Validation of Guidelines for Evaluating the Moisture Susceptibility of Warm Mix Asphalt Technologies

September 28, 2016

Today's Presenters

- **Moderator**: Ed Harrigan, TRB
- Amy Epps Martin, Texas A&M University
- Edith Arambula, Texas A&M Transportation Institute

NCHRP is...

A state-driven national program

- The state DOTs, through AASHTO's Standing Committee on Research...
  - Are core sponsors of NCHRP
  - Suggest research topics and select final projects
  - Help select investigators and guide their work through oversight panels

NCHRP delivers...

Practical, ready-to-use results

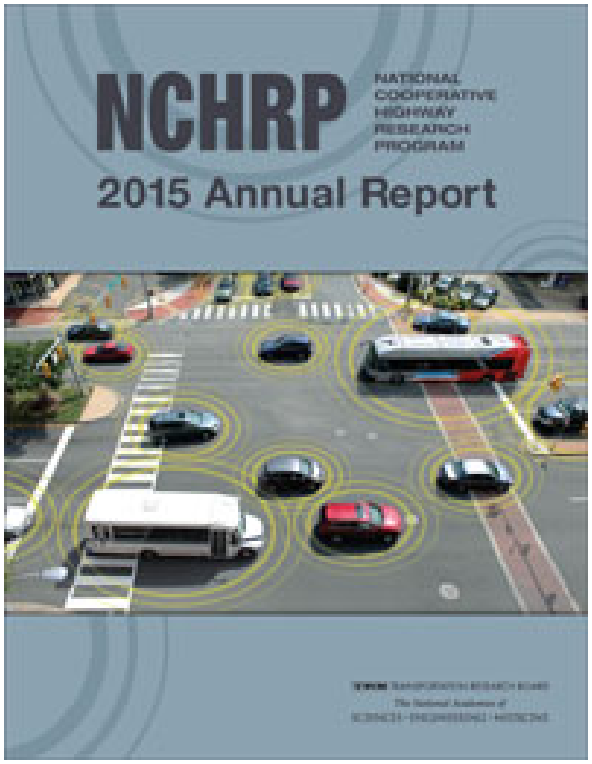
- Applied research aimed at state DOT practitioners
- Often become AASHTO standards, specifications, guides, manuals
- Can be directly applied across the spectrum of highway concerns: planning, design, construction, operation, maintenance, safety

A range of approaches and products

- Traditional NCHRP reports
- Syntheses of highway practice
- IDEA Program
- Domestic Scan Program
- Quick-Response Research for AASHTO
- Other products to foster implementation:
  - *Research Results Digests*
  - *Legal Research Digests*
  - *Web-Only Documents and CD-ROMs*

NCHRP Webinar Series

- Part of TRB's larger webinar program
- Opportunity to interact with investigators and apply research findings.



Today’s First Presenter

- Amy Epps Martin, Texas A&M University

NCHRP 9-49B
VALIDATION OF GUIDELINES FOR EVALUATING THE MOISTURE SUSCEPTIBILITY OF WARM MIX ASPHALT TECHNOLOGIES

Amy Epps Martin
Edith Arámbula Mercado
Fan Yin

Webinar – September 2016

INTRODUCTION

- WMA with foaming or additives provide economic, environmental, & engineering benefits

- Concerns remain regarding moisture susceptibility

(http://www.ksasphalt.com/Warmix.html)

NCHRP 9-49 Performance of WMA Technologies: Stage I – Moisture Susceptibility

- Information gathering
- 3 standard laboratory tests & field performance
- LMLC, PMLC, & Cores from 9 mixtures in 4 field projects
- Appropriate aging protocols
- Guideline Thresholds to identify and limit WMA moisture susceptibility
- NCHRP Report 763

NCHRP 9-49
Web Survey

Current Use of WMA	54% Trial Projects	40% Routine Use	Others
Quantity of WMA	44% 2-5 Projects	21% 5-10 Projects	23% Routine
Preferred Technologies	DBG, Evotherm, Sasobit, Advera, Terex, and AQUABlack		
Use of Anti-stripping Additives	48% Yes		
Organizational Practice	73% Allow	12% Not Allow	Others
Moisture Susceptibility Testing in Mix Design	76% Yes		
Preferred Moisture Susceptibility Tests	61% TSR	17% HWTT	Others
Observed Field Pavement Failure or Distress	91% None (Moisture Damage)	6% Compaction Issues	3% Thermal Cracking

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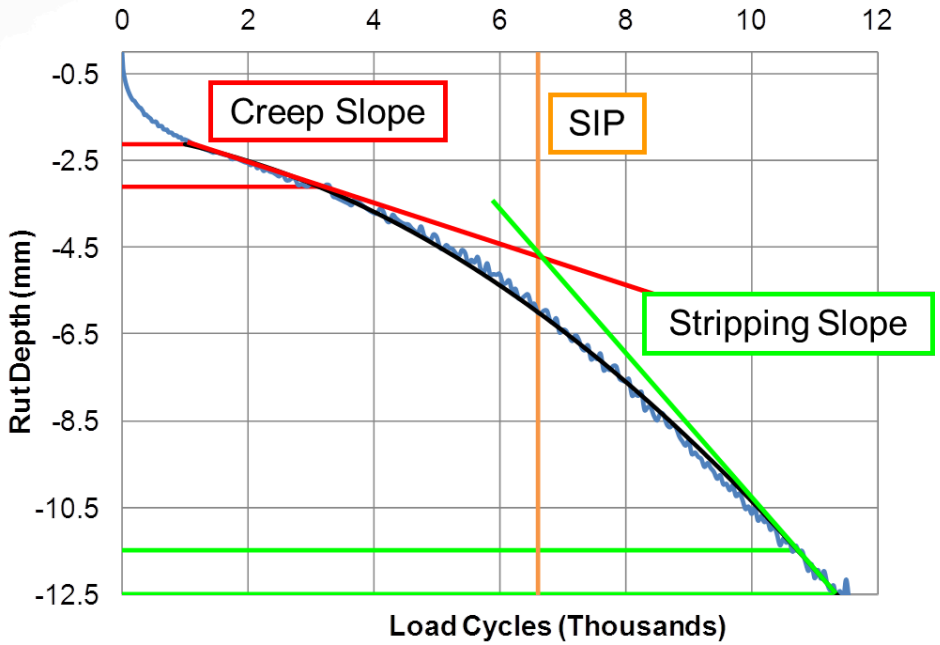
Laboratory Tests

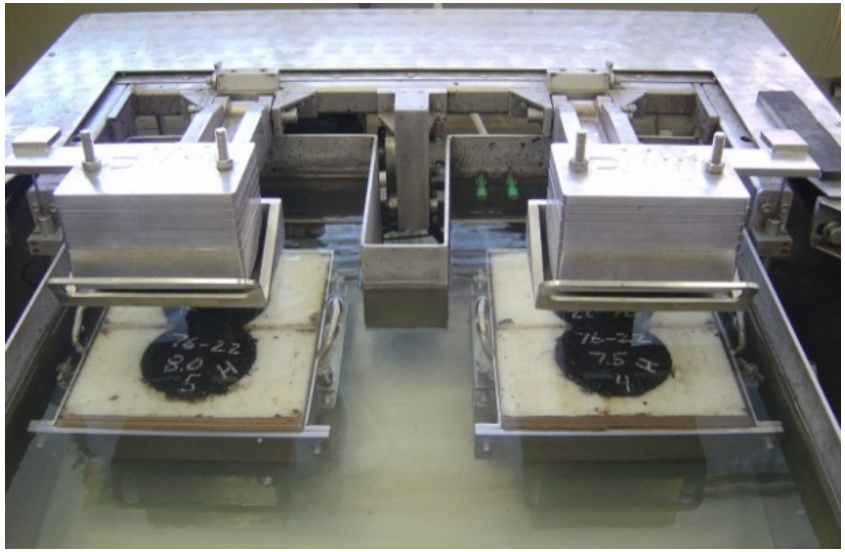
- Indirect Tensile (IDT) Strength
  - Lottman Conditioning
  - Dry/Wet IDT Strength @25°C
  - Tensile Strength Ratio (TSR)

- Resilient Modulus (M_R)
  - Lottman Conditioning
  - Dry/Wet M_R Stiffness @25°C
  - M_R-ratio

NCHRP 9-49
Laboratory Tests

- Hamburg Wheel Tracking Test
  - Stripping Inflection Point (SIP)
  - Stripping Slope





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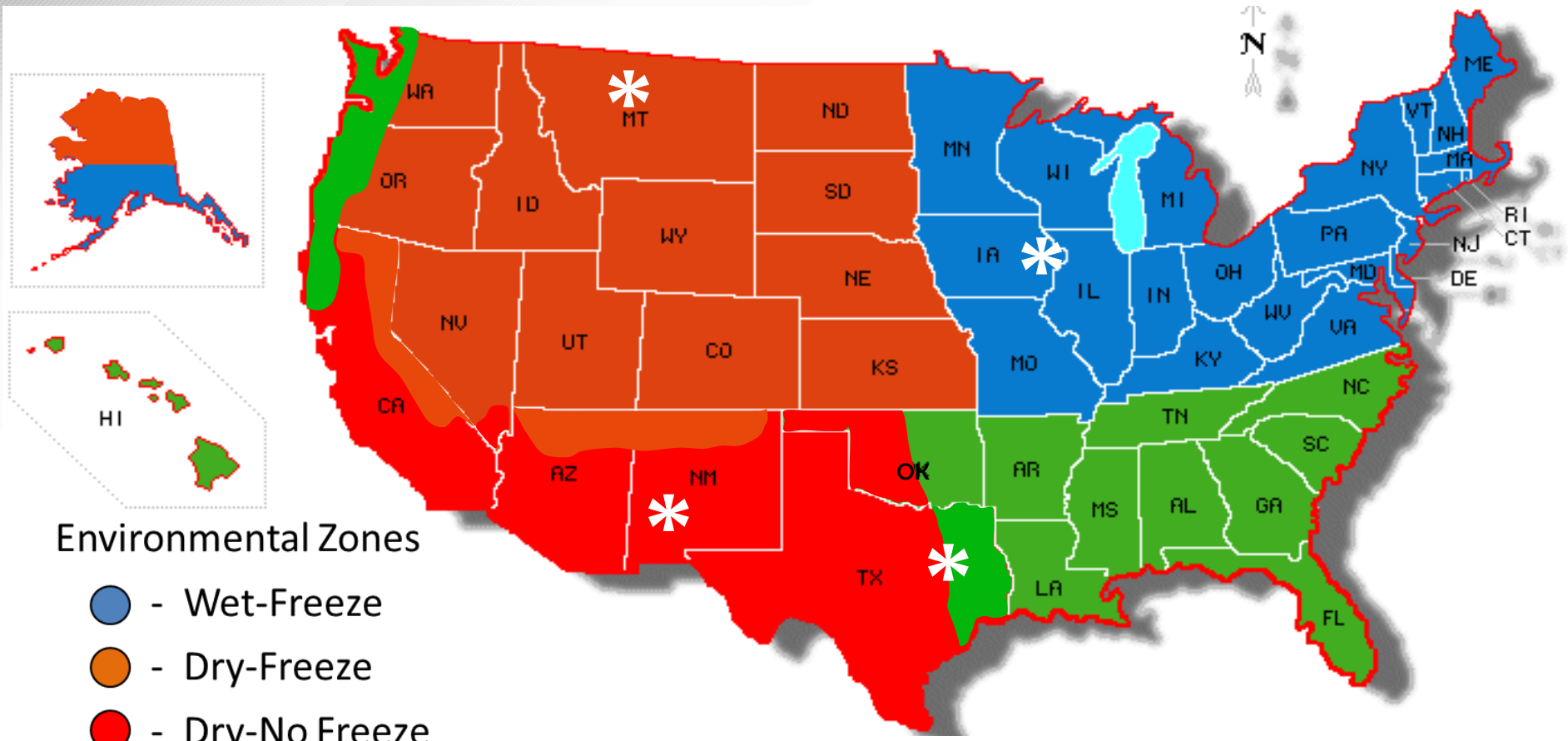
Field Projects



