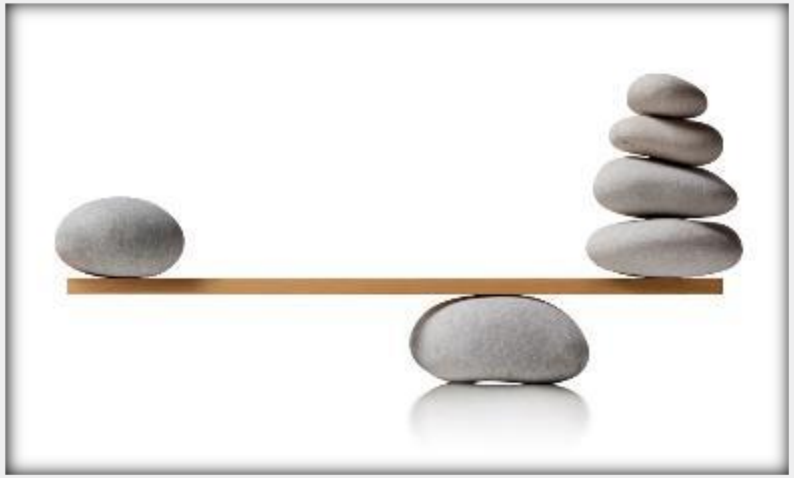
Balanced Mix Design — Is This The Future?

Targeting Quality Through Partnership

Shane Buchanan
Oldcastle Materials

Discussion Items – Questions to be Answered

1. What is Balanced Mix Design (BMD)?
2. Why the need for BMD?
3. What is VDOT doing?
4. What are the most common performance tests (rutting and cracking) for BMD?
5. What is the current national state of practice for BMD?
6. How does a BMD compare with a volumetric mix design?
7. What about acceptance testing with a BMD approach?
8. What is the future of BMD?



What is Balanced Mix Design (BMD)?

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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.”***

- Use the right mix for the job!

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/

Why the need for BMD?

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Why the Need for a New Mix Design Approach?

- **Problems:**
  - Dry mixes exist in some areas.
  - Volumetrics alone can not adequately evaluate mix variables, such as recycle, warm-mix additives, polymers, rejuvenators, and fibers.
- **Solutions:**
  - **Recognize performance issues** related to dry mixes in some areas. (Note: Many performance issues are caused by 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!**

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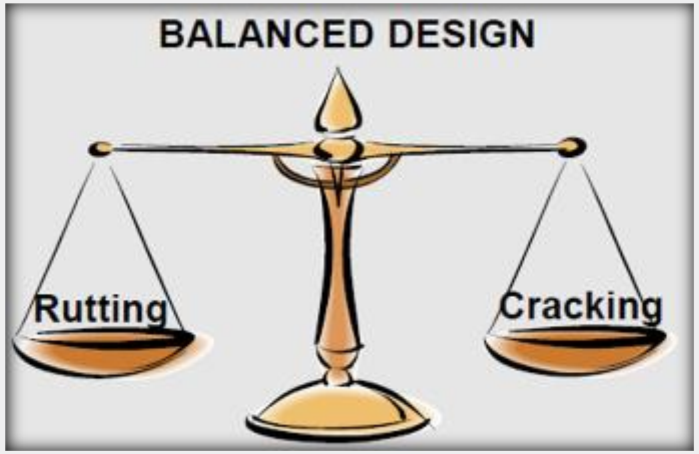
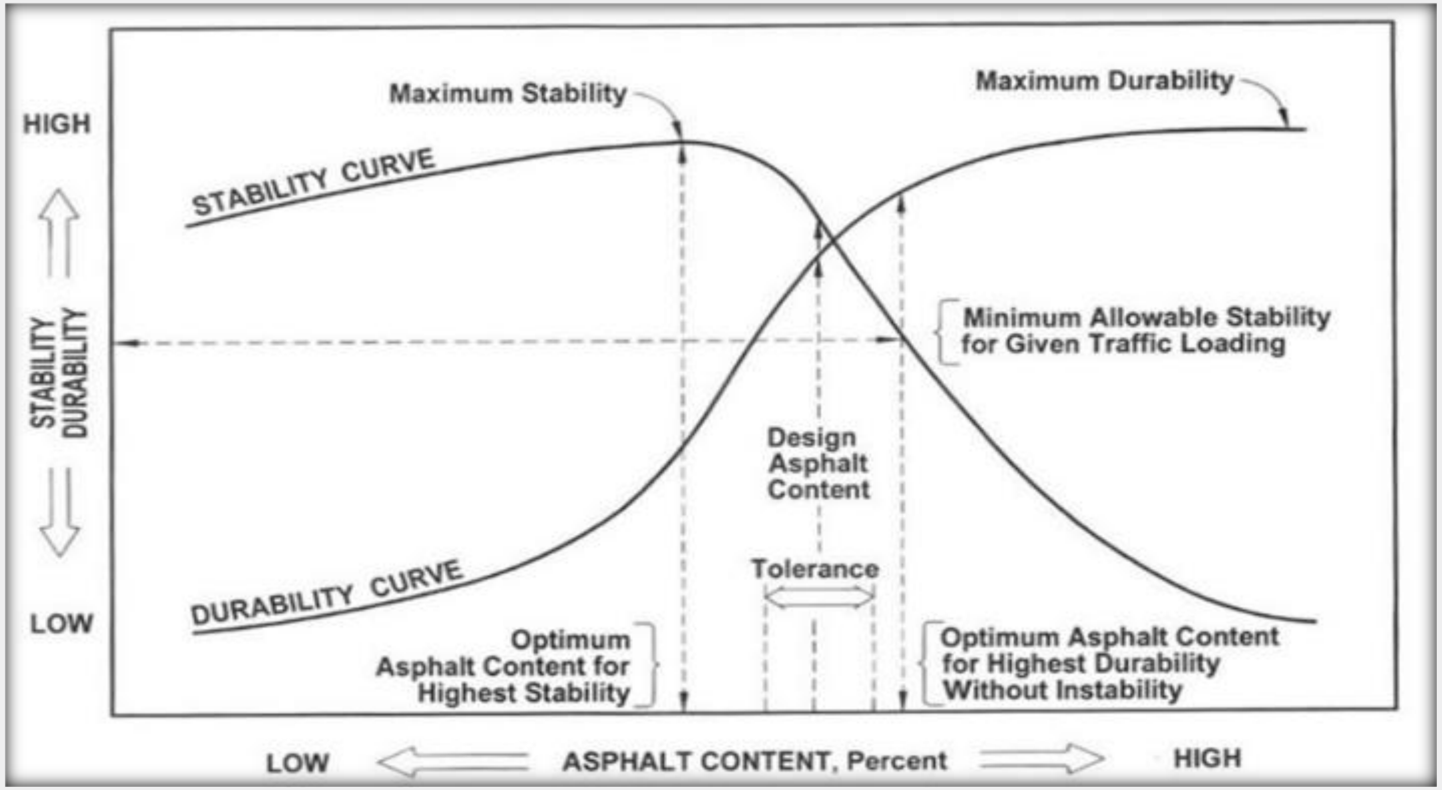
Pavement Performance General Overview

