Designation: C150/C150M – 19a

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.

NOTE—Table 1, Table 4, and Fig. X1.1 were corrected and the yeardate changed on April 12, 2019.

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]

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

C151/C151M Test Method for Autoclave Expansion of Hydraulic Cement

C183/C183M Practice for Sampling and the Amount of Testing of Hydraulic Cement

C185 Test Method for Air Content of Hydraulic Cement Mortar

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

[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 12, 2019. Published April 2019. Originally approved in 1940. Last previous edition approved in 2019 as C150/C150M – 19. DOI: 10.1520/C0150_C0150M-19A.

[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**

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
Equivalent alkalies (Na_2O + 0.658 K_2O), % †	C114	[G]	[G]	[G]	[G]	[G]	[G]
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^H, max, %	See Annex A1	. . .	. . .	100[C,I]	. . .	. . .	. . .
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]

† Editorially corrected.

[A] See Note 2.
[B] Does not apply when the sulfate resistance limit in Table 4 is specified.
[C] Does not apply when the cement complies with the heat of hydration limit in Table 4.
[D] It is permissible to exceed the values in the table for SO_3 content, provided it has been demonstrated by Test Method C1038/C1038M 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 7.
[E] See Annex A1 for calculation.
[F] Not applicable.
[G] Report equivalent alkalies as part of the manufacturer's certification. See Note 5.
[H] See Note 6.
[I] 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

[A] These optional requirements apply only when specifically requested. Verify availability before ordering. See Note 2.
[B] See Annex A1 for calculation.

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/C1038M 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
C1778 Guide for Reducing the Risk of Deleterious Alkali-Aggregate Reaction in Concrete
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:

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/C151M	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]	8.0 [1160]	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]	14.0 [2030]	. . .	. . .	7.0 [1020]	15.0 [2180]
28 days		. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	17.0 [2470]	21.0 [3050]
Time of setting; Vicat test:[E]	C191										
Time of setting, minutes, not less than		45	45	45	45	45	45	45	45	45	45
Time of setting, minutes, 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, or the cement complies with the heat of hydration limit in Table 4.
[D] The strength at any specified test age shall be not less than that attained at any previous specified test age.
[E] 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:									
Isothermal Conduction Calorimetry:									
3 days, max, kJ/kg [cal/g]	C1702	. . .	. . .	335 [80][B]	335 [80][B] †	. . .	. . .	200 [50][C]	. . .
7 days, max, kJ/kg [cal/g]		. . .	. . .	. . .	. . .	. . .	. . .	225 [55][C]	. . .
Strength, not less than the values shown:									
Compressive strength, MPa [psi]	C109/C109M								
28 days		28.0 [4060]	22.0 [3190]	28.0 [4060]	22.0 [3190]	. . .	. . .	. . .	. . .
Sulfate resistance,[D] 14 days, max, % expansion	C452	. . .[E]	. . .[E]	. . .[E]	. . .[E]	. . .	. . .	. . .	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

† Editorially corrected.

[A] These optional requirements apply only when specifically requested. Verify availability before ordering. See Note 2.
[B] The limit for the sum of $C_3S + 4.75C_3A$ in Table 1 shall not apply when the cement complies with this limit.
[C] The limits of C_3S, C_2S, C_3A, and Fe_2O_3 in Table 1 shall not apply when the cement complies with this limit.
[D] 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.
[E] 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).

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 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 standard composition requirements in Table 1 require reporting of equivalent alkalies. Cements with a maximum of 0.60 % equivalent alkalies were historically designated as "low-alkali cements" and recommended for use with aggregates susceptible to alkali-silica reaction (ASR). However, low-alkali cements (in the absence of other mitigation measures) may not be effective in mitigating ASR. Guidance on formulating concrete mixtures, including calculating alkali loading using equivalent alkali content of cement to minimize the potential for ASR, is provided in Guide C1778.

NOTE 6—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 C1702 three-day heat of hydration limit of 315 kJ/kg [75 cal/g].

NOTE 7—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/C1038M 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/C183M.

8.2 Practice C183/C183M 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/C151M.
9.1.5 *Strength*—Test Method C109/C109M.
9.1.6 *Time of Setting by Vicat Needles*—Test Method C191.
9.1.7 *False Set*—Test Method C451.
9.1.8 *Heat of Hydration*—Test Method 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 *Calcium Sulfate (Expansion of) Mortar*—Test Method C1038/C1038M.

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,

[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.

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 8). 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 8—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 chloride content as determined using Test Methods C114, in percent by mass of the cement, in the manufacturer's report (see Note 9).

NOTE 9—Chlorides in concrete come from multiple ingredients and cement chloride content may be required to estimate concrete chloride content. Requirements for concrete chloride content are provided in building codes and other documents.

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 10—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 11—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, $C_3A = 3CaO{\cdot}Al_2O_3$. 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: $\%\ CaCO_3 = 2.274 \times \%\ CO_2$.

NOTE A2.2—For verification of limestone content of cement, the purchaser must analyze for CO_2 content and make a correction for the