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METHODS FOR TESTING OF MINERAL AGGREGATES FOR CEMENT CONCRETE MIXES PART 2 - PHYSICAL PROPERTIES

SRI LANKA STANDARDS INSTITUTION

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PART 2 : PHYSICAL PROPERTIES

SLS 728:Part 2:1985

Gr. 14

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SRI LANKA STANDARD

METHODS FOR TESTING OF MINERAL AGGREGATES FOR CEMENT CONCRETE MIXES

PART 2 : PHYSICAL PROPERTIES

FOREWORD

This Sri Lanka Standard was authorised for adoption and publication by the Council of the Sri Lanka Standards Institution on 1985-11-20, after the draft, finalised by the Drafting Committee on Mineral Aggregates for Cement Mixes, has been approved by the Civil Engineering Divisional Committee.

This standard is being issued in four parts as follows:

Part 1 : Size, shape and classification - size and shape of mineral aggregates including clay, silt and dust and an aggregate classification.

Part 2 : Physical properties - relative density, water absorption, bulk density (mass per unit volume), voids, bulking and moisture content.

Part 3 : Mechanical properties - aggregate impact value, aggregate crushing value, ten per cent fines value and aggregate abrasion value.

Part 4 : Chemical properties - estimation of organic impurities and chloride content.

The Drafting Committee has taken into consideration the views of specialists in Civil Engineering and has related the standard to the practices followed in this country. Further the need for international co-ordination among standards prevailing in different countries has also been recognized. These considerations led the Drafting Committee to derive assistance from the publications of British Standards Institution and Indian Standards Institution.

Some of the tests are intended for use in obtaining assurance that material complies with Sri Lanka Standard or other requirements, for research, production control or assessment of variation. However, other methods are not intended for assurance testing and their suitability for other purposes is defined.

Dimensions given in this standard are in SI units. However, provision has been made for the use of non-metric apparatus, in certain cases as a temporary measure.

In reporting the result of a test or analysis made in accordance with this standard, if the final value observed or calculated is to be rounded off, it shall be done in accordance with CS 102.

1 SCOPE

This part of this standard specifies test methods for the determination of the relative density, water absorption, bulk density, voids, bulking and moisture content of aggregates.

2 REFERENCES

This standard makes reference to the following Sri Lanka Standards:

CS 102 Presentation of numerical values

CS 124 Test sieves

SLS ... Glossary of terms covering all allied aspects of concrete reinforced concrete and pre-stressed concrete

SLS 262 Sampling, analysis and testing of concrete

Part 2 Methods of testing concrete

SLS ... Sampling of mineral aggregates for cement concrete mixes.

3 REPORTING

3.1 General

The report shall affirm that the tests were done in accordance with this standard. Any departure from the specified test procedure shall be described with reasons for the departure and, if possible, estimates of its affect on the test results. The report shall also include details of any special processing of the sample, other than that required by the methods, carried out in the laboratory. For example, crushing to provide larger quantities of smaller sizes or the separation of constituents from an as-dug gravel.

3.2 Certificate of sampling

The report shall affirm that a certificate of sampling was received with the sample and shall declare all the information given on the certificate. If a certificate was not received this shall be stated in the report.

4 SIGNIFICANCE OF RESULTS

The distribution of the results of any test on any material stems from a number of contributing factors. In assessing the significance of the results the repeatability and reproducibility of the test should be recognized.

5 DETERMINATION OF RELATIVE DENSITIES AND WATER ABSORPTION

5.1 General

Three main methods are described for aggregates, a wire basket method for aggregates larger than 10 mm, a gas jar method for aggregates between 40 mm and 5 mm and a pycnometer or gas jar method for aggregates 10 mm and smaller. A buoyancy method using a bucket, as described in **SLS 262:Part 2**, is allowed as an alternative for aggregates between 40 mm and 5 mm.

As with any porous material the value obtained for the relative density of an aggregate depends on the details of the method of test. Furthermore, different sizes of the same aggregate often have different values of relative density and absorption. Therefore, when comparing different aggregates it is essential that the test be made on samples reasonably of the same grading.

The wire basket method for aggregates larger than 10 mm is not suitable for testing friable aggregates which may break down during the test and therefore the gas jar method for aggregates between 40 mm and 5 mm should be used for such material.

5.2 Sampling

The sample for these tests shall be taken in accordance with **SLS**... (Sampling of mineral aggregates for cement concrete mixes.)

5.3 Method for aggregate all larger than 10 mm

5.3.1 *Apparatus*

The following apparatus is required.

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

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

5.3.1.3 A wire mesh basket having apertures not larger than 6.5 mm, or a perforated container of convenient size, preferably chromium plated and polished, with wire hangers (not thicker than 1 mm) suspending it from the balance.

5.3.1.4 A stout watertight container in which the basket may be freely suspended.

5.3.1.5 Two dry soft absorbent cloths, each not less than 750 mm x 450 mm.

5.3.1.6 A shallow tray of area not less than 0.065 m^2.

5.3.1.7 An airtight container of similar capacity to the basket.

5.3.1.8 A 10.0 mm test sieve complying with the requirements of coarse tolerance test sieves given in **CS 124**.

5.3.1.9 A supply of water free from any impurity (e.g. dissolved air) that would significantly affect its density. If distilled or deionized 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.

5.3.2 *Sample for test*

A sample of not less than 2 kg of aggregate shall be tested. Aggregates which have been artificially heated shall not normally be used; if such material is used the fact shall be stated in the report. Two tests shall be made.

The sample for test 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 thereafter drained.

5.3.3 *Test procedure*

Place the prepared test sample in the wire basket and immerse it in the water described in **5.3.1.9** at a temperature of 27 ± 5 °C with a cover of at least 50 mm of water above the top of the basket.

Immediately after immersion remove the entrapped air from the sample by lifting the basket containing it 25 mm above the base of the tank and allowing it to drop 25 times at about once per second. The basket and aggregate shall remain completely immersed during this operation and for a period of 24 ± 0.5 h.

Again jolt the basket and sample and weigh them in water at a temperature of 27 ± 5 °C. If it is necessary for them to be transferred to a different tank for weighing, jolt them 25 times as described above in the new tank before weighing (mass m_1).

Then remove the basket and aggregate from the water and allow them to drain for a few minutes, after which gently empty the aggregate from the basket on to one of the dry cloths, and return the empty basket to the water, jolt it 25 times and weigh it in water (mass m_2).

With the cloth gently surface-dry the aggregate placed on the dry 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_o). If the apparent relative density only is required the operations described in this paragraph may be omitted.

Then place the aggregate in the oven in the shallow tray at a temperature of 105 ± 5 °C and maintain it at this temperature for 24 ± 0.5 h. Then remove it from the oven, cool it in the airtight container, and weigh it (mass m_3). If the relative density on a saturated and surface dried basis only is required, the operations described in this paragraph may be omitted.

5.3.4 *Calculations*

$$\text{Relative density on an oven-dried basis} = \frac{m_3}{m_o - (m_1 - m_2)}$$

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

$$\text{Apparent relative density} = \frac{m_3}{m_3 - (m_1 - m_2)}$$

$$\text{Water absorption (per cent of dry mass)} = \frac{m_o - m_3}{m_3} \times 100$$

where,

m_o is the mass, in g, of the saturated surface-dry aggregate in air

m_1 is the apparent mass, in g, in water of the basket containing the sample of saturated aggregate

m_2 is the apparent mass, in g, in water of the empty basket

m_3 is the mass, in g, of the oven-dried aggregate in air.

