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StandardSpecification for Lightweight Aggregate for Internal Curing of Concrete[1]

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1. Scope

1.1 This specification covers lightweight aggregate intended to provide water for internal curing of concrete. It includes test methods for determining the absorption and desorption properties of lightweight aggregate.

NOTE 1—Internal curing provides an additional source of water to sustain hydration and substantially reduce the early-age autogenous shrinkage and self-desiccation that can be significant contributors to early-age cracking. Appendix X1 provides guidance on calculating the quantity of lightweight aggregate for internal curing.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance. Some values have only SI units because the inch-pound equivalents are not used in practice.

NOTE 2—Sieve size is identified by its standard designation in Specification E11. The alternative designation given in parentheses is for information only and does not represent a different standard sieve size.

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

1.4 *This specification 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:*[2]

C29/C29M Test Method for Bulk Density (“Unit Weight”) and Voids in Aggregate
C40 Test Method for Organic Impurities in Fine Aggregates for Concrete
C87 Test Method for Effect of Organic Impurities in Fine Aggregate on Strength of Mortar
C114 Test Methods for Chemical Analysis of Hydraulic Cement
C125 Terminology Relating to Concrete and Concrete Aggregates
C128 Test Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate
C136 Test Method for Sieve Analysis of Fine and Coarse Aggregates
C142 Test Method for Clay Lumps and Friable Particles in Aggregates
C330/C330M Specification for Lightweight Aggregates for Structural Concrete
C641 Test Method for Iron Staining Materials in Lightweight Concrete Aggregates
C702 Practice for Reducing Samples of Aggregate to Testing Size
C1498 Test Method for Hygroscopic Sorption Isotherms of Building Materials
C1608 Test Method for Chemical Shrinkage of Hydraulic Cement Paste
C1698 Test Method for Autogenous Strain of Cement Paste and Mortar
D75 Practice for Sampling Aggregates
E11 Specification for Woven Wire Test Sieve Cloth and Test Sieves

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms used in this practice, refer to Terminology C125.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *absorption, A_{72}, n*—of lightweight aggregate, the increase in mass of a specimen of oven-dry lightweight aggregate due to water penetrating into the permeable pores of the particles after being submerged for 72 h, expressed as percentage of oven-dry mass.

3.2.2 *autogenous shrinkage, n*—reduction in volume due to chemical shrinkage of a sealed cementitious mixture, not subjected to external forces and under constant temperature, measured from the time of final setting.

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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.

3.2.2.1 *Discussion*—The chemical shrinkage leads to emptying of the internal pores (see self-desiccation) that causes the formation of menisci in the partially water-filled pores. The menisci in turn give rise to internal tensile stresses that cause bulk shrinkage. While autogenous shrinkage is due to the chemical shrinkage, the magnitude of autogenous shrinkage is less than the chemical shrinkage after setting occurs, because the aggregate particles and the hydrated cement paste network restrain the shrinkage. The restraint may in turn lead to cracking.

3.2.3 *chemical shrinkage, n*—the reduction in volume of cementitious paste that occurs during hydration because the hydration products occupy less volume than the volume occupied originally by the water and unhydrated cementitious materials.

3.2.4 *density (OD), n*—of lightweight aggregate, the mass of oven-dry lightweight aggregate particles per unit volume of aggregate particles, where the volume includes the permeable and impermeable pores within the particles but does not include the voids between the particles.

3.2.5 *desorption, n*—of lightweight aggregate, the decrease in mass of lightweight aggregate originally containing absorbed water due to water leaving the permeable pores as the aggregate attains moisture equilibrium with the surrounding environment maintained at constant temperature and a relative humidity less than 100 %.

3.2.6 *internal curing, n*—supplying water within a cementitious mixture using pre-wetted lightweight aggregate, or other materials that readily release water from within the particles, thereby mitigating self-desiccation and sustaining hydration.

3.2.7 *oven-dry (OD), adj*—related to lightweight aggregate particles, the condition in which the specimen of lightweight aggregate has been dried by heating in an oven at 110 ± 5 °C [230 ± 10 °F] for sufficient time to reach a constant mass.

3.2.8 *relative density, (OD), n*—of lightweight aggregate, the ratio of the density (OD) of the lightweight aggregate to the density of water at a stated temperature.

3.2.9 *wetted surface-dry (WSD), adj—related to lightweight aggregate particles*, the condition in which the permeable pores of lightweight aggregate particles are filled with water, to the extent achieved by submerging an oven-dry specimen for 72 h, and the surfaces of the particles are dry.

3.2.10 *self-desiccation, n*—reduction in the internal relative humidity of a sealed cementitious mixture, due to chemical shrinkage, that may reduce the rate of hydration or stop hydration.

