Designation: C 917 – 05

Standard Test Method for Evaluation of Cement Strength Uniformity From a Single Source[1]

This standard is issued under the fixed designation C 917; 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 is intended for use in instances in which the purchaser desires information on the strength uniformity of a hydraulic cement produced at a single source. 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 inch-pound units are to be regarded as the standard. The values in parentheses are for information only.

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 and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:* [2]

C 109/C 109M Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)
C 150 Specification for Portland Cement
C 219 Terminology Relating to Hydraulic Cement
C 595 Specification for Blended Hydraulic Cements
C 1157 Performance Specification for Hydraulic Cement
E 456 Terminology Relating to Quality and Statistics

3. Terminology

3.1 *Definitions*—For definitions of terms relating to this test method, refer to Terminologies C 219 and E 456.

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 C 150, C 595, and C 1157.

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

5. Sampling

5.1 All sampling shall be performed by quality control or testing personnel or someone 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 125 tons (115 Mg) 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 125 tons (115 Mg) 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 5-lb (approximately 2.3-kg) grab samples and thoroughly mix together to obtain a minimum 10-lb (4.5-kg) test sample. Sample only through hatches in the top of the unit. Remove approximately a 12-in. (300-mm) 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, the sample shall consist of a minimum of two separate 5-lb (approximately 2.3-kg) grab samples thoroughly mixed together or at least 10 lb (4.5 kg) 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 25 000 tons (23 000 Mg) per month, take samples at a rate of at least ten per month and at least two per week. When shipment or rate

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[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.

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

6. Procedure

6.1 Test all samples for 7- and 28-day compressive strength in accordance with Test Method C 109/C 109M 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.

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 C 109/C 109M 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 Mix duplicate batches of mortar to determine the effect of testing variations on the uniformity of results made in a single laboratory. Make duplicate batches on a day different from the original batch of mortar.

6.2.1 When a uniformity 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 average range, $\bar{R}$, for the available duplicates, then calculate standard deviation and coefficient of variation for testing according to 7.1.3 and 7.1.4, respectively. 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, use only the ten most recent results of duplicate testing in the calculation of the standard deviation and coefficient of variation for testing. See Table 1.

6.2.2 When at least ten sets of duplicate batches have been made and the coefficient of variation for testing is less than 4.0 %, the frequency of testing duplicate batches can be reduced to one out of ten consecutive cement samples. Resume testing one sample out of three if the coefficient of variation later exceeds 4.0 %. If the coefficient of variation for testing 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 single-laboratory testing variation 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*:

$$\bar{X} = \frac{X_1 + X_2 + \ldots + X_n}{n} \tag{1}$$

where:

$\bar{X}$ = average strength,

$X_1, X_2, \ldots, X_n$ = strength of individual tests, each of which is composed of the average of cubes in accordance with Test Method C 109/C 109M, and

n = number of individual samples.

7.1.2 *Total Standard Deviation*:

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

where:

S_t = standard deviation, psi.

7.1.3 *Standard Deviation For Testing*:

$$S_e = 0.862\bar{R}$$

S_e = standard deviation estimated from tests of duplicate batches mixed in a single laboratory,

R = range, the difference between the strengths of the duplicate batches from a single sample (all numbers are positive),

$\bar{R}$ = average of the individual ranges, R, for the preceding ten tests of duplicate batches. See 6.2.1 if fewer than ten ranges are available, and

0.862 = range coefficient for duplicate tests of the same sample of cement.

7.1.4 *Coefficient of Variation for Testing*:

$$V_e = 100\,S_e/\bar{X}$$

where:

V_e = coefficients of variation estimated from tests of duplicate batches mixed in a single laboratory, and

$\bar{X}$ = average of the strengths of the duplicate batches from which $\bar{R}$ is calculated.

7.1.5 *Standard Deviation Corrected For Testing Variations*:

$$S_c = \sqrt{S_t^2 - S_e^2} \tag{3}$$

where:

S_c = net standard deviation of cement corrected for testing error,

S_t = total standard deviations for all tests included in the calculation, and

S_e = standard deviation of duplicate tests run on split sample to evaluate testing error.

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.

