



# Standard Specification for Blended Hydraulic Cements<sup>1</sup>

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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:<sup>2</sup>

- 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)

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.10 on Hydraulic Cements for General Concrete Construction.

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<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

- 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-μm (No. 325) Sieve
- C465 Specification for Processing Additions for Use in the Manufacture of Hydraulic Cements
- C563 Test Method for Approximation of Optimum SO<sub>3</sub> 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
- IEEE/ASTM SI 10 Standard for Use of the International System of Units (SI): the Modern Metric System

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

### 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 in accordance with 4.2.1 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 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 SO<sub>3</sub> 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

TABLE 1 Chemical Requirements

| Cement Type <sup>A</sup>                                  | 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 <sub>3</sub> , max, % <sup>B</sup> | C114                   | 3.0                             | 4.0               | 4.0                  | 3.0                  |
| Sulfide reported as S <sup>2-</sup> , max, %              | C114                   | 2.0                             | 2.0               | ...                  | ...                  |
| Insoluble residue, max, % <sup>C</sup>                    | C114                   | 1.0                             | 1.0               | ...                  | ...                  |
| Loss on ignition, max, %                                  | C114                   | 3.0 <sup>D</sup>                | 4.0 <sup>D</sup>  | 5.0 <sup>D</sup>     | 10.0                 |

<sup>A</sup> The chemical requirements in this table are applicable to all air-entrained cement equivalents.

<sup>B</sup> It is permissible to exceed the values in the table for SO<sub>3</sub> content, provided it has been demonstrated by Test Method C1038 that the cement with the increased SO<sub>3</sub> 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.

<sup>C</sup> Insoluble residue maximum limit does not apply to ternary blended cements.

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

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;
  - 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 (see 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 (see 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 SO<sub>3</sub> 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) two different pozzolans, (2) slag and a pozzolan, (3) a pozzolan and a limestone, or (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 SO<sub>3</sub> 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 SO<sub>3</sub> 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, ± % |
|--------------------------------------------------|----------------|
| Silicon dioxide (SiO <sub>2</sub> )              | 3              |
| Aluminum oxide (Al <sub>2</sub> O <sub>3</sub> ) | 2              |
| Calcium oxide (CaO)                              | 3              |

**NOTE 10**—This means that if the manufacturer's statement of the composition says "SiO<sub>2</sub>: 32 %," the cement when analyzed, shall be found to contain between 29 and 35 % SiO<sub>2</sub>.

**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. 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.

**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 2**. When specified, blended cement with special properties shall conform to applicable physical requirements in **Table 3**, and requirements for compressive strength and air content in **Table 3** supersede those in **Table 2**.

**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

**TABLE 2 Physical Requirements for Blended Cements**

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

<sup>A</sup> Both amount retained when wet-sieved on 45-μm (No. 325) sieve and specific surface by air permeability apparatus, m<sup>2</sup>/kg, shall be reported on all mill test reports requested under **15.4**.

<sup>B</sup> 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.

<sup>C</sup> 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 3 Physical Requirements for Blended Cements with Special Properties

| Special Property Designation <sup>A</sup>          | Applicable Test Method | A               | MS <sup>B</sup> | HS <sup>B</sup>   | MH          | LH          | R <sup>C</sup> |
|----------------------------------------------------|------------------------|-----------------|-----------------|-------------------|-------------|-------------|----------------|
| Air content of mortar:                             |                        |                 |                 |                   |             |             |                |
| minimum, volume %                                  | C185                   | 16 <sup>D</sup> | ...             | ...               | ...         | ...         | ...            |
| maximum, volume %                                  |                        | 22 <sup>D</sup> | 12              | 12                | 12          | 12          | 12             |
| Compressive strength, <sup>E</sup> 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 <sup>F</sup> | ...         | ...         | ...            |
| Expansion at 1 year                                |                        | ...             | ...             | 0.10 <sup>F</sup> | ...         | ...         | ...            |
| Mortar expansion, max, %:                          |                        |                 |                 |                   |             |             |                |
| 14 days                                            | C227                   | ...             | ...             | ...               | ...         | ...         | 0.020          |
| 8 weeks                                            |                        | ...             | ...             | ...               | ...         | ...         | 0.060          |

<sup>A</sup> 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 2.

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

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

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

<sup>E</sup> 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.

<sup>F</sup> 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.

