Quality Control for Concrete Paving: A Tool for Agency and Industry

- QC by contractors, concrete suppliers, and material suppliers is an integral part of an agency’s QA program

- QC includes:
  - operational level programs
  - project-level QC plans

- QC provides many benefits to both agency and contractor
Quality Control for Concrete Paving: A Tool for Agency and Industry

This document includes information necessary for contractors to:

• understand common agency QC requirements,
• develop and implement the appropriate tools, processes, and procedures and to meet these requirements,
• develop and implement continuous improvement activities to improve their ability to meet agency QA requirements, and
• recognize that good quality control will lead to a number of benefits including higher efficiency and productivity, increased profit, and safer operations.

Overview

• Section 1: Introduction
• Section 2: Introduction to QC, organizational-level QC
• Section 3: QC for suppliers of materials for concrete pavements
• Section 4: Introduction to PEM, QC processes supporting PEMs
• Section 5: QC methods for concrete pavement construction
  • mixture design, mixture verification/field setup, mixture and construction QC, construction acceptance.
  • best practices to support development of a QC plan
• Section 6: QC tools
  • checklists, control charts and process adjustments, records management
Section 1: Introduction

• Overview of the guide

• Message to Agencies
  • Agencies gain many benefits from contractor QC:
    • improved quality of construction as contractors enhance their QC plans
    • an increased confidence in contractor QC data, and use of QC data in the agency’s QA program
    • confidence to consider loosening or removing restrictive prescriptive specifications
    • confidence to consider implementing performance-type specifications

It is hoped that this guide helps agencies develop, improve, or enhance their specifications and QA provisions regarding contractor QC

• financial incentives tied to QC are encouraged
• aim to relax or eliminate restrictive prescriptive specifications, move to performance-type specifications
• Appendix A: list of QC requirements commonly/less commonly specified

Appendix A: Review of Agency QC Requirements

• Common requirements are provided in standard font
• Less commonly specified requirements in italics

2. QC Requirements for Concrete Mixture Components
  • Material sources and information regarding their status in the agency's qualification program(s).
  • Sampling techniques for components of concrete
  • Aggregates
    • Specific gravity
    • Absorption
    • Gradation
    • Abrasion resistance
    • Percent passing No. 200
    • Fractured faces
    • Verification of non-alkali-reactive materials
  • Cement and supplementary cementitious materials
    • Mill test reports
    • Material composition test results
    • Supplier material certification or other information to ensure material is an agency approved product
  • Admixtures and other materials used in concrete
    • Supplier material certification or other information to ensure material is an agency approved product
  • Water
    • Provisions for use of non-potable water source
    • Provisions for recycled concrete aggregates, including those produced on-site, produced near-site, or sourced from a local producer
    • Other information relevant to QC testing of specific materials
    • Disposition of unsatisfactory materials
Section 1: Introduction

- **Definitions** – from 23 CFR 47, TRB Glossary, and those used in this document - QC Program, QC Plan, QC Process

- Elements of a QA Program

![Diagram of QA Program Elements]

Section 2: Quality Control Fundamentals

- **Introduction to QC**
  
  1. **PLAN**
     - identify problems
     - define desired outcomes
     - identify potential solutions
     - develop policies and procedures
  
  2. **DO**
     - test potential solutions
     - create process structure
     - establish systems
     - conduct training
     - measure quality characteristics
     - collect data
  
  3. **CHECK**
     - monitor and analyze data
     - study the results
     - draw conclusions
  
  4. **ACT**
     - identify lessons learned
     - implement the most promising corrective and preventative actions

“Any product, process, or service can be improved, and a successful organization is one that consciously seeks and exploits opportunities for improvements at all levels.” (Swift et al. 1998)
Section 2: Quality Control Fundamentals

• Organizational Quality Management

Contractor QC programs include the procedures and practices that occur continuously, supporting the QC required for each project.

