Balanced Mix Design (BMD)

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IDAHO ASPHALT CONFERENCE

MOSCOW, IDAHO

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Thank you Dr. Shane Buchanan

Discussion Items

- Need for Balanced Mix Design
- Performance Testing Discussion
- Balanced Mix Design Examples
- FHWA Balanced Mix Design Task Force Efforts
- Next Steps

Need for Balanced Mix Design

Balanced Mix Design Definition

- ***"Asphalt mix design using performance tests on appropriately conditioned specimens that address multiple modes of distress taking into consideration mix aging, traffic, climate and location within the pavement structure."***

- Basically, it consists of designing the mix for an intended application and service requirement.

Why the Need for a New Mix Design Approach?

- **Problems:**
  - Relying on volumetrics along to provide performance
  - Dry mixes exist in some (not all) areas
- **Solutions:**
  - **Recognize performance issues** related to dry mixes in some areas. (Note: Many performance issues are caused factors outside the mix design)
  - **Increase understanding** of the factors which drive mix performance
  - **Design for performance** and not just to “the spec”.
  - **Start thinking** outside of long held “rules and constraints”
  - **Innovate!**

Mix Design Specifications

- Largely recipe driven
  - Aggregates and grading
  - Volumetrics (Va, VMA, VFA, D/A, etc.)
  - Binder grade and/or minimum %
  - RAP and/or RAS
  - WMA
- While this <u>may</u> work, there are problems
  - What happens when the recipe fails?
  - Specifications have become ***convoluted and confounded***
    - Existing specified items compete against each other
    - New requirements get added and nothing gets removed
      - "Spec Book Creep"
  - Innovation has become stifled with our knowledge outpacing specifications

"Marshall method" pavement testing apparatus

Steps Must be Taken *Now* Towards Solutions

- **Each day**, approximately 1.4 Million tons of HMA are produced in the U.S. (M-F production basis)
  - *Equivalent to ~2500 lane miles @ 12' wide and 1.5" thick*
  - *Distance from New York to Las Vegas*

Long term research is certainly needed, but we must take steps ***NOW*** towards a solution

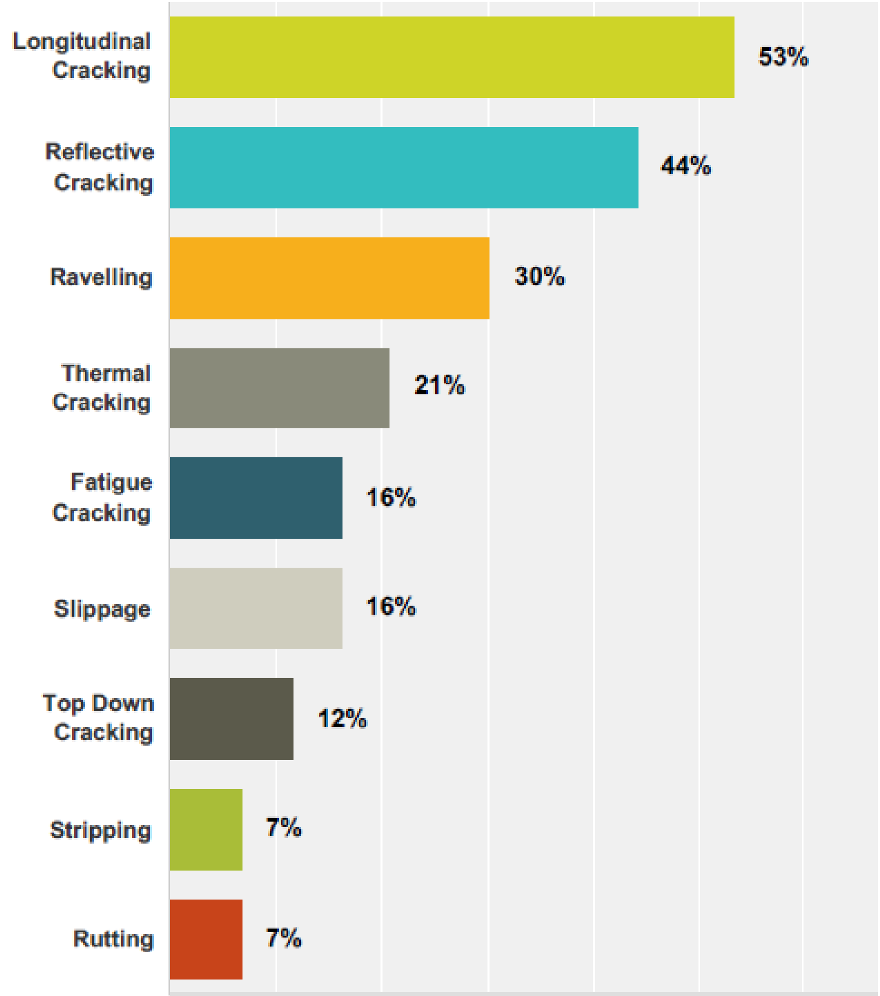
Binder Content – Design vs. Optimum (There is a difference!)

- Design and optimum binder content are often used interchangeably
  - However, they mean two different things
- There can be many design binder contents for a mix, but only one truly optimum
- Optimum indicates the best binder content based **on intended application, performance requirements/needs, and ultimately economics**
- Goal is to get as close as possible to the true **optimum** for the mix

What Type Distress Is Occurring?

Oldcastle Survey Question:
Within the past 5 years, what type of mix performance related distress has been most evident in your mixes?

~40 companies responding from ~30 states



Balance the Mix Design

Smooth Quiet Ride
Skid Resistance

Strength/
Stability

Rut Resistance

Shoving

Flushing
Resistant

Durability

Crack
Resistance

Raveling

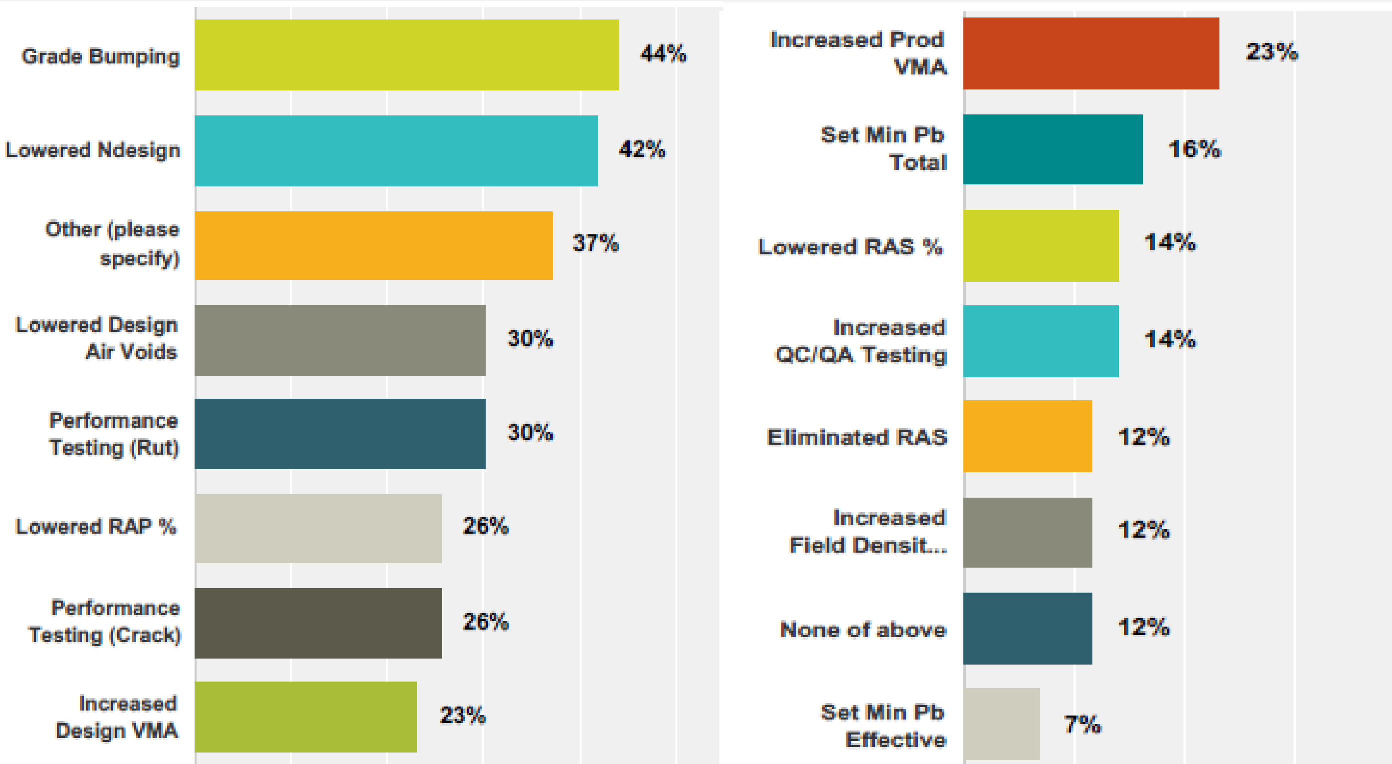
Permeability

DON'T ATTACK ONE HALF AT THE EXPENSE OF THE OTHER HALF!!

Agencies Are Searching for Solutions: Spec Changes

- Superpave system is becoming unrecognizable with specifications changing rapidly as agencies search for ways to improve durability
- **Establishing true "cause and effect" is impossible**

Survey Question: Which of the following specification changes has your DOT implemented in the last 5 years?



