Applications of Performance-Based Specifications for Mix Designs

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Outline and Objectives

- Introduction to the Performance Related/Based Specifications and Some Definitions
- Experiences of Four States:
  - California, Louisiana, Texas, New Jersey
  - PRS/PBS Framework
  - Some Results and Challenges
- Final Thoughts and Future Directions

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First Some Terminology

Performance-related specifications (PRS):
"QA specifications that describe the desired levels of key materials and construction quality characteristics that have been found to correlate with fundamental engineering properties that predict performance (e.g. air voids, compressive strength)".

Performance-based specifications (PBS):
"QA specifications that describe the desired levels of fundamental engineering properties (e.g. resilient modulus, creep properties, and fatigue) that are predictors of performance and appear in primary prediction relationships (i.e., models that can be used to predict stress, distress, or performance from combinations of predictors that represent traffic, environment, supporting materials, and structural conditions)."

TRR Circular (2002) - Glossary of Highway Quality Assurance Terms

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Highway Construction Specifications

1. RESPONSIBILITY

0% Contractor Responsibility ⟷ 100% Contractor Responsibility

Material & Methods Specifications → QA Specifications → End Result Specifications

2. SAMPLING

Little Information ⟷ More information

Representative Sampling → Statistical Specifications → 100 % Sampling

3. RELATION TO PERFORMANCE

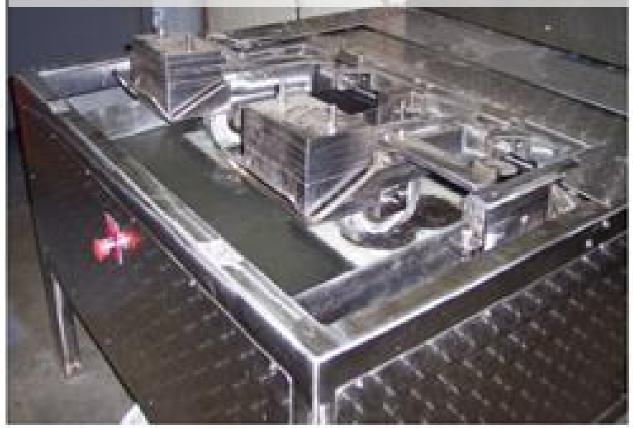
Unknown ⟷ Known

Intuitive → Performance Related Specs → Performance Based Specs → Performance Specs

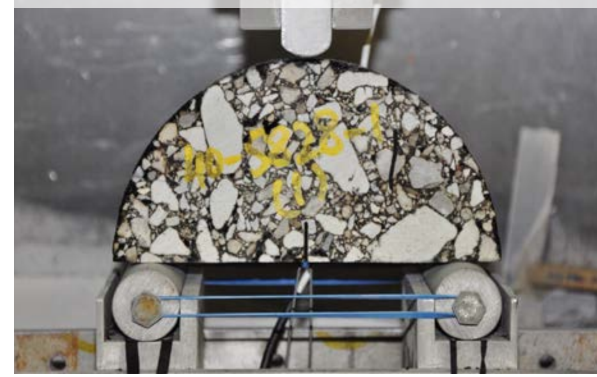
Commonly Used Tests

Uniaxial Modulus Tests

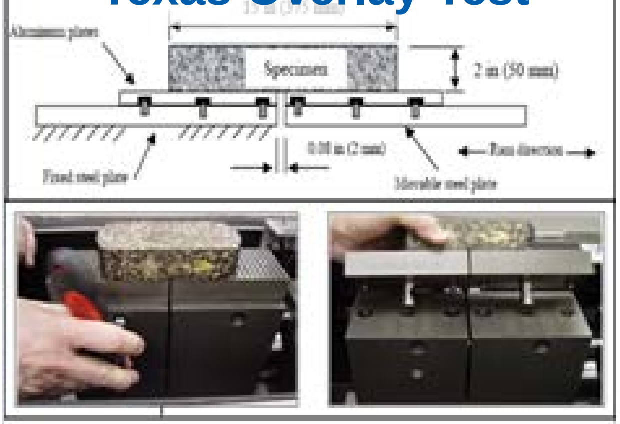
Hamburg Wheel Track



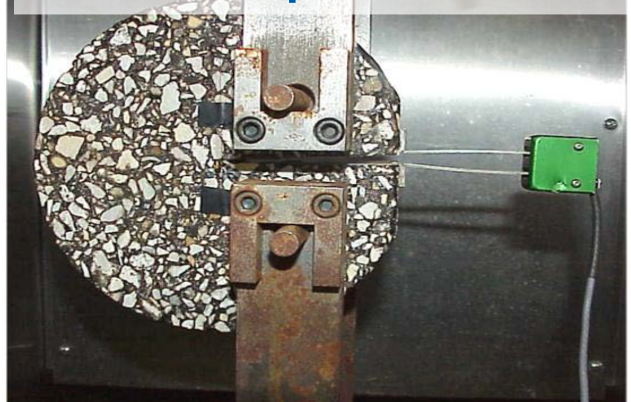
Semi Circular Bending Beam



Texas Overlay Test



Disc Compact Tension



Uniaxial Fatigue and Permanent Deformation

California Experience

Reference:
Harvey et al. (2014). Performance-Based Specifications: *California Experience to Date*.

