ASPHALT PRODUCTS 101 & ALTERNATIVES FOR PAVEMENT MAINTENANCE ON TOWN & COUNTY ROADS

PREPARED FOR:
LAKE AREA PUBLIC WORKS ASSOCIATION MEETING

Dan Swiertz, PE
Bitumix Solutions, a Division of H.G. Meigs, LLC
August 8th, 2018
First, some terminology:

“Asphalt Binder” or “Asphalt” or “Hot Oil”  
(PG 58-28 S, PG 58-34 S, PG 64-22 S... and more)

“Paving Grade” or “Oil”, *not* “Tar”  
(Production of HMA/WMA)

“Cutbacks” or “Road Oil”, *still* not Tar  
(Asphalt binder + solvent)  
(Ex.: SC-800, MAC-5, MS-5)

“Asphalt Emulsion” or “Emulsion”, not Tar either  
(CRS-2, HFRS-2, EM-8)
Why are we here?

This map shows the miles of public roads and percentage in poor condition, and the cost per year and per motorist of driving on roads in need of repair. More than two out of every five miles of America’s urban interstates are congested.

Wisconsin - Roads

115,372 miles of Public Roads, with 27% in poor condition

Minnesota - Roads

138,767 miles of Public Roads, with 15% in poor condition

FUNDING & FUTURE NEED

The U.S. has been underfunding its highway system for years, resulting in a $836 billion backlog of highway and bridge capital needs. The bulk of the backlog ($420 billion) is in repairing existing highways, while $133 billion is needed for bridges, and $173 billion for transit and $126 for passenger rail.
How did we get here?
Why the “Worst-First” approach is ineffective:

Adapted from: Nestler, J. “WisDOT Asset Management” WAPA 2017
So, I should just pave, chip seal, chip seal, chip seal, then mill-and-fill, right?
“The right treatment on the right road”

Two takeaways:
1. **Timing is everything** (*Equivalent Annual Cost*); a chip seal might last 2 years or 7 years depending on condition of existing surface, but upfront cost is the same.
2. **Assign actual numbers based on your network** (*Cost-Benefit-Value*) to determine timing (*Do NOT ignore bad roads, single-use roads, etc., prioritize them!*)

Adapted from: Nestler, J. "WisDOT Asset Management" WAPA 2017
Pavement Preservation Principles

The three metrics used in this example are defined below:

- **Equivalent Annual Cost (EAC):** The unit cost of a treatment divided by the expected service life of that treatment; EAC has units of $/yd^2/yr. This metric is useful for two reasons: (1) EAC normalizes treatments to create an even comparison between treatments and amortizes costs, and (2) if a given treatment is used on the wrong road (e.g., a surface treatment on an old, beat-up road that instead needs reconstruction; see table below), the expected life of the treatment is reduced and the EAC thereby increases, making a surface treatment more costly on that road even if unit cost is unchanged. EAC relies on pavement owners working with material suppliers to make an unbiased estimate of the expected service life of a treatment. For example:

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Unit Cost/yr</th>
<th>Est. Service Life (yr)</th>
<th>EAC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface Treatment (hypothetical, properly timed)</td>
<td>$2.00</td>
<td>5</td>
<td>$0.40</td>
</tr>
<tr>
<td>Surface Treatment (hypothetical, poorly timed)</td>
<td>$2.00</td>
<td>2</td>
<td>$1.00</td>
</tr>
<tr>
<td>Mill-and-Fill</td>
<td>$12.00</td>
<td>12</td>
<td>$1.00</td>
</tr>
<tr>
<td>Reconstruction</td>
<td>$25.00</td>
<td>20</td>
<td>$1.25</td>
</tr>
</tbody>
</table>

*Assumes treatment is properly selected and constructed*

- **Remaining Service Life (RSL):** Every pavement has a quantifiable RSL; for each year one lane-mile of road is allowed to deteriorate with no maintenance, the pavement will lose one lane-mile-year. Reconstruction and preventative surface treatments add life expectancy to a pavement, so they add lane-mile-years. Using a simple ‘check-and-balance’, two or more scenarios can be compared objectively. By comparing ‘worst-first’ with a more proactive management strategy, the proactive approach will usually add more service to the system in a given year (Example below).

