Performance Engineered Concrete Mixtures for Contractors

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Overview

• Background - North Carolina’s PEM journey

• Implementation of PEM in North Carolina at Pilot Projects
  ▪ Tests
  ▪ Results
  ▪ Contractor experience
  ▪ Lessons learned

• Moving forward

• QC Tools for PEM (and conventional approaches)
NCDOT PEM Motivation

• NCDOT specifications for concrete have changed little over the past 85 years
  ▪ Prescriptive specification
  ▪ Little room for innovation
  ▪ Mixtures typically over-designed for strength

• Resource reductions drive the need to reduce maintenance cost, increase service life

• Desire fly ash in most of our mixtures because of the benefits
  ▪ Encounter fly ash shortage throughout the years
  ▪ Need to find equivalent performance of mixtures without fly ash (“what if” scenario)

• Recently (2018) increased allowable fly ash substitution rate from 20% to 30%
  ▪ Needed data to support/encourage use of higher substitution rate, account for slower early age strength gain

• Need data to support decision to allow use of portland limestone cement

From Brian Hunter, NCDOT M&T
<table>
<thead>
<tr>
<th>Class of Concrete</th>
<th>Min. Comp. Strength @ 28 Days</th>
<th>Maximum Water-Cement Ratio</th>
<th>Consistency Max. Slump</th>
<th>Cement Content</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Air-Entrained Concrete</td>
<td>Non Air-Entrained Concrete</td>
<td>Vibrated</td>
</tr>
<tr>
<td></td>
<td></td>
<td>inch</td>
<td>lb/cu yd</td>
<td>lb/cu yd</td>
</tr>
<tr>
<td>Uniz</td>
<td></td>
<td>4.500</td>
<td>0.381</td>
<td>0.426</td>
</tr>
<tr>
<td>AA Slip</td>
<td></td>
<td>4.500</td>
<td>0.381</td>
<td>0.426</td>
</tr>
<tr>
<td>Drilled Pier</td>
<td></td>
<td>4.500</td>
<td>-</td>
<td>0.450</td>
</tr>
<tr>
<td>B Slip Formed</td>
<td>2.500</td>
<td>0.488</td>
<td>0.567</td>
<td>0.559</td>
</tr>
<tr>
<td>B Slip Formed</td>
<td>2.500</td>
<td>0.488</td>
<td>0.567</td>
<td>0.559</td>
</tr>
<tr>
<td>Sand Lightweight</td>
<td></td>
<td>4.500</td>
<td>-</td>
<td>0.420</td>
</tr>
<tr>
<td>Latex Modified</td>
<td>3.000</td>
<td>0.400</td>
<td>-</td>
<td>0.400</td>
</tr>
<tr>
<td>Flowable Fill re-entrained</td>
<td>150 max. at 56 days</td>
<td>-</td>
<td>as needed</td>
<td>-</td>
</tr>
<tr>
<td>Flowable Fill re-entrained</td>
<td>125</td>
<td>-</td>
<td>as needed</td>
<td>-</td>
</tr>
<tr>
<td>Pavement</td>
<td>4.500</td>
<td>0.559</td>
<td>-</td>
<td>1.5</td>
</tr>
<tr>
<td>Precast</td>
<td>See Table 1072-1</td>
<td>See Table 1072-1</td>
<td>-</td>
<td>6</td>
</tr>
<tr>
<td>Pretresses</td>
<td>See Table 1072-1</td>
<td>See Table 1072-1</td>
<td>-</td>
<td>8</td>
</tr>
</tbody>
</table>

What if…

- Emphasis on durability
- Sustainability considerations
- Flexibility for innovation
- Buffer against material shortages
- Opportunity for cost-savings
Each agency will have its own path to implementation

- What does this look like for North Carolina?
- An opportunity to do things better
- Impacts of this effort will be broad-reaching and will impact all stakeholders
- Not a zero-sum game (everybody should benefit!)
Preventing issues, rather than spending money/effort monitoring or addressing them

Resistivity testing for permeability (rapid electrical test)

Drilled powder samples tested for chloride content (chemical testing)

vs.
Implementing new, rapid testing technologies to replace tests that are slow, destructive, or unreliable.

