Industry Practices and Suggestions for Adjusting Asphalt Mixtures to Meet Balanced Mix Design (BMD) Specifications

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NOTICE

Research Projects and Papers

- Final Technical Brief
  - Adjustment of Mixture Design/Job Mix Formula to Satisfy Mechanical Properties, WRSC-TB-22-01
    - Praveen Gopisetti, Harold Von Quintus, Thomas Bennert, Elie Hajj and Tim Aschenbrener
    - https://www.unr.edu/wrsc/tools/asphalt/dapt-publications
    - Simply Google: “UNR BMD FHWA”

WOLF PACK NEVADA

TechBrief

WRSC-TB-22-01
January 2023

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Adjustment of Asphalt Mix Design/Job Mix Formula to Satisfy Mechanical Test Properties

This Technical Brief summarizes information related to practices and suggestions being used by industry for asphalt mixture adjustments to get acceptable test results to meet Balance Mix Design (BMD) specifications set forth by agencies. This was achieved through interviews with eight individuals with vast experience on BMD. General considerations for making adjustments and for improving rutting or cracking resistance are summarized.

Introduction

Asphalt mixture mechanical tests (e.g., Hamburg Wheel-Track, Asphalt Pavement Analyzer, Indirect Tensile Cracking) are growing in use by numerous State Departments of Transportation (DOTs) as part of their standard material specifications to complement volumetric properties and help ensure satisfactory asphalt mixture performance. These mechanical tests have been used by State DOTs as part of their Balanced Mix Design (BMD) process on pilot, shadow, or standard asphalt pavement projects. Efforts are also being made by some State DOTs to advance mechanical tests within their long-life asphalt pavement program or their mechanistic-empirical pavement design process. Thus, with well-developed asphalt mixture mechanical test methods and practices, State DOTs, contractors and consultants have valuable experiences and lessons learned that could facilitate the implementation of a mechanical test into practice by other DOTs. This Technical Brief aims to share information on the experience of individuals with adjusting mix designs to meet mechanical test requirements.

In 2020, information on positive practices, lessons learned, and challenges when implementing BMD and mechanical testing of asphalt mixtures were collected through virtual site visits.[1] The collected information was organized into three categories or topics:

- Positive practices which are those successful efforts that were used by a State DOT that could also be considered by other DOTs.
- Lessons learned which are those efforts that a State DOT would reconsider if had to do it over again.
- Challenges which are those efforts that a State DOT is still in the process of addressing.

General Approach

- Select 7 industry personnel
  - Vast experience on Balanced Mix Design (BMD)
  - Regionally diverse
  - Organizationally diverse
- Interview each over a 2-day period
  - Questions provided ahead of time so interviewee could prepare
- Conduct post interview to verify interview responses/content
- Consolidate findings and develop best practices
  - Serve as a guide to contractors planning their own experiments
  - Assist to accelerate the learning curve and facilitate implementation of BMD concepts

