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Indian Standard

METHODS OF TEST FOR AGGREGATES FOR CONCRETE

PART III SPECIFIC GRAVITY, DENSITY, VOIDS, ABSORPTION AND BULKING

(Eighth Reprint MARCH 1997)

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BUREAU OF INDIAN STANDARDS

MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG

NEW DELHI 110002

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Indian Standard

METHODS OF TEST FOR AGGREGATES FOR CONCRETE

PART III SPECIFIC GRAVITY, DENSITY, VOIDS, ABSORPTION AND BULKING

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Indian Standard

METHODS OF TEST FOR
AGGREGATES FOR CONCRETE

PART III SPECIFIC GRAVITY, DENSITY, VOIDS, ABSORPTION AND BULKING

0. FOREWORD

0.1 This Indian Standard (Part III) was adopted by the Indian Standards Institution on 22 August 1963, after the draft finalized by the Cement and Concrete Sectional Committee had been approved by the Building Division Council.

0.2 One of the major contributing factors to the quality of concrete is the quality of aggregates used therein. The test methods given in this standard are intended to assist in assessing the quality of aggregates. In a given situation, for a particular aggregate, it may not be necessary to assess all the qualities and therefore it is necessary to determine beforehand the purpose for which a concrete is being used and the qualities of the aggregate which require to be assessed. Accordingly, the relevant test methods may be chosen from amongst the various tests covered in this standard. For the convenience of the user, the test methods are grouped into the following eight parts of Indian Standard Methods of Test for Aggregates for Concrete (IS : 2386-1963):

Part   I   Particle Size and Shape

Part   II   Estimation of Deleterious Materials and Organic Impurities

Part   III   Specific Gravity, Density, Voids, Absorption and Bulking

Part   IV   Mechanical Properties

Part   V   Soundness

Part   VI   Measuring Mortar Making Properties of Fine Aggregate

Part VII   Alkali Aggregate Reactivity

Part VIII   Petrographic Examination

0.3 The Sectional Committee responsible for the preparation of this standard has taken into consideration the views of the concrete specialists, testing authorities, consumers and technologists and has related the standard to the practices followed in the country in this field. Further the need for international co-ordination among standards prevailing in

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different countries of the world has also been recognized. These considerations led the Sectional Committee to derive assistance from the published standards and publications of the following organizations:

British Standards Institution

American Society for Testing and Materials

0.4 Wherever a reference to any Indian Standard appears in these methods, it shall be taken as a reference to its latest version.

0.5 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 analysis, shall be rounded off in accordance with IS : 2-1960 Rules for Rounding Off Numerical Values (*Revised*). The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

0.6 This standard is intended chiefly to cover the technical provisions relating to testing of aggregates for concrete, and it does not include all the necessary provisions of a contract.

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1. SCOPE

1.1 This standard (Part III) covers the following tests for aggregates for concrete:

a) Determination of specific gravity and water absorption,

b) Determination of bulk density and voids,

c) Determination of necessary adjustment for bulking of fine aggregate (field method), and

d) Determination of surface moisture in fine aggregate (field method).

2. DETERMINATION OF SPECIFIC GRAVITY AND WATER ABSORPTION

2.1 Object — This test covers the procedures for determining the specific gravity, apparent specific gravity and water absorption of aggregates.

Note 1 — Three main methods are specified for use according to whether the size of the aggregate is larger than 10 mm (Method I) between 40 mm and 10 mm (Method I or II may be used); or smaller than 10 mm (Method III). An alternate method (Method IV) is also permitted.

Note 2 — The water absorption test will not always be reproducible with aggregates of high porosity.

2.2 Method I — Aggregate Larger than 10 mm

2.2.1 *Apparatus* — The apparatus shall consist of the following:

a) *Balance* — A balance or scale of capacity not less than 3 kg, readable and accurate to 0·5 g and of such a type and shape as to permit the basket containing the sample to be suspended from the beam and weighed in water.

b) *Oven* — A well ventilated oven, thermostatically controlled, to maintain a temperature of 100 to 110°C.

c) A wire basket of not more than 6·3 mm mesh or a perforated container of convenient size, preferably chromium plated and polished, with wire hangers not thicker than one millimetre for suspending it from the balance.

