Designation: C 688 – ~~96~~00

Standard Specification for Functional Additions for Use in Hydraulic Cements[1]

This standard is issued under the fixed designation C 688; 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 methods to investigate the effectiveness of a material to beneficially change the properties of hydraulic cements when the material is interground with the clinker during manufacture of the cement.

1.2 The values stated in SI units are to be regarded as the standard.

1.3 The effect of additions in cement may markedly change properties other than those they are intended to modify. This specification is designed to test for such changes. Table 1 sets forth values for those properties of cement pastes and mortars that would permit a judgment of the changes effected by an addition. Likewise, Table 2 sets forth similar criteria for concrete. Certain additions may be found effective for more than one purpose as indicated in 3.1.4 and 3.1.5.

2. Referenced Documents

2.1 *ASTM Standards:*

[1] This specification is under the jurisdiction of ASTM Committee ~~C-1~~ C01 on Cement and is the direct responsibility of Subcommittee C01.20 on Additions.
Current edition approved ~~May~~ June 10, ~~1996.~~ 2000. Published ~~July 1996.~~ September 2000. Originally published as C 688 – 71 T. Last previous edition C 688 – 9~~5~~6.

TABLE 1 Criteria for Evaluating Neat Cement and Mortar Containing Functional Cement Additions

Tests	Type of Addition					
	Water Reducing	Retarding	Accelerating	Water-Reducing and Retarding	Water-Reducing and Accelerating	Set-Control
Normal consistency, deviation from control, percentage points[A]	−1.0 min	+1.0 max	+1.0 max	−1.0 min	−1.0 mm	±1.0 max
Standard consistency (flow) deviation from control, percentage points[A]	−4.0 min	+2.0 max	+2.0 max	−4.0 min	−4.0 min	±2.0 max
Setting time, (Gillmore) deviation from control, h:min						
Initial						
At least	...	1:00 later[B]		1:00 later[B]		...
Not more than	1:00 earlier nor 1:30 later	3:30 later	1:30 earlier nor 1:30 later	3:30 later	1:30 earlier nor 1:30 later	1:00 earlier nor 1:30 later
Setting time, Vicat Initial[C]				Final		
At least	...	0:50 later[B]	...			...
Not more than	0:50 earlier 1:15 later	2:50 later	1:15 earlier 1:00 earlier 1:15 later	0:50 later[B] 2:50 later	1:15 earlier nor 1:15 later	0:50 earlier nor 1:15 later
Final						
Not more than	1:00 earlier nor 1:30 later	3:30 later	1:00 earlier nor 1:30 later	3:30 later	1:00 earlier nor 1:30 later	1:00 earlier nor 1:30 later
Compressive strength, min, percent of control:[C]						
Compressive strength, min, percent of control:[D]						
1 day in moist air	110	90	125[D]	90	125	[E]
1 day in moist air	110	90	125[E]	90	125	[F]
1 day in moist air, 2 days in water	110	90	125[D]	100	125	
1 day in moist air, 2 days in water	110	90	125[E]	100	125	
1 day in moist air, 6 days in water	110	90	100	110	110	
1 day in moist air, 27 days in water	110	95	95	110	110	
Autoclave Expansion						
max increase in % change in length compared to control	0.10	0.10	0.10	0.10	0.10	0.10
Drying Shrinkage of Mortar						
max % change in length compared to control	0.020	0.020	0.030	0.020	0.020	0.020

[A] The minus sign indicates that the percentage of water required shall be less than that of the control cement by at least the indicated percentage points.
[B] Or 50 % later, whichever is the lesser.
[C] The compressive strength of the mortar containing the addition shall not decrease with age.
[D] The grand average of the 1, 3, 7, and 28-day strengths shall be not less than 95 % of the grand average for the corresponding control cement.
[E] In cases where the accelerated set time only is required, the strength can be reduced to 100 % of the control.
[F] In cases where the accelerated set time only is required, the strength can be reduced to 100 % of the control.

