Quantifying the Benefits of Polymer Modified Asphalt

North Central Asphalt User Producer Group Meeting
Madison, WI
Feb 4-5, 2009

Mark Buncher, Ph.D., P.E.
Director of Engineering, Asphalt Institute
Overview

- PMA Performance Study Quantifying the Benefits of PMA
  - 1st Article Reprint
- LCCA Basics
  - Review
- **Understanding the True Economics of Using PMA through LCCA**
  - 2nd Article Reprint
  - Example
- A Few Other AI Initiatives (if time allows)
Design Engineer’s Perspective

• PMA is One of Many Tools Available
• Performance Benefits Acknowledged
  – Many Lab and Field Studies
• Still, the Big Question Remains:
  – How Do I Quantify the Benefits of PMA?
This study (published by AI in Feb 2005) uses national field data to determine enhanced service life of pavements containing polymer modified binders versus conventional binders. The data is from a variety of climates and traffic volumes within North America.

Same study documented in 2007 TRB Paper (07-3230): “Quantification Of The Effect Of Polymer Modified Asphalt On Flexible Pavement Performance”
Study Sponsors

Industry Associations
- The Asphalt Institute
- The Association of Modified Asphalt Producers

Federal Highway Administration

Corporate Sponsors
- Arr-Maz Products
- ATOFINA Petrochemicals, Inc.
- Dexco Polymers LP
- Dynasol LLC
- KRATON Polymers
- Polimeri Europas Americas
- Ultrapave
Study Team

Project Team

• PI: Harold L. Von Quintus, P.E.
• Associate: J. Mallela
Study Objectives

1. Quantify the effect of using PMA as compared to conventional-unmodified HMA mixtures in terms of:
   - Reducing occurrence of distresses
   - Increasing pavement life

2. Identify conditions that maximize effect of PMA to increase pavement & overlay life
   - PMA more effective in certain conditions, and less effective in others
Agency Survey: Reasons for Using PMA?

No one cited reduced fatigue cracking

R = Rutting  
T = Thermal Cracking  
F = Fatigue Cracking  
M = Moisture Damage or Stripping  
D = Durability  
R = Raveling  
T = Tenderness
**Field Test Sections**

- FHWA’s LTPP
  - SPS-1; SPS-5; SPS-6; SPS-9
  - GPS-1; GPS-2; GPS-6; GPS-7
- M.T. Ontario Modifier Study
- Accelerated Pavement Tests
  - FHWA ALF
  - NCAT Test Track
  - California HVS Studies
  - Ohio Test Road
  - Corp of Engineers
Locations of Test Sections

- PMA and At Least One Unmodified Companion

Not all 84 sections located on map.
Pavement Surface Distress Data Collected/Compared

- Fatigue Cracking
- Rutting
- Thermal Cracking

Already Thru LTPP
In this study
## Experimental Factorial – 32 Cells

<table>
<thead>
<tr>
<th>Pavement Cross Section</th>
<th>Base Foundation</th>
<th>Climate</th>
<th>Freeze</th>
<th>Non-Freeze</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Wet</td>
<td>Dry</td>
</tr>
<tr>
<td>Thin HMA (&lt;4”)</td>
<td>Fine-Grained</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Coarse-Grained</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Thick HMA (4-8”)</td>
<td>Fine-Grained</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Coarse-Grained</td>
<td>2</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Full-Depth (&gt;8”)</td>
<td>Fine-Grained</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Coarse-Grained</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>HMA Overlays</td>
<td>HMA</td>
<td>3</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>PCC</td>
<td>4</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

84 Total PMA and Companion Sections

<table>
<thead>
<tr>
<th></th>
<th>Freeze</th>
<th>Non-Freeze</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>16</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>26</td>
<td>25</td>
</tr>
</tbody>
</table>
Direct Comparisons – Rutting

Rut Depths on PMA Sections, inches
Rut Depths on Companion Sections, inches

Line of equality

- age of these sections varies
Distress Comparisons – Transverse Cracking

Transverse Cracking - Companion Sections, ft.
Transverse Cracking - PMA Sections, ft.

