Balanced Asphalt Mixture Design – National Overview

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Shane Buchanan

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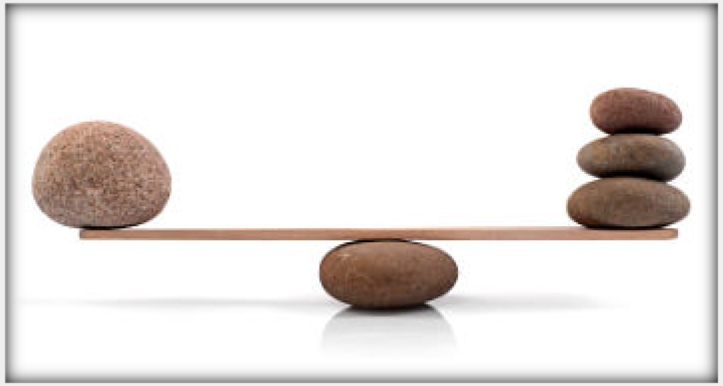
Discussion Items

1. What is Balanced Mix Design (BMD)?
2. Why the need for BMD?
3. What are the most common performance tests (rutting and cracking) for BMD?
4. What is Illinois doing?
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)?

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."***

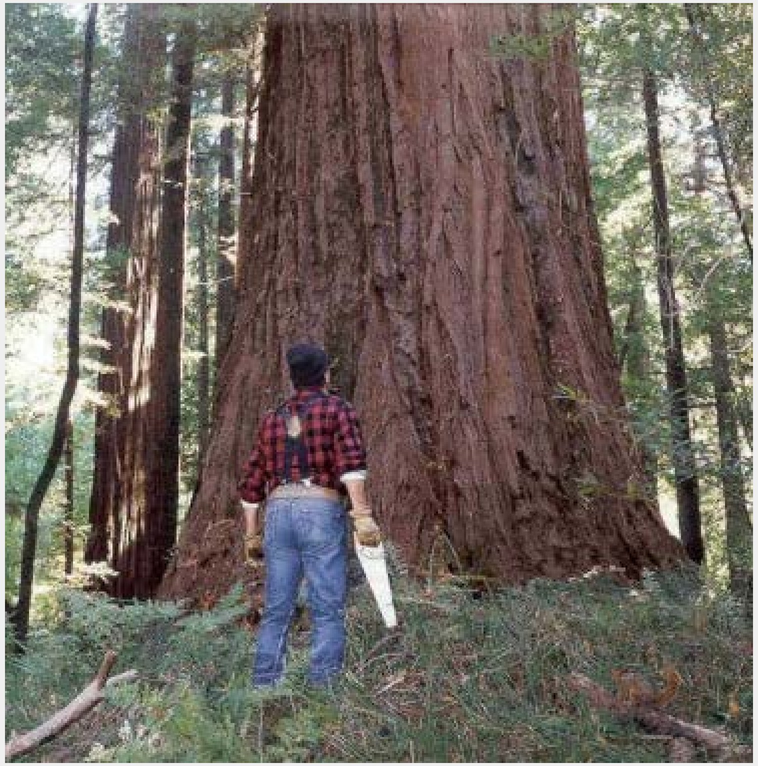
- Use the right mix for the job!

Selecting the Correct Mix

- Using the right mixture for the right job!

- Don’t design a Ferrari, if a Pinto will do the job!

- ***But*** if a Ferrari is needed, don’t provide a Pinto!



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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:**
  1. **Recognize performance issues** related to dry mixes in some areas. (Note: Many performance issues are caused by factors outside the mix design.)
  2. **Increase understanding** of the factors which drive mix performance
  3. **Design for performance** and not just to "the spec".
  4. **Start thinking** outside of long held "rules and constraints"
  5. **Innovate!**

Importance of Quality Asphalt Mixtures

- **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*

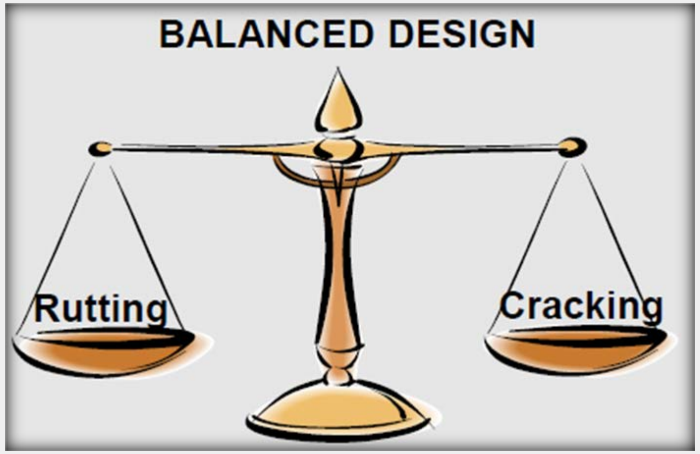
Importance of Quality Asphalt Mixtures - Illinois

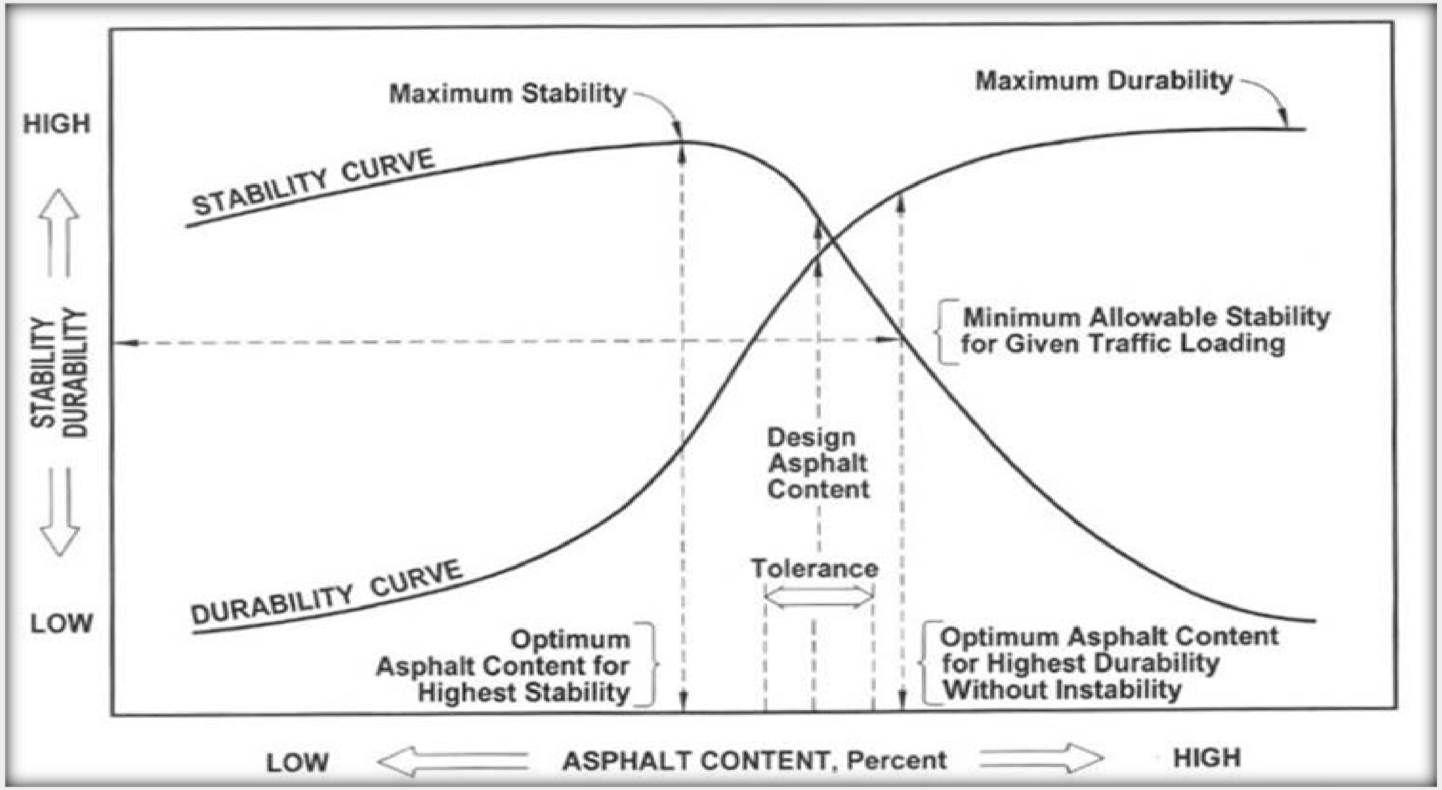
- **Each day**, approximately 52,000 tons of HMA are produced in the Illinois. (M-F production basis)
  - *Equivalent to ~94 lane miles @ 12’ wide and 1.5” thick*

ILLINOIS	Reported Values		Estimated Values	
	2015	2016	2015	2016
Tons of HMA/WMA Produced	Tons, Millions		Tons, Millions	
Total	5.2	2.2	15.8	14.1
DOT	2.3	0.8	7.1	5.0
Other Agency	1.6	0.8	4.9	5.0
Commercial & Residential	1.3	0.6	3.9	4.2
Companies Reporting	15	10		

Pavement Performance General Overview

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





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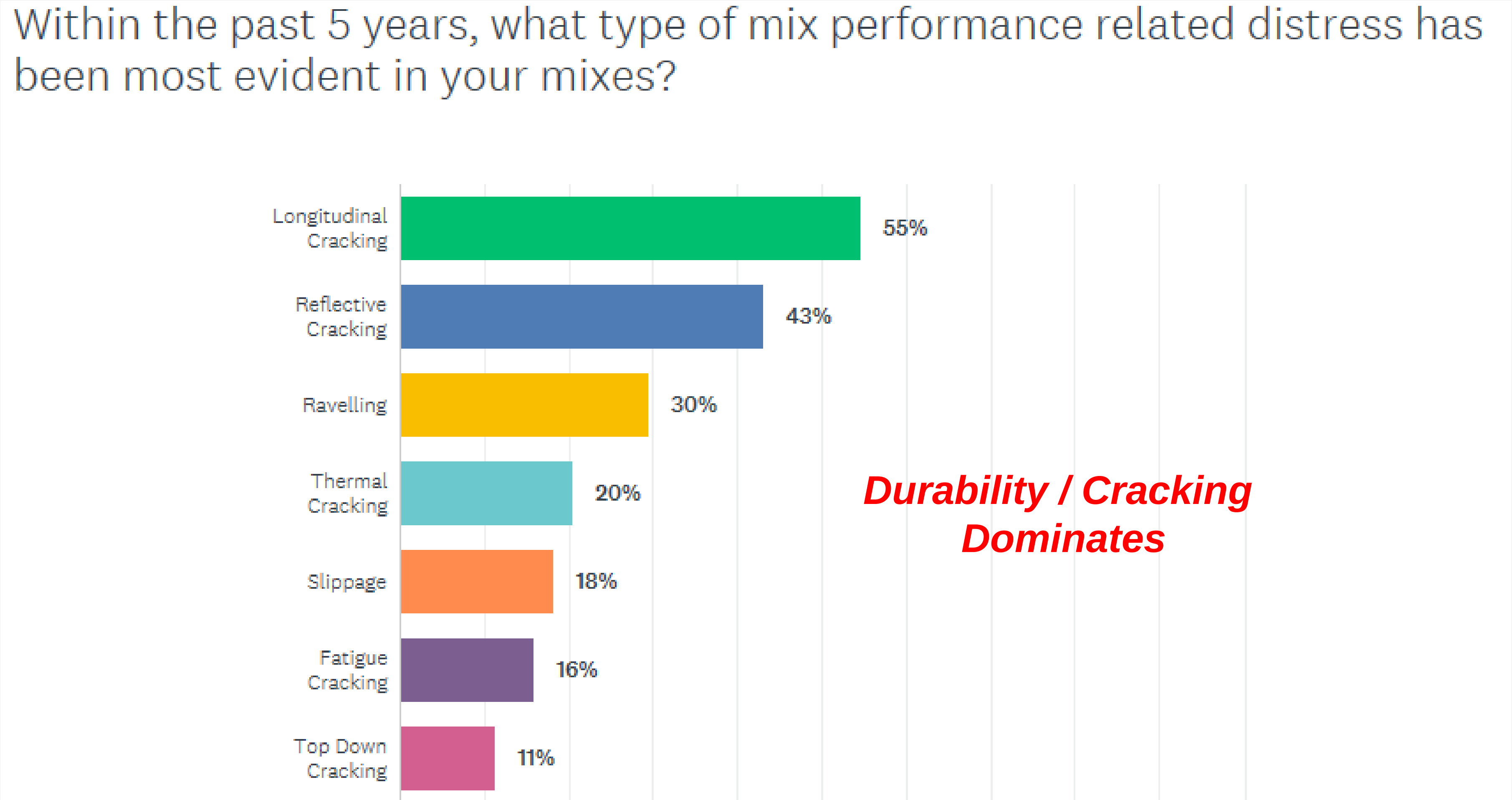
What Type Distress Is Occurring?



