

Proficiency of **Strength** Testing

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Introduction

When two laboratories make a set of cylinders from the same wheelbarrow containing a concrete sample, should they get the same strength? Not exactly! As most people involved in strength testing know there are a wide variety of factors that will impact the measured strength of the concrete from sample preparation and curing in the field to curing and testing in the laboratory.

NRMCA has recently offered a 1-day course that goes into much detail on concrete specifications submittals and strength testing. Much of the portion on strength testing is covered by Luke Snell, Eminent Scholar at Arizona State University. Based on research by him and others, Snell quantified the effects of various factors that affect the measured strength of concrete. He also provided guidance on methods to evaluate the testing proficiency of testing laboratories and technicians.

Round Robin Strength Testing

In the Washington, DC, area, an annual round robin strength testing program is conducted. The Washington Area Council of Engineering Laboratories (WACEL), with the help of ready mixed concrete producers, organizes this program. WACEL accredits its member laboratories and uses this program – the participation in a proficiency sample program – for its accreditation criteria. This is also a requirement for laboratories to conform to ASTM C1077, Practice for Laboratories Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Laboratory Evaluation.

Laboratories are solicited to participate in the program. These include commercial testing, DOT and concrete producer laboratories and about 60 facilities participate annually. The laboratory is provided an ID to maintain confidentiality of the source of results. Concrete batches, representing a nominal 4000 psi and 7000 psi concrete strength levels are produced at a ready mixed concrete plant. Approximately 150 cylinders are cast from each load. The cylinders are covered with plastic and stored for the first 24 hours in a lab environment at about 70°F. Participants pick up the cylinders, transport them to their facilities and test them on the assigned date at 28 days age. The participating labs are required to strip, cure and test the cylinders according to ASTM standard procedures.

The data reported by laboratories are analyzed according to ASTM C 802. Outliers are eliminated using recommendations in ASTM E691. Outlier data are eliminated when the range between the cylinders is large or when there was a statistically significant difference of a laboratory's strength test result from the overall average. Outlier results could be due laboratories receiving defective specimens or improper procedures and/or reporting.

Laboratories are provided ratings for each set of test results. Ratings are based on the difference between a laboratory's result and

the overall average expressed in terms of the number of standard deviations. Ratings are from 1 to 5, with a 5-rating being closer to the overall average. The sign of the rating is based on whether the laboratory's result is greater than (+) or less than (-) the average. Ratings are determined after outliers are eliminated. A continuing tendency to get low ratings should give a laboratory reason to evaluate the cause and determine whether it is systematic or random error. Sequential low ratings with the same sign can indicate systematic error that will need corrective action on equipment or testing procedures.

While in most years 6x12 inch and 4x8 inch specimens were made, in 2009 the program only prepared 4x8-inch cylinders. A set tested by a lab comprised of 3 specimens for each strength level. Figure 1 illustrates the strength results for the 4000 psi concrete reported by the labs with the lab ID beside the data point. This illustrates the premise that all tests from the same wheelbarrow of concrete will not be the same. The main variable that impacts strength – initial curing during the first 24 hours – is the same in this case and it can be assumed that the laboratories received “similar” specimens for strength testing, to the extent that similar specimens can be made.

The following precision estimates are based on the set of data in Figure 1, with CV being the coefficient of variation. These precision estimates are in-line with those stated in the precision of the test method for measuring compressive strength of concrete, ASTM C39. Note that difference between two labs with acceptable strength data (not outliers) is almost 1200 psi. This also illustrates that the laboratory procedures used for testing change the risk of rejecting acceptable product.

Average Strength, psi	5108
Max	5707
Min	4575
Number of labs (in analysis)	53
Within-test standard deviation, psi (CV)	164 (3.2%)
Multi-lab standard deviation, psi (CV)	280 (5.5%)

The within-lab precision is estimated from the range of multiple cylinders from the same set. The multi-lab precision is the expected variation of a test method when different laboratories test the same material. The compilation of the precision estimates collected in the proficiency sample testing program in the DC area is illustrated in Figure 2. This precision estimates are expressed as the coefficient of variation which is reasonably constant over a wide range of strength levels used in the program. These include 4x8 and 6x12 inch cylindrical specimens.

Conclusion

Proficiency sample testing programs provide a good opportunity for laboratories to evaluate their testing procedures and compare

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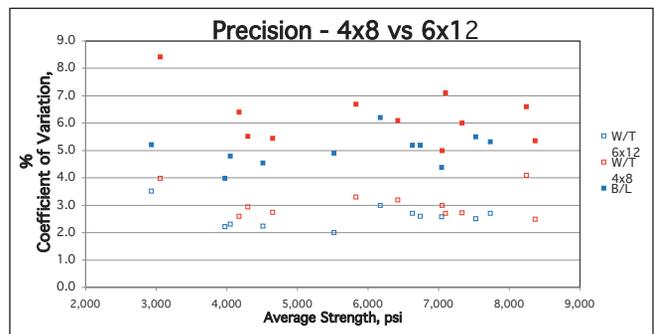
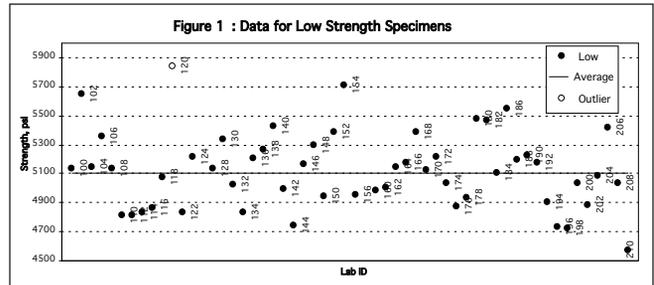
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their results to others. It provides the opportunity for participants to fine-tune and improve on their procedures if necessary. It also provides information on the precision of the test method which serves as guidance to those involved with interpreting test results, especially when these results are used for acceptance and payment decisions. ■



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