Designation: D4832 – 16

Standard Test Method for Preparation and Testing of Controlled Low Strength Material (CLSM) Test Cylinders[1]

This standard is issued under the fixed designation D4832; 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 covers procedures for the preparation, curing, transporting and testing of cylindrical test specimens of controlled low strength material (CLSM) for the determination of compressive strength.

1.2 This test method covers CLSM materials that have a higher strength than the soil but less than 8400 kPa (1200 psi). Typical strengths for most applications fall between 350 to 700 kPa (50 to 100 psi).

1.3 The CLSM used to make the molded specimens shall be sampled after all on-site adjustments have been made to the mixture proportions, including the addition of mix water and any admixtures.

1.4 This test method may be used to prepare and test cylindrical specimens of other mixtures of soil and cementitious materials, such as self-cementing fly ashes.

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

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

1.6.1 The procedures used to specify how data are collected/recorded and calculated in this standard are regarded as the industry standard. In addition, they are representative of the significant digits that should generally 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 this standard to consider significant digits used in analysis methods for engineering design.

1.7 *Units*—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.

1.7.1 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 unit is not given, unless dynamic (F=ma) calculations are involved.

1.8 *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.* See Section 7.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C31/C31M Practice for Making and Curing Concrete Test Specimens in the Field

C39/C39M Test Method for Compressive Strength of Cylindrical Concrete Specimens

C125 Terminology Relating to Concrete and Concrete Aggregates

C192/C192M Practice for Making and Curing Concrete Test Specimens in the Laboratory

C470/C470M Specification for Molds for Forming Concrete Test Cylinders Vertically

C617 Practice for Capping Cylindrical Concrete Specimens

C1231/C1231M Practice for Use of Unbonded Caps in Determination of Compressive Strength of Hardened Cylindrical Concrete Specimens

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

[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] 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

Used in Engineering Design and Construction
D5971 Practice for Sampling Freshly Mixed Controlled Low-Strength Material
D6023 Test Method for Density (Unit Weight), Yield, Cement Content, and Air Content (Gravimetric) of Controlled Low-Strength Material (CLSM)
D6024 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)[3]

3. Terminology

3.1 *Definitions:*

3.1.1 For common definitions of terms in this standard, refer to Terminology 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 about 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.

4. Summary of Test Method

4.1 Cylinders are tested to determine the compressive strength of the CLSM. The cylinders are prepared by pouring a representative CLSM sample into molds, then depending on the strength development, either curing the cylinders then removing them from the molds or removing the molds prior to curing the cylinders, and preparing the cylinders for compression testing. The cylinders are then tested to obtain compressive strengths. Duplicate cylinders are required for each test age specified.

5. Significance and Use

5.1 This test method provides standardized requirements for the preparation, curing, transporting and testing of test cylinders of CLSM under field conditions by replicating a "field cure" of the material.

5.1.1 If the cylinders are field cured, as stipulated herein, the resulting compressive strength test data may be used for the following purposes:

5.1.1.1 Acceptance testing for specified strength,

5.1.1.2 Checking the adequacy of mixture proportions for strength,

5.1.1.3 Quality control,

5.1.1.4 Determination of whether the CLSM is capable of being put in service,

5.1.1.5 Adequacy of curing.

5.2 CLSM is typically used as a backfill material around structures, particularly in confined or limited spaces. Compressive strength testing is performed to assist in the design of the mix and to serve as a quality control technique during construction. Mix design is typically based on 28-day strengths and construction control tests performed 7 days after placement. The compressive strength(s) and other test age(s) will vary according to the requirements for the end product. Additional information on the use and history of CLSM is contained in Appendix X1.

5.3 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 of CLSM are Practice D5971 and Test Methods D6023, D6024, and D6103.

5.4 There are many other combinations of soil, cement, fly ash (cementitious or not), admixtures, water quality or other materials that could be tested using this method. The mixtures will vary depending on the intended use, availability of materials, and placement requirements.

NOTE 1—The quality of the result 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 assure reliable results. Reliable results depend on many factors; Practice D3740 provides a means of evaluating some of those factors.