These formal practices and procedures should support (Taylor et al. 2019):

• personnel training
• laboratory certification
• standardization of processes and best practices
• procurement of products and services
• preliminary material testing
• equipment and process monitoring
• communication and information flow
• documentation and recordkeeping
• control of documents

Section 2: Quality Control Fundamentals

• Communication

QC relies upon good communication - written, spoken, email, text messages, paper documents, electronic files, software, models

• Refers reader to Appendix B: Poor, fair, and good QC plan provisions

Aggregate stockpile management:

• **Poor**: Aggregate stockpiles will be protected from runoff. Aggregates will be protected from the introduction of debris or other contaminants.

• **Fair**: Aggregate stockpiles will be protected from runoff using swales. Haul trucks will be unloaded adjacent to the stockpiles, and material will be placed on the stockpiles using other equipment. Contractor personnel will observe the stockpiles periodically to ensure contaminants have not been introduced to the material.

• **Good**: Aggregate stockpiles will be laid out in a manner that provides for adequate drainage away from the area. Swales and erosion control materials will be used to direct runoff as required. Prior to establishing stockpiles, the integrity of the subgrade soils will be verified and stabilized if necessary. Haul trucks used to bring aggregates to the site will be unloaded in a designated area adjacent to the stockpiles. Aggregates will then be transferred to the stockpile using a wheeled loader. Stockpiles will be maintained in a manner that minimizes segregation and prevents contaminant material from being introduced. Stockpiles will be visually inspected daily by the QC manager to ensure they are in good condition and to identify remedial actions, if necessary.
Section 2: Quality Control Fundamentals

• Quality Control Plans

**Objective of QC Plan:**

To establish a framework of activities and actions that, when implemented over the course of a project, will enable a contractor to reduce the risk of out-of-specification work, along with associated delays, costs, and impacts to reputation.

• Contractor should view QC plan as a highly beneficial tool
• List/description of typical elements
  • parties/personnel and roles/responsibilities
  • materials, tests, methods, sampling plan
  • monitoring/inspection activities
  • procedures for evaluating data
  • means for maintaining control of work
  • corrective actions
  • documentation required
• *** Discussion on choosing appropriate quality characteristics to help support acceptance

Section 2: Quality Control Fundamentals

• Understanding Variability
  • Sources of variability

• Chance cause (natural) variability vs. assignable cause (not natural) variability
Section 2: Quality Control Fundamentals

• Sampling and Statistical Process Control
  • Guidance to develop a sampling plan that is comprehensive, reliable, cost-effective, useful and understood

• Random sampling (upper) vs. Time order sampling (lower)

A sampling plan must be sufficiently robust to support production/construction of a quality product, at a reasonable cost, with an acceptable level of risk to the manufacturer or contractor.

Section 3: Supplier QC for Concrete Pavement Materials

• QC plan should ensure contractor knows and understands:
  • the specifications for all the products being supplied
  • how to measure the required uniformity of the products being supplied, and
  • adjustments to make to the process if the uniformity changes.

• Provides supplier QC practices/tests/documentation for:
  • portland cement and blended cements
  • SCM
  • admixtures
  • aggregates

• Emphasis on:
  • how to understand uniformity/variability
  • communication with suppliers

• External resources provided
Section 4: Performance Engineered Concrete Mixtures

- Introduction to PEM and AASHTO PP 84
- Links between QC and PEM
- Summary of PEM requirements
  - Strength
  - Reducing unwanted warping and cracking due to shrinkage
  - Freeze-thaw durability
  - Transport properties (permeability)
  - Aggregate stability
  - Workability
- Provides list of PEM test methods for each requirement
- Provides a recommended approach for contractor QC

With respect to a material supplier’s and/or contractor’s approach to QC, it should not matter whether a pavement is constructed under PEM specifications or traditional concrete pavement specifications.

