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PORTLAND CEMENT CONCRETE
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IOWA STATE UNIVERSITY

Using the Air Void Analyzer

for Real-Time Quality Control Adjustments in the Field

tech brief

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air content
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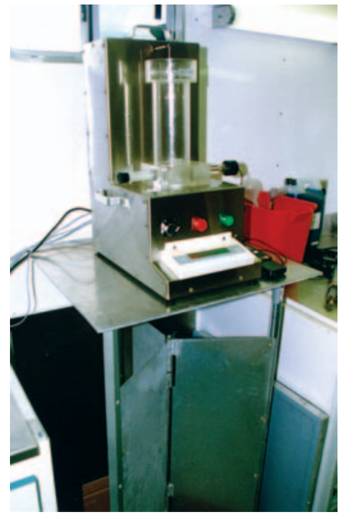
air void analyzer (AVA)
air void size and distribution
field control
freeze-thaw durability
quality control
spacing factor
specific surface

Overview



The air void analyzer (AVA) with its independent isolation base can be used to accurately evaluate the air void system—including volume of entrained air, size of air voids, and distribution of air voids—of fresh portland cement concrete (PCC) on the jobsite. With this information, quality control adjustments in concrete batching can be made in real time to improve the air void system and thus increase freeze-thaw durability. This technology offers many advantages over current practices for evaluating air in concrete.

Concrete Air Void System Parameters

The air void system of concrete is critical to providing adequate protection from freeze-thaw damage in regions where freeze-thaw occurs. Concrete air void system parameters include total volume of air, entrapped air volume, size of air voids, and distribution of air voids.

Total Volume of Air

The total volume of air in concrete is often the only factor that is regularly tested in fresh concrete, but total air content does not necessarily provide an accurate measurement of freeze-thaw durability.

Size of Air Voids

The size of air voids in concrete can be measured directly or expressed in terms of specific surface. Specific surface is the ratio of the surface area of air voids to their volume. Smaller voids have higher specific surface. Specific surface is an important factor in determining freeze-thaw durability.

Distribution of Air Voids

The number and size distribution of air voids in concrete is measured by the spacing factor parameter. Spacing factor is a measure related to the distance between the peripheries of air voids in the cement paste. Of the air void system parameters, spacing factor is the most significant indicator of freeze-thaw durability in the cement paste matrix. Usually, a spacing factor of less than 0.20 mm is preferable.

Air Void System and Freeze-Thaw Durability

Freeze-thaw cycles are one of the factors that contribute to premature concrete pavement deterioration. As water in concrete expands during freezing, the pressure increases in relation to the distance it must travel to reach the nearest air void. The more closely the air voids are spaced, the less likely it is that the pressure of freezing water will damage the concrete.

Ensuring that concrete has an adequate air void system with closely spaced air voids can ensure concrete freeze-thaw durability and also improve sulfate and scaling resistance. With adequate air void distribution, the ice formed in capillary pores in concrete during freezing will expand into adjacent voids without causing spalling and deterioration of the concrete.

Air entraining agents are added to concrete mixtures to stabilize very small air bubbles in the concrete mixture in an attempt to minimize freeze-thaw damage. However, the air void structure can be adversely affected during the construction cycle, including through the use of some high-range water-reducing admixtures and over-vibration. Conventional tests of air in concrete have not provided an effective method of measuring the entrained air during construction.

With the timely additional information obtained through AVA testing, improvements in spacing factor can be made by increasing the dosage of air entraining agent or water reducer, by using a different air entraining agent or water reducer, or by changing from an ordinary water reducer to a midrange water reducer (at a higher dosage).

Limits of Conventional Tests of Air in Concrete

Fresh Concrete Tests: Incomplete Information

Two tests are commonly used to measure the air content of freshly mixed concrete: the pressure method using the pressure meter (ASTM C 231) and the volumetric method using the roll-o-meter (ASTM C 173). These tests measure total volume of air only, not size or distribution of air voids.

Hardened Concrete Test: Too Late for Adjustments

Until recently, the only method to evaluate the complete concrete air void system was by taking a sample of the concrete after it has hardened. The spacing factor and specific surface are measured in the laboratory using a microscope and other specialized equipment (ASTM C 457). Because the hardened concrete sample is typically taken a minimum of 3 days after placement and the results are typically not available for at least two weeks, the results are obtained too late to make adjustments to the concrete mixture.