Line of equality
Distress Comparisons – Fatigue Cracking

Fatigue Cracking - PMA Sections, %
Fatigue Cracking - Companion Sections, %

Line of equality
Direct Comparisons Useful, But Still Have NOT Quantified Extended Service Life of PMA

Years for equal cracking???
Mechanistic-Empirical Analysis

• Use distress prediction models from new M.E. Pavement Design Guide for:
  – Fatigue Cracking
  – Rutting

• Damage Indices \( (DI = n / N_f) \) computed using factorial cell specific calibration
  – For each of the 32 cells

• Compare D.I. to the actual field distress measurements for both PMA and unmodified sections to obtain different “expected service lives”
### Summary of Expected Increase in Service Life, Years, Based on M-E Damage Based Analysis

Assumptions: Unmodified sections designed for 20 yr. life. Also, PMA in top 4 inches.

<table>
<thead>
<tr>
<th>Site Factor</th>
<th>Condition Description</th>
<th>Added Life</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Foundation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Expansive and plastic soils (PI&gt;35)</td>
<td></td>
<td>2-5</td>
</tr>
<tr>
<td>Frost Susceptible in cold climate</td>
<td></td>
<td>2-5</td>
</tr>
<tr>
<td>Non-expansive, coarse soils</td>
<td></td>
<td>5-10</td>
</tr>
<tr>
<td>Expansive and plastic soils (PI&gt;35)</td>
<td></td>
<td>2-5</td>
</tr>
<tr>
<td>Frost Susceptible in cold climate</td>
<td></td>
<td>2-5</td>
</tr>
<tr>
<td><strong>Water Table &amp; Drainage</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deep</td>
<td></td>
<td>5-10</td>
</tr>
<tr>
<td>Shallow; adequate</td>
<td></td>
<td>5-8</td>
</tr>
<tr>
<td>Shallow; inadequate</td>
<td></td>
<td>0-2</td>
</tr>
<tr>
<td><strong>Existing Pavement Condition</strong></td>
<td>HMA</td>
<td></td>
</tr>
<tr>
<td>Good</td>
<td></td>
<td>5-10</td>
</tr>
<tr>
<td>Poor-extensive cracking</td>
<td></td>
<td>1-3</td>
</tr>
<tr>
<td><strong>PCC</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Good</td>
<td></td>
<td>3-6</td>
</tr>
<tr>
<td>Poor-faulting &amp; cracking</td>
<td></td>
<td>0-2</td>
</tr>
<tr>
<td>Poor-faulting &amp; cracking</td>
<td></td>
<td>0-2</td>
</tr>
</tbody>
</table>
Continued:

Summary of Expected Increase in Service Life, Yrs

Assumptions: Unmodified sections designed for 20 yr. life. Also, PMA in top 4 inches.

<table>
<thead>
<tr>
<th>Site Factor</th>
<th>Condition Description</th>
<th>Added Life</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate; Temp. Fluctuations</td>
<td>Hot</td>
<td>Hot Extremes</td>
</tr>
<tr>
<td></td>
<td>Mild</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cold</td>
<td>Cold Extremes</td>
</tr>
<tr>
<td>Traffic, Truck Volumes</td>
<td>Low</td>
<td>Intersections</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Thoroughfares</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Heavy Loads</td>
</tr>
<tr>
<td></td>
<td>Moderate</td>
<td></td>
</tr>
<tr>
<td></td>
<td>High</td>
<td></td>
</tr>
</tbody>
</table>
### Generic LCCA Timeline for Conventional Unmod. versus Revised Timelines for PMA Based on Study

<table>
<thead>
<tr>
<th>Years</th>
<th>5</th>
<th>10</th>
<th>15</th>
<th>20</th>
<th>25</th>
<th>30</th>
<th>35</th>
<th>40</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>PMA in top 4 inches</th>
<th></th>
<th></th>
<th>Struc. Over.</th>
<th></th>
<th></th>
<th>Struct Over.</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>PMA in top 4 inches and in Base</th>
<th></th>
<th></th>
<th>Mill - Fill</th>
<th></th>
<th></th>
<th>Mill - Fill</th>
</tr>
</thead>
</table>
PMA benefits quantified, but does it make sense economically?
Purpose of Life Cycle Cost Analysis

• To evaluate the overall long-term economic efficiency between competing alternative investment options

Classic use is HMA alternative versus PCC alternative, but doesn’t have to be.
The Life Cycle

Initial Construction

Rehabilitation

Maintenance
Performance

Ride Quality

Cost

Time

Analysis Period

Performance Period

Remaining Life
The cost of all activities are computed at time $= 0$, accounting for discount rate (interest rate minus inflation rate) and time. This is called the NPV.
Economics of Using PMA

Use LCCA to Evaluate Actual Cost or Savings of Using PMA, Recognizing It’s Enhanced Performance
LCCA for PMA

• Compare Unmodified Alternative to PMA Alternatives
• Example Follows, But…
• Each Agency **Must** Evaluate Using Own Inputs:
  – Prices, Performance Periods (time to 1\textsuperscript{st} overlay and subsequent overlays), Thickness Designs, Timing Strategies, Discount Rate, User Costs, Etc
What LCCA Inputs for HMA Alternatives Are the Most Critical?

