TRB

TRANSPORTATION RESEARCH BOARD

Use of Performance Specifications for Asphalt Mixtures

TRB Webinar
March 30, 2017

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Villanova University

Overview of NCHRP Synthesis Report 492

Goal:

Identify state-of-the-practice strategies used by DOTs, Canadian MOTs, and other agencies on:

1. Effectively implement performance specifications & performance testing for asphalt mixtures

2. Performance tests used with volumetric properties for specifying both traditional and nontraditional plant-produced asphalt mixtures

3. Use of performance tests in asphalt QA procedures

Overarching Research Objectives

Project selection criteria?

Which criteria used in specs?

Who does testing? Internal or external?

How were performance specifications developed?

Equipment availability?

Performance testing time?

Were the benefits of testing worth the cost?

On-going research and needs?

Project Approach

- Major Tasks:

1. Review current practices by all states re: development of asphalt mixtures, with a focus on performance-based specifications (PBS)
2. Survey all state and provincial DOTs & identified 10 states & 1 local agency for further study
3. Interview DOT, local agency, and industry staff for input to develop the 7 case examples
4. Conduct detailed phone interviews to obtain specific details.

Definitions in Project Scope

Performance Based Specifications:

- Describe desired levels of fundamental engineering properties, to predict performance and used in distress models

Performance Related Specifications:

- Describe desired levels of key materials and construction quality characteristics to correlate with fundamental engineering properties that predict performance, amenable to acceptance testing at the time of construction

Data Collection

- Survey with 40 questions sent to AASHTO RAC members
- Forwarded to Materials Engineers
- 45 / 50 states responded
- Responses from Wash. DC, 2 counties, 1 city
- Responses from 10 provinces

NCHRP Synthesis 46-03 PRS Asphalt

Page description:

Dear DOT/MOT Research Engineer (or Other Agency Directors of Engineering):

The Transportation Research Board (TRB) is preparing a synthesis on performance specifications for asphalt mixtures. This is being done for the National Cooperative Highway Research Program (NCHRP), under the sponsorship of the American Association of State Highway and Transportation Officials (AASHTO), in cooperation with the Federal Highway Administration (FHWA).

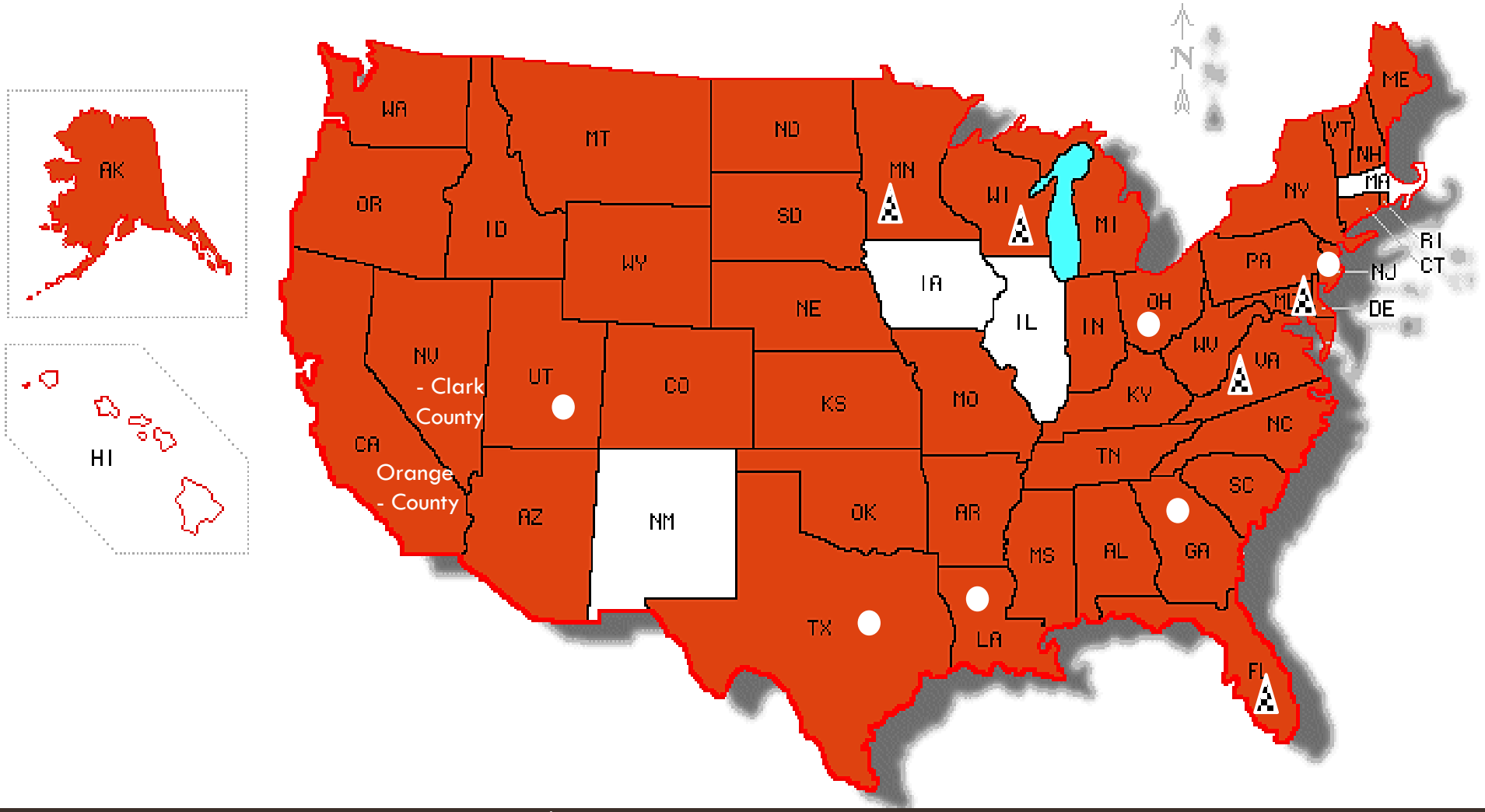
This questionnaire relates to performance testing of asphalt mixtures and how the results from these tests are used as part of performance-based or performance-related specifications by your organization. Your cooperation in completing the questionnaire will ensure the success of this effort. If appropriate, you may consider forwarding a copy of this survey to your organization's engineer who leads the efforts related to the design and construction of asphalt pavements. **If you are not the appropriate person at your to complete this questionnaire, please forward it to the correct person.**

Please complete and submit this survey by ***March 2, 2015.*** We estimate that it should take approximately 20 to 30 minutes to complete. If you have any questions, please contact our principal investigator, Dr. Leslie Myers McCarthy of Villanova University by phone at 610-519-7917 or by email at leslie.mccarthy@villanova.edu. Any supporting materials can be sent directly to Dr. McCarthy by email or at the postal address shown at the end of the survey.

QUESTIONNAIRE INSTRUCTIONS

1. To view and print the entire questionnaire, Click on the following link //surveygizmolibrary.s3.amazonaws.com/library/64484/NCHRP_Synth_4603 and print using "control p"

Survey Respondents in the U.S.

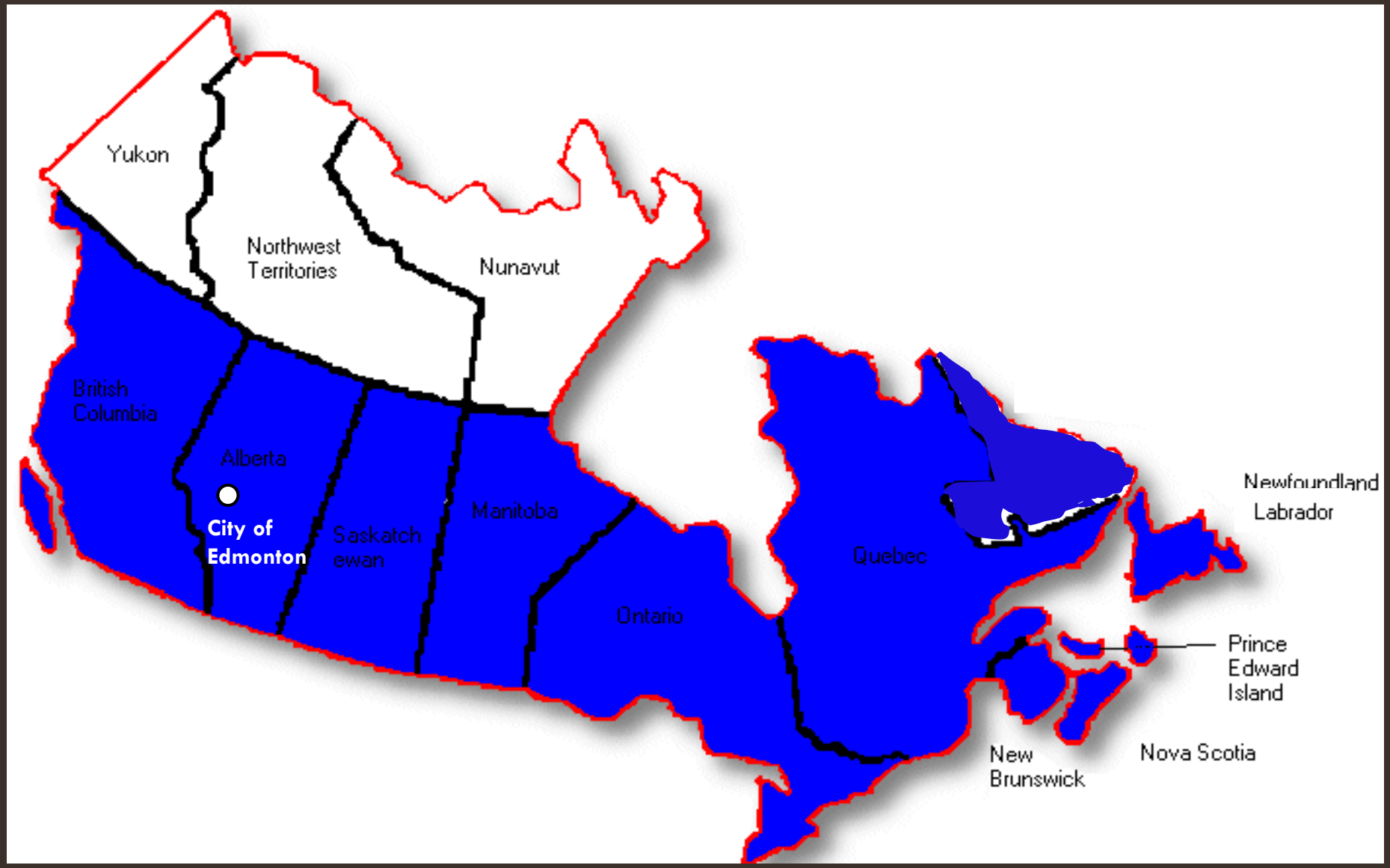


: DOT or LPA responded to survey

: DOT interviewed

: DOT interviewed and selected as case example

Canadian Survey Respondents



: MOT or LPA that responded to survey

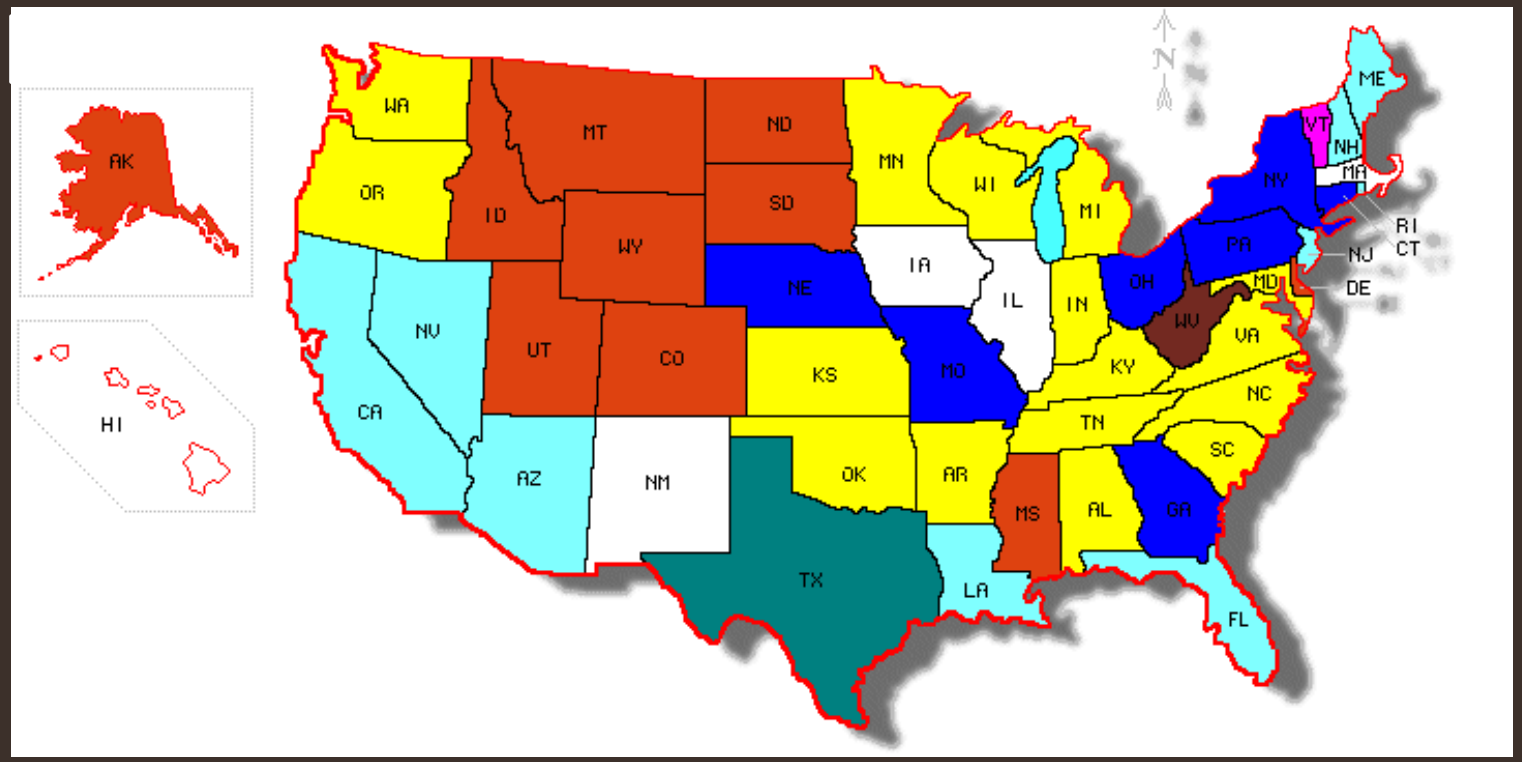
: Agency interviewed and selected as case example

Broad Findings from Survey

- Objectives of Performance Specs for Asphalt Mixes:
  - Increased pavement durability
  - Reduced maintenance
  - Better resistance to common pavement distresses

- Integration of Recycled Asphalt Materials is Common
  - DOT approaches to mix design and qualification altered
  - Performance tests integrated for <u>standard and alternative mixture designs</u> to improve pavement performance

Types of Mixtures Reported



: Use of WMA, RAP, RAS, GTR

: Use of RAP and RAS

: Use of RAP, RAS, GTR

: Use of WMA, RAP, GTR

: Use of WMA, RAP, RAS

: Use of WMA

: Use of WMA and RAP

: No response

Broad Findings from Survey (cont"d)

- Many agencies implementing PBS
  - Use of one or more performance tests
  - Researching use of PBS for improved durability through mostly cracking or rutting resistance
- Use of PBS as a standard practice only in few states
  - Large number of research projects currently underway to address performance testing for mix design and construction acceptance
  - Development of advanced mechanistic PBS system, including ME pavement design models

Challenges Reported in Survey

- Most-frequently reported challenges of moving towards PBS for design and acceptance of asphalt mixtures (out of 43 DOTs)

57%
Cost of equipment

57%
Cost of testing services (consultant labs)

42%
Lack of familiarity in paving industry

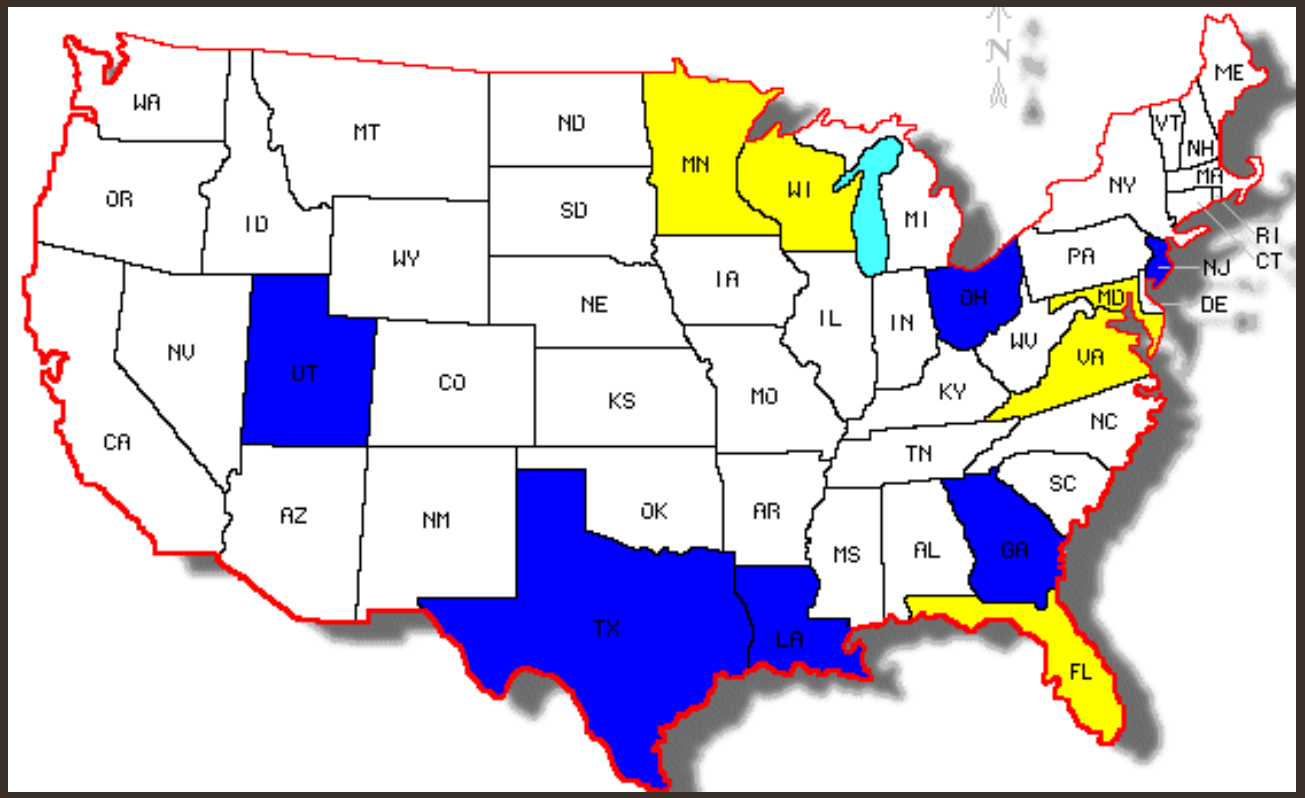
48%
Lack of training

68%
Insufficient info on how to successfully implement PBS

Agencies Interviewed & Case Examples

<u>Criteria for Case Examples included:</u>

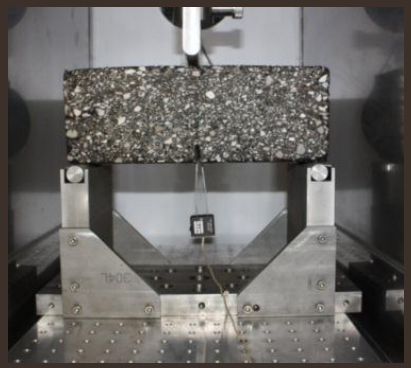
- Geographic distribution to include range of climates and paving program sizes
- Advancements in study of benefits & challenges of performance testing and performance specifications



THE CITY OF Edmonton

Consistent Themes from Case Examples

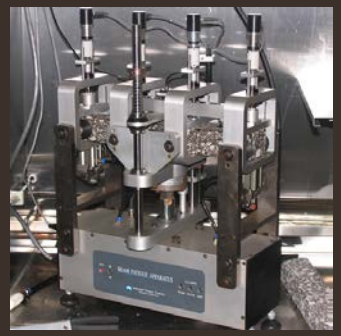
- Performance testing protocols incorporated into DOT/City standard specs
  - Primarily Hamburg, APA, and TSR tests
  - Resistance to rutting and moisture damage

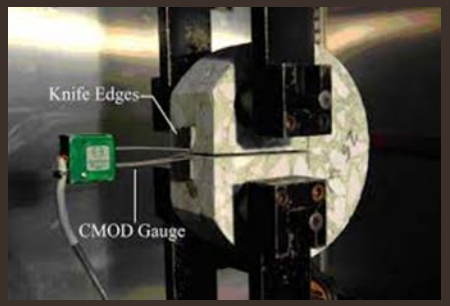


- Cracking tests are of research interest
  - Use of RAP, RAS, rubber & reduced AC content mixes… prone to premature cracking
  - Primarily BBR, SCB, and overlay test

Leading Efforts for PBS

- Case Example agencies incorporating performance testing for production acceptance
  - Primarily HWTD used for acceptance of produced mix in standard specifications
  - Pavement ME Design concepts and use of AMPT for |E*| and Flow Number - - <u>future of performance-based mix designs</u>





City of Edmonton (Alberta)

Highlights

- Use of PBS: APA run on contractor's design mixes for approval and plant mixes for acceptance
  - Also, using performance-based properties for qualification, project QC, and acceptance testing
- Field Monitoring: 70 asphalt & concrete pavement test sections in city monitored annually. All mixes tested first in lab with APA, flex beam fatigue test, and TSR
- Cost-Benefit study: Assessing relative costs-benefits of performance testing & basis of pay factors used for flexible pavements

California DOT

- Study conducted by C. Monismith et al. on I-710 Freeway Rehabilitation Pavement Performance
- Created new approach to define performance requirements for asphalt mixes, tack coat use, and compaction requirements
- Lessons learned were captured from Caltrans staff
- FWD testing and CalME analysis done to support revisions of the spec mix performance parameters incorporated in Special Provisions

Louisiana DOTD

Use of Performance Tests

- Loaded Wheel Tester (LWT) used in asphalt plant and semi-circular beam (SCB) test used for mixture design
- Plans to add SCB test of roadway samples as acceptance criteria, part of a PBS

Specification Development Underway

- Use Contractor QC tests for acceptance
- Test values related to mixture stripping and rutting for establishing PBS using LWT; SCB test for fatigue cracking potential

Overall Briefing of Findings

- 80% of DOTs require use of performance tests for moisture damage prediction prior to production
- 27% of DOTs use performance specs for mixture acceptance and pay adjustments
- APA and Hamburg WTD most common for PBS
- 30% of DOTs: Test Time and Cost are deciding factors in implementation of PBS
- Few agencies: currently assessing costs & benefits of PBS

Future Research Opportunities

Lack of…

1. Practical and cost-effective performance tests that truly reflect field performance of asphalt mixtures
2. Technology transfer for industry and agencies
3. Guidance and facilitation for implementing PBS
4. Consistency in terms related to performance specs
5. Consistency in definition of mixture types
6. Information on international efforts related to PBS

Moving Forward

- Must balance competing outcomes of time, cost, & quality.
- Industry & agencies must partner!

