Plans for Future Performance – Related Specifications (Incentives/ Disincentives)

Shreenath Rao, Ph.D., P.E.

FHWA Tollway National Open House, August 20, 2013
Performance-Related Specifications

“QA specifications that describe the desired levels of key materials and construction quality characteristics that have been found to correlate with fundamental engineering properties that predict performance”
Performance-Related Specifications

“...employ the quantified relationships containing the characteristics to predict as-constructed pavement performance. They thus provide the basis for rational acceptance/pay adjustment decisions.”
Important Definitions

- **AQC Target** – Acceptance Quality Characteristic Target: target average (and standard deviation) levels.
- **RQL** – Rejectable Quality Levels: AQC levels requiring correction or replacement.
- **MQL** – Maximum Quality Levels: AQC levels requiring no additional pay incentive.
- **PF** – Pay Adjustment Factor: Adjustment to contract payment based on the ratio of the as-built pavement Life-Cycle Costs (LCC) to the as-designed LCC.
Performance-Related Specifications

Specify the target **mean** (and **standard deviation**) levels of AQC’s that:

- Are measureable (more rapid the better)
- Have been found to correlate with performance (prediction models required)
- Are under contractor’s control (can be varied on a project)
- Can be used to compute incentives and disincentives
PRS Benefits

- The pavement design is used directly to develop the construction performance specification.
- Testing that focuses on key quality characteristics that relate to the pavement long-term performance.
- Incentives and disincentives that are justified through reduction or increase in future life-cycle costs.
- Allow contractors to be more innovative and more competitive.
- Compared to warranties, no long-term monitoring and management required.
Shadow PRS

- Develop and Evaluate PRS like FULL implementation
- Does not impact contractor pay for the shadow project
- Learning and pre-implementation tool

Paul Kovacs
Gregory Stukel
Steve Gillen

Michael Darter, Leslie Titus-Glover, Shreenath Rao, William Vavrik

DTFH61-08-C-00029
Richard Duval
Mobile Concrete Lab
Gary Crawford
Jagan Gudimettla

Tollway
Illinois

U.S. Department
of Transportation
Federal Highway
Administration

## PaveSpec 4.0
### Mechanistic-Empirical Models and AQC's

<table>
<thead>
<tr>
<th>Input</th>
<th>Significantly Impact Distress</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Transverse Cracking</td>
</tr>
<tr>
<td>Initial Smoothness</td>
<td>X</td>
</tr>
<tr>
<td>PCC Strength</td>
<td>X</td>
</tr>
<tr>
<td>PCC Thickness</td>
<td>X</td>
</tr>
<tr>
<td>PCC CTE</td>
<td>X</td>
</tr>
<tr>
<td>Effective Dowel Diameter*</td>
<td></td>
</tr>
<tr>
<td>PCC air content</td>
<td></td>
</tr>
<tr>
<td>PCC mix w/c ratio</td>
<td>X</td>
</tr>
</tbody>
</table>

*Computed by measuring dowel alignment & NCHRP 10-69 procedure*
PaveSpec 4.0 vs. PaveSpec 3.0

**GUI**
- INPUT GUIs *(new)*
- Simulation GUIs *(new)*

**PAVESPEC 4.0 ENGINE**
- Cracking.exe *(new)*
- Faulting.exe *(new)*
- Spalling.exe *(new)*
- IRI.exe *(new)*
- Simulation.exe *(new)*
- LCC.exe *(PaveSpec 3.0)*
- PF.exe *(PaveSpec 3.0)*

**OUTPUT REPORTS**
- Output GUIs *(new)*
- Files (*.docx, *.pdf) *(PaveSpec 3.0 revised)*

Modular
Not Linear
Developing PRS

Establish Performance Criteria

Identify AQC\textsuperscript{s} and Target Values

Design AQC vs. As-Constructed AQC

Pay Factor $f(\Delta \text{LCC})$

Compare As-Built and As-Designed

As-Designed

As-Constructed

M&R Plan

PAVESPEC

Quality

Pavement Age
Model ME Performance

Designed

Constructed
Select AQC's

- 28-day compressive strength (psi)
- Air content (%)
- PCC thickness (in)
- Profile Index / smoothness (in/mi)
- Effective dowel diameter*