Agencies are Searching for Solutions: Ndesign

- Ndesign varies widely w/ levels being reduced with the ***intent*** of gaining more binder
- **Problem:** **Lower gyrations do not necessarily equate to more binder**

State	Gyration Level[1]
Alabama	**60**
Arkansas	50, 75, 100, 125
Colorado	75, 100
Connecticut	75, 100
Florida	50,65,**75,100**
Idaho	50,75,100, 125
Iowa	50, 60, 65, 68, 76, 86, 96, 109, 126
Kansas	**75**, 100
Kentucky	50, 75, 100
Maine	**50**, 75
Massachusetts	50, **75, 100**
Michigan	45, 50, 76, 86, 96, 109, 126
Minnesota	40, 60, 90, 100
Mississippi	50, **65**, 85
Missouri	50, 75, **80**, 100, 125
Montana	**75**
Nebraska	40, 65, 95
Nevada	Use Hveem
New Hampshire	50, 75
New Jersey	50, **75**

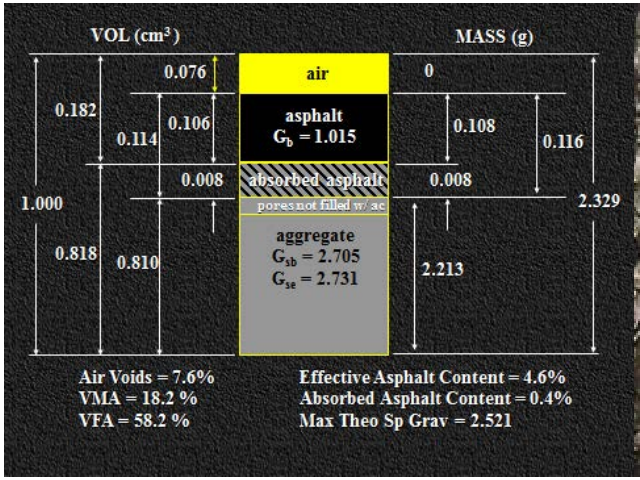
State	Gyration Level[1]
New Mexico	75, **100**, 125
New York	50, **75**, 100
North Carolina	50, **65, 75**, 100
Ohio	**65**
Oklahoma	64-22 (50), 70-28 (60) , and 76-28 (80)
Oregon	65, 80, 100
Pennsylvania	50, 75, 100
Rhode Island	**50**
Tennessee	**65** or 75 Marshall
Texas	**50**
Utah	50, **75**, 100, 125
Vermont	50, **65**, 80
Virginia	**65**
Washington	50,75,100, 125
West Virginia	50, 65, 80, 100

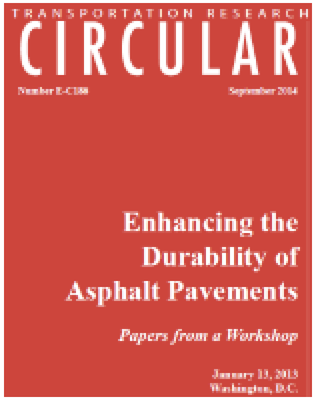
As of March 2015

Enhancing the Durability of Asphalt Pavements

- **“Volume of Effective Binder (Vbe) is the primary mixture design factor affecting both durability and fatigue cracking resistance.”**
  - ***Vbe = VMA – Air Voids***

- “A number of state highway agencies have **decreased the design gyration levels** in an attempt to increase effective binder contents. However, **decreasing the design gyrations may not always produce mixtures with higher Vbe.”**





Impact of Mix Design on Asphalt Pavement Durability

Ramon Bonaquist
Advanced Asphalt Technologies, LLC

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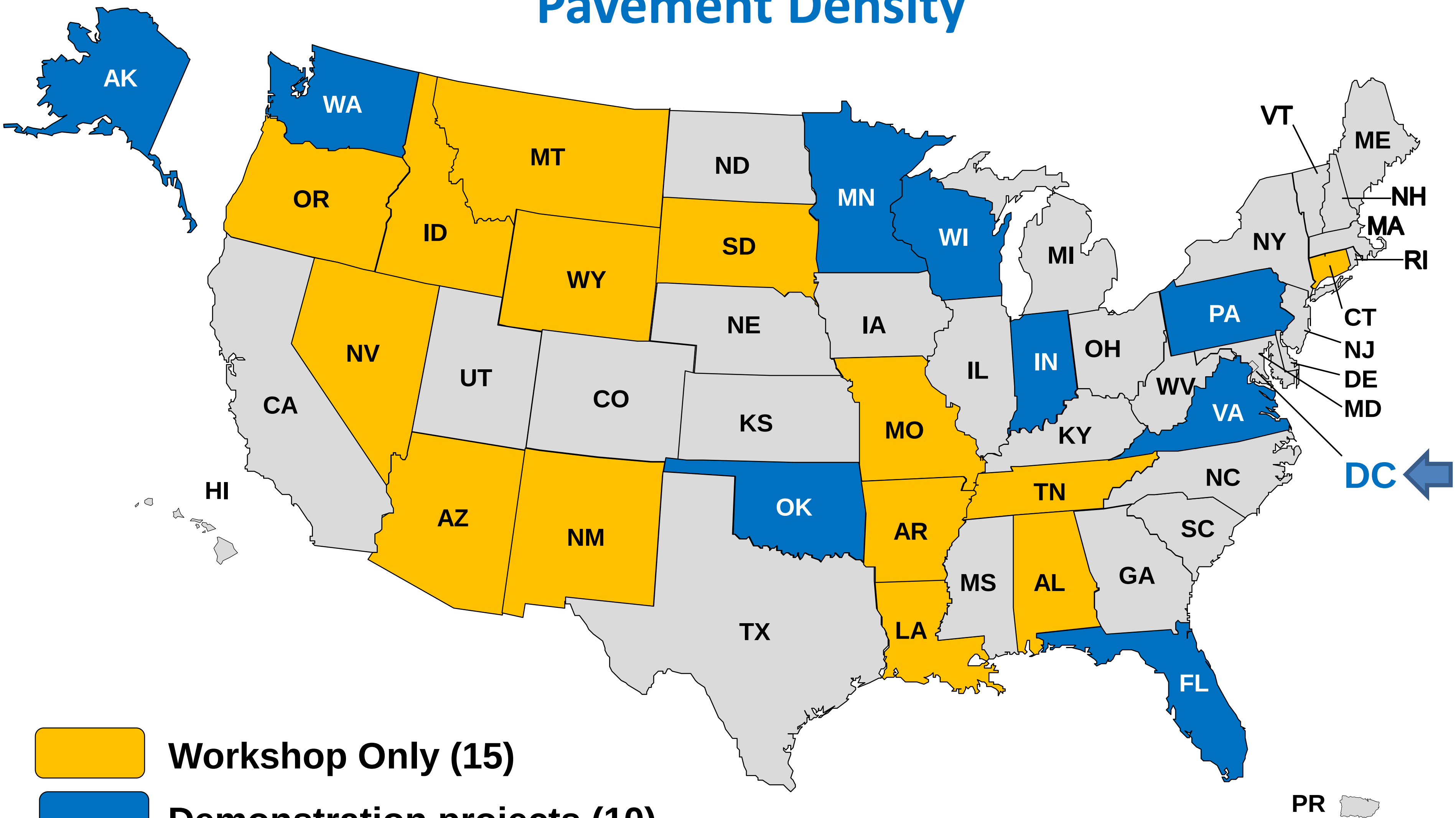
Enhanced Durability of Asphalt Pavements through Increased In-Place Pavement Density



Workshop Only (15)

Demonstration projects (10)

History of Mix Design

1890

- **Barber Asphalt Paving Company**
- Asphalt cement 12 to 15% / Sand 70 to 83% / Pulverized carbonite of lime 5 to 15%

1905

- **Clifford Richardson, New York Testing Company**
- Surface sand mix: 100% passing No. 10, 15% passing No. 200, 9 to 14% asphalt
- Asphaltic concrete for lower layers, VMA terminology used, 2.2% more VMA than current day mixes or ~0.9% higher binder content

1920s

- **Hubbard Field Method** (Charles Hubbard and Frederick Field)
- Sand asphalt design
- 30 blow, 6" diameter **with compression test (performance)** asphaltic concrete design (Modified HF Method)

Stability

1927

- **Francis Hveem** (Caltrans)
- Surface area factors used to determine binder content; **Hveem stabilometer and cohesionmeter** used
- Air voids not used initially, mixes generally drier relative to others, fatigue cracking an issue

Stability + Durability

1943

- **Bruce Marshall**, Mississippi Highway Department
- Refined Hubbard Field method, standard compaction energy with drop hammer
- Initially, only used air voids and VFA, VMA added in 1962; **stability and flow utilized**

Stability + Durability

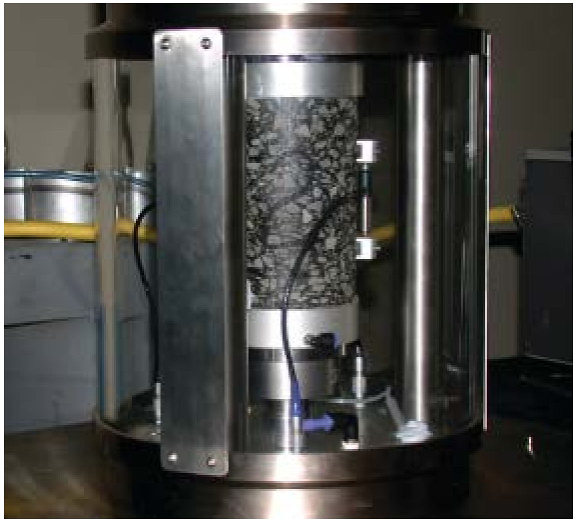
1993

- **Superpave**
- Level 1 (volumetric)
- Level 2 and 3 (performance based, but **never implemented**)

