Rutgers University Research Update

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69^{th} Annual New Jersey Asphalt Pavement Conference

RUTGERS
Center for Advanced Infrastructure
and Transportation

Acknowledgements

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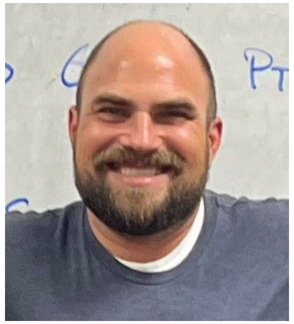
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  - Pavement Design and Management Staff, including but not limited to Robert Blight, Narinder Kohli, Nusrat Morshed
  - Materials Bureau Staff, including but not limited to Ed Inman, Mark Gillece, Ryan Rathbun, Caroline Gobrial, Ed Colligan Jr.
- PANYNJ
- NJ/PA/NY Asphalt Industry

Presentation Agenda

- What you asked about from NJAPA 2025 Survey
  - RAP/sustainability
    - Material testing advancements/performance testing
  - Performance Testing/Balanced Mixture Design (BMD)
  - New technologies on milling/paving
  - Research at Rutgers moving forward
    - Starting and on-going

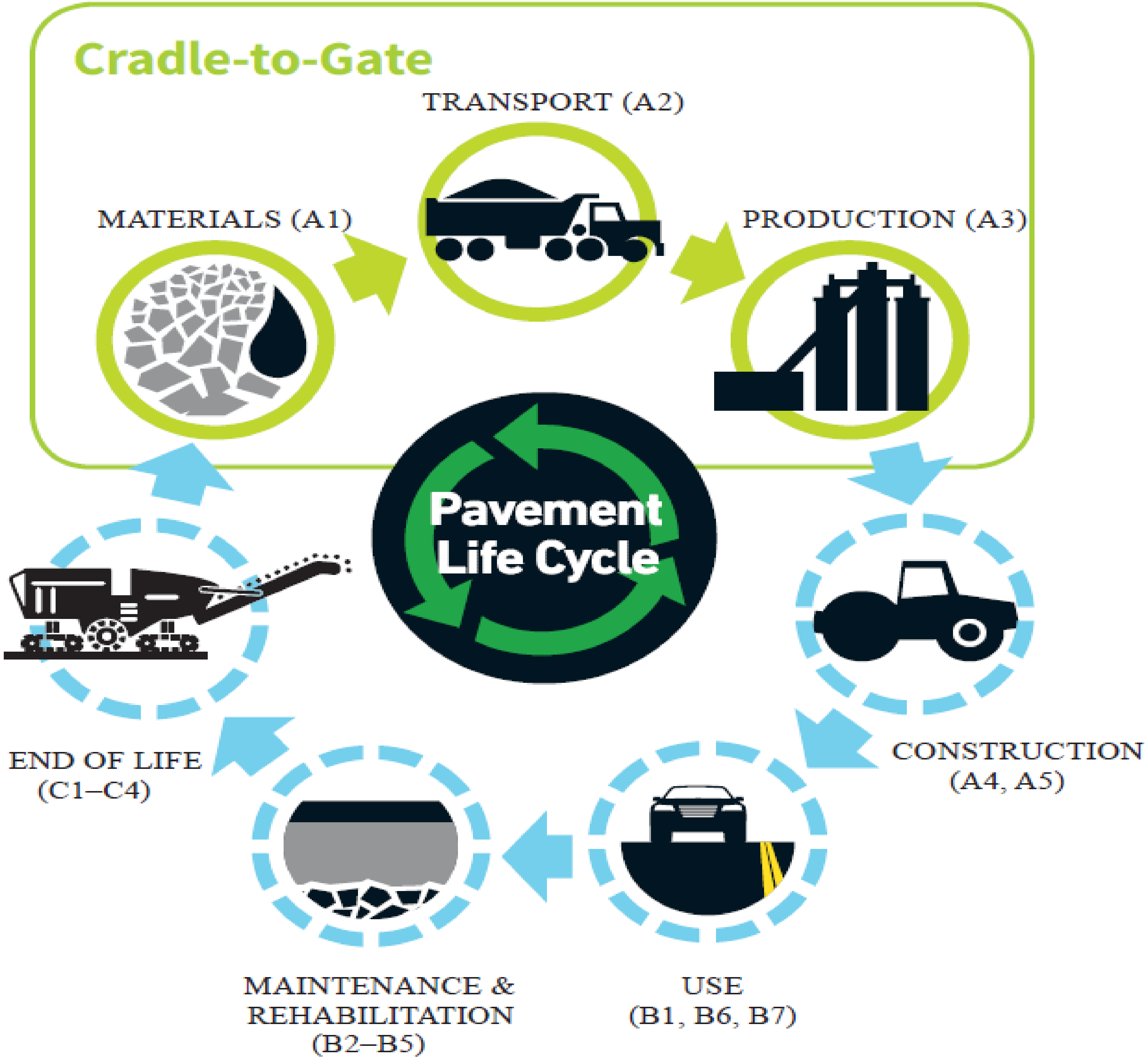
What You Asked About – 2025 Survey

- Some things you can't always answer/agree upon
  - "Keep it with the talks on blacktop and away from projects"
  - "Paving projects and different jobs in the field"
  - "Would like to hear about how NJDOT going to prevent longitudinal joint cracking on the parkway and turnpike."
  - "Have upbeat speakers that speak clearly"
  - **Please continue to fill out surveys!**

RAP/Sustainability

"Sustainability"

- The "EPD" …
  - Equivalent carbon dioxide production known as "__ kg of CO_2eq"
  - This is the Global Warming Potential (GWP)

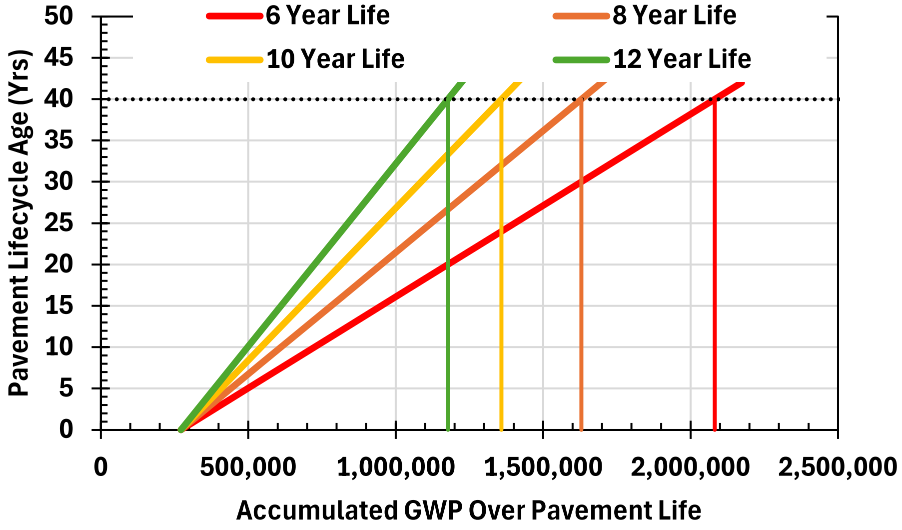


“Sustainability”