Research technician performing a test using the AVA on the isolation base

AVA Test: Timely and Complete Air Void System Analysis

The AVA is a relatively new piece of equipment that can be used to accurately evaluate the air void system of fresh, plastic concrete. A concrete sample is typically obtained from the jobsite and transported to a nearby building for testing. With results in under an hour (typically about 30 minutes), quality control adjustments in concrete batching can be made to improve the air void spacing and thus increase freeze-thaw durability.

One of the limitations of the AVA has been that it is a sensitive machine. It has been considered usable only in buildings, not in the field, because vibrations, such as those caused by wind or people movements, can have a significant effect on the AVA's results. The PCC Center at Iowa State University has recently developed an isolation base that allows AVA testing in field conditions.

Bubbles rising from the blue, viscous AVA liquid

AVA Technology Description

- The AVA is a portable device that comes in a carrying case. The AVA should be operated on a stable counter or deck. (The PCC Center isolation base is described under AVA experience.)
- The AVA riser cylinder is mostly filled with water. A blue AVA liquid with known viscosity is placed in the bottom of the cylinder. Each test requires 200 ml of liquid.
- A percussion drill is used to vibrate a wire cage into fresh concrete.
- Mortar (excluding aggregate larger than 6 mm) fills the cage.
- A syringe is used to extract a 20 cm^3 mortar sample from the cage.
- The mortar is injected into the viscous, blue liquid at the bottom of the AVA riser cylinder.
- The sample is gently stirred for 30 seconds.
- Air bubbles are released from the mortar and rise through the viscous liquid and then through the water in the rise cylinder. The rate the bubbles rise at is a function of their size—larger bubbles rise faster than smaller ones, according to Stoke's Law.
- The bubbles collect at the top of the cylinder under a buoyancy recorder bowl attached to a balance.
- The buoyancy of the bowl changes over time as air bubbles accumulate. The weight change over time is recorded for 25 minutes or until no weight change is recorded for 2 consecutive minutes. The arrival rate of air bubbles indicates their size. Their volume is calculated from the weight change.
- The AVA is used in conjunction with a laptop computer. Computer software uses an algorithm to determine the specific surface, spacing factor, and entrained air content.

AVA Experience

Since 1999, the Federal Highway Administration has used the AVA on concrete paving projects in a number of states. About half the projects that met air content specifications using conventional quality control tests (measuring only total air content) had air void spacing factors outside acceptable limits for adequate freeze-thaw durability.

In response to premature joint distress determined to be caused by poor air void spacing, the Kansas Department of Transportation began using the AVA in 2001. The cost savings for three 2001–2002 projects was estimated to be over $1 million. In 2002, the Kansas DOT developed specifications based on the AVA, establishing a minimum total air content correlated to a maximum spacing factor of 0.25 mm. The AVA is now used in Kansas for prequalification of concrete mixtures in the laboratory and verification of the mixtures at the jobsite as well as for random checks.

In 2004, the PCC Center custom-designed its Mobile Concrete Research Lab to provide a method of using the AVA in the field without being affected by vibrations. A portal was built in the floor of the mobile lab to accommodate the AVA. A three-legged stand is lowered through the floor portal to rest on the ground. A weather shield surrounds the base of the stand. The AVA sits on a deck on top of the stand within the lab. The AVA is protected by the trailer but does not touch the trailer. This provides a method of obtaining accurate AVA results in the field for more timely, convenient, and cost-effective quality control.

View of the weather shield from the exterior of the PCC Center Mobile Concrete Research Lab

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View of the weather shield from the exterior of the PCC Center Mobile Concrete Research Lab

AVA setup procedure in the PCC Center Mobile Concrete Research Lab: convert counter, remove floor portal door, lower weather shield through the floor portal, place three-legged stand on the ground protected by weather shield, place deck on top of stand, place AVA on top of deck.

Implementation Benefits

- With AVA results during construction, real-time admixture adjustments can be made that can dramatically improve the air void structure and thus the freeze-thaw durability of the concrete.
- AVA test results provide more complete concrete air void system analysis than conventional fresh concrete testing, which measures only total air content.
- AVA test results correlate closely (within 10%, based on Kansas results) with results obtained on hardened concrete using ASTM C 457.
- The AVA provides its test results in a more timely manner than concrete core tests so that real-time adjustments can be made.
- The AVA isolation base allows AVA testing on the jobsite, which equates to time and cost benefits over transporting the mortar sample to a building for AVA testing.

Additional Resources

Introducing the Air Void Analyzer (AVA): A Focus Technology of the AASHTO Technology Implementation Group. Washington, DC: Technology Implementation Group, American Association of State Highway and Transportation Officials, 2003. http://www.aashtotig.org/focus_technologies/ava/related_documents/introduction_brochure.pdf.

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