• Greatest Impact
  – Initial Costs
  – Time to 1\textsuperscript{st} Overlay

• Less Impact
  – Future Overlay Costs
  – Future Overlay Performance Periods
  – Especially in the Far Future

• Must Recognize Use of Premium Mixes or Materials (PMA)
  – Through Higher Costs but also Longer Performance Periods
Example

- 14 inch thick HMA pavement
- 2 lanes with shoulders
- 4% discount rate
- 40 year analysis period
- No user costs considered
- PMA mixtures cost 15% more
## Example Summary of Initial Costs (per lane mile) and Savings

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Initial Cost</th>
<th>%Increase</th>
<th>NPV</th>
<th>%Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Unmodified – All Layers</td>
<td>$668K</td>
<td>-</td>
<td>$1,005K</td>
<td>-</td>
</tr>
<tr>
<td>(resurface @ yr 10 &amp; 28, structural overlay @ yr 18 &amp; 34)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2) Modify top two lifts (4.5”)</td>
<td>$698K</td>
<td>4.5%</td>
<td>$964K</td>
<td>4.5%</td>
</tr>
<tr>
<td>(structural overlay @ yr 18 &amp; 34)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3) Modify top two lifts (4.5”) and bottom base lift (4”)</td>
<td>$725K</td>
<td>8.5%</td>
<td>$864K</td>
<td>14.0%</td>
</tr>
<tr>
<td>(resurface @ yr 18 &amp; 34)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Serving as Perpetual Pavement)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

# Cost to use PMA equates to approx. 1% of initial cost per inch modified
Conclusions

• PMA Benefits Quantified Through:
  – Decreased Distress Levels
  – Increased Service Life

• LCCA Can Be Utilized to Understand the True Economics of PMA
  – Depends on Performance Assumptions
Calibration Factors for Polymer-Modified Asphalts Using M-E Based Design Methods

• Presents calibration factors for rutting, fatigue cracking, and transverse cracking specific to polymer-modified asphalt (PMA) mixtures for use with the new Mechanistic-Empirical Pavement Design Guide (MEPDG).

• Analysis and methodology provided for adjusting calibration factors of asphalt mixtures to better predict the improved performance expected when using PMA.
The End
Mix Design Technology Certification Course

• Feb 24 - 27, 2009
• AI Lab and HQ, Lexington, KY

• Material selection
• Proportioning and volumetric analysis
• Sample preparation and mix testing
• Gyratory and Marshall compaction
• Hands-on lab activities
• RAP utilization
• SMA, OGFC and Warm Mix
• Optional certification exam
MS-19

Basic Asphalt Emulsion Manual

• New Edition
  – Available Jan ‘09
  – Price: $60

• Co-publish with AEMA

• Joint AI and AEMA
  Technical Writing Team

• Complete Rewrite of Content
Airport Asphalt Pavement Workshop

• Apr. 7–9, 2009

• Chicago

• Airfield Topics Covered:
  – Materials
  – Design
  – Construction
  – QC/QA
  – Preservation Practices

• All Lessons Specific to Airfields

Airport Pavement Workshop
Asphalt Pavement Design, Construction, and Maintenance
October 25 - 27, 2005
Philadelphia, Pennsylvania

The goal of this workshop is to provide up-to-date information for those designing, constructing, and managing asphalt airport pavements. This will include a review of current specifications and advisory circulars and detailed descriptions of materials as well as pavement design, construction, and preservation practices for airports.

