Implementation of Superpave In USA and other Locations Worldwide

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Asphalt concrete mixes and geosynthetics materials in road constructions
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SHRP Asphalt Program

• Objective: Define chemical and physical characteristics of asphalt and their relationship to performance in pavement systems

• Potential results:
  • Improved design capability and performance prediction.
  • Better quality control and better materials.
  • Potential savings of $100 million per year.
Strategic Highway Research Program (SHRP)

• The SHRP asphalt research program, the largest SHRP program at $53 million had three primary objectives (1987 to 1993)
  • Investigate why some pavements perform well, while others do not.
  • Develop tests and specifications for materials that will out-perform and outlast the pavements being constructed today.
  • Work with highway agencies and industry to have the new specifications put to use.

“We need a chemical spec for asphalt cement…”

https://www.pavementinteractive.org/reference-desk/design/mix-design/superpave-overview/
Distress types and conditioning

• Three types of distress considered
  • Rutting
  • Fatigue
  • Low Temperature cracking

• Three aging conditions
  • Original – what is in the tank.
  • RTFOT – immediately after constriction
    • Rolling thin film oven
  • PAV – about 7+ years of construction
    • Pressure aging device
SHRP Asphalt Program

• The final product of this research program is a new system referred to as “Superpave”, which stands for
  **SU**uperior
  **PER**forming
  Asphalt
  **PAVE**ments

• Superpave, in its final form consists of three basic components:
  • An asphalt binder specification. This is the PG asphalt binder specification.
  • A design and analysis system based on the volumetric properties of the asphalt mix. This is the Superpave mix design method.
  • Mix analysis tests and performance prediction models. This area was not fully completed and is still ongoing!
Superpave National Implementation

• 1996 – 1% of projects, 2% of tonnage
• Significant implementation by 2000
• Last state to implement – California – 2016
• Large scale implementation now exist in USA
  • Some localities, districts, small organization still using old systems
Superpave system of binder selection and mix design

• An asphalt binder specification.

• The Superpave mix design method

• Mix analysis tests and performance prediction models

Superpave - needed for the construction of quality roads
Superpave system of binder selection and mix design

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Superpave binder testing, Asphalt Institute, 2018
Asphalt binder specification

- Binder specification was different in concept to specifications previously
- Specifically developed for a climate based approach
- Temperature of test changed depending upon climate and estimated pavement temperature
Binder specification implemented in AASHTO M320

- Requirement remains constant – regardless of climate – just the test temperature changes
Superpave Asphalt Binder Specification

Grading System Based on Climate

PG 58-22

Performance Grade
Average 7-day max pavement design temp
Min pavement design temp

(orginal implementation)
Equipment and property definition

• Tests were developed to capture rheological performance in a certain stiffness range – also associated with pavement temperature

• Some new equipment incorporated into specifications for asphalt binders
Asphalt binder and mix equipment

• Binder test equipment included:

Binder Conditioning

RTFOT

PAV

Binder Testing

Rheometers

RV

DSR

BBR

DTT
Binder testing reference

• Good source of detailed information on testing which can be very helpful for training technicians with new equipment

• Available from Asphalt Institute

Changes to binder area following implementation

• Climate models updated
• Low temperature, search for a better definition
• High temperature – implementation of Jnr

• Ongoing work – not discussed in this presentation
  • New fatigue parameters, NCHRP study
  • Durability cracking parameters – two options $\Delta T_c$ and G-R being considered
Climate model update

• 1997/98 – New algorithm introduced for cold temperature
• 2003/05 – New method for high temperature
  • Old method based on 7-day high
  • New method weighted for damage
  • Implemented as degree days
    • Degree days = sum of \((T_{\text{high}} - T_{20C})\) for average year
  • Impacts warmer climates more significantly
• Implemented in 2003
• Allows users to consider different terminal conditions – size of rut depth
Russian Climate Map

• Recently analyzed all available data for Russia to produce variation of high and low PG grades based on 98% reliability and 12.5mm rut depth in same manner as USA data developed

• Corrected equation from simple polynomial to sigmoid to correct variation in PG for more northern and southern climates than found in USA
  • Equation published in 2003 only consider latitudes from 20 to 48°. Did not fit data well above latitude of 45°.
Russia Low PG – 98% reliability

• Using data from Russian weather stations – climate model implemented with Google Earth output
Russia High PG – 98% reliability, 12.5mm rut

• Output effected by selected rut depth, reliability and climate inputs
• Full software implementation
Low temperature testing

- A large effort resulted in an alternate procedure being developed
- BBR master curves are used to generated stiffness
- Thermal stress is calculated using software
- Results compared to tensile strength data
  - Published in AASHTO but not implemented!
  - Some limited use in Canada, Utah and a few other locations

\[ \sigma = \int_{\xi_0}^{\xi} E(\xi - \xi') \frac{d(\alpha \cdot \Delta T)}{d\xi'} d\xi' \]
Other methods .... include ..

