U.S. Department of Transportation
Federal Highway Administration

TURNER–FAIRBANK
HIGHWAY RESEARCH CENTER

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

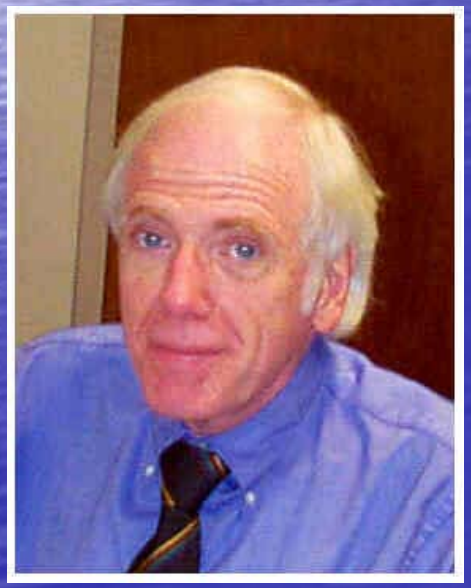
Thomas Harman

Materials & Construction Team Leader, R&D

Federal Highway Administration

www.TFHRC.gov

National Cooperative Highway Research Program



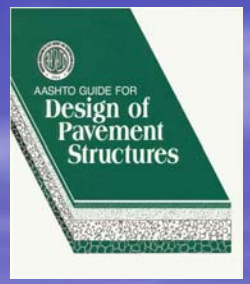
Dr. Edward Harrigan, Ph.D.
9-Series, Fall 2003

NAS - AASHTO's Research Program Since 1962

For Project Status Reports, Requests for Proposals, Online Documents, Products Developed for AASHTO Committees, and Other Information, Visit the Web at:

