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QUALITY CONTROL FOR FIELD-PLACED CONCRETE

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The quality of concrete placed in the field must be properly assessed to ensure both the performance and longevity of the structure being built. So that proper quality is achieved, concrete should be sampled at the construction site using standard testing methods.

For Pennsylvania Department of Transportation projects, execution of the test methods requires a certified field-testing technician. To become certified as a technician in Pennsylvania is a two-part process: a person must successfully complete the American Concrete Institute (ACI) Concrete Field Testing Technician Grade I course and the PennDOT Concrete Field Testing Technician Certification Program. An overview of the testing methods and their use is presented here to provide general guidance to field operations. Specific details about the certification program can be found in PennDOT Publication 536.

STARTS WITH PROPER MIXING

Quality control starts with mixing of the constituents. Concrete commonly consists of fine and coarse aggregates, Portland cement, and water. Proper determination of the relative quantities of each constituent is determined using standardized procedures and is often verified using smaller test batches prior to approval for field use. The mix design process accounts for the desired strength required for the concrete, the workability needed to place the concrete, and the proper air entrainment to survive freezing and thawing during the Pennsylvania winter season. Each of these properties can be examined through tests on the concrete both in its plastic state and after it has hardened.

ASTM TEST METHODS

Testing methods follow the requirements of ASTM International, formerly known as the American Society for Testing and Materials. The use of ASTM standard test methods ensures that repeatable and reproducible results are achieved. Essentially, this means that a properly executed test on a sample of concrete would have the same result regardless of which technician or site it was conducted at. ASTM provides requirements for determination of temperature, slump, unit weight, and air content. In addition, methods are provided for proper sampling and fabrication of concrete test specimens in the field.

Standard ASTM test methods to evaluate field-placed concrete include the following:

- C 31 – Test Method for Making and Curing Concrete Test Specimens in the Field
- C 39 – Test Method for Compressive Strength of Cylindrical Specimen
- C 138 – Test Method for Unit Weight, Yield, and Air Content (Gravimetric) of Concrete
- C 143 – Test Method for Slump of Hydraulic Cement Concrete
- C 172 – Test Method for Sampling Freshly Mixed Concrete
- C 173 – Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method
- C 231 – Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method
- C 1064 – Test Method for Temperature of Freshly Mixed Portland-Cement Concrete

Tests for slump, temperature, and air content allow for assessment of quality of the concrete, and tests for unit weight provides verification on the mix design properties.

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ASSESSMENT OF STRENGTH, WORKABILITY, AND AIR CONTENT

Concrete tests are conducted at multiple points during the field placement. Slump is typically tested from the first batch of concrete delivered and whenever changes in workability are observed. Tests for air content, temperature, and unit weight are also taken from the first batch to ensure quality of the delivered concrete. So that test results are representative of what is being placed, sampling of the material should not be made from the very beginning or end of the batch discharge.

Strength Tests—Strength tests are conducted using cylindrical concrete cylinders, which should be made in accordance with the requirements of the job. The American Concrete Institute (ACI 318) requires that at a minimum strength should be assessed for each 150 cubic yards of concrete or for every 5,000 square feet of concrete placed. The test cylinders range in size from 6 inches diameter by 12 inches high to 3 inches diameter by 6 inches high. Smaller cylinders are easier to handle; however the diameter of the cylinder must be greater than three times the maximum nominal size of the coarse aggregate. For example, a concrete with a maximum aggregate size of 0.75 inches could use a 3 x 6 inch cylinder, while an aggregate size of 1.5 inches would require a 6 x 12 inch cylinder at a minimum.

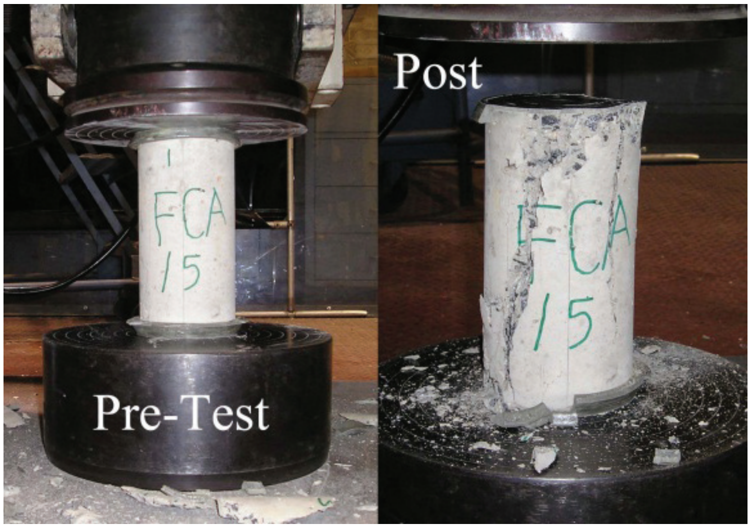
The concrete cylinders used to test concrete strength are fabricated on a site.

