



## Standard Performance Specification for Hydraulic Cement<sup>1</sup>

This standard is issued under the fixed designation C 1157; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

### 1. Scope

1.1 This specification covers hydraulic cements for both general and special applications. This is a specification giving performance requirements. There are no restrictions on the composition of the cement or its constituents.

1.2 The specification classifies cements by type based on specific requirements for general use, high early strength, resistance to attack by sulfates, and heat of hydration. Optional requirements are provided for the property of low reactivity with alkali-reactive aggregates.

1.3 For properties where values are given in both SI and inch-pound units, the values in SI units are to be regarded as the standard. Values in SI units shall be obtained by measurement in SI units or by appropriate conversion, using the Rules for Conversion and Rounding given in IEEE/ASTM SI 10, of measurements made in other units.

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

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

NOTE 1—Specification C 150 is a prescription specification for portland cement and Specifications C 595 is a specification for blended hydraulic cement where the products that may be furnished are of restricted nature and proportions and where the products must meet prescriptive requirements as to chemical and physical properties.

### 2. Referenced Documents

#### 2.1 ASTM Standards:<sup>2</sup>

<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.

- C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)
- C 114 Test Methods for Chemical Analysis of Hydraulic Cement
- C 150 Specification for Portland Cement
- C 151 Test Method for Autoclave Expansion of Portland Cement
- C 183 Practice for Sampling and the Amount of Testing of Hydraulic Cement
- C 185 Test Method for Air Content of Hydraulic Cement Mortar
- C 186 Test Method for Heat of Hydration of Hydraulic Cement
- C 188 Test Method for Density of Hydraulic Cement
- C 191 Test Method for Time of Setting of Hydraulic Cement by Vicat Needle
- C 204 Test Method for Fineness of Hydraulic Cement by Air Permeability Apparatus
- C 219 Terminology Relating to Hydraulic Cement
- C 226 Specification for Air-Entraining Additions for Use in the Manufacture of Air-Entraining Hydraulic Cement
- C 227 Test Method for Potential Alkali Reactivity of Cement-Aggregate Combinations (Mortar-Bar Method)
- C 311 Test Methods for Sampling and Testing Fly Ash or Natural Pozzolans for Use as a Mineral Admixture in Portland-Cement Concrete
- C 430 Test Method for Fineness of Hydraulic Cement by the 45- $\mu$ m (No. 325) Sieve
- C 441 Test Method for Effectiveness of Pozzolans or Ground Blast-Furnace Slag in Preventing Excessive Expansion of Concrete Due to the Alkali-Silica Reaction
- C 451 Test Method for Early Stiffening of Hydraulic Cement (Paste Method)
- C 465 Specification for Processing Additions for Use in the Manufacture of Hydraulic Cements
- C 595 Specifications for Blended Hydraulic Cements
- C 688 Specification for Functional Additions for Use in Hydraulic Cements
- C 1012 Test Method for Length Change of Hydraulic-Cement Mortars Exposed to a Sulfate Solution
- C 1038 Test Method for Expansion of Portland Cement Mortar Bars Stored in Water

IEEE/ASTM SI 10 Standard for Use of the International System of Units (SI): the Modern Metric System

### 3. Terminology

#### 3.1 Definitions:

3.1.1 Terms used in this specification are defined in Terminology C 219, except for the following terms.

3.1.2 *blended hydraulic cement*—a hydraulic cement consisting of two or more inorganic ingredients which contribute to the strength-gaining properties of the cement, with or without other ingredients, processing additions, and functional additions.

3.1.2.1 Blended hydraulic cements are made by intergrinding or other blending processes.

### 4. Nomenclature

4.1 As selected by the producer, designate cements under this specification in accordance with the following names. The nomenclature does not establish or require any limits on the composition or properties of a cement. Its only purpose is to provide a uniform means for designating the cement after its ingredients and proportions have been selected by the manufacturer, thereby providing general information about the cement when the manufacturer so chooses.

4.2 *Hydraulic Cement*—Any cement meeting the requirements of this specification is a hydraulic cement. At the option of the producer, use this designation in addition to, or in lieu of, any other proper designation.

4.3 *Portland Cement*, consisting of portland-cement clinker to which, at the option of the manufacturer, one or more of the following additions, and no others, shall have been made during manufacture.

4.3.1 Calcium sulfate set-control addition.

4.3.2 Water, including that present in clinker and other additions, in amounts such that loss-on-ignition does not exceed 3.0 % by mass of the cement.

