Designation: C 567 – ~~99a~~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 ~~methods~~ procedures to ~~measure or calculate equilibrium density and to measure over-dry densities for the purpose of design control. Test Method C 138 shall be used to~~ determine the ~~density of freshly mixed light-weight concrete for placement control.~~

~~NOTE 1—An approximate method for calculating the 28 day air-dry unit weight, the equilibrium air-dry unit weight, and a formula for estimating the~~ oven-dry ~~unit weight~~ and equilibrium densities of structural lightweight ~~concrete are provided in Section 9. The formula for estimating the oven dry unit weight is modified to estimate the equilibrium air-dry unit weight.~~ concrete.

1.2 The values stated in ~~inch-pound~~ SI units are to be regarded as the standard. The values given in parentheses are ~~provided~~ 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 ~~88 Test Method~~ 31/C 31M Practice for ~~Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate~~ Making

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[1] This test method is under the jurisdiction of ASTM Committee ~~C-9~~ C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.21 on Lightweight Aggregates and Concrete.

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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:*

~~3.1.1 *Equilibrium Air-Dry Unit Weight*—The unit weight~~

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 ~~73.4~~ 23 ± ~~3°F (23± 1.7°C)~~ 2°C (73.5 ± 3.5°F) for a period of time sufficient to reach ~~equilibrium. Equilibrium is the condition where the mass of the specimen changes not more than 0.1 % (gain or loss)~~ constant mass.

3.2.2 *oven-dry density*—the density as determined in ~~successive weighings 28 days apart.~~ 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 ~~unit weight~~ oven-dry and equilibrium densities of structural lightweight ~~concrete involves the preparation, curing,~~ concrete, by calculation or measurement. The calculated oven-dry density is determined from batch quantities and ~~measurement~~ volume of ~~lightweight structural concrete specimens.~~ a given batch of concrete. The ~~concrete~~ calculated equilibrium density is ~~mixed, placed, and tamped in concrete cylinder molds and cured in~~ approximated by adding a ~~prescribed moist room for~~ fixed quantity to the oven-dry density. Measured densities are obtained from determinations of the mass of cylindrical specimens after specified ~~curing period.~~ treatments.

5. Significance and Use

5.1 The ~~test for air-dried weight~~ measured or calculated equilibrium density of structural lightweight concrete determines whether ~~design weight~~ 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 ~~*Balance*—A balance or scale accurate within 0.3 % of the weight of the sample at any point within the range of use. The range of use~~Tamping Rod, Mallet, Measure, Balance, and Molds—These shall ~~be considered~~ conform to ~~extend from~~ the ~~weight~~ requirements of ~~the container empty to the weight of the container plus its contents.~~

~~6.2 *Tamping Rod*—A round, straight, steel rod, ⅝ in. (16 mm) in diameter and approximately 24 in. (610 mm) in length, having the tamping end rounded to a hemispherical tip the diameter of which is ⅝ in. (see~~ Test Method C 138~~)~~ and Specification C 470.

6.3~~1~~.1 *Measure*—A ~~½ ft~~ 14-L (0.5-ft^3~~(0.01 m^3) capacity)~~ measure ~~as described in 4.4 of Test Method C 138,~~ shall be the ~~standard. Measures with capacities and requirements conforming to Table 1 may be used for information purposes, except that the same capacity container shall be used for comparative purposes.~~

~~6.4 *Molds*—Molds shall be cylindrical in form. They shall be as described in Specification C 470/C 470M.~~

~~6.5~~ standard (see Note 3).

6.2 *Controlled Humidity Enclosure*~~—The preferred condition is a~~—A room controlled at 50 ± 5 % relative ~~humidity. In the event that~~ humidity and 23 ± 2°C (73.5 ± 3°F) or a ~~room in the testing laboratory is not air conditioned at 50 % relative humidity, the condition can be maintained in a~~ small ~~chamber, such as a metal container with a gasket lid. Description of the~~ chamber ~~method is described in Practice E 104.~~

[2] *Annual Book of ASTM Standards*, Vol 04.02.
[3] *Annual Book of ASTM Standards*, Vol ~~14.02.~~ 11.03.

NOTE 2—A nearly saturated solution of calcium chloride frequently replenished with the dry salts can be used as an initial desiccant for meeting the storage period, provided adequate internal air circulation is furnished and a reliable hygrometer is used. For the latter days requirements of the storage cycle, a saturated solution of magnesium nitrate can be used to maintain a relative humidity of 53.5 %.

