Balanced Flexible Pavement (Asphalt) Mixture Design

South East States Pavement Conference

October 25, 2018
Charleston, WV

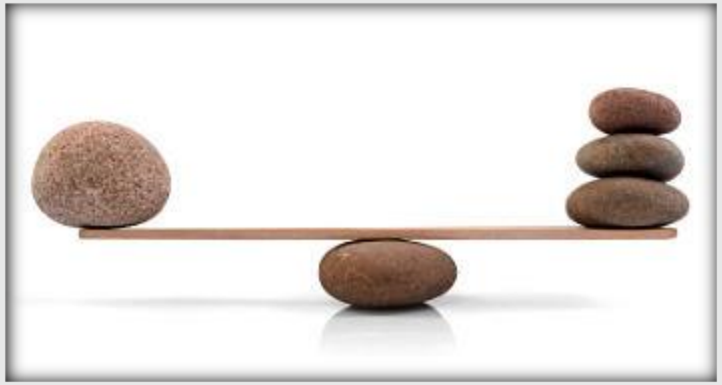
Shane Buchanan
CRH Americas Materials

West Virginia Fun Facts!

- George Brett and Jerry West are from WV
- Mother's Day first celebrated in Grafton, WV in 1908
- Home to largest steel arch bridge
  - (3000', New River Gorge)
- In Alderson, WV, lions, tigers, and other "large" felines have to be leashed when going for a walk!

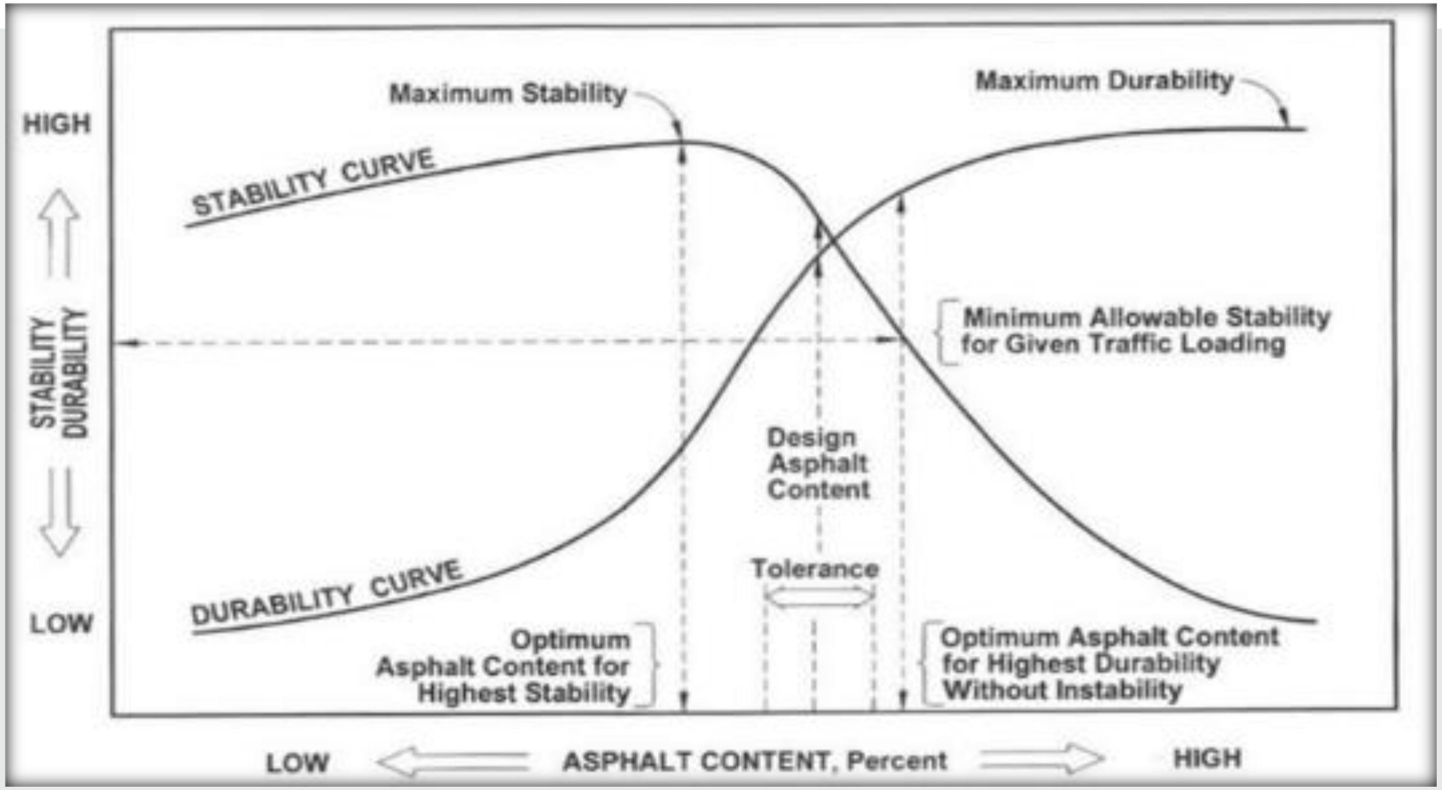
Discussion Items

- Understand the concept of Balanced Mixture Design.
- Review the most common performance tests (rutting and cracking) for BMD.
- Learn the current national state of practice for BMD.
- Learn how you can prepare for the future of asphalt mixture design.
- Discuss theory and reality pertaining to mix design.



Balanced Mix Design

Mix design based on balancing mix rutting and cracking performance instead of conventional recipe, restrictive specifications.

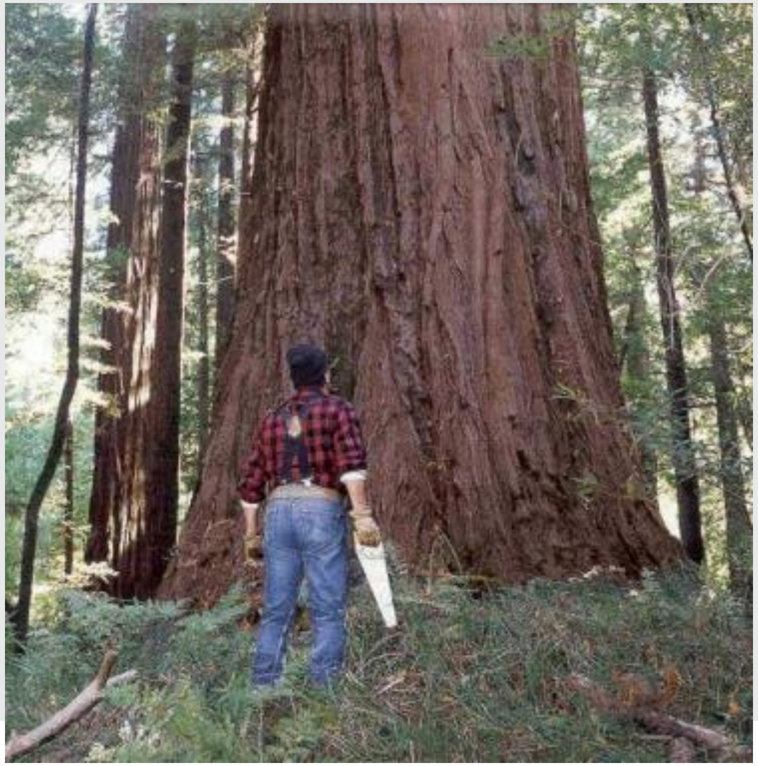


Selecting the Correct Mix

- Understand the concept of Balanced Mixture Design.

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

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



Did You Know…..

