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METHODS OF

# SAMPLING, ANALYSIS AND TESTING OF CONCRETE

PART 1 - METHODS OF

# SAMPLING FRESH CONCRETE AND MAKING TEST SPECIMENS

BUREAU OF CEYLON STANDARDS

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Gr.9



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*Sri Lanka Standards are subject to periodical revision in order to accommodate the progress made by industry. Suggestions for improvement will be recorded and brought to the notice of the Committees to which the revisions are entrusted.*

*This Standard does not purport to include all the necessary provisions of a contract.*

SRI LANKA STANDARD

# METHODS OF SAMPLING, ANALYSIS AND TESTING OF CONCRETE

## PART 1 : METHODS OF SAMPLING FRESH CONCRETE AND MAKING TEST SPECIMENS

**FOREWORD**

This Sri Lanka Standard has been prepared by the Drafting Committee on Methods of Sampling, Analysis and Testing of Concrete. It was approved by the Civil Engineering Divisional Committee of the Bureau of Ceylon Standards and was authorised for adoption and publication by the Council of the Bureau on 1974-05-21.

This standard has been prepared in 3 parts, issued separately as follows:

Part 1 - Methods of sampling fresh concrete and making test specimens;

Part 2 - Methods of testing concrete;

Part 3 - Analysis of hardened concrete.

This standard does not apply to concrete whose nominal maximum aggregate size exceeds 40 mm (1.5 in).

Part 1 of this standard describes the methods of obtaining samples of fresh concrete and making specimens that are required for the tests described in Parts 2 and 3.

The term *site* is used when samples are being taken from concrete to be used in the works and the term *laboratory* when most of the concrete is to be used in the samples.

Clause 2 gives the definitions of terms relating to sampling and Clause 3 gives the quantities of concrete required for the different tests.

Clause 4 describes the sampling of fresh concrete on site, under normal conditions. A method of checking the accuracy of regular sampling, when required by determining the number of increments required to give an acceptable standard of sampling is described in this standard. A modification of this procedure is included for cases when it is necessary to obtain some indication of the accuracy of single batch sampling.

Clause 5 describes the preparation and weighing of individual materials for mixing and sampling in the laboratory. Clause 6 describes the methods of making and curing test specimens.

All units given in this standard are metric units, with the approximate inch equivalents in brackets

The American, Australian, British, Canadian and Indian Standards have been consulted in the preparation of this standard specification and acknowledgement is made of the assistance gained therefrom.

## 1 SCOPE

The methods to be used on site to obtain representative samples of required size from a batch of fresh concrete is specified in 4 of this standard. The number of increments to form a sample under normal conditions and where necessary to check the accuracy of regular sampling is given in 4.4.

The procedure of mixing and sampling of fresh concrete in the laboratory, where accurate control of the quantities of materials and the test conditions is required is specified in 5. This method could be especially applied for the purpose of performing a preliminary test to ascertain the suitability of of the available materials or to determine suitable mix proportions.

## 2 TERMINOLOGY

For the purpose of this standard, the following definitions shall apply:

2.1 **fresh concrete**: Concrete during the initial period of two hours from addition of water to the cement.

2.2 **batch***: The unit of concrete which is to be sampled.

2.3 **sample**: A quantity of concrete taken from the batch whose properties are to be determined. The sample should therefore be representative of the batch and will normally consist of a number of increments.

2.4 **increment**: A quantity of concrete taken by a single operation of the scoop.

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* *Where a continuous mixer is used it is suggested that the output in a period of one minute should be treated as a batch for the purposes of this standard.*

**2.5 regular sampling:** The sampling of concrete nominally of the same mix received regularly from the same source, although regular sampling can be continual, a sample being taken from each batch, it is generally intermittent, samples being taken only from certain batches.

**2.6 accuracy of a result:** The closeness of agreement between an experimental result and the true value.

**2.7 range:** The arithmetic difference between the highest and the lowest values of a set.

**2.8 period average:** The average of a series of test results obtained on samples which are representative of a quantity of concrete. This quantity should be the output of a mixer during a given period, a particular volume of concrete or a structural unit.

**2.9 bias:** An effect that makes a statistical result unrepresentative by systematically distorting it (as distinct from a random error that may distort on any one occasion but balances out on the average).

## 3 QUANTITIES OF CONCRETE REQUIRED FOR TESTS

The quantities of concrete required for the different tests, based on aggregates of normal density, are as follows:

### 3.1 For fresh concrete

3.1.1 15 kg (33 lbs) for the slump, compacting factor or air content test.