5.3.5 *Reporting of results*

The mean result shall be reported for each form of relative density determined, the title of which shall be quoted in full. In no circumstances shall the shortened title *relative density* be used in relation to any values quoted. The sizes of aggregate tested, and whether it has been artificially heated before the start of the test shall be stated. Values of relative density shall be reported to the nearest 0.01 and those for water absorption to the nearest 0.1 per cent.

5.4 Method for aggregate between 40 mm and 5 mm

5.4.1 *Apparatus*

The following apparatus is required.

5.4.1.1 *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.

5.4.1.2 *A well ventilated oven*, thermostatically controlled to maintain a temperature of 105 ± 5 °C.

5.4.1.3 *A wide mouthed glass vessel* such as a gas jar, of 1.0 litres 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.

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

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

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

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

5.4.1.8 *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.

5.4.2 *Sample for test*

A sample of about 1 kg of the aggregate shall be used. Aggregates which have been artificially heated shall not normally be used; if such material is used, the fact shall be stated in the report. Two tests shall be made. The sample 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.

5.4.3 *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). If the apparent relative density only is required the operations described in this paragraph may be omitted.

Then place the aggregate in the shallow tray in the oven at a temperature of 105 ± 5 °C for 24 ± 0.5 h. Then cool it in the airtight container and weigh it (mass m_3). If the relative density on a saturated and surface-dried

basis only is required the operations described in this paragraph may be omitted.

5.4.4 *Calculations*

$$\text{Relative density on an oven-dried basis} = \frac{m_3}{m_o - (m_1 - m_2)}$$

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

$$\text{Apparent relative density} = \frac{m_3}{m_3 - (m_1 - m_2)}$$

$$\text{Water absorption (per cent of dry mass)} = \frac{m_o - m_3}{m_3} \times 100$$

where,

m_o 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;

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

m_3 is mass, in g, of the oven-dry sample in air.

5.4.5 *Reporting of results*

The mean result shall be reported for each form of relative density determined, the title of which shall be quoted in full. In no circumstances shall the shortened title *relative density* be used in relation to any values quoted. The size of aggregate tested and whether it had been artificially heated before the start of the test shall be stated. The values of relative density shall be reported to the nearest 0.01 per cent.

NOTE - As an alternative to the method described above, the apparatus described in **SLS 262:Part 2** *may be used. The method shall be as described in* **5.3** *substituting the bucket for the wire basket, a 5.0* mm *test sieve for 10.0* mm *test sieve and stirring with a rod instead of jolting to remove air from the sample.*

5.5 Method for aggregate 10 mm and smaller

5.5.1 *Apparatus*

The following apparatus is required.

5.5.1.1 *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.

5.5.1.2 *A well ventilated oven,* thermostatically controlled to maintain a temperature of 105 ± 5 °C.

5.5.1.3 *Any form of apparatus capable of holding 0.5* kg *to 1.0* kg of material up to 10 mm nominal size and capable of being filled with water to a constant volume with an accuracy of ± 0.5 ml. Both of the following vessels are suitable.

a) *A glass vessel referred to later as a pycnometer* of about one litre capacity having a metal conical screw top with an approximately 6 mm diameter hole at its apex. The screw top shall be watertight when it is screwed on to the jar, and, if necessary, a rubber or fibre washer shall be inserted in the joint. If such a washer is used, mark shall be made on the jar to correspond with a mark on the screw top so that the screw is lightened to the same position every time and the volume contained by the jar is constant throughout the test. A suitable form of vessel is illustrated in Fig. 1.

b) *A wide-mouthed glass vessel* such as a gas jar of 1.0 litres 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.

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

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

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

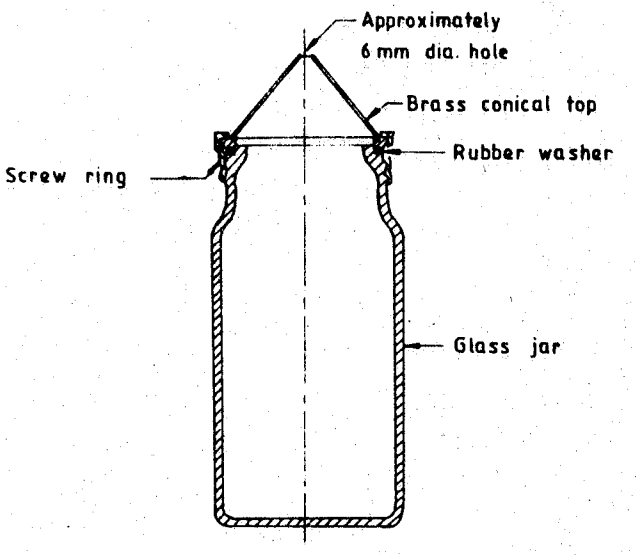


FIGURE 1 - Section of pycnometer made from preserving jar

5.5.1.7 *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.

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

5.5.1.9 *A supply of water* free from any impurity (e.g. dissolved air) that would significantly affect its density. If distilled or deionized 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.

5.5.1.10 (Optional item) *A metal mould* in the form of a frustrum of a cone 40 mm diameter at the top, 90 mm at the bottom and 75 mm high, the metal to have a minimum thickness of 900 µm.

5.5.1.11 (If item specified in **5.5.1.10** is to be used) *A metal tamper* weighing 340 ± 15 g and having a flat circular tamping face 25 ± 3 mm in diameter.

5.5.1.12 (Optional item) *A plain glass funnel.*

5.5.2 *Sample for test*

A sample of about 1 kg for material from 10 mm to 5 mm inclusive, or about 500 g if finer than 5 mm, shall be used. Aggregates which have been artificially heated shall not normally be used. If such material is used, the fact shall be stated in the report. Two tests shall be made.

The sample shall be thoroughly washed to remove all material passing the 75 µm test sieve using the following 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 µm 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.

5.5.3 *Test procedure using pycnometer*

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 µm 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 1).

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

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

Then place the aggregate in the pycnometer and fill the pycnometer with water. Screw the cone into place and eliminate any trapped air by rotating the pycnometer on its side, the hole in the apex of the cone being covered with a finger. Top up the pycnometer with water to remove any froth from the surface and so that the surface of the water in the hole is flat. Then dry the pycnometer on the outside and weigh it (mass m_1).

Empty the contents of the pycnometer into the tray, taking care to ensure that all the aggregate is transferred. Refill the pycnometer with water (see Note 2) 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 pycnometer during the first and second weighing shall not exceed 2 °C.

Then carefully drain the water from the sample by decantation through a 75 µm test sieve and return any material retained to the sample. Then place the sample in the tray, in the oven at a temperature of 105 ± 5 °C for 24 ± 0.5 h, during which period it shall be stirred occasionally to facilitate drying. Then cool it in the airtight container and weigh it (mass m_3).

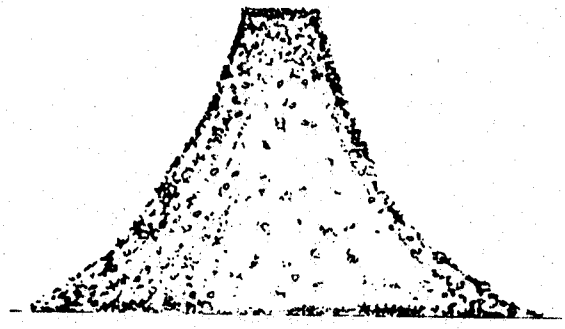
Two tests shall be made. If the relative density on a saturated and surface-dried basis only is required, the operations described in this paragraph may be omitted.

