Designation: C 567 – 00

# Standard Test Method for Determining Density of Structural Lightweight Concrete[1]

This standard is issued under the fixed designation C 567; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

*This standard has been approved for use by agencies of the Department of Defense.*

## 1. Scope

1.1 This test method provides procedures to determine the oven-dry and equilibrium densities of structural lightweight concrete.

1.2 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.3 *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. Referenced Documents

2.1 *ASTM Standards:*

C 31/C 31M Practice for Making and Curing Concrete Test Specimens in the Field[2]

C 88 Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate[2]

C 125 Terminology Relating to Concrete and Concrete Aggregates[2]

C 138 Test Method for Unit Weight, Yield, and Air Content (Gravimetric) of Concrete[2]

C 172 Practice for Sampling Freshly Mixed Concrete[2]

C 192/C 192M Practice for Making and Curing Concrete Test Specimens in the Laboratory[2]

C 470/C 470M Specification for Molds for Forming Concrete Test Cylinders Vertically[2]

E 104 Practice for Maintaining Constant Relative Humidity by Means of Aqueous Solutions[3]

## 3. Terminology

3.1 Terminology used in this test method is defined in Terminology C 125.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *equilibrium density*, *n*—the density as determined in 8.2 reached by structural lightweight concrete after exposure to relative humidity of 50 ± 5 % and a temperature of 23 ± 2°C (73.5 ± 3.5°F) for a period of time sufficient to reach constant mass.

3.2.2 *oven-dry density*—the density as determined in 8.3 reached by structural lightweight concrete after being placed in a drying oven at 110 ± 5°C (230 ± 9°F) for a period of time sufficient to reach constant mass.

## 4. Summary of Test Method

4.1 This test method provides procedures for determining the oven-dry and equilibrium densities of structural lightweight concrete, by calculation or measurement. The calculated oven-dry density is determined from batch quantities and volume of a given batch of concrete. The calculated equilibrium density is approximated by adding a fixed quantity to the oven-dry density. Measured densities are obtained from determinations of the mass of cylindrical specimens after specified treatments.

## 5. Significance and Use

5.1 The measured or calculated equilibrium density of structural lightweight concrete determines whether specified density requirements have been met. Unless otherwise specified, determine equilibrium density by calculation using the procedures in 9.2.

5.2 Test Method C 138 shall be used to determine the density of freshly mixed lightweight concrete for compliance with concrete placement specifications.

NOTE 1—The fresh density of lightweight aggregate concrete is a function of mixture proportions, air content, water demand, and the specific density and moisture content of the lightweight aggregate. Decrease in density of a specific lightweight concrete is due to moisture loss that, in turn, is a function of aggregate moisture content, ambient conditions, and the ratio of the surface area to the volume of the concrete member. For most structural lightweight concretes, equilibrium density is approached at about 90 days. For most high-strength lightweight concretes, equilibrium density is approached at about 180 days. Extensive tests demonstrate that despite variations in the initial moisture content of lightweight aggregate, the equilibrium density will be approximately 50 kg/m$^3$ (3.0 lb/ft$^3$) greater than the oven-dry density.

## 6. Apparatus

6.1 *Tamping Rod, Mallet, Measure, Balance, and Molds*—These shall conform to the requirements of Test Method C 138

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[2] *Annual Book of ASTM Standards*, Vol 04.02.

[3] *Annual Book of ASTM Standards*, Vol 11.03.

and Specification C 470.

6.1.1 *Measure*—A 14-L (0.5-ft$^3$) measure shall be the standard (see Note 3).

6.2 *Controlled Humidity Enclosure*—A room controlled at 50 ± 5 % relative humidity and 23 ± 2°C (73.5 ± 3°F) or a small chamber meeting the requirements of Practice E 104.

6.3 *Drying Oven*—An oven of appropriate size capable of maintaining a uniform temperature of 110± 5°C (230 ± 9°F), and an average evaporation rate of at least 25 g/h. Determine evaporation rate in accordance with Test Method C 88.

