**Designation: C150/C150M – 17**

# Standard Specification for Portland Cement[1]

This standard is issued under the fixed designation C150/C150M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

## 1. Scope*

1.1 This specification covers ten types of portland cement, as follows (see Note 2):

1.1.1 *Type I*—For use when the special properties specified for any other type are not required.

1.1.2 *Type IA*—Air-entraining cement for the same uses as Type I, where air-entrainment is desired.

1.1.3 *Type II*—For general use, more especially when moderate sulfate resistance is desired.

1.1.4 *Type IIA*—Air-entraining cement for the same uses as Type II, where air-entrainment is desired.

1.1.5 *Type II(MH)*—For general use, more especially when moderate heat of hydration and moderate sulfate resistance are desired.

1.1.6 *Type II(MH)A*—Air-entraining cement for the same uses as Type II(MH), where air-entrainment is desired.

1.1.7 *Type III*—For use when high early strength is desired.

1.1.8 *Type IIIA*—Air-entraining cement for the same use as Type III, where air-entrainment is desired.

1.1.9 *Type IV*—For use when a low heat of hydration is desired.

1.1.10 *Type V*—For use when high sulfate resistance is desired.

NOTE 1—Some cements are designated with a combined type classification, such as Type I/II, indicating that the cement meets the requirements of the indicated types and is being offered as suitable for use when either type is desired.

NOTE 2—Cement conforming to the requirements for all types are not carried in stock in some areas. In advance of specifying the use of cement other than Type I, determine whether the proposed type of cement is, or can be made, available.

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 references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

## 2. Referenced Documents

2.1 *ASTM Standards:*[2]

C33 Specification for Concrete Aggregates

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

C115 Test Method for Fineness of Portland Cement by the Turbidimeter

C151 Test Method for Autoclave Expansion of Hydraulic Cement

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

C191 Test Methods for Time of Setting of Hydraulic Cement by Vicat Needle

C204 Test Methods for Fineness of Hydraulic Cement by

[1] 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.

Current edition approved April 1, 2017. Published April 2017. Originally approved in 1940. Last previous edition approved in 2016 as C150/C150M – 16ε1. DOI: 10.1520/C0150_C0150M-17.

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

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

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
C266 Test Method for Time of Setting of Hydraulic-Cement Paste by Gillmore Needles
C451 Test Method for Early Stiffening of Hydraulic Cement (Paste Method)
C452 Test Method for Potential Expansion of Portland-Cement Mortars Exposed to Sulfate
C465 Specification for Processing Additions for Use in the Manufacture of Hydraulic Cements
C563 Guide for Approximation of Optimum $SO_3$ in Hydraulic Cement
C1038 Test Method for Expansion of Hydraulic Cement Mortar Bars Stored in Water
C1702 Test Method for Measurement of Heat of Hydration of Hydraulic Cementitious Materials Using Isothermal Conduction Calorimetry
E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
IEEE/ASTM SI 10 American National Standard for Use of the International System of Units (SI): The Modern Metric System

## 3. Terminology

3.1 *Definitions*—See Terminology C219.

## 4. Ordering Information

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

4.1.1 This specification number and date,

4.1.2 Type or types allowable. If no type is specified, Type I shall be supplied,

4.1.3 Any optional chemical requirements from Table 2, if desired, and

4.1.4 Any optional physical requirements from Table 4, if desired.

## 5. Ingredients

5.1 The cement covered by this specification shall contain no ingredients except as follows:

5.1.1 Portland cement clinker.

5.1.2 Water or calcium sulfate, or both. The amounts shall be such that the limits shown in Table 1 for sulfur trioxide and loss-on-ignition are not exceeded.

5.1.3 Limestone. The amount shall not be more than 5.0 % by mass such that the chemical and physical requirements of this standard are met (see Note 3). The limestone, defined in Terminology C51, shall be naturally occurring and consist of at least 70 % by mass of one or more of the mineral forms of calcium carbonate. If limestone is used, the manufacturer shall report the amount used, expressed as a percentage of cement mass, as determined using Annex A2, along with the oxide composition of the limestone.

NOTE 3—This standard permits portland cement to contain limestone, but does not require that limestone be an ingredient in the cement. Cement without ground limestone can be specified in the contract or order.