4.3.3 Processing additions up to the maximum amount demonstrating conformance to the applicable specification.

4.3.4 *Air-Entraining Portland Cement* shall contain an interground air-entraining addition.

4.4 *Blended Hydraulic Cements*:

4.4.1 *Modified Portland Cements* contain up to 15 % of a mineral ingredient besides portland-cement clinker, and, as selected by the producer, are designated “[ingredient]-modified portland cement” in accordance with the identity of the mineral ingredient used.

4.4.2 *Other Blended Hydraulic Cements* contain more than 15 % of two or more mineral ingredients and, as selected by the producer, are named in accordance with the two or, if more appropriate, three constituents present in greatest amount, listed in decreasing order of abundance by mass.

### 5. Additions

5.1 *Processing Additions*—If processing additions are used in the manufacture of cement, they shall conform to the requirements of Specification C 465.

5.2 *Functional Additions*—If functional additions of the types defined in Specification C 226 or C 688 are used in a cement, they shall conform to the requirements of the applicable specification.

### 6. Classification and Use

6.1 The types of hydraulic cement covered by this specification are given in 6.2.1-6.2.6 and are classified in accordance with specific properties.

6.2 Cements conforming to this specification shall be designated in accordance with the nomenclature with special characteristics indicated by type in accordance with the types in 6.2.1-6.2.6. When the type is not specified, the requirement of type GU shall apply.

6.2.1 *Type GU*—Hydraulic cement for general construction. Use when one or more of the special types are not required.

6.2.2 *Type HE*—High Early-Strength.

6.2.3 *Type MS*—Moderate Sulfate Resistance.

6.2.4 *Type HS*—High Sulfate Resistance.

6.2.5 *Type MH*—Moderate Heat of Hydration.

6.2.6 *Type LH*—Low Heat of Hydration.

6.3 *Additional Option*—The following additional purchase option applies for any of the principal types listed. When this option is invoked, its letter designation and title shall follow immediately after the respective letter designation and title of the principal type.

6.3.1 *Option R*—Low Reactivity with Alkali-Reactive Aggregates. When tested for potential activity with alkali-reactive aggregates, the cement shall meet the requirement (Table 1) for low reactivity with alkali-reactive aggregates.

### 7. Ordering Information

7.1 Orders for cement meeting the requirements of this specification shall include:

7.1.1 The specification designation ASTM C 1157,

7.1.2 The specification date, if other than the latest published version,

7.1.3 The quantity of cement desired,

7.1.4 The nomenclature (see Section 4) and the type of cement desired (if no type is specified, the cement shipped shall meet the requirements for Type GU).

7.1.5 *Compressive Strength Options*—Three options for compressive strength are listed in this specification. If strength other than the default minima (7.1.5.1) of Table 1 are desired, verify that the option selected is available in the area where required. Strength at an age listed in Table 1 for the Type of cement shall not be less than the strength at an earlier listed age.

7.1.5.1 *Minimum Compressive Strengths (Default)*—If the minimum strengths of the ranges listed in Table 1 are acceptable, specify the minimums of Table 1. When another option is not stated, the applicable compressive strength requirements are the minimums of the Table 2 Strength Ranges listed for each age in Table 1 for the Type of cement.

7.1.5.2 *Minimum Strength at a Listed Age*—When a minimum strength greater than a default minimum is required at a listed age, specify the minimum of one Strength Range listed in Table 2 at one age listed in Table 1 for that Type of cement.

**TABLE 1 Standard Physical Requirements**

Cement Type	Applicable Test Method	GU	HE	MS	HS	MH	LH
Fineness	C 204	A	A	A	A	A	A
Autoclave length change, max, %	C 151	0.80	0.80	0.80	0.80	0.80	0.80
Time of setting, vicat test <sup>B</sup>	C 191						
Initial, not less than, minutes		45	45	45	45	45	45
Initial, not more than, minutes		420	420	420	420	420	420
Air content of mortar volume, %	C 185	C	C	C	C	C	C
Strength range <sup>D</sup>	C 109/C 109M						
1 day		...	10	...	...	...	...
3 days		10	17	10	5	5	...
7 days		17	...	17	10	10	5
28 days		...	...	...	17	...	17
Heat of hydration	C 186						
7 days, max, kJ/kg (kcal/kg)		...	...	...	...	290 (70)	250 (60)
28 days, max, kJ/kg (kcal/kg)		...	...	...	...	...	290 (70)
Mortar bar expansion	C 1038						
14 days, % max		0.020	0.020	0.020	0.020	0.020	0.020
Sulfate expansion (sulfate resistance) <sup>E</sup>	C 1012						
6 months, max, %		...	...	0.10	0.05	...	...
1 year, max, %		...	...	...	0.10	...	...
Option R—Low Reactivity with Alkali-Reactive Aggregates <sup>F</sup>							
Expansion	C 227						
14 days, max, %		0.020	0.020	0.020	0.020	0.020	0.020
56 days, max, %		0.060	0.060	0.060	0.060	0.060	0.060
Optional Physical Requirements							
Early stiffening, final penetration, min, %	C 451	50	50	50	50	50	50
Compressive strength, <sup>G</sup>	C 109/C 109M						
28 days, min, MPa (psi)		28.0 (4060)	...	28.0 (4060)	...	22.0 (3190)	...

