TURNER-FAIRBANK HIGHWAY RESEARCH CENTER

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

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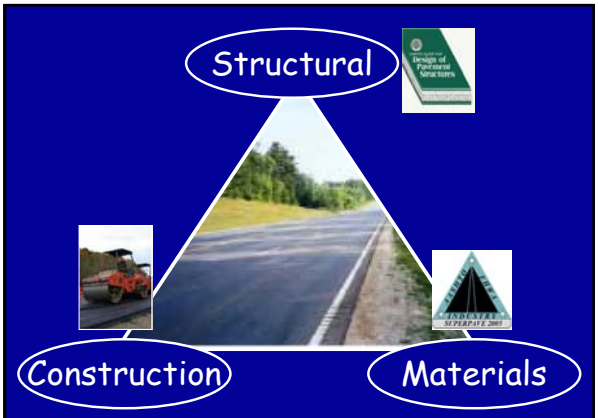
**www.TFHRC.gov**

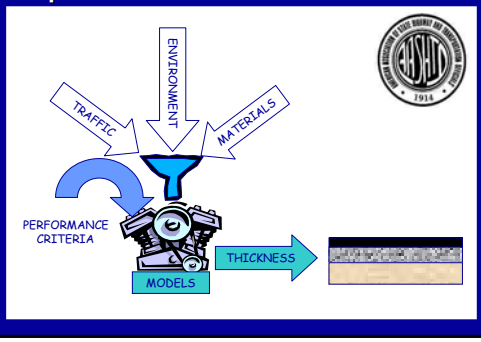
# National Cooperative Highway Research Program

**www4.trb.org/trb/crp.nsf/**

Dr. Edward Harrigan, Ph.D.
9-Series



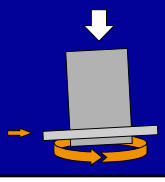

## NCHRP 1-37(A) Proposed AASHTO 2002 PDG




## 9-9(1): *Verification of the $N_{design}$ Table...*

**Does $N_{design}$ match traffic?**

***NCAT (August 2005)***



## 9-9(1): *Verification of the $N_{design}$ Table...*

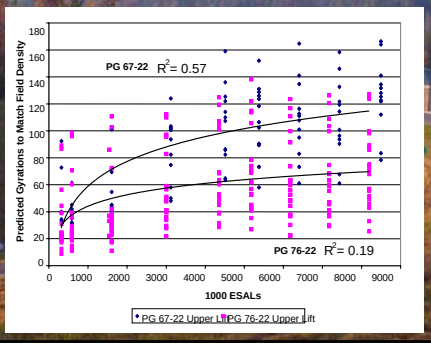
- **40 Field Projects in 16 States**
  - Gyration level
  - Aggregate gradation, fine and coarse
  - Binder grade "bump"
  - Lift thickness to NMAS ratio
- **32 NCAT Track Sections**

## 9-9(1): *Verification of Gyration Levels in the $N_{design}$ Table.*

**Preliminary Findings:**

- $N_{design}$ levels **slightly too high…**
- **Modified binders can significantly reduce rate of densification**
- **Field monitoring till 2005**

## NCHRP 9-9(1) – Predicted Gyrations to Match Test Track Density




## 9-16: *Relationship Between SGC Properties and Performance…*

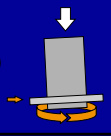
- **Can the gyratory compactor be used as a simple performance test? *NO.***
- **Can the # of gyrations at maximum stress ratio be used to identify gross mix instability? *PROBABLY.***

***Asphalt Institute (April 2002)***

## 9-16(1): *Validation of 9-16 Findings for HMA QC.*

- **Validate the use of N-$SR_{max}$, # 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)***

## 9-19: *Superpave Models, Task C…*

**Simple Performance Tests for Rutting:**

1. **Dynamic modulus, $|E^*|$**
2. **Flow number, $F_n$ (dynamic creep)**
3. **Flow time, $F_t$ (static creep)**

***Arizona State University***

## 9-29: *Simple Performance Tester for Superpave Mix Design…*

- Completed evaluation of first article simple performance testers
- 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…

- Procure 4 additional SPTs according to revised specification
- Develop ruggedness test plan
- 1 new SPT capable of measuring dynamic modulus master curve for structural design (2002 PDG)

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:
  - ≥ 3 for fine graded mixes
  - ≥ 4 for coarse-graded mixes
- Lower ratios may be used, but will require more compaction effort

## 9-25: Volumetric *Requirements Superpave…*

Which best ensures adequate durability and performance: VMA, VFA, or 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"*

## 9-25/9-31 Preliminary Findings...

- Design air voids of 4% is about right
- Rut resistance is a function of aggregate fineness relative to VMA

