Addendum to Surface Impoundment Closure Plan

Avco - Lycoming TEXTRON

September 30, 1987

The following text contains responses to comments made by Mr. Robert Leger of EPA Region 1 and Mr. Kenneth Feathers of Connecticut DEP. All responses shall be incorporated into the report.

Section 2 - Closure Plan

Delete Figure 2.1, add attached Figure 2.1

Section 4 - Decontamination of Equipment/Personnel

Insert after the second paragraph:

"General equipment types to be decontaminated include:

- *Pumps, piping, dewatering equipment
- *Backhoes, Loaders
- *HDP Lined Trucks
- *Respirator cartridge, splash suits, deconsprayer, tyvek coveralls, decon. brush and basin, plastic sheets, trash barrel, plastic trash bags, decon. soap, disposable gloves, cotton gloves, hard hats, safety goggles, first aid kit, eye wash station, boots and duct tape.

This equipment shall be decontaminated according to US EPA Region IV, April 1986 Engineering Support Branch Standard Operating Procedures and Quality Assurance Manual, Environmental Services Division, Athens, Georgia, Appendix B. Methods to determine whether equipment is decontaminated are also listed in this manual.

Landfill Cap - General Comments

Design calculations for the drainage swale are not available at this time. They will be available during final design of the cap. (Note: this is a response to a comment and shall not be incorporated into the report).

Design calculations for the drainage swale will also not be provided at this time, however ASTM C33 and ASTM D1557 design standards will be added as Appendix H. (As per request of EPA). Therefore, insert attached Appendix H.

Section I - Paragraph 4

After paragraph 4 ("Figure 4.3 shows a typical section...) insert the following paragraphs.

"The final cover design will use the potential for soil erosion from side slopes. Application of this method is presented in the July 1982 Draft RCRA Guidance Document Landfill Designer, Liner System and Final Cover, US EPA, page 28.

Construction QA/QC for backfill control, membrane placement and slope verification will be conducted according to procedures outlined in the October 1986 Technical Guidance Document Construction Quality Assurance for Hazardous Waste Land Disposal Facilities, USEPA, OSWER Report No. EPA 1, 530-SW-86-031."

Section 7A-Groundwater Monitoring

Second paragraph, third sentence. "As part of the construction...". Delete last two sentences and replace with "As part of the construction of the final cap, these wells will be replaced outside the limit of the landfill cap with screens at the same elevations as the previous wells. The objective will be to make little or no changes in the well locations so that the time series of groundwater data remains comparable with past data."

Section 8 - Post Closure Cost Estimate

Delete section 8 and replace with the following:

C) The annual operating and Maintenance Costs for the post closure care period include:

1. Quarterly sampling and analyses -

pH	$ 5.
Specific Conductance	5.
Metals	145.
Cyanides (total & amenable)	60.
Hexvalent Chrominim	25.
	$240.

Sampling eight wells plus 2 QA/QC samples
$240. x 10 samples x 4 per year = 9600/yr

4, 6, 8, 9, 10, 11, 12, 13

1, 2, 3, 5 out

7 omit ?

Personnel: 2 engineers for 1 day at $50/hr x 4 = $4000/yr

Subtotal $13,000/yr

2. Semi annual sampling and analyses -

TOC	$ 25.
TOX	85.
Methods 8010 & 8020	225.
	$335.

$335 x 10 samples x 2 per year =

Subtotal $6700/yr

3. Annual Inspections -

2 engineers for 2 days at
$50 per hour plus $400 per diem

Subtotal $2000/yr

4. Annual Reporting -

. analytic data: 1 engineer, 1 day at $50/hr
. inspection report: 1 engineer, 3 days at $50/hr

Subtotal $2100/yr

5. Annual Operation and Maintenance Costs -

Lawn mowing, erosion filling clear drainage, repair cap

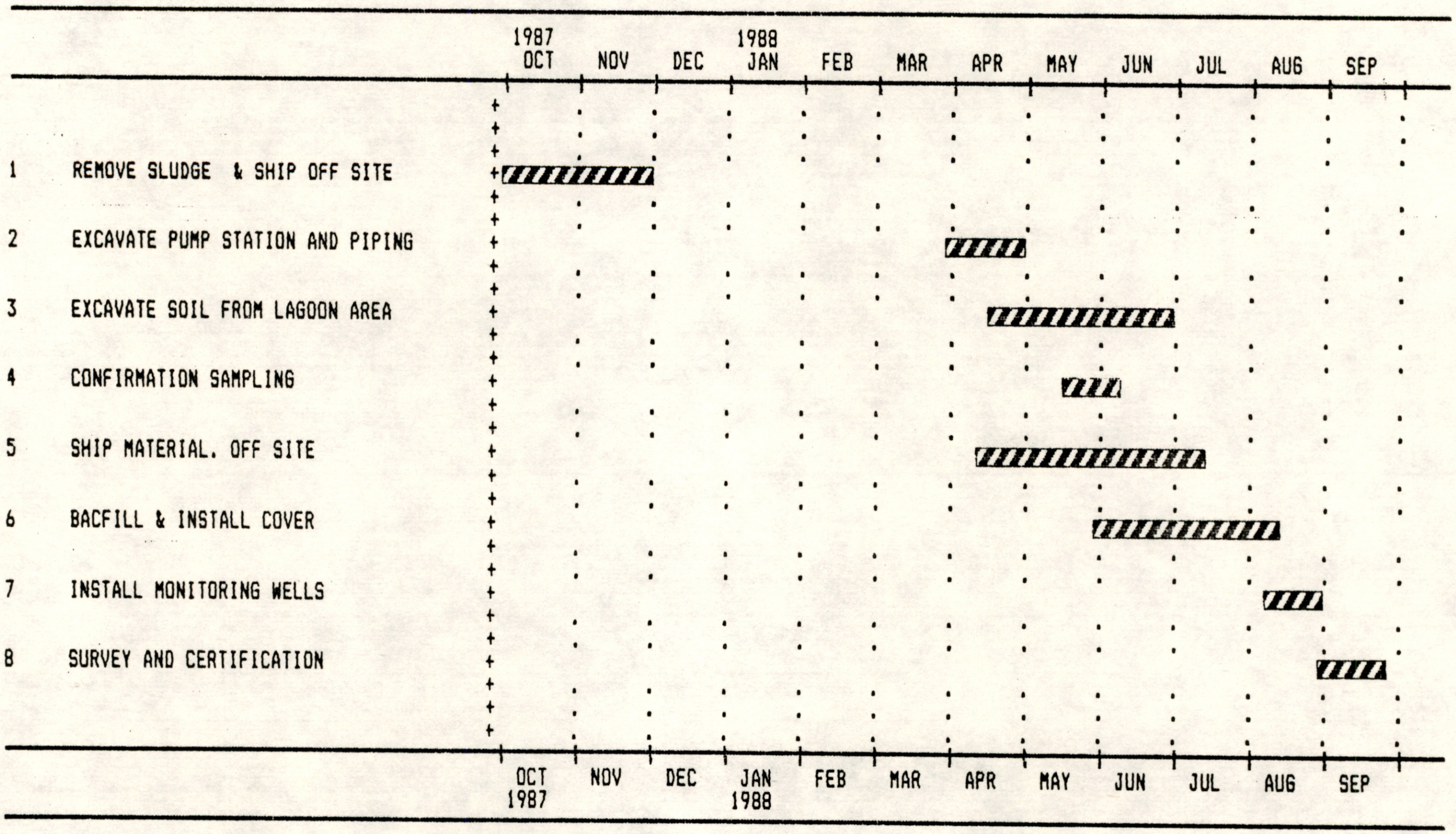
Subtotal $10,000/yr

The total annual cost for the above activities is approximately $35,000 (1987 dollars).

<u>Landfill Design References</u>

Remove references on last page of Appendix B and insert in Appendix G.

FIG. 2-1 SCHEDULE OF CLOSURE ACTIVITIES



Appendix H

ASTM C33 ASTM D1557 Standard Specifications the precautions given in 9.2.2.2 to guard against drying between time of removal from curing to testing.

10. Transportation of Specimens to Laboratory

10.1 Specimens shall not be transported from the field to the laboratory before completion of the initial curing. Specimens to be transported prior to an age of 48 h shall not be demolded prior to completion of transportation. Prior to transporting, specimens shall be cured and protected as required in Section 9. During transportation, the specimens must be protected with suitable cushioning material to prevent damage from jarring and from damage by freezing temperatures, or moisture loss. Moisture loss may be prevented by wrapping the specimens in plastic or surrounding them with wet sand or wet saw dust. When specimens are received by the laboratory, they shall be removed from molds if not done before shipment and placed in the required standard curing at 73.4 ± 3°F (23 ± 1.7°C).

