New Asphalt Technologies

North Dakota Asphalt Conference
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Bismarck, ND

Ken Swedeen, Dakota Asphalt Pavement Assoc.
New Asphalt Technologies

How can we use existing and new technology to make our pavements BETTER?
Recent HMA Developments

Performance Graded Binder
(Modified Binder)

Warm Mix Asphalt
Recent HMA Developments (Con’t)

M-E Design Principles

Asphalt Concrete

Base

Subgrade

Shear Stress \( \tau, \gamma^e \)

Tensile Strain \( \varepsilon_t \)

Vertical Compressive Strain \( \varepsilon_v \)

Porous Asphalt Pavement
Recent HMA Developments (Con’t)

SMA (Stone Matrix Asphalt) & Wearing Course Alternatives

Thermal & Compaction Control
Superpave performance grading (PG) is based on the idea that an HMA asphalt binder’s properties should be related to the conditions under which it is used. For asphalt binders, this involves expected climatic conditions as well as aging considerations.

This may require modifiers be added to the asphalt cement or binder.
PG Binder Specification

- Developed out of SHRP in 1990’s
- Addressed the weakness of prior Specifications (e.g. Penetration, Viscosity, etc.)
- Modeled on the Engineering Properties of the Binder (and Mixture) at binder storage conditions, plant conditions, aged pavement conditions and pavement service conditions (high pavement temperature~summer, cold pavement temperature~winter)
Pre-Superpave Shortcomings

- Viscosity
  - viscous effects only
- Penetration
  - empirical measure of viscous and elastic effects
- No Low Temperature Properties Measured
- Problems with Modified Asphalt Characterization
- Specification Proliferation
- Long Term Aging not Considered
Superpave Asphalt Binder Specification

- Grading System Based on Climate

**PG 58-28**

- Performance Grade
- Average 7-day max pavement design temp
- Min pavement design temp
Is a PG a Modified Binder?

“Rule of 90”

PG 64 - 34 > 64 - - 34 = 98

Probably modified !!

(Depends on Asphalt Source!)

Effect of Loading Rate

Effect of Traffic

Rounding

Reliability
### PG Binder/Crude Impact

<table>
<thead>
<tr>
<th>Low Temperature, °C</th>
<th>52</th>
<th>58</th>
<th>64</th>
<th>70</th>
<th>76</th>
</tr>
</thead>
<tbody>
<tr>
<td>-16</td>
<td>52-16</td>
<td>58-16</td>
<td>64-16</td>
<td>70-16</td>
<td>76-16</td>
</tr>
<tr>
<td>-22</td>
<td>52-22</td>
<td>58-22</td>
<td>64-22</td>
<td>70-22</td>
<td>76-22</td>
</tr>
<tr>
<td>-28</td>
<td>52-28</td>
<td>58-28</td>
<td>64-28</td>
<td>70-28</td>
<td>76-28</td>
</tr>
<tr>
<td>-34</td>
<td>52-34</td>
<td>58-34</td>
<td>64-34</td>
<td>70-34</td>
<td>76-34</td>
</tr>
<tr>
<td>-40</td>
<td>52-40</td>
<td>58-40</td>
<td>64-40</td>
<td>70-40</td>
<td>76-40</td>
</tr>
</tbody>
</table>

- **Green** = Crude Oil
- **Yellow** = High Quality Crude Oil
- **Red** = Modifier Required
PG Binder Selection

- Select Binder (PG) Based on Climate (Location)
- Select Binder (PG) Based on Mix Type, Utilization of RAP and Pavement Design
- Account for Risk Tolerance (e.g. Functional Classification)
- Account for Economics (LCCA)
- Account for Loading/Rate of Loading
### Three Closest Weather Stations For Latitude/Longitude = 44.16183/96.75146