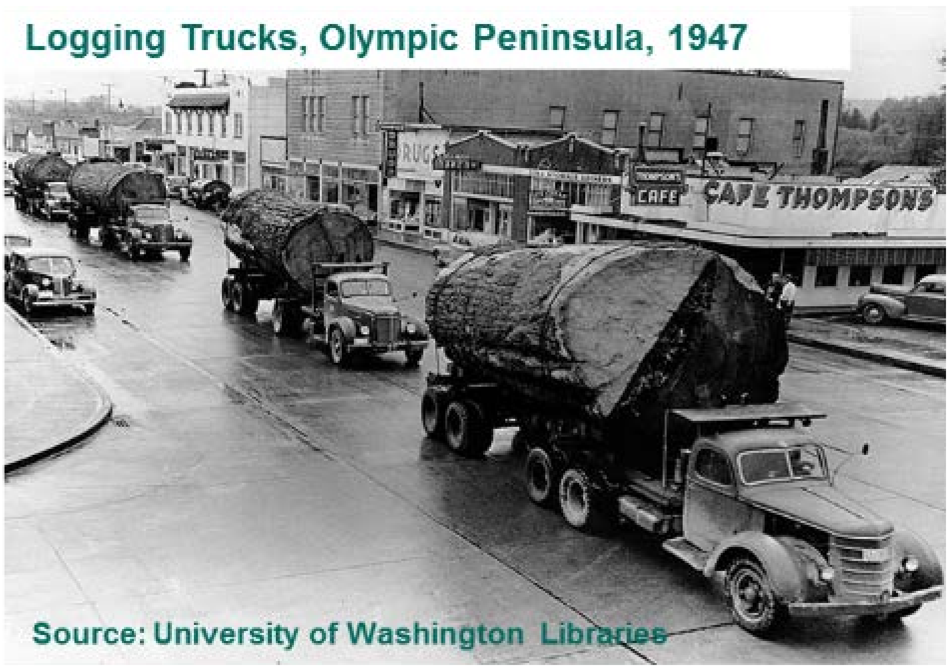
BINDER CONTENT LOWER

http://asphaltmagazine.com/history-of-asphalt-mix-design-in-north-america-part-2/

Performance Testing of Asphalt Mixes



Stability Testing



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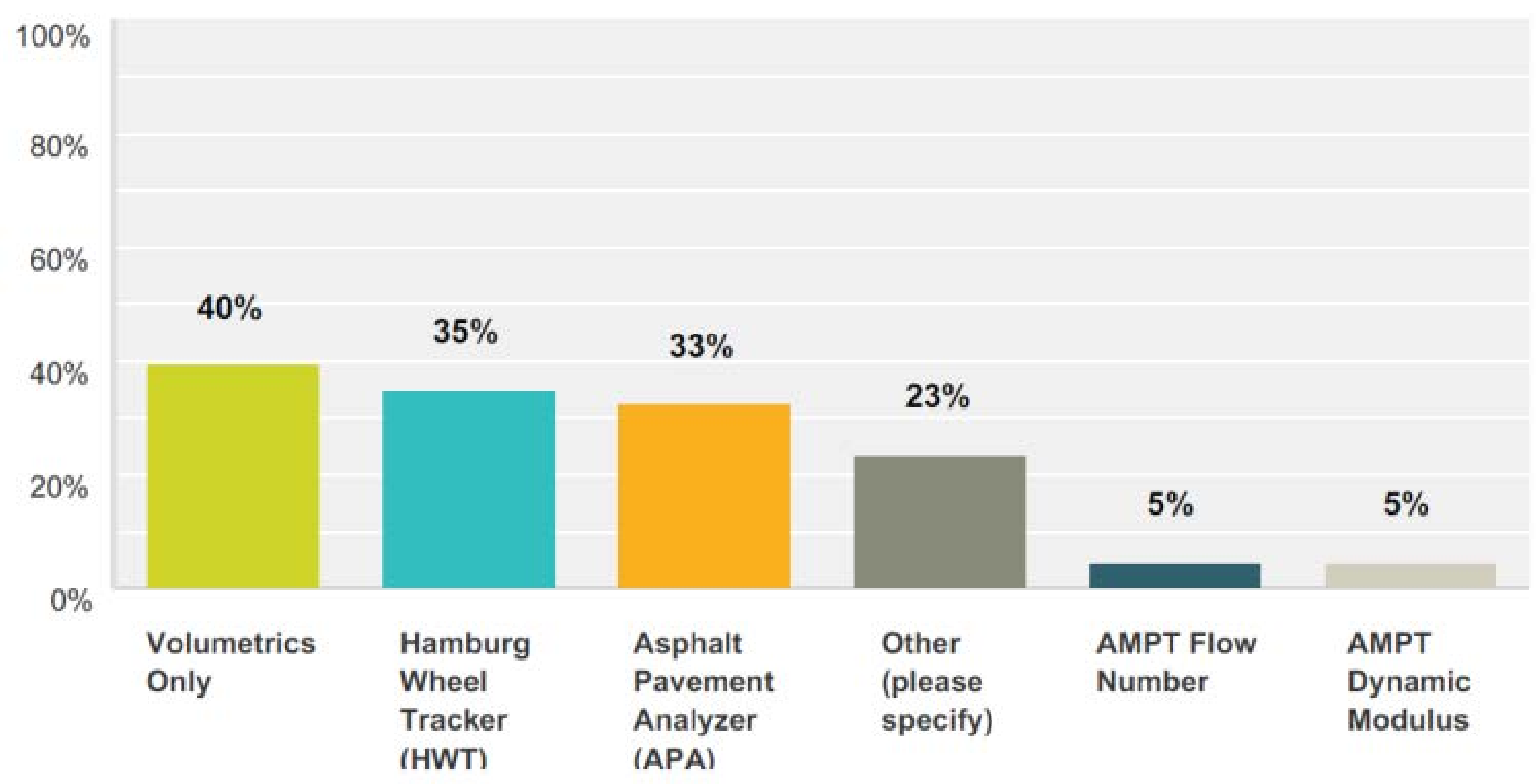
Stability Evaluation

- Evaluate mix stability with one of several available “rutting” tools.
  - Hamburg, APA, AMPT Flow Number, etc.
  - Failure criteria
    - Based on best available research (local, regional, or national)
    - Function of traffic (e.g., low, medium, high) and/or mix end use applications

Stability Evaluation Survey

Survey Question:
How does your state DOT evaluate the rutting potential of designed dense graded asphalt mixes?



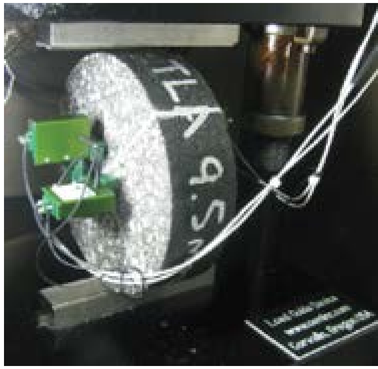
Durability Testing

Durability/Cracking Evaluation

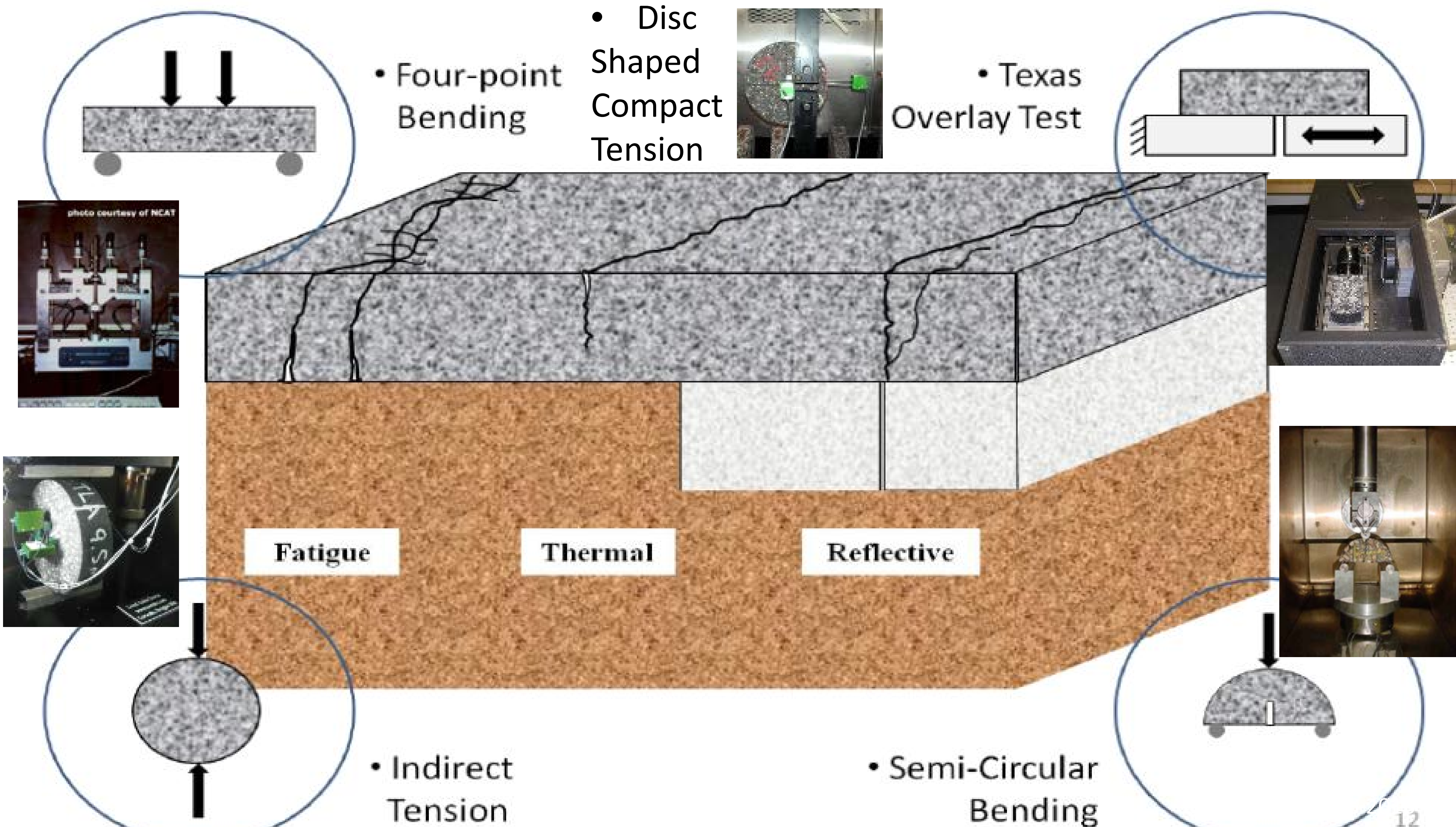
- Durability/cracking evaluation is **substantially more complicated** than stability
  - What is the mode of distress?
  - What is the aging condition?
- Cracking prediction is a known "weak" link in performance testing
  - No general consensus the best test(s) or the appropriate failure threshold

