INTERNATIONAL

Designation:C1451–05 Designation: C1451 – 11

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

This standard is issued under the fixed designation C1451; 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

1.1This 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.

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

1.1 This practice covers a procedure for determining the variability of properties of concrete materials from a single source. It includes recommendations on sampling, testing, analysis of data, and reporting.

1.2 The system of units for this practice is not specified. Dimensional quantities in the practice are presented only as illustrations of 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 and health practices and determine the applicability of regulatory limitations prior to use.*

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)
C125 Terminology Relating to Concrete and Concrete Aggregates
C219 Terminology Relating to Hydraulic Cement C294Descriptive Nomenclature for Constituents of Concrete Aggregates
C494/C494M Specification for Chemical Admixtures for Concrete C638Descriptive Nomenclature of Constituents of Aggregates for Radiation-Shielding Concrete
C917 Test Method for Evaluation of Cement Strength Uniformity From a Single Source
D75 Practice for Sampling Aggregates
D3665 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:

3.1.1 For definitions of terms relating to this practice refer to Terminology C125 , Terminology and Terminology C219, Descriptive Nomenclature C294, and Descriptive Nomenclature C638.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *lot*grab sample, *n*—a user-defined quantity, typically representing any amount of material for which uniformity information is to be calculated. —a specified quantity of material obtained in a single operation from a sampling unit.

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. —The goal of procuring a grab sample is to obtain a small portion of material that is characteristic of that in the sampling unit.

[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.

Current edition approved Nov. 1, 2005. Published November 2005. Originally approved in 1999. Last previous edition approved in 1999 as C1451–99. DOI: 10.1520/C1451-05.on Evaluation of Data (Joint C09 and C01).

Current edition approved July 1, 2011. Published August 2011. Originally approved in 1999. Last previous edition approved in 2005 as C1451–05. DOI: 10.1520/C1451-11.

[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.

***A Summary of Changes section appears at the end of this standard.**

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

3.2.2.1 *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.

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

~~3.2.2.1~~

3.2.3.1 *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~~variability 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~~variability 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 quantitative property of any concrete ingredient that can be ~~described quantitatively, and for which conventional parametric statistics are applicable.~~ measured by a standard test method. The procedure is based on grab samples, which will tend to show the maximum amount of variation in the selected material property. The procedure is useful if grab samples are obtained from sampling units that are being delivered to the user of a material and better represents the variability of the material used in concrete production compared with testing on the material for specification compliance. 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~~ Variations among test results are corrected for testing error, therefore giving an estimate of the ~~uniformity~~variability of the selected material property. The ~~uniformity~~variability 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~~variability 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~~variability 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. The required sampling frequency depends on how the data are being used and the nature of the material being evaluated. All sampling is to be performed by personnel specifically trained for this purpose. The sampling plan should be described in the report (Section 8).

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~~variability of materials during a relatively small production period to covering a very long production period. If there is no prior knowledge of the ~~uniformity~~variability 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. Alternatively, sampling may be performed on a time-based frequency.

5.4 Take random grab samples from a point in the storage and handling process of the material that will accurately reflect the ~~uniformity~~variability of the material as it will be used in concrete. Practice D3665 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 C917.

5.4.2 Sample fine and coarse aggregates in accordance with Practice D75.

5.4.3 Sample chemical admixtures in accordance with Specification C494/C494M.

5.4.4 Sample pozzolan or ~~ground granulated blast-furnace~~ slag cement in accordance with Test Method C917.

~~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~~

6.1 *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~~ —Test all samples in accordance with the appropriate ASTM Test Method for the particular property being measured. Choose a property that is expected to have a significant influence on concrete performance, and choose a test method that has good precision so that the material variability 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. Calculate the total variation among the samples, as directed 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~~. The total variation includes testing error.

6.2 *Testing Error*—Testing error comprises 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.

6.2.1 To estimate within-laboratory testing error, duplicate tests made from a single sample are required. Samples from different days must be tested in duplicate until at least ten samples have been tested in duplicate. The frequency 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 from duplicate tests conducted in each laboratory, as outlined in 7.1.4.

~~6.4~~

6.2.2 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 frequency. If 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.

6.2.3 When two or more laboratories are used to evaluate the variability 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 or d2s% value). If a larger number of samples are exchanged, then the difference between laboratories should not exceed the d2s or d2s% more than 5 % of the time.

6.3 *Single-Source Variation*—Calculate single-source variation according to ~~7.1.4~~7.1.5.

7. ~~Calculation~~

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

7.1 The calculations shall include the following:

~~NOTE1—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:*~~ 1—Standard deviation can be calculated by other methods that are available in MNL 7.[3] Electronic calculators and spreadsheets are available for obtaining the average and sample standard deviation directly after entering the test results.

7.1.1 *Average of All Test Results*—Calculate the average of all test results during the report period using Eq 1. Use only the first test result from each sample that is tested in duplicate.

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

where:

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

~~7.1.2*Standard Deviation*~~

7.1.2 *Moving Average*—After five test results are obtained, begin to calculate the moving average of the five most recent results using Eq 2. Update the moving average by adding the most recent test result and deleting the oldest previous test result.

(2) x5 = xi–4 + xi–3 + xi–2 + xi–1 + xi5

where:

$\bar{x}_5$ = moving average of five consecutive test results, and
x_i = the most recent of five consecutive test results.

7.1.3 *Total Standard Deviation*:

(3) st = (x1 – x)2 + (x2 – x)2 + ... + (xn – x)2(n – 1)

where:

s_t = total standard deviation in units of measurement.

~~7.1.3~~

7.1.4 *Testing Error:*

7.1.~~3~~4.1 The standard deviation for testing error is calculated as follows (See ~~Table 1~~Note 2):

where:

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

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

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

(4) v

NOTE 2—Table 1 is an example of test results obtained from duplicate tests on 10 samples.

7.1.4.2 If the precision of the test method is stated in terms of a coefficient of variation, calculate the coefficient of variation for testing error as follows:

$$CV_e = \frac{s_e}{\bar{x}_d} \quad (5)$$

[3] *Manual on Presentation of Data and Control Chart Analysis*, MNL7, Committee E11 on Statistical Control, ASTM International, 2010, www.astm.org.