NRMCA
NATIONAL READY MIXED CONCRETE ASSOCIATION

Acceptance Testing

What are the requirements in industry standards for obtaining samples for acceptance testing of concrete?

Industry standards, such as ACI 318, ACI 301, and ASTM C94 state that samples for acceptance testing of concrete should be obtained in accordance with Practice ASTM C172. The intent is to obtain representative samples of fresh concrete delivered to a project. Tests performed on this sample determine if concrete complies with the quality requirements of project specifications. ASTM C172 describes sampling from stationary (plant), paving, and truck mixers, and from agitating and nonagitating equipment transporting central-mixed concrete. Sampling from volumetric batching and continuous mixing equipment is also covered. ASTM C172 does not include procedures for obtaining samples from placement equipment, such as concrete pumps, conveyor belts, or crane and bucket placement.

Stationary Mixers (tilting and non-tilting) – obtain two or more portions at regularly spaced intervals during discharge of middle portion of the load. Do not sample from the first and last portions of discharge. Obtain samples from the entire discharge stream with care not to restrict the flow of concrete.

Paving – Obtain samples from at least 5 portions from a discharged pile. Avoid contamination from the subgrade.

Revolving Drum Truck Mixers or Agitators – Sample after all adjustments are made and mixed in the batch. Obtain two or more portions at regularly spaced intervals during discharge of the middle portion of the load. Do not sample from the first and last portions of discharge. Divert the complete discharge stream into the sample container. Regulate the rate of discharge when collecting sample.

Sample size is a minimum of one cubic foot if making strength specimens. Smaller samples can be used for slump and air content tests. The sample container is typically a wheelbarrow with a nonabsorbent surface. Portions of the sample should be obtained within 15 minutes. The sample should be conveyed to the point of testing and molding specimens; and combined and remixed to achieve a composite sample. Tests for slump, temperature, and air content should be started within 5 minutes after obtaining the last portion of the composite sample. Molding specimens for strength tests should be started within 15 minutes. The sample should be covered to protect it from sun, wind, contamination, and evaporation.

For strength specimens what is standard curing and why should this be done?

For determining if concrete supplied to a project complies with the specified strength requirements, industry standards such as ACI CODE-318 require that strength specimens molded at a project site be subjected to standard curing. This ensures that the potential strength of the concrete supplied is determined and is not impacted by variations in ambient temperature, freezing, or loss of moisture. Standard curing of test specimens is also required for checking the adequacy of mixture proportions for concrete strength and for quality control.

Practice ASTM C31 defines the requirements for standard curing – after specimens are molded, for the initial curing period, specimens for measuring flexural strength (beams) and compressive strength (cylinders) should be maintained in a temperature environment between 60 and 80°F and protected from loss of moisture. If the specified compressive strength is equal to or greater than 6000 psi, temperature limits are 68 and 78°F. Specimens should be placed in the initial curing environment within 15 minutes after being molded. Specimens should not be exposed to direct sunlight or radiant heating devices if used. The minimum and maximum temperature and the initial curing method during this period should be recorded and reported.

Specimens should be transported to a laboratory within 48 hours of being molded. Transportation time from the project site to the laboratory should not exceed 4 hours and specimens should be protected from damage during transportation.

At the laboratory, specimens should be placed in a moist room or immersed in lime-saturated water at a temperature maintained within 73.5±3.5°F. It should be ensured that free water is maintained at all times on the surface of specimens. Beam specimens are required to be immersed in lime-saturated water and drying of the surface should be prevented until the completion of testing.

What is field curing and when is it used?

Field curing is a process of storing test specimens in the field in a temperature and moisture environment similar to in-place concrete. Field curing is used to obtain an estimate of the in-place concrete strength; for comparison of test results of standard cured specimens or with test results of other in-place test methods; to check the adequacy of curing and protection of the concrete in the structure; to determine form or shoring removal; or to determine the in-place strength of a structural member before post-tensioning. Other methods used to estimate in-place strength, such as cast-in-place cylinders, pull-out tests, and maturity methods that measure the time-temperature dependency of strength with a pre-determined correlation are preferred over field-cured cylinders by ACI PRC-306R-16. Field-cured cylinders should not be used to determine the acceptance of concrete supplied to a project. Standard cured cylinders are used for acceptance of concrete. Field-cured cylinders are made in addition to and not in lieu of standard-cured cylinders. For more information about field curing please refer to ASTM C31.