Environmental Zones

- Wet-Freeze
- Dry-Freeze
- Dry-No Freeze
- Wet-No Freeze

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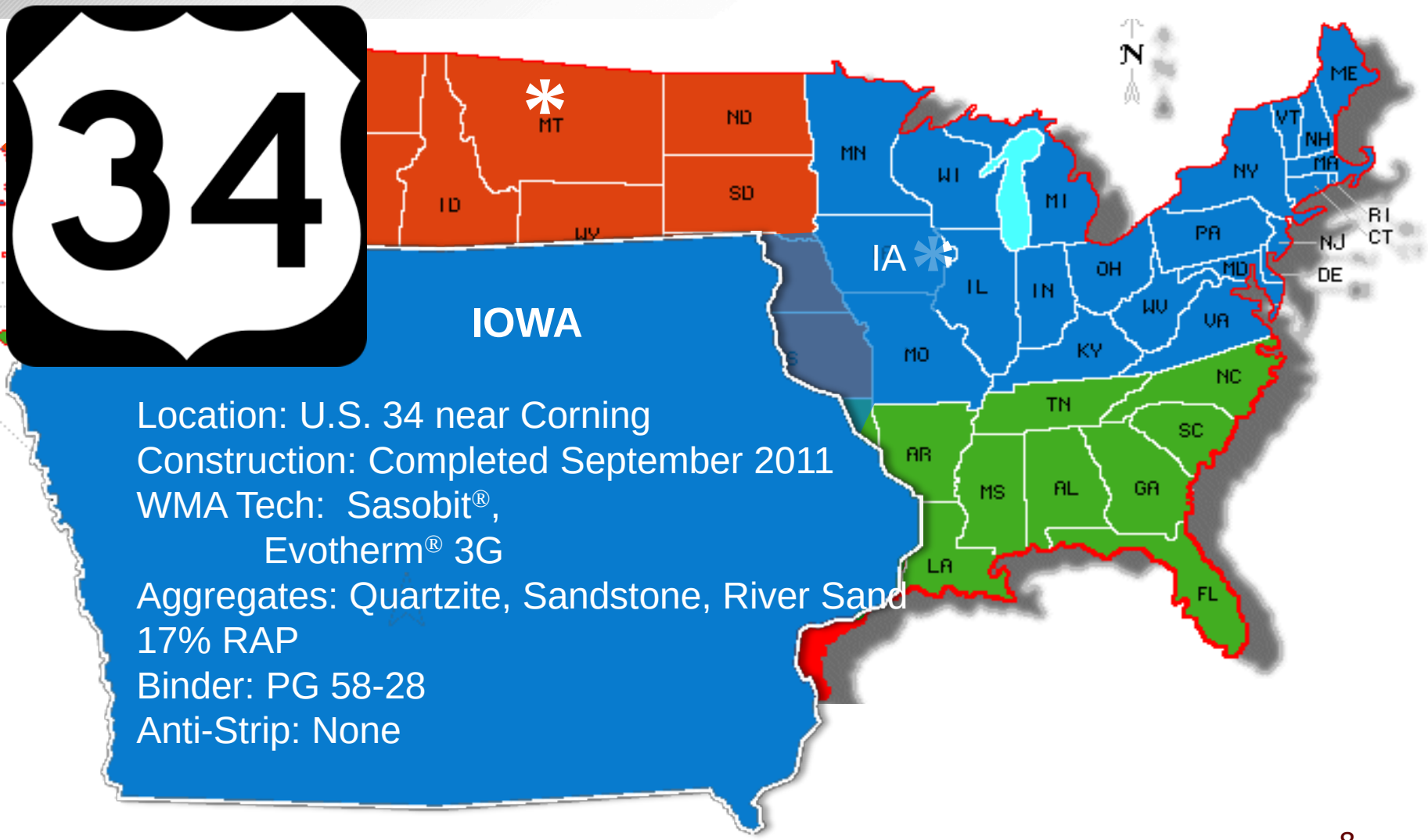
Field Projects



IOWA

Location: U.S. 34 near Corning
Construction: Completed September 2011
WMA Tech: Sasobit®,
Evotherm® 3G
Aggregates: Quartzite, Sandstone, River Sand
17% RAP
Binder: PG 58-28
Anti-Strip: None

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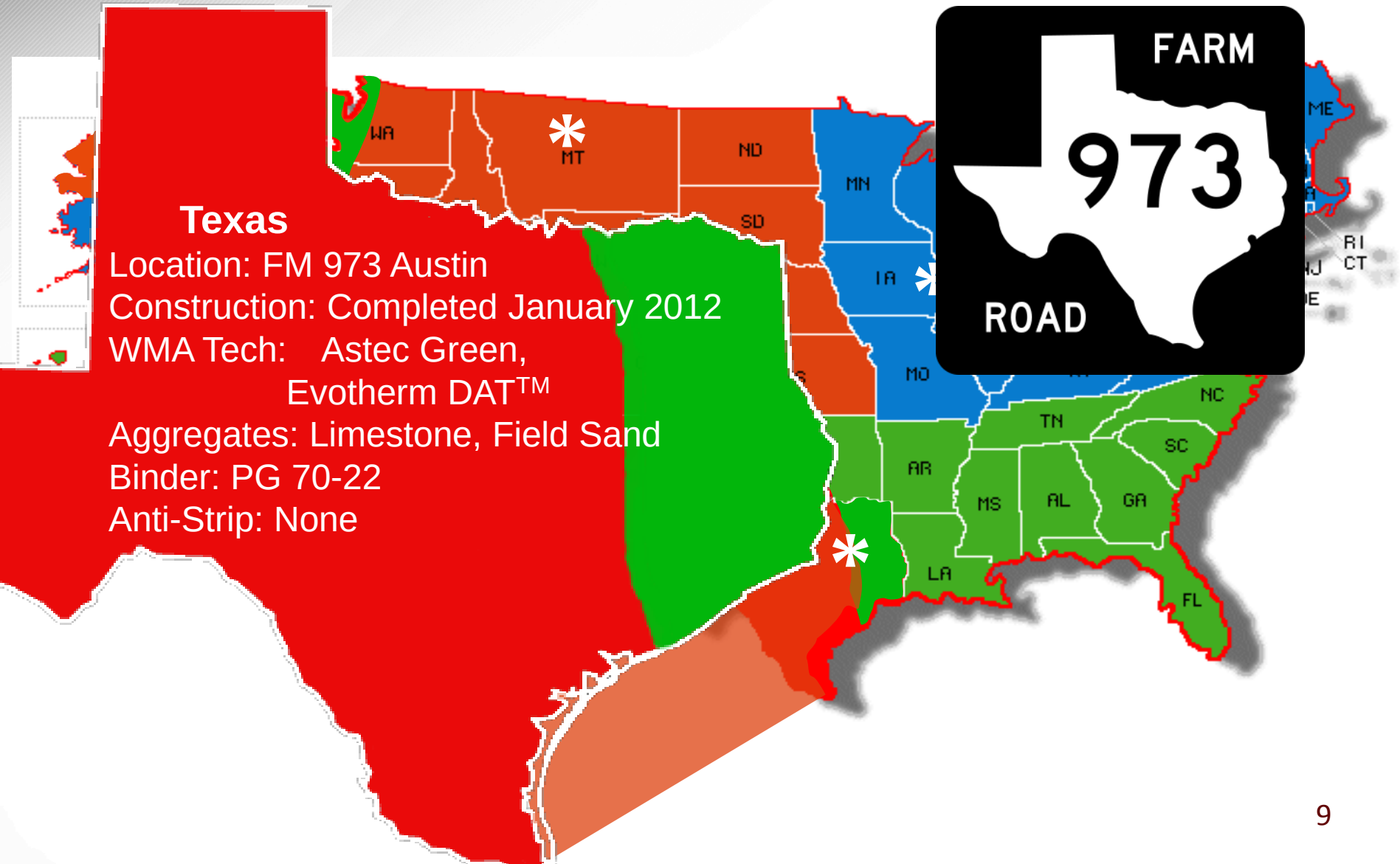
Field Projects



Texas

Location: FM 973 Austin

Construction: Completed January 2012

WMA Tech: Astec Green,
Evotherm DAT™

Aggregates: Limestone, Field Sand

Binder: PG 70-22

Anti-Strip: None

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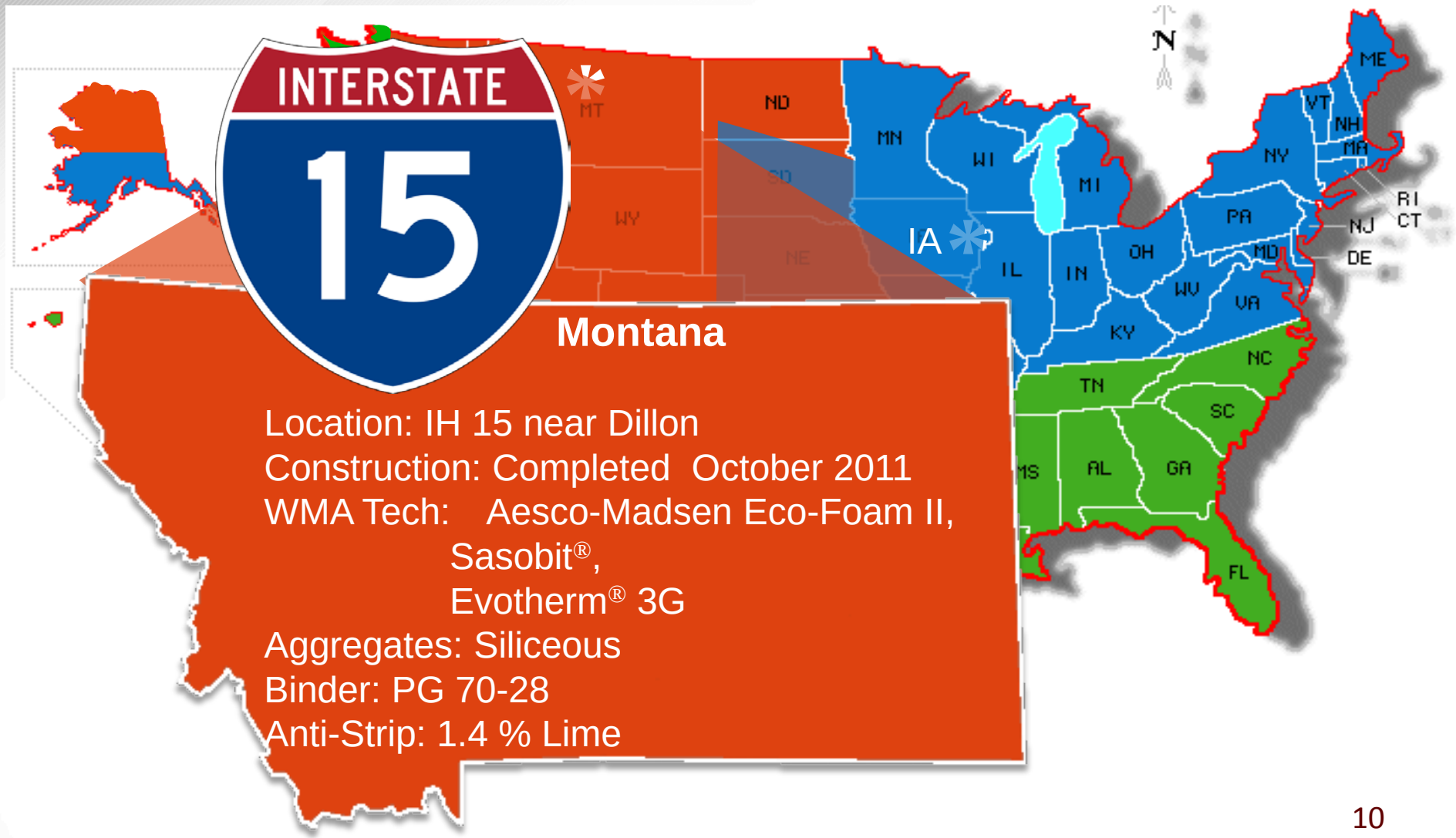
Field Projects



Montana

Location: IH 15 near Dillon
Construction: Completed October 2011
WMA Tech: Aesco-Madsen Eco-Foam II,
Sasobit®,
Evotherm® 3G
Aggregates: Siliceous
Binder: PG 70-28
Anti-Strip: 1.4 % Lime

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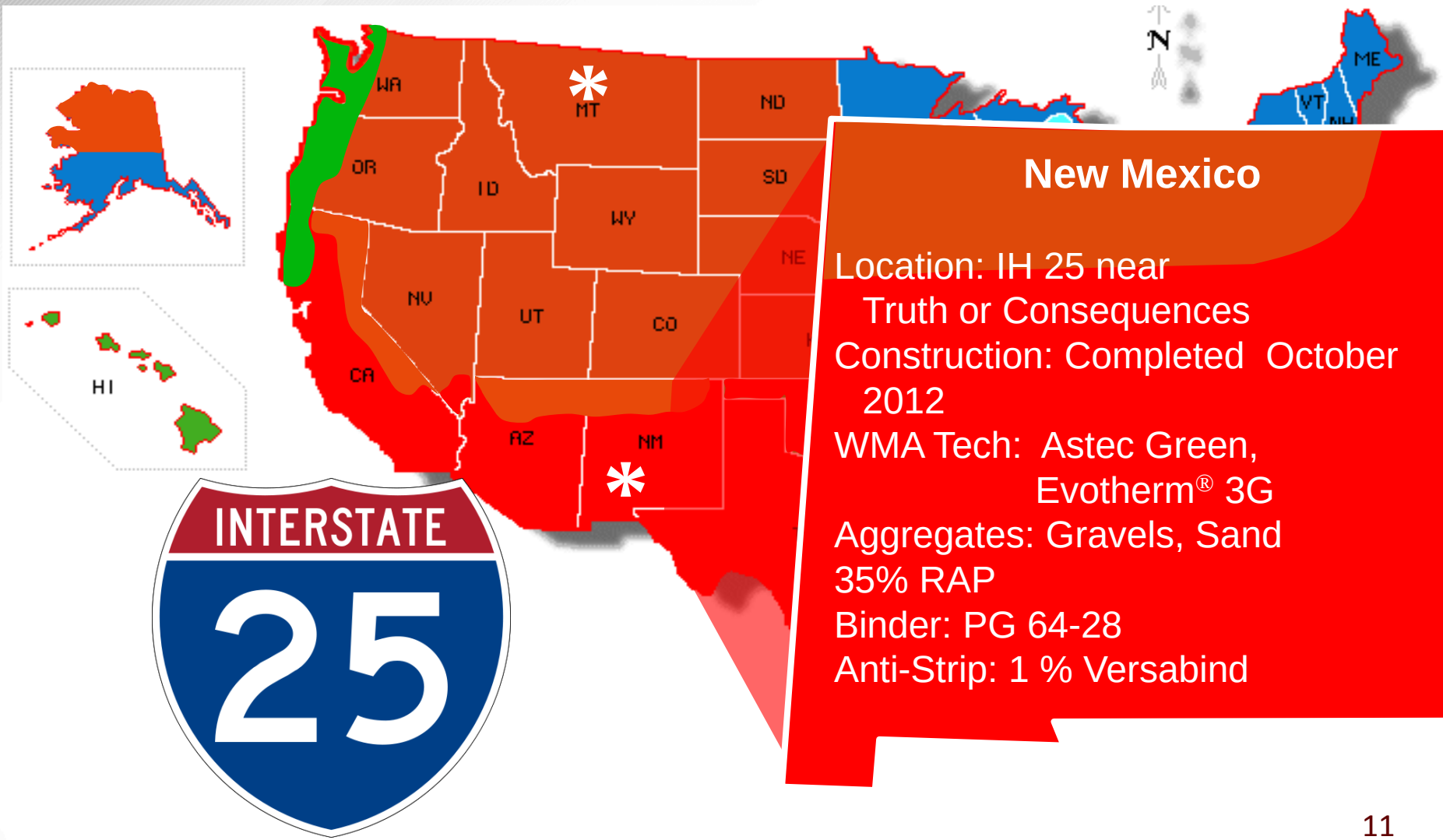
Field Projects