Introduction

- California's initial implementation of PBSs based on ME began in the late 1990s
- Pavement design framework includes PBSs and the CalME (Caltrans' Mechanistic Empirical Design Program)
- There key mix performance criteria:
  - Repetitions to 5% strain in the repeated shear strain (RSST) – AASHTO T320
  - 50% loss of stiffness in the Beam Fatigue Test – AASHTO T 321
  - Flexural stiffness at 20 °C and 10 Hz – AASHTO T 321

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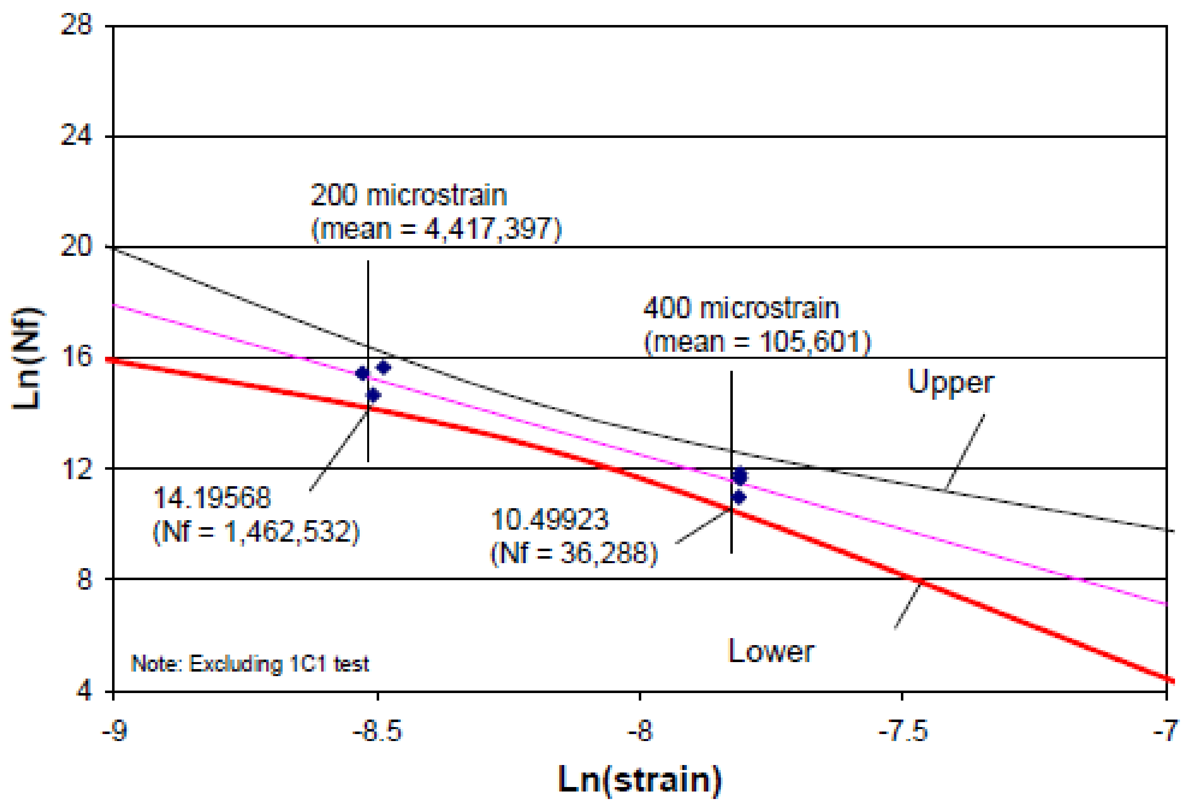
Performance Tests and Limits

- CalTrans accepts 95% of the risk of laboratory test variability
- Select limits based on 95 % confidence intervals

Beam Fatigue Test to find number of cycles to failure at 200 and 400 microstrains



Pilot Projects (2012-2014)

- Long-life rehabilitation projects
- Pavement cross-sections were designed using CalME and mix types were selected using PBS