NOTES

1 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, two following alternative methods are suggested as possible aids.

Method 1 : The following test procedure should be adopted, making use of the conical mould and tamper referred to in **5.5.1.10** *and* **5.5.1.11.**

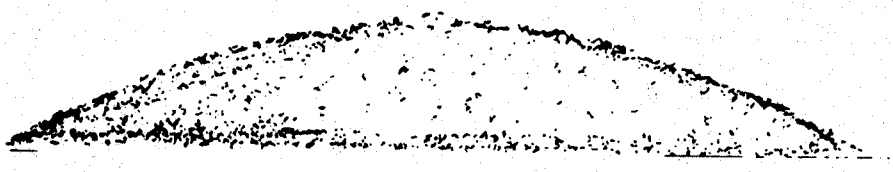
After drying the sample with a current of warm air allow it to cool to room temperature whilst thoroughly stirring it. Hold the mould with its larger diameter face downwards on a smooth non-absorbent level surface. Fill the mould loosely with part of the sample and lightly tamp 25 times through the hole at the top of the mould with the prescribed tamper. Do not refill the space left after tamping. Gently lift the mould clear of the aggregate and compare the moulded shape with Fig. 2 (a) to 2 (d).



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

(b) Aggregate slightly moist; appreciable slump observed

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



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

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

FIGURE 2 - Estimation of free running condition of fine aggregate

If the shape resembles Fig. 2 (a) or 2 (b), then there is still surface moisture present. Dry the sample further and repeat the test.

If the shape resembles Fig. 2 (c), a condition close to the saturated surface-dry condition has been achieved.

If the shape resembles Fig. 2 (d), the aggregate has dried beyond the saturated surface-dry condition and is approaching the oven-dry condition. In this case, either reject the sample and repeat the tests on a fresh sample or re-soak the same sample in water for a further 24 h and restart the tests as from the beginning of the second paragraph of **5.5.3.**

It is recommended that at least one of the drying stages, as shown in Fig. 2 (a) or 2 (b), should have been observed before the aggregate reaches the stage represented by Fig. 2 (c).

Method 2 : 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.

2 *Thoroughly dry the glass and metal threads (and the washer if used) of the pycnometer before using a second time.*

5.5.4 *Test procedure using the wide mouthed glass vessel*

The procedure shall be the same as in **5.5.3.1** except that in filling the jar with water it shall be filled just to overflowing and the glass plate slid over it to exclude any air bubbles.

5.5.5 *Calculations*

Relative density on an oven-dried basis $= \dfrac{m_3}{m_o - (m_1 - m_2)}$

Relative density on a saturated and surface-dried basis $= \dfrac{m_o}{m_o - (m_1 - m_2)}$

Apparent relative density $= \dfrac{m_3}{m_3 - (m_1 - m_2)}$

Water absorption (per cent of dry mass) $= \dfrac{m_o - m_3}{m_3} \times 100$

where,

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

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

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

m_3 is the mass, in g, of the oven-dried sample in air.

5.5.6 *Reporting of results*

The mean result shall be reported for each form of relative density determined, the title of which shall be quoted in full. In no circumstances shall the shortened title *relative density* be used in relation to any values quoted. The size of aggregate tested, and whether it had been artificially heated before the start if the test shall be stated. The values of relative density shall be reported to the nearest 0.01 and those for water absorption to the nearest 0.1 per cent.

6 DETERMINATION OF BULK DENSITY, VOIDS AND BULKING

6.1 General

The method for aggregates is by determining the mass of a sample filling a specified container, either loose or compacted.

It is emphasized that this test is intended for comparing properties of different aggregates. It is not generally suitable for use as a basis for quoting conversion factors, and for this purpose a practical test appropriate to the application should be employed.

The value of the bulking of an aggregate calculated by the standard method from the uncompacted bulk densities of the aggregates in the oven-dry condition and then containing a known moisture content, is also intended only for comparative purposes. Some other degree of compaction, provided it is the same for the material in both moisture conditions, may be more appropriate for practical purposes.

Considerably more compactive effort is used in the determination of angularity number (see **6.5** of **Part 1** of this standard) than in this test, and hence the values for bulk density and voids are different.

6.2 Sampling

The sample for these tests shall be taken in accordance with **SLS ... Sampling of Mineral aggregates for cement concrete mixes.**

6.3 Method for the determination of bulk density, and calculation of voids and bulking of aggregate.

6.3.1 *Apparatus*

The following apparatus is required:

6.3.1.1 *A cylindrical metal container* complying with the following requirements.

The container shall be made to the approximate dimensions given in Table 1 appropriate to the size of aggregate, be smooth inside and preferably be fitted with handles. It shall be watertight of sufficient rigidity to retain its form under rough usage and shall be protected against corrosion.

6.3.1.2 *A scale or balance* accurate to 0.2 per cent of the mass of the material to be weighed and of adequate capacity (this will vary according to the size of container used).

6.3.1.3 *A straight metal tamping rod* of circular cross section, 16 mm in diameter and 600 mm long, rounded at one end.

6.3.2 *Calibration*

The container shall be calibrated by determining the mass of water at 27 ± 2 °C required to fill it so that no meniscus is present above the rim of the container. The actual volume in cubic meters shall then be obtained by dividing the mass of the water in kilograms by 1 000.

6.3.3 *Condition of sample*

The test of bulk density shall be made on material oven-dry or saturated-surface dry. The test for voids shall be made on material oven-dry. The test for bulking shall be made initially on material oven-dry and then at the required test moisture content.

6.3.4 *Test procedure*

The size of the container to be used is given in Table 1. The test procedure shall be as specified in 6.3.4.1 and 6.3.4.2.

6.3.4.1 Compacted bulk density - (not applicable to moist fine aggregate)

Fill the container about one third full with the thoroughly mixed aggregate by means of a shovel or scoop, the aggregate being discharged from a height not exceeding 50 mm above the top of the container. Take care to prevent so far as is possible, segregation of the particle sizes of which the sample is composed. Then give the required number of compactive blows (see Table 1) to the aggregate, each blow being given by allowing the tamping rod rounded end to fall freely from a height of 50 mm above the surface of the aggregate, the blows being evenly distributed over the surface. Add a further similar quantity of aggregate in the same manner and give the same number of blows. Fill the container to overflowing, tamp it again with the same number of blows, and remove the surplus aggregate by rolling the tamping rod across and in contact with the top of the container, any aggregate which impedes its progress being removed by hand, and add aggregate to fill any obvious depressions. For 6 mm aggregate or smaller, the surface may be struck off, using the tamping rod as a straight-edge. Then determine the mass of the

TABLE 1 - Details of containers to be used for the bulk density tests

Nominal value*	Internal diameter (approximate)	Internal depth (approximate)	Minimum thickness of metal	Compacted bulk density		Uncompacted bulk density
				Nominal size of aggregate up to and including	Number of compactive blows per layer	Nominal size of aggregate up to and including
(1)	(2)	(3)	(4)	(5)	(6)	(7)
m^3	mm	mm	mm	mm		mm
0.03	350	300	5.0	50	100	50
0.015	250	300	4.0	28	50	14
0.007	200	225	3.0	14	30	6
0.003	150	150	3.0	6	20	-

* *Alternatively containers of 1* ft^3, $\frac{1}{2}$ ft^3, $\frac{1}{4}$ ft^3 *and 1/10* ft^3 *nominal capacity respectively would comply with these requirements.*

aggregate in the container. Make two tests and calculate the bulk density in kilograms per cubic metre using the calibrated volume determined as in **6.3.2** from the mean of the two masses.