- **GOALS**
  - **MATCH THE TEST TO THE DISTRESS**
  - **SET APPROPRIATE FAILURE THRESHOLDS**



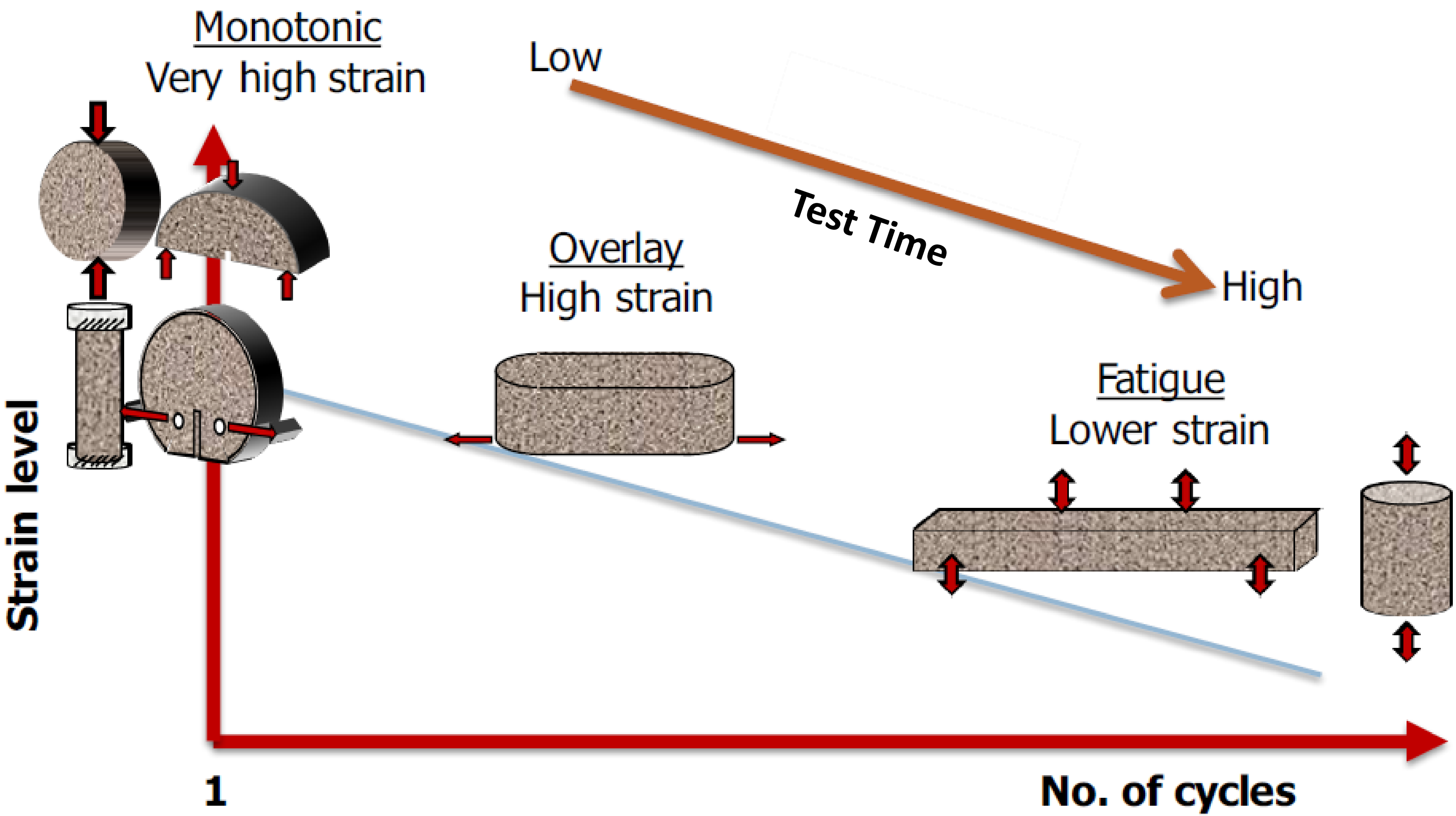


Match the Test to the Distress



From: Louay Mohammad, LTRC

Cracking Tests: Strain and Cycles Illustration



What is the Best Cracking Test? It Depends!

- NCHRP 9-57: Experimental Design for Field Validation of Laboratory Tests to Assess Cracking Resistance of Asphalt Mixtures
  - Top tests for various distresses identified by national group of academia, agency, and industry representatives

August 2016

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Responsible Senior Program Officer:
Edward T. Harrigan

Research Results Digest 399

FIELD VALIDATION OF LABORATORY TESTS TO ASSESS CRACKING RESISTANCE OF ASPHALT MIXTURES: AN EXPERIMENTAL DESIGN

This digest summarizes key findings of research conducted in NCHRP Project 09-57, "Experimental Design for Field Validation of Laboratory Tests to Assess Cracking Resistance of Asphalt Mixtures," by the Texas A&M Transportation Institute, Texas A&M University, College Station, Texas. This digest is based on the project final report authored by Dr. Fujie Zhou, Dr. David Newcomb, Mr. Charles Gurganus, Mr. Seyedamin Banihashemrad, Dr. Maryam Sakhaeifar, Dr. Eun Sug Park, and Dr. Robert L. Lytton. The complete project final report and three appendixes are available to download at http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3644.

Table 3 Cracking tests selected at the workshop.

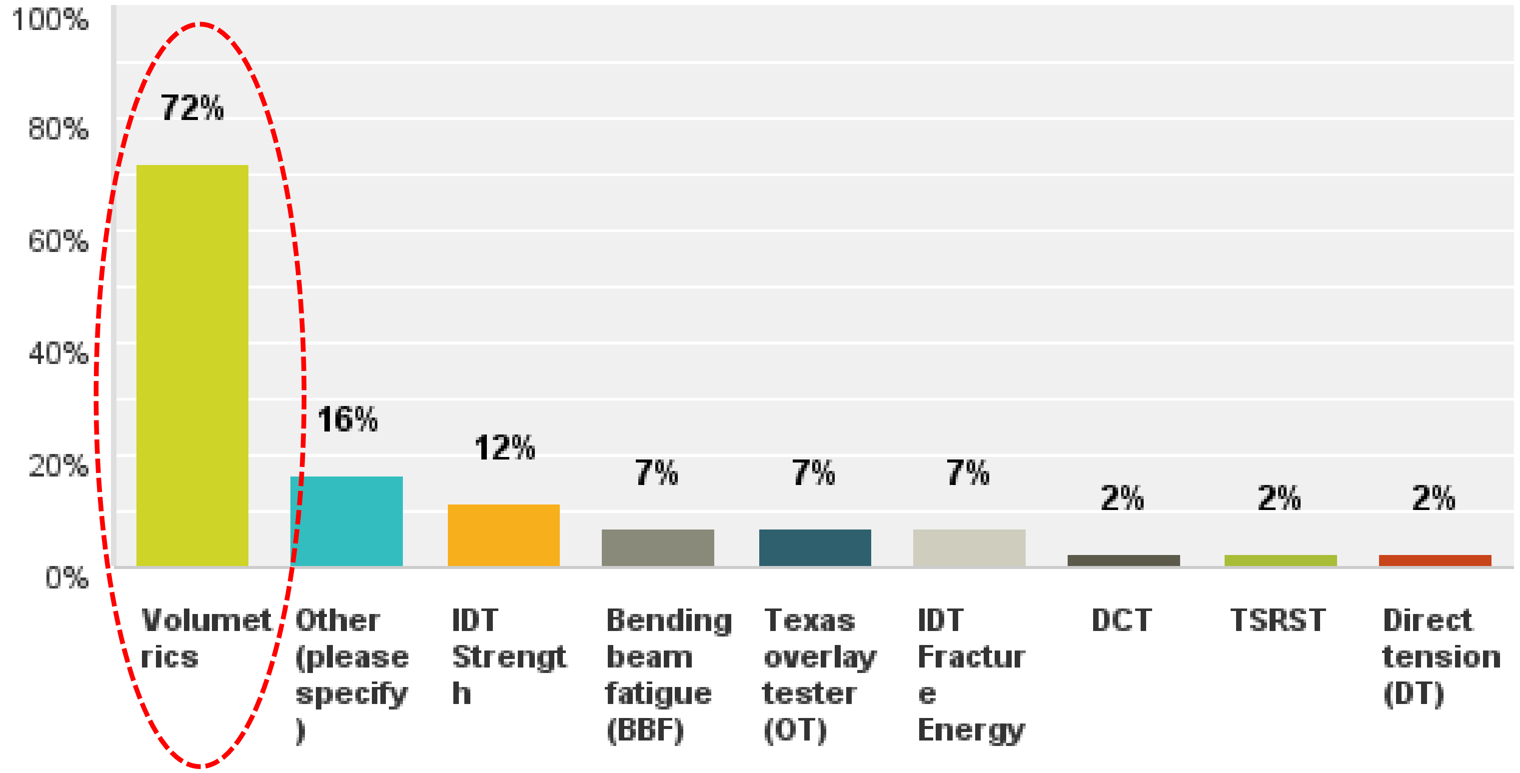
Thermal Cracking Tests	Reflection Cracking Tests	Bottom-Up Fatigue Cracking Tests	Top-Down Cracking Tests
1. DCT	1. OT	1. Beam fatigue	1. IDT-Florida
2. SCB-IL	2. SCB-LTRC	2. SCB-LTRC	2. SCB-LTRC
3. SCB (AASHTO TP 105)	3. BBF	3. OT*	

*OT for fatigue cracking was added later by request of the panel.