Red Bluff (I-5 Tehama County)	Weed (I-5 Siskiyou)	Dixon (I-80 Solano County)
30 mm Rubberized Open Graded HMA		30 mm Rubberized Open Graded HMA
90 mm PG64-28 15% RAP	60 mm PG 64-28 15% RAP	60 mm PG 64-28 15% RAP
60-200 mm PG 64-10 25% RAP	110-180 mm PG64-16 25% RAP	75-180 mm PG 64-10 25% RAP
60 mm PG 64-10 rich bottom 15% RAP	60 mm PG 64-16 rich bottom 15% RAP	30 mm PG 64-10
110 mm existing CTB	150-230 mm varying CTB	200 mm JPC

PBS Thresholds

Design Parameters (Red Bluff)	Test Method	Requirement
Permanent Deformation (min.) PG 64-28 (w	AASHTO T320 modified (Repeated	360,000 stress repetitions
Fatigue (mi PG 64-28 (w PG 64-10 (w lime) PG64-10 (wi		0,000 200 epetitions trains repetitions for 400 and 200 microstrains
Permanent Deformation (min.) PG 64-10 (with RAP and lime)	AASHTO T 324 modified (Wheel Track)	20,000 repetitions

Note that PBS allows layer and project-specific thresholds and requirements!

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Challenges

- Missing baseline material properties for locally available materials (for developing a regional database and realistic targets)
- Communicating the significance of PBS to the contractors
  - Can the PBS give explicit directions?
  - And how serious are the limits?
- Understanding mix design-PBS relationships
- Developing specifications for each layer

Challenges (cont'd)

- Procurement of lab testing services (not foreseen in near future)
- Testing repeatability (not likely part of AMRL)
- Lab vs. plant produced mixes (shift factor?)
- What if a material exceeded one by a wide margin but missed other property?

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Texas Experience

Reference:
Zhou et al. (2014). Implementation of a Performance-Based Mix Design System in Texas.

Introduction

- Primarily designed for selecting mixes for overlays
- Motivated by the increasing use of RAP and RAS
- “Balanced” mix design approach is introduced using:
  - Performance tests (Texas Overlay Test and others)
  - Project-specific cracking requirement

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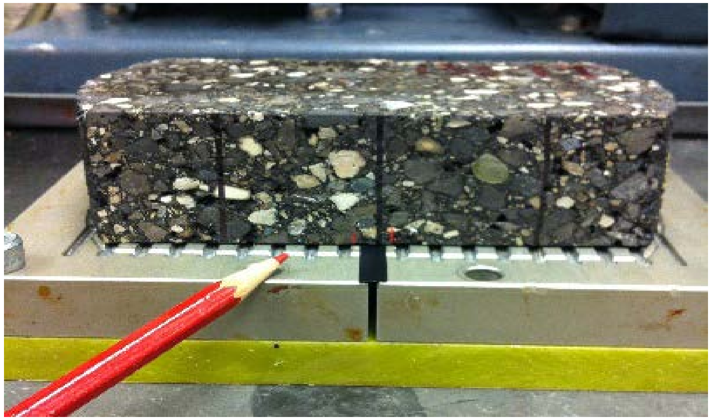
Texas Overlay Test (OT)

- Developed by Zhou et al. 2005 and improved over the years
- Conducted at room temperature at a displacement of 0.025 in and 1 Hz
- Recent studies showed good correlation to field performance (Walubita et al. 2012, Gibson et al. 2013)