6.3.4.2 Uncompacted bulk density

To determine the loose mass (uncompacted bulk density) carry out the test as described in **6.3.4.1** except that the compaction with the tamping rod shall be omitted.

6.3.5 *Calculation of voids*

In this test voids are expressed as a percentage of the volume of the test cylinder. They are determined from the difference between the volume of the test cylinder and the calculated volume of the aggregate.

$$\text{Percentage voids} = \left\{1 - \frac{b}{a \times 1\,000}\right\} 100$$

where,

a is the relative density of the aggregate, on an oven-dry basis, determined in accordance with **5.3**, **5.4**, **5.5** or **5.6**;

b is the bulk density of oven-dry aggregate as determined in **6.3.4** compacted or uncompacted as required.

6.3.6 *Calculation of bulking*

In this test bulking is expressed as the increase in volume, as a percentage of original volume, of a mass of fine aggregate whose moisture content is increased from the oven-dry condition to a test moisture content.

$$\text{Percentage bulking at test moisture content } M = \frac{b\,(100 + M)}{c} - 100$$

where,

b is the uncompacted bulk density of oven-dry fine aggregate determined according to **6.3.4**;

c is the uncompacted bulk density, as determined in accordance with **6.3.4** of fine aggregate at test moisture content;

M is the test moisture content on oven-dry basis in accordance with **7.3**.

6.3.7 *Reporting of results*

The bulk density shall be reported as the compacted or uncompacted bulk density in kilograms per cubic metre to the nearest 10 kg/m^3. The condition of the aggregate at the time of test shall be stated, i.e. oven-dry, saturated or surface-dry. The percentage voids and the percentage bulking, if required, shall be reported to the nearest whole number.

7 DETERMINATION OF MOISTURE CONTENT OF AGGREGATE

7.1 General

Four methods are described for determining the moisture content of aggregates. The oven-drying method provides a measure of the total water present in a sample of aggregate and is the standard procedure. This method is particularly appropriate when a single sample of aggregate is received at a laboratory for test.

The siphon can and buoyancy methods can be used to determine the moisture content relative to known conditions. They require the making of a preliminary test with a prepared sample of the aggregate to be tested and hence are more suited to regular testing of material from a particular source as in quality control testing.

The accuracy of these two methods relies on the relative density of the aggregates in successive samples remaining constant. Both are suitable for aggregates with a nominal size not exceeding 40 mm; the buoyance method is limited to the determination of moisture content by wet mass.

The modified drying method allows various techniques for drying appropriate to the need for speedy results. This method should be used only for control purposes. It can be used to determine the total moisture content either by dry mass or by wet mass. Where the water absorption of the particular aggregate is already known, this may be subtracted from the total moisture content to provide the free moisture content.

Care should be taken when sampling aggregates for the measurement of moisture content to ensure that the initial sample is large enough to be representative of the bulk material sampled and to prevent any significant change in moisture content occurring between the time of sampling and the time of testing. Normally a single determination of the moisture content of any one sample is adequate.

7.2 Sampling

The sample for these tests shall be taken in accordance with SLS... Sampling, of mineral aggregates for cement concrete mixes.

7.3 Standard (oven-drying) method

7.3.1 *Apparatus*

The following apparatus is required.

7.3.1.1 *A balance of adequate* capacity (normally a balance of 3 kg capacity would be appropriate) accurate to 0.5 g and of such a type as to permit the weighing of the container specified below.

7.3.1.2 *An airtight non corrodible container* capable of holding about 3 kg of samples and of self-weight not exceeding 0.8 kg.

7.3.1.3 *A scoop* (a convenient size is about 200 mm long and 120 mm wide).

7.3.1.4 *A well ventilated oven* thermostatically controlled to maintain a temperature of 105 ± 5 °C.

7.3.2 *Sample for test*

The mass of the sample of aggregate to be tested shall be between 1.8 kg and 2.2 kg. It shall be prepared taking the precautions given in **7.1**.

NOTE - The size of sample of fine aggregates may be reduced to not less than 500 g provided weighings are made using a balance of adequate capacity and accurate to 0.1 g. The size of sample of coarse aggregates with a nominal size exceeding 40 mm may need to be greater than the mass specified to permit accurate sampling; the balance used for the weighings should be accurate to 0.05 per cent of the mass of the sample.

7.3.3 *Test procedure*

Clean the container, with its lid, dry it and then weigh it (mass m_o). Then place the sample in the container by means of the scoop, replace the lid and re-weigh the whole (mass m_1). Remove the lid, place the container and sample in the oven and dry it at a temperature of 105 ± 5 °C for a period of 16 h to 24 h. Then remove the container and sample from the oven, replace the lid and allow the whole to cool for 0.5 h to 1 h, after which weigh again (mass m_2).

7.3.4 *Calculations*

The moisture content shall be calculated as follows:

$$\text{Moisture content (percentage by dry mass)} = \frac{m_1 - m_2}{m_2 - m_o} \times 100 \text{ or}$$

$$\text{Moisture content (percentage by wet mass)} = \left\{\frac{m_1 - m_2}{m_1 - m_o}\right\} \times 100$$

7.3.5 *Reporting of results*

The moisture content shall be reported to the nearest 0.1 per cent, stating whether by dry mass or by wet mass. The percentage by dry mass shall be reported unless the percentage by wet mass is specifically requested.

7.4 Siphon-can method for aggregate not exceeding 40 mm

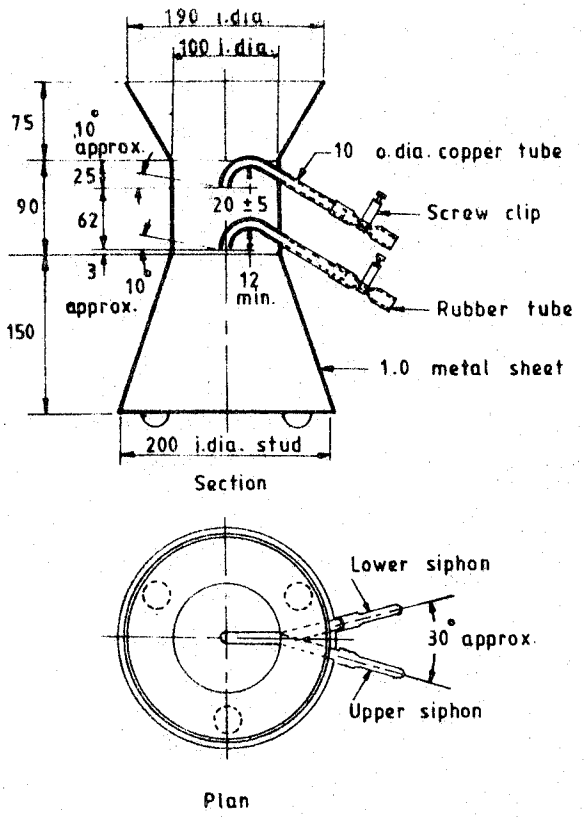
7.4.1 *Apparatus*

The following apparatus is required.

