
Standard Practice for Recognizing Surrogate Test Methods

AASHTO Designation: PP 112-21 (2023)¹

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Technical Subcommittee: 5c, Quality Assurance and Environmental



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1. SCOPE

- 1.1. This practice describes a method to assess the capability of a surrogate test to be used as a substitute for a standard test. The surrogate tests must demonstrate the capability to provide test results similar to the standard test method with a minimum of additional variability. The test results from the standard and the surrogate are compared and the error in their relationship is quantified.
- 1.2. It may be desirable to use a surrogate test to monitor material quality during construction or production, especially if the standard test method uses complex/expensive equipment, requires time-consuming sample preparation and testing techniques, uses hazardous materials, or involves destroying a portion of the material. This standard practice is intended to be applied for construction quality control but may also be used for acceptance if specifically approved by the Agency.
- 1.3. The procedure in this standard should be followed in the evaluation of potential surrogate test methods and to set parameters for their use.

2. REFERENCED STANDARDS

- 2.1. *AASHTO Standards:*
 - < R 9, Acceptance Sampling Plans for Highway Construction
 - < R 10, Definition of Terms Related to Quality and Statistics as Used in Highway Construction
 - < R 61, Establishing Requirements for Equipment Calibrations, Standardizations, and Checks
- 2.2. *ASTM Standards:*
 - < C670, Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials
 - < E2935, Standard Practice for Conducting Equivalence Tests for Comparing Testing Processes
- 2.3. *NCSL International Standard:*
 - < RP-1, Establishment and Adjustment of Calibration Intervals

3. TERMINOLOGY

- 3.1. *Definitions used herein are consistent with R 10; additional terms are provided as follows:*

- 3.1.1. *standard test*—A recognized standard test method that provides a test value and may include a precision and bias statement.
- 3.1.2. *surrogate test*—A test that has been statistically correlated with the results from a standard test method, but it is performed in a different manner than the standard test method.

4. PROCEDURE TO COMPARE STANDARD AND SURROGATE TESTS

- 4.1. The procedure involves three parts: 1) comparing the testing repeatability and reproducibility of the standard test to the repeatability and reproducibility of the surrogate test, 2) identifying the equivalence limit (E) for the test, and 3) measuring the equivalence (upper confidence limit (EUCL) and lower confidence limit (ELCL)) in the means and variance relationship between the standard and surrogate test. Every test method has inherent variability. In using a surrogate test method, the variability of the surrogate test method adds an additional component of variability to the standard test results. If that variability is minimal compared to the benefits of the surrogate test, the surrogate test is acceptable for use. This procedure identifies and quantifies the added variability, establishes a recommended limit to that variability and performs a hypothesis test to test if the difference between the standard and surrogate test results exceeds the identified limit.
- 4.2. *Step 1*—Compare the testing repeatability and reproducibility of the standard test to the repeatability and reproducibility of the surrogate test. Step 1 provides confidence that the surrogate test can be performed with similar variability by comparing the repeatability and reproducibility or by comparing the standard and surrogate test methods using a statistical F -test on the variances. R 9 Appendix X2 describes the F -test procedure, it is also a standard statistical method found in standard computer spreadsheet and statistical analysis programs.
- 4.2.1. Identify single-operator and multilaboratory precision from the standard test method, if available. See Section 4.2.2 if the standard test method does not have a precision statement. Compare the maximum ratio of the variance of the standard and surrogate procedures to an F_{critical} of 1.84 (F_{critical} from an F -test, assuming $\alpha = 0.05$ (a 95 percent confidence limit) and numerator and denominator values of $n = 30$).
- Note 1**—It is preferred to use this practice with a standard test method that has an established precision statement.
- 4.2.1.1. Identify single-operator and multi-laboratory precision of the surrogate test using ASTM C670.
- 4.2.1.2. If the repeatability standard deviation (S_r) and reproducibility standard deviation (S_R) from the standard test is greater than the surrogate tests, report the repeatability standard deviation (S_r) and reproducibility standard deviation (S_R) from the surrogate test. Perform an F -test to compare the variances as noted in Section 4.2.1, but note that the surrogate test has less variance.
- 4.2.1.3. If the repeatability standard deviation (S_r) and reproducibility standard deviation (S_R) from the standard test is less than the repeatability standard deviation (S_r) and reproducibility standard deviation (S_R) from the surrogate tests, perform an F -test to statistically compare repeatability and reproducibility variances. Confirm that the reproducibility and repeatability variance between the results obtained from the standard test and the surrogate test are statistically the same at 95 percent confidence, assuming the numerator and denominator values of $n = 30$.
- 4.2.2. If the standard test method does not have a precision and bias statement compare the variability of the tests by performing a statistical F -test on a minimum of 30 split samples that have been tested using the surrogate and standard tests. Confirm that the variance, based on the standard deviation (s^2) between the results obtained from the standard test and the surrogate test, are statistically the same at 95 percent confidence.