- **Cost-Benefit Value (CBV):** CBV helps you choose the right projects to work on given a fixed budget accounting for current pavement condition and traffic level. It is calculated as:

  \[
  CBV = \frac{\text{Traffic Level (AADT)} \times \text{Est. Service Life of Treatment}}{\text{Unit Cost of Treatment} \times \text{Pavement Condition Index (PCI)}}
  \]

**How to use these metrics:**

**Example:** A 500 lane-mile network has a budget of $3.0 million available.

**“Worst First” with No Preservation**

<table>
<thead>
<tr>
<th>Network Trend</th>
<th>Programmed Activity</th>
<th>Lane-Mile-Years</th>
<th>Total Budget</th>
</tr>
</thead>
<tbody>
<tr>
<td>Programmed</td>
<td>Reconstruction</td>
<td>200</td>
<td>$1,760,000</td>
</tr>
<tr>
<td>Programmed</td>
<td>Rehabilitation</td>
<td>168</td>
<td>$1,239,040</td>
</tr>
<tr>
<td>Programmed</td>
<td>Preservation</td>
<td>0</td>
<td>$0</td>
</tr>
<tr>
<td><strong>Totals:</strong></td>
<td></td>
<td>368</td>
<td>$2,999,040</td>
</tr>
</tbody>
</table>

**Preservation Focused**

<table>
<thead>
<tr>
<th>Network Trend</th>
<th>Programmed Activity</th>
<th>Lane-Mile-Years</th>
<th>Total Budget</th>
</tr>
</thead>
<tbody>
<tr>
<td>Programmed</td>
<td>Reconstruction</td>
<td>100</td>
<td>$880,000</td>
</tr>
<tr>
<td>Programmed</td>
<td>Rehabilitation</td>
<td>120</td>
<td>$901,120</td>
</tr>
<tr>
<td>Programmed</td>
<td>Preservation</td>
<td>424</td>
<td>$1,214,400</td>
</tr>
<tr>
<td><strong>Totals:</strong></td>
<td></td>
<td>644</td>
<td>$2,998,520</td>
</tr>
</tbody>
</table>

**Added Service Summary:**

<table>
<thead>
<tr>
<th>Programmed Activity</th>
<th>(Lane-Mile-Years) =</th>
<th>Total Network</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reconstruction</td>
<td>368</td>
<td></td>
</tr>
<tr>
<td>Rehabilitation</td>
<td>500</td>
<td></td>
</tr>
<tr>
<td>Preservation</td>
<td>500</td>
<td></td>
</tr>
</tbody>
</table>

Using the same total budget and not ignoring the reconstruction/rehabilitation needs of the network, the preservation-focused strategy added 144 lane-mile-years to the system, while the “worst-first” method actually produced a deficit! Obviously a
Asphalt 101 – Why is my road gray?

• Co-product of refinery operations:
  • Crude source (naturally occurring material)
  • Distillation (refinery) practices, advances
  • Now additives…polymers, oils, acids,….

• Asphalt is “graded” based on the local climate and traffic conditions for a given project.
  • The asphalt we use to pave I-43 is the same climate grade (PG 58-28) as what is used to pave CTH G, but I94 requires a higher traffic grade, ‘H’ or ‘V’ instead of ‘S’.
Superpave Performance Grading (PG), M332 Method

- Asphalt binder is assigned a “Performance Grade”:
  \[ \text{PG HT} - \text{LT T} \] (PG 58-28 S, for example)

PG = Performance Grade

HT\(^*\) = 7-day average maximum pavement temperature for which this binder is certified for use. (52, 58 typical in WI, MN), considering reliability

T = Traffic level designation (S, H, V, E)