- 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

Main Pavement Distresses Observed in the Field

Moisture Damage

Permanent Deformation

Fatigue Cracking

Thermal Cracking

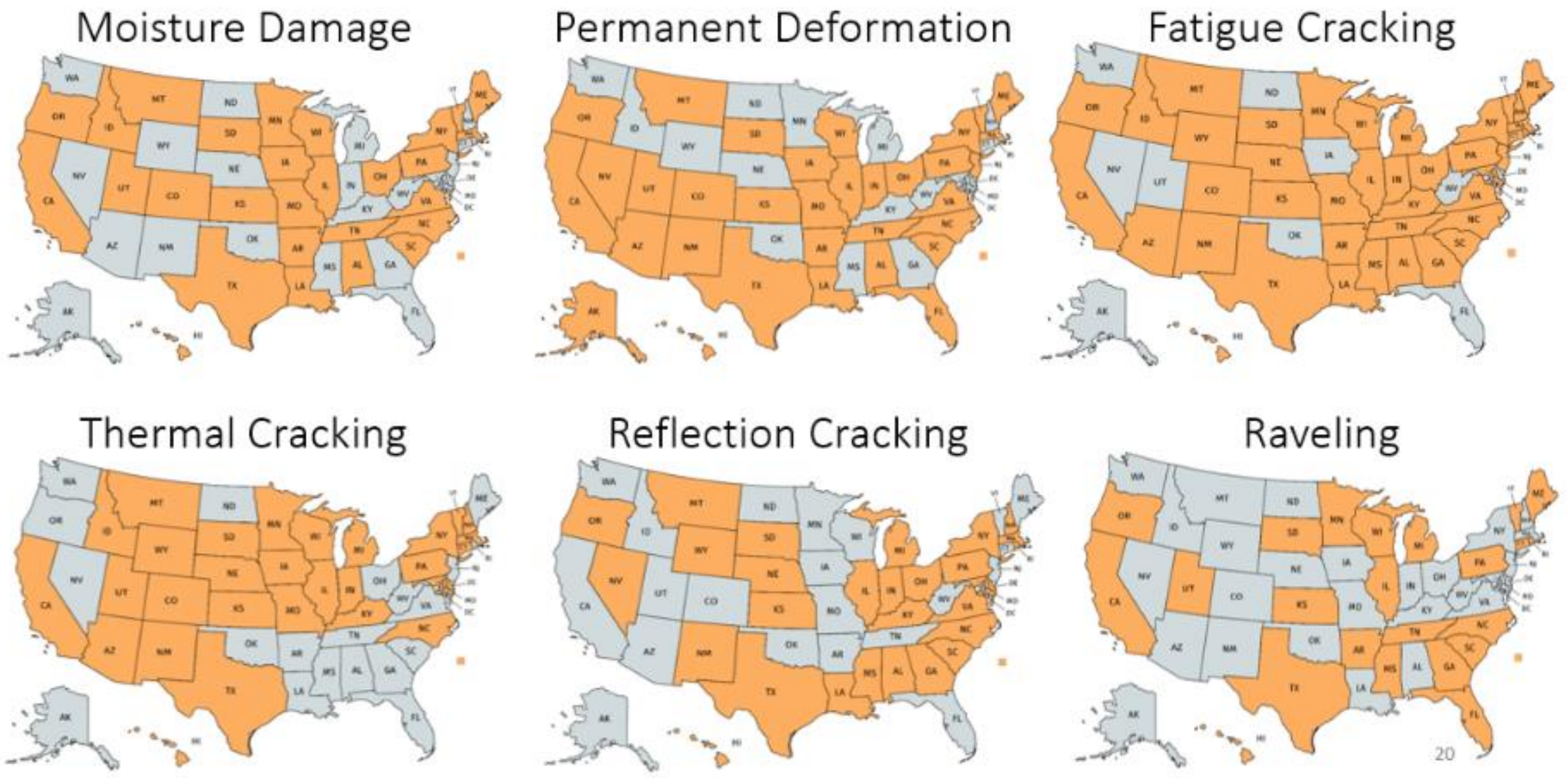
Reflection Cracking

Top-down Cracking

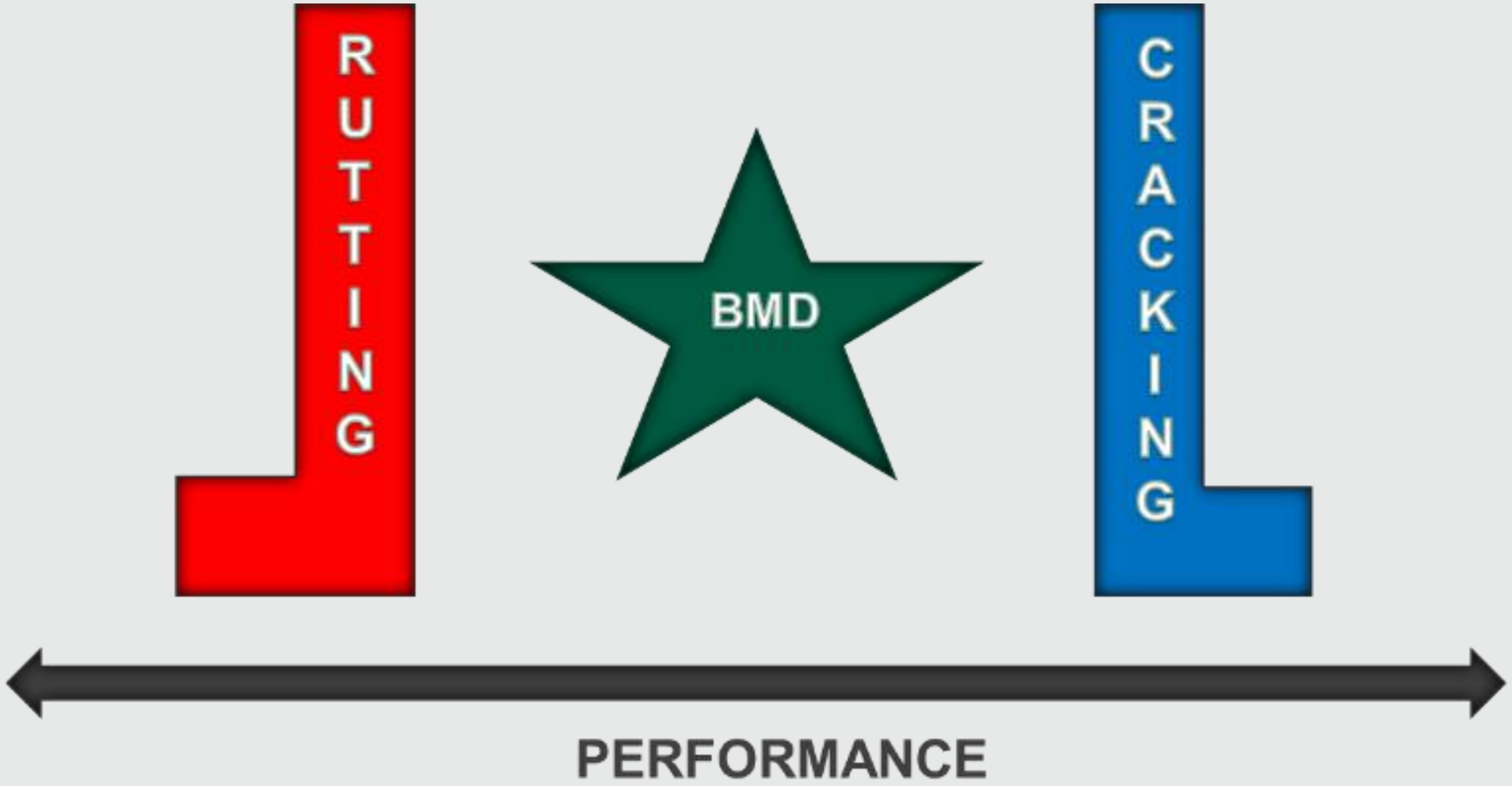
What Distress Does Your State Want to Address with Performance Testing?

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%)

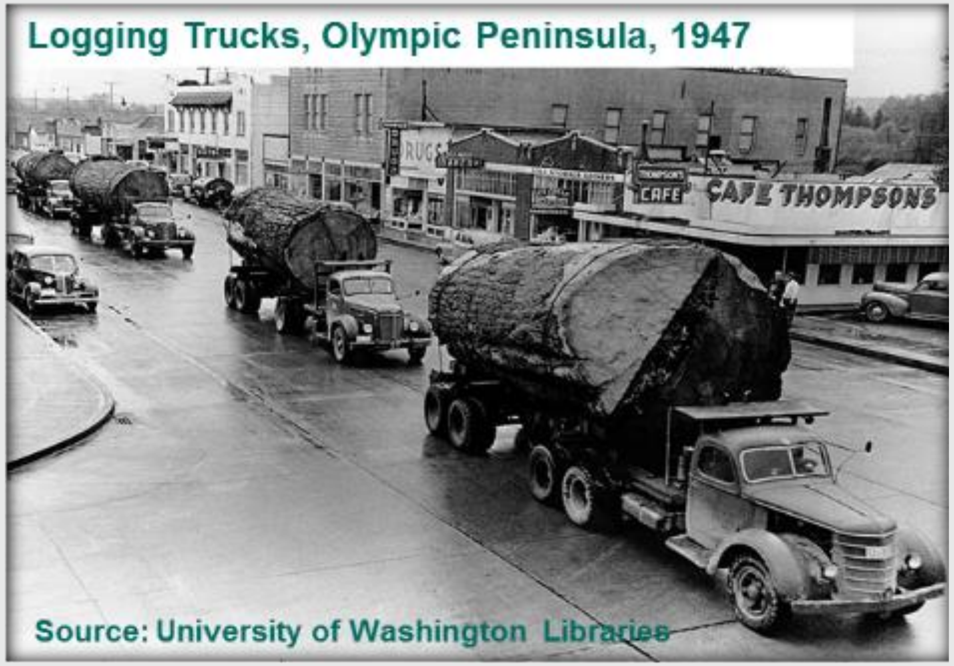
Source: NCAT Survey



What are the Most Common Performance Tests (Rutting and Cracking) for BMD?



Rutting Tests

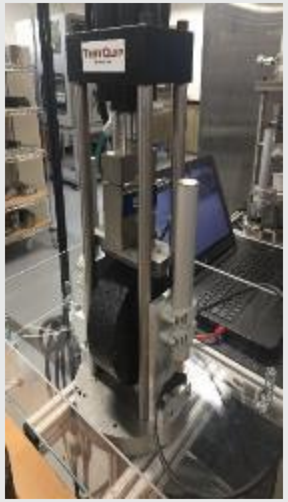


Rutting Tests

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

Hamburg Wheel Test (HWT)

Asphalt Pavement Analyzer (APA)

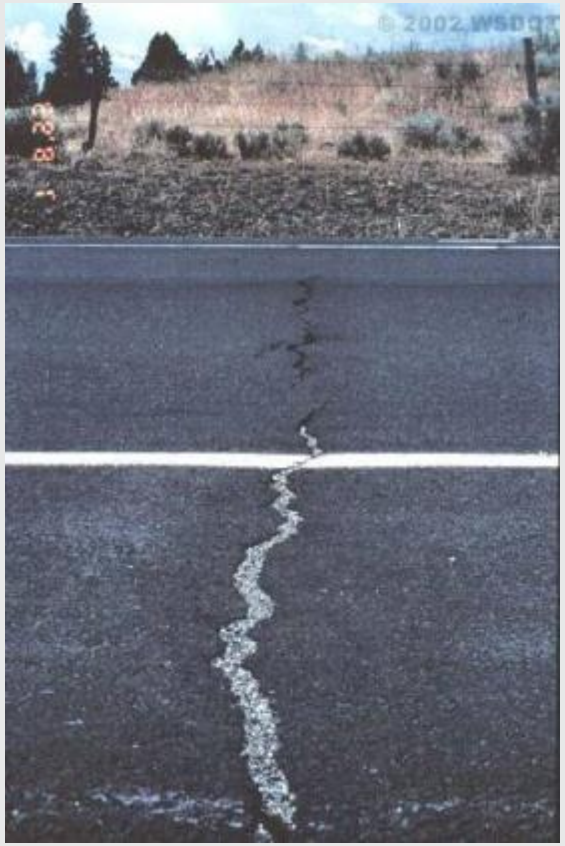


IDT - HT

AMPT Flow Number / Dynamic Modulus

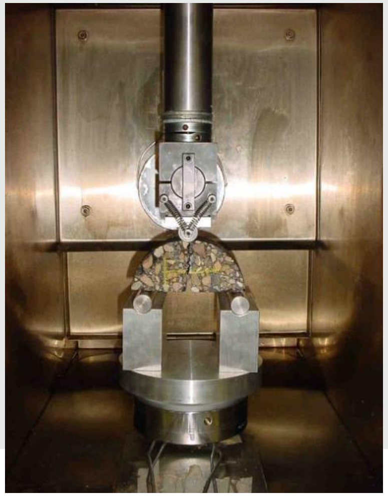
Most commonly used tests. Hamburg gaining popularity due to moisture susceptibility analysis.