7.4.1.1 *A siphon-can* with the dimensions shown in Fig. 3. It shall be watertight and of robust construction. The rubber tubes on the ends of the siphon tubes shall be no longer than necessary to accommodate the screw clips.

7.4.1.2 *Scales of at least 3 kg capacity* accurate to 1 g preferably with one pan consisting of a scoop.

7.4.1.3 *A 2 kg weight* (a full set of weights is not required).



Dimensions are in millimetres

FIGURE 3 - Siphon - can

7.4.1.4 *A 500* ml *measuring cylinder* complying with the following requirements:

i) Graduated in sub-divisions of 5 ml or less;

ii) Lowest graduation mark 50 ml;

iii) Length of scale 250 ± 25 mm;

iv) Overall height (recommended) 390 mm;

v) Diameter of base 100 mm.
(for polygonal base this dimension applies to inscribed circle).

A thick rubber ring placed round the top of the measuring cylinder may help to prevent damage.

7.4.1.5 *A metal stirring rod* with a diameter of 6.5 mm and 450 mm to 500 mm long.

7.4.2 *Calibration of siphon-can and measuring cylinder*

The operation and calibration of the siphon-can shall be checked before it is put into use for the first time, and then periodically, and at any time that a new measuring cylinder is to be used or there is reason to suspect that the siphon-can may have been damaged. The procedure shall be as follows: The siphon-can and siphon tubes shall be washed out; the tubes shall be allowed to drain and shall then be closed by screwing the clips tightly

enough to prevent air, as well as water, from escaping. The siphon-can shall be placed on a firm bench protected from wind and rain and filled with clean water until the surface is above the highest point of the upper tube.

Before use the measuring cylinder shall be fully rinsed using clean water. Then pour out the water, stand the measuring cylinder on the bench for about 5 s and pour out any further water which has collected at the bottom.

The upper siphon tube shall be opened and the water siphoned off to waste. The lower siphon tube shall then be opened, the water being collected in the measuring cylinder, and the volume discharged (V) shall be recorded, estimating to the nearest 1 ml. The test shall be repeated a number of times to ensure that consistent values of V are obtained; the average value of V shall be used in subsequent calculations.

NOTE - Inconsistent values of V are sometimes obtained if the discharge from one or both of the siphon tubes fails to stop 'cleanly'; adjustment of the angle of the inner end of the tube may overcome this difficulty.

7.4.3 *Routine procedure*

Prepare the siphon-can and measuring cylinder for use as described in the second and third paragraphs of **7.4.2** except that the siphon-can shall be filled until the surface is above the highest point of the lower siphon tube and at least 12 mm below the inlet to the upper siphon tube. Open the lower siphon tube and discharge the water to waste; then close this tube by screwing up the clip.

NOTE - This condition is also attained by closing both siphon tubes after completing a calibration test.

Weigh out to within ± 1 g, a 2 kg sample of the aggregate from a sample prepared taking the precautions given in **7.1** and transfer it, without significant loss of aggregate particles or moisture, to the siphon-can. Wet the stirring rod and allow excess water to drain off to waste. Then use it to stir the aggregate in the siphon-can, to remove any trapped bubbles of air, without damage to the siphon tubes and to draw any scum on the surface of the water from the centre to the sides. Allow excess water on the stirring rod to drain back into the siphon-can.

Open the upper siphon tube, collecting the water in the measuring cylinder, and record the volume discharged, v_w, estimating to the nearest 1 ml.

NOTE - If the water drawn off is very cloudy, the measuring cylinder should be allowed to stand for a short time to allow the solids in suspension to settle so that the level of the lowest part of the meniscus can be observed. If, however, the depth of the meniscus is known form previous experience, the level of the lowest part may be estimated from the position of the highest part.

7.4.4 *Preliminary test procedure*

Before the moisture content of the sample can be calculated it is necessary to make a preliminary test on a nominally similar sample of known moisture

content because of the effect of the relative density of the aggregate particles on the value of v_w. The procedure shall be as follows:

Thoroughly mix a sample of at least 5 kg of the aggregate in its normal damp condition to ensure that its moisture content is uniform immediately before it is to be used. Weigh and test a 2 kg sample of this material as described in **7.4.3** except that the volume of water discharged shall be recorded as v_p.

As soon as possible after weighing the sample of aggregate for this test, weigh a second 2 kg sample. Dry it to the condition appropriate to the basis on which the moisture content is to be expressed, for example, if the total water content of the aggregate is to be measured, dry the sample completely by the procedure given in **7.3.3**, or if only the surface water is to be measured, dry the sample to the saturated, surface-dry condition. Transfer the dried sample to the pan of the scales and add a measured quantity of water from the measuring cylinder to determine the volume of water, v, estimated to the nearest 1 ml, required to bring the combined mass of dried aggregate and water to 2 kg.

The constant for the particular aggregate and basis of expressing moisture content, v_b, shall be calculated from the equation:

$$v_b = v_p - \frac{v}{2\,000 - v}(2\,000 - V - v_p)$$

where,

v_p is the volume of water discharged in the preliminary test in ml;

v is the volume of water required to bring the mass of dried aggregate to 2 kg, in ml;

V is the calibration volume of the particular apparatus, in ml.

7.4.5 *Calculations*

The moisture content shall be calculated as follows:

$$\text{Moisture content (percentage by dry mass)} = \frac{v_w - v_b}{2\,000 - V - v_w} \times 100 \text{ or}$$

$$\text{Moisture content (percentage by wet mass)} = \frac{v_w - v_b}{2\,000 - V - v_b} \times 100$$

where,

v_w is the volume of water discharged from the siphon-can in the test on the sample of unknown moisture content, in ml;

v_b is the constant for the particular aggregate, obtained from the preliminary test, in ml;

V is the calibration volume of the particular apparatus, in ml.

Alternatively, the moisture content shall be interpolated from Table 2 or Table 3.

NOTE - The test may be adapted for the determination of the moisture content of a combined sample of different grades of aggregate in the proportions in which they are to be used in practice. Additional weights, corresponding to the masses of each grade needed to make a total combined sample of 2 kg, will

Table 2. Values of moisture content by dry mass(siphon-can method)