<table>
<thead>
<tr>
<th>Freeze-thaw durability</th>
<th>Permeability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Super Air Meter AASHTO TP 118</td>
<td><strong>VS.</strong></td>
</tr>
<tr>
<td>Freez Thaw Testing ASTM C666</td>
<td><strong>VS.</strong></td>
</tr>
<tr>
<td>Surface Resistivity Test AASHTO T 358</td>
<td><strong>Rapid Chloride Permeability Test AASHTO T 277</strong></td>
</tr>
</tbody>
</table>

**AASHTO TP 118**
**AASHTO T 358**
**AASHTO T 277**
Tests specified for use in targeted applications. Use of tests during prequalification to predict/improve performance.

- Resistance to cracking
  - Volumetric shrinkage (drying shrinkage)
  - Target length change established
  - Likely used for bridge applications
  - Would typically be used to prequalify mixtures, not during construction
NCDOT PEM efforts so far…

- Participation in Pooled Fund
- Two internally funded projects

- FHWA Implementation Funds
  - **Category A**: Incorporating tests in the mix design/approval process (shadow testing)
  - **Category B**: Incorporating tests in the acceptance process (shadow testing)
  - **Category D**: Requiring the use of control charts, as called for in AASHTO PP 84-17.

- RP 2019-41 “Performance Engineered Concrete Mixtures – FHWA Implementation Funds” – technology transfer activities
Overall Objectives – NCDOT’s PEM initiatives

1. Establish preliminary specification recommendations, targets for selected PEM technologies and some prescriptive provisions
   - surface resistivity ✓
   - shrinkage ✓
   - Super Air Meter ¾ ✓
   - w/cm, cementitious content (prescriptive provisions) in progress

2. Explore ways to reduce paste/cement contents
   - optimized aggregate gradation Spring 2022
   - reduced cementitious contents

3. Support pilot project implementation ✓
   - pavement projects ✓
   - bridge projects Spring 2022
   - bridge deck overlay projects Spring 2022
   in progress

4. Support technology transfer to NCDOT division/regional personnel and industry stakeholders
NCDOT PEM efforts so far…

We have collected a lot of laboratory and field data…

Established proposed targets for PEM tests and shadow specifications

Trying selected tests out on pilot projects

Evaluating targets

Gathering stakeholder feedback – contractors, material suppliers, consultants
Suggested Specification for Resistivity (Section 1000-4C)

(C) Strength and Surface Resistivity of Concrete

The compressive strength *and surface resistivity* of the concrete will be considered the average test results of two 6 inch x 12 inch cylinders, or two 4 inch x 8 inch cylinders if the aggregate size is not larger than size 57 or 57M. Make cylinders in accordance with AASHTO T 23 from the concrete delivered to the work. Make cylinders at such frequencies as the Engineer may determine and cure them in accordance with AASHTO T 23 as modified by the Department. Copies of these modified test procedures are available upon request from the Materials and Tests Unit. Testing for compressive strength should be performed in accordance with AASHTO T 22. *Testing for surface resistivity should be performed in accordance with AASHTO T 358.*

When the average compressive strength or surface resistivity of the concrete test cylinders is less than the minimum targets specified in Table 1000-1 and the Engineer determines it is within reasonably close conformity with design requirements, these properties will be considered acceptable. *When the Engineer determines average cylinder strength or surface resistivity is below the specification, the in-place concrete will be tested.* Based on these test results, the concrete will either be accepted with no reduction in payment or accepted at a reduced unit price or rejected as set forth in Article 105-3.