6. Apparatus

6.1 *Single-Use Cylindrical Molds*—Plastic single-use 150 × 300 mm (6 × 12 in.) or 100 × 200 mm (4 × 8 in.) cylinder molds with tight-fitting lids (see 9.2.2.1 regarding cautionary statement for "air-tight" lids), conforming to Specification C470/C470M. Other sizes and types of molds may be used as long as the length to diameter ratio is 2 to 1. The 150 × 300 mm (6 × 12 in.) molds are preferred for use in concrete compression apparatus (Section 6.5) because of the low strength of the material and the larger surface area of the ends of the cylinders.

6.1.1 Mold removal can be accomplished with the use of low air pressure. The pressure shall be low enough so the sample is undamaged.

6.2 *Sampling and Mixing Receptacle*—The receptacle shall be a suitable non-absorbent material (heavy-gauge metal or heavy duty plastic container, wheelbarrow, etc.) of sufficient capacity to allow easy sampling and remixing with a shovel or scoop and to allow preparation of at least two cylinders and for other tests such as described in Test Methods D5971, D6023, and D6103.

6.3 *Storage Container*—A tightly constructed, insulated, firmly braced wooden box with a cover or other suitable container for storage of the CLSM cylinders at the construction site. The container shall be equipped, as necessary, to maintain the temperature immediately adjacent to the cylinders in the range of 16 to 27°C (60 to 80°F). The location of the storage container shall be away from direct sunlight and protected from freezing temperatures for extended lengths of time (for additional guidance see Section on Curing in Practice C31/C31M).

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

The container shall be marked for identification and shall be a bright color to avoid disturbance.

6.4 *Transportation Container*—A sturdy wooden box or other suitable container constructed with adequate padding to minimize shock, vibration, or damage to the CLSM cylinders when transported to the laboratory.

6.5 *Testing Machine*—The testing machine shall meet the requirements as described in Test Method C39/C39M with the following exceptions.

6.5.1 The readability shall be a minimum of two significant digits with interpolation of the second digit not more than 0.11 kN (25 lbf) for strengths less than about 350 kPa (50 psi). For strengths greater than about 350 kPa (50 psi), the minimum readability should be two significant digits with interpolation of the second digit not more than 0.55 kN (100 lbf).

6.5.2 Since the compressive strength of CLSM cylinders will typically be 100 to 8400 kPa (about 15 to 1200 lbf/in.^{2}), the testing machine must have a loading range such that valid values of compressive strength can be obtained.

6.6 *Curing Environment*—A curing environment (water bath, damp sand, fog room) that meets the requirements of Practice C192/C192M. The cylinders may be cured in the same curing environment used for concrete cylinders at the laboratory performing the testing.

6.7 *Small Tools*—Tools and items that may be required such as shovels, pails, trowels, tamping rod and scoops.

7. Hazards

7.1 *Technical Precaution*—The procedure for the preparation of CLSM test cylinders has many similarities to preparing concrete test cylinders (Practice C31/C31M and Practice C192/C192M). However, the cylinders are much more fragile than concrete cylinders, and special care should be taken in their preparation, storage, and handling.

7.2 *Safety Hazards:*

7.2.1 Strictly observe the safety precautions stated in Practice C617.

7.2.2 If the cylinders are capped with molten sulfur mortar (which is not advised for CLSM cylinders, see Section 10 on Capping the Cylinders), wear proper personnel protective equipment, including gloves with cuffs at least 15 cm (6-in.) long. (**Warning—**Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.[4])

8. CLSM Sampling and Test Specimens

8.1 Take samples of the CLSM for each test cylinder in accordance with D5971. Record the identity of the CLSM represented and the date and time of casting.

8.2 The sample from the batch should be a minimum of 0.03 m^3 (1 ft^3) for each two cylinders to be prepared. Prepare a minimum of two compressive strength cylinders for each test age to represent each sampled batch. Additional material may be required if other testing is to be performed, such as in Test Methods D5971, D6023, and D6103.

