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SPECIFICATION FOR READY-MIXED CONCRETE

PART 2 : TEST METHODS

SRI LANKA STANDARDS INSTITUTION

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SLS 1144: Part 2:1996

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Draft Sri Lanka Standard
SPECIFICATION FOR READY-MIXED CONCRETE
PART 2 - TEST METHODS

FOREWORD

This Sri Lanka standard specification was approved by the Sectoral Committee on Building and Construction Materials and was authorized for adoption and publication as a Sri Lanka Standard by the Council of the Sri Lanka Standards Institution on 1996 - 10 - 17

Ready-mixed concrete is rapidly gaining popularity and many new producers are setting up business to cater for the increasing demand. This upsurge of interest can be mainly attributed to the convenience of its usage, and advantages outweighing the disadvantages of ready-mixed concrete in the local context.

Its advantages are:

i. Site space is saved and, on restricted sites, ready-mixed concrete is often the only way concrete can be made available;
ii. Responsibility for quality control is transferred to the producer who specializes in production of concrete;
iii. Concrete supply is unlikely to be interrupted as the producer will have adequate back-up resources;
iv. Site labour can be reduced and concrete can be conveyed and discharged at different parts of the site thus saving on distribution costs;
v. It is cheaper and less inconvenient to reject unsuitable concrete;
vi. Saving on operating, maintaining and manning a site mixing plant. which rarely works to its full capacity; and
vii. Well suited to sites where concreting takes place at infrequent intervals or in very large pours.

The disadvantages of ready-mixed concrete are:

a). Site roads and job access should be constructed to carry heavy large vehicles;
b). Deliveries may be late due to unforseen reasons such as slow traffic, accidents or breakdowns leading to disruption of site work;
c). Volume requirements should be assessed more accurately and well in advance of delivery;
d). Small amounts of concrete, for example for a base or a few kickers, can be expensive;
e). Cancellations should be made well in advance of delivery so that site requires reliable communication facilities with the producer;
f). Long delay caused by rejecting a load of concrete can have a serious effect on previously placed concrete;

g). Disputes are likely with producers who do not exercise quality control;

h). It may be expensive due to greater quality control and transport costs unless offset by savings in plant, workers and supervisory staff at site; and

i). Maintaining workability of mix right up to the time of placing requires admixtures and closer attention due to extended time of haul and evaporation.

Production of ready-mixed concrete is a complex operation. Further, for it to be viable, production should be done on a large scale. These requirements necessitate the implementation of rigid quality control measures at each stage of the production process from procurement of materials to delivery at site. Checking these measures is costly and may be out of reach of the small user while independent checking gives greater acceptance and fairer competition among different producers. Development of a Sri Lanka Standard on ready-mixed concrete and encouraging producers to obtain the SLS certification were considered timely for the development of greater confidence among users, thus encouraging further growth of this industry.

This part of the standard specifies test methods. Part 1 of this standard specifies the types, basis of supply, specification of concrete requirement, constituent materials, plant and equipment, production and delivery, inspection and records, and sampling, testing and compliance.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or measurement shall be rounded off in accordance with CS 102. The number of significant places to be retained in the rounded off value shall be the same as that of the specified value in this standard.

The Sri Lanka Standards Institution gratefully acknowledges the use of the publications of the British Standards Institution, the American Society of Testing and Materials, the Bureau of Indian Standards, the Singapore Institute of Standards and Industrial Research, the Japanese Standards Association, the Standards Australia, the South African Bureau of Standards, the Standards and Industrial Research Institute of Malaysia, and the National Bureau of Standards of China.

1 SCOPE

This part of the standard specifies test methods for the determination of mass per unit volume, air content, slump, coarse aggregate content and unit mass of air free mortar of fresh concrete, compressive strength of concrete, and chloride content of aggregate as well as analysis of fresh concrete to determine mix proportion, water/cement ratio and cement content.

2 REFERENCES

ISO 468	Surface roughness - Parameters, their values and general rules for specifying requirements.
BS 1881	Testing Concrete Part 115 - Specification for compression testing machines for concrete
CS 124	Test sieves
SLS 262	Methods of sampling, analysis and testing of concrete Part 2 - Methods of testing concrete (under preparation)
SLS 409	Engineeering drawing practice
SLS 1144	Ready-mixed concrete Part 1 - Requirements

3 DEFINITIONS

For the purpose of this standard following definitions shall apply :

3.1 ***batch:*** The quantity of concrete mixed in one cycle of operation of a batch mixer, or the quantity of concrete conveyed ready-mixed in a vehicle, or the quantity descharged during one minute from a continuous mixer.

3.2 ***concrete*** : A thoroughly mixed combination of cement, aggregates, and water with or without the addition of chemical admixtures or other materials.

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

3.4 ***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.

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

4 DETERMINATION OF SLUMP OF FRESH CONCRETE

4.1 principle of test

A sample of freshly mixed concrete is placed and compacted by rodding in a mould shaped as the frustum of a cone. The mould is raised, and concrete allowed to subside. The distance between the height of the mould and the highest point of the slumped concrete is measured and reported as the slump of the concrete. Slump does not measure the workability of concrete but is very useful in detecting variations in the uniformity of successive mixes intended to be identical.

4.2 Apparatus

4.2.1 *Mould*

Mould made of metal (galvanized steel is suitable but not aluminium) not readily attacked by cement paste and not thinner than 1.5 mm. The interior of the mould shall be smooth and free from projections such as protruding rivets and shall be free from dents. The mould shall be in the form of a hollow frustum of a cone having the following internal dimensions:

diameter of base = 200 ± 2 mm;
diameter of top = 100 ± 2 mm; and
height = 300 ± 2 mm.

The base and the top shall be open and parallel to each other and at right angles to the axis of the cone. The mould shall be provided with two handles at two-thirds of the height, and with foot pieces to enable it to be held steady. A mould which can be clamped to a base plate is acceptable as an alternative if the clamping arrangement can be released without movement of the mould.

4.2.2 *Scoop,* approximately 100 mm wide.

4.2.3 *Sampling tray,* 1.2 m x 1.2 m x 50 mm deep made from minimum 1.6 mm thick non-corrodible metal.

4.2.4 *Square mouthed shovel,* with square mouth not less than 150 mm wide.

4.2.5 *Tamping rod,* made out of straight iron or steel bar of circular cross section, 16 ± 1 mm diameter, 600 ± 5 mm long with both ends hemispherical.

4.2.6 *Rule,* graduated from 0 mm to 300 mm at 5 mm intervals, the zero point being at one end of the rule.

4.3 Sampling

Sampling of concrete shall be done in accordance with **9.3** (for the purpose of uniformity test on mixers) or **11** (for the purpose of acceptance of concrete) of **SLS 1144 : Part 1 : 1996.** When a batch of concrete is sampled, take a sample, after allowing a discharge of approximately 0.3 m^3, of six standard scoopfulls, collected from the moving stream in a bucket or other suitable container. Remix the sample on a non-absorbent surface and sub-divide into two parts. Test each part for slump.

4.4 Preparing the sample for test

Empty the smaple from the container(s) onto the sampling tray. Ensure that no more than a light covering of slurry is left adhering to the container(s).

Thoroughly mix the sample by shovelling it to form a cone on the sampling tray and turning this over with the shovel to form a new cone, the operation being carried out three times. When forming the cones deposit each shovelful of the material on the apex of the cone so that the portions which slide down the sides are distributed as evenly as possible and so that the centre of the cone is not displaced.

Flatten the third cone by repeated vertical insertion of the shovel across the apex of the cone, lifting the shovel clear of the concrete after each insertion.

4.5 Procedure

Ensure that the internal surface of the mould is clean and damp but free from superfluous moisture before commencing the test. Place the mould on a smooth, horizontal, rigid and non-absorbent surface free from vibration and shock. A carefully levelled metal plate, of adequate size to support the slumped concrete, placed on a bed of sand is suitable.

Hold the mould firmly against the surface below whilst it is filled in three layers, each approximately one-third of the height of the mould when tamped. Tamp each layer with 25 strokes of the tamping rod, the strokes being distributed uniformly over the cross-section of the layer. Tamp each layer to its full depth, ensuring that the tamping rod does not forcibly strike the surface below when tamping the first layer and just passes through the second and top layers into the layers immediately below. Heap the concrete above the mould before the top layer is tamped. If necessary, add further concrete to maintain an excess above the top of the mould throughout the tamping operation. After the top layer has been tamped, strike off the concrete level with the top of the mould with a sawing and rolling motion of the tamping rod. With the mould still held down, clean from the surface below any concrete which may have fallen onto it or leaked from the lower edge of the mould.

Remove the mould from the concrete by raising it vertically, slowly and carefully, in 5 s to 10 s, in such a manner as to impart minimum lateral or torsional movement to the concrete. The entire operation from the start of filling to the removal of the mould shall be carried out without interruption and shall be completed within 150 s.

