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

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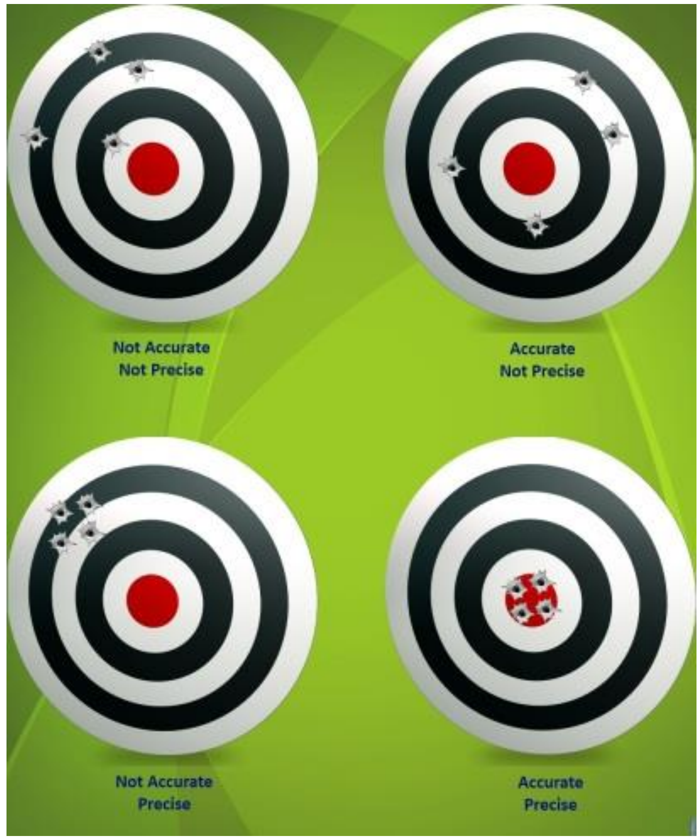
What are precision and bias statements?
Precision and bias statements are those often skimmed-over sections at the end of the AASHTO and ASTM test methods. You know - the section after the "Report" and before the "Keywords" sections. Although these statements are easy to overlook, without precision and bias statements, test methods would have no merit. These statements are the evidence that proves that the test method works.



Accurate Vs. Precise: The Bullseye Approach

Precision
Precision is a term that is thrown around loosely and commonly misunderstood. Far too often it is used interchangeably with accuracy. Unlike accuracy, precision is not a measurement of closeness from the true value; it is a measurement of closeness between individual test results. According to "The Form and Style for ASTM Standards," precision is defined as the "closeness of agreement between test results obtained under prescribed conditions." That being said, results can be accurate yet imprecise, precise yet inaccurate, and sometimes neither precise nor accurate. Precision is measured in terms of repeatability and reproducibility, which are both required to be included in ASTM test methods.

Repeatability (also called single-operator precision or intralaboratory precision), according to ASTM, is the precision of test results that are "obtained with the same test method in the same laboratory by the same operator with the same equipment in the shortest practicable period of time using test specimens taken at random from a single quantity of homogenous material." Reproducibility (also called multilaboratory precision or interlaboratory precision) is the precision of "test results obtained in different laboratories" using the same test method "on random test units from the same lot of homogeneous material." Both reproducibility and repeatability are calculated as a standard deviation of test results, and they establish upper and lower limits for the precision of a test method.