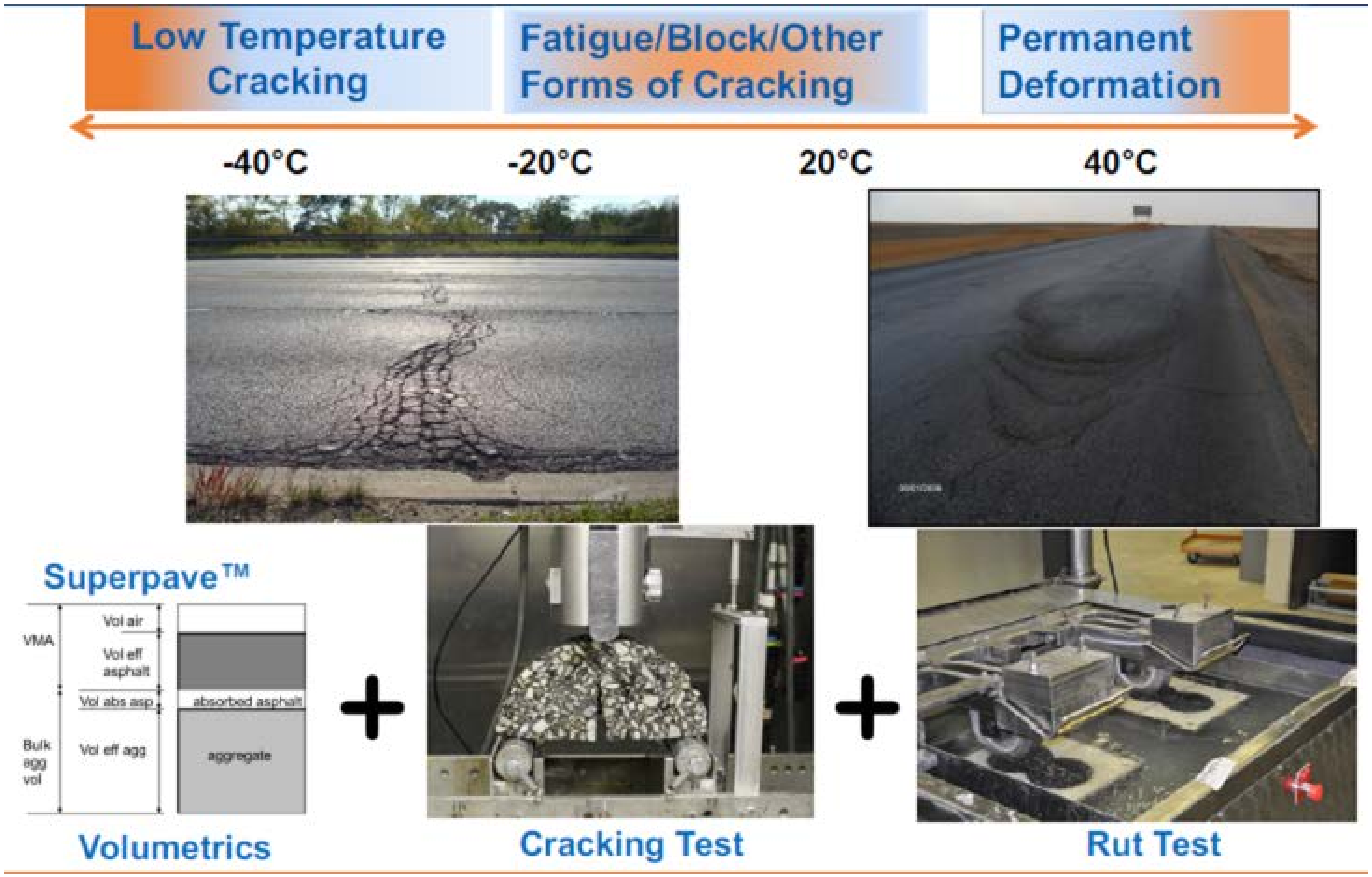
Note: SCB-IL is now I-FIT

Durability/Cracking Evaluation Survey

Survey Question:
How does your state DOT evaluate the durability/cracking potential/of designed dense graded asphalt mixes?



Use of Performance Testing in Design - Illinois



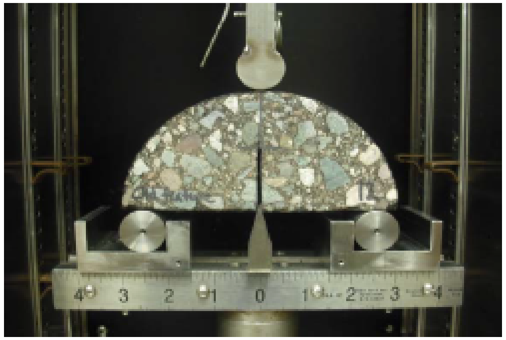
From: Imad Al-Qadi, University of Illinois

Use of Performance Testing in Design - Wisconsin

Thermal Cracking
DC(t)

LT (-18 or -24°C)

Fatigue
Semi-Circular Bend



IT (25°C)

Rutting
Hamburg

HT (50°C)

Long Term Aging – AASHTO R30 (5 days at 85°C)

- SCB and DCT
- Recovered binder grade and ΔTc

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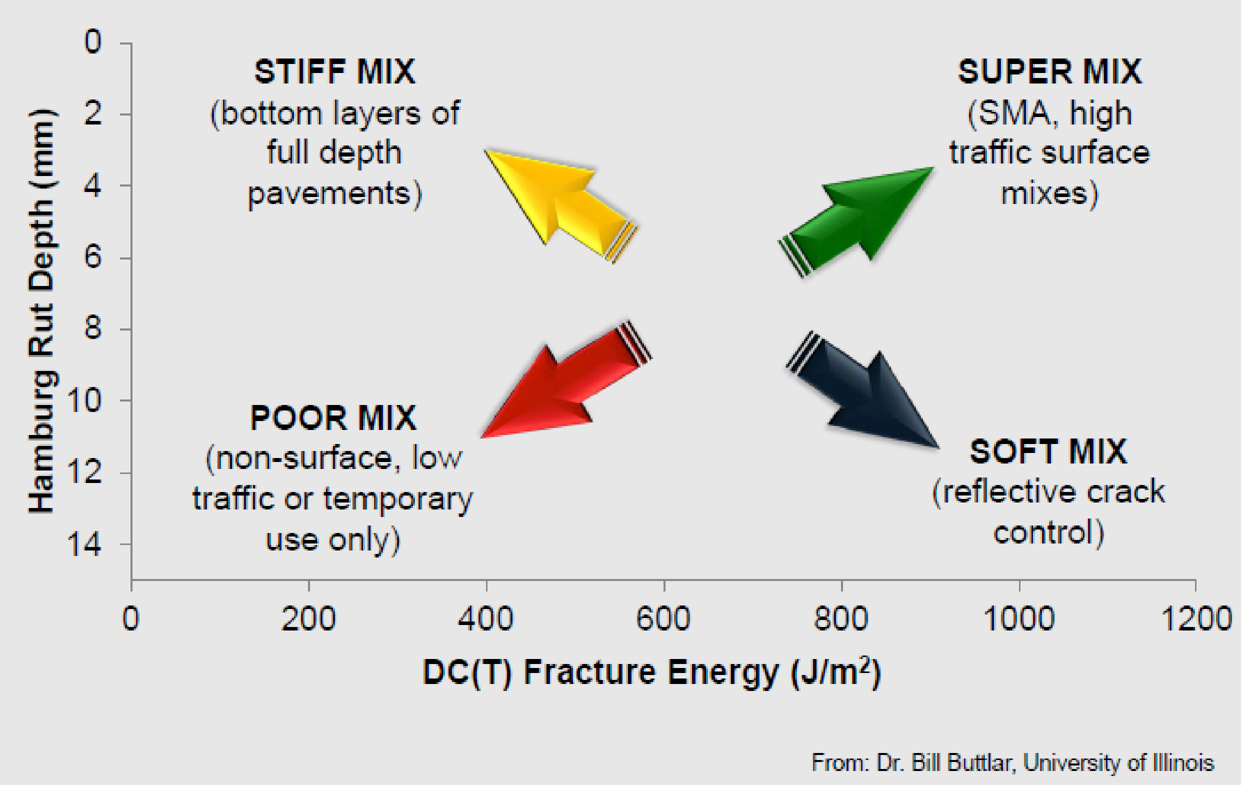
From: Erv. Dukatz, Mathy Construction, TRB 2015

Performance Space Diagrams

- Performance space diagrams show the performance of a mix related to multiple tests
- Allows the mix designer to visualize the mix performance and how to engineer the mix to provide the desired performance
- Illustrates the impact of varying mix factors on performance.



FHWA Performance Based Mix Design

asphalt institute

	Fatigue Cracking	Rutting
Design Air Voids For every 1% increase	40% increase	22% decrease
Design VMA For every 1% increase	73% decrease	32% increase
Compaction Density For every 1% lower in-place Air Voids **(Increasing Density Improved Both!)**	19% decrease	10% decrease

Courtesy of Nelson Gibson

Superpave 5 – Purdue Research

- Design at 5% air voids and compact to 5% voids in field (95% G_{mm})
- Lower design gyration to increase in-place density
  - No change in rutting resistance
  - No change in stiffness
  - Improve pavement life
    - Reduced aging
- Maintained Volume of Eff. Binder (V_{be})
  - Increased VMA by 1%

Courtesy of Gerald Huber

Balanced Mix Design Task Force - Development and Work

Task Force Development

- At the request of the National Pavement Implementation Executive Task Group (PIETG) the Balanced Mix Design Task Force formed at the September 2015 FHWA Mixture and Construction ETG meeting

- Focus Areas
  - Define Balanced Mix Design
  - Determine the current “state of practice” of BMD
  - Present approaches/concepts for immediate use
  - Recommend future needs (potential research) to advance BMD approaches
  - Disseminate information

BMD Task Force Membership

Name	Affiliation	Category	e-mail
Dave Newcomb	Texas Transportation Institute	Academia/Research	d-newcomb@ttimail.tamu.edu
John Haddock	Purdue University	Academia/Research	jhaddock@purdue.edu
Kevin Hall	University of Arkansas	Academia/Research	kdhall@uark.edu
Louay Mohammad	Louisiana State University	Academia/Research	Louaym@Lsu.edu
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Bryan Engstrom	Massachusetts DOT	Agency	Brian.Pfeifer@illinois.gov
Charlie Pan	Nevada DOT	Agency	cpan@dot.state.nv.us
Curt Turgeon	Minnesota DOT	Agency	curt.turgeon@state.mn.us
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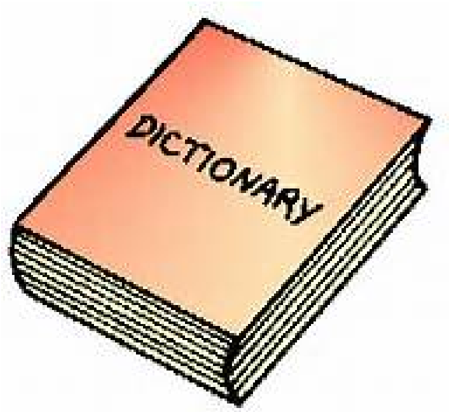
Balanced Mix Design Definition



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Balanced Mix Design Definition

- ***"Asphalt mix design using performance tests on appropriately conditioned specimens that address multiple modes of distress taking into consideration mix aging, traffic, climate and location within the pavement structure."***

- Basically, it consists of designing the mix for an intended application and service requirement.