<table>
<thead>
<tr>
<th>General</th>
<th>A=18 km</th>
<th>B=19 km</th>
<th>C=25 km</th>
</tr>
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<tbody>
<tr>
<td><strong>State</strong></td>
<td>SD</td>
<td>SD</td>
<td>SD</td>
</tr>
<tr>
<td><strong>Station ID</strong></td>
<td>0392984</td>
<td>0391076</td>
<td>0399042</td>
</tr>
<tr>
<td><strong>County/District</strong></td>
<td>moody</td>
<td>brookings</td>
<td>lake</td>
</tr>
<tr>
<td><strong>Weather Station</strong></td>
<td>flandreau 4 sw</td>
<td>brookings 2 ne</td>
<td>wentworth 2 wnw</td>
</tr>
<tr>
<td><strong>Elevation, m</strong></td>
<td>476</td>
<td>500</td>
<td>515</td>
</tr>
<tr>
<td><strong>Latitude, Longitude</strong></td>
<td>44.05 , 96.60</td>
<td>44.32 , 96.77</td>
<td>44.02 , 97.00</td>
</tr>
<tr>
<td><strong>Last Year Data Available</strong></td>
<td>1996</td>
<td>1996</td>
<td>1996</td>
</tr>
</tbody>
</table>

### Air Temperature

<table>
<thead>
<tr>
<th></th>
<th>Mean (Std. N)</th>
<th>Mean (Std. N)</th>
<th>Mean (Std. N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average 7-day High Temp.</td>
<td>32.9 (2.1, 39)</td>
<td>32.9 (2.5, 62)</td>
<td>33.4 (2.1, 35)</td>
</tr>
<tr>
<td>Low Temperature</td>
<td>-33.4 (2.7, 37)</td>
<td>-33.0 (3.4, 63)</td>
<td>-32.0 (2.6, 38)</td>
</tr>
<tr>
<td>Low Temperature Drop</td>
<td>19.6 (5.1, 36)</td>
<td>17.6 (5.8, 61)</td>
<td>16.7 (5.4, 38)</td>
</tr>
<tr>
<td>Degree Days Above 30 C</td>
<td>84 (49, 39)</td>
<td>86 (69, 62)</td>
<td>97 (56, 35)</td>
</tr>
</tbody>
</table>

### Pavement Temp. and PG

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>50.1 -24.6 (50,50)</td>
<td>50.0 -24.4 (50,50)</td>
<td>50.5 -23.6 (50,50)</td>
<td></td>
</tr>
<tr>
<td>&gt;50% Rel. PG (High, Low Rel.)</td>
<td>52 -28 (71,88)</td>
<td>52 -28 (70,86)</td>
<td>52 -28 (66,94)</td>
</tr>
<tr>
<td>58 -28 (98,88)</td>
<td>58 -28 (98,86)</td>
<td>58 -28 (98,94)</td>
<td></td>
</tr>
</tbody>
</table>
ND PG Binder Selection
(Low Temp-50% Reliability)
ND PG Binder Selection
(Low Temp-98% Reliability)
ND PG Binder Selection
(High Temp-98% Reliability)
PG Binder Considerations

• For new, resurfaced or reconstructed surfaces design the pavement and the asphalt binder
• If a polymer modified binder is called for...“don’t step over dollar bills to pick up pennies”. About $50/ton of liquid asphalt ($3/ton of mix) for upgrade 58-28 to 64-28
• A properly designed pavement and binder WILL:
  • Reduce thermal cracking and fatigue cracking saving future maintenance costs for crack sealing, pot hole patching, and associated problems
  • Provide and sustain better ride quality
  • Reduce aging and oxidation
  • Reduce rutting, particularly “green season” rutting (1st or 2nd year summer peak temperatures)
What is Warm Mix Asphalt (WMA)???
Asphalt is a *thermoplastic* material that softens as it is heated and hardens when cooled.

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**Asphalt Binder Properties**

*Consistency*

Temperature

- Liquid
- Semi-Solid
WMA Types

- Asphalt Viscosity-reducing Organic Additives
- Water-bearing Additives
- Water-based Technologies
- Chemical Additives
WMA is a process of producing bituminous mixture for pavements at a significantly lower temperature than conventional HMA.