- 4.2.3. Report which test method (standard or surrogate) has higher variance (Section 4.2.1. S_r^2 and S_R^2 or Section 4.2.2 split sample s^2), and the results from the F -test (F and p -value) from the surrogate and standard tests.
- 4.3. *Step 2*—Identify E and n . The appropriate equivalence limit, E , shall be no more than two times the reproducibility standard deviation of the standard test ($2 * S_R$), unless another value is specifically approved by the agency implementing the surrogate test. E should also be identified considering the practical significance of the test values. Identify the minimum number of split samples (n) using ASTM E2935 Section X2.1, with $\sigma = S_r$ or split sample s , $\alpha = 0.05$, and E , for a power level of at least 90 percent.
- Note 2**—See Section X1.1.3 for an example of determining n using Power curves.
- 4.4. *Step 3*—Perform a hypothesis test to identify if the error in the relationship (means and slope) between the standard and surrogate test are within the defined equivalence limit (E) defined in Section 4.3 using a minimum (n) number of samples as identified in Section 4.3. Step 3 defines the relationship between the standard and surrogate test results and provides a limit to the measure of potential error between the two test results. The procedure is similar to simple regression in that it evaluates the linear statistical relationship between the standard and surrogate test method. When performing this test the residuals should be checked for normality.
- 4.4.1. Perform a means equivalence two one-sided test (TOST) using split samples in accordance with Section 7 of ASTM E2935 and report the equivalence upper confidence limit (EUCL) and equivalence lower confidence limit (ELCL) for the difference in means. Using the same data perform a paired t -test and an F -test as described in R 9 and report the p -values.
- 4.4.2. Perform a slope equivalence test using split samples in accordance with ASTM E2935 Section 8 and report the equivalence upper confidence limit (EUCL) and equivalence lower confidence limit (ELCL) for the slope.
- 4.4.3. Plot the dot plot for residuals, residuals versus x , and line slope comparison as noted in ASTM E2935 Section 8.3 to evaluate any outliers or heteroscedasticity.
- 4.5. Report the results from Steps 1, 2, and 3, including graphs.

5. PROCEDURE TO IDENTIFY VALIDATION FREQUENCY

- 5.1. A calibration and standardization frequency for the surrogate test shall be defined following the requirements in R 61 and RP-1. Consider the frequency of calibration required for the standard test method and any uncertainty growth in the surrogate test method. It is recommended to start with a very high frequency (>1 per 30 samples) and adjust the frequency if the results remain consistent.
- 5.1.1. The surrogate test should describe the range of values and types of materials that were used in calibrating the test. The surrogate test should not be used outside the range of values used in calibrating the surrogate test.
- 5.1.2. Recalibration should be performed if the material being tested varies greatly from the material that was used to calibrate the surrogate test. If there is a concern of material changes, a quick one-test check can be performed to confirm the relationship is the same. The process in Section 4 should be repeated if the materials change outside the range previously considered or there is concern the relationship is not remaining consistent over time.