Performance-Related Mixes and Balanced Mix Design

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Presentation Overview

- Introduction
- Guideline to Developing Performance Related Specifications (PRS) for HMA
  - Identifying needs
  - Baseline/target development
  - Sampling/Testing Protocols
- Current "Northeast" Practices
- Balanced Mix Design – The Future
- Summary/Conclusions

Terms (TRB Circular E-C173)

- Performance-Based: Quality Assurance specifications that describe the desired levels of fundamental engineering properties that are predictors of performance and appear in primary prediction relationships
  - Resilient modulus, creep properties, fatigue properties
  - Models that can be used to predict pavement stress, distress, or performance
- Performance-Related: Quality Assurance 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
  - Air voids for HMA; Compressive strength for PCC
  - HMA performance testing(?)

Why the Need for PRS for HMA?

- Currently a concern among state agencies that current volumetric mixture design does not ensure good field performance
- Depending on climate, traffic, pavement conditions, different state agencies require different levels of performance
  - Not all HMA is created equal
    - New Jersey – rutting, fatigue cracking, reflective cracking
      - Different criteria required for different mix type, location in pavement, and pavement type

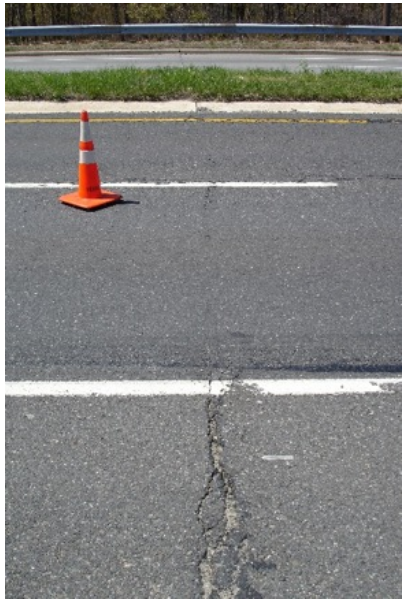
Guideline to Developing Performance Related Specifications (PRS)

Guidelines for Developing PRS

- Know your pavement performance
- Develop a baseline for performance
- Select an appropriate test procedure
- Develop testing & specification structure
- Go back and re-evaluate

Know Your Pavement

- Important to recognize pavement issues
- Testing methods should try to simulate distress types found in the field
  - Rutting, fatigue cracking, reflective cracking, thermal cracking
    - Mode of failure should be used in the lab
    - Test temperatures should model climate conditions
- Example:
  - New Jersey: Fatigue Cracking
    - Bridge Deck Mix – uses Flexural Beam fatigue
    - Bituminous Rich Intermediate Course – use Overlay Tester



Develop a Performance Baseline

- How would you like your materials to perform?
  - Historical field data (PMS)
  - Database of material properties
  - Performance criteria should be developed using the performance of local materials
    - Try to avoid "adopting" other state's specifications when you do not have history of local material performance
- New Jersey Example: High RAP Specification
  - Performance criteria based on virgin (0% RAP) mix
- NYCDOT: High RAP Specification
  - Developing performance criteria based on 30% RAP mix (30% RAP is minimum NYC must use)

Select Appropriate Test Procedure

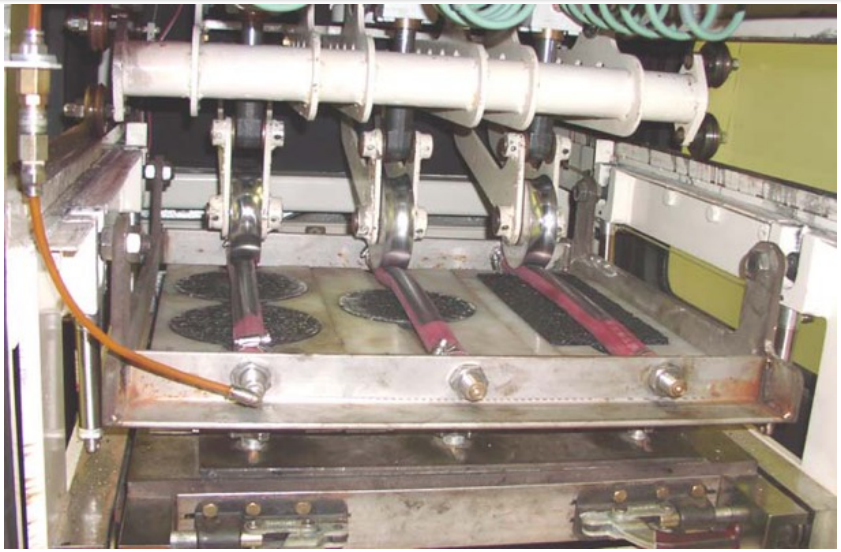
- Priorities of test procedure
  - Correlates to field performance
  - Sensitivity to mixture properties
  - Repeatability
  - Ease of use (procedure, test specimen, time and analysis)
  - Availability/Cost
- NCHRP 9-57 Study – Mixture Cracking Tests

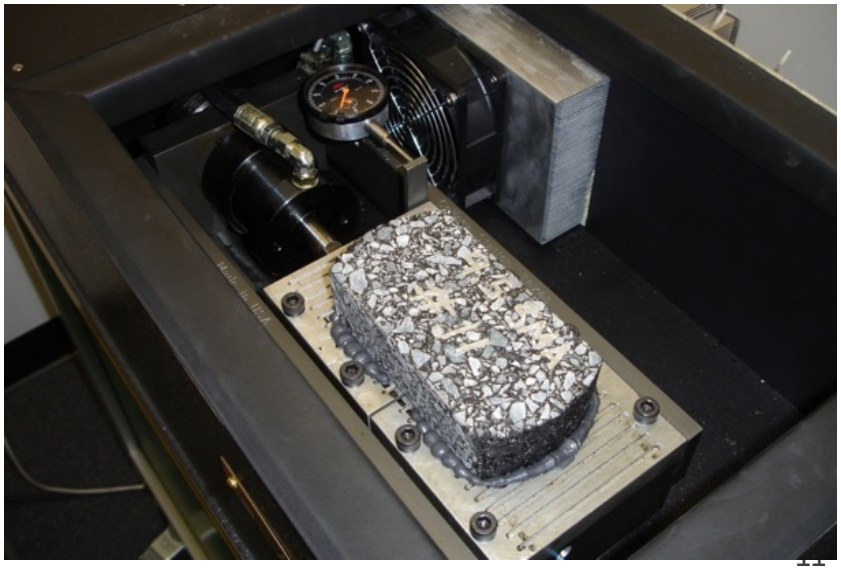
Thermal cracking tests	Reflection cracking tests	Fatigue cracking tests	Top-down cracking tests
1. DCT 2. SCB-IL 3. SCB (AASHTO TP105)	1. OT 2. SCB-LTRC 3. BBF	1. Beam fatigue 2. SCB-LTRC 3. OT*	1. IDT-Florida 2. SCB-LTRC