There are more than 20 WMA technologies currently available, at least 15 in the US.
- Fiber/Organic
- Chemical
- Physical
- Foamed/Foaming Agents

Goal: Reduce temperature requirements in production from 275-325 deg. F. (HMA) to 200-275 deg. F. (WMA)
Warm Mix Asphalt (WMA)

- Possible Benefits
  - Allowance for Construction Season & Environment
    - More Effective Late Season Paving
    - Portable Plant Setups...Long Hauls
  - Improve Pavement Quality by Increasing Density Compliance
  - Possible Winter Season Wearing Course?
  - Environmental & Personal Protection
  - Urban Pavement Alternative
Goals

- Evaluate the suitability of using Warm Mix Asphalt (WMA)
- Assess WMA suitability in all paving applications (e.g. overlays, leveling interim, etc.)
- Evaluate WMA properties (binder, aggregate & mixture)
- Evaluate WMA pavement integrity & durability characteristics w/ HMA
- Emissions evaluation (benefits) of WMA during paving & production
Conventional HMA
Mat Temp >
140 deg. Mat Temp >
Perpetual Pavements

www.AsphaltAlliance.com
Introduction

- Not a new concept
  - Full-Depth
  - Deep Strength
  - Mill & Fill
Why consider Perpetual Pavements???
Because of this.....
And this.....
And this.....
And this.....
And this.....
And this.....
And this.....probably not so much!!!
Max Tensile Strain

Pavement Foundation

1.5 - 3” SMA, OGFC or Superpave

Zone Of High Compression

High Modulus Rut Resistant Material (Varies As Needed)

Flexible Fatigue Resistant Material 3 - 4”

4” to 6” Zone Of High Compression
› Bottom-up Design and Construction

› Foundation

› Stable Paving Platform

› Minimize Seasonal Variability and Volume Change in Service

› Fatigue Resistant Lower Asphalt Layer

› Rut Resistant Upper Asphalt Layers
Mechanistic-Based Design

Material Properties (modulus values) → Pavement Model → Pavement Responses (strains, stresses, etc.) → Transfer Function → Pavement Life OK?

Minimize likelihood of tensile strains > 65 με, comp. strains > 200 με

Final Design
Mechanistic Performance Criteria Under ESAL

Limit Bending to < 65με (Monismith, Von Quintus, Nunn, Thompson)

Limit Vertical Compression to < 200με (Monismith, Nunn)
HMA Considerations

- HMA Base Layer
- Intermediate Layer
- Wearing Surface
Fatigue Resistant Asphalt Base

» Minimize Tensile Strain with Pavement Thickness
» Thicker Asphalt Pavement = **Lower Strain**
» Strain Below Fatigue Limit = **Indefinite Life**
Rut Resistant Upper Layers

- **Aggregate Interlock**
  - *Crushed Particles*
  - *Stone-on-Stone Contact*

- **Binder**
  - *High Temperature PG*
  - *Polymers*
  - *Fibers*

- **Air Voids**
  - *Avg. 4% to 6% In-Place*

- **Surface**
  - *Renewable*
  - *Tailored for Specific Use*
## Impact of Temperature Gradient on Asphalt Grade

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Use proper PG Binder as dictated by climate and depth.</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Perf. PG Binder</td>
<td>SMA, OGFC or SP 1.5 - 3”</td>
</tr>
</tbody>
</table>

- **Rut Resistant Material (Varies)**
- **Fatigue Resistant Material 3” to 4”**

**Pavement Foundation**
## Performance of Washington Interstate Flexible Pavements (based on 180 miles)

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Time Since Original Construction (years)</th>
<th>Thickness of Original AC (mm (in.))</th>
<th>Time from Original Construction to First Resurfacing (years)</th>
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</thead>
<tbody>
<tr>
<td>Average</td>
<td>31.6</td>
<td>230 (9.2)</td>
<td>12.4</td>
</tr>
<tr>
<td>Range</td>
<td>23 to 39</td>
<td>100 to 345</td>
<td>2 to 25</td>
</tr>
</tbody>
</table>
Ohio Study of Flexible Pavements