## 9-25/9-31 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

## 9-25/9-31 Preliminary Approach to Specification Modification.

- 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 models in the 2002 design guide with laboratory-measured material properties

*Fugro-BRE, Inc. (December 2003)*

## 9-30: *Plan for Calibration and Validation of HMA Models.*

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)*

## 9-34: *Improved Conditioning Procedure for Predicting Moisture Susceptibility...*

Improved conditioning based on environmental conditioning system (ECS) with a 9-19 simple performance test

*Pennsylvania Transportation Institute (March 2004)*

### 9-34: *Improved Conditioning Procedure for Predicting 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 Moisture Susceptibility…*

| | D4867 | Hamburg WTD | \|E*\| Ratio |
|---|---|---|---|
| Sandstone | 89.4% | 2.5 mm | 0.90 |
| Limestone | 86.9% | 5.0 mm | 0.83 |
| Granite | 66.0% | 6.0 mm | 0.68 |

### 9-34: *Improved Conditioning Procedure for Predicting 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

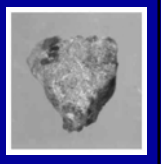
*NCAT (December 2003)*

### 4-30: *Improved Testing Methods for Critical Aggregate Shape/Texture Factors…*

Identify or develop methods for measuring shape, texture, and angularity characteristics of aggregates

*Washington State University/ TX A&M (July 2004)*

### Aggregate IMaging System…

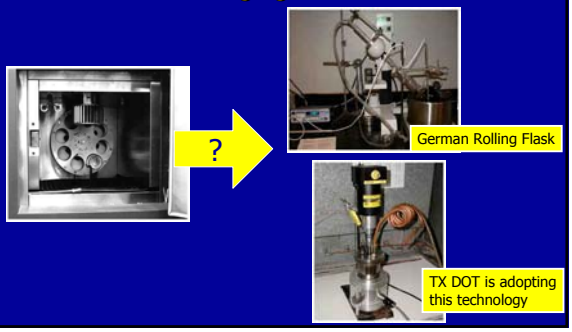


### 9-36: *Improved Procedure for Laboratory Aging of Asphalt Binders in Pavements…*

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

***Advanced Asphalt Technologies (August 2005)***

### Superpave® Binder Specification
Short Term Aging – NCHRP 9-36




## ANTICIPATED NCHRP PROJECTS

### 9-33: *A Mix Design Manual for Hot Mix Asphalt*

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)***

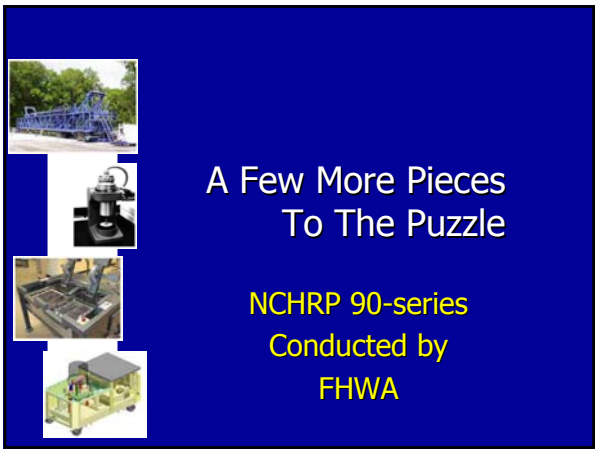
### 9-38: *Endurance Limit of HMA Mixtures to Prevent Fatigue Cracking in Flexible Pavements*

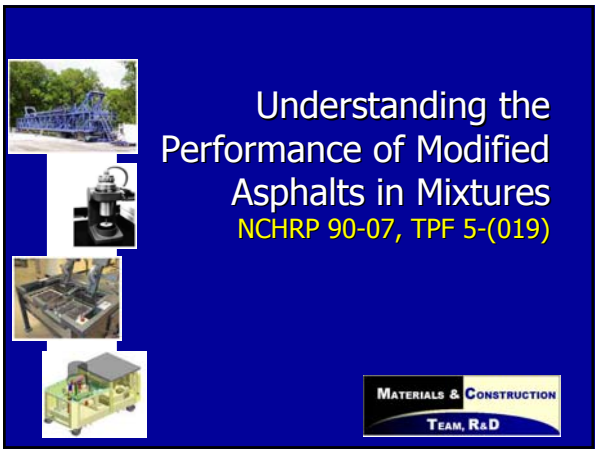
**Test the hypothesis that there is an endurance limit in the fatigue behavior of HMA mixtures and measure its value for a representative range of HMA mixtures**

