Putting the Puzzle Together
On Our National Asphalt RD&T Activities

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www.TFHRC.gov
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www4.trb.org/trb/crp.nsf/
Structural

Construction

Materials
NCHRP 1-37(A)
Proposed AASHTO 2002 PDG...
9-9(1): Verification of Gyration Levels in the $N_{\text{design}}$ Table...

How well does densification at the $N_{\text{design}}$ levels in PP28 match that developed in the field under traffic?

NCAT (August 2005)
9-9(1): Verification of Gyration Levels in the $N_{design}$ Table...

- **40 Field Projects in 16 States**
- **Independent Variables:**
  - Gyration level
  - Aggregate gradation, fine and coarse
  - Binder grade “bump”
  - Lift thickness to NMAS ratio

- **32 NCAT Track Sections**
Preliminary Findings:

- Current $N_{\text{design}}$ levels slightly too high based on results from both the field projects and NCAT Track.
- Modified binders significantly reduce rate of densification.
- Field monitoring will continue through the summer of 2005 (3 to 4 years total).
9-9(1) The Whole Truth – Predicted Gyrations to Match Test Track Density

$R^2 = 0.1944$

$R^2 = 0.5689$

PG 67-22

PG 76-22

PG 67-22 Upper Lift

PG 76-22 Upper Lift
9-16: Relationship Between SGC Properties and Performance...

- Can the gyratory compactor be used as a simple performance test? **NO.**

- Can the # of gyrations at maximum stress ratio be used to identify gross mix instability? **PROBABLY.**

*Asphalt Institute (April 2002)*
9-16(1): Validation of 9-16
Findings for HMA QC.

- Validate the use of $N - SR_{max}$, number of gyrations at maximum stress ratio, measured with the SGC as a tool for field QC of HMA production

*Asphalt Institute (December 2003)*
9-17: Accelerated Laboratory Rutting Tests: APA

- APA rut depths correlated well with field performance on an *individual* project basis
- APA-field relationships are *project-specific*, NOT global

*NCAT (June 2003)*
Simple Performance Tests for Rutting:

1. Dynamic modulus, $|E^*|$  
2. Flow number, $F_n$ (triaxial repeated load permanent deformation)  
3. Flow time, $F_t$ (static creep)
9-19: *Superpave Support and Performance Models*

**Management, Task C...**

**SPT Validation:** Correlate with field performance of field sections - IN SPS-9, NV I-80, AZ I-10, NCAT Track, MnRoad, FHWA ALF, WesTrack

**SPT Criteria:** Developed with the HMA performance models in the 2002 Pavement Design Guide
Selection Criteria for Minimum $|E^*|$ Value:

- $T_{eff} (F)$
- Design traffic in 18k-ESALs
- Location of HMA layer
- Design reliability (z-factor)
- Maximum design rut depth
Flow number may be an accurate method for directly estimating rut depth at any traffic level from a single measurement.

Flow time is a viable surrogate for flow number.
9-29: *Simple Performance Tester for Superpave Mix Design...*

- Completed evaluation of first-article simple performance testers from Shedworks/IPC and Interlaken
- Single replicate measurement COV: dynamic modulus 13%, flow time 33%

*Advanced Asphalt Technologies (November 2005)*
9-29: *Simple Performance Tester for Superpave Mix Design.*

- Phase IV in progress to procure four additional SPTs according to revised specification and develop ruggedness test plan
- One new SPT capable of measuring dynamic modulus master curve for pavement structural design

Advanced Asphalt Technologies, LLC

“Engineering Services for the Asphalt Industry”
9-27: Relationships of HMA In-Place Voids, Lift Thickness & Permeability...

Determine in-place air voids and minimum lift thicknesses needed to achieve durable, impermeable HMA pavements.

NCAT (October 2003)
9-27: Factors Affecting In-Place Air Voids...

- Recommended t/NMAS ratios for adequate in-place density:
  - $\geq 3$ for fine-graded mixes
  - $\geq 4$ for coarse-graded mixes

- Lower ratios may be used, but will require more compaction effort to achieve adequate density
9-27: Factors Affecting HMA Permeability.

- No significant difference in lab permeability between fine- and coarse-graded mixes
- Satisfactory permeability at 7\(\pm 1\)% Air Voids at \(t/\text{NMAS}=2, 3, \text{ or } 4\)
- Permeability increases as air voids and coarse aggregate ratio increase, decreases as VMA increases
9-25: Requirements for Voids in Mineral Aggregate for Superpave Mixtures...

Which volumetric design criterion best ensures adequate durability and performance: VMA, VFA, or calculated binder film thickness?

AAT (March 2004)

Advanced Asphalt Technologies, LLC

“Engineering Services for the Asphalt Industry”
9-31: Air Void Requirements for Superpave Mix Design...

Should the design air void content vary with traffic loading and climatic conditions?