Data Collection
- **Appropriate and effective predictive models**
- **Optimization of pavement designs / LCCA**
- **Reduce sampling & prep time & test complexity**

Periodic review of effectiveness of performance specs

Identify Performance Metrics

Quantify costs & benefits
- **Use of PPP, warranty, & DB hybrids offer opportunity for review**

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Development & Implementation of Low Temperature Cracking Performance Specifications in Minnesota

Eshan V. Dave, Ph.D.

University of New Hampshire

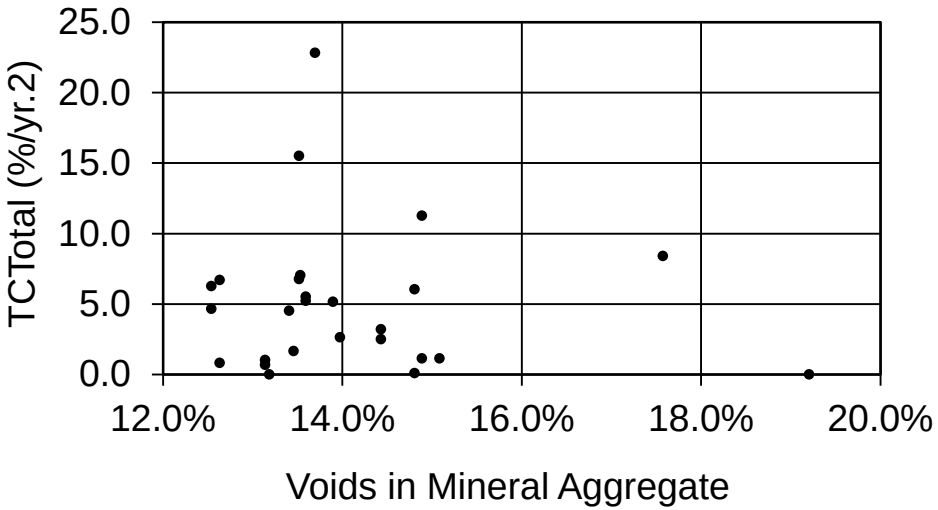
30th March 2017

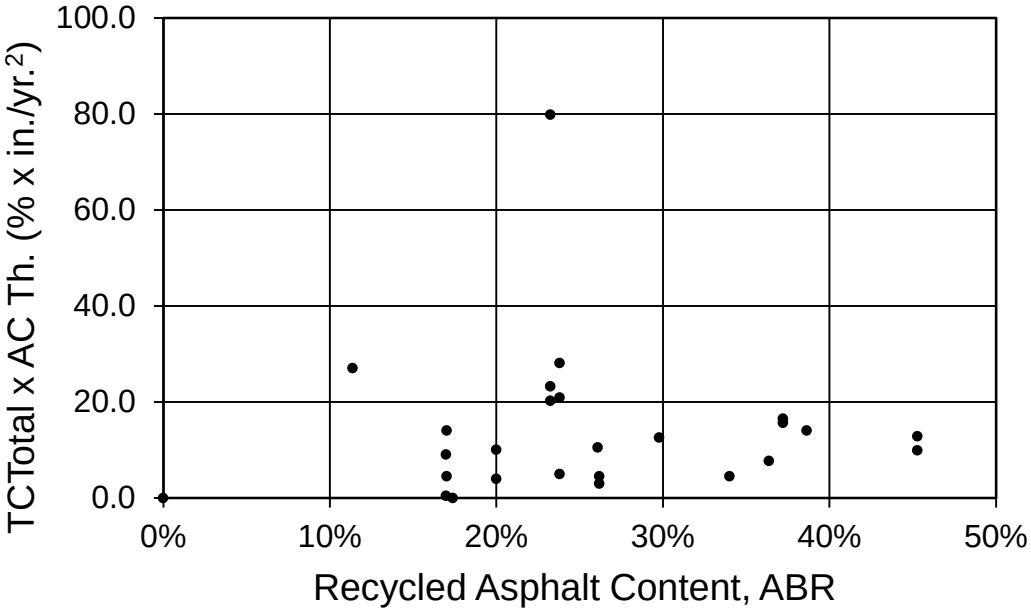
Overview

- Introduction: Performance-based Specifications
- Fracture Energy as Performance Measure
- MnDOT Performance Specifications
  - Regional Validation
  - Pilot Implementation
  - Sensitivity of Fracture Energy to Thermal Cracking Performance
  - Specification Refinement Efforts
  - Round Robin Testing
- Summary & Conclusion

Field Cracking and Volumetric Measures

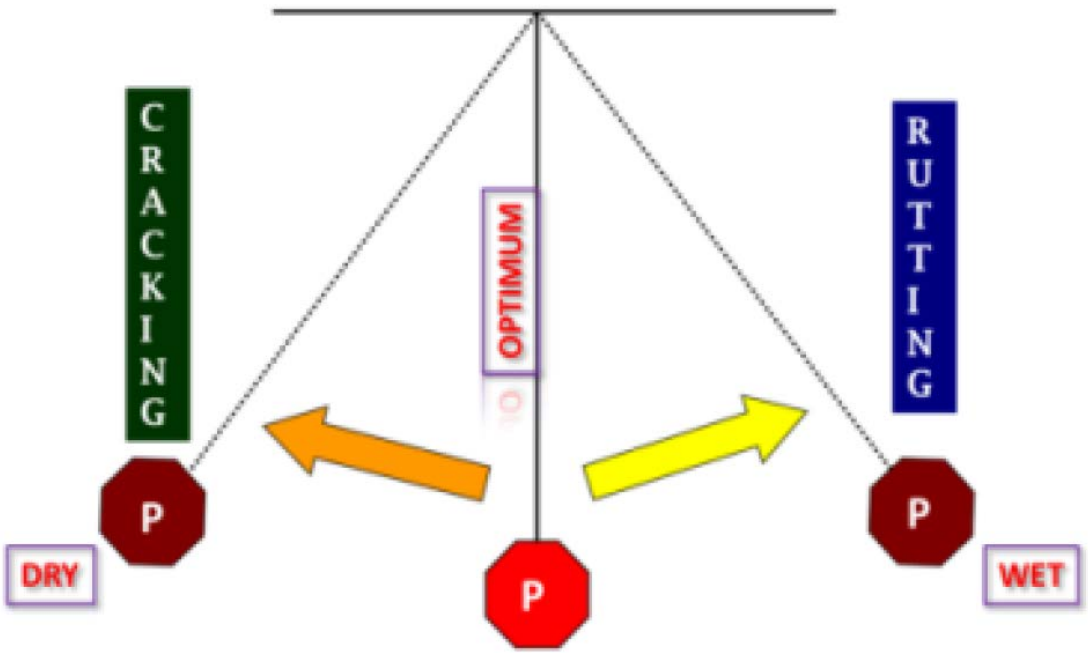
- 26 Pavement Sections
- Field Cracking Rates





Balanced Mix Design: ETG Definition

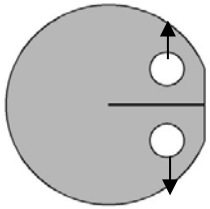
- Asphalt mix design using *performance tests* on appropriately *conditioned specimens* that address *multiple modes of distress* taking into consideration mix aging, traffic, climate and location within the pavement structure

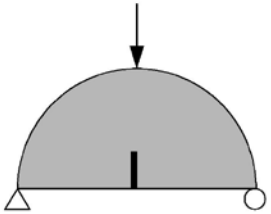


Performance Pendulum (Shane Buchanan, Oldcastle)

Overview

- Cracking performance tests are becoming mature
- Performance related/based specifications are being developed
- Fracture testing based cracking tests are starting to get adopted
  - Disk-shaped Compact Tension (DCT)
  - Semi-circular Bend (SCB)
  - Indirect Tension



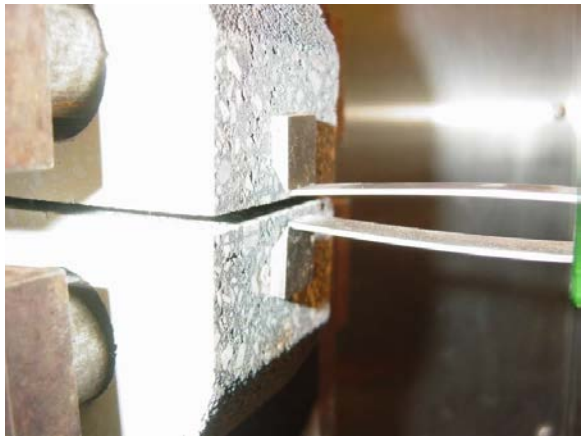


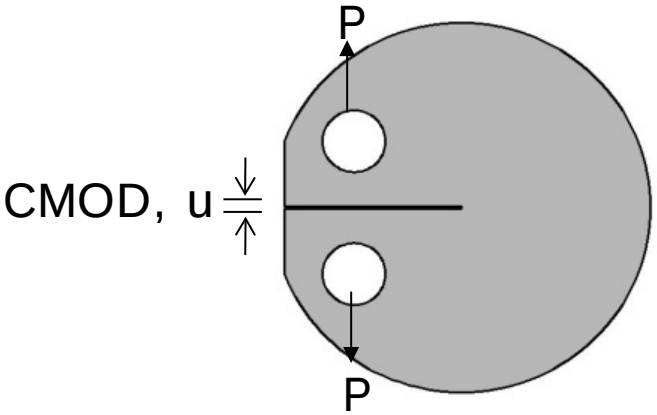
Fracture Tests in Performance Based Specifications (select examples)

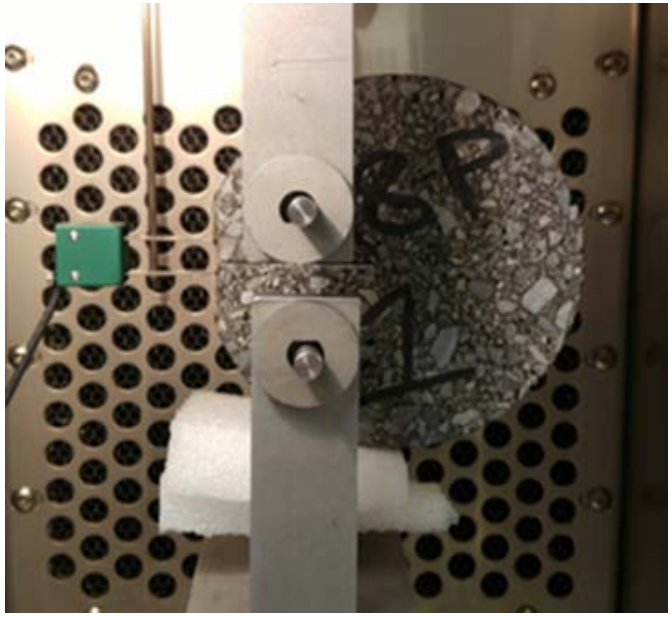
- Semi-Circular Bend (SCB)
  - LA Version Intermediate Temperature → Louisiana DOTD
    - *Wisconsin for High RAM Projects (2014 and 2015)*
  - IL and MN Version at Intermediate Temperature:
    - *Illinois in pilot implementation stages: Combination of Hamburg Wheel Tracking Test and SCB Flexibility Index (I-FIT)*
- Disk-shaped Compact Tension (DCT)
  - City of Chicago
  - Illinois Tollways
  - Wisconsin for High RAM Projects (2014 and 2015)
  - Minnesota Department of Transportation → **Discussed here**

Disk-Shaped Compact Tension (DCT) Test

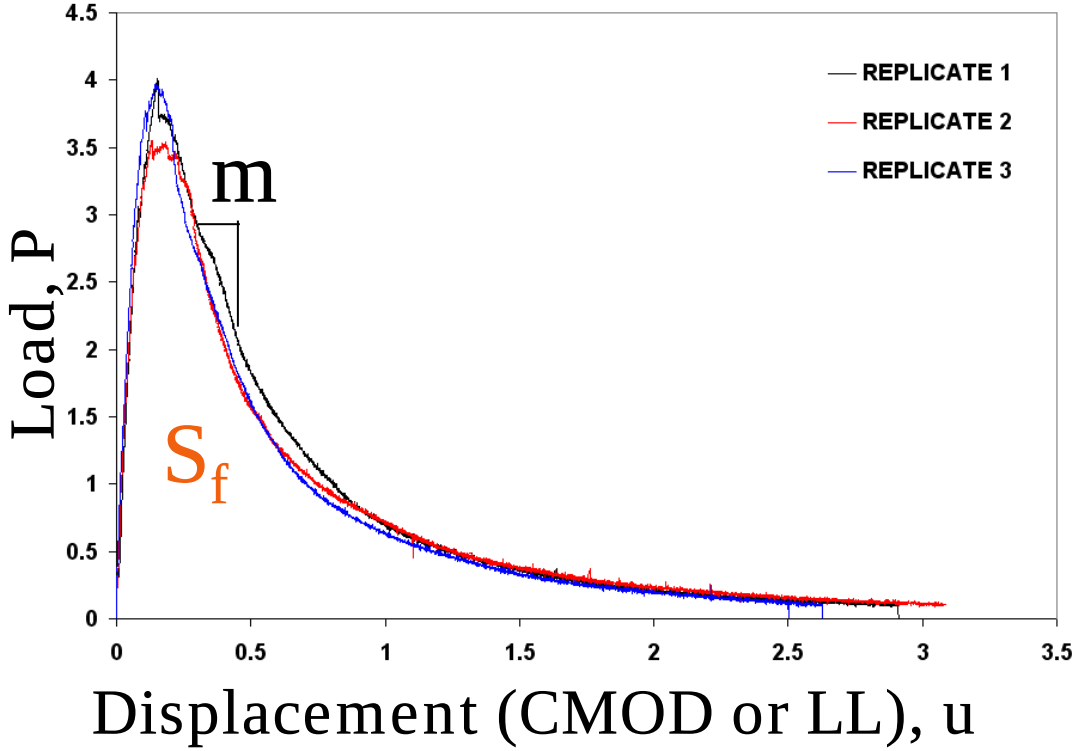
- ASTM D7313-13
- Loading Rate:
  - Crack Mouth Opening Displacement
  - CMOD Rate = 1.0 mm/min
- Measurements:
  - CMOD
  - Load

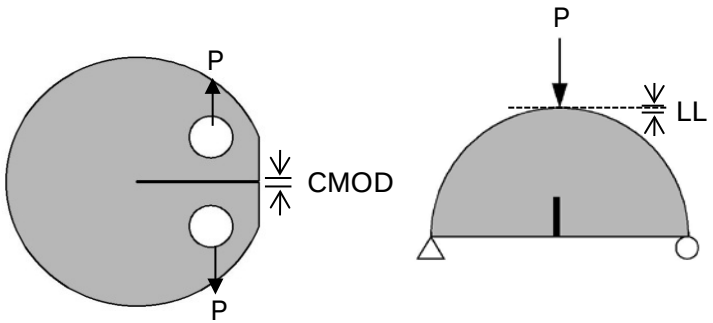






Fracture Parameters





Fracture work: Area under Load-Displacement curve

Fracture Energy, G_f: Energy required to create unit fracture surface

$$G_f = \frac{\text{Fracture Work, } S_f}{\text{Fracture Area}}$$

Flexibility Index, FI:

$$FI = G_f / m$$

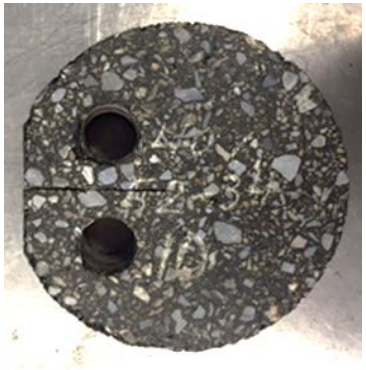
Specimen Preparations

Gyratory Specimen

50 mm (2 inch) Disk

Core loading holes

Notched

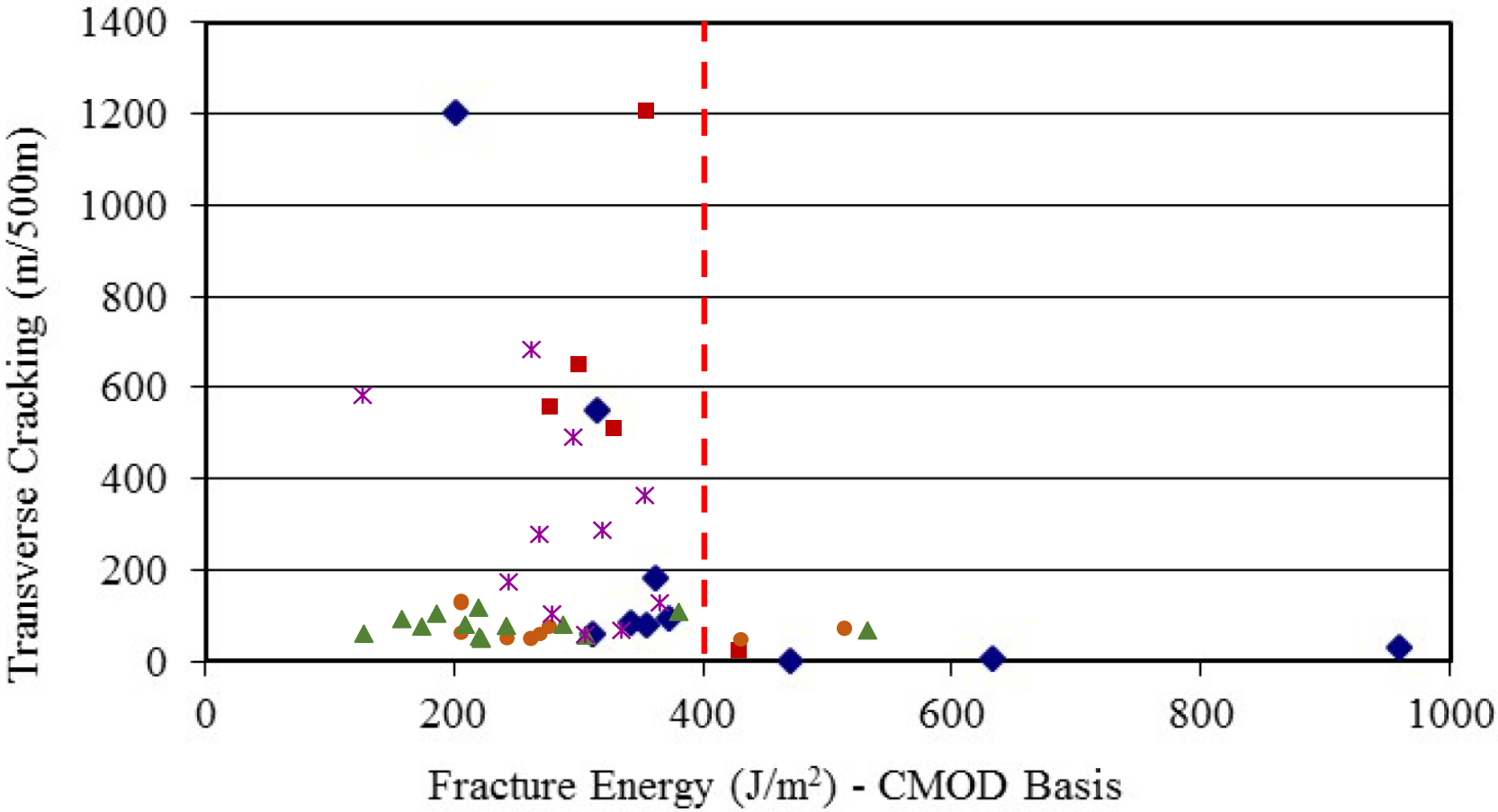


DCT

Low Temperature Cracking Pooled Fund Study

- Primary Distress: Thermal cracking
- Minnesota (Lead State), Connecticut, Iowa, Illinois, New York, North Dakota, Wisconsin
- PI: Prof. Mihai Marasteanu
- TPF-5(080): 2004 – 2006 (Phase-I)
  - Extensive evaluation of performance tests (binder and mixtures)
- TPF-5(132): 2008 – 2012 (Phase-II)
  - SCB and DCT fracture energy tests evaluated for nine pavement sections
  - 4 and 7% air void level, short term and long term aging conditions
  - Outcome: Performance specifications with limited validation through five field sections

