Designation: D 6607 – 00

Standard Practice for Inclusion of Precision Statement Variation in Specification Limits[1]

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1. Scope

1.1 This practice presents a method of determining rational specification limits by inclusion of the precision of the test method used in the specification.

2. Referenced Documents

2.1 *ASTM Standards:*

C 670 Practice for Preparing Precision And Bias Statements For Test Methods For Construction Materials[2]

C 802 Practice For Conducting An Interlaboratory Test Program To Determine The Precision Of Test Methods For Construction Materials[2]

D 2172 Test Methods for Quantitative Extraction Of Bitumen From Bituminous Paving Mixtures[3]

D 2726 Test Method for Bulk Specific Gravity and Density of Non-Absorptive Compacted Bituminous Mixtures[3]

E 177 Practice for Use Of The Terms Precision And Bias In ASTM Test Methods[4]

2.2 *Federal Highway Administration Report:*

FHWA Report HI-93–047 Materials Control and Acceptance—Quality Assurance, Federal Highway Administration, May 1993[5]

3. Terminology

3.1 For definitions of terms used in this practice, consult Practice E 177.

4. Significance and Use

4.1 Each test method has a limited precision. Even if a test is performed as carefully and as correctly as possible on a material which is as homogeneous as can be obtained, the test will still vary from one to another. A widely used measure of the variation of the test results from a test method is the standard deviation (σ). In an ASTM standard test, the standard deviation of the test method can be found in the Precision and Bias statement for the test. The "Blue Book," *Form and Style for ASTM Standards*, requires that all test methods include Precision and Bias statements. Practice C 670 and Practice C 802 provide guidance for determination of these values.

4.2 If the precision of a test method is low and the precision of the test has not been properly considered in a material specification, a uniform material with the right quality may still be rejected most of the time because of the wide variation of the test results. In order to have rational specification limits, the precision of the test used should be properly included in a specification.

4.3 This practice provides a guideline for proper inclusion of precision of the test method in a rational specification.

5. Procedure

5.1 Determine the effective standard deviation (σ_X) of the test results due to the combined effects of materials variation and test variation using Eq 1:

$$\sigma_X = (\sigma_M^2 + \sigma_T^2) \quad (1)$$

where:

σ_M = standard deviation of test property due to material variation (see Note 1), and

σ_T = standard deviation of test property due to test method (see Note 2).

NOTE 1—σ_M is the expected standard deviation of the material property when the material is produced in a properly controlled process. A standard deviation which is representative of the acceptable variation of the material can be used. It can be calculated from the data obtained from properly produced materials.

NOTE 2—σ_T is the standard deviation as given in the precision statement for the test method used to measure the test property.

5.2 Determine the standard deviation of the mean of the test results ($\sigma_{\bar{X}}$) using Eq 2:

$$\sigma_{\bar{X}} = \sigma_X / \sqrt{n} \quad (2)$$

where:

n = number of tests performed.

5.3 For a two-ended specification (with both a minimum and maximum limits), the specification limits for the average

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[2] *Annual Book of ASTM Standards*, Vol 04.02.

[3] *Annual Book of ASTM Standards*, Vol 04.03.

[4] *Annual Book of ASTM Standards*, Vol 14.02.

[5] Available from the National Technical Information Service, 5285 Port Royal, Springfield, VA 22165.

test value from n test ($\bar{x}$) should be the following:

$$\mu - Z_{\alpha/2}\,\sigma_{\bar{X}} \leq \bar{X} \leq \mu + Z_{\alpha/2}\,\sigma_{\bar{X}} \quad (3)$$

where:

μ = target property

$Z_{\alpha/2}$ = critical number of standard deviations for (1–α) confidence interval. (See Table 1 for values of $Z_{\alpha/2}$ for different specified confidence intervals.)