Conference Location and Lodging
Embassy Suites Hotel
Philadelphia International Airport
900 Bartram Avenue
Philadelphia, Pennsylvania 19153
(800) 362-2779 • (215) 365-4360 • (215) 365-3195 FAX

To Register
$745 per person
$445 for FAA personnel

To register or for more information, contact the Seminar Coordinator at (359)288-4964, or register online at www.asphaltinstitute.org

Sponsored by the Federal Aviation Administration and the ASPHALT INSTITUTE

We're driven. www.asphaltinstitute.org
AAPTP Project 06–05: Guidelines for Use of Highway Specs for HMA Airport Pavements

Research Team:
- AI Regional Engineers

Objective
- Comprehensive document that provides guidance to airport designers on the selection and modification of state highway specifications for use on airport HMA pavement projects serving less than 60,000 lb aircraft.

Key Issues
- PWL, joint density as pay item, use of contractor QC as basis of material acceptance

To be completed in next few months
Binder Spec Database

State Binder Specs

Description: The Asphalt Institute and PRI Asphalt Technologies have collaborated to develop this binder specification database. Available below (as downloadable pdf files) are individual documents for each of the 50 state highway agencies summarizing their respective asphalt binder specifications. A few additional agencies are also provided. A standardized format is used to list specification methods and criteria, PG-plus tests and requirements, typical grades, exclusions, and the agency's website where specifications can be found.

Updating: AI and PRI will periodically contact the Binder or Materials Engineer listed on each document to review the agency's information for accuracy. Corrections or comments may be e-mailed to us by using the link below. Changes will only be made after confirmation by the individual listed for that agency.

Disclaimer: While care has been taken to provide the most accurate and current information, users are warned that there may be inaccuracies and recent specification revisions may not be reflected. To ensure the most accurate information, the particular agency should be contacted.

Click HERE to fill out the form for corrections or comments.

All documents are in Adobe PDF format. You need the free Adobe Reader to view these files. If you do not have the reader you can download by clicking on the Get Adobe Reader button.
State: COLORADO

Materials: Re: Section 702 SUPERPAVE PG Binders, CDOT's Standard Specifications for Road & Bridge Construction

Date Last Reviewed: 4-4-2005
Web Address: www.colorado.gov

Materials Engineer: Tim Aschenbrener
Contact Info: tim.aschenbrener@dot.state.co.us

**ASPHALT BINDER:**

| 702.01 (b) | Description: Supplier must be certified in accordance with CP 11. Samples of PG Binder for acceptance shall be sampled on the project as stated in the Schedule of Field Materials Manual. |
| 702.01 (a) | Exclusions: Asphalt shall not be Acid or Alkaline modified. Shall not contain any used oils that have not been re-refined or reprocessed. No modifiers shall be added that do not comply with Environmental rules and regulations including 40 CFR Part 261.6(a)(3)(v) and 266/Subpart C. Modifiers shall not be carcinogenic. |

<table>
<thead>
<tr>
<th>PROPERTY</th>
<th>Test Method</th>
<th>Requirements by Performance Grade, PG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flash Point, °C</td>
<td>T 48</td>
<td>58-28 58-34 64-22 64-28 76-28</td>
</tr>
<tr>
<td>Rotational Viscosity, Pa Xs</td>
<td>135°C</td>
<td>3.0 max.</td>
</tr>
<tr>
<td>Dynamic Shear, kPa (G*/sin *, 10 rad./sec.)</td>
<td>At grade temperature</td>
<td>1.0 min.</td>
</tr>
<tr>
<td>Property</td>
<td>Requirement</td>
<td>Original</td>
</tr>
<tr>
<td>----------------------------------------------</td>
<td>-------------</td>
<td>----------</td>
</tr>
<tr>
<td>Ductility, (5 cm/min.), cm</td>
<td>4°C</td>
<td>T 51</td>
</tr>
<tr>
<td>Toughness &amp; Tenacity</td>
<td>25°C</td>
<td>CP L 2210</td>
</tr>
<tr>
<td>Acid or Base Modification</td>
<td></td>
<td>CP L 2214</td>
</tr>
<tr>
<td>PG PLUS REQUIREMENTS:</td>
<td>YES</td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**
1. Direct Tension measurements are required when needed to show conformance to M 320.
2. The Department will test for acid and alkaline modification during binder certification process. Thereafter, the Department will randomly test for acid and alkaline modification.

Disclaimer: “To ensure the most accurate and current information, the specific agency should be contacted.”
To make sure we can verify corrections, please fill out form completely.

Name

Position

Company

City

State

Phone (Required)

E-Mail (Required)

Enter correction or comment below:
No Kidding, The End

Questions?