5.1.4 Inorganic processing additions. The amount shall be not more than 5.0 % by mass of cement. Not more than one inorganic processing addition shall be used at a time. For

**TABLE 1 Standard Composition Requirements**

| Cement Type[A] | Applicable Test Method | I and IA | II and IIA | II(MH) and II(MH)A | III and IIIA | IV | V |
|---|---|---|---|---|---|---|---|
| Aluminum oxide ($Al_2O_3$), max, % | C114 | ... | 6.0 | 6.0 | ... | ... | ... |
| Ferric oxide ($Fe_2O_3$), max, % | C114 | ... | 6.0[B] | 6.0[B,C] | ... | 6.5 | ... |
| Magnesium oxide (MgO), max, % | C114 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 | 6.0 |
| Sulfur trioxide ($SO_3$),[D] max, % | C114 | | | | | | |
| When $(C_3A)^E$ is 8 % or less | | 3.0 | 3.0 | 3.0 | 3.5 | 2.3 | 2.3 |
| When $(C_3A)^E$ is more than 8 % | | 3.5 | [F] | [F] | 4.5 | [F] | [F] |
| Loss on ignition, max, % | C114 | | | | | | |
| When limestone is not an ingredient | | 3.0 | 3.0 | 3.0 | 3.0 | 2.5 | 3.0 |
| When limestone is an ingredient | | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 | 3.5 |
| Insoluble residue, max, % | C114 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 |
| Tricalcium silicate $(C_3S)^E$, max, % | See Annex A1 | ... | ... | ... | ... | 35[C] | ... |
| Dicalcium silicate $(C_2S)^E$, min, % | See Annex A1 | ... | ... | ... | ... | 40[C] | ... |
| Tricalcium aluminate $(C_3A)^E$, max, % | See Annex A1 | ... | 8 | 8 | 15 | 7[C] | 5[B] |
| Sum of $C_3S + 4.75C_3A^G$, max, % | See Annex A1 | ... | ... | 100[C,H] | ... | ... | ... |
| Tetracalcium aluminoferrite plus twice the tricalcium aluminate ($C_4AF + 2(C_3A)$), or solid solution ($C_4AF + C_2F$), as applicable, max, % | See Annex A1 | ... | ... | ... | ... | ... | 25[B] |

[A] See Note 2.
[B] Does not apply when the sulfate resistance limit in Table 4 is specified.
[C] Does not apply when the heat of hydration limit in Table 4 is specified.
[D] It is permissible to exceed the values in the table for $SO_3$ content, provided it has been demonstrated by Test Method C1038 that the cement with the increased $SO_3$ 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 6.
[E] See Annex A1 for calculation.
[F] Not applicable.
[G] See Note 5.
[H] In addition, three-day heat of hydration testing by Test Method C1702 shall be conducted at least once every six months. Such testing shall not be used for acceptance or rejection of the cement, but results shall be reported for informational purposes.

**TABLE 2 Optional Composition Requirements[A]**

| Cement Type | Applicable Test Method | I and IA | II and IIA | II(MH) and II(MH)A | III and IIIA | IV | V | Remarks |
|---|---|---|---|---|---|---|---|---|
| Tricalcium aluminate ($C_3A$)[B], max, % | See Annex A1 | ... | ... | ... | 8 | ... | ... | for moderate sulfate resistance |
| Tricalcium aluminate ($C_3A$)[B], max, % | See Annex A1 | ... | ... | ... | 5 | ... | ... | for high sulfate resistance |
| Equivalent alkalies ($Na_2O + 0.658K_2O$), max, % | C114 | 0.60[C] | 0.60[C] | 0.60[C] | 0.60[C] | 0.60[C] | 0.60[C] | low-alkali cement |

[A] These optional requirements apply only when specifically requested. Verify availability before ordering. See Note 2.
[B] See Annex A1 for calculation.
[C] Specify this limit when the cement is to be used in concrete with aggregates that are potentially reactive and no other provisions have been made to protect the concrete from deleteriously reactive aggregates. Refer to Specification C33 for information on potential reactivity of aggregates.