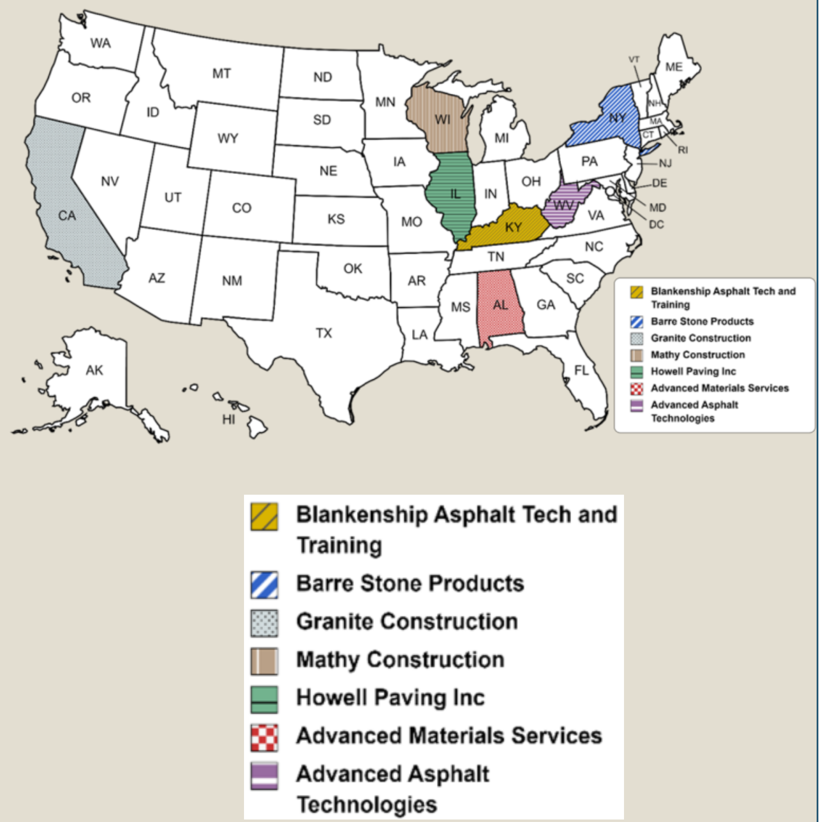
Overview

1. Interviewees and Their Experience
2. BMD Approach Considerations & Mechanical Testing
3. Adjustments to Asphalt Mixture Components to Satisfy BMD
4. Suggestions for Improvements Going Forward
5. Conclusions

Interviewees & Their Experience

Interviewees

Names of the Interviewees	Current Position and Organization	Number of Years in Current Position	Positions/Experience with other Organizations
Ramon Bonaquist	Chief Operating Officer, Advanced Asphalt Technologies	24 years	Research Engineer, FHWA (10 years)
Andrew Hanz	Vice President of Technology and Research, Mathy Construction	8 years	Graduate student and Postdoctoral associate at University of Wisconsin Madison
Brian Prowell	Principal Engineer, Advanced Materials Services	15 years	Assistant Director- NCAT Virginia Transportation Research Council Instructor – Virginia Tech
Michael Kleames & Marty McNamara	Quality Manager III & Director of Quality Control, Granite Construction	7 years & 21 years	Geotechnical consultant for private engineering firms & Consultant focusing on pavement management systems and pavement design
Philip Blankenship	Owner and CEO, Blankenship Asphalt Tech and Training	4 years	Asphalt Institute Kentucky Transportation Cabinet Koch Industries
Greg Rose	Quality Manager, Barre Stone Products	6 years	Material Producer for private firms- 30 years
Pat Koester	Vice President (Production), Howell Paving Inc	17 years in current position and 28 years overall with the organization	Illinois DOT (District 7) – 10 years



Balanced Mixture Design (BMD) Approaches

- Approach A – Volumetric Design with Performance Verification
- Approach B – Volumetric Design with Performance Optimization
- Approach C – Performance Modified Volumetric Design
- Approach D – Performance Design

- References:
  - AASHTO PP 105-20 (2022), *Standard Practice for Balanced Design of Asphalt Mixtures*
  - FHWA Tech Brief, 2022, *Balanced Asphalt Mix Design: Eight Tasks for Implementation*, FHWA-HIF-22-048

Interviewee/Organization Experience with BMD Approaches

- Enormous experience by the interviewees
- Each organization in table has implemented an in-house approach to incorporating BMD practices
  - In some cases, it was found that a hybrid approach (combining philosophies of different approaches) work best for them

Organization	States worked with on BMD Projects	BMD Approach	Number of Annual Projects/Asphalt Mixture Tonnage
Advanced Asphalt Technologies	Pennsylvania	• Approach A	Mostly involved in Research and Development projects. Mixture designs are typically done by producers in West Virginia.
Mathy Construction	Wisconsin, Minnesota, Iowa	• Approach A	30 to 40 projects.
Advanced Materials Services	Alabama, New Jersey, Florida, California, Arizona	• Approach A • Approach B • Approach C for 50% RAP mixes and also with the AASHTO Pavement ME® software for forensic analysis	15 to 20 projects. Multiple projects on high performance pavements (racetracks and port facility pavements).
Granite Construction	California	• Approach D	238,300 tons (2020 and 2021 paving seasons).
Blankenship Asphalt Tech and Training	Kentucky	• Approach A • Kentucky is still in the process of implementing BMD	10 to 20 projects.
Barre Stone Products	New York	• Approach A	25,000 to 100,000 tons a year.
Howell Paving Inc	Illinois	• Approach A • Approach B	Varies.