- Examined Performance on 4 Interstate Routes
  - HMA Pavements - Up to 34 Years without Rehabilitation or Reconstruction
  - "No significant quantity of work . . . for structural repair or to maintain drainage of the flexible pavements."
  - Only small incremental increases in Present Cost for HMA pavements.
Data from GPS-6 (FHWA-RD-00-165)

Conclusions

- **Most AC Overlays ≥ 15 years before Rehab**
- **Many AC Overlays > 20 years before Significant Distress**

Thicker overlays mean less:
- Fatigue Cracking
- Transverse Cracking
- Longitudinal Cracking
TRL Report 250
Nunn, Brown, Weston & Nicholls

Design of Long-Life Flexible Pavements for Heavy Traffic

http://www.trl.co.uk
Overall Summary

- No structural deformation or roadbase fatigue cracking.
- Distresses confined to surface
  - Rutting
  - Cracking
- Roadbase stiffens with age and reduces deflection.
Longitudinal crack in M1 TRL
Perpetual Pavement

› Structure Lasts 50+ years.
  » Bottom-Up Design and Construction
  » Indefinite Fatigue Life

› Renewable Pavement Surface.
  » High Rutting Resistance
  » Tailored for Specific Application

› Consistent, Smooth and Safe Driving Surface.
› Environmentally Friendly
› Avoids Costly Reconstruction.

www.AsphaltAlliance.com
References

TRB Circular No. 503
On-line at www4.nas.edu
“Is it possible to have a stormwater best management practice (BMP) that reduces impervious areas, recharges groundwater, improves water quality, eliminates the need for detention basins, and provides a useful purpose besides stormwater management? This seems like a lot to expect from any stormwater measure, but porous asphalt pavement on top of recharge beds has a proven track record.”
Porous Asphalt Pavement
Gap Graded, Fines Starved, High A/C Content HMA
On Infiltration Bed/Drain Rock
<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>% Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2 in.</td>
<td>100</td>
</tr>
<tr>
<td>3/8 in.</td>
<td>95</td>
</tr>
<tr>
<td>#4</td>
<td>35</td>
</tr>
<tr>
<td>#8</td>
<td>15</td>
</tr>
<tr>
<td>#16</td>
<td>10</td>
</tr>
<tr>
<td>#30</td>
<td>2</td>
</tr>
</tbody>
</table>

Percent bituminous 5.75-6.0% by weight
Infiltration Bed

Recharge Trench
porous asphalt

standard asphalt
“One of the most common questions relates to concerns about freezing conditions. Freezing has not been an issue, even in very cold climates. We were quite surprised when the owners of early installations first told us that there was less need to snowplow on the porous pavement surfaces. The underlying stone bed tends to absorb and retain heat so that freezing rain and snow melt faster on the porous pavement. The water drains through the pavement and into the bed below with sufficient void space to prevent any heaving or damage, and the formation of "black ice" is rarely observed. The porous surfaces tend to provide better traction for both pedestrians and vehicles than does conventional pavement. Not a single system has suffered freezing problems”
Thermal & Compaction Technology

Temperature Control
Intelligent Compaction

www.AsphaltAlliance.com
Mix Temperature

- Major Factor in Compaction/Density
- Compaction/Density Major Factor in Pavement Durability
- Uniformity & Consistency, as in all paving operations, are equally important in the final operation: Rolling
- Segregation (mechanical) and Longitudinal Joint Failures are two major contributing factors on premature failure or reduction of pavement life
Cost of Compaction

- Least expensive part of the paving process
- Aggregates and oil are expensive in comparison
- Compaction adds little to the cost of a ton of asphalt
Effect of Compaction

- Compaction is equally important in extending pavement life
- Saves money in maintenance costs
- Understanding compaction is very important
Importance of Compaction

- Improve Mechanical Stability
- Improve Resistance to Permanent Deformation
- Reduce Moisture Penetration
- Improve Fatigue Resistance
- Reduce Low-Temperature Cracking Potential
Factors Affecting Compaction

- Properties of the Materials
- Environmental Variables
- Laydown Site Conditions
Mix Temperature

- Major effect on compaction
- Must compact while oil is still fluid enough to allow aggregate movement
- When oil is stiff, aggregates lock
Temperature of mat passing under screed affects mat workability.

