
Standard Practice for

**Definition of Terms Related to
Quality and Statistics as Used
in Highway Construction**

AASHTO Designation: R 10-22

Technically Revised: 2022

Editorially Revised: 2022

**Tech Subcommittee: 5c, Quality Assurance and
Environmental**



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1. SCOPE

- 1.1. This standard practice is to provide standard definitions for terms used in specifications, test methods, and the various quality assurance procedures.

2. REFERENCED DOCUMENTS

- 2.1. *ASTM Standards:*
- E177, Standard Practice for Use of the Terms Precision and Bias in ASTM Test Methods
 - E691, Standard Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method
 - E1325, Standard Terminology Relating to Design of Experiments

3. GENERAL PROVISIONS

- 3.1. It is recommended that AASHTO specifications and procedures, including standard practices, incorporate the following accepted terms as defined. These terms and their definitions are directed primarily to the various quality assurance sampling and acceptance plans. Where a definition conflicts with a standard, the standard will govern.

4. TERMINOLOGY

- 4.1. *acceptable quality level (AQL)*—the level of established quality for a quality characteristic that is fully acceptable. [For example, when the quality measure used is percent within limits (PWL), the AQL is the established (not estimated) PWL at which the lot of material is fully acceptable for that quality characteristic. Acceptance plans should be designed so that work meeting all AQL(s) will receive an expected pay (EP) of 100 percent.]
- 4.2. *acceptance*—the process whereby all factors used by the agency (i.e., sampling, testing, and inspection) are evaluated to determine the degree of compliance with contract requirements and to determine the corresponding value for a given product. [Owner acceptance measurements (sampling, testing, and inspection) are always considered in the acceptance decision process. QC measurements (sampling, testing, and inspection results) may or may not be used in the acceptance decision process. PC measurements are not used by the agency in the acceptance decision process.] [Where contractor test results are used in the agency's acceptance decision, the

acceptance process includes contractor testing, agency verification and validation, and possibly dispute resolution.]

- 4.3. *acceptance constant (k)*—the minimum allowable quality index (Q). [The acceptance constant k is the acceptance limit associated with the quality index quality measure. In other words, for acceptance, Q must be greater than or equal to k .]
- 4.4. *acceptance limit*—also called rejection limit. In variables acceptance plans, the limiting upper or lower value, placed on a quality measure, that will permit acceptance of a lot. [While the test values for material samples are evaluated against specification limits and engineering limits, the computed quality level for a specific quality measure is evaluated against the acceptance limit. For example, the minimum allowable PWL called for in a QA specification might be 50 PWL. This is the acceptance limit.]
- 4.5. *acceptance number (c)*—in attributes acceptance plans, the maximum number of defective or nonconforming units in the sample that will permit acceptance of the inspected lot or batch.
- 4.6. *acceptance plan*—also called “acceptance sampling plan” or “statistical acceptance plan.” An agreed-upon process for evaluating the acceptability of a lot of material. It includes: lot size and sample size (i.e., number of samples), quality measure, acceptance limit(s), evaluation of risks, and pay adjustment provisions.
- 4.7. *acceptance sampling and testing*—sampling and testing performed by the agency, or its designated agent, to evaluate acceptability of the final product. Also called “verification sampling and testing” when specifically used to validate the contractor’s data.
- 4.8. *acceptance quality characteristic (AQC)*—a quality characteristic that is measured and used to determine acceptability.
- 4.9. *accepted reference value*—a value that serves as an agreed-upon reference for comparison, and which is derived as: (1) a theoretical or established value, based on scientific principles; (2) an assigned or certified value, based on experimental work of some national or international organization; or (3) a consensus or certified value, based on collaborative experimental work under the auspices of a scientific or engineering group.
- 4.10. *accredited laboratories*—laboratories that are recognized by a formal accrediting body as meeting quality system requirements including demonstrated competence to perform standard test procedures.
- 4.11. *action limits*—see *control limits*.
- 4.12. *accuracy*—the degree to which a measurement, or the mean of a distribution of measurements, tends to coincide with the true population mean. [When the true population mean is not known, the degree of agreement between the observed measurements and an accepted reference value may be used to quantify the accuracy of the measurements.]
- 4.13. *adjusted pay schedule*—see *pay adjustment schedule*.
- 4.14. *adjusted pay system*—see *pay adjustment system*.
- 4.15. *aesthetic value*—the worth of an item of construction in terms of pleasing appearance or gratifying performance.
- 4.16. *alpha (α) error*—see *seller’s risk*.

