Development and Implementation of the Superpave System in the USA And its Relationship to Pavement Design

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Superpave

- The final product of the SHRP asphalt program area is Superpave. Superpave is an acronym which stands for:

  Superior Performing Asphalt Pavements
What is Superpave?
Performance-Based Specifications
Design and Analysis Tools
Why Superpave?

- In the 1980’s pavement performance for the US highways was not improving.
- Demands on the system were increasing.
- New materials coming on the market were difficult to evaluate.
Why SHRP?

- In the 1980’s procedures and practices could not assure performance.
- Unacceptable Risk.

2 Weeks Old!
Changes

- Increased traffic and loadings
- Supply sources/changes
- Use of recycled materials (RAP)
- Drum plants vs. batch plants
- Personnel experience
- Staff reductions
Distress Modes in Asphalt

• Primary three are:
  – Rutting
  – Fatigue cracking
  – Low-temperature cracking
The Superpave System

- A performance-related binder specification
- A performance-related mix specification
- Mixture analysis tool (AMPT)
Specification criteria is a function of environment and traffic level.
Production | Rutting | Fatigue Cracking | Thermal Cracking

Production

Rutting

Fatigue Cracking

Thermal Cracking

Time

No aging

RTFO - aging

PAV - aging

RV

DSR

BBR

DTT
7 Asphalt Binders

<table>
<thead>
<tr>
<th></th>
<th>AZ</th>
<th>CRM</th>
<th>PG 70-22</th>
<th>Air Blown</th>
<th>SBS</th>
<th>TX</th>
<th>TBCR</th>
<th>TP</th>
<th>PG 70-22</th>
<th>SBS 64-40</th>
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Relationship between $G^*/\sin \delta$ and ALF rutting

Existing SHRP specification has poor relationship to rutting for modified systems.
Multi Stress Creep and Recovery

Test using the DSR applying a 1 sec creep stress followed by 9 sec recovery.
Relationship between Jnr and ALF rutting

\[ y = 4.7357x - 1.1666 \]
\[ R^2 = 0.8167 \]

MSCR can adjust for field conditions and has excellent relations to performance.
Miss I55 6yr rut Jnr 3.2 kPa

$y = 0.2907x + 0.1297$

$R^2 = 0.7499$
## AASHTO MP 19

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<thead>
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<th>Original</th>
<th>RTFOT</th>
<th>PAV</th>
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<td>Min 1.0</td>
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<td>64</td>
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<td>RTFOT</td>
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<td>64 Standard</td>
<td>[(MSCR3.2 – MSCR 0.1)/MSCR 0.1] &lt; .75</td>
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<tr>
<td>MSCR 3.2&lt;2.0</td>
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<td>64 Very heavy</td>
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<td>MSCR3.2 &lt;1.0</td>
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<td>DSR G*sinδ</td>
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<td>Max 5000</td>
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<td>H &amp; V grade</td>
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<tr>
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<td>28</td>
<td>25</td>
<td>22</td>
</tr>
<tr>
<td>Max 6000</td>
<td>19</td>
<td>16</td>
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</table>

Low temp BBR and DTT remain unchanged.
Asphalt Mixture Behavior

- Permanent Deformation
- Fatigue Cracking
- Low Temperature Cracking
Major Steps in Superpave

- Selection of Materials
- Selection of a Design Aggregate Structure
- Selection of the Design Binder Content
- Evaluation of Dynamic Modulus, $|E^*|$, and Creep Compliance
- Evaluation of Moisture Sensitivity of the Design Mixture
FHWA .45 Power Chart

Percent Passing

100

1

0.075

0.3

2.36

4.75

9.5

12.5

19.0

Sieve Size (mm) Raised to 0.45 Power

max density line

control point

nom max size

max size
# Original Superpave Gyration Levels

<table>
<thead>
<tr>
<th>Traffic (ESALs)</th>
<th>Design 7-day Maximum</th>
<th>Air Temperature (°C)</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>&lt; 39</td>
<td>39 - 41</td>
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<td></td>
<td>( N_i ) ( N_d ) ( N_m )</td>
<td>( N_i ) ( N_d ) ( N_m )</td>
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<tr>
<td>&lt;3 ( \times 10^5 )</td>
<td>7 68 104</td>
<td>7 74 114</td>
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<tr>
<td>&lt;1 ( \times 10^6 )</td>
<td>7 76 117</td>
<td>7 83 129</td>
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<tr>
<td>&lt;3 ( \times 10^6 )</td>
<td>7 86 134</td>
<td>8 95 150</td>
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<tr>
<td>&lt;1 ( \times 10^7 )</td>
<td>8 96 152</td>
<td>8 106 169</td>
</tr>
<tr>
<td>&lt;3 ( \times 10^7 )</td>
<td>8 109 174</td>
<td>9 121 195</td>
</tr>
<tr>
<td>&lt;1 ( \times 10^8 )</td>
<td>9 126 204</td>
<td>9 139 228</td>
</tr>
<tr>
<td>( \geq 1 \times 10^8 )</td>
<td>9 143 235</td>
<td>10 158 262</td>
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</table>
# US Superpave (ESAL$_{80kN}$) SGC Compaction Effort