Performance Criteria

- PI/IRI
- Transverse cracking
- Joint faulting
- Joint spalling

*Computed by measuring dowel alignment & NCHRP 10-69 procedure
Work Plan for Shadow I-90 Illinois Tollway

1. Conduct project coordination meetings
   - select location, gather information, develop sampling & testing plan

2. Collect and analyze historical data
   - AQCs, M & R criteria, costs, discount rate, etc.

3. Develop PRS pay factors
   - PaveSpec 4.0, PaveSpec 3.0

4. Prepare for PRS implementation on project
   - layout of lots & sublots, sampling & testing details
Work Plan for Shadow I-90 Illinois Tollway

5. Conduct field sampling and testing on selected portion of project
   FHWA MCL + Illinois Tollway QC/QA data

6. Evaluate PRS results
   Incentives/disincentives for each lot; how they compare with conventional specifications

7. Prepare final report and presentation
   feedback to Tollway and FHWA on PRS
Pavement Type Selection Report

- I-90 (West Section)
- Traffic
- Design
- Reliability & Performance Criteria
- Support conditions
- M & R strategies
- Costs & other miscellaneous data
Project Information

- **Performance criteria:**
  - 172 in/mi IRI, 0.12 in faulting, 15% slabs cracked, 95% reliability

- **Traffic**
  - ~44 million trucks, 51% in design direction, 70% in design lane, 65% Class 9, 1.5% compound growth

- **30-year design**
  - 12” PCC, 3” HMA, 3+9” Aggregate Base, 1.5” dowels
  - 12.5’ slab width, 15’ joint spacing

- **Lots/sublots**
  - 1 lot ~ 5000 lane-ft (10 sublots)
  - Consistent with Tollway lots/sublots
## Maintenance and Rehabilitation Strategy

<table>
<thead>
<tr>
<th>Year</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Construct new JPCP with HMA shoulders</td>
</tr>
</tbody>
</table>
| 11   | Mainline—Reseal 100% transverse joints (TJ) and 100% longitudinal joints (LJ)  
Shoulder—Rout and seal all cracks; Apply microsurface |
| 18   | Mainline—Concrete full-depth patching (3.5% of area); Reseal 100% TJ and 100% LJ  
Shoulder—Rout and seal all cracks; Apply microsurface |
| 25   | Mainline—Concrete full-depth patching (5.0% of area); Diamond grind; Reseal 100% TJ and 100% LJ  
Shoulder—Rout and seal all cracks; Apply microsurface |
| 30   | Mainline—Concrete full-depth patching (6.0% of area); Apply 4.0-in SMA overlay  
Shoulder—Apply 4.0-in HMA overlay |
| 38   | Mainline—Rout and seal all cracks  
Shoulder—Rout and seal all cracks |
| 44   | Mainline—Remove 4.0-in SMA; Concrete full-depth patching (7.0%); Apply 4.0-in SMA overlay  
Shoulder—Rout and seal all cracks; Apply microsurface |

Varies

as-constructed vs. as-designed
Historical AQC Data

- Means and Standard Deviations
- IMIRS (Illinois Materials Inspection and Reporting System) database
  - Compressive strength, air content
- Historical QC/QA data over last 2-5 years
  - Smoothness, thickness
- Other sources
  - National historical dowel alignment data
PaveSpec 4.0
### PaveSpec 4.0

#### Specification Development
- Performance
- Sampling and Testing
- Structure
- Traffic
- Climate
- Maintenance and Rehabilitation
- Unit Costs
- Simulation Control

#### Performance Indicator and AQC's
<table>
<thead>
<tr>
<th>Indicator</th>
<th>Threshold Value</th>
<th>AQC's that be Influenced</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transverse joint faulting (in)</td>
<td>0.12</td>
<td>Thickness, Coefficient of Thermal Expansion, Dowel Diameter</td>
</tr>
<tr>
<td>Transverse joint spacing (%)</td>
<td>20</td>
<td>Compressive Strength, Thickness, Air Content, Water/Cement Ratio</td>
</tr>
<tr>
<td>Transverse slab cracking (%)</td>
<td>15</td>
<td>Flexural Strength, Thickness, Coefficient of Thermal Expansion</td>
</tr>
<tr>
<td>Smoothness (in/mile)</td>
<td>12</td>
<td>Flexural Strength, Thickness, Coefficient of Thermal Expansion</td>
</tr>
</tbody>
</table>