3.1.2 40 kg (88 lbs) for determination of weight per cubic metre.

**3.1.3** 5 kg (11 lbs) for analysis of non-air entrained concrete with nominal maximum aggregate size less than 25 mm (1 in).

**3.1.4** 10 kg (22 lbs) for analysis of non air entrained concrete with nominal maximum aggregate size greater than 25 mm (1 in) and of air entrained concrete with nominal aggregate size less than 25 mm (1 in).

**3.1.5** 20 kg (44 lbs) for analysis of air entrained concrete with nominal maximum aggregate size greater than 25 mm (1 in).

**3.2 For hardened concrete**

**3.2.1** 3 kg (7 lbs) for making each 100 mm (4 in) cube.

**3.2.2** 10 kg (22 lbs) for making each 150 mm (6 in) cube.

**3.2.3** 15 kg (33 lbs) for making each 100 mm (4 in) x 100 mm (4 in) x 500 mm (20 in) beam.

**3.2.4** 40 kg (88 lbs) for making each, 150 mm (6 in) x 150 mm (6 in) x 750 mm (30 in) beam.

**3.2.5** 15 kg (33 lbs) for making each, 150 mm (6 in) diameter x 300 mm (12 in) long cylinder.

**3.2.6** 5 kg (11 lbs) for making each, 100 mm (4 in) diameter x 200 mm (8 in) long cylinder.

**3.2.7** 5 kg (11 lbs) for making each, 75 mm (3 in) x 75 mm (3 in) x 300 mm (12 in) Prism.

## 4 SAMPLING FRESH CONCRETE ON SITE

### 4.1 Apparatus

#### 4.1.1 *Scoop*

The size of the scoop for sampling from a moving stream of concrete shall normally be such that when full it will hold an increment weighing about 5 kg (11 lbs) and that for sampling from a heap such that when full it will hold an increment weighing about 3.5 kg (8 lbs). These scoops will provide a sample of the minimum permitted size in the specified number of increments. When larger samples are required larger scoops holding increments weighing upto about 7 kg (15 lbs) may be used, but it will generally be preferable to increase the number of increments instead.

When it is required to check the accuracy of regular sampling and the results of the checking procedure indicate that a larger number of increments is required, either the sample size shall be larger or a smaller scoop shall be used. Scoops holding not less than 2.5 kg (6 lbs) for sampling from a moving stream or not less than 1.5 kg (3 lbs) for sampling from a heap will be found useful for obtaining a sample of the minimum permitted size.

#### 4.1.2 *Containers*

Two or more containers are required, each capable of holding a sample of the required size. The inside of the container shall be smooth and made of non-absorbent material.

### 4.2 Procedure for sampling

Wherever possible the sampling should be done when the concrete takes the form of a moving stream, such as when it flows down the discharge chute of the mixer or is being conveyed on a belt. As an alternative, concrete may be sampled from a heap, but this method is less satisfactory. Concrete cannot be sampled satisfactorily from a discharging lorry or dumper.

### 4.2.1 *General*

The procedure used in sampling shall include the use of every precaution that will assist in obtaining samples that will be representative of the true nature and condition of the concrete samples, as given in 4.2.2 and 4.2.3.

### 4.2.2 *Sampling from streams, conveyers or chutes*

The person taking the sample should be able to reach the whole cross section of the stream without undue physical strain, since biased samples may result if part of the stream of concrete is difficult to reach. Increments shall be taken at equally spaced intervals, for example, when four increments are required, about the time when one fifth, two fifths, three fifths and four fifths of the concrete have been discharged, and if more than four increments are taken at correspondingly shorter but equally spaced intervals.

Increments should preferably be taken from the whole width and thickness of the stream in one operation.

Where the sample is to be taken from a falling stream of concrete the sampling scoop shall be plunged into the stream from the back and front alternately, the scoop being inverted when necessary whilst it is passed to the far side of the stream prior to sampling with a forward movement. Where the sample is to be taken from a conveyor or chute the scoop should sweep the bottom to ensure that the whole thickness of the stream is sampled.

If the whole stream cannot be covered by one increment without overfilling the scoop the stream shall be sampled systematically by taking increments from all parts, for example, when four increments are to be taken, the first and third increments shall be taken starting from the front of the stream and the second and fourth increments starting from the back. The weight of concrete collected from the various parts should, so far as is possible be in proportion to the flow at these points. Where more than one sample (see **4.4** and **4.5**) is required the increments shall be put in turn into separate containers for the separate samples, the increments for one sample being spaced evenly between the increments for the other sample or samples. When the whole stream cannot be covered by one increment successive increments shall be taken from the same part of the stream followed by increments from the different part or parts so that increments from similar positions are included in each sample.