BMD Approach Considerations & Mechanical Testing

Critical Volumetric Criteria & Mechanical Tests Used

- Effective asphalt-based volumetric parameters and air voids found to be most critical by all interviewees
- Mechanical tests highly influenced by regional State DOTs use
  - "Simpler the better…"

Organization	Volumetric Properties	Mechanical Tests for Mix Design	Mechanical Tests for Production or QA
Advanced Asphalt Technologies	• Air Voids • Binder Content by Volume	• HT-IDT • IDEAL-CT	• HT-IDT • IDEAL-CT
Advanced Materials Services	• Air Voids • VMA • VFA	• HWT • IDEAL-CT	• HWT
Granite Construction	• Air Voids • VMA • OBC • DPe	• FN • HWT • SCB	• FN • HWT • SCB
Blankenship Asphalt Tech and Training	• VMA • Air Voids	• HWT • IDEAL-RT • IDEAL-CT	• HWT • IDEAL-RT • IDEAL-CT
Barre Stone Products	• VMA • Air Voids • VFA	• HT-IDT • IDEAL-RT • SCB • IDEAL-CT	• N/A
Howell Paving Inc	• Air Voids • VFA • VMA • Asphalt Content	• HWT • SCB • I-FIT • TSR	• HWT • SCB • I-FIT

BMD Approach Considerations
– Volumetric Properties vs Mechanical Testing -

- Lack of understanding regarding impact of mixture component adjustments to final mix performance
  - High degree of experience with respect to asphalt plant modifications and change in volumetrics
  - How to make plant adjustments to improve rutting? Cracking?
- State DOTs need to understand some volumetric criteria may need to be relaxed to achieve desired performance
  - Ex. – Reduced air voids to achieve fatigue cracking, while verifying rutting resistance
  - Ex. – Allow higher dust to binder for high RAP mixes when fatigue cracking passes

Primary Reason for Selecting BMD Approach to Mix Design (not in any order)

- Practicality and simplicity ("BMD process is not that complicated")
- Higher quality asphalt mixtures
  - Net result of better performing asphalt pavement
- Easier to obtain high quality, standardized test equipment
- Coordination and communication with State DOTs improved
- Results in a better QA program with the State DOTs
- Helps with distress specific issues
  - Ex. – Approach A found to help address NJDOT issues with
    - Composite pavement reflective cracking
    - Perpetual pavement design
    - Bridge deck waterproof overlays

BMD Approach Considerations
–Mechanical Test Specimen Conditions, NYSDOT -

NYSDOT – Summary of Testing Criteria for Performance Engineered Mixtures (PEM)

At the Plant		High Temp. IDT	IDEAL-CT Index	SCB FI
Test Method		ASTM D6931, NCHRP 9-33	ASTM D8225	AASHTO T393
Gyratory Specimen Height (mm); 3 Replicates; 7 +/-1 % air voids		80 +/-5 mm	<= 19mm 62+/-1; > 19mm 95 +/-1	50 +/- 1
Aging	Lab Mixed	2 hrs loose mix volumetric conditioning at compaction temp	4 hours loose mix volumetric conditioning at compaction temp	4 hours loose mix volumetric conditioning at compaction temp
	Plant Mixed	Reheat loose mix to compaction temp	Reheat loose mix to compaction temp	Reheat loose mix to compaction temp
Test Temp & Conditioning (Water Bath)		44C for 2 hrs +/- 10 minutes	25C for 2 hrs +/- 10 minutes	25C for 2 hrs +/- 10 minutes

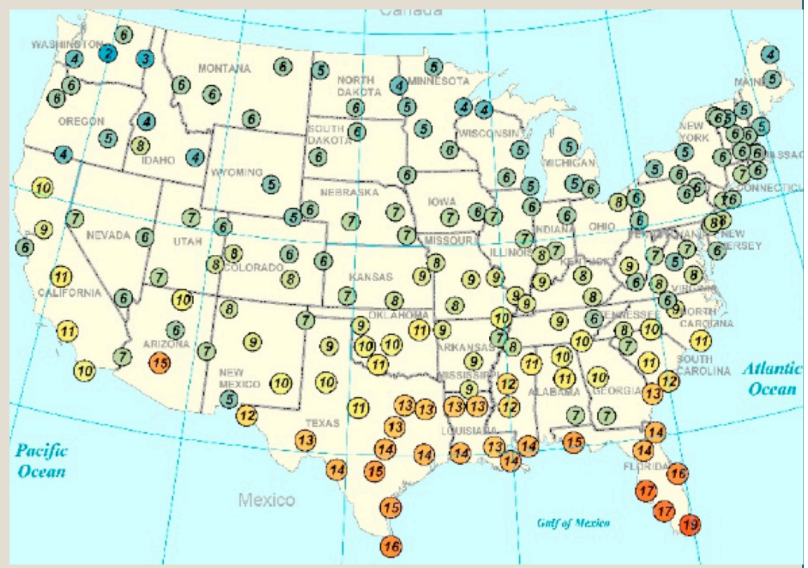
BMD Approach Considerations –Mechanical Test Specimen Conditions, KY & CA -