***(About March 2004)***

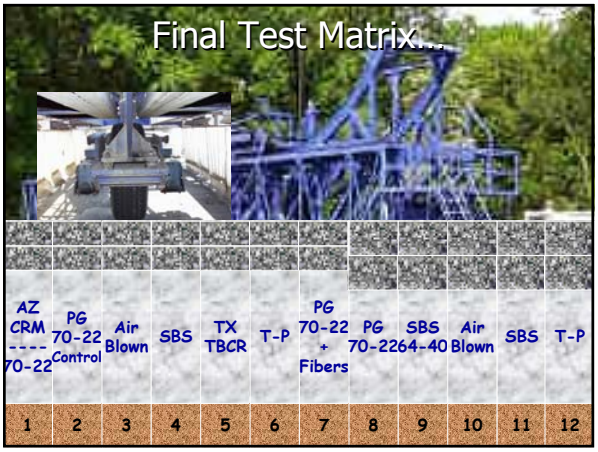
### "The Puzzle"

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1-37a PDG | | 9-19 Adv. Models | 9-30 Models Calib. | | | | |
| | 9-9 $N_{des}$ | 9-16 $N_{SRMax}$ | 9-19 9-29 SPT --- *9-17 APA* | 9-25 9-31 Voids (PRS) | 9-33 Design Manual | 9-34 $H_2O$ SPT | 9-35 4-30 Agg. | 9-36 Aging Binder |
| | *9-22 PRS* | | | | | | | Future 9-38 Endur Limits |

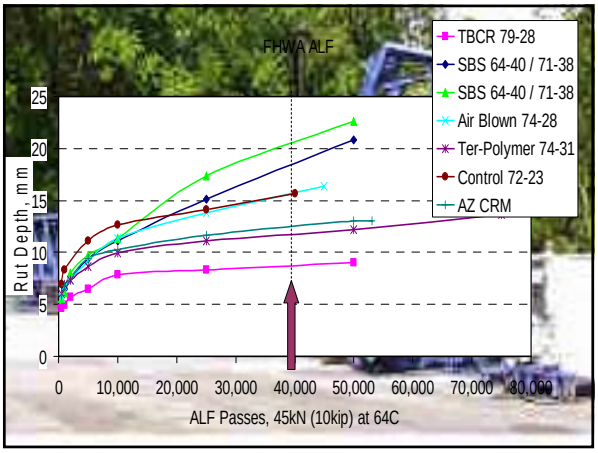

A Few More Pieces
To The Puzzle
NCHRP 90-series
Conducted by
FHWA

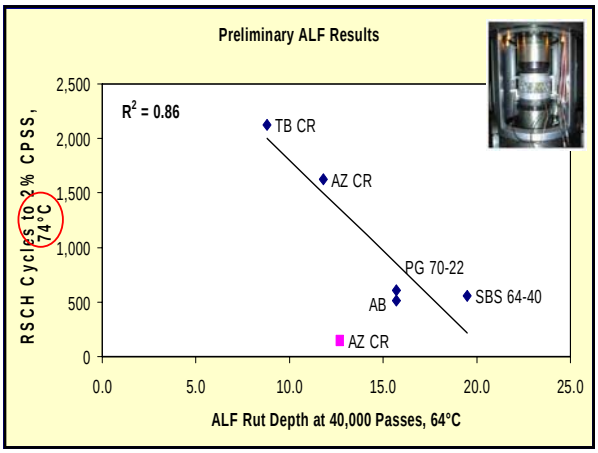

Understanding the
Performance of Modified
Asphalts in Mixtures
NCHRP 90-07, TPF 5-(019)
Materials & Construction
Team, R&D


REFINEMENT
Superpave™
Partnerships with Products
19 State DOT's & 11 Industry Sponsors


Final Test Matrix...
AZ CRM ---- 70-22
PG 70-22 Control
Air Blown
SBS
TX TBCR
T-P
PG 70-22 + Fibers
PG 70-22
SBS 64-40
Air Blown
SBS
T-P
1
2
3
4
5
6
7
8
9
10
11
12

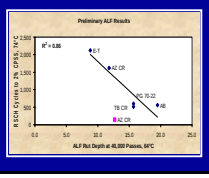

ALF - Laboratory
Preliminary Results


FHWA ALF
TBCR 79-28
SBS 64-40 / 71-38
SBS 64-40 / 71-38
Air Blown 74-28
Ter-Polymer 74-31
Control 72-23
AZ CRM
Rut Depth, mm
0
5
10
15
20
25
0
10,000
20,000
30,000
40,000
50,000
60,000
70,000
80,000
ALF Passes, 45kN (10kip) at 64C




## Significance

- Superpave Shear Tester
  Repeated Shear at Constant Height to
  2% Cumulative Permanent Shear Strain
  **Tracks ALF Rutting Performance**




## 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 Pa *(Superpave)*
- $|G^*|/(1 \ (1/\tan\delta \sin\delta))$ = 50 Pa *(Shenoy)*
- % $\gamma_{acc}$ No Criterion *(Bahia)*
- $\eta'$ = 250 Pa ş LSV *(Dongre'/D'Angelo)*
- $\eta_0$ = 250 Pa ş ZSV *(Rowe)*
- *MRV = 50 cc/10min* *(Shenoy)*