4.2.3 *Sampling from heaps*

When concrete is sampled from heaps not all of the material is freely accessible and some bias will be inevitable.

The increments should wherever possible be distributed through the depth of the concrete as well as over the exposed surface.

*NOTES :*

*1 The number of increments required for a particular accuracy of sampling will normally be greater than that required when the sample is taken from a moving stream and it is particularly desirable that the procedure for checking the accuracy of sampling should be applied.*

*2 Heap shall include a batch of concrete discharged on the site.*

**4.3 Number of increments under normal conditions**

When it is not required to obtain an indication of the accuracy of sampling each sample shall consist of not less than four increments taken as described above where sampling is from a falling stream conveyor or chute, and not less than six such increments where sampling is from a heap.

**4.4 Number of increments when it is required to check the accuracy of regular sampling**

When it is required to check the accuracy of regular sampling, unless there is previous experience to suggest that a large number of increments are likely to be required, each sample shall consist of four increments taken as described above where sampling is from a falling stream, conveyor or chute, and six increments when sampling is from a heap. The number of increments required to give an acceptable standard of sampling shall then be determined by any suitable statistical analysis or by the method described in Appendix A, which requires that two independent samples shall be taken from each of at least the first 10 batches to be sampled. Thereafter, although only one sample need to be taken from each batch, as described in **4.5**, the procedure adopted shall be as nearly as possible identical to the procedure adopted for the initial duplicate sampling.

**4.5 Number of increments and samples when it is required to indicate the accuracy of single batch sampling**

When it is required to obtain some indication of the accuracy of this form of sampling, at least three independent samples shall be taken from the batch. Each sample shall consist of not less than four increments where sampling is from a falling stream, conveyor or chute and not less than six increments where sampling is from heaps. If the increments are taken from a moving stream of concrete they shall be taken at regular intervals during the discharge, successive increments being put in turn into the three containers for the separate samples.

The average result of the tests carried out on three or more samples and the range of the results shall be reported.

### 4.6 Recording of samples

The following information shall be recorded for each sample:

a) Project;

b) Date and time of sampling;

c) Identification of sample;

d) Mix proportions and water/cement ratio;

e) Type of aggregate, and type and brand of cement;

f) Method of sampling (for example, duplicate sampling from a conveyor);

g) Number of increments in sample;

h) Type of mixer from which delivered;

j) Location of the sampled batch after placing; and

k) Ambient temperature and weather conditions.

## 5 MIXING AND SAMPLING FRESH CONCRETE IN THE LABORATORY

### 5.1 Sampling of materials

#### 5.1.1 *Cement*

Test samples of cement shall be representative of that to be used on the site.

#### 5.1.2 *Aggregate*

Test samples of aggregates shall be taken from larger lots by quartering or by splitting (Sri Lanka Standard on Aggregates*).

### 5.2 Preparation of materials

#### 5.2.1 *Cement*

The sample of cement, on arrival at the laboratory, shall be thoroughly mixed dry, either by hand or in a suitable mixer, in such a manner as to ensure the greatest possible uniformity in the material, care being taken to avoid the intrusion of foreign matter. The cement shall then be stored in a dry place, preferably in airtight metal containers.

#### 5.2.2 *Aggregates*

The samples of aggregates shall be of the desired grading. The aggregates shall be either in an air dried condition, or alternatively soaked in water for at least 24 h before use. In general, the aggregates shall be separated into fine and coarse fractions and re-combined for each concrete batch in such a manner

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* *Under preparation.*

as to produce the desired grading. Where unusual gradings are being investigated both fine and coarse fractions shall be further separated into different sizes.

#### 5.2.3 *Temperature*

All materials shall be brought to a temperature of $27 \pm 2$ °C before commencing the mixing of the concrete.

### 5.3 Tests on materials

If any of the individual materials are required to be tested they shall be tested in accordance with the requirements of the appropriate Ceylon Standards CS 107 Ordinary portland cement and CS ...*

### 5.4 Proportion of materials

The proportion of the materials, including the water, in concrete mixes used for determining the suitability of the materials available, shall be similar in all respects to those expected to be employed in the work.

