Balanced Mix Design (BMD) Implementation in TxDOT

SEAUPG Annual Meeting
November 16, 2023

Amy Epps Martin, TTI

Texas A&M Transportation Institute · CTR · Texas Department of Transportation

Outline

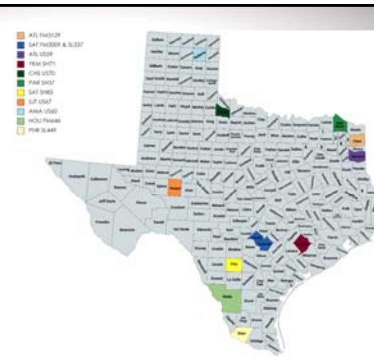
- Overall Implementation Effort Update
- Proposed Specification Changes
- Mixture Test Evaluation with Field Performance

TxDOT BMD Implementation Effort

- 2019 - Present
- Review, Revise, & Further Develop SS 3074
- Collaborative Effort
  - TxDOT MTD + Districts
  - TTI @ Texas A&M
  - CTR @ UT
  - CTIS @ UTEP
  - TxDOT-Industry BMD Working Group
  - Contractors
  - Materials Suppliers
- 2019-2022: 9 Field Test Projects with 33 Test Sections
- 2022-2025: 4 Field Pilot Projects Planned to Date

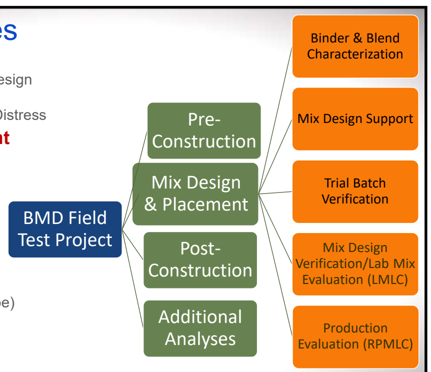
Field Projects

- 2019: ATL
- 2020: SAT x2, YKM, ATL, PAR
- 2021: SJT, CHS, PHR
- 2022: SJT, SAT
- 2023: PHR, AMA, HOU x2



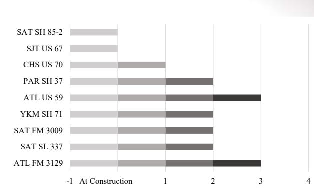
Evaluation Phases

- Pre-Construction
  - Plans, Specs, Pavement Design
  - FWD, GPR
  - Evaluation Subsections & Distress
- **Mix Design & Placement**
- Post-Construction
  - Cores
  - Distress
  - (Texture & Friction)
- Additional Analyses
  - Variability
  - Multi-Phase (Specimen Type)
  - Aging
  - Correlations



Field Project Monitoring

- Coring + Evaluation soon after construction and @ approximately 1-year intervals
- Evaluation includes cracking measurements, rutting evaluation, and visual observation of any other distresses