- 4.17. *alpha sub PF (α_{PF})*—see *seller's risk*. For acceptance plans with pay adjustments, the probability that acceptable quality level (AQL) material or construction will be assessed a pay factor less than PF with respect to a single acceptance quality characteristic. For example, α_{100} for a compressive strength pay adjustment acceptance plan is the probability that AQL compressive strength material will be assessed less than 100 percent pay for compressive strength; this probability includes the probability of rejection, α_0 , with respect to compressive strength. [The use of α_{PF} addresses the need to quantify, for pay adjustment acceptance plans, the probabilities associated with each possible pay decision regarding AQL material (e.g., payment of 0, 70, 80, 90, 100, or 105 percent for AQL material). A seller (contractor) is usually most interested in α_{100} .]
- 4.18. *alternative hypothesis (H_a)*—the hypothesis to be accepted if the null hypothesis (H_0) is disproved (i.e., rejected).
- 4.19. *analysis of variance (ANOVA)*—a mathematical method of isolating causes of variation.
- 4.20. *assignable cause*—a source of variation, usually due to error or process change, which can be detected by statistical methods and corrected within economic limits. [When assignable causes are identified and removed, the production process is “in control.”]
- 4.21. *attribute*—a characteristic that, by its presence or absence, classifies a unit or segment as conforming or nonconforming.
- 4.22. *attributes acceptance plan*—a statistical acceptance procedure where the acceptability of a lot of material or construction is evaluated by (1) noting the presence or absence of some characteristic or attribute in each of the units or samples in the group under consideration, and (2) counting how many units do or do not possess this characteristic.
- 4.23. *average*—a measure of central value that usually refers to the arithmetic mean ($\bar{X}$). May also refer to the median or mode. [The mean, median, and mode are equal for a normal distribution. As a distribution becomes more skewed, the mean, median, and mode will differ more and more.]
- 4.24. *average absolute deviation (AAD)*—for a series of test results, the mean of absolute deviations from a target or specified value. [Its use as an acceptance measure is not recommended.]
- 4.25. *average run length (ARL)*—in a sample sense, the average number of times that a process will have been sampled and evaluated before a shift in process level is signaled. In a unit sense, the average number of units that will have been produced before a shift in level is signaled. [A long ARL is desirable for a process located at its specified level (to minimize calling for unneeded investigation or corrective action) and a short ARL is desirable for a process shifted to some undesirable level (so that corrective action will be called for promptly). ARL curves are used to describe the relative quickness in detecting level shifts of various control chart systems.]
- 4.26. *batch*—a specified quantity of material produced through a uniform operation or process. [A batch is usually smaller than a lot.]
- 4.27. *beta (β) error*—see *buyer's risk*.
- 4.28. *beta sub PF (β_{PF})*—see *buyer's risk*. For acceptance plans with pay adjustments, the probability that rejectable quality level (RQL) material will be assessed a pay factor greater than or equal to PF. For example, β_{100} for a compressive strength pay adjustment acceptance plan is the probability that RQL compressive strength material will be assessed 100 percent pay or more for compressive strength. [The use of β_{PF} addresses the need to quantify, for pay adjustment acceptance plans, the probabilities associated with each possible pay decision regarding RQL material (e.g., payment of 0, 70, 80, 90, 100, or 105 percent for RQL material). A buyer (agency) is usually most interested in β_{100} .]