6.6 Practice E 104.

6.3 *Drying Oven*—The—An oven shall be of appropriate size capable of being heated continuously between 110 ± maintaining a uniform temperature of 110± 5°C (230 ± 9°F), and the an average evaporation rate of evaporation shall average at least 25 g/h. Determination of evaporating Determine evaporation rate is described 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 P*Specimens for Deptermining Equilibrium Density and Oven-dry Density*—Determine the equilaib-rium densixty 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 unit weight density of the freshly mixed concrete in accordance with Test Method C 138 with the following exceptions:

8.1.1 Vibration of specimens as described in 6.4.3 of Practice C 192/C 192M shall be permitted if applicable.

8.1.2 Where the procedure is by rodding, it shall be in accordance with 7.2 of Test Method C 138, except that concrete in containers with capacities of 0.50 ft^3 (0.014 m^3) or less shall be rodded 25 strokes/layer; containers greater than 0.50 ft^3(0.014 m^3) and 1.0 ft^3 (0.03 m^3) shall be rodded 50 strokes per layer.

8.1.3 The net weight of the sample shall be recorded to the nearest 0.3 %. C 138.

NOTE 3—CEB-FIP Manual of Design & Technology 1977[4] reports 3—Numerous observations indicate that equilibrium 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 structural lightweight concrete is equal to the calculated dry density plus equilibrium moisture content at 5 % consolidated by volume which equals 50 rodding, in accordance with Practice C 192/C 192M or Practice C 31/C 31M will average 40 kg/m^3 (3 pcf).

8.2 Determine(2.5 lb/ft^3) higher than the air-dry unit weight on 6 by 12 in. (152 by 305 mm) cylinders. Make test specimens fresh density as measured using a 14-L (0.5-ft^3) measure in accordance with Practice C 192/C 192M. Cover test specimens made to check the adequacy Test Method C 138.

8.2 *Measurement of Equilibrium Density*—To measure the laboratory design for unit weight of concrete, or as the basis for acceptance, immediately (Note 5) after molding with one of the following: (*1*) a paraffin-coated cardboard lid, (*2*) a metal lid, (*3*) a polyethylene sheet tightly secured around the cylinder, or (*4*) other waterproof sheet material. During the first 7 days, store all test specimens under conditions that maintain the temperature immediately adjacent to the specimens in the range of 60 to 80°F (16 to 27°C) and that prevent loss of moisture from the specimens. The specimen may be stripped after 24 h and wrapped securely with a polyethylene sheet or bag to prevent evaporation. When single-use molds are used, the specimen may remain in the mold for the entire 6-day curing period (see 8.3).

NOTE 4—Delay is permissible in cases where concrete tends to bleed excessively.

8.3 On the sixth day, equilibrium density, remove the specimens cylinders from their molds or curing condition on the sixth day and immerse in water at 73.4 23 ± 3°F (23± 1.7°C) 2°C (73.5 ± 3°F) for 24 h. Determine Measure the saturated surface-dry weights.

NOTE 5—Where specimens are stripped after 24 h apparent mass of age they may be used at that time for determining the cylimmnders while suspended and saturated surface dry weights (C completely submerged in water and B record as "C," the mass of 8.4). Return the suspended-immersed cylinder. Remove from the water ansd allow to drain for 1 min by placing the curing condition until they have reached cylinder on a 9.5-mm (⅜-in.) or coarser sieve cloth. Remove visible water with a damp cloth, determine the age mass and record as "B," the mass of 7 days.

8.4 Dry the saturated-surface-dry cylinder. Dry the cylinders for 21 days at a temperature of 73.4 ± 3°F (23 ± 1.7°C) with all surfaces exposed, in a relative controlled humidity enclosure as described in 6.2 until the mass of 50± 5 %. Weigh 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 calculate record as "A," the air-dry weight per cubic foot (or cubic metre) mass of the dried cylinder. Calculate the

equilibrium density of the concrete from the following equations: Eq 1 and 2.

~~Weight, lb/ft^3 = (A × 62.3)/(B–C)~~ (1)

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

~~Weight, kg/m^3 = (A × 997)/(B–C)~~ (2)

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

BC

where:

E_m = measured equilibrium density, kg/m^3(lb/ft^3),
A = ~~28 day weight~~mass of ~~concrete cylinder,~~ cylinder as dried, ~~lb (kg),~~ kg (lb),
B = ~~saturated, surface-dry weight~~mass of saturated surface-dry cylinder, ~~lb (kg),~~ kg (lb), and
C = ~~suspended-immersed weight~~apparent mass of suspended-immersed cylinder, ~~lb (kg).~~ kg (lb).

