**Designation: C642 – 13**

# Standard Test Method for
# Density, Absorption, and Voids in Hardened Concrete[1]

## 1. Scope*

1.1 This test method covers the determinations of density, percent absorption, and percent voids in hardened concrete.

1.2 The text of this test method references notes and footnotes which provide explanatory information. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of this standard.

1.3 The values stated in SI units are to be regarded as the standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

## 2. Significance and Use

2.1 This test method is useful in developing the data required for conversions between mass and volume for concrete. It can be used to determine conformance with specifications for concrete and to show differences from place to place within a mass of concrete.

## 3. Apparatus

3.1 *Balance,* sensitive to 0.025 % of the mass of the specimen.

3.2 *Container,* suitable for immersing the specimen and suitable wire for suspending the specimen in water.

## 4. Test Specimen

4.1 Whenever possible, the sample shall consist of several individual portions of concrete, each to be tested separately. The individual portions may be pieces of cylinders, cores, or beams of any desired shape or size, except that the volume of each portion shall be not less than 350 cm$^3$ (or for normal weight concrete, approximately 800 g); and each portion shall be free from observable cracks, fissures, or shattered edges.

## 5. Procedure

5.1 *Oven-Dry Mass*—Determine the mass of the portions, and dry in an oven at a temperature of 110 ± 5°C for not less than 24 h. After removing each specimen from the oven, allow it to cool in dry air (preferably in a desiccator) to a temperature of 20 to 25°C and determine the mass. If the specimen was comparatively dry when its mass was first determined, and the second mass closely agrees with the first, consider it dry. If the specimen was wet when its mass was first determined, place it in the oven for a second drying treatment of 24 h and again determine the mass. If the third value checks the second, consider the specimen dry. In case of any doubt, redry the specimen for 24-h periods until check values of mass are obtained. If the difference between values obtained from two successive values of mass exceeds 0.5 % of the lesser value, return the specimens to the oven for an additional 24-h drying period, and repeat the procedure until the difference between any two successive values is less than 0.5 % of the lowest value obtained. Designate this last value *A*.

5.2 *Saturated Mass After Immersion*—Immerse the specimen, after final drying, cooling, and determination of mass, in water at approximately 21°C for not less than 48 h and until two successive values of mass of the surface-dried sample at intervals of 24 h show an increase in mass of less than 0.5 % of the larger value. Surface-dry the specimen by removing surface moisture with a towel, and determine the mass. Designate the final surface-dry mass after immersion *B*.

5.3 *Saturated Mass After Boiling*—Place the specimen, processed as described in 5.2, in a suitable receptacle, covered with tap water, and boil for 5 h. Allow it to cool by natural loss of heat for not less than 14 h to a final temperature of 20 to 25°C. Remove the surface moisture with a towel and determine the mass of the specimen. Designate the soaked, boiled, surface-dried mass *C*.

5.4 *Immersed Apparent Mass*—Suspend the specimen, after immersion and boiling, by a wire and determine the apparent mass in water. Designate this apparent mass *D*.

## 6. Calculation

6.1 By using the values for mass determined in accordance with the procedures described in Section 5, make the following calculations:

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**\*A Summary of Changes section appears at the end of this standard**

$$\text{Absorption after immersion, } \% = [(B - A)/A] \times 100 \quad (1)$$

$$\text{Absorption after immersion and boiling, } \% = [(C - A)/A] \times 100 \quad (2)$$

$$\text{Bulk density, dry} = [A/(C - D)] \cdot \rho = g_1 \quad (3)$$

$$\text{Bulk density after immersion} = [B/(C - D)] \cdot \rho \quad (4)$$

$$\text{Bulk density after immersion and boiling} = [C/(C - D)] \cdot \rho \quad (5)$$

$$\text{Apparent density} = [A/(A - D)] \cdot \rho = g_2 \quad (6)$$

$$\text{Volume of permeable pore space (voids), } \% = (g_2 - g_1)/g_2 \times 100 \quad (7)$$

$$\text{or } (C - A)/(C - D) \times 100$$

where:
- $A$ = mass of oven-dried sample in air, g
- $B$ = mass of surface-dry sample in air after immersion, g
- $C$ = mass of surface-dry sample in air after immersion and boiling, g
- $D$ = apparent mass of sample in water after immersion and boiling, g
- $g_1$ = bulk density, dry, $\text{Mg/m}^3$ and
- $g_2$ = apparent density, $\text{Mg/m}^3$
- $\rho$ = density of water = $1\ \text{Mg/m}^3$ = $1\ \text{g/cm}^3$.