3.3 *Symbols:*

A_{72} = the 72-h absorption, expressed as a percentage of the oven-dry mass.

G_{OD} = relative density (oven-dry) of lightweight aggregate.

G_{ODN} = relative density (oven-dry) of normal weight aggregate.

M_{LWA} = calculated mass of oven-dry lightweight aggregate needed for internal curing per unit volume of concrete, kg/m^3 [lb/yd^3].

M_{NWA} = mass of normal weight aggregate in oven-dry condition to be removed, kg/m^3 [lb/yd^3].

M_{OD} = mass of lightweight aggregate specimen in oven-dry condition, g.

M_{PS} = mass of pycnometer containing lightweight aggregate specimen and filled with water, g.

M_{PW} = mass of pycnometer filled with water, g.

M_{SD} = mass of lightweight aggregate specimen in wetted surface-dry condition, g.

M_{94} = equilibrium mass of aggregate originally in wetted surface-dry condition and subsequently stored at 94 % relative humidity, g.

C_f = cementitious materials content of concrete mixture, kg/m^3 [lb/yd^3].

CS = chemical shrinkage of cementitious material, expressed as kg water/kg of cement [lb/lb] (see Note 3).

S = degree of saturation of lightweight aggregate relative to wetted surface-dry condition (0 to 1.0).

w/cm = water-cementitious materials ratio, kg/kg [lb/lb].

α_{max} = maximum potential degree of hydration of cementitious materials expressed as a decimal fraction (0 to 1.0).

W_{LWA} = mass of water released by lightweight aggregate in going from the wetted surface-dry condition to the equilibrium mass at a relative humidity of 94 %, expressed as a fraction of the oven-dry mass.

NOTE 3—Chemical shrinkage is measured in units of volume of water per unit mass of cement. In using the value of chemical shrinkage to calculate the required amount of lightweight aggregate for internal curing, the volume of water is converted to the mass of water. Hence chemical shrinkage is expressed as mass of water per unit mass of cement.

4. Ordering Information

4.1 The direct purchaser of lightweight aggregate for internal curing shall include the following information in the purchase order as applicable.

4.1.1 Reference to this specification, as Specification C1761.

4.1.2 Whether the order is for fine aggregate, coarse aggregate, or combined fine and coarse aggregate.

4.1.3 Quantity in metric tons [tons] or cubic meters [cubic yards].

4.1.4 If the order is for coarse aggregate or combined fine and coarse aggregate, provide the nominal size designation as given in Table 1 or alternative grading as agreed between the purchaser and aggregate supplier.

4.1.5 Whether certification shall be furnished indicating that the material was sampled and tested in accordance with this specification and found to meet the requirements.

4.1.6 Whether a report of the results of aggregate tests shall be furnished.

4.1.7 Whether the results of tests of concrete properties are required.

4.1.8 Any exceptions or additions to this specification.

5. Materials and Manufacture

5.1 Two general types of lightweight aggregate are covered by this specification, as follows:

TABLE 1 Grading Requirements

Nominal Size Designation	Percentages (Mass) Passing Sieves Having Square Openings									
	25.0 mm (1 in.)	19.0 mm (¾ in.)	12.5 mm (½ in.)	9.5 mm (⅜ in.)	4.75 mm (No. 4)	2.36 mm (No. 8)	1.18 mm (No. 160)	300 µm (No. 50)	150 µm (No. 100)	75 µm[A] (No. 200)
Fine aggregate:										
4.75 mm to 0 (No. 4 to 0)	. . .	. . .	. . .	100	85–100	. . .	40–80	10–35	5–25	. . .
Coarse aggregate:										
25.0 to 4.75 mm (1 in. to No. 4)	95–100	. . .	25–60	. . .	0–10	. . .	. . .	. . .	. . .	0–10
19.0 to 4.75 mm (¾ in. to No.4)	100	90–100	. . .	10–50	0–15	. . .	. . .	. . .	. . .	0–10
12.5 to 4.75 mm (½ in. to No. 4)	. . .	100	90–100	40–80	5–40	0–20	0–10	. . .	. . .	0–10
9.5 to 2.36 mm (⅜ in. to No. 8)	. . .	. . .	100	80–100	5–40	0–20	0–10	. . .	. . .	0–10
Combined fine and coarse aggregate:										
12.5 mm to 0 (½ in. to 0)	. . .	100	95–100	. . .	50–80	. . .	. . .	5–20	2–15	0–10
9.5 mm to 0 (⅜ in. to 0)	. . .	. . .	100	90–100	65–90	35–65	. . .	10–25	5–15	0–10

[A] The surfaces of pyro-processed lightweight aggregate particles finer than the 75 µm (No. 200) sieve are not deleterious and may be moderately pozzolanic.