Organization	Item	Rutting	Cracking	Moisture Damage
Blankenship Asphalt Tech & Training (KY)	Test	Hamburg	IDEAL-CT	Hamburg
	Aging Protocol	4 hr @ 135C (design) 2 hr @ 135C (plant after sampling)	4 hr @ 135C (design) 2 hr @ 135C (plant after sampling)	4 hr @ 135C (design) 2 hr @ 135C (plant after sampling)

Organization	Item	Rutting	Cracking	Moisture Damage
Granite Construction (CA)	Test	AASHTO T378 AMPT	SCB Flexibility Index	Hamburg
	Aging Protocol	Plant drop asphalt mixture in metal cans; store for 24 hrs; Reheat for 2.5 hrs and compact	Plant drop asphalt mixture in metal cans; store for 24 hrs; Reheat for 2.5 hrs and compact	Plant drop asphalt mixture in metal cans; store for 24 hrs; Reheat for 2.5 hrs and compact

BMD Approach Considerations –Mechanical Test Specimen Conditions -

- **Aging** for fatigue cracking will be challenging for day-to-day operations
  - Some interviewees noted impact of long-term aging can be estimated by impact of short-term aging (Bonaquist – WHRP Report, WisDOT ID No. 0092-14-06)
    - AAT – for typical materials, long-term aging not necessary – utilize agency material specifications
- NCHRP Project 9-54
  - Number of days of loose mix conditioning at 95C to simulate 8 years of field aging
    - NJ: 8 days
    - WI: 5 days
    - TX: 9 to 16 days
- Continuing research
  - NRRA (Pooled fund program by Minnesota DOT)
  - NCHRP Project 9-70 (in development)



Adjustments to Asphalt Mixture Components to Satisfy BMD

INDIVIDUAL RESPONSES/RECOMMENDATIONS

Adjustments to Asphalt Mixture Components to Satisfy BMD
–Advanced Asphalt Technologies -

- Rutting:
  - Use of "Resistivity Rutting Model" provides insights into factors that significantly impact rutting
  - IDT at high temperature is great for rutting assessment – fast and cheap
  - Limit or reduce VMA (effective asphalt content) to reduce rutting
  - Rutting decreases as RAP content increases
  - Stiffer binders (PMA, RAP) will generally improve rutting resistance

- Cracking:
- Effective volume of binder is generally governing factor (higher = cracking resistance)
- Pay close attention to recycled asphalt
- Cracking tests will provide justification relative to reclaimed binder ratio (RBR) and effectiveness of recycling agents
- If low temperature cracking, binder properties is predominant factor (except for case of weak aggregates)

Adjustments to Asphalt Mixture Components to Satisfy BMD –**Advanced Asphalt Technologies -**

- Resistivity-Rutting Model
  - Christensen and Bonaquist (2015), TRR
  - Developed from NCHRP 9-25 and 9-31
  - Includes Jnr, AV%, VMA%, gradation, Gsb, design & field compaction, aging, and ESAL traffic speed
  - Provide MESAL's to a maximum rut depth of 12 mm (95% confidence interval)

UNR/FHWA Webinar link:
https://scholarworks.unr.edu/handle/11714/8447

$$TR = 1.31\times10^{-4} N_{des}^{1.578}(PK_aK_s)^{1.238}\left(\frac{V_{QC}}{V_{IP}}\right)^{1.09}$$

Where:

TR = million ESALs to a maximum rut depth of 12 mm (95 % confidence level)
P = resistivity, s/nm
$= \frac{S_a^2 G_a^2}{4.9 J_{nr,3.2} VMA^3}$
$J_{nr,3.2}$ = the non-recoverable compliance at 1 second loading and 3.2 kPa stress (Pa)
K_a = age hardening ratio, determined from the Mirza-Witczak global aging system
$\cong 0.62 \times (t/2)^{0.37}$, where t is total design life in months
K_s = speed correction
= $(v/70)$, where v is the average traffic speed in km/hr

Resistivity Parameter Calculation

Inputs

Sa =	5.70	m^2/kg
Ga =	2.719	Gsb, unitless
Jnr, 3.2 =	0.00096	1/Pa
VMA =	15.3	%, unitless
Resistivity, P =	14.2	**s/nm**