### 5.5 Weighing and mixing

The quantities of cement, each size of aggregate, and water for each batch shall be determined by weight, to an accuracy of 1 part in 1000 of the total weight of the batch.

The concrete shall be mixed in a room having an atmospheric temperature of $27 \pm 5$ °C and a relative humidity of not less than 50 per cent. The concrete shall be mixed by hand, or preferably on a laboratory batch mixer, in such a manner as to avoid loss of water or other materials.

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* *CS ... Aggregates (under preparation)*

The quantity of concrete in each batch shall be at least 10 per cent greater than that required for the tests.

If the admixtures are to be incorporated the manufacturer's instructions shall be followed.

### 5.5.1 *Machine mixing*

The size of the batch shall be not less than one half of the rated capacity of the mixer. Where the mixer is charged by a power loader the skip shall be loaded with about one half of the coarse aggregate, then with the fine aggregate, then with the cement and finally with the remaining coarse aggregate on top. (If all in aggregate is used the skip shall be loaded first with about one half of the aggregate, then with the cement and finally with the remaining aggregates on top). Where the mixer is hand loaded it shall be charged with the dry materials in a similar manner and the water shall be added immediately before the rotation of the drum or pan is started. The period of mixing shall be not less than 2 min and not more than 3 min after all the materials are in the mixer. When using pan mixers not fitted with a discharging gate the concrete shall be heaped together before sampling. When using other types of mixer the discharged concrete shall be re-mixed on a non-porous surface in such a manner as to ensure uniformity.

### 5.5.2 *Hand mixing*

The concrete batch shall be mixed on a non-porous surface with a shovel, trowel or similar suitable implement, using the following procedure:

The cement and fine aggregate shall be mixed dry until the mix is uniform.

The coarse aggregate shall be added and mixed dry with the cement and fine aggregate until the coarse aggregate is uniformly distributed throughout the batch.

The water shall then be added and mixed for at least 3 min until the concrete appears to be homogenous.

**5.6 Sampling of concrete**

For each test required, a representative sample shall be obtained of the fresh concrete during a period of 2 h (unless otherwise specified) from the addition of water to the mix. Provided that care is taken to ensure that no water or other material is lost the concrete used for the tests on fresh concrete may be re-mixed with the remainder of the batch before making any specimens. The period of re-mixing shall be as short as possible, yet sufficient to produce a homogenous mass.

**5.7 Recording of samples**

The following information shall be recorded for each sample:

a) Project;

b) Date and Time of mixing;

c) Identification of sample;

d) Mix proportions, water/cement ratio and aggregate/cement ratio;

e) Details of materials, including moisture condition of the aggregates (details shall include source and type of aggregates, type and brand of cement etc.); and

f) Method of mixing.

## 6 SIZE OF TEST SPECIMENS

### 6.1 Size of test cubes

The cube shall be 100 mm or 150 mm in size.

### 6.2 Size of test beams

The beams shall be 150 mm x 150 mm x 750 mm or 100 mm x 100 mm x 500 mm.

### 6.3 Size of test cylinders

The standard size of the cylinder shall be of diameter 150 mm and 300 mm long. 100 mm diameter 200 mm long cylinders may be used, for specific purposes provided that the maximum aggregate size does not exceed 25 mm.

### 6.4 Size of test prisms

The prisms shall be 75 mm x 75 mm x 300 mm.

## 7 APPARATUS FOR MAKING TEST SPECIMENS

### 7.1 General

The mould shall be of ferrous metal and stout enough to prevent distortion. The surface hardness of each internal face shall be at least 95 Rockwell (Scale B) Hardness Value. It shall be constructed in such a manner as to facilitate the removal of the moulded specimen without damage. The parts of the mould when assembled shall be positively and rigidly held together, and suitable means of ensuring this, both during the filling and on subsequent handling of the filled mould, shall be provided.

Each mould shall be provided with a steel base-plate which shall be rigidly attached to the mould, and shall support it without leakage or distortion.

The surface, texture of each internal face shall be 3.2 µm CLA (Centre Line Average).

The tolerances (defined as per SLS 409 Engineering Drawing Practice) the assembled moulds shall be as specified in 7.1.1 to 7.1.3.

In assembling the cleaned mould ready for use, the joints between the sections (in the case of cylinders at the longitudinal opening) of the mould and between the base of the mould and the baseplate shall be thinly coated with mould oil and firmly fixed to prevent escape of water. The internal faces of the assembled mould shall also be thinly coated with mould oil to prevent adhesion of the concrete.