**Suggested addition to Table 1000-1**

<table>
<thead>
<tr>
<th>Class of Concrete</th>
<th>Minimum surface resistivity at 56 days (kΩ-cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AA</td>
<td>15.0*</td>
</tr>
<tr>
<td>Pavement</td>
<td>11.0</td>
</tr>
</tbody>
</table>

*A 56 day minimum of 16.0 kΩ-cm can be required at the engineer’s discretion for applications where risk of chloride ion penetration is high.*
FHWA Implementation Project – Concrete Pavement

- I-85 widening project north of Charlotte, NC
  - 5.3 miles long
  - Existing 4-lane interstate widened to provide 4 additional travel lanes (2 lanes in each direction)
  - 500,000 SY of concrete pavement construction (12” thick JPCP)
  - Two phases:
    - April 2018 to September 2018
    - April 2019 to October 2019
Surface Resistivity

All lots of slipformed (460SLNS) and hand placed (496HP) mixtures met the proposed target of 11 kΩ·cm by 90 days.

Slipformed mixture:
• 85 of 106 (80.1%) met target by 56 days
• 11 of 21 lots not making the target were very close (>10.5 kΩ·cm) at 56 days

Handplaced mixture:
• 4 lots of hand placed mixture that didn’t make 56-day target were >10 kΩ·cm at 56 days

Proposed resistivity target for pavement concrete from previous research
Surface Resistivity

- Control charts show reduction in variability of the concrete produced.
- Standard deviation for 3-day resistivity reduced by almost half between Phases 1 and 2.
- Standard deviation for 28-day paving also showed significant reduction (1.09 kΩ·cm to 0.79 kΩ·cm)
FHWA Implementation Project Outcomes

This project resulted in:

• Contractor use of PEM tests, trial run of shadow specs and performance targets:
  • Box Test
  • SAM
  • surface resistivity

• Technology transfer to regional/divisional NCDOT personnel

Support of a contractor and commitment to use of PEM tools on their next project
Contractor Experience / Lessons Learned

• PEM tests were integrated into two-year project without additional QC staff to support the extra testing

• **Box Test** highly useful for mixture development and modifications during project
  - SAM test was successfully performed, data exhibited undesirable variability
    - Additional training needed, use consistent operator
  - **Surface resistivity** straightforward to perform, readily integrated into QC practices
    - Provided insight into consistency of material produced
    - Pilot project should show satisfactory durability performance
    - PEM tests will be used in future projects, including mixture design phase
Structural Concrete PEM Implementation Project
I-485 Widening (I-5507 Design Build)

- I-485 widening project south of Charlotte, NC
  - 18.2 miles long
  - High-occupancy toll (HOT) lanes along entire stretch of roadway
  - 17 structures, 15.3 miles of new sound wall
  - 3 year duration

- Concrete Supply Co. is providing most structural mixtures
  - AA, Drilled Pier, A

- PEM Shadow Testing
  - SAM, surface resistivity, shrinkage
  - Completed Spring/Summer/Fall 2021
• **SAM** testing by agency/contracted personnel, both before and after the pump

• **Resistivity** testing by NCDOT regional lab

• **Shrinkage** – round robin testing to assess lab variability (UNC Charlotte, Wood, NCDOT)

• Concrete supplier also gathering data for resistivity and SAM

Data collected on multiple components of about 8 structures, including deck overlays
SAM data collection at current PEM implementation site (I-485 Widening)
Contractor Experience / Lessons Learned

- Engaged local ready-mix supplier, multiple testing laboratories

- **SAM** test was successfully performed, data shows far less variability
  - Additional training worked, use consistent operator(s)

- **Shrinkage** round robin
  - Two labs reported highly similar shrinkage results, variability
  - Third lab reported substantially higher shrinkage, double the range in measurements
  - May require additional training for participants
  - Likely used for mixture development/approval phase, selected projects only

Quantifying benefits of PEM implementation is a key goal of these pilot projects
- Benefits to contractor
- Benefits to agency
More information on PEM and NCDOT’s initiatives