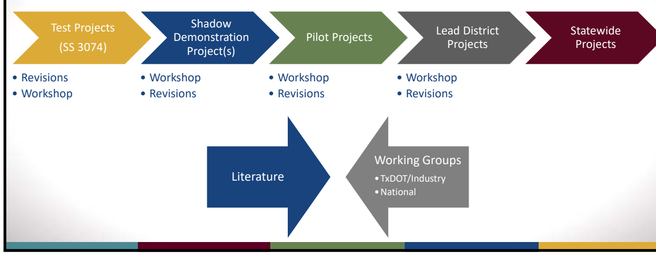


TxDOT BMD Overview w/ FHWA 8 Tasks

Task		Description	Notes	Status	Date (Completed or Planned Completion)
1	Motivation/ Benefits	Understand why use BMD what are the benefits?		Complete	2019
2	Overall Planning	Identification of Champions and Establishing a Stakeholders Collaboration	TxDOT, UTEP, CTIS, TTI Working Group	Complete	2019
		Doing Homework		Continuous	2019-2025
		Establishing Goals		Complete	2019
		Mapping the Tasks		Complete	2019
		Identifying Available External Technical Information and Support		Complete	2019
		Developing an Implementation Timeline		Complete	2019
3	Select Performance Tests	Identifying Primary Modes of Distress	Cracking, Rutting, Skid	Complete	2019
		Identifying and Assessing Performance Tests	OT, HWT, CT, RT, Friction	Complete	2019-2022
		Validating the Performance Tests	2019-2022 Sections	Ongoing	2023
4	Acquiring Equipment and Training	Acquiring Equipment & Managing Resources	New contractor-grade acquired	Complete	2023
		Conducting Initial Training		Complete	2024
		Evaluating Performance Tests	2019-2022 Sections	Continuous	2019-2023
		Conducting Inter-Laboratory Studies	TTI, CTIS, UTEP, NCAT RR	Ongoing	2019-2023
5	Establishing Baseline Data	Reviewing Historical Data & Information Management System	TxDOT Benchmarking Data	Complete	2023
		Conducting Benchmarking studies	WesTrack	Ongoing	2023-2024
		Conducting Shadow Projects	AMA US 60, HOU FM 646, PAR SH 37	In Progress	2024
		Analyzing Production Data	Summary Reports	Ongoing	2019-2025
		Determining How to Adjust Asphalt Mixtures Containing Local Materials	Strategies (Binder Bump, RBA, RA)	In Progress	2023-2024
6	Specifications and Program Development	Sampling and Testing Plans	High RAP Guide	In Progress	2023-2024
		Pay Adjustment Factors (If Part of the Goals)		Not Started	??
		Developing Pilot Specifications and Policies	SS 3074 Revisions	In Progress	2019-2024
		Conducting Pilot Projects	2023-2024 Sections	Not Started	2023-2024
		Final Analysis and Specification Revisions		Not Started	2025
7	Training/ Certifications	Developing and/or Updating Training and Certification Programs	Based on 2023-2024 Sections	Not Started	2024-2025
		Establishing or Updating Laboratory Accreditation Program Requirements		Not Started	2024-2025
8	Implementation			Not Started	2026

TxDOT BMD Implementation Effort

produce implementable BMD&A specification that balances engineering performance (rutting, cracking) & provides economic and environmental benefits



Proposed Specification Changes

Next Steps including consideration of resources & innovation

TABLE 1. SUMMARY OF REQUIREMENTS AND FLEXIBILITY OF BMD APPROACHES (CHKAIBAN ET AL., 2022; HAJJ ET AL., 2022).

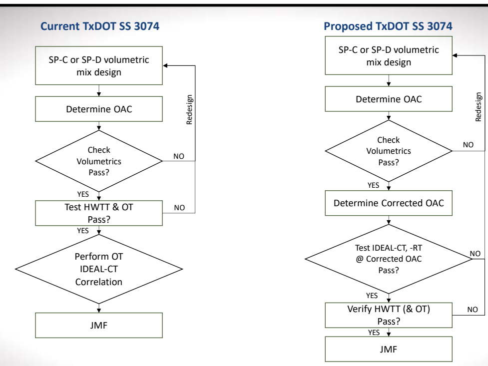
Approach	Volumetric Requirements	Performance Requirements	Flexibility	Innovation
A-Volumetric Design with Performance Verification	Full Compliance	Full Compliance	Most Conservative Approach	Lowest Potential
B-Volumetric Design with Performance Optimization	Full Compliance at Preliminary Optimum Binder Content	Performance Optimization through Modification of Binder Content	Slightly more Flexible than Approach A	Limited Innovation Potential
C-Performance Modified Volumetric Design	Some of the Requirements Relaxed or Eliminated	Performance Optimization by Adjusting Initial Binder Content or Component Material Properties or Proportions	Less Conservative than Approach A and Approach B	Medium Degree of Innovation Potential
D-Performance Design	Limited of No Requirements	Performance Optimization by Adjusting Mixture Components and Proportions*	Least Conservative Approach	Highest Degree of Innovation Potential

*SHAs may set minimum requirements for binder quality and aggregate properties. Once the laboratory test results meet the performance criteria, the mixture volumetric properties may be checked for use in production.

TABLE 2. BMD IMPLEMENTATION STATUS (AS OF JANUARY 2021) (YIN ET AL., 2021).

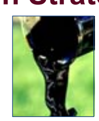
BMD Approach	State	Applicable Mixture Type	Rutting Test	Cracking Test	Performance Testing for Production Acceptance?
A	Illinois	High ESAL Mixtures	HWT	I-FIT	Yes, HWT for "Pass/Fail"
	Louisiana	Wearing and Binder Course Mixtures	HWT	SCB-Jc	Yes, "Pass/Fail"
	New Jersey	Specialty Mixtures	APA	OT, BBF	Yes, "Pass/Fail" or Pay Adjustment
	Texas	Surface Mixtures	HWT	OT, IDEAL-CT	Yes, "Pass/Fail"
	Vermont	Superpave Type IVS Mixtures	HWT	I-FIT	Yes, PWL
A & D	Virginia	Surface Mixtures	APA	Cantabro, IDEAL-CT	Yes, "Pass/Fail"
C	California	Long-Life Pavement Mixtures	FN, HWT	BBF, I-FIT	Yes, HWT for "Pass/Fail"
	Missouri	Mainline Pavement Mixtures	HWT	I-FIT, IDEAL-CT	Yes, HWT for "Pass/Fail", I-FIT & IDEAL-CT for Pay Adjustment
	Oklahoma	Superpave Mixtures	HWT	IDEAL-CT	No
D	Alabama	Superpave Mixtures	HT-IDT	AL-CT	Yes, "Pass/Fail"
	Tennessee	All Mixtures	HWT	IDEAL-CT	To be determined