Section 5: QC for Concrete Pavement Construction

- Implementation of a QC Process

- Each stage is described
- A framework is provided, showing QC items associated with each stage
- Subsequent sections describe each phase of paving, associated QC activities

Section 5 is heavily based on materials presented in:

*Field Reference Manual for Quality Concrete Pavements* (Fick et al. 2012)
### Section 5: Example Framework for Pavement Construction QC

<table>
<thead>
<tr>
<th>Item</th>
<th>Mixture Design (prequalification)</th>
<th>Mixture Verification (field setup)</th>
<th>Mixture and Construction QC</th>
<th>Mixture and Construction Acceptance</th>
</tr>
</thead>
<tbody>
<tr>
<td>QC Plan</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Determination of Mixture Materials</td>
<td>✔</td>
<td>✔</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aggregate Grading</td>
<td>✗</td>
<td>✗</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mixture Proportioning</td>
<td>✗</td>
<td>✗</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature Sensitivity of Mixture</td>
<td>✗</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mixture Properties (Example for PEM shown)</td>
<td>✗</td>
<td>✗</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• As specified</td>
<td>• As specified</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Flexural strength at 3, 7, and 28 days</td>
<td>• Compressive strength at 3 and 7 days</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Compressive strength at 3, 7, and 28 days</td>
<td>• Volume of paste</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Volume of paste</td>
<td>• Restrainted volume change at 180 days</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• w/cm</td>
<td>• Unit weight</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Fresh air content</td>
<td>• Fresh air content</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Calcium oxychloride limit</td>
<td>• Combined gradation</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Apparent F factor</td>
<td>• Modified VKelly Test</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Combined gradation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Slump</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-Paving Activities</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subgrade</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subbase(s)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steel Placement</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paver Controls</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paving Equipment Setup</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Mixture Production

| Stockpile Management | ✔                                 |                                    |                      |                                    |
| Plant Calibration    | ✗                                 |                                    |                      |                                    |
| Transporting Concrete Mixture | ✗                                 |                                    |                      |                                    |

### Mixture Adjustments

| Mixture Adjustments | Appropriate adjustments include: |                                    | Appropriate adjustments include: |                                    |
|                    | • Subtraction/addition of water (not to exceed the w/cm of the approved mixture design) |                              | • Subtraction/addition of water (not to exceed the w/cm of the approved mixture design) |                                    |
|                    | • Adjustment of admixture dosages |                              | • Adjustment of admixture dosages |                                    |
|                    | • Minor reproportioning of aggregates |                          | • Minor reproportioning of aggregates |                                    |
|                    | • Heating or cooling the mixture |                              | • Heating or cooling the mixture |                                    |

### Paving

| Spreading Concrete |                                    |                                    | • Pavement thickness |                                    |
| Fixed Form Placement |                                    |                                    | • Pavement smoothness |                                    |
| Slipform Placement |                                    |                                    |                      |                                    |
| Hand Finishing     |                                    |                                    |                      |                                    |
| Texturing          |                                    |                                    |                      |                                    |
| Curing             |                                    |                                    |                      |                                    |
| Sawing Joints      |                                    |                                    |                      |                                    |
| Sealing Joints     |                                    |                                    |                      |                                    |
| Backfill Pavement Edges |                    |                                    |                      |                                    |
| Open to Construction Traffic |              |                                    |                      |                                    |
| Open to Public Traffic |                                    |                                    |                      |                                    |
### Section 5: QC Guidance for Each Step of Process

#### Staking and Stringline or Stringless QC

<table>
<thead>
<tr>
<th>Key inspection items</th>
<th>QC measurements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spot check paving hubs and grades for accuracy by checking against a known benchmark.</td>
<td>Staking and stringline or stringless</td>
</tr>
<tr>
<td>Visually inspect stringline for abrupt changes and/or discontinuities (stringline only).</td>
<td>Random survey check of paving hubs.</td>
</tr>
<tr>
<td>Check that pins and wands are solid and resistant to moving (stringline only).</td>
<td>Random check of stringline elevation and alignment relative to paving hub information (not applicable to string which has been eyeball adjusted for smoothness) (stringline only).</td>
</tr>
<tr>
<td>Depending on the offset used, subgrade and subbase that has pumped may move the paving hub from its surveyed elevation and alignment. Correct the subgrade/subbase and re-survey.</td>
<td></td>
</tr>
</tbody>
</table>