Immediately after the mould is removed, measure the slump to the nearest 5 mm by using the rule to determine the difference between the height of the mould and of the highest point of the specimen being tested.

NOTES

1. Some indication of the cohesiveness and workability of the mix can be obtained if, after the slump measurement has been completed, the side of the concrete is tamped gently with the tamping rod. A well proportioned concrete mix which has an appreciable slump will gradually slump further, but a badly proportioned mix is likely to fall apart.

2. The workability of a concrete mix changes with time due to the hydration of the cement and, possibly, loss of moisture. Tests on different samples should, therefore, be carried out at a constant time interval after mixing if strictly comparable results are to be obtained.

3. Concretes having slumps less than 13 mm may not be adequately plastic and concretes having slumps greater than about 230 mm may not be adequately cohesive for this test to have significance. Caution should be exercised in interpreting such results.

4.6 Expression of results

The test is only valid if it yeilds a true slump, this being a slump in which the concrete remains substatially intact and symmetrical as shown in Figure **1(a)**. If the specimen shears, as shown in Figure **1(b)** or collapses, as shown Figure **1(c)**, take another sample and repeat the procedure.

Record the true slump to the nearest 5 mm.

NOTE *If two consecutive tests on a sample of concrete show a falling away or shearing off a portion of the concrete from the mass of the specimen, the concrete probably lacks necessary plasticity and cohesiveness for the slump test to be applicable.*

Caution : When cement is mixed with water, alkali is released. Take precautions to avoid dry cement entering the eyes, mouth and nose when mixing concrete. Prevent skin contact with wet cement or concrete by wearing suitable protective clothing. If cement or concrete enters the eye, immediately wash it out thoroughly with clean water and seek medical treatment without delay. Wash wet concrete off the skin immediately.

(a) True slump (b) Shear slump (c) Collapse slump

FIGURE 1 - Forms of slump

5 DETERMINATION OF CHLORIDE CONTENT OF SEA SAND

5.1 Principle of test

Chloride in sea sand is dissolved in water and titrated against a silver nitrate solution of known strength to determine the chloride content.

5.2 Sampling

A sample not less than 13 kg shall be obtained by collecting sand from not less than 25 increments from different positions of the sand stockpile in such a way to represent, as far as possible, the average quality of the sand stockpile.

Mix the sample in the laboratory'and divide the sample to the required size using a typical riffle box. Prepare three subsamples of sand, each about 500 g, for three tests.

5.3 Apparatus

5.3.1 *Balance*

A balance, capable of weighing to 1 kg, accurate to 0.1 g.

5.3.2 *Balance*

A balance, capable of weighing to 100 g, accurate to 0.001 g.

5.3.3 *Oven*

A well ventilated oven, capable of being controlled to maintain a temperature of 105 ± 5°C.

5.3.4 *Flask*

Two 1000 ml volumetric flasks.

5.3.5 *Measuring cylinder*

A 1000 ml graduated measuring cylinder.

5.3.6 *Measuring cylinder*

A 10 ml graduated measuring cylinder.

5.3.7 *Pipette*

A 100 ml pipette.

5.3.8 *Pipette*

A 25 ml pipette.

5.3.9 *Conical flask*

A 250 ml conical flask.

5.3.10 *Wash bottle*

A wash bottle containing distilled water.

5.3.11 *Reagent bottle*

An amber-coloured glass reagent bottle.

5.3.12 *Plastic bottle*

Three plastic bottles, wide mouth, with screw tops, 1 litre to 1.25 litre capacity.

5.3.13 *Funnel*

A suitable funnel and good quality filter paper.

5.4 Reagents

5.4.1 *General*

Use only reagents of recognized analytical reagent grade,and only distilled water or water of equivalent quality.

5.4.2 *Silver nitrate solution (0.01 N)*

Weigh 1.703 g of dried silver nitrate, dissolve in distilled water and dilute to 1000 ml in a volumetric flask. Store the solution in the amber-coloured glass reagent bottle and protect from prolonged exposure to sunlight.

5.4.3 *Sulphuric acid (0.1 N)*

Add 2.8 ml of concentrated sulphuric acid using a 5 ml graduated pipette to 500 ml of deionised water in a 1000 ml volumetric flask. Dilute to 1000 ml.

5.4.4 *Methyl orange indicator*

Dissolve 0.5 g of methyl orange powder in deionised water and dilute to 1000 ml in a measuring cylinder.

5.4.5 *Potasium chromate indicater*

Dissolve 50 g of potasium chromate (K_2CrO_4) in 100 ml of deionised water. Add standard silver nitrate solution until a definite red precipitate is formed. Allow solution to stand for 12 hours,filter and dilute the solution to 1000 ml with deionised water.

5.5 Procedure

Dry a subsample by heating at a temperature not exceeding 110°C to remove surface water. Measure the mass of the dry subsample which is about 500g. Place it in the wide mouth, screw topped plastic bottle. Add 500 ml of distilled water and allow to stand for 24 h,with occasional shaking. Take a 100 ml portion of the supernatant liquid by means of the pipette and transfer to the 250 ml conical flask. (If the supernatant liquid is discoloured by suspended silt or clay, it should be filtered before the portion is taken). Add few drops of methyl orange so that colour becomes light yellow. Then add a few drops of 0.1 N sulphuric acid until the sample was pink. Add 1 ml of potasium chromate indicator using a pipette so that colour becomes yellow.

Fill the burette with 0.01 N silver nitrate and titrate till the colour of the solution becomes brick-red. Note the amount of silver nitrate added from the burette. Repeat the procedure,using distilled water instead of the chloride solution to determine an indicator blank and note the silver nitrate added from the burette.

5.6 Expression of results

Use the following formulae to obtain chloride content in sand :-

(a) Chloride ion as mg/l =

$$\frac{(\text{------ ml of AgNo}_3 - \text{blank}) \times \text{Normality of AgNO}_3 \times 35450}{\text{---- ml of sample}}$$

(b) Chloride content (per cent) =

$$\frac{\text{Weight of Cl ion (mg/l)}}{\text{Weight of dry sand (mg/l)}} \times 100$$

The average of three determinations shall be reported as the chloride salt content to the nearest 0.01% .

6 DETERMINATION OF RELATIVE DENSITY OF COARSE AGGREGATE

6.1 Principle of test

Mass of the saturated surface dry aggregate sample in air, mass of the vessel containing aggregate sample after filling the vessel with water, and mass of the vessel filled with water only, are used to determine the relative density on a saturated and surface-dried basis.

6.2 Apparatus

6.2.1 *A balance* of capacity not less than 3 kg accurate to 0.5 g and of such a type as to permit the weighing of the vessel containing the aggregate and water.

6.2.2 *A wide mouthed glass vessel* such as a gas jar, of 1.0 litre to 1.5 litres capacity, with a flat ground lip and a plane ground disc of plate glass to cover it, giving a watertight fit.

6.2.3 *Two dry soft absorbent cloths,* each not less than 750 mm by 40 mm.

6.2.4 *A shallow tray* of area not less than 0.03 mm^2.

6.2.5 *An airtight container* large enough to take the sample.

6.2.6 *A 5.00 mm test sieve* complying with the requirements of coarse tolerance test sieves given in CS 124.

6.2.7 *A supply of water* free from any impurity (e.g. dissolved air) that would significantly affect its density. If distilled or deionised water is not available in sufficient quantity, tap water which has been freshly boiled and cooled to room temperature may be used. This water shall be used throughout the test.

6.3 Sampling

A sample not less than 25 kg shall be obtained by collecting coarse aggregate from not less than 25 increments from different positions of the coarse aggregate stockpile in such a way to represent, as far as possible, the average quality of the coarse aggregate stockpile.

Mix the sample in the laboratory and divide the sample to required size using a typical riffle box. Prepare two subsamples, each about 1 kg, for the two tests. Each subsample shall be thoroughly washed on the test sieve to remove finer particles, particularly clay, silt and dust, which would otherwise be lost during the test thereby affecting the result, and drained.

6.4 Test procedure

Immerse the prepared test sample in water in the glass vessel. It shall remain immersed at a temperature of 27 ± 5°C for 24 ± 0.5 h. Soon after immersion and again at the end of the soaking period, remove air entrapped in, or bubbles on the surface of the aggregate by gentle agitation. This may be achieved by rapid clockwise and anti-clockwise rotation of the vessel between the operator's hands.

Overfill the vessel by adding water and slide the plane ground glass disc over the mouth so as to ensure that no air is trapped in the vessel. Then dry the vessel on the outside and weigh it (mass m_1).

Then empty the vessel and refill with water only, sliding the glass disc into position as before. Then dry the vessel on the outside and weigh it (mass m_2).