Source: Oldcastle Intercompany Survey 2015

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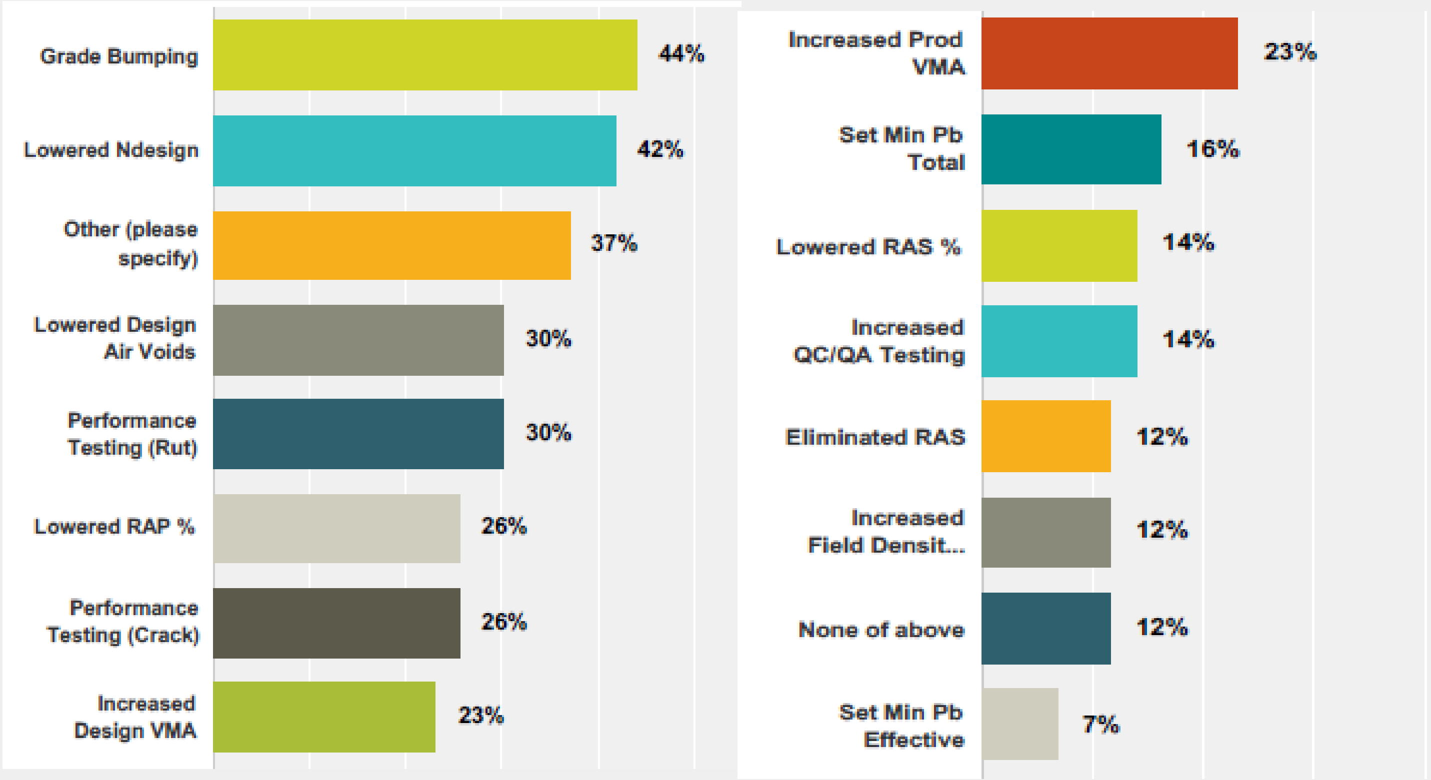
Agencies Are Searching for Solutions: Spec Changes

- 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**

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



Source: Oldcastle Intercompany Survey 2015

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Agencies are Searching for Solutions: Example

- Alabama DOT Example
  1. Ndesign = 60 gyrations for all mixes
  2. Increased design VMA by 0.5%
  3. Minimum total binder content for non-RAS and RAS mixes (0.2% higher)
  4. 3.5% design voids for RAS mixes

1. AIR VOIDS (Va).

The design air voids for all levels of traffic is 3.5 % for mixes containing RAS and 4.0 % for all other mixes.

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2. VOIDS IN MINERAL AGGREGATE (VMA).

The job mix shall be designed at a minimum VMA given in the following table.

VOIDS IN MINERAL AGGREGATE DESIGN VMA FOR SUPERPAVE ***		
Maximum Aggregate Size * (inches) {mm}	Nominal Aggregate Size (inches) {mm}	Minimum VMA (%)
3/8 {9.5 }	No. 4 {4.75}	16.5 **
1/2 {12.5 }	3/8 {9.5}	15.5
3/4 {19.0 }	1/2 {12.5}	14.5
1 {25.0 }	3/4 {19.0}	13.5
1.5 {37.5 }	1 {25.0}	12.5

2

* As defined in Subarticle 424.02(c)
** All 3/8" (9.5 mm} mixes where the ESAL range is greater than A/B shall have a maximum VMA of 18.0.
*** Production VMA may be 0.5 lower than design VMA.

LIQUID ASPHALT BINDER CONTENT (Pb) CRITERIA FOR SUPERPAVE			
Maximum Aggregate Size* (inches) {mm}	Nominal Aggregate Size (inches) {mm}	Minimum Liquid Asphalt Binder Content (Pb) by Percent of Total Mix**	Minimum Liquid Asphalt Binder Content (Pb) for mixes containing RAS by Percent of Total Mix**
3/8 {9.5 }	No. 4 {4.75}	5.90	6.1
1/2 {12.5 }	3/8 {9.5}	5.50	5.7
3/4 {19.0 }	1/2 {12.5}	5.10	5.3
1 {25.0 }	3/4 {19.0}	4.40	4.6
1.5 {37.5 }	1 {25.0}	4.20	4.4

* As defined in Subarticle 424.02(d)
** Nd = 60

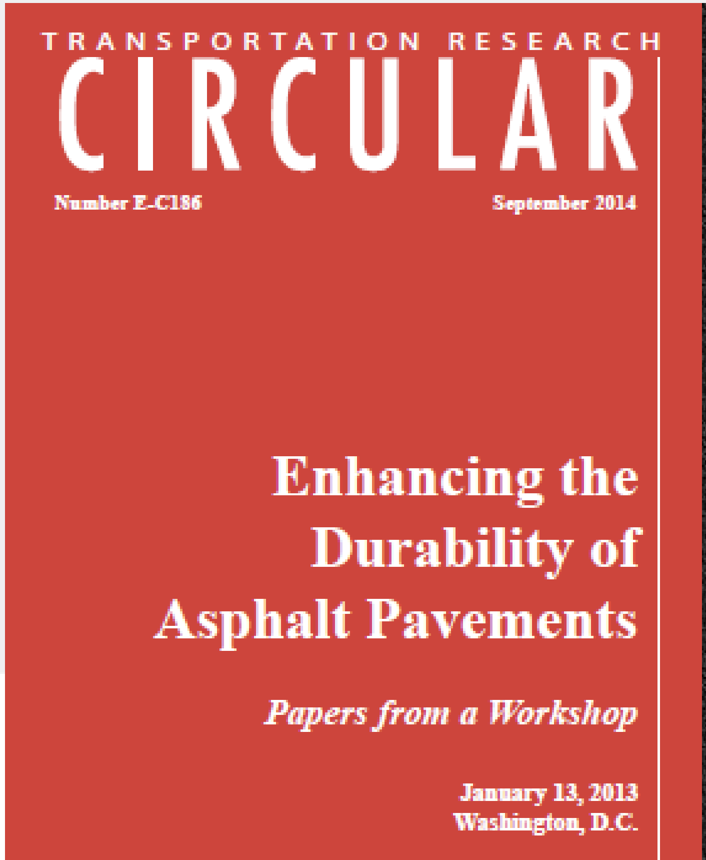
3

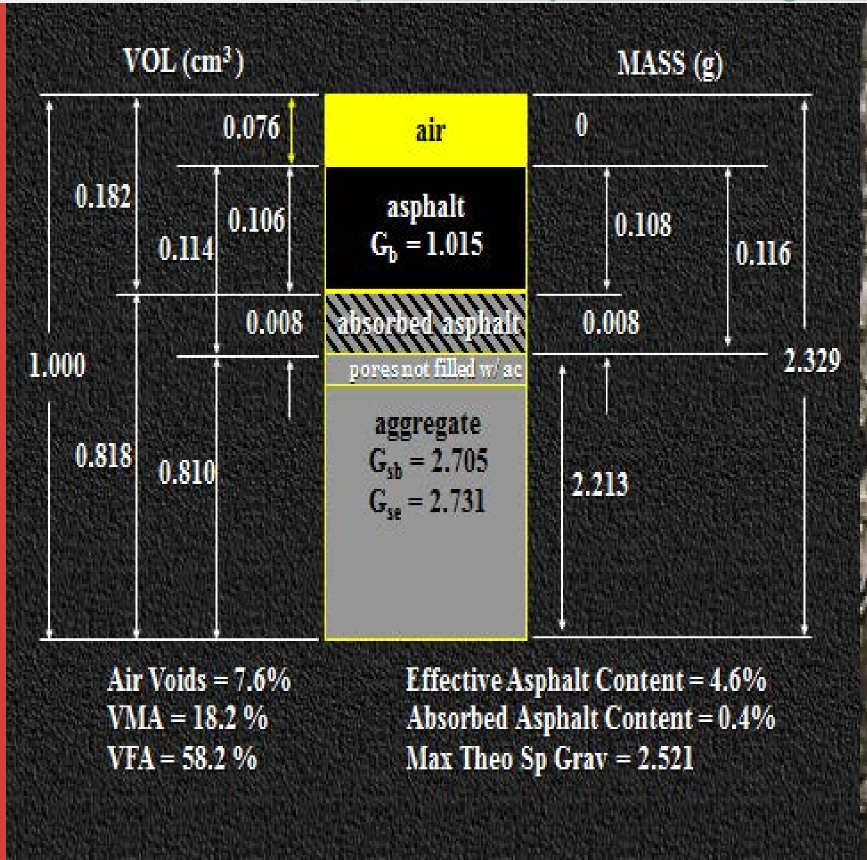
1

What is the Main Key to Enhancing the Durability of Asphalt Mixtures?

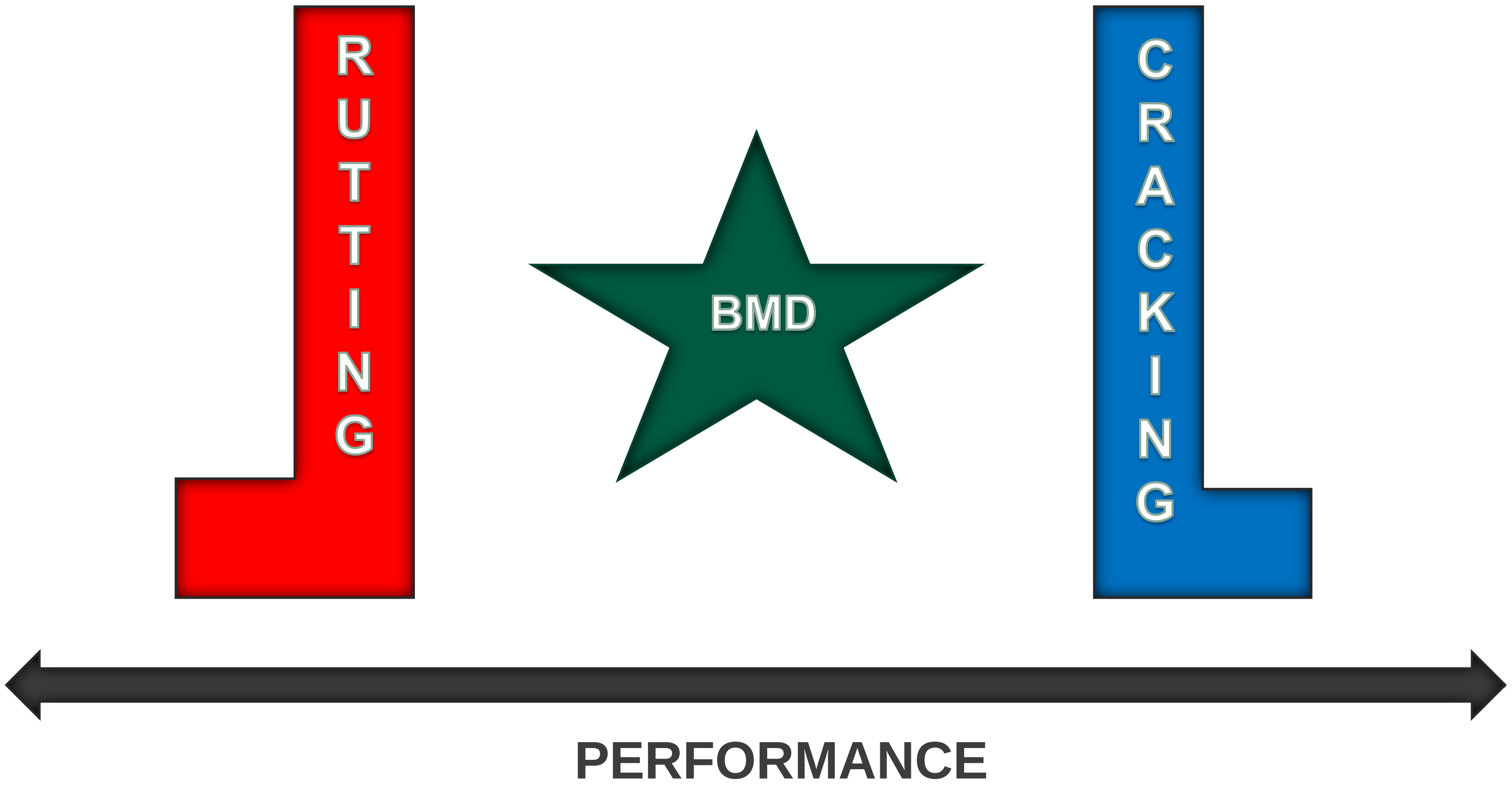
- "**Volume of Effective Binder (Vbe)** is the primary mixture design factor affecting both durability and fatigue cracking resistance."
  - ***Vbe = VMA – Air Voids***

http://onlinepubs.trb.org/onlinepubs/circulars/ec186.pdf





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



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Why Should We Test Mixtures in the Lab?

