



Designation: C1451 – 18

# Standard Practice for Determining Variability of Concrete-Making Materials From a Single Source<sup>1</sup>

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 reappraisal. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reappraisal.

## 1. Scope\*

1.1 This practice covers a procedure for determining the variability of concrete-making materials from a single source by measuring a characteristic property of the material. It includes recommendations on sampling, testing, analysis of data, and reporting.

1.2 The system of units for this practice is not specified. Units used in examples of calculation methods are for illustration purposes. The calculation methods described in this practice can be used with either SI or inch-pound 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:<sup>2</sup>

[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](#)

[C494/C494M Specification for Chemical Admixtures for Concrete](#)

[C917/C917M Test Method for Evaluation of Variability of Cement from a Single Source Based on Strength](#)  
[D75/D75M Practice for Sampling Aggregates](#)  
[D3665 Practice for Random Sampling of Construction Materials](#)

## 3. Terminology

### 3.1 Definitions:

3.1.1 For definitions of terms relating to this practice refer to Terminology [C125](#) and Terminology [C219](#).

### 3.2 Definitions of Terms Specific to This Standard:

3.2.1 *grab sample, n*—a specified quantity of material obtained in a single operation from a sampling unit.

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

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

3.2.2.1 *Discussion*—The minimum lot size is defined by a user and can be the total amount of material in a production run where manufacturing conditions are unchanged or 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.

3.2.3.1 *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 sampling unit is often the amount of material in a single conveyance to the concrete producer, such as a delivery truck, rail-car, or barge. The term *sublot* is sometimes used as an alternative for *sampling unit*.

## 4. Significance and Use

4.1 This practice provides a systematic procedure for sampling and determining the variability of user-selected properties of concrete-making materials. 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-making materials. A concrete materials specification may make reference to this practice as

<sup>1</sup> 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 (Joint C09 and C01).

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<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto: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

a means of obtaining variability information, but needs to define the properties to be measured and the lot size and sample unit to be used. This practice is applicable to both producers and consumers of concrete-making materials, although details of application of the practice may vary, depending on the intended purpose of the user of this practice.

4.2 The procedure is applicable to any quantitative property of any concrete-making material that can be measured by a standard test method. The procedure is based on grab samples, which will tend to show the maximum amount of variation of the material being evaluated. 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 than tests performed on the material for specification compliance that are documented on a mill test report or material certification. 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. Variations among test results on separate samples within a lot are corrected for testing error, therefore giving an estimate of the variability of the selected material property. The variability of the selected material property provides the user with one indicator of the source variation of the concrete-making material.

4.3 Although variability in properties of concrete-making 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 variability of concrete-making materials 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 variability is critical to the interpretation of results. The sampling plan will vary, depending on the details of concrete-making 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 defining the sampling plan is to establish 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 variability of materials during a relatively small production period to covering a very long production period. If there is no prior knowledge of the variability of a material, or if it is suspected that the material might show considerable variation,

a relatively intense sampling plan might be designed initially. If prior knowledge indicates that the material is relatively uniform, 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 of samples obtained, although for small lot sizes, the number of sampling units may equal the number of samples being taken. Alternatively, sampling may be 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 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/C917M.

5.4.2 Sample fine and coarse aggregates in accordance with Practice D75/D75M.

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

5.4.4 Sample pozzolan or slag cement in accordance with Test Method C917/C917M.

## 6. Procedure

6.1 *Total Variation*—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. 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. Grab samples from separate sampling units must be tested in duplicate until results of at least ten duplicate tests are obtained. 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.

6.2.2 If the testing error exceeds the single operator 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 single operator precision, reduce the frequency of duplicate testing. If the testing error exceeds 1.5 times the single operator precision, 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 7.1.5.

7. Calculation

7.1 The calculations shall include the following:

NOTE 1—Standard deviation can be calculated by other methods that are available in MNL 7.<sup>3</sup> 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.

$$\bar{x} = \frac{x_1 + x_2 + \dots + x_n}{n} \tag{1}$$

where:

- $\bar{x}$  = average of all test results,
- $x_1, x_2, \dots, x_n$  = individual determinations, and
- $n$  = number of individual determinations.

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.

$$\bar{x}_5 = \frac{x_{i-4} + x_{i-3} + x_{i-2} + x_{i-1} + x_i}{5} \tag{2}$$

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:*

$$s_t = \sqrt{\frac{(x_1 - \bar{x})^2 + (x_2 - \bar{x})^2 + \dots + (x_n - \bar{x})^2}{(n - 1)}} \tag{3}$$

where:

- $s_t$  = total standard deviation in units of measurement.

7.1.4 *Testing Error:*

7.1.4.1 The standard deviation for testing error is calculated as follows (See Note 2):

$$s_e = \sqrt{\frac{\sum d^2}{2k}} \tag{4}$$

where:

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

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:

$$CV_e = \frac{s_e}{\bar{x}_d} \tag{5}$$

where:

- $CV_e$  = coefficient of variation for testing error estimated from duplicate determinations made in a single laboratory, and
- $\bar{x}_d$  = overall average of duplicate determinations.

7.1.5 *Single-Source Variation:*

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

$$s_c = \sqrt{s_t^2 - s_e^2} \tag{6}$$

TABLE 1 Example Illustrating Calculation of Testing Error

Date	Sample No.	Test "a," MPa	Test "b," MPa	Average, MPa	d <sup>2</sup>	
01/06	3	43.9	45.7	44.8	3.24	
01/16	6	43.1	41.5	42.3	2.56	
01/30	9	41.7	42.2	42.0	0.25	
02/05	12	41.5	43.0	42.2	2.25	
02/13	15	38.6	37.4	38.0	1.44	
02/21	18	37.9	38.1	38.0	0.04	
03/04	21	43.6	43.3	43.4	0.09	
03/14	24	40.8	41.4	41.1	0.36	
03/19	27	43.4	41.7	42.6	2.89	
03/27	30	43.8	44.2	44.0	0.16	
k = 10				Average, $\bar{x}_d = 41.8$		
					$\sum d^2$	13.28
					Testing Standard Deviation, $s_e$	0.81
					Testing Coefficient of Variation, $v_e$	1.9 %

<sup>3</sup> Manual on Presentation of Data and Control Chart Analysis, MNL7, Committee E11 on Statistical Control, ASTM International, 2010, www.astm.org.