LTPP High Temp @ 20mm Below

Temp, C =	54	**Select PG grade**	Known
Jnr, 3.2kPa =	N.A.		
If Jnr, 3.2 kPa Known, Select "Known" Above and Enter Value Here			**0.96**

Determined at the yearly, 7-day average maximum pavement temperature at 20 mm below the surface according to LTPPBind 3.1

Design, Field, and Project Information

Existing Service Time in Field =	6	months
Ka (age hardening ratio) =	0.88	
Vehicle Speed =	56.5	km per hr
Ks (speed correction) =	0.81	
V_{QC} (design air voids, %) =	4	%
V_{IP} (in-place air voids, %) =	6	%
Lab Compaction Level =	75	Gyrations

(50 gyr = 35 blows; 75 gyr = 50 blows; 100 gyr = 75 blows)

Typical Aircraft Speeds (kmh)
Taxiways = 37 to 56
Runways = Up to 270
(1 kmh = 0.62 mph)

Final Calculation

Rut Resistivity, TR =	**1.3**	**MESAL's to 7.2mm rut depth (50% Confidence)**
		MESAL's to 12mm rut depth (95% Confidence)

Mix Gradation

Size (mm)	% Passing
37.5	100.0
25	100.0
19	100.0
12.5	96.8
9.5	89.3
4.75	55.8
2.36	35.9
1.18	26.6
0.6	19.9
0.3	12.9
0.15	8.4
0.075	6.2
Sa_1 (m^2/kg)	5.51
Sa_2 (m^2/kg)	5.89
Sa_{ave} (m^2/kg)	5.70

= Calculation being conducted (Do not change cell)
= Data/decision needed

Adjustments to Asphalt Mixture Components to Satisfy BMD – **Advanced Materials Services -**

- ## Rutting:
- Use a polymer modified binder to improve rutting resistance
- Increase angularity of sand-sized particles

- ## Cracking:
- Add more binder & increase VMA
- Increase VFA to improve overall cracking performance
- Reduce air voids (as low as 2% with reasonable amount of RAP and polymer modified binder)
- Customize cracking test for needs
  - Overlay Tester for composite pavements
  - Flexural beam for flexible pavements (although high variability makes it challenging to interpret for BMD)

To balance performance, reduce air voids to as low as allowed while using RAP and/or polymer to maintain stability

Adjustments to Asphalt Mixture Components to Satisfy BMD – **Blankenship Asphalt Tech -**

- Rutting:
- Evaluate gradation combinations based on VMA and optimize JMF based on rutting mechanical test outcome
- Lower natural sand and/or increase manufactured (angular) sand
- Look at dust particle size – dust type matters

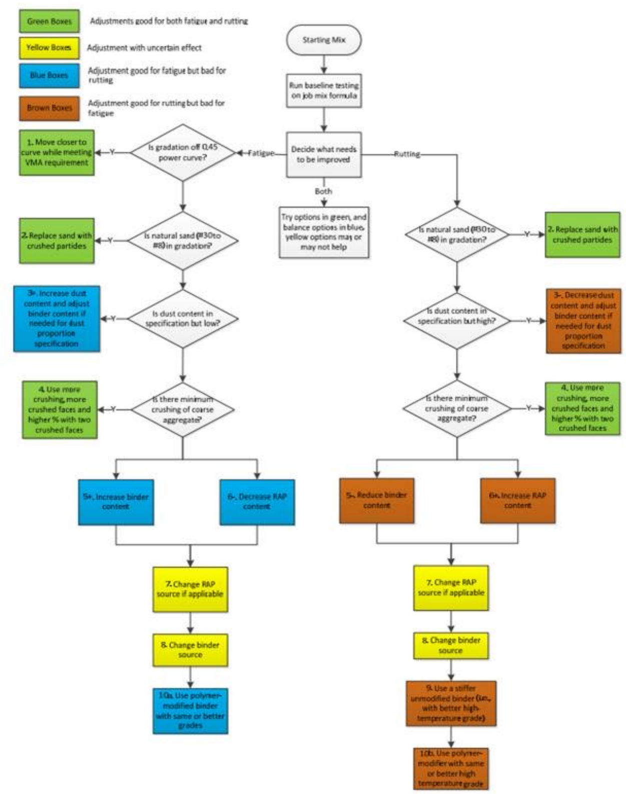
- Cracking:
- Add more binder
- Aggregates may need to be washed (high fines content)
- Adjust binder type – use a softer binder
- Personal experience has shown IDEAL-CT may not capture full benefit of polymer, rubber, fibers and other additives – need to investigate your own materials