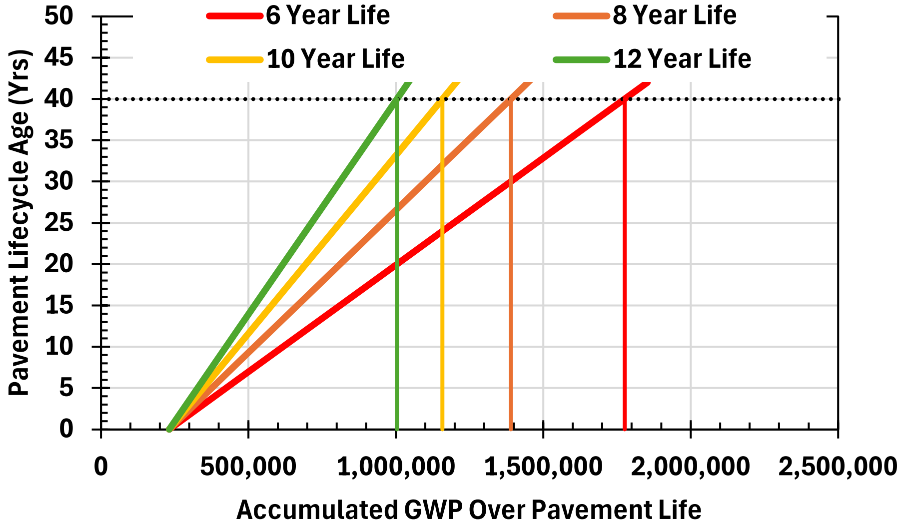
- **Sustainability ≠ Recycling**
  - Sustainability is the concept of maintaining something at a certain rate for a period of time (i.e. – resources, infrastructure, etc) – a social goal over a long period of time!
    - Longer pavement life will equate to lower Global Warming Potential (GWP) and lower RAP production and over the life cycle of the pavement
- Example:
  - 5000 ton paving project – 40 Year Design Life Before Reconstruction
    - Assuming all production and construction practices the same
      - Except changing RAP contents (assuming direct substitution – no other changes/additives)
  - From NAPA EPD website, NJ is rather consistent with RAP EPD impact
    - For every 1% RAP, 0.3 to 0.4 kg CO_2eq per ton of HMA is reduced
    - Ex. – NJ Asphalt Supplier:
      - 15% RAP = 54.37 kg eqCO_2 per ton HMA
      - 25 % RAP = 50.38 kg eqCO_2 per ton HMA