Fracture Energy as Performance Measure: Results from Various Studies (~ 50 sections)

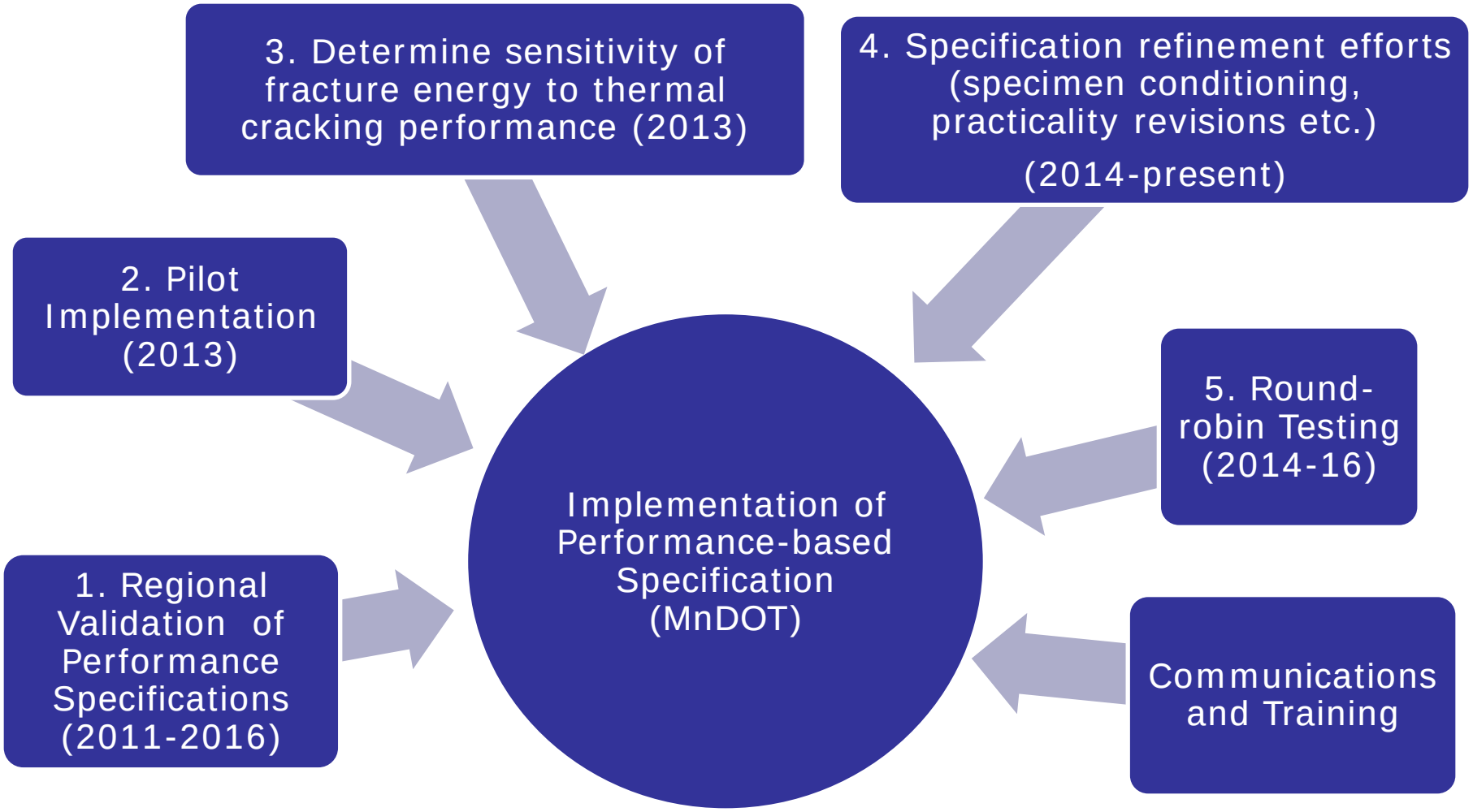


Pooled Fund Study LTC Performance Specifications

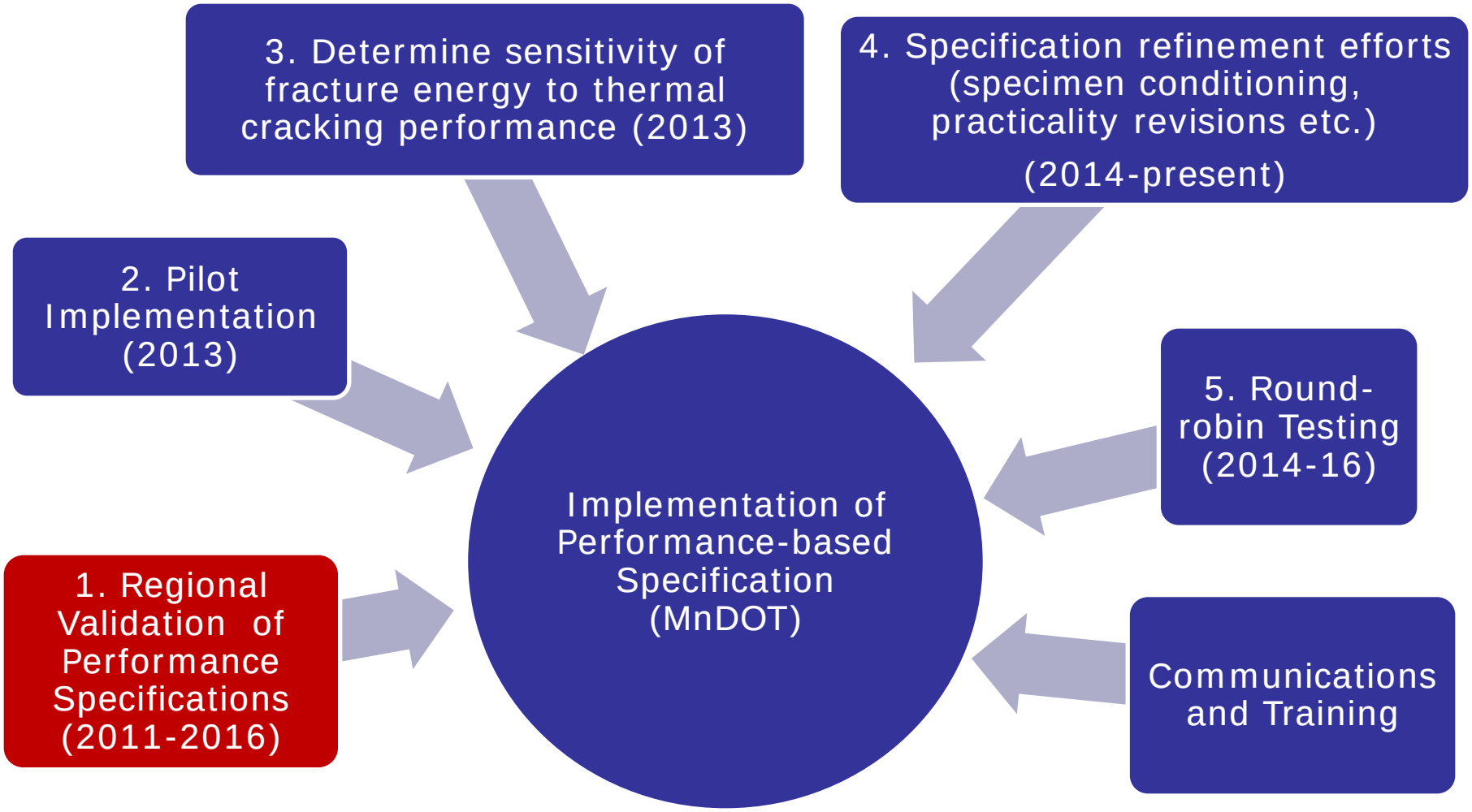
- Based on traffic levels
- Limits based on:
  - Fracture energy test @ 10°C above 98% reliability Superpave Low Temperature PG (PGLT)
  - Low temperature cracking performance model (*IlliTC*)

Limits	**Project Criticality / Traffic Level**		
	High (> 30M ESALs)	Medium (10 – 30M ESALs)	Low (< 10M ESALs)
DCT Fracture Energy (J/m^2)	690	460	400
IlliTC Cracking Prediction (m/km)	< 4	< 64	Not required

MnDOT Implementation of Performance Specification

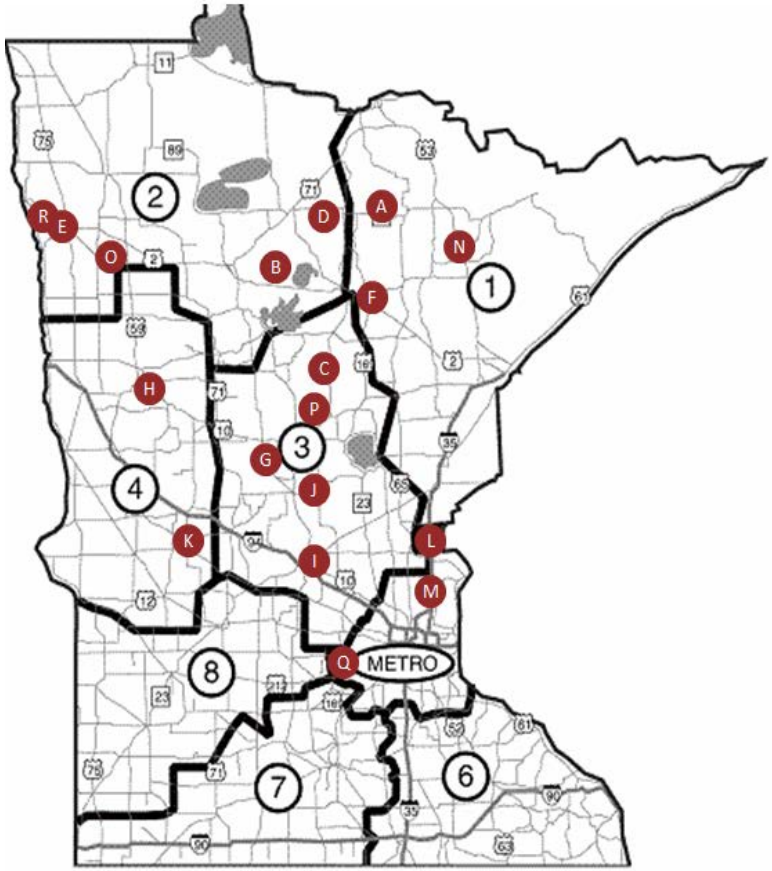


MnDOT Implementation of Performance Specification

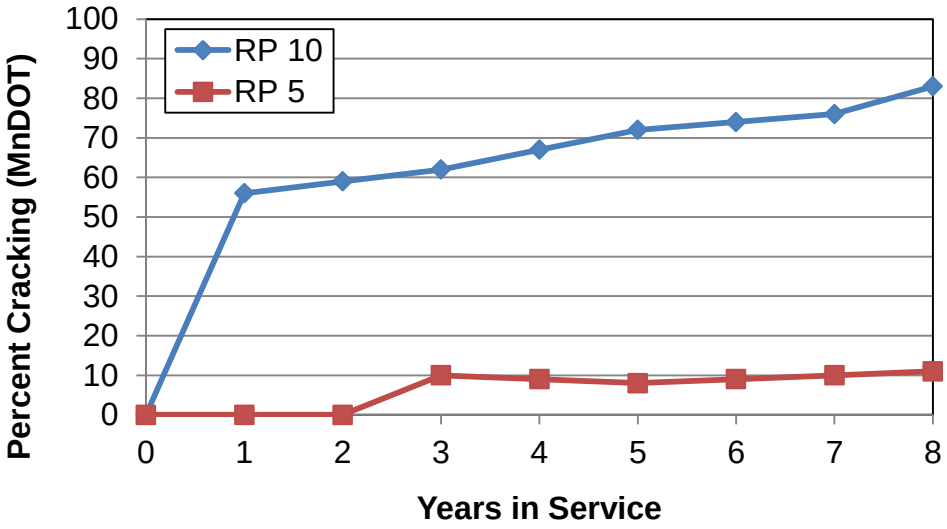


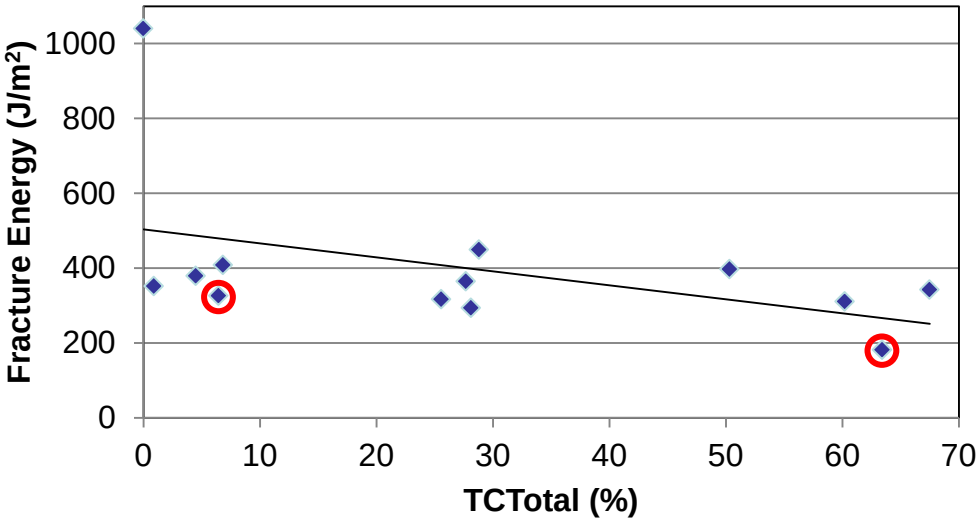
Minnesota Regional Validation Studies (2011 – 2015)

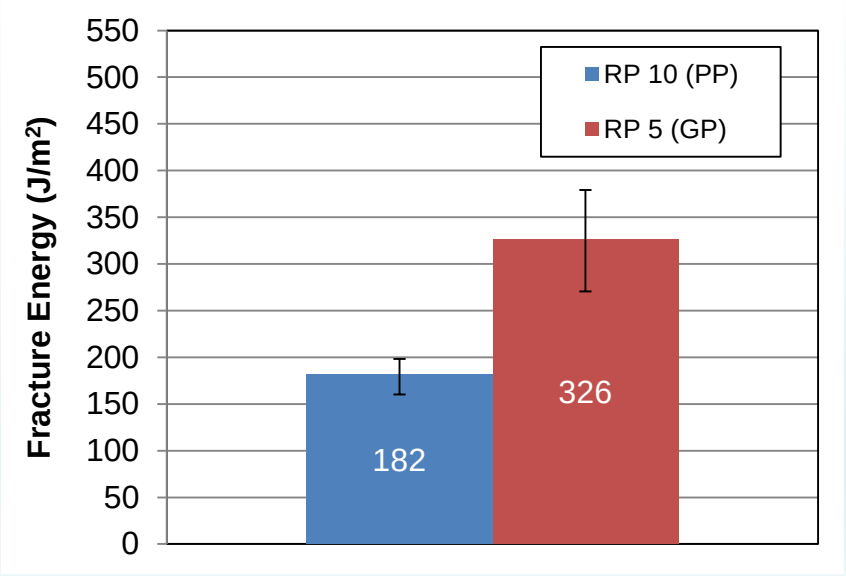
- 18 sites and 26 sections
  - *Companion sections*
- 2004 – 2013 construction years
- Captures different binder grades and aggregates in Minnesota
- Different construction types: New construction, overlay, and full-depth reclamation
- Different design traffic levels



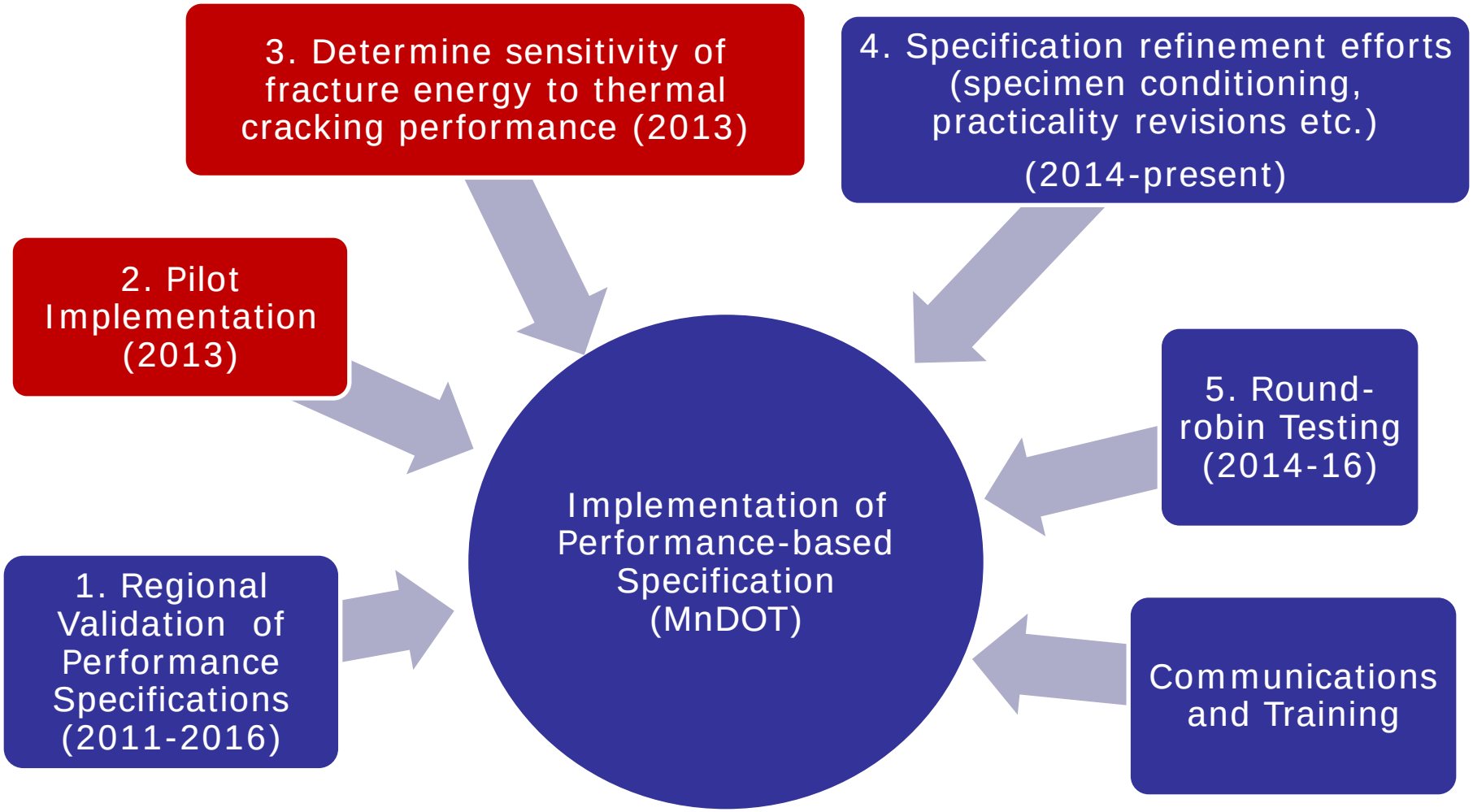
Local Validation Example: Field Cracking Performance vs. Fracture Energy





