HMA Performance-Related Specification (HMA-PRS)

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How PRS Works

1. **Pavement Design**
2. **Planning**
   - Establish Performance Criteria
   - Identify AQCs and Target Values
   - Determine Incentives/Disincentives
   - Pay Factor

**SOFTWARE**

- How PRS Works
- Planning
- Pavement Design
- Performance

**Graphs**

- Quality
  - Designed
  - Constructed
  - Design AQC vs. As-Constructed AQC

- Performance
  - As-Designed
  - As-Constructed

**Model Performance**

**Δ Life**

**I/DI**
Challenges in PRS Acceptance

- Testing efficiency and simplicity - **Completed**
- Standardization of test methods - **Ongoing**
- Reliability of performance prediction models - **Completed**
- Predictive relationships between AQCs and performance prediction model parameters - **Ongoing**
- Same principles and methods between mix design and PRS - **Ongoing**
Asphalt Mixture Performance Tester
## PBMD Laboratory Tests

<table>
<thead>
<tr>
<th>Property</th>
<th>Test Method</th>
<th># Tests</th>
<th>Testing Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modulus</td>
<td>Dynamic modulus test (AASHTO TP 79/PP 61)</td>
<td>3</td>
<td>1 day</td>
</tr>
<tr>
<td>Fatigue Cracking/Thermal</td>
<td>Direct tension cyclic test - SVECD</td>
<td>4</td>
<td>1.5 days</td>
</tr>
<tr>
<td>Cracking</td>
<td>(AASHTO TP 107)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rutting</td>
<td>Triaxial stress sweep test</td>
<td>4</td>
<td>1 day</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>11</strong></td>
<td><strong>3.5 days</strong></td>
</tr>
</tbody>
</table>
S-VECD Material Properties

- **$|E^*|$ Mastercurve**: Graph showing $|E^*|$ against reduced frequency.
- **Time-Temperature Shift Factor**: Graph showing log shift factor against temperature.
- **Damage Characteristic Curve**: Graph showing damage characteristic ($C$) against load level ($S$).
- **Energy-Based Failure Criterion**: Graph showing energy release rate ($G^r$) against cycle life ($N_f$).
Pavement Performance Prediction

LVECD Program
Damage Contours after 20 Years

Damage Factor ($N/N_f$) Distribution - @ September 1, 2021

- **Control**
- **Advera**
- **Sasobit**
- **Evotherm**
Field Validation of Models
Fatigue Cracking Transfer Function

Damage

Distress
Transfer Functions

\[
\%FC = \frac{100}{1 + \left(\frac{2.5D}{100}\right)^C}
\]

where \(\%FC = \% \text{ fatigue cracking},\)

\(D = \% \text{ damage predicted from LVECD},\) and

\(C = -0.83 - 724(1 + h_{ac})^{-3.103}\)

\[
RD_{Field} = \frac{RD_{LVECD}}{0.6946} - 4.2839
\]
Validation/Calibration Project - I

- NCAT Test Sections
  - Control
  - OGFC
  - High RAP
  - RAP + WMA
  - Foam WMA
  - Evotherm

Diagram:
- Surface (9.5 mm) 1.25" (32 mm)
- Intermediate (19 mm) 2.75" (70 mm)
- Base (19 mm) 3.00" (76 mm)
- Dense Graded Aggregate Base 6.00" (152 mm)
- Stiff Subgrade
Fatigue Prediction

NCAT

Before Calibration

No. of Cycles

Damage Area (%) 50
40
30
20
10
0
1.0E+06 1.0E+07 1.0E+08

After Calibration

No. of Cycles

LVECD Crack Area (%) 80
70
60
50
40
30
20
10
0
1.0E+07 1.0E+08

Field
Validation/Calibration Project - II

- Manitoba WMA Pavements
  - Surface layer: Control, Advera, Sasobit, Evotherm
  - Intermediate layer: Surface mixture + 35% RAP
Fatigue Prediction

MIT-WMA
Validation/Calibration Project – III

- Manitoba RAP Pavements
  - Surface layer
    - 0% RAP + PG 58-28
    - 15% RAP + PG 58-28
    - 50% RAP + PG 58-28
    - 50% RAP + PG 52-34 (soft binder)
  - Base layer: PG 58-28 mixture + 70% RAP

<table>
<thead>
<tr>
<th>0% RAP</th>
<th>15% RAP</th>
<th>50% RAP</th>
<th>50% RAP</th>
</tr>
</thead>
<tbody>
<tr>
<td>150/200 pen (PG 58-28)</td>
<td>150/200 pen (PG 58-28)</td>
<td>200/300 pen (PG 52-34)</td>
<td>150/200 pen (PG 58-28)</td>
</tr>
</tbody>
</table>

70% RAP Base Layer
Fatigue Prediction

**MIT-RAP**
Prediction Accuracy after Calibration

\[ y = 0.77x + 0.51 \]

\[ R^2 = 0.81 \]
Brazilian Pavements for Development of M-E Pavement Design Method