Concrete strength is the most critical characteristic when considering structural performance. Concrete has a both a tension and a compression strength associated with it. In most cases, however, the tension strength is low and is neglected during design. To accommodate tension in a concrete member, steel reinforcement is added.

Compression strength is typically defined in terms of the strength at an age of 28 days after placement. PennDOT (Publication 408) defines a number of classes of concrete based on application.

Class AAA is used for bridge decks and is required to have a compressive strength of 4,000 psi at 28 days (i.e., one square inch of concrete supports a load of 4,000 pounds); class AA is used for paving and has a required minimum strength of 3,500 psi at 28 days.

Strength is most sensitive to the water-cement ratio (i.e., the weight of water divided by the weight of cement), which is part of the mix design and which typically ranges from 0.4 to 0.5 for standard ready-mix concrete [PCA, 1990]. Addition of water on the job site can reduce the water-cement ratio and severely affect the strength of the concrete. Any additions should be approved by the concrete supplier.



Compression testing of a 4 by 8 inch cylinder will test the concrete's strength.

Strength is assessed through fabrication and testing of concrete cylinders fabricated during placement of the concrete at the job site. ASTM standards are followed for fabrication and curing (C31) and testing of cylinders (C39). Testing is typically conducted at seven and 28 days after fabrication, using a universal test machine.

Workability Tests—Workability refers to the ability of the plastic concrete to flow. This is commonly assessed by a standardized slump test (ASTM C143). The method requires placement of three layers of plastic concrete into a standard 12-inch-tall slump cone. Each layer is rodded 25 times, the top surface is floated, and the area around the cone is cleared. Once this is done, the cone is slowly lifted upward.

A standardized slump test requires placement of three layers of plastic concrete into a standard 12-inch-tall slump cone. Each layer is rodded 25 times, the top surface is floated, and the area around the cone is cleared. Then, the cone is slowly lifted upward. Slump is the measurement of the change in height.

Without the support of the cone, the plastic concrete will slump from its original 12-inch height to a shorter height. The slump is the measurement of the change in height. Stiff concrete will have a small slump (i.e., 1 inch), while concrete with easy flow will have a large slump (6 to 8 inches). The slump is affected by the water-cement ratio, aggregate size, and air content. For most construction applications, concrete can be adequately placed with a slump from 1 to 4 inches.

Proper consolidation of the concrete often requires vibration of the plastic concrete. This can be accomplished through immersion-type vibrators or form vibrators. In some cases, hand methods such as rodding or spading will be sufficient. The goal of the process is to provide adequate consolidation so that voids are eliminated.

Excessive vibration can result in settlement of the aggregate, which can compromise the strength and durability of the hardened concrete.

Air Content Tests—Resistance to freezing, thawing, and de-icing chemicals is achieved by the use of entrained air in the concrete. Air entrainment creates closely spaced microscopic air voids in the concrete that allow freezing water to disperse in the hardened concrete without localized blow-out. Air entrainment is achieved through the use of chemical admixtures or air-entraining Portland cement. Most PennDOT projects require air entrainment between 3.5 and 5.0 percent. The amount of air is assessed from the plastic concrete using ASTM C231 or ASTM C173. In addition, air content can be evaluated for existing structures by coring and optical examination of the internal surface in accordance with ASTM C457.

Immersion vibrators are used for consolidation of the concrete. In some cases, hand methods such as rodding or spading are sufficient.

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The proper quality control of field-placed concrete requires a number of physical tests to be performed in the field and after placement. This tech sheet presents an abbreviated summary of some of the test methods used to provide a basic understanding of issues related to quality control. This overview is by no means comprehensive. Quality control tests must be executed by a certified technician and performed in accordance with the project requirements.

Further information on the certification programs and background information on the test procedures and design methods can be found in the reference documents.

References

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