Designation: C917/C917M – 18

Standard Test Method for Evaluation of Variability of Cement from a Single Source Based on Strength[1]

This standard is issued under the fixed designation C917/C917M; 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 test method covers a procedure for determining the variability of a hydraulic cement produced at a single source using strength tests as the characteristic property. It is intended that this test method normally be used for the predominant cement manufactured at a cement plant. Guidelines for sampling, testing, presentation of results, and evaluation are given.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as the 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. One system of units is used in the Figure and Tables in this standard to illustrate the calculation methods that are applicable independent of the system of units.

1.3 *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.*

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]

C109/C109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)

C150 Specification for Portland Cement

C219 Terminology Relating to Hydraulic Cement

C595 Specification for Blended Hydraulic Cements

C1157 Performance Specification for Hydraulic Cement

C1451 Practice for Determining Variability of Ingredients of Concrete From a Single Source

E456 Terminology Relating to Quality and Statistics

3. Terminology

3.1 *Definitions*—For definitions of terms relating to this test method, refer to Practice C1451 and Terminologies C219 and E456.

4. Significance and Use

4.1 This test method is designed to present in a standardized format information on the variability of strength of cement from a single source over a period of time. It can be applied to all hydraulic cements covered in Specifications C150, C595, and C1157. The results derived from this test method are intended for information only and are not requirements of any existing ASTM specification. A specification may refer to this test method to obtain information on the variability of cement from a single source.

4.2 The procedure is based on obtaining samples from locations during the delivery of cement to the user and is more representative of the variability of cement used in concrete production than test data reported on mill test reports. Variation determined from the test results is corrected for testing error, therefore giving the user one indicator of the source variation of the cement.

NOTE 1—It should be recognized that concrete strength variability is influenced by other factors in addition to cement strength variability.

4.3 This test method does not provide information on the relationship between the variability of cement and the variability of concrete properties. The user can, along with supplementary information or correlative testing of concrete properties, develop quantitative estimates of the effects.

5. Sampling

5.1 Establish a sampling plan that includes the lot size, sampling frequency, location and procedure of sampling, and

[1] This test method is under the jurisdiction of ASTM Committee C01 on Cement and is the direct responsibility of Subcommittee C01.27 on Strength.

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[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.

handling and retention of samples. Sampling shall be performed by personnel specifically trained for this purpose.

5.2 Take random grab samples from delivery units or during the loading or unloading process. Delivery units larger than 115 Mg [125 tons] shall be sampled during loading or unloading. If samples are taken during loading or unloading, the two or more portions that are to be composited to make a sample shall be taken during the transfer to no more than 115 Mg [125 tons] of cement. Identify samples by the date on which the cement they represent was shipped or received.

NOTE 2—Standard statistical procedures are recommended for ensuring that samples are selected by a random procedure. These procedures can be used to select the days within a month or within a week that samples will be taken. Then the delivery unit or the time of day can be chosen randomly.

5.3 If taken from a truck or rail car, take at least two separate grab samples of approximately equal size and thoroughly mix together to obtain a minimum 5-kg [10-lb] test sample. Sample only through hatches in the top of the unit. Remove approximately a 300-mm [12-in.] layer of cement. Make a hole before obtaining a sample to avoid collecting dust collector material that may be discharged into the delivery unit after the cement flow ceases.

5.4 If taken from another point in the loading or unloading process, a minimum 5-kg [10-lb] sample shall be obtained as two separate grab samples of approximately equal size and thoroughly mixed together or as accumulated by a continuous sampler. Take care to avoid segregation and contamination of samples taken from screws, pneumatic systems, or air slides.

5.5 When samples are taken at the cement plant and shipments or rate of production of the cement exceeds 23 000 Mg [25 000 tons] per month, take samples at a rate of at least ten per month and at least two per week. When shipment or rate of production of the cement is less than 23 000 Mg [25 000 tons] per month, take samples at a rate of at least one per 2300 Mg [2500 tons]. When samples are taken at the cement plant, in no instance shall samples be taken more frequently than one per 180 Mg [200 tons] of cement shipped or received, except that sampling of consecutive shipments is permitted when they result from randomization.

