Designation: C 796 – 04

# Standard Test Method for Foaming Agents for Use in Producing Cellular Concrete Using Preformed Foam[1]

This standard is issued under the fixed designation C 796; 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 furnishes a way of measuring, in the laboratory, the performance of a foaming chemical to be used in producing foam (air cells) for making cellular concrete.

1.2 This test method includes the following:

1.2.1 Manufacture of laboratory quantities of cellular concrete.

1.2.2 Determination of the air content of the freshly prepared cellular concrete and of the hardened concrete after handling in conventional machinery.

1.2.3 Determination of the following properties of the hardened concrete: compressive strength, tensile splitting strength, density, and water absorption. It may not be necessary to study all of the above properties in all cases, depending on the proposed use of the material.

1.3 The values stated in inch-pound 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.*

1.5 The text of this standard references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

## 2. Referenced Documents

2.1 *ASTM Standards:* [2]

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

C 150 Specification for Portland Cement

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

C 495 Test Method for Compressive Strength of Lightweight Insulating Concrete

C 496/C 496M Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens

C 511 Specification for Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes

C 802 Practice for Conducting an Interlaboratory Test Program to Determine the Precision of Test Methods for Construction Materials

C 869 Specification for Foaming Agents Used in Making Preformed Foam for Cellular Concrete

## 3. Terminology

3.1 *Definitions:*

3.1.1 *cellular concrete*—a lightweight product consisting of portland cement, cement-silica, cement-pozzolan, lime-pozzolan, or lime-silica pastes, or pastes containing blends of these ingredients and having a homogeneous void or cell structure, attained with gas-forming chemicals or foaming agents (for cellular concretes containing binder ingredients other than, or in addition to portland cement, autoclave curing is usually employed).[3] In cellular concrete the density control is achieved by substituting macroscopic air cells for all or part of the fine aggregate. Normal-weight coarse aggregate is usually not used but lightweight aggregates, both fine and coarse, are often utilized in cellular concrete.

3.2 *Symbols:*

$D_{ex1}$ = experimental density of the concrete before pumping, $lb/ft^3 (kg/m^3)$

$D_{ex2}$ = experimental density of the concrete after pumping, $lb/ft^3 (kg/m^3)$

$D_{th}$ = theoretical density of the plastic mix based on absolute volume, $lb/ft^3 (kg/m^3)$

$D_d$ = design density of the text mixture, $lb/ft^3 (kg/m^3)$

$SGC$ = specific gravity of cement = 3.15

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[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.23 on Chemical Admixtures.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] ACI Committee 116, "Cement and Concrete Terminology," American Concrete Institute, Publication SP-19, 1967, p. 144.

$T$ = time required to overfill the container, min
$T_1$ = time required to generate 1 ft$^3$(1 m$^3$) of foam, min
$V$ = volume of foam container, ft$^3$(m$^3$)
$V_a$ = volume of air required in the test batch, ft$^3$(m$^3$)
$V_c$ = volume of test specimen (cylinder), ft$^3$(m$^3$)
$V_f$ = volume of foam in the test batch, ft$^3$(m$^3$)
$V_w$ = volume of water absorbed by test specimen in 24 h, ft$^3$(m$^3$)
$W_1$ = net weight of foam in overfilled container before striking off, lb (kg)
$W_2$ = net weight of foam in container after striking off, lb (kg)
$W_c$ = weight of cement in the test batch, lb (kg)
$W_f$ = weight of foam in the test batch, lb (kg)
$W_{TW}$ = total weight of water in the test batch, including weight of foam, lb (kg)
$W_{uf}$ = density of foam, lb/ft$^3$(kg/m$^3$)
$W_w$ = weight of water added to test batch at mixer, lb (kg)

## 4. Summary of Test Method

4.1 This test method includes the following:

4.1.1 Manufacture of laboratory quantities of cellular concrete.

4.1.2 Determination of the air content of freshly prepared cellular concrete and of hardened concrete after handling in conventional machinery.

4.1.3 Determination of the following properties of hardened concrete: compressive strength, tensile splitting strength, density, and water absorption. It may not be necessary to study all of the above properties in all cases, depending on the proposed use of the material.

## 5. Significance and Use

5.1 This test method is used to develop data for comparison or compliance with the requirements of Specification C 869.

## 6. Apparatus

6.1 *Mixer*—The mixer shall be a power-driven paddle-type mixer with a capacity of at least 4 ft$^3$(0.12 m$^3$), an operating speed of 40 to 50 r/min (4.2 to 5.2 rad/s), and equipped with rubber wiper blades.