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

e) Two dry soft absorbent cloths each not less than 75 × 45 cm.

f) A shallow tray of area not less than 650 cm².

g) An airtight container of capacity similar to that of the basket.

2.2.2 *Sample* — A sample of not less than 2 000 g of the 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, and it is recommended that the two samples should not be tested concurrently.

2.2.3 *Test Procedure* — The sample shall be thoroughly washed to remove finer particles and dust, drained and then placed in the wire basket and immersed in distilled water at a temperature between 22°C and 32°C with a cover of at least 5 cm of water above the top of the basket.

2.2.3.1 Immediately after immersion the entrapped air shall be removed 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 the rate of about one drop per second. The basket and aggregate shall remain completely immersed during the operation and for a period of $24 \pm 1/2$ hours afterwards.

2.2.3.2 The basket and the sample shall then be jolted and weighed in water at a temperature of 22 to 32°C. If it is necessary for them to be transferred to a different tank for weighing, they shall be jolted 25 times as described above in the new tank before weighing (weight A_1).

2.2.3.3 The basket and the aggregate shall then be removed from the water and allowed to drain for a few minutes, after which the aggregate shall be gently emptied from the basket on to one of the dry clothes, and the empty basket shall be returned to the water, jolted 25 times and weighed in water (weight A_2).

2.2.3.4 The aggregate placed on the dry cloth shall be gently surface dried with the cloth, transferring it to the second dry cloth when the first will remove no further moisture. It shall then be spread out not more than one stone deep on the second cloth, and lest exposed to the atmosphere away from direct sunlight or any other source of heat for not less than 10 minutes, or until it appears to be completely surface dry (which with some aggregates may take an hour or more). The aggregate shall be turned over at least once during this period and a gentle current of unheated air may be used after the first ten minutes to accelerate the drying of difficult aggregates. The aggregate shall then be weighed (weight B).

NOTE — If the apparent specific gravity only is required the operations described in 2.2.3.4 may be omitted.

2.2.3.5 The aggregate shall then be placed in the oven in the shallow tray, at a temperature of 100 to 110°C and maintained at this temperature for $24 \pm 1/2$ hours. It shall then be removed from the oven, cooled in the airtight container and weighed (weight C).

2.2.4 *Calculations* — Specific gravity, apparent specific gravity and water absorption shall be calculated as follows:

$$\text{Specific gravity} = \frac{C}{B-A}$$

$$\text{Apparent specific gravity} = \frac{C}{C-A}$$

$$\text{Water absorption (percent of dry weight)} = \frac{100\ (B-C)}{C}$$

where

$A =$ the weight in g of the saturated aggregate in water ($A_1 - A_2$),

$B =$ the weight in g of the saturated surface-dry aggregate in air, and

$C =$ the weight in g of oven-dried aggregate in air.

2.2.5 *Reporting of Results* — The individual and mean results shall be reported. The size of the aggregate tested shall be stated, and whether it has been artificially heated.

2.3 Method II — Aggregate Between 40 mm and 10 mm

2.3.1 *Apparatus* — The apparatus shall consist of the following:

a) *Balance* — A balance or scale of capacity not less than 3 kg, readable and accurate to 0·5 g, and of such a type as to permit the weighing of the vessel containing the aggregate and water.

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b) *Oven* — A well ventilated oven, thermostatically controlled to maintain a temperature of 100 to 110°C.

c) *Glass Vessel or Jar* — A wide-mouthed glass vessel such as a jar of about 1·5 litres capacity, with a flat ground lip and a plane ground disc of plate glass to cover it, giving a virtually watertight fit.

d) *Cloths* — Two dry soft absorbent cloths, each not less than 75 × 45 cm.

e) *Tray* — A shallow tray of area not less than 325 cm².

f) *Container* — An airtight container large enough to take the sample.

2.3.2 *Sample* — A sample of about one kilogram 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 and it is recommended that the two samples should not be tested concurrently.