- Achieving Balanced Mixture Performance is Key to a Long Lasting Pavement





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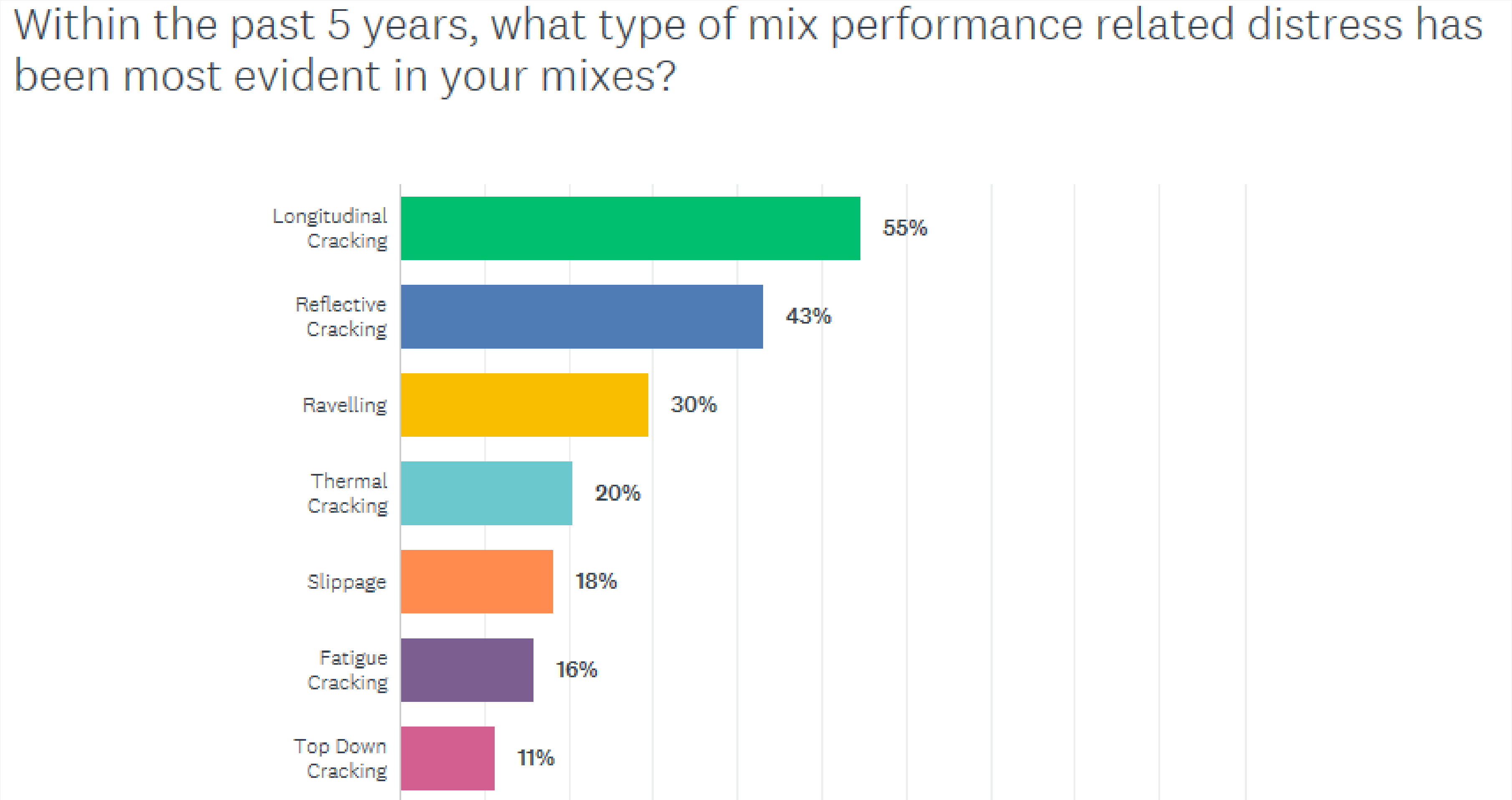
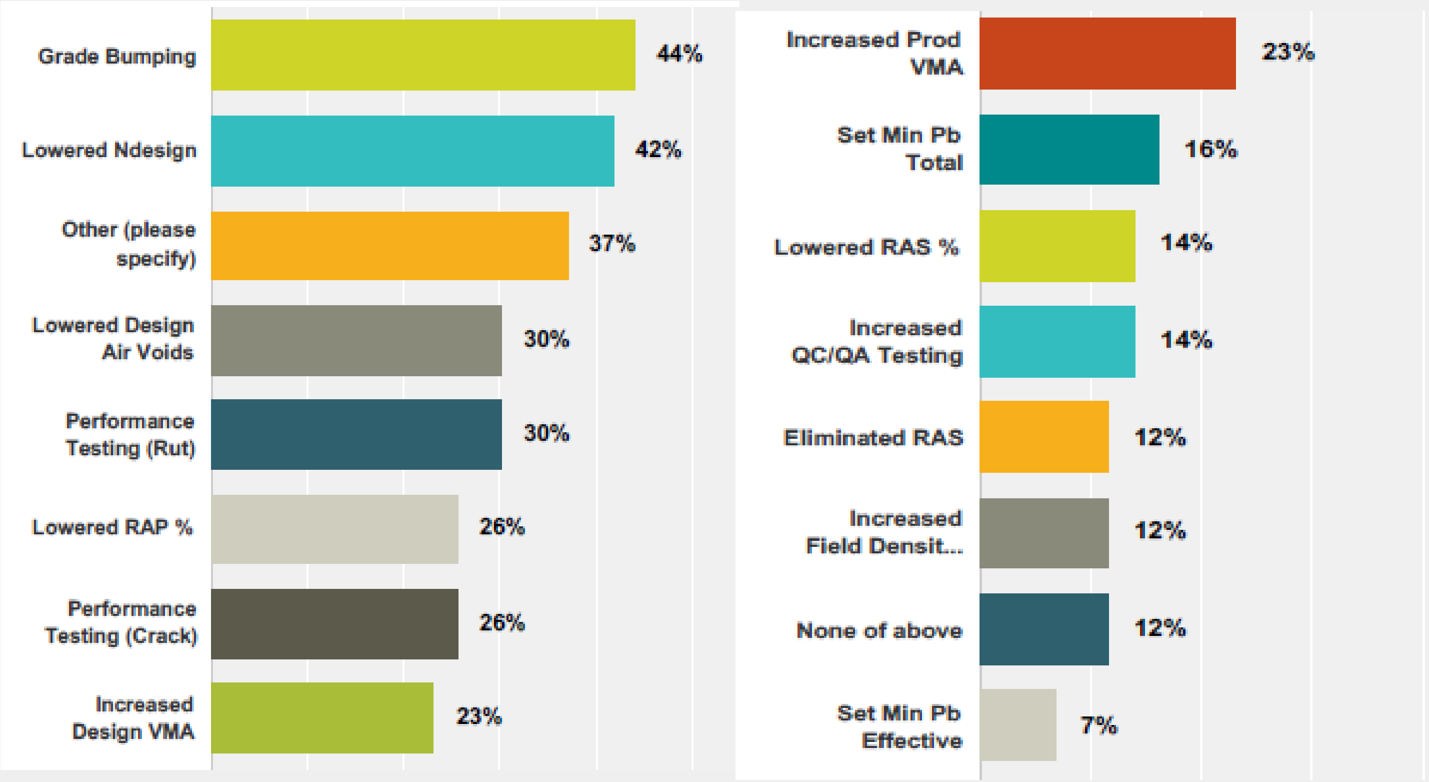
What Type Distress Is Occurring?



Agencies Are Searching for Solutions: Spec Changes

- Superpave system is becoming unrecognizable with specifications changing rapidly as agencies search for ways to improve durability
- Specifications have become convoluted and confounded
- Existing specified items compete against each other
- New requirements get added and nothing gets removed
- Establishing true “cause and effect” is impossible

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



What’s VDOT doing?

VDOT – Specification Highlights

- Low Ndesign Levels = 50, 65
- Adjusted D/Pbe
- Lower design air void target for Level E mix

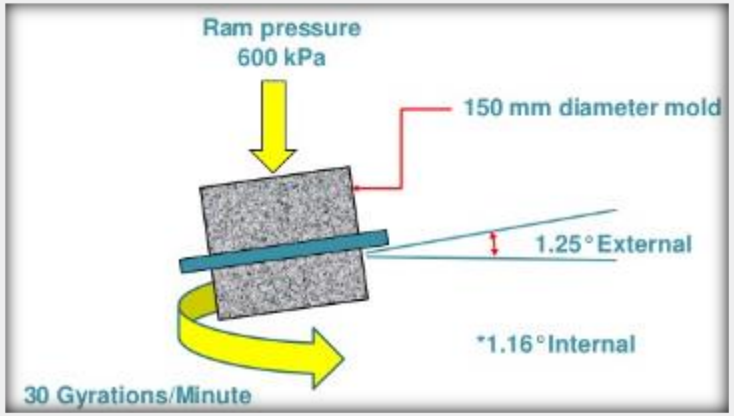


TABLE II-14
Mix Design Criteria

Mix Type	VTM (%) Production	VFA (%) Design	VFA (%) Production	Min. VMA (%)	Fines/Asphalt Ratio	No. of Gyrations N Design
SM-9.0A [1,2]	2.0-5.0	75-80	70-85	16	0.6-1.3	65
SM-9.0D [1,2]	2.0-5.0	75-80	70-85	16	0.6-1.3	65
SM-9.0E [1,2]	2.0-5.0	75-80	70-85	16	0.6-1.3	65
SM-9.5A [1,2]	2.0-5.0	75-80	70-85	16	0.7-1.3	50
SM-9.5D [1,2]	2.0-5.0	75-80	70-85	16	0.7-1.3	50
SM-9.5E [1,2]	2.0-5.0	75-80	70-85	16	0.7-1.3	50
SM-12.5A [1,2]	2.0-5.0	73-79	68-84	15	0.7-1.3	50
SM-12.5D [1,2]	2.0-5.0	73-79	68-84	15	0.7-1.3	50
SM-12.5E [1,2]	2.0-5.0	73-79	68-84	15	0.7-1.3	50
IM-19.0A [1,2]	2.0-5.0	69-76	64-81	13	0.6-1.2	65
IM-19.0D [1,2]	2.0-5.0	69-76	64-81	13	0.6-1.2	65
IM-19.0E [1,2]	2.0-5.0	69-76	64-81	13	0.6-1.2	65
BM-25.0A [2,3]	1.0-4.0	67-87	67-92	12	0.6-1.3	65
BM-25.0D [2,3]	1.0-4.0	67-87	67-92	12	0.6-1.3	65

[1] Asphalt content should be selected at 4.0% air voids for A & D mixes, 3.5% air voids for E mix.
[2] Fines-asphalt ratio is based on effective asphalt content.
[3] Base mix shall be designed at 2.5% air voids. BM-25A shall have a minimum asphalt content of 4.4% unless otherwise approved by the Engineer. BM-25D shall have a minimum asphalt content of 4.6% unless otherwise approved by the Engineer.

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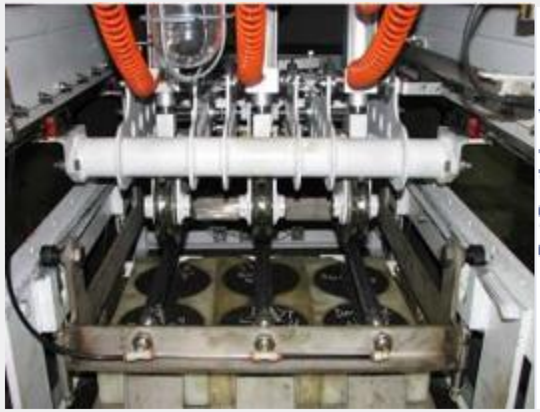
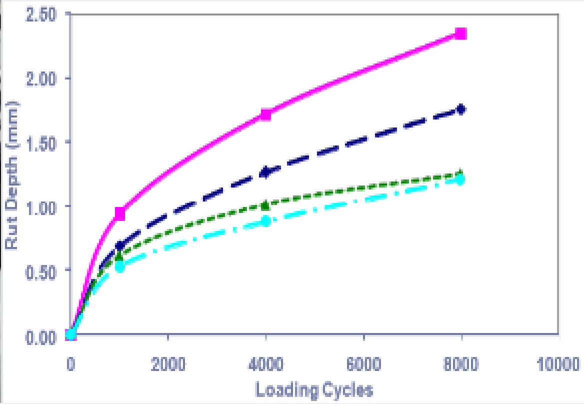
VDOT – Specification Highlights (Performance Testing)

- VTM 110 – APA Rut Testing

Mix Designation	Traffic Level (ESAL)	Maximum Rut Depth, mm
A	0 to 3,000,000	7.0
D	3,000,000 to 10,000,000	5.5
E, S	> 10,000,000	3.5





What are the most common performance tests (rutting and cracking) for BMD?

