Concrete in Ohio

Curing Jobsite Concrete Test Specimens and Low Strength Results

Technical information prepared by Ohio Concrete

Most construction project specifications require acceptance testing as a crucial part of quality assurance and adhere to building code requirements. ACI Code-318 and ACI Spec-301 establish standards for acceptance testing of concrete using certified ACI Concrete Field Testing Technicians. They require that strength acceptance specimens be standard- cured in accordance with ASTM C31. These specimens form the basis for determining whether the concrete complies with the project's contract requirements. The most critical and often violated testing requirement directly impacting strength results is the initial curing of the test specimens at the jobsite. Studies *(NRMCA/ASCC, 2024; Obla et al., 2005)* have found that lack of adherence to initial curing requirements per ASTM C31 can result in a 20% average reduction of the concrete's potential 28-day strength. Consequently, this often leads to unnecessary investigations, project delays, and finger pointing.

Jobsite Curing of Concrete Test Specimens

Jobsite curing of test specimens (cylinders or beams) follows one of two methodologies according to their specific purpose; Standard-curing or Field-curing. Each method is designed to evaluate concrete for different reasons.

Standard-cured specimens are used for:

- Acceptance testing for specified strength.
- Adequacy of mixture proportions for strength.
- Producer quality control.

Field-cured specimens are used for:

- Determination of whether a structure can be put into service.
- Comparison with test results of standard-cured specimens or from various in-place test methods.
- Adequacy of curing and protection of concrete in the structure.
- Form or shoring removal time.

S***tandard-cured*** specimens are intended to:

- Evaluate concrete delivered and placed at the jobsite with reduction of variations by standardized temperature and moisture condition.
- Simulate specimens fabricated and cured in a laboratory-controlled environment.

Standard-curing begins with an initial curing environment as close as possible to optimal conditions over the first 24 to 48 hours after casting and before transfer to final curing at the testing laboratory. This curing method requires that sample moistures be preserved and that temperatures be maintained at the jobsite within a specified range during that period.

The less common ***field-cured*** specimens are meant to:

- Evaluate estimated in-place strength of the concrete under field conditions.
- Simulate the exposure conditions of the placed structure.

Field-curing is used to imitate the in-place environment of the concrete as placed and maintained. These test specimen moistures and temperatures are to be simulated to match closely with the concrete placement that the specimens represent. ***Note: Because moistures and temperatures vary considerably from "standard-curing" requirements, field-cured specimens cannot be used to confirm concrete mix design conformance with project strength specifications.***

For more accurate in-place strengths, "match-cured" systems could be employed which use thermo-couple linked systems and special curing boxes with heating/cooling systems that are capable of matching the temperatures experienced by the main concrete placement. Maturity test methods are another effective way to predict in-place strengths, but pre-planning and testing is necessary to establish strength-maturity curves in advance.

Importance of Jobsite Curing

Of critical importance is the initial sample storage and protection at the jobsite to ensure that the test specimens gain strength properly in order to serve the purpose for which they are intended. Small, seemingly insignificant, deviations from the curing and protection procedures may result in apparent low strength test results, which can result in project delays, additional testing costs and deteriorations in construction team relationships. Since the results from a typical set of concrete test specimens may influence the acceptance of a few thousand to tens of thousands of dollars worth of construction labor and materials, it is in the best interest of every project team to make sure that these tasks are completed properly.

Improper curing procedures will produce:

- Inconsistent results.
- Unnecessary delays.
- Unreliable results.
- Additional expenses.

Any deviations in the procedures outlined in ASTM C31, **Standard Practices for Making and Curing Test Specimens in the Field**, will likely result in a lower perceived strength, which create unnecessary delays and higher costs for the project.

There is one proven way to significantly reduce the risk for strength quality control issues. **Make sure your project holds a Concrete Pre-Construction Meeting with all Stakeholders involved in the concrete construction process.**

Pre-construction Meeting *(ACI Committee 132, 5pp.; NRMCA, 2024, 5pp.)*

The best time and place to discuss expectations relative to test specimen curing is at the pre-construction meeting. At the meeting, the construction team, including the testing agency, should discuss the following items related to test specimen curing:

- What type of curing is required by the specifications or construction limitations?
  - Standard-curing for acceptance testing of the specified strength.
  - Field-curing to determine whether a structure can safely be put into service.
- Who is responsible for providing the storage and curing facilities?
  - The licensed design professional should direct who (owner, contractor or testing agency) is to supply and maintain the appropriate equipment to store and cure the test specimens at the jobsite.
  - The contractor should provide an area for storage, including water and power, specifically for curing specimens.
  - Testing agency must ensure the facility and equipment meet ASTM standard requirements.
- How much equipment and personnel will be necessary to sample concrete, fabricate specimens, and complete initial curing?
- Any other items required to provide and maintain the required temperature range and prevent moisture loss in an acceptable initial curing environment.

Standard-Curing Requirements

For specimens requiring ***standard curing*** (acceptance testing), strict adherence to the following conditions and procedures is required.

Storage

Specimens should be molded at the place where they will receive initial curing, however, if this is not practical, they may be moved a minimal distance to the initial curing area within a maximum time of 15 minutes.

Initial Curing Environment

Specimens shall be stored in the following well-maintained conditions:

- The initial curing temperature is 60-80°F for concrete with a specified strength under 6,000 psi and 68-78°F for concrete with a specified strength of 6,000 psi or more.
- Storage temperature shall be maintained by using heating and cooling devices, as needed.

