Designation: C 1451 – 05

Standard Practice for Determining Uniformity of Ingredients of Concrete From a Single Source[1]

This standard is issued under the fixed designation C 1451; 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 practice covers a procedure for determining the uniformity of properties of concrete materials from a single source. It includes recommendations on sampling, testing, analysis of data, and reporting.

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

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 125 Terminology Relating to Concrete and Concrete Aggregates

C 219 Terminology Relating to Hydraulic Cement

C 294 Descriptive Nomenclature for Constituents of Concrete Aggregates

C 494/C 494M Specification for Chemical Admixtures for Concrete

C 638 Descriptive Nomenclature of Constituents of Aggregates for Radiation Shielding Concrete

C 917 Test Method for Evaluation of Cement Strength Uniformity from a Single Source

D 75 Practice for Sampling Aggregates

D 3665 Practice for Random Sampling of Construction Materials

2.2 *Other Document*

MNL 7 (STP 150) Manual on Presentation of Data and Control Chart Analysis, 6th edition

3. Terminology

3.1 *Definitions*—For definitions of terms relating to this practice refer to Terminology C 125, Terminology C 219, Descriptive Nomenclature C 294, and Descriptive Nomenclature C 638.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *lot*, *n*—a user-defined quantity, typically representing any amount of material for which uniformity information is to be calculated.

3.2.1.1 *Discussion*—The minimum lot size is generally the amount of material in a single conveyance, such as a truck load, a rail-car load, or a barge load. At the other extreme, a lot might be defined by a user as the total amount of material used in a single construction or by a supplier as the amount of material produced over a given interval of time.

3.2.2 *sampling unit*, *n*—amount of material from which a grab sample is taken.

3.2.2.1 *Discussion*—Generally a lot is subdivided into sampling units, and then sampling units are chosen at random for taking of grab samples. The size of the sampling unit is user-defined, depending on the purposes of the evaluation. The term *sub lot* is sometimes used to define this concept.

4. Significance and Use

4.1 This practice provides a systematic procedure for sampling and determining the uniformity of user-selected properties of ingredients of concrete. Results derived from application of the practice are generally intended for information only and are not requirements of any existing ASTM specification on concrete or concrete materials. A concrete materials specification may make reference to this practice as a means of obtaining uniformity information, but needs to define the properties to be measured and the lot size and sample unit to be used. The practice is applicable to both producers of concrete materials and to consumers of concrete materials, although details of application of the practice may vary, depending on the intended purpose of the user of the practice.

4.2 The procedure is applicable to any property of any concrete ingredient that can be described quantitatively, and for which conventional parametric statistics are applicable. The

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[1] This practice is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.94 on Evaluation of Data.

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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.

procedure is based on grab samples, which will tend to show the maximum amount of variation in the selected material property. The procedure was developed for application to materials from a single source, but it can be applied to a materials delivery stream from more than one source, depending on the purposes of the user of the practice. Calculations are corrected for testing error, therefore giving an estimate of the uniformity of the selected material property. The uniformity of the selected material property provides the user with one indicator of the source variation of the concrete ingredient.

4.3 Although variability in properties of concrete materials can be a significant cause of variability in concrete properties, this practice does not purport to give information on this relationship. This practice does give information on uniformity of ingredients from which the user can, along with supplementary information or correlative testing of concrete properties, develop quantitative estimates of the effects.

5. Sampling

5.1 The sampling plan underlying the analysis of uniformity is critical to the interpretation of results. The sampling plan will vary, depending on the details of concrete materials supply and user-defined purpose of the evaluation. The sampling plan should, at a minimum, address the lot size and sampling frequency, location and procedure of sampling from sampling unit, and handling of samples. All sampling is to be performed by personnel specifically trained for this purpose.

5.2 The first step in determining the sampling plan is to define the objective and scope of the evaluation. This requires considerable experience and knowledge of details involved with the particular production under evaluation. The objective and scope of the evaluation may vary between users and producers of materials. It may also range from determining the uniformity of materials during a relatively small production period to covering a very long production period. If there is no prior knowledge of the uniformity of a material property, or if it is suspected that the material might show considerable variation, a relatively intense sampling plan might be designed initially. If the prior knowledge indicates that the material property is relatively stable, then a less intense sampling plan might be designed.