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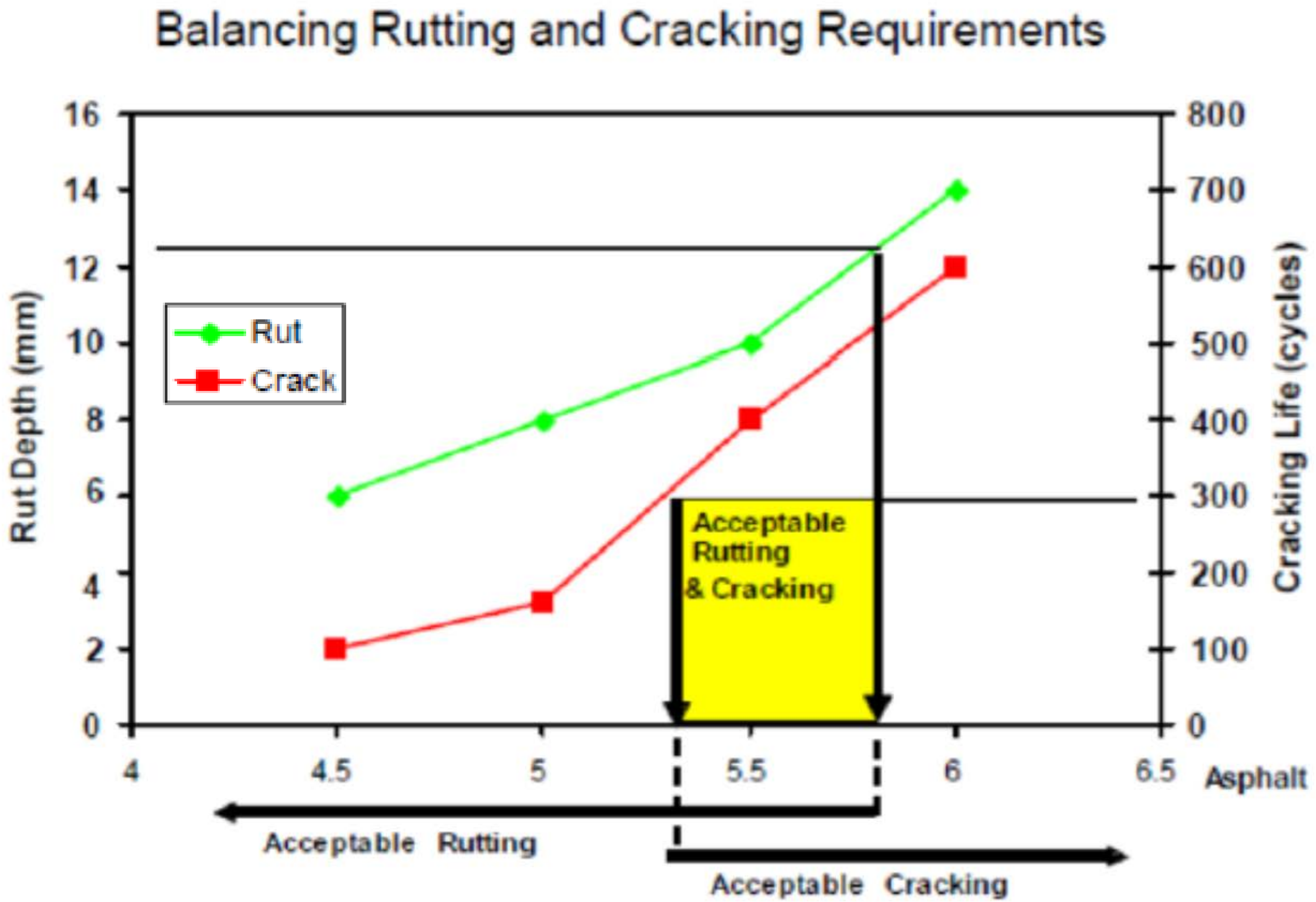
Balanced Mix Design Steps



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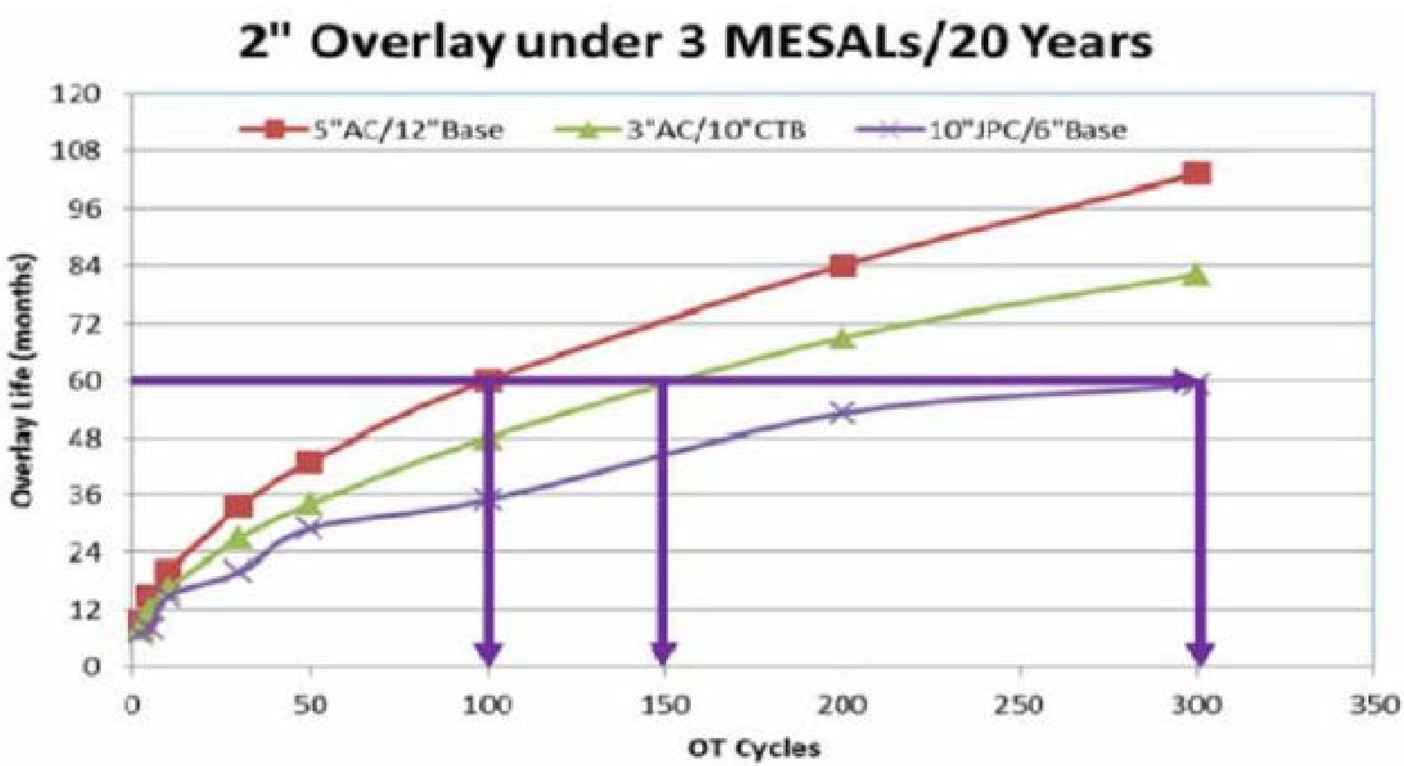
Project-Specific Cracking Criteria