NOTE 2—In the initial stage of CLSM usage, preparation of three cylinders is recommended to obtain reliable compressive strength data for each test age. Subsequently, two cylinders may be used to maintain testing records and to ascertain an overall quality of the mix. However, since the cylinders are fragile and may be damaged during transportation, mold removal, and capping, preparation of an extra cylinder may be necessary to provide the minimum number of test cylinders (see Note 4 and 10.2). In addition, it may be useful to determine the density of the test cylinders to help evaluate the uniformity of the compressive strength values.

9. CLSM Cylinder Molding and Curing

9.1 *Place of Molding*—Mold cylinders promptly on a level, rigid, horizontal surface free from vibration and other disturbances. The cylinders should be prepared at a place as near as practicable to the location where they are to be stored during the first four days.

9.2 *Placing the CLSM:*

9.2.1 Thoroughly mix the CLSM in the sampling and mixing receptacle to avoid segregation and to maintain homogeneity. Because CLSM mixtures can bleed easily (the appearance of free water at the surface), the sample must be routinely mixed during cylinder production to ensure homogeneity, avoid segregation and ensure that the cylinder produced represents the material placed in the trench.

9.2.2 With a scoop or pail, scoop through the center portion of the receptacle and pour the CLSM into the mold. Repeat until the mold is full. Tap the outsides of the cylinder mold no more than ten times with a tamping rod or open face of the hand to close holes that remain and to release entrapped air voids, assuring complete filling of the mold. If necessary, level off the top layer with the trowel or straight-edge so it remains even and relatively smooth. Place a lid or plastic bag loosely on the mold.

NOTE 3—The placement of CLSM into the cylinder molds generally does not follow Practices C31/C31M or C192/C192M as the placement is not done in layers and does not require rodding or vibrating. However if the CLSM mixture contains high gravel contents, Practice C31/C31M should be followed with the applicable layering, rodding and/or vibration pertaining to the cylinder mold size.

9.2.2.1 Use of an airtight lid has been known to cause low strength materials to crack, possibly due to the creation of a vacuum inside the mold. If an airtight lid is contemplated, its use should be evaluated before doing routine testing. A pin-sized hole in the lid has been used successfully in many cases.

9.2.2.2 Some mixtures will bleed rapidly, that is, free water will appear in the sample while in the mixing receptacle and also while in the mold. Obtaining the material to fill the cylinder must be done quickly after mixing. A few minutes after filling the mold, thoroughly mix the CLSM in the sampling and mixing receptacle and place a scoopful in the top of the mold, displacing the water. This refilling may be required again after about 15 min. Smooth the top and cover after all refilling is finished.

9.3 *Curing:*

9.3.1 Store the cylinders at the construction site in the storage container until the fourth day after preparation. Refer to 9.2 for curing requirements.

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

9.3.2 The cylinders shall be stored under conditions that maintain the temperature immediately adjacent to the cylinders in the range of 16 to 27°C (60 to 80°F). The cylinders must always be protected from freezing. After the first day, provide a high humidity environment by surrounding the cylinders with wet burlap or other highly adsorbent material.

9.3.3 On the fourth day, carefully transport the cylinders to the site of the curing environment in the transportation container and place in a curing environment (see 6.6).

9.3.4 The cylinders are typically left at the contruction site for four days and then transported to a curing environment. If extremely low strength CLSM (below 350 kPa) would be damaged by moving on the fourth day, then the cylinders are to be placed in a water storage tank with a temperature between 16° and 27°C (60° and 80°F) at the construction site until they are able to be moved without damage.

10. Capping the Cylinders

10.1 On the day of testing, carefully remove the molds from the cylinders and allow the cylinders to air-dry for 4 to 8 h before capping. If the upper surface of the cylinder is not a horizontal plane, use a wire brush to flatten the surface. Brush off all loose particles. Provide a cap for the cylinders using one the following methods:

10.1.1 Cap the cylinder using gypsum plaster in accordance with Practice C617.

10.1.2 Use elastomeric pads in accordance with Practice C1231/C1231M. The results of the qualification tests in Practice C1231/C1231M for acceptance of the caps must not indicate a reduction of strength of more than 20 %, rather than 2 % as stated in Practice C1231/C1231M. The larger difference is acceptable because of the less critical uses of CLSM and 20 % is estimated to be the inherent variation in compressive strength results because of the lower strength values, for example 350 kPa (50 psi). Although compressive strengths below 10 MPa (1500psi) are not within the scope of Practice C1231/C1231M, acceptable results have been found in many laboratories. Qualification testing shall be performed prior to using unbonded capping systems for acceptance testing of CLSM mixtures.