6.2 *Foam Generator*—The foam generator shall be a laboratory-sized generator approved by the manufacturer of the foam being used and shall be similar to the type used in the field.

6.3 *Pump*—The pump shall be an open or closed throat-type pump and shall be run at 260 to 630 r/min (27.2 to 66.0 rad/s). The pump shall be equipped with a 4.5-ft$^3$(0.13-m$^3$)" feed" reservoir and 50 ft (15 m) of open-end 1-in. (25-mm) inside diameter rubber hose on the pump discharge, the exit end of the hose being at the same height as the pump.

6.4 *Curing Cabinet*—The curing cabinet shall be as described in Specification C 511.

6.5 *Molds*—The cylindrical molds for compression test specimens shall be as described in the Apparatus section of Test Method C 495. The molds for all other test specimens shall conform to the cylinder molds in the Apparatus section of Practice C 192/C 192M.

6.6 *Strike-Off Plate for Molds*—A ¼-in. (6-mm) thick, flat steel plate at least 8 in. (200 mm) longer and 2 in. (50 mm) wider than the diameter of the mold.

6.7 *Scales*—Scales and weights shall be accurate to within 0.1 % of the weight of the material being measured.

6.8 *Compression Machines*—Compression testing machines used for compressive strength tests and tensile-splitting strength tests shall conform to the requirements of Test Methods C 495 and C 496/C 496M, respectively.

6.9 *Drying Oven*—The drying oven shall be as described in Test Method C 88.

6.10 *Compressed Air*—A source of compressed air capable of maintaining pressures in the range of 60 to 100 psi (0.4 to 0.7 MPa) to ±1 psi (±0.007 MPa).

6.11 *Weighing Container for Concrete*— A machined-steel container of 0.5 ft$^3$(0.014 m$^3$) volume with a flat smooth rim.

6.12 *Strike-Off Plate for Weighing Container*—A ¼-in. (6-mm) thick, flat steel plate, at least 8 in. (200 mm) longer and 2 in. (50 mm) wider than the diameter of the rim of the weighing container.

6.13 *Stop Watch*—A stop watch graduated in seconds and minutes.

6.14 *Calipers*—Calipers to span 3, 6, and 12 in. (76, 152, and 305 mm).

6.15 *Foam Weighing Container*—A lightweight vessel of approximately 2 ft$^3$(0.06 m$^3$) capacity, with a smooth rim for striking off.

6.16 *Strike-Off Plate for Foam Weighing Container*—A ¼-in. (6-mm) thick, flat steel plate at least 8 in. (200 mm) longer and 2 in. (50 mm) wider than the diameter of the rim of the container.

6.17 *Small Tools*—Small tools such as a rubber-headed hammer and a trowel shall be provided.

## 7. Materials and Proportions

7.1 *Cement*—The cement used shall be Type I or Type III portland cement meeting the requirements of Specification C 150.

7.2 *Water-Cement Ratio*—The water requirement will vary with the type and source of cement. For the purpose of these tests, $w/c$ = 0.58 for Type I cement and $w/c$ = 0.64 for Type III cement shall be used. However, if a particular cement or foaming agent used with these values of $w/c$ does not produce a satisfactory mix, a trial mix or mixes may be made using a different water-cement ratio.

7.3 *Batch Quantities*—The cement quantity shall be sufficient to allow molding all the test specimens from one test batch. The mixture water-cement ratio determined from 7.2 shall be used to make the test batch.

7.3.1 The foaming solution in the foam shall be considered as part of the total mixing water. Foam volume shall be adjusted for the batch to produce a density after pumping of 40 ± 3 lb/ft$^3$(641 ± 48 kg/m$^3$).

## 8. Procedure

8.1 Make an aqueous solution of the foaming agent in the dilution specified by the manufacturer. If the dilution is not specified, preliminary tests are necessary to determine the required dilution. A suggested starting point for such tests is 40 parts water to 1 part foaming agent, by volume.

8.2 Charge the foam generator with the amount of foaming solution suggested by the manufacturer of the generator.

8.3 Connect the generator with the source of compressed air, adjusting the pressure to that recommended by the manufacturer of the foaming agent being tested.

