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Standard Specification for Blended Hydraulic Cements¹

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This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope

1.1 This specification pertains to blended hydraulic cements for both general and special applications, using slag, pozzolan, limestone, or some combination of these, with portland cement or portland cement clinker or slag with lime.

NOTE 1—This specification prescribes ingredients and proportions, with some performance requirements whereas Performance Specification C1157 is a hydraulic cement specification in which performance criteria alone govern the products and their acceptance.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard. Values in SI units [or inch-pound units] shall be obtained by measurement in SI units [or inch-pound units] or by appropriate conversion, using the Rules for Conversion and Rounding given in IEEE/ASTM SI 10, of measurements made in other units [or SI units]. Values are stated in only SI units when inch-pound units are not used in practice.

1.3 The text of this standard refers to notes and footnotes, which provide explanatory material. These notes and footnotes (excluding those in tables and figures) are not requirements of the standard.

2. Referenced Documents

2.1 ASTM Standards:²

- C51 Terminology Relating to Lime and Limestone (as used by the Industry)
- C109/C109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)
- C114 Test Methods for Chemical Analysis of Hydraulic Cement
- C150 Specification for Portland Cement
- C151 Test Method for Autoclave Expansion of Hydraulic Cement
- C157/C157M Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete
- C183 Practice for Sampling and the Amount of Testing of Hydraulic Cement
- C185 Test Method for Air Content of Hydraulic Cement Mortar
- C186 Test Method for Heat of Hydration of Hydraulic Cement
- C187 Test Method for Amount of Water Required for Normal Consistency of Hydraulic Cement Paste
- C188 Test Method for Density of Hydraulic Cement
- C191 Test Methods for Time of Setting of Hydraulic Cement by Vicat Needle
- C204 Test Methods for Fineness of Hydraulic Cement by Air-Permeability Apparatus
- C219 Terminology Relating to Hydraulic Cement
- C226 Specification for Air-Entraining Additions for Use in the Manufacture of Air-Entraining Hydraulic Cement
- C227 Test Method for Potential Alkali Reactivity of Cement-Aggregate Combinations (Mortar-Bar Method)
- C311 Test Methods for Sampling and Testing Fly Ash or Natural Pozzolans for Use in Portland-Cement Concrete
- C430 Test Method for Fineness of Hydraulic Cement by the 45- μ m (No. 325) Sieve
- C465 Specification for Processing Additions for Use in the Manufacture of Hydraulic Cements
- C511 Specification for Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes

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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.



- C563 Test Method for Approximation of Optimum SO₃ in Hydraulic Cement Using Compressive Strength
 C688 Specification for Functional Additions for Use in Hydraulic Cements
 C821 Specification for Lime for Use with Pozzolans
 C1012 Test Method for Length Change of Hydraulic-Cement Mortars Exposed to a Sulfate Solution
 C1038 Test Method for Expansion of Hydraulic Cement Mortar Bars Stored in Water
 C1157 Performance Specification for Hydraulic Cement
 E11 Specification for Woven Wire Test Sieve Cloth and Test Sieves
 E350 Test Methods for Chemical Analysis of Carbon Steel, Low-Alloy Steel, Silicon Electrical Steel, Ingot Iron, and Wrought Iron
 E1019 Test Methods for Determination of Carbon, Sulfur, Nitrogen, and Oxygen in Steel, Iron, Nickel, and Cobalt Alloys by Various Combustion and Fusion Techniques
 IEEE/ASTM SI 10 Standard for Use of the International System of Units (SI): the Modern Metric System
 2.2 CSA Standards:
 CSA A3004-D2 Determination of Total Organic Carbon in Limestone

3. Terminology

3.1 *Definitions*—The terms used in this specification are defined in Terminology C219, except for the following terms:

3.1.1 *binary blended cement, n*—a blended hydraulic cement consisting of portland cement with either a slag, a pozzolan, or a limestone.

3.1.2 *slag, n*—the term slag is used within this standard to denote either slag cement or granulated blast-furnace slag.

3.1.3 *ternary blended cement, n*—a blended hydraulic cement consisting of portland cement with either a combination of two different pozzolans, slag and a pozzolan, a pozzolan and a limestone, or a slag and a limestone.