TABLE 1 Number of Layers Required for Specimens

Specimen Type and Size, as Depth, in. (mm)	Mode of Compaction	Number of Layers	Approximate Depth of Layer, in. (mm)
Cylinders:			
12 (305)	rodding	3 equal	4 (100)
Over 12 (305)	rodding	as required	4 (100)
12 (305) to 18 (460)	vibration	2 equal	half depth of specimens
Over 18 (460)	vibration	3 or more	8 (200) as near as practicable
Beams:			
6 (152) to 8 (200)	rodding	2 equal	half depth of specimen
Over 8 (200)	rodding	3 or more	4 (100)
6 (152) to 8 (200)	vibration	1	depth of specimen
Over 8 (200)	vibration	2 or more	8 (200) as near as practicable

TABLE 2 Number of Roddings to be Used in Molding Cylinder Specimens

Diameter of Cylinder, in. (mm)	Number of Strokes/Layer
6 (152)	25
8 (200)	50
10 (250)	75

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This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, Pa. 19103.

Designation: C 33 – 86

Standard Specification for CONCRETE AGGREGATES[1]

This standard is issued under the fixed designation C 33; 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 specification has been approved for use by agencies of the Department of Defense and for listing in the DoD Index of Specifications and Standards.

1. Scope

1.1 This specification defines the requirements for grading and quality of fine and coarse aggregate (other than lightweight or heavyweight aggregate) for use in concrete.[2]

1.2 The information in this specification may be used by a specifier (designer, architect, engineer, etc.) to define the quality and grading of the aggregate to be used in the concrete in the structure. The specification may be also used by a contractor, concrete supplier, or other purchaser as a purchase document describing the material to be furnished by the aggregate producer.

NOTE 1—This specification is regarded as adequate to ensure satisfactory materials for most concrete. It is recognized that, for certain work or in certain regions, it may be either more or less restrictive than needed. The specifier should ascertain that aggregates specified are or can be made available in the area of the work, with regard to grading, physical, or chemical properties, or combination thereof.

1.3 *Units of Measurement:*

1.3.1 With regard to sieve sizes and the size of aggregate as determined by the use of testing sieves, the values in inch-pound units are shown for the convenience of the user; however, the standard sieve designation shown in parentheses is the standard value as stated in Specification E 11.

1.3.2 With regard to other units of measure, the values stated in inch-pound units are to be regarded as standard.

2. Applicable Documents

2.1 *ASTM Standards:*

C 29 Test Method for Unit Weight and Voids in Aggregate[3]

C 40 Test Method for Organic Impurities in Fine Aggregates for Concrete[3]

C 87 Test Method for Effect of Organic Impurities in Fine Aggregate on Strength of Mortar[3]

C 88 Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate[3]

C 117 Test Method for Materials Finer than 75-μm (No. 200) Sieve in Mineral Aggregates by Washing[3]

C 123 Test Method for Lightweight Pieces in Aggregate[3]

C 125 Definitions of Terms Relating to Concrete and Concrete Aggregates[3]

C 131 Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine[3]

C 136 Method for Sieve Analysis of Fine and Coarse Aggregates[3]

C 142 Test Method for Clay Lumps and Friable Particles in Aggregates[3]

C 227 Test Method for Potential Alkali Reactivity of Cement-Aggregate Combinations (Mortar-Bar Method)[3]

C 289 Test Method for Potential Reactivity of Aggregates (Chemical Method)[3]

C 294 Descriptive Nomenclature of Constitu-

[1] This specification is under the jurisdiction of ASTM Committee C-9 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.03.05 on Methods of Testing and Specifications for Physical Characteristics of Concrete Aggregates.

Current edition approved March 27, 1986. Published May 1986. Originally published as C 33 – 21 T. Last previous edition C 33 – 85. Changes from the previous revision have included references to heavyweight aggregates in 1.1, 2.1, and footnote 2.

[2] For lightweight aggregates, see Specifications C 331, C 332, and C 330; for heavyweight aggregates see Specification C 637 and Descriptive Nomenclature C 638.

[3] *Annual Book of ASTM Standards*, Vol 04.02.

ents of Natural Mineral Aggregates[3]

C 295 Practice for Petrographic Examination of Aggregates for Concrete[3]

C 330 Specification for Lightweight Aggregates for Structural Concrete[3]

C 331 Specification for Lightweight Aggregates for Concrete Masonry Units[3]

C 332 Specification for Lightweight Aggregates for Insulating Concrete[3]

C 342 Test Method for Potential Volume Change of Cement-Aggregate Combinations[3]

C 535 Test Method for Resistance to Degradation of Large-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine[3]

C 586 Test Method for Potential Alkali Reactivity of Carbonate Rocks for Concrete Aggregates (Rock Cylinder Method)[3]

C 637 Specifications for Aggregates for Radiation-Shielding Concrete[3]

C 638 Descriptive Nomenclature of Constituents of Aggregates for Radiation Shielding Concrete[3]

C 666 Test Method for Resistance of Concrete to Rapid Freezing and Thawing[3]

D 75 Practice for Sampling Aggregates[3]

D 3665 Practice for Random Sampling of Construction Materials[4]

E 11 Specification for Wire-Cloth Sieves for Testing Purposes[3]

2.2 *Related Document:*

3. Ordering Information

3.1 The purchaser shall include the following information in the purchase order when applicable:

3.1.1 Reference to this specification, C 33, and date of issue,

3.1.2 Whether the order is for fine aggregate or for coarse aggregate,

3.1.3 Quantity, in tons or metric tons (Note 2),

3.1.4 When the order is for fine aggregate (Note 3):

3.1.4.1 Whether the optional grading in 5.2 applies,

3.1.4.2 Whether the restriction on reactive materials in 6.3 applies,

3.1.4.3 In the case of the sulfate soundness test (7.1) which salt is to be used. If none is stated, either salt may be used,

3.1.4.4 The appropriate limit for material finer than No. 200 sieve (Table 1). If not stated, the 3.0 % limit shall apply,

3.1.4.5 The appropriate limit for coal and lignite (Table 1). If not stated, the 1.0 % limit shall apply.

3.1.5 When the order is for coarse aggregate (Note 3):

3.1.5.1 The grading (size number) (9.1 and Table 2),

3.1.5.2 The class designation (10.1 and Table 3),

3.1.5.3 Whether the restriction on reactive materials in 10.2 applies,

3.1.5.4 In the case of the sulfate soundness test (Table 3), which salt is to be used. If none is stated, either salt may be used.

3.1.6 Any exceptions or additions to this specification (see Notes 1 and 3).

NOTE 2—The weight should be determined as loaded in the hauling unit, including any natural moisture present. No water should be added at the time of loading.

NOTE 3—The specifier (architect, engineer, etc.) should include in the contract documents his requirements as to the items listed in 3.1.4, 3.1.5, and 3.1.6. Otherwise, any grading or quality described in this specification which is furnished may be deemed to be acceptable, even though it may later prove to be unsatisfactory in service.

FINE AGGREGATE

4. General Characteristics

4.1 Fine aggregate shall consist of natural sand, manufactured sand, or a combination thereof.

5. Grading

5.1 *Sieve Analysis*—Fine aggregate, except as provided in 5.2, 5.3, and 5.4, shall be graded within the following limits:

Sieve (Specification E 11)	Percent Passing
⅜-in. (9.5 mm)	100
No. 4 (4.75-mm)	95 to 100
No. 8 (2.36-mm)	80 to 100
No. 16 (1.18-mm)	50 to 85
No. 30 (600-μm)	25 to 60
No. 50 (300-μm)	10 to 30
No. 100 (150-μm)	2 to 10

5.2 The minimum percent shown above for material passing the No. 50 (300-μm) and No. 100 (150-μm) sieves may be reduced to 5 and 0 respectively, if the aggregate is to be used in air-entrained concrete containing more than 400 lb of cement per cubic yard (237 kg/m^3) or in nonair-entrained concrete containing more than 500 lb of cement per cubic yard (297 kg/m^3) or if an approved mineral admixture is used to supply the deficiency in percent passing these sieves. Air-entrained concrete is here considered to be concrete containing air-entraining cement or an air-entraining agent and having an air content of more than 3 %.

[4] *Annual Book of ASTM Standards*, Vol 04.03.

5.3 The fine aggregate shall have not more than 45 % passing any sieve and retained on the next consecutive sieve of those shown in 5.1, and its fineness modulus shall be not less than 2.3 nor more than 3.1.

5.4 Fine aggregate failing to meet the sieve analysis and fineness modulus requirements of 5.1, 5.2, or 5.3, may be accepted provided that concrete made with similar fine aggregate from the same source has an acceptable performance record in similar concrete construction; or, in the absence of a demonstrable service record, provided that it is demonstrated that concrete of the class specified, made with the fine aggregate under consideration, will have relevant properties at least equal to those of concrete made with the same ingredients, with the exception that a reference fine aggregate be used which is selected from a source having an acceptable performance record in similar concrete construction.

NOTE 4—Fine aggregate that conforms to the grading requirements of a specification, prepared by another organization such as a state transportation agency, which is in general use in the area, should be considered as having a satisfactory service record with regard to those concrete properties affected by grading.

NOTE 5—Relevant properties are those properties of the concrete which are important to the particular application being considered. STP 169B[5] provides a discussion of important concrete properties.

5.5 For continuing shipments of fine aggregate from a given source, the fineness modulus shall not vary more than 0.20 from the base fineness modulus. The base fineness modulus shall be that value that is typical of the source. If necessary, the base fineness modulus may be changed when approved by the purchaser.

