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.

Designation: C1600/C1600M – 23

Standard Specification for Rapid Hardening Hydraulic Cement[1]

This standard is issued under the fixed designation C1600/C1600M; 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 is for rapid hardening hydraulic cements. 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 very early compressive strength development.

1.3 The values stated in either SI units or inch-pound units shall be regarded separately as standard. The values stated in each system are not exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.* (**Warning—**Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.[2])

1.6 *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:*[3]

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

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

C219 Terminology Relating to Hydraulic and Other Inorganic Cements

C441/C441M Test Method for Effectiveness of Pozzolans or Ground Blast-Furnace Slag in Preventing Excessive Expansion of Concrete Due to the Alkali-Silica Reaction

C596 Test Method for Drying Shrinkage of Mortar Containing Hydraulic Cement

C1012/C1012M Test Method for Length Change of Hydraulic-Cement Mortars Exposed to a Sulfate Solution

C1038/C1038M Test Method for Expansion of Hydraulic Cement Mortar Bars Stored in Water

C1107/C1107M Specification for Packaged Dry, Hydraulic-Cement Grout (Nonshrink)

C1437 Test Method for Flow of Hydraulic Cement Mortar

2.2 *Other Standards*

EN 14647 Calcium Aluminate Cement - Composition, specifications and conformity criteria

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms used in this specification, see Terminology C219.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *Rapid Hardening Hydraulic Cement, n*—a hydraulic or blended hydraulic cement which exhibits rapid strength gain

[1] This specification is under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.13 on Special Cements.

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[2] See the section on Safety, Manual of Cement Testing, *Annual Book of ASTM Standards*, Vol 04.01.

[3] 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**

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during the first 24 h of hydration, with or without other constituents, processing additions, and functional additions.

4. Nomenclature, Classifications and Use

4.1 Cements conforming to this specification shall be designated "Rapid Hardening Hydraulic Cement" by the producer with the high early strength gain characteristic indicated by type in accordance with the types described in 4.2.

4.2 The specification is for five types of rapid hardening cement as follows:

4.2.1 *Type URH*—Ultra Rapid Hardening For use where *ultra high* early strength is desired (see Table 1).

4.2.2 *Type VRH*—Very Rapid Hardening For use where *very high* early strength is desired (see Table 1).

4.2.3 *Type MRH*—Medium Rapid Hardening for use where *mid-range* rapid hardening high early strength is desired (see Table 1).

4.2.4 *Type GRH*—General Rapid Hardening for use when the higher strength properties of a Type VRH or a Type MRH cement is not required (see Table 1).

4.2.5 *Type RH-CAC*—Rapid hardening cement which requires accelerated conversion testing (see Table 1).

5. Ordering Information

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

5.1.1 This specification designation and date.

5.1.2 The quantity of cement desired.

5.1.3 The type of cement desired.

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

6. Chemical Composition

6.1 The chemical composition for the cement is not specified. However, the purchaser shall have the option to request the cement composition from the producer. If analyzed, the procedure used shall be Test Methods C114.

7. Physical Properties

7.1 Cement of the type specified shall conform to all of the applicable standard physical requirements in Table 1.

7.2 The water/cement ratio used to determine strength requirement compliance shall be reported in the manufacturer's certification.

7.3 The density for the cement is not specified. However, the density shall be determined by the manufacturer and reported in the manufacturer's certification.

8. Sampling

8.1 When the purchaser desires that the cement be sampled and tested to verify compliance with this specification, the finished cement shall be sampled in accordance with Practice C183/C183M at the mill or at the job site in accordance with the purchaser's requirements (see Note 1).

NOTE 1—Practice C183/C183M is not designed for manufacturing quality control and is not required for manufacturer's certification.

9. Test Methods

9.1 When testing cement for compliance with this specification, use the following methods, with modifications or exceptions as indicated:

9.1.1 *Autoclave Expansion*—Determine autoclave expansion by Test Method C151/C151M as specified in Table 1.

9.1.2 *Time of Setting*—Determine the time of setting using Test Method C191 as specified in Table 1. Immediately after molding the test specimen in the conical ring, determine the penetration of the needle at this time and every 3 min. until the needle no longer penetrates to the bottom of the specimen, then every 1 min. until final set is determined.

9.1.3 *Compressive Strength*—Determine compressive strength using Test Method C109/C109M as modified herein. Tests shall be run at each age specified in Table 1. The mixing water requirement in Test Method C109/C109M shall be adjusted to produce a flow of 110 ± 5 as determined using Test Method C1437.

TABLE 1 Standard Physical Requirements
(must be reported on manufacturer's certification)

	Cement Type				
	URH	VRH	MRH	GRH	RH-CAC
Minimum Compressive Strength (see Section 9 for procedures), min, MPa [psi]					
1½ h	21 [3000]	12 [1700]	. . .	. . .	6 [800]
3 h	28 [4100]	15 [2200]	10 [1500]	7 [1000]	20 [2900]
6 h	. . .	. . .	14 [2000]	10 [1500]	28 [4100]
1 day	35 [5100]	24 [3500]	17 [2500]	14 [2000]	34 [4900]
7 days	41 [6000]	28 [4100]	28 [4100]	24 [3500]	. . .
28 days	57 [8300]	35 [5100]	31 [4500]	28 [4100]	. . .
Converted	n/a[B]	n/a[B]	n/a[B]	n/a[B]	34 [4900]
Maximum Drying Shrinkage, %					
7 days	0.06	0.06	0.08	0.10	0.10
28 days, air storage	0.07	0.07	0.09	0.12	0.12
Minimum Time of Final Set C191 Apparatus					
Minutes[A]	10	10	10	10	10
Maximum Autoclave, expansion %	0.8	0.8	0.8	0.8	0.8

[A] The initial setting time typically ranges from 10 to 45 min for rapid hardening cements of various types and composition.
[B] Requirement is not applicable to this cement type.