Next Steps



High RAP Mitigation Strategies

- Utilizing different virgin binder
  - softer grade
  - different source (ΔT_c)
  - polymer-modified
- Incorporating additive
  - rejuvenator
  - WMA
- Decreasing recycled binder availability (RBA)



Considering Decreased RBA

- For 75% RBA, CT_{Index} increased + RT_{Index} decreased
- Significant change in flexibility (l_{75}/m_{75}) but not toughness (G_f)

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

- Consider for RAP > 20% and/or PGH > 100C
- More open gradation facilitates additional binder

GDOT (GA) Corrected OAC (COAC) Approach

- OAC determined using volumetrics
- Corrected OAC (COAC) determined using decreased RBA
- Performance verified at COAC
- Volumetrics are not verified
- Initially Implemented in 2012 with 75% RBA, reduced to 60% in 2019

Corrected Optimum Asphalt Content (COAC)

(60% RAP Binder Contribution)

RAP and Virgin Binder Calculation

- Total optimum AC in mix design = 4.25%
- Percentage of RAP in mix design = 30%
- AC in RAP = 5.09% • RAP AC contribution = (5.09 x .30) = 1.53%
- Using GDOT 0.60 RAP binder credit ratio
- 1.53% x 0.60 = 0.92% • 1.53% – 0.92% = 0.61%
- JMF COAC = 4.25 + 0.61 = **4.86%**
- Virgin AC % = 4.86 – 1.53% = 3.33%

For this example, 0.61% increase in virgin binder content. All mix design performance testing will be conducted at 4.86% binder content.

Considering Relaxing Volumetrics?

- Evaluate data from pilot projects to determine how volumetrics (%Density, VMA, & DP) change with decreased RBA strategy
- Allow for higher effective/available & virgin binder content by decreasing RBA below 100%
- Utilize COAC approach
- Propose how volumetrics might be relaxed?

Mixture Test Evaluation with Field Performance

Texas A&M Transportation Institute

Rutting Evaluation

- HWTT (Tex 242-F)
  - $N_{12.5} \geq$ 10k for PG64
  - $N_{12.5} \geq$ 15k for PG70
  - $N_{12.5} \geq$ 20k for PG76
- IDEAL-RT (Draft Tex XXX-F)
  - $RT_{Index} \geq$ 60 for PG64
  - $RT_{Index} \geq$ 65 for PG70
  - $RT_{Index} \geq$ 75 for PG76
- Aging [LMLC: STOA 2hr@T_{comp}, RPMLC: Reheat to T_{comp}]

Cracking Evaluation

- OT (Tex 248-F)
  - CPR ≤ 0.45
  - CFE ≥ 1.0
- IDEAL-CT (Tex 250-F)
  - $CT_{Index} \geq$ 80
- Aging
  - LMLC: STOA 2hr@T_{comp} [+ MTOA 20hr@95C for mix design?]
  - RPMLC: Reheat to T_{comp}

Field Performance

- Majority expected based on CT & RT
- Most PC agrees with CT
- Monitoring of ALL sections this fall
  - First time for SAT 85, SJT 67
  - First time for CHS 70, SAT 337, YKM 71 for rutting

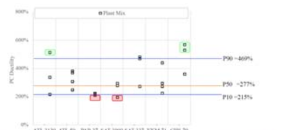


FIGURE 43. PC DUCTILITY OF EXTRACTED PLANT MIX BINDERS FOR AVERAGE 2019-2021 BMD FIELD PROJECT LOCATIONS.

