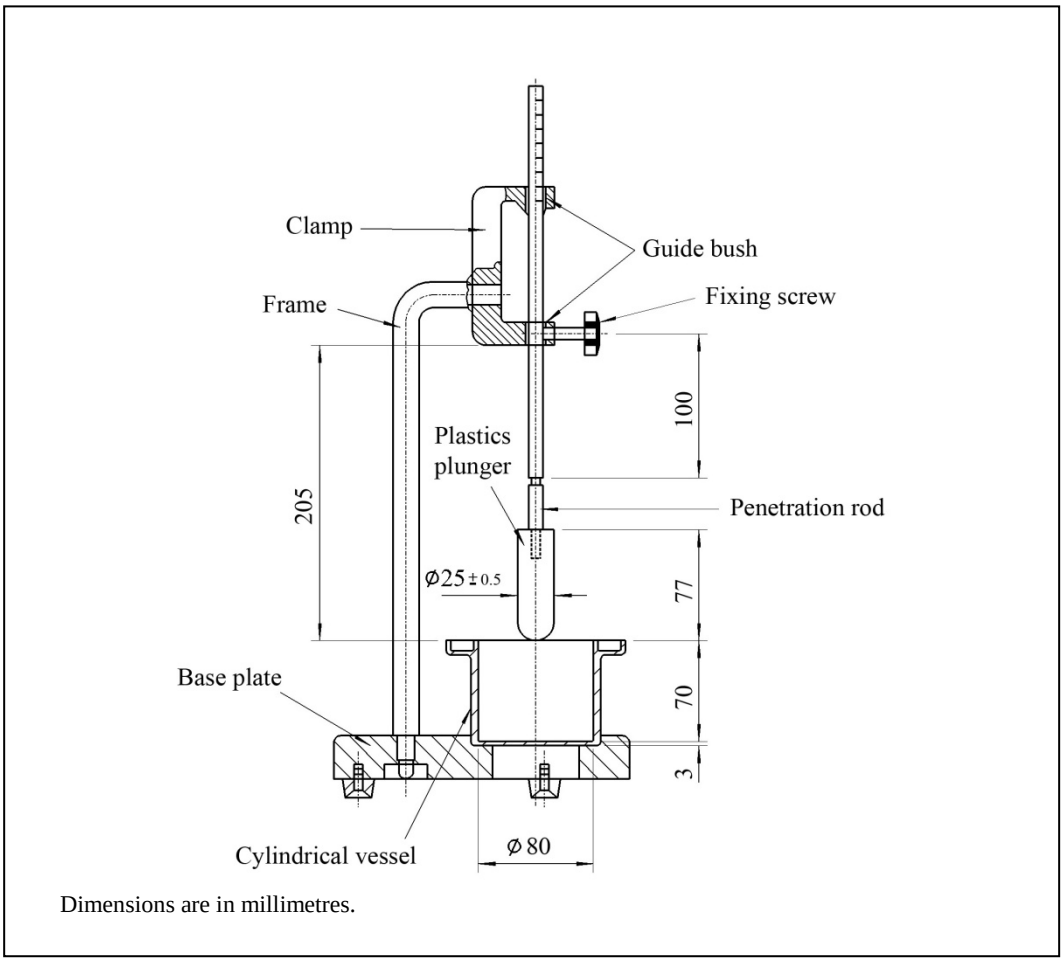


Figure 22.2 - Plunger test apparatus

The following additional apparatus is required:

(4) Tamper

The tamper shall consist of a rigid, non-absorptive rod of circular cross-section, approximately 40 mm in diameter and approximately 200 mm long. The tamping face shall be fat and at right angles to the length of the tamper. The mass of the tamper shall be 250 ± 15 g.

(5) Trowel

(6) Palette knife

(j) Stiffening test apparatus (see Section 3 of CS1)

(k) Compressive strength test apparatus

The following apparatus is required:

(1) Moulds

The mould shall consist of an open frame of removable walls forming three compartments when assembled as shown in Figure 22.3. Moulds shall be provided for prisms with a nominal length of 160 mm and a cross section of 40 mm × 40 mm. The mould shall be made of steel with walls approximately 10 mm thick. Each internal side face of the mould shall be case hardened to have at least 400 HV Vickers hardness value in accordance with BS EN ISO 6507-1. All parts of the mould shall be clearly marked with a reference number to enable the mould

to be correctly reassembled after demoulding. The internal dimensions and tolerance of each mould compartment shall be 160 ± 1 mm long, 40.0 ± 0.2 mm wide and 40.1 ± 0.1 mm height. The flatness tolerance over the whole of each internal side face of the mould shall not be greater than 0.03 mm. The perpendicularity tolerance for each internal face with respect to the bottom surface of the mould and the adjacent internal face as datum faces shall not be greater than 0.2 mm.

