The Skinny on Precision and Bias: Aiming Our Sights on Bias

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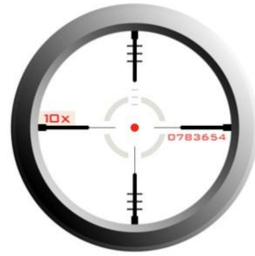
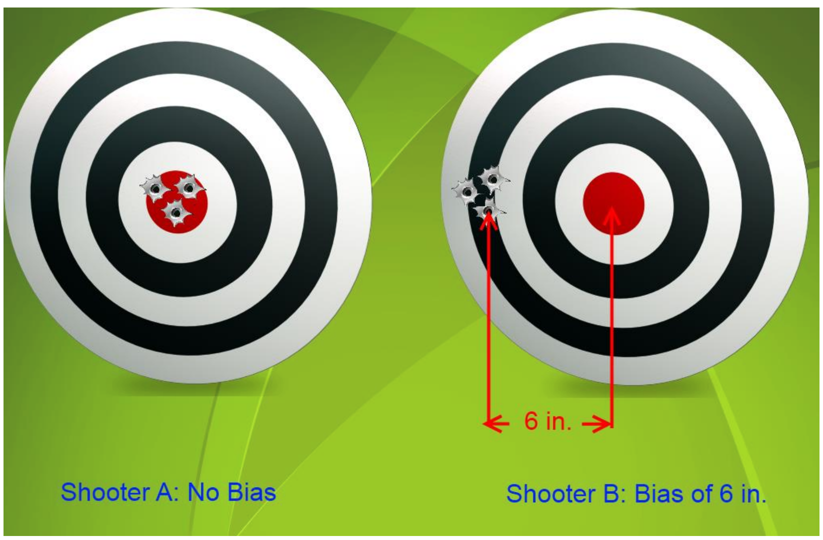


Our previous article examined precision and its importance in materials testing. This is the follow-up article in which we will address bias, which is the other component of the precision and bias statements frequently found at the end of AASHTO and ASTM test methods.

What is Bias?

Bias, or systematic error, is defined by *Form and Style for ASTM Standards*, as the “error inherent in the test method that contributes to the difference between a population mean of test results and the accepted reference or true value.” To put it another way, bias is the accepted reference value subtracted from the mean of a large number of test results. Bias results from any systematic process in which there is a distortion of the measured value from the true value. Since it is the result of a systematic process, any amount of bias in the measurements that we make is predictable and consistent. For example, one cause of systematic error could be a batch of equipment that has been manufactured slightly out of tolerance. This contrasts with random error (precision), which is unpredictable and is typically due to interpolation, human error, and other environmental factors.

An easy way to grasp bias might be to think of target shooting. If Shooter A can consistently hit a bull’s eye at 20 feet, there is no bias in his method. If Shooter B uses the same gun to take the same shot under the same conditions, but reliably misses six inches to the left of center, we can state that Shooter B has a 6-inch bias inherent to his method. Since this error is consistent and predictable, Shooter B need only aim 6 inches to the right to correct for this bias.



Accepted Reference Values

From *ASTM E177, Standard Practice for Use of the Terms Precision and Bias in ASTM Test Methods*, we learn that “an accepted reference value is a value that serves as an agreed-upon reference for comparison.” A good example would be the accepted knowledge that pure water freezes at exactly 0°C at sea level. This information can then be used to verify the calibration of thermometers. When pure water freezes, we know the temperature to be exactly 0°C, and consequently the thermometer should read exactly 0°C. The difference between the known reference value of 0°C and the temperature measurement by the thermometer is the bias.

So how are reference values determined? Again, *ASTM E177* gives guidance on acceptable means for establishing reference values. These values fall in to three distinct classes of values: (1) an established or theoretical value determined using accepted scientific principles, (2) an assigned value based on experimental work, or (3) a consensus value based on collaborative experimental work.

Determining Bias

In order for our bias statements to have validity, a minimum number of trials must be conducted to minimize the effect of the random component of measurement error. ASTM requires that at least thirty or more test results, measured independently, be used during the creation of a bias statement. It should be noted that equipment can create a bias in test results. However, this error is due to a flaw in the equipment, not the test method. This type of systematic error is not considered or included in the estimation of the bias of a test method.

There are very few construction materials test methods that contain bias statements. This is due to the fact that there are no accepted reference materials for many common construction materials, such as aggregate, soil, and asphalt. These types of materials are naturally occurring in our environment and are inherently subject to a high degree of variability.

Real-World Examples
A typical bias statement looks something like this:

> Bias—When experimental results are compared with accepted reference values (or known values from accurately compounded specimens), the bias of the test method is found with 95% confidence to be between *x* and *y*.

This means that, statistically, we are confident that the bias of the test method is between values *x* and *y* 95% of the time. (For a great explanation of confidence intervals, check out Bob Lutz's article, "Measurement Uncertainty for Hillbillies".)

One example of a construction material that includes a bias statement can be found in *ASTM D7635/D7635M, Standard Test Method for Measurement Thickness of Coatings Over Fabric Reinforcement*. Since the material used in the coating is synthetic, the manufacturer is able to provide a known value for the thickness of the material being tested. By utilizing multiple laboratories, a population average of (thickness) results is established. Comparing the known and the observed values allows us to establish the bias.

Putting Bias Statements to Use
So now you understand what a bias statement is and how it is developed. But what are you supposed to do if you run into a standard that has a bias statement? This part is easy. In some cases, if a method is known to have a bias, it will be corrected for in the calculations section of the standard. If this is the case, the precision and bias section of the standard will include a statement to that fact, and you don't have to do anything. In other cases, it may be appropriate to correct for a known bias when reporting test results. If you do this, be sure to include a statement clearly indicating that your measurements have been corrected for bias in the test report.

The next time you're skimming a test method, take a glance at the precision and bias statement. In many cases, there will either be no reference at all to bias, or there will a brief sentence simply stating that since there are no known reference materials, a bias statement is not applicable. Either way, it will give you piece of mind to know that the writers of the standard at least considered bias when developing the test method.