Quality in the Concrete Paving Process

Raising the Quality Bar - Everyone Wins!

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What?

• Quality Assurance
  – We *test and inspect* to insure pavement meets specifications
  – We have *quality procedures* to insure long life pavements
  – These are not the same!
Testing vs. Quality

• Testing does not insure quality
• Testing is a tool to achieve quality
• Testing and inspection allow us to anticipate and avoid problems
• We use test results to achieve quality
Quality in the Concrete Paving Process

Workshops

Upcoming Workshops to date

Alaska
Hawaii

Quality in the Concrete Paving Process
Agenda

• Workshop Introduction
• Module 1: Quality Assurance Concepts
• Module 2: Materials and Characteristics for Quality Pavement
• Module 3: Pre-Paving and Mix Production
• Module 4: Paving
• Module 5: Utilizing Quality Concepts
• Module 6: Quality in Field Practice

Both contractors and agency personnel!
Reference Materials

• Participant Workbook
  – All the presentation slides
  – Class exercises
Reference Materials

• Testing Guide
  – Identified concrete tests for critical concrete properties
  – What to test
  – Purpose
  – How to test
  – What does it mean?
  – Implication
Reference Materials

• Quality Manual
  – What to inspect
  – How to inspect
  – Format of the Workshop
  – QC Plan
  – Checklists
  – Both contractors and agency
Reference Materials

• Flash Drive
  – ACPA: *Concrete Pavement Field Reference: Pre-Paving*
  – ACPA: *Concrete Pavement Field Reference: Paving*
  – NHI Course 134064: *Transportation Construction Quality Assurance*
  – Example QC Plan
  – Example spreadsheets for control charts
Contractor Benefits

• Contractors who consistently meet specifications have an advantage at the bidding table
  
  – Reduce Penalties
    • Done right the first time
    • Reduced Re-Work
    • QC costs are typically a fraction of re-work costs
  
  – Increase Incentives
    • Know you will get full incentive
    • Use incentive to reduce bid amount

• Allows energy for monitoring the process, not wasting it on fixing problems
Agency Benefits

• Agency receives improved quality without additional cost
• Finish project sooner
  – Frees up personnel sooner
  – Open to the public sooner
• Avoids time needed to assess re-work and determine penalty
• Creates a better working environment
• Public gets a longer lasting pavement
Core Elements of a QA Program

- Quality Assurance
- Quality Control
- Agency Acceptance
- Independent Assurance
- Dispute Resolution
- Qualified Labs
- Qualified Personnel
Acceptance Plans that Recognize Inherent Variability

• Based on proven mathematical probability (MIL 414)
• Take into account the sources of inherent variability
• Provide a more realistic assessment of degree of conformance
Quality Measurement Tools

• Two principal tools used to measure conformance with requirements:
  – Inspection
  – Testing
Inspection Components

- Equipment
- Materials
- Workmanship
- Environmental Conditions
Measuring Quality with Testing

• Three criteria must be identified to assess Quality through testing:
  – Quality Characteristics
  – Quality Measures
  – Quality Limits
Sampling

• “The process of selecting one or more samples from a population (Lot).”

• Key elements of sampling system:
  – Lots
  – Statistical Samples
    - Minimum of 3 samples
    - Ideally 8 to 20 random samples
  – Sublots
  – Samples
Random Sampling

- Removes bias
- All materials have an equal probability of being sampled
- Appropriate for acceptance testing
- Appropriate for statistical process control
Sources of Variability

- Material
- Process
- Sampling
- Testing

Composite Variability
Validity of Sampling Data

• The principles associated with Normal Distribution can be applied to determine the Quality of a Lot of Material, assuming:

1) “Multiple” (n ≥ 3) samples are used
2) All samples are “Randomly” obtained
3) Samples are obtained from the same Lot under “Controlled Conditions”
Re-Sampling vs. Re-Testing

• Re-sampling
  – Take a new material sample
  – Replace the original sample with the new