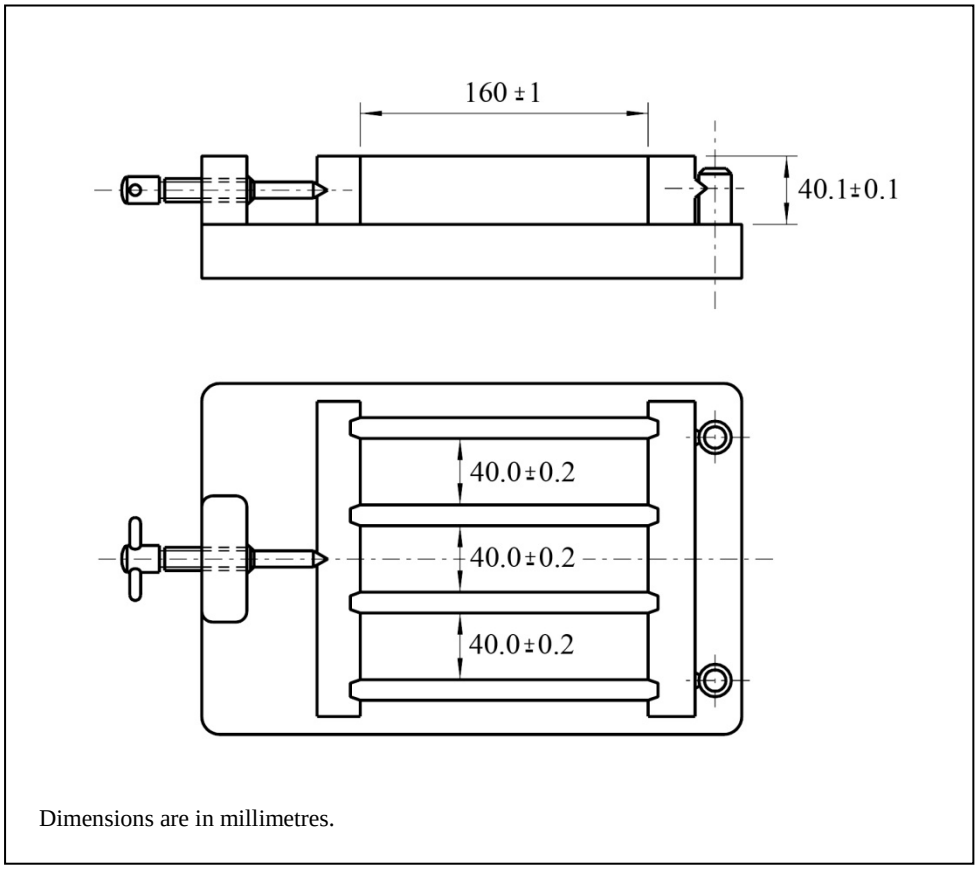


Figure 22.3 - Mould for forming test specimens

(2) Tamper

The tamper shall consist of a rigid, non-absorptive rod of square cross-section, each side of which is 12 ± 1 mm. The tamping face shall be fat and at right angles to the length of the tamper. The mass of the tamper shall be 50 ± 1 g.

(3) Storage chamber

The storage chamber shall be capable of maintaining a temperature of 20 ± 2°C and a relative humidity of 95 ± 5%.

(4) Trowel

(5) Palette knife

(6) Compression testing machine

The machine shall be capable of applying a compressive force up to 1,000 kN and shall be capable of being operated to give a uniform rate of loading as specified in Cl. 22.9. The machine shall comply with the requirements of CS1 for a class 1 or class 2 machine. The machine may be operated with or without a spherical seating.

The testing machine shall be equipped with a jig assembly conforming to the requirements shown in Figure 22.4.