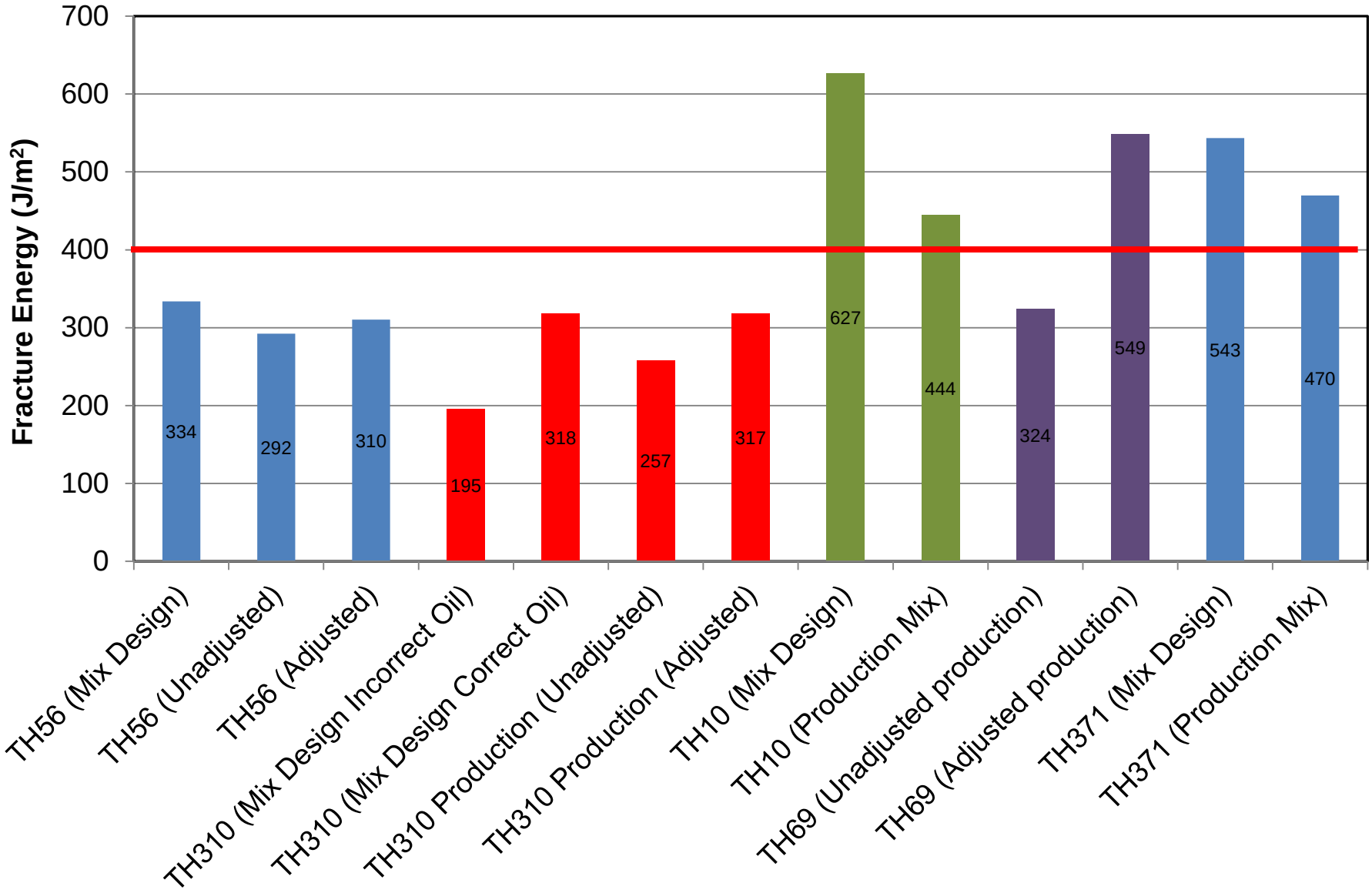


Implementation of Performance Specification



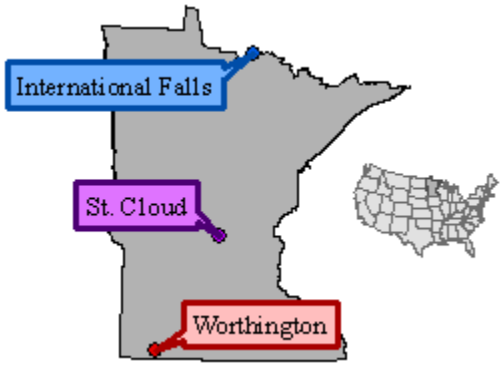
Pilot Implementation (2013)

- Pilot Implementation on 5 projects
  - Contractor provide samples at mix design
    - *TSR pucks, 7% AV, +/- 0.5%*
  - DCT tests are conducted
    - *If mix passes, approve for paving*
    - *Passing value of G_f > 400 J/m^2*
  - If mix fails, adjust mix & try again
    - *MnDOT paid for difference in cost (D-I funds)*
    - *Adjusted mix was used for paving a section of project*
  - Testing is also conducted on production mixes


Fracture Energy (J/m²)
700
600
500
400
300
200
100
0
334
292
310
195
318
257
317
627
444
324
549
543
470
TH56 (Mix Design)
TH56 (Unadjusted)
TH56 (Adjusted)
TH310 (Mix Design Incorrect Oil)
TH310 (Mix Design Correct Oil)
TH310 Production (Unadjusted)
TH310 Production (Adjusted)
TH10 (Mix Design)
TH10 (Production Mix)
TH69 (Unadjusted production)
TH69 (Adjusted production)
TH371 (Mix Design)
TH371 (Production Mix)

Determine Sensitivity of Thermal Cracking to Fracture Energy

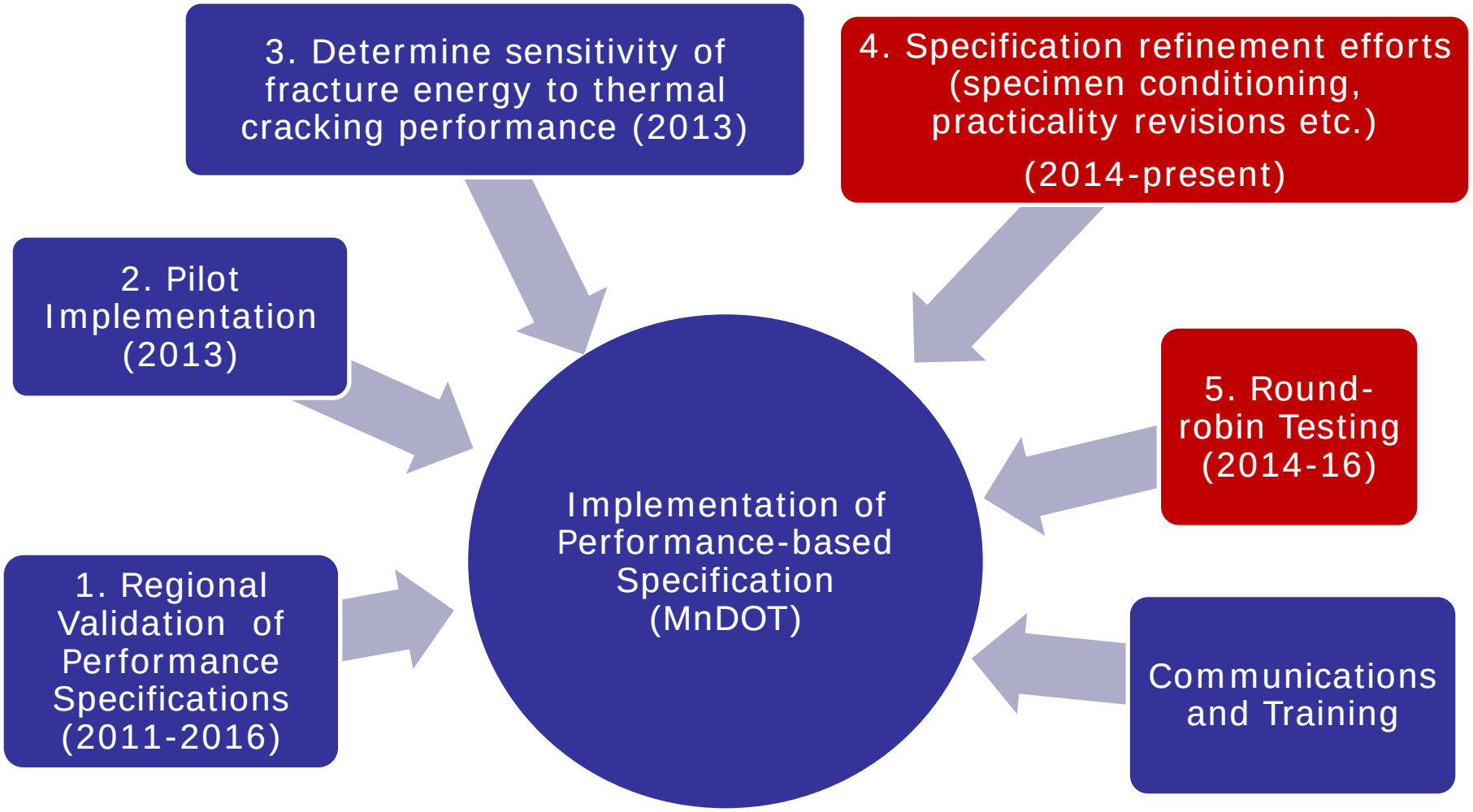
- Objective: Determine the allowable variability in fracture energy for purposes of job specification
  - Req. fracture energy = 400 J/m^2 (if actual is 375 J/m^2 is it too low?)
- Approach:
  - Simulate different combinations of climates, mixes, pavement structures with different fracture energies using *IlliTC*



Asphalt Mix	PG28R	PG28R	PG34R	PG34
Clima				ld
Paver				5
Fra				els
No Damage (ND)	No data	No data	No data	≥425
Damaged (D)	450	425-450	375-450	300-375
Cracked (C)	≤425	≤400	≤350	No data

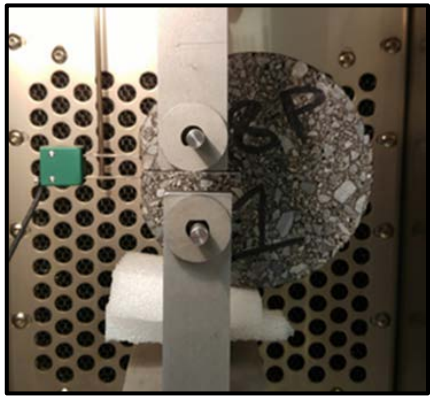
Variation of fracture energy by 25 J/m^2 might be sufficient in changing the thermal cracking performance of the pavement

Implementation of Performance Specification

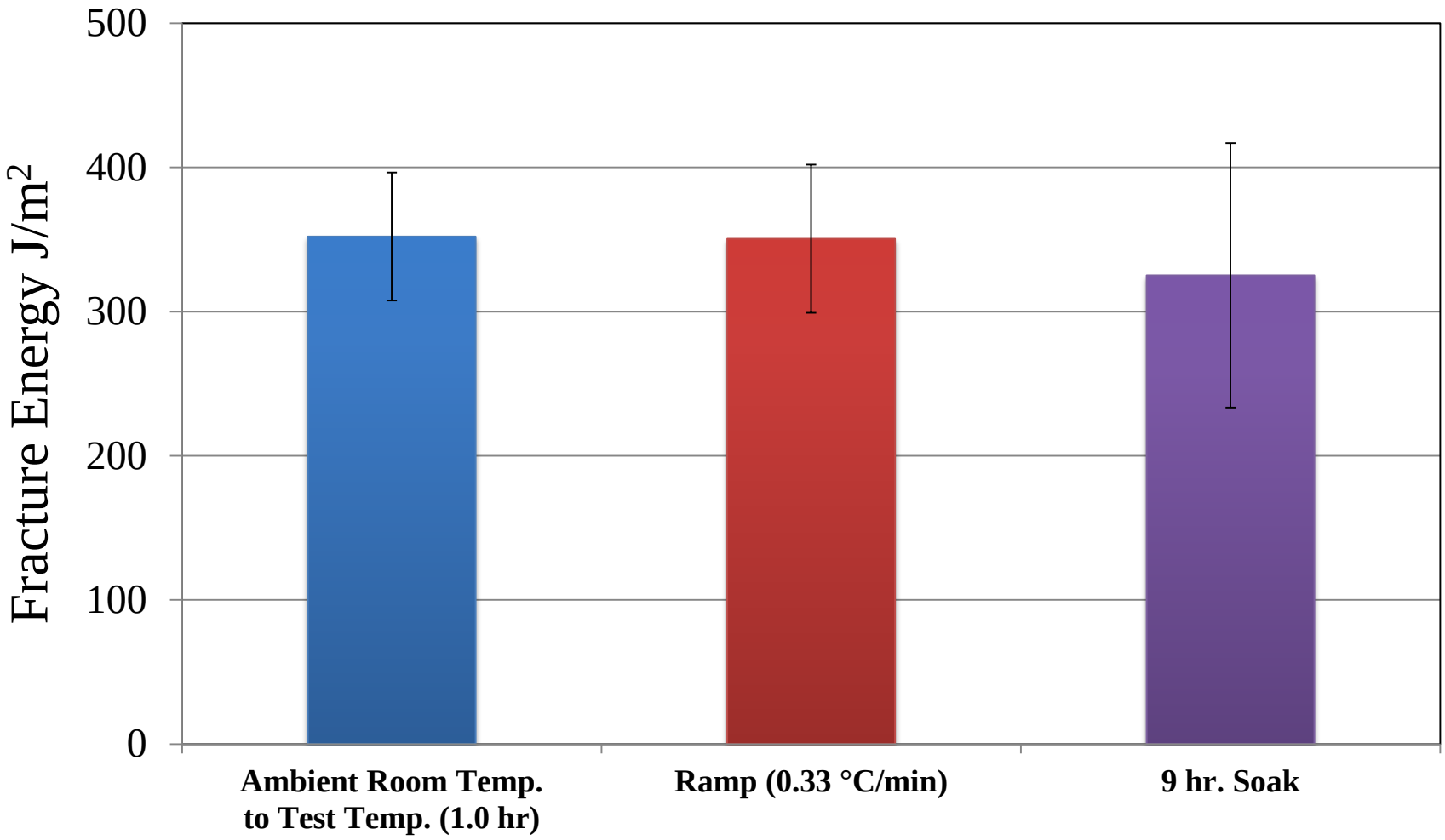


Specification Refinement

- GOAL: Improve ease, practicality and repeatability of test procedure
- Research was needed to increase ease and practicality of DCT testing
  - *ASTM D7313-13 requires DCT specimens to be conditioned between 8-16 hours at test temperature before testing begins.*
- Extensive evaluation of temperature conditioning procedures was conducted to investigate different temperature conditioning scenarios



Temperature Conditioning Study: Sample Results



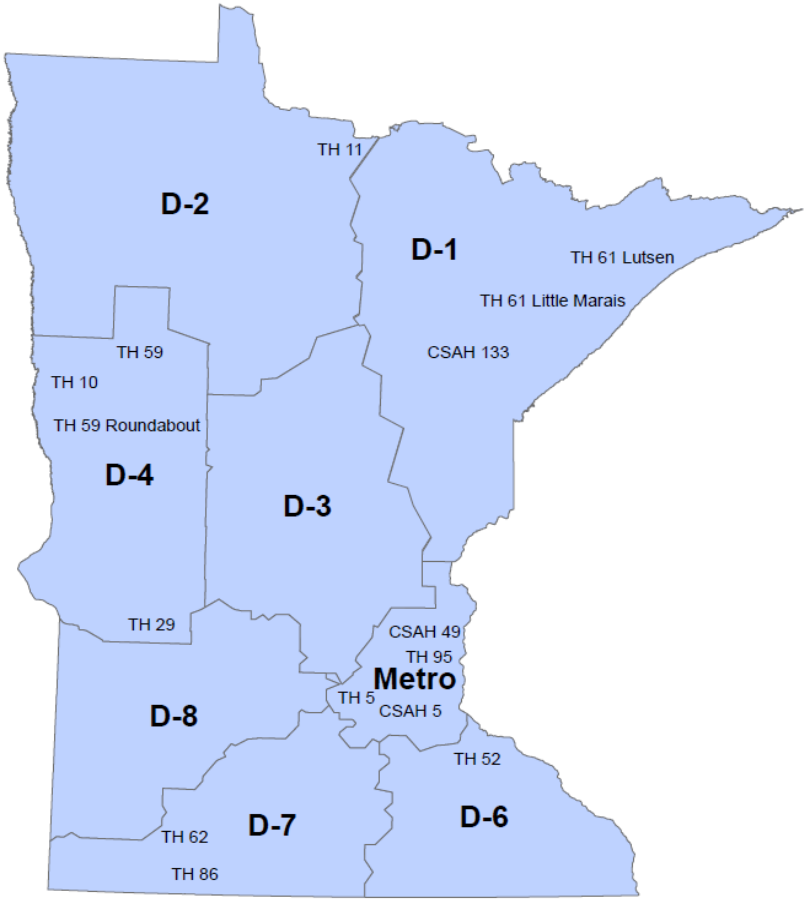
Specification Refinement

- Several changes/additions to ASTM specification
  - "MnDOT Modified" version

- Temperature Conditioning Study Final Results
  - Specimens must reach test temperature in no faster than 0.75 hours, but within 1.5 hours.
  - Specimens must stay in conditioning chamber for a minimum of 2 hours before testing.
  - All testing must be finished within 6 hours of initial placement into conditioning chamber

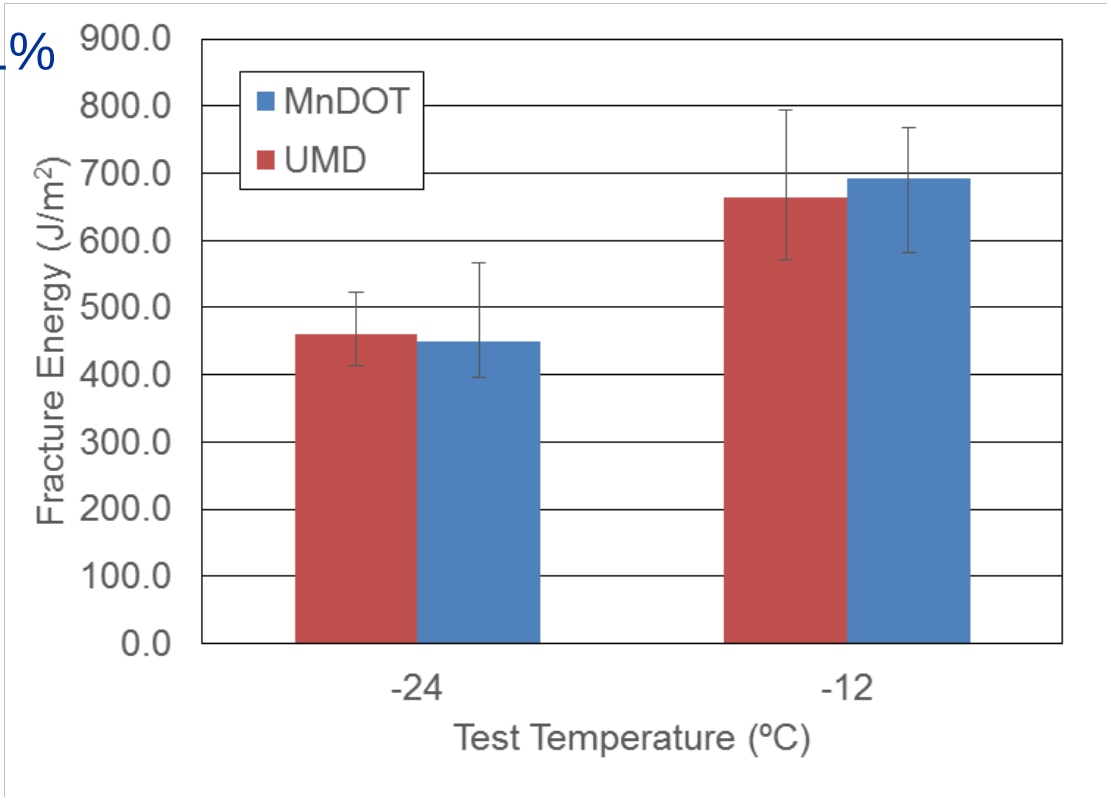
DCT Specifications: Inter-laboratory "Round Robin" Comparison Study

- *Loose mix sampled from 16 projects*
- *Participating labs include:*
  - *American Engineering Testing*
  - *Braun Intertec*
  - *MnDOT OMRR*
  - *UMD/UNH*
  - 4 specimens/project tested by each lab
- *Gyratory specimens compacted by MnDOT*