- Acknowledging the fact that mixture performance is not the only parameter
  - Switching to developing mix designs for project-specific conditions
- Two-step process:
  - Step 1: Predict performance and select cracking requirement to meet design performance goal (i.e. target OT cycles to failure required to achieve less than 50% reflective cracking after 5 years)
  - Step 2: Design a mix with the required OT cycles

ME Overlay Design Program

- An overlay cracking prediction program is developed to:
  - ... rlay
  - ... limate,



New Jersey DOT Experience

Reference:

Bennert et al. (2014). Implementation of Performance-Based Specifications for Asphalt Mix Design and Production Quality Control for New Jersey.

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Introduction

- NJDOT has developed a **Performance-Based Mixture Design and Quality Program**
- The objective of the program is to "engineer" mixes for specific performance needs

<u>PERFORMANCE-BASED ACCEPTANCE PROCEDURE</u>

Volumetric Design → PB Tests at NJDOT → Construction of Test Strip → Production and Sampling

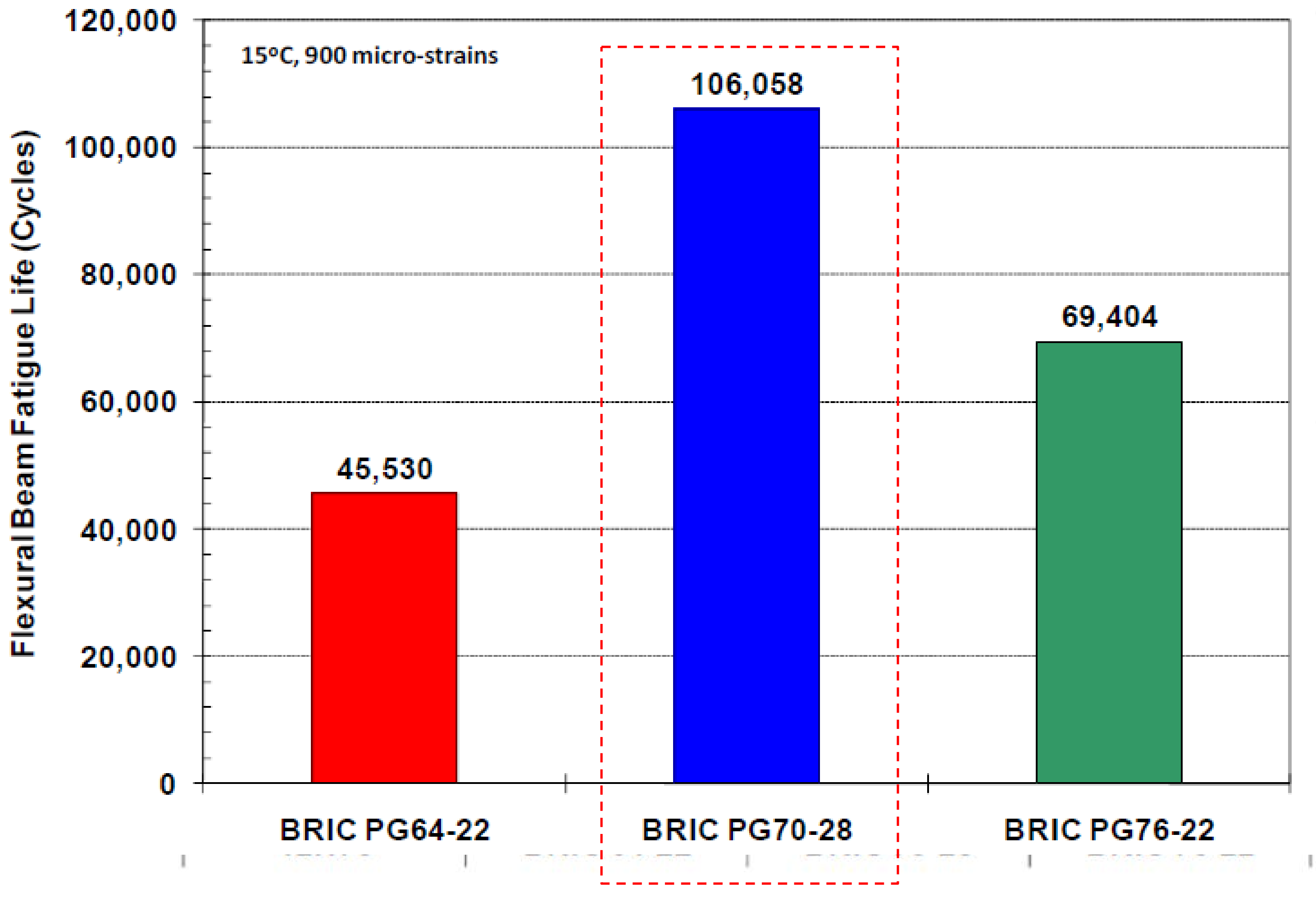
Performance Tests

- A combination of the three following tests:
  - Asphalt Pavement Analyzer (APA) – AASHTO T340
  - Flexural Beam Fatigue – AASHTO T 321
  - Overlay Tester (Texas DOT Procedures)

Mixture Categorization

- Five mixture categories were established for specific applications:
  - High-performance thin overlay (HPTO)
  - Binder-rich intermediate course (BRIC)
  - Bridge-deck waterproofing course
  - Bottom-rich base course (BRBC)
  - High RAP (HRAP)

Mixture Fine-Tuning (BRIC)



High RAP (HRAP) Mixes

- In 2012, NJDOT implemented PBS for HRAP:
  - Final mixture to meet a fatigue cracking and permanent deformation test criteria
  - No maximum limits
  - "If you can produce a RAP mixture that performs as well as a virgin mix, then the NJDOT will accept it."

Tests	Requirement			
	Surface Course		Intermediate Course	
	PG 64-22	PG 76-22	PG 64-22	PG 76-22
APA @ 8,000 loading cycles	< 7 mm	< 4 mm	< 7 mm	< 4 mm
Overlay Tester (NJDOT B-10)	> 150 cycles	> 175 cycles	> 100 cycles	> 125 cycles

Louisiana's Experience

Reference:
Cooper et al. (2014). Balanced Asphalt Mixture Design Through Specification Modification.

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Introduction

- Developed a “Balanced” mix design approach
- Two laboratory tests and performance criteria:
  - Rutting: Loaded Wheel Tracking (LWT) Test – AASHTO T 324
  - Cracking: Semi-Circular Bend (SCB) Test
- Thresholds were determined based on a regional database