**Checklist**

- Verify the survey has provided the correct grades for the requested offset and grade type (projected or level).
- Pins are placed at appropriate intervals (25 ft or less in tangent sections, closer spacing through tight curves).
- Wands are adjusted for alignment (stringline should be directly above the hub).
- Stringline is set to the correct elevation with respect to the hub.
- Stringline is uniformly taut.
- Stringline is marked for visibility to prevent accidental bumping.

#### Dowel Basket QC

<table>
<thead>
<tr>
<th>Key inspection items</th>
<th>Dowel baskets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spot check transverse spacing and offset from the edge of the pavement.</td>
<td>Dowel baskets</td>
</tr>
<tr>
<td>Bond breaker applied, if applicable.</td>
<td>Embedment of the cover of bars should be verified by probing behind the paver at 300 ft intervals (at least 1 bar for each basket across the width of the slab should be located).</td>
</tr>
<tr>
<td>Visually inspect for alignment – correct misaligned bars.</td>
<td>Non-destructive devices such as the MIT Scan, MIT Scan T2, ground penetrating radar or pachometer (cover meter) can be used to evaluate dowel-joint placement.</td>
</tr>
<tr>
<td>Verify that basket locations are marked on both sides of the pavement.</td>
<td></td>
</tr>
<tr>
<td>Baskets should be anchored so that the stake is on the downstream side of the basket frame.</td>
<td></td>
</tr>
<tr>
<td>Check the stability of the baskets – are they anchored adequately to withstand the force of a slipform paver pushing concrete over them?</td>
<td></td>
</tr>
</tbody>
</table>

**Checklist**

- Correct dowel dimension (diameter and length).
- Basket height is appropriate for the pavement thickness.
- Bar spacing is specified.
- Bar coating is as specified and not unduly damaged.
- Bond breaker is adequate.
- Verify that the dowel location is marked adequately on both sides of the slab to ensure proper joint sawing.
Section 5: QC Guidance for Each Step of Process

Mixture Production QC

**Key inspection items**
- Review aggregate moisture testing and moisture compensation on the batch tickets.
- Periodically monitor mixing time.
- Check that the aggregate moisture contents used for adjusting batch proportions is representative of the material being taken from the stockpiles.

**Mixture production QC measurements**
- Sieve analysis and combined gradation.
- Aggregate moisture content.
- Concrete temperature*.
- Unit weight*.
- Air content*.

* at a minimum, each of these quality measurements should be checked randomly every 1,000 cubic yards at the plant site and compared to samples obtained at the point of delivery. Other PEM tests should be included to ensure agency specifications are met, or at the discretion of the contractor.

**Checklist**
- Batch proportions match the approved mixture design (daily).
- Moisture compensation is representative of the aggregates being batched (at least 2 times per day, more if necessary).
- Material inventories are adequate.
- Mixing drum is clean of dried materials which could break loose.
- Mixing blades are not overly worn.

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Aggregate stockpiles (upper, from FHWA MCTC) and maturity testing (lower, from Lane Construction)

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Section 5: Recommended laboratory tests for each stage

- Mixture prequalification tests
- Field setup tests
- Mixture QC tests (table shown below)
- Mixture Acceptance