The difference in the temperature of the water in the vessel during the first and second weighings shall not exceed 2°C.

Drain the aggregate and place it on a dry cloth and gently surface-dry it with the cloth, transferring it to a second dry cloth when the first will remove no further moisture. Then spread it out not more than one stone deep on the second cloth and leave it exposed to the atmosphere away from direct sunlight or any other source of heat until all visible films of water are removed but the aggregate still has a damp appearance. Then weigh the aggregate (mass m_0).

6.5 Calculation

$$\text{Relative density on a saturated and surface-dried basis} = \frac{m_0}{m_0 - (m_1 - m_2)}$$

where,

m_0 is the mass, in g, of the saturated surface-dry sample in air;

m_1 is the mass, in g, of the vessel containing sample and filled with water; and

m_2 is the mass, in g, of the vessel filled with water only.

6.6 Reporting of results

The mean value shall be reported to the nearest 0.01.

7 DETERMINATION OF RELATIVE DENSITY OF FINE AGGREGATE

7.1 Priciple of test

Mass of the saturated surface-dry aggregate sample in air, mass of the vessel containing aggregate sample after filling the vessel with water, and mass of the vessel filled with water only, are used to determine the relative density on a saturated and surface-dried basis.

7.2 Apparatus

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

7.2.2 *A wide mouthed glass vessel*, capable of holding 0.5 kg of fine aggregate and capable of being filled with water to a constant volume with an accuracy of ± 0.5 ml, such as a gas jar of 1.0 litre to 1.5 litres capacity, with a flat ground disc lip and a plane ground disc of plate glass to cover it, giving a watertight fit.

7.2.3 *A means of supplying a current of warm air* such as a hair drier.

7.2.4 *A watertight tray* of area not less than 0.03 m^2.

7.2.5 *An airtight container* large enough to take the sample.

7.2.6 *A container of a size sufficient to contain the sample* covered with water and to permit vigorous agitation without loss of any part of the sample or water.

7.2.7 *A 75 mm test sieve* conforming to CS 124 and a nesting sieve to protect the 75 m test sieve, e.g. a 1.18 mm sieve.

7.2.8 *A supply of water* free from any impurity (e.g. dissolved air) that would significantly affect its density. If distilled or deionised water is not available in sufficient quantity, tap water which has been freshly boiled and cooled to room temperature may be used. This water shall be used throughout the test.

7.2.9 *A plain glass funnel.*

7.3 Sampling

A sample of not less than 13 kg shall be obtained by collecting fine aggregate from not less than 25 increments from different positions of the fine aggregate stockpile in such a way to represent, as far as possible, the average quality of the fine aggregate stockpile.

Mix the sample in the laboratory and divide the sample to the required size using a typical riffle box. Prepare two subsamples of fine aggregate, each about 500 g, for two tests.

7.4 Test procedure

Place the test sample in the container and add enough water to cover it. Agitate vigorously the contents of the container and immediately pour the wash water over the sieves, which have previously been wetted on both sides and arranged with the coarser sieve on top.

The agitation shall be sufficiently vigorous to result in the complete separation from the coarse particles of all particles passing the 75 m test sieve, and to bring the fine material into suspension in order that it will be removed by decantation of the wash water. Take care to avoid, as far as possible, decantation of the coarse particles of the sample. Repeat the operation until the wash water is clear. Return all material retained on the sieves to the washed sample.

Transfer the washed aggregate to the tray and add further water to ensure that the sample is completely immersed. Soon after immersion, remove bubbles of entrapped air by gently agitation with a rod.

Keep the sample immersed in water for 24 ± 0.5 h, the water temperature being maintained at 27 ± 5 °C for at least the last 20 h of immersion.

Then carefully drain the water from the sample by decantation through a 75 m test sieve, covered by the protective coarser sieve, any material retained being returned to the sample. Then expose the aggregate to a gentle current of warm air to evaporate surface moisture and stir it at frequent intervals to ensure uniform drying until no free surface moisture can be seen and, in the case of aggregate finer than 5 mm, it just attains a free running condition (see Note below).

Then weigh the saturated and surface-dry sample (mass m_0).

Then place the fine aggregate in the wide mouthed glass vessel and fill with water just to overflowing and slide the glass plate over it to exclude any air bubbles. Dry the vessel on the outside and weigh it (mass m_1).

Empty the contents of the vessel into the tray, taking care to ensure that all the fine aggregate is transferred. Refill the vessel with water to the same level as before, dry it on the outside and weigh it (mass m_2).

The difference in the temperature of the water in the vessel during the first and second weighings shall not exceed 2°C.

NOTE

The 'free running' or 'saturated surface-dry' condition of the fine aggregate (smaller than 5 mm) is sometimes difficult to identify and, in order to help in identification, the following method is suggested as a possible aid.

A dry glass funnel may be used to help determine the 'free running' condition of aggregate finer than 5 mm.

With the funnel inverted over the sample tray pour some of the sample over the sloping sides by means of a small scoop. If still damp, particles of the aggregate will adhere to the sides of the funnel. Continue drying until subsequent pouring shows no sign of particles sticking to the glass.

7.5 Calculation

Relative density on a saturated and surface-dried basis

$$= \frac{m_0}{m_0 - (m_1 - m_2)}$$

where,

m_0 is the mass, in g, of the saturated surface-dry sample in air;

m_1 is the mass, in g,of the wide mouthed glass vessel containing sample and filled with water only; and

m_2 is the mass, in g, of the wide mouthed glass vessel filled with water only.

7.6 Reporting of results

The mean of the two results shall be reported to the nearest 0.01.

8 DETERMINATION OF RELATIVE DENSITY OF CEMENT

8.1 Principle of test

The density of cement is determined by displacement of a non-reactive liquid in a density bottle.

8.2 Displacement liquid

Kerosene, free of water or naptha, shall be used in the density determination.

8.3 Apparatus

8.3.1 *Density of bottle,* of nominal capacity 50 ml.

8.3.2 *Small funnel* to fit inside the neck of the density bottle.

8.3.3 *Balance* capable of weighing up to 100 g to an accuracy of ± 0.0005 g.

8.4 Procedure

Clean the density bottle, dry it and weigh. Then fill it to the top of the capillary bore with distilled water. Without using undue force,insert the stopper with a slight twist, care being taken to avoid trapping air bubbles. After ensuring the air bubbles are absent and that bottle is filled to the top of the capillary bore, remove with dry filter paper any water on the top of the neck of the bottle where stopper and neck meet, and dry the sides and the top of the stopper, taking care not to withdraw any water from the capillary. Weigh the bottle with distilled water.

Empty the density bottle and stopper,clean it and dry it. Repeat the above procedure, but filling the bottle with kerosene instead of distilled water. Weigh it.

Empty the density bottle and stopper, clean it and dry it. Place an 8 g to 10 g representative sample of cement in the bottle by means of a small funnel. Fix the stopper and weigh it.

Add sufficient kerosene to cover the cement sample and half fill the bottle, ensuring that the cement is thoroughly wetted by swirling the contents gently, care being taken to keep cement particles clear of the neck of the bottle. Fill the bottle to the top of capillary bore with kerosene and remove any excess of kerosene with filter paper as before. Weigh the density bottle.

Make two separate determinations on different portions of the sample of cement. If the two results of S differ by more than 0.030 or if two results of D differ by more than 30 kg/m³, discard the results and make two fresh determinations.

8.5 Expression of results

Relative density of cement, S, is given by:

$$S = \frac{(m_5 - m_1)\ (m_3 - m_1)}{(m_5 + m_3 - m_4 - m_1)\ (m_2 - m_1)}$$

where,

m_1	is the mass of the empty bottle;
m_2	is the mass of the bottle with water;
m_3	is the mass of the bottle with kerosene;
m_4	is the mass of the bottle with cement and kerosene; and
m_5	is the mass of the bottle with cement.

Express S to the third decimal place.

Density of cement, D,is given by

$$D = S \times 1000 \text{ kg/m}^3$$

where S is defined above.
Express D to the nearest 1kg/m³.

9 DETERMINATION OF MASS PER UNIT VOLUME, AIR CONTENT, COARSE AGGREGATE CONTENT AND UNIT MASS OF AIR FREE MORTAR IN FRESH CONCRETE

9.1 Principle of test

9.1.1 *Mass per unit volume*

A standard container of known capacity, is filled with fresh concrete, compacted and weighed. The measured mass and the known volume of the concrete in the container are used to determine the mass per cubic metre of fresh concrete.

9.1.2 *Air content*

This is obtained by determining, experimentally, the density of concrete containing the air and comparing it with the theoretical or calculated density computed on an air free basis using the relative densities of constituents and the known mix proportion.