- Asphalt Binder Cracking Device (ABCD) (Kim, 2007)
  - Determines Critical Cracking Temperature
  - Asphalt pored into a ring
  - Sensors record cracking temperature

- BBR Strength of Asphalt Binders (Marasteanu, 2012)
  - A BBR test performed at a constraint strain rate
  - Modified BBR
  - Determines strength
  - Thermal stress computation or use directly
High temperature performance

- Multi-stress creep recovery (MSCR) test
- Measures Jnr – average from 10 load cycles
- Also reported is % recovery
- Test is considered an improvement over $G^* \cdot \sin \delta$
- Implemented in ASSHTO M332

Test using the DSR applying a 1 sec creep stress followed by 9 sec recovery.
MSCR test performed in DSR

- PG 64 (Standard, Heavy, Very heavy, Extreme) based on traffic

  - PG 64S-XX $J_{nr} \geq 4.5$
  - PG 64H-XX $J_{nr} \geq 2$
  - PG 64V-XX $J_{nr} \geq 1$
  - PG 64E-XX $J_{nr} \geq 0.5$

\[ \text{Higher Strains in MSCR!!} \]

- $\gamma_p = \text{peak strain}$
- $\gamma_u = \text{un-recovered strain}$
- $\gamma_r = \text{recovered strain}$

\[ J_{ur} = \frac{\gamma_u}{\tau} \]

\[ \% \text{ recovery} = \frac{100 \times \gamma_r}{\gamma_p} \]
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Superpave mix design

- AASHTO and ASTM specifications cover the practice

- Good reference document is Asphalt Institute MS-2
  - Note the current MS-2 includes what information was previously in SP-2
Superpave Gyratory Compactor

• Basis
  • Texas equipment
  • French operational characteristics

• 150 mm diameter
  • up to 37.5 mm nominal size

• Height Recordation
Gyratory compaction

- Original methods developed in USA
- Implemented in France
- USA looked during SHRP project at French and USA methods
  - Adopted SHRP methods with 1 – degree angle
  - Realized that 1 – degree angle not achieved – so accepted angle that was in common compactors implemented (Pine and Troxler)

1950’s – Texas Gyratory Compactor

Francis Moutier with LCPC Gyratory Compactor

SHRP/Superpave Gyratory Compactors
Gyratory compaction – final adoption

• 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
Mixture volumetrics

- Concept based on Voids in Mineral Aggregate and Voids Filled with Binder
- Design selected when 4% air voids achieved
- Method effectively controlled effective volume of binder
- Similar in concept to older methods published by Asphalt Institute and others – except that 4% air voids fixed
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

- Values change as function of traffic level
Superpave gradation controls

• Originally a restricted zone existed in all specifications
• Many state DOTs have now removed
Determine Nini, Ndes, and Nmax – version 3

• AASHTO R35 - Superpave Gyratory Compaction Effort
  • These have changed since Superpave first introduced
    • 1996, 2004 to 2010
  • Current requirements are significantly less complex

<table>
<thead>
<tr>
<th>20-Year Design Traffic, ESALs (millions)</th>
<th>$N_{design}$ (Number of Design Gyrations)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 0.3</td>
<td>50</td>
</tr>
<tr>
<td>0.3 to &lt; 3</td>
<td>75</td>
</tr>
<tr>
<td>3 to &lt; 10</td>
<td>100</td>
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<tr>
<td>10 to &lt; 30</td>
<td>100</td>
</tr>
<tr>
<td>&gt; 30</td>
<td>125</td>
</tr>
</tbody>
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2010
Moisture Sensitivity, AASHTO T 283

Measured on Proposed Aggregate Blend and Asphalt Content

3 Conditioned Specimens
3 Dry Specimens

Tensile Strength Ratio

80% minimum (Varies by DOT)

6 to 8% air
Dry
6 to 8% air
55 to 80% saturation
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
Selection of Design Asphalt Binder Content
Combined volumetric chart for QC

• Can combine the mix design and QC information to a single chart with
  • Effective volume of binder
  • Volume of Stone
  • Voids in Mineral Aggregate
  • Voids in Mix
  • Voids filled with binder
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Superpave Equipment

• Initial devices not adopted/not used
  • Superpave shear tester (fatigue and stiffness modulus)
  • Indirect tensile test (low temperature cracking)
  • Environmental Conditioning System (ECS) (moisture damage)

• Limited use
  • Bending beam fatigue

• Implemented
  • Indirect tensile test (water damage – AASHTO T283)
  • Wheel tracking tests
    • Asphalt Pavement Analyzer (APA)
    • Hamburg Wheel Tracking (HWT) device
Hamburg

• Adopted by many states for water damage and deformation control
  • Originally developed in Hamburg Germany based on UK design of Immersion Wheel Tracking Test
  • Implemented in USA following study in mid-1990s
  • Immersion wheel tracking had best performance with expected results – SHRP research paper - 1993
Superpave implementation

• Teamwork between agencies (owners) and industry has been key
  • Now 25-years of various groups
    • Expert task groups
    • Lead states
    • Regional Asphalt User Producer Groups

• Important to know limitations and assumptions in system as implementation takes place in other locations

• Ongoing improvements to system
  • Industry
  • NCHRP studies
  • FHWA, etc.
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Thank you for listening ....

Questions?
Discussion?

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