**AAT (March 2004)**

Advanced Asphalt Technologies, LLC

“Engineering Services for the Asphalt Industry”
Preliminary Findings...

- Design air voids of 4% is about right

- Rut resistance is a function of aggregate fineness relative to VMA
Preliminary Findings...

- Fatigue resistance increases with effective binder content
- Permeability decreases with decreasing VFA and increasing aggregate fineness
- Age hardening is a function of aggregate, binder, and permeability

- Design VMA ± 1% as a function of aggregate surface area
- Design air voids 3 to 5%
- Minimum $V_{be}/VFA$ requirements:
  - 10% / 70% within 100-mm of surface
  - 8% / 65% otherwise
9-30: Plan for Calibration and Validation of HMA Models...

Experiment design for refining the calibration of the HMA performance models in the 2002 design guide with laboratory-measured material properties

Fugro-BRE, Inc. (December 2003)

Overall Requirements:

- $2-3$ million
- 2 years for sampling and testing
- 60 pavement sections
- Mainly non-LTPP pavement sections with emphasis on APT experiments

_Fugro-BRE, Inc. (December 2003)_
Improved conditioning procedure based on use of the environmental conditioning system (ECS) with a 9-19 simple performance test

Pennsylvania Transportation Institute (March 2004)
Improved Conditioning Procedure for Predicting HMA Moisture Susceptibility...

Initial Findings:

- $F_n$ and $F_t$ tests cannot reliably identify moisture susceptible mixes

- $|E^*|$ test has the potential to distinguish between good and poor performing mixes
### 9-34: Improved Conditioning Procedure for Predicting HMA Moisture Susceptibility...

<table>
<thead>
<tr>
<th></th>
<th>D4867</th>
<th>Hamburg WTD</th>
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<th>E*</th>
<th>Ratio</th>
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<tr>
<td>Sandstone</td>
<td>89.4%</td>
<td>2.5 mm</td>
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<tr>
<td>Limestone</td>
<td>86.9%</td>
<td>5.0 mm</td>
<td>0.83</td>
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<tr>
<td>Granite</td>
<td>66.0%</td>
<td>6.0 mm</td>
<td>0.68</td>
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9-34: Improved Conditioning Procedure for Predicting HMA Moisture Susceptibility.

Remainder of the project will investigate the ability of the $|E^*|/ECS$ combination to predict the moisture sensitivity of a large number of HMA mixes with documented field performance.
9-35: Aggregate Properties and Their Relationship to the Performance: A Critical Review

Identify consensus, source, and other aggregate properties that significantly impact HMA performance

NCAT (December 2003)
4-30: Improved Testing Methods for Critical Aggregate Shape/Texture Factors...

Identify or develop methods for measuring shape, texture, and angularity characteristics of aggregates used in hot-mix asphalt and hydraulic cement concrete

*Washington State University/ TX A&M (July 2004)*
Aggregate IMaging System...
9-36: Improved Procedure for Laboratory Aging of Asphalt Binders in Pavements...

Improved procedure for short-term laboratory aging usable in a purchase specification such as AASHTO M320

- For both neat and modified binders
- Quantifies binder volatility
- Extendible to long-term aging
- Mimics PP2 mix aging

Advanced Asphalt Technologies (August 2005)
Superpave® Binder Specification
Short Term Aging – NCHRP 9-36

TX DOT is adopting this technology
ANTICIPATED PROJECTS
Update the 1993 method and manual:

- Simple performance test(s)

- As-delivered 2002 design guide performance models and software

- Updated volumetric criteria

- Framework for integrated mix and structural design?

(RFP Issue: December 2003)
Endurance Limit of HMA Mixtures to Prevent Fatigue Cracking in Flexible Pavements

Test the hypothesis that there is an endurance limit in the fatigue behavior of HMA mixtures and measure its value for a representative range of HMA mixtures

(About March 2004)
Recent Publications


- NCHRP Report 478, “Relationship of Superpave Gyratory Compaction Properties to HMA Rutting Behavior”
## "The Puzzle"

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<td>9-25 Voids</td>
<td>9-25 Voids</td>
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**Future**
9-38 Endur Limits
Smooth Roads Ahead
A Few More Pieces
To The Puzzle

NCHRP 90-series
Conducted by
FHWA
90-01: Mobile Asphalt Lab
90-01: Mobile Asphalt Labs

- Provide “Hands-on” of Superpave System
  - Volumetric Mix Design
  - Field QC/QA Procedures, NCHRP 9-7
  - Dynamic Angle Validation (DAV)
  - Performance Related Specifications 9-22
  - Simple Performance Test 9-29

- 4 to 6 week visits

- Data used to support ETG’s
90-02: Binder lab

- Continuous support to the States:
  - Training / Ruggedness / Development / Validation

- Trouble shooting of binder problems

- Further Development of the DT
  - Ruggedness
90-03 Mix Tenderness...