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

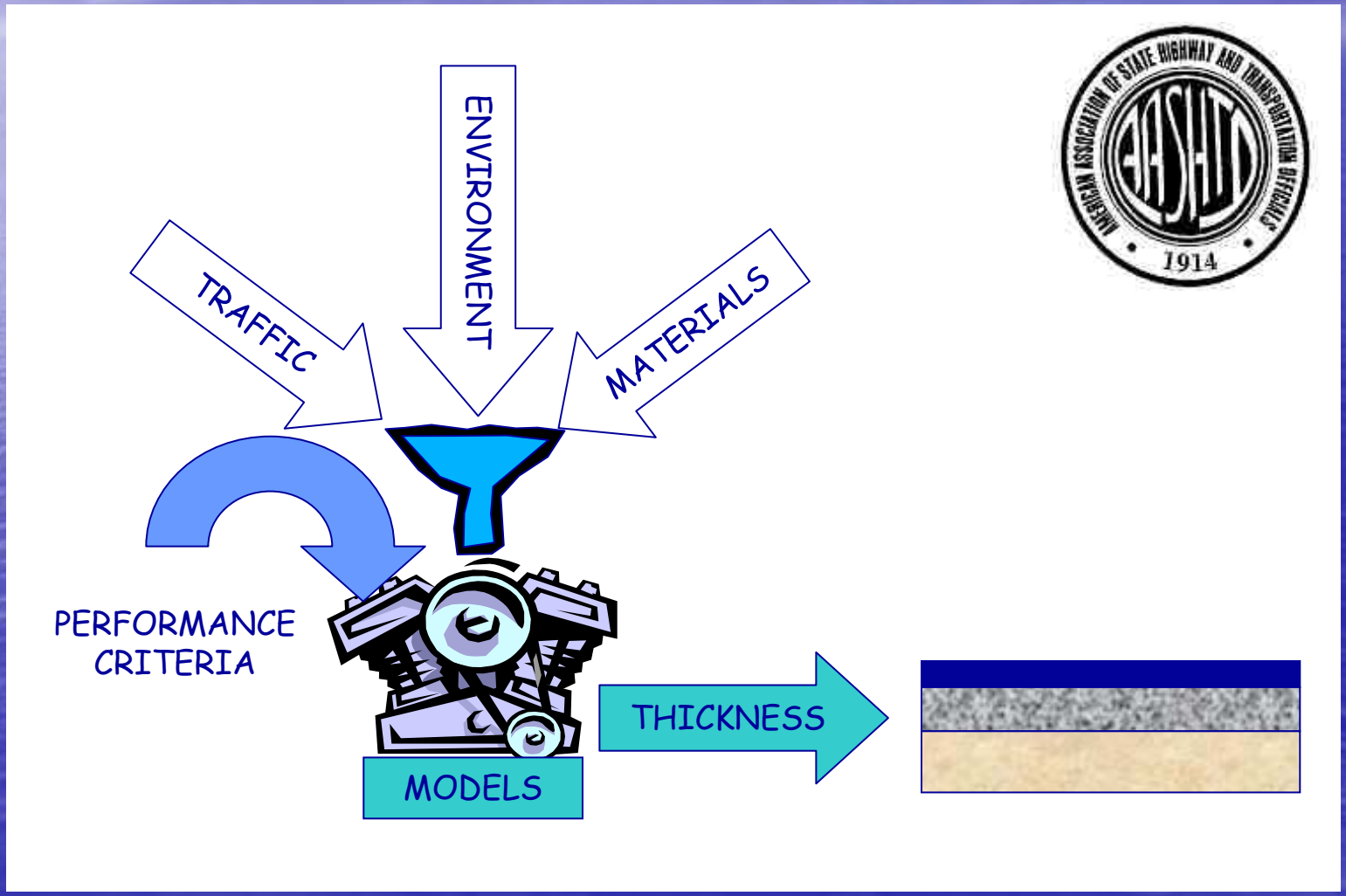
Structural



Construction

Materials

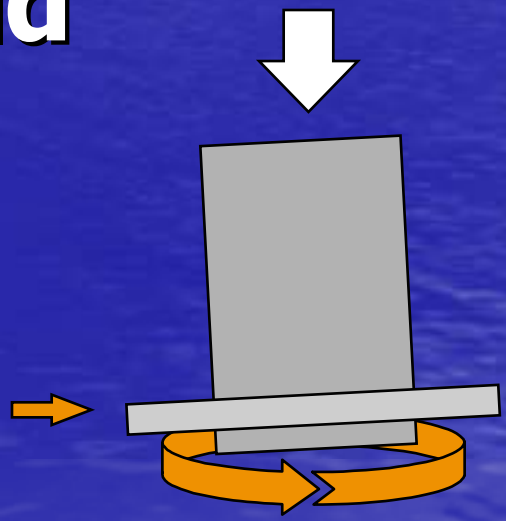
NCHRP 1-37(A) Proposed AASHTO 2002 PDG…



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

How well does densification at the N_{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…*