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Main Pavement Distresses Observed in the Field

- **Rutting**
  - Rutting in asphalt mixture(s) layers (focus of rutting performance testing)

- **Fatigue cracking**
  - Bottom-up cracking
  - Top-down cracking

- **Reflection Cracking**
  - Cracking from underlying cracks/joints

- **Low temperature cracking**
  - Shrinkage of mixture due to low temperatures

- **Moisture Damage (Stripping)**

Test Mixtures in the Lab to Help Ensure Field Performance

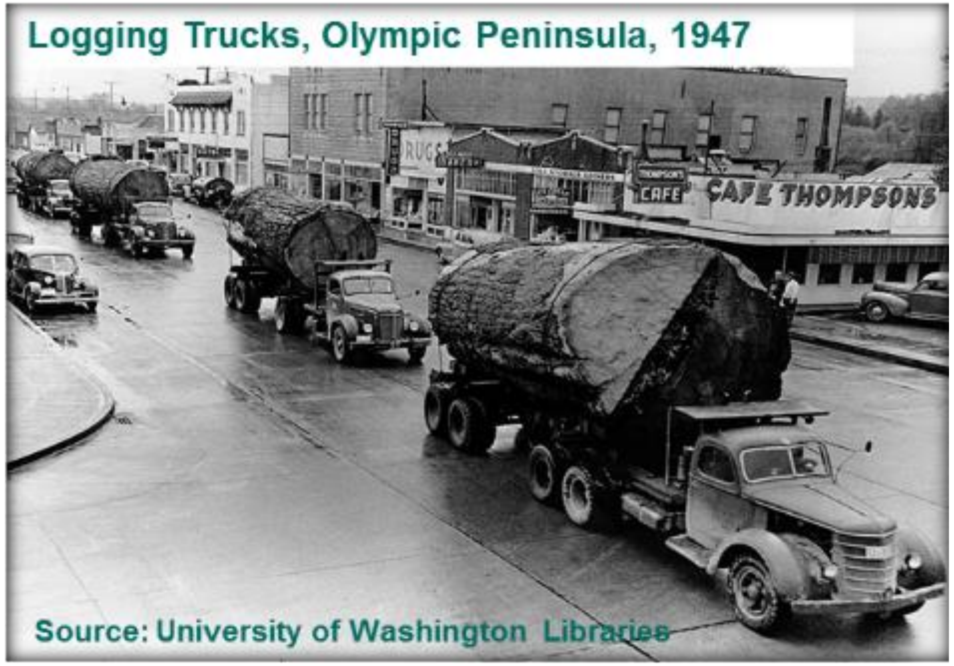
- Mixtures need to be evaluated in the lab during design to help ensure the required field performance can be achieved.

Lab Test (Hamburg Wheel Tracker)

Lab Test Results

Expected Field Performance

Stability Testing (Rutting)



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Rutting Tests

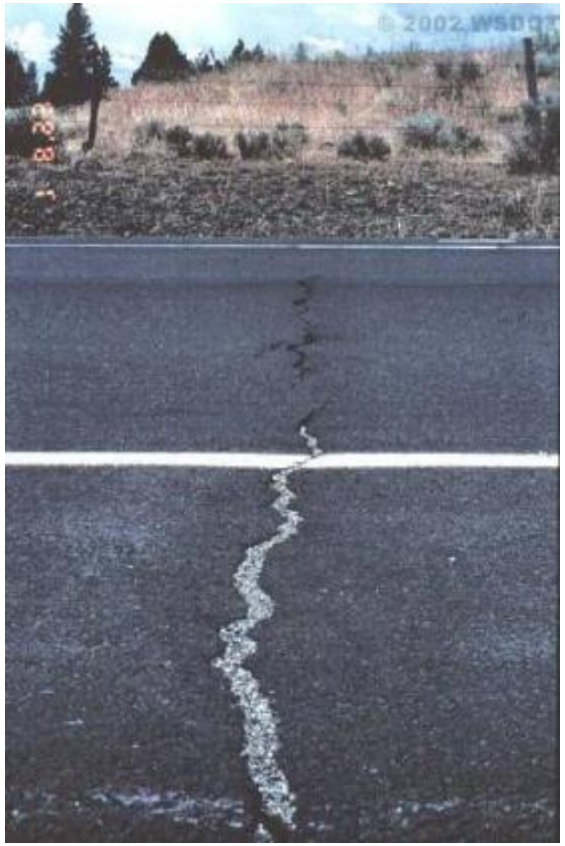
- Rutting can be evaluated with several available tests based on the user preference.

Hamburg Wheel Test (HWT)

Asphalt Pavement Analyzer (APA)

AMPT Flow Number

Durability Testing (Cracking)



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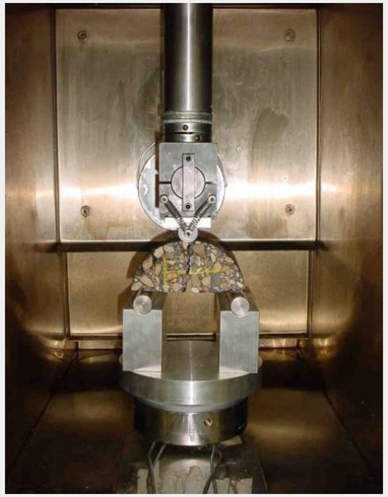
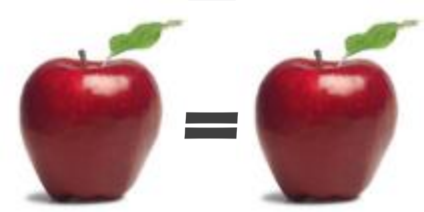
Durability/Cracking Evaluation

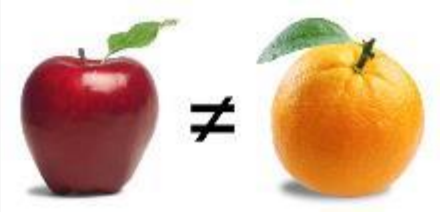
- Durability/cracking evaluation is substantially more complicated than stability.
- Main question is "**What is the anticipated mode of distress?**"
- Cracking prediction is a known "weak" link in performance testing.
- No general consensus the best test(s) or the appropriate failure threshold.
- **GOALS**
  - **MATCH THE TEST TO THE DISTRESS**
  - **SET APPROPRIATE FAILURE THRESHOLDS**

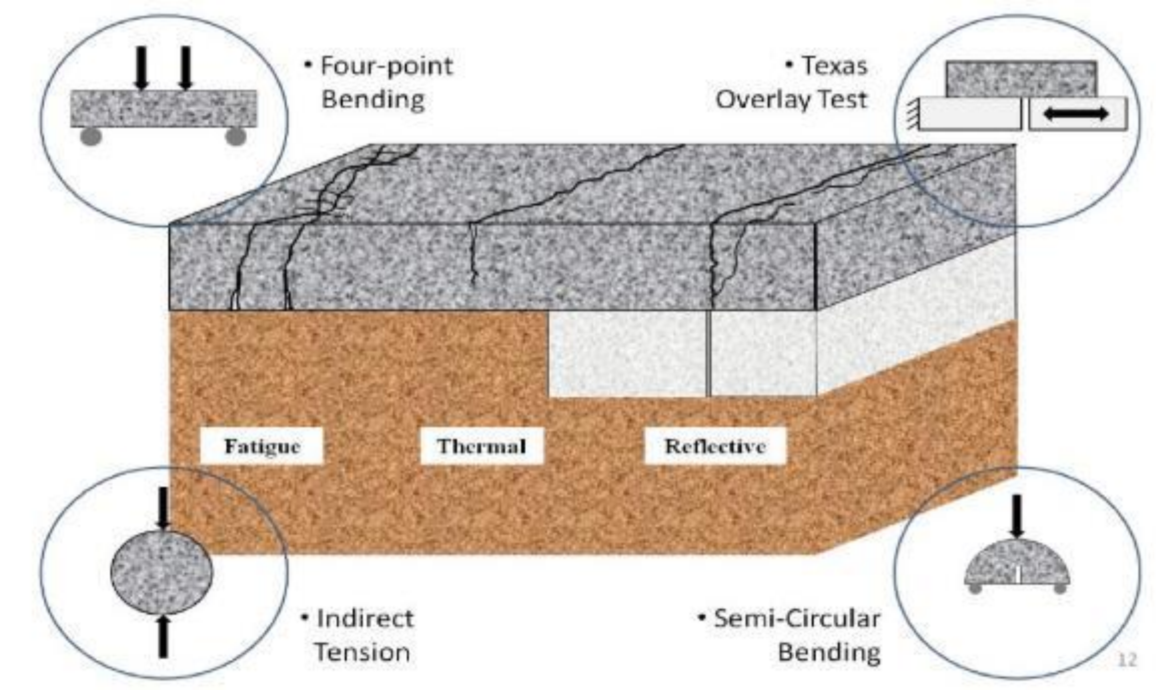


What is the Anticipated Mode of Distress for Testing?

- Test selection must be a function of the anticipated mode of distress.
- Typical distress modes
  - Fatigue cracking (top down/bottom up)
  - Low temperature (thermal) cracking
  - Reflection (reflective) cracking
- Various empirical and mechanistic tests are available for use.
- Match apples to apples, not apples to oranges!