Lower design air void requirements when traffic conditions not major concern (i.e. – lower volumes)

Adjustments to Asphalt Mixture Components to Satisfy BMD – **Granite Construction** -

- Utilizes a flowchart framework developed by UC-Davis for CalTrans
  - Change one parameter at a time to minimize confusion
  - Found some adjustments have benefitted BMD performance but was out of specification for gradation tolerances. More flexibility by agencies necessary for successful implementation
  - **Experience has shown that volumetrics are not impacted by stiffness changes (i.e. – binder grade, RAP binder grade, etc.) to the same degree as mechanical tests**

Rongzong, Wu., Harvey, J., Buscheck, J, and Mateos, A., *UCPRC-RR-2017-12*. 1-112.



Adjustments to Asphalt Mixture Components to Satisfy BMD **– Howell Paving-**

- Rutting:
  - Recycled materials usually needed to meet Hamburg criterion while still being cost-effective
  - Replace neat binder with PMA
  - Use higher percentages of crushed sand

- Cracking:
  - Use lower range of design air voids to increase asphalt content
  - Binder source makes a difference – same PG grade not always same performance

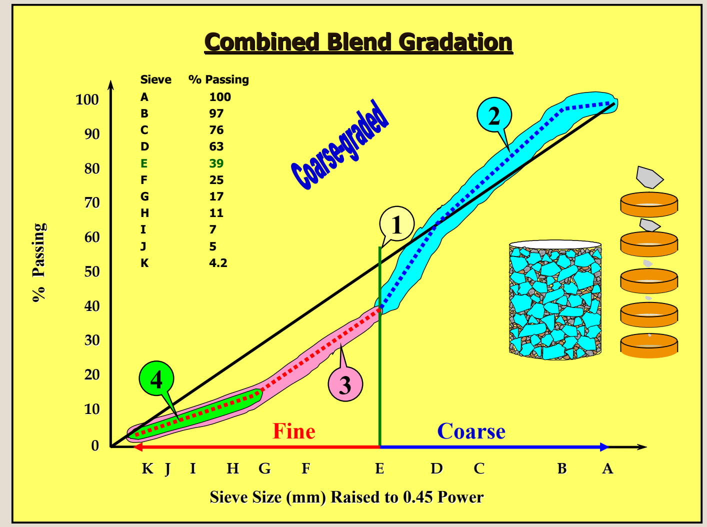
Adjustments to Asphalt Mixture Components to Satisfy BMD – Mathy Construction -

- Rutting:
  - If the result is close to HWT passing criterion, anti-strip is used.
  - If the result is far from the passing criterion;
    - Increase PG grade
    - Modify gradation and aggregate structure to reduce VMA
    - Increased use of manufactured fines (i.e. – increased angularity)

- Cracking:
- Found adjustments have been mix dependent - "one size fits all" approach doesn't work
- If stiffness type test, use a softer binder or increase VMA
- When using RAP:
  - Mechanical tests can help to optimize RAP content
  - **RAP type matters**
- Note: The test temperature for cracking tests should be adjusted based on geographical location (or binder grade). The adjustment can be asphalt mixture type dependent.

Adjustments to Asphalt Mixture Components to Satisfy BMD
– **General Comments by Interviewees** -

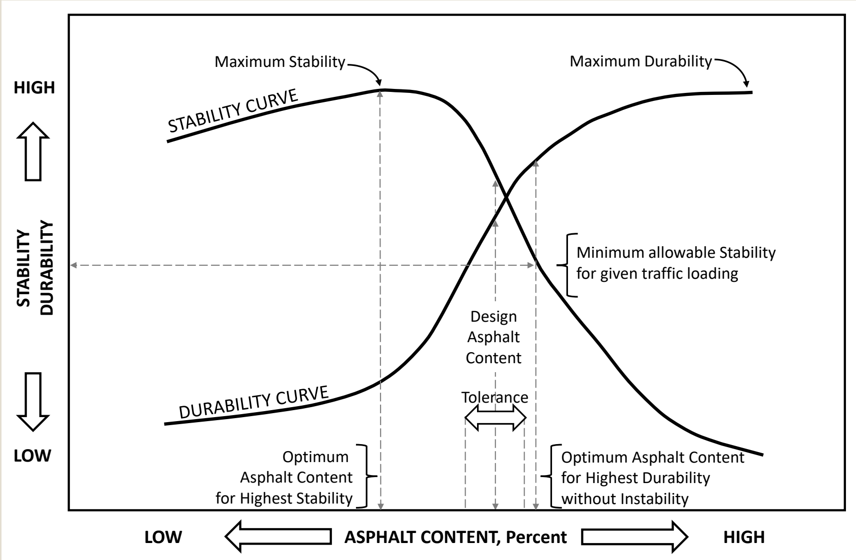
- General Considerations when Making Adjustments
  - Follow a systematic approach for making changes. One change at a time to understand impact
    - Produce sufficient mixture after adjustment to make accurate determination of impact (drum plant requires 50 to 100 tons minimum)
  - Look into Bailey method concepts to define the impact on aggregate properties on effective asphalt content
    - Aggregate shape, surface texture, and packing/structure