NOTE 2—Relevant terms in Terminology C219 applicable to this standard include portland cement, portland-cement clinker, hydraulic cement, slag cement, granulated blast-furnace slag, pozzolan, and calcium sulfate. Limestone is defined in Terminology C51.

4. Classification

4.1 This specification applies to the following types of blended cement that generally are intended for use as indicated.

4.1.1 Blended hydraulic cements for general concrete construction.

4.1.1.1 *Type IS*—Portland blast-furnace slag cement.

4.1.1.2 *Type IP*—Portland-pozzolan cement.

4.1.1.3 *Type IL*—Portland-limestone cement.

4.1.1.4 *Type IT*—Ternary blended cement.

4.2 *Reporting:*

4.2.1 The naming practice for blended cements shall be made by adding the suffix (X) to the type designation under 4.1.1, where (X) equals the targeted percentage of slag, pozzolan or limestone, in the product expressed as a whole number by mass of the final blended product, within the allowable variation as stated in 15.3.

4.2.2 The naming practice for ternary blended cements shall be made by adding the suffixes (AX) and (BY) to the Type IT designation under 4.1.1, where:

A is either “S” for slag, “P” for pozzolan, or
 “L” for limestone,

whichever is present in larger amount by mass, and

X is the targeted percentage by mass of constituent A, and

B is either “S” for slag, “P” for pozzolan, or

“L” for limestone, and

Y is the targeted percentage by mass of constituent B.

Both X and Y values are expressed as a whole number by mass of the final blended product, within the allowable variation as stated in 15.3. If X and Y are the same, list the two constituents in alphabetical order by constituent type (limestone, pozzolan, or slag).

NOTE 3—Examples of the naming practice per 4.2.1 and accordance with 4.2.2.1 and 4.2.2 are shown below (all percentages by mass):

Binary blended cement with 80 % portland cement and 20 % slag

= Type IS(20).

Binary blended cement with 85 % portland cement and 15 % pozzolan

= Type IP(15).

Binary blended cement with 90 % portland cement and 10 % limestone

= Type IL(10).

Ternary blended cement with 70 % portland cement, 20 % slag
 and 10 % pozzolan = Type IT(S20)(P10).

Ternary blended cement with 65 % portland cement, 25 % of one
 pozzolan and 10 % of another pozzolan = Type IT(P25)(P10).



- Ternary blended cement with 60 % portland cement and 20 % of slag and 20 % pozzolan = Type IT(P20)(S20).
- Ternary blended cement with 80 % portland cement, 10 % limestone and 10 % pozzolan = Type IT(L10)(P10).
- Ternary blended cement with 75 % portland cement, 15 % slag and 10 % limestone = Type IT(S15)(L10).

4.2.3 A simplified naming practice is used in this standard for practicality and clarity when referring to specific requirements for binary and ternary blended cements that are applicable to a range of products or in ternary blended cements when requirements are applicable to only one constituent within a specific range (%). (See Note 4.)

NOTE 4—Examples of the simplified naming practices per in accordance with 4.2.3 are shown below:

- 1) An example when requirements are applicable to a range of products can be found in Table 1, where the maximum SO₃ content of 3 % applies to: binary blended cements with slag contents <70 %, indicated as IS(<70); and ternary blended cements with a pozzolan content less than the slag content and the slag content is less than 70 %, indicated as IT(P<S<70).
- 2) An example when requirements are applicable to only one constituent within a specific range (%) of that constituent can be found in 9.2, where testing is required only when the slag content is <25 %. Because the requirement is based on the slag content only with no relation to the pozzolan or limestone content, a simplified naming practice is employed and the range of ternary blended cements is indicated as Type IT(S<25).

4.3 Special Properties:

4.3.1 Air-entraining cement, when desired by the purchaser, shall be specified by adding the suffix (A) to the type designation under 4.1.1.

NOTE 5—A given mass of blended cement has a larger absolute volume than the same mass of portland cement. This should be taken into consideration in purchasing cements and in proportioning concrete mixtures.