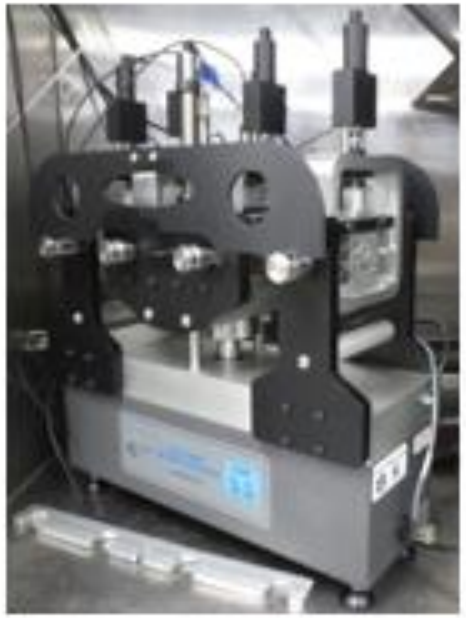




GOALS
1. MATCH THE TEST TO THE DISTRESS
2. SET APPROPRIATE FAILURE THRESHOLDS

Fatigue (Bottom Up or Top Down) Related Cracking Tests

Bottom Up

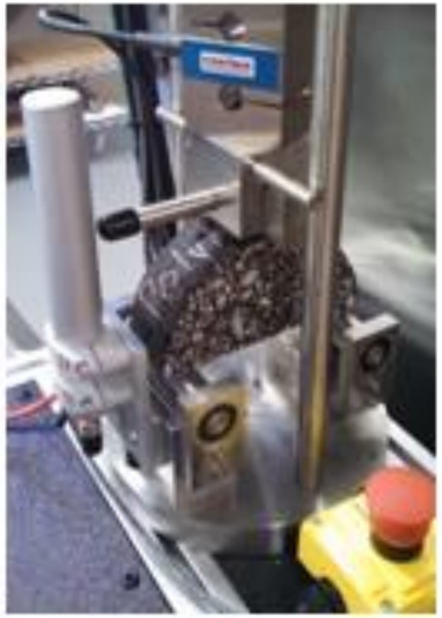


Bending Beam Fatigue

Bottom Up

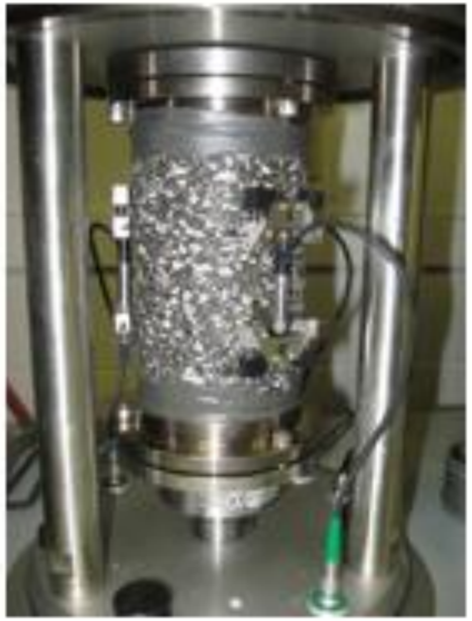
Texas Overlay Test

Bottom Up /
Top Down



SCB
- **LTRC – Jc**
- **IFIT**

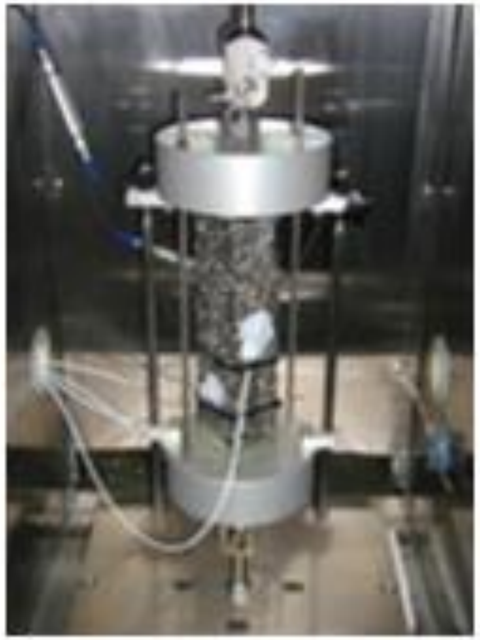
Bottom Up



Direct Tension Cyclic Fatigue, S-VECD

Thermal Cracking Tests

IDT Creep Compliance



TSRST

SCB at Low Temp

Disk Shaped Compact Tension (DCT)

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Reflection (Reflective) Cracking Tests

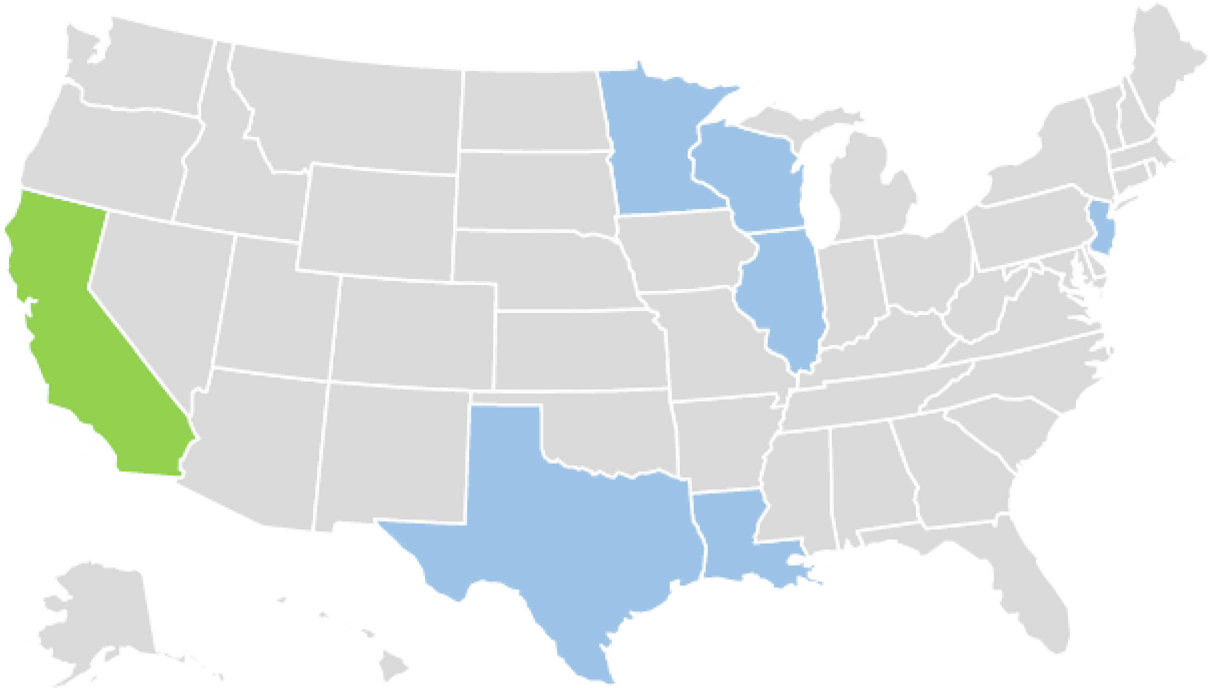
Disk Shaped Compact Tension (DCT)

Texas Overlay Test

SCB (IFIT)

What is the current national state of practice for BMD?

Agency Practices For Balanced Mix Design



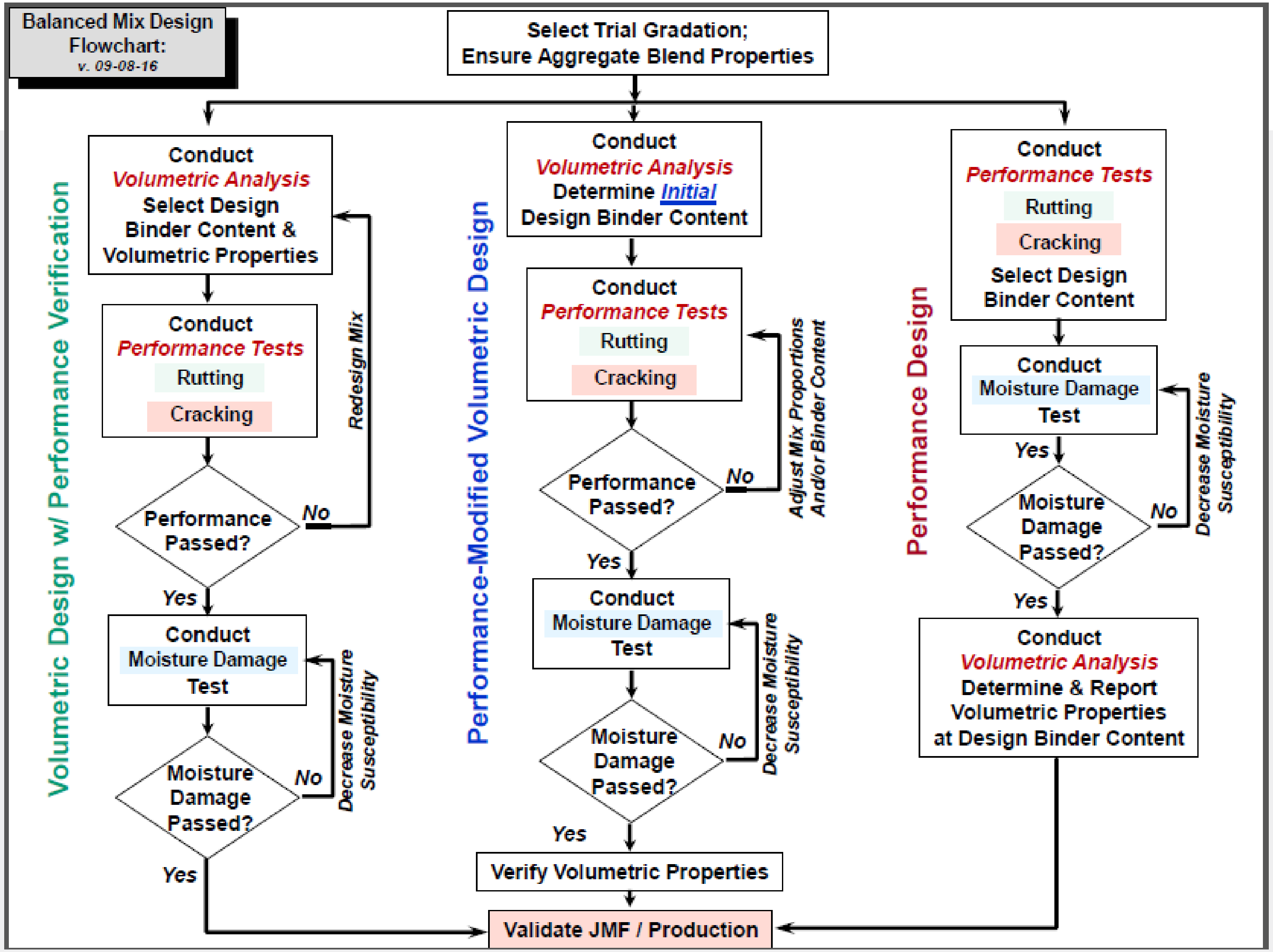
What Typically Drives a State Agency Practice?