The jig assembly shall be placed between the machine platens for transmitting the load of the compression testing machine to the compression surfaces of the mortar specimen via the upper and lower platens of the jig. The platens of the jig shall be made of tungsten carbide or steel with surface hardness of at least 600 HV Vickers hardness value in accordance with EN ISO 6507-1. The platens shall be 40.0 ± 0.1 mm wide, 40.0 ± 0.1 mm long and at least 10 mm thick. The flatness tolerance for the contact faces shall be 0.01 mm. The upper platen of the jig receives the load from the upper platen of the machine through an intermediate spherical seating of the jig. This spherical seating forms part of an assembly, which shall be able to slide vertically without appreciable friction in the jig guiding its movement. The jig shall be kept clean and the spherical seating shall be free to move in such a way that the upper platen of the jig will accommodate itself initially to the shape of the specimen and then remain fixed during the test.

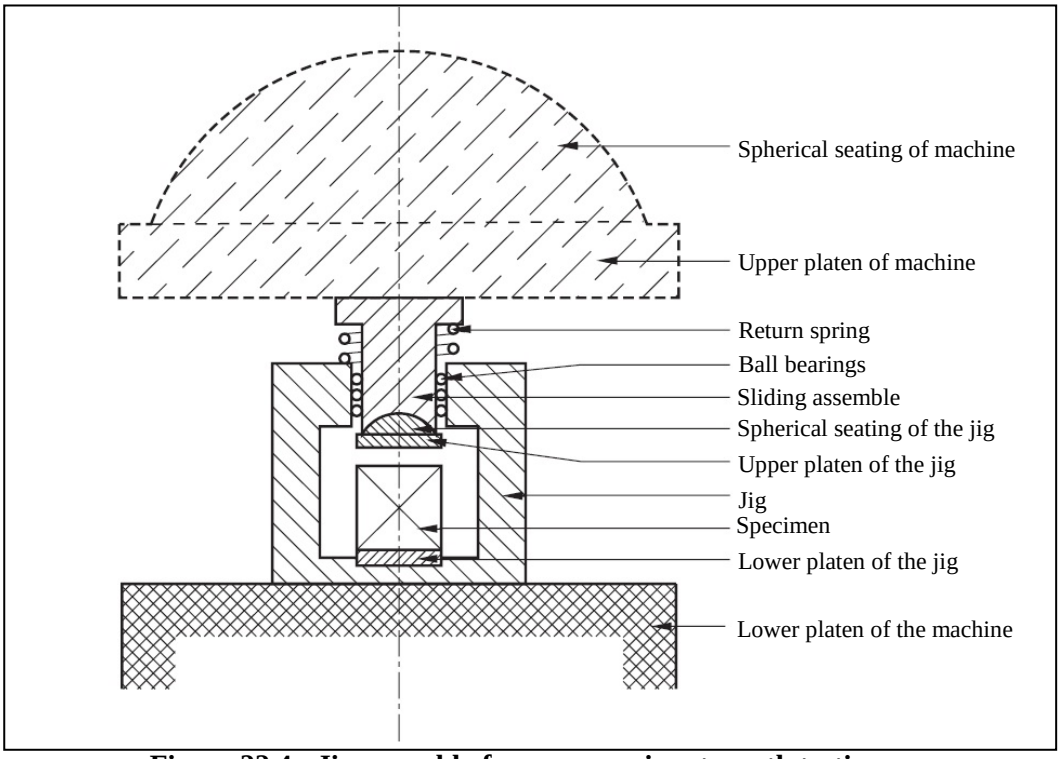


Figure 22.4 - Jig assembly for compressive strength testing

NOTE 1: *The spherical seating of the jig may be lubricated but only to such an extent that movement of the upper platen of the jig cannot take place under load during the test. Lubricants, which are effective under high pressure, are not suitable.*

NOTE 2: *It is desirable that the sliding assembly should return automatically to its initial position after crushing the specimen.*

NOTE: *All apparatus shall comply with the general requirements of Section 7 of this Standard.*

22.5 PREPARATION OF TEST PORTION

The laboratory sample shall be spread onto trays and allowed to be dried naturally in the laboratory at ambient temperature.

The laboratory sample shall be reduced in accordance with the procedures described in Cl. 8.6 of Section 8 of this Standard to produce a sub-sample with a minimum mass of 10 kg.

The sub-sample shall be dried at a temperature of 40 ± 5°C and shall be sieved through a 4 mm test sieve to obtain a minimum mass of 8 kg. The dried sub-sample shall be further reduced in accordance with the procedures described in Cl. 8.6 of Section 8 of this Standard to produce four test portions, each with a mass of 1,900 ± 100 g.

Two of the test portions shall be retained in sealed containers without further treatment. The other two test portions shall be weighed and put into a furnace and heated to a temperature of 480 ± 25°C for 4 ± 0.25 h separately. The heated test portions shall be allowed to cool down to ambient temperature for overnight in the furnace and shall then be weighed and recorded the loss in mass.