- Mix Tenderness
  - Asphalt Institute
  - Major cause of tenderness is moisture
  - Minor affect gradation
  - Recommendations
Understanding the Performance of Modified Asphalts in Mixtures
NCHRP 90-07, TPF 5-(019)
Partnerships with Products
19 State DOT’s & 11 Industry Sponsors
Historical Perspective

- ‘86 Initial Trials
- ‘89 WASHTO Field Tests
- ‘90 Super Single Tire
- ‘93 SHRP binder validation
- ‘98 Ultra-Thin Whitetopping
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<tr>
<td>AZ</td>
<td>CRM</td>
<td>PG 70-22</td>
<td>Air Blown</td>
<td>SBS</td>
<td>TX TBCR</td>
<td>T-P PG 70-22 + Fibers</td>
<td>PG 70-22 264-40</td>
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Final Test Matrix...
Binder Specification
Parameters
Preliminary Results
High Temperature Parameters

- $|G^*|/\sin \delta$ @ 10 radians (Superpave)
- $|G^*|/(1-(1/\tan \delta \sin \delta))$ @ 0.25 radians (Shenoy)
- $\% \gamma_{acc}$ Repeated Creep @ 300 Pa (Bahia)
- $\eta'$ @ 0.01 radians/s, LSV (Dongre'/D’Angelo)
- $\eta_0$ @ ~0 radians/s, ZSV (Rowe)
- MVR, 1.225kg load, cc/10min (Shenoy)
High Spec. Temperature, $T_{HS}$

- $|G^*|/\sin \delta = 2200 \text{ Pa}$ (Superpave)
- $|G^*|/(1-(1/\tan \delta \sin \delta)) = 50 \text{ Pa}$ (Shenoy)
- $\% \gamma_{acc} \text{ No Criterion}$ (Bahia)
- $\eta' = 250 \text{ Pa-s, LSV}$ (Dongre'/D’Angelo)
- $\eta_0 = 250 \text{ Pa-s, ZSV}$ (Rowe)
- $MRV = 50 \text{ cc/10min}$ (Shenoy)
High-Temperature Performance
I-80, Nevada
Same gradation - different binders.

PG 63-22 modified
No rutting

PG 67-22 unmodified
15mm of rutting
High Temperature (Rutting)
Repeated Creep Recovery Test

PG 67-22 Neat AC

PG 63-22 Modified
Repeated Creep Test Results
Two binders of Same PG-Grade

- B 6281 (PG74-28)
- B 6289 (PG74-31)

Limited Recovery, AB ALF, 15.7mm, s=0.24
Higher recovery, T-P ALF, 8.8mm, s=0.15
Repeated Creep Test Results
Two binders of Different PG-Grades

- B 6280 (PG71-38)
- B 6286 (PG79-28)

SBS
ALF, 19.5mm, s=0.30

TBCR
ALF, 8.8mm, s=0.15
Superpave®
Binder Specification
Direction
# Superpave® Binder Specification

**Rutting, Fatigue, and Low-Temp. Cracking**

<table>
<thead>
<tr>
<th>WHEN</th>
<th>WHAT</th>
<th>HOW</th>
<th>WHERE</th>
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<tbody>
<tr>
<td>Construction</td>
<td>Safety Pumpability Rutting</td>
<td>Flash Point Rot Visc $G^*/\sin *$</td>
<td>230 min 3 Pa-s max T(high)</td>
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<tr>
<td>Early $(RTFO)$</td>
<td>Rutting</td>
<td>$G^*/\sin *$</td>
<td>T(high)</td>
</tr>
<tr>
<td>Late $(+PAV)$</td>
<td>Fatigue Low Temp</td>
<td>$G^* \sin *$ BBR/DTT</td>
<td>T(inter) $T_{CR}$</td>
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</table>
Binder Specification
Direction

- To better handle neat asphalts
- To address modifiers
- To do it faster, better, and more economical!

*** RULES ***
TESTS NEED TO BE:
- EASY TO SET UP
- EASY TO PERFORM
- EASY TO ANALYZE
**Superpave® Binder Spec. II**
**PG based on Degree Days**

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<tbody>
<tr>
<td>Construction</td>
<td>Safety</td>
<td>Flash Point Rot Visc $f(G^*) ZSV$</td>
<td>230 min 3 Pa-s max</td>
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<tr>
<td></td>
<td>Pumpability</td>
<td></td>
<td>T(high)</td>
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<tr>
<td></td>
<td>Rutting</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Early</td>
<td>Fatigue</td>
<td>$f''(G^*) DT$</td>
<td>T(inter) $T_{CR}$</td>
</tr>
<tr>
<td>Tx Device (+MW)</td>
<td>Low Temp</td>
<td>DT / ABC</td>
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