In compaction of concrete either a compacting bar or suitable vibrating equipment shall be used. The compacting bar for cubes and beams shall be a steel bar weighing 1.8 kg, 380 mm long and having a ramming face of area 25 $mm^2$. In the case of cylinders, the steel bar shall weigh 1.8 kg and be 480 mm long and have a ramming face of 25 mm diameter.

**7.1.1** ***Test cubes***

**7.1.1.1** Tolerances

a) Dimensions

The depth of the mould and the distance between either pair of opposite internal faces, each based on the average of four symmetrically placed measurements, shall be the nominal size ± 0.15 mm.

b) Flatness

The tolerances ('Flatness 1') for each internal face shall be 0.03 mm wide. That for the joint faces, for the bottom surface of the mould and for the top surface of the baseplate shall be 0.06 mm wide.

c) Squareness

The squareness tolerance (Squareness 1') for each internal face with respect to the bottom surface of the mould and the adjacent internal face as datum faces shall be 0.5 mm wide.

d) Parallelism

The parallelism tolerance ('Parallelism 1') for the top surface of the mould with respect to the bottom surface of the mould as datum face shall be 1.0 mm wide.

**7.1.2** *Test beams*

**7.1.2.1** Construction

It shall be constructed with the longer dimension horizontal.

**7.1.2.2** Tolerances

a) Dimensions

The depth and internal width of the mould each based on the average of 6 measurements symmetrically placed along the axis of the mould shall be the nominal size ± 0.15 mm.

b) Flatness

The flatness tolerance ('Flatness 1') for each internal side face shall be 0.03 mm wide per 150 mm length and 0.15 mm wide for the entire surface. That for the joint faces for the bottom surface of the mould and for the top surface of the baseplate shall be 0.06 mm wide per 150 mm length and 0.25 mm for the entire surface.

c) Squareness

The squareness tolerance ('Squareness 1') for each internal side face will respect to the bottom surface of the mould as datum face shall be 0.5 mm wide.

d) Parallelism

The parallelism tolerance ('Parallelism 1') for the top surface of the mould with respect to the bottom surface of the mould as datum face, and one internal side face with respect to the other internal side face as datum face shall be 1.0 mm wide.

### 7.1.3 *Test cylinders*

#### 7.1.3.1 Construction

Each mould shall also be provided either with a glass capping plate or with a metal top plate which can be rigidly attached to the mould. The plates shall be of either glass not less than 6.5 mm in thickness or machined metal not less than 13.0 mm thickness and having surface dimension of at least 25 mm larger than the diameter of the mould.

#### 7.1.3.2 Tolerances

a) Dimensions

The internal diameter of the mould based on the average of three pairs of measurements at right angles to each other symmetrically placed along the axis of the mould, shall be the nominal size ± 0.15 mm. The length, based on the average of four symmetrically placed measurements shall be the nominal size ± 0.5 mm.

b) Flatness

The flatness tolerance ('Flatness 1') for the top surface of the base plate and for the contact base of the capping or top plate shall be 0.03 mm wide; that for the top and bottom surfaces of the mould shall be 0.06 mm wide and that for the joint faces shall be 0.06 mm per 150 mm length and 0.15 mm for the entire surface.

c) Squareness

The squareness tolerance ('Squareness 2') for the axis of the mould with respect to the bottom surface of the mould as datum face shall be a cylinder of diameter 1.0 mm perpendicular to the datum face.

d) Parallelism

The parallelism tolerance ('Parallelism 1') for the top surface of the mould with respect to the bottom surface of the mould as datum face shall be 1.0 mm wide.

e) Cylindricity

The cylindricity tolerance for the inner cylindricity surface shall be an annular zone 0.5 mm wide.

## 8 COMPACTING TEST SPECIMENS

### 8.1 General

The test specimens shall be made as soon as practicable after sampling, in such a way as to produce full compaction of the concrete with neither segregation nor laitance.

The mould shall be filled in layers approximately 50 mm deep and each layer shall be compacted either by hand or by vibration. After the top layer has been compacted the surface of the concrete shall be finished level and smooth with the top of the mould by means of a trowel.

In the case of cylinders the surface shall be prepared as described in 10.

### 8.2 Procedure for compacting of concrete in the mould - by hand

When compacting by hand, the standard compacting bar shall be used and the strokes of the bar shall be distributed in a uniform manner over the cross-section of the mould.