**TABLE 3 Standard Physical Requirements**

| Cement Type[A] | Applicable Test Method | I | IA | II | IIA | II(MH) | II(MH)A | III | IIIA | IV | V |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Air content of mortar,[B] volume %: | C185 | | | | | | | | | | |
| max | | 12 | 22 | 12 | 22 | 12 | 22 | 12 | 22 | 12 | 12 |
| min | | ... | 16 | ... | 16 | ... | 16 | ... | 16 | ... | ... |
| Fineness, specific surface, $m^2/kg$ | | | | | | | | | | | |
| Air permeability test | C204 | | | | | | | | | | |
| min | | 260 | 260 | 260 | 260 | 260 | 260 | ... | ... | 260 | 260 |
| max | | ... | ... | ... | ... | 430[C] | 430[C] | ... | ... | 430 | ... |
| Autoclave expansion, max, % | C151 | 0.80 | 0.80 | 0.80 | 0.80 | 0.80 | 0.80 | 0.80 | 0.80 | 0.80 | 0.80 |
| Strength, not less than the values shown for the ages indicated as follows:[D] | | | | | | | | | | | |
| Compressive strength, MPa [psi]: | C109/C109M | | | | | | | | | | |
| 1 day | | ... | ... | ... | ... | ... | ... | 12.0 [1740] | 10.0 [1450] | ... | ... |
| 3 days | | 12.0 [1740] | 10.0 [1450] | 10.0 [1450] | 8.0 [1160] | 10.0 [1450]<br>7.0[E] [1020][E] | 8.0 [1160]<br>6.0[E] [870][E] | 24.0 [3480] | 19.0 [2760] | ... | 8.0 [1160] |
| 7 days | | 19.0 [2760] | 16.0 [2320] | 17.0 [2470] | 14.0 [2030] | 17.0 [2470]<br>12.0[E] [1740][E] | 14.0 [2030]<br>9.0[E] [1310][E] | ... | ... | 7.0 [1020] | 15.0 [2180] |
| 28 days | | ... | ... | ... | ... | ... | ... | ... | ... | 17.0 [2470] | 21.0 [3050] |
| Time of setting; Vicat test:[F] | C191 | | | | | | | | | | |
| Time of setting, min, not less than | | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 | 45 |
| Time of setting, min, not more than | | 375 | 375 | 375 | 375 | 375 | 375 | 375 | 375 | 375 | 375 |

[A] See Note 2.
[B] Compliance with the requirements of this specification does not necessarily ensure that the desired air content will be obtained in concrete.
[C] Maximum fineness limits do not apply if the sum of $C_3S + 4.75C_3A$ is less than or equal to 90.
[D] The strength at any specified test age shall be not less than that attained at any previous specified test age.
[E] When the optional heat of hydration in Table 4 is specified.
[F] The time of setting is that described as initial setting time in Test Method C191.

**TABLE 4 Optional Physical Requirements[A]**

| Cement Type | Applicable Test Method | I and II | IA and IIA | II(MH) | II(MH)A | III | IIIA | IV | V |
|---|---|---|---|---|---|---|---|---|---|
| False set, final penetration, min, % | C451 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 |
| Heat of hydration[B] (alternative methods): | | | | | | | | | |
| Isothermal Conduction Calorimetry: | | | | | | | | | |
| 3 days, max, kJ/kg [cal/g] | C1702 | . . . | . . . | 255 [60][C] | 255 [60][C] | . . . | . . . | 200 [50][D] | . . . |
| 7 days, max, kJ/kg [cal/g] | | . . . | . . . | . . . | . . . | . . . | . . . | 225 [55][D] | . . . |
| Heat of solution: | | | | | | | | | |
| 7 days, max, kJ/kg [cal/g] | C186 | . . . | . . . | 290 [70][C] | 290 [70][C] | . . . | . . . | 250 [60][D] | . . . |
| 28 days, max, kJ/kg [cal/g] | | . . . | . . . | . . . | . . . | . . . | . . . | 290 [70][D] | . . . |
| Strength, not less than the values shown: | | | | | | | | | |
| Compressive strength, MPa [psi] | C109/C109M | | | | | | | | |
| 28 days | | 28.0 [4060] | 22.0 [3190] | 28.0 [4060]<br>22.0[C] [3190][C] | 22.0 [3190]<br>18.0[C] [2610][C] | . . . | . . . | . . . | . . . |
| Sulfate resistance,[E] 14 days, max, % expansion | C452 | . . .[F] | . . .[F] | . . .[F] | . . .[F] | . . . | . . . | . . . | 0.040 |
| Gillmore test: | C266 | | | | | | | | |
| Initial set, min, not less than | | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 |
| Final set, min, not more than | | 600 | 600 | 600 | 600 | 600 | 600 | 600 | 600 |
| Turbidimeter test | C115 | | | | | | | | |
| min | | 150 | 150 | 150 | 150 | . . . | . . . | 150 | 150 |
| max | | . . . | . . . | 245[G] | 245[G] | . . . | . . . | 245 | . . . |