#### Strength AQC
- Compressive

#### Acceptance Quality Characteristic

<table>
<thead>
<tr>
<th>AQC’s</th>
<th>Status</th>
<th>Sample Method</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCC compressive strength (psi)</td>
<td>Required</td>
<td>Normal</td>
<td>5300</td>
<td>875</td>
</tr>
<tr>
<td>PCC thickness (in)</td>
<td>Required</td>
<td>Normal</td>
<td>12</td>
<td>0.25</td>
</tr>
<tr>
<td>PCC coefficient of thermal expansion (in/in/°F)</td>
<td>Required</td>
<td>Normal</td>
<td>0.000005</td>
<td>0.000005</td>
</tr>
<tr>
<td>PCC air content (%)</td>
<td>Required</td>
<td>Normal</td>
<td>5</td>
<td>1.5</td>
</tr>
<tr>
<td>PCC water cement ratio</td>
<td>Required</td>
<td>Normal</td>
<td>0.38</td>
<td>0.04</td>
</tr>
<tr>
<td>Dowel Diameter (in)</td>
<td>Required</td>
<td>Normal</td>
<td>1.4</td>
<td>0.05</td>
</tr>
<tr>
<td>Initial smoothness (in/mi)</td>
<td>Required</td>
<td>Normal</td>
<td>75</td>
<td>10</td>
</tr>
</tbody>
</table>

Note: Select AQC's to sample. Unnecessary AQC's cannot be sampled. If you select not to sample a required AQC, you must specify an as-designed value instead.
PaveSpec 4.0
PaveSpec 4.0

Maintenance
- Repair 100% of spalled joints with full-depth repairs
- Repair 100% of cracked slabs with full-depth replacement

Global Rehabilitation Sequence
- 1st: Diamond Grinding, Assumed Life: 5 years, Stat IRI: 125 in/mile, End IRI: 175 in/mile
- 2nd: AC Overlay, Assumed Life: 14 years, Stat IRI: 70 in/mile, End IRI: 175 in/mile
- 3rd: AC Overlay, Assumed Life: 14 years, Stat IRI: 70 in/mile, End IRI: 175 in/mile
- 4th: AC Overlay, Assumed Life: 14 years, Stat IRI: 50 in/mile, End IRI: 175 in/mile

Note: If needed, 4th rehabilitation is repeated until end of analysis life
PaveSpec 3.0* Results (Compressive Strength)

*Placeholders while PaveSpec 4.0 software is being developed and tested
PaveSpec 3.0* Results (Thickness)

*Placeholders while PaveSpec 4.0 software is being developed and tested
PaveSpec 3.0* Results (Air Content)

*Placeholders while PaveSpec 4.0 software is being developed and tested
PaveSpec 3.0* Results (Smoothness)

*Placeholders while PaveSpec 4.0 software is being developed and tested
Lot Composite Pay Factors

\[ PF_{lot} = \left( \frac{PF_{str}}{100} \right) \cdot \left( \frac{PF_{air}}{100} \right) \cdot \left( \frac{PF_{thk}}{100} \right) \cdot \left( \frac{PF_{smth}}{100} \right) \cdot \left( \frac{PF_{dowel}}{100} \right) \times 100 \]

Maximum Composite PF: 105%
Minimum Composite PF: 80%*

- *Provided AQCs are above the RQLs for strength, air content, dowel diameter and thickness, and below the RQL for smoothness.
- Accept or reject concrete on a sublot-by-sublot basis.
- If RQL not met for any particular AQC, all current procedures for nonconforming materials shall apply for that particular sublot.
- No incentive/disincentive for a sublot with nonconforming materials.
Where do we go from here?

- Finalize analysis of historical data
- Finalize PRS Pay Factors
- Collect AQC data for lots/sublots (FHWA MCL + Illinois Tollway QA/QC data)
- Compute means/standard deviations for each lot
- Compute incentives/disincentives for each lot
- Final report & presentation
THANK YOU