Durability Testing (Cracking)



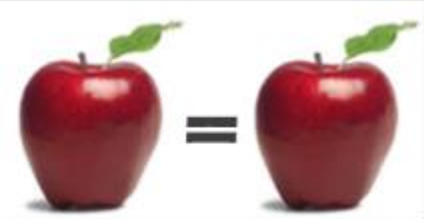
Durability/Cracking Evaluation

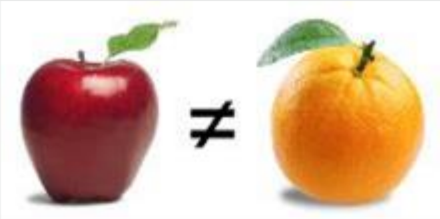
- Durability/cracking evaluation is substantially more complicated than stability with aging being one main variable.
- No general consensus the best test(s) or the appropriate failure threshold.
- MANY different tests are available with more being developed.
- Main question is “What is the anticipated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

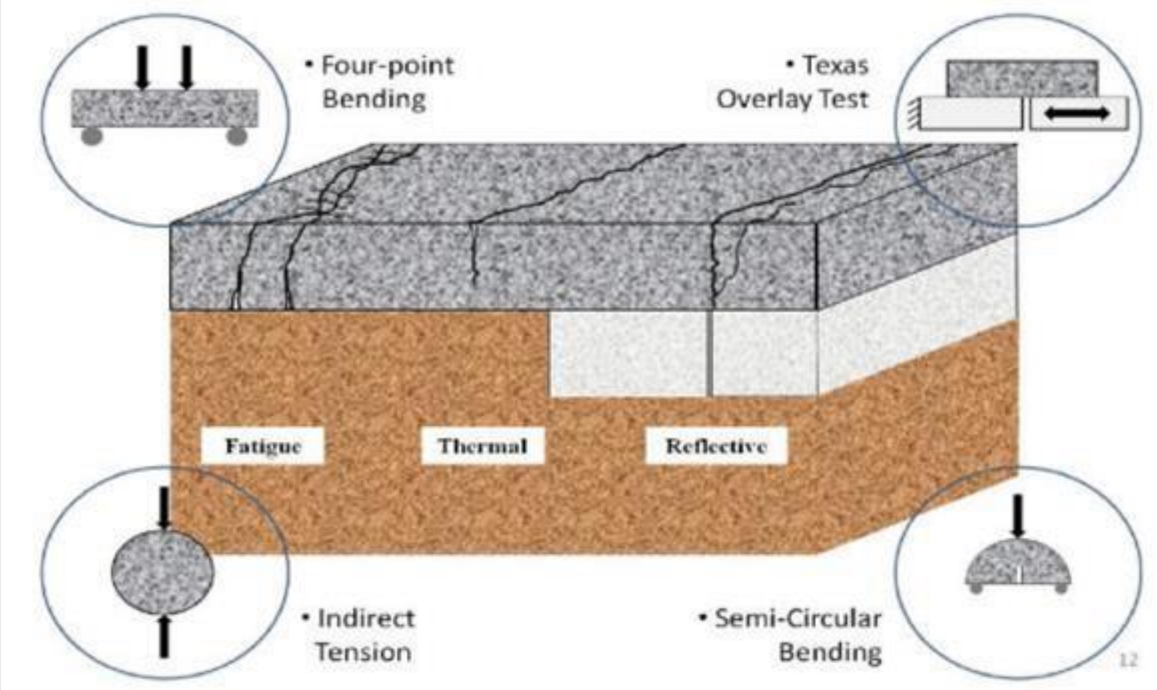


First Question for Durability Testing:
What is the Anticipated Mode of Distress for Testing?

- Many test are available with each targeting a specific specimen response (i.e., field distress)
- 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**

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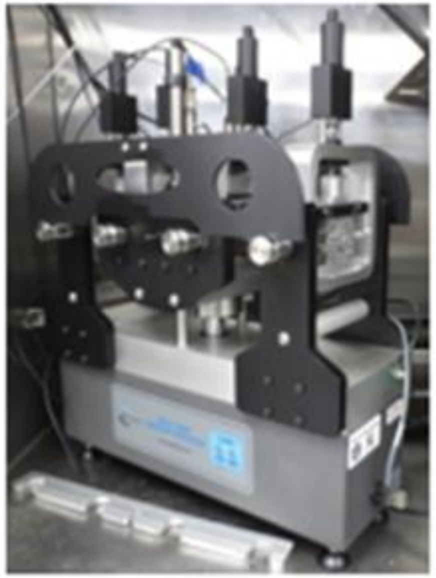
Fatigue (Bottom Up or Top Down) Related Cracking Tests

Bottom Up



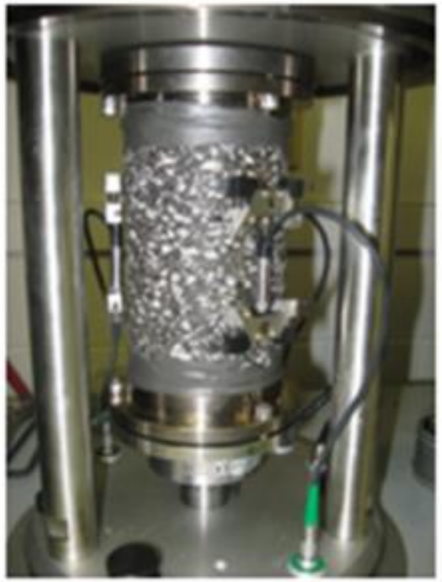
Bending Beam Fatigue

Texas Overlay Test

Bottom Up / Top Down

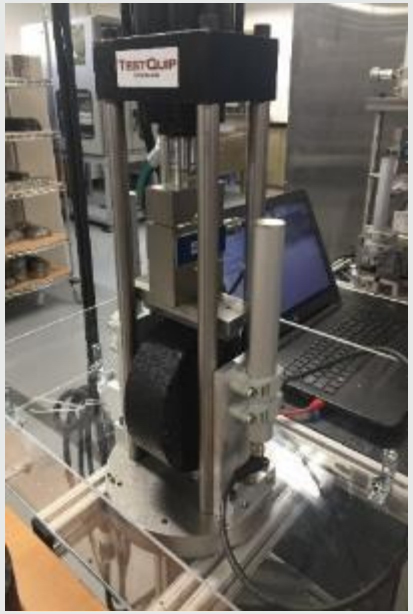
SCB
- LTRC – Jc
- IFIT

Bottom Up



Direct Tension Cyclic Fatigue, S-VECD

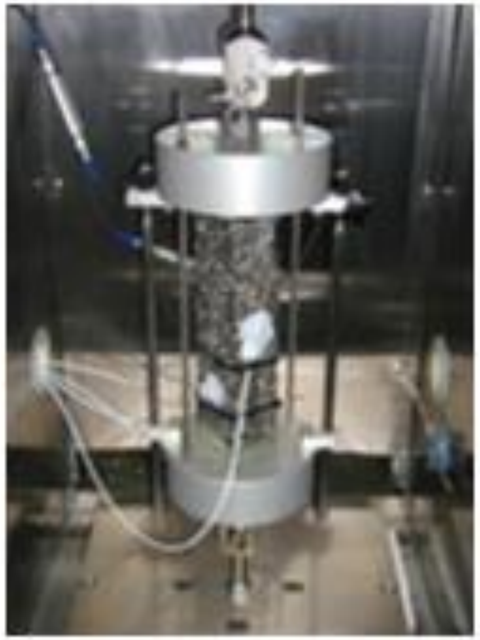
Bottom Up / Top Down



IDEAL CT ★

Thermal Cracking Tests

IDT Creep Compliance



TSRST

SCB at Low Temp

Disk Shaped Compact Tension (DCT)

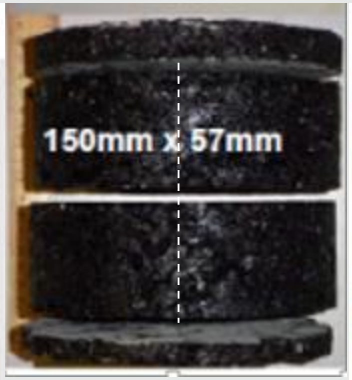
Reflection (Reflective) Cracking Tests

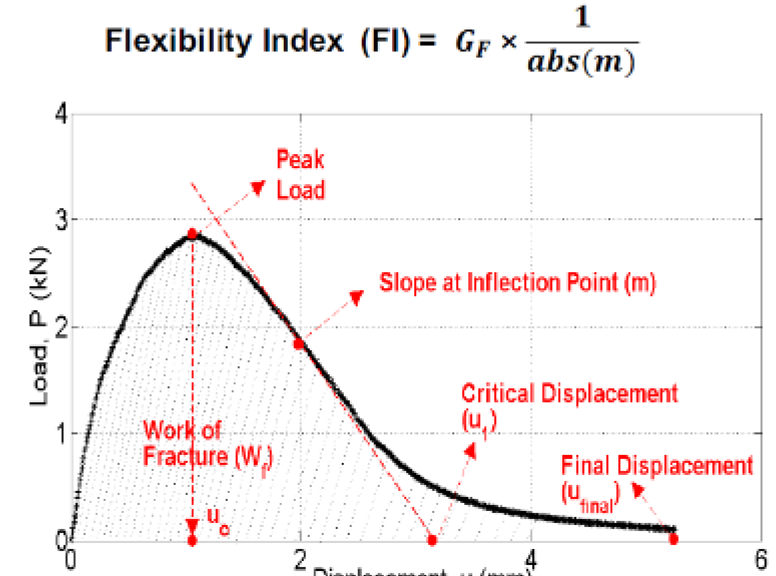
Disk Shaped Compact Tension (DCT)

Texas Overlay Test

SCB (IFIT)