8.4 Using the stop watch, calibrate the generator as follows. Weigh the empty foam container and determine its volume. Overfill the container with foam, measuring the time required using a stop watch then weigh. Strike off the excess foam, holding the strike-off plate in a horizontal position (plane of the plate horizontal) and moving it across the top of the container with a sawing action. Again weigh. Calculate the time required per cubic foot (or cubic metre) of foam using the following equation:

$$T_1 = (T \times W_2)/(W_1 \times V) \quad (1)$$

8.4.1 Calculate also the unit weight of the foam as follows:

$$W_{uf} = W_2/V \quad (2)$$

8.4.2 Calculate the length of time required to generate the required volume of foam, $V_f\ T_1$, as follows:

$$V_f T_1 = 62.4\ V_a T_1/(62.4 - W_{uf})\ (V_f T_1 = 1000\ V_a T_1/(1000 - W_{uf})) \quad (3)$$

8.4.3 Calculate the weight, $W_f$, of the required volume of foam, $V_f W_{uf}$.

NOTE 1—The weight of the foam will usually range from 2 to 4 lb/ft$^3$ (32 to 64 kg/m$^3$) depending on the foam chemical used. Adjust the unit weight of foam, $W_{uf}$, to the manufacturer's recommendation if the foam generator is adjustable.

8.4.3.1 If Type I cement is used, weigh out 58.0 – $W_f$ lb (26.31 – $W_f$ kg) of water, $W_w$, and 100.0 lb (45.36 kg) of Type I cement.

8.4.3.2 If Type III cement is used, weigh out 64.0 – $W_f$ lb (29.03 – $W_f$ kg) of water, $W_w$, and 100.0 lb (45.36 kg) of Type III cement.

8.5 Wet the mixer with water and drain. Add the water, $W_w$, and start the mixer. Gradually add the cement (over a period of ½ min). With a trowel, break up any lumps of undispersed cement. Mix for 5 min.

8.6 While still mixing, add $V_f$ ft$^3$(m$^3$) of foam. The required foam time is $V_f T_1$. Mix for 2 min after all the foam has been added. Discharge the mixer into the pump feed reservoir. Immediately, proceed to 8.7.

8.7 *Weighing*—Fill a tared weighing container with a representative sample of the concrete in the reservoir. Before taking the sample, carefully mix the concrete in the reservoir to assure better uniformity without entrapping large air bubbles in the mix. Use a paddle of proper size to reach the bottom of the reservoir. Use a scoop to transfer the concrete to the container and tap the sides of the container briskly with the rubber hammer during the filling operation. Overfill the container and strike off the excess concrete, holding the strike-off plate in a horizontal position (plane of plate horizontal) and moving it across the top of the container with a sawing motion. Wipe the surface of the container free of spilled concrete with a cloth. Weigh the full container. Calculate the density of the concrete and record as the density before pumping ($D_{ex1}$).

8.7.1 Pump the batch of concrete through the 50-ft (15-m) hose, discharging it into a sampling basin. From the sampling basin, take a second density sample as in 8.7, weigh, and record as the density after pumping ($D_{ex\ 2}$).

8.8 *Molding*—Immediately, fill the cylinder molds with concrete from the sampling basin. Tap the sides of the mold with the rubber hammer while the mold is being filled. The minimum number of specimens required is four cylinders, 3 by 6 in. (76 by 152 mm) and ten cylinders 6 by 12 in. (152 by 305 mm).

8.8.1 As soon as possible after casting, strike off the top surface of each specimen and cover the specimen with a plastic bag to prevent evaporation, without marring the surface.

8.9 *Removal from Molds and Curing*— Follow the applicable requirements of the Test Specimen section of Test Method C 495 with the following exception: continue air drying from day 25 to day 28 in place of oven drying the specimens. Do not oven dry specimens that are to be load-tested.

8.10 *Compressive Strength*—Test four 3 by 6-in. (76 by 152-mm) cylinders for compressive strength in accordance with Test Method C 495.

8.11 *Tensile Splitting Strength*—Test four 6 by 12-in. (152 by 305-mm) cylinders for tensile splitting strength at age 28 days in accordance with Test Method C 496/C 496M, for lightweight concrete.

8.12 *Oven-Dry Weight*—Determine the oven-dry density in accordance with the section on Oven-Dry Weight of Test Method C 495. Use three 6 by 12-in. (152 by 305-mm) cylinders from 7.9 at age 28 days.

8.13 *Water Absorption*:

8.13.1 Take three 6 by 12-in. (152 by 305-mm) specimens from 8.9 at age 28 days. Take the dimensions with calipers as described in the Test Specimen Section of Test Method C 495.

8.13.2 Submerge the specimens 6 in. (150 mm) below the water surface. Maintain the water temperature at 73.5 ± 3.5 °F (23.0 ± 2.0 °C). Remove from water, allow excess water to run off (30 s) and weigh. This is the wet weight of the specimen.