4.3.2 Moderate heat of hydration, when desired by the purchaser, shall be specified by adding the suffix (MH) to the type designation under 4.1.1.

4.3.3 Moderate sulfate resistance, when desired by the purchaser, shall be specified by adding the suffix (MS) to the type designation under 4.1.1.

4.3.4 High sulfate resistance, when desired by the purchaser, shall be specified by adding the suffix (HS) to the type designation under 4.1.1.

4.3.5 Low heat of hydration, when desired by the purchaser, shall be specified by adding the suffix (LH) to the type designation under 4.1.1.

4.3.6 Resistance to alkali-silica reactive aggregate expansion, when desired by the purchaser, shall be specified by adding the suffix (R) to the type designation under 4.1.1.

NOTE 6—Special characteristics attributable to slag, pozzolan or limestone will vary based on quantities contained within the blended cements. Type IT cements with greater than 5 % limestone and Type IL cements are not permitted as moderate (MS) or high (HS) sulfate resistance cements, pending results of further research.

5. Ordering Information

5.1 Orders for material under this specification shall include the following:

- 5.1.1 Specification number,
- 5.1.2 Type or types required,
 - 5.1.2.1 Indicate allowable slag, pozzolan, or limestone maximum or minimum percentage by mass, if required.
- 5.1.3 Optional special properties required (see 4.3):
 - 5.1.3.1 MS if moderate sulfate resistance is required;
 - 5.1.3.2 HS if high sulfate resistance is required;
 - 5.1.3.3 MH if moderate heat of hydration is required;
 - 5.1.3.4 LH if low heat of hydration is required;

TABLE 1 Chemical Requirements

Cement Type ^A	Applicable Test Method	IS(<70), IT(P<S<70), IT(L<S<70)	IS(≥70), IT(S≥70)	IP, IT(P≥S), IT(P≥L)	IL, IT(L≥S), IT(L≥P)
Magnesium oxide (MgO), max, %	C114	...	...	6.0	...
Sulfate reported as SO ₃ , max, % ^B	C114	3.0	4.0	4.0	3.0
Sulfide reported as S ²⁻ , max, %	C114	2.0	2.0	...	...
Insoluble residue, max, % ^C	C114	1.0	1.0	...	...
Loss on ignition, max, %	C114	3.0 ^D	4.0 ^D	5.0 ^D	10.0

^A The chemical requirements in this table are applicable to all air-entrained cement equivalents.

^B It is permissible to exceed the values in the table for SO₃ content, provided it has been demonstrated by Test Method C1038 that the cement with the increased SO₃ will not develop expansion exceeding 0.020 % at 14 days. When the manufacturer supplies cement under this provision, supporting data shall be supplied to the purchaser. See Note 9.

^C Insoluble residue maximum limit does not apply to ternary blended cements.

^D For ternary blended cements with limestone, loss on ignition is a maximum of 10.0 % by mass.



- 5.1.3.5 R if resistance to alkali-silica reactive aggregate expansion is required;
 - 5.1.3.6 A if air entraining is required;
 - 5.1.3.7 Accelerating addition, if required;
 - 5.1.3.8 Retarding addition, if required;
 - 5.1.3.9 Water reducing addition, if required;
 - 5.1.3.10 Water reducing and accelerating addition, if required; and
 - 5.1.3.11 Water reducing and retarding addition, if required.
- 5.1.4 Certification, if desired (see Section 15).

NOTE 7—It is important to check for availability of various options. Some multiple options are mutually incompatible or unattainable.

6. Materials

6.1 Materials permitted to be used as ingredients in cements manufactured to comply with this specification are:

6.1.1 *Portland Cement*—For purposes of this specification, portland cement meeting the requirements of Specification C150 is suitable. Portland cement or other hydraulic materials, or both, containing high free lime are not prohibited from use as long as the autoclave test limits for the blended cement are met.

6.1.2 *Portland Cement Clinker*.

6.1.3 *Slag*—Slag shall be slag cement or granulated blast-furnace slag and comply with requirements in Section 9.

6.1.4 *Pozzolan*—Pozzolan shall comply with requirements in Section 9.