22.6 CONSTITUENTS

The Portland cement shall be stored in an airtight container.

22.7 MIX QUANTITIES

22.7.1 General requirements

Each mortar mix shall contain either a test portion of the unheated aggregate or a test portion of the heated aggregate as described in Cl. 22.5, and shall also contain Portland cement with a mass equal to one quarter of the aggregate mass in the mix. The test portion and the cement shall be weighed to ± 1 g.

The water content of the mortar containing the unheated aggregate shall be chosen to produce a standard consistence, defined as a mean plunger penetration of 23 ± 5 mm, when determined by the plunger test method given below:

(a) Preparation of test sample

Water shall be added to the mixture of the test portion and cement to form fresh mortar with a minimum volume of 1.5 L and a consistence appropriate for its use. The length of mixing period shall be measured from the moment when all the constituents are introduced into the mixer.

Before testing, the fresh mortar shall be gently stirred by hand using a palette knife or trowel for 5 to 10 s to counteract any false setting, but without any additional mixing of the batch. Any deviation from the mixing procedure shall be noted. Two test samples shall be prepared and tested.

(b) Procedure

The penetration rod as shown in Figure 22.1 shall be secured in its initial position by using the fixing screw. The plunger shall be wiped clean with a damp cloth and dried before use. The cylindrical vessel shall be filled with mortar in two layers, each layer being compacted by 10 short strokes of the tamper, to ensure uniform filling of the vessel. The excess mortar shall be skimmed off with a palette knife or trowel, leaving the mortar surface plane and level with the top rim of the vessel. The filled vessel shall be placed on the base plate and the fixing screw shall be released, allowing the plunger to fall freely, starting from its initial position. The penetration of the plunger into the mortar shall be determined by taking the reading of the scale on the lower side of the upper guide bush to the nearest mm.

(c) Calculation and expression of results

The mean value of the plunger penetration shall be calculated from all the individual values for each mortar test sample, to the nearest mm. If the two individual values deviate from their mean value by less than 10%, this mean value shall be taken as the plunger penetration value of the mortar. If the two individual plunger penetration values deviate from their mean value by more than 10%, then the test shall be repeated using further mortar from the laboratory sample and if the results deviate from their mean value by less than 10%, the mean value from the repeat test shall be taken as the plunger penetration value of the mortar. If the results differ by more than 10%, the measurements shall be considered unsatisfactory and fresh test samples shall be prepared from the laboratory sample stated in Cl. 22.5 and the test shall be repeated.

22.7.2 Trial mixes

A series of trial mixes shall be prepared by using the unheated aggregate to establish the required water content of the mix. The water content shall be varied successively and the consistence of each trial mix shall be determined until the correct value of consistence is attained. The mass of water obtained in the last mix shall be recorded and the water-cement ratio shall then be calculated.

NOTE: *The unheated test aggregate should have moisture content similar to that of the heated (control) aggregate when it was weighed before putting into the furnace for heating. It is recommended to prepare the control mixes on the same day after the test mixes. Laboratory conditions should be kept as similar as possible on the two mixing days.*

22.7.3 Test mixes

The required mass of cement for each unheated test portion (see Cl. 22.7.1) shall be calculated. The mass of water required for each mortar mix shall be calculated by using the water-cement ratio obtained from the trial mixes as described in Cl. 22.7.2, and shall be weighed to ± 0.5 g

22.7.4 Control mixes

The water-cement ratio of the heated aggregate control mortar mix is the same as that of the unheated aggregate test mortar mix and the required mass of cement and water for the control mortar mix shall be calculated as described in Cl. 22.7.3. The mass lost by the corresponding portion of aggregate during the heating as detailed in the 3rd para. of Cl. 22.5 shall be added to the calculated mass of water to derive the total mass of water required. The required mass of water shall then be weighed to ± 0.5 g.

22.7.5 Mixing procedure

Four mixes, one for each test portion, are required. All the materials shall be kept at a temperature of 20 ± 2°C before commencing the mixing procedure. Mixing of all the materials shall be in a controlled environment with a temperature of 20 ± 2°C and a relative humidity of not less than 50%. Each mix shall be prepared using the following procedure:

(a) The test portion and then the cement shall be placed in the dry mixing bowl (see Cl. 22.4 (g)) and shall then be mixed for 30 s by using the mixer. Mixing shall continue and the water shall be added during the next 30 s. Mixing shall then continue for a further 60 s after all the water has been added.