[A] These optional requirements apply only when specifically requested. Verify availability before ordering. See Note 2.
[B] The method used shall be identified on all test reports that include this data. If test results do not meet requirements of the heat of solution method, the isothermal conduction calorimetry method shall be used, and the requirements for the isothermal conduction calorimetry method shall govern.
[C] The limit for the sum of $C_3S + 4.75C_3A$ in Table 1 shall not apply when this optional limit is requested. These strength requirements apply when the optional heat of hydration requirement is requested.
[D] When the heat of hydration limit is specified, it shall be instead of the limits of $C_3S$, $C_2S$, $C_3A$, and $Fe_2O_3$ listed in Table 1.
[E] When the sulfate resistance is specified, it shall be instead of the limits of $C_3A$, $C_4AF + 2\ C_3A$, and $Fe_2O_3$ listed in Table 1.
[F] Cement meeting the high sulfate resistance limit for Type V is deemed to meet the moderate sulfate resistance requirement of Type II and Type II(MH).
[G] Maximum fineness limits do not apply if the sum of $C_3S + 4.75\ C_3A$ is less than or equal to 90.

amounts greater than 1.0 %, they shall have been shown to meet the requirements of Specification C465 for the inorganic processing addition in the amount used or greater. If an inorganic processing addition is used, the manufacturer shall report the amount used, expressed as a percentage of cement mass, along with the oxide composition of the processing addition. See Note 4.

NOTE 4—These requirements are based on data and recommendations by Taylor.[3]

5.1.5 Organic Processing additions. They shall have been shown to meet the requirements of Specification C465 in the amounts used or greater and the total amount of organic processing additions used shall not exceed 1.0 % by mass of cement.

5.1.6 Air-entraining addition (for air-entraining portland cement only). The interground addition shall conform to the requirements of Specification C226.

## 6. Chemical Composition

6.1 Portland cement of each of the ten types shown in Section 1 shall conform to the respective standard chemical requirements prescribed in Table 1. In addition, optional chemical requirements are shown in Table 2.

NOTE 5—The limit on the sum, $C_3S + 4.75C_3A$, in Table 1 provides control on the heat of hydration of the cement and is consistent with a Test Method C186 seven-day heat of hydration limit of 335 kJ/kg [80 cal/g], or a Test Method C1702 three-day heat of hydration limit of 315 kJ/kg [75 cal/g].

NOTE 6—There are cases where performance of a cement is improved with $SO_3$ in excess of the Table 1 limits in this specification. Guide C563 is one of several methods a manufacturer can use to evaluate the effect of sulfate content on cement characteristics. Whenever $SO_3$ 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.

## 7. Physical Properties

7.1 Portland cement of each of the ten types shown in Section 1 shall conform to the respective standard physical requirements prescribed in Table 3. In addition, optional physical requirements are shown in Table 4.

## 8. Sampling

8.1 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.

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

## 9. Test Methods

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

9.1.1 *Chemical Analysis*—Test Methods C114.
9.1.2 *Air Content of Mortar*—Test Method C185.
9.1.3 *Fineness by Air Permeability*—Test Method C204.
9.1.4 *Autoclave Expansion*—Test Method C151.
9.1.5 *Strength*—Test Method C109/C109M.
9.1.6 *Time of Setting by Vicat Needles*—Test Method C191.

[3] Taylor, P., "Specifications and Protocols for Acceptance Tests on Processing Additions in Cement Manufacturing," *NCHRP Report 607*, Transportation Research 3 Board, Washington, DC 20008, 96 pp. Available at www.trb.org.

9.1.7 *False Set*—Test Method C451.

9.1.8 *Heat of Hydration*—Test Method C186 or C1702.

9.1.9 *Sulfate Resistance*—Test Method C452 (sulfate expansion).

9.1.10 *Time of Setting by Gillmore Needles*—Test Method C266.

9.1.11 *Fineness by Turbidimeter*—Test Method C115.

9.1.12 *Calcium Sulfate (Expansion of) Mortar*—Test Method C1038.