NOTE
As an alternative, air content can also be measured, using an air content apparatus which is pressurised by air as specified in ***SLS 262*** *Part 2.*

9.1.3 *Coarse aggregate content*

This is obtained by proportioning the mass of a sample of fresh concrete in a container of known volume, and the saturated surface dry mass of coarse aggregate retained on 5.0 mm sieve from the sampled amount of fresh concrete.

9.1.4 *Unit mass of air free mortar*

This is obtained by dividing the mass of fresh concrete in a container of known volume less saturated and surface dry mass of coarse aggregate, from the above sampled concrete, retained on the 5.0 mm seive, by the volume of air free mortar in the above sampled amount of fresh concrete.

9.2 Apparatus

9.2.1 *A balance* capable of weighing up to 50 kg to an accuracy of 0.1 kg.

9.2.2 *A tamping rod* of steel weighing 1.8 kg, 380 mm long and having ramming face 25 mm square, or by means of a suitable vibrating table.

9.2.3 *A straight edge*

9.2.4 *A container* conforming to the dimensions specified in Table 1. It shall have a smooth internal surface and shall be water-tight and of sufficient rigidity to retain its shape under rough usage. The rim of the container shall be machined to a plane surface perpendicular to its axis. For convenience the container should be provided with handles.

TABLE 1 Dimensional requirements for cylindrical container

Nominal capacity m^3 (1)	Inside diameter mm (2)	Inside height mm (3)	Minimum thickness of metal mm (4)
0.01	200 ± 1.6	320 ± 1.6	4

9.2.5 *A 5.00 mm test sieve* complying with the requirements of coarse tolerance test sieves given in **CS 124**.

9.2.6 *A supply of water* free from any impurity (e.g. dissolved air) that would significantly affect its density. If distilled or deionised water is not available in sufficient quantity, tap water which has been freshly boiled and cooled to room temperature may be used. This water shall be used throughout the test.

9.2.7 *A balance* of capacity not less than 3 kg accurate to 0.5 g and of such a type as to permit the weighing of the vessel containing the aggregate and water.

9.2.8 *A wide mouthed glass vessel* such as a gas jar, of 1.0 litre to 1.5 litres capacity, with a flat ground lip and a plane ground disc of plate glass to cover it, giving a watertight fit.

9.2.9 *Two dry soft absorbent cloths,* each not less than 750 mm by 40 mm.

9.2.10 *A shallow tray* of area not less than 0.03 m^2.

9.2.11 *An airtight container* large enough to take the sample.

9.3 Calibration of container

The container shall be calibrated by determining the mass of water at room temparature required to fill it so that no meniscus is present above the rim. The capacity of the container is obtained by dividing the above mass by the unit mass of water, namely 1000 kg/m^3.

9.4 Sampling

Three samples shall be taken from a full section of the flow of concrete at mid-point of discharge of each of three different truck loads selected at random. If less than three truck loads are used, the three samples shall be so positioned that they are representative of widely separated portions of the concrete delivered, but not the beginning or end of any truck load.

9.5 Test procedure

The container shall be filled with concrete as soon as practicable after sampling, in such a way as to produce full compaction of the concrete with neither segregation nor excessive laitence.

The container shall be filled in layers approximately 50 mm deep and each layer shall be compacted by hand or filled in larger layers and vibrated as described below. After the top layer has been compacted the surface of the concrete shall be struck off level with the top of the container by means of the straightedge.

Compacting by hand - When compacting by hand the standard tamping rod shall be used and the strokes of the rod shall be distributed in a uniform manner over the cross - section of the container.

The number of strokes per layer required to produce the full compaction will vary according to the type of concrete but in no case shall the concrete be subjected to less than 60 strokes per layer.

Compacting by vibration - When compacting by vibration each layer shall be vibrated by means of a suitable vibrator or vibrating table until full compaction is attained.

The container containing the fully compacted concrete shall be weighed and the mass of the concrete determined.

Place small portions of the fresh concrete in a 5.00 mm test sieve and thoroughly wash it on the test sieve to remove all finer particles that pass through the test sieve. Transfer the washed coarse aggregate to the airtight container.

Drain the aggregate and place it on a dry cloth laid in the shallow tray and gently surface dry it with the cloth, transferring it to a second dry cloth, laid in the tray as before, when the first cloth will remove no further moisture. Then spread it out not more than one stone deep on the cloth and leave it exposed to the atmosphere away from direct sunlight or any other source of heat until all visible films of water are removed but the aggregate still has a damp appearance. Then weigh the coarse aggregate.

Obtain samples of coarse aggregate, fine aggregate and cement used on the ready-mixed plant to produce this concrete and determine their relative densities as specified in **6**,**7** and **8** of this part of the standard.

Observe or obtain the mix proportion, by weight, used at the ready-mixed plant to produce this fresh concrete under study.

9.6 Calculations and reporting of results

9.6.1 *Mass per unit volume*

The mass per cubic metre of the fresh concrete shall be calculated by dividing the mass of fully compacted concrete in the container by the capacity of the container.

Mean of the three values shall be reported to the nearest 0.1 kg/m^3.

9.6.2 *Air content*

Air content shall be determined using the following equations:

$$A = \frac{Wt - Wa}{Wt} + 100 \quad \text{and}$$

$$Wt = \frac{Wc + Wt + N + Ww}{[Wc/(Sc \times W)] + [Wf/(Sf \times W)] + [N/(S \times W)] + [Ww/W]}$$

where,

Wa = actual mass of concrete (including air) produced per unit volume in kg/m^3 (**9.6.1**);

Wt = calculated mass of concrete per unit volume assuming it to be air free;

Wc = total mass of coarse aggregate used in the batch at the ready-mixed plant;

Wf = total mass of fine aggregate used in the batch at the ready-mixed plant;

Ww = total mass of mixing water used in the batch at the ready-mixed plant;

N = the mass of cement used in the batch at the ready-mixed plant;

A = the air content (per cent);

Sc = relative density of coarse aggregate on a saturated and surface-dried basis (6);

Sf = relative density of fine aggregate on a saturated and surface dried basis (7);

S = relative density of cement (8) (If ordinary Portland cement is used, this can be assumed as 3.15, but if greater accuracy is desired actual measurement is desirable); and

W = 1000 kg/m^3

The mean of the three values of air content shall be reported to the nearest 0.1 per cent.

9.6.3 *Coarse aggregate content*

Coarse aggregate content shall be determined using the following equation:

$$P = \frac{c}{b} \times 100$$

where,

P = coarse aggregate content;

c = saturated surface dry mass in kg of coarse aggregate retained on 5.00 mm sieve, resulting from washing all material finer than this sieve from the fresh concrete; and

b = mass of sample, in kg of fresh concrete in the container of known capacity.

The mean of three values of coarse aggreagate content shall be reported to the nearest 0.1 per cent.

9.6.4 *Unit mass of air free mortar*

Unit mass of air free mortar shall be calcuated as follows:

$$M = \frac{b - c}{\left[V - \left\{ \frac{V \times A}{100} + \frac{c}{1000Sc} \right\} \right]}$$

where,

M = unit mass of air free mortar in kg/m^3;

b = mass in kg of concrete sample in the container of known capacity;

c = saturated surface dry mass in kg retained on 5.00 mm sieve, resulting from washing all material finer than this sieve from the fresh concrete;

V = volume in m^3 of the container of known capacity;

A = air content of concrete in per cent (9.6.2); and

Sc = relative density of coarse aggregate on a saturated and surface-dried basis (see 6).

The mean of three values of unit mass of air free mortar shall be reported to the nearest 0.1 kg/m^3.

10 DETERMINATION OF MIX PROPORTION

10.1 Principle of test :

Sample of concrete is weighed in air and in water. Then, the coarse aggregate fraction is separated by washing the concrete sample over a 5 mm sieve, while the fine aggregate fraction is separated by washing the remainder over a 150 µm sieve. The mass of fine and coarse aggregate portions are determined by weighing in water, while mass of cement is obtained as a difference between the mass in water of the concrete sample and of the aggregates. The proportions of constituents in the sampled concrete is computed using relative densities of the constituent materials and a grading correction factor for fine aggregate. The test should be done as soon as possible after concrete production as loss of water can occur by evaporation as well as hydration. The addition of a chemical substance to disperse air is used when air-entrained concrete is to be analysed.

10.2 Reagent

The following reagent is required for air-entrained concrete only: *Tri-n-butyl phosphate,* laboratory reagent grade.

10.3 Apparatus

10.3.1 *General*

The following apparatus is required (see Figure 2)

10.3.2 *Balance* of suitable type to suspend the containers described in **10.3.4**, capable of weighing 5 kg to an accuracy of ± 0.5 g.

