British Standard

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Testing concrete —

Part 114: Methods for determination of density of hardened concrete

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Electricity Supply Industry in England and Wales
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Institute of Concrete Technology
Coopted member

This British Standard, having been prepared under the direction of the Cement, Gypsum, Aggregates and Quarry Products Standards Committee, was published under the authority of the Board of BSI and comes into effect on 31 January 1983

The following BSI references relate to the work on this standard:
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Contents

Foreword

This Part of this British Standard, prepared under the direction of the Cement, Gypsum, Aggregates and Quarry Products Standards Committee, is a revision of clause **2** of BS 1881- 5:1970 which has been deleted by Amendment No. 1 to that standard. The density test has been revised to distinguish between the procedures required to obtain the density of as-received, saturated or oven-dried specimens.

No estimate of repeatability or reproducibility is given in this Part of this standard. Reference should be made to BS 5497-1 for further information on the determination of repeatability and reproducibility.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 6, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

1 Scope

This Part of this British Standard describes the methods for determining the density of hardened concrete in the following conditions:

a) as-received in the laboratory (see clause **8**);

b) saturated (see clause **9**);

c) oven-dried (see clause **10**).

NOTE The titles of publications referred to in this Part of this standard are listed on the inside back cover.

2 Definitions

For the purposes of this Part of this standard the definitions given in BS 5328 apply.

3 Density

Density (ρ) is the mass of a unit volume of hardened concrete expressed in kilograms per cubic metre.

$$\rho = \frac{m}{V}$$

where

m can be m_1 = the mass of the as-received specimen in air (in kg);

or m_2 = the mass of the saturated specimen in air (in kg);

or m_3 = the mass of the oven-dried specimen in air (in kg);

V can be V_1, V_2 = the volume of the specimen calculated from its dimensions (in m^3);

V_3 = the volume of the specimen determined by the displacement of water (in m^3).

NOTE Determination of the volume by water displacement is preferred.

4 Apparatus

4.1 *Balance*, equipped with a stirrup for weighing the specimen in both air and water to an accuracy of 0.1 % of the mass. Some suitable types of stirrup are shown in Figure 1. (For use in clauses **7**, **8**, **9** and **10**.)

The balance shall be calibrated on initial commissioning and at least annually thereafter using weights of which the accuracy can be traced to the national standard of mass. The balance shall be checked after relocation or disturbance. A certificate stating the accuracy shall be obtained from the organization carrying out the check.

4.2 *Water tank*, fitted with a device to maintain the water level constant and of sufficient size to allow the specimen on the stirrup to be fully immersed to constant depth.

(For use in clauses **7** and **9** and clauses **8** and **10** if the volume is determined in accordance with clause **7**.)

4.3 *Ventilated oven*, complying with BS 2648, except that the internal space may exceed 0.085 m^3, in which the temperature is controlled at 105 ± 5 °C. (For use in clause **10**.)

5 Test specimens

The volume of the specimen shall be not less than 40 d^3, where d is the nominal maximum size of the aggregate. If the shape or size of the sample is such that it is not possible to use all of it, a smaller specimen may be taken from the original, provided that the prepared specimen is representative of the as-received sample.

6 Procedure for determination of the volume by calculation

6.1 General. Only regular shaped specimens shall be measured for the calculation of volume.

NOTE The water displacement method is the preferred method for cut or cored specimens.

Record all measurements of dimensions to the nearest millimetre.

6.2 Procedure

6.2.1 *Cylindrical cored specimens*. Measure the length parallel to the axis at four evenly distributed positions and take two pairs of measurements of the diameter at one-third points along the length, the two measurements in each pair being made at right angles to each other. Calculate the average length and diameter from each of the four measurements taken and using the average dimensions, calculate the volume V_1 of the specimen (in m^3).

6.2.2 *Sawn (cut) rectilinear prismatic specimens*. Measure the height and width at four points across each pair of opposite faces. Calculate the average for each of the four measurements and calculate the volume V_1 of the specimen (in m^3).

6.2.3 *Certified moulded specimens*. For cubes and beams, confirm that the moulded dimensions between opposite vertical faces and the height as cast are within 1 % of the nominal dimensions. For cylinders, confirm that the moulded diameter and length as cast are within 1 % of the nominal dimensions. If all dimensions are within 1 %, calculate the volume V_2 of the specimen from the nominal dimensions (in m^3).