5.4 For a one-ended specification (with only a maximum or minimum limit), the specification limit for the average test value from n test ($\bar{x}$) should be the following:

TABLE 1 Z Values for Different Confidence Levels

Confidence Level (1 – α):	90 %	95 %	97.5 %	99.0 %
$Z_{\alpha/2}$ (Two-End Specification)	1.645	1.960	2.243	2.575
Z_{α} (One-End Specification)	1.282	1.645	1.960	2.327

$$\bar{X} \geq \mu - Z_{\alpha}\,\sigma_{\bar{X}} \text{ (with a minimum limit)} \quad (4)$$

or

$$\bar{X} \leq \mu + Z_{\alpha}\,\sigma_{\bar{X}} \text{ (with a maximum limit)} \quad (5)$$

APPENDIXES

X1. First Example of the Application of Precision Limits to Specification Writing

X1.1 Problem Statement

X1.1.1 A specification is to be written for the asphalt content of an asphalt mixture with aggregate water absorption capacity of less than 1.25 %. Three Reflux asphalt extraction tests are to be run and the average of three test results is to be used for acceptance purpose. The target asphalt content is 6.2 %. It is assumed that the contractor can reasonably control the asphalt content with a standard deviation of 0.20 % (see Note X1.1).

NOTE X1.1—Typical standard deviations of different material properties can be found in FHWA Report HI-93–047. The typical range of standard deviation of asphalt content was given as 0.15 % – 0.30 %.

X1.2 Precision statement for Test Methods D 2172(Method B—Reflux) is given in Table X1.1.

TABLE X1.1 Mixes with Agg. of Water Absorption < 1.25 %

	Standard Deviation	Acceptable Range of Two Test Results
Single-Operator	0.19 %	.054 %
Multi-Operator	0.23 %	0.65 %

X1.3 The combined standard deviation of the measured asphalt content:

$$\sigma_x = \sqrt{(0.2^2 + 0.23^2)} = 0.305\ \% \quad (X1.1)$$

X1.4 The standard deviation of the mean of three test results:

$$\sigma_{\bar{x}} = 0.305 / \sqrt{3} = 0.176\ \% \quad (X1.2)$$

X1.5 Specification limits using a 95 % confidence interval:

$$\begin{aligned} &= 6.2\ \% \pm Z_{\alpha/2}\ (0.176\ \%) \\ &= 6.2\ \% \pm 1.96\ (0.176\ \%) \\ &= 6.2\ \% \pm 0.3\ \% \end{aligned} \quad (X1.3)$$

X2. Second Example

X2.1 Problem Statement

X2.1.1 A specification is to be written for the asphalt content of the asphalt mixture as described in Example 1. However, the average of seven test results (instead of three test results) is to be used.

X2.2 The combined standard deviation of the measured asphalt content is the same as in Example 1:

$$\sigma_x = \sqrt{(0.2^2 + 0.23^2)} = 0.305\ \% \quad (X2.1)$$

X2.3 The standard deviation of the mean of seven test results:

$$\sigma_{\bar{x}} = 0.305 / \sqrt{7} = 0.115\ \% \quad (X2.2)$$

X2.4 Specification limits using a 95 % confidence interval:

$$\begin{aligned} &= 6.2\ \% \pm 1.96\ (0.115\ \%) \\ &= 6.2\ \% \pm 0.2\ \% \end{aligned} \quad (X2.3)$$

X3. Third Example

X3.1 Problem Statement

X3.1.1 A specification is to be written for the compacted density of an asphalt mixture with non-absorptive aggregate. The target density is 2.365 g/cm^3. Five density measurements in accordance with Test Method D 2726 are to be made, and the average test result is to be used for acceptance purposes. It is assumed that the contractor can control the density of the mixture with a standard deviation of 0.02 g/cm^3.

X3.2 Precision statement for Test Method D 2726 is in Table X3.1.

TABLE X3.1 Precision Statement Values

	Standard Deviation	Acceptable Range of Two Test Results
Single-Operator Precision	0.0124	0.035
Multi-Operator Precision	0.0269	0.076

X3.3 The combined standard deviation of the measured density:

$$\sigma_x = \sqrt{(0.200^2 + 0.0269^2)} = 0.0335\ g/cm^3 \quad (X3.1)$$

X3.4 The standard deviation of the mean of five test results:

$$\sigma_{\bar{x}} = 0.0335 / \sqrt{5}) = 0.0150\ g/cm^3 \quad (X3.2)$$

X3.5 Specification limit using a 95 % confidence interval:

Minimum average measured density

$$= 2.365 - Z_{\alpha}\,(0.015) = 2.365 - 1.65\,(0.115)^3 = 2.340\ g/cm \quad (X3.3)$$

X3.6 With this specification, a contractor who compacts the asphalt mixture to an average density of 2.356 g/cm^3 would meet the specification 95 % of the time.