LT\(^*\) = single minimum pavement temperature for which this binder is certified for use. (-28 or -34 typical for WI, MN), considering reliability

*We also use LT, MT, and HT to describe ESALs for WisDOT mix designs, but for this slide we’re talking temperature....
Guidance:

- Wisconsin Asphalt Paving Association (WAPA) worked with WisDOT to develop guidelines for selecting binder:

  - **Lower Layers:** 58-28 S
  - **Overlays:** 58-28 S, H, or V**
  - **Upper Layers:**
    - Southern Asphalt Zone: 58-28 S, H, or V**
    - Northern Asphalt Zone: 58-34 S, H, or V**

*Where might I see “H” designations?*
What are asphalt emulsions?

- Emulsion: insoluble dispersion of small droplets ['dispersed phase'] of one liquid in another liquid ['continuous phase'].
  - Common Examples: mayonnaise, cosmetic creams, some paints.

In the most common case of asphalt emulsions:
- **Dispersed Phase**: Asphalt (~55-70% B.W.)
- **Continuous Phase**: ‘Water’ (~30-45% B.W.)
- Emulsions are *inherently unstable*…eventually the asphalt will separate from the water…
How are asphalt emulsions produced?

Liquid Asphalt + Polymer (sometimes) + Water + Emulsifier

Fuel & other additives also common

‘Soap Solution’

Colloid Mill

Provides mechanical energy to shear asphalt

Emulsion

A typical recipe may include:

- 32% Water
- 68% Asphalt
- ~2% polymer B.W. of asphalt
- ~0.5% emulsifier B.W. emulsion
Life cycle of an asphalt emulsion…

1. Dispersion of asphalt droplets in a water + emulsifier medium. Emulsion is fluid and generally brown in color. Consistency: from watery to warm honey.

2. Asphalt particles begin to flocculate and coalesce; water is removed from the system by evaporation, absorption, or by chemical reactions. Films turn black and are usually ‘tacky’.

3. Asphalt particles coalesce completely and a uniform film is formed; water is almost completely removed from system. Films are black and may be tacky or semi-solid depending on application. The resulting film is (nearly) the same as the asphalt that you started with to produce the emulsion.
What are Asphalt Cutbacks

- Asphalt cement is solvent in petroleum fuel
  - Fuel is used to ‘cut’ the viscosity of the base asphalt
    - Still need to be heated, but less than pure asphalt
  - Provides more ‘workability’ at ambient temperature
  - Helps ‘wet’ dusty surfaces
- Fuel designed to “partially” evaporate over time, leaving behind base asphalt with a small amount of fuel.
- FYI: In Wisconsin, when the term “Hot Applied” is used in terms of Chip Sealing (Seal Coating), it is generally assumed to mean using an asphalt cutback.
  - MAC-5
  - MS-5
Which asphalt material or treatment is “best” for my roads? (in no particular order)

1. **Your experience**
   - Not: “this is the way it has always been done”
   - But: “we’ve had good success with this material and this aggregate source/design in the past” then ask WHY?

2. **Your specification & Climate (requirements)**
   - Time to open? High traffic? Special demands?

3. **Your contractor**
   - Many specialize in certain types of application
   - …But don’t be afraid to ask
A few common treatments and examples over the lifespan of a new road…

1. Fog seal, high performance “Mastic Seal” ✓
2. Chip seal (single), Slurry Seal ✓✓
3. Scrub seal, Chip seal (double), Slurry Seal ✓✓
4. Wedge/Seal, crack fill then Scrub Seal
5. HMA overlay
6. Mill & HMA overlay ✓✓
7. In-place recycling & overlay
8. Full-depth reconstruction
9. Crack filling (as needed)
“Mastic” Seals

- Problem: Oxidation and H2O intrusion starts from Day-1
- One Solution: High performance pavement sealers have entered the marketplace that produce a lasting, black surface and eliminate chips
  - These materials are tailored to the climate and type of project (road, parking lot, or rec. trail)
Mastic Seals

