Field Validation of NCHRP 9-22A QRSS Software in Rhode Island: Preliminary Results

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Assistant Professor
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Introduction

• **NCHRP 9-22A Team**
  – Dr. Edward Harrigan, Transportation Research Board, project sponsor
  – Mr. Jim Moulthrop, Fugro Consultants, principal investigator
  – Drs. Matt Witczak, Myung Jeong, Mohamed El-Basyouny, Mr. Joe Phillips, AMEC/Arizona State University, southwest operations
  – Dr. Leslie McCarthy and Dave Mensching, Villanova University, northeast operations

• **Validation Sites**: Rhode Island, Texas, Utah
Overall Goal of Project

- Achieving Quality Assurance for HMA that:
  - Better methods/more accurate
  - Quicker / easier
  - Balanced with cost efficiency

QA Definition*

“All planned and systematic actions necessary to provide confidence that a product or facility will perform satisfactorily in service”

*TRB, Glossary of Highway Quality Assurance Terms
Introduction to QRSS Software

- Quality Assurance (NCHRP 9-22)

<table>
<thead>
<tr>
<th>Evaluation By PRS</th>
<th>Comparison</th>
<th>Evaluation By PRS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design JMF Mix Quality</td>
<td></td>
<td>As-Built Mix Quality</td>
</tr>
</tbody>
</table>

Standard, Criteria
NCHRP 9-22 Characteristics

- Developed based upon Performance Related Specification (PRS)
- Incorporated three performance prediction models (MEPDG basis)
- Included major asphalt mix characterization properties: dynamic modulus and creep compliance
- Utilized stochastic methods: Monte Carlo simulation and Rosenblueth approach
- Used service life concept to describe the pavement quality
- Calculated pay factors from predicted service life differences
Existing method vs. proposed method

- 9-22 utilizes mix volumetrics in estimating dynamic modulus (E*) and creep compliance, and ultimately pavement performance

  **Current: Volumetric-Based Procedure**

- 9-22A directly measures E* and creep compliance from Simple Performance Test (SPT) equipment on field mix samples

  **Research: Field-Based Procedure**
# General Comparison of Both Procedures

<table>
<thead>
<tr>
<th></th>
<th>Volumetric-based Procedure (9-22)</th>
<th>Field-based Procedure (9-22A)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Accuracy</strong></td>
<td>Good</td>
<td>Better</td>
</tr>
<tr>
<td><em><em>E</em> and D Measurement</em>*</td>
<td>Use of Regression (Predictive) Models</td>
<td>Use of Actual Lab Test (E* and D Tests)</td>
</tr>
<tr>
<td><strong>Supplemental Lab Test</strong></td>
<td>Gradation Air voids Asphalt content Specific gravities</td>
<td>Air voids Asphalt Content Specific gravity (G\text{mm})</td>
</tr>
<tr>
<td><strong>Analysis Time</strong></td>
<td>Faster</td>
<td>Fast</td>
</tr>
<tr>
<td><strong>Software</strong></td>
<td>QRSS (C# language basis)</td>
<td>PRS QA Computer Program (VBA – EXCEL basis)</td>
</tr>
</tbody>
</table>
How does a field-based method work?
Three main steps to get to pavement performance

1. Obtain field mix during production
   - Loose plant mix
   - Randomization (Sublots)
   - Field cores (not on this job however)

2. Manufacture test specimens in the lab with loose mix
   - Simulation of field mix condition
   - Number of specimens

3. Conduct E* test
   - Test condition (frequency and temperature)
Field-based Solution

- **Find Mean and Variance of \( E^* \) for As-Built Mix**
  - Manufacture Specimens w/ low and high air voids
  - Perform \( E^* \) test at the SPT effective temperature and frequency
  - Develop an \( E^*_{\text{eff}} \) and air voids relationship
  - Separately for rutting and fatigue cracking
Comparison of Service Life (Each Lot) (As-Design Mix vs. As-Built Mix)

As-Design
As-Built

Predicted Life Difference

Cumulative Frequency Distribution (%)

Service Life (year)
Computation of Pay Adjustment Factor (Each Lot)
Field Validation in Northeast:
Rt 102 near Foster, Rhode Island
Preconstruction Operations

• Photographs of preconstruction condition

• Info on structural and performance history (from Pavement Management System at RIDOT)

• Info on contract cost estimates (from RIDOT Construction) & resources involved

• Info on JMF mix design, QA plan, specs, etc. (from RIDOT Materials)
# Pavement Structure & Data