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

Select Appropriate Test Procedure

- Example: New Jersey
  - Rutting: Asphalt Pavement Analyzer (AASHTO T340)
  - Fatigue Cracking:
    - Bridge Decks – Flexural Beam Fatigue (AASHTO T321)
    - BRIC, HRAP – Overlay Tester (NJDOT B-10; TxDOT Tx-248F)
  - Rt 80 in New Jersey
    - 2015 construction
    - NJDOT HPTO mixture
    - Testing indicated 1st 4 nights' production failed rutting criteria

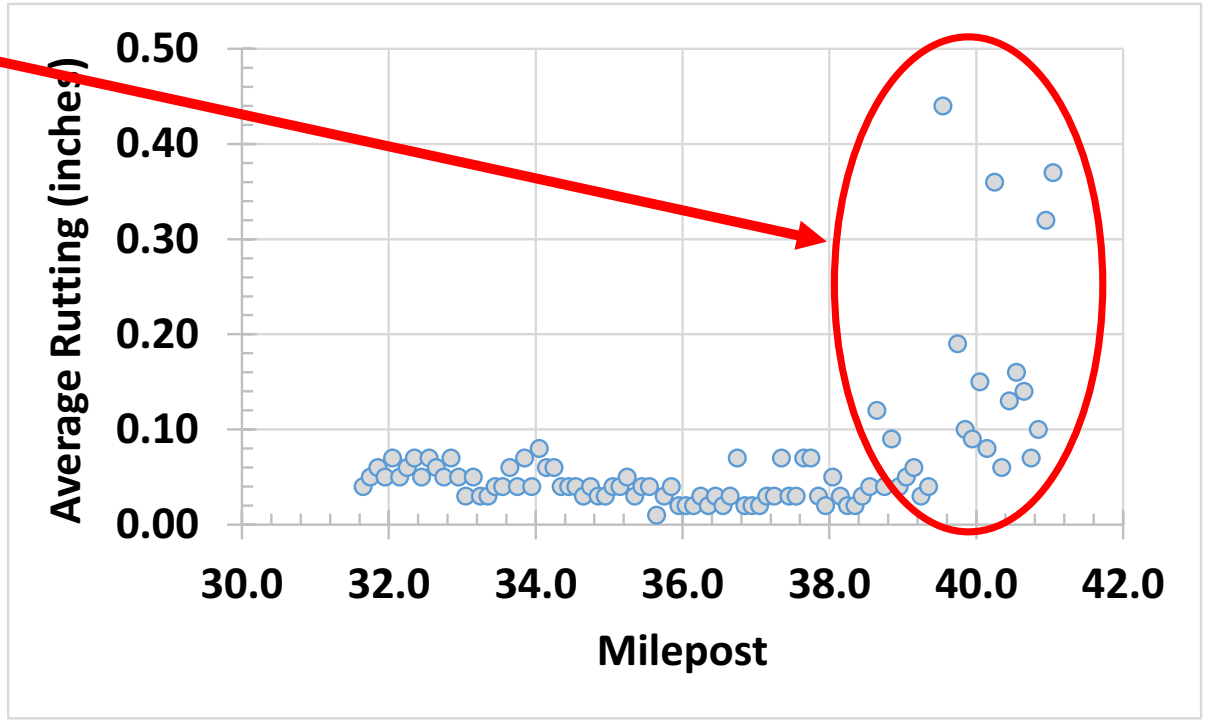




Select Appropriate Test Procedure

- Example: New Jersey HPTO – AASHTO T340

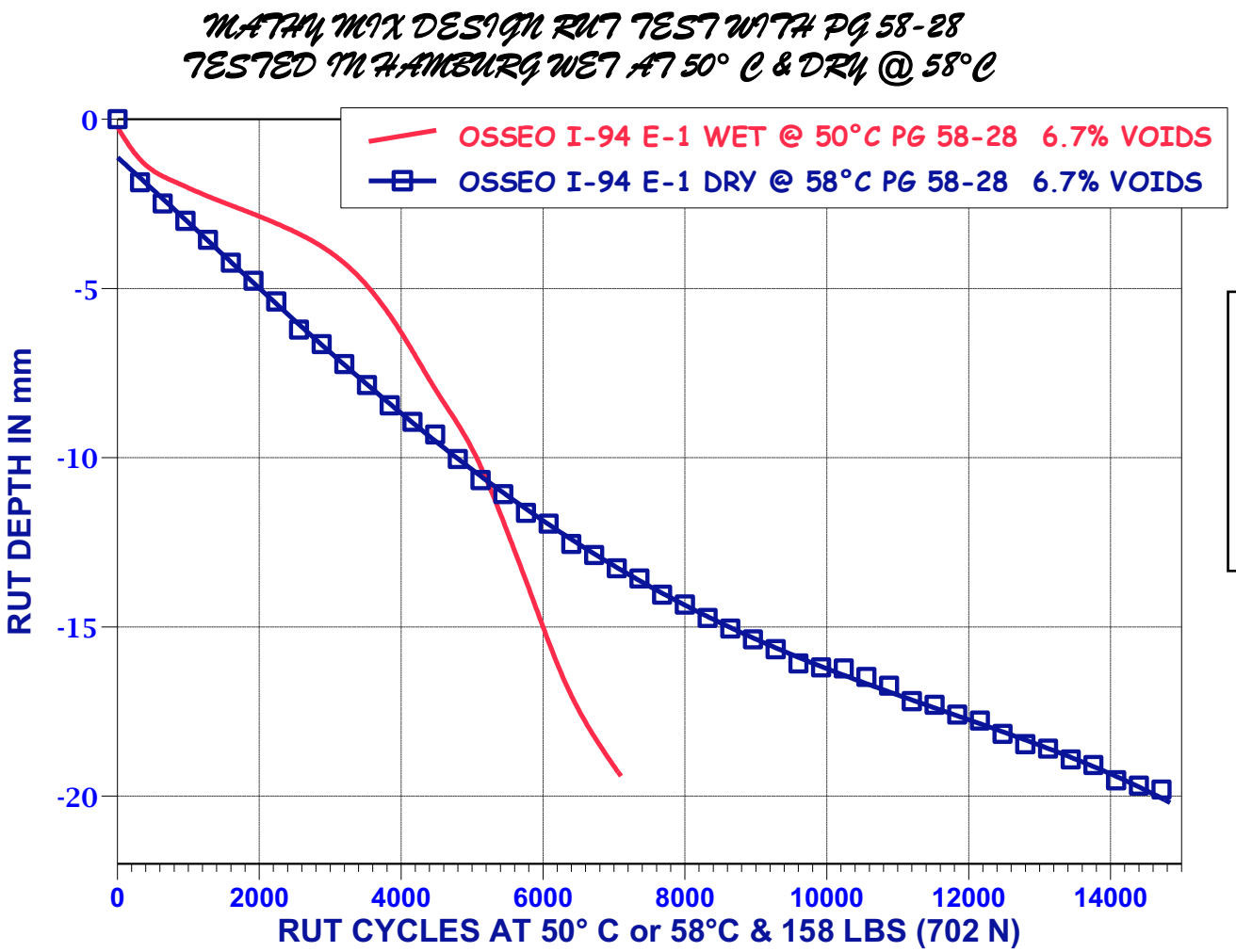
Date	APA (mm)
5/27/2015	6.56
5/28/2015	6.23
5/29/2015	6.5
6/3/2015	6.84
6/4/2015	3.66
6/5/2015	3.87
6/9/2015	3.92
6/10/2015	4.32
6/11/2015	3.98
6/12/2015	3.73
6/17/2015	3.83
6/18/2015	2.94
6/19/2015	2.73
6/24/2015	3.99