- 4.29. *bias*—an error, constant in direction, that causes a measurement, or the mean of a distribution of measurements, to be offset from the true population mean.
- 4.30. *biased sampling*—a sampling procedure whereby samples obtained from a lot do not have an equal probability of being chosen. [Some examples of conventional biased approaches to sampling that have been used by agencies and contractors include representative sampling, uniform interval sampling, quota sampling, and selective sampling.]
- 4.31. *buyer's risk* (β)—also called “agency’s risk or risk of a Type II” or “beta (β) error.” It is the risk to the agency of accepting rejectable quality level (RQL) material or workmanship. [For an accept/reject acceptance plan, it is the probability that an acceptance plan will erroneously accept RQL material or workmanship with respect to a single acceptance quality characteristic. For variables acceptance plans using adjusted pay schedules, it is equivalent to β_{PF} , where $PF = 100$. It is the probability that a variable payment acceptance plan will erroneously fully accept RQL material or workmanship at 100 percent pay or greater with respect to a single acceptance quality characteristic.]
- 4.32. *calibration*—a set of operations that establish, under specified conditions, the relationship between values of quantities indicated by a measuring instrument or measuring system, or between values represented by a material measure or a reference material, and the corresponding values realized by standards. [The purpose of calibration is to ensure that measurements made by the laboratory are traceable to the International System of Units (SI). Where traceability of measurements to SI units is not possible or relevant, measurements must be traceable to certified reference materials, agreed-upon methods, or consensus standards. Uncertainty estimates obtained during calibration are used to judge if an instrument is suitable for its intended purpose. There is a need to re-establish traceability or recalibrate only when instrument measurements drift out of control (as determined through verification of calibration). See *standardization*.]
- 4.33. *certified technician*—a technician certified by some agency or organization as proficient in performing certain duties. [A certified technician is considered to be qualified. A qualified technician may or may not be certified. See *qualified technician*.]
- 4.34. *chance cause*—a source of variation that is inherent in any production process and cannot be eliminated because it is due to random, expected causes.
- 4.35. *characteristic*—a measurable property of a material, product, or item of construction.
- 4.36. *class*—a group of data values (measurements, observations, or test values) that all satisfy a given set of conditions associated with a frequency distribution.
- 4.37. *class frequency*—the number of data values falling into a particular class.
- 4.38. *classification*—the acts of evaluating if an attribute or variable does or does not conform to requirements, and the documentation of results.
- 4.39. *class interval*—the difference in value between the lower and the upper limits of a given class.
- 4.40. *class limits*—the upper and lower values that define a given class.
- 4.41. *class midpoint*—the central value of a particular class.
- 4.42. *cluster sampling*—the random selection of clusters (i.e., groups or bundles) from a population. For each cluster selected, random sampling of the contained elements may then be performed. [Examples of cluster sampling are selection of city blocks as primary sampling units; selection of a household as a cluster of people (of which only one may be interviewed); selection of bundles of

rods or pipe from a shipment; and selection, from a shipment, of cartons that contain boxes or packages within them.]

- 4.43. *coefficient of determination (r^2)*—a measure of the relationship between a single dependent random variable or response Y and a known independent variable X . It represents the proportion of the total variation of Y due to X . For instance, if $r^2 = 0.81$ ($r = \pm 0.9$. See *correlation coefficient*), then 81 percent of the variation in the values of Y may be accounted for by the relationship with the variable X . [The value of r^2 from a regression model cannot be evaluated as “good” or “bad” in singularity; it can only be judged relative to other models that have been estimated on similar phenomena. Thus, an r^2 of 0.30 for one phenomenon might be extremely informative, while for another phenomenon it might be uninformative.]
- 4.44. *coefficient of variation (v)*—the ratio of the standard deviation to the mean expressed as a percent. It provides a measure of dispersion or spread relative to the mean.
- 4.45. *combined pay factor*—see *composite pay factor*.
- 4.46. *component of variance*—a part of the total variance identified with a specified source of variability.
- 4.47. *composite pay factor*—also called “combined pay factor or overall pay factor.” A multiplication factor, often expressed as a percentage, that considers two or more quality characteristics and is used to determine the contractor’s final payment for a unit of work. [Methods typically employed to arrive at this factor are (1) calculate either a standard or a weighted average of individual pay factors, (2) multiply individual pay factors, or (3) use the lowest individual pay factor. Composite pay can also be calculated by adding the sum of individual pay adjustments to the bid price, as would likely be the case when pay adjustments are expressed in direct dollar amounts.]
- 4.48. *computer simulation*—use of a computer to generate conditions approximating actual or operational conditions. [Computer simulation is a powerful and convenient tool to solve certain problems that are intractable by other methods.]
- 4.49. *confidence interval*—an estimate of an interval in which the estimated parameter will lie with predetermined probability (called the “confidence level”).
- 4.50. *confidence level*—if a large number of confidence intervals are constructed, the proportion of time that the estimated parameter will lie within the interval. [A confidence level is usually expressed as a percentage, typically ranging from 90 to 99 percent. *Confidence level* = 1 – confidence coefficient (α).]
- 4.51. *confidence limits*—the end points of a confidence interval.
- 4.52. *conflict resolution*—see *dispute resolution*.
- 4.53. *conformal index (CI)*—a measure of the dispersion of a series of results around a target or specified value, expressed as the square root of the quantity obtained by summing the squares of the deviations from the target value and dividing by the number of observations. The standard deviation is a measure of precision, but the CI is a measure of exactness (accuracy) or degree of conformance with the target. [Its use as an acceptance measure is not recommended.]
- $$CI = \sqrt{\sum (X_i - T)^2 / n} \quad (1)$$
- 4.54. *conformance*—an affirmative indication or judgment that a product or process has met project requirements; also, the state of having met the requirements.