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

TABLE 1 Calculation of Standard Deviation for Testing

Date	Sample Number	7-Day Data				Average^A		Range^B		$\bar{R}^C$		S_e^D		V_e^E	Note
		Test A		Test B											
		psi	(MPa)	psi	(MPa)	psi	(MPa)	psi	(MPa)	psi	(MPa)	psi	(MPa)		
01 /06	3	4900	(33.7)	4960	(34.2)	4930	(34.0)	60	(0.41)	. . .	. . .	. . .	. . .	. . .	. . .
01 /16	6	4580	(31.5)	4670	(32.2)	4625	(31.8)	90	(0.62)	. . .	. . .	. . .	. . .	. . .	. . .
01 /30	9	4650	(32.0)	4850	(33.4)	4750	(32.7)	200	(1.37)	. . .	. . .	. . .	. . .	. . .	. . .
02 /05	12	4400	(30.3)	4510	(31.1)	4455	(30.7)	110	(0.75)	. . .	. . .	. . .	. . .	. . .	. . .
02 /13	15	4380	(30.2)	4300	(29.6)	4340	(29.9)	80	(0.55)	108	(0.74)	93	(0.64)	2.02 %	Av. 5
02 /21	18	4700	(32.4)	4770	(32.8)	4735	(32.6)	70	(0.48)	102	(0.70)	88	(0.60)	1.89 %	Av. 6
03 /04	21	4470	(30.8)	4610	(31.7)	4540	(31.3)	140	(0.96)	107	(0.73)	92	(0.64)	2.00 %	Av. 7
03 /14	24	4030	(27.7)	3970	(27.3)	4000	(27.5)	60	(0.41)	101	(0.69)	87	(0.60)	1.92 %	Av. 8
03 /19	27	4970	(34.2)	4820	(33.2)	4895	(33.7)	150	(1.03)	107	(0.73)	92	(0.63)	2.01 %	Av. 9
03 /27	30	4550	(31.3)	4530	(31.2)	4540	(31.3)	20	(0.13)	96	(0.67)	84	(0.58)	1.84 %	Av. 10 (6)
04 /30	40	4750	(32.7)	4920	(33.9)	4835	(33.3)	170	(1.17)	109	(0.75)	94	(0.65)	2.06 %	Av. last 10
05 /31	50	5030	(34.6)	4820	(33.2)	4925	(33.9)	210	(1.44)	121	(0.83)	104	(0.72)	2.27 %	Av. last 10
06 /29	60	4830	(33.3)	4720	(32.5)	4775	(32.9)	110	(0.75)	112	(0.77)	97	(0.67)	2.10 %	Av. last 10
07 /28	70	4400	(30.3)	4460	(30.7)	4430	(30.5)	60	(0.41)	107	(0.73)	92	(0.64)	2.00 %	Av. last 10
08 /30	80	4550	(31.3)	4460	(30.7)	4505	(31.0)	90	(0.62)	108	(0.74)	93	(0.64)	2.02 %	Av. last 10
09 /25	90	4930	(34.0)	5000	(34.4)	4965	(34.2)	70	(0.48)	108	(0.74)	93	(0.64)	2.01 %	Av. last 10
10 /26	100	4950	(34.1)	4820	(33.2)	4885	(33.6)	130	(0.89)	107	(0.73)	92	(0.64)	1.97 %	Av. last 10
11 /25	110	4670	(32.2)	4720	(32.5)	4695	(32.3)	50	(0.34)	106	(0.73)	91	(0.63)	1.93 %	Av. last 10
12 /21	120	4450	(30.6)	4520	(31.1)	4485	(30.9)	70	(0.48)	96	(0.67)	84	(0.58)	1.80 %	Av. last 10

Date	Sample Number	28-Day Data				Average^A		Range^B		$\bar{R}^C$		S_e^D		V_e^E	Note
		Test A		Test B											
		psi	(MPa)	psi	(MPa)	psi	(MPa)	psi	(MPa)	psi	(MPa)	psi	(MPa)		
01 /06	3	6370	(43.9)	6620	(45.6)	6495	(44.7)	250	(1.72)	. . .	. . .	. . .	. . .	. . .	. . .
01 /16	6	6250	(43.1)	6020	(41.5)	6135	(42.3)	230	(1.58)	. . .	. . .	. . .	. . .	. . .	. . .
01 /30	9	6050	(41.7)	6120	(42.2)	6085	(41.9)	70	(0.48)	. . .	. . .	. . .	. . .	. . .	. . .
02 /05	12	6020	(41.5)	6230	(42.9)	6125	(42.2)	210	(1.44)	. . .	. . .	. . .	. . .	. . .	. . .
02 /13	15	5600	(38.6)	5420	(37.3)	5510	(38.0)	180	(1.24)	188	(1.29)	162	(1.12)	2.67 %	Av. 5
02 /21	18	5500	(37.9)	5530	(38.1)	5515	(38.0)	30	(0.20)	162	(1.11)	139	(0.96)	2.33 %	Av. 6
03 /04	21	6320	(43.5)	6280	(43.3)	6300	(43.4)	40	(0.27)	144	(0.99)	124	(0.86)	2.06 %	Av. 7
03 /14	24	5920	(40.8)	6010	(41.4)	5965	(41.1)	90	(0.62)	138	(0.94)	119	(0.82)	1.97 %	Av. 8
03 /19	27	6300	(43.4)	6050	(41.7)	6175	(42.5)	250	(1.72)	150	(1.03)	129	(0.89)	2.14 %	Av. 9
03 /27	30	6350	(43.7)	6410	(44.2)	6380	(44.0)	60	(0.41)	141	(0.97)	122	(0.84)	2.00 %	Av. 10 (6)
04 /30	40	6050	(41.7)	5940	(40.9)	5995	(41.3)	110	(0.75)	127	(0.87)	109	(0.75)	1.82 %	Av. last 10
05 /31	50	6670	(46.0)	6530	(45.0)	6600	(45.5)	140	(0.96)	118	(0.81)	102	(0.70)	1.68 %	Av. last 10
06 /29	60	6350	(43.7)	6190	(42.6)	6270	(43.2)	160	(1.10)	127	(0.87)	109	(0.75)	1.80 %	Av. last 10
07 /28	70	6500	(44.8)	6300	(43.4)	6400	(44.1)	200	(1.37)	126	(0.86)	109	(0.75)	1.78 %	Av. last 10
08 /30	80	6200	(42.7)	6150	(42.4)	6175	(42.5)	50	(0.34)	113	(0.77)	97	(0.67)	1.58 %	Av. last 10
09 /25	90	6630	(45.7)	6540	(45.1)	6585	(45.4)	90	(0.62)	119	(0.82)	103	(0.71)	1.63 %	Av. last 10
10 /26	100	6230	(42.9)	6010	(41.4)	6120	(42.2)	220	(1.51)	137	(0.94)	118	(0.81)	1.88 %	Av. last 10
11 /25	110	5920	(40.8)	6020	(41.5)	5970	(41.1)	100	(0.68)	138	(0.95)	119	(0.82)	1.90 %	Av. last 10
12 /21	120	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .

Notes: Initially one out of three samples are tested in duplicate until at least ten duplicate test results are available.

[A] Average of the test results A and B.

[B] Absolute difference between tests A and B.

[C] Average range is calculated for a minimum of five duplicate tests. Subsequently, ranges of the ten most recent duplicate tests are averaged.

[D] Standard deviation for testing is calculated as in 7.1.3: $S_e = 0.862 \times \bar{R}$.

[E] Coefficient of variation for testing is calculated as in 7.1.4: $V_e = 100\ S_e / \bar{X}$. Note that $\bar{X}$ is the average strength of the duplicate batches from which $\bar{R}$ is determined.

8. Report

8.1 Sufficient information shall be provided to identify the cement sampled including:

8.1.1 Name of manufacturer and location,

8.1.2 Type of cement or other identification,

8.1.3 Location of sampling,

8.1.4 Laboratory designation, and

8.1.5 Period of time represented by the report.

8.2 For ongoing programs, the minimum period covered by the report shall include all strength tests made in the preceding three months, but in no instance less than that period of time necessary to include 28-day strength tests of 20 consecutive samples.

8.2.1 The report shall not cover a period of time greater than 12 months or tests of more than 120 samples.

8.3 The report of strength results shall be either in tabular form as shown in Table 2 or in graphical form as shown in Fig. 1, at the option of the reporting organization.

NOTE 5—For purposes of analyzing trends, the graphical presentation is to be preferred. Additionally, the average and standard deviation as calculated in Section 7 shall be shown.

8.4 Report the available 7 and 28-day compressive strength results on each sample including the date on which the sample was taken. Each value reported will be the average of tests of three cubes made from the same batch, except when one or more cubes are faulty. See Test Method C 109/C 109M.

8.4.1 Report the results of tests of duplicate batches tested within the period covered by the report. When duplicate batches are made from a cement other than that being tested during the same period of time, by the same laboratory, these test results will not normally be reported on a regular basis, but results of such tests will be made available on request. However, report the standard deviation, S_e, and the coefficient of variation, V_e, of duplicate batches.

8.5 The report shall include the following values calculated from the reported data. Each cement sample shall be represented only by a single result at each age in these calculations. The second of a pair of duplicate batch test results shall not be included in overall calculations, but shall be used only to establish testing error.

8.5.1 Calculated from the reported seven-day strength data:

(1) $\bar{X}_7$, the average,

(2) S_{t7}, the total standard deviation,

(3) n_7, the number of samples tested,

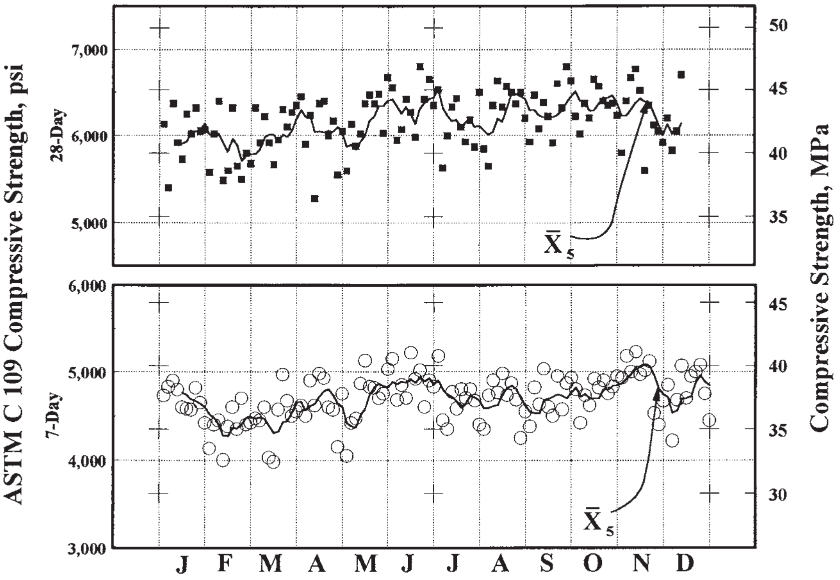
(4) S_{c7}, the standard deviation corrected for testing, and

(5) $\bar{X}_{5-7}$, the moving averages of the five most recent seven-day results.