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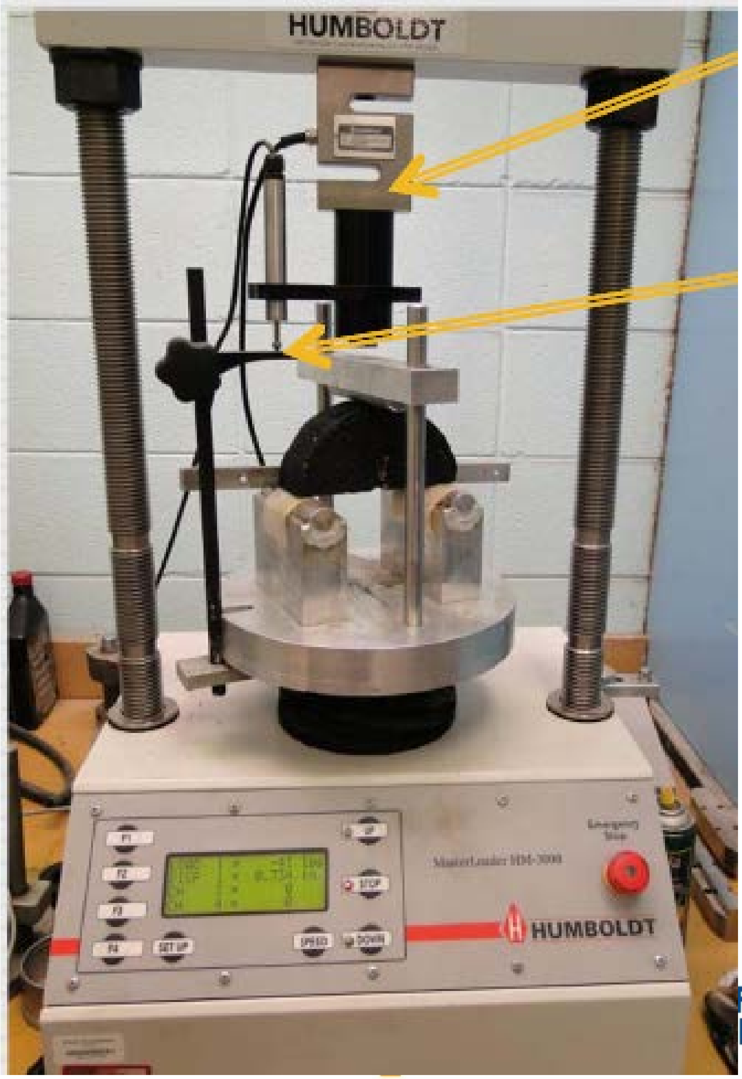
Modified SCB Test

- Conducted at 25 °C
- Slow loading rate
- Requires 3 sets of specimens at different notch lengths