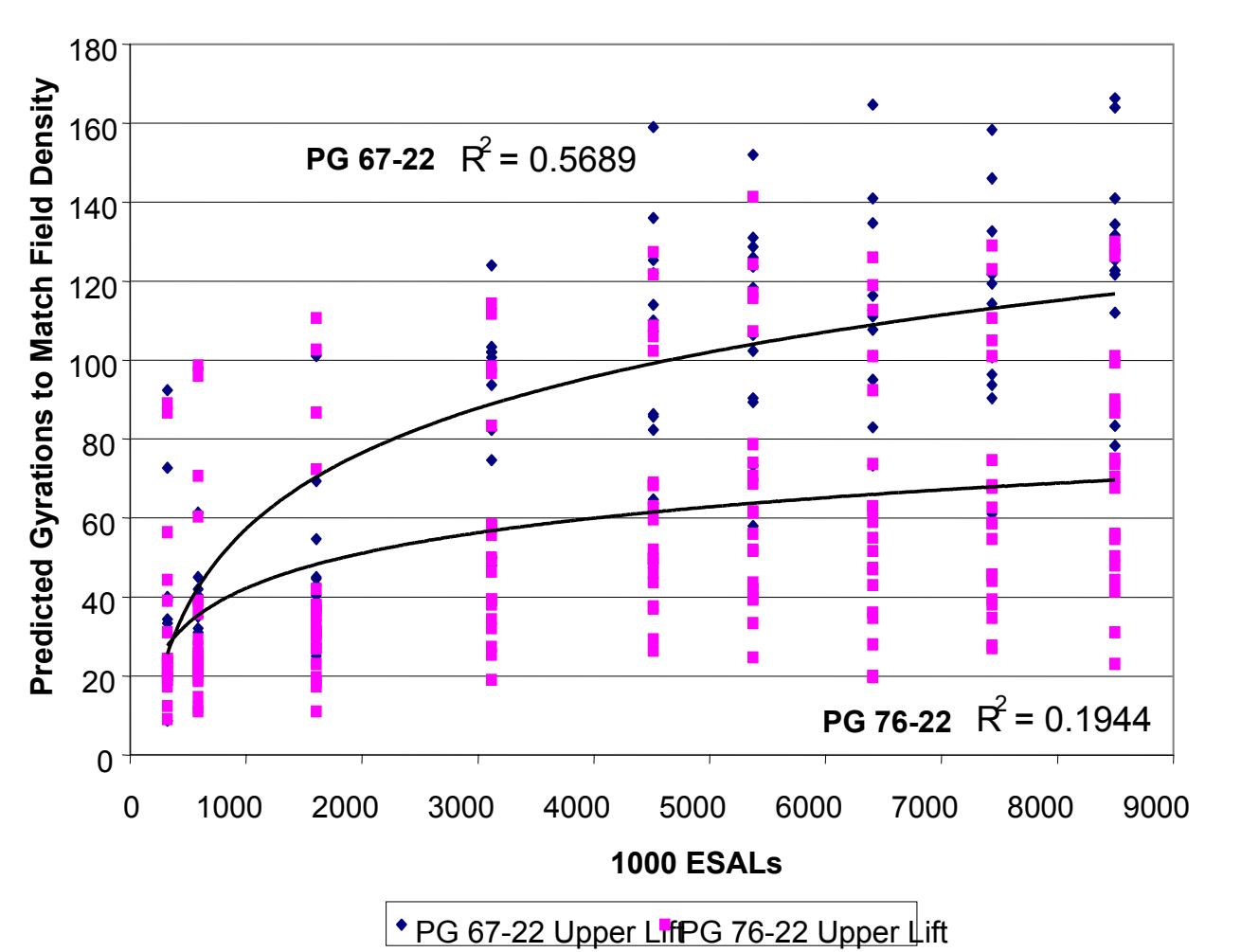
- **40 Field Projects in 16 States**
  Independent Variables:
  - Gyration level
  - Aggregate gradation, fine and coarse
  - Binder grade "bump"
  - Lift thickness to NMAS ratio
- **32 NCAT Track Sections**

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

Preliminary Findings:

- **Current N_{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



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

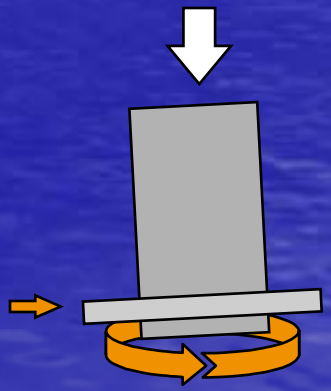
- Can the gyratory compactor be used as a simple performance test? ***NO***.
- Can the # of gyrations at maximum stress ratio be used to identify gross mix instability? ***PROBABLY***.

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*

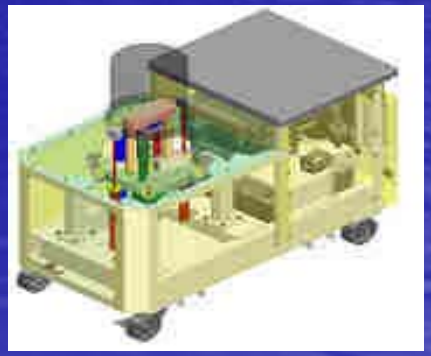
- APA rut depths correlated well with field performance on an *individual* project basis
- APA-field relationships are project-specific, NOT global

NCAT (June 2003)

9-19: *Superpave Support and Performance Models Management, Task C...*

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)**



Arizona State University

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

9-19: *Superpave Support and Performance Models Management, Task C...*

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

9-19: *Superpave Support and Performance Models Management, Task C.*

- 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%

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

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:
  - ≥ 3 for fine-graded mixes
  - ≥ 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±1% Air Voids at t/NMAS=2, 3, 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?