• Re-testing
  – Perform another, separate test
  – Perform the test on the split from the original sample
Analysis and Application of QC Test Results

• Control charts
  – Used to plot and monitor consecutive QC test results
  – Results can be tracked against a process target/limits
  – Can help to identify whether the process is in control
Control Charts

• Control charts do not
  – Eliminate variability
  – Tell you where your problem lies
  – Tell you how to correct the problem

• Some control charts
  – Help distinguish between the inherent chance causes of variability and assignable causes
Acceptance Function

• Acceptance is not focused on directing the methods used to achieve conformance

• The primary objectives of agency acceptance are:
  – Measure the Quality of all materials produced and placed by the contractor
  – Determine the corresponding payment the contractor should receive
Acceptance Function

• Quality measurement is achieved through three general acceptance activities:
  – Monitoring the adequacy of contractor QC activity
  – Performing acceptance inspection to identify visually deficient work
  – Performing Acceptance sampling and testing for key quality characteristics

• Agency is obtaining information to confirm that all products meet the specified quality level
Module 2:
Materials and Characteristics for Quality Pavement
Concrete Materials

- Cements / Supplementary cementitious materials
- Aggregates
- Water
- (Admixtures)
How SCM’s Work

**Cement**

Calcium Silicates + Water → CSH + CH

Causes Stuff to Harden
Calcium Hydroxide

**Secondary Reaction**

Fly Ash / Slag

Supplemental Cementitious Material + Water + CH → CSH

Calcium Carbonate

Begins after the cement reaction
Chemical Admixtures

- Air entraining admixtures (AEA)
- Water reducers
- Set modifying admixtures

To make good concrete better, not to fix bad concrete!!
Quality in the Concrete Paving Process

Strength

• Affects fatigue cycles
• Controlled by w/cm
  – Other factors are indirect
  – Strength and durability are not the same
Permeability

• **Test (Surrogate tests for durability)**
  
  – Rapid Chloride Permeability Test (Indirectly)
  
  – Wenner Probe/Surface Resistivity Test (Indirectly)

Rapid Chloride Permeability Test

Surface Resistivity Test
Unit Weight

• Test
  – Unit Weight

• Quality Indicator for:
  – Uniformity
    • Batching tolerances
  – Air Content
Calorimetry

- Test
  - Calorimetry (heat signature)

- Quality Indicator for:
  - Cementitious system
  - Strength development
  - Time of set
  - Sawing window
  - Uniformity
Air Content

- Test
  - Air Content

- Quality Indicator for:
  - Freeze-thaw damage
  - Strength

Air 1%  Strength 5%
Air Void System

• Why?
  – Water expands when it freezes

• What are we looking for?
  – Small bubbles close together
  – Air void system is more important than total air content

Expansion of 9%
Quality Control Stage

- Monitor mixture quality during production and react to changes
  - Gradation
  - Slump
  - Unit weight
  - Air content
  - Microwave water content
  - Strength
  - Permeability
Incompatibility

• All materials meet specification, yet the mixture is unsatisfactory
  – Early stiffening
  – Air entrainment
  – Strength development

• Due to chemical reactions between materials

• Change mix temperature, SCM dose and/or admixture type

• Refer to page 9 of the “Testing Guide”
Volume Shrinkage

- Drying
- Thermal
- Plastic
- Autogenous
- Settlement

Not to scale
Pre-Paving Activities

1. Subgrade/Subbase Construction
2. Staking, Stringline and Stringless Construction
3. Fine Grading
4. Dowel Basket Placement
5. Steel Placement (CRCP)
6. Paver Preparation
7. Aggregate Stockpile Management
8. Plant Set-Up and Calibration
9. Mixture Production
10. Transporting Concrete
Dowel Basket Placement

• Load transfer
• Why?
Paver Preparation

- Extrusion process

- Check slab dimensions and cross-slopes
Aggregate Stockpile Management

• Minimize segregation
  – Build long and wide-NOT high!
  – Build stockpiles in tiers to avoid segregation
Aggregate Stockpile Management