Bill Pine, Heritage Construction & Materials, IN

Adjustments to Asphalt Mixture Components to Satisfy BMD – **General Comments by Interviewees -**

- General Considerations when Making Adjustments
  - Reduce the focus on strict air void range or reduce the low-end tolerance of the air void
    - Traditional 3 to 5% plant voids; allow 2 to 5% as long as rutting passes
  - Balance the use of volumetric properties and mechanical testing. Don't focus solely on mechanical testing to solve issues
  - Simple consideration – get as much asphalt in the mix until you have stability/rutting issues
    - Can counteract rutting issues with stiffer binder at high temperatures (PMA and/or recycled asphalt)



Suggestions for Improvements Going Forward

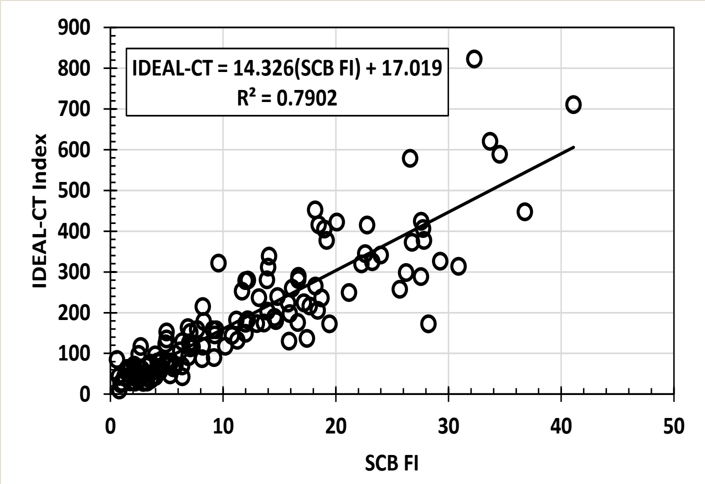
Suggestions to Improvements Moving Forward

- Research and Training Needs
  - A coordinated national effort to develop some type of regional/national training program
    - FHWA Balanced Mixture Design
    - NCAT BMD Guide/Lab Training
    - Virginia Education Center for Asphalt Technology (VECAT)
      - Current Youtube channel
- A need for established training program for technicians running the mechanical tests
  - Initiate/develop State DOT certification programs with periodic renewal
  - Encourage external training by State DOTs
  - Initiate work-force training programs at Universities

https://www.youtube.com/watch?v=5UEndoMNdGc

Suggestions to Improvements Moving Forward

- Importance of training (industry and State level)
  - Accreditation program for mechanical testing needed
    - AASHTO Re:source availability
      - Hamburg Wheel Tracking (AASHTO T324)
      - Asphalt Pavement Analyzer (AASHTO T340) – new for 2023
      - IDEAL-CT Index (ASTM D8225) – new for 2023
- Which test? Impact on suppliers/contractors working in multiple states
  - Can test relationships be established and used interchangeably?
  - Ex. Mathy Construction supplies to WI (HWT; SCB FI; IDEAL-CT), IA (HWT; DCT), MN (HWT, DCT), and IL (HWT, SCB FI)



Suggestions to Improvements Moving Forward

- If BMD adds mechanical test criteria without adding additional benefit, why bother?
  - Pay adjustments?
  - Must allow more flexibility to optimize design
  - Relax specification (Recycled asphalt content, dust to binder, gradation tolerances)
- Criteria must consider pavement conditions – tied back to structural design
  - Layer specific
  - Traffic specific
  - Similar to Superpave material selection criteria

Test	NJDOT High RAP Requirement			
	Surface Course		Intermediate/Base Course	
	PG64-22	PG76-22	PG64-22	PG76-22
APA Rutting	< 7 mm	< 4 mm	< 7 mm	< 4 mm
Overlay Tester	> 200 cycles	> 275 cycles	> 100 cycles	> 150 cycles