2.3.3 *Test Procedure* — The sample shall be screened on a 10-mm IS sieve, thoroughly washed to remove fine particles of dust, and immersed in distilled water in the glass vessel; it shall remain immersed at a temperature of 22 to 32°C for 24 ± 1/2 hours. Soon after immersion and again at the end of the soaking period, air entrapped in or bubbles on the surface of the aggregate shall be removed by gentle agitation. This may be achieved by rapid clockwise and anti-clockwise rotation of the vessel between the operator's hands.

2.3.3.1 The vessel shall be overfilled by adding distilled water and the plane ground-glass disc slid over the mouth so as to ensure that no air is trapped in the vessel. The vessel shall be dried on the outside and weighed (weight *A*).

2.3.3.2 The vessel shall be emptied and the aggregate allowed to drain. Refill the vessel with distilled water. Slide the glass disc in position as before. The vessel shall be dried on the outside and weighed (weight *B*).

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

2.3.3.4 The aggregate shall be placed on a dry cloth and gently surface dried with the cloth, transferring it to a second dry cloth when the first will remove no further moisture. It shall then be spread out not more than one stone deep on the second cloth, and left exposed to the atmosphere away from direct sunlight or any other source of heat for not less than 10 minutes or until it appears to be completely surface dry (which with some aggregates may take an hour or more) The aggregate

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shall be turned over at least once during this period and a gentle current of unheated air may be used after the first ten minutes to accelerate the drying of difficult aggregates. The aggregate shall then be weighed (weight C).

NOTE — If the apparent specific gravity only is required, the operations described in 2.3.3.4 may be omitted.

2.3.3.5 The aggregate shall be placed in the oven in the shallow tray, at a temperature of 100 to 110°C for 24 $\pm$ 1/2 hours. It shall then be cooled in airtight container and weighed (weight D).

2.3.4 *Calculations* — Specific gravity, apparent specific gravity and water absorption shall be calculated as follows:

$$\text{Specific gravity} = \frac{D}{C - (A - B)}$$

$$\text{Apparent specific gravity} = \frac{D}{D - (A - B)}$$

$$\text{Water absorption (percent of dry weight)} = \frac{100 (C - D)}{D}$$

where

A = weight in g of vessel containing sample and filled with distilled water,

B = weight in g of vessel filled with distilled water only,

C = weight in g of saturated surface-dry sample, and

D = weight in g of oven-dry sample.

2.3.5 *Reporting of Results* — The individual and mean results shall be reported. The grading of aggregate tested shall be stated, and whether it has been artificially heated.

2.4 Method III — Aggregate Smaller Than 10 mm

2.4.1 *Apparatus* — The apparatus shall consist of the following:

a) *Balance* — A balance or scale of capacity not less than 3 kg, readable and accurate to 0·5 g, and of such a type as to permit the weighing of the vessel containing the aggregate and water.

b) *Oven* — A well ventilated oven, thermostatically controlled, to maintain a temperature of 100 to 110°C.

c) *Vessel* — Any form of vessel capable of holding 0·5 to 1 kg of material up to 10 mm in size and capable of being filled with water to a constant volume with an accuracy of $\pm$ 0·5 ml. Either of the two following vessels is suitable:

1) A glass vessel, referred to later as a pycnometer, of about

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one litre capacity having a metal conical screw top with a 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, a mark shall be made on the jar to correspond with a mark on the screw top so that the screw is tightened to the same position every time and the volume contained by the jar is constant throughout the test. A suitable vessel can be made from a 1-kg fruit preserving jar in which the glass lid normally used is replaced by a sheet metal cone as shown in Fig. 1; or

2) A wide-mouthed glass vessel, such as a gas jar, of about 1·25 litres capacity, with a flat ground lip and a plane ground disc of plate glass to cover it, giving a virtually watertight fit.

d) A means of supplying a current of warm air, such as a hair drier.

e) A tray of area not less than 325 cm².

f) An airtight container large enough to take the sample.

g) Filter papers and funnel.

2.4.2 *Test Procedure*

2.4.2.1 *Using the pycnometer* — A sample of about 1 kg for 10 mm to 4·75 mm or 500 g if finer than 4·75 mm, shall be placed in the tray and covered with distilled water at a temperature of 22 to 32°C. Soon after immersion, air entrapped in or bubbles on the surface of the aggregate shall be removed by gentle agitation with a rod. The sample shall remain immersed for 24 ± 1/2 hours.