5.3 The second step is to define the size of the *lot* and the size of the *sampling unit* (see 3.2). Typically a lot is divided into a number of sampling units; then sampling units are selected at random for the taking of grab samples. Typically, the number of sampling units is larger than the number actually sampled, although for small lot sizes, the number of sampling units may equal the number of samples being taken.

5.4 Take random grab samples from a point in the storage and handling process of the material that will accurately reflect the uniformity of the material as it will be used in concrete. Practice D 3665 provides general guidance. Additional guidance for specific materials is listed in 5.4.1-5.4.4. Identify samples by the date on which the material was shipped or received, its source, and designated type and applicable specifications.

5.4.1 Sample cement in accordance with Test Method C 917.

5.4.2 Sample fine and coarse aggregates in accordance with Practice D 75.

5.4.3 Sample chemical admixtures in accordance with Specification C 494/C 494M.

5.4.4 Sample pozzolan or ground granulated blast-furnace slag in accordance with Test Method C 917.

5.5 The required sampling frequency depends on how the data are being used and the nature of the material being evaluated. The sampling plan used should be described in the report (Section 8).

6. Procedure

6.1 *General*—Test all samples in accordance with the appropriate ASTM Test Method for the particular property being measured. Choose a property and method that has good precision so that the material uniformity is not masked by the testing error. It is also advisable to select a method that does not incur significant cost and is conducted frequently so the operators are proficient with the procedure. Variation within a single source is estimated by first calculating total variation from test data on grab samples, and then correcting this by subtracting variation inherent in the test method (testing error). Best results are obtained if all tests are conducted in the same laboratory, but guidance is provided if it is necessary to use data from more than one laboratory.

6.2 *Total Variation*—Test all samples in accordance with the appropriate ASTM Standard Test Method for the particular test property being measured. Choose a property and method that has good precision so that the material uniformity is not masked by the testing error. It is also advisable to select a method that does not incur significant cost and is conducted frequently so the operators are proficient with the procedure. Calculate the total variation among the samples, as directed in 7.1.2.

6.3 *Testing Error*—Testing error is composed of components due to within-laboratory variation and between-laboratory variation. If results are obtained from only one laboratory, then between-laboratory variation makes no contribution. If data are obtained from more than one laboratory, it is preferable to keep data from each one separate during data analysis, pooling estimates of variation at the end of the analysis.

6.3.1 To estimate within-laboratory testing error, duplicate tests made from a single sample are required. Samples must be tested in duplicate on different days until at least ten samples have been tested in duplicate. The rate of duplicate tests initially should be at least once in five samples and not less frequently than once per month. Calculate the testing error standard deviation and the coefficient of variation, as outlined in 7.1.3. If the testing error exceeds the single laboratory precision (1s or 1s%) reported in the precision statement for the applicable test method, but is less than 1.5 times this value, continue duplicate tests at this same rate. When the testing error is equal to or less than the testing error reported in the precision statement, reduce the frequency of duplicate testing. If the testing error exceeds 1.5 times the testing error reported in the precision statement, the data are of unacceptable precision, and the laboratory procedure and equipment should be thoroughly examined. Use the results of duplicate tests, indicating acceptable precision to estimate the within-laboratory testing error for all other types of similar materials tested in that laboratory during the same period of time.

6.3.2 When two or more laboratories are used to evaluate the uniformity of a source, then additional tests of a standard sample or exchanged portions of the same sample may be necessary to determine differences in testing that are likely to be obtained in the different laboratories. When two laboratories exchange portions of the sample and run single tests, results from the laboratories shall not differ by more than the multi-laboratory precision (D2S value) of the average of the two laboratories. If a larger number of samples are exchanged, then the difference between laboratories exceed the D2S no more than 5 % of the time.

6.3.3 Calculate the testing error from duplicate tests conducted in each laboratory as outlined in 7.1.3.

6.4 *Single-Source Variation*—Calculate single-source variation according to 7.1.4.

7. Calculation

7.1 The calculations shall include the following (Note 1):

NOTE 1—Values for averages and standard deviations can be calculated by other methods that are available in MNL 7 (STP 150). Electronic calculators and spreadsheets are available for obtaining these statistics directly.

7.1.1 *Average Measurement*:

$$\bar{x} = \frac{x_1 + x_2 + ... + x_n}{n} \quad (1)$$

where:

$\bar{x}$ = average measurement,
$x_1, x_2, ... x_n$ = individual measurements, and
n = number of individual tests.