- **SHAs are selecting different performance tests.**
- Variance is **driven by different pavement distress considerations** (e.g., thermal cracking in Minnesota versus top-down cracking in Florida).
- Additionally, SHAs are **sometimes selecting performance tests based on the intended mix application or mix component of interest.**
  - **1) Determine the problem/need then 2) find a solution.**
  - For example,
    - Caltrans is addressing high traffic mixtures,
    - WisDOT and IDOT are addressing recycled materials,
    - LADOTD is focusing on wearing and binder course mixtures, and
    - TxDOT and NJDOT are both focused on high-performance and specialty mixtures.

BMD Approaches

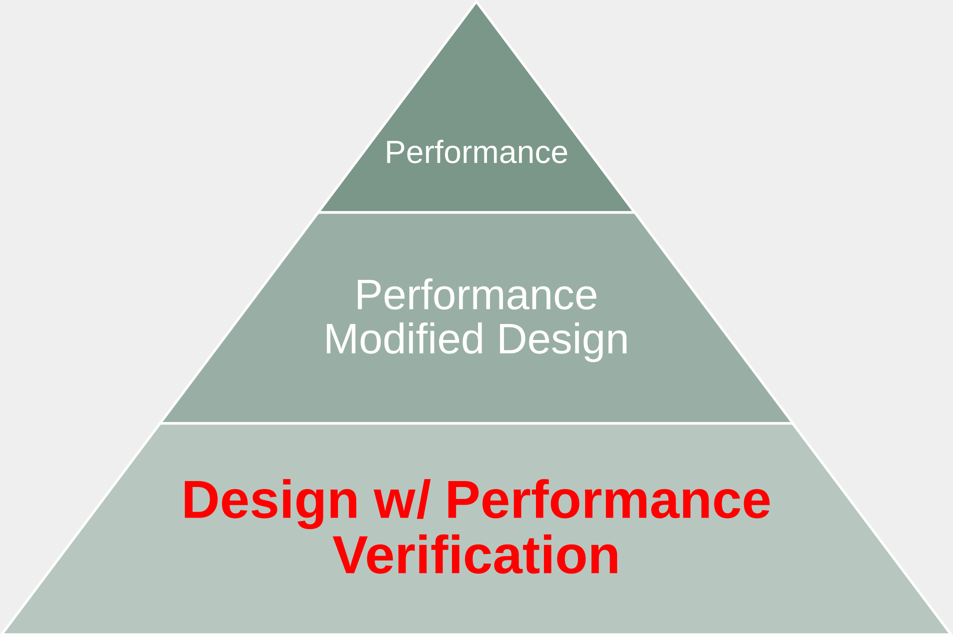
- Three general mix design approaches.

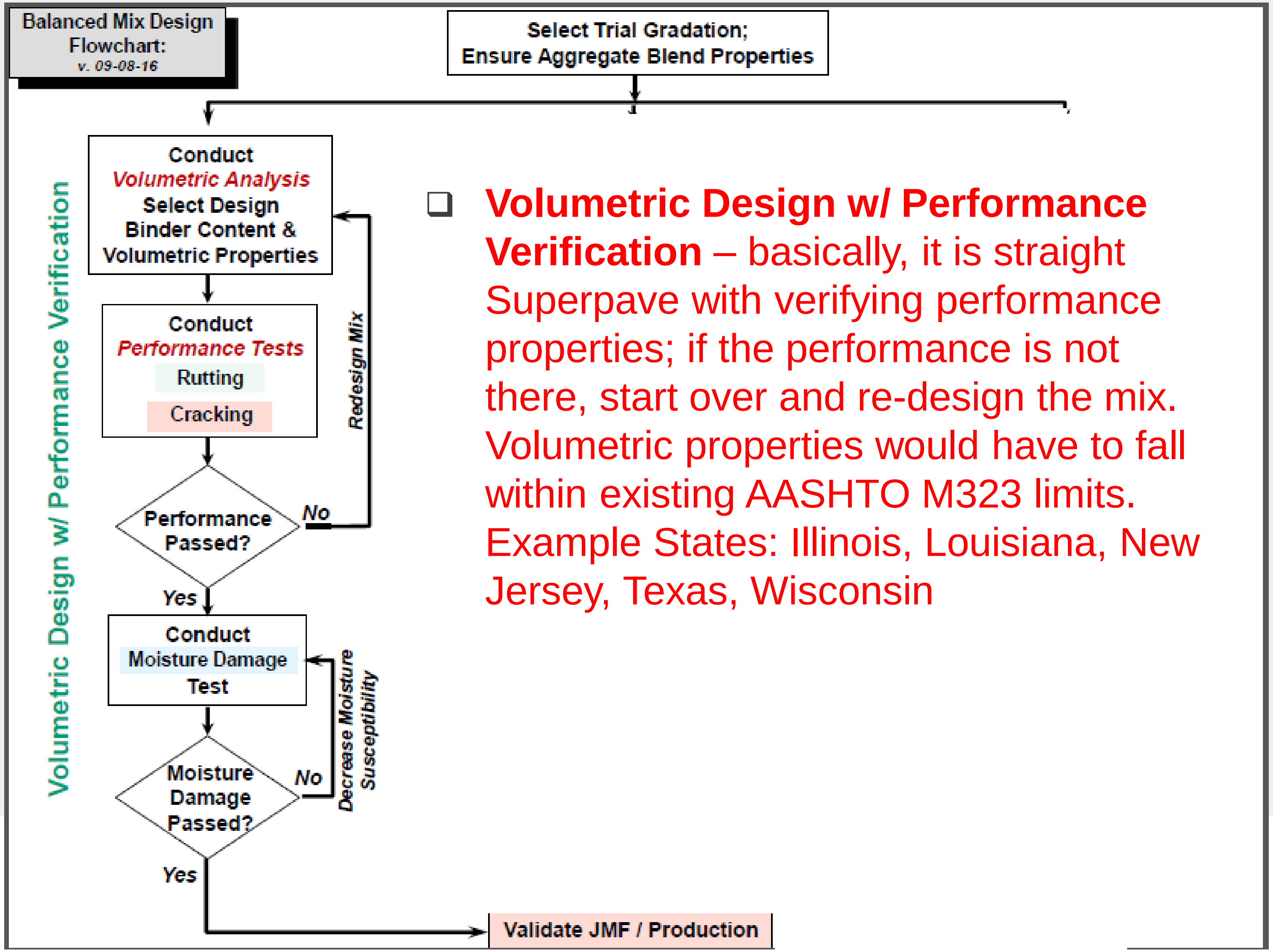
1. Volumetric Design w/ Performance Verification
2. Performance Modified Volumetric Design
3. Performance Design



Graphic Developed by Kevin Hall (FHWA BMD Task Force), 2016

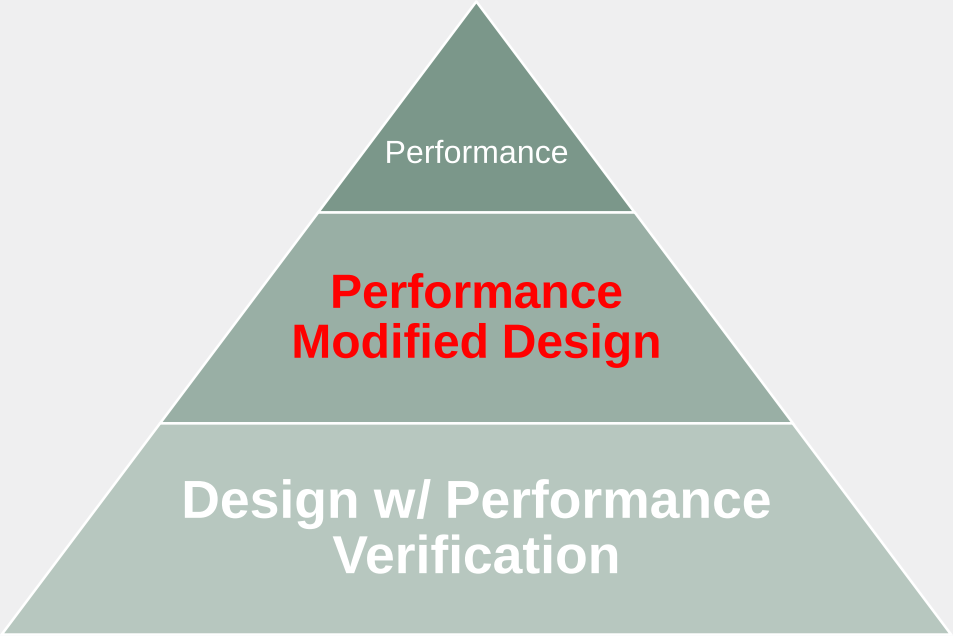
Volumetric Design w/ Performance Verification