6. Procedure

6.1 *Total Variation*—Test all samples for 7- and 28-day compressive strength in accordance with Test Method C109/C109M using three specimens for each test age. To be comparable, all tests used in a single evaluation must be made in a single laboratory and preferably by the same laboratory operator. Calculate the total variation among the samples as directed in 7.1.3. When duplicate tests are made on a sample in accordance with 6.2, include only the first test result to calculate the total variation. The total variation includes the component of testing error.

NOTE 3—When separate evaluations of a single source are made by two or more laboratories, additional tests of a standard cement or exchange of portions of the same sample of cement may be necessary to determine differences in testing that are likely to be obtained in the different laboratories. Five or more batches may be necessary to obtain a valid comparison between laboratories. Statistical techniques must be used to assess the validity of differences that might be obtained. Participation in the Cement Proficiency Sample Program of the CCRL by both laboratories will be helpful in resolving differences that are found.

6.1.1 When two laboratories exchange portions of the same sample and prepare single batches, results from the two laboratories shall not differ by more than 18.7 % of the average of the two laboratories (see Test Method C109/C109M multilaboratory d2s). If a larger number of samples are exchanged the difference in average strength shall not exceed $18.7/\sqrt{n}$ % of the overall average strength, where n is the number of samples exchanged and tested by each laboratory. A more precise calculation is outlined in Appendix X1.

6.2 *Testing Error*—Mix duplicate batches of mortar from the same sample to estimate the within-laboratory testing error. Make duplicate batches on a day different from the original batch of mortar.

6.2.1 When a testing program is started on shipments from a single source, make duplicate batches of mortar from every third cement sample. When duplicate tests have been made from a minimum of five cement samples, calculate the within-laboratory testing error according to 7.1.4. Increase the number of duplicate batches used in the calculation until the results of ten cement samples are used in the calculation. After that time,

TABLE 1 Example Illustrating Calculation of Testing Error[A]

Date	Sample Number	7-day Strength, MPa			d^2	k	S_e, MPa[B]	$\bar{X}_d$, MPa	V_e, %[C]
		Test A	Test B	Average					
01/06	3	33.7	34.2	34.0	0.25				
01/16	6	31.5	32.2	31.9	0.49				
01/30	9	32.0	33.4	32.7	1.96				
02/05	12	30.3	31.1	30.7	0.64				
02/13	15	30.2	29.6	29.9	0.36	5	0.61	32.1	1.91 %
02/21	18	32.4	32.8	32.6	0.16	6	0.57	32.2	1.78 %
03/04	21	30.8	31.7	31.3	0.81	7	0.58	32.1	1.81 %
03/14	24	27.7	27.3	27.5	0.16	8	0.55	31.5	1.76 %
03/19	27	34.2	33.2	33.7	1.00	9	0.57	31.7	1.80 %
03/27	30	31.3	31.2	31.3	0.01	10	0.54	31.7	1.71 %
04/30	40	32.7	33.9	33.3	1.44	10	0.59	31.6	1.88 %
05/31	50	34.6	33.2	33.9	1.96	10	0.65	31.7	2.06 %
06/29	60	33.3	32.5	32.9	0.64	10	0.60	31.7	1.89 %

[A] This example is in SI units. The same concept applies in inch-pound units. The same calculations should be performed for 28-day strength.
[B] Determined in accordance with 7.1.4.1.
[C] Determined in accordance with 7.1.4.2.

use only the ten most recent results of duplicate testing in the calculation of the testing error. See Table 1.

6.2.2 When at least ten sets of duplicate batches have been made and the coefficient of variation for testing error is less than 4.0 %, the frequency of testing duplicate batches can be reduced to one in ten consecutive cement samples. Resume a frequency of testing one in three samples if the coefficient of variation for testing error exceeds 4.0 %. If the coefficient of variation for testing error exceeds 5.5 %, the data are of questionable precision, and laboratory procedures and equipment should be thoroughly examined.