<table>
<thead>
<tr>
<th>HMA Surface</th>
<th>1.5” HMA Surface</th>
<th>PG76 – 28</th>
</tr>
</thead>
<tbody>
<tr>
<td>HMA Binder</td>
<td>2.5” HMA Binder</td>
<td>PG64 – 28</td>
</tr>
<tr>
<td>Reclaimed HMA Base</td>
<td>5” Reclaimed HMA Base</td>
<td>Cold recycled Base</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>RI DOT Pavement Management System</th>
<th>RI DOT Construction</th>
<th>QA (RIDOT Materials)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RI 102 2010-CR-009</strong></td>
<td>HPMS</td>
<td>Bid package $###,### Final cost info</td>
</tr>
<tr>
<td>Project Length 1.2 mi.</td>
<td>Maintenance History/Costs</td>
<td>Structural Design</td>
</tr>
<tr>
<td>Crack Seal History</td>
<td>Traffic Information (ADT)</td>
<td>Creep compliance results</td>
</tr>
<tr>
<td>Year 1 daily ESALs 3500</td>
<td>602</td>
<td>SPT test results</td>
</tr>
<tr>
<td>JMF Sample collection</td>
<td></td>
<td>QA data</td>
</tr>
<tr>
<td></td>
<td></td>
<td>JMF</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sample collection</td>
</tr>
<tr>
<td>Traffic</td>
<td>Structure</td>
<td>Climate</td>
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<tr>
<td>----------------------------------------------</td>
<td>-----------------------------------------------</td>
<td>----------------------------------------------</td>
</tr>
<tr>
<td>☑ Design Speed</td>
<td>☑ Thickness</td>
<td>☑ Location, Interpolation</td>
</tr>
<tr>
<td>☑ Growth rate unless specified, use 4%</td>
<td>☑ 1.5” surface, 2.5” base, 5” reclaimed base</td>
<td></td>
</tr>
<tr>
<td>☑ Design Life 20</td>
<td>☑ Subgrade information FWD data</td>
<td></td>
</tr>
<tr>
<td>☑ Year 1 Daily ESALs 16,811</td>
<td>☑ Design air-voids 4%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>☑ AC by Wt 19mm 5.3%, 9.5mm 6.7%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>☑ Binder Type surface 76-28 base 64-28</td>
<td></td>
</tr>
<tr>
<td></td>
<td>☑ Gb 1.03</td>
<td></td>
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<tr>
<td></td>
<td>☑ Design gradation</td>
<td></td>
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<tr>
<td></td>
<td>☑ Target in-situ air-voids unless specified, use 7%</td>
<td></td>
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<tr>
<td></td>
<td>☑ Target in-situ Gsb</td>
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<tr>
<td></td>
<td>☑ Target in-situ Gmm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>☐ E* data (from AMEC)</td>
<td></td>
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<tr>
<td></td>
<td>☑ Creep compliance data (from AMEC)</td>
<td></td>
</tr>
</tbody>
</table>
Why do we want to generate an estimate of cost to the Contractor & the DOT?

Is this field-based QRS approach going to be cost effective for both industry and state?
Materials Quantities Collected

• Raw JMF Materials
  a) One 5-gallon bucket of baghouse fines
  b) Six 1-gallon cans of liquid binder
  c) Ten buckets of aggregate, per lift
  • Split on proportions in JMF

Use to replicate the mix design Test in SPT
Materials Quantities Collected

• Field mix
  a) 5 Lots from each AC pavement layer
  b) 4 sublots from each Lot *(4 samples per day)*

• 50 buckets: 20 for base, 30 for surface lift

• Totals ~ 2500 lbs of hot mix

Compact and test in SPT
Prediction of potential thermal cracking

- Obtain in-place Air Voids (mean and variance)
- Manufacture three plugs w/ air voids of
  - \( \mu - 1.2 \sigma \)
  - \( \mu \)
  - \( \mu + 1.2 \sigma \)

![Diagram showing the process of cutting and trimming plugs from the Gyratory Compactor to individual specimens for creep compliance.](image)
Test Matrix for Thermal Cracking

- Creep Compliance Test

<table>
<thead>
<tr>
<th>Test Temp.</th>
<th>µ - 1.2 σ</th>
<th>µ</th>
<th>µ + 1.2 σ</th>
</tr>
</thead>
<tbody>
<tr>
<td>-20°C</td>
<td><img src="image1.png" alt="Graph" /></td>
<td><img src="image2.png" alt="Graph" /></td>
<td><img src="image3.png" alt="Graph" /></td>
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<tr>
<td>-10°C</td>
<td><img src="image4.png" alt="Graph" /></td>
<td><img src="image5.png" alt="Graph" /></td>
<td><img src="image6.png" alt="Graph" /></td>
</tr>
<tr>
<td>0°C</td>
<td><img src="image7.png" alt="Graph" /></td>
<td><img src="image8.png" alt="Graph" /></td>
<td><img src="image9.png" alt="Graph" /></td>
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</tbody>
</table>

In-place Va
Post Construction Operations

- Ship raw materials & field mix to AMEC
- Average thickness of each lift paved
- **RI DOT**: FWD testing after completion of each layer (i.e., after reclaimed HMA base, after AC binder lift, then after AC surface placed)
- **RI DOT**: IRI at completion of construction (partner with Mass Highway)
Next Steps

• Estimate cost to RI DOT for implementing field-based QRS:
  – DOT QA cost / subcontracts to materials labs
  – Lab certification costs
  – Sampling
  – Density testing in field (nuclear gauge??)
  – Labor/cost for SPT testing
    • SPT equipment
    • Coring device
    • Environmental chamber
    • Labor/cost for SPT testing
Next Steps

1. JMF replication done at AMEC labs
2. Materials & SPT testing done at AMEC labs
3. Analysis using 9-22 QRSS software done at Villanova
4. Analysis using SPT-methodology software done at Villanova
5. Performance and pay factors (bonus, penalty) for Rt 102 job predicted & presented to RI DOT
THANK YOU, NESMEA & NEAUPG!!

Ed Harrigan, NCHRP
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