## 9. Calculation

9.1 *Air Content*:

9.1.1 Determine the experimental density of the freshly mixed concrete at the mixer, $D_{ex1}$, and at the pump discharge (end of hose), $D_{ex2}$, by dividing the net weights of the samples from 8.7 and 8.7.1 by the volume of the container. Record to the nearest 0.5 lb/ft$^3$(8 kg/m$^3$).

9.1.2 Determine the experimental density of the specimens from 8.12 before and after drying from the weights and volumes of the specimens. Use three 6 by 12-in. (152 by 305-mm) cylinders. Record to the nearest 0.5 lb/ft$^3$(8 kg/m$^3$).

9.1.3 Determine the air content of the freshly mixed concrete from the experimental densities, before and after pumping, and the theoretical density, $D_{th}$, based on the absolute volume. Record the air content to the nearest 1 %. Calculate the theoretical density in lb/ft$^3$(kg/m$^3$) as follows:

*Inch-Pound Units:*

$$D_{th} = (W_w + W_c + W_f)/[(W_w/62.4) + (W_c/(SGC \times 62.4)) + (W_f/62.4)] \quad (4)$$

*SI Equivalents:*

$$D_{th} = (W_w + W_c + W_f)/[(W_w/1000) + (W_c/(SGC \times 1000)) + (W_f/1000)] \quad (5)$$

9.1.3.1 Calculate the air content before pumping or the percent of air at the mixer as follows:

$$\text{Air content before pumping} = 100\,[1 - (D_{ex1}/D_{th})] \quad (6)$$

9.1.3.2 Calculate the air content after pumping, or the percent of air at end of hose as follows:

$$\text{Air content after pumping} = 100\,[1 - (D_{ex2}/D_{th})] \quad (7)$$

NOTE 2—Using the prescribed procedure and assuming the specific gravity of cement is 3.15 and that the total water used is 58.0 lb (26.31 kg) for Type I cement, the theoretical density is 109.9 lb/ft$^3$(1761 kg/m$^3$). Similarly, for Type III cement the total water is 64.0 lb (29.03 kg) and the theoretical density is 106.9 lb/ft$^3$(1712 kg/m$^3$).

9.1.4 Calculate the loss of air during pumping as the difference between the air content before and after pumping. Record to the nearest 1 %.

$$\text{Loss of air, \% by volume} = 100\,[(D_{ex2} - D_{ex1})/D_{th}] \quad (8)$$

9.1.5 Calculate the design density ( $D_d$) of the test mixture in lb/ft$^3$(kg/m$^3$) as follows:

*Inch-Pound Units:*

$$D_d = (W_w + W_c + W_f)/[(W_w/62.4) + (W_c/SGC \times 62.4) + V_f] \quad (9)$$

*SI Equivalents:*

$$D_d = (W_w + W_c + W_f)/[(W_w/1000) + (W_c/SGC \times 1000) + V_f] \quad (10)$$

9.2 *Water Absorption*:

9.2.1 Find the average weight of water absorbed by the cylinders by subtracting the average dry weight of cylinders (see 8.12) from the average wet weight of cylinders (see 8.13). Record to the nearest 0.1 lb (or 0.05 kg).

9.2.2 Find the average volume of water absorbed by dividing the average weight of water absorbed by the density of water in lb/ft$^3$(kg/m$^3$). Determine the water absorption using the following equation:

$$\text{absorption, \% by volume} = (V_w/V_c) \times 100 \quad (11)$$

Record absorption to the nearest 0.5 %.

## 10. Report

10.1 Using the degrees of precision specified in Section 9, report the following:

10.1.1 Identification of chemical tested, including manufacturer's name, brand, and lot number,

10.1.2 Water to cement ratio and type of cement used,

10.1.3 Air content before and after pumping,

10.1.4 Oven-dry density,

10.1.5 Water absorption, % by volume,

10.1.6 Compressive strength,

10.1.7 Loss of air during pumping, %,

10.1.8 Tensile splitting strength, and

10.1.9 Difference between design density and experimental densities before and after pumping.

## 11. Precision and Bias

11.1 *Precision*[4]

11.1.1 Data used to develop the precision statement were obtained using the inch-pound version of this test method. The precision indices shown in parenthesis are exact conversions of the values in inch-pound units. Data were obtained from three laboratories for one material.

11.1.2 *Single-Operator Precision*—The single-operator standard deviations are listed in the third column of Table 1.