NOTE 6—The base fineness modulus should be determined from previous tests, or if no previous tests exist, from the average of the fineness modulus values for the first ten samples (or all preceding samples if less than ten) on the order. The proportioning of a concrete mixture may be dependent on the base fineness modulus of the fine aggregate to be used. Therefore, when it appears that the base fineness modulus is considerably different from the value used in the concrete mixture, a suitable adjustment in the mixture may be necessary.

6. Deleterious Substances

6.1 The amount of deleterious substances in fine aggregate shall not exceed the limits prescribed in Table 1.

6.2 *Organic Impurities:*

6.2.1 Fine aggregate shall be free of injurious amounts of organic impurities. Except as herein provided, aggregates subjected to the test for organic impurities and producing a color darker than the standard shall be rejected.

6.2.2 A fine aggregate failing in the test may be used, provided that the discoloration is due principally to the presence of small quantities of coal, lignite, or similar discrete particles.

6.2.3 A fine aggregate failing in the test may be used, provided that, when tested for the effect of organic impurities on strength of mortar, the relative strength at 7 days calculated in accordance with Test Method C 87, is not less than 95 %.

6.3 Fine aggregate for use in concrete that will be subject to wetting, extended exposure to humid atmosphere, or contact with moist ground shall not contain any materials that are deleteriously reactive with the alkalies in the cement in an amount sufficient to cause excessive expansion of mortar or concrete, except that if such materials are present in injurious amounts, the fine aggregate may be used with a cement containing less than 0.60 % alkalies calculated as sodium oxide equivalent ($Na_2O + 0.658K_2O$) or with the addition of a material that has been shown to prevent harmful expansion due to the alkali-aggregate reaction. (See Appendix X1)

7. Soundness

7.1 Except as provided in 7.2 and 7.3, fine aggregate subjected to five cycles of the soundness test shall have a weighted average loss not greater than 10 % when sodium sulfate is used or 15 % when magnesium sulfate is used.

7.2 Fine aggregate failing to meet the requirements of 7.1 may be accepted, provided that concrete of comparable properties, made from similar aggregate from the same source, has given satisfactory service when exposed to weathering similar to that to be encountered.

7.3 Fine aggregate not having a demonstrable service record and failing to meet the requirements of 7.1 may be accepted, provided it gives

[5] *Significance of Tests and Properties of Concrete and Concrete Making Materials, STP 169B*, ASTM, 1978.

ing and thawing tests (see Test Method C 666).

COARSE AGGREGATE

8. General Characteristics

8.1 Coarse aggregate shall consist of gravel, crushed gravel, crushed stone, air-cooled blast furnace slag, or crushed hydraulic-cement concrete, or a combination thereof, conforming to the requirements of this specification.

NOTE 7—Although crushed hydraulic-cement concrete has been used as an aggregate with reported satisfactory results, its use may require some additional precautions. Mixing water requirements may be increased because of the harshness of the aggregate. Partially deteriorated concrete, used as aggregate, may reduce freeze-thaw resistance, affect air void properties or degrade during handling, mixing, or placing. Crushed concrete may have constituents that would be susceptible to alkali-aggregate reactivity or sulfate attack in the new concrete or may bring sulfates, chlorides, or organic material to the new concrete in its pore structure.

9. Grading

9.1 Coarse aggregates shall conform to the requirements prescribed in Table 2 for the size number specified.

NOTE 8—The ranges shown in Table 2 are by necessity very wide in order to accommodate nationwide conditions. For quality control of any specific operation, a producer should develop an average gradation for the particular source and production facilities, and control the gradation within reasonable tolerances from this average. Where coarse aggregate sizes numbers 357 or 467 are used, the aggregate should be furnished in at least two separate sizes.

10. Deleterious Substances

10.1 Except for the provisions of 10.3, the limits given in Table 3 shall apply for the class of coarse aggregate designated in the purchase order or other document (Notes 9 and 10). If the class is not specified, the requirements for Class 3S, 3M, or 1N shall apply in the severe, moderate, and negligible weathering regions, respectively (see Table 3 and Fig. 1).

NOTE 9—The specifier of the aggregate should designate the class of coarse aggregate to be used in the work, based on weathering severity, abrasion, and other factors of exposure. (See Table 3 and Fig. 1.) The limits for coarse aggregate corresponding to each class designation are expected to ensure satisfactory performance in concrete for the respective type and location of construction. Selecting a class with unduly restrictive limits may result in unnecessary cost if materials meeting those requirements are not locally available. Selecting a class with lenient limits may result in unsatisfactory performance and premature deterioration of the concrete. While concrete in different classes of coarse aggregate, the specifier may wish to require the coarse aggregate for all concrete to conform to the same more restrictive class to reduce the chance of furnishing concrete with the wrong class of aggregate, especially on smaller projects.

NOTE 10—For coarse aggregate in concrete exposed to weathering, the map with the weathering regions shown in Fig. 1 is intended to serve only as a guide to probable weathering severity. Those undertaking construction, especially near the boundaries of weathering regions, should consult local weather bureau records for amount of winter precipitation and number of freeze-thaw cycles to be expected, for determining the weathering severity for establishing test requirements of the coarse aggregate. For construction at altitudes exceeding 5000 ft (1520 m) above sea level, the likelihood of more severe weathering than indicated by the map should be considered.

10.2 Coarse aggregate for use in concrete that will be subject to wetting, extended exposure to humid atmosphere, or contact with moist ground shall not contain any materials that are deleteriously reactive with the alkalies in the cement in an amount sufficient to cause excessive expansion of mortar or concrete except that if such materials are present in injurious amounts, the coarse aggregate may be used with a cement containing less than 0.60 % alkalies calculated as sodium oxide equivalent ($Na_2O + 0.658K_2O$) or with the addition of a material that has been shown to prevent harmful expansion due to the alkali-aggregate reaction. (See Appendix X1.).

10.3 Coarse aggregate having test results exceeding the limits specified in Table 3 may be accepted provided that concrete made with similar aggregate from the same source has given satisfactory service when exposed in a similar manner to that to be encountered; or, in the absence of a demonstrable service record, provided that the aggregate produces concrete having satisfactory relevant properties (see Note 5).

METHODS OF SAMPLING AND TESTING

11. Methods of Sampling and Testing

11.1 Sample and test the aggregates in accordance with the following methods, except as otherwise provided in this specification. Make the required tests on test samples that comply with requirements of the designated test methods. The same test sample may be used for sieve analysis and for determination of material

finer than the No. 200 (75-μm) sieve. Separated sizes from the sieve analysis may be used in preparation of samples for soundness or abrasion tests. For determination of all other tests and for evaluation of potential alkali reactivity where required, use independent test samples.

11.1.1 *Sampling*—Practice D 75 and Practice D 3665.

11.1.2 *Grading and Fineness Modulus*—Method C 136.

11.1.3 *Amount of Material Finer than No. 200 (75-μm) Sieve*—Test Method C 117.

11.1.4 *Organic Impurities*—Test Method C 40.

11.1.5 *Effect of Organic Impurities on Strength*—Test Method C 87.

11.1.6 *Soundness*—Test Method C 88.

11.1.7 *Clay Lumps and Friable Particles*—Test Method C 142.

using a liquid of 2.0 specific gravity to remove the particles of coal and lignite. Only material that is brownish-black, or black, shall be considered coal or lignite. Coke shall not be classed as coal or lignite.

11.1.9 *Weight of Slag*—Test Method C 29.

11.1.10 *Abrasion of Coarse Aggregate*—Test Method C 131 or Test Method C 535.

11.1.11 *Reactive Aggregates*—See Appendix X1.

11.1.12 *Freezing and Thawing*—Procedures for making freezing and thawing tests of concrete are described in Test Method C 666.

11.1.13 *Chert*—Test Method C 123 is used to identify particles in a sample of coarse aggregate lighter than 2.40 specific gravity, and Practice C 295 to identify which of the particles in the light fraction are chert.

TABLE 1 Limits for Deleterious Substances in Fine Aggregate for Concrete

Item	Weight Percent of Total Sample, max
Clay lumps and friable particles	3.0
Material finer than No. 200 (75-μm) sieve:	
Concrete subject to abrasion	3.0[A]
All other concrete	5.0[A]
Coal and lignite:	
Where surface appearance of concrete is of importance	0.5
All other concrete	1.0

[A] In the case of manufactured sand, if the material finer than the No. 200 (75-μm) sieve consists of the dust of fracture, essentially free of clay or shale, these limits may be increased to 5 and 7 %, respectively.