IFIT Background Information





IDEAL CT Background Information

- Similar to IFIT
- **Uncut!**
- 62 mm height specimen

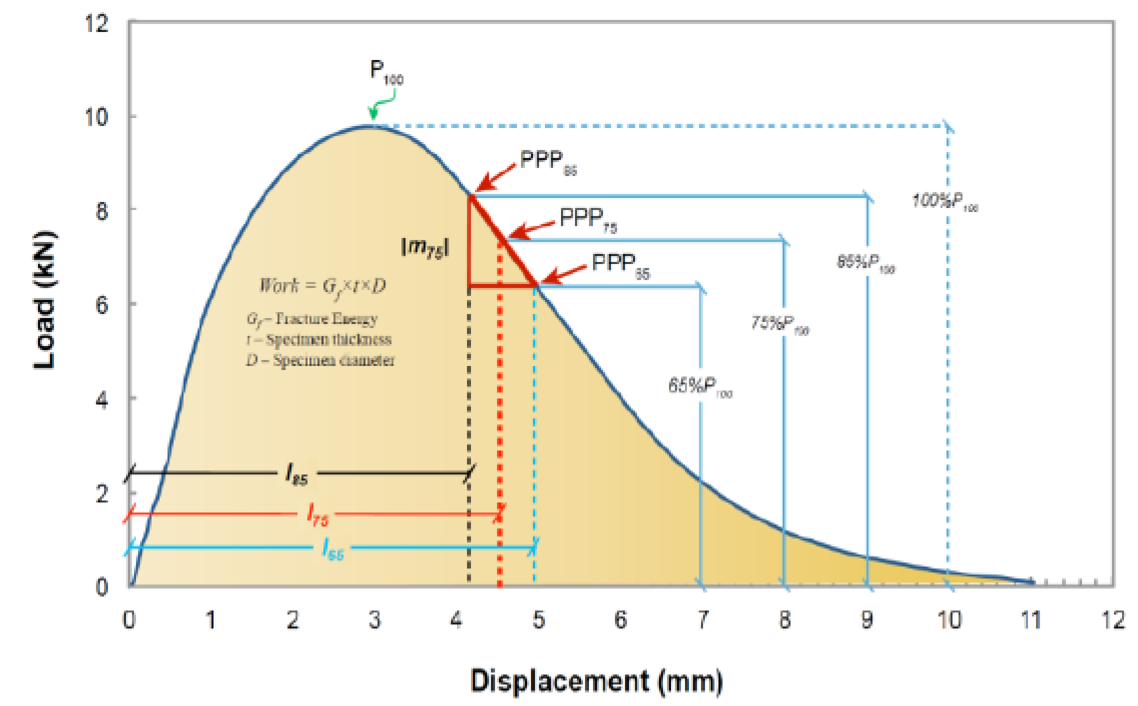


Figure 2. *Illustration of the PPP₇₅ Point and Its Slope* $|m_{75}|$

$$CT_{Index} = \frac{G_f}{|m_{75}|} \times \left(\frac{l_{75}}{D}\right)$$

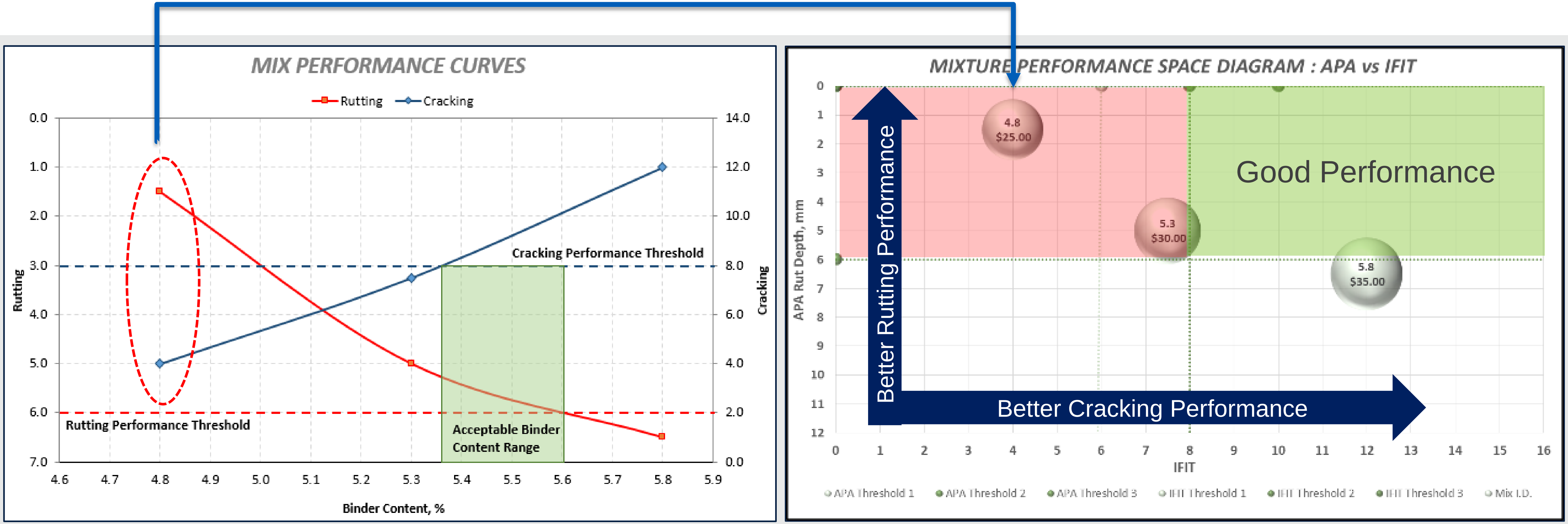
https://www.youtube.com/watch?v=OB4pQDB2Yfs

Texas A&M Transportation Institute

Indirect Tension Asphalt Cracking Test (IDEAL-CT)
NCHRP IDEA Project 195: Development of an IDEAL Cracking Test for Asphalt Mix Design, Quality Control and Quality Assurance