New Mexico

Location: IH 25 near Truth or Consequences

Construction: Completed October 2012

WMA Tech: Astec Green, Evotherm® 3G

Aggregates: Gravels, Sand

35% RAP

Binder: PG 64-28

Anti-Strip: 1 % Versabind

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Field Performance

Iowa Field Project
17 months in-service

Sasobit (EB)

Evotherm (EB)

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Performance Summary

Field Project	Const Date	Climate	Materials	Traffic	Field	Lab
IA	Sept 2011	Wet, F/T	PG58-28 17% RAP	Moderate, US Hwy	✗ Raveling	= WMAs vulnerable early, some ok w/age; HMAs marginal; lab tests separate
TX	Jan 2012	Hot, Wet	PG70-22	Heavy Trucks, FM Road	✓	"=" WMAs vulnerable early, ok w/age
MT	Oct 2011	Cold, Multi-F/T	PG70-28 1.4% Lime	Heavy, Interstate	✓	= except wet IDT/TSR, on-site
NM	Oct 2012	Dry, Cold Winter, Hot Summer	PG64-28 35% RAP 1% Versabind	Heavy, Interstate	✓	= except wet IDT/TSR, LMLC; M_R-ratio, LMLC & Foaming on-site

NCHRP 9-49
Thresholds (LMLC)

Development | Verification

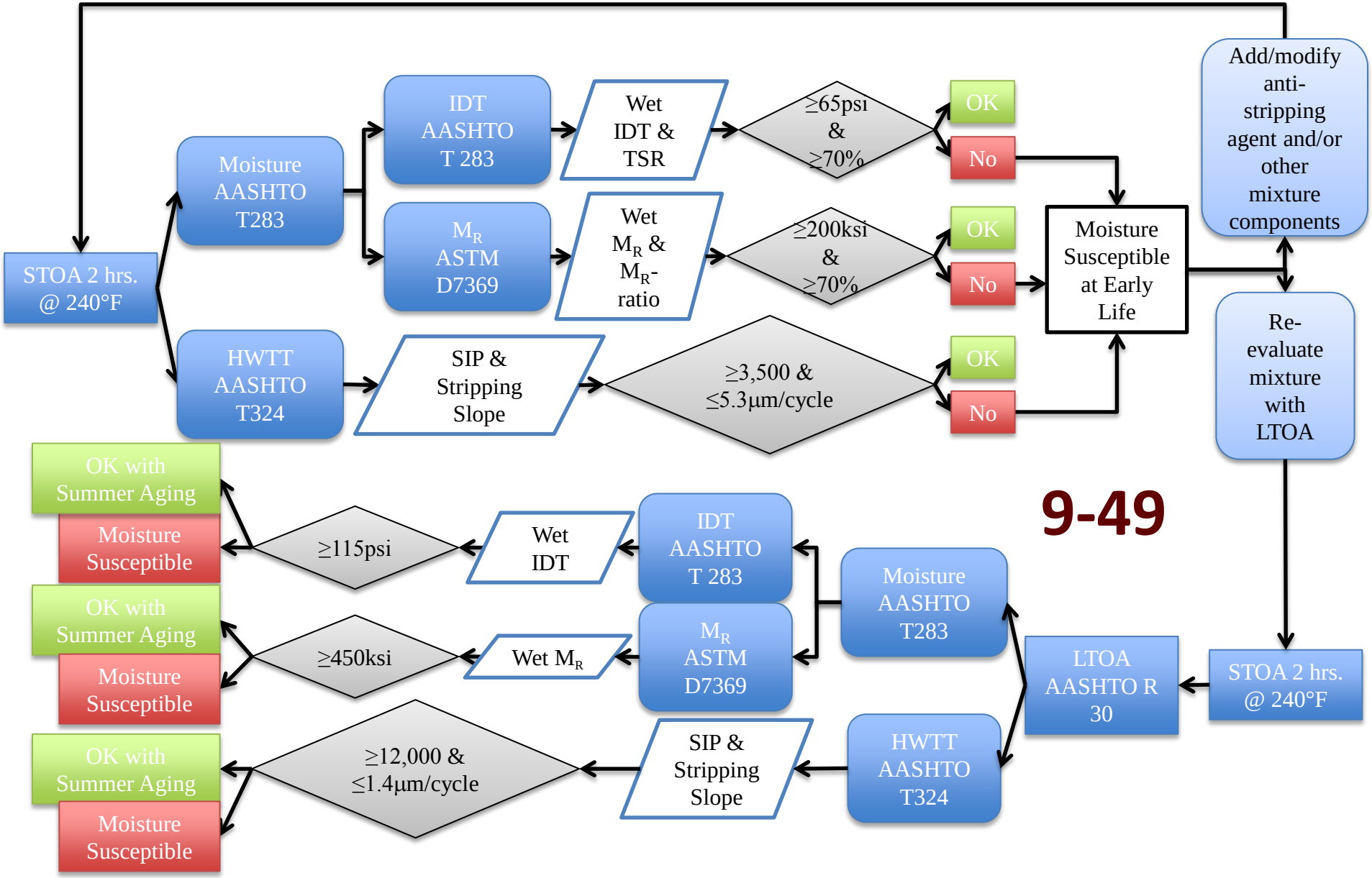
Test Parameter	Iowa		Texas		Montana			New Mexico	
	Evotherm	Sasobit	Evotherm	Foaming	Evotherm	Sasobit	Foaming	Evotherm	Foaming
Wet IDT (psi)	50	47	88	77	76	74	77	81	72
TSR (%)	84	77	7						
Wet M_R (ksi)	133	164	281	239	261	321	234	296	
M_R-ratio (%)	72	77	80					69	76
SIP (cycle)	1677	2176	6256	4				>20000	>20000
Stripping Slope (mm/cycle)	10	6.6	1.7	2.9	0			0	0

IA Use of Anti-stripping Agents
- Mixtures are likely still moisture susceptible at early life
- WMA Sasobit + Lime improved M_R and M_R-ratio

TX Use of Anti-stripping Agents
- Improved with Lime

TX LTOA
- Improved after aging

NM LTOA
- Improved after aging



WMA Mix Design with LMLC

select single test method and use throughout

NCHRP 9-49B Performance of WMA Technologies: Stage I – Moisture Susceptibility Validation

- Review of Recent Relevant Literature
- Follow-Up Web Survey
- Collaboration with NCHRP 9-47A and 9-49A
- Validation of 9-49 Thresholds
- Laboratory Experiment to assess alternate moisture conditioning protocols and explore various specimen-drying methods
- NCHRP Report 817

NCHRP 9-49B
Web Survey

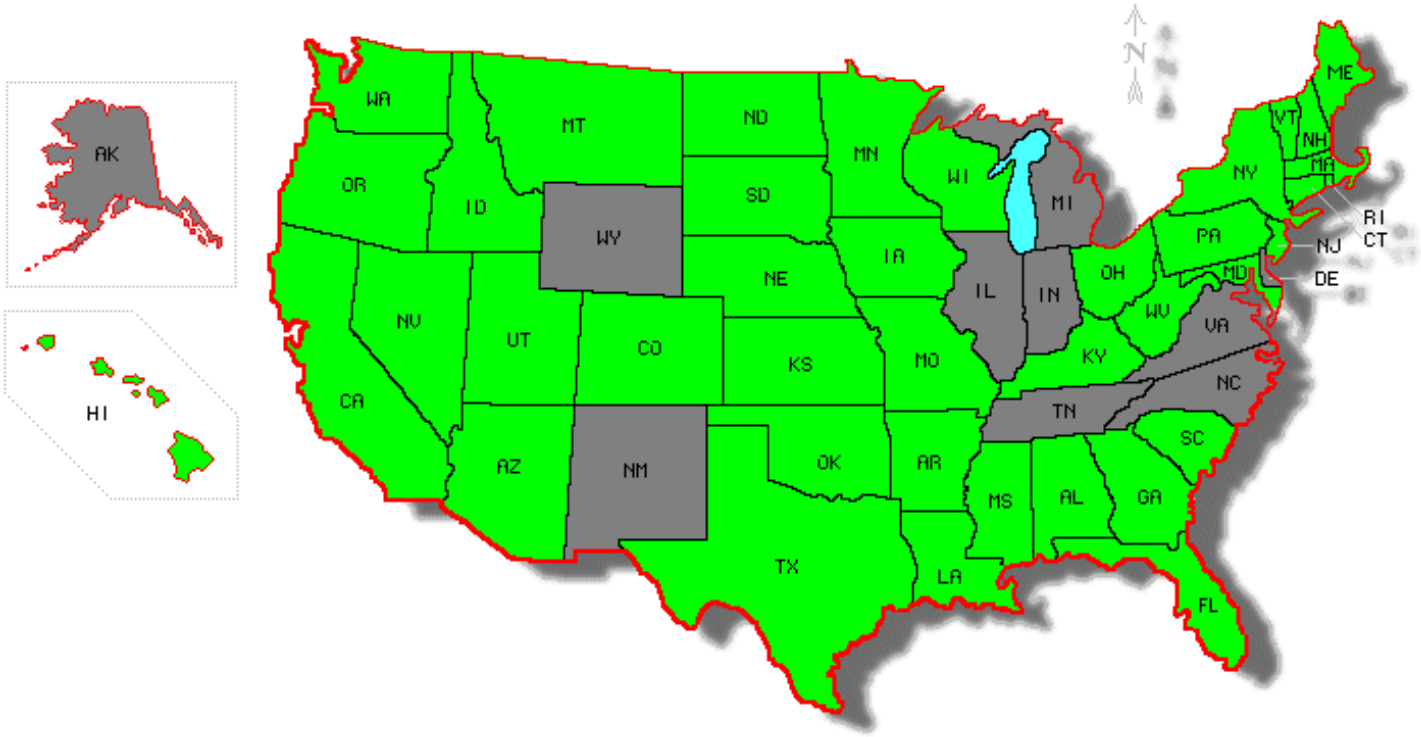
Validate flow chart

- WMA pavements with moisture susceptibility data
  - Mix design
  - Quality assurance
- Moisture susceptibility criteria
- WMA technology and materials
- Field performance

NCHRP 9-49B
Web Survey

Respondents

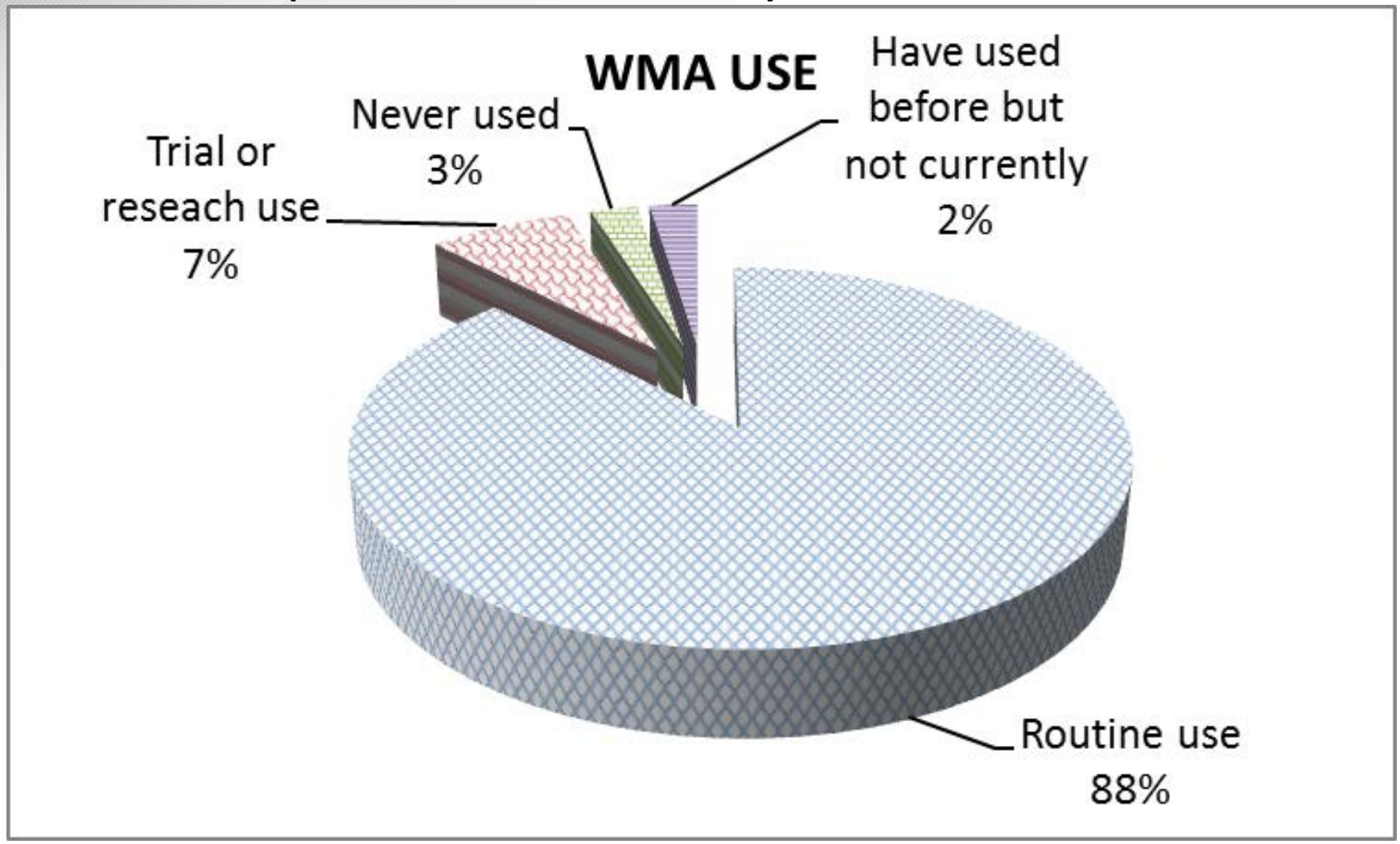
41 of 50 states
(82% response rate)