TABLE 2 Grading Requirements for Coarse Aggregates

Size Number	Nominal Size (Sieves with Square Openings)	Amounts Finer than Each Laboratory Sieve (Square-Openings), Weight Percent												
		4 in. (100 mm)	3½ in. (90 mm)	3 in. (75 mm)	2½ in. (63 mm)	2 in. (50 mm)	1½ in. (37.5 mm)	1 in. (25.0 mm)	¾ in. (19.0 mm)	½ in. (12.5 mm)	⅜ in. (9.5 mm)	No. 4 (4.75 mm)	No. 8 (2.36 mm)	No. 16 (1.18 mm)
1	3½ to 1½ in. (90 to 37.5 mm)	100	90 to 100	...	25 to 60	...	0 to 15	...	0 to 5	...	...	...	...	...
2	2½ to 1½ in. (63 to 37.5 mm)	...	...	100	90 to 100	35 to 70	0 to 15	...	0 to 5	...	...	...	...	...
3	2 to 1 in. (50 to 25.0 mm)	...	...	...	100	90 to 100	35 to 70	0 to 15	...	0 to 5	...	...	...	...
357	2 in. to No. 4 (50 to 4.75 mm)	...	...	...	100	95 to 100	...	35 to 70	...	10 to 30	...	0 to 5	...	...
4	1½ to ¾ in. (37.5 to 19.0 mm)	...	...	...	...	100	90 to 100	20 to 55	0 to 15	...	0 to 5	...	...	...
467	1½ in. to No. 4 (37.5 to 4.75 mm)	...	...	...	...	100	95 to 100	...	35 to 70	...	10 to 30	0 to 5	...	...
5	1 to ½ in. (25.0 to 12.5 mm)	...	...	...	...	...	100	90 to 100	20 to 55	0 to 10	0 to 5	...	...	...
56	1 to ⅜ in. (25.0 to 9.5 mm)	...	...	...	...	...	100	90 to 100	40 to 85	10 to 40	0 to 15	0 to 5	...	...
57	1 in. to No. 4 (25.0 to 4.75 mm)	...	...	...	...	...	100	95 to 100	...	25 to 60	...	0 to 10	0 to 5	...
6	¾ to ⅜ in. (19.0 to 9.5 mm)	...	...	...	...	...	...	100	90 to 100	20 to 55	0 to 15	0 to 5	...	...
67	¾ in. to No. 4 (19.0 to 4.75 mm)	...	...	...	...	...	...	100	90 to 100	...	20 to 55	0 to 10	0 to 5	...
7	½ in. to No. 4 (12.5 to 4.75 mm)	...	...	...	...	...	...	...	100	90 to 100	40 to 70	0 to 15	0 to 5	...
8	⅜ in. to No. 8 (9.5 to 2.36 mm)	...	...	...	...	...	...	...	...	100	85 to 100	10 to 30	0 to 10	0 to 5

TABLE 3 Limits for Deleterious Substances and Physical Property Requirements of Coarse Aggregate for Concrete

NOTE—See Fig. 1 for the location of the weathering regions and footnote E to this table for the computation of the weathering index. The weathering regions are defined as follows in terms of the weathering index:

(S) Severe Weathering Region—Weathering Index greater than 500 day-inches (1270 day-cm).
(M) Moderate Weathering Region—Weathering Index 100 to 500 day-inches (254 to 1270 day-cm).
(N) Negligible Weathering Region—Weathering Index less than 100 day-inches (254 day-cm).

Class Designation	Type or Location of Concrete Construction	Maximum Allowable, %						
		Clay Lumps and Friable Particles	Chert[C] (Less Than 2.40 sp gr SSD)	Sum of Clay Lumps, Friable Particles, and Chert (Less Than 2.40 sp gr SSD)[C]	Material Finer Than No. 200 (75-μm) Sieve	Coal and Lignite	Abrasion[A]	Magnesium Sulfate Soundness (5 cycles)[B]
	Severe Weathering Regions							
1S	Footings, foundations, columns and beams not exposed to the weather, interior floor slabs to be given coverings	10.0	...	...	1.0[D]	1.0	50	...
2S	Interior floors without coverings	5.0	...	...	1.0[D]	0.5	50	...
3S	Foundation walls above grade, retaining walls, abutments, piers, girders, and beams exposed to the weather	5.0	5.0	7.0	1.0[D]	0.5	50	18
4S	Pavements, bridge decks, driveways and curbs, walks, patios, garage floors, exposed floors and porches, or waterfront structures, subject to frequent wetting	3.0	5.0	5.0	1.0[D]	0.5	50	18
5S	Exposed architectural concrete	2.0	3.0	3.0	1.0[D]	0.5	50	18
	Moderate Weathering Regions							
1M	Footings, foundations, columns, and beams not exposed to the weather, interior floor slabs to be given coverings	10.0	...	...	1.0[D]	1.0	50	...
2M	Interior floors without coverings	5.0	...	...	1.0[D]	0.5	50	...
3M	Foundation walls above grade, retaining walls, abutments, piers, girders, and beams exposed to the weather	5.0	8.0	10.0	1.0[D]	0.5	50	18
4M	Pavements, bridge decks, driveways and curbs, walks, patios, garage floors, exposed floors and porches, or waterfront structures subject to frequent wetting	5.0	5.0	7.0	1.0[D]	0.5	50	18

TABLE 3 *Continued*

Class Designation	Type or Location of Concrete Construction	Maximum Allowable, %						
		Clay Lumps and Friable Particles	Chert[C] (Less Than 2.40 sp gr SSD)	Sum of Clay Lumps, Friable Particles, and Chert (Less Than 2.40 sp gr SSD)[C]	Material Finer Than No. 200 (75-µm) Sieve	Coal and Lignite	Abrasion[A]	Magnesium Sulfate Soundness (5 cycles)[B]
5M	Exposed architectural concrete	3.0	3.0	5.0	1.0[D]	0.5	50	18
		Negligible Weathering Regions						
1N	Slabs subject to traffic abrasion, bridge decks, floors, sidewalks, pavements	5.0	...	...	1.0[D]	0.5	50	...
2N	All other classes of concrete	10.0	...	...	1.0[D]	1.0	50	...

[A] Crushed air-cooled blast-furnace slag is excluded from the abrasion requirements. The rodded or jigged unit weight of crushed air-cooled blast-furnace slag shall be not less than 70 lb/ft^3 (1120 kg/m^3). The grading of slag used in the unit weight test shall conform to the grading to be used in the concrete. Abrasion loss of gravel, crushed gravel, or crushed stone shall be determined on the test size or sizes most nearly corresponding to the grading or gradings to be used in the concrete. When more than one grading is to be used, the limit on abrasion loss shall apply to each.

[B] The allowable limits for soundness shall be 12 % if sodium sulfate is used.

[C] These limitations apply only to aggregates in which chert appears as an impurity. They are not applicable to gravels that are predominantly chert. Limitations on soundness of such aggregates must be based on service records in the environment in which they are used.

[D] This percentage may be increased under either of the following conditions: (*1*) if the material finer than the No. 200 (75-µm) sieve is essentially free of clay or shale the percentage may be increased to 1.5; or (*2*) if the source of the fine aggregate to be used in the concrete is known to contain less than the specified maximum amount passing the No. 200 (75-µm) sieve (Table 1) the percentage limit (L) on the amount in the coarse aggregate may be increased to $L = 1 + [(P)/(100 - P)] (T - A)$, where P = percentage of sand in the concrete as a percent of total aggregate, T = the Table 1 limit for the amount permitted in the fine aggregate, and A = the actual amount in the fine aggregate. (This provides a weighted calculation designed to limit the maximum mass of material passing the No. 200 (75-µm) sieve in the concrete to that which would be obtained if both the fine and coarse aggregate were supplied at the maximum tabulated percentage for each of these ingredients.)

[E] Weathering Index. The effect of weathering is related to the weathering index, which for any locality is the product of the average annual number of *freezing cycle days* and the average annual *winter rainfall* in inches (or centimetres), defined as follows: *A Freezing Cycle Day* is any day during which the air temperature passes either above or below 32°F (0°C). The average number of freezing cycle days in a year may be taken to equal the difference between the mean number of days during which the minimum temperature was 32°F (0°C) or below and the mean number of days during which the maximum temperature was 32°F (0°C) or below. *Winter Rainfall* is the sum, in inches (or centimetres) of the mean monthly corrected precipitation (rainfall) occurring during the period between and including the normal date of the first occurrence of freezing (32°F, 0°C) in the fall and the normal date of the last occurrence of freezing (32°F, 0°C) in the spring. The winter rainfall for any period is equal to the total precipitation less one tenth of the total fall of snow, sleet, and hail. Rainfall for a portion of a month is prorated.