C 39 Test Method for Compressive Strength of Cylindrical Concrete Specimens[2]
C 78 Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)[2]
C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or 50-mm Cube Specimens)[3]
C 143 Test Method for Slump of Hydraulic Cement Concrete[2]
C 150 Specification for Portland Cement[3]
C 151 Test Method for Autoclave Expansion of Portland Cement[3]
C 157 Test Method for Length Change of Hardened Hydraulic Cement Mortar and Concrete[2]
C 187 Test Method for Normal Consistency of Hydraulic Cement[3]
C 191 Test Method for Time of Setting of Hydraulic Cement by Vicat Needle[3]
C 219 Terminology Relating to Hydraulic Cement[3]
C 226 Specification for Air-Entraining Additions for Use in the Manufacture of Air-Entraining Portland Cement[3]
C 232 Test Method for Bleeding of Concrete[2]
C 234 Test Method for Comparing Concretes on the Basis of the Bond Developed with Reinforcing Steel[2]
C 266 Test Method for Time of Setting of HydraulicCement Paste by Gillmore Needles[3]
C 403 Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance[2]
C 451 Test Method for Early Stiffening of Portland Cement (Paste Method)[3]
C 465 Specification for Processing Additions for Use in the Manufacture of Hydraulic Cements[3]
C 595M Specification for Blended Hydraulic Cements[3]

[2] *Annual Book of ASTM Standards*, Vol 04.02.
[3] *Annual Book of ASTM Standards*, Vol 04.01.

TABLE 2 Criteria for Evaluating Concrete Containing Functional Cement Additions[A]

Tests	Type of Addition				
	Water Reducing	Retarding	Accelerating	Water-Reducing and Retarding	Water-Reducing and Accelerating
Water content, max, percent of control	95	...	...	95	95
Time of setting, (penetration) deviation from control, h:min:					
Initial					
At least	...	1:00 later[B]		1:00 later[B]	
Not more than	1:00 earlier nor	3:30 later	3:30 earlier	3:30 later	3:30 earlier
Final	1:00 later				
Not more than	1:00 earlier nor 1:30 later	3:30 later	...	3:30 later	...
Compressive strength, min, percent of control:[C]					
1 day[D]	110	85	125[E]	100	125
3 days	110	85	125[E]	100	125
7 days	110	90	100	110	110
28 days	110	90	95	110	110
3 months	100	90	95	100	100
1 year	100	90	95	100	100
Flexural strength, min, percent of control:[C]					
1 day[D]	100	85	110	90	110
3 days	100	85	110	100	110
7 days	100	90	100	100	100
28 days	100	90	90	100	100
3 months	100	90	90	100	100
1 year	100	90	90	100	100
Bond strength, percent of control:					
28 days	100	90	100	100	100
Volume change, expressed as change in length, max, increase over control, percentage points:					
28 days	0.010	0.010	0.030	0.010	0.010
3 months	0.010	0.010	0.030	0.010	0.010
1 year	0.010	0.010	0.030	0.010	0.010
Durability factor, min, percent of control[F]	80	80	80	80	80

[A] The values in the table are intended to allow for normal variation in test results. For example, the object of the 90 % compressive strength requirement for a retarding addition is to require a level of performance comparable to that of the reference concrete.

[B] Or 50 % later, whichever is the lesser.

[C] The compressive and flexural strength of the concrete containing the addition under test at any test age shall be not less than 90 % of that attained at any previous test age. The objective of this limit is to require that the compressive or flexural strength of the concrete containing the addition under test shall not decrease with age.

[D] One-day strengths applicable only to Type III cement. One-year strength tests shall be made; however, the addition may be approved after completion of the 3-month strength results, at the discretion of the purchaser.

[E] In cases where the accelerated set time only is required, the strength can be reduced to 100 % of the control.

[F] This requirement is applicable only when the addition is to be used in air-entrained concrete.

C 596 Test Method for Drying Shrinkage of Mortar Containing Portland Cement[3]
C 666 Test Method for Resistance of Concrete to Rapid Freezing and Thawing[2]
C 845 Specification for Expansive Hydraulic Cement[3]
C 1157M Performance Specification for Blended Hydraulic Cement[3]

3. Terminology

3.1 *Definitions:*

3.1.1 *accelerating addition*—a functional addition that accelerates the setting or early strength, or both, of concrete and mortar.

3.1.2 *retarding addition*—a functional addition that retards the setting of concrete and mortar.

3.1.3 *set-control addition*—a functional addition composed essentially of calcium sulfate in any hydration state from $CaSO_4$ to $CaSO_4 \cdot 2H_2O$.

3.1.4 *water-reducing addition*—a functional addition used to reduce the quantity of mixing water required to produce concrete and mortar of a given consistency.