~~9. Calculations and Reporting for Rapid Information~~

~~9.1 An estimated air-dry weight may be calculated for project control. This test method should~~

8.3 *Measurement of Oven-Dry Density*—After 24 h but not ~~b~~ 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 ~~acceptance~~ 72 h or ~~design control. This test method should be used only when rapid information~~ until constant mass is ~~desired.~~

~~9.2 *Calculated Oven-Dry Weight*—An approximate calculated oven-dry weight may be determined for application in~~ reached. Maintain oven temperature at 110 ± 5°C (230 ± 9°F). Allow cylinders to cool to room temperature and determine the ~~approximate method where all batch quantities,~~ mass and record as "D," the ~~moisture content~~ mass of the ~~aggregates,~~ oven-dried cylinder. Repeat oven-drying and ~~the volume~~ determination of mass at 24-h intervals until the ~~batch~~ mass of ~~concrete are known from~~ the ~~following equation:~~ specimen changes not more than 0.5 % in successive weighings 24 h apart. Determine the oven-dry density from Eq 3 and 4.

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

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

~~$O_c = (W_{df} + W_{dc} + 1.2W_{ct})/S$~~ (5)

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

1.2V

where:

O_c = ~~approximate~~calculated oven-dry ~~weight, lb/ft~~ density, kg/m^3 ~~(kg/m~~(lb/ft^3),
~~W~~M_{df} = ~~weight~~mass of dry fine aggregate in batch, ~~lb (kg),~~ kg(lb),
~~W~~M_{dc} = ~~weight~~mass of dry coarse aggregate in batch ~~lb (,~~ kg(lb),
~~W~~M_{ct} = ~~weight~~mass of cement in batch, ~~lb (kg),~~ kg (lb),
1.2 = ~~quantity of cement, plus weight of water of hydration (considering water of hydration~~factor to ~~be 20 % of~~ approximate the ~~weight~~ mass of cement~~)~~ plus chemically combined water, and
~~S~~ V = volume of concrete produced by the ~~batch, ft~~ batch m^3 ~~(m~~(ft^3).

9.3~~2~~ *Calculation of Approximate~~d~~ Equilibrium ~~Unit Weight—~~* Using Density—Using the ~~procedure and definitions~~ oven-dry density determined in accordance with 8.3 or 9.~~2~~1, calculate the approximate equilibrium ~~unit weight may be calculated by:~~ density from Eq 6 and 7.

~~$E_c = O_c + 3$~~ (6)

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

or

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

where:

E_c = calculated equilibrium unit weight. density (see Note 1).

9.4 *Observed Oven-Dry Weight*—Store the test specimens for the first 24 h under conditions that maintain temperature immediately adjacent to the specimens in the range from 60 to 80°F (16 to 27°C)

10. Report

10.1 When oven-dry and that prevent loss of moisture from equilibrium densities are determined by measurements, the specimens. After 24 h remove the cylinder from the mold and place in the drying oven for 72 h. Maintain the oven at 110 ± 5°C (230 ± 9°F). Allow the specimens to cool to room temperature and then weigh.

9.5 *Approximate Air-Dry Weight*—Calculate the approximate air-dry weight per cubic foot (cubic metre) from the report shall include following equation:

$$D = O + (F - O)P \quad (5)$$

where:

D = approximate air-dry weight, lb/ft information:

10.1.1 Fresh density, kg/m^3 (kg/m(lb/ft^3),

F = fresh unit weight, lb/ft).

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 (kg/m(0.5 lb/ft^3), determined in accordance with 9.1,

O = oven-dry weight, lb/ft).

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 (kg/m(0.5 lb/ft^3), determined in accordance with 9.2 or 9.3, and

P = a constant which is).

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

10.2.1 Fresh density, kg/m^3 (lb/ft^3).

10.2.2 Mass of the differential between the fresh cement and oven-dry weights that approximates the weight dry aggregates, batched, kg (lb).

10.2.3 Volume of retained moisture in the concrete when it is air dry. The value ranges produced from 0.75 to 0.25.

NOTE 6—Observations indicate that the batch, m^3 P may vary between 0.75 and 0.25 because of variations in aggregates and mix designs. The value for a specific aggregate may be obtained from(ft^3).

10.2.4 Calculated oven-dry density, to the laboratory supplying the initial mix design or from the aggregate supplier. In the absence of a special value for nearest 10 kg/m^3 P, 0.75 shall be used.

10. Precision and Bias

10.1 At present, there is insufficient data available(0.5 lb/ft^3).

10.2.5 Calculated approximate equilibrium density, to justify a precision and bias statement for this test method. 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

11.1 air-dry unit weight;

12.1 equilibrium density; lightweight concrete; unit weight oven-dry density