Impact of Pavement Life on GWP Production

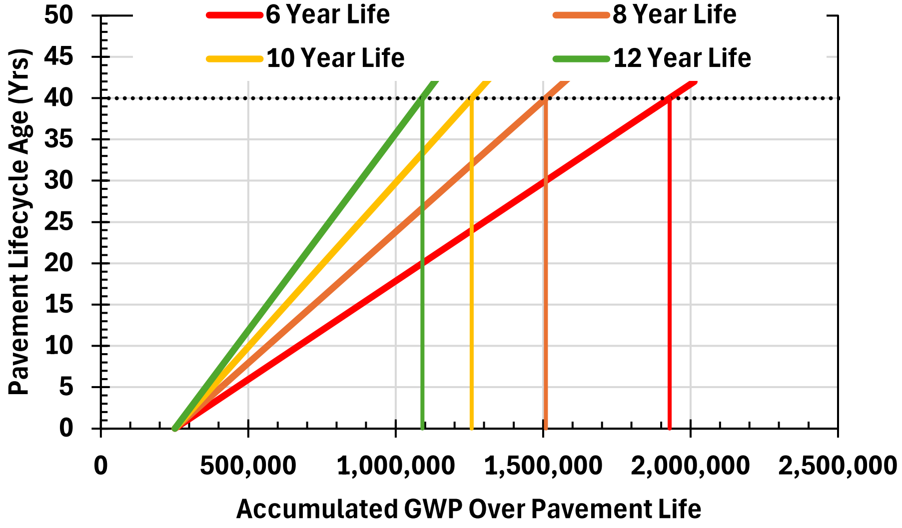
15% RAP



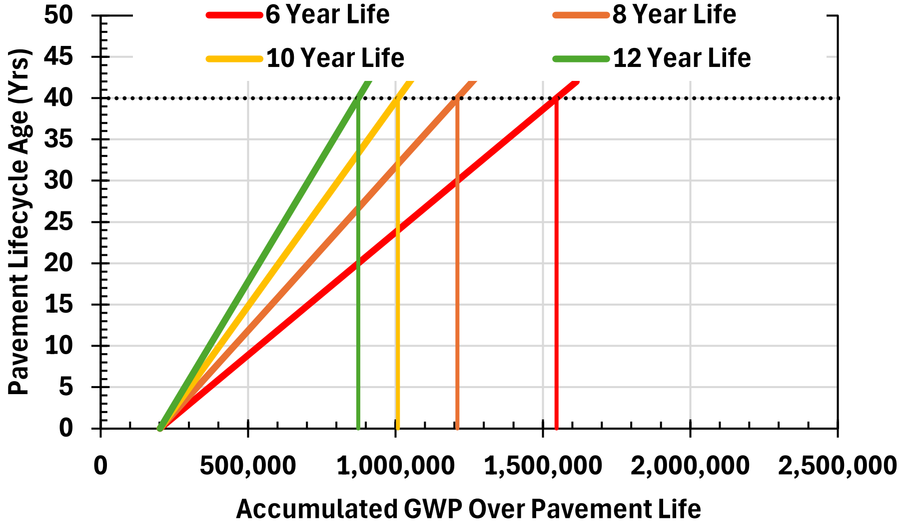