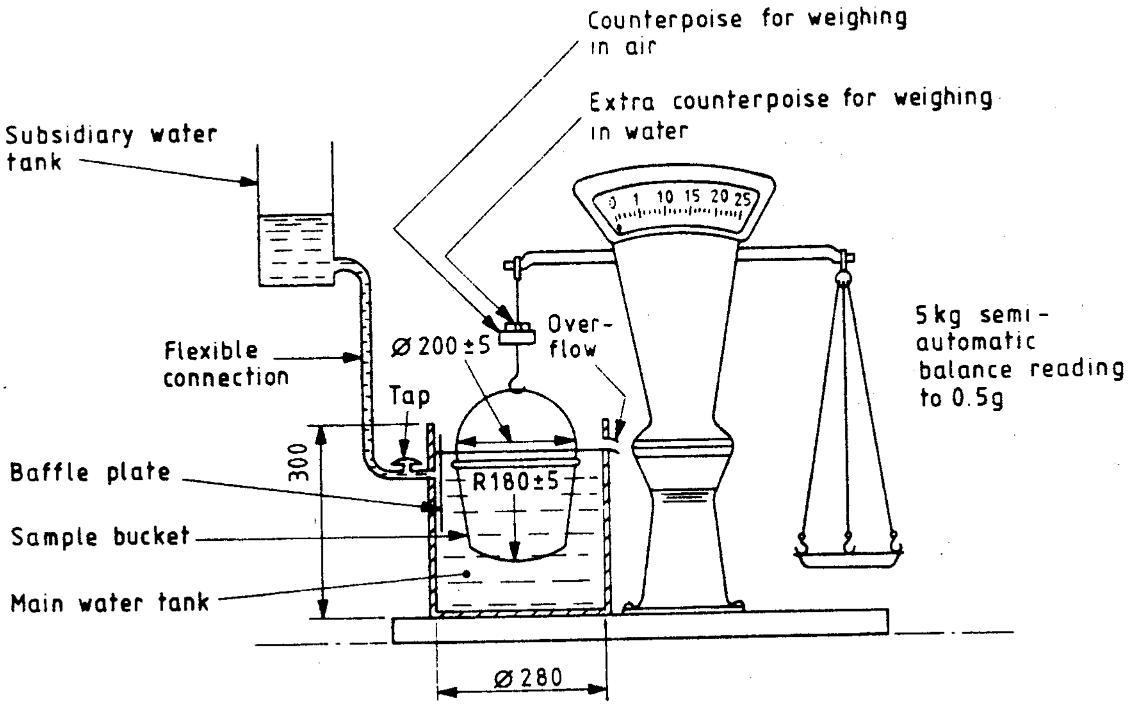
10.3.3 *Two counterpoises for the balance,* one to obtain equilibrium when an empty container is weighed in air and the other when one of the empty containers is weighed in water.

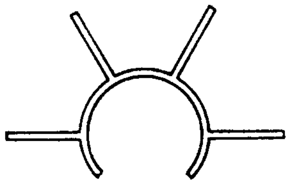
10.3.4 *Bucket shaped containers* made of corrosion resisting metal, each 200 ± 5 mm diameter at the top, and 180 ± 5 mm deep, having smooth sloping sides and a rounded bottom to prevent the trapping of air during immersion.

***NOTE** : It is advantageous that eight containers are avilable and that each container is of the same mass in air correct to ± 0.25 g, and each is clearly marked with the difference between its loss in mass when immersed in water and the mass of the second counterpoise.*

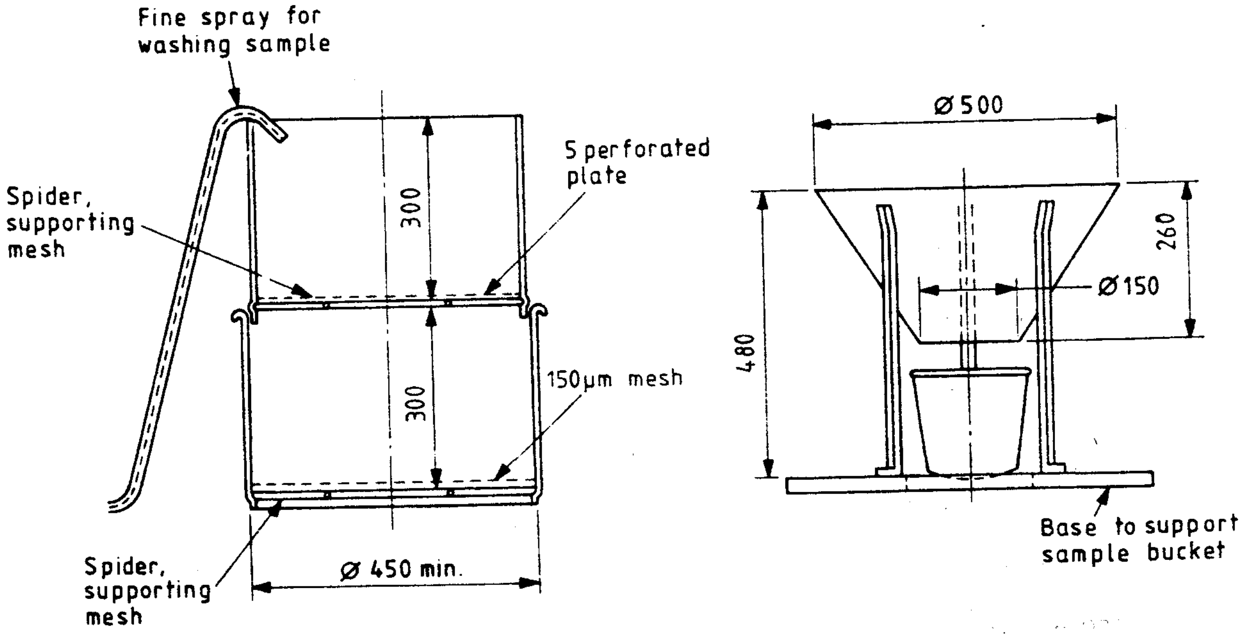
10.3.5 *Immersion apparatus* consists of a main tank of approximately 280 mm diameter and approximately 300 mm deep, fitted with an overflow spout such that the lip of a container hung from the balance is completely immersed when the main tank is filled to overflowing.

A tap of 6 mm bore is fitted to the main tank and connected by a flexible pipe to a supply of water,e.g. a subsidiary tank as shown in Figure 2.





Plan of spider to support mesh



Dimensions in millimetres

FIGURE 2 - Apparatus for determination of mix proportion

This connection enables the bulk of the water in the main tank to be dropped to below the lip of a container suspended from the balance; alternatively, a suitable bailing vessel should be provided for lowering the water level.

A baffle plate is fitted inside the main tank, such that any flow of water into the main tank does not disturb the water and, therefore, the contents of the container.

10.3.6 *Two nesting sieves,* approximately 450 mm diameter by approximately 300 mm deep, the upper sieve being fitted with perforated plate of 5 mm aperture size, and the lower sieve being fitted with woven wire cloth of 150 µm aperture size; both meshes complying with the requirements of **CS 124**.

10.3.7 *Means of transferring the washed aggregate from the sieves to the containers,* e.g. a funnel 500 mm diameter at the top, 150 mm diameter at the bottom and 260 mm deep, supported in a suitable frame (see Figure **2**).

10.3.8 *Hose fitted with a nozzle* that, when fed with water at normal mains pressure, gives a fine spray strong enough to move the particles of fine aggregate over the surface of the 150 µm sieve.

10.3.9 *Metal stirring rod* of sufficient length and strength, e.g. 450 mm long by 16 mm diameter, for the operator to be able to stir a concrete sample in its container.

10.3.10 *A scoop,* of galvanized iron or other suitable material, that when just filled will contain about of 4 kg of concrete.

10.3.11 *Sample containers* of appropriate size and suitable material, e.g. 15 litre plastic buckets.

10.3.12 *A sampling tray or plate* of non-absorbent material and of a suitable size, e.g. a tray 1.2 m x 1.2 m x 50 mm deep made from 1.6 mm minimum thickness steel sheet galvanized.

10.3.13 *A square-mouthed shovel,* in which the square mouth is not less than 150 mm wide.

10.4 Calibration tests

10.4.1 *General.* Determine the density of the cement (see **10.4.2**),(if Portland cement is not used) and the relative densities of the coarse and fine aggregates (see **10.4.3**).

Determine also a grading correction factor to allow for that fraction of the coarse and fine aggregate, used in the concrete, that passes a 150 µm sieve (see **10.4.4**).

NOTE

The accuracy of the analysis results depends to a great extent on the reliability of the estimates obtained from the above determinations. It cannot be assumed that the results of the calibration tests will remain constant.

10.4.2 *Density of cement*

Assume that the density of the cement, if Portland cement is used, is 3150 kg/m³. If other cements are used, determine their densities by the method described in **8**.

10.4.3 *Determination of the relative densities of the aggregates*

10.4.3.1 *Aggregate samples.* Obtain bulk samples, from each of the stockpiles of the coarse and fine aggregates to be used in the concrete to be analysed.