- Mixtures need to be evaluated in the lab 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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Main Pavement Distresses Observed in the Field

Moisture Damage

Permanent Deformation

Fatigue Cracking

Thermal Cracking

Reflection Cracking

Top-down Cracking

Source: NCAT

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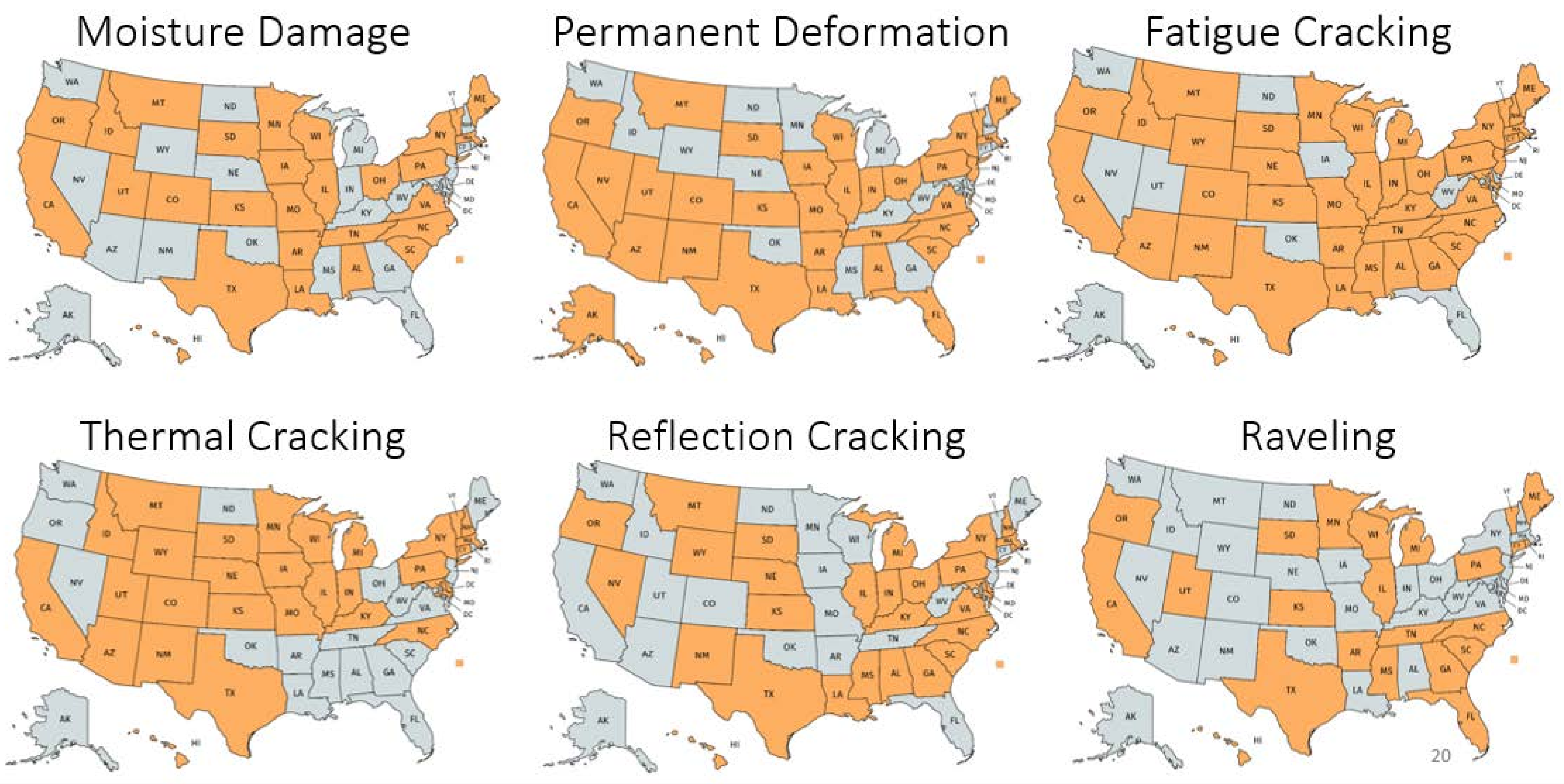
What Distress Does Your State Want to Address with Performance Testing?

Answers (DOT)	# (%) Response
Fatigue cracking	40 (88%)
Rutting	33 (70%)
Thermal cracking	30 (64%)
Reflection cracking	29 (62%)
Moisture damage	28 (60%)
Raveling	23 (49%)
Others (block cracking, slippage, etc.)	22 (51%)

Source: NCAT Survey



Rutting Tests

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

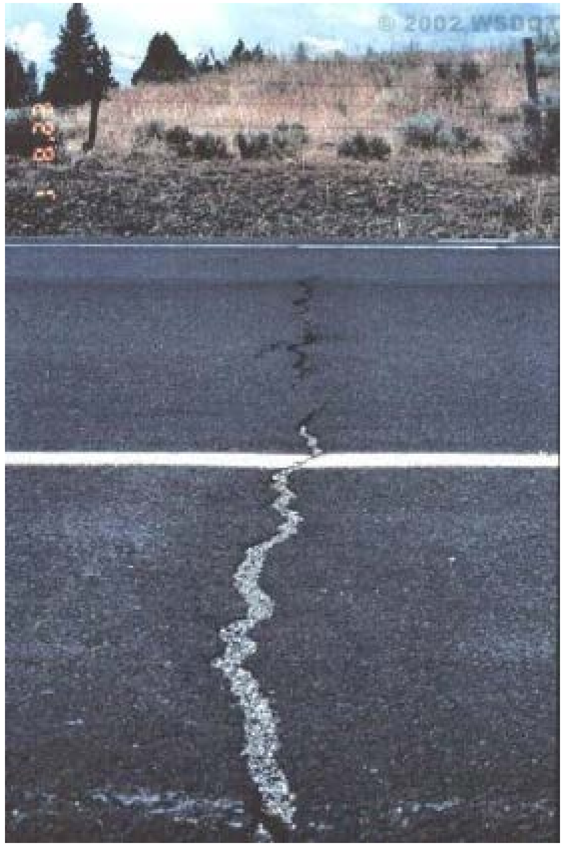
Hamburg Wheel Test (HWT)

Asphalt Pavement Analyzer (APA)

AMPT Flow Number

Most commonly used tests. Hamburg gaining popularity due to moisture susceptibility analysis.

Durability Testing (Cracking)



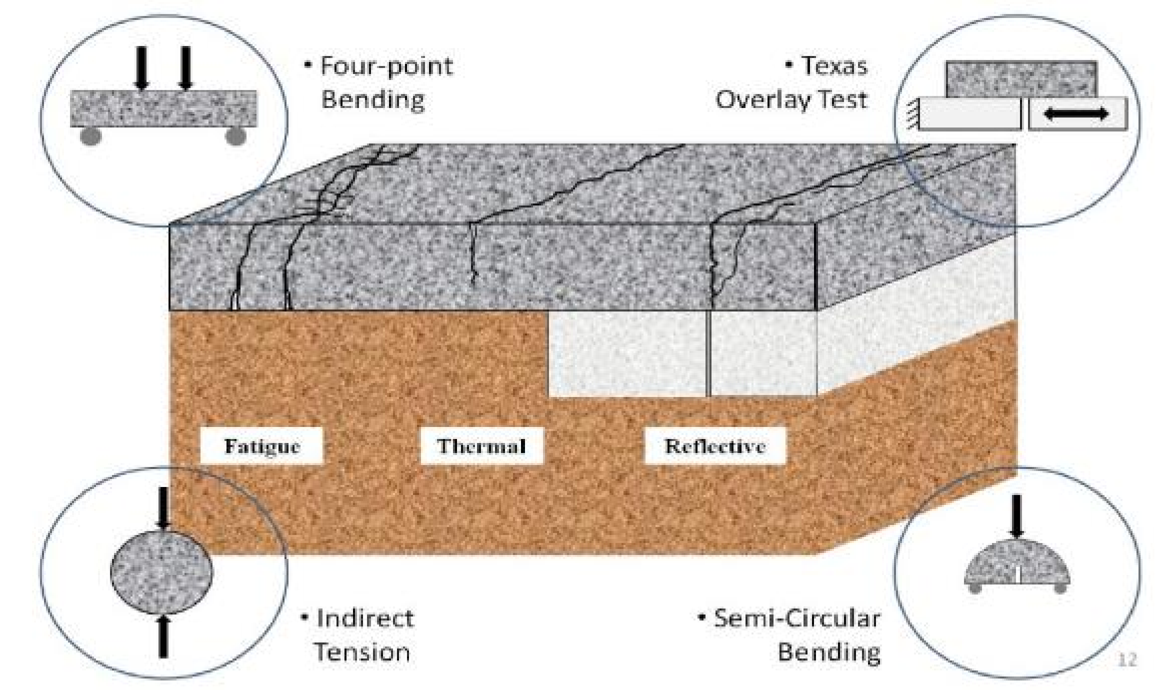
Durability/Cracking Evaluation

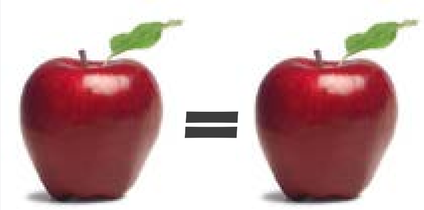
- Durability/cracking evaluation is substantially more complicated than stability with aging being one main variable.
- No general consensus the best test(s) or the appropriate failure threshold.
- MANY different tests are available with more being developed.
- Main question is “**What is the anticipated mode of distress?”**

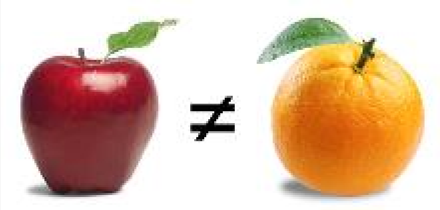


First Question for Durability Testing:
What is the Anticipated Mode of Distress for Testing?