35% RAP



25% RAP

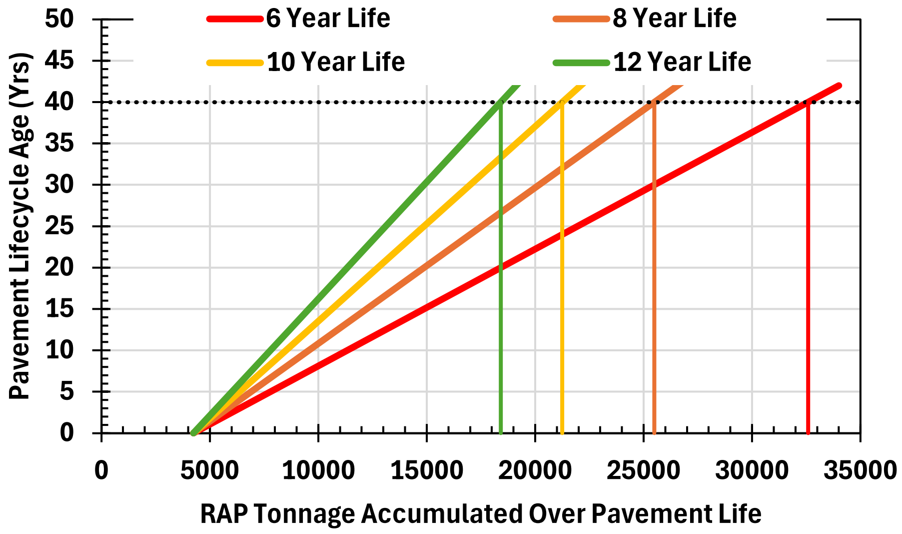


50% RAP

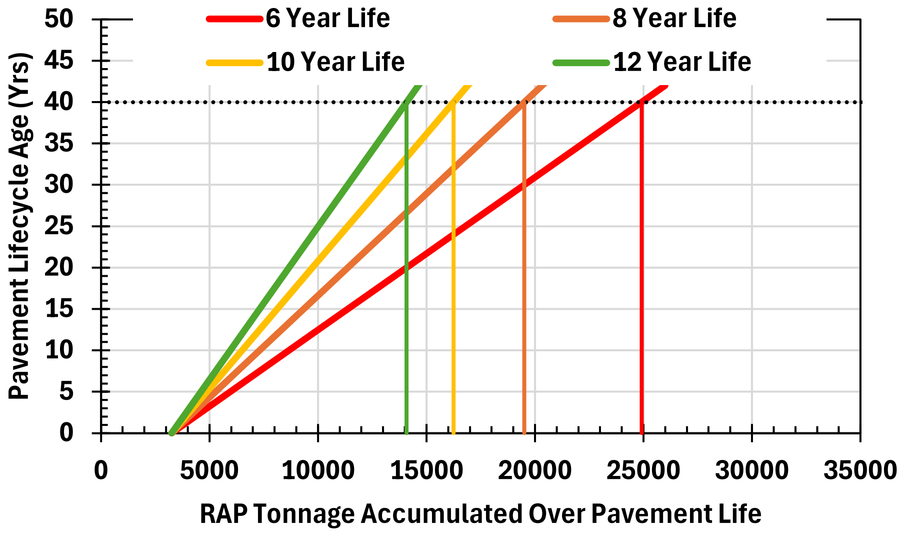


Impact of Pavement