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)

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 HMA performance 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 HMA Moisture Susceptibility…*

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

Pennsylvania Transportation Institute (March 2004)

9-34: *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…*

	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 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

?

German Rolling Flask

TX DOT is adopting this technology

ANTICIPATED 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)

Recent Publications

- **NCHRP Web Document 54, "Precision Estimates of Selected Volumetric Properties of HMA Using Non-Absorptive Aggregate"**
- **NCHRP Report 478, "Relationship of Superpave Gyratory Compaction Properties to HMA Rutting Behavior"**

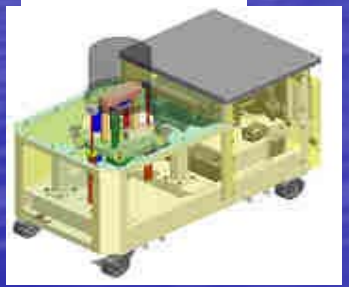
"The Puzzle"

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


Smooth
Roads Ahead



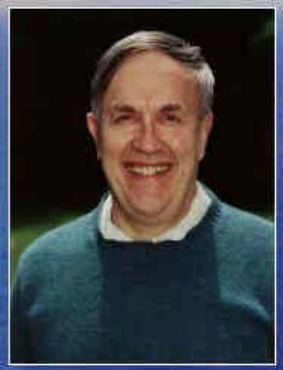
A Few More Pieces To The Puzzle

NCHRP 90-series Conducted by FHWA

FHWA Asphalt Pavement Teams
www.TFHRC.gov


Ernie

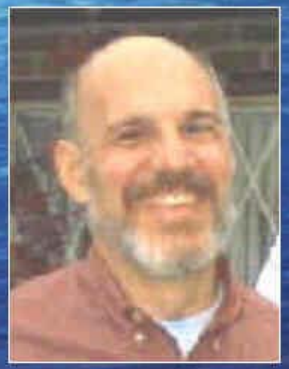

Tom


Terry


Kevin


Jack


Katherine


John D


John B


Matt


Mike


Jason


Leslie

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

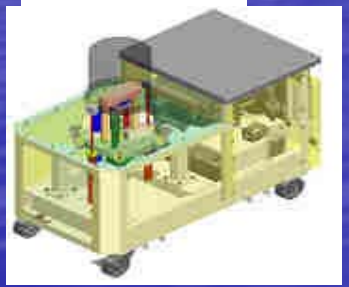
- 4 to 6 week visits
- Data used to support ETG's

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)

MATERIALS & CONSTRUCTION TEAM, R&D

REFINEMENT

Superpave™

Partnerships with Products

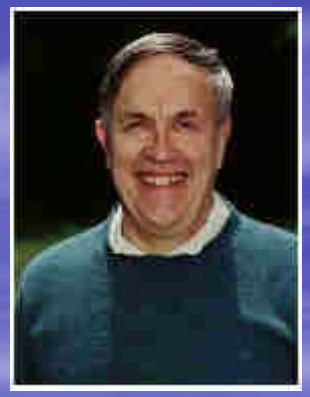
19 State DOT's & 11 Industry Sponsors

Historical Perspective

- ✓'86 Initial Trials
- ✓'89 WASHTO Field Tests
- ✓'90 Super Single Tire
- ✓'93 SHRP binder validation
- ✓'98 Ultra-Thin Whitetopping

Final Test Matrix…

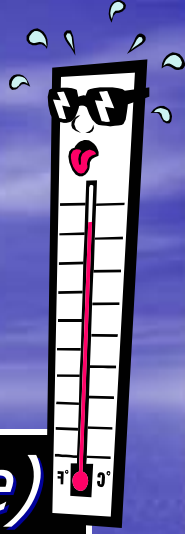
AZ CRM ---- 70-22	PG 70-22 Control	Air Blown	SBS	TX TBCR	T-P	PG 70-22 + Fibers	PG 70-22	SBS 64-40	Air Blown	SBS	T-P
1	2	3	4	5	6	7	8	9	10	11	12