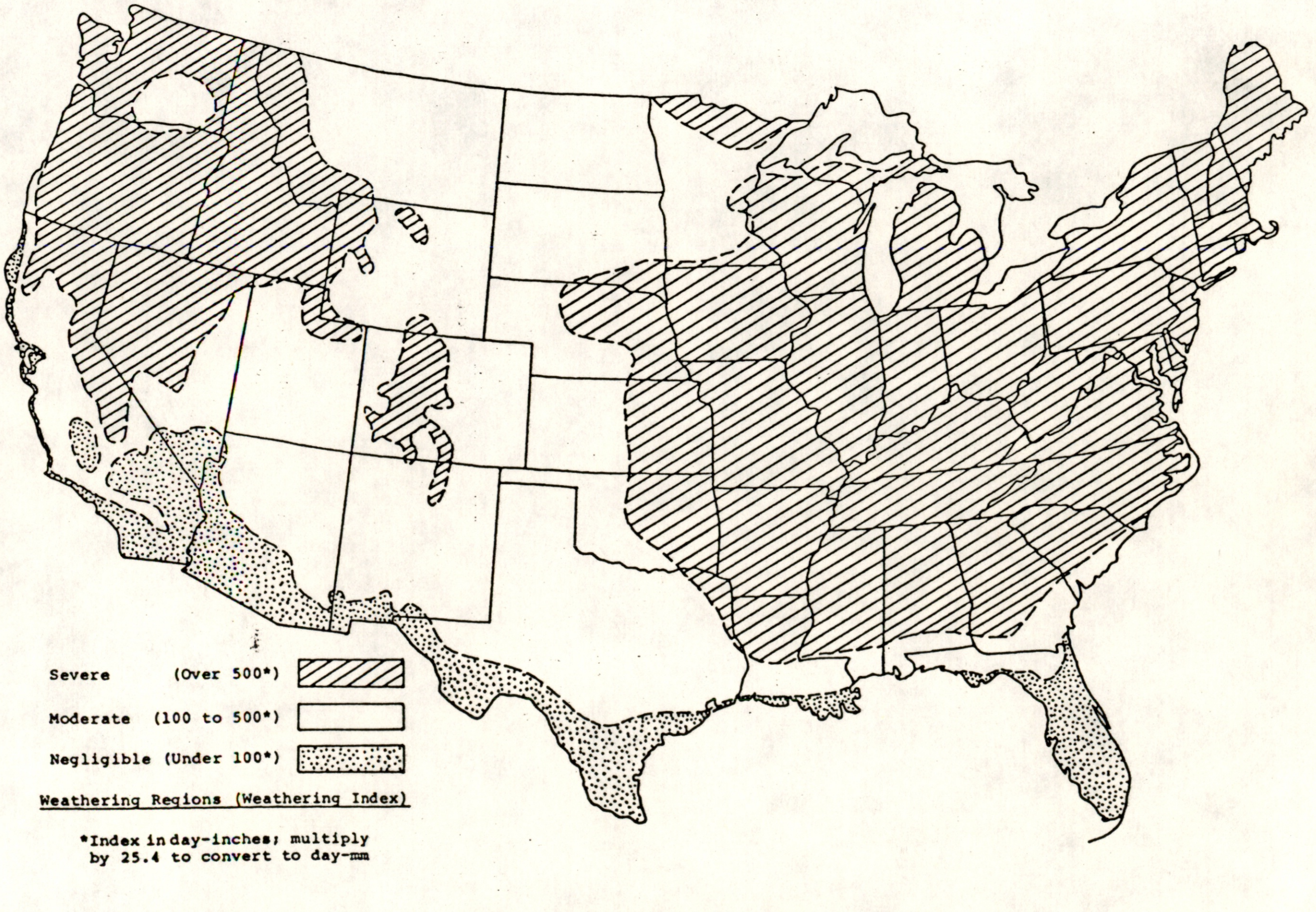


FIG. 1 Location of Weathering Regions

APPENDIX

(Nonmandatory Information)

XI. METHODS FOR EVALUATING POTENTIAL REACTIVITY OF AN AGGREGATE

X1.1 A number of methods for detecting potential reactivity have been proposed. However, they do not provide quantitative information on the degree of reactivity to be expected or tolerated in service. Therefore, evaluation of potential reactivity of an aggregate should be based upon judgment and on the interpretation of test data and examination of concrete structures containing a combination of fine and coarse aggregates and cements for use in the new work. Results of the following tests may assist in making the evaluation:

X1.1.1 *Practice C 295*—Certain materials are known to be reactive with the alkalies in cements. These include the following forms of silica: opal, chalcedony, tridymite, and cristobalite; intermediate to acid (silica-rich) volcanic glass such as is likely to occur in rhyolite, andesite, or dacite; certain zeolites such as heulandite; and certain constituents of some phyllites. Determination of the presence and quantities of these materials by petrographic examination is helpful in evaluating potential alkali reactivity. Some of these materials render an aggregate deleteriously reactive when present in quantities as little as 1.0 % or even less.

X1.1.2 *Test Method C 289*—In this test method, aggregates represented by points lying to the right of the solid line of Fig. 2 of Test Method C 289 usually should be considered potentially reactive.

X1.1.2.1 If R_c exceeds 70, the aggregate is considered potentially reactive if S_c is greater than R_c.

X1.1.2.2 If R_c is less than 70, the aggregate is considered potentially reactive if S_c is greater than 35 + (R_c/2).

X1.1.2.3 These criteria conform to the solid line curve given in Fig. 2 of Test Method C 289. The test can be made quickly and, while not completely reliable in all cases, provides helpful information, especially where results of the more time-consuming tests are not available.

X1.1.3 *Test Method C 227*—The results of this test method when made with a high-alkali cement, furnish information on the likelihood of harmful reactions occurring. The alkali content of the cement should be substantially above 0.6 %, and preferably above 0.8 %, expressed as sodium oxide. Combinations of aggregate and cement that have produced excessive expansions in this test usually should be considered potentially reactive. While the line of demarcation between non-reactive and reactive combinations is not clearly defined, expansion is generally considered to be excessive if it exceeds 0.05 % at 3 months or 0.10 % at 6 months. Expansions greater than 0.05 % at 3 months should not be considered excessive where the 6-month expansion remains below 0.10 %. Data for the 3-month tests should be considered only when 6-month results are not available.

X1.1.4 *Test Method C 342*—This test method is intended primarily for research concerning the potential expansion of cement-aggregate combinations subjected to variations of temperature and water saturation during storage under prescribed conditions of test. Its use is mainly by those interested in research on aggregates that are found in parts of Kansas, Nebraska, Iowa and possibly other adjoining areas.

X1.1.4.1 In addition to its usefulness in research, this test method has been found useful in the selection of aggregates of the so-called "sand-gravel" type found mainly in some parts of Kansas, Nebraska and Iowa, which contain very little coarse material; generally 5 to 15 % retained on the No. 4 (4.75-mm) sieve. Much work has been done on the problems of using these aggregates successfully in concrete and is reported in summary in the "Final Report of Cooperative Tests of Proposed Tentative Method of Test for Potential Volume Change of Cement-Aggregate Combinations," Appendix to Committee C-9 Report, Proceedings, ASTM, Volume 54, 1954, p. 356. It indicates that cement-aggregate combinations tested by this procedure in which expansion equals or exceeds 0.200 % at an age of 1 year may be considered unsatisfactory for use in concrete exposed to wide variations of temperature and degree of saturation with water. In that geographical region, the problem has been reduced through the use of partial replacement of the "sand-gravel" with limestone coarse aggregate.

X1.1.5 *Potential Reactivity of Carbonate Aggregates*—The reaction of the dolomite in certain carbonate rocks with alkalies in portland cement paste has been found to be associated with deleterious expansion of concrete containing such rocks as coarse aggregate. Carbonate rocks capable of such reaction possess a characteristic texture and composition. The characteristic texture is that in which relatively large crystals of dolomite are scattered in a finer-grained matrix of calcite and clay. The characteristic composition is that in which the carbonate portion consists of substantial amounts of both dolomite and calcite, and the acid-insoluble residue contains a significant amount of clay. Except in certain areas, such rocks are of relatively infrequent occurrence and seldom make up a significant proportion of the material present in a deposit of rock being considered for use in making aggregate for concrete. Test Method C 586 has been successfully used in (*1*) research and (*2*) preliminary screening of aggregate sources to indicate the presence of material with a potential for deleterious expansions when used in concrete.

Standard Specification for INORGANIC AGGREGATES FOR USE IN GYPSUM PLASTER[1]

This standard is issued under the fixed designation C 35; 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.

$^{\epsilon 1}$ NOTE—Section 2 was added editorially and subsequent sections renumbered in May 1985.

1. Scope

1.1 This specification covers those aggregates most commonly used in gypsum plaster, which include perlite, sand (natural and manufactured), and vermiculite. Other aggregates may be employed, provided tests have demonstrated them to yield plaster of satisfactory quality.

2. Applicable Documents

2.1 *ASTM Standards:*

C 29 Test Method for Unit Weight and Voids in Aggregate[2]

C 40 Test Method for Organic Impurities in Fine Aggregates for Concrete[2]

C 136 Method for Sieve Analysis of Fine and Coarse Aggregates[2]

D 75 Practice for Sampling Aggregates[2]

3. Definitions

3.1 *perlite aggregate*—a siliceous volcanic glass properly expanded by heat.

3.2 *sand aggregate:*

3.2.1 *natural sand*—the fine granular material resulting from the natural disintegration of rock or from the crushing of friable sandstone.

3.2.2 *manufactured sand*—the fine material resulting from the crushing and classification by screening, or otherwise, of rock, gravel or blast furnace slag.

3.3 *vermiculite aggregate*—a micaceous mineral properly expanded by heat.

4. Grading

4.1 *Sieve Analysis*—The aggregate, except as provided in 4.2, shall be graded within the limits specified in Table 1.

4.2 For natural or manufactured sand, no more than 50 % shall be retained between any two consecutive sieves shown in 4.1, nor more than 25 % between the No. 50 (300-μm) and No 100 (150-μm) sieves.

4.3 For natural or manufactured sand, the amount of material finer than a No. 200 (75-μm) sieve shall not exceed 5 %.

5. Weight of Lightweight Aggregates

5.1 The weight of perlite aggregate shall be not less than 6 nor more than 12 lb/ft³ (96 to 192 kg/m³).

5.2 The weight of vermiculite aggregate shall be not less than 6 more than 10 lb/ft³ (96 to 160 kg/m³).

6. Impurities

6.1 Water-soluble impurities in sand shall not exceed 0.15 weight % and sodium ion content shall not exceed 0.02 weight %.