$V_w = v_w + V$ $V_b = v_b + V$

v_w \ V_b	710	715	720	725	730	735	740	745	750	755	760	765	770	775	780	785	790	795	800
710	0.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
715	0.4	0.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
720	0.8	0.4	0.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
725	1.2	0.8	0.4	0.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
730	1.6	1.2	0.8	0.4	0.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
735	2.0	1.6	1.2	0.8	0.4	0.0	-	-	-	-	-	-	-	-	-	-	-	-	-
740	2.4	2.0	1.6	1.2	0.8	0.4	0.0	-	-	-	-	-	-	-	-	-	-	-	-
745	2.8	2.4	2.0	1.6	1.2	0.8	0.4	0.0	-	-	-	-	-	-	-	-	-	-	-
750	3.2	2.8	2.4	2.0	1.6	1.2	0.8	0.4	0.0	-	-	-	-	-	-	-	-	-	-
755	3.6	3.2	2.8	2.4	2.0	1.6	1.2	0.8	0.4	0.0	-	-	-	-	-	-	-	-	-
760	4.0	3.6	3.2	2.8	2.4	2.0	1.6	1.2	0.8	0.4	0.0	-	-	-	-	-	-	-	-
765	4.5	4.0	3.6	3.2	2.8	2.4	2.0	1.6	1.2	0.8	0.4	0.0	.	-	-	-	-	-	-
770	4.9	4.5	4.1	3.7	3.3	2.8	2.4	2.0	1.6	1.2	0.8	0.4	0.0	-	-	-	-	-	-
775	5.3	4.9	4.5	4.1	3.7	3.3	2.9	2.4	2.0	1.6	1.2	0.8	0.4	0.0	-	-	-	-	-
780	5.7	5.3	4.9	4.5	4.1	3.7	3.3	2.9	2.5	2.0	1.6	1.2	0.8	0.4	0.0	-	-	-	-
785	6.2	5.8	5.3	4.9	4.5	4.1	3.7	3.3	2.9	2.5	2.1	1.6	1.2	0.8	0.4	0.0	-	-	-
790	6.6	6.2	5.8	5.4	5.0	4.5	4.1	3.7	3.3	2.9	2.5	2.1	1.7	1.2	0.8	0.4	0.0	-	-
795	7.1	6.6	6.2	5.8	5.4	5.0	4.6	4.1	3.7	3.3	2.9	2.5	2.1	1.7	1.2	0.8	0.4	0.0	-
800	7.5	7.1	6.7	6.2	5.8	5.4	5.0	4.6	4.2	3.8	3.3	2.9	2.5	2.1	1.7	1.2	0.8	0.4	0.0
805	7.9	7.5	7.1	6.7	6.3	5.9	5.4	5.0	4.6	4.2	3.8	3.3	2.9	2.5	2.1	1.7	1.3	0.8	0.4
810	8.4	8.0	7.6	7.1	6.7	6.3	5.9	5.5	5.0	4.6	4.2	3.8	3.4	2.9	2.5	2.1	1.7	1.3	0.8
815	8.9	8.4	8.0	7.6	7.2	6.8	6.3	5.9	5.5	5.1	4.6	4.2	3.8	3.4	3.0	2.5	2.1	1.7	1.3
820	9.3	8.9	8.5	8.1	7.6	7.2	6.8	6.4	6.0	5.5	5.1	4.7	4.2	3.8	3.4	3.0	2.5	2.1	1.7
825	9.8	9.4	8.9	8.5	8.1	7.7	7.2	6.8	6.4	6.0	5.5	5.1	4.7	4.3	3.8	3.4	3.0	2.6	2.1
830	10.3	9.8	9.4	9.0	8.5	8.1	7.7	7.3	6.8	6.4	6.0	5.6	5.1	4.7	4.3	3.8	3.4	3.0	2.6
835	-	10.3	9.9	9.4	9.0	8.6	8.2	7.7	8.3	6.9	6.4	6.0	5.6	5.2	4.7	4.3	3.9	3.4	3.0
840	-	-	10.3	9.9	9.5	9.1	8.6	8.2	7.8	7.3	6.9	6.5	6.0	5.6	5.2	4.7	4.3	3.9	3.4
845	-	-	-	-	10.0	9.5	9.1	8.7	8.2	7.8	7.4	6.9	6.5	6.1	5.6	5.7	4.8	4.2	3.9
850	-	-	-	-	-	10.0	9.6	9.1	8.7	8.3	7.8	7.4	7.0	6.5	6.1	6.7	5.2	4.5	4.5
855	-	-	-	-	-	-	10.0	9.6	9.2	8.7	8.3	7.9	7.4	7.0	6.6	6.1	5.5	5.2	4.8
860	-	-	-	-	-	-	-	10.1	9.6	9.2	8.8	8.3	7.9	7.5	7.0	6.6	6.1	5.7	5.3
865	-	-	-	-	-	-	-	-	10.1	9.7	9.3	8.8	8.4	7.9	7.5	7.0	6.6	6.2	5.7
870	-	-	-	-	-	-	-	-	-	10.2	9.7	9.3	8.8	8.4	8.0	7.5	7.1	6.6	6.2
875	-	-	-	-	-	-	-	-	-	-	10.2	9.8	9.3	8.9	8.4	8.0	7.6	7.1	6.7
880	-	-	-	-	-	-	-	-	-	-	-	10.3	9.8	9.4	8.9	8.5	8.0	7.6	7.1
885	-	-	-	-	-	-	-	-	-	-	-	-	10.3	9.8	9.4	9.0	8.5	8.1	7.6
890	-	-	-	-	-	-	-	-	-	-	-	-	-	10.4	9.9	9.5	9.0	8.6	8.1
895	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.0	9.5	9.0	8.6
900	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.0	9.5	9.1
905	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.0	9.6
910	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.1

be required. Preliminary and routine tests should be made as described in **7.4.3** *and* **7.4.4,** *except that the different grades of aggregate are weighed out separately (to within ± 5 g where the different grades are of nominally the same relative density).*

Table 3. Values of moisture content by wet mass(siphon-can method)