District	County	Highway	Mix	Cracking Expected	Rutting Expected
San Antonio	Comal County	SL 0337	Control RAP (1)	YES	
			Virgin (2)		YES
			High RAP (3)		YES
	Guadalupe County	FM 3009	Mix 7B High RAP+Softer Binder (4)		YES*
			Mix 5 High RAP+Rejuvenator (3)		YES*
			Control RAP (1)		YES*
	Frio County	SH 0085	Virgin		
			High RAP		
			Control		
Atlanta	Cass County	FM 3129	Control RAP (1)		
			Virgin (2)		
			RAP/RAS (3)	YES*	
	Harrison County	US 0059	Control SMA		YES?
			RAP		
			RAP+Softer Binder		
			High RAP WMA		
Paris	Red River County	SH 0037	Coarse Graded	*	YES*
			Fine Graded	YES*	*
			Dense Graded	YES*	*
			Control	YES*	*
Yoakum	Colorado County	SH 0071	Control Tom-C (1)		
			Mix 3-High RAP SAC-B @ (275F) (3)		YES
			Mix 4- Higher RAP @ (275F) (4)		YES
			Dense-D (2)	YES	YES
Childress	Foard County	US 0070	Mix 3-Binder Change		
			Mix 7-Alt. Gradation		
			Control		
San Angelo	Reagan County	US 0067	Control 1		
			2A-1 High RAP		
			2B-High RAP+Softer Binder BW	YES	
			2C-High RAP+Softer BS	YES	
			Mix 3-SAC B Limestone	YES	
			Mix 4- TR Binder, SAC B Limestone	YES	

*Cracking or rutting observed during field inspection

IDEAL-RT Evaluation: vs HWTT

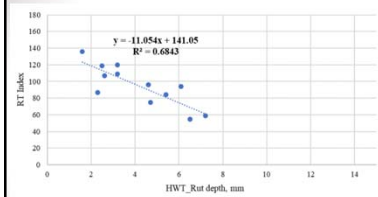
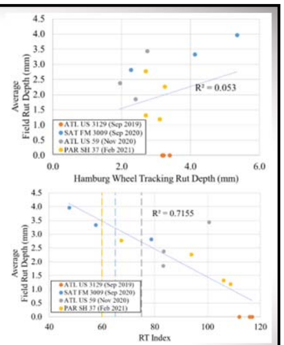


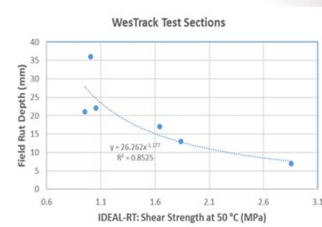
FIGURE 28. RUTTING TEST CORRELATION FOR SP MIXTURES WITH MODIFIED BINDERS.

- IDEAL-RT correlates well with HWTT for SP mixtures with commonly used modified binders
- IDEAL-RT is much faster, making it more practical for production testing

IDEAL-RT Evaluation: BMD Rutting Data



IDEAL-RT Evaluation: WesTrack Correlation

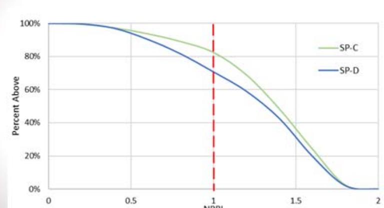


HWTT Evaluation

- Pros
  - Well known and widely used
  - Repeated load better simulates traffic
  - Moisture susceptibility evaluation possible
  - Simple test with good repeatability
- Cons
  - Longer testing time
  - May not discriminate between some mixtures

HWTT Evaluation: TxDOT Benchmarking

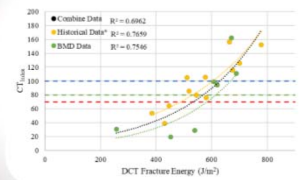
- 83% of SP-C and 71% of SP-D mixtures passed
- ~1,800 SP C/D mixtures measured

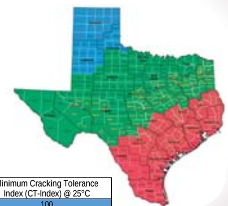


Mix	Passing	Observations
A Coarse Base	74%	205
B Level Up	85%	56
B Fine Base	85%	1705
SP-C Surface	83%	1044
C Level Up	75%	71
C Coarse Surface	82%	3082
SP-D Fine	71%	787
D Level Up	80%	185
D Fine Surface	75%	4167
F Fine Mixture	55%	124
TOM C	92%	195
SMA C	95%	107

IDEAL-CT Evaluation: Intermediate & Low-T

- For cold weather considerations, CT Index should be > 45 (DCT ≈ 400 J/m²)
- Considering 2 tier IDEAL-CT threshold
- Considering lowering IDEAL-CT thresholds based on TxDOT benchmarking
- Propose adjusting threshold after MTOA?



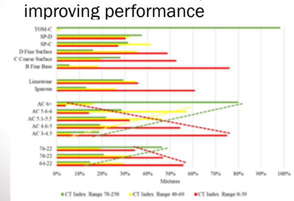


*Historical Data sourced from Newcomb et al. "Test Methods to Quantify Cracking Resistance of Asphalt Binders and Mixtures", 2021.