Source: diymaps.net (c)

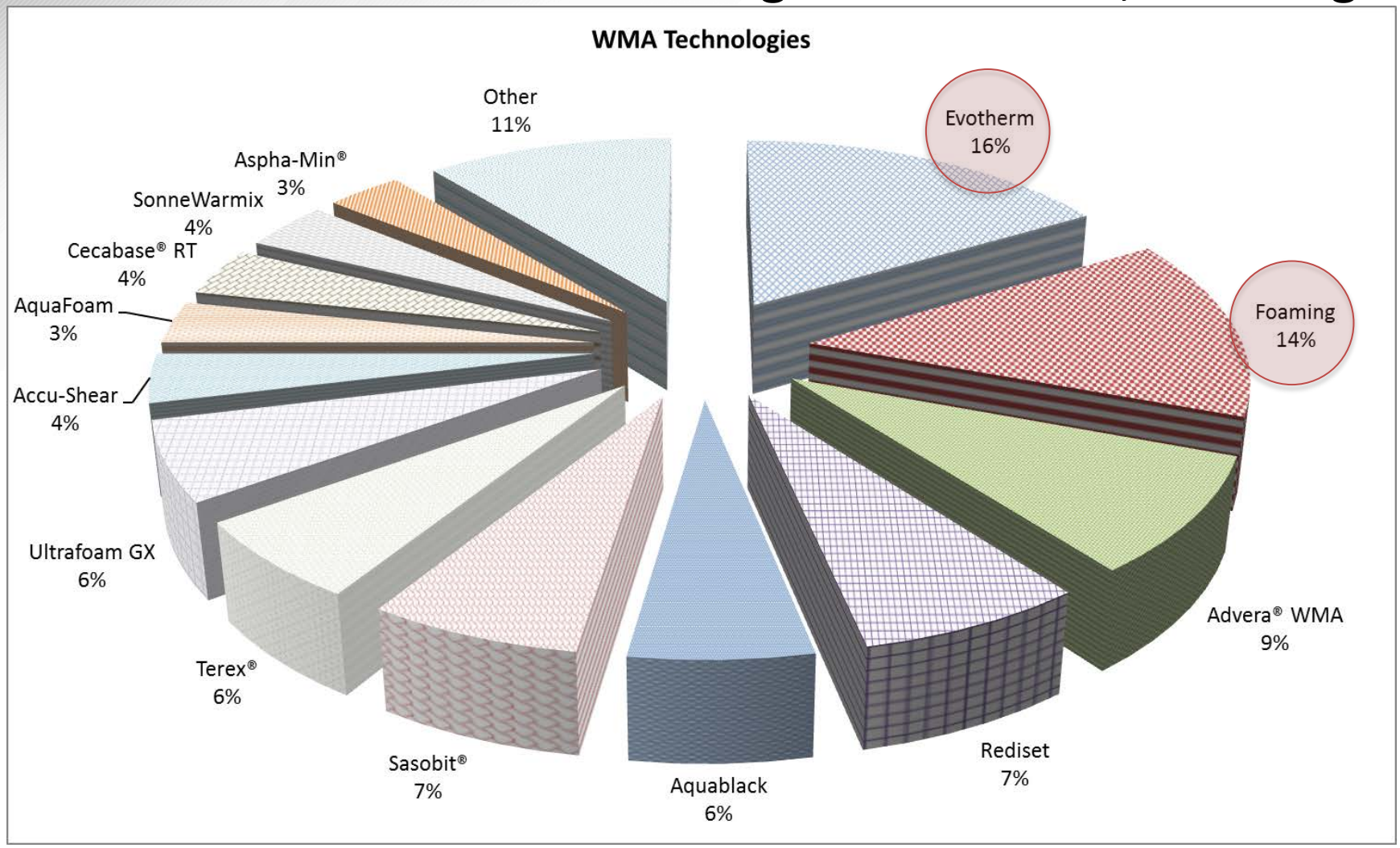
Web Survey

WMA pavements routinely used in most states

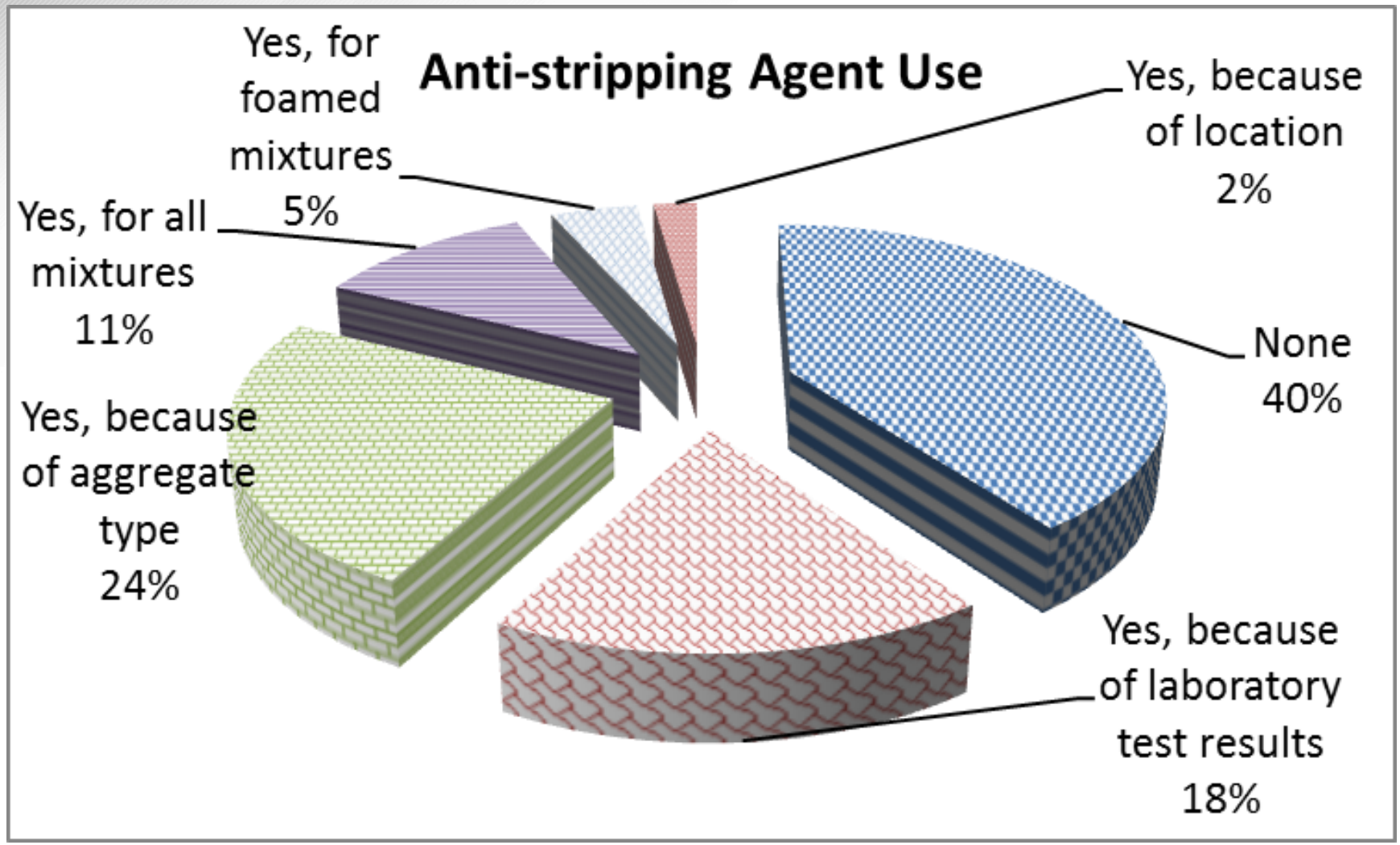


NCHRP 9-49B
Web Survey

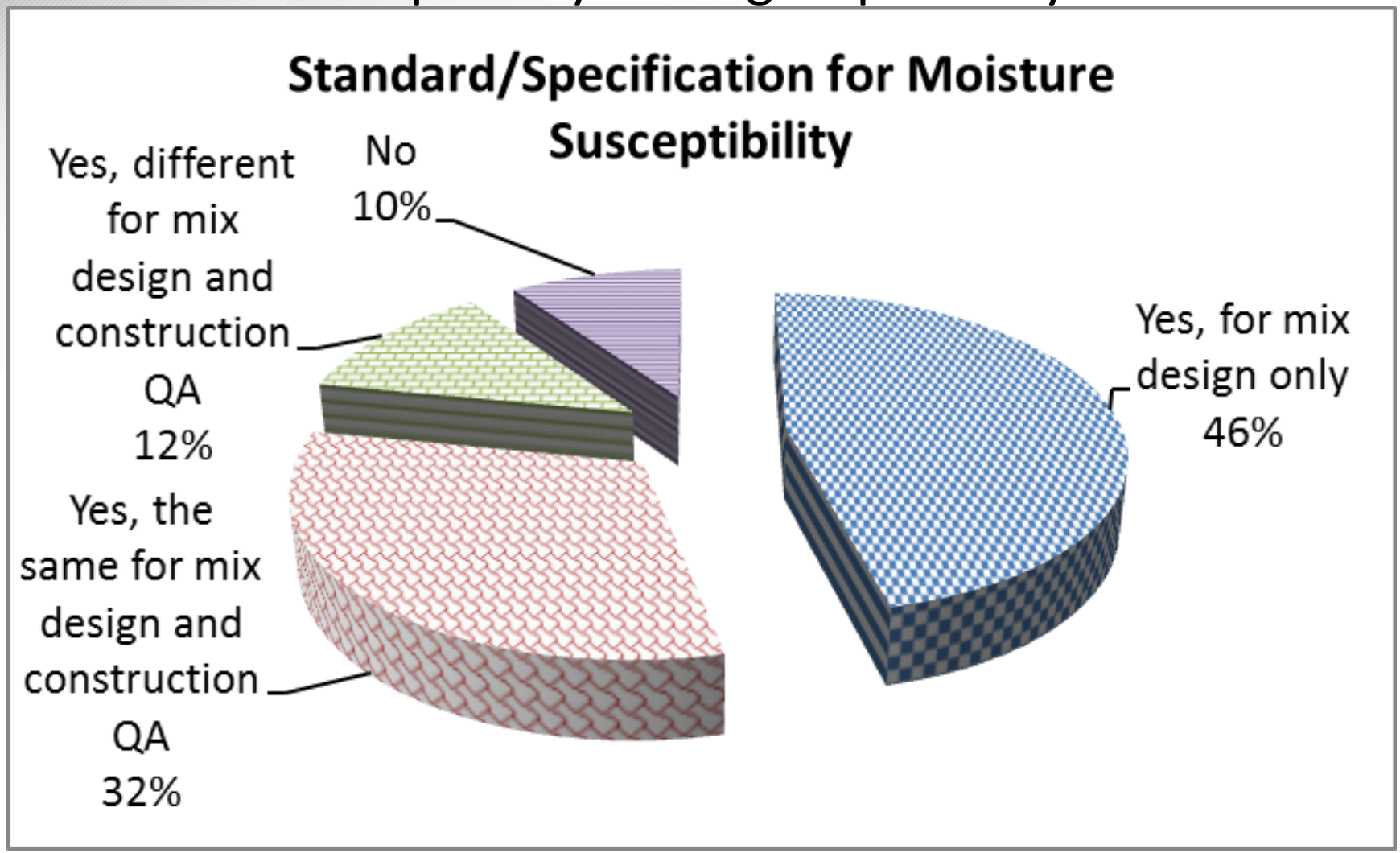
Most common WMA technologies: Evotherm, Foaming