- These are central-plant produced and applied by a certified applicator.
- Process is quick and comparable to chip sealing in terms of service life.
- Many municipalities don’t like the mess of chip sealing (dust, loose chips, etc.) but understand the benefit of preservation (residents also like black).
Mastic Seals

- Advanced materials made for parking lots/rec trails to moderate volume highways

CTH A, Sheboygan County, completed July, 2018
“Chip Seals” (A.K.A. Seal Coat)

- Objective: A single-layer thickness of aggregate bound to existing roadway surface with asphalt binder:

- Contractor must select:
  - Appropriate Aggregate
  - Appropriate asphalt binder
  - Rates at which to lay each ingredient.
Designing a chip seal

- What to look for: **Functional distress only**
  - thermal cracking, surface raveling, MINOR fatigue
- Engineers have control over 3 major aspects of the construction process:
  - Selection of aggregate
  - Selection of application rates
  - Selection of the emulsion
- We **do not** have control over one very important factor
  - **WEATHER**
    - We want warm, dry, low humidity
    - High humidity – longer cure times
    - Rain – dilutes and washes away emulsion
    - However – favorable weather will not make up for poor construction practice!

*All of these factors must be considered for a successful project...*
What am I looking for?
Let’s Look at a few examples from around the State:

- *Traditionally*: Most Wisconsin County ‘chips’ will be 100% passing the 3/8” sieve, and be primarily contained on the ¼” and No. 4 sieves (called an FA-2.5 in some areas)

- *More recently*: Trend toward moving smaller, e.g., 100% passing the ¼” sieve and up to 60% or so passing the No. 4 (called FA-2)

- BOTH will produce excellent results, IF size/shape/gradation is accounted for...
  - DO NOT assume that using the same methods will produce the same result if aggregates change.

- In both cases:
  - Look for “most” aggregate to be retained on 1-2 successive sieves.
  - Look for less than 1% dust for cationic, and less than ~2.5% for HF.
  - Look for highly fractured stone (avoid using ‘Pea Stone’…it’s cheap for a reason)
  - Look for cubical stone, not potato chips.
Signs something isn’t right:

- Normal wear and tear is expected,
- Excessive chip loss
- Bleeding/Flushing
- Running off are not...

Things to pay attention to:
- Pavement temperature
- Precip. Forecast
- Shade
- Time to open
“Scrub Seals”

- Specialized process AND emulsion designed to address slightly more advanced crack patterns and aging.
Scrub Seals

- Finished look is the same as a chip seal.
Fog seals

- Light coating of asphalt emulsion
  - Over existing surface – can ‘rejuvenate’, add residue
  - Over chip seal to aid in chip retention
- Traditionally, CRS-2(P) dilute or CSS-1H dilute have been used:
  - Application Rate Fog Seal: ~ 0.1 gal/sy (diluted) → 0.05 gal/sy (undiluted)
- “Newer” quick-fogs are entering the market
Skipping Ahead: Reclamation (FDR)

Good candidates….

- Extensive structural distress; could be accompanied by functional distress
  - Adequate base stability – soft spots need to be corrected
  - Subgrade quality
  - Sufficient base depth
  - Patching: OK, but adds variability in materials
What are some advantages?

• **Maintenance**: side slope (mowing operations)
• **Safety** – edge effects: “growing the road”
• The complete existing cross-section does not need to be reclaimed if already overbuilt:
  • Mill 2-3 inches, save RAP
  • FDR on remaining layer
  • Overlay with mix incorporating RAP from millings
• **Do we need a structural overlay in all instances?**
  • Experience is no:
Field order of operations

- Material pre-pulverized to specified depth
  - Material is compacted using padfoot rollers until feet walk out
  - Moisture content monitored
  - Graded to rough shape

- Stabilization train injects material to predetermined depth < initial pulverization depth
  - Compacted using padfoot rollers
  - Graded to shape and drum rollers to finish