• Uniform Moisture
  – Stable and well drained foundation underneath stockpiles
  – Place a separation layer on top of soil
  – Draw from areas of known moisture content
Aggregate Stockpile Management

- Mud balls
Recommended Practices

• Adequate mixing time
  – Uniformity
  – Air entrainment
  – Strength
  – Workability
Transporting Concrete

• Maintain haul route
Paving Activities

Refer to the “Field Reference Manual for Quality Concrete Pavements” for details on steps shown in italics

11. Concrete Placement
12. Slipforming
13. Insertion of Dowels and/or Tie Bars
14. Hand Finishing
15. Texturing
16. Curing
17. Sawing
18. Weather Adjustments
Spreading Concrete

- Continuous supply of concrete to the paver
- Consistent head => smoothness
Consolidation

- Match vibrator frequency to workability and paver speed
- Electronic vibrator monitor
Key Inspection Items

• One contactor example
• Tape QC Inspection list on the paver
  • Stringline – constant
  • Edge slump – every 50’
  • Offset alignment – every 50’
  • Slab width – every 50’
Key Inspection Items

• Check dowel location
  • Real-time
  • NDT

• Core verification after first day
  – Depth
  – Alignment
  – Position relative to sawn joint
QC Measurements

• Verify dowel bar location behind the paver
Key Inspection Items

- Periodically verify steel location behind the paver
  - Cover meter (pachometer)
  - GPR after hardened
  - MIT-SCAN-2
Key Inspection Items

• MIT-SCAN-2
  • Cut the tie wires
Recommended Practices

- Identify bumps and dips – overlap straightedge by 1/2
- Correct bumps and dips
Texturing

• Macro Texture
  – Wet weather skid resistance
  – Reduce hydroplaning
Group Activity

Why do we Cure?
Recommended Practices

• Adequate number of saws on the project
Module 6: Quality in Field Practice
Quality in the Concrete Paving Process

Slump

- Measure of consistency
- Quick and easy
Air Void Analyzer

- Air void system
- Initially to verify a good air void system
- For QC, not for specification compliance
- Higher total air => lower spacing factor

<table>
<thead>
<tr>
<th>Spacing Factor, in</th>
<th>0.01 in Limit</th>
<th>·0.015 in Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>At the plant</td>
<td>Intervals</td>
<td></td>
</tr>
<tr>
<td>Total Air</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- 5.2% 6.5% 6.0% 6.5% 5.0% 5.3%
Heat Signature

- Cementitious system
- Strength development
  - Time of set
  - Sawing window
- Incompatibilities
- Uniformity
Permeability

• Surface Resistivity Test
  – Easy and quick test

• Rapid Chloride Permeability Test
  – Takes more time and effort- old stand by
Heat Signature vs. Surface Resistivity

\[ y = 1351.9e^{-0.046x} \]

\[ R^2 = 0.9141 \]
HIPERPAV

[Example]

• Software tool for assessing cracking risk
HIPERPAV
• Software tool for assessing cracking risk

Placement on the night of 5/21/12

@ 5:00 A.M.
HIPERPAV

- Software tool for assessing cracking risk

**Placement on the night of 5/22/12**

**@ 4:00 A.M.**
Maturity

- Maturity curve
  - Temperature and time factor can be used to determine in-place pavement strength

![Maturity Curve - Standard Cured Beams](image)

- Opening strength = 550 psi MOR
- Specimens Cast on 5/16/12
- 820 C-Hrs
Maturity

- Maturity curve
  - Temperature and time factor can be used to determine in-place pavement strength

Maturity number = 820 °C-Hrs

Field Maturity (5/18/12)

Field Maturity (5/21/12)

Opening strength = 550 psi MOR
MIT-SCAN-T2

• Thickness example
  – Design thickness = 11”
  – Average thickness (T2)= 12.3”
Air/Unit Weight

- Normally they will run parallel
  - Unit weight changes if air content changes
  - Unit weight changes if water (slump) changes
- When they diverge
  - Change in materials or proportions
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