The water shall then be carefully drained from the sample, by decantation through a filter paper, any material retained being returned to the sample. The aggregate including any solid matter retained on the filter paper shall be exposed to a gentle current of warm air to evaporate surface moisture and shall be stirred at frequent intervals to ensure uniform drying until no free surface moisture can be seen and the material just attains a ' free-running ' condition. Care shall be taken to ensure that this stage is not passed. The saturated and surface-dry sample shall be weighed (weight *A*).

Note — If the apparent specific gravity only is required, the operations described in this paragraph may be omitted, although for material finer than 4·75 mm some surface drying may be desirable to facilitate handling.

The aggregate shall then be placed in the pycnometer which shall be filled with distilled water. Any trapped air shall be eliminated by rotating the pycnometer on its side, the hole in the apex of
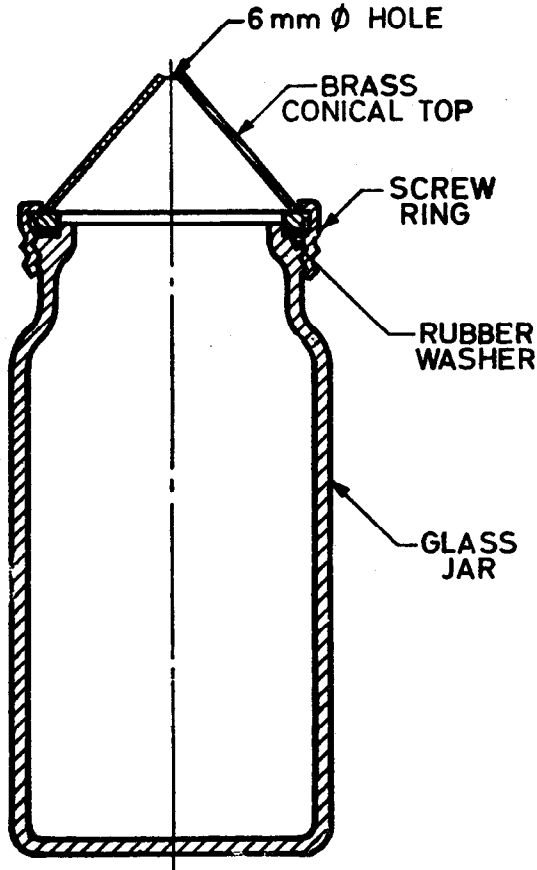
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FIG. 1 SECTION OF PYCNOMETER MADE
FROM FRUIT JAR

the cone being covered with a finger. The pycnometer shall be topped up with distilled water to remove any froth from the surface and so that the surface of the water in the hole is flat. The pycnometer shall be dried on the outside and weighed (weight B).

The contents of the pycnometer shall be emptied into the tray, care being taken to ensure that all the aggregate is transferred. The pycnometer shall be refilled with distilled water to the same level as before, dried on the outside and weighed (weight C). The difference in the temperature of the water in the pycnometer during the first and second weighings shall not exceed 2°C.

The water shall then be carefully drained from the sample by decantation through a filter paper and any material retained returned to the sample. The sample shall be placed in the oven in the tray at a temperature of 100 to 110°C for 24 ± 1/2 hours, during which period it shall be stirred occasionally to facilitate drying. It shall be cooled in the air-tight container and weighed (weight D).

Two tests shall be made.

2.4.2.2 Using the second (gas jar) apparatus described in **2.4.1** (c), the procedure shall be the same 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.

2.4.3 *Calculations* — Specific gravity, apparent specific gravity and water absorption shall be calculated as follows:

$$\text{Specific gravity} = \frac{D}{A - (B - C)}$$

$$\text{Apparent specific gravity} = \frac{D}{D - (B - C)}$$

$$\text{Water absorption (percent of dry weight)} = \frac{100 \ (A - D)}{D}$$

where

A = weight in g of saturated surface-dry sample,

B = weight in g of pycnometer or gas jar containing sample and filled with distilled water,

C = weight in g of pycnometer or gas jar filled with distilled water only, and

D = weight in g of oven-dried sample.