Select Appropriate Test Procedure

- Be careful of adopting test methods and criteria developed by other agencies
  - Should you consider a rutting and fatigue cracking to "balance" performance?
- Be careful of selecting test procedures where results may be dependent on multiple failure mechanisms
  - Example: Hamburg Wheel Tracking (TxDOT) for rutting
    - Running test under water couples stripping and rutting – which mode of distress dominates?

Ex. - Hamburg: Rutting or Stripping or Both?

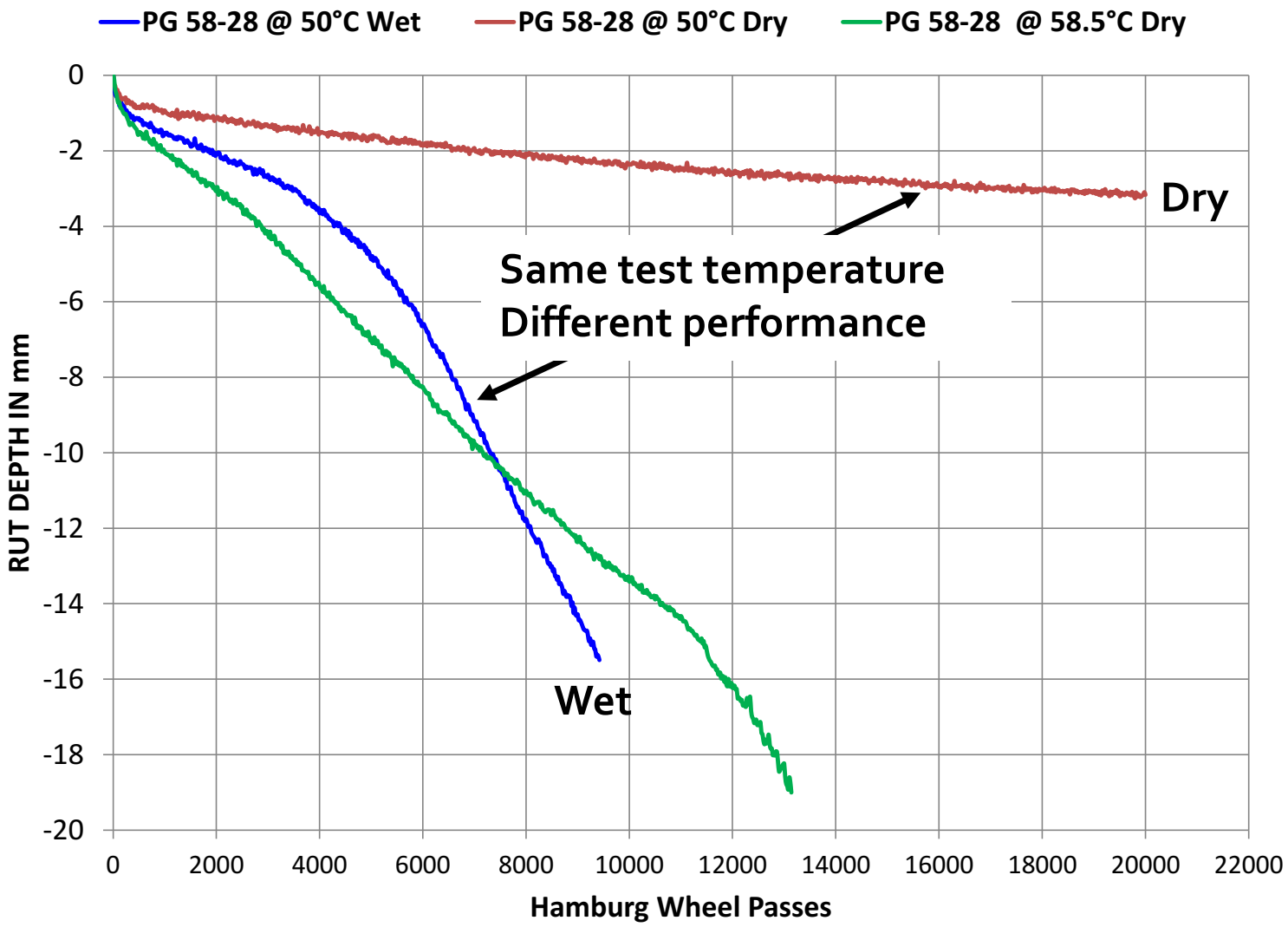


Rutting rates for wet HWT before and after stripping onset are different. Rutting rate for dry HWT is uniform.

(Reinke, 2016)

11/09/03 21:39:29 E:\PMW DATA\MATHY 2003 MIX DESIGN\COMPARE WET & DRY OSSEO I-94 RUT TEST.spf

Ex. - Hamburg: Rutting or Stripping or Both?



(Reinke, 2016)

Develop Specification Structure

- Stage of testing
  - Should it be included during mix design? Test strip? QC/QA?
- Frequency of testing
  - Lot, night's production?
  - Keep in mind time requirements of the test method
- Responsible testing laboratory
  - State lab, consultant, university partner, asphalt plant under state inspection
  - AMRL accreditation required?
- Handling failing results
  - Remove/replace, pay adjustment, stop production to adjust mix