6.2 Sand, when subjected to the colorimetric test for organic impurities, shall develop a color no darker than the standard, unless it is established by adequate tests that the impurities causing the color are not harmful in plaster.

[1] This specification is under the jurisdiction of ASTM Committee C-11 on Ceiling and Walls and is the direct responsibility of Subcommittee C 11.02 on Specifications and Test Methods for Accessories and Related Products.

Current edition approved Sept. 24, 1976. Published November 1976. Originally published as C 35 – 21 T. Last previous edition C 35 – 70 (1975).

[2] Annual Book of ASTM Standards, Vol 04.02.

Standard Test Methods for MOISTURE-DENSITY RELATIONS OF SOILS AND SOIL-AGGREGATE MIXTURES USING 10-lb (4.54-kg) RAMMER AND 18-in. (457-mm) DROP[1]

This standard is issued under the fixed designation D 1557; 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.

These methods have been approved for use by agencies of the Department of Defense and for listing in the DoD Index of Specifications and Standards.

1. Scope

1.1 These laboratory compaction methods cover the determination of the relationship between the moisture content and density of soils and soil-aggregate mixtures (Note 1) when compacted in a mold of a given size with a 10-lb (4.54-kg) rammer dropped from a height of 18 in. (457 mm) (Note 2). Four alternative procedures are provided as follows:

1.1.1 *Method A*—A 4-in. (101.6-mm) mold; material passing a No. 4 (4.75-mm) sieve;

1.1.2 *Method B*—A 6-in. (152.4-mm) mold; material passing a No. 4 (4.75-mm) sieve;

1.1.3 *Method C*—A 6-in. (152.4-mm) mold; material passing a ¾-in. (19.0-mm) sieve; and

1.1.4 *Method D*—A 6-in. (152.4-mm) mold; material passing a ¾-in. (19.0-mm) sieve, corrected by replacement for material retained on a ¾-in. sieve.

NOTE 1—Soils and soil-aggregate mixtures should be regarded as natural occurring fine- or coarse-grained soils or composites or mixtures of natural soils, or mixtures of natural and processed soils or aggregates such as silt, gravel, or crushed rock.

NOTE 2—These laboratory compaction test methods when used on soils and soil-aggregates which are not free-draining will, in most cases, establish a well-defined optimum moisture content and maximum density (see Section 7). However, for free-draining soils and soil-aggregate mixtures, these methods will not, in many cases, produce a well-defined moisture-density relationship and the maximum density obtained will generally be less than that obtained by vibratory methods.

1.2 The method to be used should be indicated in the specifications for the material being tested. If no method is specified, the provisions of Section 5 shall govern.

2. Applicable Documents

2.1 *ASTM Standards:*

C 127 Test Method for Specific Gravity and Absorption of Coarse Aggregate[2]

D 854 Test Method for Specific Gravity of Soils[3]

D 2168 Methods for Calibration of Laboratory Mechanical-Rammer Soil Compactors[3]

D 2216 Method for Laboratory Determination of Water (Moisture) Content of Soil, Rock, and Soil-Aggregate Mixtures[3]

D 2487 Test Method for Classification of Soils for Engineering Purposes[3]

D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)[3]

E 11 Specification for Wire-Cloth Sieves for Testing Purposes[4]

3. Apparatus

3.1 *Molds*—The molds shall be cylindrical in shape, made of rigid metal and be within the capacity and dimensions indicated in 3.1.1 or 3.1.2. The molds may be the "split" type, consisting either of two half-round sections, or a section of pipe split along one element, which can be securely locked in place to form a cylinder meeting the requirements of this section. The molds may also be the "taper" type, providing the internal diameter taper is uniform and is not more than 0.200 in./linear ft (16.7 mm/linear m) of mold height. Each mold shall have a base plate assembly and an extension collar assembly, both made of rigid metal and constructed so they can be securely attached to or detached from the mold. The extension collar assembly shall have a height extending above the top of the mold of at least 2 in. (50 mm) which may include an upper section that flares out to form a funnel providing there is at least a ¾-in. (19-mm) straight cylindrical section beneath it.

3.1.1 *Mold*, 4.0 in. (101.6 mm) in diameter, having a capacity of $^1/_{30}$ ± 0.0004 ft³ (944 ± 11 cm³) and conforming to Fig. 1.

3.1.2 *Mold*, 6.0 in. (152.4 mm) in diameter, having a capacity of $^1/_{13.333}$ ± 0.0009 ft³ (2124 ± 25 cm³) and conforming to Fig. 2.

3.1.3 The average internal diameter, height, and volume of each mold shall be determined before initial use and at intervals not exceeding 1000 times the mold is filled. The mold volume shall be calculated from the average of at least six internal diameter and three height measurements made to the nearest 0.001 in. (0.02 mm), or from the amount of water required to completely fill the mold, corrected for temperature variance in accordance with Table 1. If the average internal diameter and volume are not within the tolerances shown in Figs. 1 or 2, the mold shall not be used. The determined volume shall be used in computing the required densities.

3.2 *Rammer*—The rammer may be either manually operated (see 3.2.1) or mechanically operated (see 3.2.2). The rammer shall fall freely through a distance of 18.0 ± $^1/_{16}$ in. (457.2 ± 1.6 mm) from the surface of the specimen. The manufactured weight of the rammer shall be 10.00 ± 0.02 lb (4.54 ± 0.01 kg). The specimen contact face shall be flat.

3.2.1 *Manual Rammer*—The specimen contact face shall be circular with a diameter of 2.000 ± 0.005 in. (50.80 ± 0.13 mm). The rammer shall be equipped with a guide-sleeve which shall provide sufficient clearance so that the free fall of the rammer shaft and head will not be restricted. The guidesleeve shall have at least four vent holes at each end (eight holes total) located with centers ¾ ± $^1/_{16}$ in. (19.0 ± 1.6 mm) from each end and spaced 90 deg apart. The minimum diameter of the vent holes shall be ⅜ in. (9.5 mm).

3.2.2 *Mechanical Rammer*—The rammer shall operate mechanically in such a manner as to provide uniform and complete coverage of the specimen surface. There shall be 0.10 ± 0.03 in. (2.5 ± 0.8 mm) clearance between the rammer and the inside surface of the mold at its smallest diameter. When used with the 4.0-in. (101.6-mm) mold, the specimen contact face shall be circular with a diameter of 2.000 ± 0.005 in. (50.80 ± 0.13 mm). When used with the 6.0-in. (152.4-mm) mold, the specimen contact face shall have the shape of a section of a circle of a radius equal to 2.90 ± 0.02 in. (73.7 ± 0.5 mm). The sector face rammer shall operate in such a manner that the vertex of the sector is positioned at the center of the specimen. The mechanical rammer shall be calibrated and adjusted, as necessary, in accordance with 3.2.3.

3.2.3 *Calibration and Adjustment*—The mechanical rammer shall be calibrated, and adjusted as necessary, before initial use; near the end of each period during which the mold was filled 1000 times; before reuse after anything, including repairs, which may affect the test results significantly; and whenever the test results are questionable. Each calibration and adjustment shall be in accordance with Methods D 2168.

3.3 *Sample Extruder* (optional)—A jack, frame, or other device adapted for the purpose of extruding compacted specimens from the mold.

3.4 *Balances*—A balance or scale of at least 20-kg capacity sensitive to ±1 g and a balance of at least 1000-g capacity sensitive to ±0.01 g.

3.5 *Drying Oven*, thermostatically-controlled, preferably of the forced-draft type, capable of maintaining a temperature of 230 ± 9°F (110 ± 5°C) for determining the moisture content of the compacted specimen.

3.6 *Straightedge*—A stiff metal straightedge of any convenient length but not less than 10 in. (254 mm). The scraping edge shall have a straightness tolerance of ±0.005 in. (±0.13 mm) and shall be beveled if it is thicker then ⅛ in. (3 mm).

[1] These methods are under the jurisdiction of ASTM Committee D-18 on Soil and Rock.
Current edition approved April 27, 1978. Published July 1978. Originally published as D 1557 – 58 T. Last previous edition D 1557 – 70.

[2] *Annual Book of ASTM Standards*, Vol 04.02.

[3] *Annual Book of ASTM Standards*, Vol 04.08.

[4] *Annual Book of ASTM Standards*, Vols 04.01, 04.02, 04.06, 05.05, and 14.02.

3.7 *Sieves*, 3-in. (75-mm), ¾-in. (19.0-mm), and No. 4 (4.75-mm), conforming to the requirements of Specification E 11.

3.8 *Mixing Tools*—Miscellaneous tools such as mixing pan, spoon, trowel, spatula, etc., or a suitable mechanical device for thoroughly mixing the sample of soil with increments of water.

4. Procedure

4.1 *Specimen Preparation*—Select a representative portion of quantity adequate to provide, after sieving, an amount of material weighing as follows: Methods A—25 lb (11 kg); Methods B, C, and D—50 lb (23 kg). Prepare specimens in accordance with either 4.1.1 through 4.1.3 or 4.1.4.