When should you investigate low strength test results?

A test result is the average of two cylindrical specimens tested at the same age, typically 28 days.

There are two acceptance criteria for compressive strength tests (in psi) in ACI 318:

1. The running average of 3 consecutive tests should be equal to or greater than the specified strength, f'_c
2. Each individual test result should be equal to or greater than $(f'_c - 500)$ or 0.9 f'_c when $f'_c \geq 5000$ psi

According to ACI 318, a low strength investigation should be conducted when strength tests do not comply with criterion 2. If criterion 1 is not met, steps should be taken to increase the strength. It does not trigger a low-strength investigation. Also, if an individual strength test is less than the specified strength, f'_c, but complies with criterion 2, it does not call for an investigation of low strength or to increase strength level. However, it may be prudent to take steps increase the strength to avoid a potential non-compliance of subsequent tests.

How do you investigate low strength test results?

Initially, it should be verified that sampling, molding test specimens, standard curing, and testing was conducted in accordance with the ASTM standards. If these are in order, the designer should determine using design calculations whether structural capacity of the portion of the structure represented by the low strength test result is deficient. Non destructive testing, such as rebound hammer or penetration probes can be used to evaluate the relative strength compared to a section of the structure that has acceptable strength. Finally, three cores should be extracted from the portion of the structure represented by the low strength. The cores should be sealed in plastic bags, transported to the lab and trimmed if necessary. The cores should be tested at least 5 days after last wetted, and within 7 days. If core strength results are deficient, load testing to evaluate structural capacity may be necessary. NRMCA Publication 133-11 is a good resource that suggests a sequence of steps to consider.

What are the acceptance criteria for core tests?

There are two acceptance criteria for core strength test results in ACI 318

1. The average of three cores should equal or exceed 0.85 f'_c
2. The strength of each core should equal or exceed 0.75 f'_c

What do ACI standards say about distribution of test result?

ACI 318 requires that **all** test results should be distributed to the impacted stakeholders including the ready mixed concrete producer. ACI 301 and ASTM C94 also state that test results should be distributed to concrete producer in a timely manner. ACI 318, in the commentary, explains that it is important for test results to be provided to the concrete producer so that corrective action can be taken if strength test results are trending low so as to avoid a situation where strength tests will fail the acceptance criteria. It is also important that all test results are forwarded because this is useful in establishing the strength of concrete mixtures for future projects based on the mixture proportioning requirements in ACI 301. With the possibility of distributing test results electronically, there is no cost to the testing agency and thereby no reason to withhold test results from the entity whose product is tested. This distribution should be supported by the entity that establishes a contract with the testing agency.

What are the ACI 318 and 301 requirements for third party acceptance testing?

Testing agencies engaged for acceptance testing of concrete should conform to ASTM C1077. This standard establishes a quality system for testing agencies, requires oversight and test report review by a licensed engineer, requires technicians maintain current certification for tests performed in the field and in the laboratory, and requires technicians to be trained and evaluated on performance of test methods at least annually. ASTM C1077 also requires testing agencies to participate in proficiency sample testing programs that evaluate their results to other participants in the program and that the facility be inspected nominally every two years. Testing agencies should maintain accreditation that verifies their conformance to ASTM C1077.

Specifications Details

Can water be added to a truck mixer at the jobsite?

ASTM C94 does permit the addition of water at the jobsite. The addition is permitted if the slump is less than required and if the mixing water content based on the mix design is not exceeded with the addition of water. This requires that all sources of water introduced to the concrete batch be determined, documented, and preferably the limit of the addition by the contractor or purchaser is stated on the delivery ticket. Any addition of water requested by the purchaser should be documented and signed off on the delivery ticket so that this is part of the record for the quality of the batch supplied. ASTM C94 also recognizes the use of automated systems that estimate the slump of concrete in the mixer and add water (or admixtures) to increase slump to the target level. These systems should maintain a record of these additions. ASTM C94 also permits adjustments to a batch of concrete with air entraining admixture to increase the air content or water reducing admixtures to increase slump. All adjustments to a batch of concrete should be followed by at least 30 revolutions of the mixer at mixing speed to incorporate the water or admixture addition in the concrete and get it mixed to the required homogeneity.