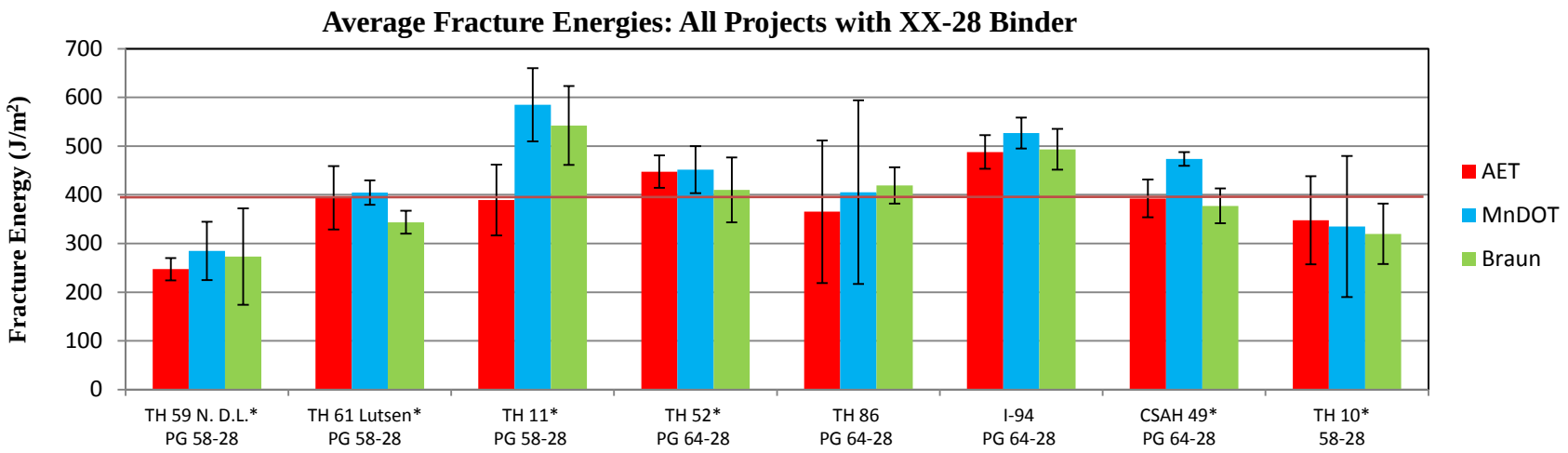


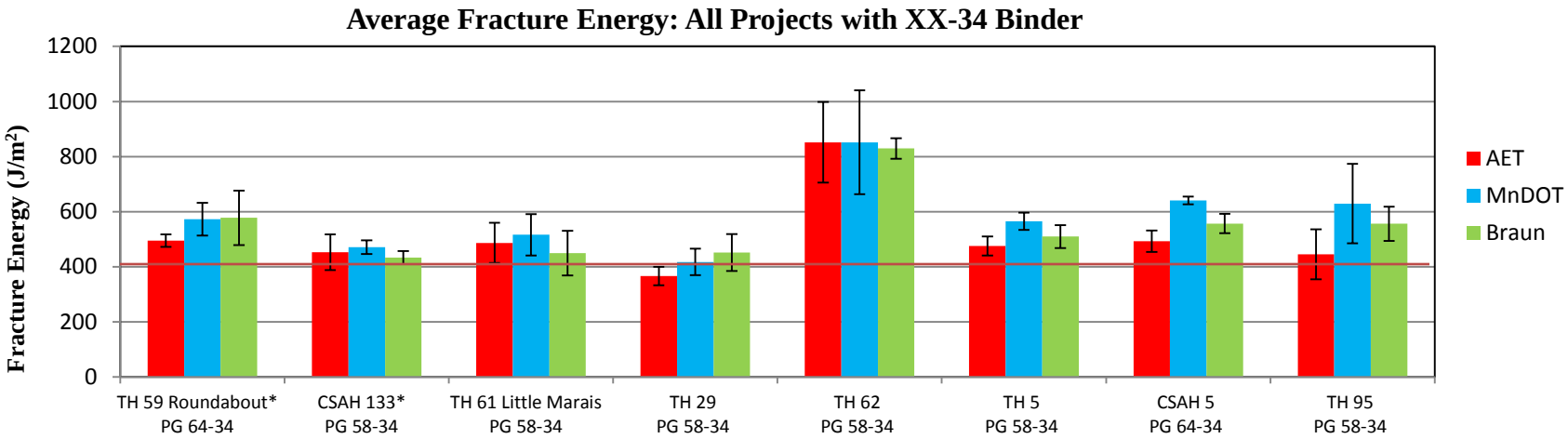
Preliminary Interlab Comparison Study

- Field sampled material (I-94)
  - SPWEA540E, PG 64-28
- Samples tested at MnDOT and UMD
- Interlab differences:
  - Fracture Energy: 2.4–8.1%
  - Peak Load: 0.7–4.6%



Round Robin Testing: 8 Projects, 4 Labs

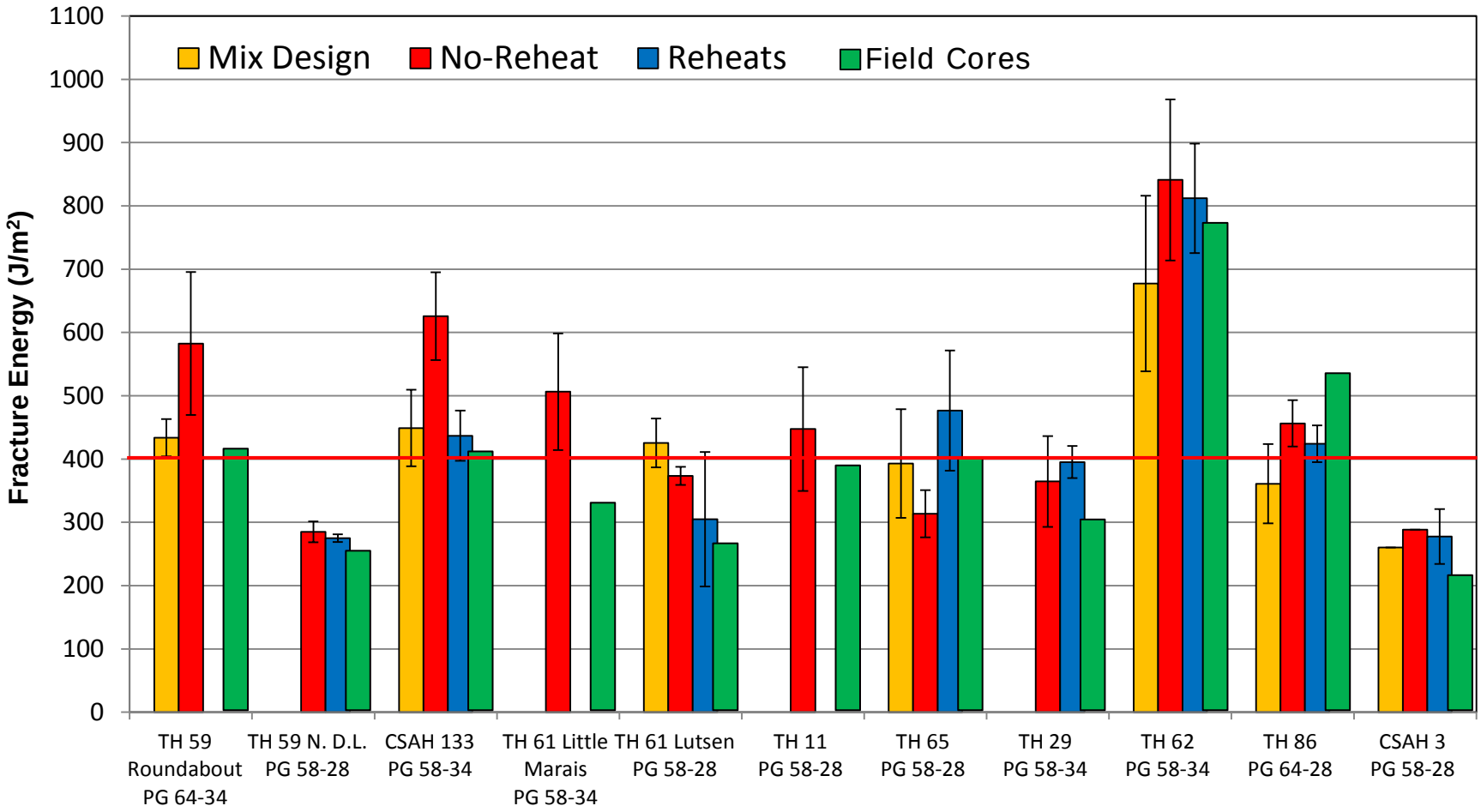




Effects of Specimen Preparation and Sampling on Fracture Energy

- *Issue: Change in fracture energy between mix design samples and production samples*
- *Samples collected from 11 locations across MN*
- *Sample Types:*
  - *At mix design (provided by contractor)*
  - Loose mix collected during production
    - *4 cylinders re-heated and compacted by MnDOT*
    - *4 specimens compacted on site by contractor*
  - *Loose mix collection site marked. Field cores taken 1-2 days after initial collection.*

Aging Evaluation Study



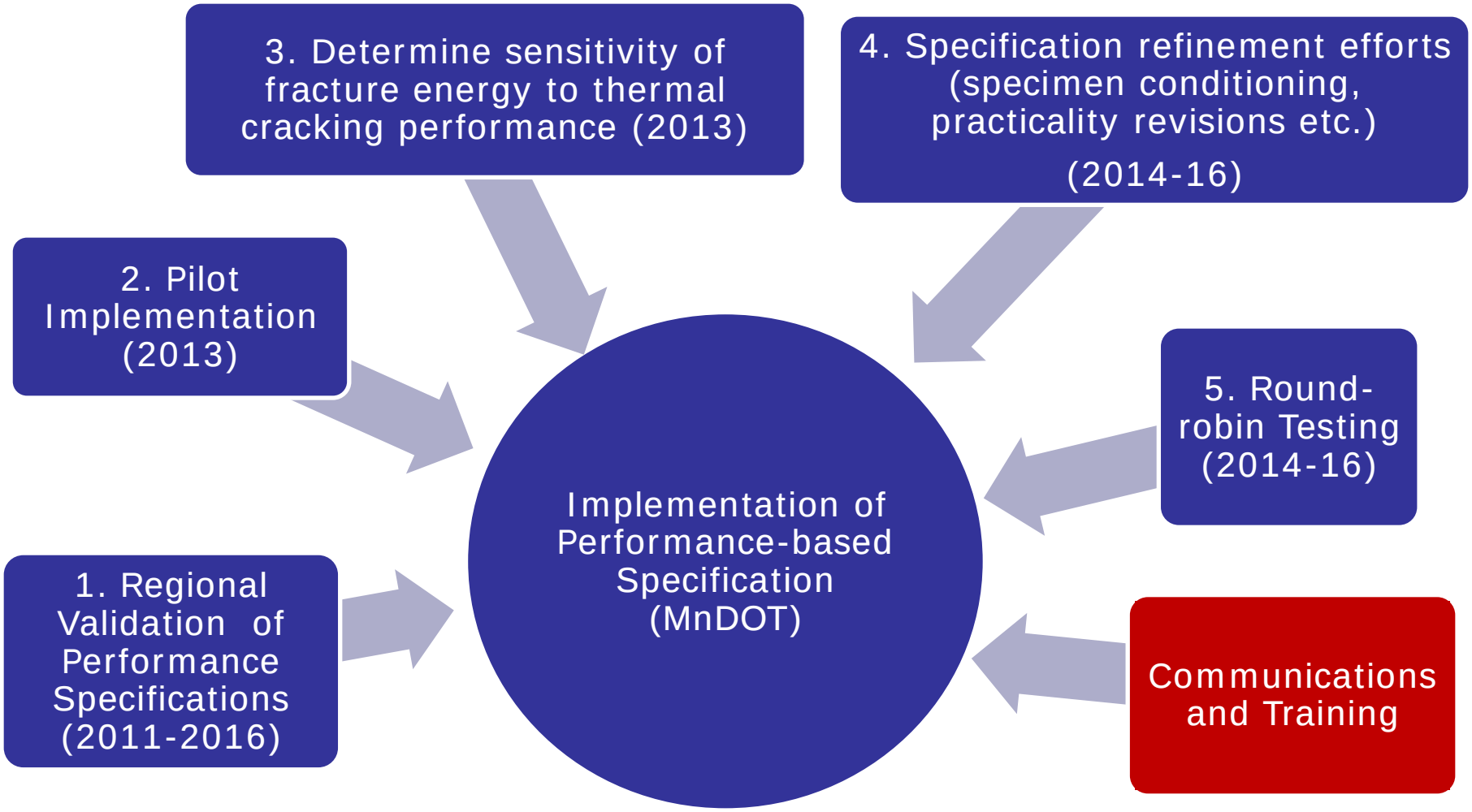
MnDOT DCT Fracture Energy Provisional Performance Specifications

Table DCT-1 Minimum Average Fracture Energy Mixture Design Requirements for Wearing Course*	
Traffic Level	Fracture Energy
Traffic Level 2-3 / PG XX-34	450 J/m^2
Traffic Level 4-5 / PGXX-34	500 J/m^2

Table 2360-9 Allowable Differences between Contractor and Department Test Results*	
Item	Allowable Difference
DCT - Fracture Energy (J/m^2)	90
*Test a minimum of six (6) DCT test specimens according to ASTM D7313-13 MnDOT Modified revision dated September 1, 2015 to determine the average fracture energy of the submitted mix design (see MnDOT Modified for requirements of when greater than 6 specimens are to be tested).	

Table DCT-2 Minimum Average Fracture Energy Mixture Production Requirements for Wearing Course*	
Traffic Level / PG Grade	Fracture Energy (J/m^2)
Traffic Level 2-3 / PG XX-34	400
Traffic Level 4-5 / PGXX-34	450

Implementation of Performance Specification



Summary

- With current evolution of asphalt mixtures (additives, recycling, production technologies) volumetric measures are no longer sufficient for controlling performance
- Fracture energy based performance tests (DCT, SCB) have shown very promising results
- Use of these tests in performance based specifications (as well as or balanced mix designs) are starting to become popular
- Implementation of performance test requires strong partnerships (agency, industry and researchers)
- MnDOT specification development: local validation, specification refinement, round-robin testing, training and communications

Currently Ongoing Efforts

- Minnesota DOT:
  - Continued training and adoption
  - Extending DCT specifications to address reflective cracking in asphalt overlays
- National Level:
  - Pooled Fund Study (NCAT, MnROAD partnership)
  - Several agencies are working on adoption efforts (Illinois, Missouri, Washington, Wisconsin etc.)
  - NCHRP 09-57 succession study
- Lot of work is going on, stay tuned!

Thank you for your attention!

Acknowledgement: Shongtao Dai, John Garrity, Chelsea Hanson, Luke Johanneck, Dave Van Deusen, Joe Voels

Questions / Comments?

Contact: eshan.dave@unh.edu

NJDOT EXPERIENCE WITH ASPHALT MIXTURE PERFORMANCE

Robert Blight
Supervising Engineer, NJDOT Pavement Design & Technology Section

ACKNOWLEDGEMENTS

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- Frank Fee, NuStar retired
- Susan Gresavage, NJDOT
- Phil Bertucci, NJDOT
- Narinder Kohli, NJDOT
- Vasudevan Ganarajan, NJDOT

OUTLINE

- Performance tests NJDOT is using for asphalt mixture testing
- NJDOT asphalt mixtures with performance test requirements, limits
- Relative comparison of NJDOT asphalt mixtures using lab performance test data
- Field performance of NJDOT asphalt mixtures
- NJDOT future with asphalt mixture performance specifications

HOW DO WE DEFINE PERFORMANCE?

The manner in which or the efficiency with which something reacts or fulfills its intended purpose.

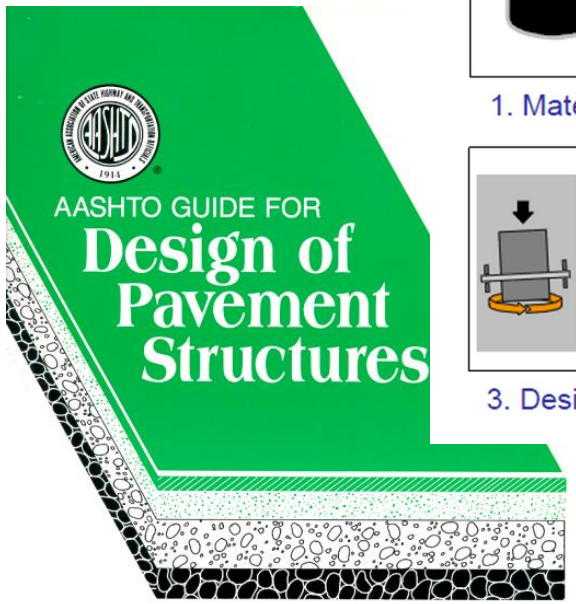
- Webster College Dictionary

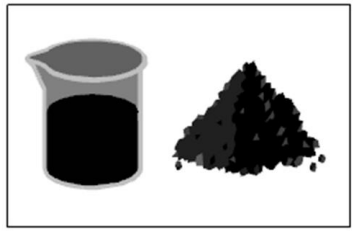
WHY ADD ASPHALT MIXTURE PERFORMANCE TESTING?

- Heavy traffic
  - Increase in truck freight with upgrade of Port Terminals and Panama Canal upgrades
- Severe Weather
  - High frequency of freeze/thaw
- Diverse Geology
- 50-60% of NJDOT roadways poorly performing composite
- Durability, cracking, longitudinal joint, and raveling issues

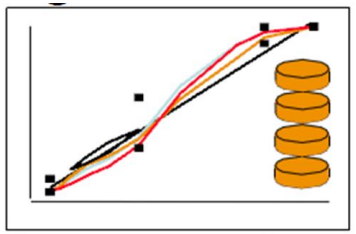
WHY ADD ASPHALT MIXTURE PERFORMANCE TESTING?

- "SuperPave" mix design methodology resulted in dry mixtures lacking in adequate asphalt liquid binder
- AASHTO 1993 Pavement Designs for overlays not feasible
  - Excessive increase in profile
  - Many geometric/environmental constraints
  - Design life not being met
- Continually changing waste products in asphalt mixes
  - Base asphalt, RAP/RAS, REOB, additives

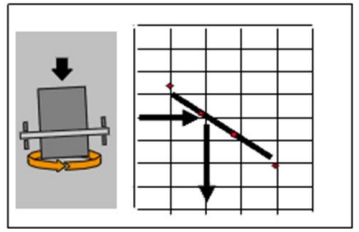




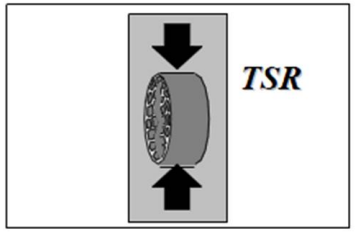
1. Materials Selection



2. Design Aggregate Structure



3. Design Binder Content



4. Moisture Sensitivity

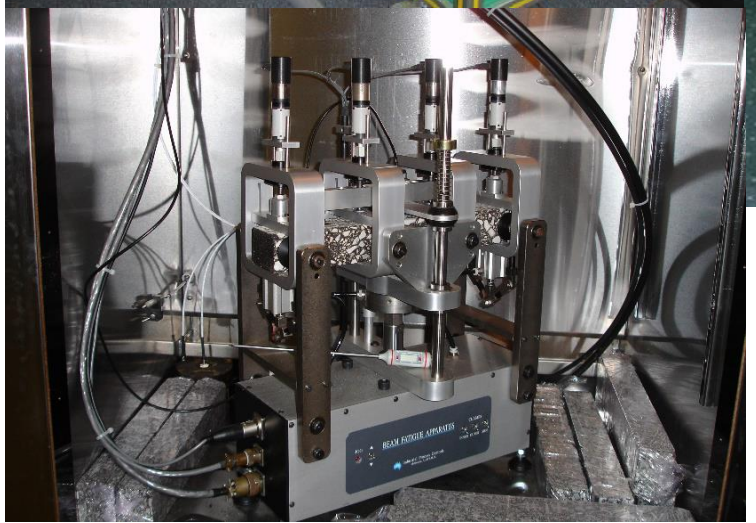
WHY ADD ASPHALT MIXTURE PERFORMANCE TESTING?