Binder Specification Parameters

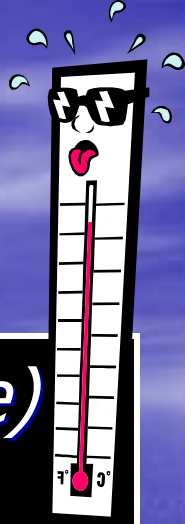
Preliminary Results

High Temperature Parameters



- $|G^*|/\sin\delta$ @10 radians *(Superpave)*
- $|G^*|/(1-(1/\tan\delta \sin\delta))$ @0.25 radians *(Shenoy)*
- % γ_{acc} Repeated Creep @ 300 Pa *(Bahia)*
- η' @ 0.01 radians/s, LSV *(Dongre'/D'Angelo)*
- η_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)*
- % γ_{acc} No Criterion *(Bahia)*
- $\eta' = 250$ Pa-s, LSV *(Dongre'/D'Angelo)*
- $\eta_0 = 250$ Pa-s, ZSV *(Rowe)*
- *MRV = 50 cc/10min* *(Shenoy)*

High-Temperature Performance
I-80, Nevada

Same gradation - different binders.

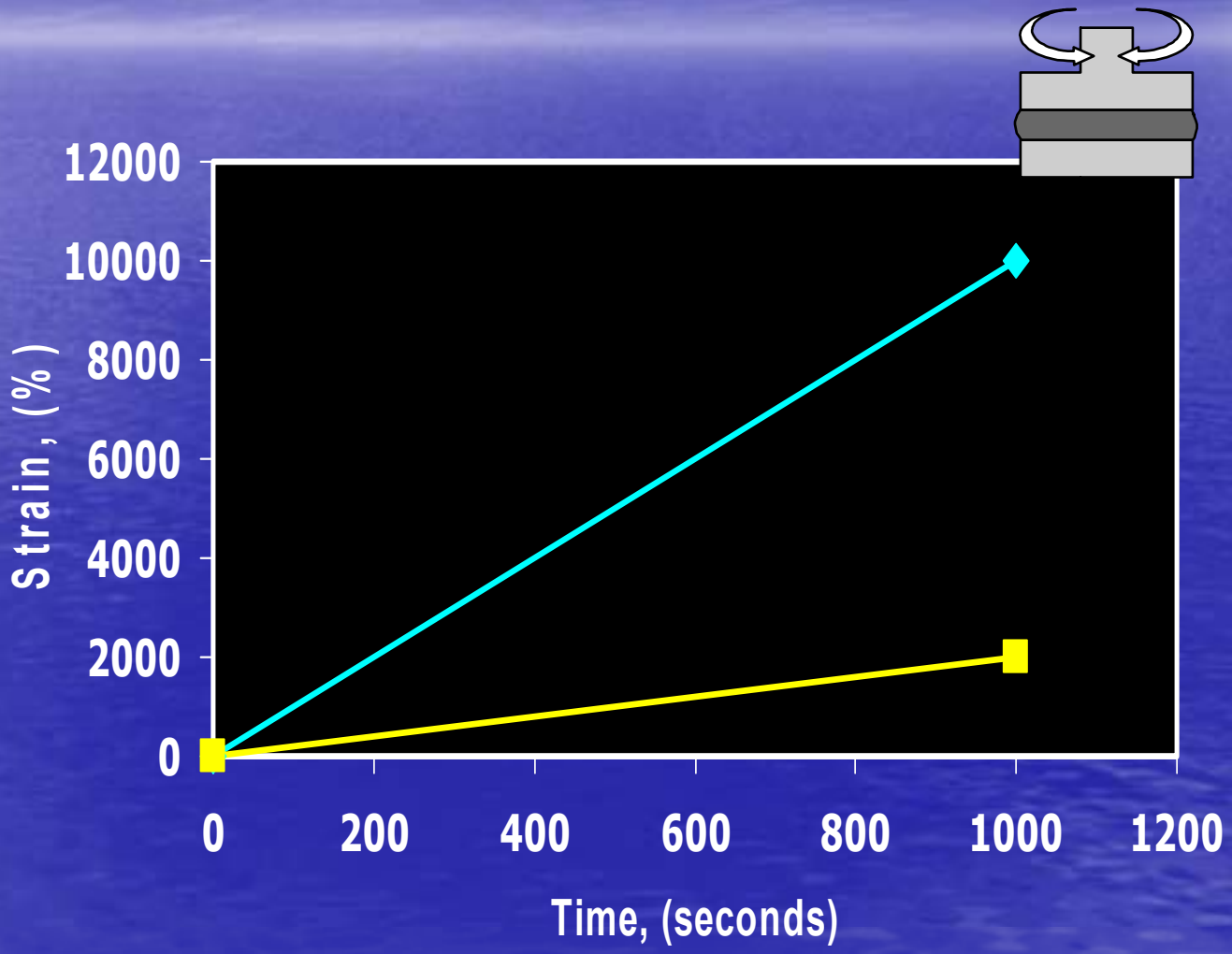
PG 63-22 modified
No rutting

PG 67-22 unmodified
15mm of rutting

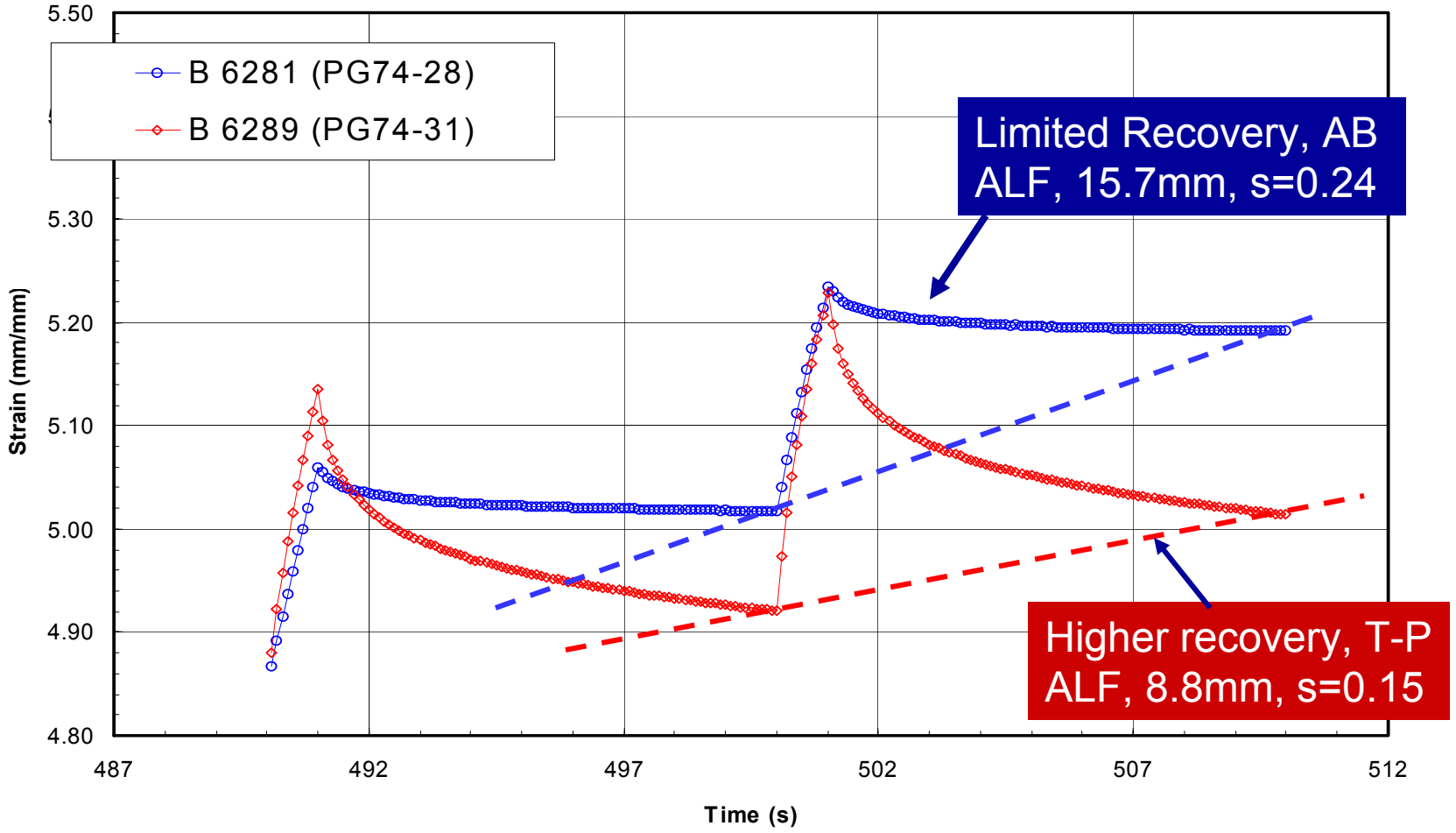
High Temperature (Rutting) Repeated Creep Recovery Test