6.1.5 *Limestone*—Limestone, as defined in Terminology C51, shall be naturally occurring and comply with the requirements indicated in 8.2.

6.1.6 *Hydrated Lime*—Hydrated lime used as part of a blended cement shall meet the requirements of Specification C821, except that when interground in the production process there shall be no minimum fineness requirement.

6.1.7 *Air-Entraining Addition*—When air-entraining cement is specified, an addition meeting the requirements of Specification C226 shall be used.

6.1.8 When processing additions are used in the manufacture of cement, they shall have been shown to meet the requirements of Specification C465 in the amounts used or greater, greater (see Section subsection 15.2).

6.1.9 When functional additions (used at the sole option of the purchaser) are used they shall have been shown to meet the requirements of Specification C688 when tested with the cement to be used, in the amount used or greater, greater (see Section subsection 15.2).

6.1.10 *Other Additions*—The cement covered by this specification shall contain no additions except as provided for above except that water or calcium sulfate (see Terminology C219), or both, if added, shall be in amounts so that the limits shown in Table 1 for sulfate reported as SO₃ and loss on ignition are not exceeded.

7. Manufacture

7.1 *Binary Blended Cement*—Binary blended cement shall be a hydraulic cement consisting of an intimate and uniform blend (see Note 8) produced either by intergrinding or blending or by a combination of intergrinding and blending portland cement clinker or portland cement with a pozzolan or a slag, or a limestone. Any slag, pozzolan, or limestone used as an ingredient or addition in portland cement used to manufacture a binary blended cement shall be included in the total amount of those materials reported in 4.2 or 15.1. The following requirements shall apply:

7.1.1 *Portland Blast-Furnace Slag Cement*—Portland blast-furnace slag cement shall be a hydraulic cement in which the slag constituent is up to 95 % by mass of the blended cement. Portland blast-furnace slag cement with a slag content equal to or exceeding 70 % by mass, is permitted to contain hydrated lime.

7.1.2 *Air-Entraining Portland Blast-Furnace Slag Cement*—Air-entraining portland blast-furnace slag cement shall be portland blast-furnace slag cement to which sufficient air-entraining addition has been added so that the resulting product complies with the air content of mortar requirements.

7.1.3 *Portland-Pozzolan Cement*—Portland-pozzolan cement shall be a hydraulic cement in which the pozzolan constituent is up to 40 % by mass of the blended cement.

7.1.4 *Air-Entraining Portland-Pozzolan Cement*—Air-entraining portland-pozzolan cement shall be portland-pozzolan cement to which sufficient air-entraining addition has been added so that the resulting product complies with the air content of mortar requirements.

7.1.5 *Portland-Limestone Cement*—Portland-limestone cement shall be a hydraulic cement in which the limestone content is more than 5 % but less than or equal to 15 % by mass of the blended cement.

7.1.6 *Air-Entraining Portland-Limestone Cement*—Air-entraining portland-limestone cement shall be portland-limestone cement to which sufficient air-entraining addition has been added so that the resulting product complies with the air content of mortar requirements.

7.2 *Ternary Blended Cement*—Ternary blended cement shall be a hydraulic cement consisting of an intimate and uniform blend (see Note 8) produced either by intergrinding, by blending, or a combination of intergrinding, and blending portland cement clinker or portland cement with ~~1~~(1) two different pozzolans, ~~2~~(2) slag and a pozzolan, ~~3~~(3) a pozzolan and a limestone, or ~~4~~(4) a slag

and a limestone. Ternary blended cement Type IT(S \geq 70) shall have a maximum limestone content of 15 % by mass and is permitted to contain hydrated lime. All other ternary blended cements shall have a maximum pozzolan content of 40 % by mass of the blended cement, a maximum limestone content of 15 % by mass of the blended cement, and the total content of pozzolan, limestone, and slag shall be less than 70 % by mass of the blended cement. Any slag, pozzolan, or limestone used as ingredient in portland cement used to manufacture a blended cement shall be included in the total amount of those materials reported in 4.2 or 15.1.

NOTE 8—The attainment of an intimate and uniform blend of two or more types of fine materials is difficult. Consequently, adequate equipment and controls must be provided by the manufacturer. The purchasers should assure themselves of the adequacy of the blending operation.