Life on RAP Production

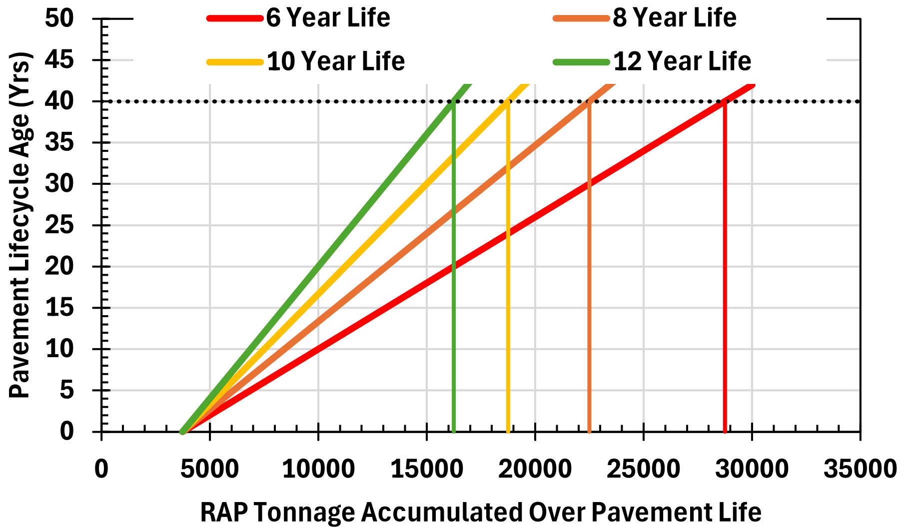
15% RAP



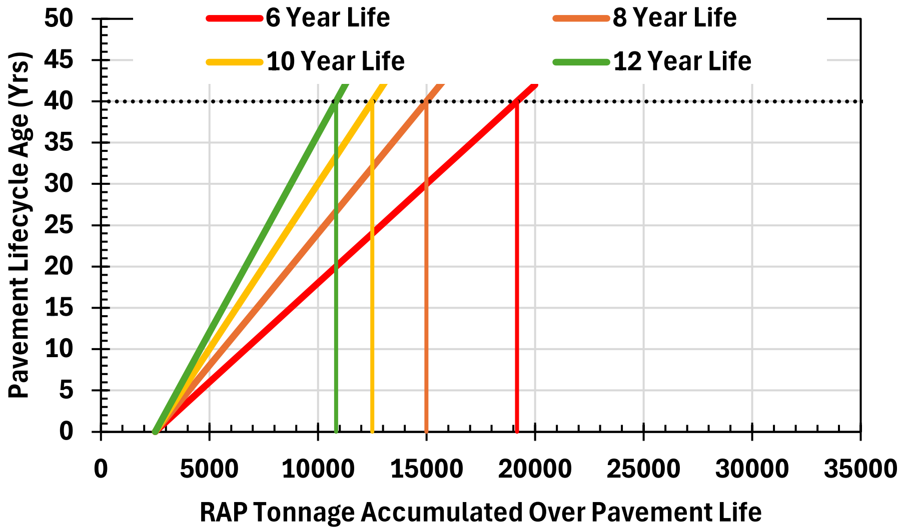
35% RAP



25% RAP