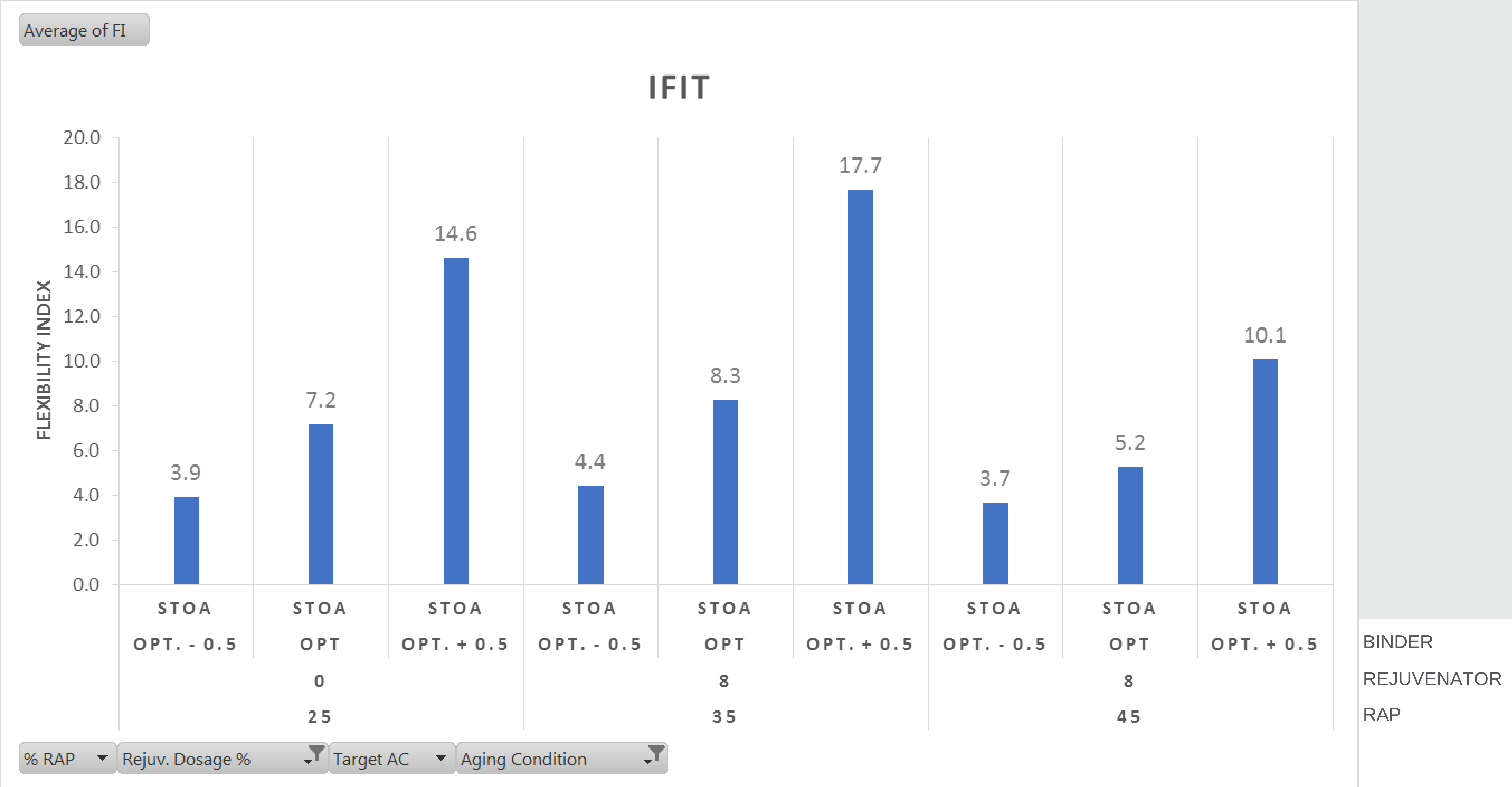
Time View: 0:40 to 1:40

Balanced Mix Design

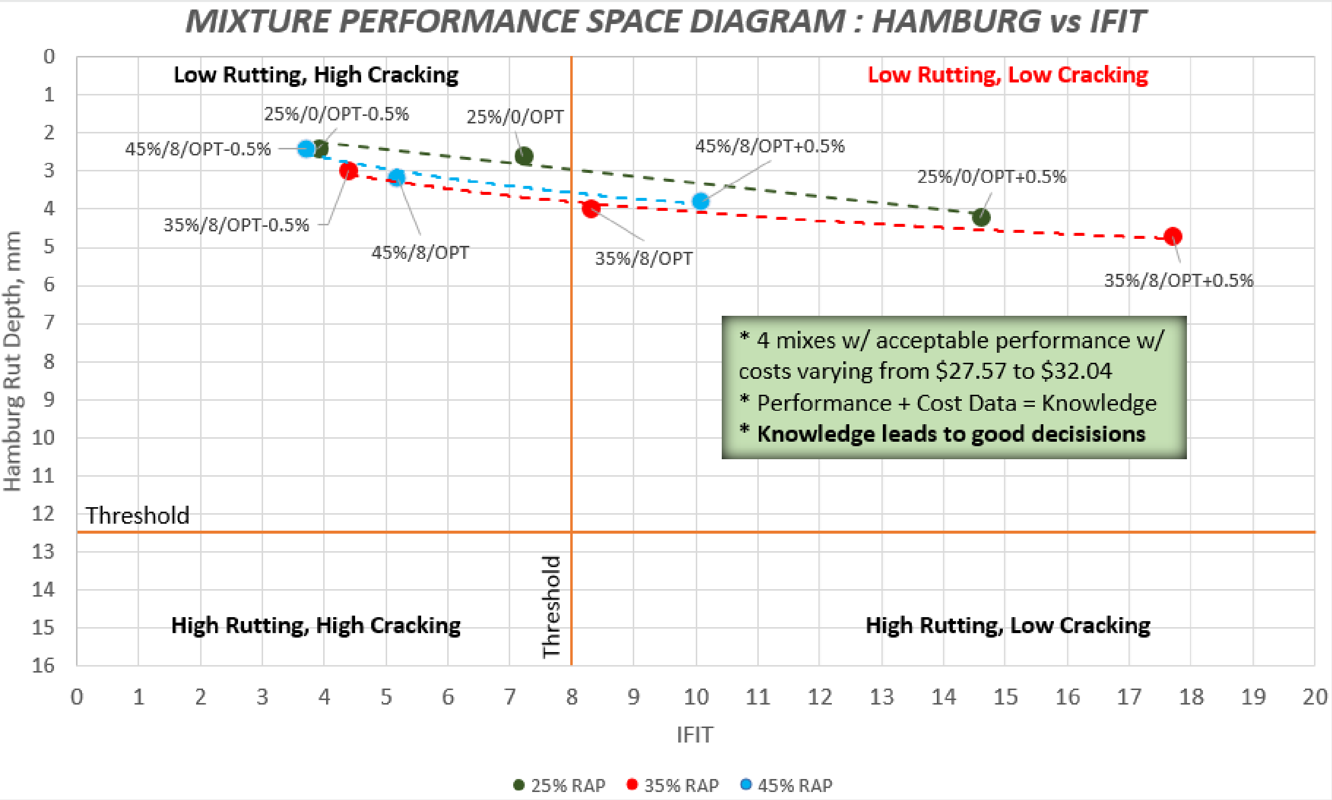


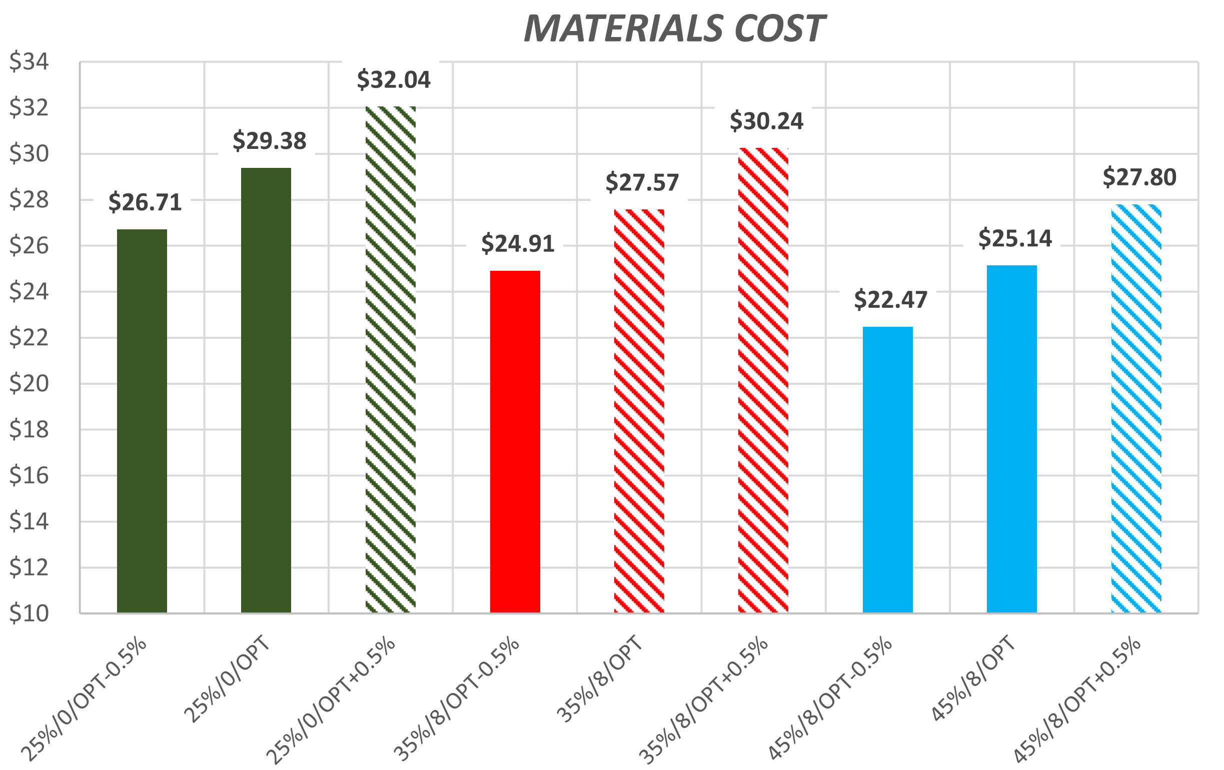
CRH

Mix Testing – IFIT Results

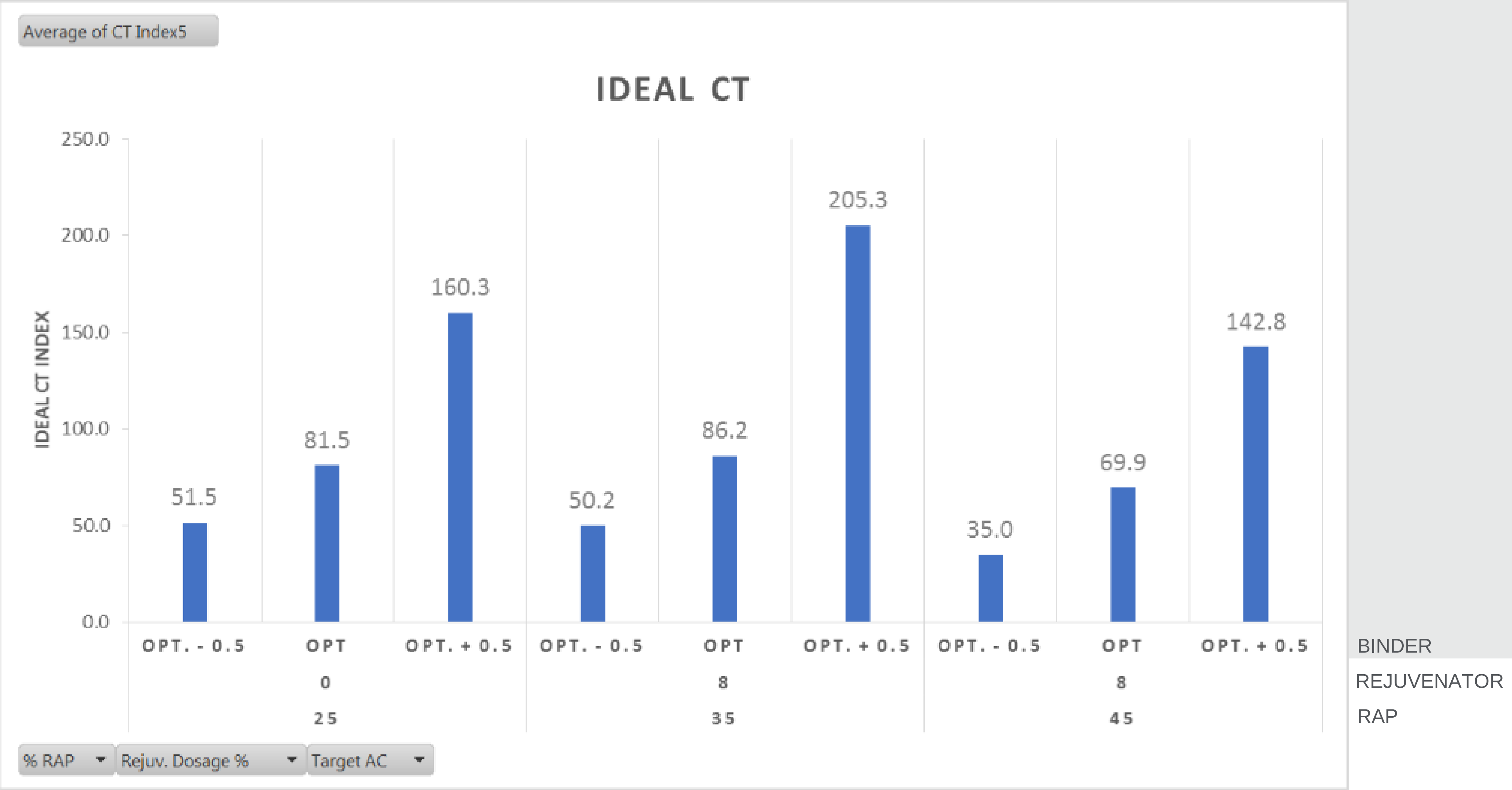


Performance Space Diagram (Hamburg vs IFIT)