- Many test are available with each targeting a specific specimen response (i.e., field 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	Bottom Up	Bottom Up / Top Down	Bottom Up
			
Bending Beam Fatigue	**Texas Overlay Test**	**SCB** - **LTRC – Jc** - **IFIT**	**Direct Tension Cyclic Fatigue, S-VECD**

Thermal Cracking Tests

IDT Creep Compliance

TSRST

SCB at Low Temp

Disk Shaped Compact Tension (DCT)

Reflection (Reflective) Cracking Tests

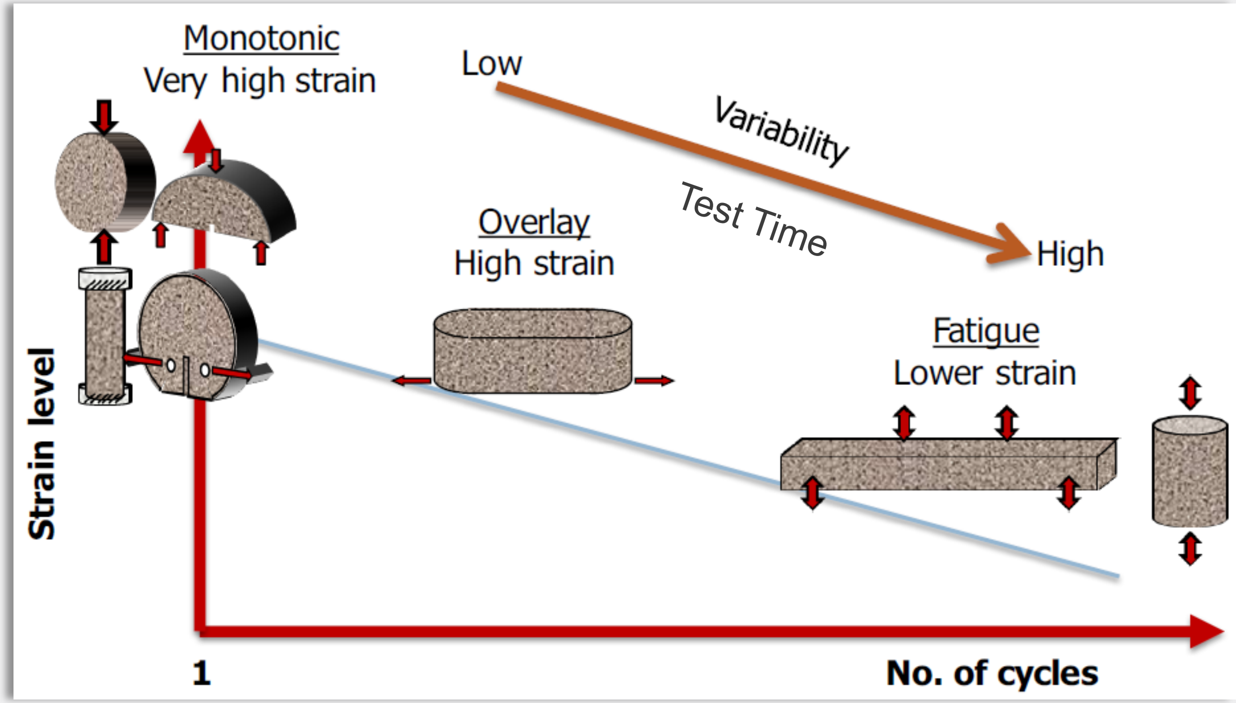
Disk Shaped Compact Tension (DCT)

Texas Overlay Test

SCB (IFIT)

Performance Tests

- **Empirical** tests will tend to have monotonic loading + high strains and can be conducted in a shorter time period.
- **Mechanistic** tests will tend to have cyclic loading + low strains and will require a longer test time.
- Each test is developed to **evaluate a certain mixture response.**
- Multiple tests may be needed.
- Use caution when trying to relate one test to another (e.g., IFIT vs DCT).

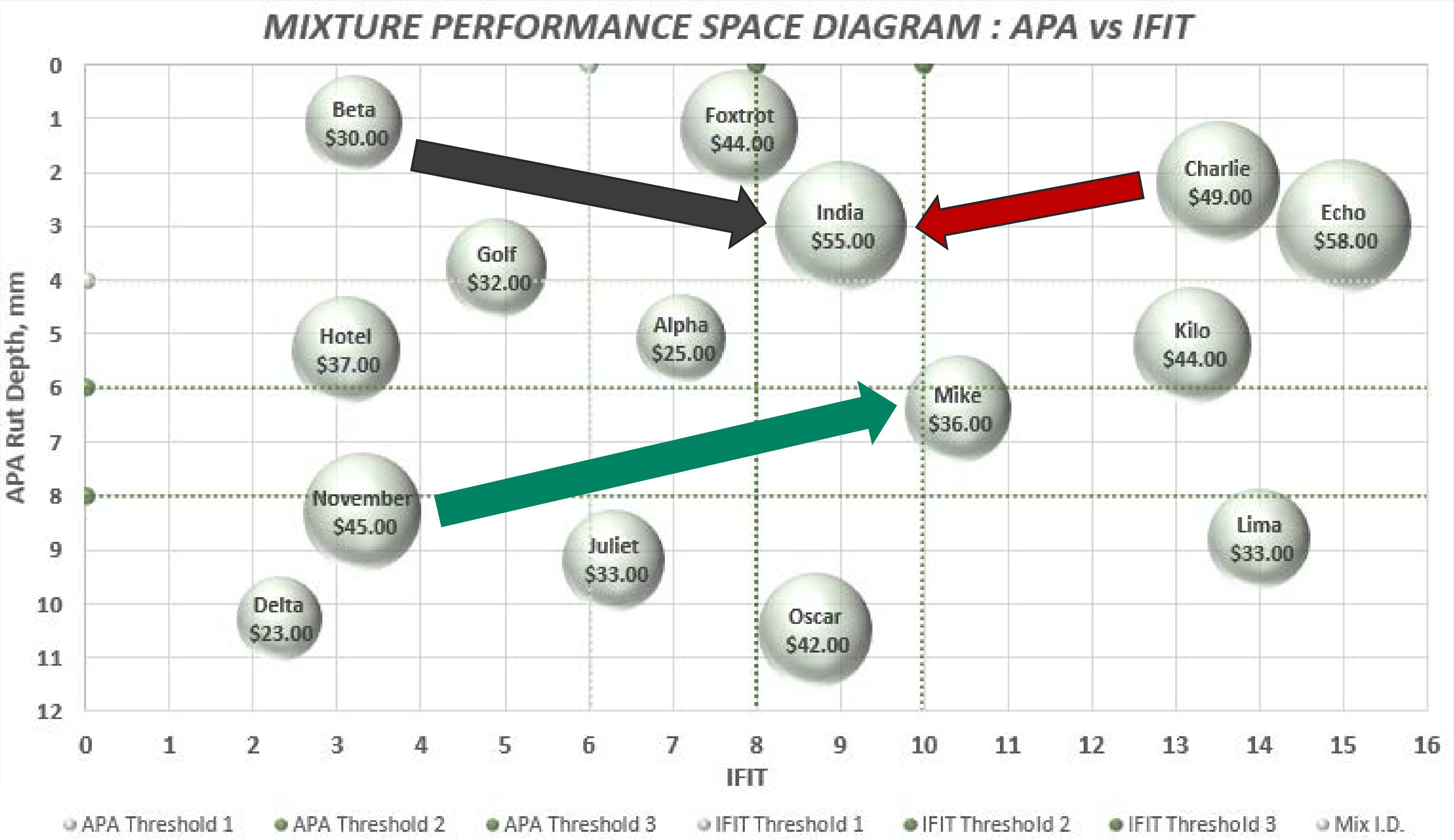


Key Test Considerations

1. *Strong relationship to performance*
2. *Sensitive to mix variation (e.g., binder, aggregate, grading, etc.)*
3. *Practical: cost, time, complexity*
4. *Repeatable, reproducible*

Performance Space Diagrams

- Performance testing within a BMD allows an improved visualization of mix performance relative to economics.
- **Allows for effective mix optimization!**



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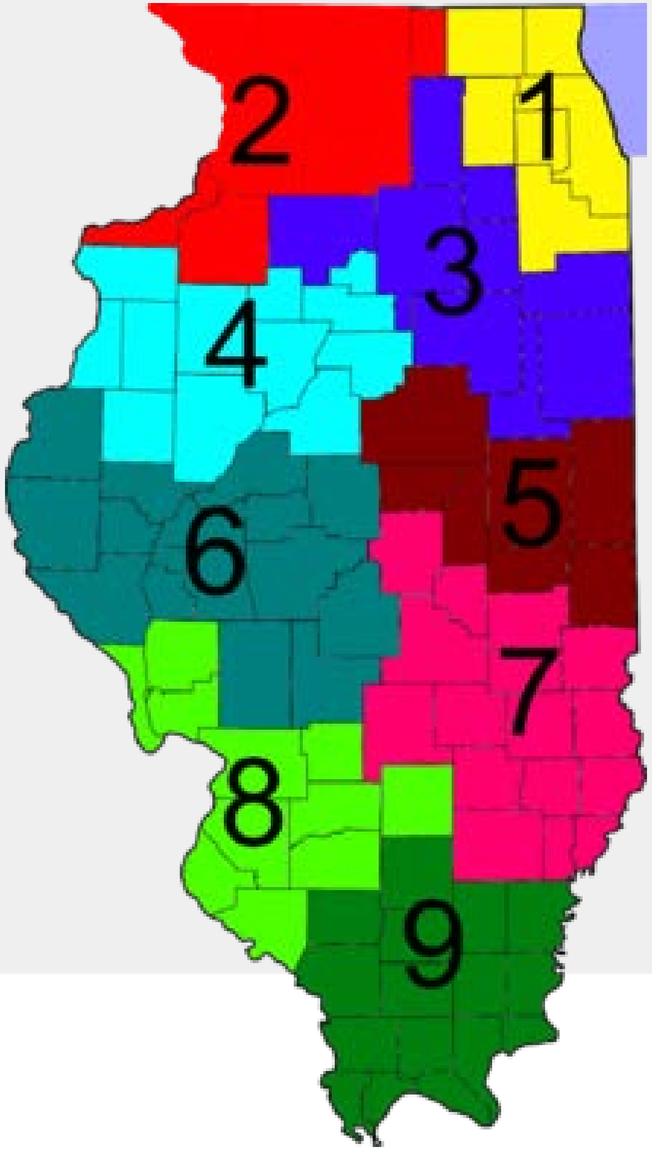
Example Data for Illustration Purposes

What’s Illinois DOT Doing?

IDOT – BMD (IFIT) Activities

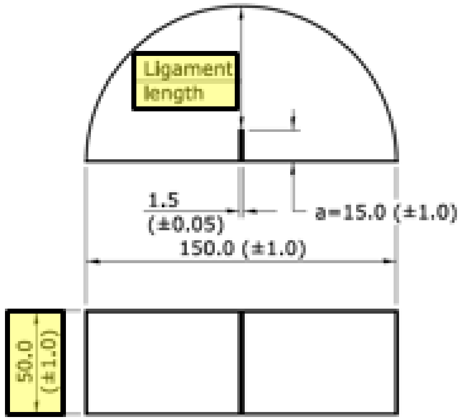
- Illinois DOT is a leader for the asphalt industry (agency + contractor).
- **Work efforts with BMD, specifically the IFIT development, should be applauded and serve as a model for other states!**

Illinois Department of Transportation

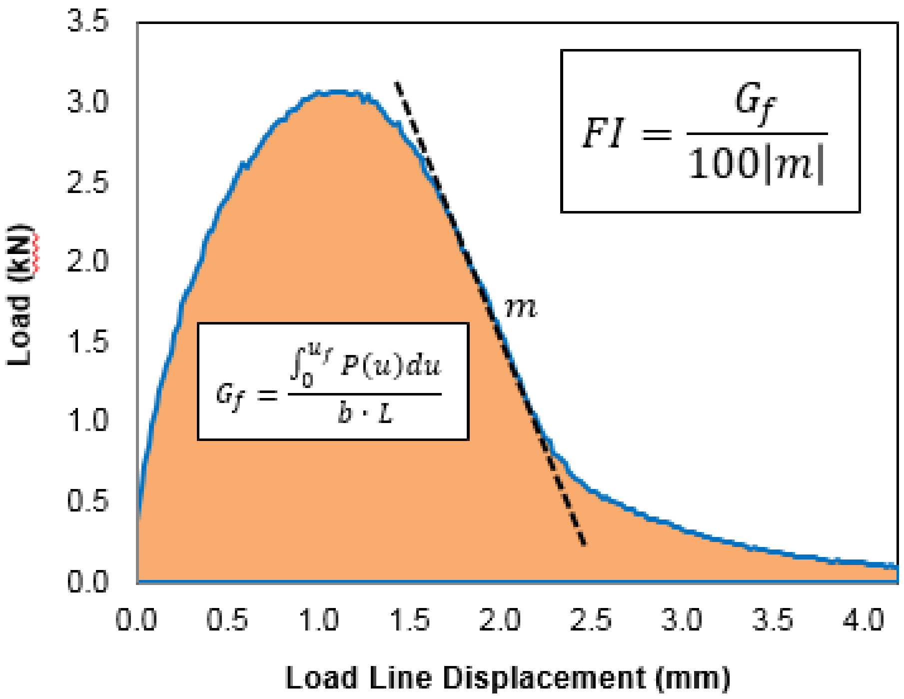


IFIT Overview

- ITP 405/AASHTO TP124
- Conditioning
  - 25°C ± 0.5°C for 2.0 ± 0.5h
- Load Line Displacement Loading Rate
  - 50mm/min



Units in mm



Illinois Department of Transportation

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Source: Brian Hill, Illinois Department of Transportation's Implementation of I-FIT, NAPA Mid Year Meeting 2017

IDOT – BMD (Hamburg and IFIT)

(1) Hamburg Wheel Test Criteria. The maximum allowable rut depth shall be 0.5 in. (12.5 mm). The minimum number of wheel passes at the 0.5 in. (12.5 mm) rut depth criteria shall be based on the high temperature binder grade of the mix as specified in the mix requirements table of the plans.