## 7. Sampling, and Making, and Curing Test Specimens

7.1 *Sampling*—Sample field-mixed concrete in accordance with Practice C 172.

7.2 *Specimens for Determining Equilibrium Density and Oven-dry Density*—Determine the equilibrium density and oven-dry density on 150 by 300-mm (6 by 12-in.) concrete cylinders.

7.2.1 Make test cylinders in accordance with Practice C 192/C 192M or C 31/C 31M, whichever is applicable. Make three cylinders for equilibrium density measurements, and make three cylinders for oven-dry density measurements.

7.3 *Curing Specimens*:

7.3.1 Unless otherwise specified, test cylinders used for the determination of equilibrium density shall be cured in accordance with Practice C 192/C 192M or the standard curing procedure in Practice C 31/C 31M for six days.

NOTE 2—Cylinders may be stripped after 24 h and wrapped securely with a plastic sheet or bag to prevent loss of moisture, or may remain in covered molds until the time of test.

7.3.2 Unless otherwise specified, for the first 24 h or until the time of test, store the test cylinders used for the determination of oven-dry density under conditions that maintain a temperature adjacent to the cylinders in the range from 16 to 27°C (60 to 80°F) and that prevent loss of moisture from the cylinders.

## 8. Procedure

8.1 *Measurement of Freshly Mixed Concrete Density*—Determine the density of the freshly mixed concrete in accordance with Test Method C 138.

NOTE 3—Numerous observations indicate that the same compactive effort used on smaller concrete specimens will cause the fresh densities to be higher. The fresh density as determined from measurements on 150 by 300-mm (6 by 12-in.) cylinders of lightweight concrete consolidated by rodding, in accordance with Practice C 192/C 192M or Practice C 31/C 31M will average 40 kg/m$^3$ (2.5 lb/ft$^3$) higher than the fresh density as measured using a 14-L (0.5-ft$^3$) measure in accordance with Test Method C 138.

8.2 *Measurement of Equilibrium Density*—To measure the equilibrium density, remove the cylinders from their curing condition on the sixth day and immerse in water at 23 ± 2°C (73.5 ± 3°F) for 24 h. Measure the apparent mass of the cylinders while suspended and completely submerged in water and record as "C," the mass of the suspended-immersed cylinder. Remove from the water and allow to drain for 1 min by placing the cylinder on a 9.5-mm (⅜-in.) or coarser sieve cloth. Remove visible water with a damp cloth, determine the mass and record as "B," the mass of the saturated-surface-dry cylinder. Dry the cylinders with all surfaces exposed, in a controlled humidity enclosure as described in 6.2 until the mass of the specimen changes not more than 0.5 % (gain or loss) in successive determinations of mass 28 days apart. Determine the mass of the dried cylinders and record as "A," the mass of the dried cylinder. Calculate the equilibrium density of the concrete from Eq 1 and 2.

$$E_m\,(Density,\ kg/m^3) = (A \times 997) / (B-C) \quad (1)$$

$$E_m\,(Density,\ lb/ft^3) = (A \times 62.3) / (B-C)) \quad (2)$$

where:

$E_m$ = measured equilibrium density, kg/m$^3$(lb/ft$^3$,
$A$ = mass of cylinder as dried, kg (lb),
$B$ = mass of saturated surface-dry cylinder, kg (lb), and
$C$ = apparent mass of suspended-immersed cylinder, kg (lb).