3.1.5 *water-reducing and accelerating addition*—a functional addition that reduces the quantity of mixing water required to produce concrete of a given consistency and that accelerates the setting or early strength development, or both, of concrete and mortar.

3.1.6 *water-reducing and retarding addition*—a functional addition that reduces the quantity of mixing water required to produce concrete and mortar of a given consistency and simultaneously retards the setting of concrete and mortar.

NOTE 1—This section is intended to provide a specification that may be applied to calcium sulfates as defined in Terminology C 219.

NOTE 2—It should be realized that some calcium sulfates, particularly some byproduct calcium sulfates, have produced cements with undesired set behavior after storage.

4. Ordering Information

4.1 The purchaser shall specify the type of functional addition desired.

5. Materials

5.1 *Cements*—The cements used in the evaluation of the addition shall be as described in Section 4.1 of Specification C 465 with the following exceptions:

5.1.1 At least one of the Type I cements shall contain not less than 9 percent tricalcium aluminate (C_3A).

5.1.2 Disregard the last sentence of Section 4.1.5 of Specification C 465 and substitute the following:" Each control cement shall comply with all the requirements in the specification (C 150, C 595, C 845, and C 1157M) applicable to that type of cement. The method shall be adequate for the qualitative and quantitative determination of the addition in the finished cement, and shall be fully described in the report of the tests on the addition."

5.2 *Aggregates*—The aggregates used in the evaluation of the addition shall be in accordance with the Aggregates portion of the Materials section of Specification C 465, using proportions specified in Concrete Mixtures section of that specification.

6. General Requirements

6.1 The cement, mortar, and concrete in which each of the additions is used shall conform to the respective requirements prescribed in Table 1 and Table 2, except that if the test cement fails to meet the requirements of Table 1, but possesses all the requirements listed in Table 2, then the requirements of Table 2 shall govern approval of the addition.

6.2 The trade name, source, and character of the material shall be specified and the means for the quantitative determination of the proposed addition in the finished cement, shall be furnished by the manufacturer or seller of the addition, and the results of such pertinent quantitative analysis shall form a part of the record of tests of the addition.

6.3 At the request of the purchaser of an addition for a specific functional purpose, the manufacturer shall state in writing the content of any substance which is known to or believed to impair other desirable properties of the cement or concrete.

6.4 The additions shall be evaluated by comparing cements containing the "test addition" to cements ground from similar clinkers from the same source. Those cements without test additions are referred to in this specification as "control cements."

6.4.1 *Special Provisions for Set-Control Additions Conforming to* 3.1.3:

6.4.1.1 The additions shall be evaluated by comparing cements containing the "test addition" to control cements ground from similar clinkers from the same source and under the same grinding conditions with the mill temperatures being within ±3°C (5°F) of the same value. The control cements shall be produced with calcium sulfate at any hydration state having a past record of satisfactory usage as an addition for portland cement.

6.4.1.2 Each test cement shall contain sufficient test addition $CaSO_4$ to produce a sulfur trioxide (SO_3) content that differs by no more than 0.24 percentage points from that of the control cement. The SO_3 shall be expressed as a percentage of the mass of the cement and reported to the nearest 0.01 %.

6.4.1.3 The test cements containing the additions shall conform to the requirements of 8.1 and Table 1. The cements need not be tested in concrete according to the requirements of 8.2 and Table 2.

6.5 The amount of addition to be interground with the cement for evaluation purposes shall be such as to produce the desired effects as listed in Table 1. When these tests show compliance with the requirements of this specification, the addition shall be used only in amounts up to the maximum amount tested in any one of the five cements used in the evaluation. For a cement requiring more than the established amount, a separate compliance test on this one cement can be made which will then establish the new maximum amount which can be used.

6.6 The cement produced with the functional additions shown in Section 3 shall comply with the specification for the respective cement and the ordinarily determined properties of cement paste, mortar, or concrete made with the cement containing the test addition shall not differ from these same properties of the cement paste, mortar, or concrete made with the control cement as indicated by the standard tests, except as provided in Table 1 and Table 2.

6.7 Generally, the addition rates required for functional purposes are several times greater than those needed for processing purposes and the resultant increase in flowability, or lubricity, from these increased addition rates may cause sufficient reduction in mill retention time to affect significantly the particle size distribution of the treated cement. The test addition may, in instances where the full-scale tests have shown reduced mill retention time to be significant, be determined for acceptance purposes by making supplementary laboratory or pilot batch mill grinds.