TABLE 4 Requirements for Pozzolan for Use in Blended Cements and for Slag for Use in Portland Blast-Furnace Slag Cement Type IS(&lt; 25) and Ternary Blended Cement Type IT(S&lt;25)

| Pozzolan and Slag, as applicable                                                                                                                       | Applicable Test Method |      |
|--------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------|------|
| Fineness; Amount retained when wet-sieved on 45-μm (No. 325) sieve, max, %                                                                             | C430                   | 20.0 |
| Alkali reactivity of pozzolan for use in Types IP(<15); IT(P<15) and IP(<15)-A; IT(P<15)-A cements, six tests, mortar bar expansion at 91 days, max, % | C227                   | 0.05 |
| Activity index with portland cement, at 28 days, min, %                                                                                                | (see Annex A1)         | 75   |
| Loss on ignition of pozzolan, max, %                                                                                                                   | C311                   |      |
| Natural pozzolan                                                                                                                                       |                        | 10.0 |
| Fly ash                                                                                                                                                |                        | 6.0  |
| Silica fume                                                                                                                                            |                        | 6.0  |

fineness requirement and the activity index requirement of Table 4. 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 4. Such pozzolan, or slag that is to be interground with portland cement clinker shall, before testing for conformance with requirements of Table 4, 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 4 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 Na<sub>2</sub>O, calculated as Na<sub>2</sub>O + 0.658 K<sub>2</sub>O, 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 4.

## 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.

TABLE 5 Aggregate Grading Requirements for Mortar Expansion Test

| Sieve Size       |                  | Weight % |
|------------------|------------------|----------|
| Passing          | Retained on      |          |
| 4.75-mm (No. 4)  | 2.36-mm (No. 8)  | 10       |
| 2.36-mm (No. 8)  | 1.18-mm (No. 16) | 25       |
| 1.18-mm (No. 16) | 600-μm (No. 30)  | 25       |
| 600-μm (No. 30)  | 300-μm (No. 50)  | 25       |
| 300-μm (No. 50)  | 150-μm (No. 100) | 15       |



## 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**.

11.1.4 *Autoclave Expansion*—Test Method **C151**, except that, in the case of portland blast-furnace slag cement Type IS( $\geq 70$ ) or ternary blended cement Type IT(S $\geq 70$ ), the test specimens shall remain in the moist cabinet for a period of 48 h before being measured for length, and the neat cement shall be mixed for not less than 3 min nor more than 3½ min.

11.1.5 *Time of Setting*—Test Method **C191**.

11.1.6 *Air Content of Mortar*—Test Method **C185**, using the actual specific gravity of the cement, if it differs from 3.15 by more than 0.05, in calculating the air content.

11.1.7 *Compressive Strength*—Test Method **C109/C109M**.

11.1.8 *Heat of Hydration*—Test Method **C186**.

11.1.9 *Normal Consistency*—Test Method **C187**, except that in the case of portland blast-furnace slag cement IS( $\geq 70$ ) or ternary blended cement IT(S $\geq 70$ ), the paste shall be mixed for not less than 3 min nor more than 3½ min.

11.1.10 *Specific Gravity*—Test Method **C188**.

11.1.11 *Water Requirement*—The mass of mixing water added to the six-cube batch in accordance with Test Method **C109/C109M**, as a percentage of the total cementing ingredients.

11.1.12 *Mortar Expansion of Blended Cement*—Test Method **C227**, using crushed Pyrex glass No. 7740<sup>3</sup> as aggregate and the grading prescribed in **Table 5**.

11.1.13 *Mortar Expansion of Pozzolan for Use in Portland-Pozzolan Cement Types IP(<15) and IP(<15)-A or Ternary Blended Cement Types IT(P<15) and IT(P<15)-A*—Using the pozzolan and the clinker or cement that are to be used together in the production of the blended cement, prepare portland-pozzolan cements Types IP(<15) and IP(<15)-A or ternary blended cement Types IT(P<15) and IT(P<15)-A containing 2.5, 5, 7.5, 10, 12.5, and 15 mass % of the pozzolan. These blends shall be tested in accordance with Test Method **C227** using a sand judged to be a nonreactive by the mortar bar test in Test Method **C227**. The expansion of the mortar bars shall be measured at 91 days, and all the six blends shall meet the expansion requirement in **Table 4**.

11.1.14 *Drying Shrinkage*—Test Method **C157/C157M**. Make three specimens using the proportion of dry materials of 1 part of cement to 2.75 parts of Test Method **C109/C109M** graded Ottawa sand. Use a curing period of 6 days and an air

storage period of 28 days. Report the linear contraction during air storage based on an initial measurement after the 6-day water-curing period.

11.1.15 *Activity Index with Portland Cement*—Test in accordance with **Annex A1**.

11.1.16 *Sulfate Resistance*—see Test Method **C1012**.