What Does this Mean for My Laboratory?
Suppose your lab is conducting several standard Proctor tests (*AASHTO T 99* or *ASTM D698*) on the same material. How do you know if your optimum moisture content and maximum density values are meaningful? *ASTM D698* details the study in which the precision statement was developed and provides its results. *ASTM E177, Standard Practice for Use of the Terms Precision and Bias in ASTM Test Methods,* tells us that the repeatability and reproducibility limits should not differ by more than the difference two-sigma limit (d2s). I hope you got that! Basically, this means that in 20 standard Proctor tests on the same material, your optimum moisture content and maximum density results between two tests should not be equal to or exceed the d2s limits more than once. Alternatively, you can reference column 5 in Table 3 of *ASTM D698*, "Acceptable Range of Two Test Results." Table 3 indicates that for soil type CH, the repeatability for optimum moisture content and maximum density should not differ by more than 0.7% and 1.3 pounds per cubic foot (pcf), respectively. The acceptable range of two results is the same as the d2s limit. Therefore, the difference between two properly conducted tests should not exceed this limit. Otherwise, you may want to investigate your testing practices or equipment.

TABLE 3 Summary of Test Results from Triplicate Test Laboratories (Standard Effort Compaction)												
(1) Number of Triplicate Test Labs			(2) Test Value (Units)	(3) Average Value			(4) Standard Deviation			(5) Acceptable Range of Two Results		
Soil Type												
CH	CL	ML		CH	CL	ML	CH	CL	ML	CH	CL	ML
Single-Operator Results (Within-Laboratory Repeatability):												
11	12	11	$\gamma_{d,\,max}$ (pcf)	97.2	109.2	106.3	0.5	0.4	0.5	1.3	1.2	1.3
11	12	11	w_{opt} (%)	22.8	16.6	17.1	02	0.3	0.3	0.7	0.9	0.9
Multilaboratory Results (Between-Laboratory Reproducibility):												
11	12	11	$\gamma_{d,\,max}$ (pcf)	97.2	109.2	106.3	1.4	0.8	0.6	3.9	2.3	1.6
11	12	11	w_{opt} (%)	22.8	16.6	17.1	0.7	0.5	0.5	1.8	1.5	1.3

Copy of Table 3 from ASTM D698: "Acceptable Range of Two Test Results"

Keep in mind that sometimes precision is expressed in terms of the coefficient of variation instead of the standard deviation. The coefficient of variation is the ratio of the standard deviation to the mean, and is often multiplied by 100 to represent the standard deviation as a percentage of the mean. The coefficient of variation is used to illustrate variation of a data set from the average value.

Other Considerations

Not only is the precision and bias statement a fun read, but it has practical value that can be incorporated into your technician competency evaluation program. Use the data in the precision statement to check each of your technicians' repeatability on an individual test. Incorporating this strategy into your technician competency evaluation program will not only improve each of your technician's quality of work, but will also give you confidence that your lab is consistently providing quality test results.

So the next time you are thumbing your way through your favorite test method, take a moment and reflect on the information that lay before you in the precision and bias statement. As you can see, precision statements are very useful. Not only can you use the limits as an indicator of your lab's quality, but they are an indicator of a test method's quality as well.

Bias

Now that we're clear on the meaning and use of precision statements, in my next article we will discuss bias statements and how they can be utilized as a valuable laboratory tool.

References

- AASHTO, "AASHTO T99, Moisture-Density Relations of Soils Using a 2.5-kg(5.5-lb) Rammer and a 305-mm (12-in) Drop," *Standard Specifications for Transportation Materials and Methods of Sampling and Testing*, Part 2A: Tests, 2010.
- ASTM International, "ASTM C670, Standard Practice for Preparing Precision and Bias Statements for Test Methods for Constructions Materials," *Book of Standards*, Volume 14.02, 2010.
- ASTM International, "ASTM D698, Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effor (12 400 ft-lbf/ft3 (600 kN-m/m3))," *Book of Standards*, Volume 04.08, 2008.
- ASTM International, "ASTM E177, Standard Practice for Use of the Terms Precision and Bias in ASTM Test Methods," Book of Standards, Volume 14.02, 2010.
- ASTM International, "ASTM E456, Terminology Relating to Quality and Statistics," *Book of Standards*, Volume 14.02, 2008.
- ASTM International, "ASTM E691, Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method," *Book of Standards*, Volume 14.02, 2010.
- ASTM International, "Form and Style for ASTM Standards," October 2011.