Anti-stripping agents required by the majority of states

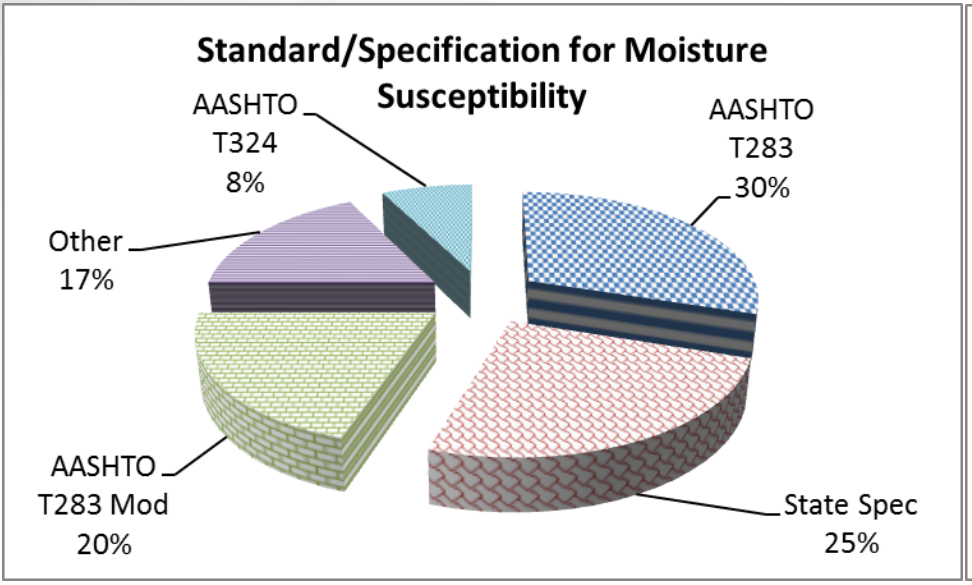


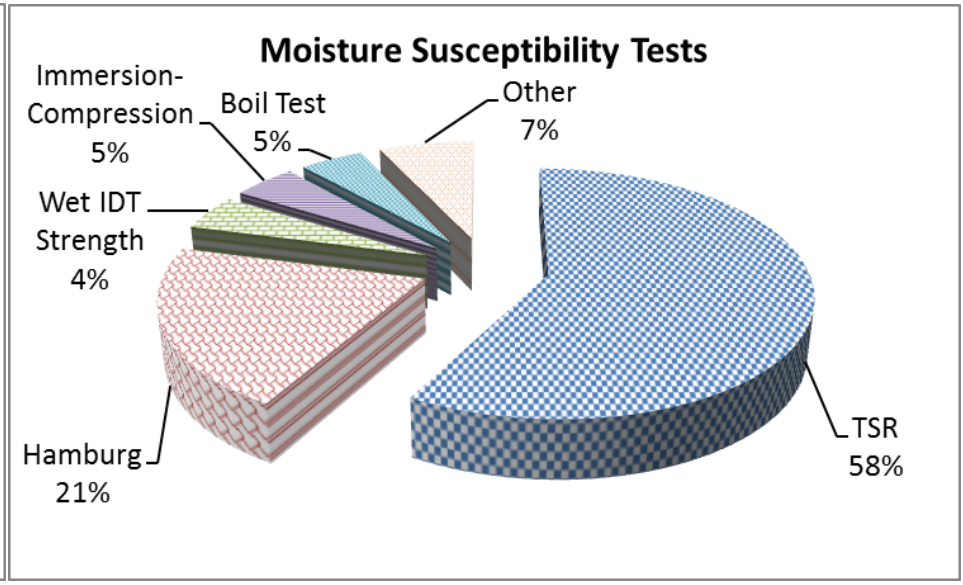
Moisture susceptibility testing required by most states



NCHRP 9-49B
Web Survey

Most common test method used is AASHTO T 283

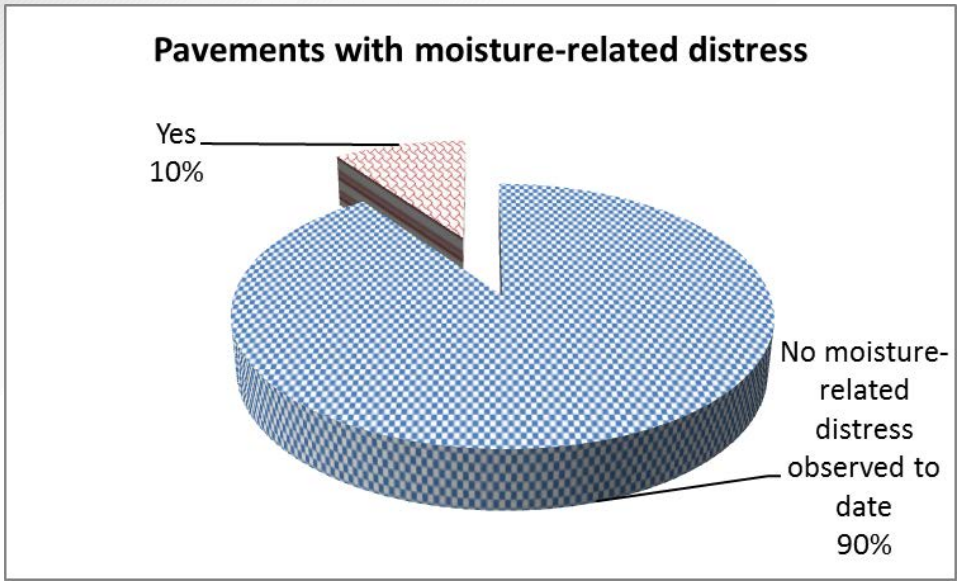


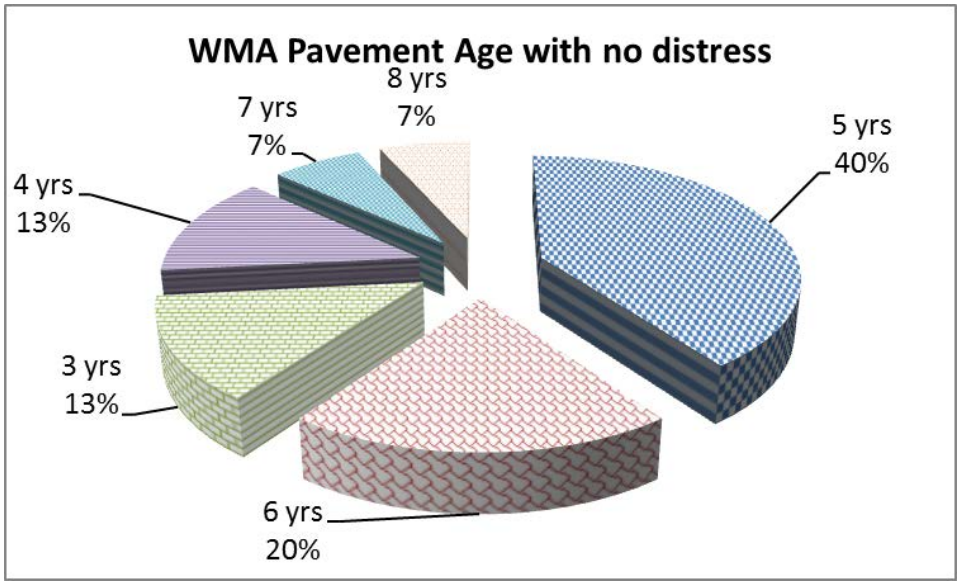


Most common test parameter is Tensile Strength Ratio (TSR)

NCHRP 9-49B
Web Survey

Adequate WMA pavement performance



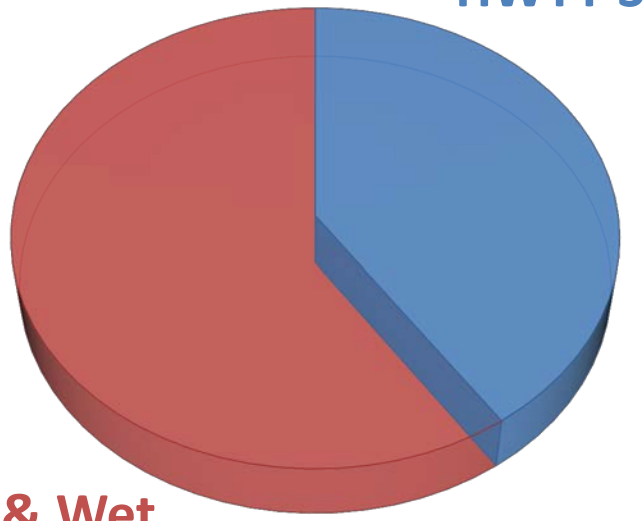


Typical WMA pavement age 5-6 years

NCHRP 9-49B
Threshold Validation

- 64 WMA mixtures from 44 field projects identified from web-survey respondents and NCHRP projects 9-47A and 9-49A

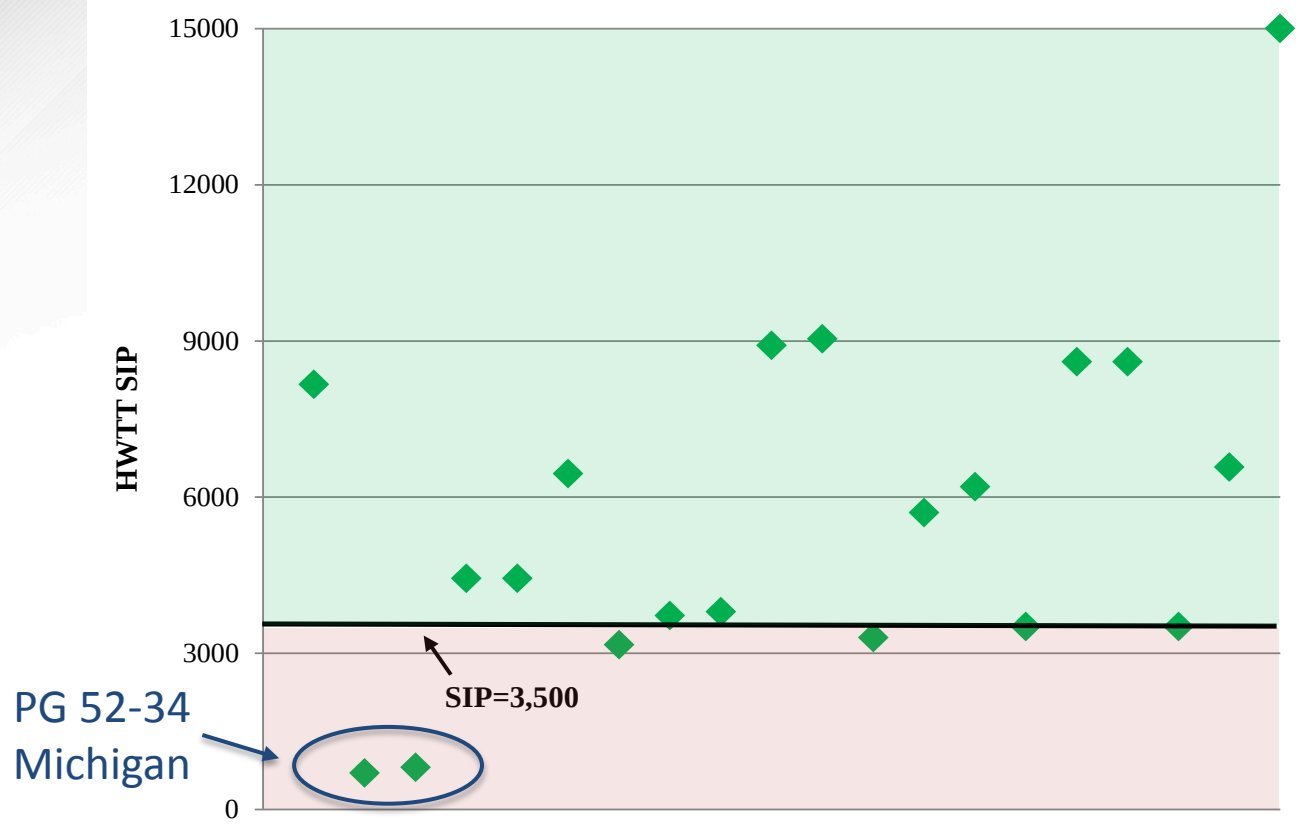
- Moisture susceptibility data
  - Mix design
  - QC/QA
  - Pavement performance



NCHRP 9-49B
Threshold Validation

HWTT SIP

89% Performance Correlation



Good field performance

Poor field performance

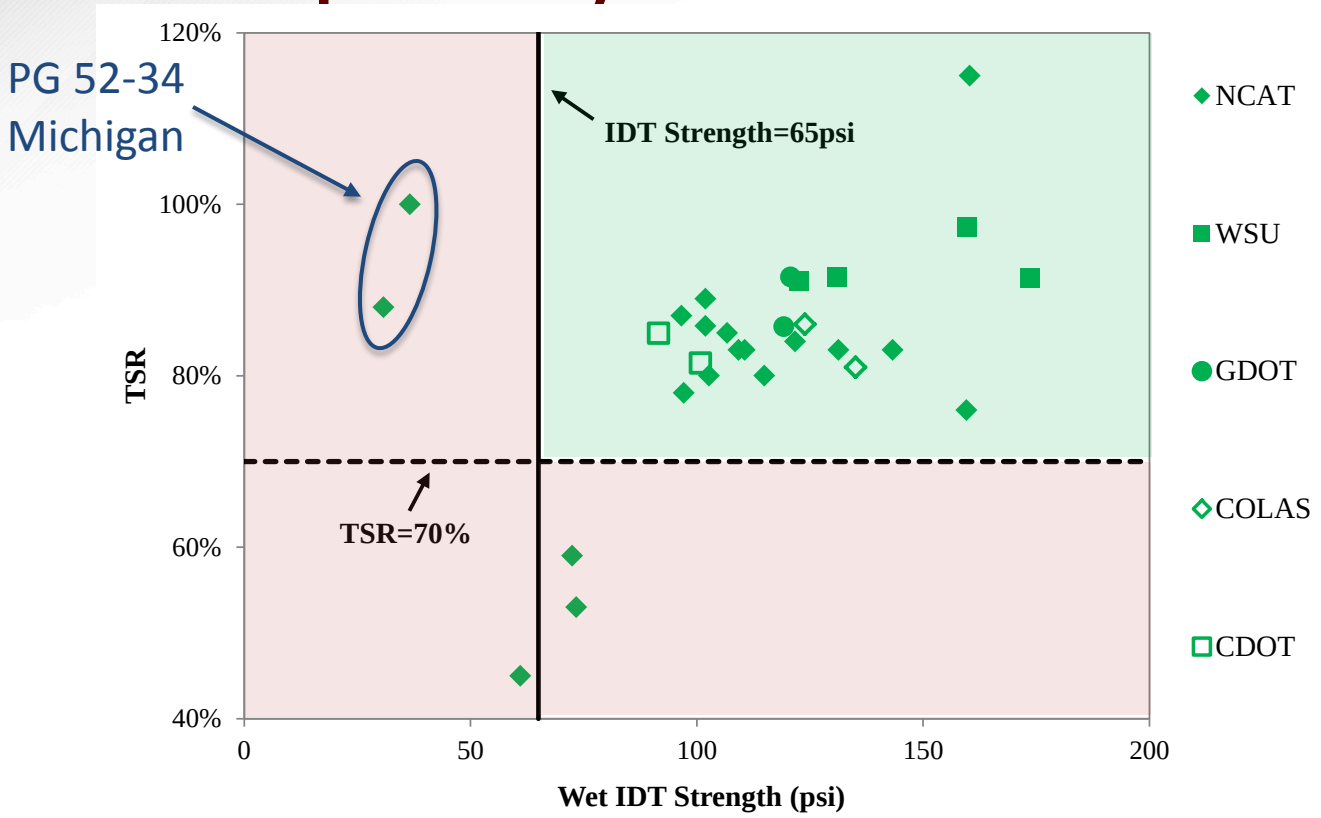
Lab results > thresholds

Lab results < thresholds

NCHRP 9-49B
Threshold Validation

TSR & Wet IDT Strength (on-site PMLC specimen)