8.5.2 Calculated from the reported 28-day strength data:

(1) $\bar{X}_{28}$, the average,

ABC Cement Inc., Qualitytown, NJ
Type I
Sampled on truck loading, Qualitytown
ABC Qualitytown Laboratory
Report date: January 5, 1992



Test Data for cement produced from
January 2 to December 21, 1991

Average Strength, psi (MPa)

$\bar{X}_7 = 4695$ (32.3) n = 120

$\bar{X}_{28} = 6170$ (42.5) n = 114

Average 5 most recent, psi (MPa)

$\bar{X}_{5\text{-}7} = 4846$ (33.4)

$\bar{X}_{5\text{-}28} = 6140$ (42.3)

Total Std. Dev., psi (MPa)

$S_{t7} = 270$ (1.85)

$S_{t28} = 334$ (2.30)

Testing Std. Dev., psi (MPa)

$S_{e7} = 87$ (0.59)

$S_{e28} = 122$ (0.84)

Corrected Std. Dev., psi (MPa)

$S_{c7} = 255$ (1.75)

$S_{c28} = 310$ (2.14)

FIG. 1 Uniformity Test Report

(2) S_{t28}, the total standard deviation,

(3) n_{28}, the number of samples tested,

(4) S_{c28}, the standard deviation corrected for testing, and

(5) $\bar{X}_{5-28}$, the moving averages of the five most recent 28-day results.

8.5.3 The calculations in 8.5.1 and 8.5.2 shall not be made and reported until five results are available. The moving average of the five most recent results should be updated with each successive result by adding the new value in the calculation and deleting the oldest previous value (see Table 1).

8.5.4 Whenever the reporting agency concludes that a consistent change in strength-producing properties has occurred, at its option, it may discontinue calculation until results from five additional samples of the cement have been obtained. In this instance, the values (8.5.1 and 8.5.2) calculated from the samples before the change shall also be reported (see 8.2.1).

8.5.5 When there is a break in the calculation, the sampling dates included in each set of calculated values (8.5.1 and 8.5.2) shall be clearly identified.

9. Keywords

9.1 cement; sampling; statistics; strength; uniformity

TABLE 2 Sample Uniformity Test Report

BC Cement Inc., Qualitytown, N.J.
Type I
Sampled on truck loading, Qualitytown
ABC Qualitytown LaboratoryReport Date: January 5, 1992

Item	7-Day	28-Day	7-Day	28-Day
Dates Represented:				
From:	01/02/91	01/02/91	(This space is provided for use if a break in the calculation is made. See 8.5.4 and 8.5.5.)	
To:	12/21/91	12/05/91		
Average Strength, psi (MPa), $\bar{X}$	4695 (32.3)	6170 (42.5)		
Total Standard Deviation, psi (MPa), S_t	270 (1.85)	334 (2.30)		
Number of Tests (n)	120	114		
Testing Standard Deviation, psi (MPa), S_e	84 (0.58)	119 (0.82)		
Number of Tests (n)	10	10		
Corrected Standard Deviation, psi (MPa), S_c	256 (1.77)	312 (2.15)		