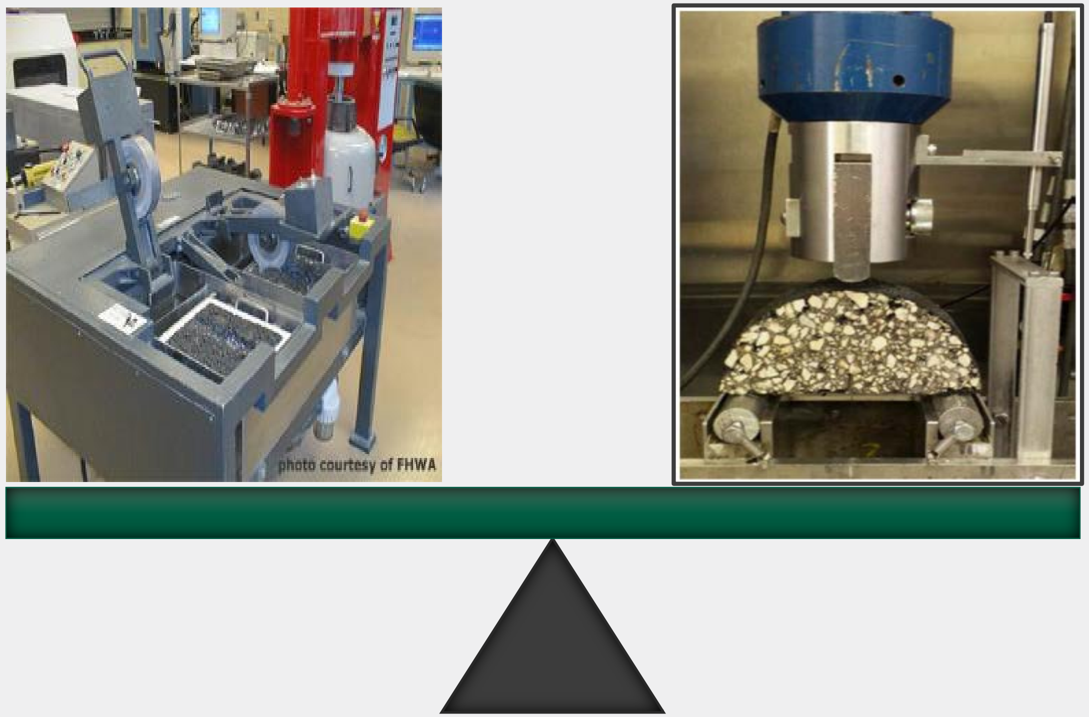
Illinois Modified AASHTO T 324 Requirements [1/]

PG Grade	Number of Passes
PG 58-xx (or lower)	5,000
PG 64-xx	7,500
PG 70-xx	15,000
PG 76-xx (or higher)	20,000

(3) I-FIT Flexibility Index (FI) Criteria[1/]. The minimum allowable FI shall be as follows:

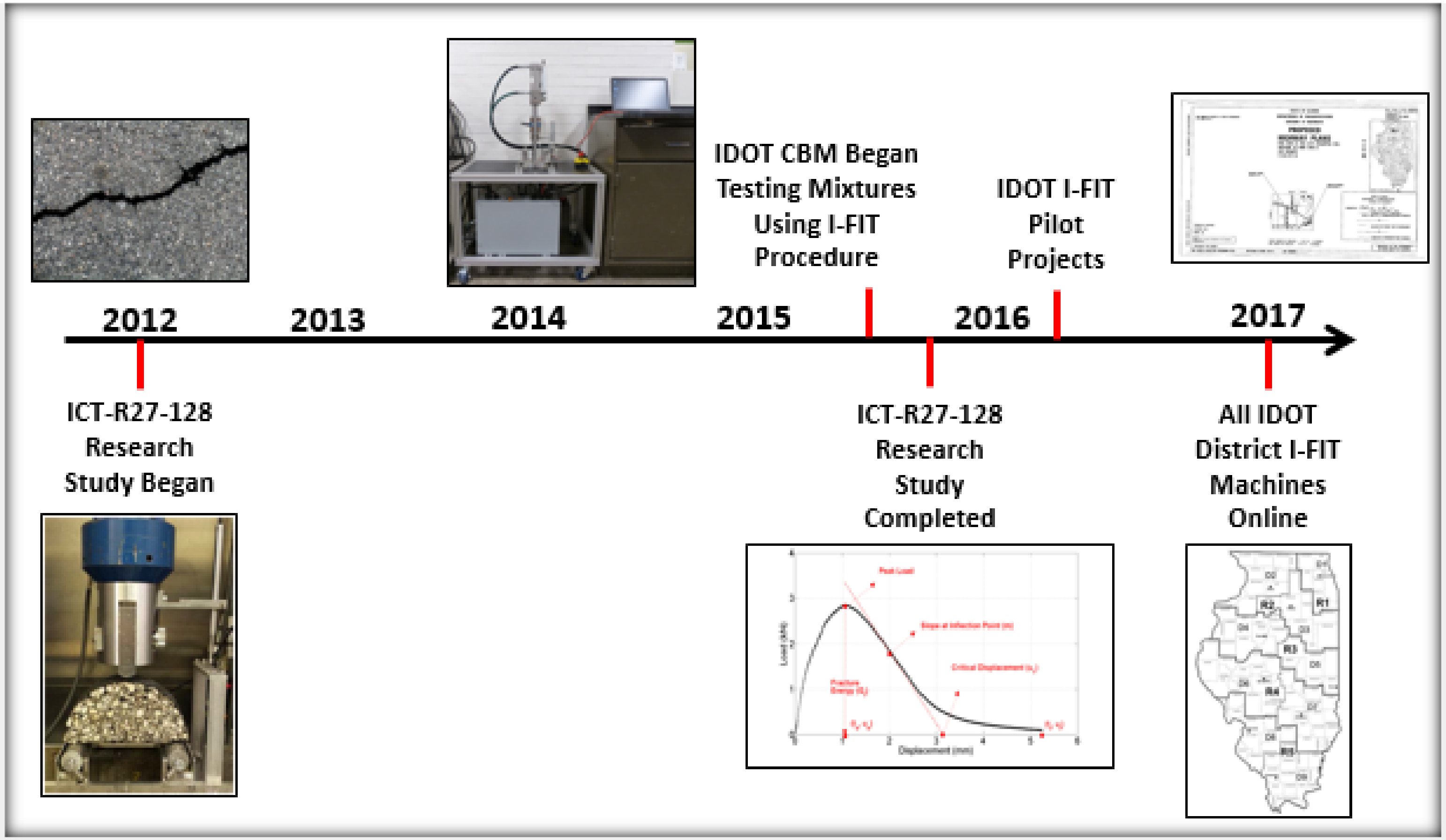
Minimum Flexibility Index (FI)	
HMA	8.0
SMA	8.0

Hamburg **IFIT**



IDOT – BMD (IFIT) Activities

- Per Brian Pfeifer…
  - In 2016, the Districts constructed 11 pilot projects statewide and DOT purchased I-FIT equipment for all the Districts
  - In 2017, I-FIT spec was used on another 15 projects, with most of those completed
  - Completed three sets of round robin testing with 30 labs.
  - Collected data from over 700 different mixes statewide
  - Phase in implementation, with Interstate projects in 2019 and full implementation in 2020
  - Research underway focused on aging



Source: Brian Hill, Illinois Department of Transportation's Implementation of I-FIT, NAPA Mid Year Meeting 2017

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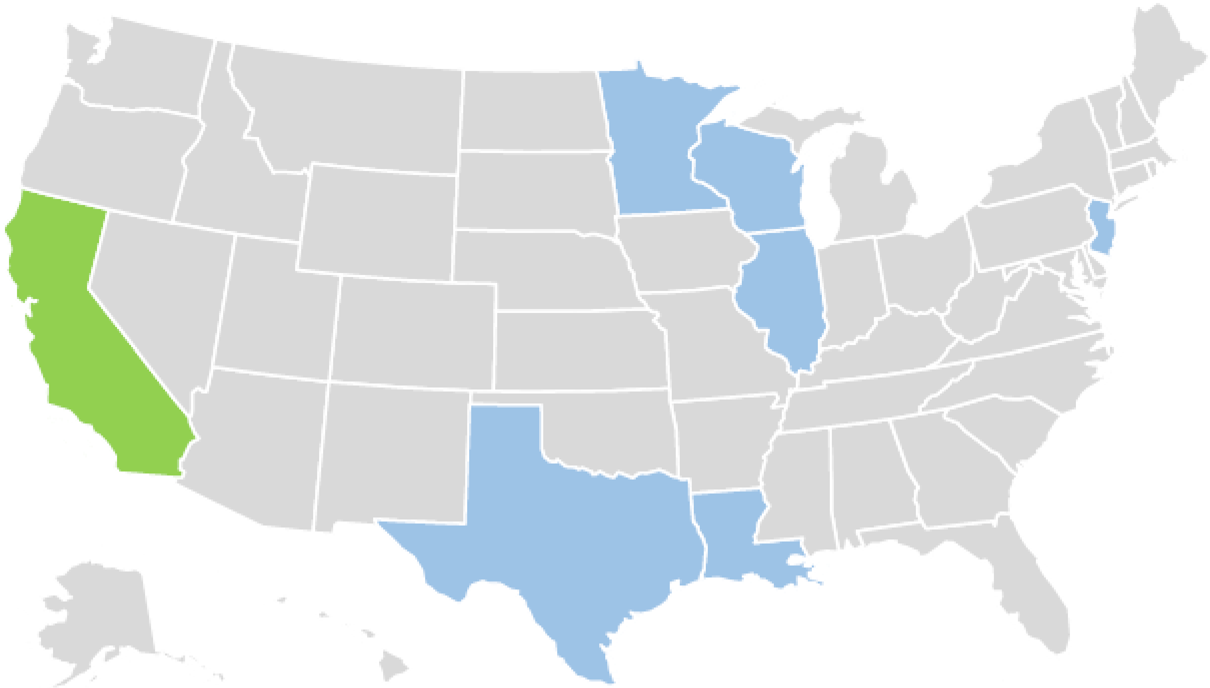
What is the current national state of practice for BMD?

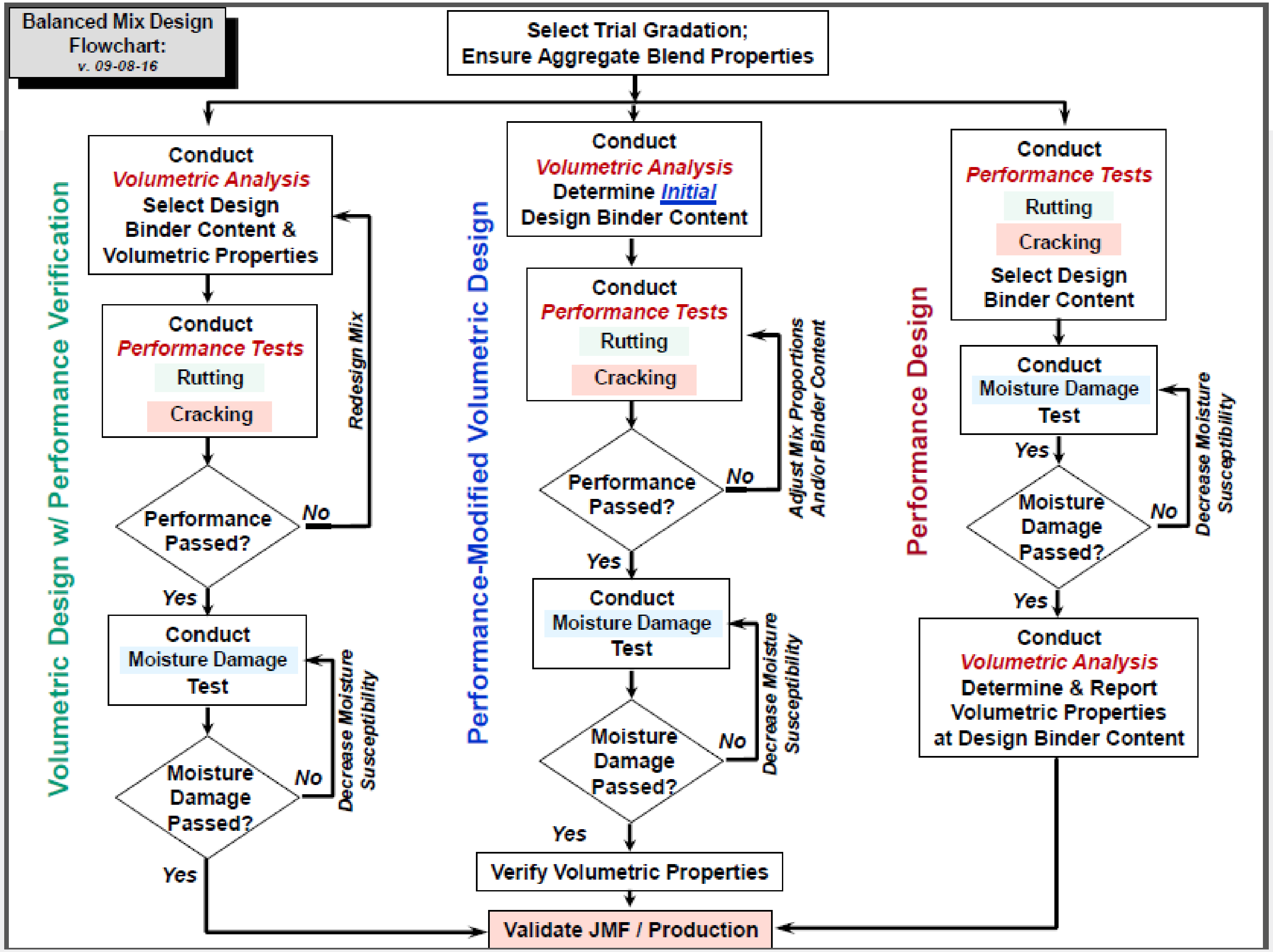
Agency Practices For Balanced Mix Design



