Designation: D6023 – 16

Standard Test Method for Density (Unit Weight), Yield, Cement Content, and Air Content (Gravimetric) of Controlled Low-Strength Material (CLSM)[1]

This standard is issued under the fixed designation D6023; 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.

1. Scope*

1.1 This test method explains determination of the density (Note 1) of freshly mixed Controlled Low-Strength Material (CLSM) and gives formulas for calculating the yield, cement content, and the air content of the CLSM. This test method is based on Test Method C138/C138M for Concrete.

NOTE 1—Unit Weight was the previous terminology used to describe the property determined by this test method, which is mass per unit volume.

1.2 All observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practice D6026.

1.2.1 The procedures used to specify how data are collected/recorded and calculated in the standard are regarded as the industry standard. In addition, they are representative of the significant digits that generally should be retained. The procedures used do not consider material variation, purpose for obtaining the data, special purpose studies, or any considerations for the user's objectives; and it is common practice to increase or reduce significant digits of reported data to be commensurate with these considerations. It is beyond the scope of these test methods to consider significant digits used in analysis methods for engineering data.

1.3 The values stated in SI units are to be regarded as standard. The values given in parentheses are mathematical conversions to inch-pound units, which are provided for information only and are not considered standard. Reporting of test results in units other than SI shall not be regarded as nonconformance with this test method.

1.3.1 The converted inch-pound units use the gravitational system of units. In this system, the pound (lbf) represents a unit of force (weight), while the unit for mass is slugs. The converted slug is not given, unless dynamic (F=ma) calculations are involved.

1.3.2 It is common practice in the engineering/construction profession to concurrently use pounds to represent both a unit of mass (lbm) and of force (lbf). This implicitly combines two separate system of units; that is, the absolute system and the gravitational system. It is scientifically undesirable to combine the use of two separate sets of inch-pound units within a single standard. As stated, this standard includes the gravitational system of inch-pound units and does not use/present the slug unit for mass. However, the use of balances or scales recording pounds of mass (lbm) or recording density in lbm/ft^3 shall not be regarded as nonconformance with this standard.

1.4 CLSM is also known as flowable fill, controlled density fill, soil-cement slurry, soil-cement grout, unshrinkable fill, "K-Krete," and other similar names.

1.5 *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. (***Warning—***Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.*[2]*)*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

C29/C29M Test Method for Bulk Density ("Unit Weight") and Voids in Aggregate

C125 Terminology Relating to Concrete and Concrete Aggregates

C128 Test Method for Relative Density (Specific Gravity) and Absorption of Fine Aggregate

C138/C138M Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete

C150/C150M Specification for Portland Cement

C231/C231M Test Method for Air Content of Freshly Mixed

[1] This test method is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.15 on Stabilization With Admixtures.

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[2] Section on Safety Precautions, *Manual of Aggregate and Concrete Testing*, Annual Book of ASTM Standards, Vol. 04.02.

[3] 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.

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

Concrete by the Pressure Method
D653 Terminology Relating to Soil, Rock, and Contained Fluids
D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction
D4832 Test Method for Preparation and Testing of Controlled Low Strength Material (CLSM) Test Cylinders
D5971/D5971M Practice for Sampling Freshly Mixed Controlled Low-Strength Material
D6024/D6024M Test Method for Ball Drop on Controlled Low Strength Material (CLSM) to Determine Suitability for Load Application
D6026 Practice for Using Significant Digits in Geotechnical Data
D6103 Test Method for Flow Consistency of Controlled Low Strength Material (CLSM) (Withdrawn 2013)[4]

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of common technical terms used in this standard, refer to Terminology standards C125 and D653.

3.1.2 *Controlled Low Strength Material (CLSM), n*—a mixture of soil, aggregates (sand, gravel, or both), cementitious materials, water, and sometimes admixtures, that hardens into a material with a higher strength than the soil, but less than 8400 kPa (1200 psi).

3.1.2.1 *Discussion*—Used as a replacement for compacted backfill, CLSM can be placed as a slurry, a mortar, or a compacted material and typically has strengths of 350 to 700 kPa (50 to 100 psi) for most applications.