8. Chemical Composition

8.1 *Blended Cement*—Cement of the type specified shall conform to the applicable chemical requirements prescribed in Table 1.

NOTE 9—There are cases where performance of a cement is improved with SO₃ in excess of the Table 1 limits in this specification. Test Method C563 is one of several methods a manufacturer can use to evaluate the effect of sulfate content on cement characteristics. Whenever SO₃ content of a cement exceeds Table 1 limits, Test Method C1038 results provide evidence that excessive expansion does not occur at this higher sulfate content.

8.1.1 If the purchaser has requested the manufacturer to state in writing the composition of the blended cement purchased, the composition of the cement furnished shall conform to that shown in the statement within the following tolerances (see Note 10).

	Tolerance, \pm %
Silicon dioxide (SiO ₂)	3
Aluminum oxide (Al ₂ O ₃)	2
Calcium oxide (CaO)	3

NOTE 10—This means that if the manufacturer’s statement of the composition says “SiO₂: 32 %,” the cement when analyzed, shall be found to contain between 29 and 35 % SiO₂.

8.2 *Limestone*—Limestone for use in the manufacture of portland-limestone cement, or a ternary blended cement in which limestone is an ingredient, shall have a calcium carbonate content of at least 70 % by mass. Such limestone shall meet the requirements of Table 2 for methylene blue index and total organic carbon content.

8.3 *Pozzolan*—Pozzolan for use in the manufacture of portland-pozzolan cement, or a ternary blended cement in which pozzolan is an ingredient, shall meet the loss-on-ignition requirement of Table 4.

9. Physical Properties

9.1 *Blended Cement*—Blended cement of the type specified shall conform to the applicable physical requirements prescribed in Table 3. When specified, blended cement with special properties shall conform to applicable physical requirements in Table 4, and requirements for compressive strength and air content in Table 4 supersede those in Table 3.

9.2 *Pozzolan or Slag*—Pozzolan or slag that is to be blended with cement shall be tested in the same state of subdivision as that in which it is to be blended. Pozzolan shall conform to the fineness requirement and the activity index requirement of Table 5. Slag that is to be used for portland blast-furnace slag cements Type IS(<25) or ternary blended cements Type IT(S<25) shall conform to the activity index requirement of Table 5. Such pozzolan, or slag that is to be interground with portland cement clinker shall, before testing for conformance with requirements of Table 5, be ground in the laboratory to a fineness at which it is believed to be present in the finished cement. It is the manufacturer’s responsibility to decide on the fineness at which the testing is to be carried out, and when requested to do so by a purchaser, to report the information upon which the decision was based.

9.3 Pozzolan for use in the manufacture of portland-pozzolan cement, Type IP(<15) and IP(<15)-A or ternary blended cements Type IT(P<15) and Type IT(P<15)-A, shall meet the requirements of Table 5 when tested for mortar expansion of pozzolan as described in 11.1.13. If the alkali content of the clinker to be used for the production lots changes by more than 0.2 % total as equivalent Na₂O, calculated as Na₂O + 0.658 K₂O, from that of the clinker with which the acceptance tests were carried out, the pozzolan shall be retested to show compliance with the requirements of Table 5.

TABLE 2 Requirements for Limestone for Use in Blended Cements

	Applicable Test Method	
CaCO ₃ content, min. % by mass	C114	70 ^A
Methylene blue index, max, g/100 g	See Annex A2	1.2
Total organic carbon, max, % by mass	See Annex A3	0.5

^A The calcium carbonate content of limestone shall be determined by multiplying the CaO content of the limestone determined by Test Methods C114 by a factor of 1.785.



