Improving Hot Mix Asphalt Performance with SUPERPAVE

SUPERPAVE Update for Intevep
April 8, 2002
Asphalt Mixture Behavior

- Permanent Deformation
- Fatigue Cracking
- Low Temperature Cracking
Rutting in Subgrade or Base

- Original profile
- Asphalt layer
- Weak subgrade or underlying layer
- Subgrade deformation
Rutting in Asphalt Layer

original profile

weak asphalt layer

shear plane
Mixture Resistance to Rutting

- Asphalt Binder
  - stiff and elastic at high temperatures
- Aggregate
  - high interparticle friction
  - gradation acts like one large elastic stone
Fatigue Cracking

- Distress in Wheelpath
- Progressive Damage
  - longitudinal cracking
  - alligator cracking
  - potholes
- Affected by
  - asphalt binder
  - aggregates
  - pavement structure
HMA Fatigue Behavior

- Longer Fatigue Life
  - flexible materials
  - low stress/strain level
- Shorter Fatigue Life
  - stiff materials
  - high stress/strain level
- Exception
  - thick pavements
  - non-deflecting support layers

Heavy Trucks
Cures for Fatigue Cracking

- Design for actual number of heavy loads
- Keep subgrade dry (i.e., low deflections)
- Use thicker pavements
- Use non-moisture susceptible materials
- Use paving materials that are resilient
Fatigue Cracking

HMA must be strong & resilient

tensile stresses at bottom of pavement
Experience with Perpetual Pavements
Mike Nunn – TRL/ UK

Rate of structural rutting (mm/msa)

Thickness of bituminous layer (mm)
Top-Down Fatigue Cracking

Top-down fatigue cracking on New Jersey I-287
Top-Down Cracking

Core from New Jersey I-287
Pre-Superpave Asphalt Mixture Design
Pre-Superpave Mix Design Shortcomings

- Marshall Mix Design
  - impact compaction unrealistic
  - Marshall stability not related to performance
- Hveem Mix Design
  - equipment more expensive and not portable
  - some volumetric properties not emphasized
  - asphalt content selection very subjective
Goals of SHRP

- **Performance Spec for “Binders”**
  - physical property tests
- **Mix Design System**
- **Mixes that resist rutting and cracking**
  - component requirements
  - volumetric proportioning
- **Performance Based Mix Analysis System**
Goals of Compaction Method

- Simulate field densification
  - Accommodate large aggregates
- Measure compactability
- Conducive to field QC
SUPERPAVE Gyratory Compactor (SGC)

- Ram pressure: 600 kPa
- 150 mm diameter mold
- 30 gyrations per minute
- 1.25 degrees per minute
**4 Steps of Superpave Mix Design**

1. **Materials Selection**
2. **Design Aggregate Structure**
3. **Design Binder Content**
4. **Moisture Sensitivity**
Three tiered approach

**Level 1** – Volumetric mix design

**Level 2&3** – Mix Performance tests and models
Performance Based Tests

Superpave Shear Tester (SST)  Indirect Tensile Tester (IDT)
Superpave Performance Testing
What Are We Doing?

Performance Test

Rut Depth
ESALs

Performance Prediction
Shearing Behavior of Aggregate

Before Load

After Load

shear plane
Aggregate Properties

- **Consensus Properties** - *required*
  - coarse aggregate angularity (CAA)
  - fine aggregate angularity (FAA)
  - flat, elongated particles
  - clay content

- **Source Properties** - *agency option*
  - toughness
  - soundness
  - deleterious materials
Contrasting Stone Skeletons

Cubical Aggregate

Rounded Aggregate
# Coarse Aggregate Angularity

<table>
<thead>
<tr>
<th>Traffic ESALs</th>
<th>Depth from Surface</th>
<th>Minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 - 30 x 10^6</td>
<td>95/90</td>
<td>80/75</td>
</tr>
<tr>
<td></td>
<td>95% one fractured face</td>
<td></td>
</tr>
<tr>
<td></td>
<td>90% two+ fractured faces</td>
<td></td>
</tr>
</tbody>
</table>
Fine Aggregate Angularity

- Measured on - 2.36 mm Material
- Based on Air Voids in Loose Sample
- AASHTO T 304
- Requirements Depend on
  - depth of layer within pavement
  - traffic level
Fine Aggregate Angularity

uncompacted voids = \( \frac{V - \frac{M}{G_{sb}}}{V} \times 100\% \)
## Fine Aggregate Angularity

<table>
<thead>
<tr>
<th>Traffic ESALs</th>
<th>Depth from Surface</th>
<th>% air voids in loose sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 - 30 x 10^6</td>
<td>&lt; 100 mm</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td>&gt; 100 mm</td>
<td>40 Minimum</td>
</tr>
</tbody>
</table>