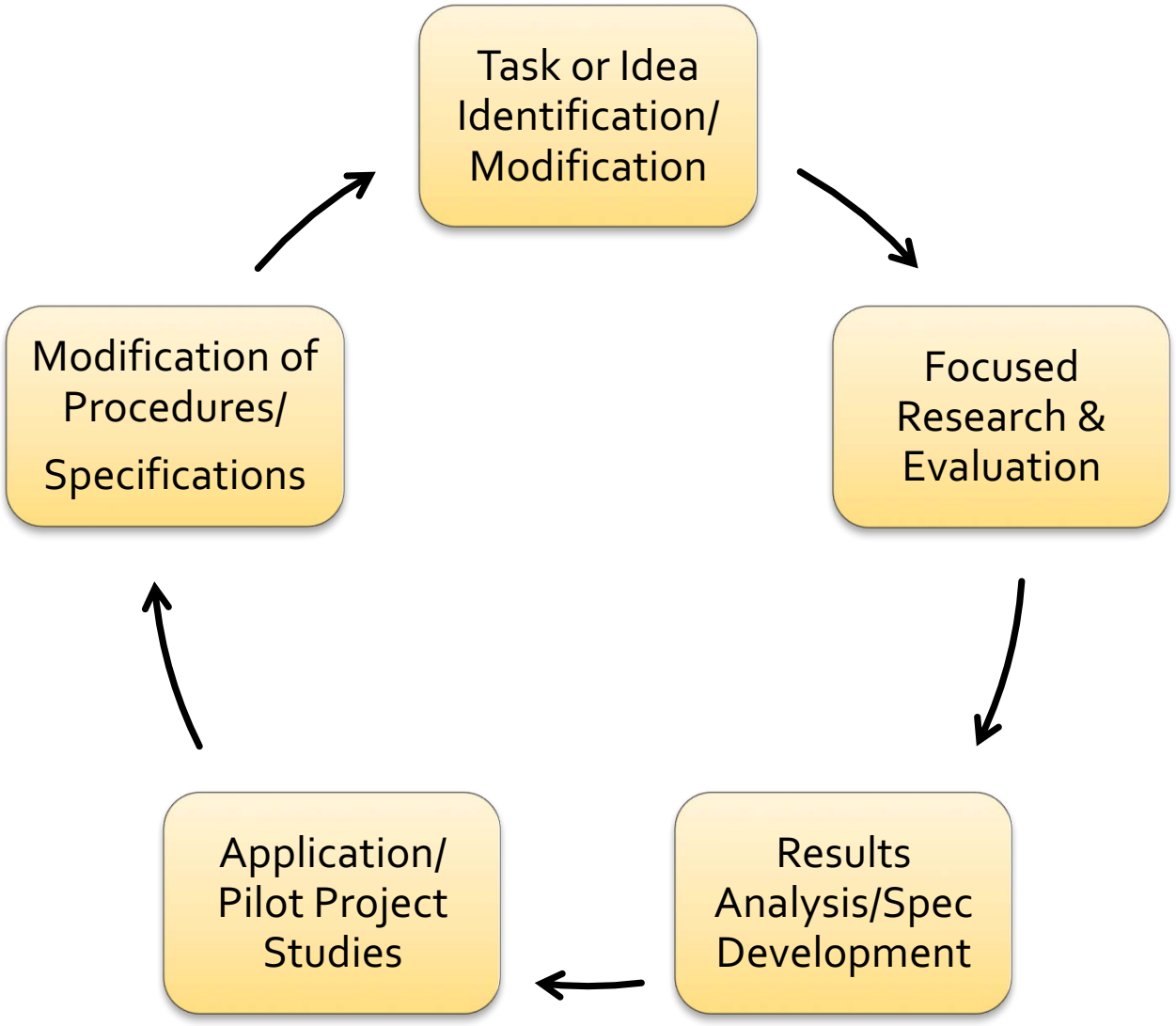
Develop Specification Structure

- Example: New Jersey
  - Testing conducted;
    - During mix design, required test strip, 1st and every other Lot
      - Small production quantities are tested once per night production
  - Testing laboratory;
    - Up to 1/2016 – University Partner (Rutgers – AMRL Accredited)
    - 1/2016 – Present – NJDOT Central Laboratory
  - Handling failing results
    - Mix design – must conduct redesign until passes
    - Test strip – must conduct another test strip until passes
    - Mainline – pay adjustment (negative only at this time)

Develop Specification Structure

Table 902.11.04-2 Performance Testing Pay Adjustments for HMA HIGH RAP					
	Surface Course		Intermediate Course		
	PG 64-22	PG 76-22	PG 64-22	PG 76-22	PPA
APA @ 8,000 loading cycles, mm (AASHTO T 340)	t ≤ 7 7 > t > 10 t ≥ 10	t ≤ 4 4 > t > 7 t ≥ 7	t ≤ 7 7 > t > 10 t ≥ 10	t ≤ 4 4 > t > 7 t ≥ 7	0 – 1 – 5
Overlay Tester, cycles (NJDOT B-10)	t ≥ 150 150 > t > 100 t ≤ 100	t ≥ 175 175 > t > 125 t ≤ 125	t ≥ 100 100 > t > 75 t ≤ 75	t ≥ 125 125 > t > 90 t ≤ 90	0 – 1 – 5

Go Back and Re-evaluate



"Northeast" States Survey Performance Related Specs

Northeast Survey

- Brief email survey sent out to "Northeast" states regarding current/potential use of PRS
  1. Is your state using PRS, and if so, at what level?
  2. Who conducts the testing?
  3. What pavement distresses are you concerned with?
  4. What performance tests are you using?
  5. What types of asphalt mixtures are you using PRS?
- States responding
  - 8 Northeast (CT, DE, NH, NJ, NY, PA, RI, VT) + Missouri

Northeast Survey

- At what level is your state using PRS?
  - 2 states using/developing PRS solely for mixture design acceptance
  - 1 state using/developing PRS for mixture design and Quality Acceptance
  - 2 states using/developing PRS for quality acceptance
  - 2 states still working on PRS
  - 2 states not interested at the moment

Northeast Survey

- Who is/would be responsible for testing within your PRS?
  - 3 states using solely their agency laboratory
  - 1 state combining agency and consultant services
  - 2 states combining agency and university partner
  - 1 state requiring contractor to hire accredited laboratory

Northeast Survey

- What pavement distresses are you most concerned with?
  - Fatigue cracking (7 states)
  - Thermal cracking (6 states)
  - Rutting (5 states)

Northeast Survey

- Performance tests you are using/considering?
  - Rutting
    - Hamburg Wheel Tracking: 3 states
    - Asphalt Pavement Analyzer: 2 states
    - AMPT Flow Number: 1 state
  - Fatigue cracking
    - Semi-circular Bend (SCB): 3 states
    - Overlay Tester: 2 states
    - Flexural Beam Fatigue: 2 states
  - Thermal cracking
    - Disc Compact Tension (DCT): 1 state

Northeast Survey

- Performance tests you are using/considering?