50% RAP

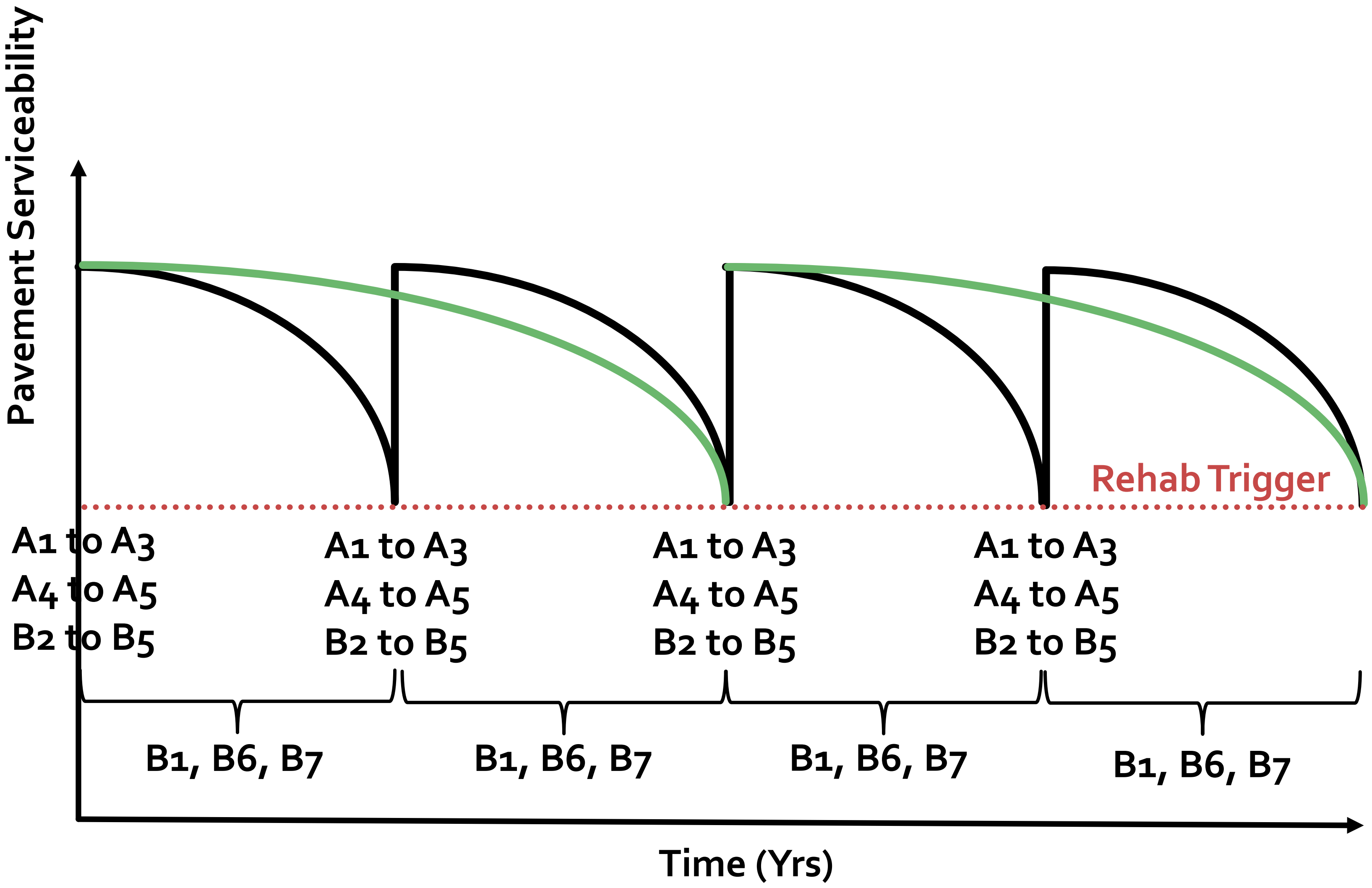


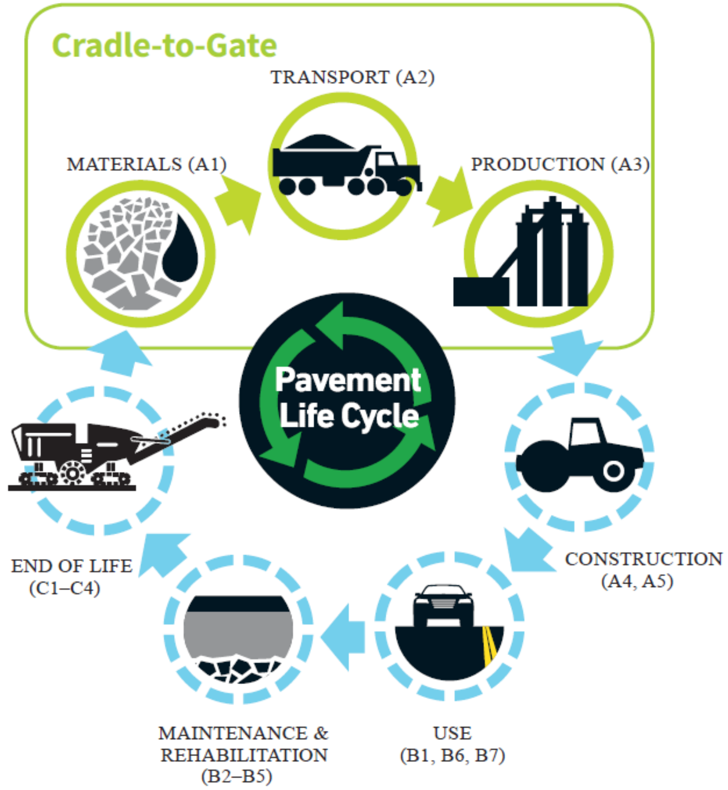
Impact of Pavement Life on GWP Production