<table>
<thead>
<tr>
<th>Concrete property</th>
<th>Test description</th>
<th>Test method</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Workability</td>
<td>Aggregate gradation</td>
<td>ASTM C136 / AASHTO T 27, ASTM C566, AASHTO T 255</td>
<td>Use the individual gradations and proportions to calculate the combined gradation</td>
</tr>
<tr>
<td></td>
<td>Combined gradation</td>
<td>Tarantula curve</td>
<td>Monitor uniformity</td>
</tr>
<tr>
<td></td>
<td>Aggregate moisture content</td>
<td>ASTM C29</td>
<td>Affects w/cm ratio and workability</td>
</tr>
<tr>
<td></td>
<td>Slump</td>
<td>ASTM C143 / AASHTO T 119</td>
<td>Indicates uniformity batch to batch</td>
</tr>
<tr>
<td>Air void system</td>
<td>Super Air Meter (SAM)</td>
<td>AASHTO TP 118</td>
<td>Indicates uniformity batch to batch</td>
</tr>
<tr>
<td>Unit weight</td>
<td>Unit weight</td>
<td>ASTM C138 / AASHTO T 121</td>
<td>Indicates uniformity batch to batch</td>
</tr>
<tr>
<td>Strength development</td>
<td>Compressive or flexural strength</td>
<td>ASTM C39 / AASHTO T 22 and/or ASTM C78 / AASHTO T 97</td>
<td>Indicates uniformity batch to batch</td>
</tr>
<tr>
<td>Maturity</td>
<td>ASTM C1074</td>
<td></td>
<td>Opening times</td>
</tr>
<tr>
<td>Transport</td>
<td>Resistivity/F-Factor</td>
<td>Soak/store samples in salt solution</td>
<td>Monitor over time</td>
</tr>
<tr>
<td></td>
<td>Hydration</td>
<td>Semi-adiabatic calorimetry</td>
<td>Indicates uniformity batch to batch</td>
</tr>
</tbody>
</table>

---
Section 5: Acceptance

• Summary of acceptance tests (table shown below)

<table>
<thead>
<tr>
<th>Property</th>
<th>Construction QC Test method / comments</th>
<th>Acceptance Test method</th>
</tr>
</thead>
</table>
| Vibration monitoring | On board monitors  
                      • Monitor that all vibrators are operating  
                      • Ensure vibrator speed is appropriate for paver speed | On board monitors      |
| Thickness        | Probe behind paver                                                                                 | MIT-SCAN-T3            |
| Smoothness       | Real-time smoothness monitoring                                                                      | Hardened smoothness –  
                      inertial profiler     |
| Dowel alignment  | MIT-DOWEL-SCAN                                                                                      | MIT-DOWEL-SCAN         |

Appendix C: QC Plan Outline

• QC plans reviewed from several contractors
• QC Plan Outline is *generic*
  • Can serve as a checklist of items that can be considered when developing a new QC plan or enhancing an existing plan
  • Presented in a bulleted outline format
  • Suggested typical content for each section is provided

• Narrative describing the process
• QC measurements
  o Frequency
  o Locations
  o Action limits
  o Suspension limits
• Checklist items
• Visual inspection items
• Corrective actions
Appendix D: Model QC Plan

- Heavily based on the Typical “Model Quality Control Plan” prepared by the NorthEast Transportation Training and Certification Program (NETTCP 2009)

- 10 Section format
  - Terms and Definitions (optional)
  - Scope and Applicable Specifications
  - Quality Control Organization
  - Quality Control Laboratories
  - Materials Control
  - Quality Control Sampling and Testing
  - Production Facilities
  - Field Operations
  - Appendices

- NETTCP Template/Framework Used
  - Some text provided to aid in developing content and specific QC provisions
  - Sample tables provided
    * Information in RED should be developed or modified to meet the agency requirements and contractor preferences. Other text can also be modified as appropriate.

Model QC plan will need to be modified to suit the needs of the project, the requirements of the agency, and preferences of the contractor.

### 4.6 MATERIALS CONTROL

#### 4.6.1 Materials: Suppliers

The following material suppliers will be providing materials for the concrete pavement. All material suppliers will be responsible for testing and inspecting to verify materials meet the appropriate specifications prior to delivery to the project.