<sup>A</sup> Both amount retained when wet sieved on the 45- $\mu$ m (No. 325) sieve and specific surface area by air permeability apparatus in  $m^2/kg$  shall be reported on all certificates of test results requested from the manufacturer.

<sup>B</sup> Time of setting refers to initial setting time in Test Method C 191.

<sup>C</sup> Air content shall be reported on all certificates of test results requested from the manufacturer. A given value in mortar does not necessarily assure that the desired air content will be obtained in concrete.

<sup>D</sup> Lowest Strength Range whose minimum shall apply at the specified age unless a higher Strength Range is specified by the purchaser. See Table 2 for the applicable strength limits.

<sup>E</sup> In the testing of HS cement, testing at one year shall not be required when the cement meets the 6 month limit. An HS cement failing the 6 month limit shall not be rejected unless it also fails the one year limit.

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

<sup>G</sup> When 28-day strengths are specified, sufficient time must be allowed for completion of the test. When required on a certificate of test results, special arrangements shall be made for storage of the cement pending completion of the test.

**TABLE 2 Strength Range Limits**

Strength Range	Applicable Test Method	5	10	17	25	35	45
Compressive strength min, Mpa (psi)	C 109/C 109M	5 (725)	10 (1450)	17 (2465)	25 (3625)	35 (5075)	45 (6525)
Compressive strength max, Mpa (psi)	C 109/C 109M	15 (2175)	20 (2900)	30 (4350)	40 (5800)	60 (8700)	...

**7.1.5.3 Strength Range at a Listed Age**—When cement is required that is within a particular range of strength, specify cement as being within one Strength Range from Table 2 at one age listed for that cement Type in Table 1.

NOTE 2—Listed ages for Type HE in Table 1 are 1 and 3 days; listed ages for Types GU, MH, and MS are 3 and 7 days; listed ages for Type HS are 3, 7, and 28 days; listed ages for Type LH are 7 and 28 days.

**7.1.5.4 Strength Range at Desired Age**—When cement is required that is within a particular range of strength, specify cement as being within one Strength Range from Table 2 at one age selected from among 3, 7, and 28 days, except that when Type HE is specified, one Strength Range shall be selected

from among 1, 3, 7, or 28 days. If no Strength Range is specified, only the minimum strengths of all the ranges in Table 1, as established in Table 2, shall apply.

**7.1.6** A statement that the low reactivity with alkali-reactive aggregates option is invoked, when such is desired, and

**7.1.7** A request for the manufacturer's certification, if desired.

**7.1.8** 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 C 183.

**7.1.9** Practice C 183 is not designed for manufacturing quality control and is not required for manufacturer's certification.

## 8. Chemical Composition

**8.1** The chemical composition for the cement is not specified. However, the cement and the individual constituents interground or blended to produce it shall be analyzed.

## 9. Physical Properties

**9.1** Cement of the type specified shall conform to all of the applicable physical requirements of Table 1.

9.2 When optional requirements for early stiffening or 28-day strength are specified, the cement shall conform to the applicable optional limits of Table 1.

9.3 Pozzolan to be used as an ingredient of a cement shall not cause unacceptable expansion due to an alkali-aggregate reaction. To determine that a pozzolan meets this requirement, test it for alkali-reactivity potential. If the mortar expansion exceeds 0.05 % at the 91-day age for any of the three pozzolan-containing compositions, the pozzolan shall be considered potentially reactive and unacceptable under this specification. If the average total alkali content of any lot of the cement, expressed as  $\text{Na}_2\text{O}$  equivalent<sup>3</sup>, changes by more than 0.10 % by mass from that with which the alkali-reactivity potential tests were carried out, rerun the test for alkali-reactivity of the pozzolan.