6.2.3 Use the results of duplicate tests indicating acceptable precision to estimate the within-laboratory testing error for all other types of cement tested in that laboratory during the same period of time, provided that duplicate tests have been made on at least one sample per month.

7. Calculation

7.1 The calculations shall include the following:

7.1.1 *Average Strength*—Calculate the average strength of all test results during the reporting period. Use only the first test result from each sample that was tested in duplicate.

$$\bar{X} = \frac{X_1 + X_2 + \ldots + X_n}{n} \quad (1)$$

where:

$\bar{X}$ = average strength, MPa [psi],
$X_1, X_2, \ldots, X_n$ = individual strength test results, each of which the average of cubes in accordance with Test Method C109/C109M, and
n = number of individual samples.

7.1.2 *Moving Average*—After five test results are obtained, calculate the moving average of strength of the five most recent results.

$$\bar{X}_5 = \frac{X_{i-4} + X_{i-3} + X_{i-2} + X_{i-1} + X_i}{5} \quad (2)$$

where:

$\bar{X}_5$ = Moving average of five consecutive strength results, MPa [psi], and
X_i = The most recent of five consecutive strength results, MPa [psi].

7.1.3 *Total Standard Deviation:*

$$S_t = \sqrt{\frac{(X_1 - \bar{X})^2 + (X_2 - \bar{X})^2 + \ldots + (X_n - \bar{X})^2}{(n - 1)}} \quad (3)$$

where:

S_t = total standard deviation, MPa [psi].

7.1.4 *Testing Error:*

7.1.4.1 Calculate the standard deviation for testing error as follows:

$$S_e = \sqrt{\frac{\Sigma d^2}{2k}} \quad (4)$$

where:

S_e = standard deviation for testing error estimated from tests of duplicate batches mixed in a single laboratory from different samples, MPa [psi],
d = difference between duplicate determinations for each sample, and
k = number of sets of duplicate batches tested.

7.1.4.2 Calculate the coefficient of variation for testing error as follows:

$$V_e = \frac{S_e}{\bar{X}_d} \times 100 \quad (5)$$

where:

V_e = coefficient of variation estimated from tests of duplicate batches mixed in a single laboratory from different samples, and
$\bar{X}_d$ = Overall average of duplicate tests, MPa [psi].

7.1.5 *Single-source Variation:*

7.1.5.1 Variation of cement from a single source, expressed in terms of standard deviation, corrected for testing error, is calculated as follows:

$$S_c = \sqrt{S_t^2 - S_e^2} \quad (6)$$

where:

S_c = single-source standard deviation corrected for testing error, MPa [psi].

The addition of the subscript 28 or 7 indicates the type of strength data used in the calculation.

NOTE 4—Values for averages and standard deviations can be calculated by other methods that are available in ASTM STP 15 D.[3] Electronic calculators are available for obtaining these statistics directly.

7.1.5.2 Variation of cement from a single source, expressed in terms of coefficient of variation, corrected for testing error, is calculated as follows:

$$V_c = \frac{S_c}{\bar{X}} \times 100 \quad (7)$$

where:

V_c = Single source coefficient of variation corrected for testing error, %.

7.1.5.3 If data are collected from two laboratories, calculate the single source variation of each laboratory using Eq. 6. Calculate the pooled single-source standard deviation as follows:

$$\bar{S}_c = \sqrt{\frac{(n_1 - 1)S_{c1}^2 + (n_2 - 1)S_{c2}^2}{n_1 + n_2 - 2}} \quad (8)$$

where:

$\bar{S}_c$ = pooled estimate of single-source standard deviation, MPa [psi],

[3] *Manual on Presentation of Data and Control Chart Analysis, ASTM STP 15 D,* ASTM 1976.