  - Temperatures shall be recorded using a maximum-minimum thermometer or other accepted temperature monitoring device, and the data shall be provided on the strength test report.
  - The environment must prevent moisture loss from the test specimens. Submersion in water is the easiest way to prevent moisture loss and maintain consistent temperatures.
- Specimens shall be shielded from direct sunlight exposure or radiant heating devices.
- Cylinders should not be moved or transported for at least 8 hours after final set or 16 hours after casting. Cylinders must be transported to the testing laboratory within 48 hours of casting unless otherwise specified. During transportation, cylinders should be protected from damage, temperature, and moisture loss. Transportation time to the laboratory is required to be within 4 hours.

Final Curing

Upon completion of initial curing and transportation to the testing laboratory:

- Store strength specimens within 30 minutes after removing the molds.
- Use a water storage tank or moist room meeting the requirements of ASTM C511.

- Cure cylindrical test specimens in continuous contact with water while maintaining a final curing temperature at 73.5 ±3.5°F.
- Beam test specimens are stored in the same environment except that they must be stored in water saturated with calcium hydroxide at least 20 hours prior to testing.

Field-Curing Requirements

For specimens requiring ***field curing*** (form removal or service requirements), strict adherence to the following conditions and procedures is required:

- Store specimens in/on the structure as close to the area represented by the sample.
- Protect the surfaces of the specimens in the same manner the structure is protected.
- Ensure the specimens receive the same temperature and moisture condition as the structure.
- Test the specimens in the same moisture condition as the structure.

  Ex: Specimens from structures allowed to dry should be tested dry.
- At the specified test time, as required by the project, immediately transport specimens to the testing laboratory, protecting from damage, temperature, and moisture loss, and perform strength testing. Transportation time is not to exceed 4 hours.

Note: ACI 306 recommends field curing should not be allowed during cold weather concreting.

Low Strength Results

The impact of failing to adhere to proper curing of jobsite concrete test specimens per the standard requirements is lowered strength of the tested specimens. These results therefore should be considered invalid and not used for acceptance.

The primary reasons for low strength tests directly related to jobsite curing are:

- Failure to maintain moisture in the specimens.
- Failure to maintain the required temperature range – too hot or too cold (including exposure to freezing temperatures).
- Late movement or disruption of cylinders after casting.
- Failure to properly protect early age concrete cylinders during transport to the testing laboratory.

Steps to investigate when low concrete strength test results are reported:

- Collect all field test reports, concrete batch tickets (including any information provided by the ready-mix producer and testing laboratory), and analyze the results before taking action.
- Review the dates and times of batching, sampling, pick up from jobsite and delivery to the laboratory.
- Review concrete and ambient temperatures, number of days specimens were left in the field, procedures used for initial curing in the field, duration of transportation, and subsequent curing in the laboratory.
- Review for any reported testing specimen defects.

Some low results are normal on most projects:

ACI Code-318 and ACI Spec-301 recognize that when mixtures are proportioned to meet the requirements of the standards, low strength results will occur about once or twice in 100 tests due to normal variability. For this reason, ACI states that the strength of Standard-cured test cylinders is satisfactory if:

- The rolling average of 3 consecutive strength tests *(one strength test equals the average of two 6x12 cylinder breaks, or three 4x8 cylinder breaks from the same sample)* meets or exceeds the specified design strength, f'c and no individual strength test is
  - More than 500 psi below f'c (for f'c <5000 psi), or
  - More than 10% below f'c (for f'c > 5000 psi)
  - A minimum of 5 strength tests are needed from each class of concrete for this acceptance criteria to apply.

In-Place Strength Testing

The in-place strength of concrete will not typically be equivalent to that measured on standard-cured specimens due to handling, placing, consolidation, and curing concrete structures. Structural design principles recognizes this and ACI has a process of assuring the structural safety of the concrete construction.

Means of measuring, estimating or comparing the strength of in-place concrete includes non-destructive methods and cores.

Common non-destructive methods include rebound hammer test (ASTM C805) and penetration resistance test (ASTM C803). These methods can also be used to locate potential low in-place strength prior to coring.

If cores are required to investigate the concrete in question, they should be obtained and tested in accordance with ASTM C42.

- A minimum of three cores should be obtained for each area represented by a set of strength tests indicating potential low strength.
- Core specimens shall be placed immediately in watertight bags or containers for moisture conditioning.
- Cores should be tested a minimum of 5 days after they were last wetted (by sawing or coring)

Concrete in an area represented by core tests shall be considered structurally adequate if both the following are satisfied:

- The average of three cores is equal to at least 85% of f'c, and,
- No single core is less than 75% of f'c

If the structural adequacy is not demonstrated via core results, a structural evaluation of the concrete component based on the strength established by testing may be performed.

Accountability

To avoid unnecessary low-strength investigations and detrimental impact on concrete performance the owner or their representative (designer or contractor) should select a proficient testing agency and establish a contract to provide reliable testing services in compliance with the acceptance testing requirements of ACI CODE-318. The contract for quality assurance testing should assign the responsible entity who provides systems used to store test specimens that will comply with initial curing temperature and moisture retention requirements; and require the test report to include information on the curing method and maximum and minimum temperatures recorded during the initial curing period.

Adherence to the standards for acceptance testing of concrete will limit the occurrence of low-strength test results to genuine situations where there could be a problem with the mixture. This minimizes additional costs for evaluation and delays in a project schedule. The requirements of standards should be enforced on projects and nonconformance to them should invalidate the results.

If you believe you have observed a deviation from a recommended ASTM or ACI practice, you should document the apparent deviation(s) via photographs and other records and report them to the responsible parties in charge who were identified during the project pre-construction meeting. This reporting will not only help ensure that the information is properly recorded on the laboratory test report but also provides the testing agency an opportunity to undertake corrective action .

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