(b) Operation of the mixer shall be stopped and any material adhered to the paddle and sides shall be removed by a scraper and put back into the bowl, taking particular care to ensure that no unmixed materials remain at the bottom of the bowl. This part of the

procedure shall be completed within 60 s. The bowl shall be covered with a damp cloth and shall be allowed to stand for 5 min.

(c) The bowl is put back to the mixer and the mortar shall be mixed for a further 60 s.

22.8 MEASUREMENT OF STIFFENING TIME

After completion of the mixing for each mortar as described in Cl. 22.7.5, the stiffening time shall be determined immediately in accordance with Section 3 of CS1.

The stiffening times of the duplicate test portions of unheated and heated (control) aggregates shall be recorded.

22.9 COMPRESSIVE STRENGTH OF HARDENED MORTAR

Three 160 mm × 40 mm × 40 mm prisms from each mortar mix shall be prepared and tested using the following procedures:

(a) Preparation and storage of test specimens

After completion of the mixing for each mortar in Cl. 22.7.5, the mould shall be filled up with mortar in two approximately equal layers, each layer being compacted by 25 strokes of the tamper. The excess mortar shall be skimmed off with a trowel or palette knife, leaving the mortar surface plane and level with the top of the mould. The mould shall then be stored in a storage chamber at temperature of 20 ± 2°C with relative humidity of 95 ± 5%. After one day, the specimens shall be removed from the mould and shall subsequently be stored on the grid with triangular section webs in the storage chamber with the same condition.

(b) Procedure

The specimen shall be tested at 28 days after casting and immediately after removing from the storage chamber. Any loose grit or other material from the sides of the specimen as cast shall be removed. The density of each prism after de-moulding shall be determined. For the compressive strength test, each prism shall be broken into two halves of approximate 80 mm × 40 mm × 40 mm by suitable means which do not cause any harmful stresses to the prism halves. This will result in six half prisms.

The platen of the testing machine and the jig assembly shall be wiped with a clean cloth.

The half prism specimen shall be placed between the platens of the jig, with its long axis perpendicular to the vertical axis of the jig. It shall be arranged so that the cast end of the half prism is 16 ± 0.1 mm from the nearer edge of the platens of the jig and the load will be applied to the specimen faces which have been cast against the steel mould and to the whole width of the specimen faces in contact with the platens of the jig. The jig assembly shall be centred laterally within ± 0.5 mm on the lower platen of the testing machine.

The load shall be applied at a uniform rate in the range of 10 N/s to 50 N/s so that failure occurs within a period of 30 s to 90 s. The test shall be repeated for the remaining half prism specimens

The maximum load applied to the specimen shall be recorded in N during the test. The compressive strength of the specimen shall be calculated as the maximum load carried by the specimen divided by the area of the platens (40 mm x 40 mm).

The 12 compressive strengths for the duplicate test portions of unheated and heated (control) aggregates shall be recorded to the nearest 0.05 N/mm^2 and their means to the nearest 0.1 N/mm^2.

22.10 CALCULATION AND EXPRESSION OF RESULTS

22.10.1 Stiffening time

The change in stiffening time shall be calculated by subtracting the mean stiffening time of the heated aggregate mortar from the mean stiffening time of the unheated aggregate mortar. The result shall be calculated to the nearest 15 min.

NOTE: *A negative result indicates that the setting of the mortar has been accelerated by the organic substances in the aggregate.*

22.10.2 Compressive strength

The percentage decrease (S) in the 28-day compressive strength of the unheated aggregate mortar shall be calculated as a percentage to the nearest 1% by the following equation:

$$S = \frac{B - A}{B} \times 100$$

where

A is the mean compressive strength of the six unheated aggregate prisms (in N/mm^2); and

B is the mean compressive strength of the six heated (control) aggregate prisms (in N/mm^2).

NOTE: *Organic substances can entrain air in mortar mixes and entrained air can affect the compressive strength. The presence of entrained air can be assessed by comparing the mean mass and density of the two sets of prisms.*

22.11 TEST REPORT

The report shall affirm that the stiffening time and compressive strength of aggregate mortar were determined in accordance with this Section of the Standard and whether or not a copy of the certificate of sampling is available. If available, a copy of the sampling certificate shall be provided. The test report shall contain the following additional information:

(a) Sample identification.

(b) The change in stiffening time.

(c) The percentage decrease in the 28-day compressive strength of the unheated aggregate mortar.