

Table 1, continued

Test Method	Purpose	Potential Construction Issues	Property	Laboratory
Concrete maturity (ASTM C 1074 / AASHTO T 325)	Estimates in-place strength; may be used as a criterion for opening a pavement to traffic.	Maturity estimates of in-place strength are only valid if the pavement is constructed using the same mix design used to develop the maturity curve.	Strength development	Mobile
Flexural strength and compressive strength (ASTM C 78 / ASTM C 39 / ASTM C 39M / AASHTO T 97 / AASHTO T 22)	Indicates concrete's ability to carry the intended loads.	Conditions that may skew strength test results include variations from the standard load rate, beam wetness, specimen size, and consolidation.	Strength development	Mobile
Air-void analyzer (AVA)	Monitors the spacing factor of the air-void system, which directly affects freeze-thaw resistance of concrete.	Can indicate variations in the mixture or air-void system impacts due to transporting/handling.	Air content	Mobile
Air content (plastic concrete, pressure method) (ASTM C 231 / AASHTO T 152)	Monitors entrained air, which is essential to the long-term durability of concrete subjected to freeze-thaw cycles.	Air contents greater than 4.5 percent are generally adequate. Monitor regularly (every two hours at least). Check bubble spacing and size with AVA.	Air content	Mobile
Air content (hardened concrete) (ASTM C 457)	Monitors total air content, spacing factor, and other parameters.	Spacing factor should be less than 0.2 mm (0.008 in.).	Air content	Central
Chloride ion penetration (ASTM C 1202 / AASHTO T 277)	Monitors chloride resistance and indirectly measures concrete permeability, a critical parameter in all durability-related distress mechanisms.	Influenced by w/cm ratio; use of fly ash, GGBF slag, or silica fume; consolidation practices, and curing and finishing practices.	Permeability	Central
Coefficient of thermal expansion (ASTM C 531 / AASHTO TP 60)	Monitors potential for temperature-related expansion and contraction of concrete, which can impact joint durability and cracking risk.	Joint layout, spacing, and width should be monitored during construction to ensure adherence to design specifications.	Thermal movement	Central



Technical Summary

A summary of chapter 9 (pages 241–272) of the *IMCP Manual* (reference information on page 4)

Quality Assurance and Quality Control

This document is one of a set of technical summaries of chapters 1 through 10 of the *Integrated Materials and Construction Practices for Concrete Pavements: A State-of-the-Practice Manual* (IMCP manual). The summaries provide an overview of the manual and introduce its important concepts. To be useful for training, the summaries should be used in conjunction with the manual.

This document summarizes the principles of quality control (QC) and quality assurance (QA). This document also describes how good record-keeping methods can support effective data analysis, explains how to maintain high testing standards, and outlines the key QA/QC parameters used in concrete batching and construction activities.

What are QA and QC?

QA consists of all the activities conducted by the owner, agency, or its representatives in order to confirm that the delivered pavement product meets specifications. QC refers to all activities conducted by the contractor (such as batching, placing, and finishing) to ensure that the product will meet or exceed QA specifications.

QA and QC test methods do not necessarily correlate for two reasons:

- Not all performance specifications are directly measurable.
- Not all laboratory tests can be completed in the field.

Also, the contractor may require different and/or more frequent tests than those specified to ensure quality control (e.g., aggregate moisture testing).

Why is QC Important for Concrete Optimization?

By monitoring materials and processes at all stages of design and placement, contractors can preempt problems or variations rather than simply react to them. Clear and

accurate QC data can help contractors make well-informed, on-target process control adjustments, which are important for achieving uniformity and other desired concrete properties.

Quality of Testing

Repeatability and reproducibility of results are critical for both QC and QA functions. To support consistency, the following criteria should be met:

- QA and QC personnel are adequately trained and certified.
- Testing facilities are certified by AASHTO, ASTM, or other qualifying organization.

Still, the nature of the materials and the tests is such that test results are only estimates of actual pavement properties. All tests have different built-in levels of precision and variability that must be accounted for.

Documenting Test Results

Proper documentation is necessary for accurate interpretation of QA and QC testing data. A good record-keeping system usually includes the following elements:

- Clear, consistent labeling of samples.
- Accurate recording of sample locations and/or times.
- Legible handwriting on testing worksheets.
- Organized filing system.