<table>
<thead>
<tr>
<th>Material</th>
<th>Type/Brand</th>
<th>Supplier</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fly Ash</td>
<td>Class F</td>
<td>Mid-Central Fly Ash</td>
<td>Brillion, USA</td>
</tr>
<tr>
<td>Coarse Aggregate</td>
<td>No. 375/575</td>
<td>Rocky Aggregates</td>
<td>Minnetonka, USA</td>
</tr>
<tr>
<td>Fines Aggregates</td>
<td>CS3</td>
<td>Sandy Sands Gravel</td>
<td>Minneapolis, USA</td>
</tr>
<tr>
<td>Admixtures</td>
<td>Air entraining admixture</td>
<td>Chemical Admixture Company</td>
<td>Syosset, USA</td>
</tr>
</tbody>
</table>

4.2 Applicable Specifications and Standards:

* Describe specifications and standards applicable to each material. Provide information detailing how materials will meet such specification and standard either at the producer/supplier or upon delivery to the project site.

4.2.1 Plant Layout and Materials Delivery/Storage

* Describe plant layout, including delivery/land routes, drainage provisions, storage areas and storage facilities.

4.2.1.1 Consistently materials

* Provide information on delivery and storage of consistent materials.

4.2.2.1 Aggregates

* Provide information on delivery and storage of aggregates. Provide details on stockpile management and means to protect materials from contamination. Describe the established procedures used to monitor stockpiles and how minimum variability will be controlled. Also describe plant batching procedures.

### 5.0 QUALITY CONTROL, SAMPLING AND TESTING

The requirements and procedures to be used for QC sampling and testing of concrete, materials used to produce concrete, and concrete pavement are shown below.

#### 5.1 Lot and batch sizes

Each Lot of material will represent material from the same course, be produced or obtained under the same controlled process, and will possess identical specified properties. The Lot is identified with a Lot number or code. The Lot number or code is a unique code assigned to the Lot. This code is used by the QC laboratory to identify the Lot. The Lot size and corresponding individual size for each mix is identified in the following table.

* Modify table to include item names, materials, lot sizes, and individual sizes as appropriate.

<table>
<thead>
<tr>
<th>Item</th>
<th>Material type</th>
<th>Lot size</th>
<th>Individual size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggregate</td>
<td>Coarse aggregate</td>
<td>1000 CY</td>
<td>80 CY</td>
</tr>
<tr>
<td></td>
<td>Fine aggregate</td>
<td>1000 CY</td>
<td>80 CY</td>
</tr>
<tr>
<td>Concrete</td>
<td>Fresh concrete</td>
<td>2000 CY</td>
<td>1000 CY</td>
</tr>
<tr>
<td></td>
<td>Concrete pavement</td>
<td>1000 CY</td>
<td>1000 CY</td>
</tr>
</tbody>
</table>

* Modify table as appropriate.

#### 5.2 Random Sampling Plan

* Modify description of random sampling plan as appropriate. Provide documents related to random sampling in Appendix.

PCC Paving Contractors will establish a random sampling plan for QC sampling and testing for each lot of material prior to placement of the lot. All samples will be obtained randomly in accordance with AASHTO TP561. The random sample location for each batch will be determined by station, offset, and depth within the batch.

All random sample locations will be documented on standard test report forms (TP64). A copy of the random sampling forms is included in Appendix D. PCC Paving Contractors will provide the State Transportation Agency a copy of the random sampling locations in completed form (TP64) for each placement, during the run of the placement each day.

#### 5.3 Sample Identification System

* Modify sample identification system as appropriate.