- Test output is critical J-integral



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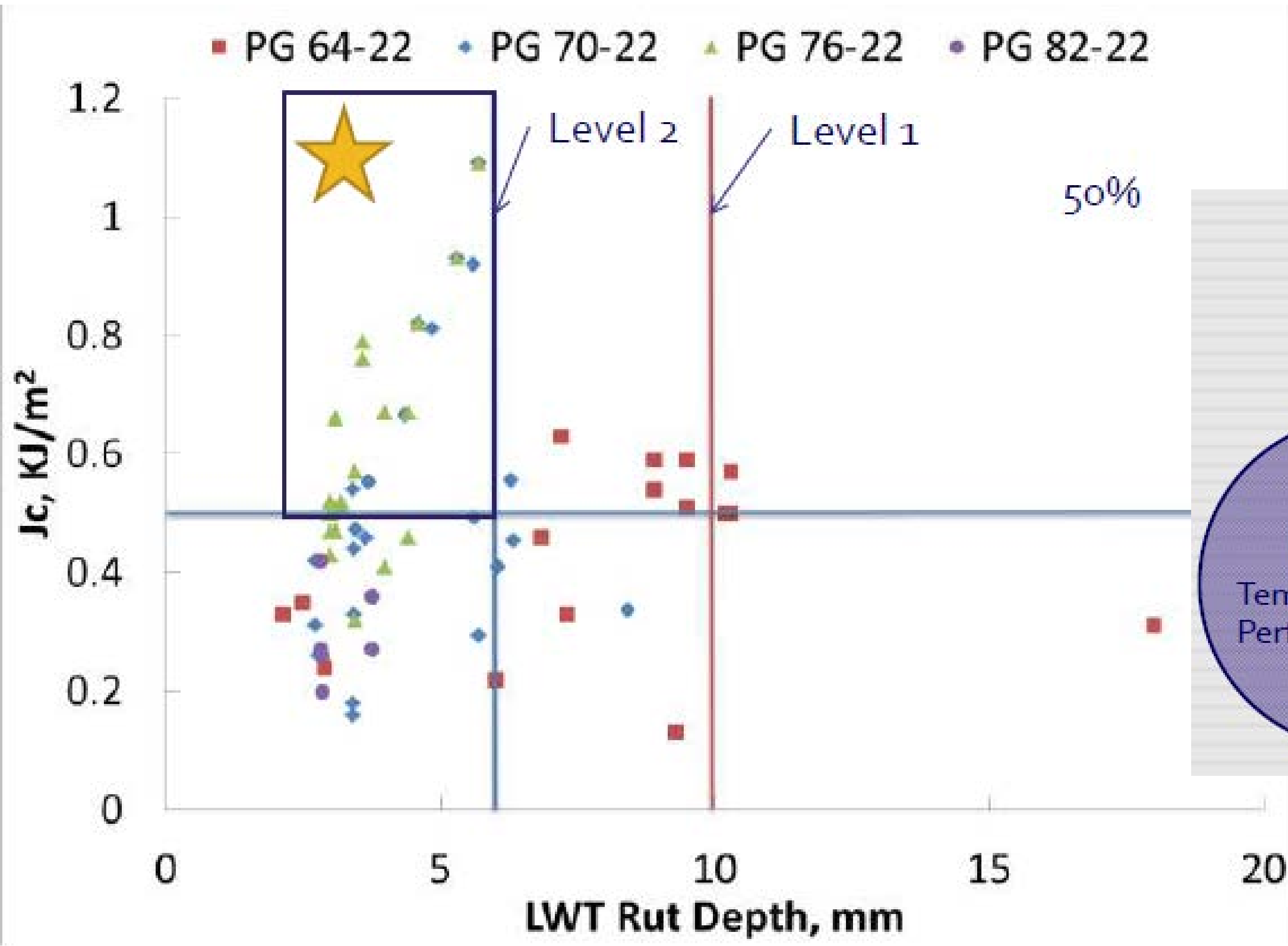
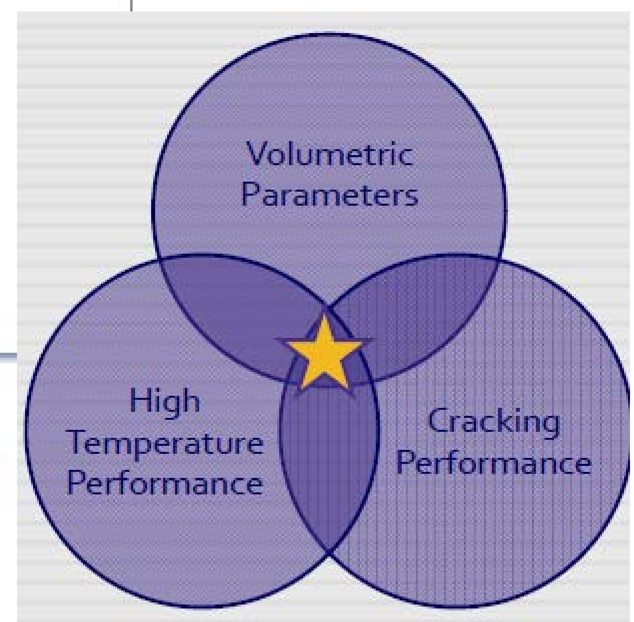
“Three Pillars” of Performance