Control charts, used primarily for process control, are useful for identifying and analyzing statistical shifts in concrete materials and processes (figure 1). Their visual format provides a simple and effective means for interpreting acceptable and unacceptable levels of test result variability. Statistical control charts can also be used to show when a specific process is trending out of limits.

National Concrete Pavement Technology Center



August 2007

This technical summary is based on chapter 9 of the *IMCP Manual* (Taylor, P.C., et al. 2006. *Integrated Materials and Construction Practices for Concrete Pavement: A State-of-the-Practice Manual*, Ames, Iowa, Iowa State University [FHWA HIF-07-004] [www.cptechcenter.org/publications/imcp/]) and was sponsored by the Federal Highway Administration. (References for any citations in this summary are at the end of the chapter.)

Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the view of Federal Highway Administration or Iowa State University.

CP Tech Center Mission

The mission of the National Concrete Pavement Technology Center is to unite key transportation stakeholders around the central goal of advancing concrete pavement technology through research, tech transfer, and technology implementation.

Iowa State University does not discriminate on the basis of race, color, age, religion, national origin, sexual orientation, gender identity, sex, marital status, disability, or status as a U.S. veteran. Inquiries can be directed to the Director of Equal Opportunity and Diversity, Iowa State University, 3680 Beardshear Hall, 515-294-7612.

For More Information

Marcia Brink, Managing Editor
CP Tech Center, Iowa State University
2711 S. Loop Drive, Suite 4700
Ames, IA 50010-8664
515-294-8103, mbrink@iastate.edu
www.cptechcenter.org/



Monitoring Batching Operations

To ensure a uniform mix from batch to batch, the material must be homogeneous and the handling systems consistent. The batch plant should be continuously monitored and regularly calibrated to maintain control of water-to-cementitious materials (w/cm) ratio, aggregate moisture, and materials batching tolerances.

Water-Cementitious Materials Ratio

The w/cm ratio may be the most critical variable of concrete construction, but it is difficult to measure directly. It is important to carefully monitor and adjust the batching process to provide a high degree of control over w/cm ratio.

Aggregate Moisture

Monitor aggregate moisture content during batching so that mix water adjustments can be made accordingly. It is common to conduct moisture testing on representative aggregate samples once or twice daily.

Most difficulties with surface moisture stem from fine aggregate. Good stockpile management (allowing fine aggregate stockpiles to drain) will help maintain uniform moisture content. Surface moisture is often measured with moisture meters attached to the batching equipment.

Batching Tolerances

Aggregates and cementitious materials should be batched by weight, while liquid components (such as mix water and liquid admixtures) can be batched by volume.

Specifications

A suite of tests that comprises best practices for QC testing during construction of concrete pavements has been identified in the TPF-5(066) project. Common test methods for QC monitoring activities at the batch plant are listed in table 1.

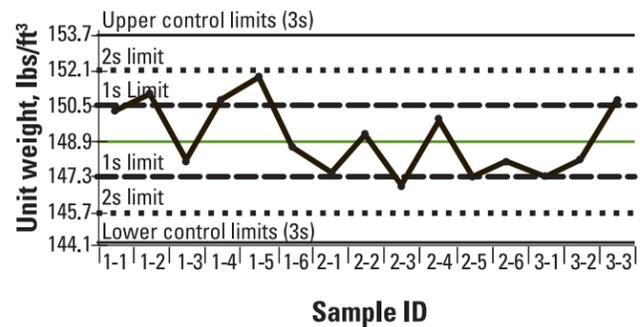


Figure 1. Example control chart. Control charts visually represent a range of test results so that statistical shifts can be easily identified.

Monitoring Construction

During construction, the concrete temperature, air-void system, amount of vibration, and dowel bar locations must be monitored and adjusted as necessary.

Temperature

The temperature of concrete as placed and shortly thereafter can have a large impact on both the fresh and hardened properties of the slab. An optimal temperature for freshly placed concrete is between 10 and 15°C (50 and 60°F), and the concrete should not exceed 30 to 33°C (85 to 90°F).

Air Content

Achieving the target air-void system characteristics is one of the most challenging aspects of controlling concrete mixtures. In construction projects, a common tolerance for air content is within -1 to +2 percentage points of the target specification value.

Tests should be conducted at the batch plant and behind the paver (if practical), at one of the following frequencies:

- Every hour.
- Every 100 lane-miles (300 lane-feet) of paving.
- Every 50 m³ (70 yd³) of concrete.
- When strength samples are made.