A sample not less than 25 kg shall be obtained by collecting coarse aggregate from not less than 25 increments from different positions of the coarse aggregate stockpile in such a way to represent, as far as possible, the average quality of the coarse aggregate stockpile.Mix the sample in the laboratory and divide the sample to required size using a typical riffle box. Prepare two subsamples,each about 1 kg, for the two tests. Each subsample shall be thoroughly washed on the 5.00 mm test sieve to remove finer particles, particularly clay, silt and dust, which would otherwise be lost during the test thereby affecting the result, and drained.

A sample of not less than 13 kg shall be obtained by collecting fine aggregate from not less than 25 increments from different positions of the fine aggregate stockpile in such a way to represent, as far as possible, the average quality of the fine aggregate stockpile. Mix the sample in the laboratory and divide the sample to the required size using a typical riffle box. Prepare two subsamples of fine aggregate, each about 500 g for two tests.

10.4.3.2 Procedure

Determine the relative densities of the coarse and fine aggregates under conditions identical with those to be applied when the concrete is to be analysed.

Do not permit any differences in the water temperature, at the time of making any weighings under water, to exceed 2°C.

NOTE :

The water temperature needs to be maintained within the same range when carrying out the analysis.

Treat the samples in pairs, one of coarse aggregate and one of fine aggregate, and carry out the following procedure on each of the pairs.

Place a sample of the fine aggregate in one of the clean containers. Support the 5.0 mm sieve on the funnel, with the container and fine aggregate beneath the funnel. Totally transfer the paired sample of coarse aggregate to the sieve. Then wash the coarse aggregate under a spray of water for 1 min to 2 min to ensure the removal of particles finer than the 5.0 mm sieve, collecting this fraction in the container with the fine aggregate.

Totally transfer the washed coarse aggregate to a clean container using the funnel, then fill the container to within 25 mm of the lip. Stir the aggregate until any entrapped air is removed, i.e. for about 1 min, and hang the container, in the water tank, from the balance (see Figure 2). Steadily raise the water level in the main tank, which is initially below the lip of the container, until the container is filled with water and water starts to flow from the overflow spout. Weigh the coarse aggregate in water.

Follow the same balancing and weighing procedures with the container holding the fine aggregate.

NOTE:

During all weighings, limit the maximum movement of the container to 5 mm to restrict the error caused by variations in its displacement.

If the aggregates have been oven dried, time will be rquired for water to be absorbed by the aggregates before a steady mass in water is obtained. In such a case, stir the aggregates, and weigh after 10 min immersion to ensure that it does not differ by more than 0.5 g from the previous weighing. If necessary, stir and reweigh the container and contents at 10 min intervals until the above condition is met. Record the time taken to obtain this condition.

Record the final mass in water as B_a for the coarse aggregate, and B_s for the fine aggregate.

Carefully drain the water from each container, if necessary filtering the water from the fine aggregate through a filter paper and returning any retained material. Dry the coarse and fine aggregates separately to the saturated surface dry condition (see **6.4** and **7.4**).

Transfer the coarse aggregate onto a dry cloth and surface dry it. Continue the process with a second dry cloth when the first will remove no further moisture. On the second cloth, spread the aggregate out not more than one stone deep and leave it until the aggregate just becomes surface dry.

NOTE:
A source of heat, e.g. a fan heater of low wattage, may be used to assist drying provided no internal water is removed.

Expose the fine aggregate to a gentle current of warm air to evaporate the surface moisture. Stir the aggregate at frequent intervals to ensure uniform drying. Continue these processes until the fine agregate just attains a free-running condition (see **7.4** Note).

Record the mass in air of the saturated surface dry aggregates as A_a for the coarse aggregate and A_s for the fine aggregate. Retain the fine aggregate for the determination of the grading correction factor (10.4.4).

10.4.3.3 Calculation of relative densities.

Calculate the relative densities as follows:

$$\text{relative density of coarse aggregate} = \frac{A_a}{A_a - B_a}$$

$$\text{relative density of fine aggregate} = \frac{A_s}{A_s - B_s}$$

Where A_a, A_s, B_a, B_s are as defined in 10.4.3.2.

10.4.3.4 Duplicate determination

Repeat the procedure for another subsample each and then calculate the average values of the relative densities of the coarse aggregate and fine aggregate.

10.4.4 Determination of grading correction factor

10.4.4.1 Test samples

Use the same test samples, that had previously been used to determine the relative density of the fine aggregates, for the determination of the grading correction factor.

10.4.4.2 Procedure.

Totally transfer a fine aggregate sample to the 150 µm sieve. Wash the fine aggregate under the spray until the water passing through the sieve is clear, i.e. about 10 min. Wash the aggregate retained on the sieve into a clean container through the funnel. Cover the aggregate with water to within 25 mm of the lip of the container and stir to remove entrapped air. Immerse the container in the water tank and determine the mass in water of the fine aggregate D_s as in 10.4.3.2.

Calculate the grading correction factor C_s from the equation:

$$C_s = \frac{B_s}{D_s}$$

Where B_s is as defined in **10.4.3.2**.

Repeat this operation and calculate the average of the two estimates to provide the value to be used in the calculation of the mass of the constituents.

10.5 Analysis of concrete

10.5.1 *Sampling*

Take a sample in accordance with 11 of **SLS 1144 : Part 1 : 1996.** When a batch of concrete is sampled, take a sample, after allowing a discharge of approximately 0.3 m^3, of six standard scoopfulls, collected from the moving stream in a bucket or other suitable container. Remix the sample on a non-absorbent surface.

10.5.2 *Sample reduction to provide the test samples*

The following description of the sample reduction procedure refers to concrete of low workability, but the general approach should be adopted also when subsampling all concretes. For more workable concretes, the terms 'heap' and 'cone' should not be applied rigidly.

Place the concrete sample in a heap on one side of the tray or plate. Then, shovel-by-shovel, transfer the concrete to the opposite side of the tray to form a cone; do this by depositing the second and each subsequent shovelful of concrete on the apex of the cone being formed so that the portions which slide down the sides do not displace the centre of the cone to any marked extent. Cone the concrete three times.

Flatten the third cone by repeated vertical insertions of the shovel across the apex of the cone, lifting the shovel clear after each insertion. Ensure that the flattened heap is reasonably uniform in thickness and diameter. Quarter along two diameters, intersecting at right angles, using the shovel. Combine opposite quarters to form two separate subsamples.

Treat each subsample separately to obtain two test samples, i.e. one from each subsample.

Reduce the subsamples by further coning and quartering, and putting aside two opposite quarters until the two remaining quarters are of the required mass to provide a test sample of mass 4 ± 0.5 kg.

10.5.3 *Procedure*

Place a test sample, obtained as in **10.5.2**, in a clean, dry container and determine its mass in air W.

Fill the container with water at the required temperature (see **10.4.3.2**) to within 25 mm of the lip. At this stage, add 10 ml of tri-n-butyl phosphate if air-entrained concrete is being analysed. Stir the contents of the container until as much entrapped air, and for air-entrained concrete as much entrained air as possible, is removed. i.e. for 1 min to 2 min. Hang the container in the water tank, from the balance (see Figure 2), taking all necessary care to prevent the container lip from failing below the water level in the tank. Then carefully fill the container with water to the lip and allow the contents to settle for 5 min. Adjust the water level in the tank. without disturbing the material in the container, until the water just overflows from the spout. Do not add more water to the tank and, when overflow has ceased, determine the sample mass in water w.

Change the water in the tank, if it becomes contaminated, to prevent a change in its density.

Totally transfer the sample to the nest of sieves, 5 mm over the 150 μm, and wash the concrete until it is free from cement, i.e. for at least 2 min. Transfer the clean coarse aggregate from the 5 mm sieve to a clean container through the funnel. Fill the container with water to within 25 mm of the lip and stir the contents to remove entrapped air. Immerse the container in the water and determine the mass in water of the coarse aggregate w_a.

Wash the fine aggregate on the 150 μm sieve for a further 10 min or until it is free of cement, and the washing water is clear. Determine the mass in water of the fine aggregate w_s by the same procedure that was used for the coarse aggregate.

Repeat the above procedure with the second test sample.