83% Performance Correlation



Good field performance

Poor field performance

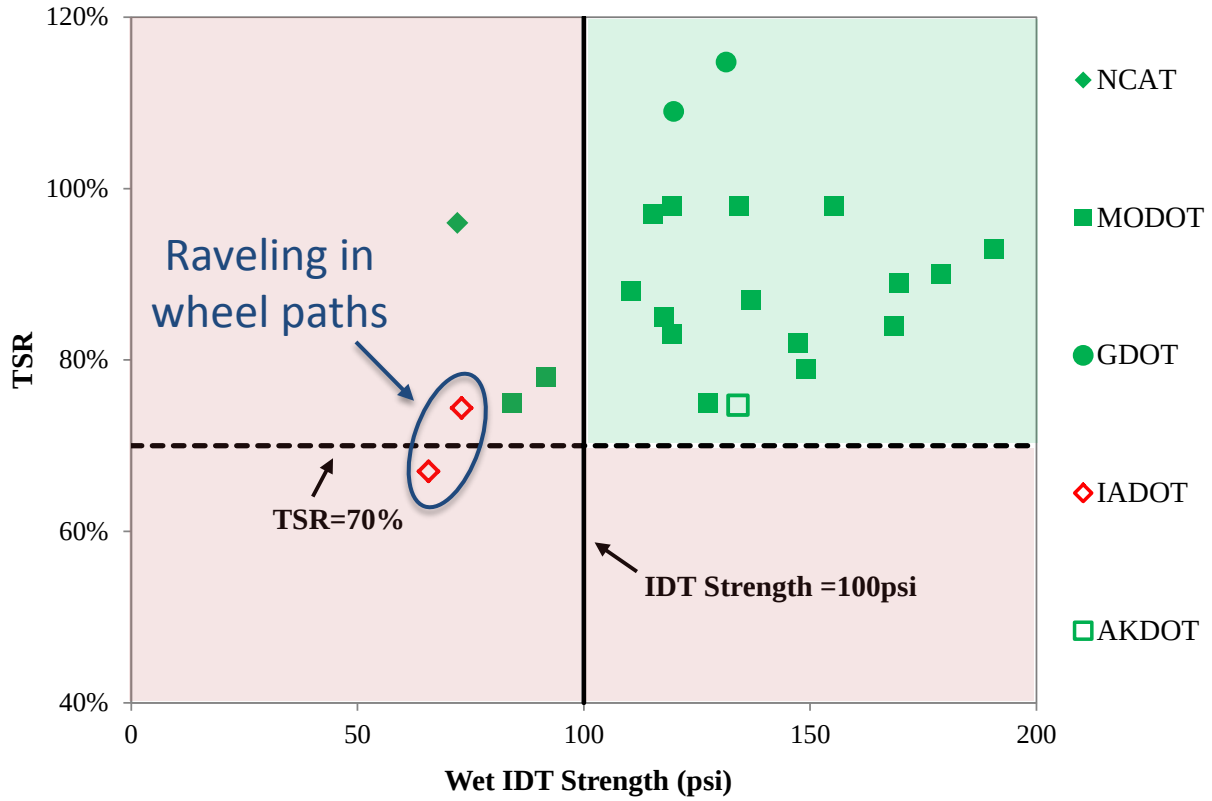
Lab results > thresholds

Lab results < thresholds

NCHRP 9-49B
Threshold Validation

TSR & Wet IDT Strength (off-site PMLC specimen)

87% Performance Correlation



Good field performance

Poor field performance

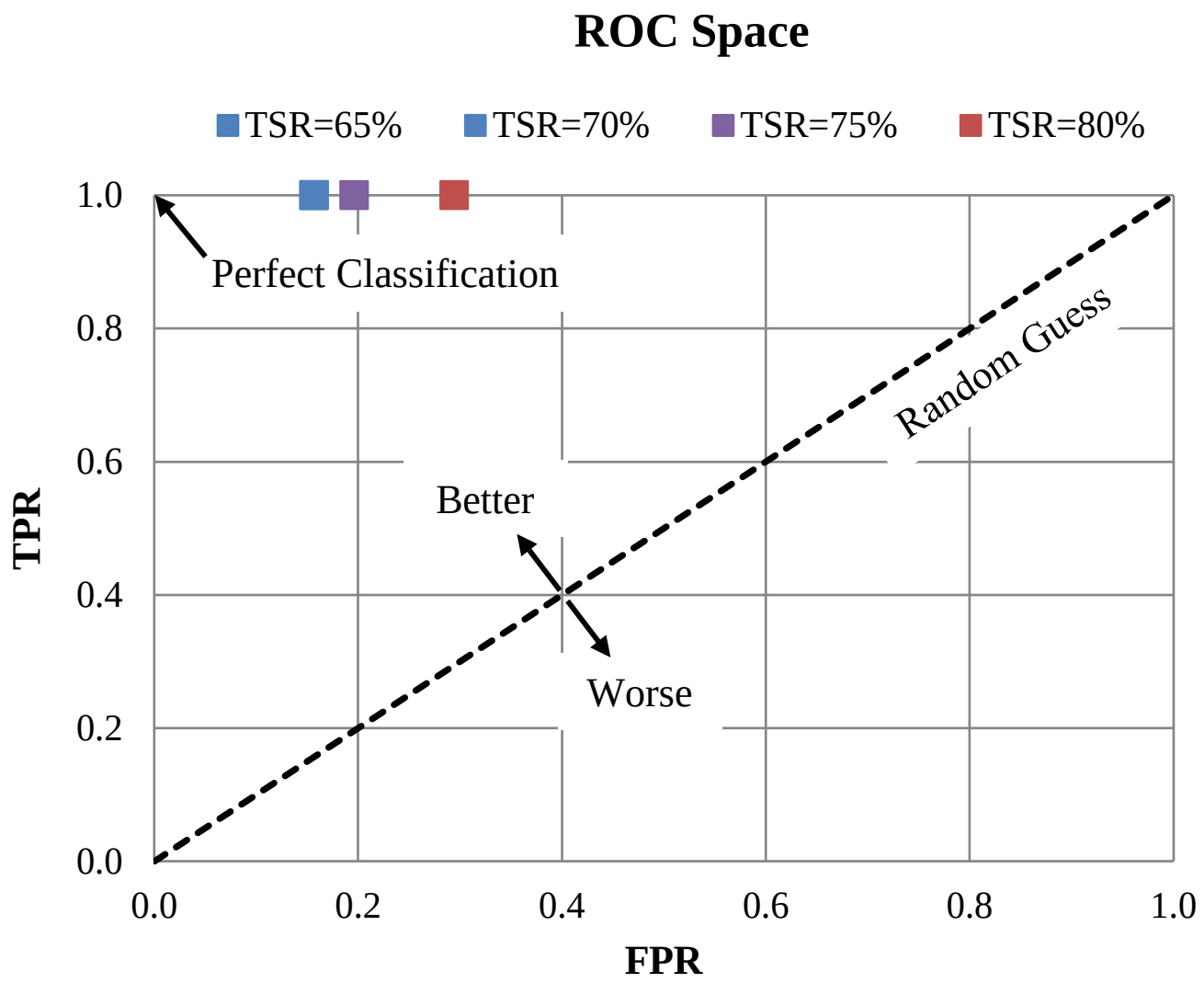
Lab results > thresholds

Lab results < thresholds

NCHRP 9-49B
ROC ANALYSIS - TSR

TSR Threshold	LAB : FIELD	65%	70%	75%	80%
True Positive	FAIL : FAIL ✔	2	2	2	2
False Negative	PASS : FAIL ✘	0	0	0	0
False Positive	FAIL : PASS ✘	8	8	10	15
True Negative	PASS : PASS ✔	43	43	41	36
TPR	---	1.00	1.00	1.00	1.00
FPR		0.16	0.16	0.20	0.29
Accuracy		0.85	0.85	0.81	0.72