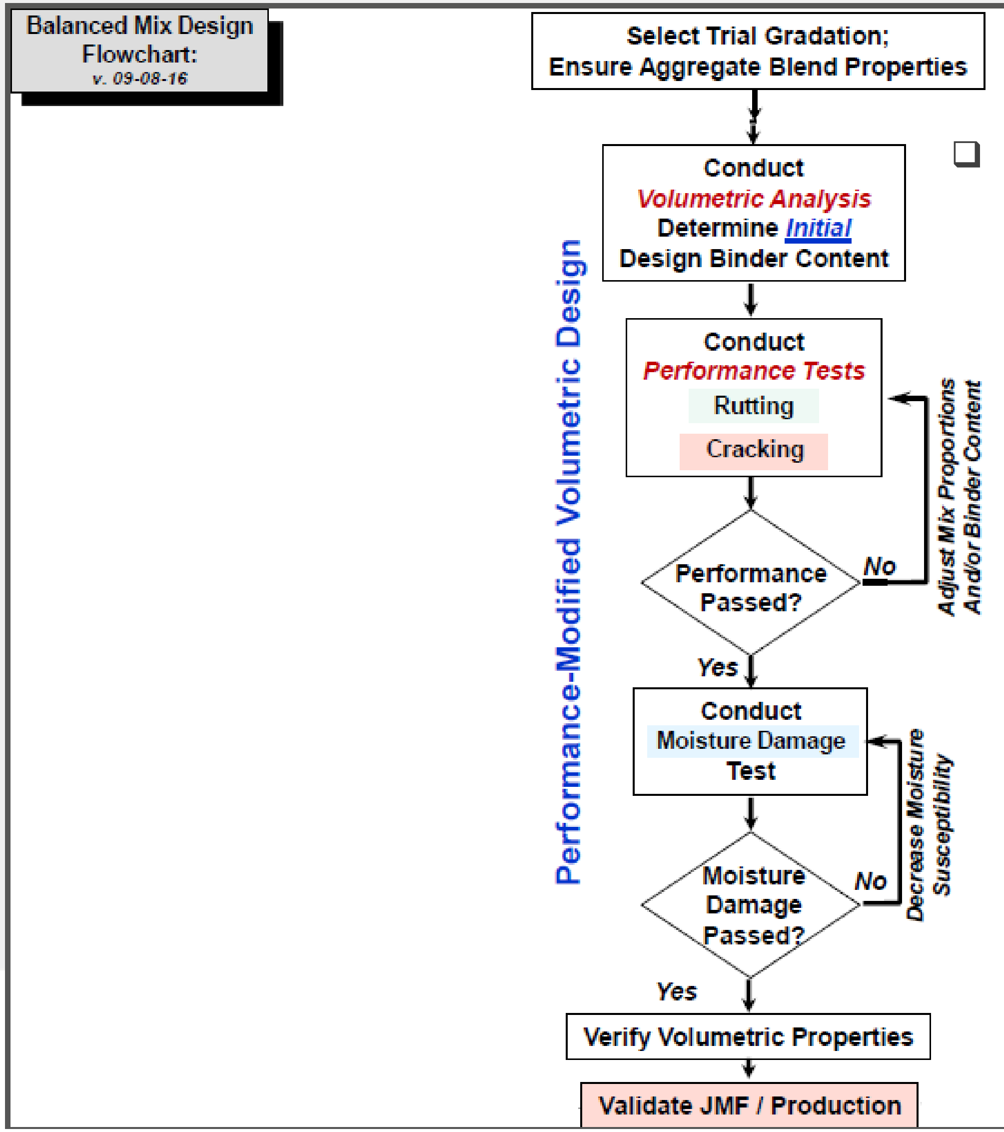




- **Volumetric Design w/ Performance Verification** – basically, it is straight Superpave with verifying performance properties; if the performance is not there, start over and re-design the mix. Volumetric properties would have to fall within existing AASHTO M323 limits. Example States: Illinois, Louisiana,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

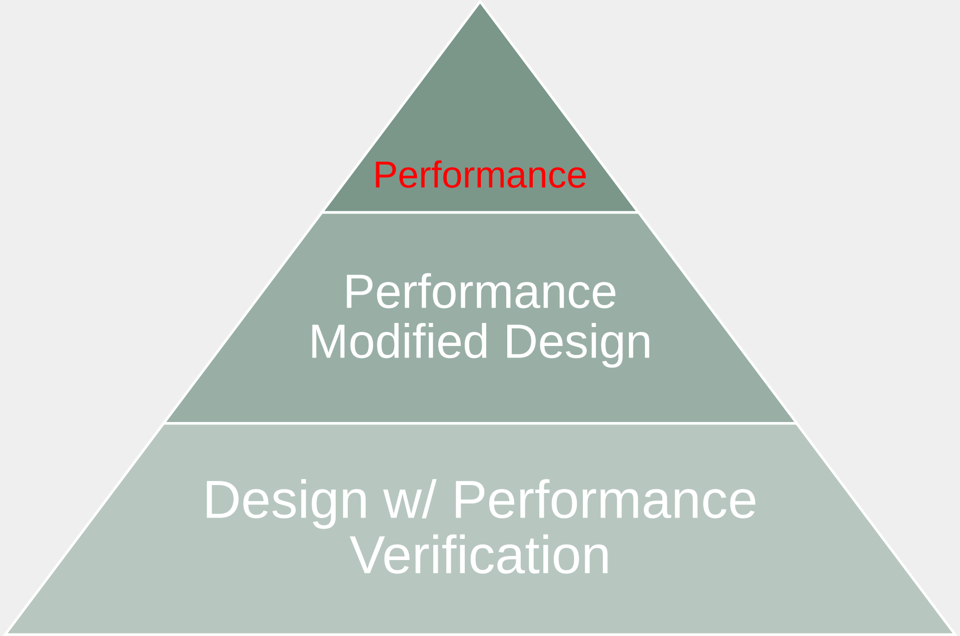
Performance Modified Volumetric Design



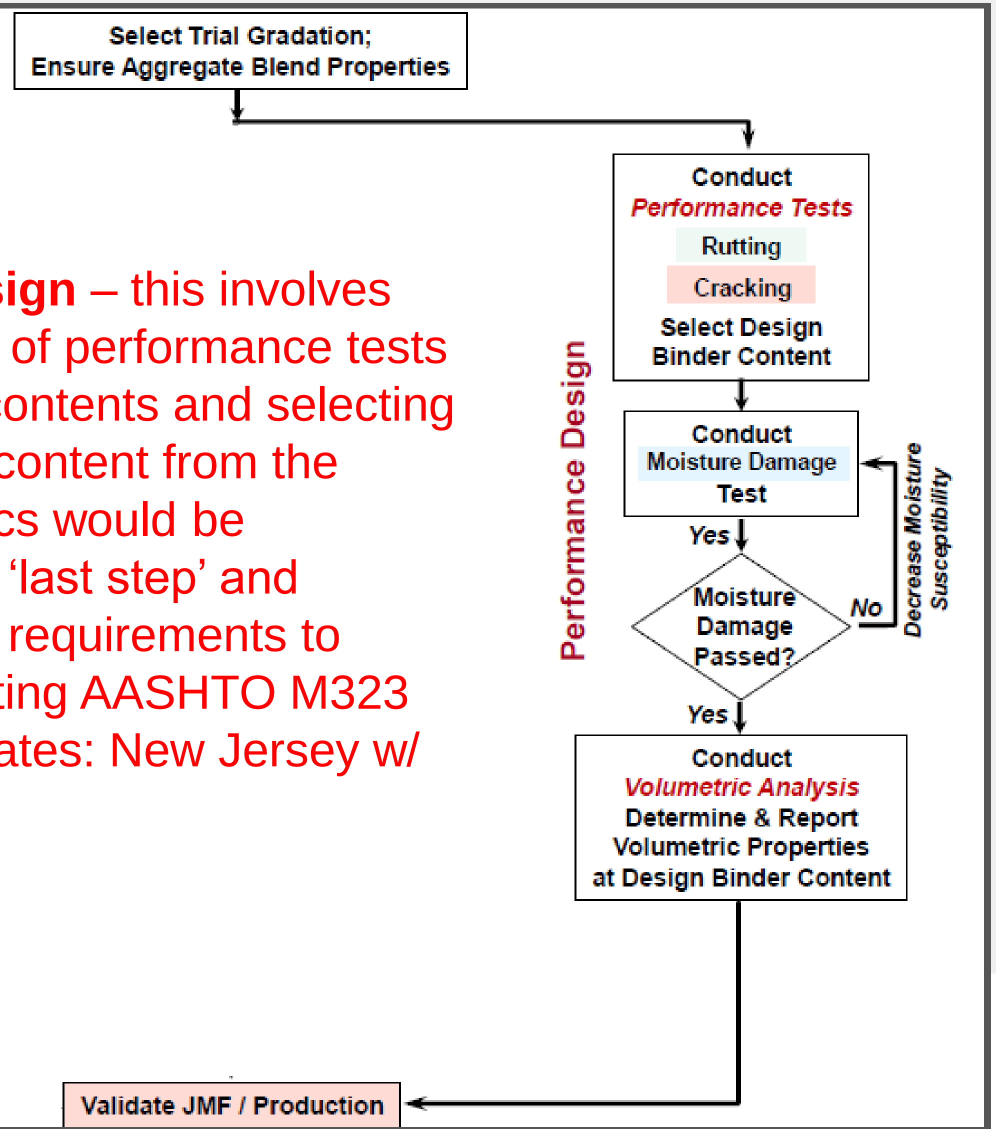


- **Performance-Modified Volumetric Design** – the initial design binder content is selected using AASHTO M323/R35 prior to performance testing; the results of performance testing could 'modify' the mixture proportions (and/or) adjust the binder content – and the final volumetric properties may be allowed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