Mix Design		Quality Control	
Rutting	Flow Number	Rutting	Hamburg
	APA		APA
	Hamburg		
Fatigue Cracking	Flexural Beam	Fatigue Cracking	Flexural Beam
	Overlay Tester		Overlay Tester
	SCB		SCB
Thermal Cracking	N.A.	Thermal Cracking	DCT

Northeast Survey

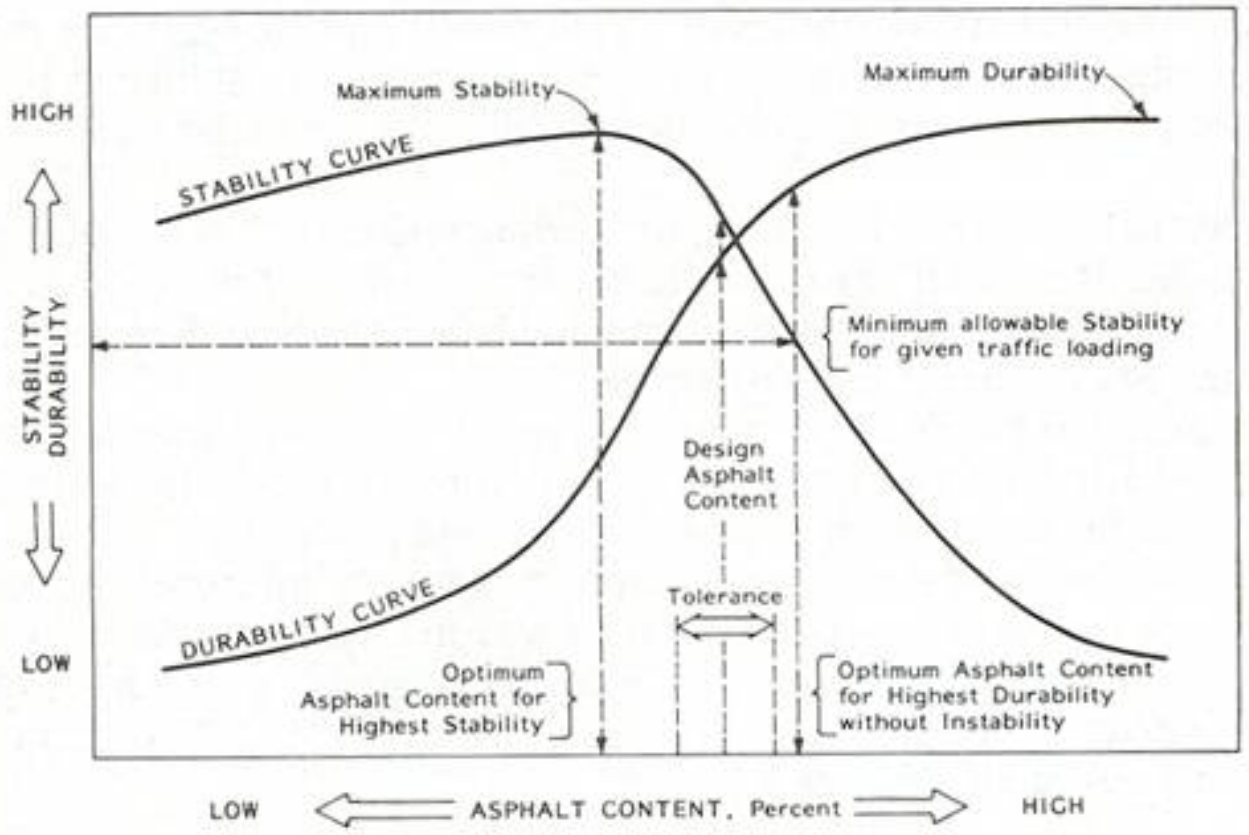
- What types of asphalt mixtures are you concentrating PRS on?
  - Specialty mixes (High RAP, Bridge Deck, etc): 3 states
  - High traffic volume: 1 state
  - When job requires > 6000 tons: 1 state
  - All HMA: 1 state

The Future – Balanced Mix Design

Balanced Mixture Design (BMD)

Original Intent of HMA Design

Get as much asphalt binder in the mixture to improve the Durability until the Stability of the mixture is no longer acceptable. Somewhere in the middle the mix is "balanced"!



(Hveem, 1940)

NJDOT Balanced Mixture Design – Proof of Concept

Dense Graded Mix - Balancing Design

- Hypothesis: Asphalt mixtures should be designed to optimize performance, not around a target air void content
- Use as much asphalt to ensure durability before stability (rutting) is an issue
- Similar to conventional mix design process:
  - Start at dry AC content
  - Add asphalt at 0.5% increments – measure rutting and cracking
  - Determine AC range where rutting and cracking are optimized
  - Conduct volumetric work to compliment performance

Proof of Concept – Design Approach

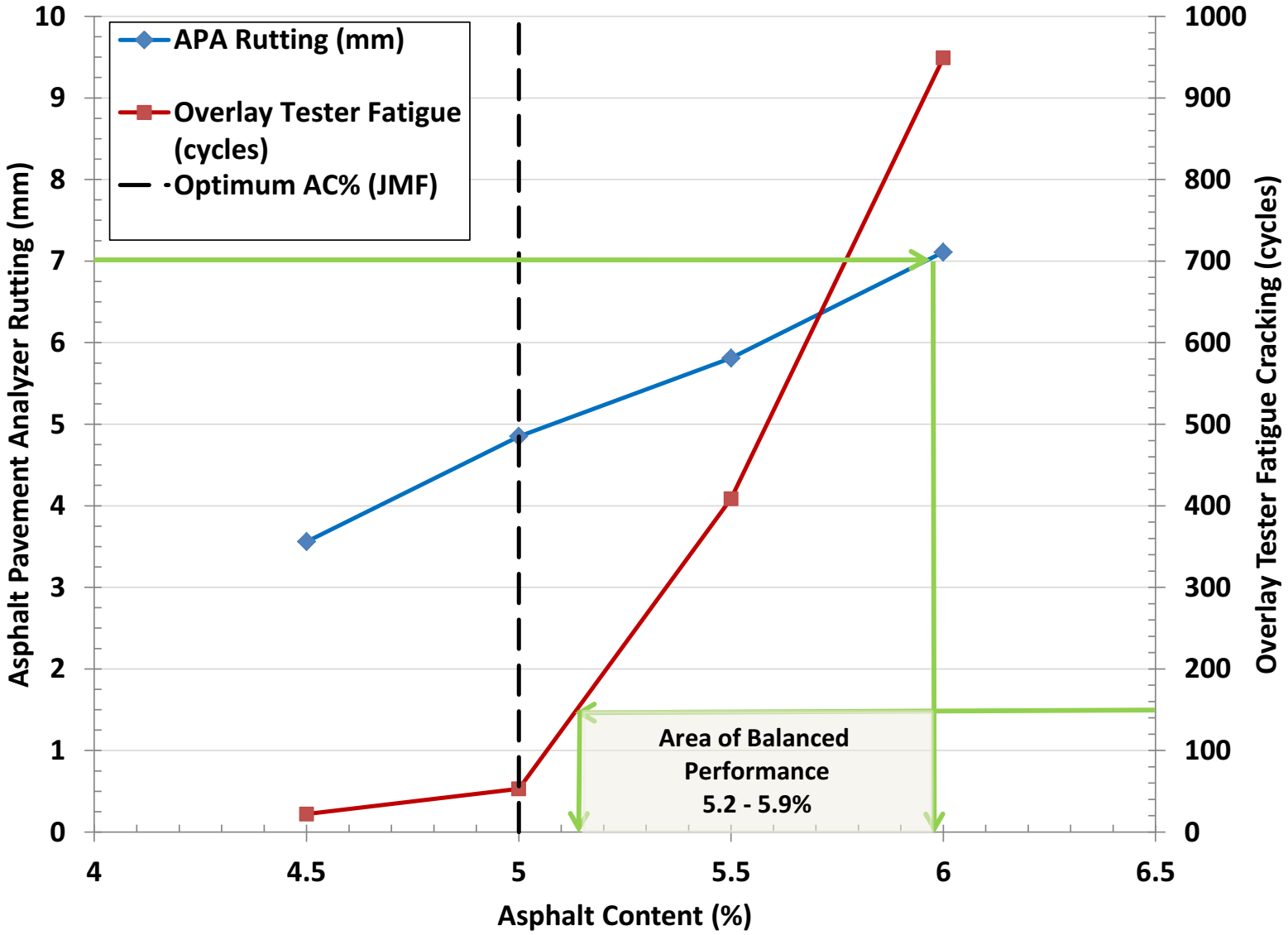
- Evaluated 8 approved NJDOT surface course mixtures
  - 9.5 and 12.5 NMAS mixes
  - PG64-22 (64S) and PG76-22 (64E) binders
  - Trap Rock aggregate; Granite/Gneiss aggregate
  - 15% RAP
  - Evaluated Balanced Design (rutting vs cracking) at different AC%
- Determine Balanced Design Air Voids at the Balanced asphalt content