NOTE 4—Sulfur mortars are not recommended for capping CLSM cylinders because the strength of the cap is generally significantly greater than the CLSM cylinder strength, which may lead to erroneous results. For cylinder strengths below about 4000 kPa (600 psi), it is recommended to use other capping methods. However if sulfur mortar is used, oil should be placed on the capping plate to ensure release of the capping material from the capping plate. More oil may be required on the capping plate when capping CLSM cylinders than is normally used when capping concrete cylinders, capped CLSM cylinders will normally contain more air voids between the cap and the cylinder than capped concrete cylinders, and this should be considered if the caps are tapped to check for voids.

10.2 Use the same capping method throughout each project to avoid any variation in the test results from using different capping systems.

10.3 CLSM cylinders are more fragile than concrete cylinders and must be handled carefully during the mold removal and during capping.

11. Compressive Strength Testing

11.1 *Placement of Capped Cylinder*—Place the lower bearing block, with its hardened face up, on the table or platen of the testing machine directly under the spherically seated (upper) bearing block. Wipe clean the bearing faces of the upper and lower bearing blocks and of the test cylinder, and place the test cylinder on the lower bearing block. Carefully align the axis of the cylinder with the center of thrust of the spherically seated block. As the spherically seated block is brought to bear on the top of the cylinder, rotate its movable portion gently by hand so that uniform seating is obtained.

11.2 *Rate of Loading*—Apply the load continuously and without shock. Apply the load at a constant rate such that the cylinder will fail in not less than 2 min. Make no adjustment in the controls of the testing machine while a specimen is yielding rapidly immediately before failure.

11.3 Apply the load until the cylinder fails, and record the maximum load, to either two or three significant digits, carried by the cylinder during the test. For about one out of every ten cylinders, continue the loading until the cylinder breaks enough to examine the appearance of the interior of the specimen. Note any apparent segregation, lenses, pockets, and the like in the specimen.

12. Calculation

12.1 Calculate and record the compressive strength of the test cylinder to either two or three significant digits as follows:

$$C = \frac{L}{\pi(D^2)/4} \quad (1)$$

where:

C = compressive strength, kPa (lbf/in.^{2}),
D = nominal diameter of cylinder (normally 150 mm or 6 in.), and
L = maximum load, kN (lbf).

13. Report: Test Data Sheet(s)/Form(s)

13.1 The methodology used to specify how data are recorded on the test data sheet(s)/form(s), as given below, is covered in 1.6.

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

13.2.1 Sample/cylinder identifying information, such as Project No., Mix No., Cylinder No., location, etc.

13.2.2 Mix Design, if known.

13.3 Record as a minimum the following test cylinder data:

13.3.1 Date, time and name of individual molded CLSM specimens.

13.3.2 Diameter and length, mm (in.), to two significant digits (See 6.1). Diameter dimension is needed to verify that it correlates with the nominal diameter used in the above equation.

13.3.3 Cross-sectional area, mm^2 (in.^{2}), to two significant digits (See 6.1).

13.3.4 Maximum load, kN (lbf), to either two or three significant digits (See 11.3).

13.3.5 Compressive strength, kPa (lbf/in.^{2}), to either two or three significant digits (See 12.1).

13.3.6 Age of cylindrical specimen (See 8.2) in days to nearest 0.1.

13.3.7 Appropriate remarks as to type of failure, defects noted, or non-uniformity of CLSM, such as apparent segregation, lenses, pockets, and the like in the cylindrical specimen (See 11.3).

13.3.8 Method of capping (See 10).

14. Precision and Bias

14.1 *Precision*—Test data on precision is not presented. It is either not feasible or too costly at this time to have ten or more laboratories participate in a round-robin testing program.

14.1.1 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.

14.2 *Bias*—There is no accepted reference value for this test method, therefore, bias cannot be determined.