- Work close to paver when mat is cool.
- Add rollers when mat is cool.
- Use more force if possible.
Intelligent Compaction

- Proper in-place density is vital for good performance
- Conventional compaction equipment and procedures have limitations...

- Intelligent compaction technology goal is to find “a better way”
Conventional Limitations

- Provides little or no “on the fly” feedback for roller operator
  - Better if constant feedback is provided during the compaction process
- Over or under-compaction often occurs
  - Better if operator can tell when and if density has been obtained
IC TPF / FHWA Definition

GPS-based documentation systems
- Continuous recordation of materials stiffness
- Continuous recordation of corresponding roller location
- Color-coded mapping of stiffness, temperature and number of passes
Caterpillar
Sakai IC Roller Project

- Temperature

Shoulder side (Supported)

Longitudinal Joint

Paving Direction

Temp

60.0 70.0 80.0 90.0 100.0 110.0 120.0 130.0

-10.0 0.0 10.0 20.0 30.0 40.0 50.0 60.0
Common Methods of Measuring Thermal Segregation

- Infrared Thermometers – less than $200
- Infrared Cameras – less than $5K
- Pave-IR System – less than $30K
# Comparison of Thermal Profiling Techniques

<table>
<thead>
<tr>
<th>Test Device</th>
<th>Strengths</th>
<th>Weaknesses</th>
</tr>
</thead>
</table>
Example report from project with minimal thermal segregation

<table>
<thead>
<tr>
<th>Thermal Profile Summary Report</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Profile ID:</strong> Demo - minimal thermal segregation</td>
</tr>
<tr>
<td><strong>Profile Number:</strong> 1</td>
</tr>
<tr>
<td><strong>Status:</strong> Demonstration</td>
</tr>
<tr>
<td><strong>County:</strong></td>
</tr>
<tr>
<td><strong>Tested By:</strong> SDS</td>
</tr>
<tr>
<td><strong>Test Location:</strong> 1019</td>
</tr>
<tr>
<td><strong>Material Code:</strong> TY C HMA</td>
</tr>
<tr>
<td><strong>Material Name:</strong></td>
</tr>
<tr>
<td><strong>Producer:</strong></td>
</tr>
<tr>
<td><strong>Area Engeneer:</strong></td>
</tr>
</tbody>
</table>

| Course/Lift: | 1 | **Temperature Differential Threshold:** 25.0 |
| Segment Length (ft): | 150 | **Sensors Ignored:** - |

**Thermal Profile Results Summary**

<table>
<thead>
<tr>
<th>Number of Profiles</th>
<th>Moderate $25.0^\circ F &lt; \text{differential} \leq 50.0^\circ F$</th>
<th>Severe differential $&gt; 50.0^\circ F$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>Percent</td>
<td>Number</td>
</tr>
<tr>
<td>46</td>
<td>8</td>
<td>17</td>
</tr>
</tbody>
</table>

ID: Demo - minimal thermal segregation
Example report from project with severe thermal segregation
Data from ND 30
Border States Paving: 8/26/2011 (Conv. HMA)
Data from US 18 Oglala-Pine Ridge Border States Paving: 10/18/2011 (Conv. HMA)
Data from US 18 Oglala-Pine Ridge WBL
Border States Paving: 10/19/2011 (Advera WMA)
Data from US 18 Oglala-Pine Ridge EBL Border States Paving: 10/20/2011 (Advera WMA)
Data from US 18 Oglala-Pine Ridge WBL
Border States Paving: 10/23/2011 (Foamed WMA)
Data from US 18 Oglala-Pine Ridge WBL
Border States Paving: 10/27/2011 (Evotherm WMA)
Data from US 18 Oglala-Pine Ridge EBL
Border States Paving: 10/28/11 (Evotherm WMA)
Data from US 18 Oglala-Pine Ridge EBL
Border States Paving: 10/27/11 (Evotherm WMA)
Conclusions

