

discussion of construction
issues and techniques

The process of testing concrete and quality assurance criteria for ready mixed concrete delivered to projects are reasonably well established. The owner or the owner's representative hires an independent testing and/or inspection agency to perform quality assurance functions during the construction of the Work. Industry standards provide requirements for the following:

- qualification of testing agencies and testing technicians performing tests at the jobsite and in the laboratory
- frequency of testing
- standardized procedures for obtaining samples and performing tests
- acceptance criteria for fresh and hardened concrete tests
- referee testing and criteria when test results fail to meet the acceptance criteria

Industry standards require that the concrete supplier maintains a quality control plan. Quality control on the part of a ready mixed concrete supplier constitutes proactive actions that ensure that quality of the product is maintained; consistency of product characteristics is assured between loads and for the duration of the project; and steps are taken to avoid the delivery of non-conforming product. Quality control constitutes management of materials used for concrete, the concrete mixtures being produced, and the production process. Certification of production facilities, such as that administered by the National Ready Mixed Concrete Association (NRMCA), provides some assurance that the concrete plants and delivery vehicles comply, at a minimum, with industry standards.

The Need

With regards to strength requirements, the concrete supplier should be able to respond to situations when strength test results are trending towards potential non-compliance. Prior to a project, the supplier is required to use a complete test record from previous projects as a basis for establishing their concrete mixture proportions and properties for new Work, and to provide this documentation in a submittal to the engineer of record.

To ensure that this occurs, it is essential that the concrete supplier be provided ALL reports of acceptance tests performed by third-party testing agencies on the concrete mixtures delivered during the a project. These test reports should be provided in a timely manner so that strength test and other data can be charted and proactive action can be taken to ensure that specified requirements for concrete, especially strength, are not violated. *Figure 1 (page 16)* illustrates a chart of the individual strength test results plotted along with the specified strength and the ACI 318 acceptance criteria for these data. The overall average of the

complete strength test record is also plotted. The overall average can be plotted for smaller sets of strength tests to observe a change in the average strength during different periods. *Figure 2 (page 16)* plots the running average of 3 consecutive strength tests relative to the specified strength. The running average of 3 tests should not fall below the specified strength. More involved quality control charting processes, such as cusum (cumulative sum) charts are also used to gain an early indication of a decreasing trend of test results. Some of these are discussed in ACI 214R, *Guide to Evaluation of Strength Test Results of Concrete*.

When low strength problems occur, considerable time and money is expended to evaluate the cause and to take corrective actions. It is thereby beneficial to all parties to minimize the risk of low strength concrete. From the perspective of the engineer of record, he/she is assured that characteristics of concrete are consistent with the needs of the project, corrective action can be taken when a decreasing trend is observed and before there is a non-conformance with the project specifications, and dispute resolution and the associated project delays and increased cost can be avoided.

Why is the distribution of test reports an issue? Some testing agencies do not provide test reports to concrete suppliers because they believe these reports should only go to the entity that contracted with them for the testing services. Some testing agencies believe that distribution of test reports to several entities increases their cost, although this concern should be less of an issue with the widespread availability of electronic communications. Some testing agencies only provide failing strength test results to concrete suppliers to notify them that a problem exists. Clearly this is undesirable because, if all previous tests were provided to the concrete supplier, a trend or anomaly may have been observed and a failing test result could have likely been avoided.

Many concrete producers have established relationships with local testing agencies to ensure that test reports of all tests performed on their concrete are distributed to them. With the ease of web-based test reporting systems, the distribution of test reports is streamlined and can be readily accessed by pertinent project team members.

Revisions to ACI 318

Important revisions were approved in the ACI 318-11 *Building Code Requirements for Structural Concrete* to address issues related to testing of concrete and reporting of results. Section 5.6.1 of ACI 318-11 has been revised to address distribution of test results. The following is the excerpt from the Code:

continued on next page

Acceptance Test Reports of Ready Mixed Concrete

Who Should Get Them?

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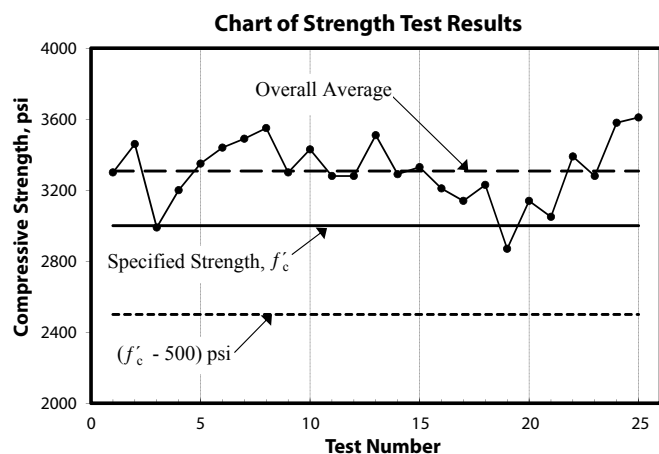


Figure 1: Monitoring strength test results relative to strength acceptance criteria.

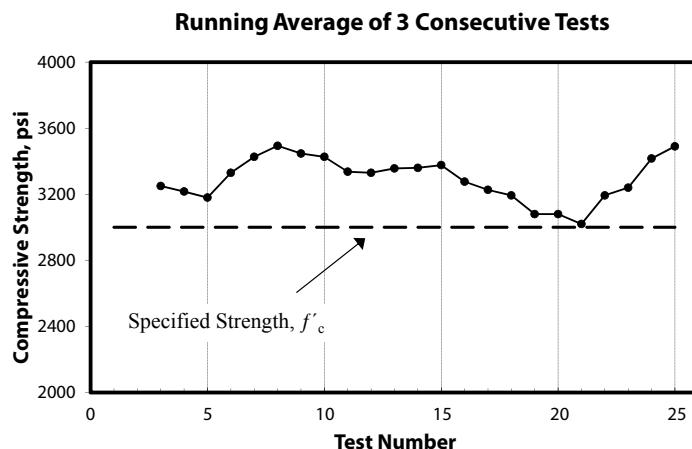


Figure 2: Running average of 3 consecutive test results relative to the specified strength.