3.1.3 *yield*—the volume of CLSM produced from a mixture of known quantities of the component materials.

4. Summary of Test Method

4.1 The density of the CLSM is determined by filling a measure with CLSM, determining the mass, and calculating the volume of the measure. The density is then calculated by dividing the mass by the volume. The yield, cement content, and the air content of the CLSM is calculated based on the masses and volumes of the batch components.

5. Significance and Use

5.1 This test method provides the user with a procedure to calculate the density of freshly mixed CLSM for determination of compliance with specifications, for determining mass/volume relationships or conversions such as those found in purchase agreements, and also for quality control purposes.

5.2 This test method is intended to assist the user for quality control purposes and when specified to determine compliance for air content, yield, and cement content of freshly mixed CLSM.

5.3 This test method is not meant to predict the air content of hardened CLSM, which may be either higher or lower than that determined by this test method.

5.4 This test is one of a series of quality control tests that can be performed on CLSM during construction to monitor compliance with specification requirements. The other tests that can be used during construction control are Test Methods D4832, D6024/D6024M, and D6103.

NOTE 2—The quality of the results produced by this standard is dependent on the competence of the personnel performing it and the suitability of the equipment and facilities used. Agencies that meet the criteria of Practice D3740 are generally considered capable of competent and objective testing/sampling/inspection/ and the like. Users of this standard are cautioned that compliance with Practice D3740 does not in itself ensure reliable results. Reliable results depend on many factors; Practice D3740 provides a means of evaluation some of those factors.

6. Apparatus

6.1 *Balance*—A balance or scale accurate to within 0.3 % of the test load at any point within the range of use. The range of use shall be considered to extend from the mass of the measure empty to the mass of the measure plus the CLSM.

6.2 *Filling Apparatus*—Scoop, bucket or pail of sufficient capacity to facilitate filling the measure in a rapid, efficient manner.

6.3 *Sampling and Mixing Receptacle*—The receptacle shall be a suitable container, wheelbarrow, and the like of sufficient capacity to allow easy sampling and remixing of the CLSM.

6.4 *Measure*—A cylindrical container made of steel or other suitable metal (Note 3). It shall be watertight and sufficiently rigid to retain its form and calibrated volume under rough usage. Measures that are machined to accurate dimensions on the inside and provided with handles are preferred. All measures, except for measuring bowls of air meters shall conform to the requirements of Test Method C29/C29M. The minimum capacity of the measure shall conform to the requirements of Table 1. When measuring bowls of air meters are used, they shall conform to the requirements of Test Method C231/C231M. The top rim of the air meter bowls shall be smooth and plane within 0.3 mm (0.01 in.) (Note 4).

NOTE 3—The metal should not be readily subject to attack by cement paste. However, reactive materials such as aluminum alloys may be used in instances where, as a consequence of an initial reaction, a surface film is rapidly formed, which protects the metal against further corrosion.

NOTE 4—The top rim is satisfactorily plane if a 0.3-mm (0.01-in.) feeler gauge cannot be inserted between the rim and a piece of 6 mm (¼ in.) or thicker plate glass laid over the top of the measure.

6.5 *Strike-Off Plate*—A flat rectangular strike-off plate conforming to the requirements of Test Method C138/C138M.

TABLE 1 Minimum Capacity of Measure

Nominal Maximum Size of Coarse Aggregate[A]		Capacity of Measure, min[B]	
in.	mm	ft^3	L
1	25.0	0.2	6
1½	37.5	0.4	11
2	50	0.5	14

[A] Aggregate of a given nominal maximum size may contain up to 10 % of particles retained on the sieve referred to.
[B] To provide for wear, measures may be up to 5 % smaller than indicated in this table.

[4] The last approved version of this historical standard is referenced on www.astm.org.

6.6 *Calibration Equipment*—A piece of plate glass, preferably at least 6 mm (¼ in.) thick and at least 25 mm (1 in.) larger than the diameter of the measure to be calibrated. A thin film of vacuum, water pump or chassis grease smeared on the flange of the bowl will make a watertight joint between the glass plate and the top of the bowl.