Agency Practices Related to BMD

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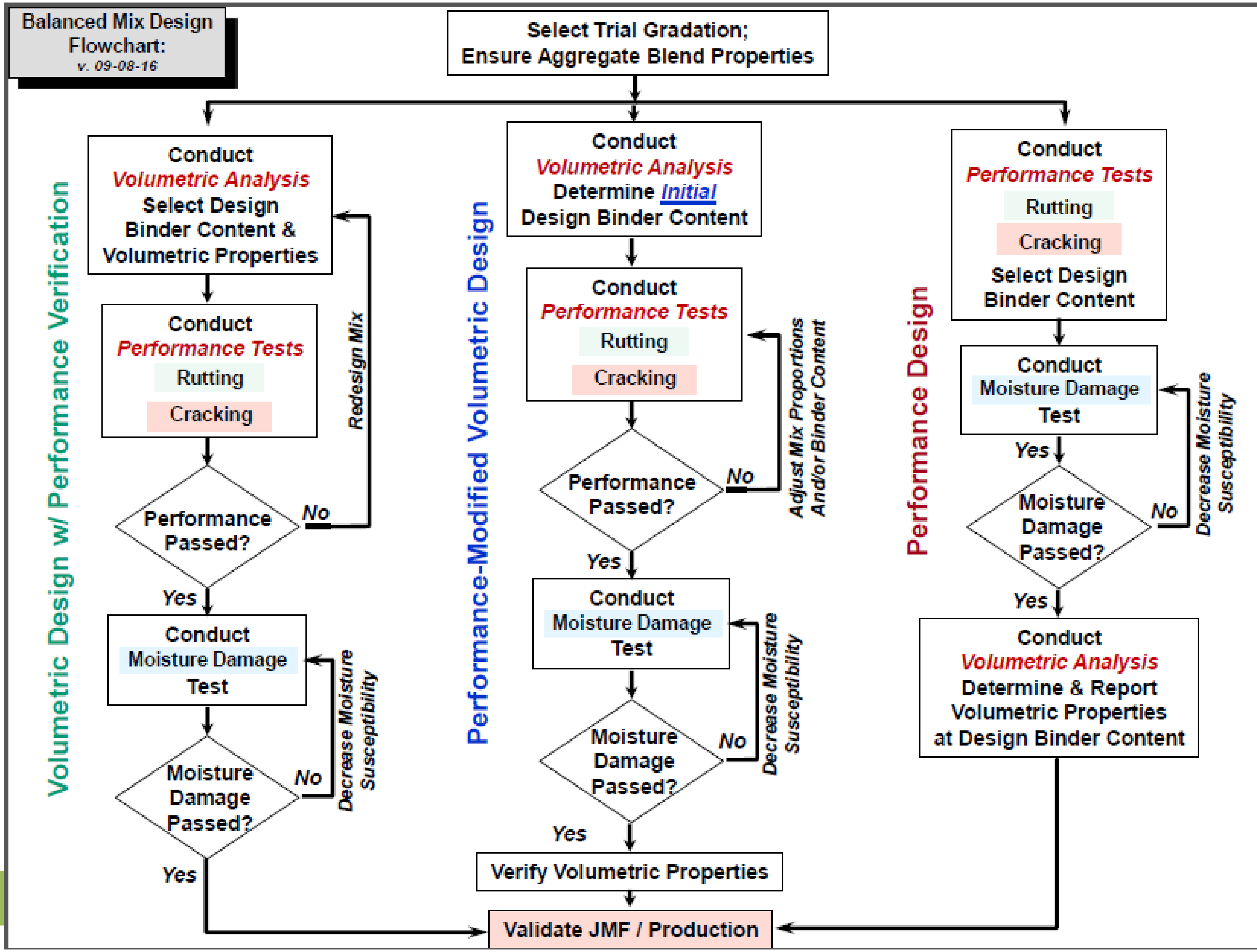
Agency Approaches – 3 Main Approaches Identified



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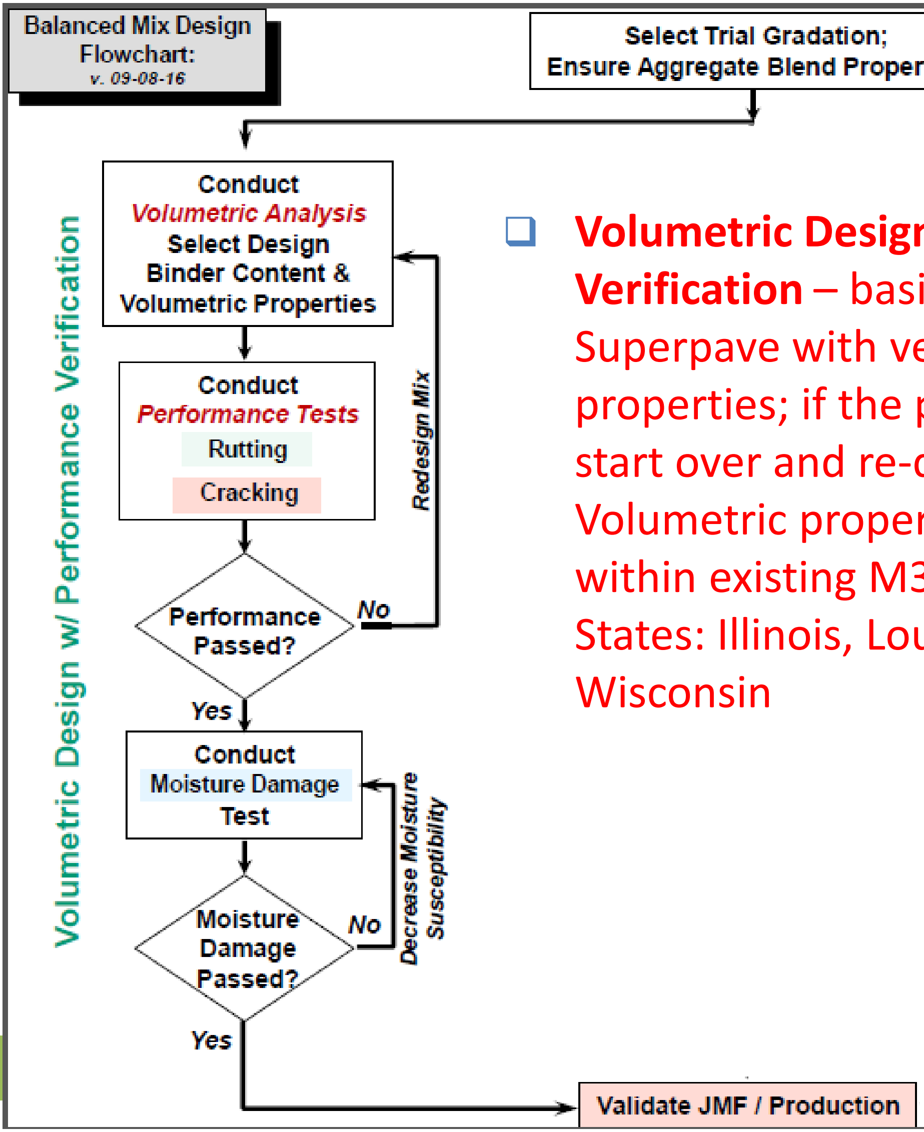
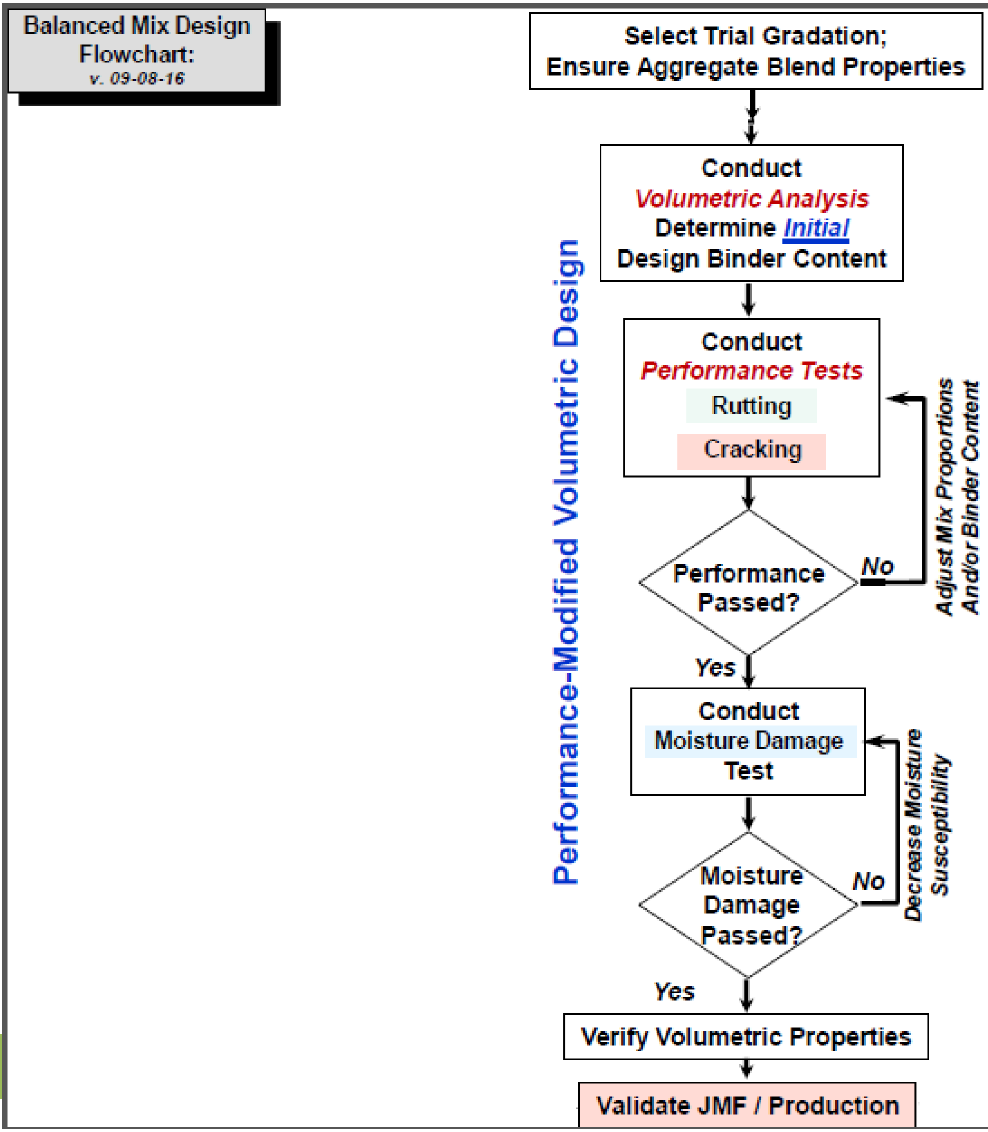
Volumetric Design w/ Performance Verification