11.1.17 *Loss on Ignition of Pozzolan*—Test Methods **C311**.

## 12. Testing Time Requirements

12.1 The following periods from time of sampling shall be allowed for the completion of testing:

|             |         |
|-------------|---------|
| 3-day test  | 8 days  |
| 7-day test  | 12 days |
| 14-day test | 19 days |
| 28-day test | 33 days |
| 8-week test | 61 days |

## 13. Inspection

13.1 Facilities shall be provided to the purchaser for careful inspection and sampling of the finished cement. Inspection and sampling of finished cement shall be at the mill or distribution site controlled by the manufacturer, or at any other location as agreed by the purchaser and seller.

13.2 The manufacturer shall provide suitable facilities to enable the inspector to check the relative masses of the constituents used, and the intergrinding or blending operation used to produce the cement. The plant facilities for intergrinding or blending and inspection shall be adequate to ensure compliance with the provisions of this specification.

## 14. Rejection

14.1 At the option of the purchaser, cement shall be rejected if it fails to meet any of the requirements of this specification applicable to the cement. Such rejection shall apply to an optional requirement only if that option has been invoked for the cement.

14.2 When the purchaser requires, cement in bulk storage for a period greater than six months shall be resampled and retested and, at the option of the purchaser, shall be rejected if it fails to meet any of the applicable requirements of this specification. Cement so rejected shall be the responsibility of the owner of record at the time of sampling for retest.

14.3 When the purchaser requires, packages more than 2 % below the mass marked thereon shall be rejected; or if the average mass of packages in any shipment, as shown by determining the mass of 50 packages taken at random, is less than that marked on the packages, the entire shipment, at the option of the purchaser, shall be rejected.

## 15. Certification

15.1 At the request of the purchaser, the manufacturer shall state in writing the source, targeted amount, and composition of the essential constituents used in manufacture of the blended cement and the composition of the blended cement purchased.

15.2 At the request of the purchaser, the manufacturer shall state in writing the nature, amount, and identity of any processing, functional, or air-entraining addition used; and also, if requested, shall supply test data showing compliance of

<sup>3</sup> Pyrex Glass No. 7740 is available as lump cullet from the Corning Glass Works, Corning, NY; this is the sole source of supply of the apparatus known to the committee at this time. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,<sup>1</sup> which you may attend.



any such processing addition with the provisions of Specification C465 and of any such functional addition with the provisions of Specification C688, and of any such air-entraining addition with the provisions of Specification C226.

15.3 At the request of the purchaser, the manufacturer shall also state in writing that the amounts of a constituent in the finished cement will not vary more than the percentages listed in Table 6 with a 99% probability of compliance between lots or within a lot (see Note 11).

NOTE 11—To satisfy the 99% probability of compliance, the manufacturing process must be capable of producing a cement such that the standard deviation of the determined mass percentage of silica fume, metakaolin, or limestone in the cement is less than 1%. For all other ingredients, the standard deviations of their determined mass percentages have to be less than 1.9%. The variation in determined mass percentage includes that due to the amount and chemistry of the constituent, as well as that due to variation in verification testing. As an example, Type IP(5) made with silica fume indicates a blended hydraulic cement determined to contain between 2.5% and 7.5% silica fume by mass. A Type IP(20) cement made with fly ash indicates a blended cement determined to contain between 15% and 25% fly ash by mass.

15.4 Upon request of the purchaser in the contract or order, a manufacturer's certification shall be furnished indicating that the material was tested during production or transfer in accordance with this specification, that it complies with this

specification, and a report of the test results shall be furnished at the time of shipment (to include both amount retained on the 45- $\mu$ m (No. 325) sieve and specific surface by the air permeability method).

## 16. Packaging and Package Marking

16.1 When the cement is delivered in packages, the words, "portland blast-furnace slag cement," "portland-pozzolan cement," "portland-limestone cement," or "ternary blended cement" as appropriate; the type of cement, name and brand of the manufacturer, and the mass of the cement contained therein, shall be plainly marked on each package. When the cement contains a functional addition listed in 5.1.3.6 – 5.1.3.11, the type of functional addition shall be plainly marked on each package. Similar information shall be provided in the shipping documents accompanying the shipment of packaged or bulk cement. All packages shall be in good condition at the time of inspection.

## 17. Storage

17.1 The cement shall be stored in such a manner as to permit easy access for proper inspection and identification of each shipment, and in a suitable weathertight building that will protect the cement from dampness and minimize warehouse set.