5.1.1 Aggregates produced by expanding, pelletizing, or sintering products such as blast-furnace slag, clay, diatomite, fly ash, shale, or slate, and

5.1.2 Aggregate prepared by processing natural materials, such as pumice, scoria, and tuff.

5.2 The aggregate shall be composed predominately of lightweight-cellular and granular inorganic materials.

6. Chemical Requirements

6.1 *Organic Impurities*—Test Method C40. Lightweight aggregate shall not produce a color darker than the standard color solution, unless it is demonstrated that when the aggregate is tested for the effect of organic impurities on strength of mortar, the relative strength at 7 days, determined in accordance with Test Method C87, is not less than 95 %.

6.2 *Staining*—Test Method C641. Lightweight aggregate shall produce a stain index of less than 60. Lightweight aggregate producing a stain index of 60 or higher shall be subject to rejection if the deposited stain is found upon chemical analysis to contain an iron content, expressed as Fe_2O_3, equal to or greater than 1.5 mg/200 g of sample.

6.2.1 *Loss on Ignition*—Test Method C114. The loss on ignition of lightweight aggregates shall not exceed 5 %.

NOTE 4—Some aggregate may contain carbonates or water of hydration that contribute to loss on ignition but may not affect the quality of the product. Therefore, when evaluating an aggregate, consideration should be given to the material characteristics that cause the ignition loss.

7. Physical Properties

7.1 *Clay Lumps and Friable Particles*—Test Method C142. The total amount of clay lumps and friable particles shall not exceed 2 % by dry mass.

7.2 *Grading*—Test Method C136 as modified in Specification C330/C330M. The grading shall conform to the requirements shown in Table 1 or established by mutual agreement between interested parties.

NOTE 5—In general, a volume of lightweight aggregate (fine or a combination of coarse and fine) for internal curing will replace an equal volume of normal weight aggregate in an existing conventional concrete mixture. The grading of the lightweight aggregate can be chosen to closely match the existing grading of the normal weight aggregates, or to fill in a gap in the existing normal weight aggregate grading, such as using a mid-range size lightweight aggregate to enhance the gradation of a gap-graded mixture (**1**).[3]

7.2.1 *Uniformity of Grading*—For continuing shipments of fine aggregate from a given source, the fineness modulus shall not vary more than 7 % from the base fineness modulus. The base fineness modulus shall be that value that is typical of the source. The purchaser has the authority to approve a change in the base fineness modulus. For coarse aggregate and combined fine and coarse aggregate, the uniformity of grading requirements of Specification C330/C330M shall apply.

TABLE 2 Maximum Dry Loose Bulk Density

Size Designation	Maximum Density kg/m³ [lb/ft³]
Fine aggregate	1120 [70]
Coarse aggregate	880 [55]
Combined fine and coarse aggregate	1040 [65]

7.3 *Bulk Density*—Test Method C29/C29M. The dry bulk density using the shoveling method of compaction shall conform to the requirements of Table 2 using a 14 L [½ ft^3] measure.

7.4 *Water Absorption*—The lightweight aggregate shall have a 72-h absorption not less than 5 % when tested in accordance with Section 10.

7.5 *Desorption Properties*—The lightweight aggregate shall release at least 85 % of its absorbed water at 94 % relative humidity when tested in accordance with Section 11.

8. Sampling

8.1 Sample lightweight aggregates in accordance with Practice D75.

8.2 Reduce sample to test sizes in accordance with Practice C702.

[3] The boldface numbers in parentheses refer to the list of references at the end of this standard.

9. Number of Tests and Retests

9.1 *Tests on Aggregates*—One representative sample is required of sufficient size to prepare specimens for the following tests: organic impurities, staining, loss on ignition, grading, clay lumps and friable particles, bulk density, absorption and relative density (OD), and desorption from WSD to 94 % relative humidity.

9.2 *Tests on Internally Cured Concrete*—When specified by the purchaser, at least three specimens are required for each of the following tests of concrete: compressive strength, shrinkage, resistance to freezing and thawing, and presence of popout materials. At least eight specimens are required for splitting tensile strength tests. Tests shall be performed in accordance with Specification C330/C330M and test results shall comply with Specification C330/C330M.

TEST METHODS

10. Absorption and Relative Density

10.1 *Scope:*

10.1.1 This test method uses the pycnometer method to determine the 72-h absorption and relative density (oven-dry) of lightweight aggregate for internal curing.

10.2 *Significance and Use:*

10.2.1 It is difficult to obtain complete saturation of the permeable pores in some lightweight aggregate particles. In this test method, a 72-h soaking period of essentially dry aggregate is used to define the absorption.