BMD Approaches

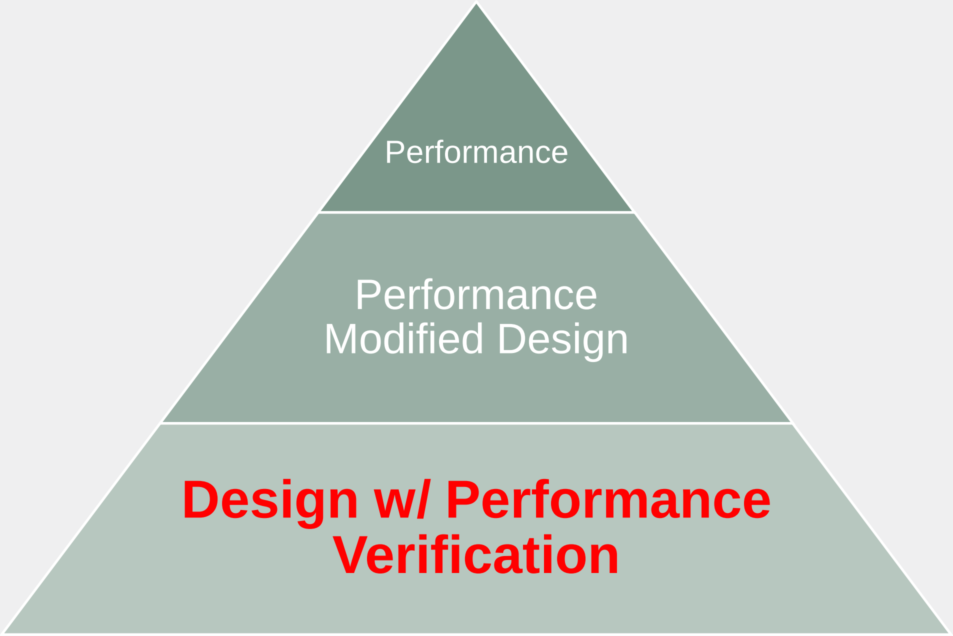
- Three general mix design approaches.

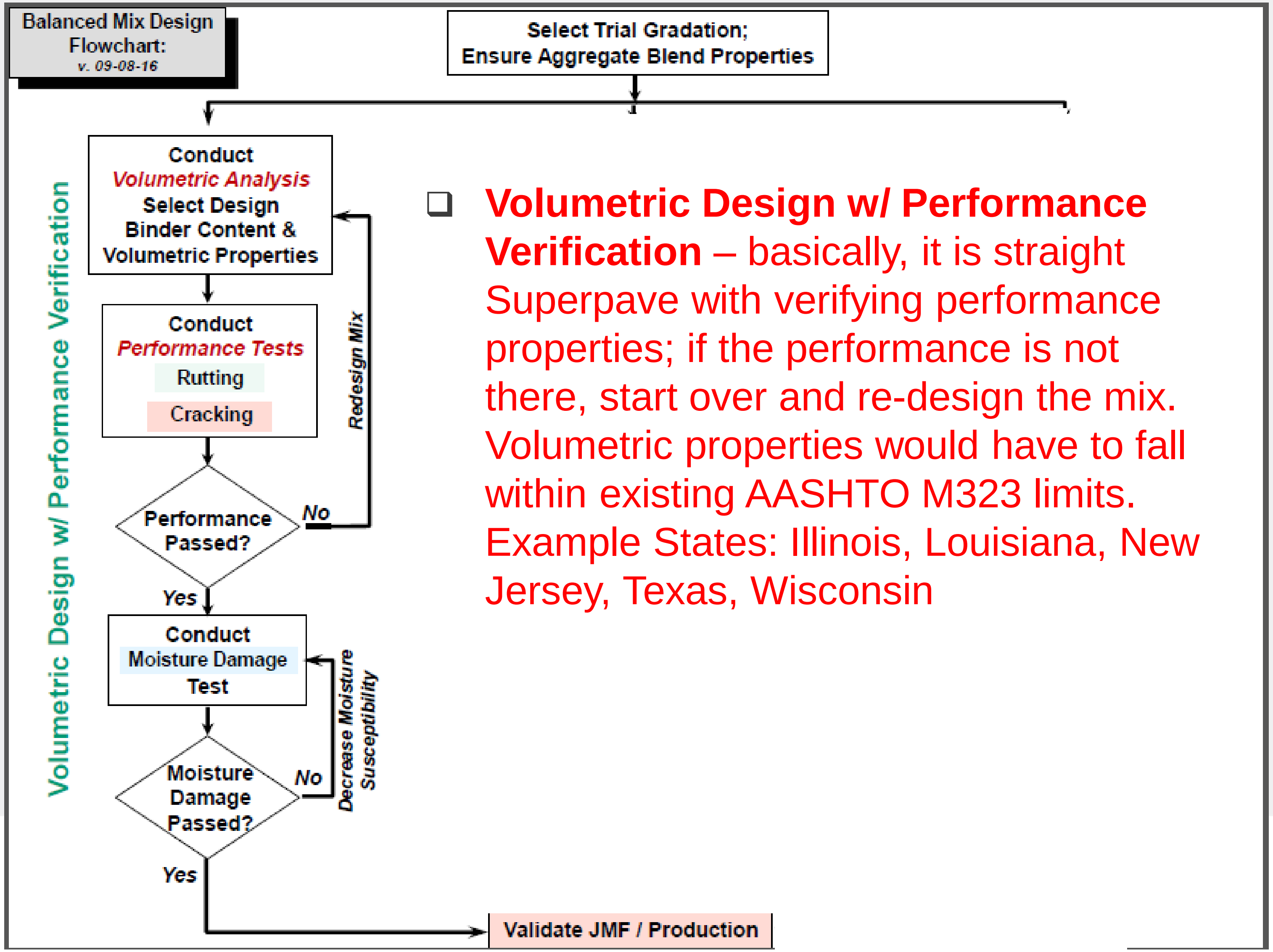
1. Volumetric Design w/ Performance Verification
2. Performance Modified Volumetric Design
3. Performance Design



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

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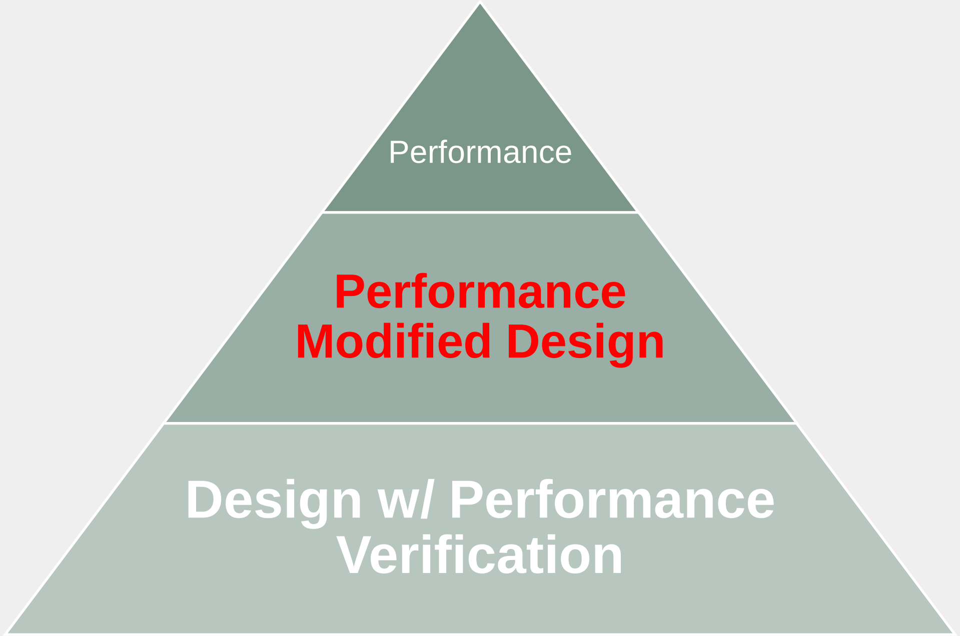
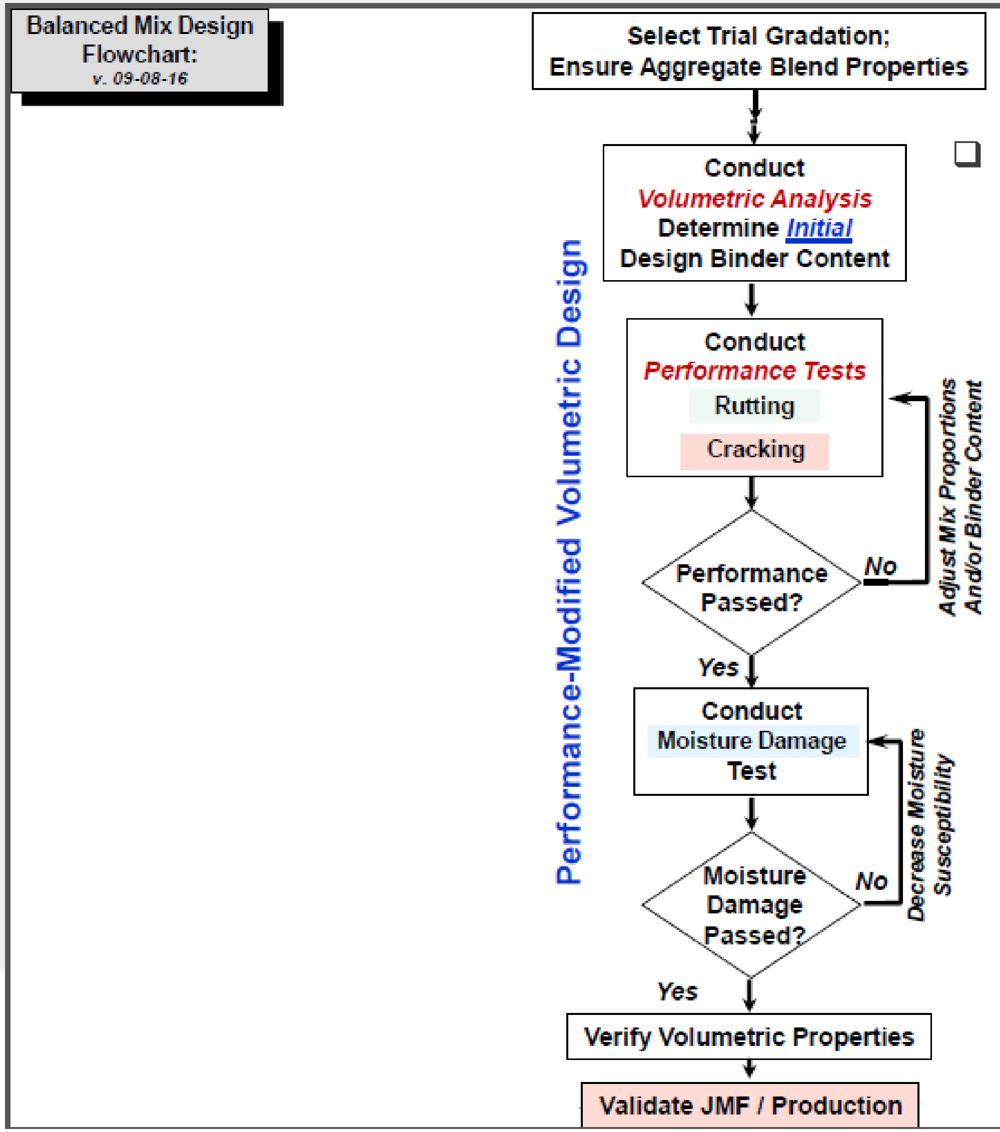
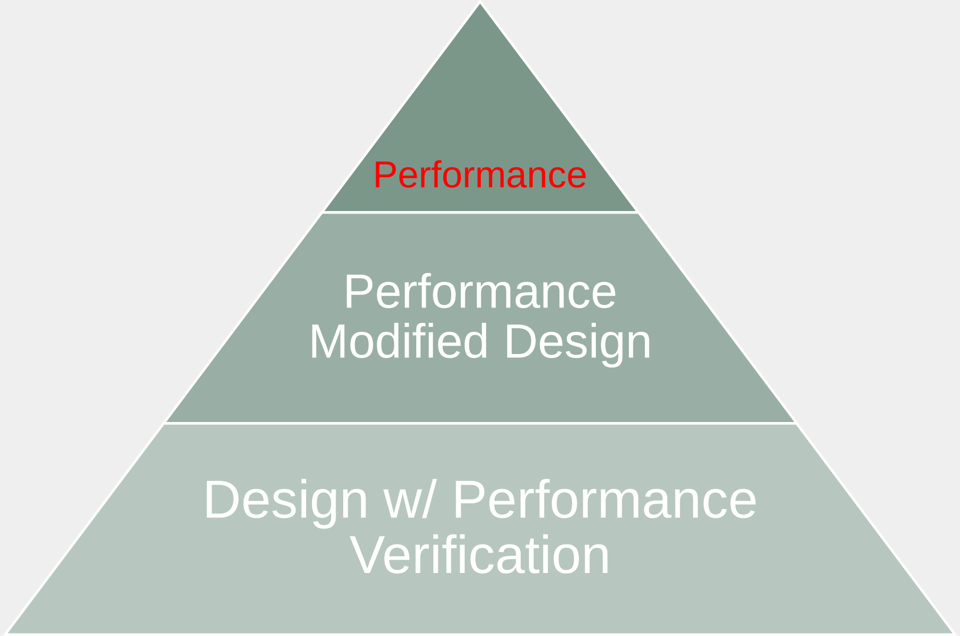
Performance Modified Volumetric Design