6.8 Furthermore, the effect of the addition on the properties of the cement, mortar, or concrete shall be within the limits of Section 8 and Table 1 and Table 2. In the event tests are conducted by making laboratory or pilot batch mill tests, this fact shall be entered in the report as specified in Section 9, and the specific tests shall be indicated.

6.9 After it has been documented once by the test results that a specific trade name and source of an addition have met the requirements of this specification, further tests shall be waived for subsequent shipments of the same product. Each shipment, however, shall be identified as to trade name, source, and date of shipment, and shall be essentially identical to nature and composition to that same trade name product which initially met the requirements of this specification.

7. Sampling

7.1 Sample the cements in accordance with the Sampling Cement section of Specification C 465. The quantity of sample shall be sufficient to make all the evaluation tests prescribed by this method. (A minimum of 300 kg (650 lb) per lot of cement is usually satisfactory.)

8. Test Methods

8.1 *Cements and Mortars*—Test the cements and mortars in accordance with the following ASTM test methods (see Table 1):

8.1.1 *Autoclave Expansion*—Test Method C 151.

8.1.2 *Drying Shrinkage of Mortar*—The length change of air-stored mortar bars made with the test cement shall not be more than 0.020 percentage points greater than that of similar mortar bars made with the control cement cured and tested according to Test Method C 596, except that for accelerators, an increased shrinkage of 0.03 percentage points will be allowed.

8.1.3 *Normal Consistency*—Test Method C 187.

8.1.4 *Standard Consistency (Flow)*—Test Method C 109.

8.1.5 *Setting Time*—Test Method C 266.

8.1.5.1 For set-control additions conforming to 3.1.3 repeat the setting time tests 3 months after grinding. Keep cement samples for these tests in sealed metal containers with minimum air contact.

8.1.6 *Compressive Strength*—For functional additions having no water-reducing effects, use Test Method C 109. For functional additions having some water-reducing effects, use Test Method C 109 except that mortars for both the test and the control specimens shall be made to a flow of 110 ± 5. In either case, there shall be six specimens for each condition of test.

8.1.6.1 It is required that cubes for companion cements be made and tested on the same days with storage of specimens side by side in the same section of the moist cabinet during the 24-h curing period. However, in water storage, store control and test specimens in separate tanks. If less than four specimens are left for each period, after discarding faulty cubes, make a retest.

NOTE 3—It is suggested that three batches of nine cubes each be made for each cement, then six cubes be picked at random for each age of test and the three excess cubes held to replace any faulty cubes found.

8.1.7 *False Set*—For set-control additions conforming to 3.61.3, perform false set tests initially and 3 months after grinding in accordance with Test Method C 451. The final penetration in percent shall be no less than 75 % as great as that with the control cement.

8.2 *Concretes*—Test the plastic and hardened concretes in accordance with the following ASTM methods (see Table 2):

8.2.1 *Consistency*—The consistency (slump) of the concrete produced with the test cement shall not differ from that of the control concrete by more than ±13 mm (±½ in.), when tested in accordance with Test Method C 143, and each shall have a slump of 64 ± 13 mm (2½ ± ½ in.).

8.2.2 *Water Content*—The maximum water content of the test concrete shall be as shown in Table 2 when compared with the control concrete of similar consistency tested as in 8.2.1.

8.2.3 *Time of Setting*—Test Method C 403.

8.2.4 *Compressive Strength*—Test Method C 39.

8.2.5 *Flexural Strength*—Test Method C 78.

8.2.6 *Bond to Steel*—Test Method C 234.

8.2.7 *Volume Change*—Test Method C 157.

8.2.8 *Resistance to Freezing and Thawing (Durability Factor)*—Test Method C 666. The air content of both the control and test concrete shall be 6 ± 0.5 % obtained by admixing appropriate quantities of any of the reference air entraining agents listed in the General Requirements of Specification C 226.

8.2.9 *Bleeding*—At the request of the purchaser, test the bleeding characteristics in accordance with Test Method C 232.

9. Report

9.1 The report shall conform to the Report section of Specification C 465, except that comparison of test results shall be made to the requirements prescribed in this specification instead of to the requirements of Specification C 465.

10. Keywords

10.1 additions; functional; hydraulic cement