Date Shipped	Sample No.^{A}	7-Day				28-Day				Date Shipped	Sample No.	7-Day				28-Day			
		Test a		Average 5		Test a		Average 5				Test a		Average 5		Test a		Average 5	
		psi	(MPa)	psi	(MPa)	psi	(MPa)	psi	(MPa)			psi	(MPa)	psi	(MPa)	psi	(MPa)	psi	(MPa)
01 /02	1	4730	(32.6)			6130	(42.3)			07 /02	61	5180	(35.7)	4906	(33.8)	6530	(45.0)	6550	(45.2)
01 /03	2	4830	(33.3)			5400	(37.2)			07 /07	62	4450	(30.7)	4792	(33.0)	5630	(38.8)	6316	(43.6)
01 /06	3a	4900	(33.8)			6370	(43.9)			07 /09	63	4350	(30.0)	4742	(32.7)	6000	(41.4)	6232	(43.0)
01 /08	4	4800	(33.1)			5920	(40.8)			07 /11	64	4770	(32.9)	4716	(32.5)	6330	(43.7)	6168	(42.5)
01 /14	5	4600	(31.7)	4772	(32.9)	5730	(39.5)	5910	(40.8)	07 /12	65	4580	(31.6)	4666	(32.2)	6430	(44.3)	6184	(42.6)
01 /16	6a	4580	(31.6)	4742	(32.7)	6250	(43.1)	5934	(40.9)	07 /13	66	4800	(33.1)	4590	(31.7)	6100	(42.1)	6098	(42.1)
01 /21	7	4570	(31.5)	4690	(32.3)	6020	(41.5)	6058	(41.8)	07 /19	67	4700	(32.4)	4640	(32.0)	5930	(40.9)	6158	(42.5)
01 /24	8	4820	(33.2)	4674	(32.2)	6320	(43.6)	6048	(41.7)	07 /20	68	4800	(33.1)	4730	(32.6)	6180	(42.6)	6194	(42.7)
01 /30	9a	4650	(32.1)	4644	(32.0)	6050	(41.7)	6074	(41.9)	07 /24	69	4670	(32.2)	4710	(32.5)	5870	(40.5)	6102	(42.1)
01 /31	10	4420	(30.5)	4608	(31.8)	6070	(41.9)	6142	(42.4)	07 /28	70a	4400	(30.3)	4674	(32.2)	6500	(44.8)	6116	(42.2)
02 /03	11	4130	(28.5)	4518	(31.2)	5580	(38.5)	6008	(41.4)	08 /02	71	4350	(30.0)	4584	(31.6)	5850	(40.3)	6066	(41.8)
02 /05	12a	4400	(30.3)	4484	(30.9)	6020	(41.5)	6008	(41.4)	08 /05	72	4730	(32.6)	4590	(31.7)	5650	(39.0)	6010	(41.4)
02 /06	13	4450	(30.7)	4410	(30.4)	6400	(44.1)	6024	(41.5)	08 /07	73	4900	(33.8)	4610	(31.8)	6350	(43.8)	6044	(41.7)
02 /07	14	4000	(27.6)	4280	(29.5)	5490	(37.9)	5912	(40.8)	08 /09	74	4760	(32.8)	4628	(31.9)	6630	(45.7)	6196	(42.7)
02 /13	15a	4380	(30.2)	4272	(29.5)	5600	(38.6)	5818	(40.1)	08 /10	75	4980	(34.3)	4744	(32.7)	6330	(43.7)	6162	(42.5)
02 /17	16	4600	(31.7)	4366	(30.1)	6320	(43.6)	5966	(41.1)	08 /19	76	4730	(32.6)	4820	(33.2)	6570	(45.3)	6306	(43.5)
02 /19	17	4350	(30.0)	4356	(30.0)	5650	(39.0)	5892	(40.6)	08 /20	77	4870	(33.6)	4848	(33.4)	6500	(44.8)	6476	(44.7)
02 /21	18a	4700	(32.4)	4406	(30.4)	5500	(37.9)	5712	(39.4)	08 /24	78	4680	(32.3)	4804	(33.1)	6370	(43.9)	6480	(44.7)
02 /25	19	4400	(30.3)	4486	(30.9)	5800	(40.0)	5774	(39.8)	08 /25	79	4250	(29.3)	4702	(32.4)	6500	(44.8)	6454	(44.5)
02 /27	20	4420	(30.5)	4494	(31.0)	5680	(39.2)	5790	(39.9)	08 /30	80a	4550	(31.4)	4616	(31.8)	6200	(42.8)	6428	(44.3)
03 /04	21a	4470	(30.8)	4468	(30.8)	6320	(43.6)	5790	(39.9)	09 /01	81	4380	(30.2)	4546	(31.4)	5930	(40.9)	6300	(43.4)
03 /07	22	4450	(30.7)	4488	(31.0)	5920	(40.8)	5844	(40.3)	09 /05	82	4820	(33.2)	4536	(31.3)	6470	(44.6)	6294	(43.4)
03 /12	23	4600	(31.7)	4468	(30.8)	6220	(42.9)	5988	(41.3)	09 /08	83	4630	(31.9)	4526	(31.2)	6080	(41.9)	6236	(43.0)
03 /14	24a	4030	(27.8)	4394	(30.3)	5920	(40.8)	6012	(41.5)	09 /10	84	5030	(34.7)	4682	(32.3)	6380	(44.0)	6212	(42.8)
03 /15	25	3980	(27.4)	4306	(29.7)	5670	(39.1)	6010	(41.4)	09 /15	85	4600	(31.7)	4692	(32.4)	6220	(42.9)	6216	(42.9)
03 /18	26	4570	(31.5)	4326	(29.8)	5950	(41.0)	5936	(40.9)	09 /20	86	4500	(31.0)	4716	(32.5)	5920	(40.8)	6214	(42.9)
03 /19	27a	4970	(34.3)	4430	(30.6)	6300	(43.4)	6012	(41.5)	09 /21	87	4950	(34.1)	4742	(32.7)	6600	(45.5)	6240	(43.0)
03 /22	28	4670	(32.2)	4444	(30.6)	6100	(42.1)	5988	(41.3)	09 /23	88	4570	(31.5)	4730	(32.6)	6320	(43.6)	6288	(43.4)
03 /25	29	4500	(31.0)	4538	(31.3)	6270	(43.2)	6058	(41.8)	09 /24	89	4870	(33.6)	4698	(32.4)	6800	(46.9)	6372	(43.9)
03 /27	30a	4550	(31.4)	4652	(32.1)	6350	(43.8)	6194	(42.7)	09 /25	90a	4930	(34.0)	4764	(32.9)	6630	(45.7)	6454	(44.5)
04 /02	31	4620	(31.9)	4662	(32.2)	6450	(44.5)	6294	(43.4)	10 /01	91	4800	(33.1)	4824	(33.3)	6220	(42.9)	6514	(44.9)
04 /05	32	4500	(31.0)	4568	(31.5)	5900	(40.7)	6214	(42.9)	10 /02	92	4420	(30.5)	4718	(32.5)	6020	(41.5)	6398	(44.1)
04 /10	33	4900	(33.8)	4614	(31.8)	6230	(43.0)	6240	(43.0)	10 /05	93	4730	(32.6)	4750	(32.8)	6370	(43.9)	6408	(44.2)
04 /12	34	4620	(31.9)	4638	(32.0)	5280	(36.4)	6042	(41.7)	10 /07	94	4620	(31.9)	4700	(32.4)	6200	(42.8)	6288	(43.4)
04 /14	35	4980	(34.3)	4724	(32.6)	6370	(43.9)	6046	(41.7)	10 /08	95	4920	(33.9)	4698	(32.4)	6650	(45.9)	6292	(43.4)
04 /16	36	4930	(34.0)	4786	(33.0)	6400	(44.1)	6036	(41.6)	10 /13	96	4820	(33.2)	4702	(32.4)	6570	(45.3)	6362	(43.9)
04 /18	37	4600	(31.7)	4806	(33.1)	6000	(41.4)	6056	(41.8)	10 /15	97	4900	(33.8)	4798	(33.1)	6400	(44.1)	6438	(44.4)
04 /23	38	4570	(31.5)	4740	(32.7)	6170	(42.6)	6044	(41.7)	10 /19	98	4750	(32.8)	4802	(33.1)	6350	(43.8)	6434	(44.4)
04 /25	39	4150	(28.6)	4646	(32.0)	5550	(38.3)	6098	(42.1)	10 /21	99	4830	(33.3)	4844	(33.4)	6370	(43.9)	6468	(44.6)
04 /30	40a	4750	(32.8)	4600	(31.7)	6050	(41.7)	6034	(41.6)	10 /26	100a	4950	(34.1)	4850	(33.4)	6230	(43.0)	6384	(44.0)