15. Keywords

15.1 backfill; CLSM; compressive strength; construction control; mix design; quality control; soil stabilization

APPENDIX

(Nonmandatory Information)

X1. HISTORY

X1.1 This standard was developed to provide an accepted, consensus method of preparing and testing CLSM cylinders. Because the cylinders are more fragile than normal concrete cylinders, the standard provides a workable method of preparation and testing based on much trial and error.

X1.2 CLSM is a combination of soil, aggregates (sand, gravel, or both), cementitious materials (Portland Cement, fly ashes or natural pozzolans), sometimes admixtures, and enough potable water so that the mixture has the consistency of a thick liquid. In this form, the CLSM flows readily into openings, filling voids, and provides a hardened material that has a strength greater than the untreated soil used in the mix. Some cementitious fly ashes have been successfully used in place of the portland cement.

X1.3 Although the primary use to date of CLSM or other similar materials has been as embedment for pipelines, it also has been used as trench backfill and structure backfill.[5,6]

X1.4 Typically, CLSM contains about 5 to 10 % Portland cement. One of the definite advantages is that CLSM may be produced using local soils. As opposed to a lean concrete slurry, the soil for the CLSM can contain up to about 20 to 25 % nonplastic or slightly plastic fines. Although clean concrete sands have been used, the presence of fines can help keep the sand-sized particles in suspension. This allows the mixture to flow easier and helps prevent segregation. Soils that are basically sand sizes work best with the maximum particle size compatible with the space to be filled. Central batch plants with the slurry delivered in ready-mix trucks, trench-side, trail-along portable batch plants and mobile continuous mixers have been used, with the latter two normally used when the soil comes from the trench excavation.

X1.5 *Testing Techniques:*

X1.5.1 The 150 by 300-mm plastic cylinders (see 6.1) are suggested as a matter of economics; that size is not necessary based on the particle sizes normally used in CSLM. A minimum test age of 7 days is recommended for construction control testing because the cylinders may not be intact enough for transporting and testing in 3 days. In addition, the testing that has been done for 3-day strength has resulted in extremely erratic values.

X1.5.2 The mounding of the material in the cylinders was found to be necessary for mixtures that did not contain many fines; the water bled so quickly that a space was left on top of the cylinders and the hardened cylinders were not of a uniform height.

X1.5.3 At the moisture content required for the mixture to have the necessary flow properties, consolidation of the CSLM in the cylinder mold by vibration is not necessary.

X1.6 *Typical Use:*

X1.6.1 The use of CLSM as pipe embedment illustrates the relationship between the testing requirements and a typical application. For pipe installations, CLSM is used to fill the gap between the pipe and the excavated trench. The CLSM transfers the load from the pipe to the in situ material, so the native soil must be able to provide the necessary support for the pipe. The circular trench bottom shape is advantageous because it reduces excavation quantities and thus reduces handling of the soil materials. The CLSM eliminates the problem of trying to shape a cradle in the trench bottom to fit the pipe. A cradle is labor intensive and may not result in full contact between the pipe and the soil. The CLSM does ensure uniform support for the pipe. Placement of the CLSM is much faster

[5] Lowitz, C. A., and DeGroot, G., "Soil-Cement Pipe Bedding, Canadian River Aqueduct," *Journal of the Construction Division*, ASCE, Vol 94, No. C01, 1968.

[6] "Cement-Treated Pipeline Bedding," Portland Cement Association Publication No. PA0011.01.

than compacting the soil in layers alongside the pipe, and potential damage to the pipe from the compacting equipment is eliminated. It is also quicker than flooding and jetting or the saturation and vibration methods of compacting granular bedding materials. This faster installation is a distinct advantage where the construction is in populated areas or through streets.

X1.6.2 Fluidized thermal backfill (FTB) is a specialized type of CLSM used around underground electric transmission and distribution cables to conduct heat away from the cable. The thermal resistivity of CLSM can be evaluated using the appropriate ASTM or IEEE methods.

SUMMARY OF CHANGES

In accordance with Committee D18 policy, this section identifies the location of changes to this standard since the last edition (2010) that may impact the use of this standard. (December 15, 2016)

(1) Revised 1.7.

(2) Revised Section 3.