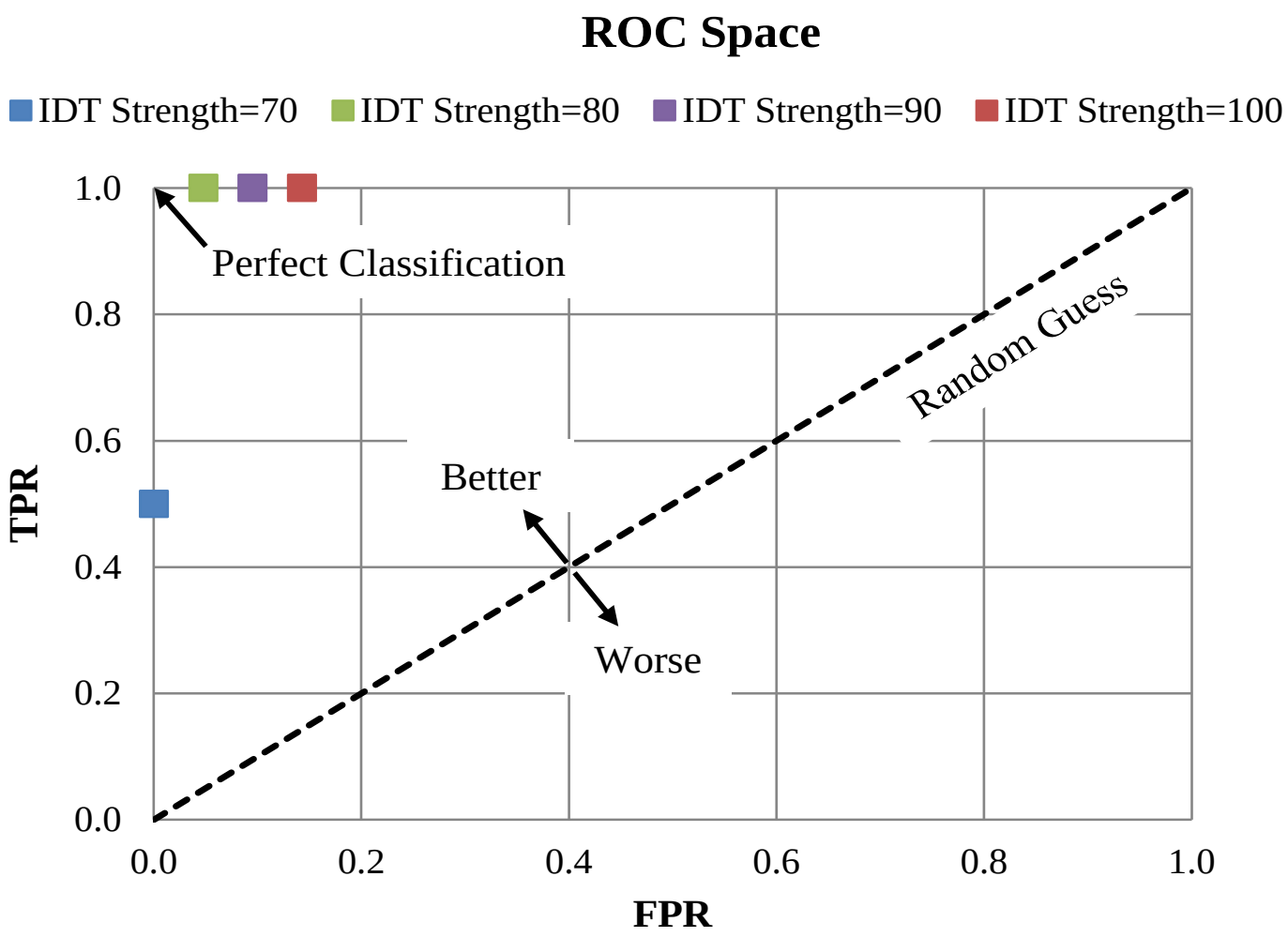
NCHRP 9-49B
ROC ANALYSIS - TSR



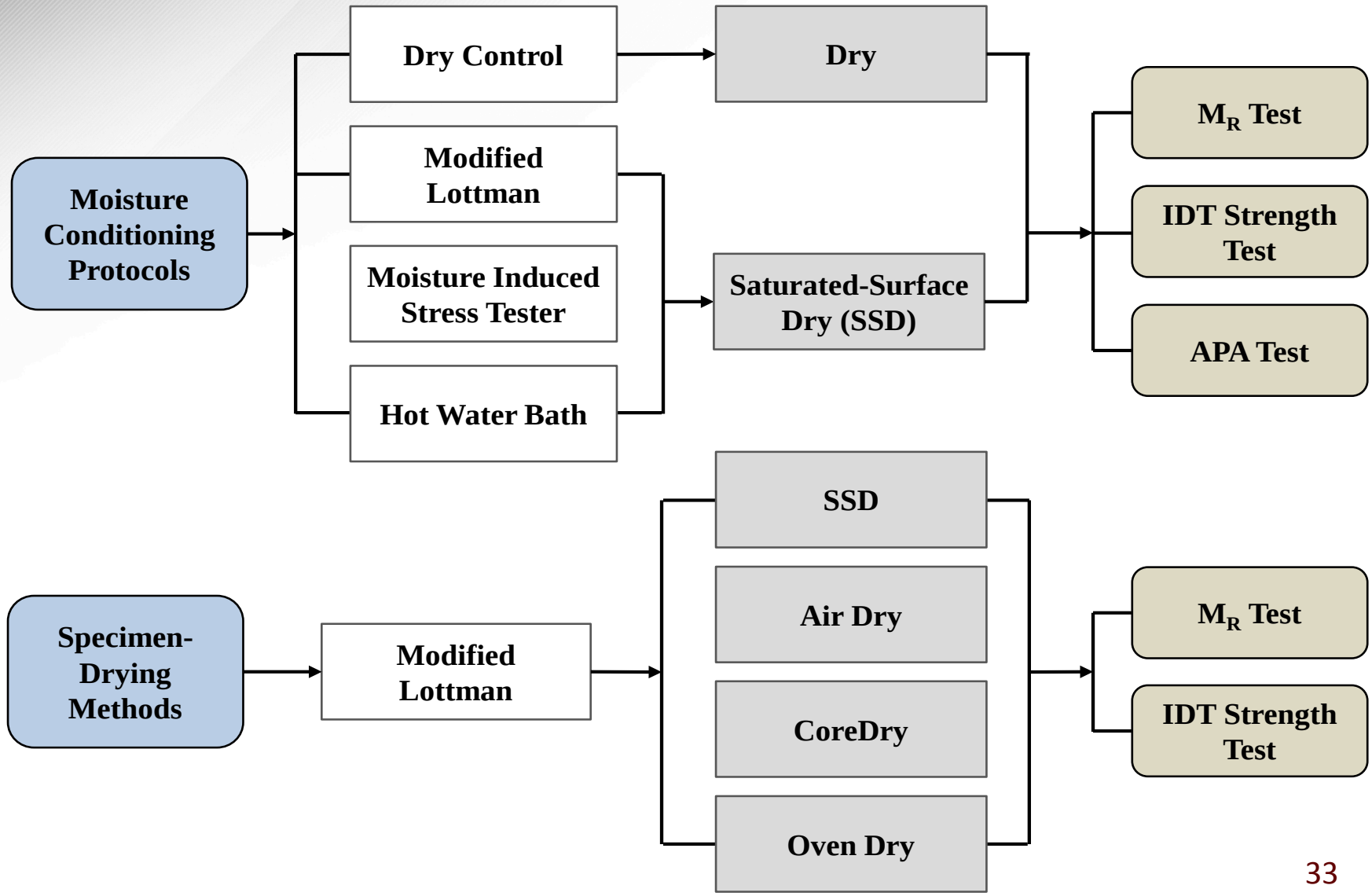
ROC ANALYSIS – IDT Strength

Wet IDT Strength Threshold	LAB : FIELD	70 psi	80 psi	90 psi	100 psi
True Positive	FAIL : FAIL ✔	1	2	2	2
False Negative	PASS : FAIL ✘	1	0	0	0
False Positive	FAIL : PASS ✘	0	1	2	3
True Negative	PASS : PASS ✔	21	20	19	18
TPR	---	0.50	1.00	1.00	1.00
FPR		0.00	0.05	0.10	0.14
Accuracy		0.96	0.96	0.91	0.87

ROC ANALYSIS – IDT Strength

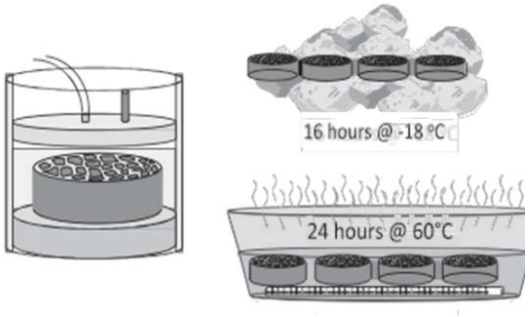


NCHRP 9-49B
LABORATORY EXPERIMENT



Moisture Conditioning Protocols

- Modified Lottman (AASHTO T283)
  - Vacuum saturation + 1 freeze/thaw cycle
  - 3 Days

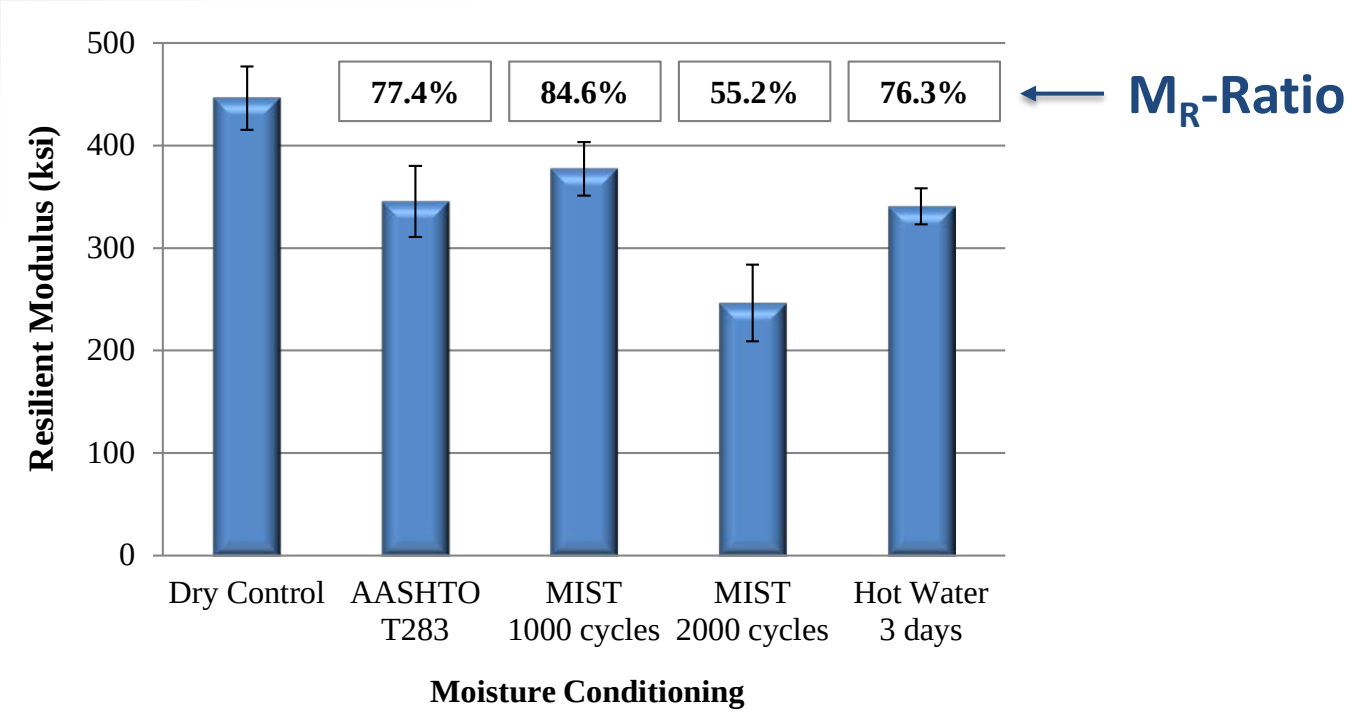


- Moisture Induced Stress Tester (MIST)
  - Temperature: 60°C
  - Pressure: 40 psi
  - 1,000 and 2,000 cycles
  - 0.5 Day

- Hot Water Bath (HWB)
  - Temperature: 60°C
  - 3 Days

LABORATORY EXPERIMENT

Wet M_R Stiffness at 25°C

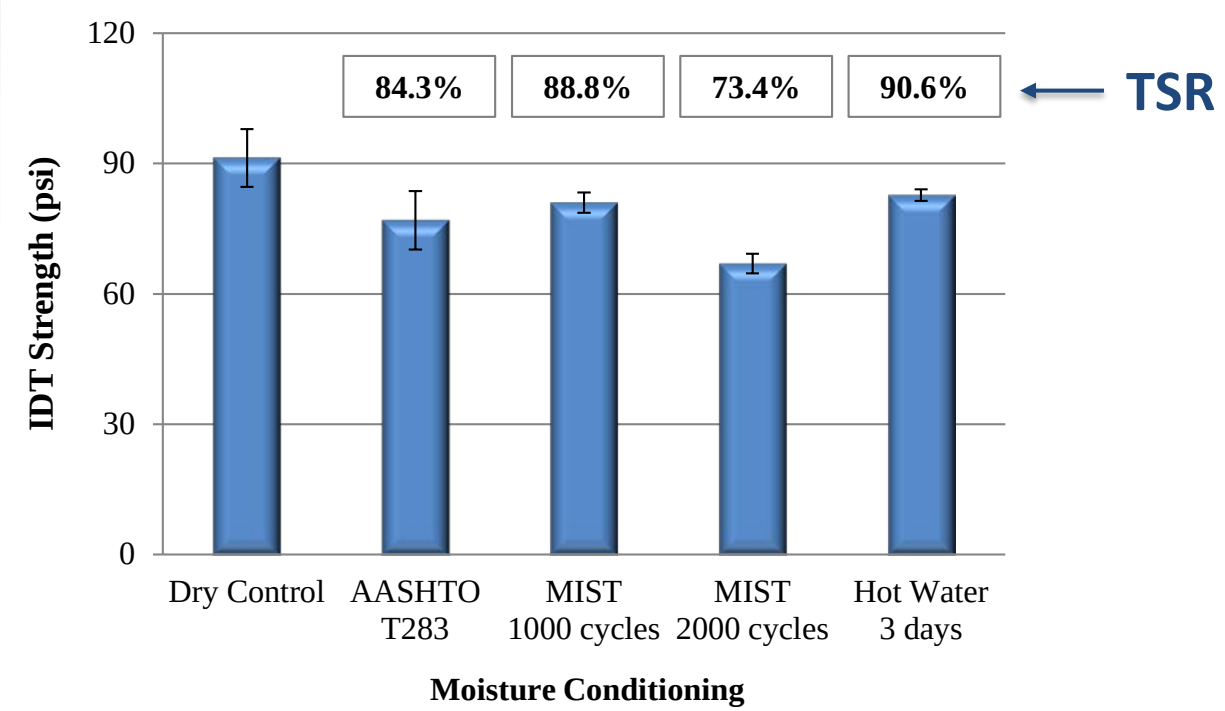


Reduced stiffness for all moisture conditioning protocols

T 283 = 1,000 MIST = 3-day HWB > 2,000 MIST

LABORATORY EXPERIMENT

Wet IDT Strength at 25°C

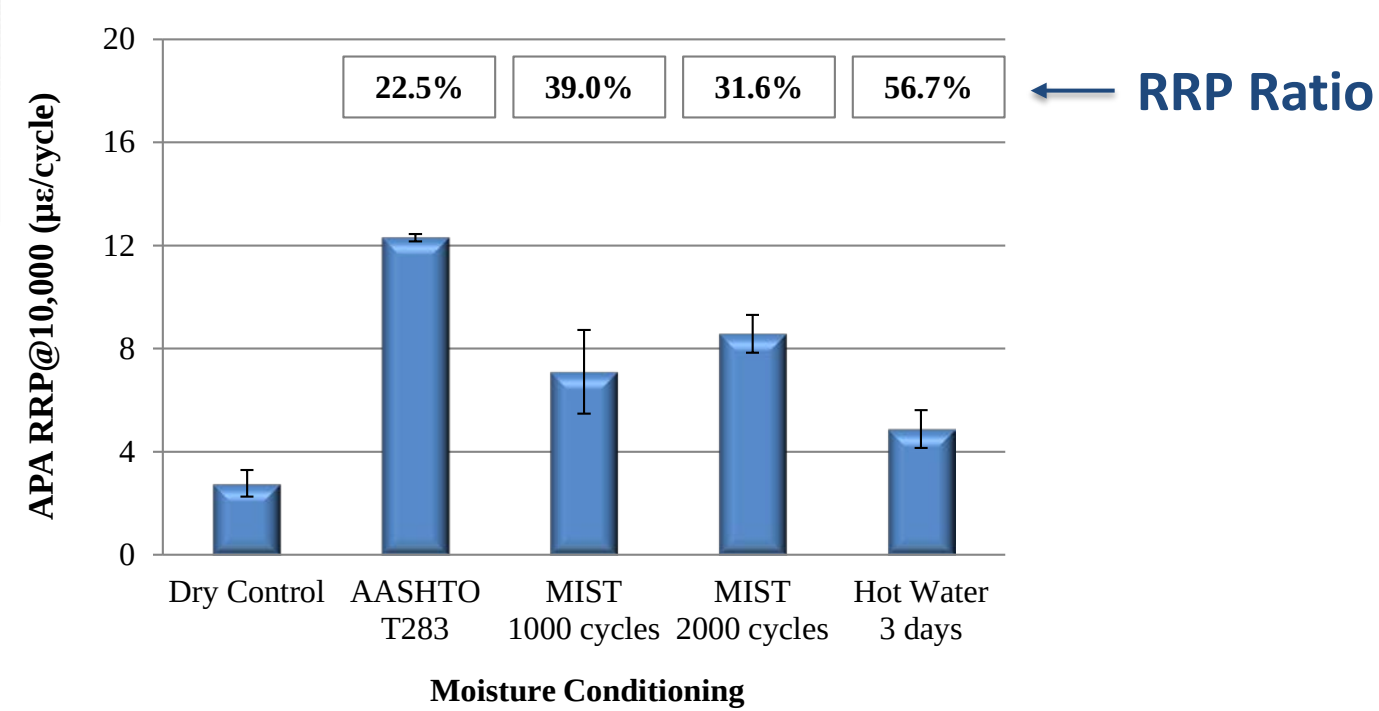


Reduced strength for all moisture conditioning protocols

T 283 = 1,000 MIST = 3-day HWB > 2,000 MIST

LABORATORY EXPERIMENT

APA Rutting Resistance at 50°C



Reduced rutting resistance for all moisture conditioning protocols

3-day HWB ≥ 1,000 MIST = 2,000 MIST > T 283

LABORATORY EXPERIMENT

Statistical Analysis Results

Moisture Conditioning Protocols	M_R Stiffness	IDT Strength	APA RRP
Dry Control	A	A	A
Modified Lottman	B	B	D
1,000-cycle MIST	B	B	B-C
2,000-cycle MIST	C	C	C-D
3-day HWB	B	B	B