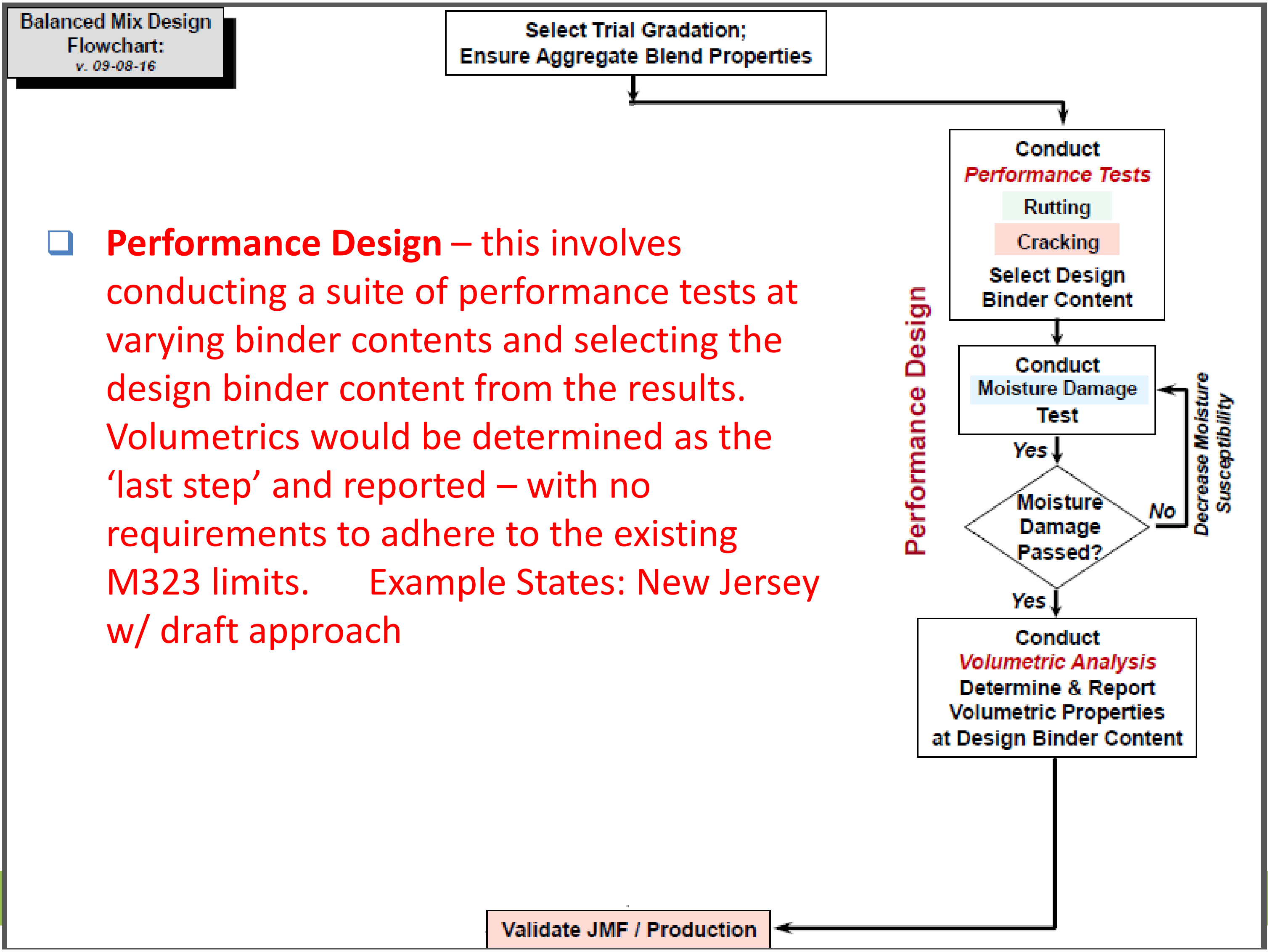
- **Volumetric Design w/ Performance Verification** – basically, it is straight Superpave with verifying performance properties; if the performance is not there, start over and re-design the mix. Volumetric properties would have to fall within existing M323 limits. Example States: Illinois, Louisiana, New Jersey, Texas, Wisconsin

Performance Modified Volumetric Design



- **Performance-Modified Volumetric Design** – the initial design binder content is selected using M323/R35 prior to performance testing; the results of performance testing could 'modify' the mixture proportions (and/or) adjust the binder content – and the final volumetric properties may be allowed to drift outside existing M323 limits. Example State: California

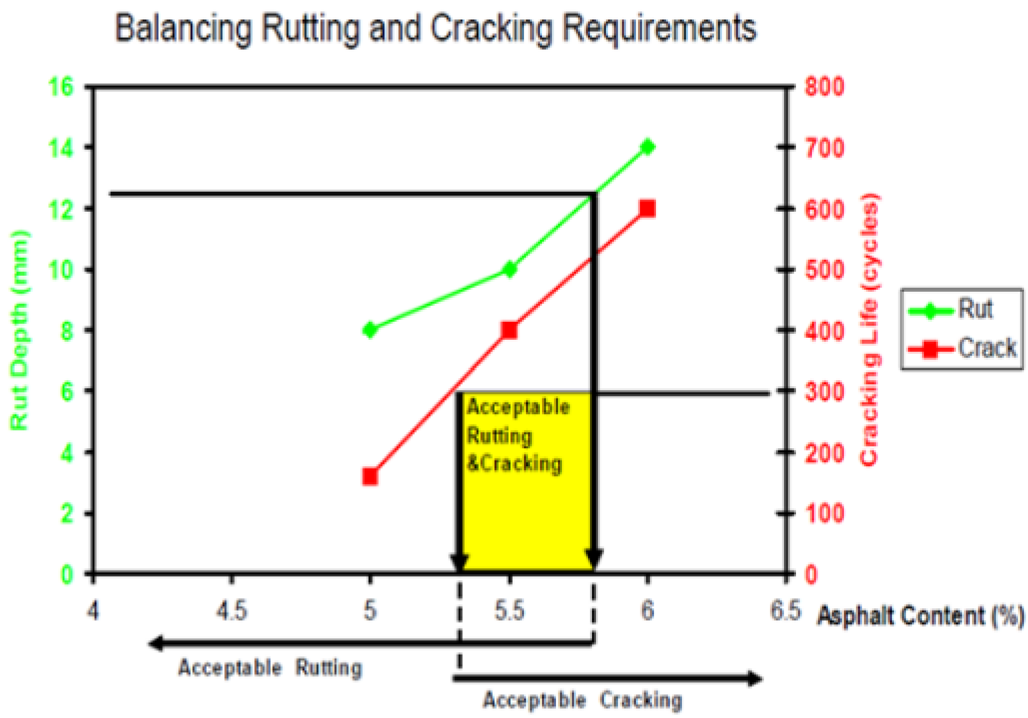
Performance Design



- **Performance Design** – this involves conducting a suite of performance tests at varying binder contents and selecting the design binder content from the results. Volumetrics would be determined as the 'last step' and reported – with no requirements to adhere to the existing M323 limits. Example States: New Jersey w/ draft approach

BMD Basic Example – Volumetric Design w/ Performance Verification

- **Texas DOT**
  - Volumetric design conducted
  - Hamburg Wheel Tracking Test (HWTT) AASHTO T 324
  - Overlay Tester (OT) Tex-248-F
  - Three asphalt binder contents are used: optimum, optimum +0.5%, and optimum -0.5%.
  - The HWTT specimens are short-term conditioned.
  - The OT specimens are long-term conditioned.