7. Sample

7.1 Obtain the sample for freshly mixed CLSM in accordance with Practice D5971/D5971M.

7.2 The size of the sample shall be approximately 125 to 200 % of the quantity required to fill the measure.

8. Verification of Measure

8.1 Verify the measure and determine the calibration factor (1/volume), following the procedure outlined in Test Method C29/C29M.

NOTE 5—For the calculation of density, the volume of the measure in acceptable metric units should be expressed in cubic metres, or the factor as $1/m^3$. However, for convenience the size of the measure may be expressed in litres.

8.2 Measures shall be reverified at least once a year or whenever there is reason to question the accuracy of the verification.

9. Procedure

9.1 Place the measure on a level, rigid, horizontal surface free from vibration and other disturbances.

9.2 *Placing the CLSM:*

9.2.1 Start this procedure within 5 min after obtaining the sample of CLSM and complete as expeditiously as possible.

9.2.2 Thoroughly mix the sample of CLSM in the sampling and mixing receptacle to ensure uniformity.

9.2.3 With the filling apparatus, scoop through the center portion of the sample and pour the CLSM into the measure. Repeat until the measure is full.

9.3 On completion of filling, the measure shall not contain a substantial excess or deficiency of CLSM. An excess of CLSM protruding approximately 3 mm (⅛ in.) above the top of the mold is optimum. To correct a deficiency, add a small quantity of CLSM.

9.4 *Strike-Off*—After filling, strike-off the top surface of the CLSM and finish it smoothly with the flat strike-off plate using great care to leave the measure just level full. The strike-off is best accomplished by pressing the strike-off plate on the top surface of the measure to cover about two thirds of the surface and withdrawing the plate with a sawing motion to finish only the area originally covered. Then place the plate on the top of the measure to cover the original two thirds of the surface and advance it with a vertical pressure and a sawing motion to cover the whole surface of the measure. Several final strokes with the inclined edge of the plate will produce a smooth finished surface.

9.5 *Cleaning and Mass Measurement*—After strike-off, clean all excess CLSM from the exterior of the measure and determine the gross mass of the CLSM in the measure to an accuracy consistent with the requirements of 6.1.

10. Calculation

10.1 *Density*—Calculate the mass of the CLSM in megagrams, kilograms, or grams (pounds) by subtracting the mass of the measure from the gross mass. Calculate the density, W, by multiplying the mass of the CLSM by the calibration factor for the measure determined in 8.1.

10.2 *Yield*—Calculate the yield as follows:

$$Y_f\,(\mathrm{ft}^3) = W_1/W \tag{1}$$

or,

$$Y\,(\mathrm{yd}^3) = W_1/(27W) \tag{2}$$

or,

$$Y\,(\mathrm{m}^3) = W_1/W \tag{3}$$

where:

Y_f = volume of CLSM produced per batch, ft^3,
Y = volume CLSM produced per batch, m^3 (ft^3),
W = density of CLSM, kg/m^3 (lb/ft^3), and
W_1 = total mass of all materials batched, kg (lb) (Note 6).

NOTE 6—The total mass of all materials batched is the sum of the masses of the cement, the fly ash, the filler aggregate in the condition used, the mixing water added to the batch, and any other solid or liquid materials used.

10.3 *Relative Yield*—Relative yield is the ratio of the actual volume of CLSM obtained to the volume as designed for the batch calculated as follows:

$$R_y = Y/Y_d \tag{4}$$

where:

R_y = relative yield,
Y = volume CLSM produced per batch, m^3 (yd^3), and
Y_d = volume of CLSM, which the batch was designed to produce, m^3 (yd^3).

NOTE 7—A value for R_y greater than 1.00 indicates an excess of CLSM being produced whereas a value less than this indicates the batch to be "short" of its designed volume.