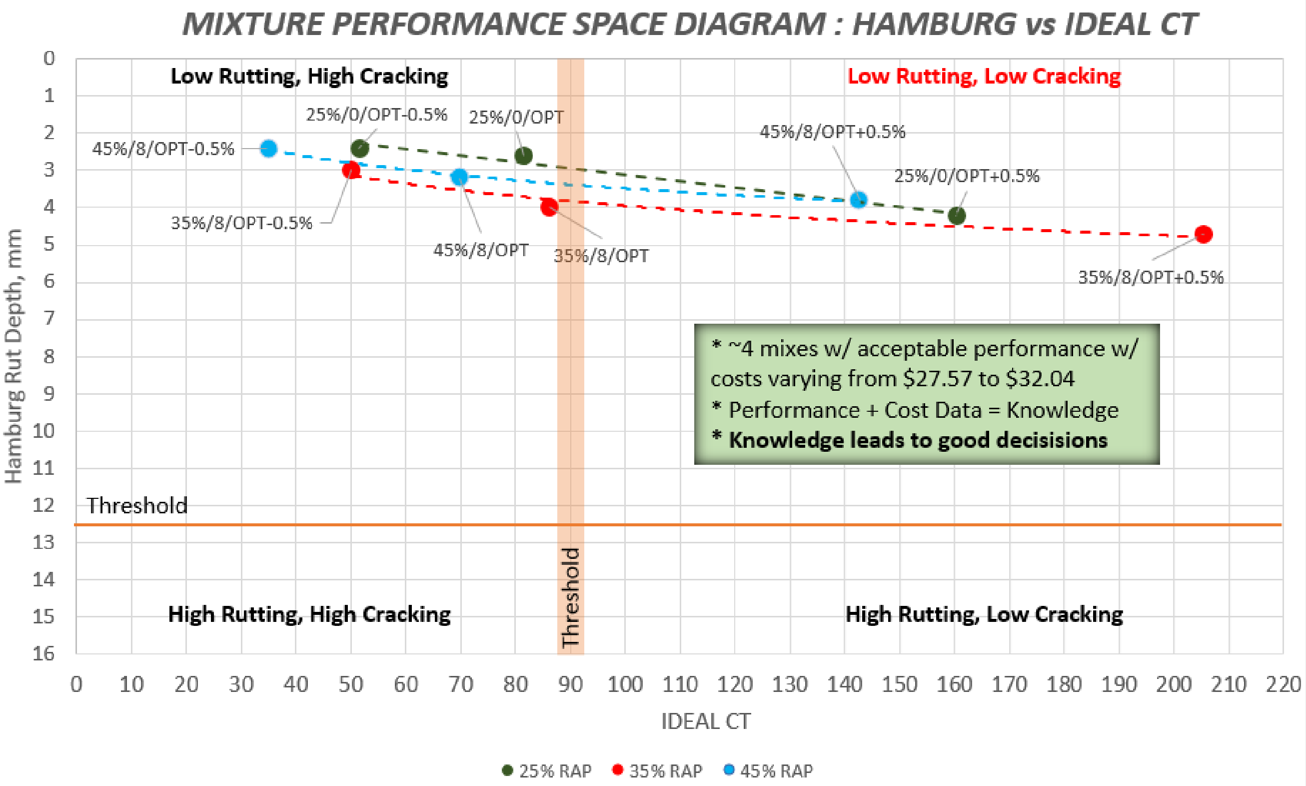


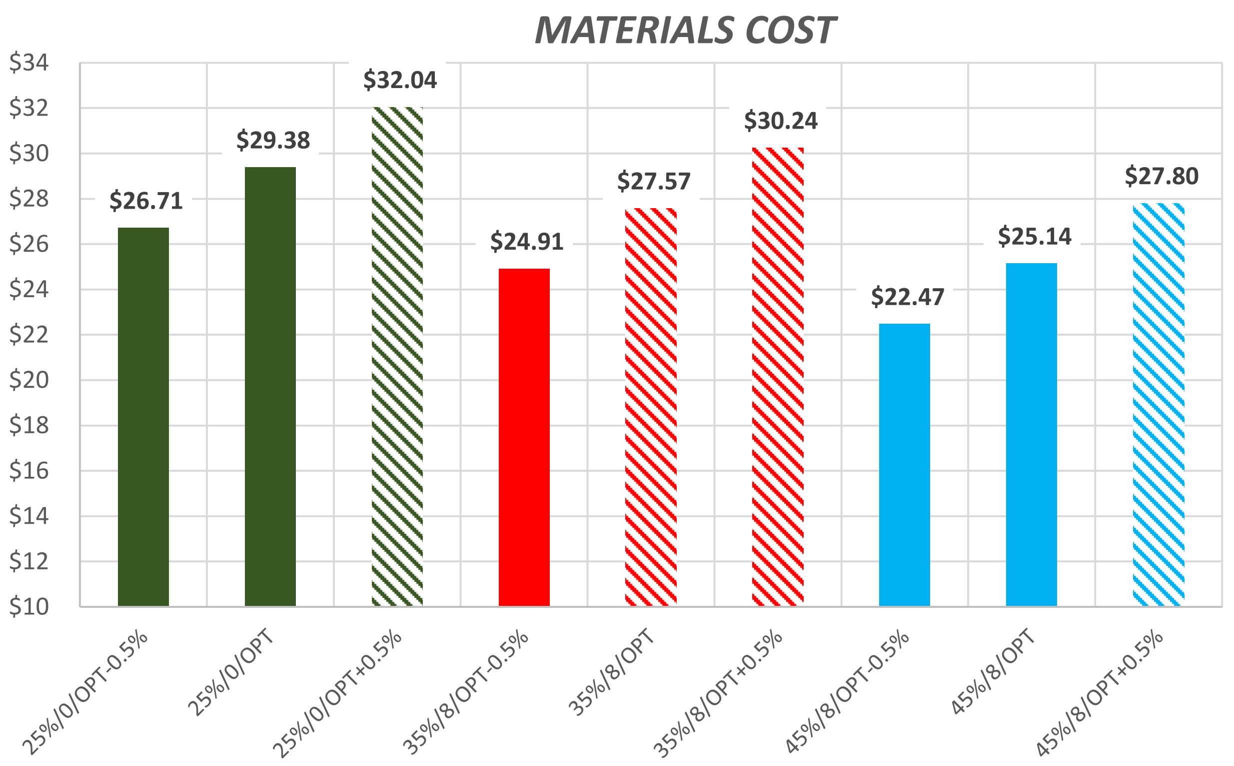


Mix Testing – IDEAL CT Results

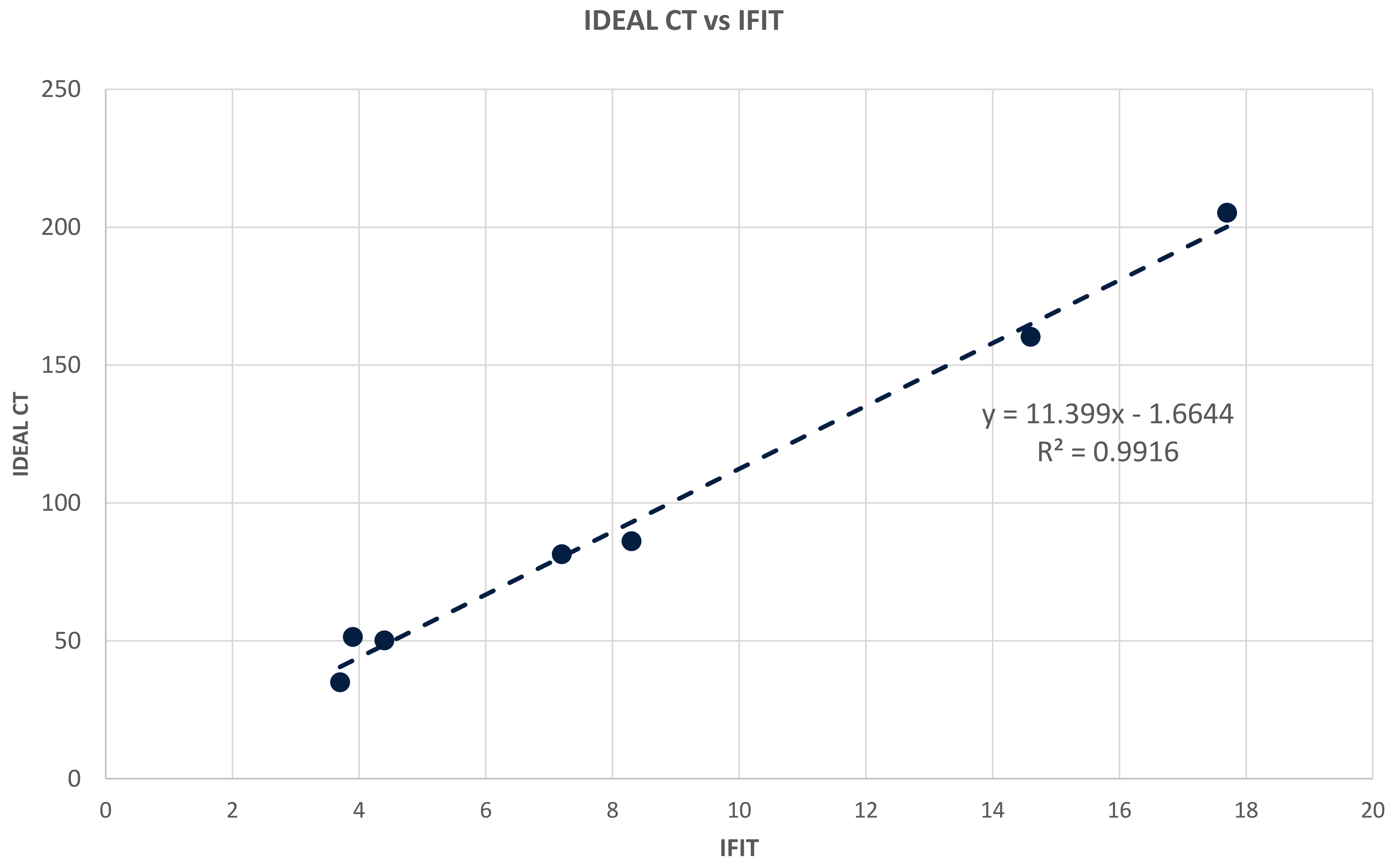


Performance Space Diagram (Hamburg vs IDEAL CT)