Balancing Design – Performance Criteria/Thresholds

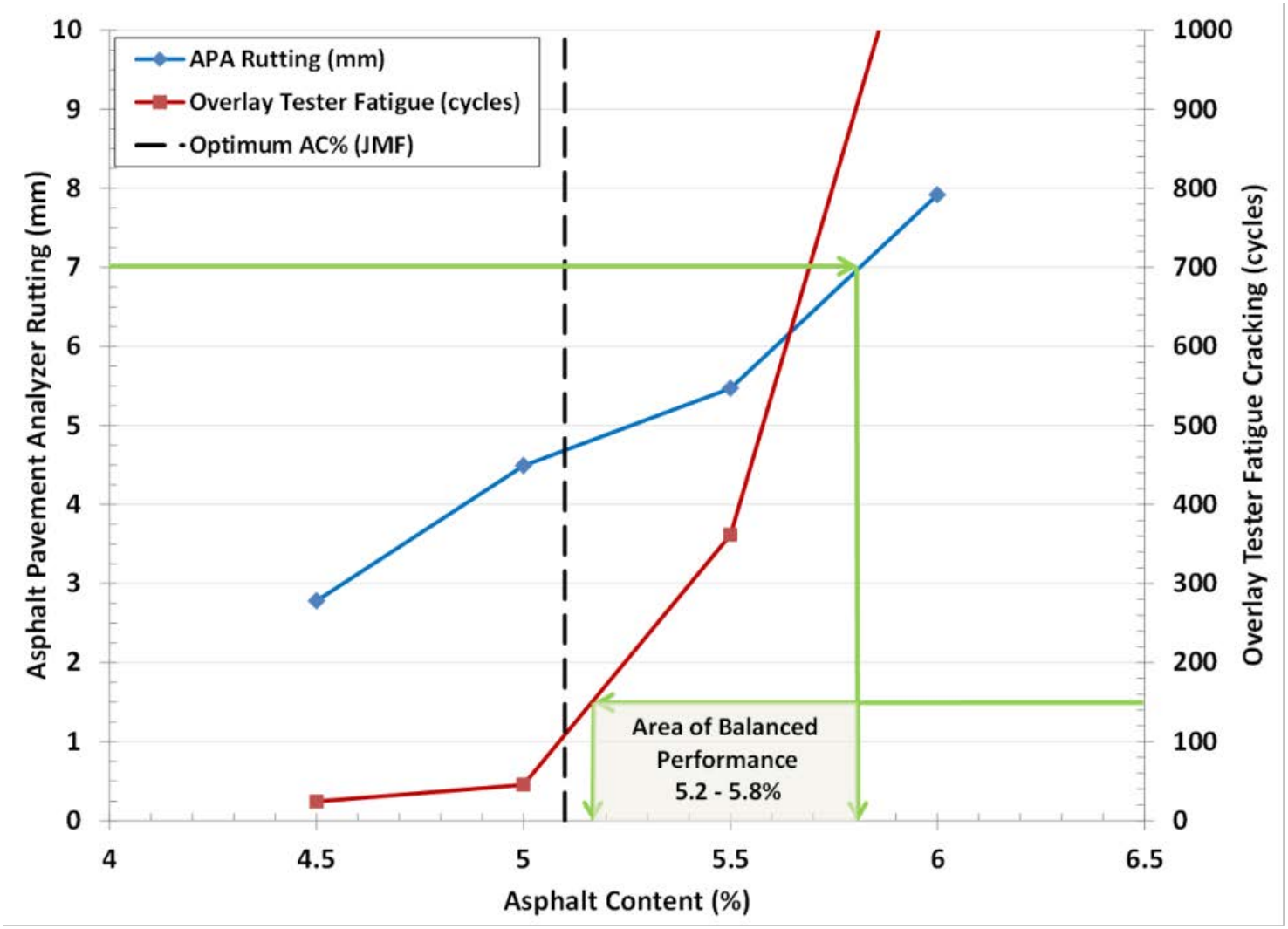
- Criteria: performance criteria established by testing a large number (and variety) of sampled loose mix. Criteria based on:
  - Location in pavement (surface or intermediate/base)
  - Traffic (Low = PG64-22; Moderate to High = PG76-22)

Test	Requirement			
	Surface Course		Intermediate Course	
	PG 64-22	PG 76-22	PG 64-22	PG 76-22
APA @ 8,000 loading cycles (AASHTO T 340)	< 7 mm	< 4 mm	< 7 mm	< 4 mm
Overlay Tester (NJDOT B-10)	> 150 cycles	> 175 cycles	> 100 cycles	> 125 cycles