TABLE 1 Single Operator Precision

| Test | Avg. of Laboratory Averages | Standard Deviation (1s) | Acceptable Range of Two Results (d2s) |
|---|---|---|---|
| Compressive Strength, psi (MPa) | 427 (2.9) | 61 (0.4) | 171 (1.2) |
| Splitting Tensile Strength, psi (MPa) | 46 (0.3) | 9 (0.06) | 24 (0.2) |
| Density, lb/ft$^3$ (kg/m$^3$) | 31.3 (501) | 1.7 (27) | 4.8 (77) |
| Absorption, % | 17.8 | 0.6 | 1.8 |

Therefore, results of two properly conducted tests by the same operator are not expected to differ by more than the values shown in the fourth column of Table 1.

11.1.3 *Multilaboratory Precision*—The multilaboratory standard deviations are listed in the third column of Table 2. Therefore, results of two properly conducted tests on the same material by two different laboratories are not expected to differ by more than the values shown in the fourth column of Table 2.

11.1.4 The numbers of laboratories and materials used in the interlaboratory study do not meet the minimum requirements for determining precision prescribed in Practice C 802. This precision statement is provisional. Within five years, additional data that meets the requirements of Practice C 802 will be obtained and processed.

11.2 *Bias*

11.2.1 Since there is no accepted reference material for determining the bias of this test method, no statement on bias is made.

[4] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:C09–1027.

TABLE 2 Multilaboratory Precision

| Test | Avg. of Laboratory Averages | Standard Deviation (1s) | Acceptable Range of Two Results (d2s) |
|---|---|---|---|
| Compressive Strength, psi (MPa) | 427 (2.9) | 68 (0.5) | 190 (1.3) |
| Splitting Tensile Strength, psi (MPa) | 46 (0.3) | 8.6 (0.06) | 24 (0.2) |
| Density, lb/ft$^3$ (kg/m$^3$) | 31.3 (501) | 2.0 (32) | 5.6 (90) |
| Absorption, % | 17.8 | 0.6 | 1.8 |

# APPENDIX

## (Nonmandatory Information)

## X1. DERIVATION OF FORMULA FOR FOAM VOLUME

X1.1 The formula for foam volume required for the test batch may be derived as follows:

X1.1.1 Knowing the wet density, 40 lb/ft$^3$ (641 kg/m$^3$), calculate the volume of air required as follows:

*Inch-Pound Units:*

$$\text{Wet density, } 40 \text{ lb/ft}^3 = (W_{TW} + W_c)/[(W_{TW}/62.4) + (W_c/(3.15 \times 62.4)) + V_a] \quad \text{(X1.1)}$$

*SI Equivalents:*

$$\text{Wet density, } 641 \text{ kg/m}^3 = (W_{TW} + W_c)/[(W_{TW}/1000) + (W_c/(3.15 \times 1000)) + V_a] \quad \text{(X1.2)}$$

X1.1.2 Solving for the volume of air required in cubic feet (or cubic metres):

*Inch-Pound Units:*

$$V_a = (0.359\, W_{TW} + 0.7965\, W_c)/40 \text{ ft}^3 \quad \text{(X1.3)}$$

*SI Equivalents:*

$$V_a = (0.359\, W_{TW} + 0.7965\, W_c)/641 \text{ m}^3 \quad \text{(X1.4)}$$

X1.2 The air volumes required for the test batches are as follows:

| Type of Cement | $V_a$, ft$^3$(m$^3$) |
|---|---|
| Type I | 2.51 (0.071) |
| Type III | 2.57 (0.073) |

X1.3 Treating the diluted foam chemical as water (sp gr = 1) the following relationships between air volume and foam volume may be stated:

$$V_f = V_a + (W_f/62.4)/\text{ft}^3 \quad \text{or} \quad V_f = V_a + (W_f/1000)/\text{m}^3 \quad \text{(X1.5)}$$

X1.4 If $W_{uf}$ is the unit weight of foam, then $W_f = W_{uf} \times V_f$ and the equation in X1.3 may be stated in the following manner:

$$V_f - (W_{uf}V_f/62.4) = V_a \text{ ft}^3 \quad \text{or} \quad V_f - (W_{uf}V_f/1000) = V_a\text{m}^3 \quad \text{(X1.6)}$$

$$V_f = V_a/[1 - (W_{uf}/62.4)]/\text{ft}^3 \quad \text{or} \quad V_f = V_a/[1 - (W_{uf}/1000)]/\text{m}^3, \quad \text{and} \quad \text{(X1.7)}$$

$$V_f = 62.4\, V_a/(62.4 - W_{uf})/\text{ft}^3 \quad \text{or} \quad V_f = 1000\, V_a/(1000 - W_{uf})/\text{m}^3 \quad \text{(X1.8)}$$