## 10. Sampling

10.1 Provide adequate facilities for sampling the finished cement. Sample the finished cement at the mill or at the job site as may be specified by the purchaser.

## 11. Test Methods

11.1 When testing a cement for compliance with this specification, use the following methods, with modifications or exceptions as indicated.

11.2 *Chemical Analysis*—Chemically analyze the cement using Test Methods C 114 for major and minor oxides present in greatest quantity that together, including loss-on-ignition, constitute at least 98 % of the total mass of the cement and for insoluble residue. Obtain a chemical analysis of each ingredient included in the cement in amounts greater than 1 % by mass; use appropriate analytical methods, such as Test Methods C 311 for pozzolan or other methods consistent with the principles of Test Methods C 114.

11.2.1 *Sulfate*—Any appropriate method for determining  $\text{SO}_3$  shall be used. If the reference method of Test Methods C 114 is used, the sample need not be completely decomposed as long as excess acid is used.

11.2.2 *Loss-on-Ignition*—For pozzolan, use the method for portland cement in Test Methods C 114, except ignite the sample at 700 to 800°C using an uncovered porcelain crucible. For cements containing sulfides or other constituents which gain weight on heating, use the slag cement procedure in Test Methods C 114.

11.2.3 *Sodium and Potassium Oxides*—For pozzolans or pozzolan-containing cements, the procedure for solution of cement in the procedure for total alkali given in Test Methods C 114 often will not dissolve all of the alkalies. Complete dissolution of the alkalies is essential for accurate analysis. For cements, igniting the sample prior to dissolving will often make the alkalies soluble in acid. Other approaches are igniting with lime, hydrated lime, or calcium carbonate or fusion with lithium borate prior to dissolving, especially for pozzolans. A blank must be run.

### 11.3 Fineness:

11.3.1 Determine fineness by Test Method C 204.

11.3.2 Determine amount retained on the 45- $\mu\text{m}$  (No. 325) sieve by Test Method C 430.

11.4 Determine autoclave expansion by Test Method C 151, except that for cements with 1-day compressive strengths below 3.4 MPa (500 psi), mix the neat cement paste for not less than 3, nor more than 3½ min, and store the test specimen in the moist cabinet for a period of 48 h before being demolded and measured for length.

11.5 Determine the time of setting using Test Method C 191. Only time of initial setting is required.

11.6 Test the mortar for air content using Test Method C 185 using the actual density of the cement, as determined by Test Method C 188, if it differs from 3.15  $\text{Mg}/\text{m}^3$  by more than 0.05  $\text{Mg}/\text{m}^3$ .

11.7 Determine compressive strength using Test Method C 109/C 109M. Tests shall be run at each age specified in Table 1 and, if optional requirements are selected, at the age specified in the optional requirements of Table 1. The mixing water requirement in Test Method C 109/C 109M shall be adjusted to produce a flow of  $110 \pm 5$  for blended hydraulic cements.

11.8 Determine heat of hydration using Test Method C 186.

11.9 Determine sulfate resistance using Test Method C 1012.

11.10 Determine reactivity of cement with alkali-reactive aggregate (Option R) using Test Method C 227 using crushed borosilicate glass, as described in Test Method C 441, as aggregate.

11.11 Determine alkali reactivity of pozzolan using Test Method C 227. Use all constituents, except the pozzolan, at the same relative proportions as they are used in the cement. Prepare blends containing the pozzolan at 0.0 %, the percentage intended for use in the cement, the intended level +5 %, and the intended level -5 %. Test these blends in accordance with Test Method C 227 using sand judged to be non-reactive by Test Method C 227.

11.12 Determine early stiffening using Test Method C 451.

11.13 Determine mortar bar expansion using Test Method C 1038 using a 14-day immersion period.

## 12. Testing Time Requirements

12.1 Apply the testing requirements of Practice C 183.

12.2 The purchaser shall make necessary arrangements for shipment of samples to the testing laboratory. Add the time required for transport to the laboratory to the minimum time intervals allowed from receipt of the samples by the testing laboratory.

12.3 The minimum time allowed from receipt of samples by the testing laboratory to the report of test results shall be determined by the required age of specimen at the time of testing plus seven days.

12.4 A written report of results of applicable tests shall be available within not more than three days of the interval indicated in 12.3.

12.5 These time limits do not apply to retesting or additional testing.

NOTE 3—Aging effects on small samples of cement stored for long periods of time can produce test results that are not representative of the fresh cement nor of cement stored in large quantity for equal periods of time.