## 18. Keywords

18.1 blended hydraulic cement; fly ash cement; hydraulic cement; portland blast-furnace slag cement; portland-limestone cement; portland-pozzolan cement; pozzolanic cement; slag; granulated blast-furnace slag

**TABLE 6 Permitted Variation in Mass Percentage of Constituent**

| Constituent                        | Maximum variation in amount from target, % by mass of blended cement |
|------------------------------------|----------------------------------------------------------------------|
| Silica fume, metakaolin, limestone | $\pm 2.5$                                                            |
| All other constituents             | $\pm 5.0$                                                            |

## ANNEX

### (Mandatory Information)

#### A1. ACTIVITY INDEX WITH PORTLAND CEMENT

##### A1.1. Specimen Preparation

A1.1.1 Mold, cure, and test the specimens from a control mix and from a test mix in accordance with Test Method C109/C109M. The portland cement used in the control mix shall meet the requirements of Specification C150, and shall be the type, and if available, the brand of cement to be used in the work. Make three-cube batches as follows: (For 6- or 9-cube batches, double or triple, respectively, the amounts of dry ingredients.)

###### A1.1.1.1 Control Mix:

250 g of portland cement  
687.5 g of graded Ottawa sand  
X mL of water required for flow of 100 to 115

###### A1.1.1.2 Pozzolan Test Mix:

162.5 g of portland cement  
g of pozzolan:  
87.5  $\times$  sp gr of the sample/sp gr of the portland cement

687.5 g of graded Ottawa sand

Y mL of water required for flow of 100 to 115

###### A1.1.1.3 Slag Test Mix:

75 g of portland cement  
g of slag:  
175  $\times$  sp gr of the slag/sp gr of the portland cement  
687.5 g of graded Ottawa sand  
Z mL of water required for flow of 100 to 115

##### A1.2 Storage of Specimens

A1.2.1 After molding, place the specimens and molds (on the base plates) in the moist room or closet at  $23.0 \pm 2.0^\circ\text{C}$  [ $73.5 \pm 3.5^\circ\text{F}$ ] for 20 to 24 h. While in the moist room or closet, protect the surface from dripping water. Remove the molds from the moist room or closet and remove the cubes from the molds. Place the cubes in close-fitting metal or glass containers (Note A1.1), seal the containers airtight, and store at

38.0 ± 2.0°C [100.0 ± 3.5°F] for 27 days. Allow the specimens to cool to 23.0 ± 2.0°C [73.5 ± 3.5°F] before testing.

NOTE A1.1—Use any metal container having a capacity of three cubes if it can be sealed airtight by soldering. Containers of light-tinned sheet metal with inside dimensions of 52 by 52 by 160 mm [2 by 2 by 6.25 in.] have been found to be satisfactory. Wide-mouth Mason jars of 1-L capacity have been found to be satisfactory, provided care is taken to prevent breakage.

(**Warning**—Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.)<sup>4</sup>

### A1.3 Compressive Strength Test

A1.3.1 Determine the compressive strength of the three specimens of the control mix and of the test mix at an age of 28 days in accordance with Test Method **C109/C109M**.

### A1.4. Calculation

A1.4.1 Calculate the activity index with portland cement as follows:

$$\text{Activity index with portland cement} = (A/B) \times 100 \quad (\text{A1.1})$$

<sup>4</sup> Section on Safety, Manual of Cement Testing, *Annual Book of ASTM Standards*, Vol 04.01.

where:

*A* = average compressive strength of test mix cubes, MPa, and

*B* = average compressive strength of control mix cubes, MPa.

### A1.5. Precision and Bias

A1.5.1 *Precision*—Single operator precision, on blended cements using fly ash is essentially the same as on fly ash/cement blends in Research Report RR:C09-1001<sup>5</sup> and it was found to have 3.8 % coefficient of variation (1s %). This indicates that results of two properly conducted tests by the same operator are not expected to differ by more than 10.7 % (d2s) of the average of two results. Since the test is performed solely for the purpose of manufacturer certification of raw material quality, no multilaboratory precision is applicable.

A1.5.2 *Bias*—Since there are no standard reference materials, bias cannot be determined.

<sup>5</sup> Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:C09-1001. Contact ASTM Customer Service at service@astm.org.

## SUMMARY OF CHANGES

Committee **C01** has identified the location of selected changes to this standard since the last issue (C595/C595M – 15<sup>e1</sup>) that may impact the use of this standard. (Approved March 15, 2016.)

(1) Revised **8.2** and **15.3**.

(2) Added **Table 6** and **Note 11**.

(3) Removed previous 2.2, 11.1.17, 11.1.18, Table 2, Annexes A2 and A3, and Appendix X1..

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