> Rounder particles pack tighter together -- less air
Flat, Elongated Particles

- Measured on + 4.75 mm Material
- Based on Dimensional Ratio of Particles
  - ratio of max to min dimension < 5
- ASTM D 4791
- Requirements Depend on
  - traffic level
Flat, Elongated Particles

1:5 pivot point

fixed post (B)

fixed post (A)

swinging arm
Flat, Elongated Particles

<table>
<thead>
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<th>Traffic</th>
<th>ESALs</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 - 30 x 10^6</td>
<td>10</td>
<td>Percentage of flat and elongated particles</td>
</tr>
</tbody>
</table>
Superpave Aggregate
Gradation

- Use 0.45 Power Gradation Chart
- Blend Size Definitions
  - maximum size
  - nominal maximum size
- Gradation Limits
  - control points
  - restricted zone
Superpave Aggregate Gradation

Percent Passing

Sieve Size (mm) Raised to 0.45 Power

Design Aggregate Structure
## Superpave Mix Size Designations

<table>
<thead>
<tr>
<th>Superpave Designation</th>
<th>Nom Max Size (mm)</th>
<th>Max Size (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>37.5 mm</td>
<td>37.5</td>
<td>50</td>
</tr>
<tr>
<td>25 mm</td>
<td>25</td>
<td>37.5</td>
</tr>
<tr>
<td>19 mm</td>
<td>19</td>
<td>25</td>
</tr>
<tr>
<td>12.5 mm</td>
<td>12.5</td>
<td>19</td>
</tr>
<tr>
<td>9.5 mm</td>
<td>9.5</td>
<td>12.5</td>
</tr>
</tbody>
</table>
Practical ESALs (20 year life)

1 truck / day = 7,300 EAL
10 truck / day = 73,000 EAL
100 truck / day = 730,000 EAL

\[
\text{EAL} = \frac{\text{Trucks/Day}}{\text{Trucks/Day}}
\]

<table>
<thead>
<tr>
<th>EAL</th>
<th>Trucks/Day</th>
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<tbody>
<tr>
<td>300,000</td>
<td>40</td>
</tr>
<tr>
<td>3,000,000</td>
<td>400</td>
</tr>
<tr>
<td>10,000,000</td>
<td>1,300</td>
</tr>
<tr>
<td>30,000,000</td>
<td>3,900</td>
</tr>
</tbody>
</table>

Note: 1 ESAL/truck
## SUPERPAVE Gyratory Compaction Effort

<table>
<thead>
<tr>
<th>ESAL's</th>
<th>N ini</th>
<th>N des</th>
<th>N max</th>
<th>App</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 0.3</td>
<td>6</td>
<td>50</td>
<td>75</td>
<td>Light</td>
</tr>
<tr>
<td>0.3 to &lt; 3</td>
<td>7</td>
<td>75</td>
<td>115</td>
<td>Medium</td>
</tr>
<tr>
<td>3 to &lt; 10</td>
<td>8</td>
<td>100*</td>
<td>115</td>
<td>High</td>
</tr>
<tr>
<td>10 to &lt; 30</td>
<td>8</td>
<td>100</td>
<td>115</td>
<td>High</td>
</tr>
<tr>
<td>≥ 30</td>
<td>9</td>
<td>125</td>
<td>205</td>
<td>Heavy</td>
</tr>
</tbody>
</table>

Base mix (< 100 mm) option to drop one level, unless the mix will be exposed to traffic during construction. Too high ESAL level = Too little asphalt binder.
Three Points on SGC Curve

- \( N_{ini} \)
- \( N_{des} \)
- \( N_{max} \)

Log Gyrations

% \( G_{mm} \)
Superpave Mixture Requirements

- Specimen Height
- Mixture Volumetrics
  - Air Voids
  - Voids in the Mineral Aggregate (VMA)
  - Voids Filled with Asphalt (VFA)
- Mixture Density Characteristics
- Dust Proportion
- Moisture Sensitivity
Mixture Density

Limit for $N_{\text{max}}$

Limit for $N_{\text{ini}}$

Log Gyrations

$G_{mm}$

% $G_{mm}$
Evaluate Aggregate Structure

% $G_{mm}$

weak aggregate structure

strong aggregate structure

Log Gyrations

10 100 1000
Design Asphalt Binder Content

% Gmm

Number of Gyrations (Ndes)

4.2% AC
4.5% AC
4.8% AC
5.1% AC
Moisture Sensitivity
AASHTO T 283

- Measured on Proposed Aggregate Blend and Asphalt Content

80% minimum

3 Conditioned Specimens
3 Dry Specimens

Tensile Strength Ratio
CONCLUSIONS

- Training needed for everyone if SUPERPAVE is to be used successfully
- PG Grade System provides the right asphalt for varying climate and traffic conditions
- SUPERPAVE places more tools in the Pavement Designers’ Tool Box
- Designers can solve pavement problems they were unable to in the past using SUPERPAVE