2.4.4 *Reporting of Results* — The individual and mean results shall be reported and the grading of the aggregate shall be stated.

2.5 Method IV — Alternate Method

2.5.1 The specific gravity and water absorption of aggregate smaller than 40 mm may be determined by using the apparatus described in IS : 1199-1959 Methods of Sampling and Analysis of Concrete, but distilled water shall be used in place of tap water.

2.5.2 When testing aggregate between 40 mm and 10 mm the procedure shall be as described in **2.2** substituting the bucket for the wire basket and stirring with a rod instead of jolting to remove air from the sample.

2.5.3 When testing aggregate smaller than 10 mm the apparatus shall be used in the same way as above, but the sequence of operations shall be

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as given in **2.4**. After transferring the sample to the bucket, water shall be added to cover the aggregate by at least 25 mm and the sample stirred to remove air. The bucket shall then be filled with water and the level of water in the tank raised slowly to avoid, as far as possible, the loss of fine particles from the sample in the bucket to the tank.

3. DETERMINATION OF BULK DENSITY AND VOIDS

3.1 Object — This method of test covers the procedure for determining unit weight or bulk density and void of aggregates.

> NOTE 1 — The bulk density is the weight of material in a given volume, and for the purpose of this standard it is measured in kilograms per litre. The bulk density of an aggregate is affected by several factors, including the amount of moisture present and the amount of effort introduced in filling the measures.

> NOTE 2 — It is emphasized that this is a laboratory test intended for comparing properties of different aggregates. It is not generally suitable for use as a basis for quoting mix design conversion factors.

> NOTE 3 — Considerably more compactive effort is used in the determination of angularity number [see IS : 2386 (Part I)-1963] than in this test, and hence the values for bulk density and voids are different.

3.2 Apparatus — The apparatus shall consist of the following:

a) *Balance* — A balance sensitive to 0·5 percent of the weight of the sample to be weighed.

b) *Cylindrical Metal Measure* — The measure shall preferably be machined to accurate internal dimensions and shall be provided with handles. It shall also be watertight, and of sufficient rigidity to retain its form under rough usage, and should be protected against corrosion.

  The measure shall be of 3, 15 or 30 litres capacity, according to the maximum nominal size of the coarsest particles of aggregate and shall comply with the requirements given in Table I.

c) *Tamping Rod* — A straight metal tamping rod of cylindrical cross-section 16 mm in diameter and 60 cm long, rounded at one end.

TABLE I SIZE OF CONTAINER FOR BULK DENSITY TEST

[*Clause* 3.2 (b)]

SIZE OF LARGEST PARTICLES	NOMINAL CAPACITY	INSIDE DIAMETER	INSIDE HEIGHT	THICKNESS OF METAL Min
	litre	cm	cm	mm
4·75 mm and under	3	15	17	3·15
Over 4·75 mm to 40 mm	15	25	30	4·00
Over 40 mm	30	35	31	5·00

3.3 Calibration — The measure shall be calibrated by determining the weight of water at 27°C required to fill it such that no meniscus is present above the rim of the container. The capacity in litres shall be obtained by dividing the weight of water in kilograms required to fill the container at 27°C by the weight of water in one litre at 27°C, which may be taken as one kilogram.

3.4 Procedure

3.4.1 *Condition of Specimen* — The test shall normally be carried out on dry material when determining the voids, but when bulking tests are required material with a given percentage of moisture may be used.

3.4.2 *Rodded or Compacted Weight* — The measure shall be filled about one-third full with thoroughly mixed aggregate and tamped with 25 strokes of the rounded end of the tamping rod. A further similar quantity of aggregate shall be added and a further tamping of 25 strokes given. The measure shall finally be filled to over-flowing, tamped 25 times and the surplus aggregate struck off, using the tamping rod as a straightedge. The net weight of the aggregate in the measure shall be determined and the bulk density calculated in kilograms per litre.