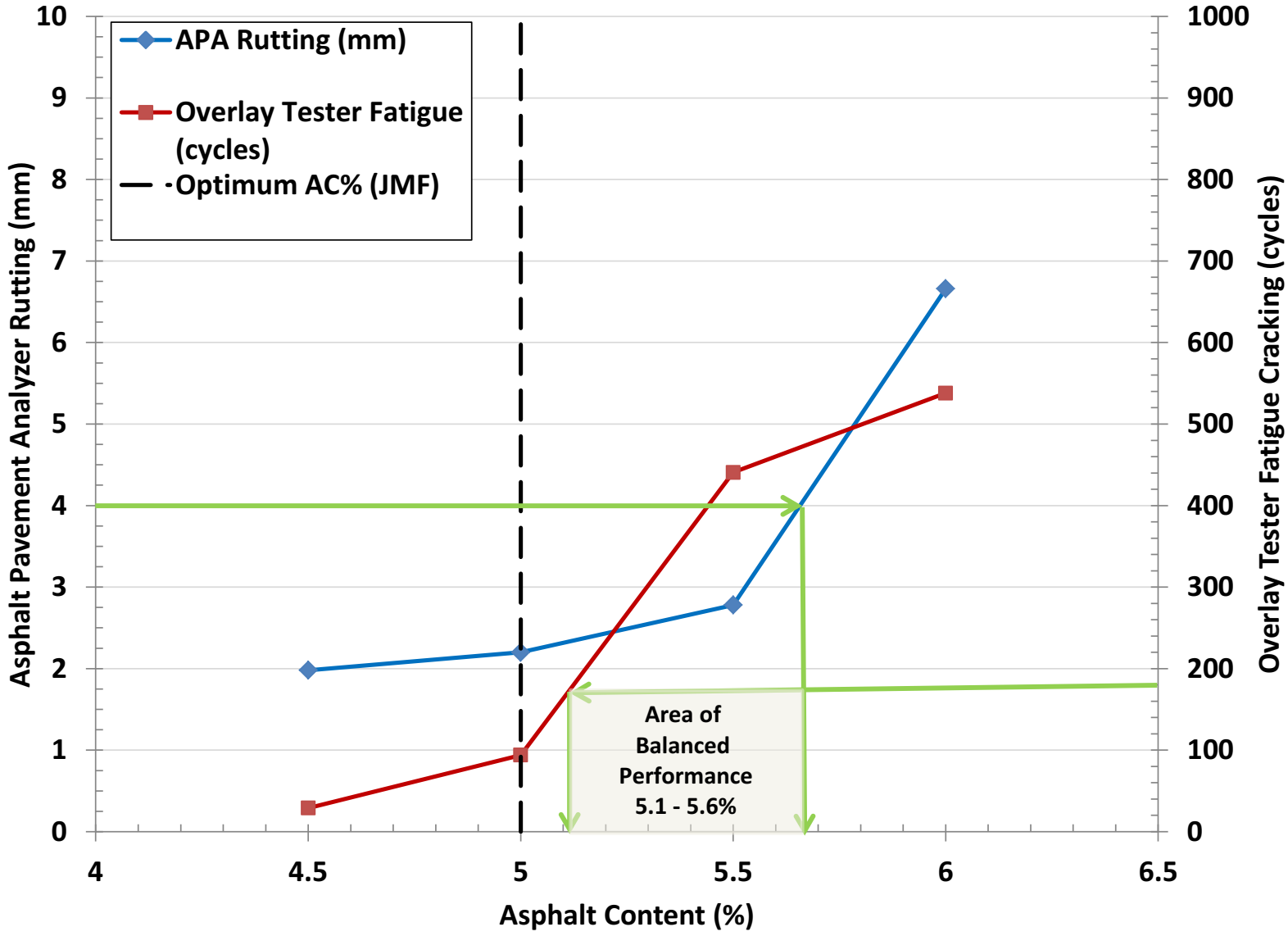
9.5M64, Source #1 - Balanced



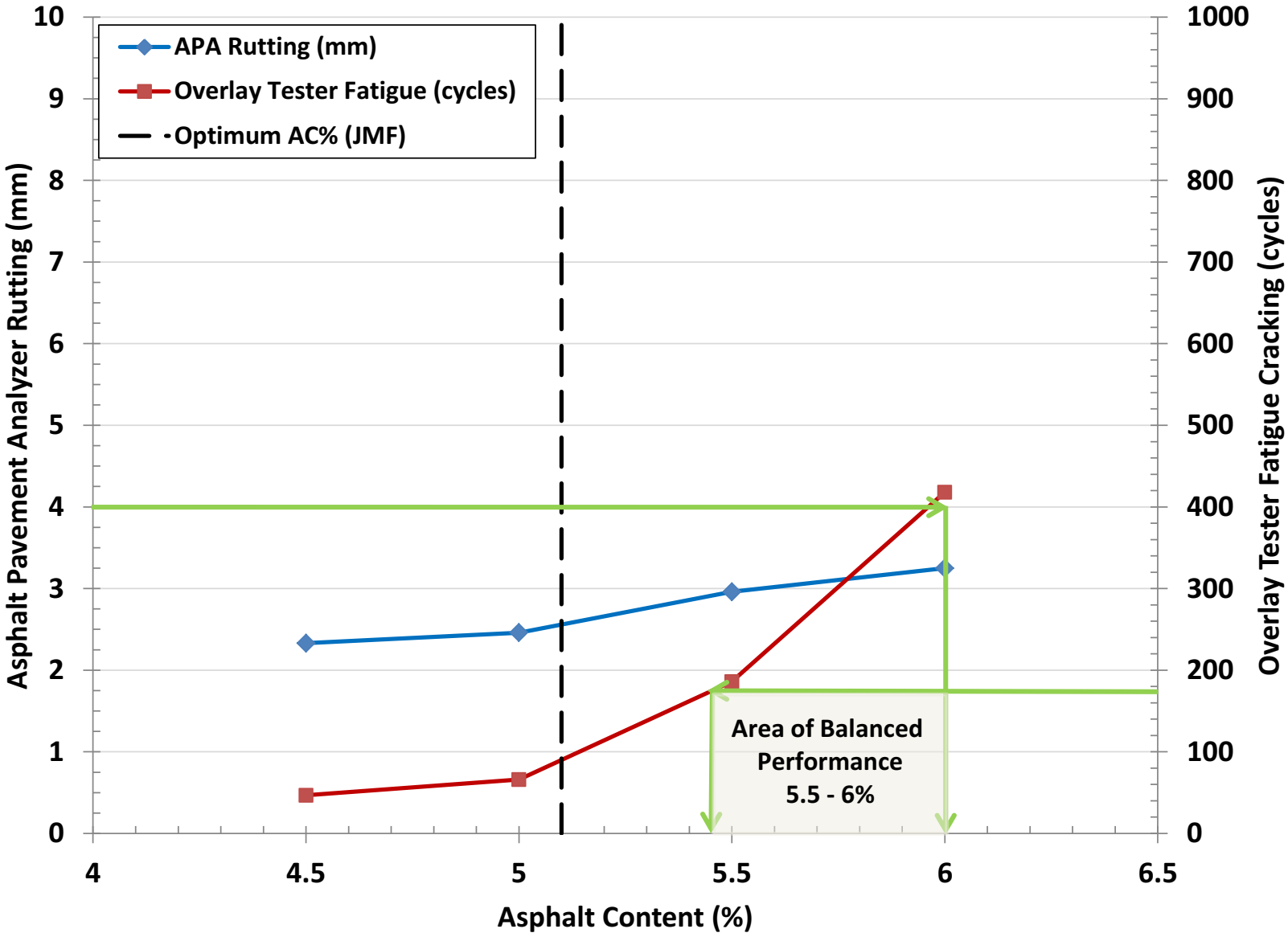
12.5M64, Source #1 - Balanced



9.5M76, Source #1 - Balanced



12.5M76, Source #1 - Balanced



Optimum Asphalt Content Summary

Mix Type (Supplier #1)	Volumetric Optimum AC% (N_{des} = 75	Balanced Mix Design	
		Optimum AC (%)	Air Voids @ AC% (N_{des} = 75 gyrations)
#1, 9.5M64	5.0	5.2 - 5.9 (5.6%)	2.8
#1, 9.5M76	5.0	5.1 - 5.6 (5.4%)	3.9
#1, 12.5M64	5.1	5.2 - 5.8 (5.5%)	3.0
#1, 12.5M76	5.1	5.5 - 6.0 (5.8%)	3.5