TABLE 3 Physical Requirements for Blended Cements

Cement Type	Applicable Test Method	IL, IP, IS(<70), IT(S<70)	IS(≥70), IT(S≥70)
Fineness	C204, C430	A	A
Autoclave expansion, max, % ^B	C151	0.80	0.80
Autoclave contraction, max, % ^B	C151	0.20	0.20
Time of initial setting, Vicat test: ^C			
Set, minutes, not less than	C191	45	45
Set, hours, not more than		7	7
Air content of mortar, volume %, max	C185	12	12
Compressive strength, min, MPa [psi]:			
3 days	C109/C109M	13.0 [1890]	...
7 days		20.0 [2900]	5.0 [720]
28 days		25.0 [3620]	11.0 [1600]

^A Both amount retained when wet-sieved on 45-μm (No. 325) sieve and specific surface by air permeability apparatus, m²/kg, shall be reported on all mill test reports requested under 15.4.

^B The specimens shall remain firm and hard and show no signs of distortion, cracking, checking, pitting, or disintegration when subjected to the autoclave expansion test.

^C The time of setting of cements containing a user-requested accelerating or retarding functional addition need not meet the limits of this table, but shall be stated by the manufacturer.

TABLE 4 Physical Requirements for Blended Cements with Special Properties

Special Property Designation ^A	Applicable Test Method	A	MS ^B	HS ^B	MH	LH	R ^C
Air content of mortar:							
minimum, volume %	C185	16 ^D	...	...	...	...	...
maximum, volume %		22 ^D	12	12	12	12	12
Compressive strength, ^E min, MPa [psi]:							
3 days	C109/C109M	10.4 [1510]	11.0 [1600]	11.0 [1600]	10.4 [1510]	...	13.0 [1890]
7 days		16.0 [2320]	18.0 [2610]	18.0 [2610]	16.0 [2320]	11.0 [1600]	20.0 [2900]
28 days		20.0 [2900]	25.0 [3620]	25.0 [3620]	20.0 [2900]	21.0 [3050]	25.0 [3620]
Heat of hydration, max, kJ/kg [cal/g]:							
7 days	C186	...	...	...	290 [70]	250 [60]	...
28 days		...	...	...	330 [80]	290 [70]	...
Water requirement, max weight % of cement	C109/C109M	...	...	...	...	64	...
Drying shrinkage, max, %	C157/C157M	...	...	...	...	0.15	...
Sulfate resistance, max, %:							
Expansion at 180 days	C1012	...	0.10	0.05 ^F	...	...	...
Expansion at 1 year		...	...	0.10 ^F	...	...	...
Mortar expansion, max, %:							
14 days	C227	...	...	...	...	...	0.020
8 weeks		...	...	...	...	...	0.060

^A These requirements apply only if specified and are designated by suffixes A, MS, HS, MH, LH, or R as appropriate to type designations IL, IP, IS(<70), or IT(S<70). See 4.3. Requirements for fineness, autoclave expansion, autoclave contraction, and time of setting shall conform to Table 3.

^B Type IT cements with greater than 5% limestone and Type IL cements are not permitted as moderate (MS) or high (HS) sulfate resistance cements.

^C Compliance with this requirement shall not be required unless the cement will be used with alkali-silica reactive aggregate.

^D These air content requirements apply to cements with multiple special property designations when one of those designations is (A).

^E When multiple special property designations are applied, the set of strength requirements for the special property designation with the lowest 7-day minimum strength requirement shall apply.

^F Testing at one year shall not be required when the cement meets the 180-day limit. A cement failing the 180-day limit shall not be rejected unless it also fails the one-year limit.

10. Sampling

10.1 Sample the materials in accordance with the following methods:

10.1.1 *Sampling Blended Cements*—Practice C183.

10.1.1.1 When the purchaser desires that the cement be sampled and tested to verify compliance with this specification, perform sampling and testing in accordance with Practice C183.

10.1.1.2 Practice C183 is not designed for manufacturing quality control and is not required for manufacturer's certification.

10.1.2 *Sampling Pozzolan*—Test Methods C311. One 2 kg [4 lb] sample shall be taken from approximately each 360 Mg [400 tons] of pozzolan.

11. Test Methods

11.1 Determine the applicable properties enumerated in this specification in accordance with the following test methods:

11.1.1 *Chemical Analysis*—Test Methods C114, with the special provisions noted therein applicable to blended cement analyses.

11.1.2 *Fineness by Sieving*—Test Method C430.

11.1.3 *Fineness by Air-Permeability Apparatus*—Test Method C204.