- Physical & thermal segregation are the “Cancer of HMA Paving Industry”
- You cannot always see it. It grows with time. It often results in the early death of the pavement - often the only reason some HMA pavement are in need of rehabilitation
- There are many known & suspected causes & cures – No consensus
- Identifying & Eliminating Thermal Segregation is a Major Goal for Quality Paving
Wearing Course Alternatives

- Chip Seal
- Slurry Seal
- Microsurfacing
- Dense Graded Hot Mix Asphalt
- “Engineered” Wearing Course
SMA (Stone Matrix Asphalt) & Smaller Aggregate Size (NMAS) Durable Wearing Courses
Rut Resistant Wearing Course?

I-29 Sioux Falls South SMA
Review of HMA Research Projects at UND
Funded by NDDOT

Presented to the DAPA
Annual Meeting, Deadwood, SD
January 8-9, 2009

Presented by
Nabil Suleiman, Ph.D.
Civil Engineering Department
University of North Dakota
Evaluation of North Dakota’s 4.75 mm Local Gyratory Mixtures for Thin Overlay Applications
4.75 mm Mix Project

- Objectives
  - To evaluate the rutting resistance performance of the 4.75 mm mixes
  - To evaluate benefits/impacts of the 4.75 mm mixes as thin overlays or as maintenance appl. for med. to low vol. highways
  - To show that the 4.75 mm NMAS mixtures are useful in providing utility for fine aggregate stockpile screenings
Original Scope

- Prepare local Superpave samples (4.75 mm NMAS)
  - Binder: .................................. PG 64-28, PG 58-28
  - Aggregate blend (%NF/%CF): ..100/0;80/20;60/40
  - Aggregate gradation: ................. 4.75 (#4) NMAS
  - Mix Design Air Voids: ................. 4%
  - APA Air Voids: .......................... 7%

- Perform volumetric analysis

- Conduct rut tests using the APA .. Dry and wet
## Gradations

<table>
<thead>
<tr>
<th>Aggregate</th>
<th>Nat. Fines</th>
<th>Crushed Fines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sieve Size</td>
<td>% Passing</td>
<td>% Passing</td>
</tr>
<tr>
<td>5/8&quot;  (16mm)</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>1/2&quot;  (12.5mm)</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>3/8&quot;  (9.5mm)</td>
<td>100.0</td>
<td>99.0</td>
</tr>
<tr>
<td>#4    (4.75mm)</td>
<td>96.2</td>
<td>94.9</td>
</tr>
<tr>
<td>#8    (2.36mm)</td>
<td>86.1</td>
<td>71.8</td>
</tr>
<tr>
<td>#16   (1.18mm)</td>
<td>71.3</td>
<td>47.1</td>
</tr>
<tr>
<td>#30   (0.6mm)</td>
<td>50.7</td>
<td>31.0</td>
</tr>
<tr>
<td>#50   (0.3mm)</td>
<td>25.4</td>
<td>18.8</td>
</tr>
<tr>
<td>#100  (0.15mm)</td>
<td>8.5</td>
<td>11.9</td>
</tr>
<tr>
<td>#200  (0.075mm)</td>
<td>5.5</td>
<td>8.9</td>
</tr>
</tbody>
</table>
Issues

- Realizing the utility of the 4.75 mm mixes as low-cost rut-resistant thin overlays for med. or LVR
- A cost-effective maintenance treatment alternative
- Providing use for CFs and NFs
- Benefit to roadway agencies, local HMA producers, and local aggregate producers on issues regarding aggregate availability and specification compliance
4.75 mm Mix Project

• Implementation

– If research study is successful, thin-lift applications of the 4.75 mm mixes can be implemented as cost-effective overlays for medium and LVR roads.

– The 4.75 mm mixtures can also be implemented as a low-cost maintenance treatment alternative for almost all pavement types.
Thanks!

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