$V_w = v_w + V \quad V_b = v_b + V$

V_w	V_b 710	715	720	725	730	735	740	745	750	755	760	765	770	775	780	785	790	795	800
710	0.0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
715	0.4	0.0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
720	0.8	0.4	0.0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
725	1.2	0.8	0.4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
730	1.6	1.2	0.8	0.4	0.0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
735	1.9	1.6	1.2	0.8	0.4	0.0	–	–	–	–	–	–	–	–	–	–	–	–	–
740	2.3	1.9	1.6	1.2	0.8	0.4	0.0	–	–	–	–	–	–	–	–	–	–	–	–
745	2.7	2.3	2.0	1.6	1.2	0.8	0.4	0.0	–	–	–	–	–	–	–	–	–	–	–
750	3.1	2.7	2.3	2.0	1.6	1.2	0.8	0.4	0.0	–	–	–	–	–	–	–	–	–	–
755	3.5	3.1	2.7	2.4	2.0	1.6	1.2	0.8	0.4	0.0	–	–	–	–	–	–	–	–	–
760	3.9	3.5	3.1	2.7	2.4	2.0	1.6	1.2	0.8	0.4	0.0	–	–	–	–	–	–	–	–
765	4.3	3.9	3.5	3.1	2.8	2.4	2.0	1.6	1.2	0.8	0.4	0.0	–	–	–	–	–	–	–
770	4.7	4.3	3.9	3.5	3.1	2.8	2.4	2.0	1.6	1.2	0.8	0.4	0.0	–	–	–	–	–	–
775	5.0	4.7	4.3	3.9	3.5	3.2	2.8	2.4	2.0	1.6	1.2	0.8	0.4	0.0	–	–	–	–	–
780	5.4	5.1	4.7	4.3	3.9	3.6	3.2	2.8	2.4	2.0	1.6	1.2	0.8	0.4	0.0	–	–	–	–
785	5.8	5.4	5.1	4.7	4.3	4.0	3.6	3.2	2.8	2.4	2.0	1.6	1.2	0.8	0.4	0.0	–	–	–
790	6.2	5.8	5.5	5.1	4.7	4.3	4.0	3.6	3.2	2.8	2.4	2.0	1.6	1.2	0.8	0.4	0.0	–	–
795	6.6	6.2	5.9	5.5	5.1	4.7	4.4	4.0	3.6	3.2	2.8	2.4	2.0	1.6	1.2	0.8	0.4	0.0	–
800	7.0	6.6	6.2	5.9	5.5	5.1	4.8	4.4	4.0	3.6	3.2	2.8	2.4	2.0	1.6	1.2	0.8	0.4	0.0
805	7.4	7.0	6.6	6.3	5.9	5.5	5.2	4.8	4.4	4.0	3.6	3.2	2.8	2.4	2.0	1.6	1.2	0.8	0.4
810	7.8	7.4	7.0	6.7	6.3	5.9	5.6	5.2	4.8	4.4	4.0	3.6	3.0	2.9	2.5	2.2	2.7	1.2	0.8
815	8.1	7.8	7.4	7.1	6.7	6.3	6.0	5.6	5.2	4.8	4.4	4.0	3.7	3.3	2.9	2.5	2.1	1.7	1.2
820	8.5	8.2	7.8	7.5	7.1	6.7	6.3	6.0	5.6	5.2	4.8	4.5	4.1	3.7	3.3	2.9	2.5	2.0	1.7
825	8.9	8.6	8.2	7.8	7.5	7.1	6.7	6.4	6.0	5.6	5.2	4.9	4.5	4.1	3.7	3.3	2.9	2.5	2.1
830	9.3	8.9	8.6	8.2	7.9	7.5	7.1	6.8	6.4	6.0	5.6	5.3	4.9	4.5	4.1	3.7	3.3	2.9	2.5
835	9.7	9.3	9.0	8.6	8.3	7.9	7.5	7.2	6.8	6.4	6.0	5.7	5.3	4.9	4.5	4.1	3.7	3.3	2.9
840	10.1	9.7	9.4	9.0	8.7	8.3	7.9	7.6	7.2	6.8	6.5	6.1	5.7	5.3	4.9	4.5	4.3	3.7	3.3
845	–	10.1	9.8	9.4	9.1	8.7	8.3	8.0	7.6	7.2	6.9	6.5	6.1	5.7	5.3	4.9	4.5	4.1	3.8
850	–	–	10.2	9.8	9.4	9.1	8.7	8.4	8.0	7.6	7.3	6.9	6.5	6.1	5.7	5.3	5.0	4.5	4.2
855	–	–	–	10.2	9.8	9.5	9.1	8.8	8.4	8.0	7.7	7.3	6.9	6.5	6.1	5.8	5.4	5.0	4.6
860	–	–	–	–	10.2	9.9	9.5	9.2	8.8	8.4	8.1	7.7	7.3	6.9	6.6	6.2	5.8	5.4	5.0
865	–	–	–	–	–	10.3	9.9	9.6	9.2	8.8	8.5	8.1	7.7	7.3	7.0	6.6	6.2	5.8	5.4
870	–	–	–	–	–	–	10.3	10.0	9.6	9.2	8.9	8.5	8.0	7.8	7.4	7.0	6.6	6.2	5.8
875	–	–	–	–	–	–	–	–	10.0	9.6	9.3	8.9	8.5	8.2	7.8	7.4	7.0	6.6	6.2
880	–	–	–	–	–	–	–	–	–	10.0	9.7	9.3	8.9	8.6	8.2	7.8	7.4	7.2	6.7
885	–	–	–	–	–	–	–	–	–	–	10.1	9.7	9.3	9.0	8.6	8.2	7.9	7.5	7.3
890	–	–	–	–	–	–	–	–	–	–	–	10.1	9.8	9.4	9.0	8.6	8.3	7.9	7.5
895	–	–	–	–	–	–	–	–	–	–	–	–	10.2	9.8	9.4	9.1	8.7	8.3	7.9
900	–	–	–	–	–	–	–	–	–	–	–	–	–	10.2	9.8	9.5	9.1	8.7	8.3
905	–	–	–	–	–	–	–	–	–	–	–	–	–	–	10.2	9.9	9.5	9.1	8.8
910	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	10.3	9.9	9.5	9.2
915	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	10.3	10.0	9.6
920	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	10.0

7.4.6 *Reporting of results*

The moisture content shall be reported to the nearest 0.1 per cent stating whether by dry mass or by wet mass and the condition of dryness on which the result is based.

The percentage by dry mass shall be reported unless the percentage by wet mass is specifically requested.

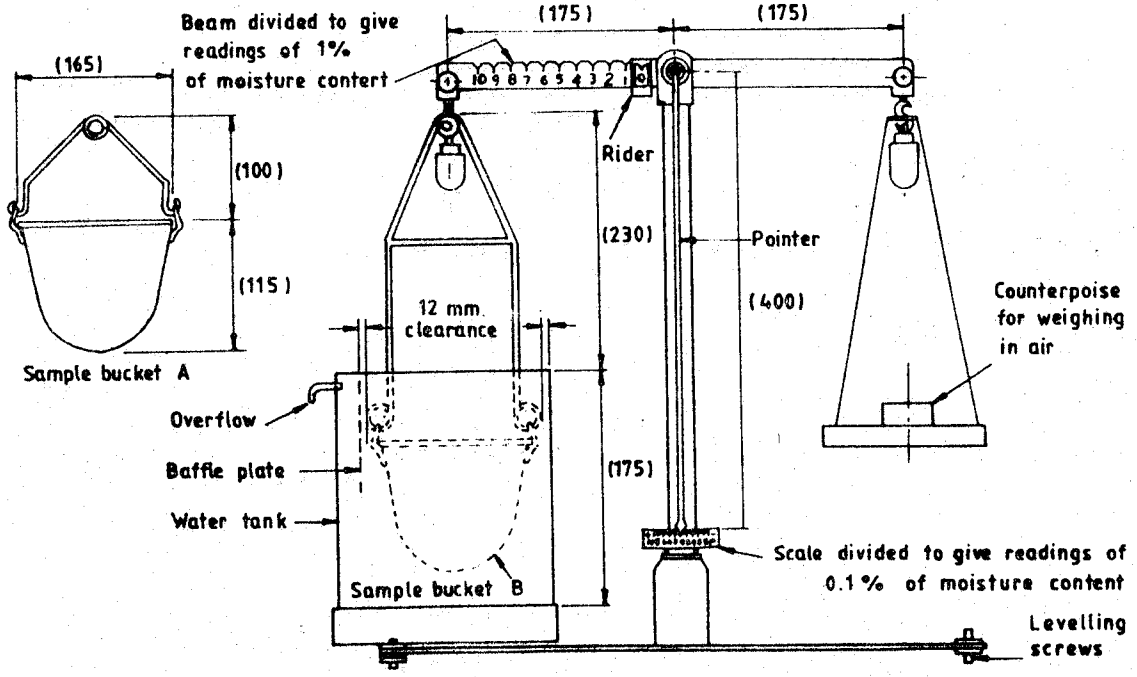
7.5 Buoyancy method for aggregate not exceeding 40 mm

7.5.1 *Apparatus*

The following apparatus, one form of which is shown in Fig. 4 is required.

7.5.1.1 *A beam balance,* arranged so that when the long handled sample bucket (B), hung from one arm of the beam is immersed in water the system is out of balance by 1 kg ± 1 g, the other arm carrying the weights pan being the heavier. The first arm shall carry a rider and a notched scale reading from 0 to 10 in unit divisions and the balance shall be provided with a pointer and scale graduated from + 1.0 to - 1.0 in divisions of 0.1. The mass of the rider and the balance of the beam and pointer shall be arranged in such a way that one rider division on the arm represents 1 per cent of the out-of-balance component, i.e. 10 g, and one division on the pointer scale represents 0.1 per cent of the out-of-balance component, i.e. 1 g.