TABLE 2 *Continued*

Date Shipped	Sample No.[A]	7-Day				28-Day				Date Shipped	Sample No.	7-Day				28-Day			
		Test a		Average 5		Test a		Average 5				Test a		Average 5		Test a		Average 5	
		psi	(MPa)	psi	(MPa)	psi	(MPa)	psi	(MPa)			psi	(MPa)	psi	(MPa)	psi	(MPa)	psi	(MPa)
05 /05	41	4050	(27.9)	4424	(30.5)	5600	(38.6)	5874	(40.5)	10 /29	101	4930	(34.0)	4872	(33.6)	5800	(40.0)	6230	(43.0)
05 /07	42	4420	(30.5)	4388	(30.3)	6130	(42.3)	5900	(40.7)	11 /02	102	5180	(35.7)	4928	(34.0)	6400	(44.1)	6230	(43.0)
05 /09	43	4470	(30.8)	4368	(30.1)	5880	(40.6)	5842	(40.3)	11 /04	103	5000	(34.5)	4978	(34.3)	6670	(46.0)	6294	(43.4)
05 /15	44	4870	(33.6)	4512	(31.1)	6020	(41.5)	5936	(40.9)	11 /06	104	5230	(36.1)	5058	(34.9)	6770	(46.7)	6374	(44.0)
05 /17	45	5130	(35.4)	4588	(31.6)	6370	(43.9)	6000	(41.4)	11 /09	105	4970	(34.3)	5062	(34.9)	6520	(45.0)	6432	(44.4)
05 /19	46	4830	(33.3)	4744	(32.7)	6470	(44.6)	6174	(42.6)	11 /12	106	5020	(34.6)	5080	(35.0)	5600	(38.6)	6392	(44.1)
05 /21	47	4820	(33.2)	4824	(33.3)	6370	(43.9)	6222	(42.9)	11 /15	107	5120	(35.3)	5068	(35.0)	6350	(43.8)	6382	(44.0)
05 /27	48	4700	(32.4)	4870	(33.6)	6480	(44.7)	6342	(43.7)	11 /17	108	4530	(31.2)	4974	(34.3)	6120	(42.2)	6272	(43.3)
05 /29	49	4750	(32.8)	4846	(33.4)	6030	(41.6)	6344	(43.8)	11 /19	109	4400	(30.3)	4808	(33.2)	6050	(41.7)	6128	(42.3)
05 /31	50a	5030	(34.7)	4826	(33.3)	6670	(46.0)	6404	(44.2)	11 /25	110a	4670	(32.2)	4748	(32.7)	5920	(40.8)	6008	(41.4)
06 /08	51	5150	(35.5)	4890	(33.7)	6550	(45.2)	6420	(44.3)	11 /26	111	4850	(33.4)	4714	(32.5)	6200	(42.8)	6128	(42.3)
06 /10	52	4680	(32.3)	4862	(33.5)	5950	(41.0)	6336	(43.7)	11 /30	112	4220	(29.1)	4534	(31.3)	5830	(40.2)	6024	(41.5)
06 /12	53	4850	(33.4)	4892	(33.7)	6070	(41.9)	6254	(43.1)	12 /04	113	4680	(32.3)	4564	(31.5)	6050	(41.7)	6010	(41.4)
06 /16	54	4700	(32.4)	4882	(33.7)	6420	(44.3)	6332	(43.7)	12 /05	114	5070	(35.0)	4698	(32.4)	6700	(46.2)	6140	(42.3)
06 /18	55	5220	(36.0)	4920	(33.9)	6270	(43.2)	6252	(43.1)	12 /10	115	4700	(32.4)	4704	(32.4)	. . .	. . .	. . .	. . .
06 /21	56	4920	(33.9)	4874	(33.6)	5980	(41.2)	6138	(42.3)	12 /12	116	4950	(34.1)	4724	(32.6)	. . .	. . .	. . .	. . .
06 /23	57	5020	(34.6)	4942	(34.1)	6800	(46.9)	6308	(43.5)	12 /14	117	5000	(34.5)	4880	(33.7)	. . .	. . .	. . .	. . .
06 /25	58	4600	(31.7)	4892	(33.7)	6420	(44.3)	6378	(44.0)	12 /16	118	5080	(35.0)	4960	(34.2)	. . .	. . .	. . .	. . .
06 /27	59	4900	(33.8)	4932	(34.0)	6650	(45.9)	6424	(44.3)	12 /19	119	4750	(32.8)	4896	(33.8)	. . .	. . .	. . .	. . .
06 /29	60a	4830	(33.3)	4854	(33.5)	6350	(43.8)	6440	(44.4)	12 /21	120a	4450	(30.7)	4846	(33.4)	. . .	. . .	. . .	. . .