## 10. Inspection

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

## 11. Rejection

11.1 The cement shall be rejected if it fails to meet any of the requirements of this specification.

11.2 At the option of the purchaser, retest, before using, cement remaining in bulk storage for more than six months or cement in bags in local storage in the custody of a vendor for more than three months after completion of tests and reject the cement if it fails to conform to any of the requirements of this specification. Cement so rejected shall be the responsibility of the owner of record at the time of resampling for retest.

11.3 Packages shall identify the mass contained as net weight. 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 selected at random, is less than that marked on the packages, the entire shipment shall be rejected.

## 12. Manufacturer's Statement

12.1 At the request of the purchaser, the manufacturer shall state in writing the nature, amount, and identity of any air-entraining addition and of any processing addition used, and also, if requested, shall supply test data showing compliance of such air-entraining addition with Specification C226 and of such processing addition with Specification C465.

12.2 When limestone is used, the manufacturer shall state in writing the amount thereof and, if requested by the purchaser, shall supply comparative test data on chemical and physical properties of the cement with and without the limestone (see Note 7). The comparative tests do not supersede the normal testing to confirm that the cement meets chemical and physical requirements of this standard. The amount of limestone in cement shall be determined in accordance with Annex A2.

NOTE 7—Comparative test data may be from qualification tests performed by the manufacturer during formulation of the cement with limestone.

12.3 At the request of the purchaser, the manufacturer shall report the total chloride content, in percent by mass of the cement, in the manufacturer's report (see Note 8).

NOTE 8—Chlorides in concrete come from multiple ingredients and cement chloride content may be required in the estimation of concrete chloride content. Requirements for concrete chloride content are provided in building codes and other documents. Total chloride content is higher than water-soluble chloride content, which is commonly referenced in codes.

## 13. Packaging and Package Marking

13.1 When the cement is delivered in packages, the words "Portland Cement," the type of cement, the name and brand of the manufacturer, and the mass of the cement contained therein shall be plainly marked on each package. When the cement is an air-entraining type, the words "air-entraining" 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.

NOTE 9—With the change to SI units, it is desirable to establish a standard SI package for portland cements. To that end 42 kg [92.6 lb] provides a convenient, even-numbered mass reasonably similar to the traditional 94-lb [42.6-kg] package.

## 14. Storage

14.1 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 weather-tight building that will protect the cement from dampness and minimize warehouse set.

## 15. Manufacturer's Certification

15.1 Upon request of the purchaser in the contract or order, a manufacturer's report shall be furnished at the time of shipment stating the results of tests made on samples of the material taken during production or transfer and certifying that the cement conforms to applicable requirements of this specification.

NOTE 10—Guidance on preparing the manufacturer's report is provided in Appendix X1.

## 16. Keywords

16.1 hydraulic cement; portland cement; specification

## ANNEXES

**(Mandatory Information)**

## A1. CALCULATION OF POTENTIAL CEMENT PHASE COMPOSITION

A1.1 All values calculated as described in this annex shall be rounded according to Practice E29. When evaluating conformance to a specification, round values to the same number of places as the corresponding table entry before making comparisons. The expressing of chemical limitations by means of calculated assumed phases does not necessarily mean that the oxides are actually or entirely present as such phases.

A1.2 When expressing phases, C = CaO, S = $SiO_2$, A = $Al_2O_3$, F = $Fe_2O_3$. For example, $C_3A$ = 3CaO·$Al_2O_3$. Titanium dioxide and phosphorus pentoxide ($TiO_2$ and $P_2O_5$) shall not be included with the $Al_2O_3$ content. See Note A1.1.

NOTE A1.1—When comparing oxide analyses and calculated phases from different sources or from different historic times, be aware that they may not have been reported on exactly the same basis. Chemical data obtained by Reference and Alternate Test Methods of Test Methods C114 (wet chemistry) may include titania and phosphorus as alumina unless proper correction has been made (see Test Methods C114), while data obtained by rapid instrumental methods usually do not. This can result in small differences in the calculated phases. Such differences are usually within the precision of the analytical methods, even when the methods are properly qualified under the requirements of Test Methods C114.