NOTE - The condition of balance is achieved when the system is in equilibrium with the rider and the pointer both indicating zero. The system is out of balance by 1 kg ± 1 g *when the addition of 1* kg *to the bucket suspension above the water is required to restore a condition of balance.*



Dimensions are in millimetres (those in parenthesis are typical values only)

FIGURE 4 - Buoyancy moisture meter

7.5.1.2 *Long handled bucket* (B) made of corrosion resisting metal and of such mass as to provide the out-of-balance condition described above. The bucket shall be 165 mm diameter at the top and 115 mm deep, having sloping sides and a rounded bottom so as to avoid entrapping any air when it is immersed in water. The handle shall be designed such that the volume of material immersed does not change by more than 1 ml when the pointer moves from + 1.0 to - 1.0.

7.5.1.3 *A short handled bucket* (A) similar in shape and dimensions to the long handled one and of such mass that when it is hung on the balance in place of the long handled bucket it is clear of the water and the system is again out-of-balance by 1 kg.

7.5.1.4 *A water tank* with an overflow outlet, screened by a baffle plate, near the top of the tank. The tank shall be of such a size that when it is full to the overflow level and the long handled bucket is hung on the arm of the balance the bucket is completely immersed.

7.5.1.5 *One hollow counterpoise* with a screwed closure for each type of aggregate to be tested. Each counterpoise shall be approximately 0.5 kg in mass before being adjusted by the addition of shot to suit the corresponding aggregate.

7.5.1.6 *A quantity of shot* up to 0.5 kg for each type of aggregate to be tested.

7.5.2 *Calibration of the instrument*

If it is desired to use the apparatus to determine the free moisture content of the aggregate, i.e. the amount of moisture in excess of that in the saturated surface-dry condition as a percentage of the wet mass, the apparatus shall be calibrated using a saturated surface-dry sample of the aggregate prepared as follows.

Particles larger than 10 mm shall be dried by the method described in the fifth paragraph of **5.3.3** and particles 10 mm or smaller shall be dried by the method described in the third paragraph of **5.5.3.**

Similarly, if it is desired to use the apparatus to determine the total moisture content as a percentage of the wet mass, the apparatus shall be calibrated using an oven-dry sample of the aggregate prepared as described in **7.3.3.**

When the sample of aggregate has been prepared in the appropriate condition, the short handled bucket (A) shall be suspended from the balance and prepared aggregate poured into it until the beam balances. The long handled bucket (B) shall then be approximately half filled with water and the sample of aggregate in bucket (A) poured into it slowly, taking care to entrap as little air as possible. A further sample of prepared aggregate shall be weighed out in bucket (A) as before and not more than half of it transferred to bucket (B) as before. The mixture of aggregate and water in bucket (B) shall be stirred vigorously until all entrapped air has been removed.

The tank shall be approximately half filled with water and bucket (B) suspended from the balance. The tank shall then be filled with water until it overflows, the water being poured in behind the baffle plate to avoid

disturbing the sample. Further aggregate shall then be transferred from bucket (A) to bucket (B) until the beam balances. Where coarse aggregate is being used, this may necessitate adjusting the quantity of aggregate by addition and removal of individual particles until balance is obtained. Aggregate removed from bucket (B) during this procedure shall be returned to bucket (A) but shall first be dried to the prepared condition if its wet mass exceeds 5 g.

When oven-dry aggregate is used for the preliminary test the aggregate in bucket (B) shall be left immersed for 20 min and the quantity again adjusted so that balance is obtained. This procedure shall be repeated until the system does not depart from balance in 20 min by more than 0.5 per cent as indicated by the pointer scale.

Bucket (B) shall then be removed from the balance and bucket (A) with the remaining aggregate shall be suspended from the balance. One of the counterpoises shall be placed in bucket (A) and shot added to it until the beam balances. The mass of the counterpoise is thus adjusted to suit the relative density of the particular aggregate and the basis of expressing moisture content.

NOTE - If the relative density of the aggregate is previously known, the required mass of the counterpoise may be calculated as $\frac{1}{d-1}$ kg

where,

d is the relative density on a saturated and surface-dried basis if free moisture is required or the apparent relative density if the total moisture is required.

In general, however, the practical adjustment as described above is preferable and does not require an ordinary balance and set of weights.

7.5.3 *Test procedure*

Suspend the empty short handled bucket (A) from the balance and place the calibrated counterpoise on the scale pan. Then pour aggregate from a sample, prepared taking the precautions given in 7.1, into bucket (A) until the beam balances. Where coarse aggregate is being used this may necessitate adjusting the quantity of aggregate by addition and removal of individual particles until balance is obtained. Approximately half fill the long handled bucket (B) with water and pour the sample of aggregate in bucket (A) into it slowly taking care to entrap as little air as possible. Vigorously stir the mixture of aggregate and water until all entrapped air has been removed.

Approximately half fill the tank with water and suspend bucket (B) from the balance. Then fill the tank with water until it overflows, the water being poured in behind the baffle plate to avoid disturbing the sample. Then remove the counterpoise from the scale pan and balance the beam by moving the rider until the pointer is reading on the scale. Then read off the moisture content by wet mass from the positions of the rider and the pointer, each division on the balance arm representing a moisture content of 1 per cent and each division on the scale representing 0.1 per cent.

7.5.4 *Reporting of results*

The moisture content shall be reported to the nearest 0.1 per cent, stating that the moisture content is by wet mass, and stating the condition of dryness on which the results are based.

7.6 Modified drying method

7.6.1 *Apparatus*

The following apparatus is required.

7.6.1.1 *A balance* of adequate capacity and accuracy of such a type as to permit weighing of the sample or the sample and the tray.

7.6.1.2 *A means of heating the sample* such as a radiant heater or hotplate.

7.6.1.3 *A shallow tray.*

7.6.1.4 *A spatula* or other implement for stirring the sample during drying.

7.6.2 *Sample for test*

The mass of the sample of aggregate to be tested shall be chosen by the tester having regard to the purpose for which the result is required and the consequent need for the sample to be representative of a bulk quantity. Normally a mass of about 1 kg will be suitable for coarse aggregates and 0.5 kg for fine aggregate. The sample shall be prepared taking the precautions given in **7.1**.

7.6.3 *Test procedure*

Weigh the sample (mass m_o) place it in the tray and heat it, taking care to ensure that the aggregate does not reach a temperature where splitting or decomposition could occur. During heating stir the aggregate frequently, with the spatula, to ensure even exposure of the aggregate to the air and the source of heat. Keep the spatula in the tray until the aggregate is dry to avoid loss of solid material.

When the sample is considered to be dry weigh it and record the mass. Then return it to the tray, heat it again for a further 5 min and reweigh it. The sample shall be regarded as dry when the difference between consecutive weighings does not exceed 0.1 per cent of the last recorded mass. Continue the cycles of heating and weighing until this condition is achieved and record the final mass as mass m_1.

7.6.4 *Calculations*

The moisture content shall be calculated as follows:

$$\text{Moisture content (percentage by dry mass)} = \frac{m_o - m_1}{m_1} \times 100 \text{ or,}$$

$$\text{Moisture content (percentage by wet mass)} = \frac{m_o - m_1}{m_o} \times 100$$

7.6.5 *Reporting of results*

The moisture content shall be reported to the nearest 0.1 per cent stating whether by dry mass or wet mass.

The percentage by dry mass shall be reported unless the percentage by wet mass is specifically requested.

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