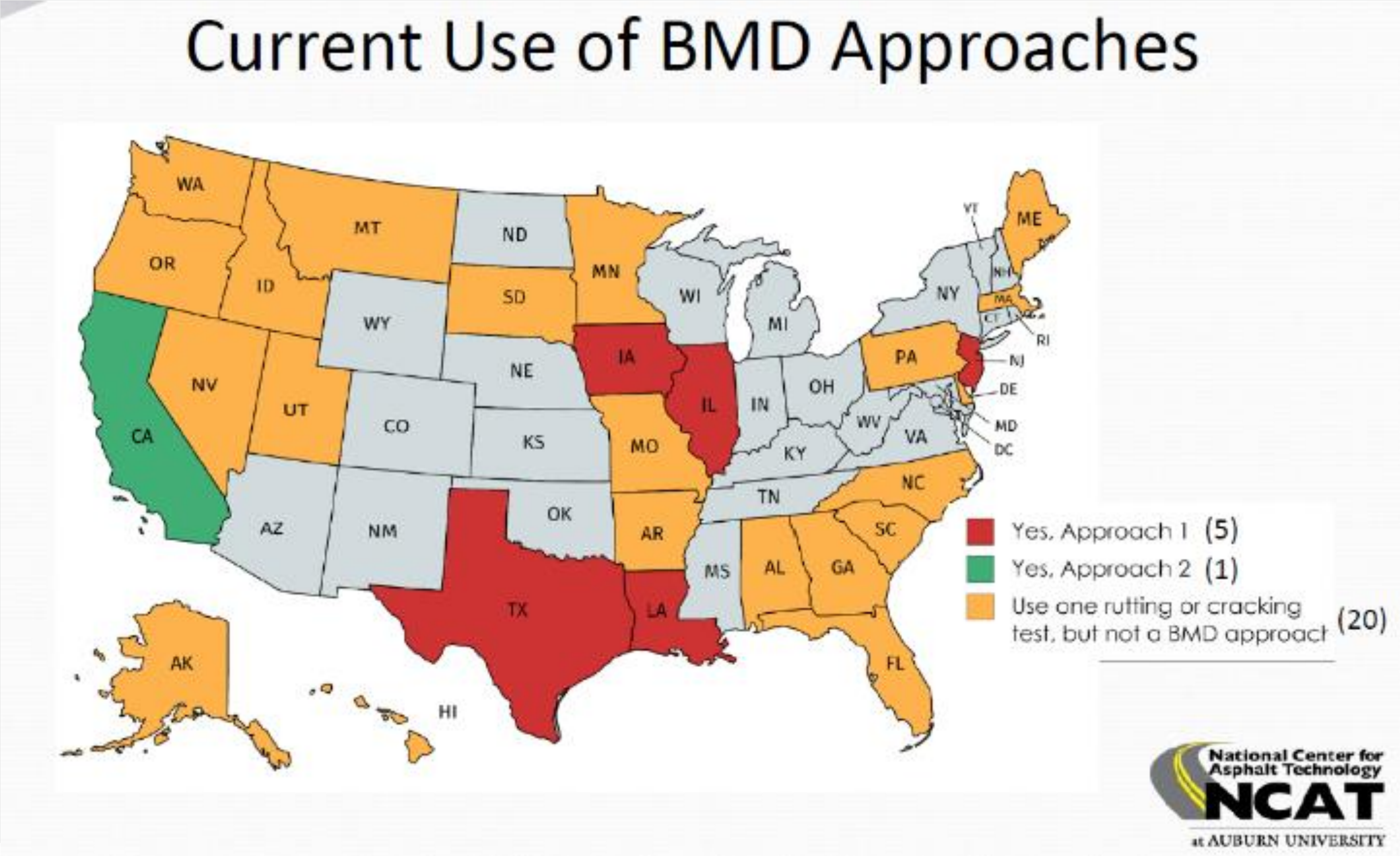


IDEAL CT vs IFIT

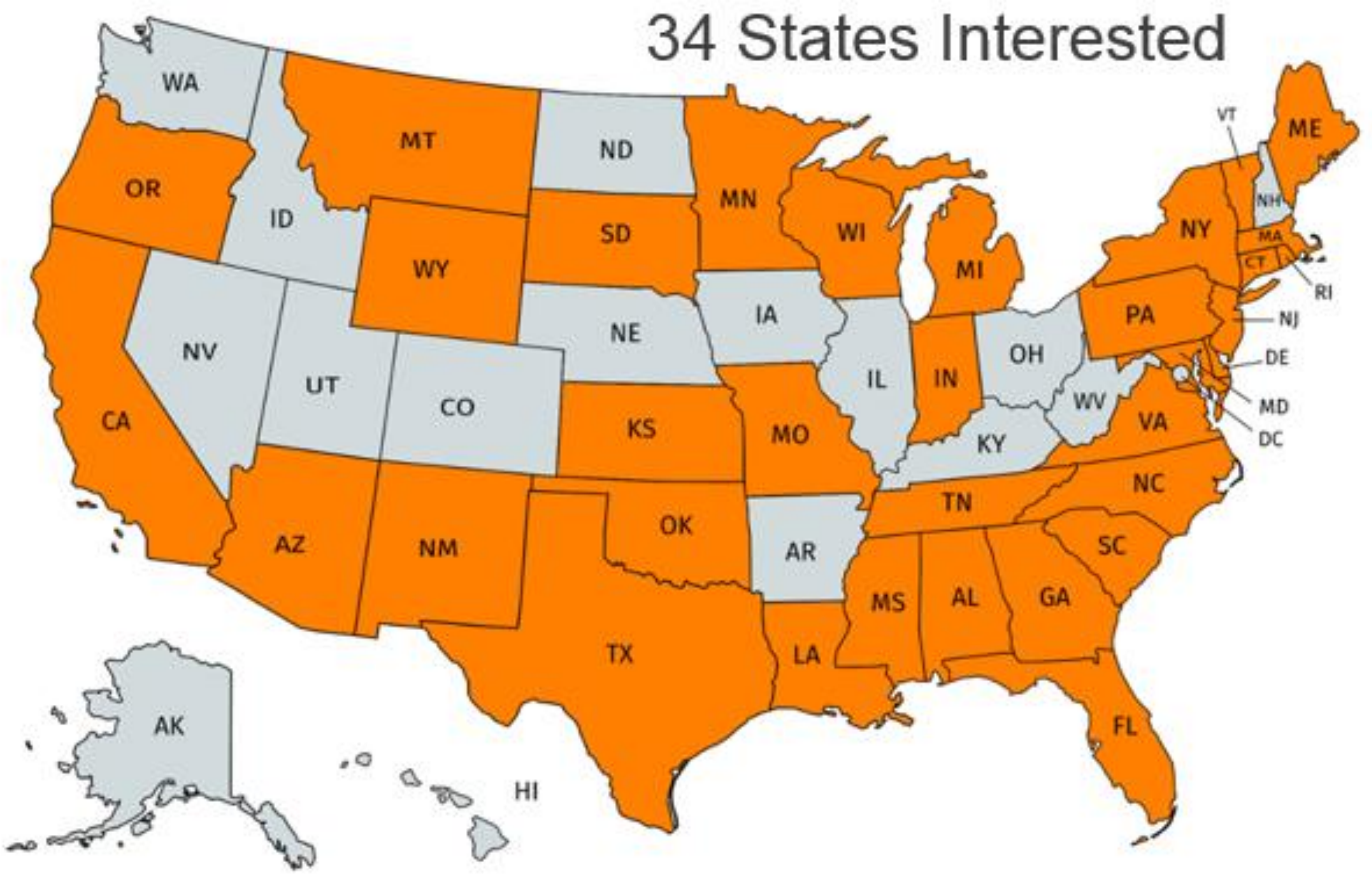


Takeaway:
Can use IDEAL CT during production as a quicker control tool.

NCAT BMD Survey Results



NCAT BMD Survey Results – State Interest in BMD



Illinois Balanced Mix Design

Illinois Department of Transportation

- Phased implementation
  - 26 Pilot projects 2016/2017
  - All Interstate projects 2019
  - **Full implementation 2020**

Hamburg

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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

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Louisiana Balanced Mix Design

- Louisiana DOT implemented BMD in the 2016 Standard Specifications for **all DOT projects.**

Hamburg

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Louisiana SCB

Table 502-6[1]
Asphalt Concrete General Criteria

Nominal Max., Size Agg.	0.5 inch (12.5 mm)			0.75 inch (19 mm)			1.0 inch (25 mm)				1.5 inch (37.5 mm)	SMA
Type of Mix	Incidental Paving[2,9]	Wearing Course		Wearing Course	Binder Course		Binder Course		Base Course[9]	ATB[8,9]	Base Course[9]	Wearing
Level[3]	A	1	2	2	1	2	1	2	1	1	1	2
LWT, max. rut-design, mm @ # passes, @ 50°C	10 @ 10,000	10 @ 20,000	6 @ 20,000	6 @ 20,000	10 @ 20,000	6 @ 20,000	10 @ 20,000	6 @ 20,000	12 @ 20,000	10 @10,000	12 @ 20,000	6 @ 20,000
Dust/Effective Asphalt Ratio, %		0.6 – 1.6										
SCB, min, Jc, KJ/m2 @ 25°C	All mix design level 1 must meet minimum 0.5 Jc , All mix design level 2 must meet minimum 0.6 Jc.											

- *Hamburg research began prior to 2000*
- *SCB research began in 2004*

New Jersey Balanced Mix Design

- NJDOT High RAP Design incorporates BMD

Asphalt Pavement Analyzer (APA)

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Texas Overlay Tester

Table 902.13.03-2 Performance Testing Requirements for HMA HIGH RAP Design				
	Requirement			
	Surface Course		Intermediate and Base Course	
Test	PG 64-22	PG 64E-22	PG 64-22	PG 64E-22
APA @ 8,000 loading cycles (AASHTO T 340)	≤ 7 mm	≤ 4 mm	≤ 7 mm	≤ 4 mm
Overlay Tester (NJDOT B-10)	≥ 200 cycles	≥ 275 cycles	≥ 100 cycles	≥ 150 cycles

Texas DOT Balanced Mix Design

- TxDOT currently uses BMD for selected specialty mixes.
- New SS 344 developed for Superpave BMD.

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Hamburg

Texas Overlay Tester

Special Specification 344

Superpave Mixtures - Balanced Mix Design

1. DESCRIPTION

Construct a hot-mix asphalt (HMA) pavement layer composed of a compacted, Superpave (SP) mixture of aggregate and asphalt binder mixed hot in a mixing plant utilizing a Balanced Mix Design (BMD) approach.

- SS 344 allows TxDOT Districts to use on a case by case basis.
  - Delta Tc (<6C) and Methylene Blue (<10) requirements
  - Grade “dumps” reduced
  - Simplified recycle material requirements

From Robert Lee (TxDOT, Now CRH)

Texas DOT Balanced Mix Design Performance

Table 11A
Hamburg Wheel Test Requirements

High-Temperature Binder Grade	Test Method	Minimum # of Passes @ 12.5 mm[1] Rut Depth, Tested @ 50°C
PG 64 or lower	Tex-242-F	10,000[2]
PG 70		15,000[3]
PG 76 or higher		20,000

1. When the rut depth at the required minimum number of passes is less than 3 mm, the Engineer may require the Contractor to lower the Ndesign level to no less than 35 gyrations.
2. May be decreased to no less than 5,000 passes when shown on the plans.
3. May be decreased to no less than 10,000 passes when shown on the plans.

Table 11B
Overlay Test Requirements

Mixture Property	Test Method	Surface Mixtures	Intermediate and Base Mixtures
Critical Fracture Energy (CFE),[1] in.-lb/in.^{2}, Min	Tex-248-F	1.0	1.0
Crack Progression Rate (CPR),[1] Max		0.45	0.55

1. If the requirement is not meet, the Engineer may approve the mix if the average number of cycles is ≥300 cycles.

Crack Initiation Parameter
Crack Propagation Parameter

From Robert Lee (TxDOT, Now CRH)

Oklahoma DOT Balanced Mix Design Performance

OKLAHOMA DEPARTMENT OF TRANSPORTATION
SPECIAL PROVISION
FOR
BALANCED MIX DESIGN REQUIREMENTS

These Special Provisions amend and where in conflict, supersede applicable sections of the 2009 Standard Specifications for Highway Construction, English and Metric and applicable Special Provisions.

NOTE: It is the intent of this special provision to allow the contractor/producer the option to design and produce HMA/WMA meeting Balanced Mix Design (BMD) requirements that does not necessarily meet the requirements of 2009 Standard Specifications and current Special Provisions. In addition, during production, JMF tolerances of 2009 Standard Specifications and current Special Provisions will be applied. An open communication should be established during the HMA/WMA design process between the contractor/producer and ODOT Materials Division Bituminous Branch to facilitate the approval process. The final HMA/WMA design will be at the discretion of the ODOT Bituminous Branch Manager.

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Hamburg **IFIT**

Table 708:11a
Hamburg Rut Test Requirements[a, b]

Binder Grade	Minimum Number of Passes to 12.50 mm Rut Depth, Tested at 122 °F (50C)
PG 64	10,000
PG 70	15,000
PG 76	20,000

Table 708:8
Mix Design Properties of Laboratory Molded Specimens

Property	Superpave			SMA	PFC	RBL
	PG64	PG70	PG76	PG76	PG76	PG64
Cantabro	Report Only					
I-FIT	≥ 8.0	≥ 8.0	≥ 8.0	---	---	---

Notes:
Hamburg + IFIT @ 7% voids, Cantabro @ 4%
Short term aging used (R30)

BMD Activities at the 2018 NCAT Test Track

- Balanced Mix Design is a key focus area
  - **TXDOT (2 sections)**
    - Texas Bit Mix (Materials)
  - **OKDOT (2 sections)**
    - APAC Central (OK) Mix Design and Materials
  - **Cargill (2 sections)**

Texas Department of Transportation

DOT Oklahoma Department of Transportation

Cargill Helping the world thrive

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Current / Completed State DOT Research

- Various State DOTs have research activities focused on BMD

State DOT	Research Title
California	Simplified **Performance Based** Specifications for Long Life AC Pavements (Funding unknown)
Idaho	Development and Evaluation of **Performance Measures** to Augment Asphalt Mix Design in Idaho (170K)
Indiana	Performance **Balanced** Mix Designs for Indiana's Asphalt Pavements (243K)
Minnesota	**Balanced** Design of Asphalt Mixtures (140K)
Texas	Develop Guidelines and Design Program for Hot-Mix Asphalts Containing RAP, RAS, and Other Additives through a **Balanced** Mix Design Process (524K)
Wisconsin	1. Analysis and Feasibility of Asphalt Pavement Performance-Based Testing Specifications (Funding Unknown, completed) 2. Regressing Air Voids for **Balanced** HMA Mix Design (150K)
Oklahoma	Implement **Balanced** Asphalt Mix Design in Oklahoma (111K)
Nebraska	*Feasibility and Implementation of **Balanced Mix Design** in Nebraska (120K)*
Virginia	***Performance Mixture Design** for Asphalt Mixtures: Phase I, Roadmap and Specification Development (456K)*

Balanced Mix Design – The Future

- BMD / Performance Based Mix Design is Coming!
- New Draft BMD AASHTO Standards

Standard Specification for

Balanced Mix Design

AASHTO Designation: M XXX-XX

Technical Section: 2d, Proportioning of Asphalt–Aggregate Mixtures

AASHTO

Standard Practice for

Balanced Design of Asphalt Mixtures

AASHTO Designation: R xx-xx

Technical Section: 2d, Proportioning of Asphalt–Aggregate Mixtures

AASHTO

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So…I'm a Agency Engineer, What to Do to Prepare?