NOTE Go/no go gauges of appropriate size are recommended as a convenient means for making the checks in this clause.

Measure any dimension not within 1 % of the nominal value at four evenly distributed positions in accordance with **6.2.2** for cubes and beams or **6.2.1** for cylinders. Calculate the average value and use it in the calculation of volume V_2 in place of the nominal value.

7 Procedure for determination of the volume by water displacement

7.1 General. The water displacement method is not applicable to specimens of no-fines concrete with large pores

7.2 Procedure. Place the specimen on the stirrup (**4.2**), and fully immerse it in water in the tank (**4.3**). Ensure that the stirrup does not touch the bottom of the tank and that air bubbles are not trapped on the surfaces of the specimen and the stirrup. Weigh the completely immersed specimen and record its apparent mass m_w (in kg), correcting for the apparent mass of the empty stirrup when weighed immersed in water to the same depth as when holding the specimen. Immediately remove the specimen from the stirrup, and after wiping off surplus water from the surfaces using a moist cloth, weigh in air and record its mass m_a (in kg).

7.3 Calculation. Taking the density of water as 1 000 kg/m^3, calculate the volume V_3 of the specimen (in m^3) from the following formula:

$$V_3 = \frac{m_a - m_w}{1\,000}$$

8 Procedure for determination of as-received density

8.1 General. This applies to specimens cut from a structure and tested on arrival in the laboratory or to moulded specimens which have not been cured in water to a saturated state.

8.2 Procedure. Weigh the specimen as-received in air and record its mass m_1 (in kg).

8.3 Calculation. Determine the volumes of the specimen V_1 or V_2 (in m^3) by calculation in accordance with clause **6**. Alternatively, determine the volume V_3 (in m^3) by the water displacement method, in accordance with clause **7**. Calculate the as-received density using the appropriate formula:

a) for volume calculated in accordance with **6.2.1** or **6.2.2** $\rho_1 = \frac{m_1}{V_1}$

b) for volume calculated in accordance with **6.2.3** $\rho_2 = \frac{m_1}{V_2}$

c) for volume obtained by water displacement in accordance with clause **7** $\rho_3 = \frac{m_1}{V_3}$

9 Procedure for determination of saturated density

9.1 Procedure. Fully immerse the specimen in water at 20 ± 2 °C until constant mass is achieved as shown by two measurements, 24 h apart, giving a difference of less than 0.2 % in the mass of the wet specimen in air. Before each weighing, wipe off surplus water from the surface using a moist cloth. Record the constant mass m_2 (in kg).

Specimens cured in water in accordance with BS 1881-111 for more than 3 days immediately prior to testing may be assumed to be saturated to a constant mass for this test.

9.2 Calculation. Determine the volume of the specimen V_1 or V_2 (in m^3) by calculation in accordance with clause **6**. Alternatively, determine the volume V_3 (in m^3) by the water displacement method in accordance with clause **7**. Calculate the saturated density using the appropriate formula:

a) for volume calculated in accordance with **6.2.1** or **6.2.2** $\rho_4 = \frac{m_2}{V_1}$

b) for volume calculated in accordance with **6.2.3** $\rho_5 = \frac{m_2}{V_2}$

c) for volume obtained by water displacement in accordance with clause **7** $\rho_6 = \frac{m_2}{V_3}$

10 Procedure for determination of oven-dried density

10.1 Procedure. Place the specimen in the ventilated oven (**4.4**) and dry it at 105 ± 5 °C until constant mass is achieved as shown by two measurements, 24 h apart, giving a difference of less than 0.2 % in the mass of the dry specimen. Before each weighing, cool the specimen to near room temperature in a dry airtight vessel or desiccator. Record the constant mass m_3 (in kg).

10.2 Calculation. Determine the volume of the specimen, V_1 or V_2 (in m^3), by calculation in accordance with clause **6**. Alternatively, determine the volume V_3 (in m^3) by the water displacement method in accordance with clause **7**. Calculate the oven-dried density using the appropriate formula:

a) for volume calculated in accordance with **6.2.1** or **6.2.2** $\rho_7 = \frac{m_3}{V_1}$

b) for volume calculated in accordance with **6.2.3** $\rho_8 = \frac{m_3}{V_2}$

c) for volume obtained by water displacement in accordance with clause **7** $\rho_9 = \frac{m_3}{V_3}$

11 Calculation and expression of results

11.1 General

The density of each specimen shall be calculated using the appropriate formula given in clause **8**, **9** or **10** and it shall be expressed in kilograms per cubic metre. Report whether the volume was determined by water-displacement or by calculation, and report the density (as-received or saturated or oven-dried) to the nearest 10 kg/m^3.