## 7. Example

7.1 Assume a sample having the following characteristics:

7.1.1 Mass of the solid part of the specimen = 1000 g.

7.1.2 Total volume of specimen (including solids, "permeable" voids, and "impermeable" voids) = 600 $\text{cm}^3$.

7.1.3 Absolute density of solid part of specimen = 2.0 $\text{Mg/m}^3$.

7.1.4 Void space in specimen contains initially only air (no water).

7.2 Then, it follows that there are 500 $\text{cm}^3$ of solids and 100 $\text{cm}^3$ of voids making up the specimen, and the void content is $\frac{1}{6}$ = 16.67 %.

7.3 Assume that on immersion 90 mL of water is absorbed.

7.4 Assume that after immersion and boiling 95 mL of water is absorbed.

7.5 Based on the assumptions given in 7.1 – 7.4 above, the data that would be developed from the procedures given in Section 5 would be as follows:

7.5.1 Oven-dry mass, $A$ = 1000 g.

7.5.2 Mass in air after immersion, $B$ = 1090 g.

7.5.3 Mass in air after immersion and boiling, $C$ = 1095 g.

7.5.4 Apparent mass in water after immersion and boiling, $D$ = 495 g.

NOTE 1—Since loss of mass in water is equal to mass of displaced water, and volume of specimen = 600 $\text{cm}^3$, mass of specimen in water after immersion and boiling is 1095 – 600 = 495 g.

7.6 By using the data given above to perform the calculations described in Section 6, the following results will be obtained (Note 2):

$$\text{Absorption after immersion, } \% = [(B - A)/A] \times 100 = [(1090 - 1000)/1000] \times 100 = 9.0 \quad (8)$$

$$\text{Absorption after immersion and boiling, } \% = [(C - A)/A] \times 100 = [(1095 - 1000)/1000] \times 100 = 9.5 \quad (9)$$

$$\text{Bulk density, dry} = [A/(C - D)] \cdot \rho = [1000/(1095 - 495)] \times 1 = 1.67\ \text{Mg/m}^3 = g_1 \quad (10)$$

$$\text{Bulk density after immersion} = [B/(C - D)] \cdot \rho = [1090/(1095 - 495)] \times 1 = 1.82 \quad (11)$$

$$\text{Bulk density after immersion and boiling} = [C/(C - D)] \rho = [1095/(1095 - 495)] \times 1 = 1.83\ \text{Mg/m}^3 \quad (12)$$

$$\text{Apparent density} = [A/(A - D)] \rho = [1000/(1000 - 495)] \times 1 = 1.98\ \text{Mg/m}^3 = g_2 \quad (13)$$

$$\text{Volume of permeable voids, } \% \quad (14)$$

$$= [(g_2 - g_1)/g_2] \times 100 = [(1.98 - 1.67)/1.98] \times 100$$

$$= 15.8,\ \text{or } [(C - A)/(C - D)] \times 100$$

$$= [(1095 - 1000)/(1095 - 495)] \times 100 = 15.7$$

NOTE 2—This test method does not involve a determination of absolute density. Hence, such pore space as may be present in the specimen that is not emptied during the specified drying or is not filled with water during the specified immersion and boiling or both is considered "impermeable" and is not differentiated from the solid portion of the specimen for the calculations, especially those for percent voids. In the example discussed it was assumed that the absolute density of the solid portion of the specimen was 2.0 $\text{Mg/m}^3$, the total void space was 16.67 %, and the impermeable void space was 5 $\text{cm}^3$. The operations, if performed, and the calculations, if performed as described, have the effect of assuming that there are 95 $\text{cm}^3$ of pore space and 505 $\text{cm}^3$ of solids, and indicate that the solid material, therefore, has an apparent density of 1.98 rather than the absolute density of 2.00 $\text{Mg/m}^3$ and the specimen has a percentage of voids of 15.8 rather than 16.67.

Depending on the pore size distribution and the pore entry radii of the concrete and on the purposes for which the test results are desired, the procedures of this test method may be adequate, or they may be insufficiently rigorous. In the event that it is desired to fill more of the pores than will be filled by immersion and boiling, various techniques involving the use of vacuum treatment or increased pressures may be used. If a rigorous measure of total pore space is desired, this can only be obtained by determining absolute density by first reducing the sample to discrete particles, each of which is sufficiently small so that no impermeable pore space can exist within any of the particles. If the absolute density were determined and designated $g_3$, then:

$$\text{Total void volume, } \% = (g_3 - g_1)/g_3 \times 100 \quad (15)$$

$$= (2.00 - 1.67)/2.00 \times 100 = 16.5$$

## 8. Precision and Bias

8.1 *Precision*—At present there are insufficient data available to justify attempting to develop a precision statement for this test method.

8.2 *Bias*—Bias for this test method cannot be determined since there is no reference standard available for comparison.

## 9. Keywords

9.1 absorption; concrete-hardened; density; voids