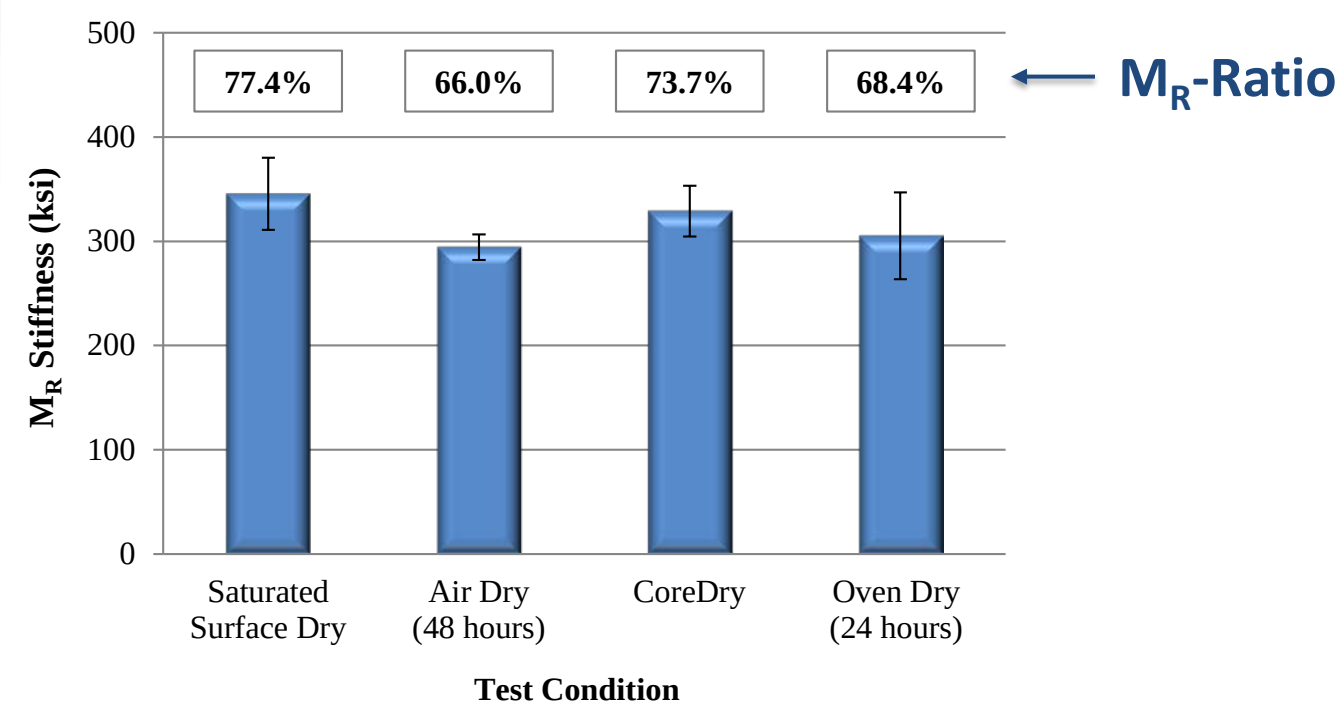
1,000 MIST and 3-day HWB proposed as two alternatives to the AASHTO T283 protocol for use in the moisture susceptibility guideline

Specimen-Drying Methods

- Saturated-surface dry (SSD) per AASHTO T 166
- 48-hour air dry at 25°C
- 24-hour oven dry at 40°C
- CoreDry per AASHTO PP 75

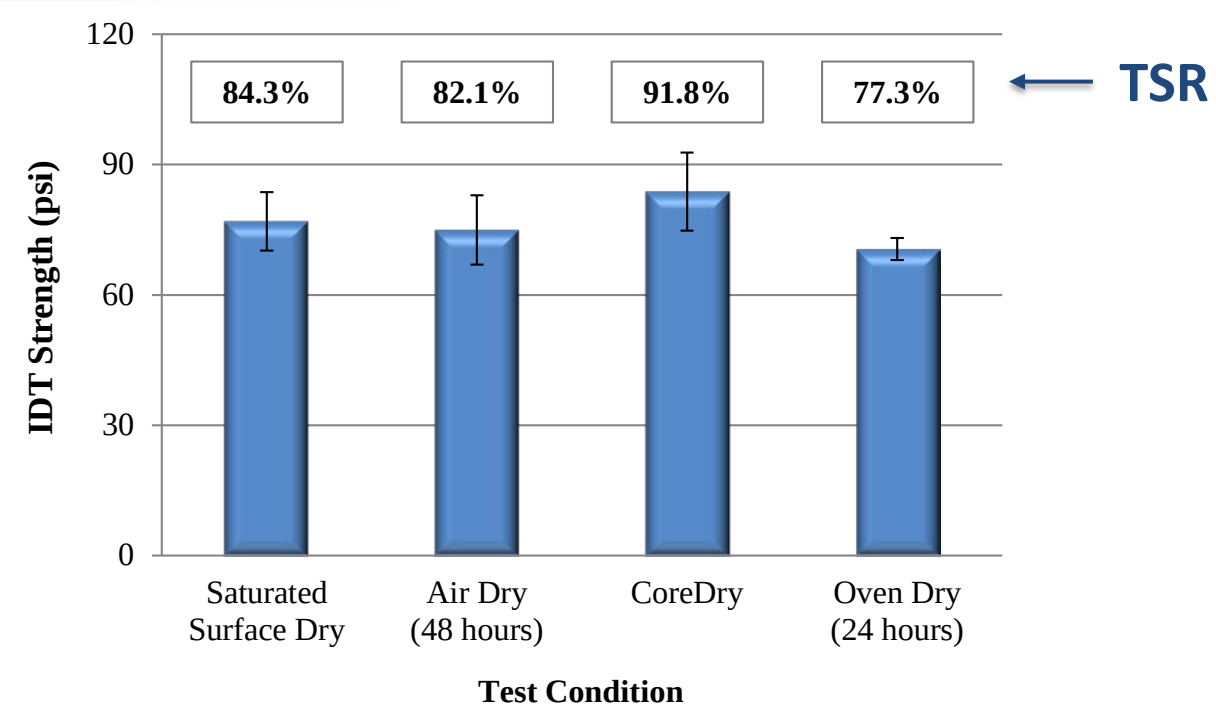
LABORATORY EXPERIMENT

M_R Stiffness at 25°C



SSD = CoreDry = Air Dry = Oven Dry

IDT Strength at 25°C



CoreDry ≥ SSD = Air Dry ≥ Oven Dry

Specimen-Drying Methods

SSD method

- "Entrapped" water biased stiffness and strength measurements due to pore pressure and incompressibility

Air dry & oven dry methods

- Long time requirement

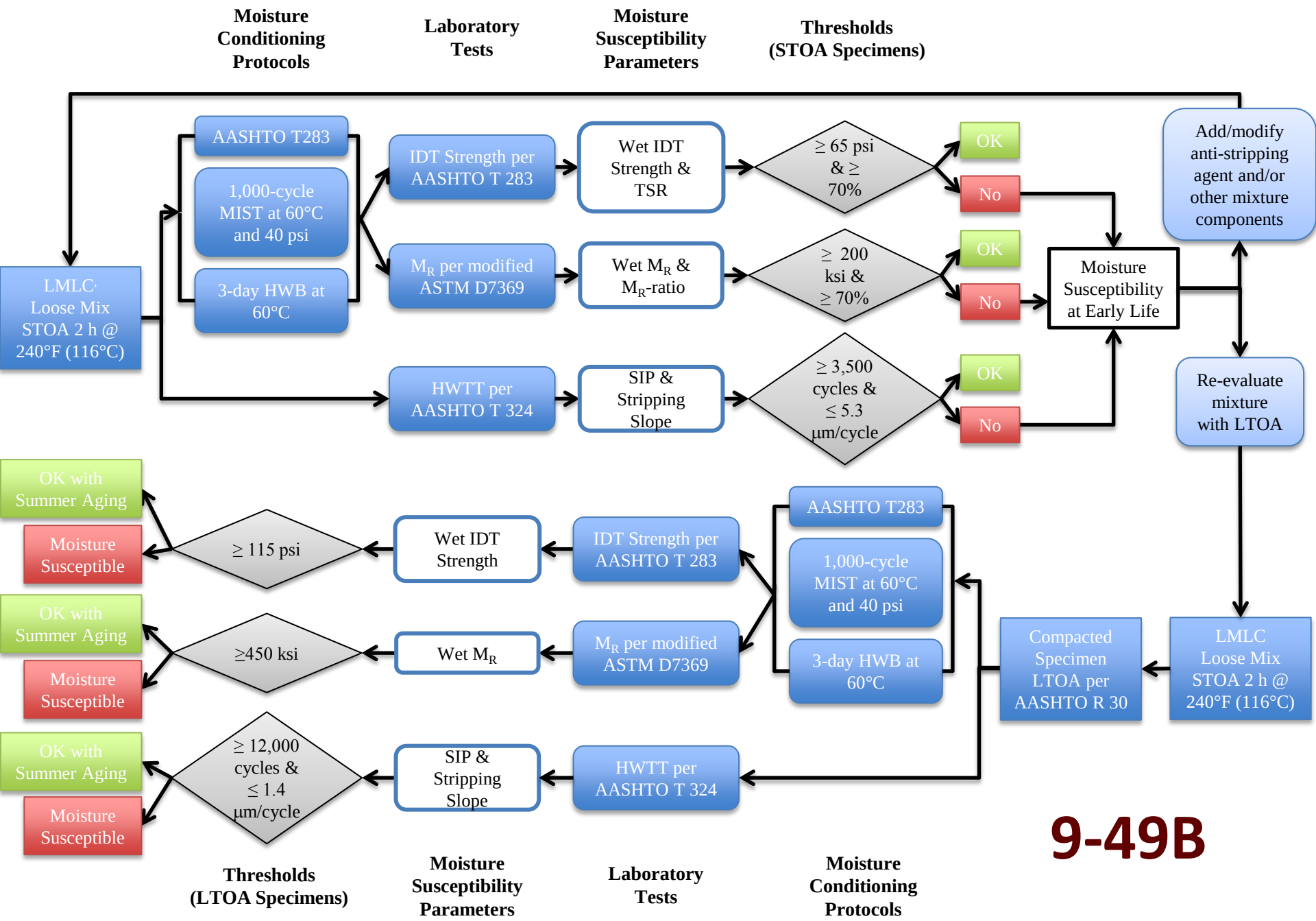
CoreDry method

- Short time requirement

NCHRP 9-49B CONTRIBUTIONS

- Commentary on Guideline Thresholds for Revising Appendix to AASHTO R 35

- Revised Guideline Thresholds with flexibility in Laboratory Tests & Moisture Conditioning Protocols


Moisture Conditioning Protocols
Laboratory Tests
Moisture Susceptibility Parameters
Thresholds (STOA Specimens)
LMLC Loose Mix STOA 2 h @ 240°F (116°C)
AASHTO T283
1,000-cycle MIST at 60°C and 40 psi
3-day HWB at 60°C
IDT Strength per AASHTO T 283
M_R per modified ASTM D7369
HWTT per AASHTO T 324
Wet IDT Strength & TSR
Wet M_R & M_R-ratio
SIP & Stripping Slope
≥ 65 psi & ≥ 70%
≥ 200 ksi & ≥ 70%
≥ 3,500 cycles & ≤ 5.3 µm/cycle
OK
No
Moisture Susceptibility at Early Life
Add/modify anti-stripping agent and/or other mixture components
Re-evaluate mixture with LTOA
LMLC Loose Mix STOA 2 h @ 240°F (116°C)
Compacted Specimen LTOA per AASHTO R 30
AASHTO T283
1,000-cycle MIST at 60°C and 40 psi
3-day HWB at 60°C
IDT Strength per AASHTO T 283
M_R per modified ASTM D7369
HWTT per AASHTO T 324
Wet IDT Strength
Wet M_R
SIP & Stripping Slope
≥ 115 psi
≥450 ksi
≥ 12,000 cycles & ≤ 1.4 µm/cycle
OK with Summer Aging
Moisture Susceptible
Thresholds (LTOA Specimens)
Moisture Susceptibility Parameters
Laboratory Tests
Moisture Conditioning Protocols

9-49B

Thank You!

Questions?