Graphic adapted from Wirtgen Cold Recycling Technology, 2012
A quick primer on mix designs


- Beginning with 2017 season, WisDOT has overhauled their asphalt mix design process:
  - “E” mixtures are reclassified:

<table>
<thead>
<tr>
<th>Current “E” Mixes</th>
<th>ESAL Level (20 years)</th>
<th>New Classification</th>
<th>ESAL Level (in millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>E-0.3</td>
<td>&lt; 300,000</td>
<td><strong>LT</strong></td>
<td>Light Traffic &lt; 2 M</td>
</tr>
<tr>
<td>E-1</td>
<td>300,000 to &lt; 1,000,000</td>
<td></td>
<td><strong>MT</strong> Medium Traffic 2 M – 8 M</td>
</tr>
<tr>
<td>E-3</td>
<td>1,000,000 to &lt; 3,000,000</td>
<td></td>
<td><strong>MT</strong> Medium Traffic 2 M – 8 M</td>
</tr>
<tr>
<td>E-10</td>
<td>3,000,000 to &lt; 10,000,000</td>
<td></td>
<td><strong>MT</strong> Medium Traffic 2 M – 8 M</td>
</tr>
<tr>
<td>E-30</td>
<td>10,000,000 to &lt; 30,000,000</td>
<td></td>
<td><strong>HT</strong> Heavy Traffic &gt; 8 M</td>
</tr>
<tr>
<td>E-30X</td>
<td>≥ 30,000,000</td>
<td></td>
<td><strong>HT</strong> Heavy Traffic &gt; 8 M</td>
</tr>
</tbody>
</table>


Mix Designs, Cont’d

WisDOT has also recently adopted efforts to INCREASE the amount of virgin AC that is going into new mixtures:

460.2.1 General

Revised 460.2.1 to regress air voids from 4.0% design to 3.0% target. This change was implemented in ASP 6 effective with the December 2016 letting.

1. Furnish a homogeneous mixture of coarse aggregate, fine aggregate, mineral filler if required, SMA stabilizer if required, recycled material if used, warm mix asphalt additive or process if used, and asphaltic material. Design mixtures conforming to table 460-1 and table 460-2 to 4.0% air voids to establish the aggregate structure.

2. Determine the target JMF asphalt binder content for production from the mix design data corresponding to 3.0% air voids (97% Gmm) target at the design the number of gyrations (Ndes). Add liquid asphalt to achieve the required air voids at Ndes.

3. For SMA, determine the target JMF asphalt binder content for production from the mix design data corresponding to 4.0% air voids (96% Gmm) target at Ndes.
Great, so which design do I use?

• LT, MT, or HT?
  • Choose **based on your design ESALS**
  • Extreme circumstances? Farm implements, slow traffic, etc.
    • May consider moving to MT
• Nominal Max Size (NMAS): 3 (19 mm / ¾”), 4 (12.5 mm / ½”), or 5 (9.5mm / 3/8”)
  • The smaller you go, the ‘tighter’ the surface, and the more AC you get, but also costs you more.
  • The smaller you go, the thinner the lift thickness you can compact efficiently (wedging):
    • For fine graded mixtures: **3 X NMAS < Lift Thickness < 6 X NMAS**
    • For example, for a ½” mix, the lift should be between 1.5” – 3”
• RAP/RAS – NOT a bad thing, but need to be accounted for.
Wrap up:

• Every roadway network and each individual roadway is different: there is no one size fits all
  • Set up a database with real numbers and look at different options
  • There’s a saying about doing the same thing over and over and expecting different results…

• New processes (and old processes) are becoming more available.

• Ask questions.
Thank You

Dan R. Swiertz, PE
Director of Mix Design Laboratories
Bitumix Solutions, a Division of H.G. Meigs, LLC

1220 Superior Street
Portage, WI 53901-9702

Mobile: 262.483.7182
Office: 608.742.5354
Fax: 608.742.1805

E-mail: dswiertz@bitumixsolutions.com