A1.3 When the ratio of percentages of aluminum oxide to ferric oxide is 0.64 or more, the percentages of tricalcium silicate, dicalcium silicate, tricalcium aluminate, and tetracalcium aluminoferrite shall be calculated from the chemical analysis as follows:

$$\text{Tricalcium silicate } (C_3S) = (4.071 \times \%\ CaO) - (7.600 \times \%\ SiO_2) - (6.718 \times \%\ Al_2O_3) - (1.430 \times \%\ Fe_2O_3) - (2.852 \times \%\ SO_3) \quad (A1.1)$$

$$\text{Dicalcium silicate } (C_2S) = (2.867 \times \%\ SiO_2) - (0.7544 \times \%\ C_3S) \quad (A1.2)$$

$$\text{Tricalcium aluminate } (C_3A) = (2.650 \times \%\ Al_2O_3) - (1.692 \times \%\ Fe_2O_3) \quad (A1.3)$$

$$\text{Tetracalcium aluminoferrite } (C_4AF) = 3.043 \times \%\ Fe_2O_3 \quad (A1.4)$$

A1.3.1 When the alumina-ferric oxide ratio is less than 0.64, a calcium aluminoferrite solid solution (expressed as ss($C_4AF + C_2F$)) is formed. No tricalcium aluminate will be present in cements of this composition. Dicalcium silicate shall be calculated as in Eq A1.2. Contents of this solid solution and of tricalcium silicate shall be calculated by the following formulas:

$$ss(C_4AF + C_2F) = (2.100 \times \%\ Al_2O_3) + (1.702 \times \%\ Fe_2O_3) \quad (A1.5)$$

$$\text{Tricalcium silicate } (C_3S) = (4.071 \times \%\ CaO) - (7.600 \times \%\ SiO_2) - (4.479 \times \%\ Al_2O_3) - (2.859 \times \%\ Fe_2O_3) - (2.852 \times \%\ SO_3) \quad (A1.6)$$

A1.4 If no limestone or inorganic processing additions are used in the cement, or in the absence of information on limestone or inorganic processing additions use in the cement, phases shall be calculated using procedures in Eq A1.1-A1.6 without adjustment.

A1.5 In absence of information on limestone or inorganic processing additions content, results shall note that no adjustment has been made for possible use of limestone or inorganic processing additions.

A1.6 When inorganic processing additions or limestone or both are used with the base cement (portland cement clinker and any added calcium sulfate), the contents of $C_3S$, $C_2S$, $C_3A$, and $C_4AF$, shall be adjusted as follows:

A1.6.1 The percentage of $C_3S$, $C_2S$, $C_3A$, and $C_4AF$ in the base cement (see Note A1.2) shall be determined based on chemical analyses using methods in Test Methods C114 and using Eq A1.1-A1.6 as appropriate. The contents of each of these phases shall be adjusted to account for the use of limestone or inorganic processing additions as follows:

$$X_f = X_b \times \frac{(100 - L - P)}{100} \quad (A1.7)$$

*where:*

$X_b$ = the percentage by mass of $C_3S$, $C_2S$, $C_3A$, or $C_4AF$ in the base cement (portland cement clinker and any calcium sulfate),
$L$ = the percentage by mass of limestone,
$P$ = the percentage by mass of inorganic processing addition, and
$X_f$ = the percentage by mass of $C_3S$, $C_2S$, $C_3A$, or $C_4AF$ in the finished cement.

The adjusted values for the finished cement shall be reported on the manufacturer's report.

NOTE A1.2—Where the oxide analysis of the finished cement, the limestone, and inorganic processing addition, are known along with the mass percentage of limestone ($L$) and mass percentage of inorganic processing addition ($P$), one method of determining the base cement oxide composition is to use the following equation:

$$O_b = 100 \times (O_f - (L / 100 \times O_l) - (P / 100 \times O_p)) / (100 - L - P)$$

*where:*

$O_b$ = the base cement oxide content (% by mass of base cement),
$O_f$ = the finished cement oxide content (% by mass of finished cement),
$O_l$ = the limestone oxide content (% by mass of limestone), and
$O_p$ = the inorganic processing addition oxide content (% by mass of inorganic processing addition).

The base cement phase composition can be determined using these

values of oxide analyses in equations Eq A1.1-A1.6. Eq A1.7 is used to calculate the adjusted phase composition.