7.1.2 *Standard Deviation*:

$$s_t = \sqrt{\frac{(x_1 - \bar{x})^2 + (x_2 - \bar{x})^2 + ... + (x_n - \bar{x})^2}{(n-1)}} \quad (2)$$

where:

s_t = standard deviation in units of measurement.

7.1.3 *Testing Error:*

7.1.3.1 The standard deviation for testing error is calculated as follows (See Table 1):

$$s_e = \sqrt{\frac{\sum d^2}{2k}} \quad (3)$$

where:

s_e = standard deviation for testing error estimated from tests of duplicate measurements made in a single laboratory from the sample,
d = difference between duplicate determinations, and
k = number of sets of duplicate determinations.

7.1.3.2 The coefficient of variation for testing error is calculated as follows,

$$v_e = \frac{s_e}{\bar{x}_d} \quad (4)$$

where:

v_e = coefficient of variation for testing error estimated from tests of duplicate measurements made in a single laboratory from the sample, and
$\bar{x}_d$ = average measurement from duplicate tests.

7.1.4 *Single-Source Variation*:

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

$$s_c = \sqrt{s_t^2 - s_e^2} \quad (5)$$

where:

s_c = standard deviation corrected for testing error,
s_t = standard deviation for all tests included in the calculation, and
s_e = standard deviation for testing error estimated from tests of duplicate measurements made in a single laboratory from the sample.

7.1.4.2 When data are collected from two laboratories, calculate the pooled single-source standard deviation as follows:

$$\bar{s}_c = \sqrt{\frac{(n_1 - 1)s_{c1}^2 + (n_2 - 1)s_{c2}^2}{n_1 + n_2 - 2}} \quad (6)$$

where:

$\bar{s}_c$ = pooled estimate of single-source standard deviation
s_{c1} *and* s_{c2} = standard deviation corrected for testing error from lab 1 and lab 2, respectively, and
n_1 *and* n_2 = number of tests in lab 1 and lab 2, respectively.

7.1.4.3 Single-source variation expressed as coefficient of variation, corrected for testing error, is calculated as follows:

$$v_c = \frac{s_c}{\bar{x}} \quad (7)$$

TABLE 1 Example Illustrating Calculation of Testing Error

Date	Samp. No.	Test "a," MPa	Test "b," MPa	Average, MPa	d^2
01/06	3	43.9	45.7	44.8	2.97
01/16	6	43.1	41.5	42.3	2.52
01/30	9	41.7	42.2	42.0	0.23
02/05	12	41.5	43.0	42.2	2.10
02/13	15	38.6	37.4	38.0	1.54
02/21	18	37.9	38.1	38.0	0.04
03/04	21	43.6	43.3	43.4	0.08
03/14	24	40.8	41.4	41.1	0.39
03/19	27	43.4	41.7	42.6	2.97
03/27	30	43.8	44.2	44.0	0.17
	k = 10		Average, $\bar{x}_d$ = 41.9		
				Σd^2	13.0
		Testing Standard Deviation, s_e			0.81
		Testing Coefficient of Variation, v_e			1.9 %

8. Report

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

8.1.1 Name of manufacturer and location,

8.1.2 Classification or type of material, 8.1.3 Location of sampling,

8.1.4 Laboratory designation,

8.1.5 Period of time represented by the report, and

8.1.6 Description of sampling frequency.

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

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

8.3 The report of 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 2).

NOTE 2—For purposes of analyzing trends, the graphical presentation is to be preferred. The average and standard deviation, as calculated in Section 7, shall be shown.

8.4 Report the results of duplicate tests on the same sample within the period covered by the report. When duplicate tests are made from samples 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 upon request. However, report the testing standard deviation.

8.5 The report shall include the following values calculated from the reported data. Each sample shall be represented only by a single result in these calculations. The second of a pair of duplicate test results shall not be included in the overall calculation, but shall be used only to establish testing error. (See Footnote A of Table 2.)

8.5.1 Calculate from the reported data:

8.5.1.1 $\bar{x}$ = the average,

8.5.1.2 s_t = the standard deviation,

8.5.1.3 s_e = testing standard deviation,

8.5.1.4 n = the number of samples tested,

8.5.1.5 s_c = the single source variation expressed in terms of standard deviation corrected for testing, and

8.5.1.6 x_5 = the moving averages of the five most recent results.