All reports of acceptance tests shall be provided to the licensed design professional, contractor, concrete producer, and, when requested, to the owner and the building official.

The following is the discussion in the Commentary to this Code provision:

The Code requires testing reports to be distributed to the parties responsible for the design, construction, and approval of the work. Such distribution of test reports should be indicated in contracts for inspection and testing services. Prompt distribution of testing reports allows for timely identification of either compliance or the need for corrective action. A complete record of testing allows the concrete producer to reliably establish the required average strength f_{cr}' for future work.

This commentary highlights the fact that distribution of test results is important not only to the current project, but also to quantify the level of quality control of the concrete supplier, which is measured by the standard deviation of strength test results. While a component of this variability is attributed to testing, a measure of standard deviation allows for continuous improvement and facilitates better optimization and reliability of concrete mixture proportions for future projects. A complete test record from past projects is required for use as the basis of a submittal for future work. Optimization of concrete mixtures for the specified performance will avoid significant overdesign for strength. The benefits include reducing the potential for cracking of concrete associated with thermal effects, drying shrinkage and some types of chemical-related distress

that can negatively impact the service life of concrete structures.

The contractor or other owner's representative should ensure that the distribution list of test reports includes the entities listed in ACI 318. ACI Committee 311 publishes ACI 311.6, *Specification for Ready Mixed Concrete Testing Services* that can be used by the owner as part of the contract for testing and inspection on projects. One of the mandatory checklist items that is required to be addressed to make this a complete specification is to state the agency's responsibility for submittal of reports to include timelines, methods of delivery, and the distribution list. The distribution list defined in the contract with the testing agency should include the concrete supplier and all the other parties listed in ACI 318-11. Details about the acceptance testing and distribution of test results should be addressed in a concrete pre-construction conference. Details on acceptance testing that includes proper distribution of test reports, time constraints, and the distribution list should be discussed with the involvement of the engineer of record, general contractor, the concrete contractor, the concrete supplier and the testing agency. A comprehensive checklist covering various aspects of construction and testing is published by the National Ready Mixed Concrete Association and the American Society for Concrete Contractors. Include the importance of the concrete pre-construction conference and incorporation the proper report distribution and transmission method into the conference agenda. ACI Committee 132 on Responsibility in Concrete Construction is finalizing their document that defines this important process.

ACI 318-11 includes another revision regarding testing that now requires testing agencies to comply with ASTM C1077, *Standard Practice for Agencies Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Testing Agency Evaluation*. This has been a requirement in ACI 301, *Specification for Structural Concrete*, and ASTM C94, *Specification for Ready Mixed Concrete*, but is now also an ACI 318 Code requirement. ASTM C1077 establishes quality systems for testing agencies, requiring labs to have periodic inspections of their procedures and equipment, verifies qualifications of testing technicians and requires laboratories to participate in proficiency sample testing. Proficiency sample testing allows labs to compare their results to those of other labs when the same material is tested. The validation that a laboratory complies with ASTM C1077 is obtained through an accreditation program provided by several national and local entities; however, ACI 318 does not require the testing agency to be accredited. ACI 311.6 goes this extra step to require testing agencies to be accredited and lists acceptable testing agency accreditation programs.

Conclusion

It is imperative that information obtained from third-party evaluation of any product be provided to the manufacturer. This is not only of interest to the manufacturer, but it also serves the interest of the user of the product. Timely distribution of test results to all impacted parties will ensure that quality is maintained and will save time, money and prevent delays in project schedules. ■

References

- 1) ACI 318-11/ACI 318R-11, *Building Code Requirements for Structural Concrete and Commentary*, American Concrete Institute, Farmington Hills, MI, [**www.concrete.org**](http://www.concrete.org).
- 2) ACI 301-10, *Specifications for Structural Concrete*, American Concrete Institute, Farmington Hills, MI, [**www.concrete.org**](http://www.concrete.org).
- 3) ACI 311-09, *Specification for Ready Mixed Concrete Testing Services*, American Concrete Institute, Farmington Hills, MI, [**www.concrete.org**](http://www.concrete.org).
- 4) ASTM C94/C94M-12, *Specification for Ready Mixed Concrete*, Annual Book of ASTM Standards, American Society of Testing Materials, Volume 4.02, ASTM International, West Conshohocken, PA, [**www.astm.org**](http://www.astm.org).
- 5) ASTM C1077-12, *Standard Practice for Agencies Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Testing Agency Evaluation*, Annual Book of ASTM Standards, American Society of Testing Materials, Volume 4.02, ASTM International, West Conshohocken, PA, [**www.astm.org**](http://www.astm.org).
- 6) ACI 214R-11, *Guide to Evaluation of Strength Test Results of Concrete*, American Concrete Institute, Farmington Hills, MI, [**www.concrete.org**](http://www.concrete.org).
- 7) Checklist for Concrete Pre-Construction Conference, jointly published by the National Ready Mixed Concrete Association ([**www.nrmca.org**](http://www.nrmca.org)) and the American Society for Concrete Contractors ([**www.asconline.org**](http://www.asconline.org)).