4.1.1 *Dry Preparation Procedure*—If the sample is too damp to be friable, reduce the moisture content by drying until the material is friable; see 4.1.2. Drying may be in air or by the use of a drying apparatus such that the temperature of the sample does not exceed 140°F (60°C). After drying (if required), thoroughly break up the aggregations in such a manner as to avoid reducing the natural size of the particles. Pass the material through the specified sieve as follows: Methods A and B—No. 4 (4.75-mm); Methods C and D—¾-in. (19.0-mm). Correct for oversize material in accordance with Section 5, if Method D is specified.

4.1.2 Whenever practicable, soils classified as ML, CL, OL, GC, SC, MH, CH, OH and PT by Test Method D 2487 shall be prepared in accordance with 4.1.4.

4.1.3 Prepare a series of at least four specimens by adding increasing amounts of water to each sample so that the moisture contents vary by approximately 1½ %. The moisture contents selected shall bracket the optimum moisture content, thus providing specimens which, when compacted, will increase in mass to the maximum density and then decrease in density (see 7.2 and 7.3). Thoroughly mix each specimen to ensure even distribution of moisture throughout and then place in a separate covered container and allow to stand prior to compaction in accordance with Table 2. For the purpose of selecting a standing time, it is not required to perform the actual classification procedures described in Test Method D 2487 (except in the case of referee testing), if previous data exist which provide a basis for classifying the sample.

4.1.4 *Moist Preparation Method*—The following alternate procedure is recommended for soils classified as ML, CL, OL, GC, SC, MH, CH, OH and PT by Test Method D 2487. Without previously drying the sample, pass it through the ¾-in. (19.0-mm) and No. 4 (4.75-mm) sieves. Correct for oversize material in accordance with Section 5, if Method D is specified. Prepare a series of at least four specimens having moisture contents that vary by approximately 1½ %. The moisture contents selected shall bracket the optimum moisture content, thus providing specimens which, when compacted, will increase in mass to the maximum density and then decrease in density (see 7.2 and 7.3). To obtain the appropriate moisture content of each specimen, the addition of a predetermined amount of water (see 4.1.3) or the removal of a predetermined amount of moisture by drying may be necessary. Drying may be in air or by the use of a drying apparatus such that the temperature of the specimen does not exceed 140°F (60°C). The prepared specimens shall then be thoroughly mixed and stand, as specified in 4.1.3 and Table 2, prior to compaction.

NOTE 3—With practice, it is usually possible to visually judge the point of optimum moisture closely enough so that the prepared specimens will bracket the point of optimum moisture content.

4.2 *Specimen Compaction*—Select the proper compaction mold, in accordance with the method being used, and attach the mold extension collar. Compact each specimen in five layers of approximately equal height. Each layer shall receive 25 blows in the case of the 4-in. (101.6-mm) mold; each layer shall receive 56 blows in the case of the 6-in. (152.4-mm) mold. The total amount of material used shall be such that the fifth compacted layer is slightly above the top of the mold, but not exceeding ¼ in. (6 mm). During compaction the mold shall rest on a uniform rigid foundation, such as provided by a cylinder or cube of concrete weighing not less than 200 lb (91 kg).

4.2.1 In operating the manual rammer, care shall be taken to avoid rebound of the rammer from the top end of the guidesleeve. The guidesleeve shall be held steady and within 5 deg of the vertical. The blows shall be applied at a uniform rate not exceeding approximately 1.4 s per blow and in such a manner as to provide complete and uniform coverage of the specimen surface.

4.2.2 *Mold Sizes*—The mold size used shall be as follows: Method A, 4-in. (101.6-mm); Methods B, C, and D 6-in. (152.4-mm).

4.2.3 Following compaction, remove the extension collar; carefully trim the compacted specimen even with the top of the mold by means of the straightedge and determine the mass of the specimen. Divide the mass of the compacted specimen and mold, minus the mass of the mold, by the volume of the mold (see 3.1.3). Record the result as the wet density, γ_m, in pounds per cubic foot (or kilograms per cubic metre) of the compacted specimen.

4.2.4 Remove the material from the mold. Determine moisture content in accordance with Method D 2216, using either the whole compacted specimen or alternatively a representative specimen of the whole specimen. The whole specimen must be used when the permeability of the compacted specimen is high enough so that the moisture content is not distributed uniformly throughout. If the whole specimen is used, break it up to facilitate drying. Obtain the representative specimen by slicing the compacted specimen axially through the center and removing 100 to 500 g of material from one of the cut faces.

4.2.5 Repeat 4.2 through 4.2.4 for each specimen prepared.

5. Oversize Corrections

5.1 If 30 % or more of the sample is retained on a ¾-in. (19.0-mm) sieve, then none of the methods described under these methods shall be used for the determination of either maximum density or optimum moisture content.

5.2 *Methods A and B*—The material retained on the No. 4 (4.75-mm) sieve is discarded and no oversize correction is made. However, it is recommended that if the amount of material retained is 7 % or greater, Method C be used instead.

5.3 *Method C*—The material retained on the ¾-in. (19.0-mm) sieve is discarded and no oversize correction is made. However, if the amount of material retained is 10 % or greater, it is recommended that Method D be used instead.

5.4 *Method D:*

5.4.1 This method shall not be used unless the amount of material retained on the ¾-in. (19.0-mm) sieve is 10 % or greater. When the amount of material retained on the ¾-in. sieve is less than 10 %, use Method C.

5.4.2 Pass the material retained on the ¾-in. (19.0-mm) sieve through a 3-in. or 75-mm sieve. Discard the material retained on the 3-in. sieve. The material passing the 3-in. sieve and retained on the ¾-in. sieve shall be replaced with an equal amount of material passing a ¾-in. sieve and retained on a No. 4 (4.75-mm) sieve. The material for replacement shall be taken from an unused portion of the sample.

6. Calculations

6.1 Calculate the moisture content and the dry density of each compacted specimen as follows:

$$w = [(A - B)/(B - C)] \times 100$$

and

$$\gamma_d = [\gamma_m/(w + 100)] \times 100$$

where:

w = moisture content in percent of the compacted specimens,
A = mass of contained and moist specimen,
B = mass of container and oven-dried specimen,
C = mass of container,
γ_d = dry density, in pounds per cubic foot (or kilograms per cubic metre) of the compacted specimen, and
γ_m = wet density, in pounds per cubic foot (or kilograms per cubic metre) of the compacted specimen.

7. Moisture-Density Relationship

7.1 From the data obtained in 6.1, plot the dry density values as ordinates with corresponding moisture contents as abscissas. Draw a smooth curve connecting the plotted points. Also draw a curve termed the "curve of complete saturation" or "zero air voids curve" on this plot. This curve represents the relationship between dry density and corresponding moisture contents when the voids are completely filled with water. Values of dry density and corresponding moisture contents for plotting the curve of complete saturation can be computed using the following equation:

$$w_{sat} = [(62.4/\gamma_d) - (1/G_s)] \times 100$$

where:

w_{sat} = moisture content in percent for complete saturation,

γ_d = dry density in pounds per cubic foot (or kilograms per cubic metre),

G_s = specific gravity of the material being tested (see Note 4), and

62.4 = density of water in pounds per cubic foot (or kilograms per cubic metre).

NOTE 4—The specific gravity of the material can either be assumed or based on the weighted average values of: (*a*) the specific gravity of the material passing the No. 4 (4.75-mm) sieve in accordance with Test Method D 854; and (*b*) the apparent specific gravity of the material retained on the No. 4 (4.75-mm) sieve in accordance with Test Method C 127.

7.2 *Optimum Moisture Content,* w_o—The moisture content corresponding to the peak of the curve drawn as directed in 7.1 shall be termed the "optimum moisture content."

7.3 *Maximum Density*, γ_{max}—The dry density in pounds per cubic foot (or kilograms per cubic metre) of the sample at "optimum moisture content" shall be termed "maximum density."

8. Report

8.1 The report shall include the following:

8.1.1 Method used (Method A, B, C, or D).

8.1.2 Optimum moisture content.

8.1.3 Maximum density.

8.1.4 Description of rammer (whether manual or mechanical).

8.1.5 Description of appearance of material used in test, based on Practice D 2488 (Test Method D 2487 may be used as an alternative).

8.1.6 Origin of material used in test.

8.1.7 Preparation procedure used (moist or dry).

9. Precision

9.1 Criteria for judging the acceptability of the maximum density and optimum moisture content test results are given in Table 3. The standard deviation s is calculated from the equation:

$$s^2 = \frac{1}{n-1}\sum_{1}^{n}(x-\bar{x})^2$$

where:

n = number of determinations;

x = individual value of each determination; and

$\bar{x}$ = numerical average of the determinations.

9.2 Criteria for assigning standard deviation values for single-operator precision are not available at the present time.

TABLE 1 Volume of Water per Gram based on Temperature[A]

Temperature, °C (°F)	Volume of Water, ml/g
12 (53.6)	1.00048
14 (57.2)	1.00073
16 (60.8)	1.00103
18 (64.4)	1.00138
20 (68.0)	1.00177
22 (71.6)	1.00221
24 (75.2)	1.00268
26 (78.8)	1.00320
28 (82.4)	1.00375
30 (86.0)	1.00435
32 (89.6)	1.00497

[A] Values other than shown may be obtained by referring to the *Handbook of Chemistry and Physics*, Chemical Rubber Publishing Co., Cleveland, OH.