- Extending the pavement life is actually more critical than increasing RAP content with respect to RAP & GWP production
  - 15% RAP, 12 Year
    - 18,416 tons of RAP produced in 40 Years
    - 1,177,150 kg of CO_2eq produced in 40 Years
  - 25% RAP, 10 Year
    - 18,8750 tons of RAP produced in 40 Years
    - 1,258,250 kg of CO_2eq produced in 40 Years
  - 50% RAP, 6 Year
    - 19,166 tons of RAP produced in 40 Years
    - 1,545,983 kg of CO_2eq produced in 40 Years
- In essence, the more times the road needs a rehabilitation, you will be generating more RAP and GWP!

Just based on production! Does not consider extra GWP generated during additional construction/trucking operations from additional rehabilitation needs

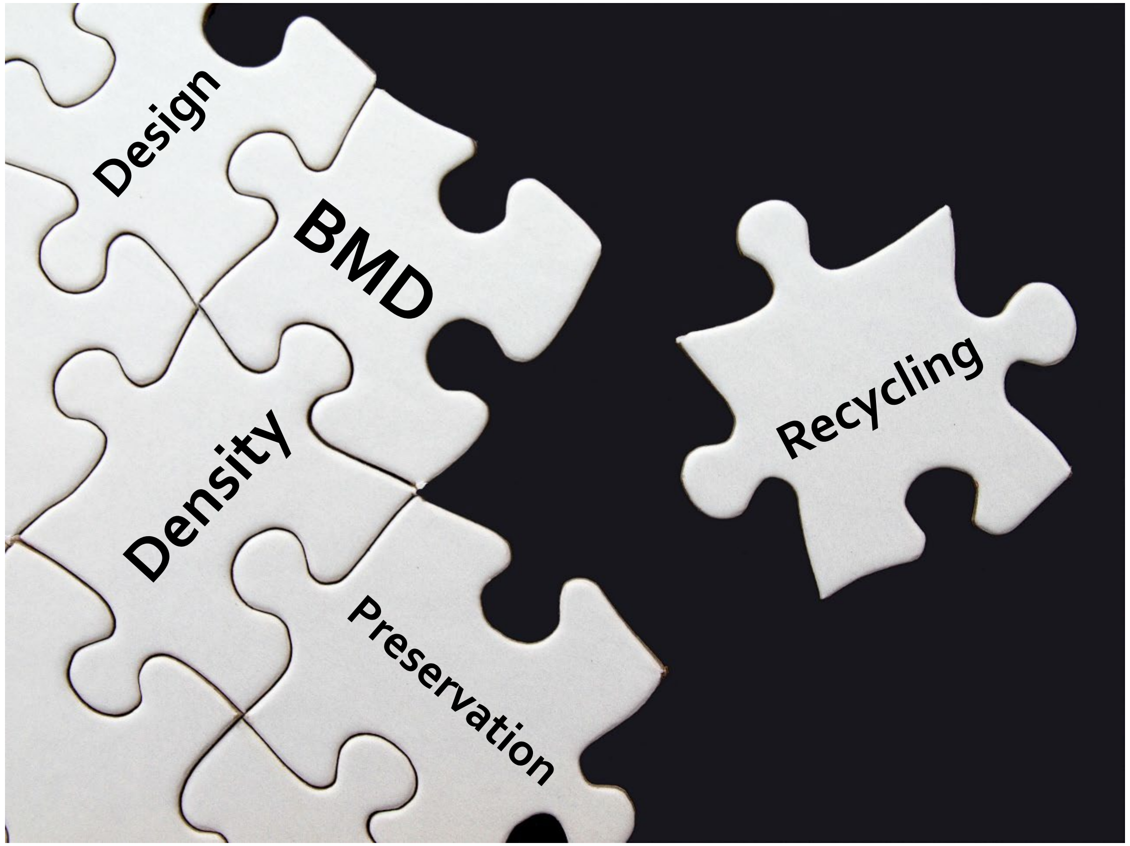
Pavement Life Cycle





Environmentally Friendly Pavements

- Materials
  - Recycled materials
  - Performance-based design (BMD)
  - HiMA
  - Anti-oxidants for asphalt
  - Synthetic binders
- Design
  - PAVEMENT-ME