<table>
<thead>
<tr>
<th>Million ESAL’s</th>
<th>(N_{\text{ini}})</th>
<th>(N_{\text{des}})</th>
<th>(N_{\text{max}})</th>
<th>App</th>
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<tr>
<td>&lt; 0.3</td>
<td>6</td>
<td>50</td>
<td>75</td>
<td>Light</td>
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<tr>
<td>0.3 to &lt; 3</td>
<td>7</td>
<td>65</td>
<td>98</td>
<td>Medium</td>
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<td>3 to &lt; 10</td>
<td>8</td>
<td>80*</td>
<td>120</td>
<td>High</td>
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<tr>
<td>10 to &lt; 30</td>
<td>8</td>
<td>80</td>
<td>120</td>
<td>High</td>
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<tr>
<td>≥ 30</td>
<td>9</td>
<td>100</td>
<td>160</td>
<td>Heavy</td>
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</table>

*Base mix (< 100 mm) option to drop one level, unless the mix will be exposed to traffic during construction.*
Equipment Specifications

AASHTO T312

• Pressure - 600 ± 18 kPa

• Angle of Gyration - 1.25 ± 0.02° external
  or, 1.16 ± 0.03° internal

• Rate of Gyration - 30 ± 0.5

• Specimen Height, nearest 0.1mm
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- **Specimen Height**, nearest 0.1mm
Dynamic Angle Validator
Dynamic Angle Validator
NCHRP Superpave Projects

• Over 15 projects for further development of Superpave
  – Binder test and procedures
  – Modified binders
  – Mix design
  – Performance testing
  – Construction Quality Assurance
Implementation
Critical Steps...

- **Equipment Standards**
  - Reference materials (binder only)
  - Certification/Calibration procedures

- **Standardized Procedures**
  - Ruggedness, assessment of procedure
  - Precision/Bias, tied to acceptance system
  - Refinement, instrumentation and software

- **Laboratory Accreditation (AMRL)**
  - Quality Manual/System
  - Proficiency Testing (annual)
Next Generation of Performance Testers

• New tests have a closer relationship to fundamental properties of the mix.
• Measured material properties tied to performance models to estimate distress.
AC Mix Performance Tester

The test can evaluate the rutting and fatigue response of the AC mix.

The equipment is relatively inexpensive and easy to use.

Test results are inputs for the Mechanistic Empirical Pavement Design Guide.
Dynamic Modulus Test
AASHTO TP 62

Cyclic Loading

75 ~ 125 με
Displacement
Dynamic Modulus $E^*$

$\sigma_0 = \text{dynamic stress}$

$\varepsilon_0 = \text{recoverable axial strain}$

$$|E^*| = \frac{\sigma}{\varepsilon_0}$$

Phase Angle

Loading Frequency

Load

Displacement

75 ~ 125 $\mu\varepsilon$
Repeated Load Test Results

Rutting

Microstrain vs. Load Cycles

- 12.5_Coarse_PG 67-22 Mix
- 12.5_Coarse_PG 76-22 Mix

Flow Number

Primary Flow
Secondary Flow
Tertiary Flow
What’s New in Flexible Pavement Design?

Mechanistic Empirical Pavement Design Guide

HMA Materials Properties Tied Directly to the Pavement Structural Design
The MEPDG Integrates

Materials Selection → Pavement Design

Pavement Design → Construction

Construction → Pavement Management

Pavement Management → Materials Selection
What’s New in Flexible Pavement Design?

- Asphalt Materials Characterization directly from Superpave
  - Binder properties determined from PG grading
  - Mix properties determined from volumetric mix design
  - Mix Modulus determined from the Superpave Asphalt Mix Performance Test
Asphalt Design Theory

Climate Inputs → EICM → Structure & Mat'l Properties → Traffic

Predicted Performance → Transfer Functions → Mechanistic Analysis
M-E Guide Outputs: Flexible

- Fatigue Cracking
- Thermal Cracking
- Rut Depth
- IRI
How do you make it work
The key is identifying the problem Requires Asking the Right Question.

- Is the rock too large?
- Or is the truck too small?
If the rock is too big
If the truck is too small
Research to Specifications

• The SHRP Experience
  – 1984 STRS Report
  – 1987 SHRP Program
  – 1993 SHRP completion
  – 1993 Implementation initiation
  – 2000 declaration of success
  – 2006 last highway agency adopts SHRP binder specification.
  – 2013 Continued Development for improvement
Sometimes to appreciate where we are ...
We need to remember where we have been.
Smooth Roads Ahead