PG 67-22 Neat AC

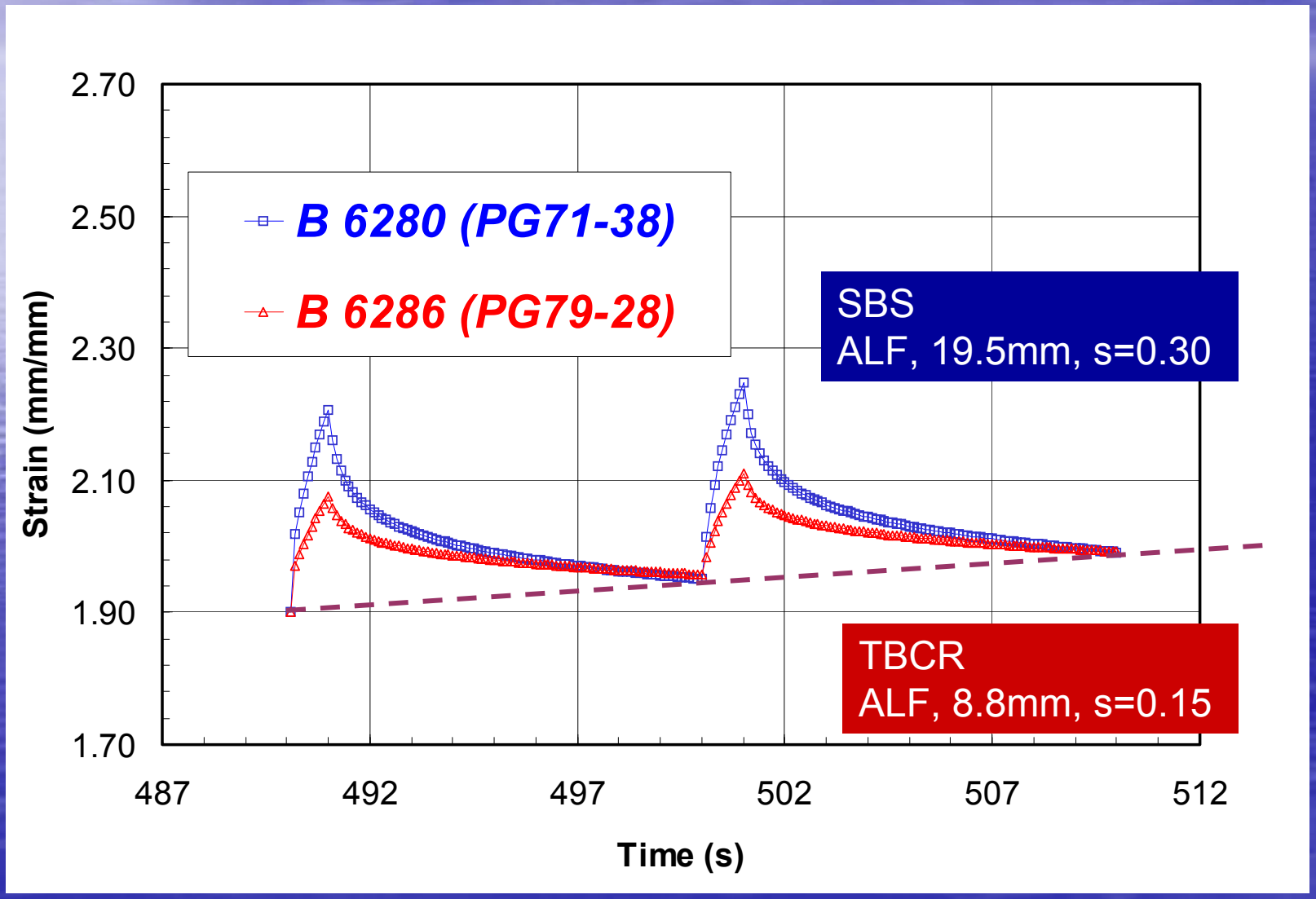
PG 63-22 Modified



Repeated Creep Test Results
Two binders of Same PG-Grade



Repeated Creep Test Results
Two binders of Different PG-Grades



Superpave®
Binder Specification Direction

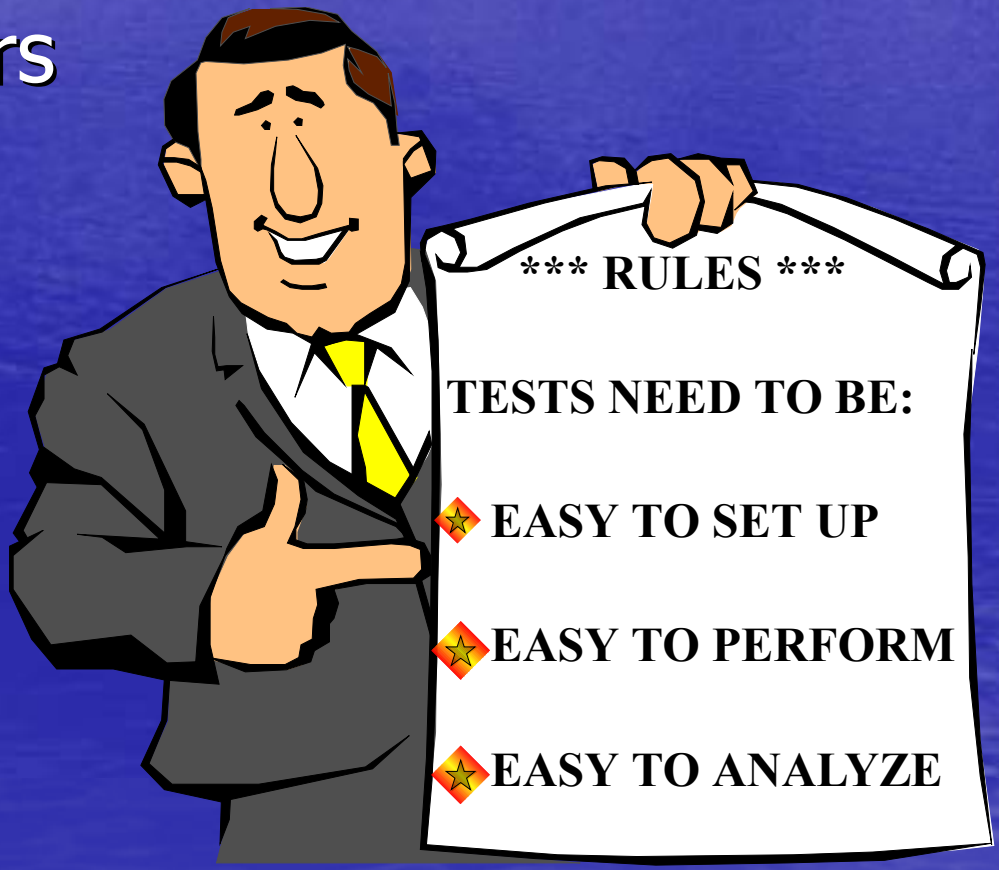
Superpave® Binder Specification

Rutting, Fatigue, and Low-Temp. Cracking

WHEN	WHAT	HOW	WHERE
Construction	Safety Pumpability Rutting	Flash Point Rot Visc $G^* / \sin \delta$	230 min 3 Pa-s max T(high)
Early *(RTFO)*	Rutting	$G^* / \sin \delta$	T(high)
Late *(+PAV)*	Fatigue Low Temp	$G^* \sin \delta$ BBR/DTT	T(inter) 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 Pumpability Rutting	Flash Point Rot Visc $f(G^* *)$ ZSV	230 min 3 Pa-s max T(high)
Early *Tx Device*	Rutting	$f(G^* *)$ ZSV	T(high)
Late *(+MW)*	Fatigue Low Temp	$f''(G^* *)$ DT DT / ABC	T(inter) T_{CR}