<sup>3</sup>  $\text{Na}_2\text{O}$  is defined as  $\% \text{Na}_2\text{O} + 0.658 \times \% \text{K}_2\text{O}$ .

### 13. Testing by the Manufacturer

13.1 Secure representative samples of cement during production or transfer and test them for compliance with this specification and for chemical analysis and fineness. Such testing shall include a chemical analysis and determination of fineness. Location and frequency of sampling are at the discretion of the manufacturer. Sampling and testing shall be either part of, or in addition to, the manufacturer's normal quality control.

#### 13.2 Special Testing:

13.2.1 The following requirements for testing apply only to tests for sulfate resistance and low reactivity with alkali-reactive aggregates.

13.2.1.1 For sulfate resistance of Types MS and HS and for Option R of any cement, make tests for compliance with the applicable requirements at least once every 12 months. Retest if the analysis of any oxide in any of the constituents, or the cement as a whole, departs by more than the values given below from values previously shown to satisfy the applicable requirements.

	Variation from composition for which compliance has been shown	
	Cement or any ingredient making up 10 % or more of the cement	Ingredients making up less than 10 % of the cement
Change in ingredient composition, any oxide, Mass %	±3	±5

Retest if the amount of a constituent making up 10 % or more of the cement is changed by 5 % or more by mass of the cement, or if a constituent making up less than 10 % of the cement or an addition is changed by 50 % or more of the amount previously present.

13.2.1.2 At the request of the purchaser, make available the manufacturer's data on compliance with sulfate resistance for Types MS or HS or Option R for any cement when such requirements are called for in the cement specification. At the option of the purchaser, the manufacturer's data on compliance shall be used instead of additional sampling and testing for acceptance or rejection of cement.

### 14. Inspection

14.1 Inspection of the material shall be as agreed upon between the purchaser and the seller as part of the purchase contract.

14.2 All packages shall be in good condition at the time of inspection.

### 15. Rejection

15.1 At the option of the purchaser, material that fails to conform to the applicable requirements of this specification for the type specified shall be rejected. Report rejection to the manufacturer or supplier promptly and in writing, stating the specific reasons for rejection.

15.2 At the option of the purchaser, packages more than 2 % below the mass marked thereon shall be rejected, and 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, reject the entire shipment.

### 16. Certification

16.1 When specified in the purchase order or contract, furnish the manufacturer's certification at the time of shipment stating the results of tests, including chemical analysis, made on cement sampled during production or transfer and certifying that the applicable requirements of this specification have been met.

16.2 At the option of the purchaser, bulk cement remaining in storage for more than six months after testing or packaged cement remaining in the possession of a vendor for more than three months shall be sampled and retested and rejected if it fails to meet any of the applicable requirements of this specification.

16.3 *Sulfate Resistance (Types MS and HS) and Low Reactivity with Aggregates (Option R)*—When specified, results from the tests demonstrating compliance with this specification shall be available for inspection and the manufacturer's report shall state that the applicable requirements of this specification for those properties have been met.

### 17. Package Marking

17.1 When the cement is delivered in packages, words stating an appropriate cement nomenclature selected by the producer, the type of cement and, if specified, compliance with Option R, the name and brand of manufacturer, the mass of cement contained therein, and a list of constituents, using generic names in decreasing order of abundance, shall be plainly marked on each package. Provide similar information with the manufacturer's certification accompanying the shipment of packaged or bulk cement.

NOTE 4—The following list contains suggested generic names for some possible ingredients of blended cements. The list is representative and is not inclusive.

Class of Ingredient	Examples of Generic Terms
Cement	Portland cement, portland cement clinker.
Calcium Ingredient	Calcium carbonate, limestone, lime, hydrated lime.
Pozzolan	Class F fly ash, Class C fly ash, uncalcined natural pozzolan, calcined natural pozzolan, silica fume.
Slag	Granulated iron blast-furnace slag.
Additions	Calcium sulfate, water reducer, accelerator, retarder, water-reducing retarder, air-entraining addition, processing addition.

### 18. Storage

18.1 The cement shall be stored in such a manner as to permit reasonable access for proper inspection and identification of each shipment and in a suitable weather-tight building, container, or package that will protect the cement from dampness and minimize warehouse set.

### 19. Keywords

19.1 blended hydraulic cement; fly ash; granulated blast furnace; hydraulic cement; pozzolan; silica fume; slag

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