10.2.2 After the prescribed soaking period and the removal of surface moisture, the aggregate is in the wetted surface-dry condition, which is analogous to the saturated surface-dry condition applicable to normal weight aggregate. The former term is used because the permeable pores in some lightweight aggregate particles are not filled completely by soaking for 72-h (**2**).

10.2.3 The absorption is used to determine the mass of lightweight aggregate needed to provide the required quantity of water for internal curing.

NOTE 6—The higher the absorption of the lightweight aggregate, the less of it will be needed to provide a given quantity of water for internal curing. For a lower absorption aggregate, more aggregate will be needed, which will result in a better distribution of water for internal curing within the cementitious mixture, assuming the grading is the same.

10.2.4 The relative density (oven-dry) is used to calculate the mass of the normal weight aggregate that is to be replaced by an equal volume of lightweight aggregate.

10.3 *Apparatus:*

10.3.1 *Balance*—Having a capacity of at least 4 kg and accurate to at least 0.1 g.

10.3.2 *Wide-mouth jars*—Glass jars with nominal capacities of 1 L [1 qt] and 2 L [2 qt].

NOTE 7—Ordinary canning jars are suitable for this purpose.

10.3.3 *Pycnometer top*—For filling the 1 L [1 qt] or 2 L [2 qt] jars with water to a repeatable level.

10.3.4 *Paper towels*—Commercial grade, either folded type or roll type.

NOTE 8—Brown paper towels make it easier to determine whether aggregate particles contain surface water during the drying procedure for bringing aggregate to the wetted surface-dry condition.

10.3.5 *Drying oven*—Of sufficient size and capable of maintaining a uniform temperature of 110 ± 5 ºC [230 ± 10 ºF].

10.3.6 *Metal pans*—For soaking aggregate under water and for drying aggregate in drying oven.

10.3.7 *Water storage container*—Approximate capacity of 20 L [5 gal] for maintaining a supply of water at the laboratory temperature of 23.0 ± 2 ºC [73.5 ± 3.5 ºF].

10.4 *Procedure:*

10.4.1 Fill the wide-mouth jar with pycnometer top with water at a temperature of 23.0 ± 2 ºC [73.5 ± 3.5 ºF]. For tests of coarse aggregate or combined coarse and fine aggregate, use the 2-L [2-qt] jar. Use the 1-L [1-qt] jar for tests of fine aggregate. Ensure that no air bubbles are present on the wall of the jar and the pycnometer top is filled to capacity. Wipe the surface of the jar to remove any surface water and weigh the filled jar to the nearest 0.1 g. Record this mass as M_{PW}.

10.4.2 Obtain a representative sample of lightweight aggregate as specified in 8.2. For coarse aggregate and for combined coarse and fine aggregate, the test size shall be in the range of 2.0 to 2.5 kg [4.5 to 5.5 lb]. For fine aggregate, the test size shall be in the range of 500 to 750 g [1 to 1.5 lb]. Place aggregate in the drying pan and dry for 24 ±1 h in the drying oven. Allow the aggregate to cool to about 50 ºC [120 ºF] or less. Cover aggregate with water and permit to stand for 72 ± 4 h at a temperature of 23.0 ± 2 ºC [73.5 ± 3.5 ºF].

10.4.3 Decant the excess water while avoiding loss of fine material. Spread the aggregate on a flat nonabsorbent surface covered with brown paper towels. Expose the aggregate to a gently moving current of air. Pat the surface of the aggregate with paper towels, and stir frequently to secure homogeneous drying. Replace the bottom towels when they become too damp to absorb additional moisture. Continue patting and stirring the aggregate, replacing the towels as they become too damp or dirty to absorb additional moisture. Repeat the patting and spreading until no moisture appears on clean paper towels. The aggregate is now in the wetted surface-dry condition.

10.4.4 For coarse aggregate and combined coarse and fine aggregate weigh out a test specimen of approximately 1500 g. For fine aggregate, weigh out a test specimen of approximately 300 g. Measure the specimen mass to the nearest 0.1 g and record the mass as M_{SD}.

10.4.5 Partially fill the pycnometer with water at 23.0 ± 2 ºC [73.5 ± 3.5 ºF]. Introduce the weighed aggregate specimen into the pycnometer and avoid loss of any material. Fill with additional water to approximately 90 % of capacity. Agitate the pycnometer to eliminate visible air bubbles (see Note 9). Refer to Test Method C128 for acceptable methods of agitating the pycnometer.

NOTE 9—About 15 to 20 min are normally required to eliminate the air bubbles by manual methods. Dipping the tip of a paper towel into the pycnometer cap has been found to be useful in dispersing the foam that sometimes builds up when eliminating the air bubbles. Optionally, a small amount of isopropyl alcohol may be used to disperse the foam.

10.4.6 After eliminating visible air bubbles, bring the water level in the pycnometer top to its capacity. Wipe off any water