- Volumetric mixture design ≠ good performance
- Need End Result Performance Related Specifications
- **NEED "BALANCED" ASPHALT MIXTURES**
  - **RUT RESISTANCE, FATIGUE RESISTANCE, REFLECTIVE CRACK REISTANCE**
  - **PERFORMANCE CRITERIA SPECIFIED FOR MIX TYPE, LOCATION IN PAVEMENT, & PAVEMENT TYPE**

NJDOT PERFORMANCE TESTS

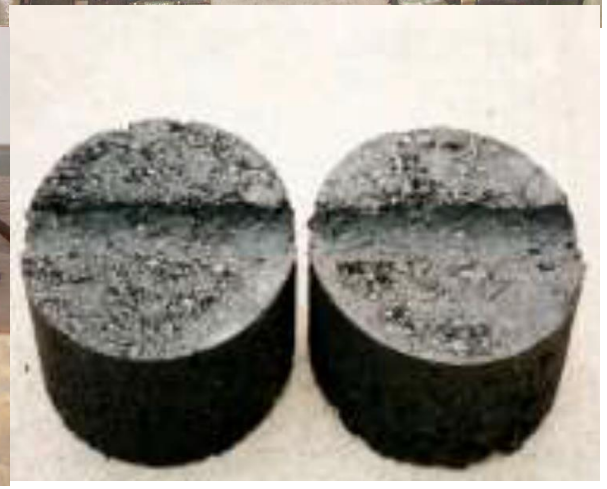
NJDOT PERFORMANCE TESTS

- Asphalt Pavement Analyzer (AASHTO T 340)
- Overlay Test or Texas Overlay Tester (NJDOT Test Method B-10)
- Flexural Beam Fatigue (AASHTO T 321)



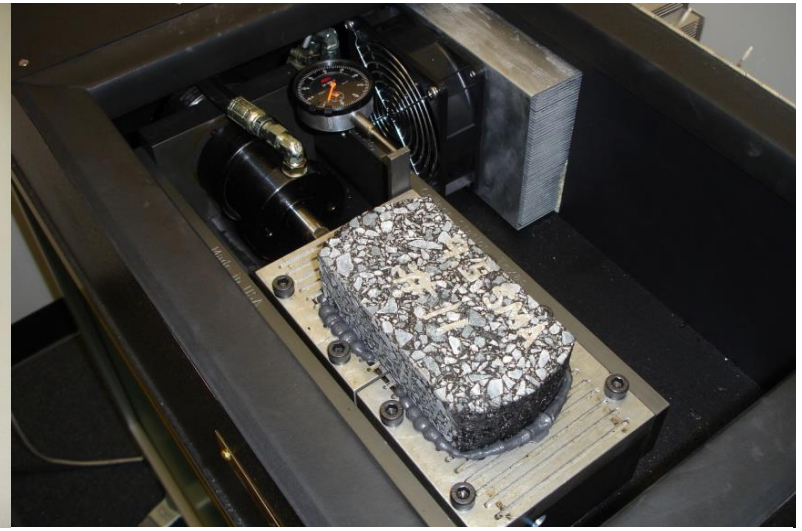
ASPHALT PAVEMENT ANALYZER

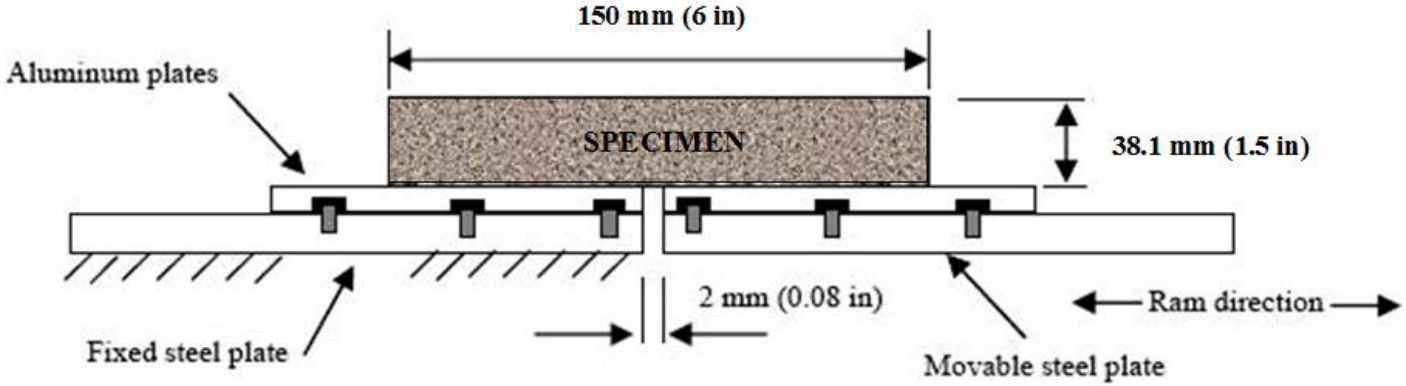
- Check Permanent Deformation via APA Rutting Test (AASHTO T 340)
- Samples compacted in gyratory (AASHTO T 312) to 77 mm height and specified air voids
- 100 lbs. wheel load, 100 PSI hose pressure
- Test @ 64°C (148°F) for 8,000 cycles, 60 cycles per minute
- APA Rutting must be **<u>less</u>** than _X_ mm to pass



OVERLAY TESTER

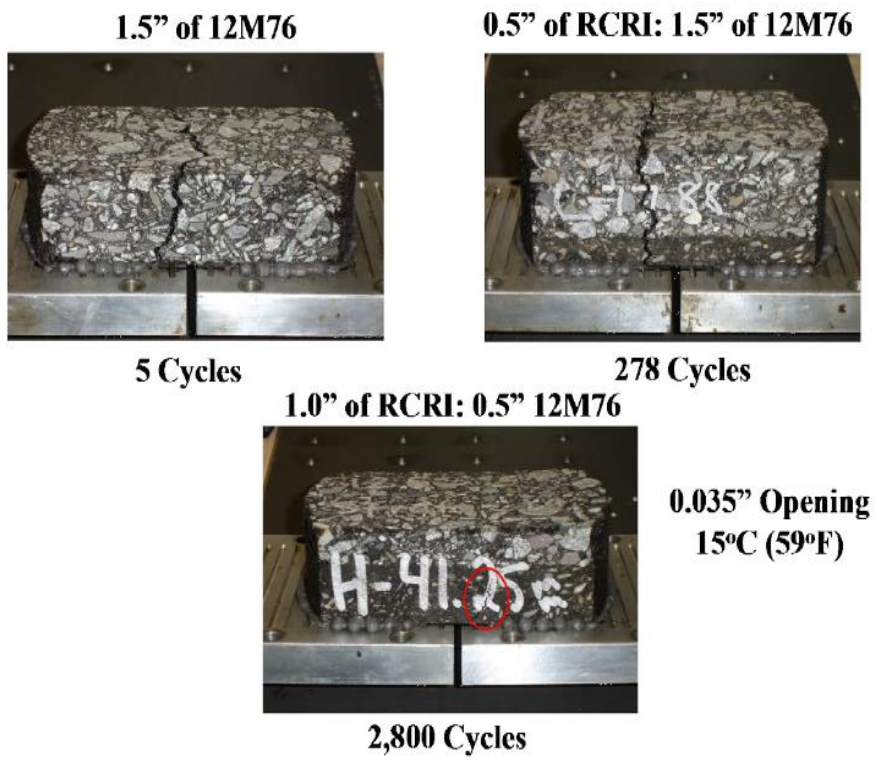
- Check Crack Resistance via Overlay Tester (NJDOT B-10)
- Samples compacted in gyratory (AASHTO T 312) to 115 mm height and specified air voids
- 6" diameter sample is trimmed to 6" length by 3" wide by 1.5" thick





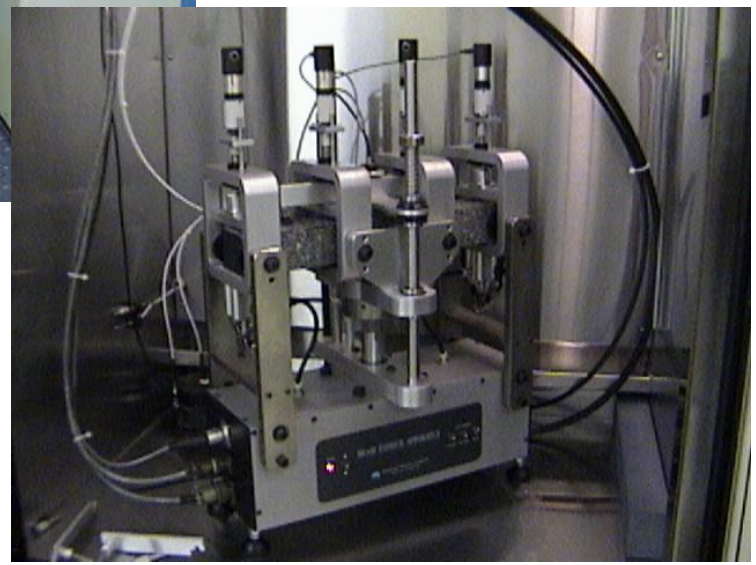
OVERLAY TESTER

- Loading: Continuously triangular displacement 5 sec loading and 5 sec unloading
- Test at 25°C (77°F) and a joint opening of 0.025 inch until failure
  - Failure is defined as discontinuity in load vs. displacement curve
- OT cycles to failure must be **<u>greater</u>** than _Y_ cycles to pass



FLEXURAL BEAM FATIGUE

- Check fatigue life by repeated flexural bending (AASHTO T 321)
- Compact in Asphalt Vibratory Compactor (AVC) and then trim to 380mm length x 50mm thick x 63mm wide
- Sample tested in four point bending device at 15°C and 10 Hz loading frequency at specified strain level
- Cycles to failure must be **greater** than _Z_ cycles to pass



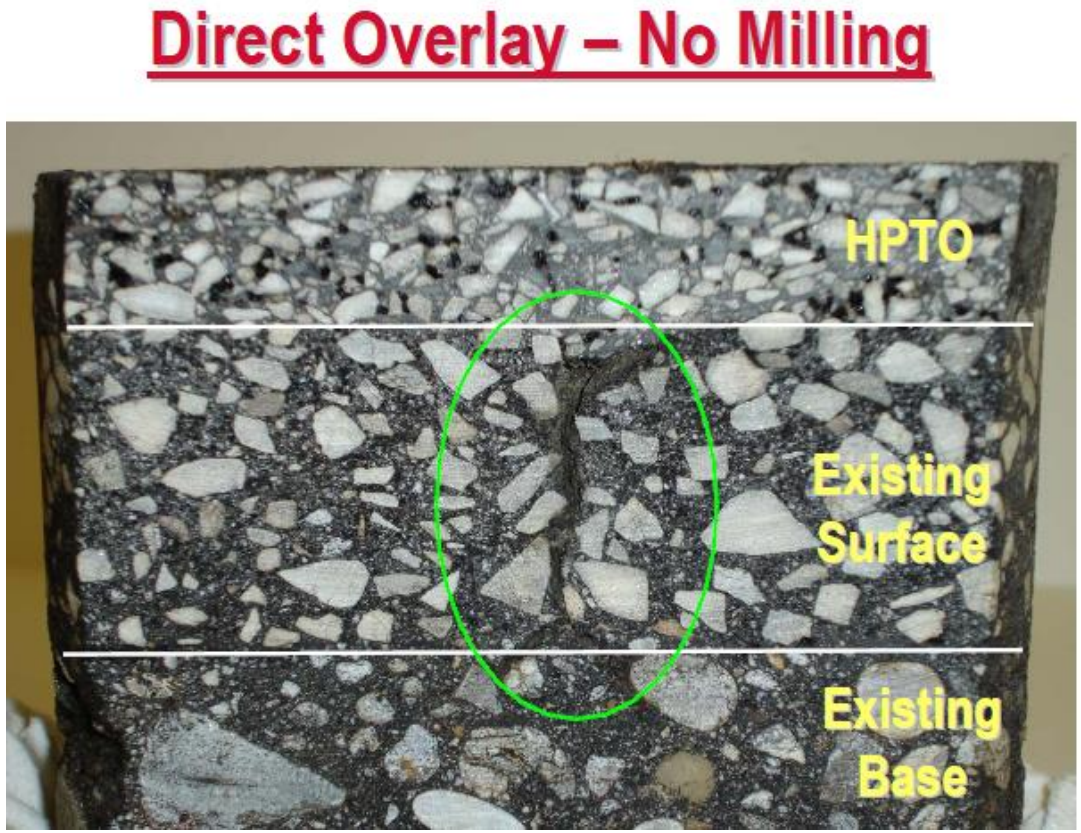
NJDOT ASPHALT MIXTURES WITH PERFORMANCE TESTS

NJDOT DESIGN & ACCEPTANCE

1. Perform volumetric design and NJDOT verification
2. Supply lab (Rutgers/NJDOT HQ Lab) prepared gyratory and bucket samples for performance testing
3. Produce mix through plant, provide samples for testing and pave test strip off site (skip step if previously approved mix)
4. Sample & test 1st Lot (test strip on project site) and every other lot during production for performance testing

HIGH PERFORMANCE THIN OVERLAY (HPTO)

- Main Purpose – used as a rut-resistant and durable thin lift mix for maintenance/pavement preservation
  - Superior leveling course
  - Overlay for bridge decks
  - Superior surface course for inlays
    - Composite pavement
- Appropriate on high or low volume roads



HIGH PERFORMANCE THIN OVERLAY (HPTO)

- 4.75mm Superpave + APA Rut Test + Overlay Crack Test
- 7.4% min PG 76-22 (PG 64E-22) or other polymer modified binder
- 3.5% Air Voids at 50 Gyrations
- 1-7% mat voids
- 1" +/- Lift Thickness
- Steel roller in static mode
- **APA Rut < 4mm (5mm) at 8000 cycles**
- **Overlay Test > 600 cycles**

HIGH PERFORMANCE THIN OVERLAY (HPTO)

- Improves ride quality
  - 70% improvement on some projects
- Seals out water
- Renew road surface
- Quick open to traffic
- Minimal RAP on Preservation
  - Lift thickness 1" typically
- Placed with a Conventional Paver or spray paver
- Bond is critical!!

BRIDGE DECK WATERPROOF SURFACE COURSE (BDWSC)

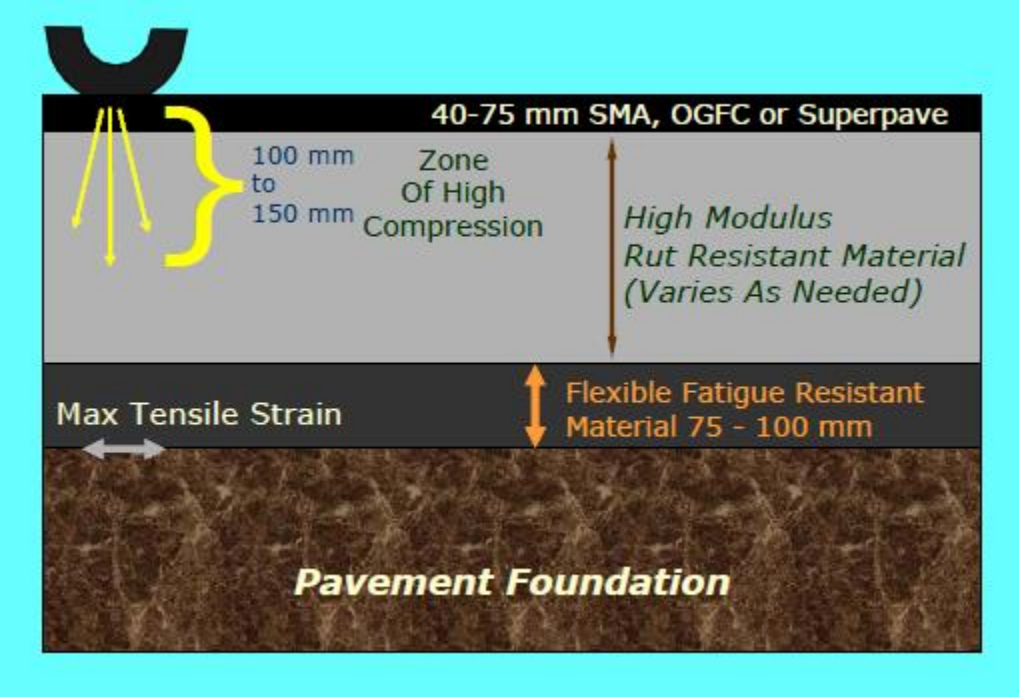
- Main Purpose – Waterproof asphalt overlay for older bridge deck structures
  - Must be capable of compaction with **no vibratory rolling (static only)**
  - Must be rut resistant and crack resistant
  - Produced and placed using conventional equipment and practices
  - Volumetric design such that the asphalt mix is **impermeable**

BRIDGE DECK WATERPROOF SURFACE COURSE (BDWSC)

- 9.5mm Superpave + APA Rut Test + Flexural Beam Fatigue Test
- Polymer modified asphalt binder specially formulated to meet mix performance criteria
- 1% Air Voids at 50 Gyrations
  - Low permeability!
- 1.5" to 2.5" Lift Thickness
- **APA Rut < 3mm at 8000 cycles (mix design)**
- **Flexural Fatigue > 100,000 cycles @ 1500 μ-strains**

BOTTOM RICH BASE COURSE (BRBC)

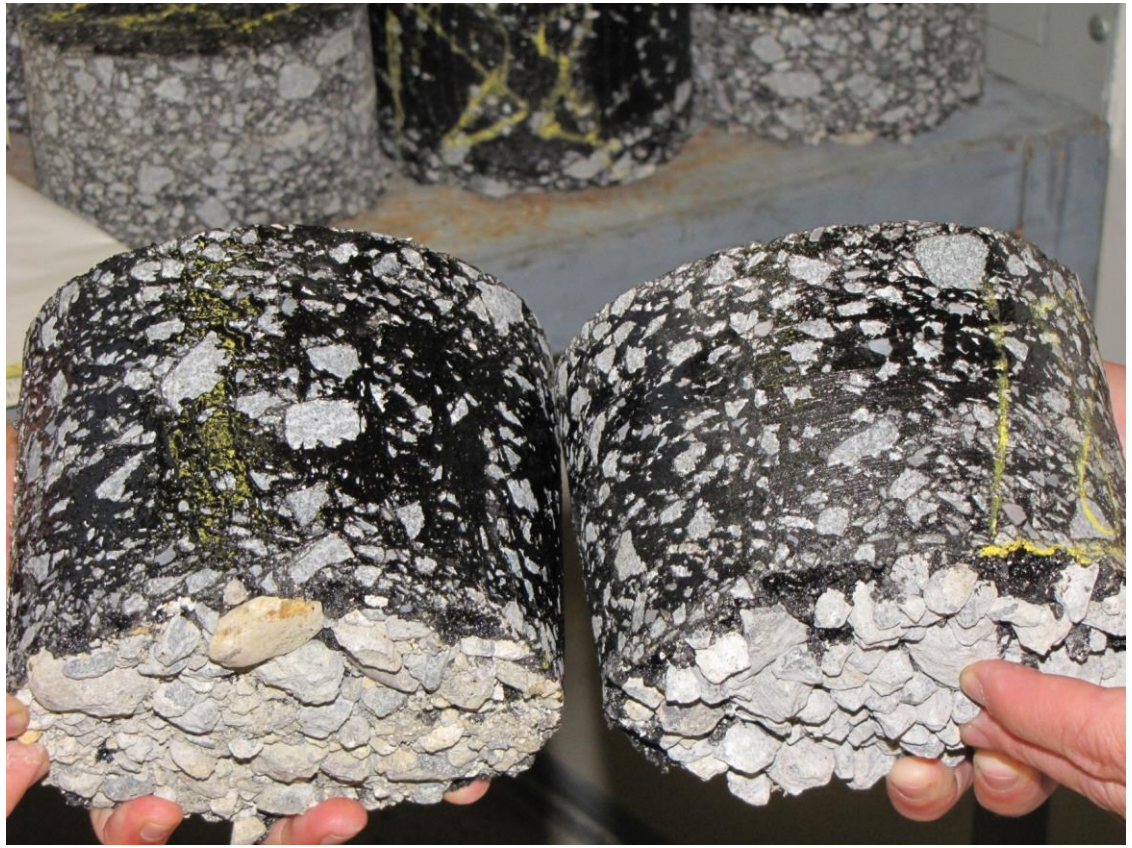
- Main Purpose – base course mixture designed specifically to meet the flexural needs of a perpetual pavement (site specific – Rt.295 Rubblization)
- 19 mm Superpave Base Course mix with 5% min. of polymer modified binder (PG76-28).
- Mix performance testing required for design (lab) and production (plant).
- Fatigue Life based on Endurance Limit procedure from NCHRP Project 9-38
  - > 100,000,000 cycles @ 100 μ-strain
- APA (rutting) < 5mm at 8,000 cycles



BOTTOM RICH BASE COURSE (BRBC)

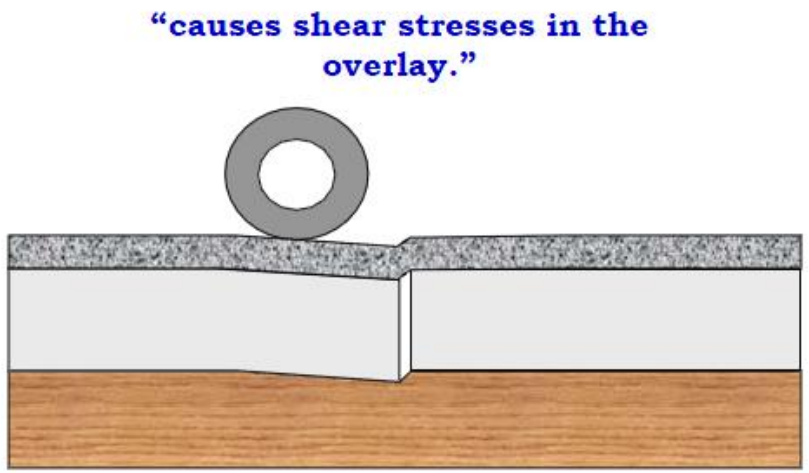
Interstate Route 295 Rubblization project MP 45 – 56