Low-Temperature Binder Grade	Minimum Cracking Tolerance Index (CT-Index) @ 25°C
PG -28 or lower	100
PG -22 & -16	80
PG -10 or higher	70

IDEAL-CT Evaluation: TxDOT Benchmarking

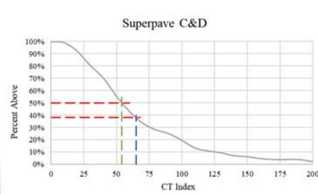
- 80 may be difficult to achieve based on benchmarking with only ~ 30% of SP C/D mixtures passing
- Higher CT_{Index} for mixtures with higher binder content and PMA
- 55% of BMD mixtures pass 80 and 70% above 60 suggesting SS3074 is improving performance

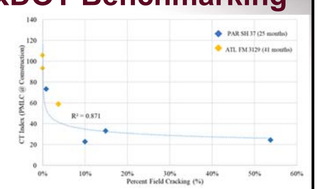


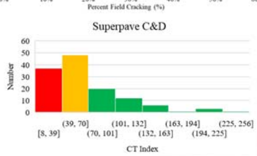
Mix	Passing CT	Average CT_{Index}	Observations
B Fine Base	4%	36	71
C Coarse Surface	20%	61	55
D Fine Surface	10%	46	125
SP-C Surface	24%	62	71
SP-D Fine Mixtures	34%	72	56
SMA	100%	340	4
TOM-C	94%	156	17
Binder			
PG64-22	12%	46	156
PG70-22	18%	53	188
PG76-22	43%	92	116
Overall	**21%**	**61**	**480**

IDEAL-CT Evaluation: TxDOT Benchmarking

- Average CT Index for SP C/D = 66, Median = 54
- Current BMD field data shows early cracking in mixture with CT Index < 40

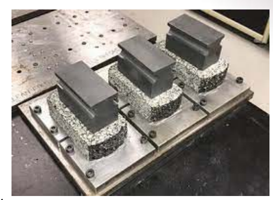




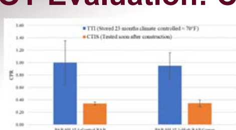


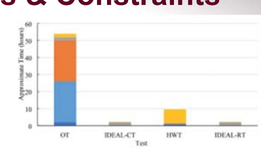
OT Evaluation

- Pros
  - Used for specialty TxDOT mixtures
  - Repeated load better simulates traffic
- Cons
  - Longer testing time
  - Complicated specimen preparation
  - CPR not very sensitive to aging
  - May not discriminate between some mixtures
  - Bolt issues casts doubt on benchmarking data
  - Results exhibit high between lab variability



OT Evaluation: Concerns & Constraints

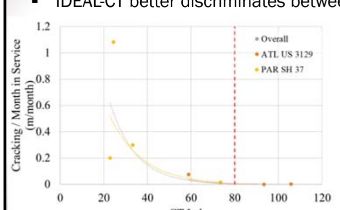


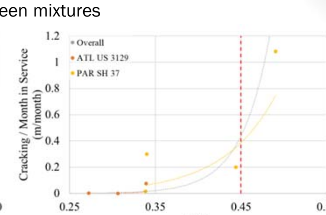


Mix	Passing CPR	Observations
Overall	96%	393
C Coarse Surface	100%	3
D Fine Surface	100%	13
SMA	100%	140
SMAR	100%	20
SP-C Surface	100%	15
SP-D Fine Mixtures	100%	8
TOM-C	96%	78

OT Evaluation: Validation

- IDEAL-CT threshold better captures mixtures susceptible to cracking
- IDEAL-CT better discriminates between mixtures





Proposed Specification Changes

Special Specification 3074
Superpave Mixtures – Balanced Mix Design

1. DESCRIPTION

Construct a hot-mix asphalt (HMA) surface 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. Payment adjustments will apply to HMA ~~placed under~~in accordance with this ~~S~~specification unless the HMA is deemed exempt in accordance with Section 344.4.9.4., "Exempt Production."

Texas A&M Transportation Institute

- Adding IDEAL-RT
- Utilizing IDEAL-CT, Limiting OT
- Changing IDEAL-CT Thresholds
- Simplifying Requirements
  - Removing IDT Strength
  - Removing Min RD by HWTT
  - Standardizing N_{design}=50
- Considering Decreased Recycled Binder Availability (RBA)
- Adjusting Mix Design & Production Testing and Frequency
- Adding Operational Tolerances

THANK YOU!

Amy Epps Martin
a-eppsmartin@tamu.edu

Acknowledgements
Implementation Partners
TxDOT, TxAPA
Contractors, Materials Suppliers