11.2 Precision. Precision data are given in Table 1. These apply to density measurements in the range 2 300 kg/m^3 to 2 400 kg/m^3 made on cubes made from concrete taken from the same sample and when each test result is obtained from a single determination of the saturated density of a single cube. They indicate the variability that occurs when making and curing the cubes (in accordance with BS 1881-108 and Part BS 1881-108-111), as well as in the measurement of their densities.

Table 1 — Precision data for measurements of the saturated density of hardened concrete

Test method	Repeatability conditions		Reproducibility conditions	
	s_r	r	s_R	R
	kg/m^3	kg/m^3	kg/m^3	kg/m^3
Clause **6**, 100 mm cubes	13.9	39	20.5	57
Clause **6**, 150 mm cubes	9.9	28	20.5	57
Clause **7**, 100 mm cubes	6.5	18	12.8	36
Clause **7**, 150 mm cubes	6.4	18	10.6	30

NOTE 1 The precision data were determined as part of an experiment carried out in 1987 in which precision data were obtained for several of the tests described BS 1881 tests. The experiment involved 16 operators. The concretes were made using an ordinary Portland cement, Thames Valley sand, and Thames Valley 10 mm and 20 mm coarse aggregates.

NOTE 2 The difference between two test results from the same sample by one operator using the same apparatus within the shortest feasible time interval will exceed the repeatability value r on average not more than once in 20 cases in the normal and correct operation of the method.

NOTE 3 Test results on the same sample obtained within the shortest feasible time interval by two operators each using their own apparatus will differ by the reproducibility value R on average not more than once in 20 cases in the normal and correct operation of the method.

NOTE 4 For further information on precision, and for definitions of the statistical terms used in connection with precision, see BS 5497-1.

12 Test report

12.1 General. The report shall affirm that the tests were made in accordance with this Part of this standard. The report shall also state whether or not certificates of sampling, specimen preparation and curing are available. If available, a copy of each certificate shall be provided.