#### 8.2.1 *Cubes*

The number of strokes per layer required to produce the specified condition will vary according to the type of concrete, but in no case shall the concrete be subjected to less than 35 strokes per layer for 150 mm cubes or 25 strokes per layer for 100 mm cubes.

#### 8.2.2 *Beams*

The number of strokes per layer required to produce the specified condition will vary according to the type of concrete, but in no case shall the concrete be subjected to less than 175 strokes per layer for 150 mm beams or 100 strokes per layer for 100 mm beams.

### 8.2.3 *Cylinders*

The number of strokes per layer required to produce the specified condition will vary according to the type of concrete, but shall not be less than 30 strokes per layer for 150 mm cylinders or 20 strokes per layer for 100 mm cylinders.

### 8.3 Procedure for compacting of concrete in the mould-by vibration

When compacting by vibration each layer shall be vibrated by means of a vibrating equipment until the condition specified in **8.1** is attached.

## 9 CURING OF TEST SPECIMENS

### 9.1 Specimens made in the laboratory

Immediately after they are made the test specimens shall be stored in a place free from vibration in moist air of at least 90 per cent relative humidity and at a temperature of $27 \pm 2$ °C for 16 h to 24 h from the time of adding the water to the other materials. This may be achieved by storing the specimens in their moulds, under a suitable damp material covered completely with polythene or other similar impervious sheeting in a room maintained at the temperature stated.

If the concrete has not achieved sufficient strength, to enable demoulding to be carried out within the stated period, the demoulding shall be delayed for a further 24 h, but this fact shall be stated in the test report. During this further period the specimens shall be stored in the moist air conditions stated.

The specimens shall be marked for later identification, removed from the moulds and, unless required for test within 24 h, immediately submerged in a tank containing clean, fresh water and kept there until taken out just before test.

Specimens to be tested at 24 h shall be stored for the period in the moist air conditions stated and demoulded just before test.

**9.2 Specimens made on site**

Immediately after they are made the test specimens shall be stored in a covered place free from vibration under a suitable damp material completely covered with polythene or other similar impervious sheeting at a temperature of 27 ± 5 °C for 16 h to 24 h from the time of adding the water to the other materials.

If the concrete has not achieved sufficient strength to enable demoulding to be carried out within the stated period the demoulding shall be delayed for a further 24 h, but this fact shall be stated in the report. During this further period the specimens shall be stored in the moist air conditions stated.

After moist curing the specimens shall be marked for later identification, removed from the moulds and, unless required for test within 24 h, immediately submerged in a tank containing clean, fresh water until they are transported to the testing laboratory.

While the specimens remain on site, records of the daily maximum and minimum air and water storage temperature shall be kept with maximum and minimum thermometers or with continuous recording instruments.

The specimens, well packed in damp sand or wet sacks and enclosed when necessary in a polythene bag or sealed container, shall be sent to the testing laboratory when they are not less than 3 days nor more than 7 days old, to arrive there in a damp condition not less than 24 h before the time of test. On arrival at the testing laboratory the specimens shall be stored in water maintained at a temperature of $27 \pm 1\ ^{o}C$ until the time of test. The specimens shall not be allowed to become dry at any time until they are tested.

Specimens to be tested at 24 h shall be stored for this period in the moist air conditions stated and demoulded just before test.

## 10 CAPPING OF CYLINDRICAL CONCRETE SPECIMENS

10.1 The ends of all cylindrical test specimens should be capped to ensure that the finished capped surface is accurate to within the following limits:

a) *Flatness:* The flatness tolerance ('Flatness 1') for the capped surface shall be 0.06 mm wide.

b) *Squareness:* (only applicable if both ends require preparation) The squareness tolerance ('squareness 3') for the end capped first with respect to the axis of the specimen as datum axis shall be 2.0 mm wide.

c) *Parallelism:* The parallelism tolerance (Parallelism 1') for the capped top surface with respect to the bottom surface of the specimen as datum face shall be 2.0 mm wide. Any slight irregularity may be removed by scraping. Caps shall be as this as practicable and shall not flow or fracture before the concrete fails when the specimen is tested. The capping shall be carried out according to one of the following methods:

### 10.2 Freshly moulded cylinders

10.2.1 Test cylinders may be capped with a thin layer of stiff, neat Portland cement paste to the exposed end after the concrete has ceased setting in the mould, generally for 2 h to 4 h after moulding. If an excessively wet mix of concrete is being tested, any free water which has collected on the surface of the specimen is removed with a sponge, blotting paper or other suitable absorbant material before the cap is formed. The surface of the concrete is left rough in order to provide a key for the capping material. The neat cement paste shall be mixed to a stiff consistency 2 h to 4 h before it is used, in order to allow the paste to go through its period of initial shrinkage. The cap is formed by placing a conical mound of paste on the specimen and then gently pressing a freshly oiled capping plate. It shall be worked on the cement paste with rotary motion until its lower surface rests on top of the mould. The plate is left in position until the cylinder is removed from the mould.