All material samples will be clearly identified as follows:

- Sample identification system
- Sample location
- Sample date
- Sample number
### Example Sampling and Testing Table

<table>
<thead>
<tr>
<th>Material</th>
<th>Test/Test Method</th>
<th>Lot Size</th>
<th>No. of Sublots</th>
<th>Testing Frequency</th>
<th>Sampling Location</th>
<th>Sampling Method</th>
<th>Report Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse and fine aggregates</td>
<td>Gradation - ASTM C136</td>
<td>5,000 SY</td>
<td>5</td>
<td>1 per sublot and/or minimum 1 per day</td>
<td>Stockpile</td>
<td>Random, per agency specification</td>
<td>Tabular and graphical: % retained, Tarantula</td>
</tr>
<tr>
<td>Fresh concrete</td>
<td>Air content - ASTM C231</td>
<td>5,000 SY</td>
<td>5</td>
<td>First 3 loads per day and repeat for 3 loads whenever admixture dosages are adjusted</td>
<td>Plant</td>
<td>Biased, start of day</td>
<td>Tabular and control chart</td>
</tr>
<tr>
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<td>N/A</td>
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<td>First 3 loads per day and repeat for 3 loads whenever admixture dosages are adjusted</td>
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<td>Fresh concrete at grade</td>
<td>Temperature - ASTM C1064</td>
<td>5,000 SY</td>
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<td>Air void system - AASHTO T 152</td>
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<td>Unit weight - ASTM C138</td>
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<td>Water content - AASHTO T 318</td>
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<td>Fresh concrete at grade</td>
<td>Compressive strength - ASTM C39</td>
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<td>One set of three or minimum set of three</td>
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<td>Resistivity - AASHTO T 358</td>
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<td>Hardened concrete</td>
<td>Thickness probe, per agency spec</td>
<td>5,000 SY</td>
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<td>All loads</td>
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<td>Thickness - ASTM C174</td>
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<td>Thickness MIT-SCAN-T3</td>
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Example lot sizes, sublots, and sampling and testing frequencies from several states specifications are provided

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### Section 6: Tools for QC

**What gets measured gets managed...**

This section provides information on tools that can be used to help record, process, and use measurements to support decision making and continuous improvement.

- Contractors are encouraged to develop a set of QC tools to support the practices included in their QC program and QC plans
  - Process diagrams, checksheets, and other tools
  - Cloud-based tools (e-ticketing, other software tools)
  - Records management guidance

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**Flowchart for Box Test (from Cook et al. 2013)**
Section 6: Run Charts and Control Charts – Guidance for Development and Use

- Run charts and control charts allow a user to quickly
  - evaluate the suitability of a material or product
  - identify trends, and
  - assess whether a process is in control

- Section 6 provides guidance and examples for:
  - selecting a quality characteristic for a chart
  - developing sampling plan
  - constructing a chart
    - central line and limits established using specification-based targets (run chart)
    - central line and limits established using statistical methods (control chart)
  - observing and understanding trends in run/control charts
  - Appendix E: in-depth statistical control-chart example

Worked example run/control charts for:
- single measurements
- two measurements

![Graph showing air content and unit weight over time with specification limits and action limits marked.](image-url)
Section 6: Control Charts – Trends that suggest assignable cause variability

Closing

• Contractor QC is an integral part of QA
• Agencies have various requirements for QC, but those requirements are only minimum provisions
• A successful QC program/plan
  • engages the appropriate personnel
  • manages the necessary processes
  • measures what matters, and
  • uses the appropriate test methods.
• QC required for each project will differ, and approaches will be unique to the contractor
• QC programs achieve success over time, and provide benefits to both agency and contractors
Acknowledgements

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- FHWA – Mike Praul, Gina Ahlstrom, Jagan Gudimettla
- CP Tech Center – Peter Taylor, Gordon Smith, Steve Tritsch, John Adam, Sharon Pronchnow
- Technical Advisory Committee

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<th>State Agencies</th>
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<tr>
<td>Maine DOT – Rick Bradbury</td>
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<td>ACPA – Leif Wathne, Gary Mitchell</td>
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<td>Illinois Tollway – Cindy Williams</td>
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Questions?

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- Al Innis, Consultant – allison.innis@gmail.com