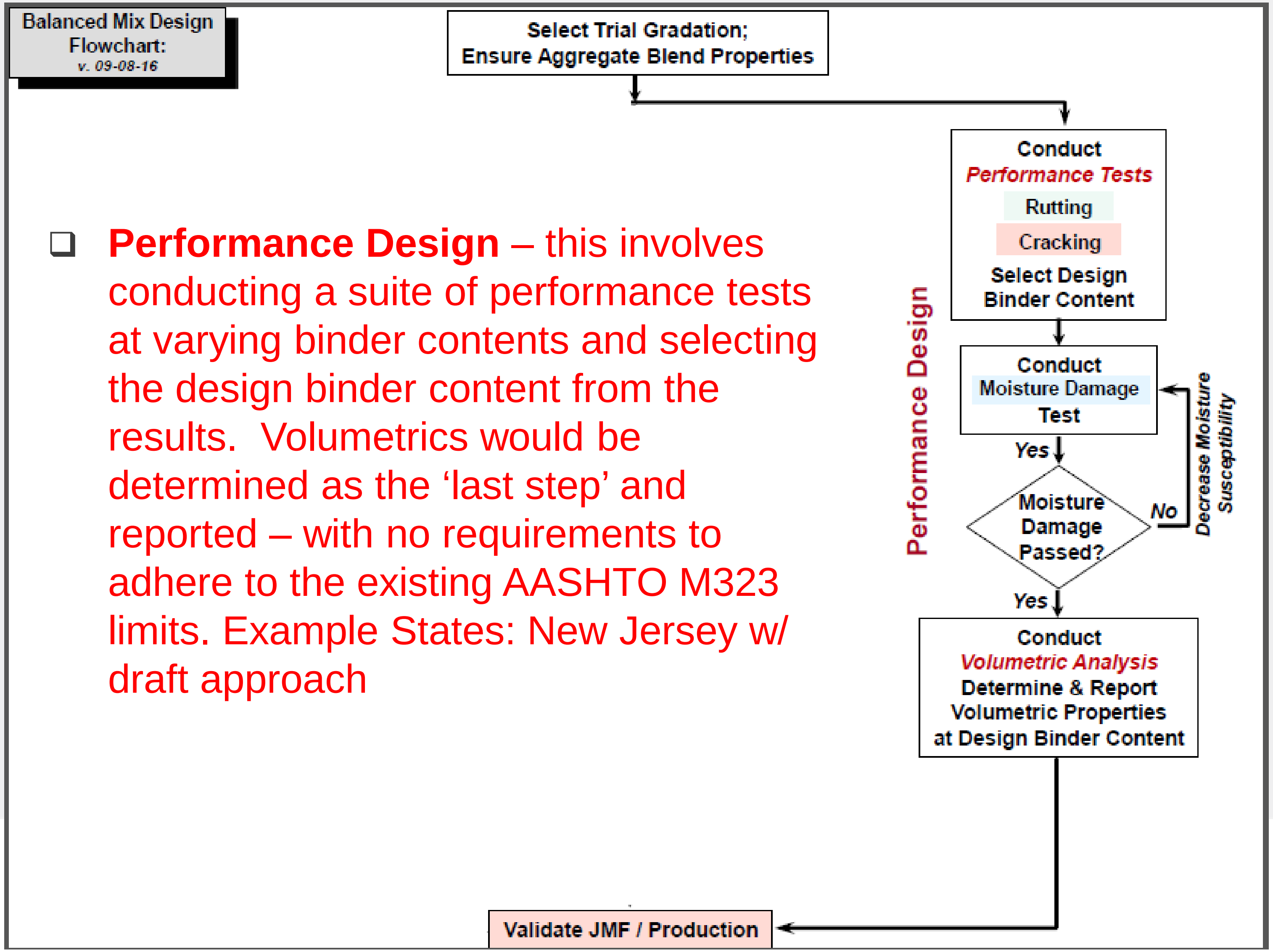




- **Performance-Modified Volumetric Design** – the initial design binder content is selected using AASHTO M323/R35 prior to performance testing; the results of performance testing could 'modify' the mixture proportions (and/or) adjust the binder content – and the final volumetric properties may be allowed 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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State Agency Practice – Mixture Design

- A number of SHAs have begun to either explore or adopt BMD approaches.

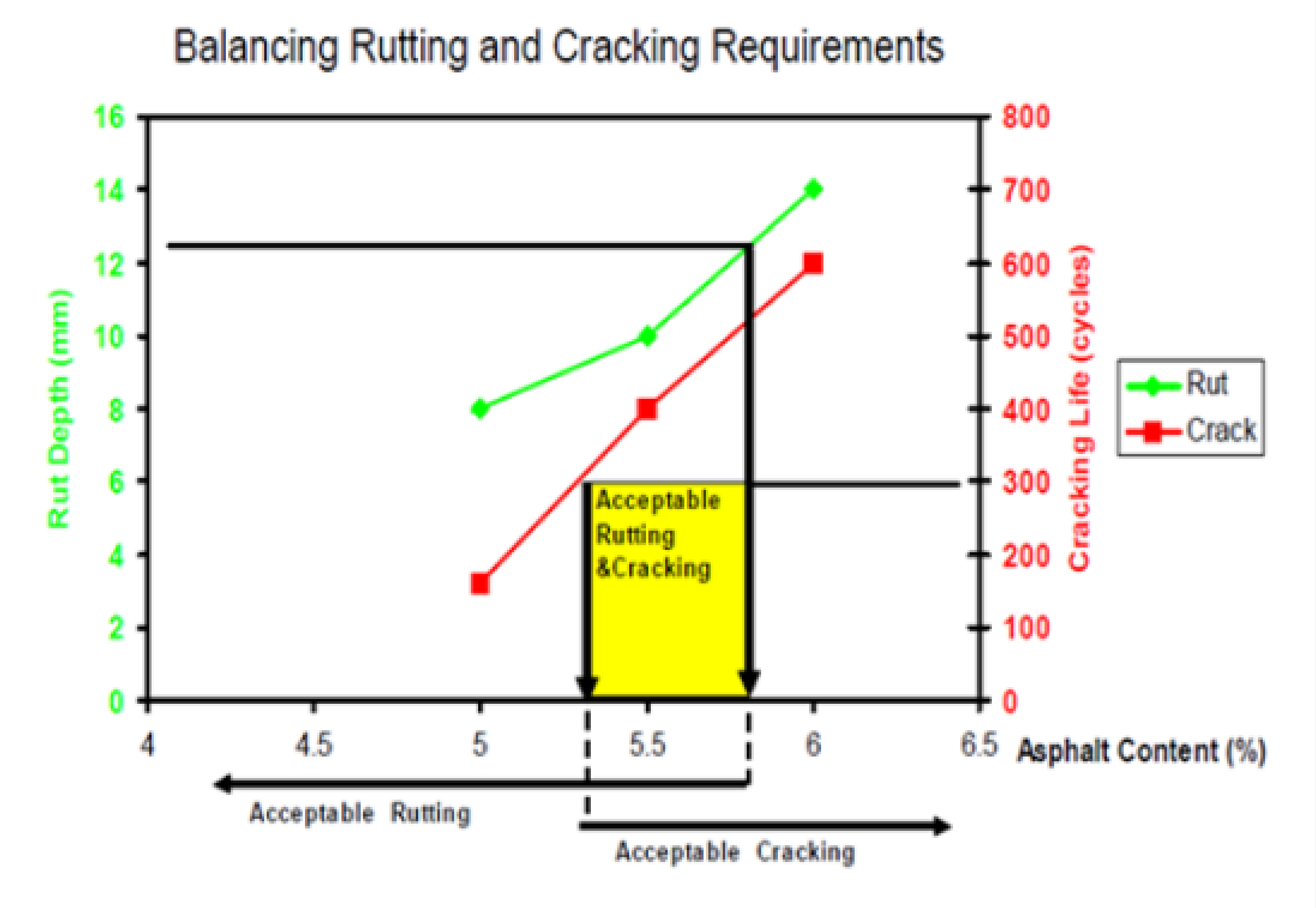
State	Design Approach	Stability Test	Durability/Cracking Test
California	Performance Mod Vol Design	SST Repeated Shear, Hamburg	Bending Beam Fatigue (BBF)
Illinois	Vol Design w/ Performance Verification	Hamburg	Semi Circular Bend (IFIT)
Louisiana	Vol Design w/ Performance Verification	Hamburg	Semi Circular Bend (LTRC)
New Jersey	Vol Design w/ Performance Verification	Asphalt Pavement Analyzer	Texas Overlay Test (OT)
Texas	Vol Design w/ Performance Verification	Hamburg	Texas Overlay Test (OT)
Wisconsin	Vol Design w/ Performance Verification	Hamburg	Disc Shaped Compact Tension + SCB (IFIT)

What Typically Drives a State Agency Practice?

- SHAs are selecting different performance tests.
- Variance is driven by 1) different pavement distress considerations (e.g., thermal cracking in Minnesota versus top-down cracking in Florida) and 2) intended mix application or mix component of interest (e.g., specialty mixes or high recycle mixes).
- BMD approaches vary, and will likely continue to vary, in the future.
  - Not unexpected…
    - How many states currently use AASHTO M323 without any modification? Not many!

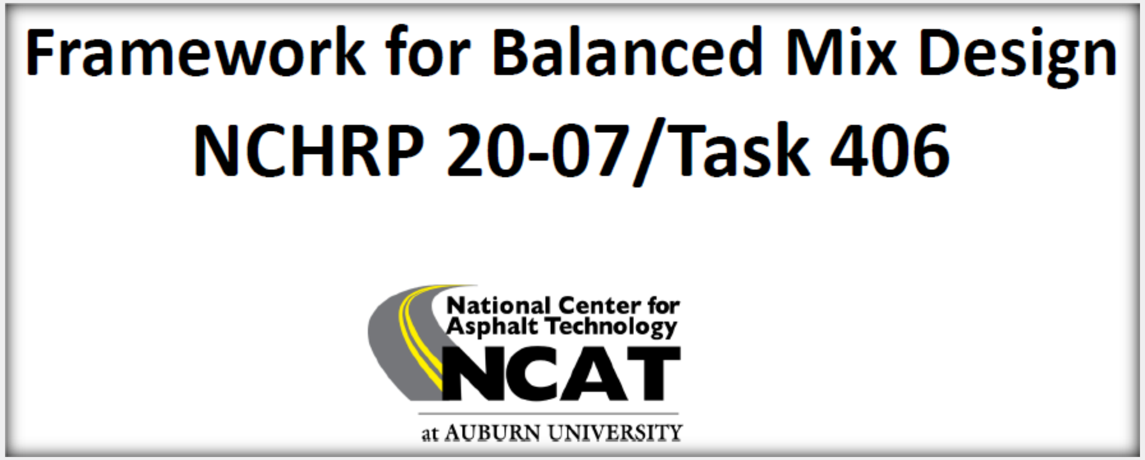
BMD Basic Example

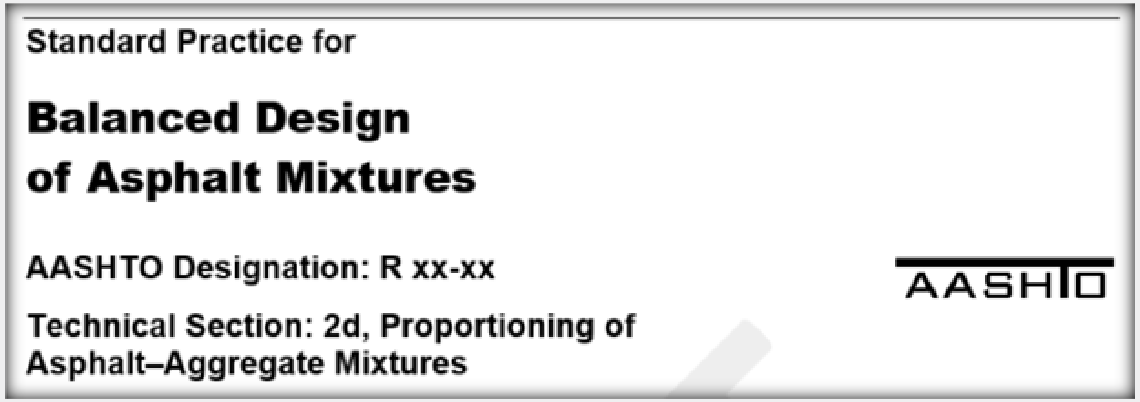
- **Texas DOT**
  - Volumetric design conducted
  - Hamburg Wheel Tracking Test (HWTT) AASHTO T 324
  - Overlay Tester (OT) Tex-248-F