[A] "a" is the first batch of two made from this sample. See Table 1.

APPENDIXES

(Nonmandatory Information)

X1. COMPARISON OF RESULTS FROM TWO LABORATORIES USING TEST METHOD C 109

X1.1 Suppose *n* samples are split and tested by each Laboratory A and B with a single batch of mortar prepared on each sample in each laboratory.

X1.2 Compute the difference in results on each sample as $X_a - X_b$:

$$d_i = X_a - X_b \tag{X1.1}$$

d_i values may be positive or negative.

X1.3 Compute the average of these differences:

$$\bar{D} = \frac{d_1 + d_2 + \ldots + d_n}{n} \tag{X1.2}$$

where:

$\bar{D}$ = average difference in psi and d_i values may be positive or negative.

X1.4 Compute the standard deviation of these differences (7.1.2),

where:

S_d= standard deviation of the difference, psi.

X1.5 Compute the value $\bar{D}\sqrt{n} / S_d$ and compare to Student's *t*[4] for $n - 1$ at $\alpha = 0.05$, where *t* is from Student's *t* distribution.

X1.6 If $\left|\bar{D}\sqrt{n} / S_d\right| \geq t$, decide that averages in the two laboratories differ significantly; otherwise, decide that there is no reason to believe they differ.

n – 1	1	2	3	4	5	6	7	8	9
t[A]	12.7	4.30	3.18	2.78	2.57	2.45	2.36	2.31	2.26

[A] At α = 0.05.

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[4] For additional information see Neville, A., and Kennedy, J., *Basic Statistical Methods for Engineers and Scientists,* International Textbooks, Scranton, Pa. 1964, pp. 143–146.

X2. WITHIN-PLANT VARIATIONS IN CEMENT STRENGTH

X2.1 With the assistance of the Cement and Concrete Reference Laboratory (CCRL), C 917 data for 1991 was collected from 87 plants in the United States and Canada.

X2.2 Information on standard deviations, coefficients of variation, and 7- and 28-day strengths is presented in Figs. X2.1-X2.7.