3.4.3 *Loose Weight* — The measure shall be filled to overflowing by means of a shovel or scoop, the aggregate being discharged from a height not exceeding 5 cm above the top of the measure. Care shall be taken to prevent, as far as possible, segregation of the particle sizes of which the sample is composed. The surface of the aggregate shall then be levelled with a straightedge. The net weight of the aggregate in the measure shall then be determined and the bulk density calculated in kilogram per litre.

3.5 Calculation of Voids — The percentage of voids shall be calculated as follows:

$$\text{Percentage of voids} = \frac{G_s - \gamma}{G_s} \times 100$$

where

G_s = specific gravity of the aggregate, and

γ = bulk density in kg/litre.

3.6 Reporting of Results — The bulk density shall be reported in kg/litre to the nearest 0·01 kg.

The voids shall be reported as a percentage to the nearest whole number.

The condition of aggregate at the time of test shall be stated, that is (a) oven dry, (b) saturated and surface dry, or (c) with a given percentage of moisture.

4. DETERMINATION OF NECESSARY ADJUSTMENT FOR BULKING OF FINE AGGREGATE (FIELD METHOD)

4.1 Object — This method of test covers the field method for determining the necessary adjustment for the bulking of fine aggregate.

4.2 General — Sand brought on to a building site or other works may contain an amount of moisture which will cause it, when loosely filled into a container, to occupy a larger volume than it would occupy if dry. If the sand is measured by loose volume, it is necessary in such a case to increase the measured volume of the sand, in order that the amount of sand put into the concrete may be the amount intended for the nominal mix used (based on dry sand) It will be necessary to increase the volume of sand by the ' percentage ' bulking. The correction to be made is only a rough approximation, because the system of measurement by loose volume is a rough method at the best, but a correction of the right order can easily be determined and should be applied in order to keep the concrete uniform.

4.3 Procedure

4.3.1 The procedure to be adopted may be varied, but two methods are suggested in **4.3.2** and **4.3.3**. Both depend on the fact that the volume of inundated sand is the same as if the sand were dry.

4.3.2 Put sufficient quantity of the sand loosely into a container until it is about two-thirds full. Level off the top of the sand and pushing a steel rule vertically down through the sand at the middle to the bottom, measure the height. Suppose this is h cm.

4.3.2.1 Empty the sand out of the container into another container where none of it will be lost. Half fill the first container with water. Put back about half the sand and rod it with a steel rod, about 6 mm in diameter, so that its volume is reduced to a minimum. Then add the remainder of the sand and rod it in the same way. Smooth and level the top surface of the inundated sand and measure its depth at the middle with the steel rule. Suppose this is h' cm.

4.3.2.2 The percentage of bulking of the sand due to moisture shall be calculated from the formula:

$$\text{Percentage bulking} = \left(\frac{h}{h'} - 1 \right) \times 100$$

4.3.3 In a 250-ml measuring cylinder, pour the damp sand (consolidated by shaking) until it reaches the 200-ml mark. Then fill the cylinder with water and stir the sand well. (The water shall be sufficient to submerge the sand completely.) It will be seen that the sand surface is now below its original level. Suppose the surface is at the mark y ml.

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The percentage of bulking of the sand due to moisture shall be calculated from the formula:

$$\text{Percentage bulking} = \left(\frac{200}{y} - 1 \right) \times 100$$

4.4 Reporting of Results — Report the percentage bulking of the sand to the nearest whole number.

5. DETERMINATION OF SURFACE MOISTURE IN FINE AGGREGATE (FIELD METHOD)

5.1 Object — This method of test covers the procedure for determining, in the field, the amount of surface moisture in fine aggregates by displacement in water. The accuracy of the method depends upon accurate information on the specific gravity of the material in a saturated surface-dry condition. The same procedure, with appropriate changes in the size of sample and dimensions of the container. may be applied to coarse aggregates.

5.2 Apparatus — The apparatus shall consist of the following:

a) *Balance* — A balance having a capacity of 2 kg or more and sensitive to 0·5 g or less.

b) *Flask* — A suitable container or flask preferably of glass or non-corrosive metal. The container may be a pycnometer, a volumetric flask, a graduated volumetric flask or other suitable measuring device. The volume of the container shall be from 2 to 3 times the loose volume of the sample. The container shall be so designed that it can be filled up to the mark, or the volume of its contents read, within 0·5 ml or less.