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
  - Interim Report Submitted
- 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


Standard Practice for
Balanced Design of Asphalt Mixtures
AASHTO Designation: R xx-xx
AASHTO
Technical Section: 2d, Proportioning of Asphalt–Aggregate Mixtures

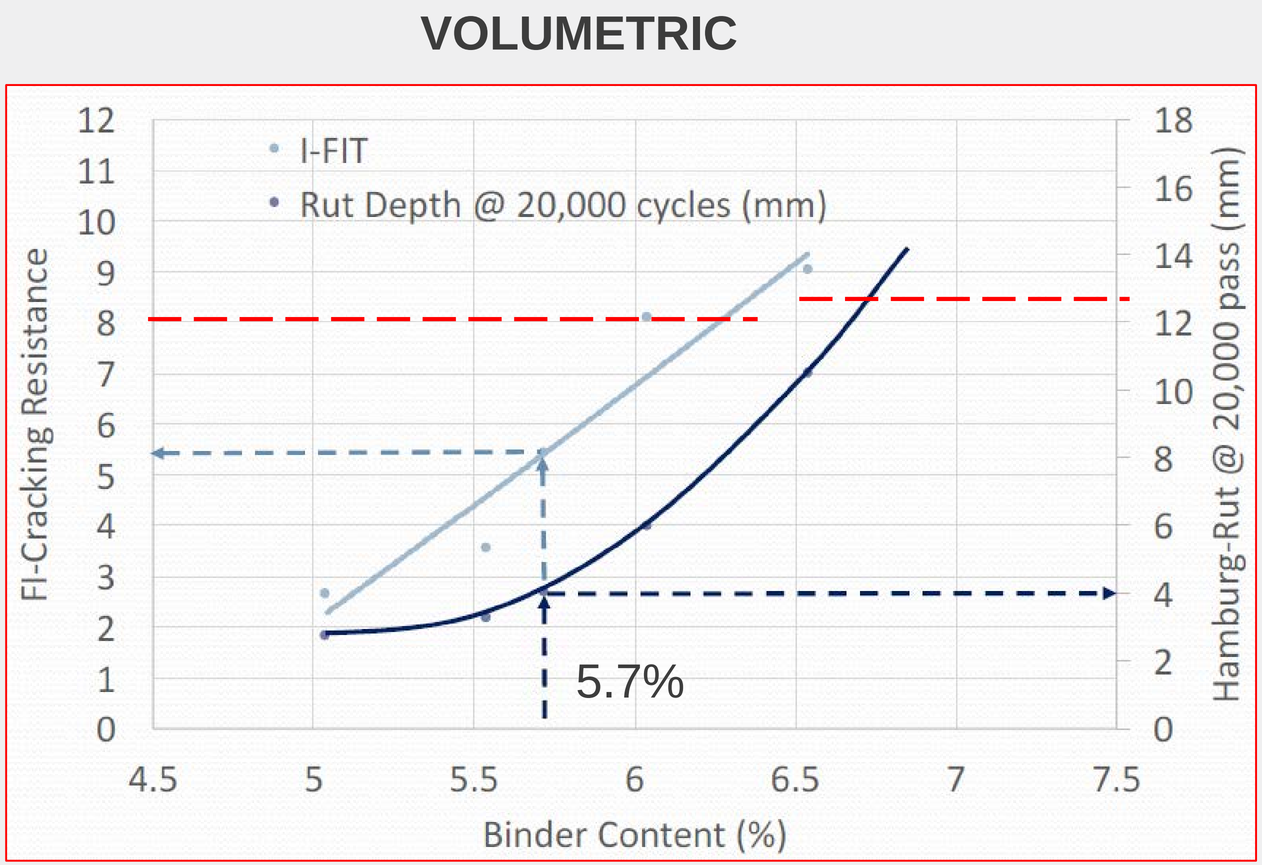
Ongoing State DOT Research

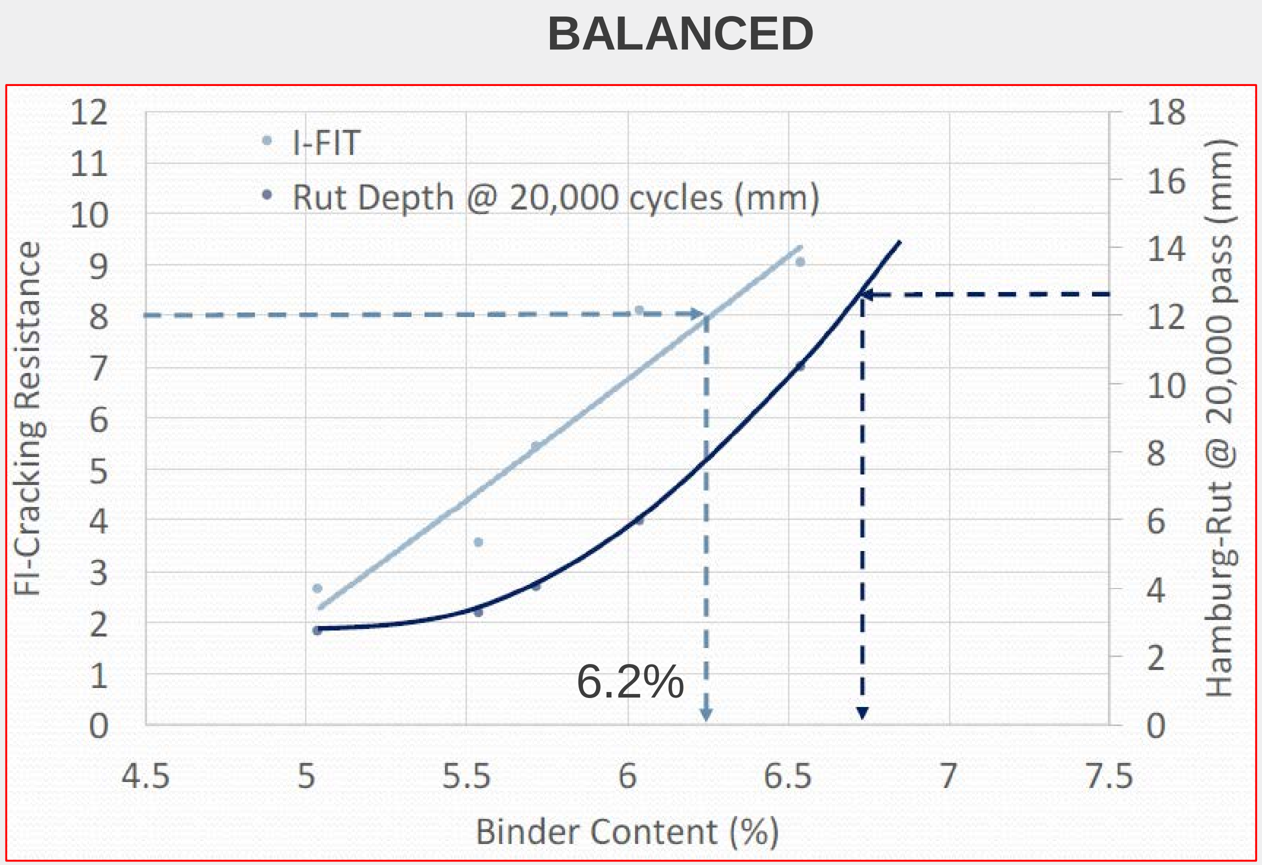
- BMD is a very "hot" topic nationally!
- Various State DOTs have current research activities focused on BMD related activities

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

How does a BMD compare with a volumetric mix design?

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





Note: Example for Illustration Purposes.

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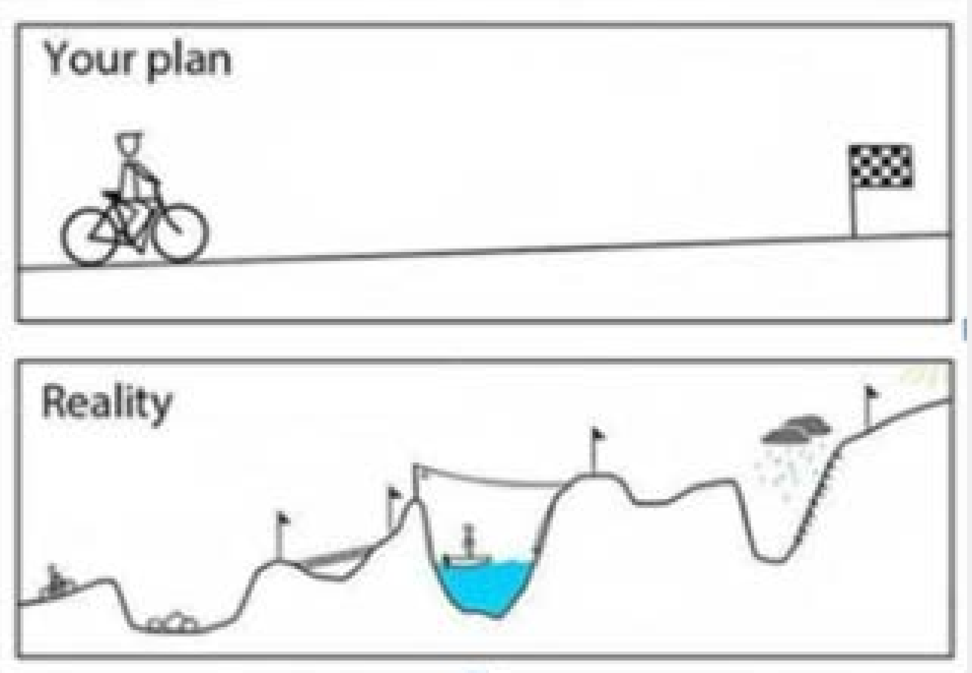
Source: NCAT Balanced Mix Design Training Course

What's the future of BMD?

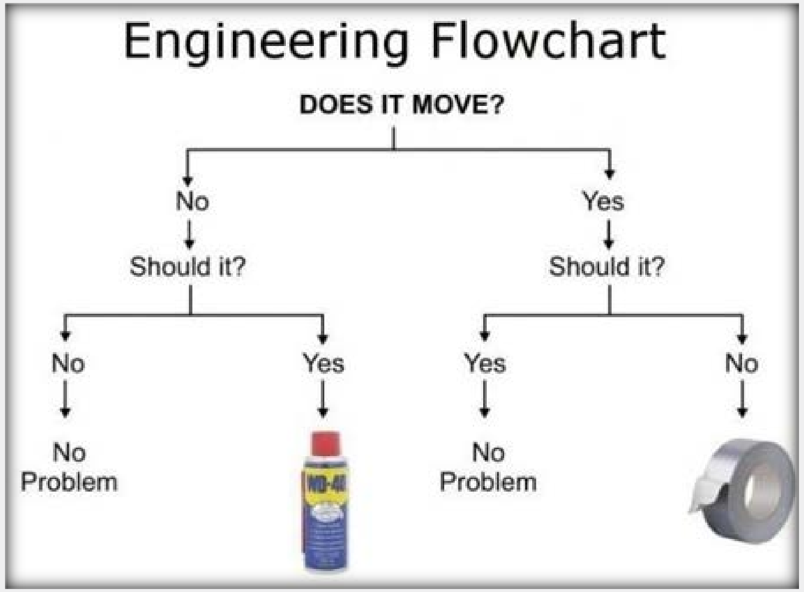
The Path Forward for Balanced Mix Design

- **Long term effort with ups/downs, but we must start now.**
- Utilize **available, proven** approaches to find **effective, implementable** solutions.
- Completion of 20-07 Task 406 and the developed AASHTO recommended practice will aid use / implementation.
- **Illinois is a great example of how to move forward!**



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

Shane Buchanan
Asphalt Performance Manager, Oldcastle Materials
205-873-3316
sbuchanan@oldcastlematerials.com

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