NOTE A1.3—For example:

Where the cement includes 3.5 % limestone and 3.0 % of an inorganic processing addition and the base cement has 60 % $C_3S$, 15 % $C_2S$, 7 % $C_3A$, and 10 % $C_4AF$, the adjusted phase composition is:

$$C_3S_f = \frac{60 \times (100 - 3.5 - 3.0)}{100} = 56\,\%$$

$$C_2S_f = \frac{15 \times (100 - 3.5 - 3.0)}{100} = 14\,\%$$

$$C_3A_f = \frac{7 \times (100 - 3.5 - 3.0)}{100} = 7\,\%$$

$$C_4AF_f = \frac{10 \times (100 - 3.5 - 3.0)}{100} = 9\,\%$$

A1.6.2 Only the percentages of $C_3S$, $C_2S$, $C_3A$, and $C_4AF$ shall be adjusted by the procedure in A1.6.1.

## A2. LIMESTONE CONTENT OF PORTLAND CEMENT

A2.1 When limestone is used, the limestone content in portland cement shall be derived from the determination of $CO_2$ in the finished cement. Analysis of $CO_2$ shall be based on methods described in Test Methods C114. The percent limestone in the cement is calculated from the $CO_2$ analysis based on the $CO_2$ content of the limestone used.

The manufacturer shall include the $CO_2$ content and calculated limestone content of the cement on the Mill Test Report.

The limestone content of the cement is calculated as follows:

$$\frac{\%\ CO_2 \text{ in the cement}}{\%\ CO_2 \text{ in the limestone}} \times 100 = \%\ \text{limestone in cement}$$

NOTE A2.1—*For example*:

Where the determined $CO_2$ content in the finished cement = 1.5 % and the $CO_2$ content of the limestone = 43 % ($CaCO_3$ in limestone = 98 %)

Then:

$$\frac{1.5}{43} \times 100 = 3.5\,\%\ \text{limestone content in cement}$$

A2.2 This specification requires that the limestone to be used must contain a minimum of 70 % $CaCO_3$. The manufacturer shall include the $CaCO_3$ content of the limestone on the manufacturer's report. Calculate the $CaCO_3$ content of the limestone as follows: % $CaCO_3$ = 2.274 × % $CO_2$.

NOTE A2.2—For verification of limestone content of cement, the purchaser must analyze for $CO_2$ content and make a correction for the content of $CaCO_3$ in the limestone in order for the data to be comparable to the manufacturer's report.

A2.3 Portland cements that do not contain limestone can contain baseline levels of $CO_2$ inherent in manufacture, for example, due to carbonation. This baseline $CO_2$ content is included as part of any calculated limestone content.

## APPENDIX

**(Nonmandatory Information)**

## X1. MANUFACTURER'S CERTIFICATION (MILL TEST REPORT)

X1.1 To provide uniformity for reporting the results of tests performed on cements under this specification, as required by Section 15 of Specification C150 entitled "Manufacturer's Certification," an example Mill Test Report is shown in Fig. X1.1.

X1.2 The identity information given should unambiguously identify the cement production represented by the Mill Test Report and may vary depending upon the manufacturer's designation and purchaser's requirements.

X1.3 The Manufacturer's Certification statement may vary depending upon the manufacturer's procurement order, or legal requirements, but should certify that the cement shipped is represented by the certificate and that the cement conforms to applicable requirements of the specification at the time it was tested (or retested) or shipped.

X1.4 The sample Mill Test Report has been developed to reflect the chemical and physical requirements of this specification and recommends reporting all analyses and tests normally performed on cements meeting Specification C150. Purchaser reporting requirements should govern if different from normal reporting by the manufacturer or from those recommended here.

X1.5 Cements may be shipped prior to later-age test data being available. In such cases, the test value may be left blank. Alternatively, the manufacturer can generally provide estimates based on historical production data. The report should indicate if such estimates are provided.

X1.6 In reporting limits from the tables in Specification C150 on the Mill Test Report, only those limits specifically applicable should be listed. In some cases, Specification C150 table limits are superceded by other provisions.

X1.7 When limestone or inorganic processing additions or both are used in the cement, additional data are reported by the manufacturer. An example additional data report is shown in

ABC Portland Cement Company
Qualitytown, N.J.