TABLE 2 Dry Preparation Method—Standing Times

Classification D 2487	Minimum Standing Time, h
GW, GP, SW, SP	no requirement
GM, SM	3
ML, CL, OL, GC, SC	18
MH, CH, OH, PT	36

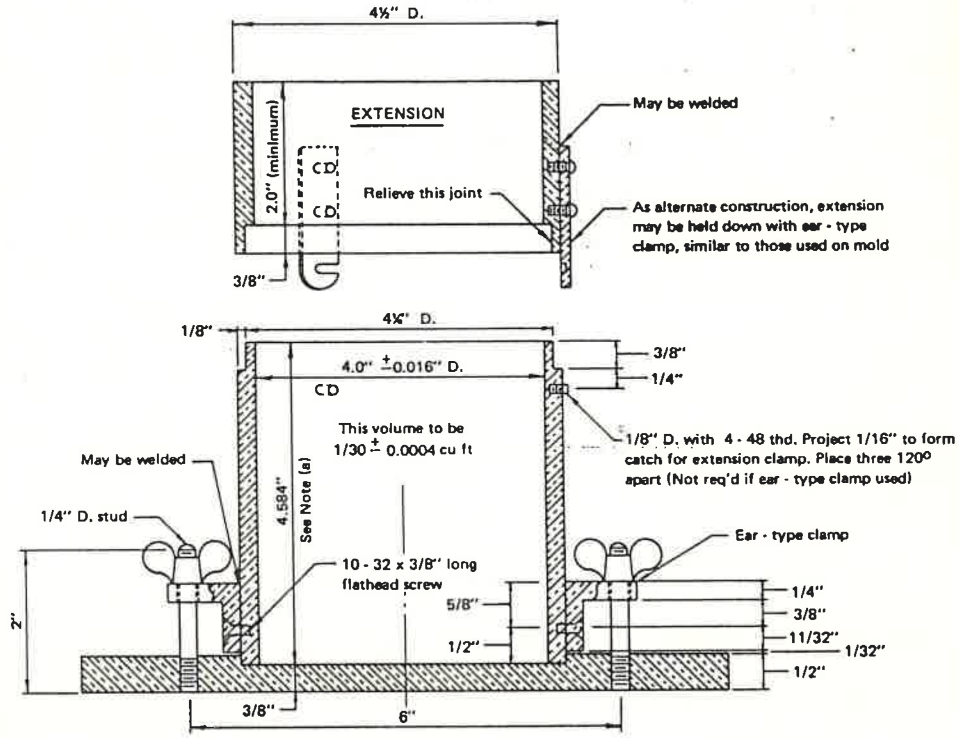
TABLE 3 Precision

	Standard Deviation, s	Acceptable Range of Two Results, Expressed as Percent of Mean Value[A]
Single-operator precision:		
Maximum density	...	1.9
Optimum moisture content	...	9.5
Multilaboratory precision:		
Maximum density	±1.66	4.0
Optimum moisture content	±0.86	15.0

[A] This column indicates a limiting range of values which should not be exceeded by the difference between any two results, expressed as a percentage of the average value. In cooperative test programs it has been determined that 95 % of the tests do not exceed the limiting acceptable ranges shown below. All values shown in this table are based on average test results from a variety of different soils and are subject to future revision.

TABLE 4 Metric Equivalents for Figs. 1 and 2

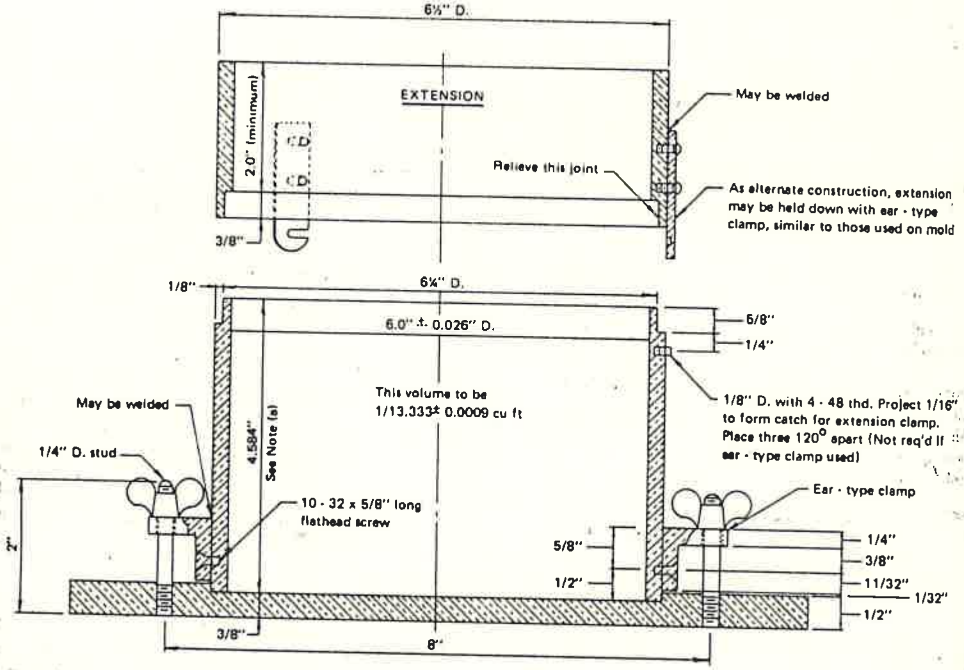
in.	mm
0.016	0.41
0.026	0.66
1/32	0.8
1/16	1.6
1/8	3.2
1/4	6.4
11/32	8.7
3/8	9.5
1/2	12.7
5/8	15.9
2	50.8
2 1/2	63.5
4	101.6
4 1/4	108.0
4 1/2	114.3
4.584	116.43
6	152.4
6 1/2	165.1
8	203.2
ft³	**cm³**
1/30	944
0.004	11
1/13.333	2124
0.0009	25



NOTE 1—The tolerance on the height is governed by the allowable volume and diameter tolerances.

NOTE 2—The methods shown for attaching the extension collar to the mold and the mold to the base plate are recommended. However, other methods are acceptable, providing the attachments are equally as rigid as those shown.

FIG. 1 Cylindrical Mold, 4.0-in. for Soil Tests (see Table 4 for metric equivalents).



NOTE 1—The tolerance on the height is governed by the allowable volume and diameter tolerances.
NOTE 2—The methods shown for attaching the extension collar to the mold and the mold to the base plate are recommended. However, other methods are acceptable, providing the attachments are equally as rigid as those shown.

FIG. 2 Cylindrical Mold, 6.0-in. for Soil Tests (see Table 4 for metric equivalents).

Standard Test Method for MOISTURE CONTENT PENETRATION RESISTANCE RELATIONSHIPS OF FINE-GRAINED SOILS[1]

This standard is issued under the fixed designation D 1558; 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 is for establishing the moisture-penetration resistance relationships of fine-grained soils as determined by the soil penetrometer.

1.2 The values stated in inch-pound units are to be regarded as the standard.

1.3 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Applicable Documents

2.1 *ASTM Standards:*

D 698 Test Methods for Moisture-Density Relations of Soils and Soil-Aggregate Mixtures, Using 5.5-lb (2.49-kg) Rammer and 12-in. (305-mm) Drop[2]

D 2216 Method for Laboratory Determination of Water (Moisture) Content of Soil, Rock, and Soil-Aggregate Mixtures[2]

E 380 Metric Practice[3]

3. Significance and Use

3.1 This test method is used with Methods A and B of Test Methods D 698 to develop relationships between moisture content, density, and penetration resistance. These relationships are used with a previously prepared family of moisture-penetration curves as a rapid field test to determine the approximate amount of moisture in the soil.

NOTE 1—When a penetration-resistance measurement of material in place is compared at a given moisture content with penetration-density curves prepared at a specified compactive effort, an approximate check of compaction (density) may be obtained.

3.2 Penetration resistance determinations are not reliable for very dry molded soil specimens or very granular soils.

4. Apparatus[f]

4.1 *Moisture-Density Apparatus*, conforming to the requirements prescribed in Test Methods D 698.

4.2 *Soil Penetrometer*—A soil penetrometer (Fig. 1) consisting of a special spring dynamometer with pressure-indicating scale on the stem of the handle. The pressure scale shall be graduated to 90 lb in 2-lb divisions with a line encircling the stem at each 10-lb interval, or graduated to 40 kg in 1-kg divisions with a line encircling the stem at each 5-kg interval. A sliding ring on the stem shall indicate the maximum pressure obtained in the test.

4.3 *Set of Penetrometer Needles*—Each penetrometer needle (Fig. 1) shall consist of a shank with a head of known end area. The set of interchangeable needles shall include the sizes given in Table 1. The needle shank shall have graduations inscribed at intervals of ½ in. (10

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[1] This test method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.08 on Special and Construction Control Tests.

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[2] *Annual Book of ASTM Standards*, Vol 04.08.

[3] *Annual Book of ASTM Standards*, Vol 14.02. Excerpts in all volumes.