10.5.4 *Calculation of mass of each constituent.*

Calculate the mass of each constituent, for each test sample, as follows:

a) the mass of coarse aggregate W_a in the sample is given by the equation:

$$W_a = w_a \times F_a ;$$

b) the mass of fine aggregate W_s in the sample is given by the equation:

$$W_s = w_s \times F_s \times C_s ;$$

c) the mass of cement W_c in the sample is given by the equation:

$$W_c = \{ w - w_a - (w_s \times C_s)\} \times F_c ;$$

d) the mass of water W_w in the sample is given by the equation:

$$W_w = W - (W_a + W_s + W_c);$$

where,

$$F_a = \frac{\text{relative density}}{\text{relative density} - 1}$$ for the coarse aggregate;

$$F_s = \frac{\text{relative density}}{\text{relative density} - 1}$$ for the fine aggregate;

$$F_c = \frac{\text{density}}{\text{density} - 1000}$$ for the cement;

C_s is the grading correction factor as found in **10.4.4**;

W is the mass of concrete sample in air;

w is the mass of concrete sample in water;

w_a is the mass of coarse aggregate in water; and

w_s is the mass of fine aggregate in water.

10.5.5 *Other Determinations*

a) Mix proportion by weight is given by the expression:

$$1 \text{ cement} : \frac{W_s}{W_c} \text{ fine aggregate} : \frac{W_a}{W_c} \text{ coarse aggregate.}$$

b) mix proportion by volume is given by the expression:

$$1 \text{ cement} : \frac{W_s}{W_c} \times \frac{d}{\rho_s . 1000} \text{ fine aggregate} : \frac{W_a}{W_c} \times \frac{d}{\rho_a . 1000} \text{ coarse aggregate}$$

c) water/cement ratio is given by the expression :

$$\frac{W_w}{W_c}$$

d) mass of each constituent per cubic metre of concrete is given by the expression :

$$\frac{W_a \text{ or } W_s \text{ or } W_c \text{ or } W_w)}{W} \times \text{ mass per cubic metre of fresh concrete (see 9.6.1)}$$

where

W_a, W_s, W_c, W_w and W are as defined in 10.5.4:

d is the density of cement;
ρ_s relative density of fine aggregate; and
ρ_a relative density of coarse aggregate.

11 DETERMINATION OF COMPRESSIVE STRENGTH OF CONCRETE

11.1 Principle of test

Compressive strength is obtained by loading to failure a concrete cube of standard dimensions subject to a compressive load. It is computed to be the maximum load applied divided by the cross-sectional area of the cube, and this property is considered the most valuable property of concrete as it gives an overall picture of the quality of concrete because compressive strength is directly related to the structure of the hardened cement paste as well as quality of aggregates.

11.2 Apparatus

11.2.1 *Mould*

11.2.1.1 Construction and assembly.

The sides of the mould shall be of ferrous metal (preferably cast iron or cast steel). The hardness of each internal face shall be at least 95 Rockwell (scale B) Hardness Value. The mould shall include a removable steel base plate. All parts of the mould shall be robust enough to prevent distortion. The base plate of a 150 mm mould should preferably have a thickness of at least 15 mm. Before assembly for use, the joints between the sides of the mould and between them and the base plate shall be thinly coated with oil or grease to prevent loss of water. The parts of the mould when assembled shall be positively located and rigidly held together in such a manner as to prevent leakage from the mould. The internal faces of the assembled mould shall be thinly coated with release agent to prevent adhesion of the concrete.

The sides of the mould shall be clearly marked with a reference number or code to enable each concrete specimen to be identified when it is demoulded and the mould to be correctly re-assembled.

A mould shall be refurbished or discarded when any dimensional deviation exceeds twice the tolerances specified in **11.2.1.2**.

11.2.1.2 Tolerances

When assembled, the dimensions and internal faces of a new mould shall be acurate within the following limits.

a) *Dimensions.*
The depth of the mould and the distance between the two pairs of opposite internal side faces, each based on the average of four symmetrically placed measurements, shall be the nominal size of 100 ± 0.15 mm or 150 ± 0.15 mm. This tolerence should be considered in conjunction with those for flatness, squareness and parallelism.

b) *Flatness.*
The flatness tolerance (see 3.1.2 of **SLS 409 : 1977**) for each internal side face shall be 0.03 mm wide. That for the joint faces, for the bottom surface of the assembled mould sides and for the top surface of the base plate shall be 0.06 mm wide.

c) *Squareness.*
The squareness tolerance (see 3.2.2 of **SLS 409 : 1977**) for each internal side face with respect to the bottom surface of the mould and the adjacent internal side faces as datum faces shall be 0.5 mm wide.

d) Parallelism.
The parallelism tolerance (see 3.2.1 of **SLS 409 : 1977**) 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) Surface texture.
The surface texture of each internal side face shall not exceed 3.2 μm R_a, when determined in accordance with **ISO 468**.

11.2.2 *Scoop,* approximately 100 mm wide.

11.2.3 *Compacting bar or vibrating hammer or vibrating table.*

A compacting bar made out of a steel bar weighing 1.8 kg, 380 mm long and having a ramming face 25 mm square, or a vibrating hammer or a vibrating table suitable for compacting the concrete in accordance with **11.4.2** or **11.4.3**.

11.2.4 *Plasterer's steel float or a steel trowel.*

11.2.5 *Sampling tray,* 1.2 m x 1.2 m x 50 mm deep made from minimum 1.6 mm thick non-corrodible metal.

11.2.6 *Square mouthed shovel,* not less than 150 mm wide.

11.2.7 *Curing tank.* A curing tank constucted from any material which is of adequate strength and will resist corrosion. The internal dimensions of the tank shall be appropriate for the number and size of the specimens to be accommodated, shall permit adequate circulation of water and shall be such that specimens can be easily removed. The tank shall contain clean water which shall be replaced at least once a month. At any point in the tank where specimens are stored the temperature shall be 27 ± 2°C.

11.2.8 *Thermometer,* suitable for measuring maximum and minimum moist air and water curing temperatures.

11.2.9 *Testing machine.* The testing machine shall comply with **BS 1881 : Part 115** .

11.2.10 *Auxiliary platens*

When auxiliary platens are used, the top auxiliary platen shall rest on and be aligned with the cube. It shall not be fixed to the upper machine platen.

NOTE

It is recommended that auxiliary platens should be used in order to save wear on the machine platens and to minimize the effect of overfilled cubes on strength measurement.

11.3 Sampling

Sampling of concrete shall be done in accordance with **9.3** (for uniformity test on mixers) or 11 (for acceptance of concrete) of SLS 1144:**Part 1 : 1996**. When a batch of concrete is sampled, take a sample, after allowing a discharge of approximately 0.3 m³, of six standard scoopfulls, collected from the moving stream in a bucket or other suitable container. Remix the sample on a non-absorbent surface. Commence making the cubes as soon as possible after sampling.

Empty the sample from the container(s) on to the sampling tray. Ensure that no more than a light covering of slurry is left adhering to the container(s).

Thoroughly mix the sample by shovelling it to from a cone on the sampling tray and turning this over with the shovel to form a new cone, the operation being carried out three times. When forming the cones, deposit 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 so that the centre of the cone is not displaced. Flatten the third cone by repeated vertical insertion of the shovel across the apex of the cone, lifting the shovel clear of the concrete after each insertion.

NOTE

The following modifications to the mixing procedures may be necessary when preparing samples of very high workability concrete (e.g. superplasticized concrete) for test.

a) Sampling tray. The vertical lips on the edges of the tray may have to be larger to contain the sample without spillage during mixing.

b) Mixing the sample. The coning procedure is not suitable for very high workability concrete and the following alternative method of mixing is recommended. Having poured the concrete on to the sampling tray, use the shovel to turn the concrete from the outside toward the centre, working progressively once round all sides of the sampling tray.

11.4 Procedure

11.4.1 *Filling the mould.*

Place the mould on a rigid horizontal surface or on the vibrating table and fill with concrete in such a way as to remove as much entrapped air as possible (without significantly reducing the amount of entrained air, if present) and to produce full compaction of the concrete with neither excessive segregation nor laitance. For this purpose, by means of the scoop, place the concrete in the mould in layers approximately 50 mm deep and compact each layer by using either the compacting bar or the vibrator in the manner described in **11.4.2** or **11.4.3**. After the top layer has been compacted, smooth it level with the top of the mould, using the plasterer's float or trowel, and wipe clean the outside of the mould.

11.4.2 *Compacting with compacting bar*

When compacting each layer with the compacting bar, distribute the strokes of the compacting bar in a uniform manner over the cross-section of the mould, and ensure that the compacting bar does not penetrate significantly any previous layer nor forcibly strike the bottom of the mould when compacting the first layer. The number of strokes per layer required to produce full compaction will depend upon the workability of the 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, except in the case of very high workability concrete. Record the number of strokes.

11.4.3 *Compacting with vibrator*

When compacting each layer by means of the hammer or vibrating table use applied vibration of the minimum duration necessary to achieve full compaction of the concrete. Over-vibration may cause excessive segregation and laitance or loss of entrained air, if present. The required duration of vibration will depend upon the workability of the concrete and the effectiveness of the vibrator and vibration shall cease as soon as the surface of the concrete becomes relatively smooth and has a glazed appearance. Record the duration of vibration.