Conclusion

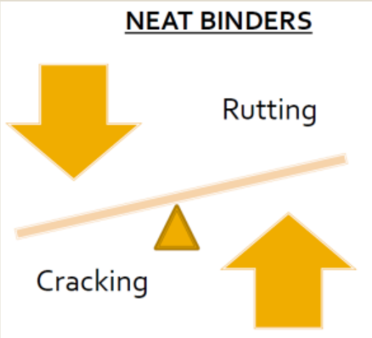
A FEW SUMMARY COMMENTS…

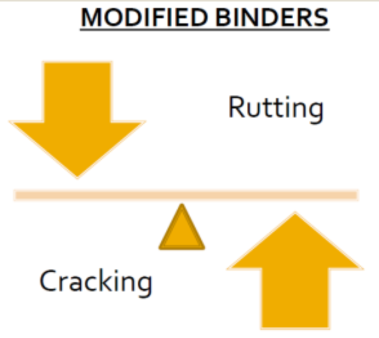
Summary

- Although interviewees had significant experience in BMD, responses to questions identified areas where work may be needed
  - Handling variability from contractor to State DOT
  - Validating lab produced vs plant produced
  - Accuracy vs practicality
  - Training on proper specimen fabrication and testing
  - Training on impact of mixture component changes to mechanical test response (plant production)
  - Accreditation program
  - Round robin programs to aid in training & equipment/technician checks
  - Where to collect necessary information for support

Summary

- Mechanical testing
  - Rutting
    - Minimize effective asphalt content (low end of VMA spec)
    - Increase high temp binder grade (PMA and/or recycled asphalt)
    - Increase angular/textured aggregates
  - Cracking
    - Increase effective asphalt content (VMA)
    - Increase VFA (increase in VMA with decrease in AV)
    - Watch impact of recycled binder
    - Binder source can impact performance with same binder grade



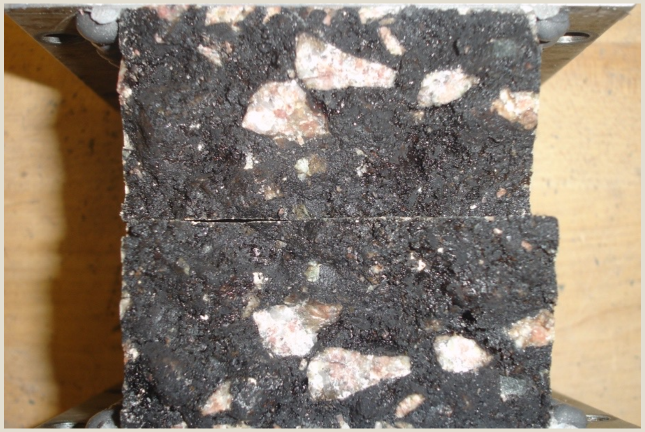


Thanks!

QUESTIONS?

BMD Approach Considerations
- Mechanical Testing Variability -

- Understanding Variability
  - Variability of mechanical test is inevitable
    - Material, material and specimen preparation, testing (equipment & operator)
      - Benchmark testing your materials may help in identifying outliers
    - Asphalt mixtures are not homogeneous by nature
      - Cracking will find the path of least resistance
  - Variability can be reduced by testing more replicates – but will be issue with timely results from plant production
  - Generally observe lower variability for rutting tests (10 to 20% COV) when compared to cracking tests (15 to 30% COV)
  - Is there a trade-off between accuracy and practicality?
    - Incorporate variability within required criteria
  - Utilize round robins for variability and training



BMD Approach Considerations
–Mechanical Testing Variability-

- Impact of **specimen preparation**
  - Procedure needs to be well defined – concerns of over the impact of cutting, trimming, specimen dwell time, and aging on final mechanical test result
  - “Follow manufacturer’s recommendation” not adequate – AASHTO T324
  - Some needed to develop their own methods to minimize variability
    - Ex. – Granite Construction

Figure Source: Granite Construction

NCHRP Synthesis Report 552, 2020, *Practices for Fabricating Asphalt Specimens for Performance Testing in Laboratories*, Jo E. Sias, Eshan Dave, & Leslie Myers McCarthy

NAPA IS-145, 2023, *Guide on Asphalt Mixture Specimen Fabrication for BMD Performance Testing*, Nathan Moore and Adam Taylor