• National Concrete Pavement Technology Center
  PEM website: https://cptechcenter.org/performance-engineered-mixtures-pem/

• NCDOT funded research reports - available at Connect NCDOT
  – https://connect.ncdot.gov/projects/research/Pages/default.aspx
    NCDOT RP 2018-14 Final Report – available now
    NCDOT RP 2019-41 Final Report – available now
    NCDOT RP 2020-23 Final Report – posted after project end 3/2022

• Report submitted to FHWA on Pilot Project for Pavement PEM
Quality Control for Concrete Paving: A Tool for Agency and Industry

- Available for download at CP Tech Center’s website.

- Improved Quality
- Improved Working Atmosphere
- Reduced Costs for Agency & Competitive Advantage for Contractor
- Fewer Quality Disputes
- Improved Public Image

Safe & Long Lasting Concrete Pavements
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 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 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
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>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 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</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>development</td>
<td>Maturity</td>
<td>ASTM C1074</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></td>
<td></td>
<td>• Indicates uniformity batch to batch</td>
</tr>
<tr>
<td>Other</td>
<td>Hydration</td>
<td>Semi-adiabatic calorimetry</td>
<td>• Indicates uniformity batch to batch</td>
</tr>
</tbody>
</table>
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
  - Frequency
  - Locations
  - Action limits
  - 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.
Appendix D: Model QC Plan

4.0 MATERIALS CONTROL

4.1 Materials Suppliers

The following material suppliers will be providing materials for the concrete pavement. All material suppliers will be responsible for testing and inspection 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 Supply</td>
<td>Bituminous, USA</td>
</tr>
<tr>
<td>Coarse-Intermediate Aggregate</td>
<td>No. 57/No. 89</td>
<td>Rocky Aggregate Company</td>
<td>Metamorphic, USA</td>
</tr>
<tr>
<td>Fine Aggregate</td>
<td>C33 natural sand</td>
<td>Sandy Banks Company</td>
<td>Siliceous, USA</td>
</tr>
<tr>
<td>Admixtures</td>
<td>Air entraining admixture bubble, 9000, Mid-range water reducer Stamped 750</td>
<td>Chemical Admixture Company</td>
<td>Synthetic, USA</td>
</tr>
</tbody>
</table>

* Modify table as appropriate.

4.2 Applicable Specifications and Standards

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

4.3 Plant Layout and Materials Delivery/Storage

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

4.3.1. Cementitious materials

* Provide information on delivery and storage of cementitious materials.

4.3.2. Aggregates

* Provide information on delivery and storage of aggregates. Provide details on stockpile management and means to protect stockpiles from contamination. Describe the stabilized foundation used beneath stockpiles and how moisture variability will be controlled. Also describe plant loading 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 Sublot Sizes

Each Lot of material will represent material from the same source, be produced or obtained under the same controlled process, and will possess normally distributed specification properties. Each Lot will be divided into Sublots of equal size in order to assess the quality characteristics of the Lot. The Lot size and corresponding sublot size for each item is identified in the following table.

<table>
<thead>
<tr>
<th>Item</th>
<th>Lot type(s)</th>
<th>Lot size</th>
<th>Sublot size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggregates</td>
<td>Coarse aggregate</td>
<td>300 CY</td>
<td>60 CY</td>
</tr>
<tr>
<td></td>
<td>Intermediate aggregate</td>
<td>300 CY</td>
<td>60 CY</td>
</tr>
<tr>
<td>Fine aggregate</td>
<td>300 CY</td>
<td>60 CY</td>
<td></td>
</tr>
<tr>
<td>Concrete</td>
<td>Fresh concrete</td>
<td>2,000 SY</td>
<td>1,000 SY</td>
</tr>
<tr>
<td></td>
<td>Hardened concrete</td>
<td>300 CY</td>
<td>See testing table below</td>
</tr>
<tr>
<td></td>
<td>Concrete pavement</td>
<td>5,000 SY</td>
<td>1,000 SY</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 test for each lot of material prior to placement of the lot. All samples will be obtained randomly in accordance with ASTM D665. The random sample location for each Sublot will be determined by station, offset, and depth within the sublot.