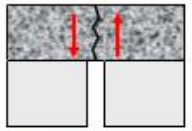
- 50 Gyrations @ 3.5% AV
- 1%-8% Mat Air Voids
- Full flexural fatigue suite required during mixture design and test strip production (AASHTO T 321)
  - 3 beams at 400 με and 3 beams at 800 με
  - Only 3 beams at 800 με during plant production (1st and every 5th Lot)



BINDER RICH INTERMEDIATE COURSE (BRIC)

- Main Purpose – Reflective Crack Relief Interlayer (RCRI) on composite pavement to withstand reflective cracking due to horizontal joint movement (environmental) and vertical joint movement (traffic)
  - Important to note – mixture placed over BRIC still needs to be flexible enough to resist residual vertical bending





Mode 1: Vertical Shear Stress

BINDER RICH INTERMEDIATE COURSE (BRIC)

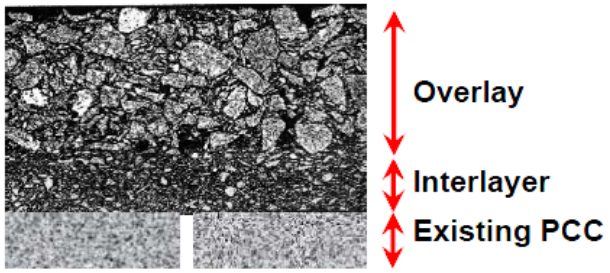
- 4.75mm Superpave + APA Rut Test + Overlay Crack Test
- 7.4% min. polymer modified binder (PG 70-28)
- 3.5% Air Voids at 50 Gyrations
- 0-6% mat voids
- 1”-1.5” Lift Thickness
- Steel roller in static mode
- **APA Rut < 6mm (7mm) at 8000 cycles**
- **Overlay Test > 700 (650) cycles**

The Solution

Reflective Crack Relief Mixtures

RCRI and RBL

- Thin (1”) fine aggregate HMA
- Highly elastic binder – modified on low PG side as well (-28°C and lower)
- Asphalt-rich, impermeable layer to keep moisture away from PCC and supporting materials



HOT MIX ASPHALT (HMA) HIGH RAP

- Main Purpose – partner with industry to allow responsible increase % Reclaimed Asphalt Pavement (RAP) in HMA
  - Minimum 20% RAP in surface course (up from 15% max)
  - Minimum 30% RAP in intermediate & base course (up from 25% max)
- Mix design and plant produced HMA High RAP **must meet APA Rut & Overlay Crack test requirements**

Table 902.11.03-2 Performance Testing Requirements for HMA HIGH RAP Design

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

HOT MIX ASPHALT (HMA) HIGH RAP

Table 902.11.03-1HMA HIGH RAP Requirements for Design

Compaction Levels	Required Density (% of Theoretical Max. Specific Gravity)		Voids in Mineral Aggregate (VMA)[2], % (minimum)					Voids Filled With Asphalt (VFA) %	Dust-to-Binder Ratio
			Nominal Max. Aggregate Size, mm						
	@N_{des}[1]	@N_{max}	25.0	19.0	12.5	9.5	4.75		
L	96.0	≤ 98.0	13.0	14.0	15.0	16.0	17.0	70 - 85	0.6 - 1.2
M	96.0	≤ 98.0	13.0	14.0	15.0	16.0	17.0	65 - 85	0.6 - 1.2

1. As determined from the values for the maximum specific gravity of the mix and the bulk specific gravity of the compacted mixture. Maximum specific gravity of the mix is determined according to AASHTO T 209. Bulk specific gravity of the compacted mixture is determined according to AASHTO T 166. For verification, specimens must be between 95.0 and 97.0 percent of maximum specific gravity at N_{des}.
2. For calculation of VMA, use bulk specific gravity of the combined aggregate include aggregate extracted from the RAP.

Table 902.11.04-1 HMA HIGH RAP Requirements for Control

Compaction Levels	Required Density (% of Theoretical Max. Specific Gravity)	Voids in Mineral Aggregate (VMA), % (minimum)					Dust-to-Binder Ratio
		Nominal Max. Aggregate Size, mm					
	@Ndes[1]	25.0	19.0	12.5	9.5	4.75	
L, M	95.0 – 98.5	13.0	14.0	15.0	16.0	17.0	0.6 - 1.3

1. As determined from the values for the maximum specific gravity of the mix and the bulk specific gravity of the compacted mixture. Maximum specific gravity of the mix is determined according to AASHTO T 209. Bulk specific gravity of the compacted mixture is determined according to AASHTO T 166.

HOT MIX ASPHALT (HMA) HIGH RAP

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)	$t \leq 7$ $7 < t < 10$ $t \geq 10$	$t \leq 4$ $4 < t < 7$ $t \geq 7$	$t \leq 7$ $7 < t < 10$ $t \geq 10$	$t \leq 4$ $4 < t < 7$ $t \geq 7$	0 – 1 – 5
Overlay Tester, cycles (NJDOT B-10)	$t \geq 150$ $150 > t > 100$ $t \leq 100$	$t \geq 175$ $175 > t > 125$ $t \leq 125$	$t \geq 100$ $100 > t > 75$ $t \leq 75$	$t \geq 125$ $125 > t > 90$ $t \leq 90$	0 – 1 – 5

FIELD PERFORMANCE OF NJDOT ASPHALT MIXTURES

BENEFIT-COST COMPARISON BASED ON LAB OVERLAY TEST RESULTS

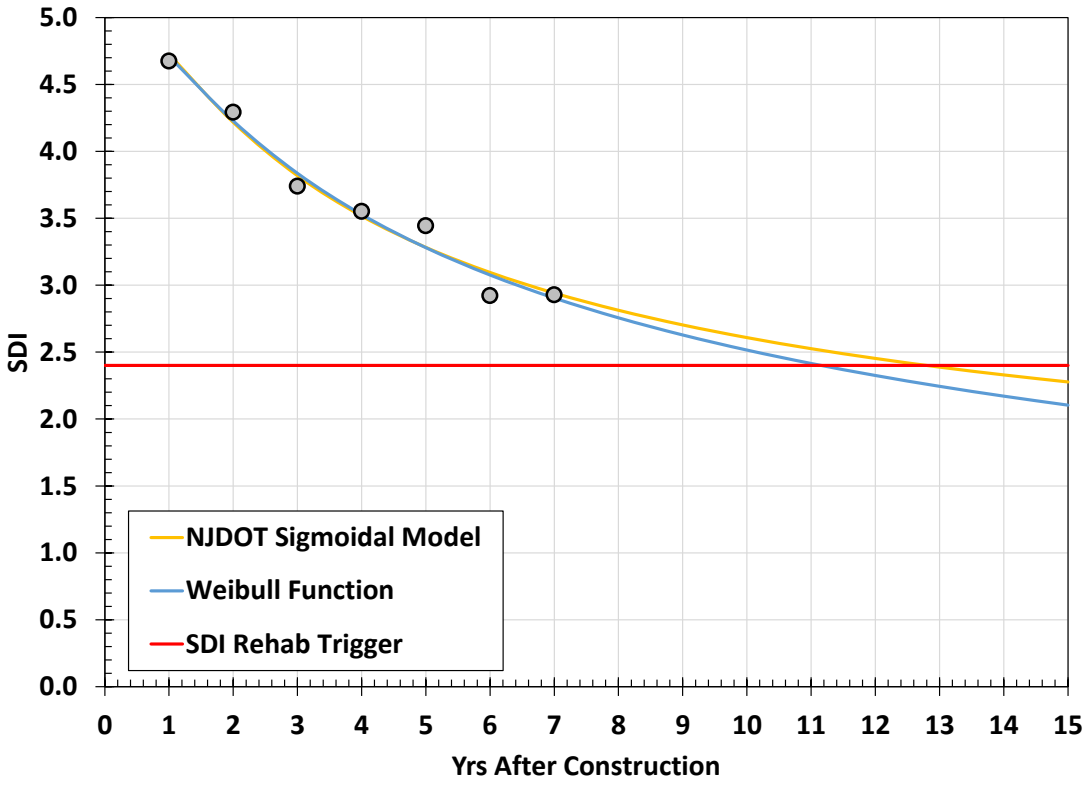
Mixture Type	Avg. Performance in Overlay Tester (cycles to failure)	Average Cost per Ton ($)	Cost Ratio of Mix Type vs HMA	Performance Ratio of Mix Type vs HMA	Benefit/Cost Ratio (Performance Ratio/Cost
HMA	91	70	1.0	1.0	1.0
HRAP (64 Mixes Only)	369	75	1.1	4.1	**3.8**
SMA	729	98	1.4	8.0	5.7
BRBC	1143	89	1.3	12.6	**9.9**
MOGFC	1039	90	1.3	11.5	8.9
AR-OGFC	1796	110	1.6	19.8	12.6
HPTO	3013	129	1.8	33.2	**18.0**
BRIC	3051	116	1.7	33.6	**20.3**
BDWSC	5000	350	5.0	55.1	**11.0**

1ST HIGH PERFORMANCE THIN OVERLAY (HPTO)

- 2008 - Interstate Route I-295 Northbound, MP 8.7 – 14.0
- Before
  - SDI = 3.42 (out of 5)
  - IRI = 90 inches/mile
  - Rutting = 0.498 inch
- Immediately after
  - SDI = 5.0
  - IRI = 89 inches/mile
- 2016
  - SDI = 4.40
  - IRI = 85 inches/mile
  - Rutting = 0.272 inch

HIGH PERFORMANCE THIN OVERLAY (HPTO)

- Rutgers performed analysis of NJDOT Pavement Management data
- HPTO constructed on "Good" pavements will last 13 years minimum
  - Surface Distress Index > 2.4
- HPTO constructed on "Poor" pavements lasts only 5 years
  - Surface Distress Index < 2.4
- Overall 1" HPTO performance equal to or better than milling 2"+ and resurfacing 2"+ with dense graded HMA



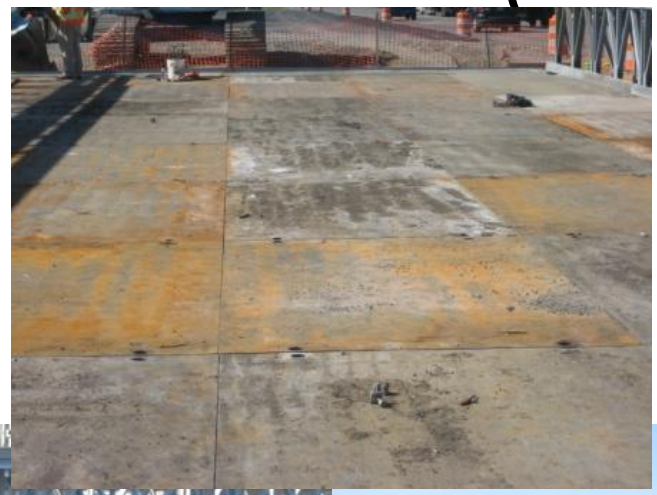
1ST BRIDGE DECK WATERPROOF SURFACE COURSE (BDWSC)

- 2008 – State Route 87 over Absecon Inlet (MP 1.1 - 1.5)
  - Before
    - SDI = 4.25
    - IRI = 274 inches/mile
  - After
    - SDI = 5.0
    - IRI = 144 inches/mile
  - 2016
    - SDI = 4.995
    - IRI = 139 inches/mile
    - Rutting = 0.1 inch
- Numerous other projects constructed from 2008 to present. No failures.

BRIDGE DECK WATERPROOF SURFACE COURSE (BDWSC)

Interstate Route 80 over Berkshire Valley Road ACROW Bridge overlay

- Nov. 2009 –Paved 2.5" to 3.5" of HMA 12.5H76 Surface Course
- March 26, 2010 –Opened to WB traffic
- April 8, 2010 –Started patching HMA due to excessive and rapid deterioration –cracking and shoving
- May 5 –6, 2010 -Removed FAILED HMA
- High deflections and poorly performing asphalt led to rapid failure

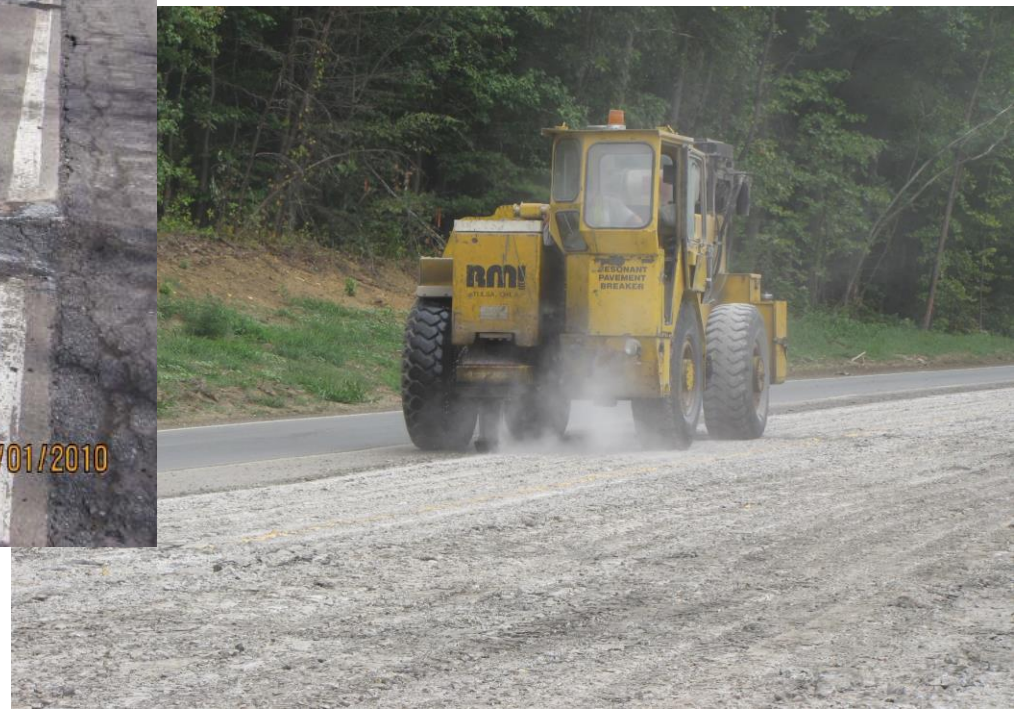


BRIDGE DECK WATERPROOF SURFACE COURSE (BDWSC)

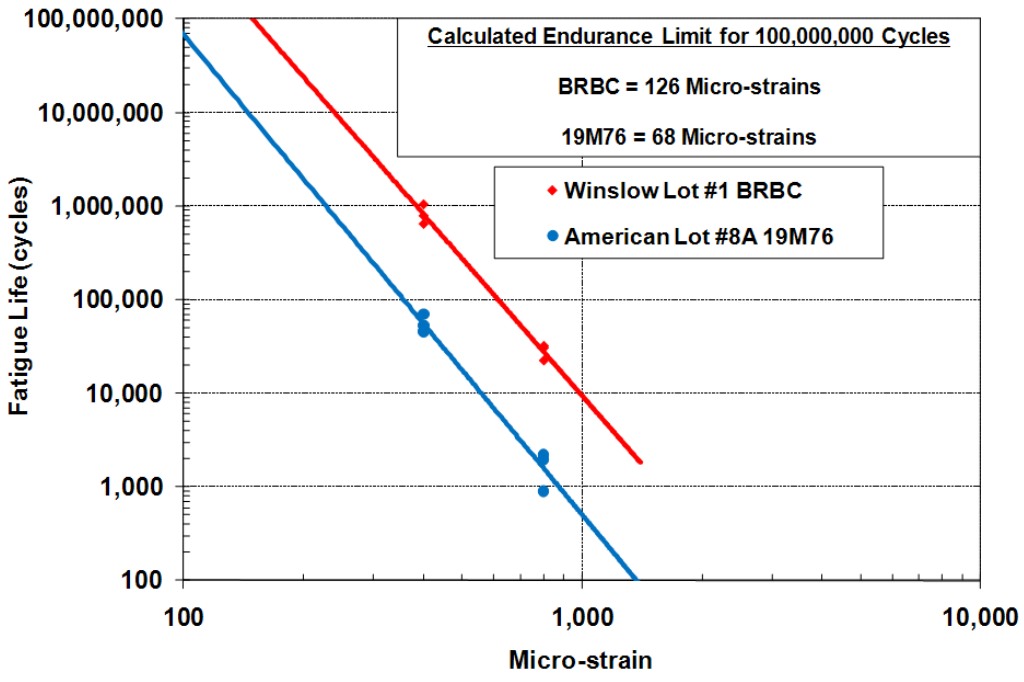
Interstate Route 80 over Berkshire Valley Road ACROW Bridge overlay

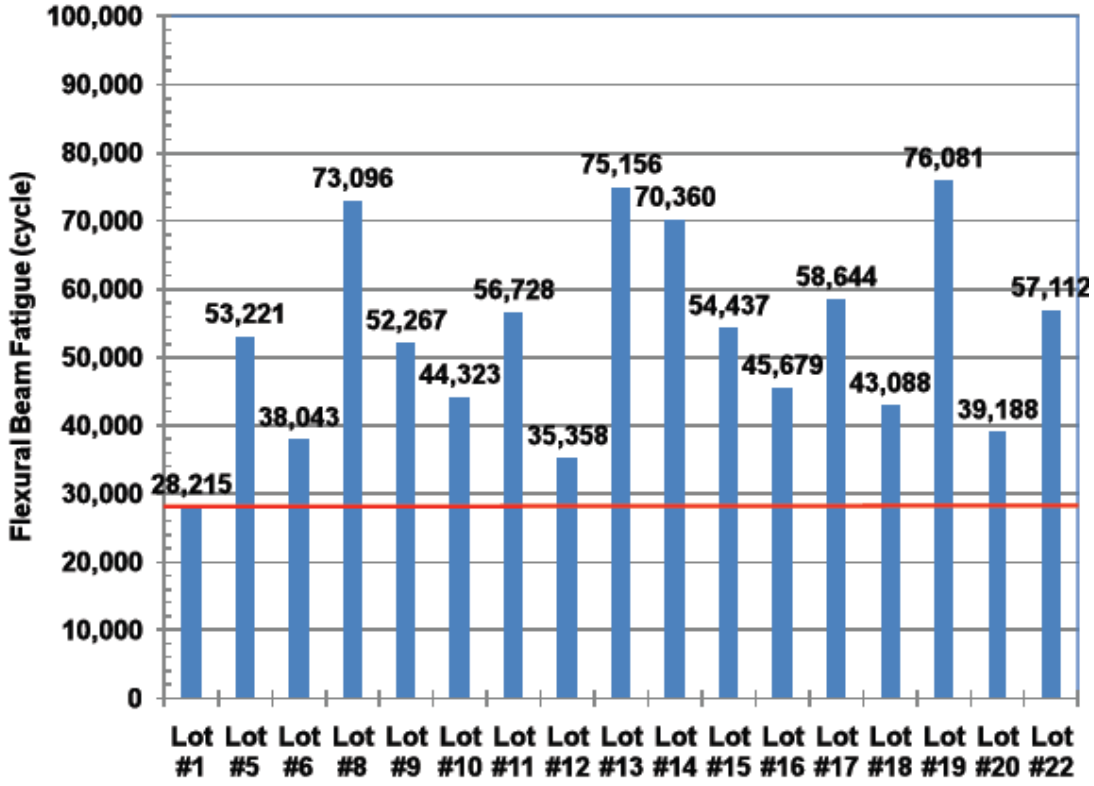
- Paved BDWSC on May 5-6, 2010
- Opened to WB traffic immediately
- WB Traffic on BDWSC until Dec.17, 2010
- Opened to EB traffic January 2011
- ACROW temporary bridge taken down at end of 2011
- **<u>1.5 years</u> of service with no distress – Right asphalt mix for the intended purpose!!**