Caps could also be formed using mortar. In this case the mortar is gauged, as soon as possible after the concrete is mixed using a cement similar to that used in the concrete and of fine sand (most of which passes a 300 µm CS woven wire sieve and is retained on a 150 µm CS woven wire sieve). The mortar shall have a water cement ratio not higher than that of the concrete and shall be of stiff consistency.

**10.2.2** The surface of the concrete is finished level with the top of the mould by means of a trowel. Then the top plate, coated with a thin film of mould oil, is pressed down on the concrete with a rotary motion until it makes complete contact with the rim of the mould. The top plate is then rigidly attached to the top of the mould and the mould with top and base plates is laid with its axis horizontal on supports which will prevent any movement. The capping plate is lightly tapped to ensure good contact with the trowelled surface of the concrete. The cylinder is allowed to harden in a horizontal position until it is removed from the mould.

### 10.3 Hardened concrete cylindrical specimens

If the methods described in **10.2** are impracticable the upper end of the hardened specimen shall be capped by one of the two following methods or some other suitable method. Before capping, the surface shall be roughened by hacking or wire brushing.

#### 10.3.1 *Moist cured specimens*

The capping material consists of a mortar composed of three parts by weight of high alumina cement to one part by weight of fine sand (most of which passes a 300 µm CS woven wire sieve and is retained on a 150 µm CS woven wire sieve). The soaked specimen is placed on a horizontal plate, and a steel collar of correct diameter and having a machined upper edge is rigidly clamped to the end of the specimen to be capped, in such a way that the upper edge is horizontal and just extends above the highest part of the concrete surface. The capping material is filled into the collar until it is in the form of a convex surface above the edge of the collar. The cappling plate, coated with a thin film of mould oil, is pressed down on the capping material with a rotary motion until it makes complete contact with the edge of the collar. The specimen with collar and plate is immediately placed in moist air of at least 90 per cent relative humidity and at a temperature of $27 \pm 5\ ^{\circ}C$, and the plate and collar are struck when the mortar is hard enough.

If both ends require preparation the whole specimen with collar and plate is turned upside down and the capping of the other end carried out in the same way. It may be found convenient to cap one on one day and the other the following day. The capped specimen shall be submerged in the tank for at least 48 h before testing.

### 10.3.2 *Air dried specimens*

The capping material consists of a mixture composed of equal parts by weight of sulphur and fine siliceous sand (most of which passes a 300 µm CS woven wire sieve), together with a small portion (1 per cent to 2 per cent) of carbon black. The mixture is heated to a temperature of about 230 $^{\circ}C$ to 250 $^{\circ}C$ and is then allowed to cool slightly while being stirred continuously. The mixture is poured on to a level machined steel plate which has been slightly warmed and thinly coated with paraffin. The specimen is placed into this layer with its axis in a vertical direction. A guide specimen is placed into this layer with its axis in a vertical direction. A guide should be used for this operation. After a few seconds the surplus material around the specimen is cut away with a sharp knife and the specimen lifted off the plate. The other other end may be capped immediately in the same way.

*NOTE - Sulphur melting pots should be used under a hood to exhaust the fumes outdoors. Heating over an open flame is dangerous because the flash point of sulphur is approximately 227 $^{\circ}C$ and the mixture can ignite due to overheating. Reheating of the mixture should be avoided as this practice tends to make the cap rubbery rather than brittle as desired.*

## 11 AGE AT TEST

Preferred ages for test are 1, 3, 7, 14 and 28 days; 13 and 26 weeks and 1 year.

11.1 Tests shall be carried out within the following tolerances:

a) Up to and including 30 h : within ± 1/2 h ;

b) Above 30 h up to and including 100 h : within ± 2 h ;

c) Above 100 h up to and including 60 days : within ± 8 h ; and

d) Above 60 days : within ± 1 day.

The ages shall be calculated from the time of the addition of the water to the other materials.