Ave = 3.3%

Mix Type (Supplier #2)	Volumetric Optimum AC% (N_{des} = 75	Balanced Mix Design	
		Optimum AC (%)	Air Voids @ AC% (N_{des} = 75 gyrations)
#2, 9.5M64	5.4	5.2 - 5.9 (5.6%)	2.9
#2, 9.5M76	5.4	5.8 - 6.0 (5.9%)	3
#2, 12.5M64	4.6	5.1 - 6.1 (5.6%)	2.8
#2, 12.5M76	4.6	5.6 - 6.1 (5.9%)	3.4

Ave = 3.0%

Recommending Optimum AC%

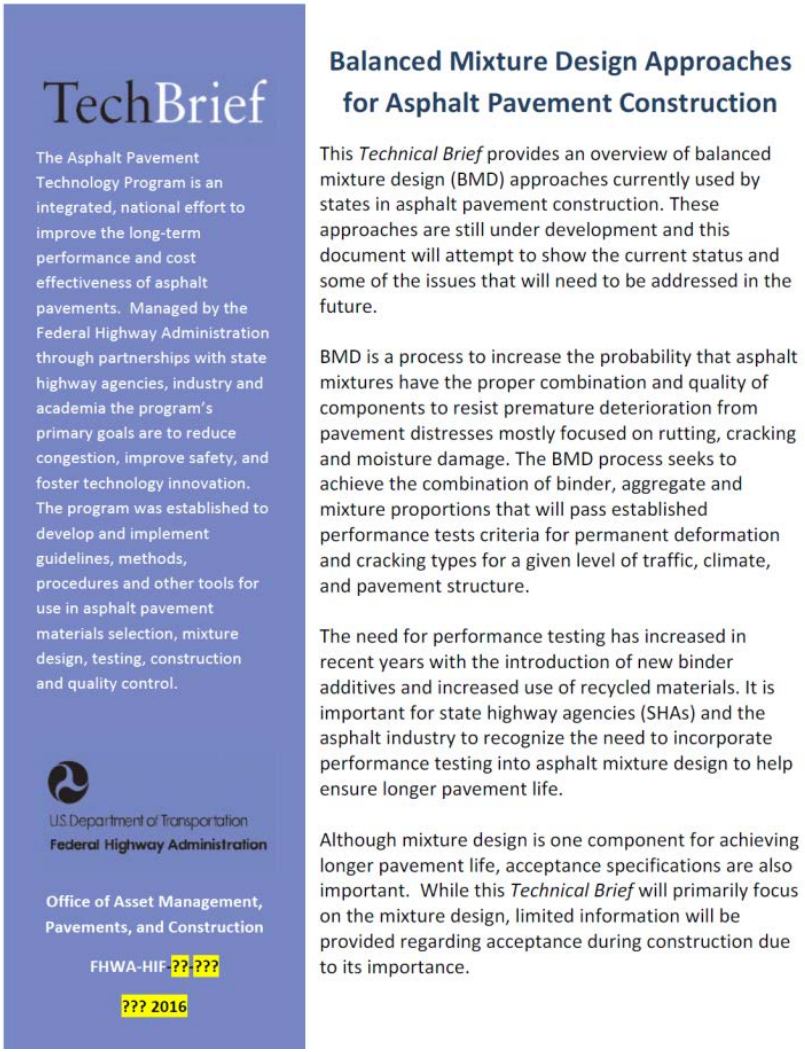
- How to recommend optimum AC%?
  - Center of range?
  - High end of range for increased fatigue resistance (Hveem)?
- How to recommend production tolerances?
  - Target center of range and maintain Balanced Design Optimum AC% ranges
  - Target center and use the lesser of the following:
    - Balanced Design AC% range
    - Current production tolerance of +/-0.35%
  - Does range in AC% indicate "robustness" of the mix?

Balanced Design Approach

- Balanced Design Approach indicating that most mixes evaluated to date are designed and produced dry of "Balanced Area" in NJ
  - Durability/cracking largest issue in NJ
  - Resultant Balanced AC% would result in compacted air voids around 3% @ 75 gyrations, but varies based on mixture type
- Changes in current production volumetrics most likely required for implementation
- Methodology for selecting "optimum AC%" needed

Balanced Mixture Design (BMD)

- Additional information
  - FHWA ETG developing TechBrief to provide information on BMD to help provide guidance
    - Going through final editing



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 Federal Highway Administration through partnerships with state highway agencies, industry and academia the program's primary goals are to reduce congestion, improve safety, and foster technology innovation. The program was established to develop and implement guidelines, methods, procedures and other tools for use in asphalt pavement materials selection, mixture design, testing, construction and quality control.

U.S. Department of Transportation
Federal Highway Administration

Office of Asset Management, Pavements, and Construction

FHWA-HIF-??-???

??? 2016

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.

BMD is a process to increase the probability that asphalt mixtures have the proper combination and quality of components to resist premature deterioration from pavement distresses mostly focused on rutting, cracking and moisture damage. The BMD process seeks to achieve the combination of binder, aggregate and mixture proportions that will pass established performance tests criteria for permanent deformation and cracking types for a given level of traffic, climate, and pavement structure.

The need for performance testing has increased in recent years with the introduction of new binder additives and increased use of recycled materials. It is important for state highway agencies (SHAs) and the asphalt industry to recognize the need to incorporate performance testing into asphalt mixture design to help ensure longer pavement life.

Although mixture design is one component for achieving longer pavement life, acceptance specifications are also important. While this *Technical Brief* will primarily focus on the mixture design, limited information will be provided regarding acceptance during construction due to its importance.

Summary/Conclusions

- HMA volumetrics do not tell the whole story
  - Used as a surrogate for actual performance testing
  - Increased use of polymers, WMA, recycled binders can change performance without changing volumetrics
- PRS can provide confidence to state agencies that HMA designed and produced will perform to a required level
- Many layers within PRS that agencies must consider
  - Not a one size fits all. Agencies need to develop specifications that best works for their traffic, pavement, and climate conditions (state/regional development)
- PRS develops the foundation needed for Balanced Mixture Design – the way mixture design was intended!


Thank you for your time!
Questions?
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