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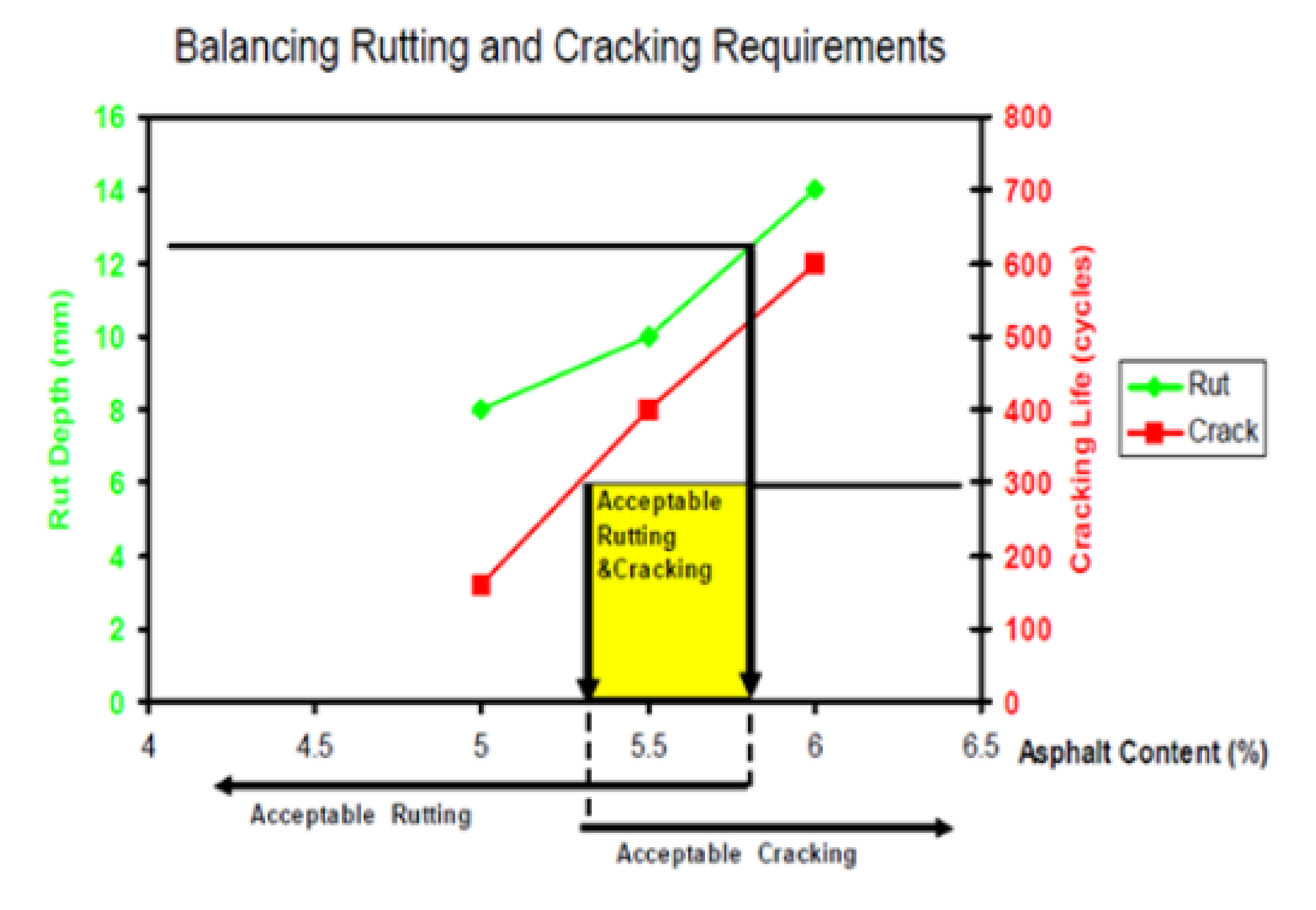
BMD Basic Example – Volumetric Design w/ Performance Verification

- **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.

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How does a BMD compare with a volumetric mix design?

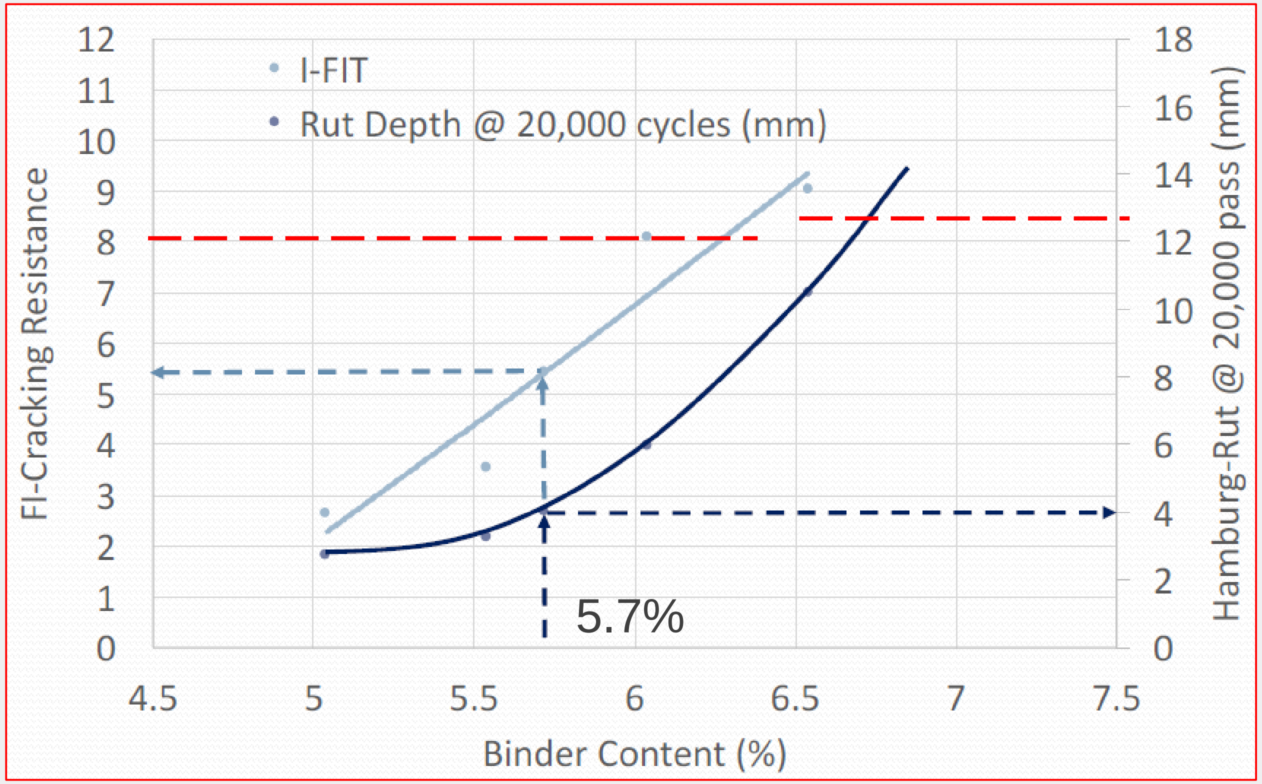
Balanced Mix Design is Really Nothing Totally New!

- Many similarities with older design approaches.

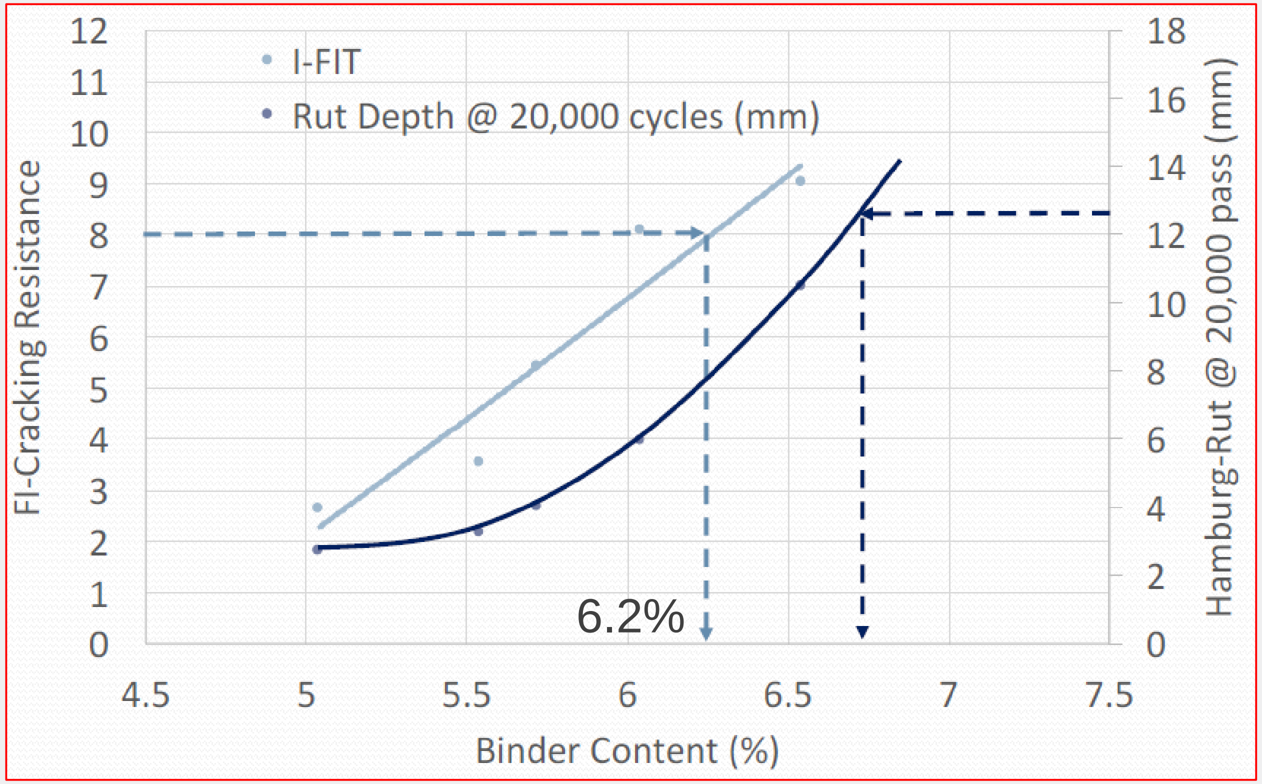
Step	Marshall	Hveem	Balanced Mix Design
Select Asphalt Binder	YES	YES* (CKE for %)	YES
Select Virgin Aggregate	YES	YES	YES
Select Recycle Content	YES	YES	YES
Compact Specimens at a Range of Binder Contents	YES	YES	YES
Calculate Volumetric Properties	YES	YES	YES
Conduct Stability Performance Testing	YES (Marshall Stability)	YES (Hveem Stabilometer)	YES (User Preference)
Conduct "Durability" Performance Testing	YES (Marshall Flow)	YES (Hveem Cohesiometer)	YES (User Preference for Target Distress)
Evaluation Performance Tests Against Developed Mix Specific Criteria	YES	YES	YES
Select Optimum Binder Content	YES	YES	YES
Determine Volumetric Properties at Optimum Binder Content	YES	YES	YES
Evaluate Moisture Susceptibility at Optimum Binder Content	YES	YES	YES
Control Mixture During Production	YES (Volumetrics)	YES (Volumetrics)	YES (Volumetrics and/or Performance Tests)

Volumetric Mix Design vs Balanced Mix Design (*Example*)