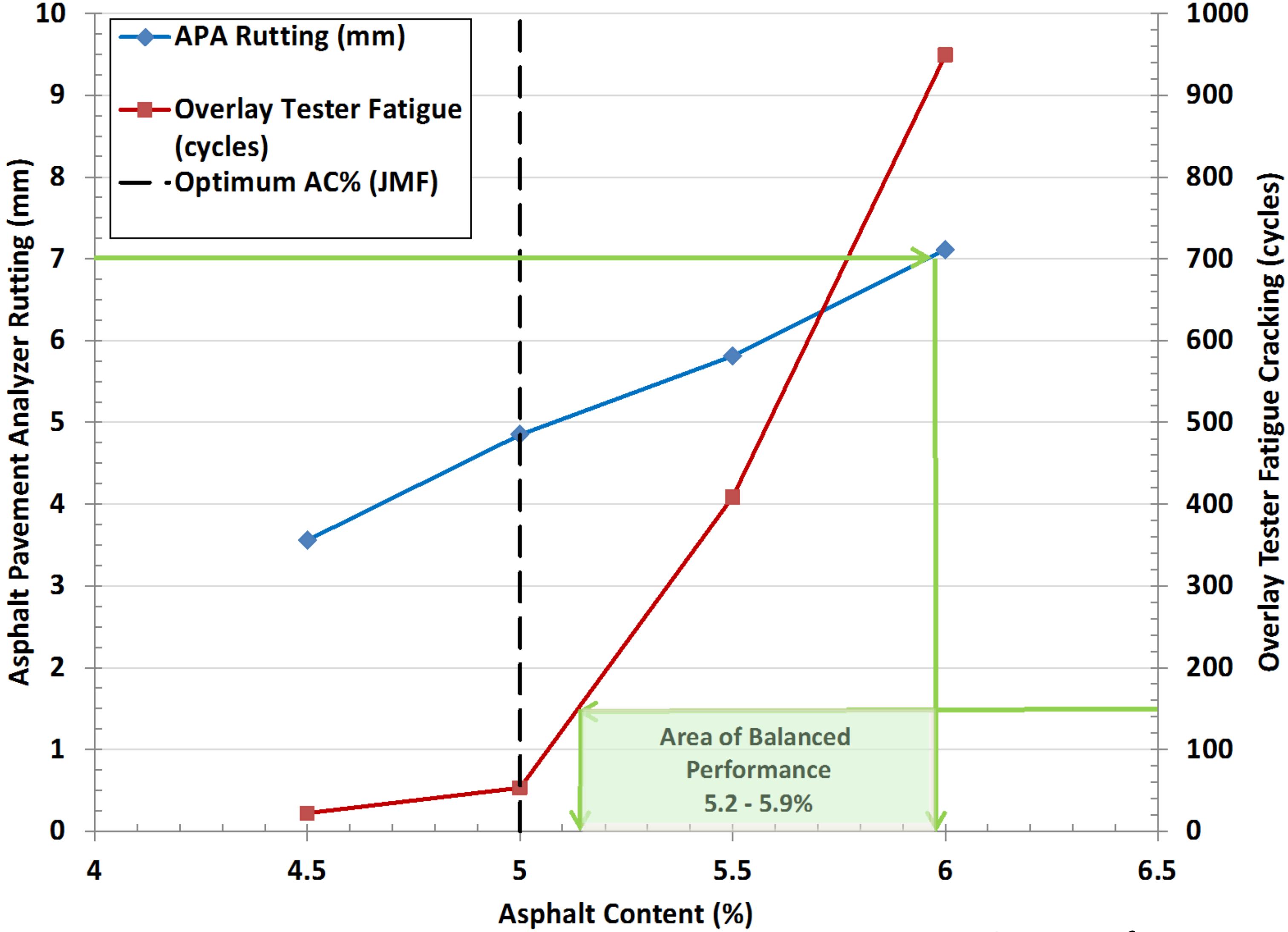


Within this acceptable range (5.3 to 5.8 percent), the mixture at the selected asphalt content must meet the Superpave volumetric criteria.

NJDOT/Rutgers

- Balanced Mixture Design Concept
- Mixes are designed to optimize performance
  - Not around a target air void content
- Take an existing virgin mix design
  - Start at a “dry” binder content
  - Add binder at 0.5% increments – measure rutting and cracking
  - Determine range where rutting and cracking are optimized
  - Conduct volumetric work
- Performance criteria (limits) already determined based on virgin mixes

New Jersey Balanced Design



Courtesy of Tom Bennert

Balanced Mix Design Research – New Jersey

- Most NJ mixes found to be below (dry) of the balanced area
- Plant QC air voids requirements need to be re-evaluated to account for the added binder
- Changes in production volumetrics are likely required to move the mixes in the right direction

FHWA Technical Brief - Draft

- Technical Brief being developed to provide a current summary of the BMD TF efforts.
- Target publication of end 2016 (or sooner).

TechBrief

The Asphalt Pavement Technology Program is an integrated, national effort to improve the long-term performance and cost effectiveness of asphalt pavements. Managed by the

Balanced Mixture Design Approaches for Asphalt Pavement Construction

This *Technical Brief* provides an overview of balanced mixture design (BMD) approaches currently used by states in asphalt pavement construction. These approaches are still under development and this document will attempt to show the current status and some of the issues that will need to be addressed in the future.

Research Proposal: NCHRP 20-07 Project

- Research Problem Statement prepared and submitted last week to AASHTO for a NCHRP 20-07 Project.
  - ***Development of a Framework for Balanced Asphalt Mixture Design and Gap Analysis***
- Goals
  - Survey of all state highway agencies (SHAs) to determine the use and status of BMD practices
  - Review of literature for the development and state-of-the-practice for performance testing,
  - Develop a practice that is a framework for BMD for implementation of performance testing in the design of asphalt mixtures,
  - Develop research problem statements with funding needs based on gaps identified for development of a more detailed standard practice for BMD, and
  - Prepare a final report that documents results, summarizes findings, draws conclusions, and presents the (a) proposed practice and (b) research problem statements based on identified gaps with funding needs and a recommended plan for submittal.

NCHRP
NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

NCHRP Project 20-07/Task ...

Project Title: *Development of a Framework for Balanced Asphalt Mixture Design and Gap Analysis*

Fiscal Year: 2016

Contract Time: 12 months

Funds: $100,000

Staff:

Staff Phone:

Staff Email:

RFP Close Date *(proposal due date)*:

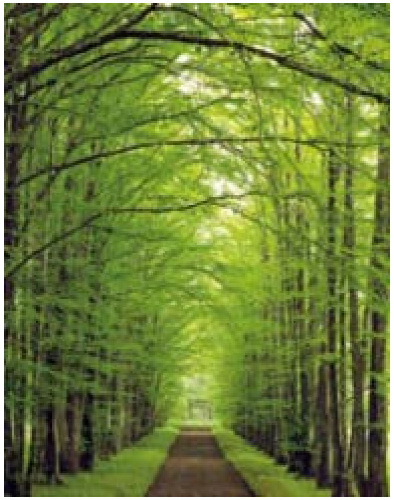
Proposals must be submitted by email to:

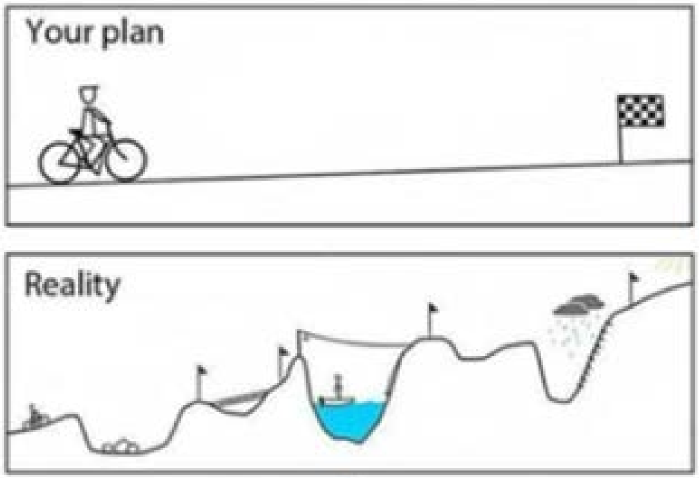
The Path Forward for Balanced Mix Design

- Recognize the need and move incrementally in the appropriate direction to limit risk of mix performance issues.

- Must continue with theoretical research/modeling efforts, but not be afraid to utilize practical approaches to find solutions.

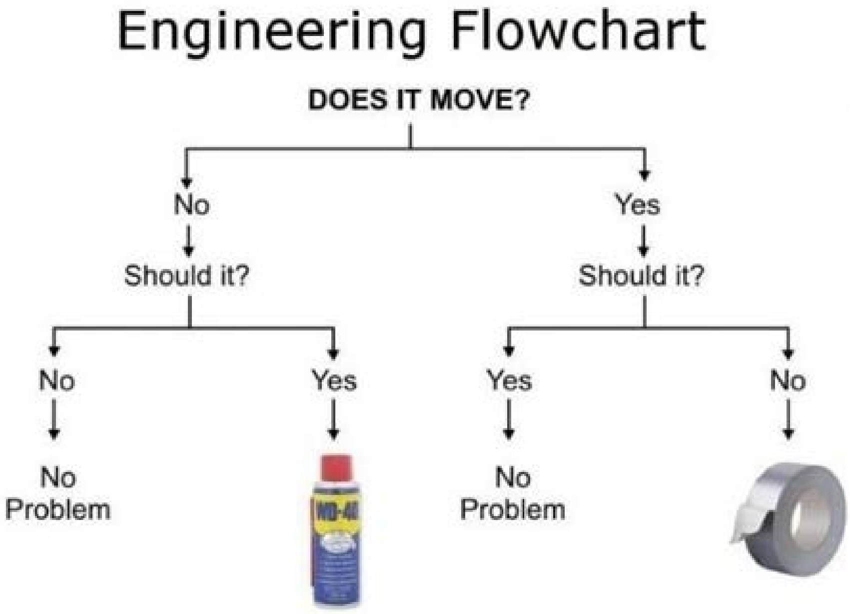
- **Recognize that this is a long term effort with ups/downs, but we must start now.**





Final Thoughts on Mix Design

- Key Points to Keep in Mind
  1. **"Use What Works"**
  2. **"Eliminate What Doesn't"**
  3. **"Be as Simple as Possible, Be Practical, and Be Correct"**



"Good doesn't have to be complicated and complicated isn't always good!"

Questions/Discussion

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What is Achievable?