Vibration

Vibration can have a significant impact on concrete pavement durability. Vibrator monitors can be used to pre-program, operate, and monitor vibrator operation, enabling real-time monitoring and subsequent data analysis.

Follow the guidelines below in regards to vibration speed or vibrations per minute (vpm):

- In well-proportioned mixtures, over 8,000 vpm can be used.
- In oversanded mixtures, reduce vibrations to 5,000 to 8,000 vpm to prevent air voids from being dispelled.

Dowel Bar Placement

Dowel bars transfer applied loads across joints and must allow freedom of movement between adjacent slabs. Dowel placement tolerances usually reference the three ways that dowel bars can be out of alignment:

- Longitudinal translation—Refers to both the position of a dowel in relation to a joint and a dowel's embedment length.
- Depth—Vertical position of a dowel within the slab.
- Horizontal and vertical skew—Degree to which the dowel rests parallel to both the centerline and the top of the slab.

Alignment

Alignment of each dowel must be within certain tolerances

to allow adequate freedom of movement between slabs. A typical tolerance for vertical and horizontal dowel skew is 6 mm (0.25 in.) per 300 mm (12 in.) of dowel length, or three percent.

Embedment length

To provide a construction tolerance, the total length of dowel bars is specified to be somewhat longer than required for embedment length. The current state of practices is to provide a minimum dowel embedment length of 150 mm (6 in.) for a joint to be effective under most loading

conditions. In highway work, dowel length is specified as 450 mm (18 in.), providing 150 mm (6 in.) of tolerance.

Dowel depth

Dowel depth is less critical to dowel and joint performance than many other factors. Problems generally do not result from placing dowels slightly above or below mid-depth in a concrete slab. Current state specifications for dowel alignment range from 1/8 inch to 3/8 inch per foot of dowel length. Various research efforts are underway to determine the most realistic value that promotes good pavement performance.

Table 1. Suite of QC Tests from TPF-5(066)

Test Method	Purpose	Potential Construction Issues	Property	Laboratory
Differential Scanning Calorimetry (DSC)	Monitors the level of sulfate forms in cement to flag potential setting problems.	Changes in workability	Workability	Central
Blaine fineness (ASTM C 204 / AASHTO T 153)	Affects rate and heat of hydration, workability, water requirement, strength gain, and permeability. Daily monitoring will provide a means of tracking cement variability.	Finer cements increase risk of incompatibility and increased water demand.	Workability	Central
Combined Grading	Can affect risk of segregation, bleeding, and shrinkage. It is desirable to blend different aggregate sizes to obtain a smooth grading curve for the aggregates.	Problems attributable to gradation may include stockpile segregation, excess bleeding, edge slump, poor consolidation, variation in slump or vibrator frequencies.	Workability	Mobile
Penetration resistance (false set) (ASTM C 359 / AASHTO T 185)	Indicates whether or not a mix is prone to false set.	Excessive vibration and loss of workability at moderate temperatures can indicate false set.	Workability	Mobile
Cementitious materials temperature profile ("coffee cup test")	Tracks heat generated during hydration to identify potential workability issues. Variability of cementitious materials and reactions may be tracked daily.	Changes in temperature profile indicate potential changes in workability, slump loss, setting time, and strength gain.	Workability	Mobile
Water/cementitious materials ratio (microwave) (AASHTO T 318)	Provides water-to-cementitious materials ratio results, which are indicative of concrete strength, within hours (compared to hardened concrete strength tests that take at least seven days).	When total water content variations are noted, plant operations should be reviewed to ensure that materials are being batched in the proper proportions.	Workability	Mobile
Unit weight (ASTM C 138 / AASHTO T 121M / AASHTO T 121)	Results provide an excellent indication of batch-to-batch uniformity and a general indication of correct batch proportioning.	When variations are observed, potential causes include consolidation, air content, batch proportions, and changes in raw material densities.	Workability	Mobile
Heat signature (adiabatic calorimetry test)	Monitors the heat of hydration generated over time; can be used to flag cementitious material variations.	Changes in heat signature may affect workability, consolidation, strength gain, saw-cutting window.	Workability	Mobile
Concrete temperature, subgrade temperature, and environmental conditions	Responding to temperature and environmental conditions allows the construction team to minimize the risk of problems.	Excessively hot, dry, windy, or cold conditions, sudden cold fronts, and rain can adversely affect a concrete pavement.	Workability	Mobile

Table 1, continued on next page