10.4 *Cement Content* (Note 8)—Calculate the actual cement content as follows:

$$N = N_t/Y \tag{5}$$

where:

N = actual cement content kg/m^3 (lb/yd^3),
N_t = mass of cement in the batch, kg (lb), and
Y = volume CLSM produced per batch, m^3 (yd^3).

NOTE 8—In determining cement content on CLSM's that contain Class C fly ash, the actual mass of Class C fly ash shall be added to the mass of cement.

10.5 *Air Content*—Calculate the air content as follows:

$$A = [(T - W)/T] \times 100 \tag{6}$$

or,

$$A = [(Y_f - V)/Y_f] \times 100\,(\text{inch} - \text{pound units}) \tag{7}$$

or,

$$A = [(Y - V)/Y] \times 100\,(\text{SI units}) \tag{8}$$

where:

A = air content (percentage of voids) in the CLSM,

T = theoretical density of the CLSM computed on an air free basis, kg/m^3 (lb/ft^3) (Note 7),
W = density of CLSM, kg/m^3 (lb/ft^3),
Y_f = volume of CLSM produced per batch, ft^3,
V = total absolute volume of the component ingredients in the batch, ft^3 or m^3, and
Y = volume CLSM produced per batch, m^3.

NOTE 9—The theoretical density is, customarily, a laboratory determination, the value for which is assumed to remain constant for all batches made using identical component ingredients and proportions. It is calculated from the following equation:

$$T = W_1/V \quad (9)$$

The absolute volume of each ingredient in cubic feet is equal to the quotient of the mass of that ingredient divided by the product of its specific gravity times 62.4. The absolute volume of each ingredient in cubic metres is equal to the mass of the ingredient in kilograms divided by 1000 times its specific gravity. For the aggregate components, the bulk specific gravity and mass should be determined by Test Method C128. A value of 3.15 may be used for cements manufactured to meet the requirements of Specification C150/C150M.

11. Report

11.1 The methodology used to specify how data are recorded on the test data sheet(s)/form(s), as given below, is covered in 1.2.

11.2 Record as a minimum the following general information (data):

11.2.1 Project Identification,

11.2.2 Identification of individual performing the test method,

11.2.3 Date test is performed, and

11.2.4 Identification of CLSM mixture.

11.3 Record as a minimum the following test data:

11.3.1 Density (unit weight) to the nearest 10 kg/m^3 (1 lb/ft^3).

11.3.2 Volume of density measure to 0.01 L (0.001 ft^3).

11.3.3 Yield, when requested, to 0.1 m^3 (0.1 yd^3).

11.3.4 Relative yield, when requested, to 0.01.

11.3.5 Cement content, when requested, to 0.5 kg (1.0 lb.).

11.3.6 Air content, when requested, to 0.1 %.

12. Precision and Bias

12.1 *Precision*—Test data on precision is not presented due to the nature of the CLSM materials tested by this test method. It is either not feasible or too costly at this time to have ten or more laboratories participate in a round-robin testing program.

12.1.1 The Subcommittee D18.15 is seeking any data from the users of this test method that might be used to make a limited statement on precision.

12.2 *Bias*—The procedure in this test method for measuring unit weight has no bias because the value for unit weight can be defined only in terms of a test method.

13. Keywords

13.1 air content; backfill; cement content; CLSM; construction control; density; flowable fill; mix design; quality control; relative yield; soil stabilization; unit weight; yield

SUMMARY OF CHANGES

In accordance with Committee D18 policy, this section identifies the location of changes to this standard since the last edition (2015) that may impact the use of this standard. (December 1, 2016)

(1) Revised 3.1.2.

In accordance with Committee D18 policy, this section identifies the location of changes to this standard since the last edition (2007) that may impact the use of this standard. (November 15, 2015)

(1) Revised 1.2.1 and 1.3.
(2) Added 1.3.1 and 1.3.2.
(3) Revised 3.1.2, the definition of CLSM to be consistent with the definition in other standards.
(4) Changed Section 8 from Calibration to Verification.
(5) Added kilograms as a unit of mass in 10.1.
(6) Revised Section 11 to current D18 practice on the report section.