9.1.3.1 *Converted Strength*—For Type RH-CAC only, determine converted strength using the water bath curing procedure in EN 14647 Annex A.7: "Rapid test to estimate the minimum long term strength of calcium aluminate concretes". This curing method is used to produce a converted strength on Test Method C109/C109M cubes to be tested as described in 9.1.3. Cube molds with a cover plate as described in Specification C1107/C1107M are required for the immediate immersion in the 38°C water bath.

NOTE 2—Conversion is described in further detail in the Appendix.

9.1.4 *Drying Shrinkage of Mortar*—Determine drying shrinkage of mortar as specified in Table 1 using Test Method C596.

9.1.5 *Sulfate Resistance*—Determine sulfate resistance using Test Method C1012/C1012M (see Table 2).

9.1.6 *Alkali Silica Reactivity*—Determine reactivity of cement with alkali-reactive aggregate using Test Method C441/C441M (see Table 2).

9.1.7 *Expansion in Water*—Determine expansion of hydraulic cement mortar bars stored in water by Test Method C1038/C1038M (see Table 2).

10. Testing Time

10.1 The age of the specimens is to be determined from the time when the cement contacts the mixing water.

10.2 Specimens to be tested at 1½, 3, and 6 h shall be removed from the molds a maximum of 10 min. prior to time of test. After the specimens are removed from the molds, keep them covered with a damp towel until time to be tested. The cubes must be tested within 10 min. of the time specified.

10.3 All other specimens shall be removed from the molds at 22 h, ± 2 h. If the specimens are removed from the molds before 24 h, keep them on the shelves of the moist closet or moist room until they are 24 h old, and then immerse the specimens except for the 24-h test, in saturated limewater for storage.

10.4 The 24-h, 7-d, and 28-d test specimens shall be broken within the permissible time tolerances prescribed in Test Method C109/C109M.

10.5 Record and calculate the compressive strength in accordance with the Calculation Section of Test Method C109/C109M.

10.6 Apply the sampling and testing requirements of Practice C183/C183M.

10.7 For testing of samples taken subsequent to shipment, 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.

10.8 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.

10.9 A written report of results of applicable tests shall be available within not more than three days after the interval specified in 10.8.

10.10 These time limits do not apply to retesting or additional testing (see Note 3).

NOTE 3—Aging effects on small samples or quantities 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.

11. Testing by the Manufacturer

11.1 Secure representative samples of cement during production or transfer and test them for compliance with this specification. 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.

12. Inspection

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

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

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TABLE 2 Optional Requirements

	Cement Type				
	URH	VRH	MRH	GRH	RH-CAC
Sulfate expansion[A] (C1012/C1012M)					
6 months, max %	0.05	0.05	0.05	0.05	0.05
1 year, max %	0.10	0.10	0.10	0.10	0.10
ASR Expansion[B] (C441/C441M)					
14 days, max %	0.020	0.020	0.020	0.020	0.020
56 days, max %	0.060	0.060	0.060	0.060	0.060
Expansion in Water (C1038/C1038M)					
14 days, max %	0.10	0.10	0.10	0.10	0.10

[A] In the testing of these cements, testing at one year shall not be required when the cement meets the 6-month limit. Cement failing the 6-month limit shall not be rejected unless it also fails the one-year limit.

[B] The test for mortar expansion is an optional requirement to be applied only at the purchaser's request and is not required unless the cement will be used with alkali-reactive aggregate.

13. Certification

13.1 When specified in the purchase order or contract, furnish the manufacturer's certification at the time of shipment stating the type of cement as defined in 4.2, the results of tests made on cement sampled during production or transfer and certifying that the applicable requirements of this specification have been met.

14. Package Marking

14.1 When the cement is delivered in packages, the words "Rapid Hardening Hydraulic Cement," the type of cement, the specification designation, the name and brand of manufacturer and the mass of cement contained therein shall be plainly marked on each package. Similar information shall be provided in the manufacturer's certification accompanying the shipment of packaged or bulk cement.

15. Storage

15.1 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.

16. Keywords

16.1 blended hydraulic cement; high early strength; hydraulic cement; rapid hardening hydraulic cements

APPENDIX

(Nonmandatory Information)

As is explained in EN 14647 and other publically available references, conversion is a well-known characteristic of calcium aluminate cement where the initially formed metastable (temporary) hydrates (CAH_{10} and C_2AH_8) convert to the stable (permanent) hydrates (C_3AH_6 and AH_3). The metastable hydrates are space filling and lead to a rapid increase in strength. However, the eventual transition to the denser stable phase results in an increased porosity in the system. This increased porosity leads to a reduction in strength. Therefore, systems that are susceptible to conversion should be tested appropriately to ensure that the long-term strength of the stable hydrate system meets the design requirements. Fig. X1.1 below shows a schematic of converted and unconverted strengths across a range of w/c for concretes produced with calcium aluminate cements in different laboratories. (Source EN 14647.)

Rapid hardening cements made by blending CAC with calcium sulfate and/or cements containing portland cement clinker do not produce the metastable hydrates and therefore should not be declared as Type RH-CAC nor should the accelerated conversion test be run. These so called binary or ternary systems produce ettringite as the primary hydrate much like many of the other types of rapid hardening cements covered by this specification.

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