Can recycled water and non-potable water be used to make concrete?

ASTM C94 permits the use of recycled and non-potable water as mixing water in concrete. Such water should comply with Specification ASTM C1602. To qualify these sources of water for use, the water should be tested and qualified. A batch of mortar or concrete is prepared with the test water and compared to one made of tap water, representing the control. The strength of test specimens at 7 days of the test batch should not be less than 90% of the strength of specimens made from the control batch. Additionally, the initial time of setting, measured in accordance with ASTM C403 should not be accelerated by more than 1 hour or retarded by more than 1.5 hours compared to that of the control batch. Additional optional limits are stated in ASTM C1602 on the composition of the water. A test sample is sent to a chemical testing laboratory. Limits are established for alkalis as Na_2Oe, chlorides, sulfates, and total solids. Any one or more of these optional limits can be specified by the purchaser when it is important to the structure being built.

Is it appropriate to specify a minimum cement content?

There are no minimum cement content requirements included in any industry standards – ACI, ASTM, and others. This type of requirement is a remnant of the past when specifications for concrete were very prescriptive (most still are). Minimum cement content in specifications, especially when the content is higher than necessary for required performance, constrains the ability of the proficient concrete producer to optimize mixtures for performance and sustainability. The cement content that is higher than needed will increase potential for cracking, increase the permeability of concrete, increase the temperature generated in the mixture, and have adverse effects on the durability of concrete. Requiring a minimum cement content for improved durability is a fallacy that should be recognized. It increases the strength considerably greater than the specified strength and thus removes the incentive to reduce material, manufacturing, and testing variabilities. In the current age where the focus is on minimizing the carbon footprint of concrete for sustainable construction, this requirement limits the ability of the concrete producer from achieving project goals.

When should a maximum w/cm be specified?

It is recognized that for a specific set of materials there is a unique relationship between *w/cm* and strength or durability. Concrete producers use the *w/cm* for proportioning concrete mixtures to achieve the required strength and durability. Within a specific plant, the relationship varies depending on air entrainment, size and type of coarse aggregate, and other factors. However, *w/cm* should not be specified if not needed. There can be a considerable difference in the performance of concrete at the same *w/cm* for different mixtures based on the cementitious materials and other materials used. Specifying a maximum *w/cm* will result in a higher cementitious materials content based on the starting water content used for target slump. It increases the strength considerably greater than the specified strength and thus removes the incentive to reduce material, manufacturing, and testing variabilities. Specifying a low max *w/cm* will also impact constructability by making mixtures stickier and more difficult to place and finish.

In industry standards, the specification of max *w/cm* is used for concrete that will be exposed to various conditions that impact its durability and thereby service life. It is used for the durability provisions in ACI 318 for exposure to freezing and thawing, exposure to moisture when a low permeability is needed, exposure to high sulfates, and for corrosion protection of reinforcement. In all cases, a consistent strength level is tied to the specified maximum *w/cm.*

A preferred option is to specify a performance alternative for permeability or other required performance. See www.nrmca.org/p2p for more information on performance-based alternatives to prescriptive limits.

Should maximum limits on SCM content be specified?

There is one condition where ACI 318-19 requires maximum limits on supplementary cementitious materials, such as coal ash, slag cement, silica fume, or natural pozzolans. This is for Exposure Class F3 that is assigned when concrete is exposed to freezing and thawing conditions and the application of deicing chemicals. The concern is an increased potential for scaling of concrete surfaces that will reduce the clear cover to reinforcement and impact corrosion. It has since been recognized that this limit is generally a consequence of finishing practice and not a characteristic of the concrete mixture. This limitation has been removed in ACI 318-25.

SCMs are beneficial to improving durability of concrete – these are used to reduce permeability, and minimize the risk of damage from alkali silica reactivity and sulfate attack. There are other benefits to fresh and hardened concrete provided by using SCMs. A specification that places a maximum limit on the quantity of SCMs risks the problem of increasing the potential for durability related deterioration if the maximum limit is lower than that needed for the improved durability.

There are situations where the concrete contractor and producer should partner to determine if higher quantities of SCMs may impact constructability. Some applications include the construction of floor slabs that require a troweled finish (though this has been done successfully), or for other situations where setting and early age strength gain is important to construction. But by and large there is no reason for specifying maximum limits on SCM content.