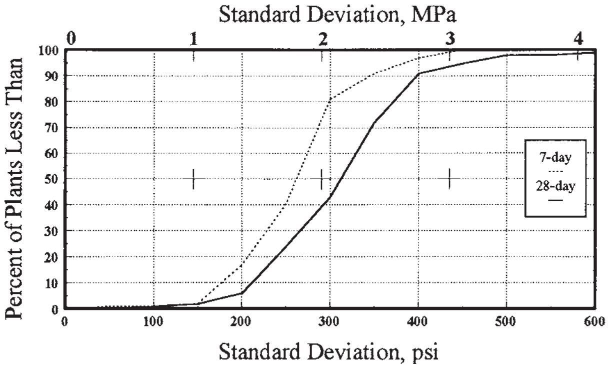

FIG. X2.1 Total Standard Deviation, St

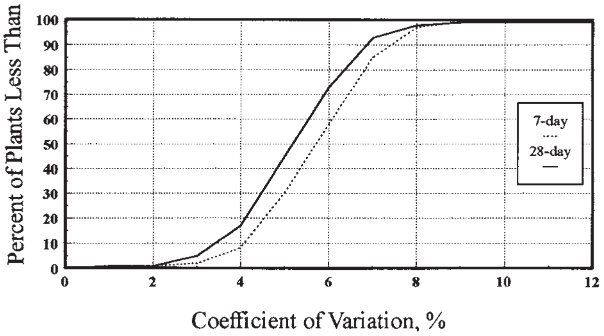

FIG. X2.2 Total Coefficient of Variation, Vt

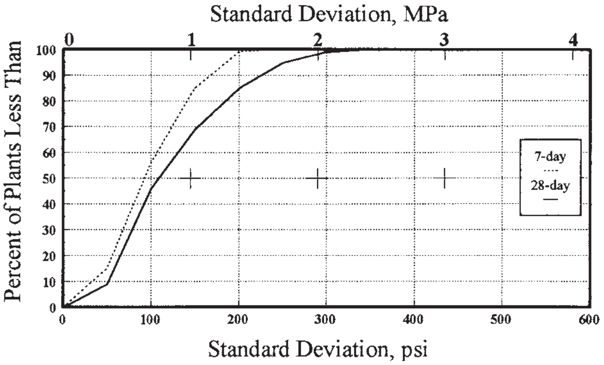

FIG. X2.3 Standard Deviation from Duplicate Batches, Se

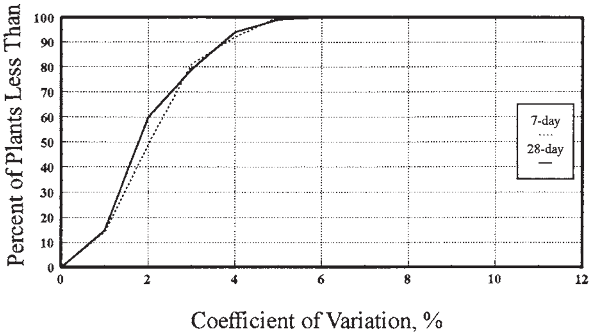

FIG. X2.4 Coefficient of Variation from Duplicate Batches, Ve

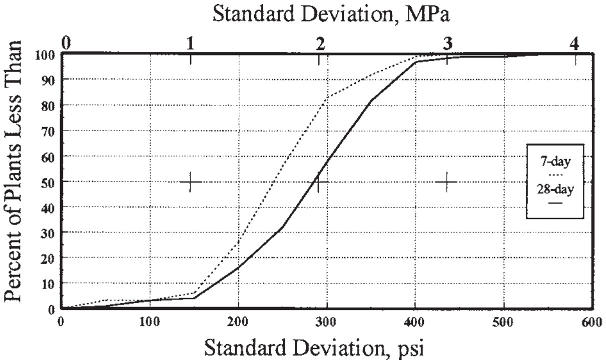

FIG. X2.5 Standard Deviation Corrected for Testing Error, Sc

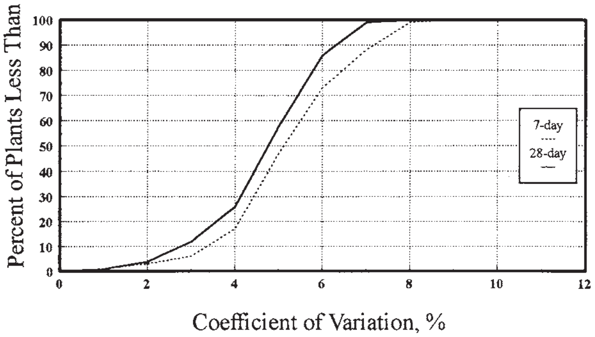

FIG. X2.6 Coefficient of Variation Corrected for Testing Error, Vc

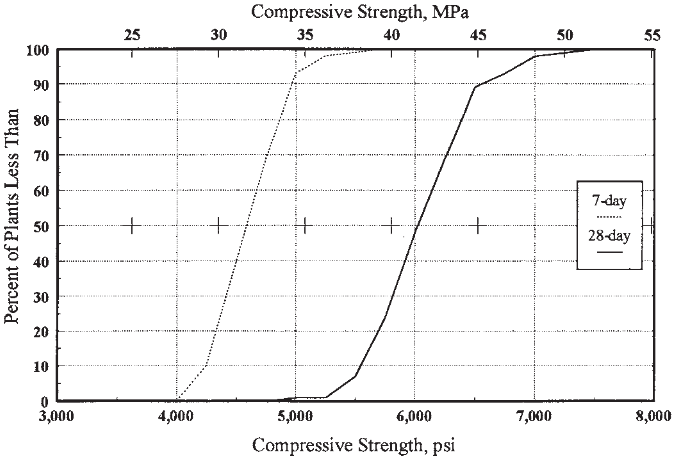

FIG. X2.7 Average Compressive Strength

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