All random sample locations will be documented on standard test report form D665. A copy of the random sampling forms is located in Appendix A. PCC Paving Contractors will provide the State Transportation Agency a copy of the random sampling locations (a completed form D665) for each placement, during the start 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:
<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 subplot 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></td>
<td>• Air content - ASTM C231</td>
<td>5,000 SY</td>
<td>5</td>
<td>First 3 loads per day; repeat for 3 loads whenever admixture dosages are adjusted</td>
<td>1. Plant</td>
<td>Biased, start of day</td>
<td>Tabular and control chart</td>
</tr>
<tr>
<td></td>
<td>• SAM - AASHTO T 152</td>
<td>N/A</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>
<td>Fresh concrete</td>
<td>• Temperature - ASTM C1064</td>
<td>5,000 SY</td>
<td>5</td>
<td>1 per subplot</td>
<td>Grade</td>
<td>Random</td>
<td>Tabular and control chart</td>
</tr>
<tr>
<td></td>
<td>• Air content - ASTM C231</td>
<td>5,000 SY</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Air void system – AASHTO T 152</td>
<td>5,000 SY</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Unit weight - ASTM C138</td>
<td>5,000 SY</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fresh concrete at grade</td>
<td>• Water content - AASHTO T 318</td>
<td>5,000 SY</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hardened concrete</td>
<td>• Compressive strength - ASTM C39</td>
<td>5,000 SY</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Resistivity - AASHTO T 358</td>
<td>5,000 SY</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concrete pavement</td>
<td>• Thickness probe, per agency spec</td>
<td>5,000 SY</td>
<td>5</td>
<td>1 per subplot</td>
<td>Grade</td>
<td>Random</td>
<td>Tabular and control chart</td>
</tr>
<tr>
<td></td>
<td>• Maturity - ASTM C1074</td>
<td>5,000 SY</td>
<td>5</td>
<td>1 per subplot</td>
<td>Grade</td>
<td>Random</td>
<td>Tabular and control chart</td>
</tr>
<tr>
<td></td>
<td>• Thickness - ASTM C174</td>
<td>5,000 SY</td>
<td>5</td>
<td>1 per subplot</td>
<td>Pavement cores</td>
<td>Random</td>
<td>Tabular and control chart</td>
</tr>
<tr>
<td></td>
<td>• Thickness MIT-SCAN-T3</td>
<td>5,000 SY</td>
<td>5</td>
<td>1 per subplot</td>
<td>Pavement cores</td>
<td>Random</td>
<td>Tabular and control chart</td>
</tr>
<tr>
<td></td>
<td>• Dowels MIT-DOWEL-SCAN</td>
<td>N/A</td>
<td>N/A</td>
<td>All dowelled joints</td>
<td>All dowelled joints</td>
<td>N/A</td>
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Example lot sizes, sublots, and sampling and testing frequencies from several states’ specifications are provided.
Section 6: Control Charts –
Trends that suggest assignable cause variability
Acknowledgements – QC Guide

- FHWA – Mike Praul, Gina Ahlstrom, Jagan Gudimettla
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- Technical Advisory Committee

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<th>State Agencies</th>
<th>Contractors</th>
<th>Industry/Associations</th>
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<td>Maine DOT – Rick Bradbury</td>
<td>Rieth-Riley – Pete Capon</td>
<td>ACPA – Leif Wathne, Gary Mitchell</td>
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<td>Michigan DOT – John Staton</td>
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<td>Illinois Tollway – Cindy Williams</td>
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<td>FHWA</td>
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<td>Mike Praul, Sam Tyson, Dennis Dvorak, Jeff Withee, Bob Conway</td>
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Thank you!

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