- Fundao project pavement test sections (27)
- National M-E project test sections (17)
Performance Prediction of Brazilian Pavements

\[ R^2 = 0.72 \]
Field Crack Area (%)

LVECD Crack Area (%)

No. of Cycles

Pavement ME

Alligator Cracking (%)
LVECD vs. Pavement ME

NCAT
LVECD vs. Pavement ME

MIT-WMA
LVECD vs. Pavement ME

MIT-RAP
Rut Depth Prediction

(a) NCAT

Total Rut Depth (mm) vs. Rut Depth

(b) FHWA

Total Rut Depth (mm) vs. Rut Depth

(c) MIT - WMA

Total Rut Depth (mm) vs. Rut Depth

(d) MIT - RAP

Total Rut Depth (mm) vs. Rut Depth
Rutting Prediction

All Sections

Before Calibration

After Calibration
Steps Involved in HMA-PRS Implementation
**Agency Actions Needed**

**Fact: Pavement structural design is available.**

**STEP 1:** Changes in fundamental properties due to a change in AQCs are estimated using predictive relations (either from agency’s material database, or from ongoing research by FHWA and NCSU).

**STEP 2:** “Typical” fundamental properties and their variance due to the variance of AQCs are input into the PRS software for the specific project in question.

**STEP 3:** Many automated simulations are performed using the PRS software to determine the predicted life from varying the AQCs in different combinations.

**STEP 4:** The agency sets the performance acceptance criteria and acceptable variance.

**STEP 5:** Agency develops a QA plan for the project (may be based on current practices).

**STEP 6:** Pay tables are created based on the change in simulated life.

**STEP 7:** A bidding specification is developed.

Note: Type of testing done (volumetric, index testing, or fundamental properties) will be dictated by the level of sophistication and accuracy desired by the agency.
Step 1: Contractor reviews the bidding specification and determines **initial job mix formulas** (one for each mix type on the project) using their selected materials in an attempt to meet the specifications.

Step 2: Based on the contractor’s knowledge, experience, and specific materials available, the contractor **evaluates their risk** in meeting the specifications. Based on this risk, the contractor makes one of the following decisions (A, B, or C):

- **A: No Bid.**
- **B: Contractor only does limited testing on the JMFs. Based mostly on volumetric testing and experience and knowledge.**
- **C: Contractor conducts performance testing and/or PBMD to assess risk and determine how to best optimize the mixes to meet the performance criteria and maximize profits.**

Step 3: Contractor makes a **QC plan**, which may or may not be above and beyond what is required by the agency in the specification.

Step 4: The contractor prepares and **submits the bid.**
Step 1: The agency determines the winning bid and awards the contract.

Step 2: The winning contractor selects and submits their JMFs to the agency for approval.

Step 3: The agency reviews the JMFs to ensure they each meet the requirements laid out in the specifications. Each mixture will be either:
- Accepted
- Rejected and require re-design

Step 4: Control strips may be used to verify the properties of the accepted mixes and construction process and the agency approves the JMFs for full production and construction.

Step 5: The agency applies their QA procedure for project monitoring.

Step 6: The project is constructed using the approved mixes. During the project AQCs are measured and changes in mixture properties are calculated using predictive relations.

Note: Regular testing of fundamental properties may be feasible during construction.

Step 7: Contractor pay is based on the AQC data and pay tables in the specifications.
Shadow PRS

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

AC Pavement Data
- In place density
- IRI

AC Mixture Data
- Binder content
- Bulk Specific Gravity
- $G_{mm}$
- Recovered Blended Agg. Gradation
- RAP/RAS Binder Content
- RAP/RAS Recovered Aggregate Gradation
- TSR
- Aggregate Moisture Content

Pay Factors

Empirical Relations?
Engineering Judgment?
Shadow PRS Acceptance Procedures

AC Pavement Data
- In place density
- IRI

AC Mixture Data
- Binder content
- Bulk Specific Gravity \( G_{mm} \)
- Recovered Blended Agg. Gradation
- RAP/RAS Binder Content
- RAP/RAS Recovered Aggregate Gradation
- TSR
- Aggregate Moisture Content

Empirical Relations?
- Engineering Judgment?
- Pay Factors

Shadow Specification (NCSU Research Effort)
- Engineering Properties
- Predictive Equations
- Performance Testing
- As-Designed Performance
- As-Constructed Performance
- Shadow Pay Factors
Final PRS Acceptance Procedures

**AC Pavement Data**
- In place density

**AC Mixture Data**
- Binder content
- Bulk Specific Gravity \( G_{mm} \)
- Recovered Blended Agg. Gradation
- RAP/RAS Binder Content
- RAP/RAS Recovered Aggregate Gradation
- TSR
- Aggregate Moisture Content

**Engineering Properties**
- Predictive Equations

**As-Designed Performance**
**As-Constructed Performance**

**Pay Factors**
Questions?