8.5.2 The calculations 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 2).

8.5.3 Whenever the reporting agency concludes that a consistent change in properties has occurred, at its option, it may discontinue calculation until results from five additional samples have been obtained. In this instance, the values calculated from samples prior to the change shall also be reported.

8.5.4 When there is a break in the calculation, the sampling dates included in each set of calculated values shall be clearly identified.

9. Keywords

9.1 concrete materials; uniformity

TABLE 2 Sample Uniformity Test Report

ABC Cement Inc., Qualitytown, NJ

Material Tested	Type I Portland Cement
Sampling Location	Truck loading, Qualitytown
Tested at	ABC Qualitytown Laboratory
Dates Represented	January – March, 2004
Property measured	28-day strength, Test Method C 109/C 109M
Sampling Frequency	10 per month
Duplicate test frequency	1 in 3
Average Strength, MPa	41.1
Total Standard Deviation, MPa, s_t	2.25
Number of Tests (n)	30
Testing Standard Deviation, MPa, s_e	0.81
Number of Duplicate tests (k)	10
Single Source Standard Deviation, MPa, s_c	2.10
Single Source Coefficient of Variation, v_c	5.1 %

Date Shipped	Samp. No.[A]	Test "a," MPa	Avg. 5, MPa	Date Shipped	Samp. No.	Test "a," MPa	Avg. 5, MPa
01/02	1	42.3		02/17	16	43.6	40.5
01/03	2	37.2		02/19	17	39.0	40.2
01/06	3a	43.9		02/21	18a	37.9	38.2
01/08	4	40.8		02/25	19	40.0	38.6
01/14	5	39.5	40.8	02/27	20	39.2	39.9
01/16	6a	43.1	40.9	03/04	21a	43.6	39.9
01/21	7	41.5	41.8	03/07	22	40.8	40.3
01/24	8	43.6	41.7	03/12	23	42.9	41.3
01/30	9a	41.7	41.9	03/14	24a	40.8	41.5
01/31	10	41.9	42.4	03/15	25	39.1	41.4
02/03	11	38.5	41.4	03/18	26	41.0	40.9
02/05	12a	41.5	41.4	03/19	27a	43.4	41.5
02/06	13	44.1	41.5	03/22	28	42.1	41.3
02/07	14	37.9	40.8	03/25	29	43.2	41.8
02/13	15a	38.6	40.1	03/27	30a	43.8	42.7

[A] "a" represents samples in which duplicate tests were conducted.

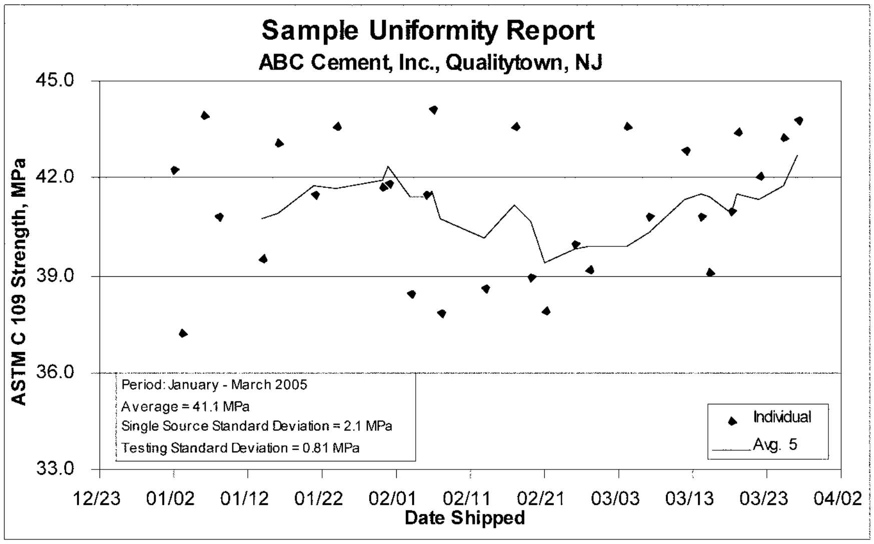

FIG. 1 Data Plots, Uniformity Test Report