11.4.4 *Curing*

Immediately after making specimens store them in a place free from vibration and in conditions which will prevent loss of moisture. If it is necessary to move the specimens to the place of storage, move them in their moulds ensuring no loss of concrete. Store the specimens either;

a) in an atmosphere with a relative humidity of not less than 90 percent in a moist air curing room or a cabinet; or

b) under damp matting or any other suitable damp material wrapped completely with polyethylene or other impervious sheeting.

NOTE

The preferred method for storing specimens is that described in (a).

Whichever method of moist air storage is used, maintain the temperature of the specimens at 27⁰ C ± 5 ⁰ C if the specimens are to be tested at an age of 7 days or more, or at 27⁰C ± 2 ⁰C if the specimens are to be tested at an earlier age.

Demould specimens to be tested at 24 h just before testing. Demould specimens to be tested at greater ages within the period 16 h to 28 h after the addition of water to the other constituents in the mix unless the concrete has not achieved sufficient strength to enable specimens to be demoulded during this period. In such cases, delay demoulding for a further 24 h. During this further period, continue the storage of the specimens in the moist air conditions.

Mark each specimen clearly and indelibly with an identification number or code. Unless required for test at 24 h, either submerge the specimens immediately in the curing tank or immediately prepare them for transporting to another location. Keep all specimens which are immediately transferred to the curing tank submerged and remove them just before testing unless it is necessary to transport them to another location for testing.

Immediately after removal from the moulds or from the curing tank, pack specimens to be transported in such a way as to prevent any significant change in moisture content.

NOTE

This may be achieved by using special boxes having compartments lined with wet felt or other suitable material.

After filling, seal each box or enclose it in polythene. Alternatively, the specimens may be packed in damp sand or in wet sacks and enclosed in a polyethylene bag. Store the transported specimens in the curing tank for not less than 24 h before the time of testing. This trasfer of specimens may take place at any time between demoulding of the specimens and 24 h before the time of testing but it shall be effected in as short a time as is practicable.

In order to provide adequate circulation of water and to facilitate the removal of the specimens from the curing tank ensure that there is at least 15 mm of water horizontally between specimens and between specimens and the sides of the tank. Continue the curing in water as long as possible up to the time of testing.

Record the daily maximum and minimum moist air and water curing temperatures using either maximum and minimum thermometers or continuous recording instruments.

11.4.5 *Age of test specimens*

Tests shall be carried out within the following tolerances on the ages for testing.

± 30 min for ages up to and including 30 h
± 2 h for ages above 30 h and up to and including 100 h
± 8 h for ages above 100 h and up to and including 60 days
± 1 day for ages above 60 days.

The ages shall be calculated from the time of adding the water to the other materials in the concrete mix.

NOTE
Preferred ages for testing are 1,2,3,7,14 and 28 days, 13 and 26 weeks and 1 year.

11.4.6 *Preparation for testing*

Test specimens shall be concrete cubes made, cured and stored as described above. Do not test cubes which have been made in badly assembled moulds or which are clearly distorted. Remove any projecting fins. Weigh each specimen, as-received or saturated.

Immerse in water, for a minimum of 5 min, those cubes which have not been cured in water or where the surfaces have been allowed to dry. Remove the cubes from the curing or density water tank and test while they are still wet.

11.4.7 *Placing the cube in the testing machine*

Ensure that all testing-machine bearing surfaces are wiped clean and that any loose grit or other extraneous material is removed from the surfaces of the cube which will be in contact with the platens. Use no packing between the cube and platens, and the spacing blocks if used.

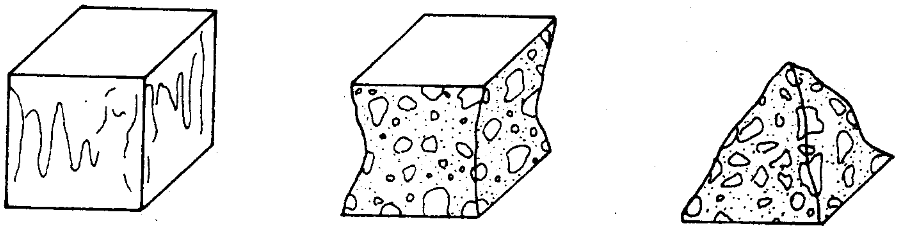
Carefully centre the cube on the lower platen and ensure that the load will be applied to two opposite cast faces of the cube. If auxiliary platens are being used, align the top auxiliary platen with the cube.

11.4.8 *Loading*

Without shock, apply and increase the load continuously at a nominal rate within the range 0.2 $N/(mm^2.s)$ to 0.4 $N/(mm^2.s)$ until no greater load can be sustained. On manually controlled machines as failure is approached the loading rate will decrease; at this stage operate the controls to maintain as far as possible the specified loading rate. Record the maximum load applied to the cube.

11.4.9 *Type of failure*

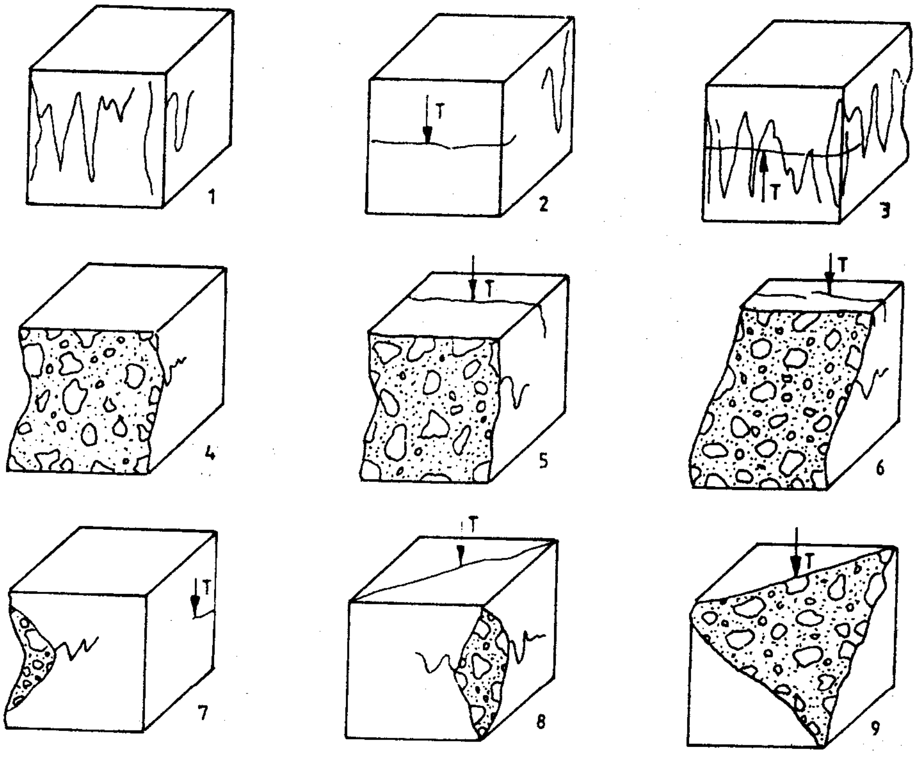
Record any unusual features in the type of failure. Refer to Figure 3 for examples of satisfactory failure, and to Figure 4 for examples of some unsatisfacatory failures.



Explosive failure

NOTE. All four exposed faces are cracked approximately equally, generally with little damage to faces in contact with the platens.

FIGURE 3 - Satisfactory failures



NOTE. T = Tensile crack

FIGURE 4 - Some unsatisfactory failures

NOTE

Unsatisfactory failures are usually caused by insufficent attention to the detail of the various procedures that have to be followed to make and test the specimens. For example, unsatisfactory failure may be due to the cubes being badly made, the use of moulds that do not comply with the specification, or mis-placement of the cubes in the testing machine. It is also possible for a machine fault to be the cause of unsatisfactory failure.

11.5 Calculation and expression of results

11.5.1 *Calculation of cross-sectional area*

Calculate the cross-sectional area of cube from nominal dimensions if both lie not more than 1 per cent above or below the nominal cube size.

If one or both dimensions is or are oversize or undersize by more than 1 per cent of the nominal cube size, calculate the cross-sectional area from the average of the actual measurements made.

11.5.2 *Calculation of strength*

Calculate the compressive strength of each cube by dividing the maximum load applied to it by the cross-sectional area. Express the results to the nearest 0.5 N/mm^2.

11.5.3 *Calculation of density*

Calculate the dinsity of each cube (as-received or saturated) by dividing the mass (as-received or saturated) by volume obtained by multiplying length, width and height of each cube.

11.5.4 *Other information*

Record condition of specimen (blow holes, non-uniform colour, distorted shape,poor dimensions), appearance of fractured concrete face (honeycombing, air bubbles, non-uniform mixing) and type of fracture (see Figure 4), if they are unusual.

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