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Final Thoughts

- There are other states in the process of adapting various versions of PRS/PBS
  - Minnesota, Wisconsin, New Hampshire, Illinois etc.
- Each state has its own way
- PRS/PBS provide opportunities for states/contractors to improve their mix designs as well as developing project-specific requirements

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Challenges and Future Directions

- Recall the caveat in the TRR Circular E-C037 appended to the definition of PBS as of 2002:
  - "[Because most fundamental engineering properties associated with pavements are currently not amenable to timely acceptance testing, performance-based specifications have not found application in highway construction.]"
- Reliability of performance prediction models
- Suitability of contracting delivery methods to adapt a true PBS framework

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Useful References

TRANSPORTATION RESEARCH
CIRCULAR

Number E-C037 April 2002

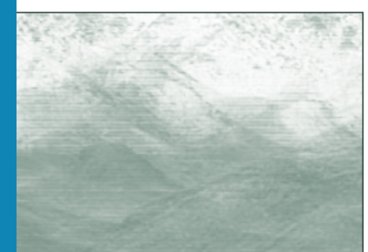
Glossary of Highway Qu
Assurance Terms

COMMITTEE ON MANAGEMENT OF QUALITY ASSURANCE

NCHRP
REPORT 455

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

...ended Performance-Related
...ication for Hot-Mix Asphalt
...Construction: Results of the
WesTrack Project



In Cooperation with
U.S. Department of Transportation
Federal Highway Administration

TRANSPORTATION RESEARCH
CIRCULAR

Number E-C189 October 2014

Application of Asphalt Mix Performance-Based Specifications

Papers Presented at the 93rd Annual Meeting of the Transportation Research Board

January 14, 2014
Washington, D.C.

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References for Case Studies

Harvey et al. (2014). Performance-Based Specifications: *California Experience to Date*. TRR Circular E-C189

Zhou et al. (2014). Implementation of a Performance-Based Mix Design System in Texas. TRR Circular E-C189

Bennert et al. (2014). Implementation of Performance-Based Specifications for Asphalt Mix Design and Production Quality Control for New Jersey. TRR Circular E-C189

Cooper et al. (2014). Balanced Asphalt Mixture Design Through Specification Modification. TRR Circular E-C189

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