5.3 Sample — A representative sample of the fine aggregate to be tested for surface moisture content shall be selected. It shall weigh not less than 200 g. Larger samples will yield more accurate results.

5.4 Procedure

5.4.1 The surface water content may be determined either by weight or by volume. In each case the test shall be made at a temperature range of 22 to 32°C.

5.4.2 *Determination by Weight* — The container shall be filled up to the mark with water and the weight in grams determined. The container shall be emptied. Enough water shall be placed in the container to cover the sample, after which the sample of fine aggregate shall be introduced into the container and the entrained air removed. The container shall then be filled to the original mark and the weight in grams

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determined. The amount of water displaced by the sample shall be calculated as follows:

$$V_s = M_c + M_s - M$$

where

V_s = weight in g of water displaced by the sample,

M_c = weight in g of container filled up to the mark with water,

M_s = weight in g of the sample, and

M = weight in g of the sample and container filled to the mark with water.

5.4.3 *Determination by Volume* — A volume of water sufficient to cover the sample shall be measured in millilitres and placed in the container. The weighed sample of fine aggregate shall then be admitted into the container and the entrained air removed. The combined volume of the sample and the water shall be determined by direct reading when a graduated flask is used. Where a pycnometer or volumetric flask of known volume is used, the combined volume of the sample and the water shall be determined by filling up to the mark with a measured volume of water and subtracting this volume from the volume of the container. The amount of water displaced by the sample shall be calculated as follows:

$$V_s = V_2 - V_1$$

where

V_s = volume in ml of water displaced by the sample,

V_2 = combined volume in ml of the sample and water, and

V_1 = volume in ml of water required to cover the sample.

5.5 Calculation

5.5.1 The percentage of surface moisture in terms of the saturated surface-dry fine aggregate and in terms of the weight of wet fine aggregate shall be calculated as follows:

$$P_1 = \frac{V_s - V_d}{M_s - V_s} \times 100$$

$$P_2 = \frac{V_s - V_d}{M_s - V_d} \times 100$$

where

P_1 = percentage surface moisture in terms of saturated surface-dry fine aggregate;

V_s = weight in g of water displaced;

V_d = the weight of the sample (M_s in **5.4.2**) divided by the specific gravity on saturated and surface-dry basis, determined as prescribed;

M_s = weight in g of the sample; and

P_2 = percentage surface moisture in terms of the weight of wet fine aggregate.

NOTE — These formulae are readily derived from basic relationships. For convenience, express P_1 in terms of the ratio r, that is, the ratio of the weight of surface moisture to the weight of the saturated surface-dry sample. It follows that:

$$ r = \frac{M_s - \dfrac{M_s}{1 + r}}{\dfrac{M_s}{1 + r}} \qquad \text{...................(1)} $$

If G is the specific gravity of the saturated surface-dry fine aggregate, then

$$ V_s = \frac{M_s}{G (1 + r)} + \left(M_s - \frac{M_s}{1 + r} \right) \qquad \text{...................(2)} $$

where the first term gives the water displaced by the saturated surface-dry fine aggregate, and the second that displaced by the surface moisture.

From equation 2,

$$ \frac{M_s}{1 + r} = \frac{V_s - M_s}{\dfrac{1}{G} - 1} \qquad \text{...................(3)} $$

By definition,

$$ M_s = V_d \times G \qquad \text{...................(4)} $$

Substituting for $\dfrac{M_s}{1 + r}$ and M_s in equation 1, and simplifying

$$ r = \frac{V_s - V_d}{M_s - V_s} \qquad \text{...................(5)} $$

The formula for P_2 may be derived by similar reasoning, or directly from that for P_1, since

$$ P_2 = \frac{\dfrac{V_s - V_d}{M_s - V_s}}{1 + \dfrac{V_s - V_d}{M_s - V_s}} \times 100 \qquad \text{...................(6)} $$

5.6 Reporting of Results — The surface moisture in the fine aggregate shall be reported to the nearest one percent and also the method of determination, that is, either by weight or by volume.

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