## 12 NUMBER OF TEST SPECIMENS

### 12.1 Specimens made in the laboratory

At least 3 specimens, preferably from different batches, shall be made for testing at each age.

### 12.2 Specimens made on site

At least 3 specimens for each age of testing which may be from different samples as defined in this standard shall be made.

## 13 REPORT

The following information shall be included in the report on each specimen:

a) Identification of test specimen;

b) Particulars of the concrete from which the test specimen was made; recorded in accordance with the requirements of the appropriate clause of this standard;

c) Method of Compaction (by hand or by vibration); and

d) Maximum and minimum storage temperature.

# APPENDIX A

## A.1 PROCEDURE FOR CHECKING THE ACCURACY OF REGULAR SAMPLING

The accuracy with which an average test result represents a given amount of concrete is influenced by:

a) the number of increments taken for each sample; and

b) the number of samples used to obtain an average for a given period.

### A.1.1 The number of increments to be taken for each sample

Where regular sampling is carried out the adequacy of the number of increments shall be checked using the results of the tests on the first 10 successive sets of duplicate samples. For this purpose the results shall be recorded as in Table 1, and the average *d*, of the difference between the results of duplicate samples and the range *c*, calculated. The ratio *c* shall then be examined and if this is less than 2.5, too few *d* increments have been taken and the number of increments shall be increased by at least 4 and the test repeated on a further 10 successive sets of duplicate samples.

*NOTE - If $\frac{c}{d}$ is greater than 10, the number of increments is unnecessarily large and may be decreased if the test is then repeated.*

### A.1.2 The number of samples to be taken for the period average

The procedure outlined above should ensure that sampling errors are small in relation to the total errors.

The accuracy of the period average is then dependent on the number of batches sampled, and this can be adjusted so that the period average will approximate to the true average for the period to within ± *e* where *e* is a value previously selected as being appropriate to the work in hand. Using the results of the tests on the first 10 sets of duplicate samples the number of samples, *n*, required in the period average is given by the expression $n = 0.1 \left(\frac{c}{e}\right)^2$ where *c* is the range obtained from the first sample in Table 1.

After the initial period duplicate samples are not regularly required but checks should be made from time to time to ensure that the standard of sampling is ~~being~~ maintained. Whether duplicate samples are tested or not, the figures for all samples shall be listed and the range *c* calculated for each group of 10 successive samples. If some tests have been made on duplicate samples the mean of the values shall be used in calculating *c*. Each range, *c*, shall then be compared with the last value obtained for *d* and if $\frac{c}{d}$ is less than 2.5 the number of increments shall be increased and full duplicate testing resumed until two successive sets of 10 duplicate samples give values of $\frac{c}{d}$ greater than 2.5. The value of *n* shall also be calculated for each range *c* and the frequency of sampling adjusted if necessary.

*NOTE - The limits given for the ratio* $\frac{c}{d}$ *and the constant in the formula for the number of samples required are based on the 5 per cent level of probability.*

TABLE 1 - MARKING OF COMPRESSIVE STRENGTH DATA

Unit $N/mm^2$

| Sample No. | Higher value | Lower value | Average value | Difference |
|---|---|---|---|---|
| 1 | 44.0 | 42.0 | 43.0 | 2.0 |
| 2 | 47.5 | 44.5 | 46.0 | 3.0 |
| 3 | 46.5 | 44.5 | 45.5 | 2.0 |
| 4 | 47.5 | 43.0 | 45.0 | 4.5 |
| 5 | 50.0 | 44.0 | 47.0 | 6.0 |
| 6 | 55.0 | 53.0 | 54.0 | 2.0 |
| 7 | 51.5 | 47.5 | 49.5 | 4.0 |
| 8 | 49.5 | 48.0 | 48.5 | 1.5 |
| 9 | 51.5 | 50.5 | 51.0 | 1.0 |
| 10 | 47.5 | 44.0 | 45.5 | 3.5 |

Average difference = 2.95 = $d$
Range of average value = 54.0 - 43.0 = 11.0 = $c$

$$\frac{c}{d} = \frac{11.0}{2.95} = 3.8$$

Which is greater than 2.5 and the number of increments is therefore acceptable. If the period average is required to be within ± 1.75 N/mm$^2$ of the true average, For example $e$ = 1.75 then the required number of batches to be tested is,

$$n = 0.15 \left(\frac{11.0}{1.75}\right)^2 = 5.76$$

Number of batches is 6.
The procedure for checking the accuracy of sampling cannot be applied to single batch sampling.

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