VOLUMETRIC



BALANCED



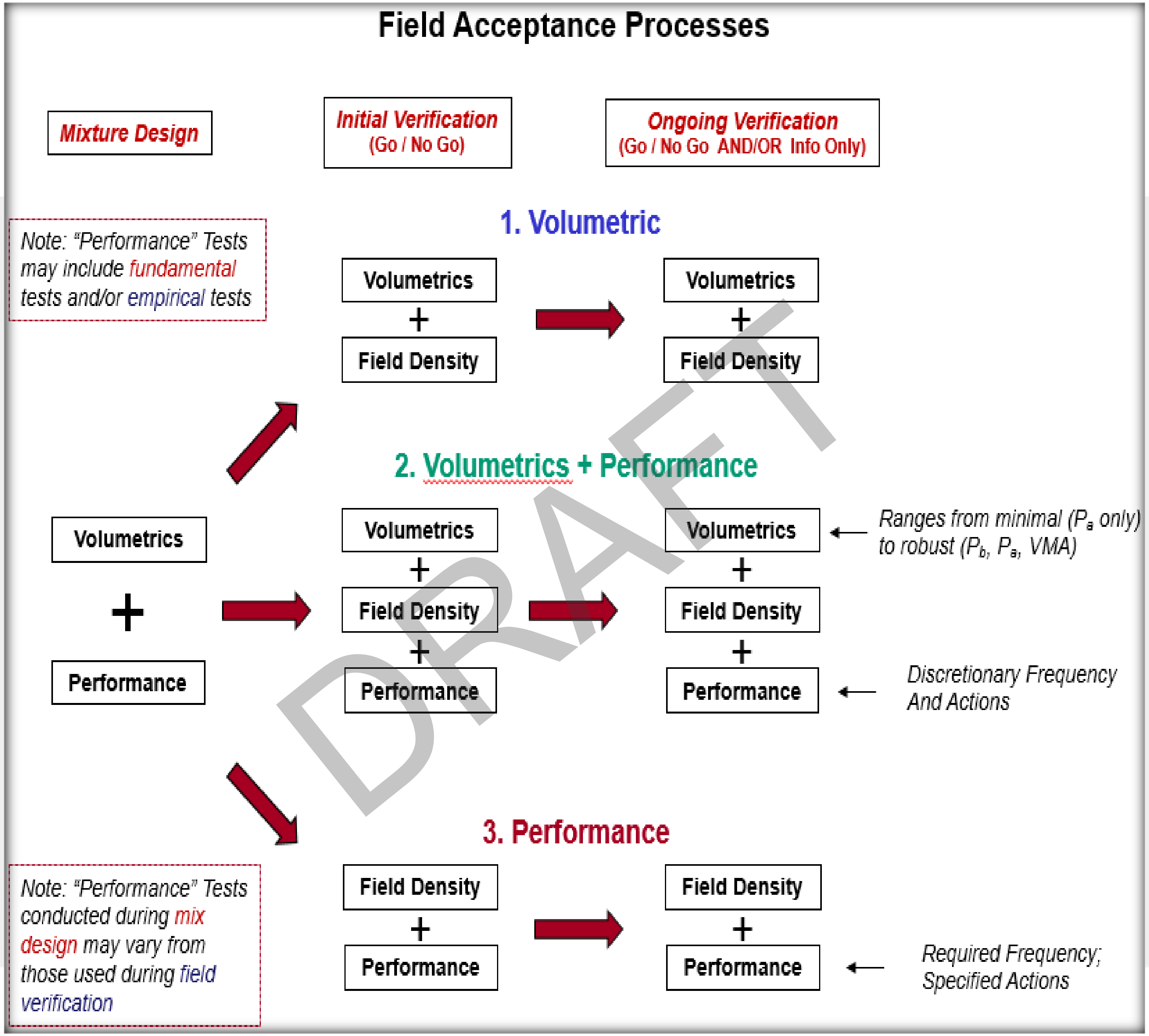
Note: Binder content difference will vary based on the mix specific conditions (e.g., current design, performance thresholds, etc.).

What about acceptance testing with a BMD approach?

BMD Field Acceptance - Approaches

- Three general field acceptance approaches.

1. Volumetric
2. Volumetrics + Performance
3. Performance



Graphic Developed by Kevin Hall (FHWA BMD Task Force), 9/14/2017

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What’s the future of BMD?

Ongoing National Research: NCHRP Project 20-07/Task 406

- **Development of a Framework for Balanced Asphalt Mixture Design**
  - 1 yr / 100k Project, Started May 2017
- The objective of this research is to develop a framework that addresses alternate approaches to devise and implement balanced mix design procedures incorporating performance testing and criteria.
- **The framework shall be presented in the format of an AASHTO recommended practice and shall encompass a wide variety of testing procedures and criteria.**

Framework for Balanced Mix Design

NCHRP 20-07/Task 406

National Center for Asphalt Technology
NCAT
at AUBURN UNIVERSITY

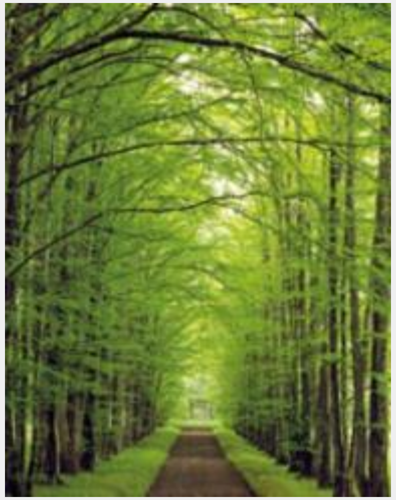
Ongoing State DOT Research

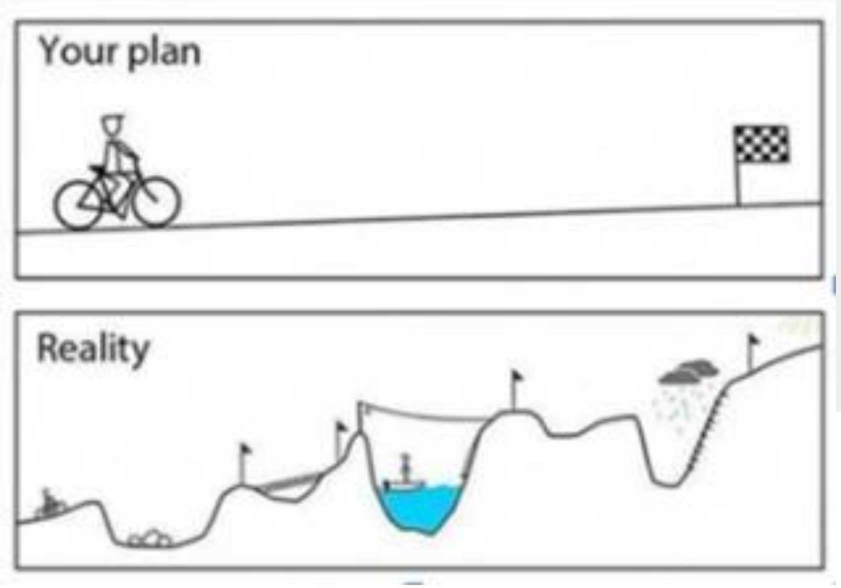
- Various State DOTs have current research activities focused on BMD related activities

State DOT	Research Title
California	Simplified Performance Based Specifications for Long Life AC Pavements
Idaho	Development and Evaluation of Performance Measures to Augment Asphalt Mix Design in Idaho
Indiana	Performance Balanced Mix Designs for Indiana's Asphalt Pavements
Minnesota	Balanced Design of Asphalt Mixtures
Texas	Develop Guidelines and Design Program for Hot-Mix Asphalts Containing RAP, RAS, and Other Additives through a Balanced Mix Design Process
Wisconsin	1. Analysis and Feasibility of Asphalt Pavement Performance-Based Testing Specifications 2. Regressing Air Voids for Balanced HMA Mix Design

The Path Forward for Balanced Mix Design

- Recognize the need and move incrementally in the appropriate direction to limit risk of mix performance issues.
- Continue with theoretical research/modeling efforts, but do not be afraid to utilize **available, proven practical** approaches to find **effective, implementable** solutions.
- Completion of 20-07 Task 406 and the developed AASHTO recommended practice will aid use / implementation.
- **Recognize this is a long term effort with ups/downs, but we must start now.**





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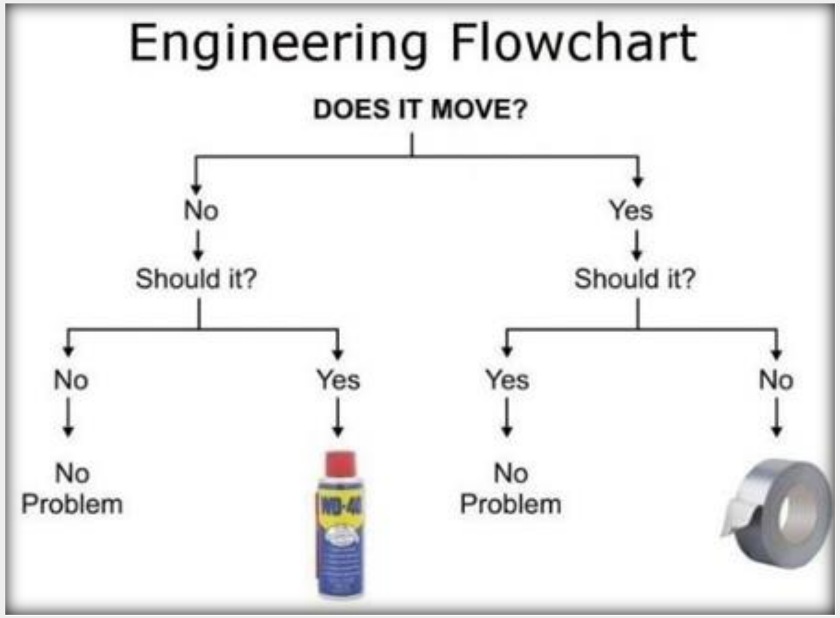
Final Thoughts

- 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!”

Thank You / Questions

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