

## **BULLETIN #5: WITHIN-TEST STRENGTH VARIABILITY HOW MUCH IS TOO MUCH**

According to the Building Code<sup>1</sup>, a strength test is considered as the average result of compression testing of two individual cylinders cast from the same sample of concrete and tested at the same age. The Code also requires that the test cylinders be prepared and cured in accordance with ASTM C 31 *Standard Practice for Making and Curing Concrete Test Specimens in the Field*<sup>2</sup>, and compression tested in accordance with ASTM C 39 *Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens*<sup>3</sup>.

Theoretically speaking, multiple test cylinders cast from the same sample of concrete should have identical compressive strength test results when tested at the same age. However, it is known that inherent variables exist in the testing of concrete that will result in some degree of difference in the compressive strength results within a set of test cylinders. This difference is known as the within-test variation. As stated in ACI 214 *Recommended Practice for Evaluation of Strength Test Result of Concrete*<sup>4</sup>, “the within-test variation is affected by variations in sampling, molding, consolidating, transporting, curing, capping, and testing specimens”. Nonetheless, the strength variation among companion test cylinders should be minimal for specimens that are properly prepared, cured, and compression tested.

The within-test variability can be measured by computing the range, which is defined as the arithmetic difference between the highest and lowest individual compressive strength measurements within a set of test cylinders. The range can then be used to assess the significance of the degree of variability. Statistical methods are used in ASTM Standards<sup>5</sup> to establish what is considered as an acceptable range for a particular test. This is known as the precision statement for the test method.

ASTM C 39 *Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens* has established a precision statement which identifies the degree of variability that may be expected to exist within a set of test cylinders. The acceptable range for a set of 6 X 12 cylinders cast under field conditions is 8% of the average strength for two specimens or 9.5% for three specimens. In addition, research studies confirm that the same levels of acceptable range would likewise apply to 4X8 cylinders cast and cured under field conditions.

The following table provides examples of the acceptable with-in test range for various levels of compressive strength for a test set (not the design strength,  $f'c$ ).

**Table 1:  
Examples of Maximum Acceptable Range Within A Set of Test Cylinders**

Average Compressive Strength of Test Set	Acceptable Within-Set Range (2 Cylinders)	Acceptable Within-Set Range (3 Cylinders)
3000	240	285
3500	280	330
4000	320	380
4500	360	430
5000	400	475
5500	440	525

Since these limits represent an acceptable range, it must be inferred that a range greater than the limits stated is unacceptable. Although a high within-test range will not identify the particular testing deficiency responsible for the excessive variability, efforts should be made to isolate the reasons for the testing error(s) and make corrective measure as needed.

The Technical Committee of the Virginia Ready-Mixed Concrete Association has supplied this information as a service to the concrete construction industry.

**References:**

- International Building Code 2003, International Code Council, Inc. Falls Church, VA, 2003
- ASTM C 31-98, Standard Practice for Making and Curing Test Specimens in the Field, ASTM International, West Conshohocken, PA, 1989
- ASTM C 39-01, Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens, ASTM International, West Conshohocken, PA, 1989
- ACI 214R-02, Recommended Practice for Evaluation of Strength Test Results of Concrete, American Concrete Institute, Farmington Hills, MI., 2002.
- ASTM C 670-03, Standard Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials, ASTM International, West Conshohocken, PA, 1989.
- Detwiler, Rachel J., Thomas, Wendy, Swor, Terry E, Acceptance Testing Using 4 X 8 in. Cylinders, Concrete International, American Concrete Institute, Farmington Hill, MI, 2006.