- 4.55. *control chart*—also called “statistical control chart.” A graphical plot of quality control measurements or test results used to identify variation in a production or placement process due to either chance causes or assignable causes. [Control charts have statistically derived control limits. Plotted values may be for individual measurements or the averages of groups of measurements. The control limits can be established statistically based on sample sizes of $n = 1$ or $n > 1$. Sample sizes of $n > 1$ are preferred, with sample sizes of $n = 3, 4$, or 5 being the most common.]
- 4.56. *control chart factor*—a factor, varying with sample size, to convert specified statistics or parameters into a central line value or control limit appropriate to the control chart.
- 4.57. *control limits*—also called “action limits.” Statistically derived boundaries applied to a control chart in controlling material production or placement. [Control limits are expressed as the upper control limit (UCL) and the lower control limit (LCL). When values of the material characteristics fall within these limits, the process is “in control.” When values fall outside the limits, there is an indication that some assignable cause is present causing the process to be “out of control.”]
- 4.58. *controlled process*—a production process in which the mean and variability of a series of tests on the product remain stable, with the variability due to chance cause only. [A process might be “in control” but produce out-of-specification material if the control limits are wider than the specification limits. Similarly, a process might be “out of control” in that the mean or variability is outside of control limits, yet the specification limits might be wide enough that the material produced is within specifications.]
- 4.59. *correlation coefficient (r)*—a measure of the relationship between a single dependent (response) random variable Y and a known independent variable X . [The correlation coefficient ranges in value from -1 to $+1$, indicating a perfect negative relationship at -1 , absence of relationship at 0 , and perfect positive relationship at $+1$. Thus, when Y varies directly with X , the correlation coefficient is positive; when Y bears an inverse relationship to X , the correlation coefficient is negative. See *coefficient of determination*.]
- 4.60. *criticality*—the classification of contract requirements by the degree to which they affect safety, performance, or life-cycle cost.
- 4.61. *data*—measurements or test values organized for computation or analysis.
- 4.62. *defect*—a failure to meet a requirement with respect to a single quality characteristic.
- 4.63. *defective*—having one or more defects.
- 4.64. *dependent variable*—see *response variable*.
- 4.65. *design of experiments*—also called “experimental design.” The arrangement in which an experimental program is to be conducted, and the selection of the levels (versions) of one or more factors or factor combinations to be included in the experiment.
- 4.66. *deviation*—the difference between an individual value and its stated value or intended level. [In practice, deviation is usually taken to infer the deviation from the mean or deviation from the target value.]
- 4.67. *disincentive*—a preestablished decrease in payment to the contractor applied to a contract bid item for which the level of materials quality and workmanship, determined by statistical means, does not meet the specified acceptable quality level (AQL). The disincentive is usually expressed as a percentage of the original contract bid price.
- 4.68. *dispersion*—the extent to which data values are scattered about a target or central value.