Plant Example | Cement Type II(MH) | Date March 9, 20xx

Production Period March 2, 20xx – March 8, 20xx

STANDARD REQUIREMENTS
ASTM C150 Tables 1 and 3

CHEMICAL

| Item | Spec. Limit | Test Result |
|---|---|---|
| $SiO_2$ (%) | [A] | 20.6 |
| $Al_2O_3$ (%) | 6.0 max | 4.4 |
| $Fe_2O_3$ (%) | 6.0 max | 3.3 |
| CaO (%) | [A] | 62.9 |
| MgO (%) | 6.0 max | 2.2 |
| $SO_3$ (%) | 3.0 max | 3.2 |
| Ignition loss (%) | 3.5 max | 2.7 |
| $Na_2O$ (%) | [A] | 0.19 |
| $K_2O$ (%) | [A] | 0.50 |
| Insoluble residue (%) | 1.5 max | 0.27 |
| $CO_2$ (%) | [A] | 1.2 |
| Limestone (%) | 5.0 max | 3.5 |
| $CaCO_3$ in limestone (%) | 70 min | 79 |
| Inorganic processing addition (ground, granulated blastfurnace slag) | 5.0 max | 3.0 |
| Potential phase composition (%)[C] | | |
| $C_3S$ | [A] | 59 |
| $C_2S$ | [A] | 10 |
| $C_3A$ | 8 max | 5 |
| $C_4AF$ | [A] | 10 |
| $C_4AF + 2(C_3A)$ | [A] | 20 |
| $C_3S + 4.75C_3A$ | 100 max | 83 |

PHYSICAL

| Item | Spec. Limit | Test Result |
|---|---|---|
| Air content of mortar (volume %) | 12 max | 8 |
| Blaine fineness ($m^2/kg$) | 260 min | 377 |
| | 430 max | |
| Autoclave expansion (%) | 0.80 max | 0.04 |
| Compressive strength (MPa) | min: | |
| 1 day | [A] | |
| 3 days | 7.0 | 23.4 |
| 7 days | 12.0 | 29.8 |
| 28 days | [A] | |
| Time of setting (minutes) (Vicat) | | |
| Initial Not less than | 45 | 124 |
| Not more than | 375 | |
| Heat of hydration (kJ/kg) (ASTM C1702) | | |
| 3 days | [B] | 245 |
| Test Method C1038 Mortar Bar Expansion (%) | [D] | 0.010[E] |

[A] Not applicable.
[B] Test result represents most recent value and is provided for information only.
[C] Adjusted per A1.6.
[D] Required only if percent $SO_3$ exceeds the limit in Table 1, in which case the Test Method C1038 expansion shall not exceed 0.020 % at 14 days.
[E] Test result for this production period not available. Most recent test result provided.

OPTIONAL REQUIREMENTS
ASTM C150 Tables 2 and 4

CHEMICAL

| Item | Spec. Limit | Test Result |
|---|---|---|
| Equivalent alkalies (%) | [F] | 0.52 |
| Chloride (%) | [F] | 0.02 |

PHYSICAL

| Item | Spec. Limit | Test Result |
|---|---|---|
| False set (%) | 50 min | 82 |
| Compressive strength (MPa) | | |
| 28 days | 28.0 min | [G] |

[F] Limit not specified by purchaser. Test result provided for information only.
[G] Test result for this production period not yet available.

We certify that the above described cement, at the time of shipment, meets the chemical and physical requirements of the ASTM C150 – XX or (other) _____ specification.

Signature: _____ Title: _____

**FIG. X1.1 Example Mill Test Report**

Fig. X1.2.

ABC Portland Cement Company
Qualitytown, N.J.

Plant: Example Cement Type II Date: March 9, 20xx

Production Period March 2, 20xx – March 8, 20xx

**Additional Data**

| | Limestone | Inorganic Processing Addition Data |
|---|---|---|
| Type | - - - | Ground, granulated blast furnace slag |
| Amount (%) | 3.5 | 3.0 |
| $SiO_2$ (%) | 12.9 | 33.1 |
| $Al_2O_3$ (%) | 3.0 | 10.9 |
| $Fe_2O_3$ (%) | 1.0 | 1.1 |
| CaO (%) | 43.5 | 44.4 |
| $SO_3$ (%) | 0.6 | 0.2 |

| Base Cement Phase Composition | |
|---|---|
| $C_3S$ (%) | 63 |
| $C_2S$ (%) | 11 |
| $C_3A$ (%) | 5 |
| $C_4AF$(%) | 11 |

We certify that the above described data represents the materials used in the cement manufactured during the production period indicated.

Signature: _____ Title: _____

**FIG. X1.2 Example Additional Data Report**

## SUMMARY OF CHANGES

Committee C01 has identified the location of selected changes to this standard since the last issue (C150/C150M – $16^{\varepsilon 1}$) that may impact the use of this standard. (Approved April 1, 2017.)

*(1)* Revised Note 3.