1ST BOTTOM RICH BASE COURSE (BRBC) – ROUTE 295 RUBBLIZATION

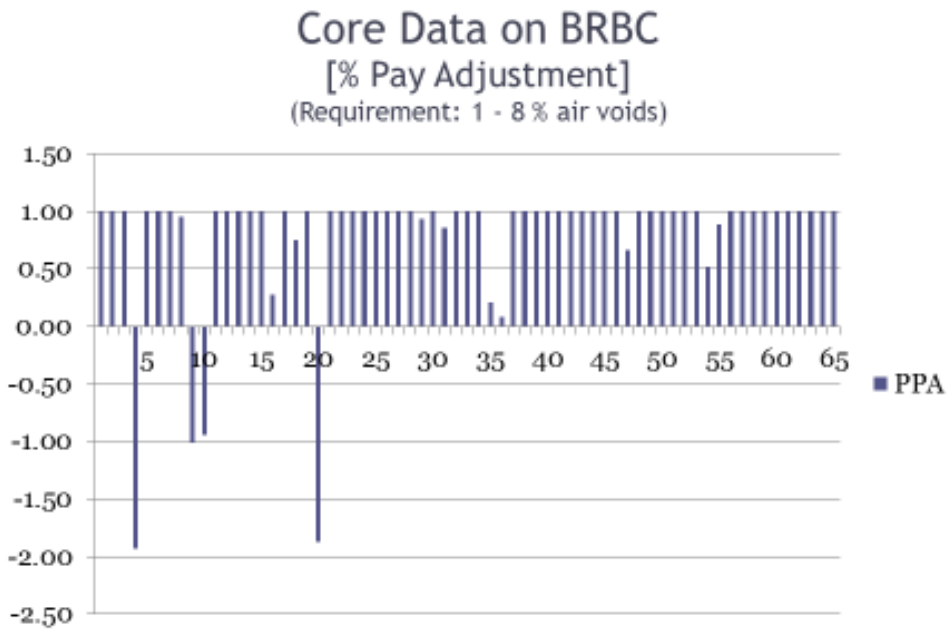


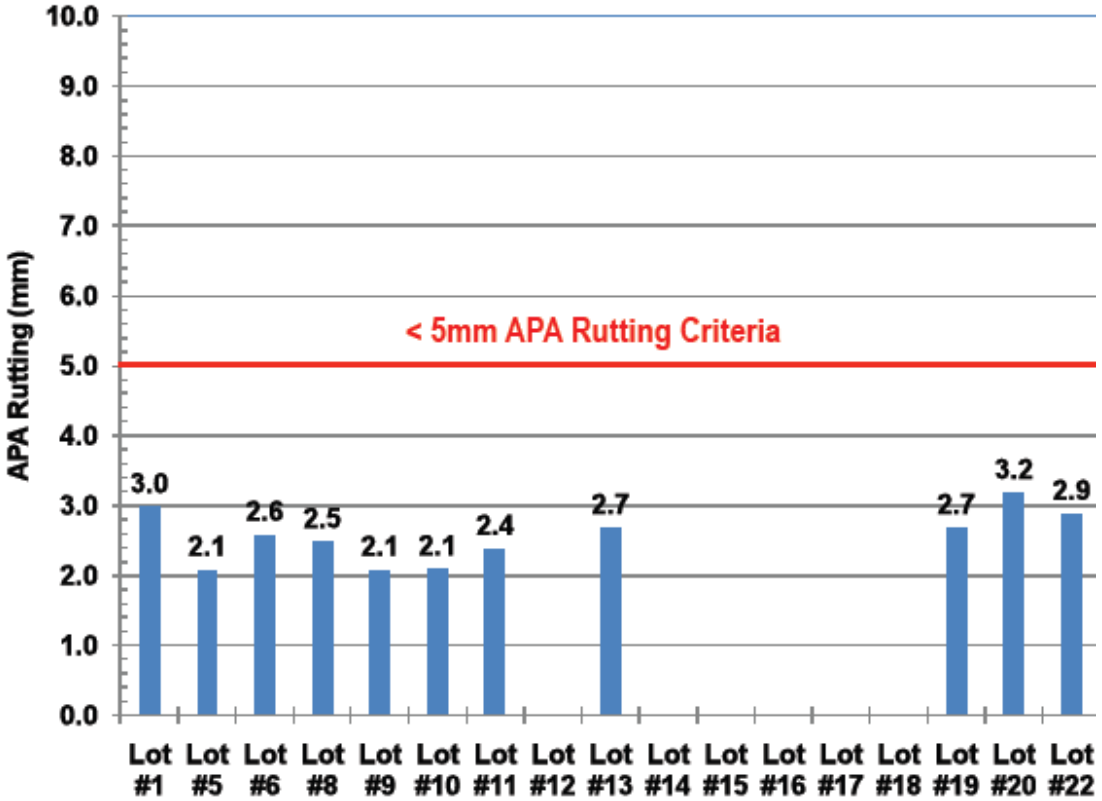
BOTTOM RICH BASE COURSE (BRBC) – ROUTE 295 RUBBLIZATION





BOTTOM RICH BASE COURSE (BRBC) – ROUTE 295 RUBBLIZATION





BOTTOM RICH BASE COURSE (BRBC) – ROUTE 295 RUBBLIZATION

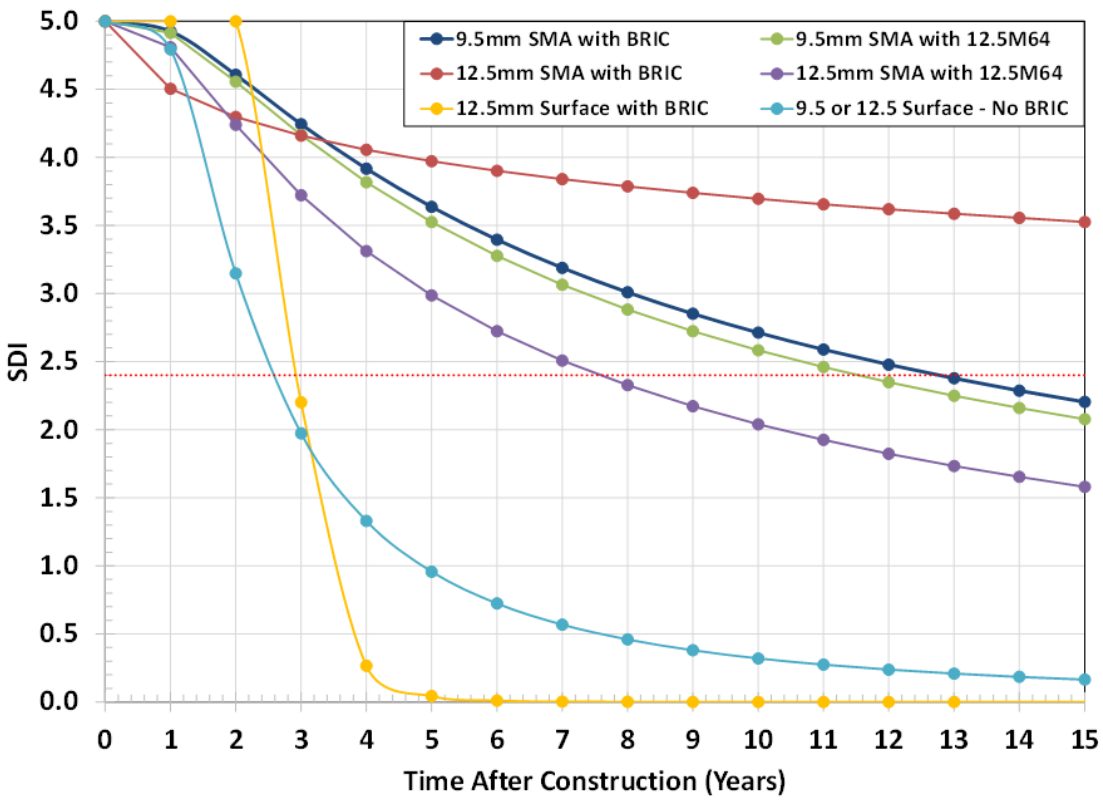
- Before (2010)
  - SDI = 2.06
  - IRI = 221 inches/mile
- After (2011)
  - SDI = 5.0
  - IRI = 65 inches/mile
- Current (2016)
  - SDI = 4.955
  - IRI = 71 inches/mile
  - Rutting = 0.124 inch

1ST BINDER RICH INTERMEDIATE COURSE (BRIC)

- Route 34 Northbound
  - Dense graded asphalt mixes above BRIC too brittle & cannot withstand residual flexing
  - Reflective Cracking occurred but performed slightly better than w/o BRIC
- Many other projects since
  - Stone Matrix Asphalt over BRIC performs best
  - SMA alone performs very well

BINDER RICH INTERMEDIATE COURSE (BRIC)

- Rutgers performed analysis of NJDOT Pavement Management data
- BRIC improves projected life, but largely influenced by surface course material
- 2" Stone Matrix Asphalt (SMA) over 1" BRIC provides 10 years more life than dense graded asphalt mixtures



1ST HOT MIX ASPHALT (HMA) HIGH RAP

- 2012 - Interstate Route I-295 Southbound MP 11.3-14.5
- Before
  - SDI = 1.45 (out of 5)
  - IRI = 103 inches/mile
  - Rutting = 0.381 inch
- Immediately after
  - SDI = 5.0
  - IRI = 48 inches/mile
- 2016
  - SDI = 4.70
  - IRI = 50 inches/mile
  - Rutting = 0.106 inch

HOT MIX ASPHALT (HMA) HIGH RAP

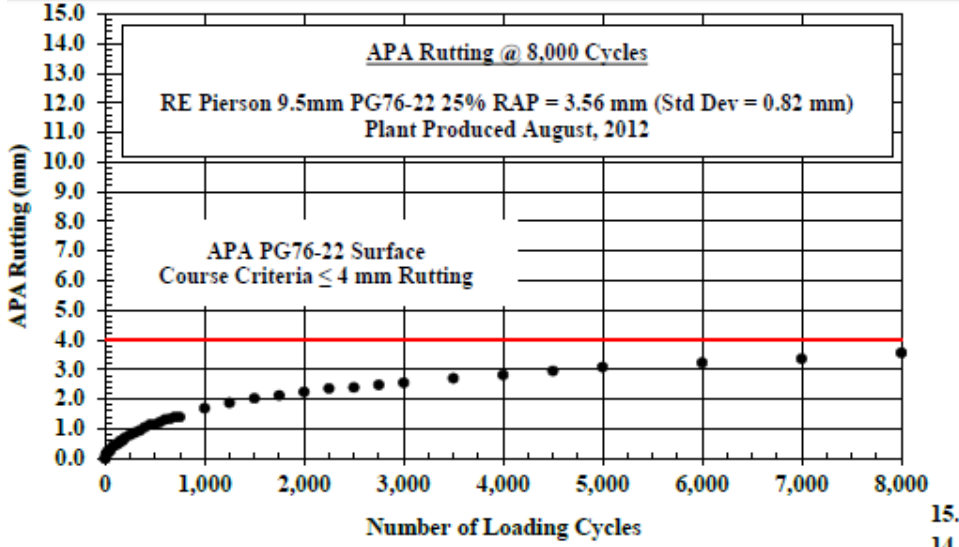
9.5M76 (SURFACE COURSE)

- 25% RAP
- 6.0% Total AC
  - 27.4% Binder Replacement
- PG70-22 (74.6-26.99)
- 25% Fine RAP Fraction Only

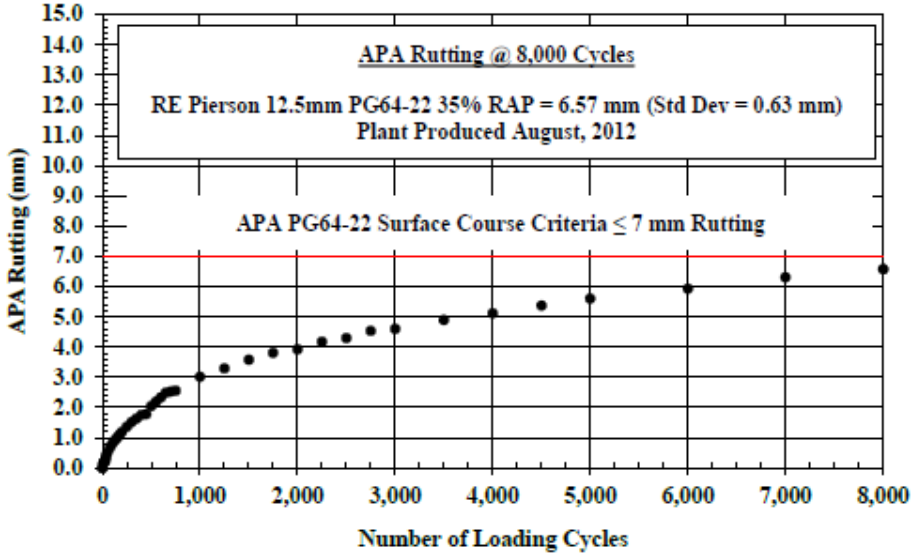
12.5M64 (INTERMED. COURSE)

- 35% RAP
- 5.8% Total AC
  - 29.7% Binder Replacement
- PG64-28 (64.8-28.29)
- 17.5% Fine RAP/ 17.5% Coarse RAP

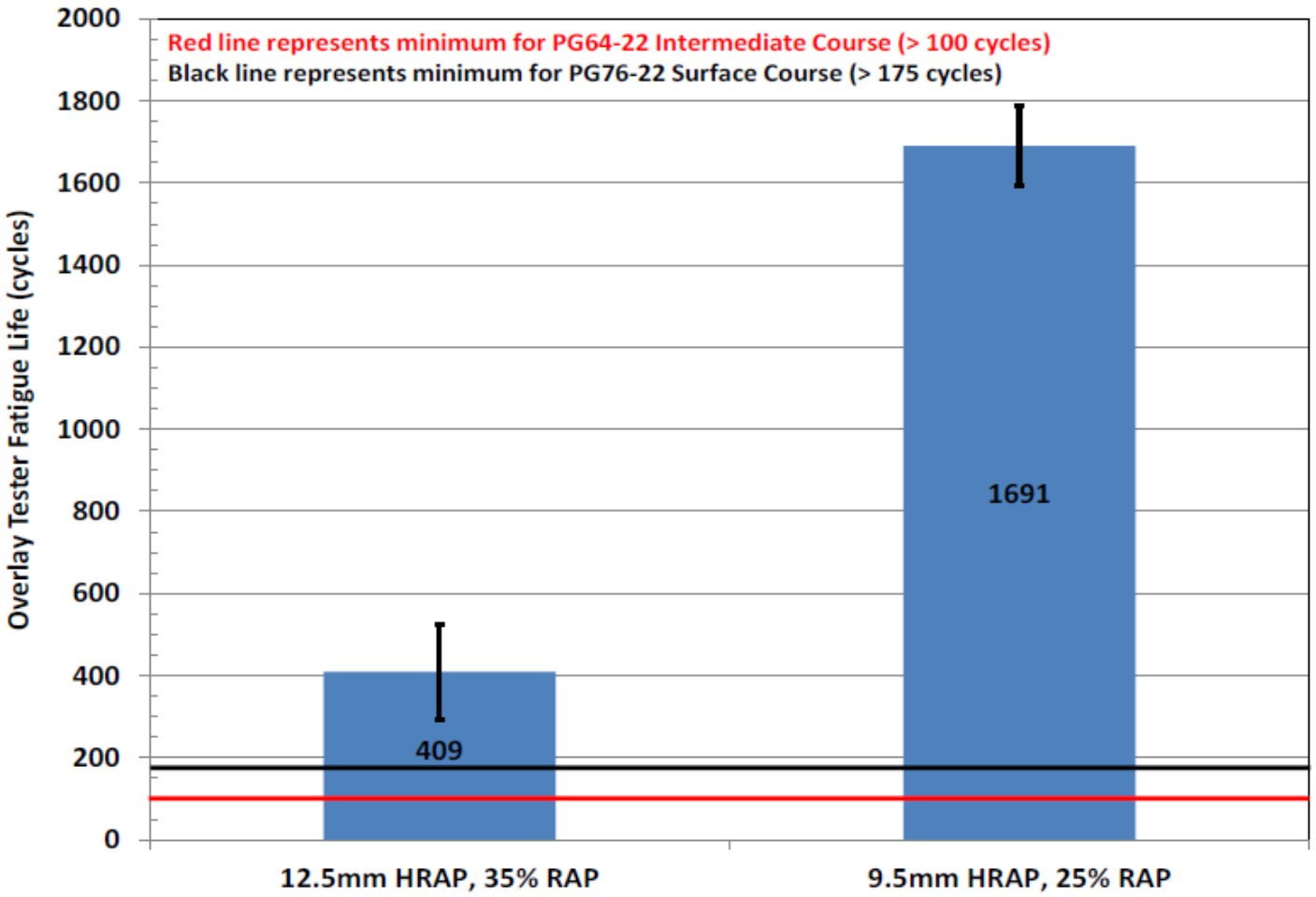
HOT MIX ASPHALT (HMA) HIGH RAP



64°C Test Temp.; 100psi Hose Pressure; 100 lb Load Load



HOT MIX ASPHALT (HMA) HIGH RAP



FUTURE

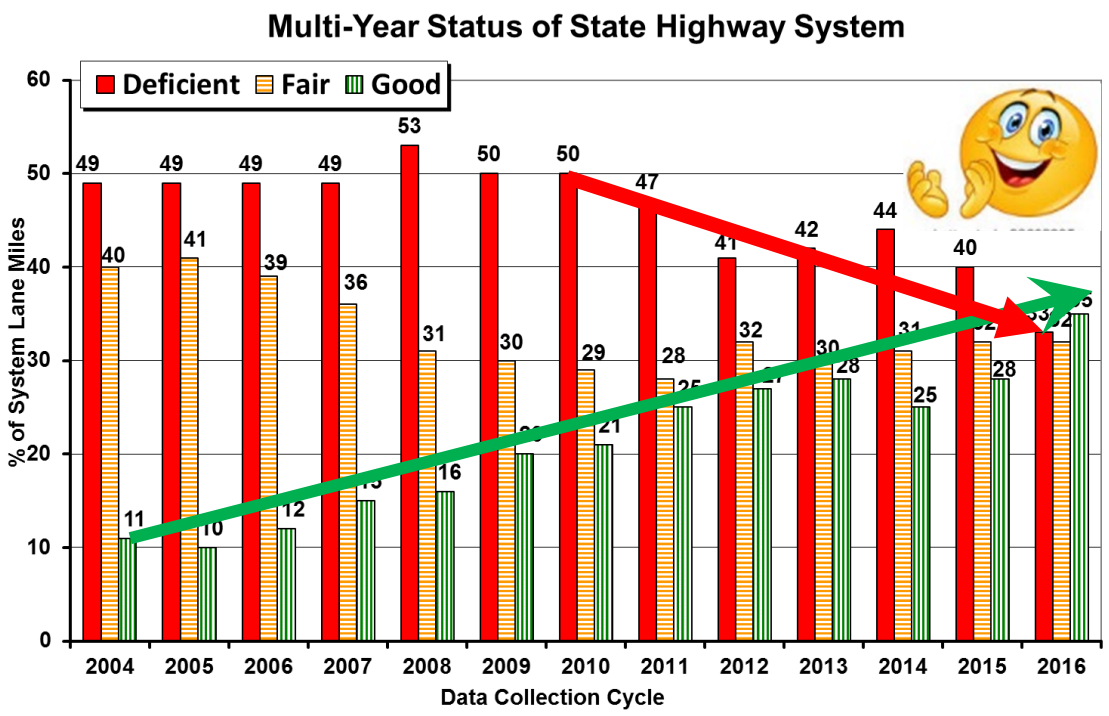
- Mixture performance test requirements for all asphalt mixtures
  - Balanced mix design
- Pay adjustment for mixture performance
- Quality control tests for mixture performance in asphalt plant labs
  - Modified Marshall equipment available in most plant labs
    - Rutting - High temperature Indirect Tensile Test (IDT)
    - Cracking – Semi-Circular Bend (SCB) Flexibility Index
- Performance testing before and after accelerated aging

FUTURE
EXAMPLE OF HPTO UPDATE

Table 902.08.03-1 Performance Testing Pay Adjustments for HPTO			
Test	**Requirement**	**Test Result**	**PPA**
APA @ 8,000 loading cycles, mm (AASHTO T 340)	5.0 maximum	$t \leq 5.0$ $5.0 < t \leq 12.0$ $t > 12.0$	0 -50(t-5)/7 -100 or Remove & Replace
Overlay Tester, cycles (NJDOT B-10)	600 minimum	$t \geq 600$ $600 > t \geq 400$ $t < 400$	0 -(600-t)/4 -100 or Remove & Replace

FUTURE

- NJDOT Roadways Improving
- WHY?
  - Funding
  - Smoothness specification
  - Pavement preservation
  - **Performance related asphalt mixture specifications**
    - **Better long term performance**
    - **Better longitudinal joints**
    - **Smoother roads**



Source: NJDOT Pavement Management

SUMMARY

- Current/Future traffic and extreme climate conditions, require more than Mill 2", Pave 2" on typical HMA
- Performance data (lab & field) justifies that these mixes are a "Smart Economic Investment"
- Need different tools in the toolbox for different problems
- Have to make sure we use the "Right Mix, On the Right Road, At the Right Time, for the Right Price"
- We must have the conviction
  - "Get what we pay for!"
  - We must demand better performance and we're willing to pay for it

THANK YOU