- 4.69. *dispute resolution*—also called “conflict resolution.” The procedure used to resolve conflicts resulting from discrepancies between the agency’s and contractor’s results of sufficient magnitude to impact payment. [The procedure may include the testing of retained split (or “referee”) samples, an investigation to identify equipment or procedural deficiencies, resampling, and retesting, or may use third-party arbitration, or both.]
- 4.70. *distribution*—an arrangement of data that shows the frequency of occurrence of each successive individual measurement or range of measurements.
- 4.71. *distribution curve*—the smooth curve describing an arrangement of data that shows the frequency of occurrence.
- 4.72. *documentation*—proof in the form of detailed records or charts supporting the effectiveness of a quality assurance system.
- 4.73. *end-result specifications*—specifications that require the contractor to take the entire responsibility for producing and placing a product. The highway agency’s responsibility is to either accept or reject the final product or to apply a pay adjustment that is commensurate with the degree of compliance with the specifications. [End-result specifications have the advantage of allowing the contractor flexibility in exercising options for new materials, techniques, and procedures to improve the quality and/or economy of the end product.]
- 4.74. *engineering limits*—the absolute limiting value(s) placed on a quality characteristic beyond which the result for an individual sample is considered to be unacceptable. [Engineering limits are established to identify material that does not provide the minimum required engineering properties. They usually have an upper engineering limit (UEL), a lower engineering limit (LEL), or both.
- 4.75. *estimator*—a statistic used to estimate a parameter to help describe the population. [The estimate may be given as a point estimate or as an interval estimate.]
- 4.76. *event*—the occurrence, or absence, of an attribute.
- 4.77. *expected pay (EP) curve*—a graphical representation of an acceptance plan that shows the relationship between the established quality of a lot and its expected pay. [The EP is the mathematical pay expectation, or average pay the contractor can expect to receive over the long run for submitted lots of a given quality. The EP should be 100 percent pay for work meeting the AQL. Both OC and EP curves should be used by the agency or organization to evaluate how well an acceptance plan is theoretically expected to work.]
- 4.78. *experimental design*—see *design of experiments*.
- 4.79. *F-test (F-statistic)*—a hypothesis test involving the comparison of the variances of two sets of data. The null hypothesis is the variance of one population equals the variance of another population.
- 4.80. *frequency*—the number of items or values that occur within a given interval (or class).
- 4.81. *frequency distribution*—a grouping of data values into intervals (or class intervals) showing the number of values in each interval.
- 4.82. *frequency histogram*—also called “histogram.” A type of bar chart that depicts the frequency of occurrence of each data value as a rectangle (or bar). The width of each rectangle represents the data interval, while the height represents the number of data values in the interval (or class interval).

- 4.83. *frequency polygon*—a broken line graph constructed by drawing line segments that join the midpoints of the top of each rectangle (or bar) in a frequency histogram.
- 4.84. *frequency table*—a tabular presentation of data consisting of a minimum of two columns. One column presents the data intervals (or classes) in some useful order and the other column presents the corresponding frequencies.
- 4.85. *graduated reduction in contract price*—reductions that are initially small for slight deviations from specified requirements but increase rapidly as the size of deviations increases.
- 4.86. *grand mean*—the sum of the means of sets or subgroups of data divided by the total number of sets or subgroups.
- 4.87. *histogram*—see *frequency histogram*.
- 4.88. *hypothesis*—a tentative theory or supposition provisionally adopted to explain certain facts and to guide in the investigation of others. [For example, a statistical hypothesis is a statement concerning the value of a population parameter that can be tested statistically to determine the validity of the statement.]
- 4.89. *hypothesis test*—a statistical procedure based on probability theory used to determine whether a hypothesis is a reasonable statement and should not be rejected, or is unreasonable and should be rejected. [Reasonableness is determined by testing the hypothesis at a specific level of statistical significance.]
- 4.90. *incentive/disincentive provision (for quality)*—a pay adjustment schedule that functions to motivate the contractor to provide a high level of quality. [A pay adjustment schedule, even one that provides for pay increases, is not necessarily an incentive/disincentive provision, as individual pay increases/decreases may not be of sufficient magnitude to motivate the contractor toward high quality.]
- 4.91. *increments*—small quantities of material of equal size that are obtained from a sampling location and combined to form a sample.
- 4.92. *independent assurance (IA)*—activities that are an unbiased and independent evaluation of all the sampling and testing (or inspection) procedures used in the quality assurance program. [IA provides an independent verification of the reliability of the acceptance (or verification) data obtained by the agency and the data obtained by the contractor. The results of IA testing or inspection are not to be used as a basis of acceptance. IA provides information for quality system management.] The Independent Assurance Program can be set up on a project basis, which is the traditional approach, or on a system basis. Frequencies for the project approach are based on project quantities, while the system approach is typically administered on a statewide basis and frequencies are based on time with the intent of covering all active personnel over multiple projects.
- 4.93. *independent sample*—a sample taken without regard to any other sample that may also have been taken to represent the material in question. [An independent sample is sometimes taken to verify an acceptance decision. This is possible because the data sets from independent samples, unlike those from split samples, each contain independent information reflecting all sources of variability, i.e., sampling, testing, materials, and construction.]
- 4.94. *independent t-test*—a hypothesis test involving the comparison of the means of two independently obtained sets of data. The null hypothesis for this test is that the mean of one normal population is equal to the mean of another normal population.