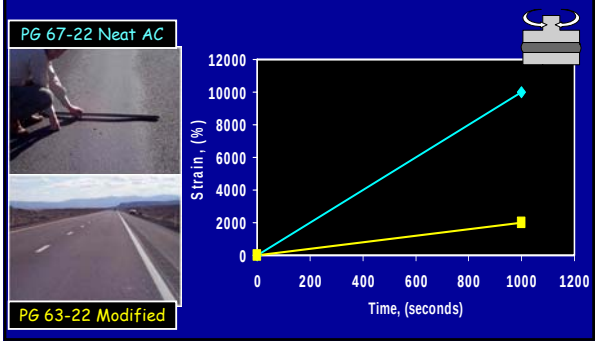
## High-Temperature Performance I-80, Nevada

Same gradation - different binders.

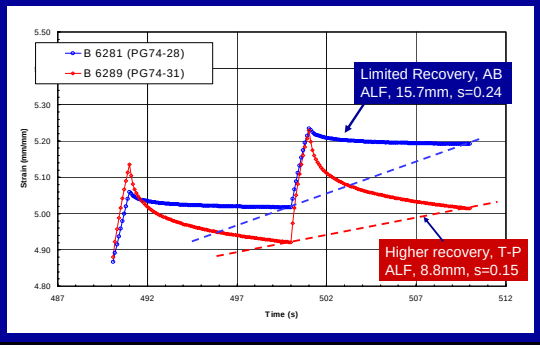
PG 63-22 modified
No rutting

PG 67-22 unmodified
15mm of rutting

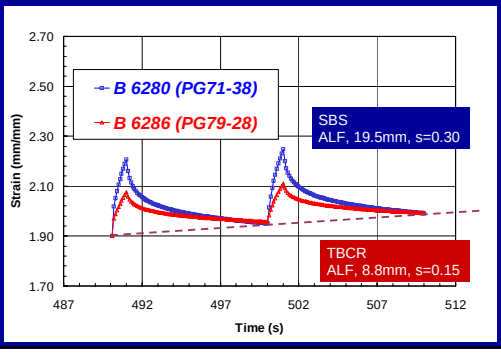
## High Temperature (Rutting) Repeated Creep Recovery Test




## Repeated Creep Test Results Two binders of Same PG-Grade




## Repeated Creep Test Results Two binders of Different PG-Grades




## Summary of Findings To Date

*Preliminary Results*

- Current specification does not adequately identify the benefits of modifiers
- RSCH tracks ALF rutting performance
- A wide range of high specification temperature parameters are being evaluated

## What's Next

- Fatigue Testing
  - Two Temperatures
- Rutting Testing
  - 7 Lanes
- Additional Sections
  - TBD
- Superpave SPT
  - |E*|, Creep
- Beam Fatigue
- Low Temp Study
  - ABCD, DT, $T_{CR}$

## Superpave® Binder Specification Direction

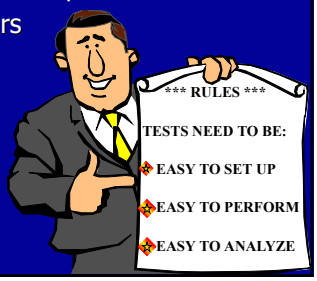
## Current Superpave® Specification

Rutting, Fatigue, and Low-Temp. Cracking

| WHEN | WHAT | HOW | WHERE |
|---|---|---|---|
| Construction | Safety<br>Pumpability<br>Rutting | Flash Point<br>Rot Visc<br>$G^*$ / sin ☒ | 230 min<br>3 Pa-s max<br>T(high) |
| Early<br>*(RTFO)* | Rutting | $G^*$ / sin ☒ | T(high) |
| Late<br>*(+PAV)* | Fatigue<br>Low Temp | $G^*$ sin ☒<br>BBR/DTT | T(inter)<br>$T_{CR}$ |

## Binder Specification Direction

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




## Superpave® Binder Spec. II

PG based on Degree Days

| WHEN | WHAT | HOW | WHERE |
|---|---|---|---|
| Construction | Safety<br>Pumpability<br>Rutting | Flash Point<br>Rot Visc<br>*f* ($G^*$ ☒ ZSV | 230 min<br>3 Pa-s max<br>T(high) |
| Early<br>*Tx Device* | Rutting | *f* ($G^*$ ☒ ZSV | T(high) |
| Late<br>*(+MW)* | Fatigue<br>Low Temp | *f*"($G^*$ ☒ DT<br>DT / ABC | T(inter)<br>$T_{CR}$ |