1. **Remember, it's still aggregate, asphalt, and air!**
2. Be aware of what's happening
3. Participate in conferences/meetings to learn more
4. Evaluate your readiness (e.g., capabilities / needs). Do you need to more people, training, equipment?
5. Act to increase readiness
6. Establish baseline (test your mixes to see where you are at)
7. Establish appropriate protocols for design and acceptance
8. Embrace the opportunity!
9. Be the leader!

"By failing to prepare, you are preparing to fail."

- Ben Franklin

So…I'm a Contractor / Producer, What to Do to Prepare?

1. Remember, it's still aggregate, asphalt, and air!
2. Be aware of what's happening
3. Participate in conferences/meetings to learn more
4. **Understand the impact of BMD on asphalt binder demand, recycle potential / availability**
5. Evaluate your readiness (e.g., capabilities / needs). Do you need to more people, training, equipment?
6. Act to increase readiness
7. Establish baseline (test your mixes to see where you are at)
8. **Optimize mixes (performance + economics)**
9. Embrace the opportunity!
10. Be the leader!

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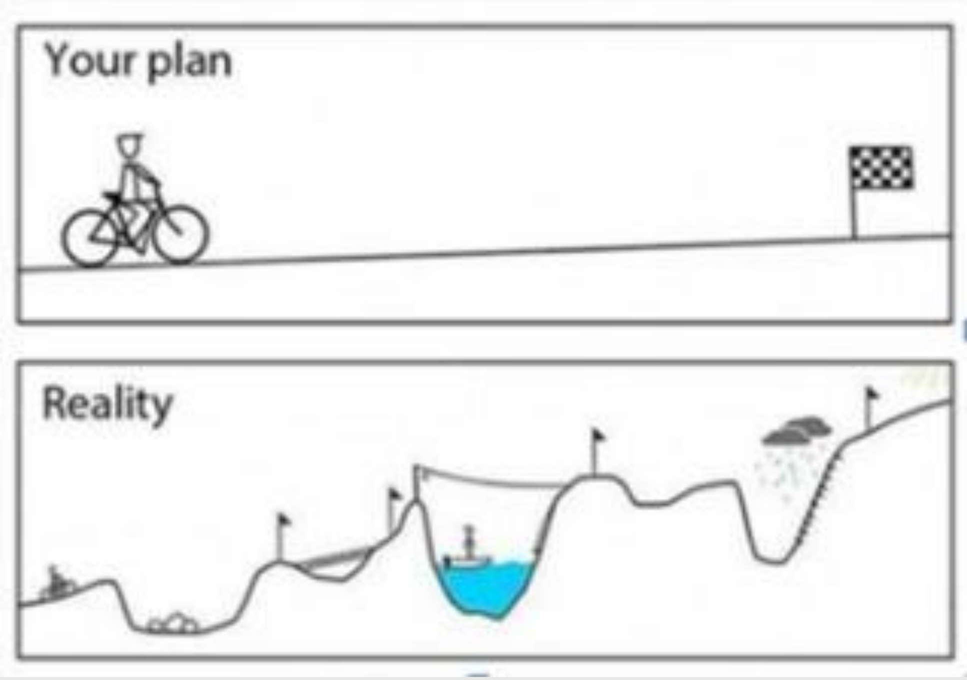
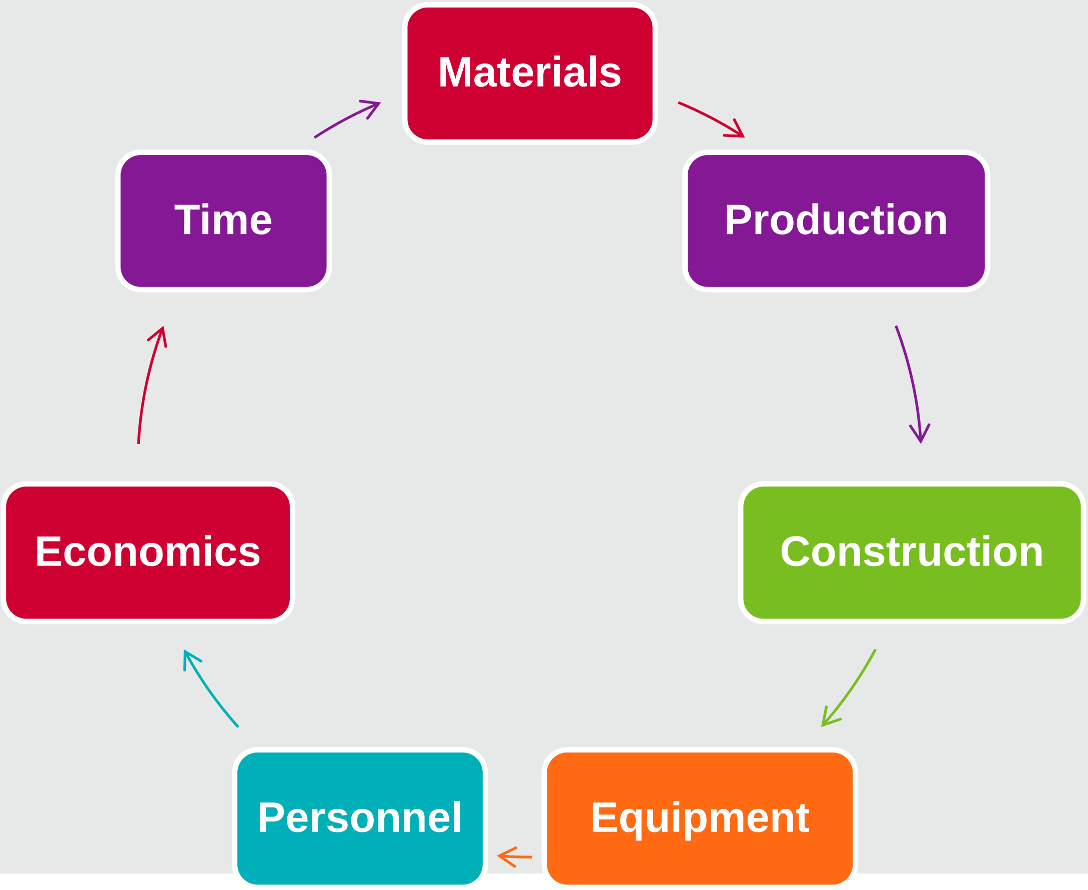
The Path Forward for Balanced Mix Design

- Long term effort with ups/downs, but we must start now.
- Utilize available, proven approaches to find effective, implementable solutions.
- Must consider testing during production.
  - IDEAL CT offers promise in this regard for fast, reliable rutting and cracking performance prediction.



Be Aware of the Total Picture!

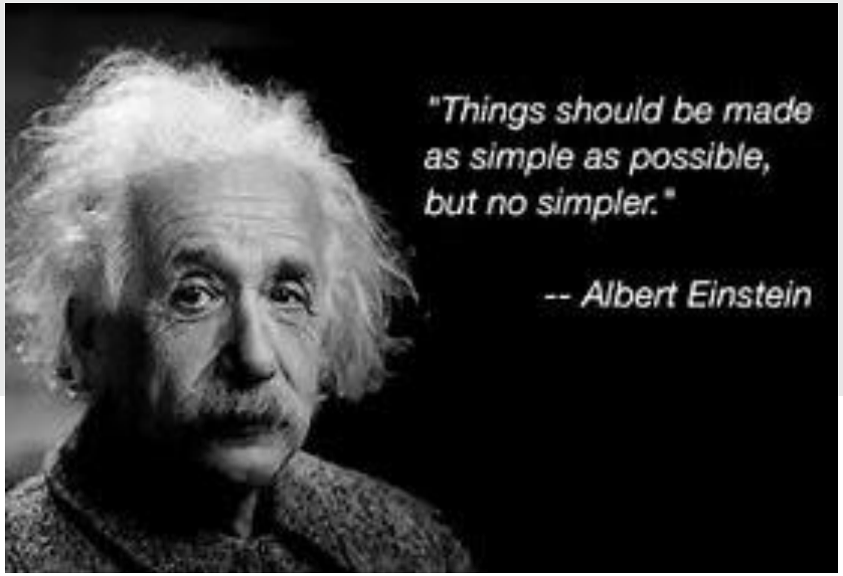


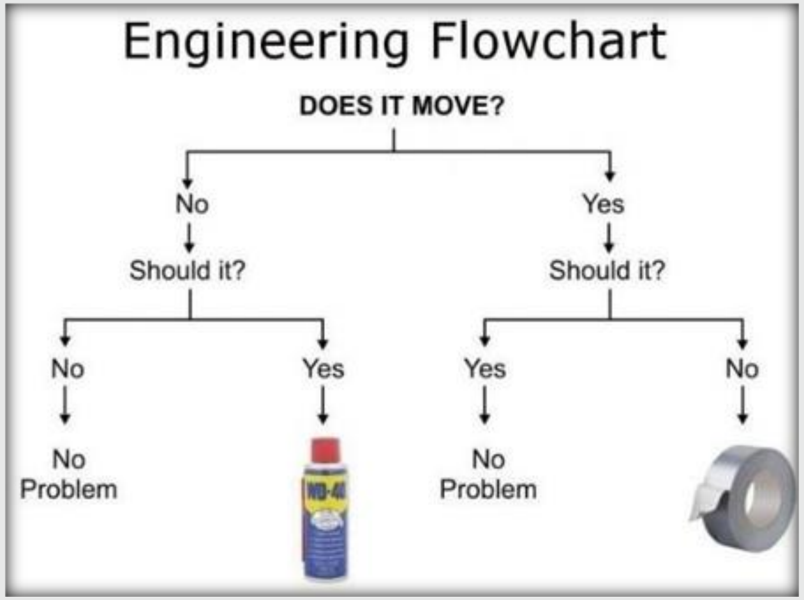
Theory and Reality

- Avoid measuring with a micrometer, marking with a piece of chalk and cutting with an ax.
- Must consider the “total picture” and not just a part.
- Applied Common Sense MUST be used.

Final Thoughts

- Key Points to Keep in Mind
- “Use What Works”
- “Eliminate What Doesn’t”
- **“Be as Simple as Possible, Be Practical, and Be Correct”**





Thank you