

BULLETIN #2: INTERPRETING COMPRESSIVE STRENGTH TEST RESULTS OF CONCRETE

Every year thousands of test cylinders are made from ready-mixed concrete delivered to construction projects. Later these cylinders are tested in compression at a laboratory and the results reported. The results of these tests can provide important information. However, considerable confusion often exists regarding the interpretation of the strength test results. When the results are misinterpreted, or misapplied, it is common practice for a needlessly expensive investigation to follow. To clarify this issue the codes and specifications related to strength testing must be examined, as well as understanding the purpose that the tests are intended to address.

In Virginia, the legally adopted code that governs regarding the strength testing of concrete is the International Building Code (IBC) which cites *ACI 318-Building Code Requirements for Structural Concrete* as the governing code document for concrete. The Code has very specific requirements pertaining to the interpretation of strength test results. As a Code reference, *ASTM C 31 Standard Practice for Making and Curing Test Specimens in the Field* clearly defines the requirements for the fabrication and curing conditions for strength test specimens as well as the intended purposes for the strength testing.

The purpose for the compressive strength testing must be considered. Strength testing may be required for any of the following reasons:

For evaluation and acceptance of the concrete.

These test specimens are referred to as:

- laboratory cured
- standard moist cured cylinders
- acceptance cylinders

The results are used to assess compliance with the design strength acceptance criteria.

To judge the adequacy of curing of the structure.

These test specimens are referred to as “field cured” specimens.

To determine the time required before forms can be removed.

These are also referred to as “field cured” specimens.

“Acceptance cylinders” are used to judge the strength potential of the concrete as delivered to the construction site, when sampled and cured under prescribed conditions. The “field-cured cylinders” are cured in an environment similar to that of the structure. The field-cured cylinders can then be used to judge either the efficiency of the curing of the structure or determine when the concrete in the structure can safely support loads in order to permit the removal of formwork. Therefore acceptance cylinders and field-cured cylinders are not interchangeable. A set of test specimens intended to be used to judge “acceptance” cannot be likewise used as “field cured” specimens for the other purposes outlined above or vice versa. A separate set of strength specimens is required for each application, and the results interpreted in their proper perspective.

Another common point of confusion is the interpretation of the strength test results of “acceptance cylinders.” Quite often a strength test result is labeled a “failure” if it is below $f'c$ by any magnitude, and core testing often follows. This all-too-common scenario clearly underscores the fact that there are many misconceptions regarding the interpretation of concrete strength test results. To clarify this issue, it is necessary to refer to the direction provided in the legally adopted standards in Virginia, which in this case is ACI 318. ACI 318 has very specific directives regarding the acceptability of strength test results in relation to the design strength, $f'c$ as stated:

“Strength level of a concrete mixture shall be acceptable if (1) and (2) are satisfied:

1. Every arithmetic average of any three consecutive strength tests equals or exceeds $f'c$.
2. No individual strength test falls below $f'c$ by more than 500 psi if $f'c$ is 5000 psi or less; or by more than $0.10f'c$ if $f'c$ exceeds 5000 psi.”

More simply stated, the concrete meets the strength specification provided that the average of three consecutive strength-tests equals $f'c$ and that no single test is more than 500 psi below $f'c$. All too often there is a rush to test core samples from the structure when a strength test result is below $f'c$. As explained above, this is not necessary in most cases. Even if the average of three consecutive tests is below $f'c$, so long as all tests are above $f'c-500$ psi, the Code merely requires that “steps shall be taken to increase the average strength of subsequent strength test results.” Core testing is only required by the Code when a strength test is more than 500 psi below the specified design strength.

In the event core testing is necessary, the Code has specific criteria that must be followed.

- 1. Number of Cores:** Three cores are required from the area of concrete represented by the strength test that is more than 500 psi below $f'c$.
- 2. Moisture Conditioning and Time of Test:** Cores cannot be compression tested the same day that they are taken. They must first be properly moisture conditioned. The moisture condition of the core samples at the time of test is critical to achieve an accurate strength measurement. The procedures to attain a uniform moisture condition are addressed in the Code reference document ASTM C 42 *Standard Practice for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete*. The standard calls for wiping off all drilling water from the cores immediately after removal then sealing the cores in a water-tight bag or container until time of compression testing. Most often, the ends of the cores will have to be saw-cut to remove irregularities and to provide an appropriate length to diameter ratio. When a wet-cut saw is used to trim the cores it will be necessary to remove any excess water from the surface of the cores, return them to the sealed container and the conditioning period begins at that point. ASTM C 42 requires a moisture conditioning period of 5 days minimum prior to compression testing.
- 3. Evaluation of Results:** The strength results of the cores do not have to achieve a strength level equal to $f'c$. The Code only requires that the average of the three cores is equal to at least 85% of $f'c$ and that no single core is less than 75% of $f'c$.

With the enormous amount of information contained in the Code and reference standards it is no surprise that confusion and misunderstandings arise related to many issues. However, this review of the Code should clarify the appropriate purpose for strength testing of concrete as well as identify the correct procedures for the interpretation of the strength test results. By following the regulations set forth in the Code quality concrete can be assured while avoiding unnecessary testing and project delays.

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 2015, International Code Council, Inc. Falls Church, VA, 2015.
- ACI 318-14 Building Code Requirements for Structural Concrete, American Concrete Institute, Farmington Hills, MI, 2014.
- ASTM C 42-13, Standard Practice for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete, ASTM International, 100 Bar Harbor Drive, West Conshohocken, PA 19428, 2013.
- ASTM C 31-12 Standard Practice for Making and Curing Test Specimens in the Field, ASTM International, 100 Bar Harbor Drive, West Conshohocken, PA 19428, 2012.