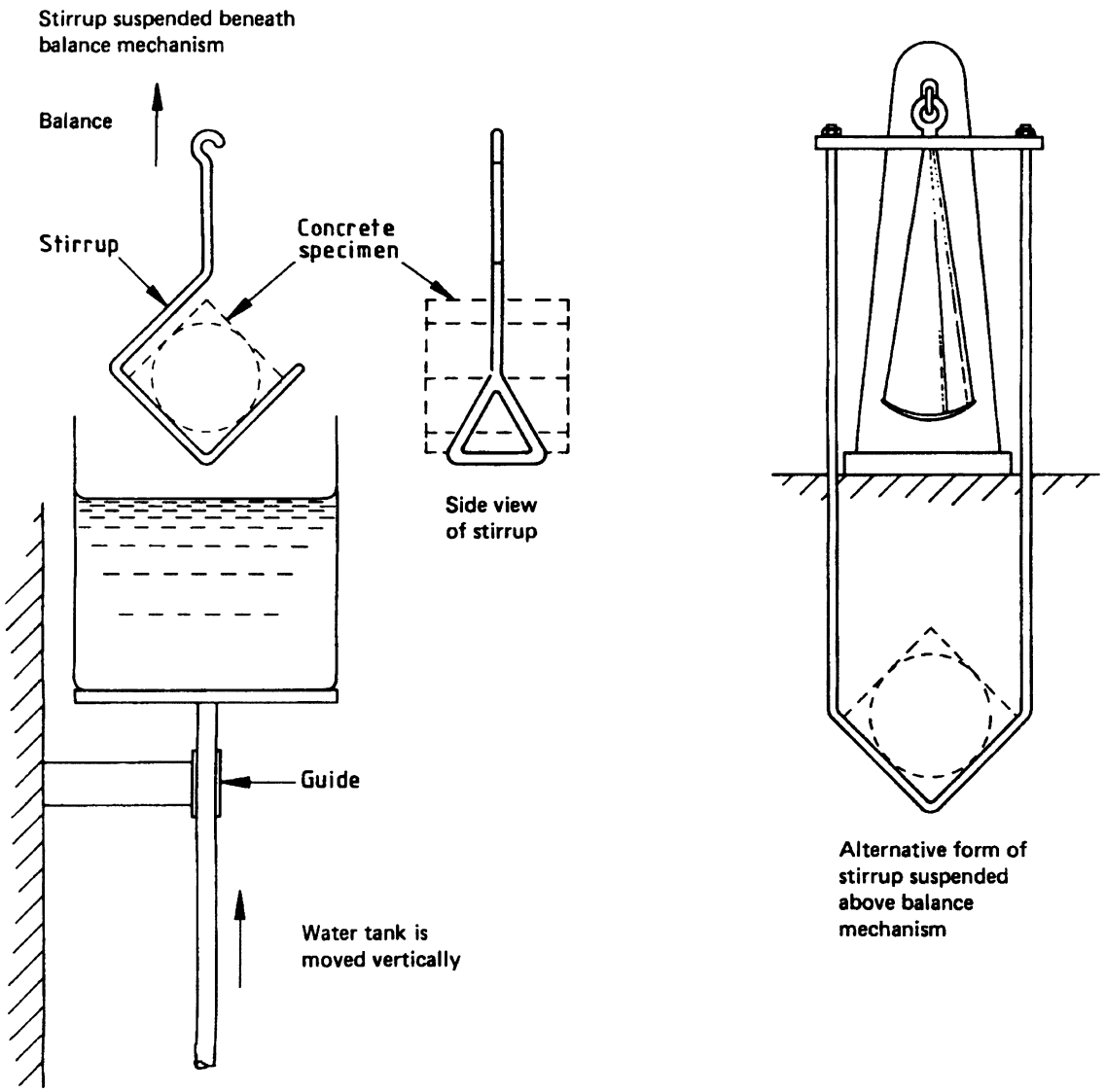

Figure 1 — Typical stirrup arrangements for determination of the volume of concrete specimens by water displacement

12.2 Information to be provided by the producer of the test specimens

12.2.1 *Mandatory information*. The following information shall be provided by the producer of the test specimens for inclusion in the test report:

a) date, time and place of sampling and sample identity number;

b) time and place of making specimens;

c) number and nominal size of specimens;

d) method of compaction (hand or vibration) including type of equipment used;

e) treatment to prepare specimen from sample if reduction is necessary e.g. sawing, coring, breaking;

f) identification number of specimens;

g) name of supplier of the specimen.

12.2.2 *Optional information*. If requested, the following information shall be provided by the producer of the test specimens for inclusion in the test report:

a) name of project and place where concrete was used;

b) name of supplier and source of concrete;

c) date and time of production of concrete or delivery to site;

d) specification of concrete mix (e.g. strength grade);

e) consistence of concrete;

f) air content of concrete (if air-entrained).

12.3 Information to be provided by the test laboratory. The following information shall be provided by the test laboratory for inclusion in the test report:

a) identification of the specimen;

b) checked nominal or measured dimensions and shape of specimen;

c) date of receipt of the specimen at the laboratory;

d) condition of the specimen when received (include poor compaction, honeycombing and bad dimensions);

e) treatment to specimen if reduction is carried out by the laboratory;

f) conditions of curing at the laboratory;

g) condition of specimen at test (as-received, saturated or oven-dry);

h) date of test;

i) age of specimen at test, if known;

j) method of determination of volume (by calculation from the measured or nominal dimensions or by water displacement);

k) mass of specimen (as-received, saturated or oven-dried);

l) type of density measured, i.e. as-received, saturated or oven-dried, and values obtained;

m) certificate that the test has been carried out to the requirement of this Part of this standard;

n) other remarks.

blank

Publications referred to

BS 1881, *Testing concrete.*
BS 1881-108, *Method for making test cubes from fresh concrete.*
BS 1881-111, *Method for normal curing of test specimens (20° Method).*
BS 2648, *Performance requirements for electrically-heated laboratory drying ovens.*
BS 5328, *Methods for specifying concrete, including ready-mixed concrete.*
BS 5497, *Precision of test methods.*
BS 5497-1, *Guide for the determination of repeatability and reproducibility for a standard test method.*

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389 Chiswick High Road
London
W4 4AL