8.3 *Measurement of Oven-Dry Density*—After 24 h but not to exceed 32 h, remove the cylinders from the mold (see Note 4). Measure the apparent mass of the cylinders while suspended and completely submerged in water and record as "G" the mass of the suspended-immersed cylinders. Remove from the water and allow to drain for 1 min by placing the cylinders on a 9.5-mm (⅜-in.) or coarser sieve cloth. Remove visible water with a damp cloth, determine the mass and record as "F," the mass of the saturated surface-dry cylinders. Place the cylinders in the drying oven for 72 h or until constant mass is reached. Maintain oven temperature at 110 ± 5°C (230 ± 9°F). Allow cylinders to cool to room temperature and determine the mass and record as "D," the mass of the oven-dried cylinder. Repeat oven-drying and determination of mass at 24-h intervals until the mass of the specimen changes not more than 0.5 % in successive weighings 24 h apart. Determine the oven-dry density from Eq 3 and 4.

$$O_m\,(Density,\ kg/m^3) = (D \times 997) / (F-G) \quad (3)$$

$$O_m\,(Density,\ lb/ft^3) = (D \times 62.3) / (F-G)) \quad (4)$$

where:

$O_m$ = measured oven-dry density, kg/m$^3$(lb/ft$^3$),
$D$ = mass of oven-dry cylinder, kg (lb),
$F$ = mass of saturated surface-dry cylinder, kg (lb), and
$G$ = apparent mass of suspended-immersed cylinder, kg (lb).

NOTE 4—Determination of oven-dry density may be specified to begin at an age other than 24-h.

## 9. Calculation

9.1 *Calculation of Oven-Dry Density*—Where mixture quantities, aggregate moisture content, and the volume of the concrete batch are known, calculate an oven-dry density using Eq 5.

$$O_c = (M_{df} + M_{dc} + 1.2\,M_{ct}) / V \quad (5)$$

where:

$O_c$ = calculated oven-dry density, kg/m$^3$ (lb/ft$^3$),
$M_{df}$ = mass of dry fine aggregate in batch, kg(lb),
$M_{dc}$ = mass of dry coarse aggregate in batch, kg(lb),
$M_{ct}$ = mass of cement in batch, kg (lb),

1.2 = factor to approximate the mass of cement plus chemically combined water, and
$V$ = volume of concrete produced by the batch $m^3$ ($ft^3$).

9.2 *Calculation of Approximate Equilibrium Density*—Using the oven-dry density determined in accordance with 8.3 or 9.1, calculate the approximate equilibrium density from Eq 6 and 7.

$$E_c = O_c + 50 \text{ kg/m}^3 \ (3 \text{ lb/ft}^3) \quad (6)$$

or

$$E_c = O_m + 50 \text{ kg/m}^3 \ (3 \text{ lb/ft}^3) \quad (7)$$

where:
$E_c$ = calculated equilibrium density (see Note 1).

## 10. Report

10.1 When oven-dry and equilibrium densities are determined by measurements, the report shall include following information:

10.1.1 Fresh density, $kg/m^3$ ($lb/ft^3$).
10.1.2 Mass of suspended-immersed cylinder, kg (lb).
10.1.3 Mass of saturated surface dry cylinder, kg (lb).
10.1.4 Mass of cylinder after reaching equilibrium, kg (lb).
10.1.5 Equilibrium density reported to nearest 10 $kg/m^3$ (0.5 $lb/ft^3$).
10.1.6 Age at which equilibrium was reached, days.
10.1.7 Mass of oven-dry cylinder, kg (lb).
10.1.8 Oven-dry density rounded to the nearest 10 $kg/m^3$ (0.5 $lb/ft^3$).

10.2 When oven-dry and approximate equilibrium densities are determined by calculation, report the following information:

10.2.1 Fresh density, $kg/m^3$ ($lb/ft^3$).
10.2.2 Mass of cement and dry aggregates, batched, kg (lb).
10.2.3 Volume of concrete produced from the batch, $m^3$ ($ft^3$).
10.2.4 Calculated oven-dry density, to the nearest 10 $kg/m^3$ (0.5 $lb/ft^3$).
10.2.5 Calculated approximate equilibrium density, to the nearest 10 $kg/m^3$ (0.5 $lb/ft^3$).

## 11. Precision and Bias

11.1 *Precision*—The precision of this test method has not yet been determined, but an industry-wide multilaboratory testing program is being coordinated. The precision statements will be included when the data is compiled and reviewed.

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

## 12. Keywords

12.1 equilibrium density; lightweight concrete; oven-dry density