  - Perpetual pavements
  - Pavement Preservation
- Construction
  - Impact of air voids/compaction
  - Bonding of pavement layers



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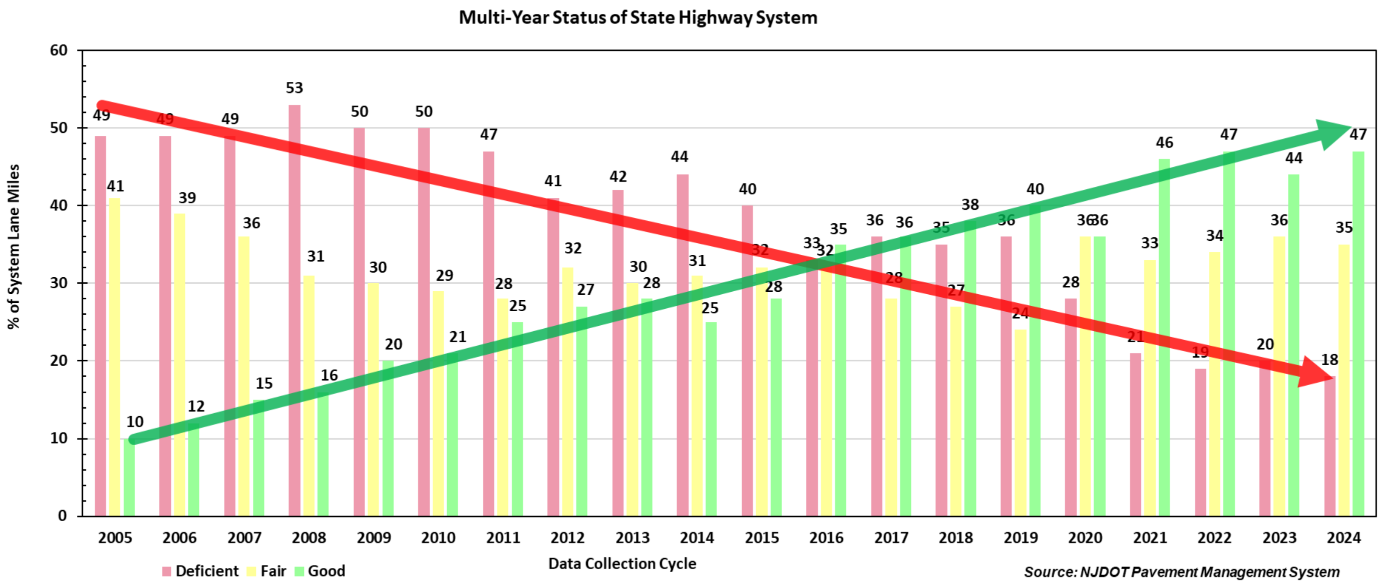


NJDOT HRAP Specification – Basic Principle

- The supplier is not held to PG grade or max. RAP content
- Have to meet basic Superpave requirements
  - NJDOT increased VMA 1% over current specs
  - Could use softer binder, rejuvenators, WMA
- However, acceptance based on final mixture performance, <u>based on database of typical "virgin" HMA</u>
  - Suppliers not required to conduct extra & sophisticated testing on RAP if they choose not to – <u>**END RESULT SPEC**</u>

To overcome issues with lack of RAP binder blending – essentially increases the virgin binder content requirement

To overcome issues with workability/compaction and helps to counteract the increase in stiffness associated with the stiffer, RAP material

NJDOT HRAP - Performance

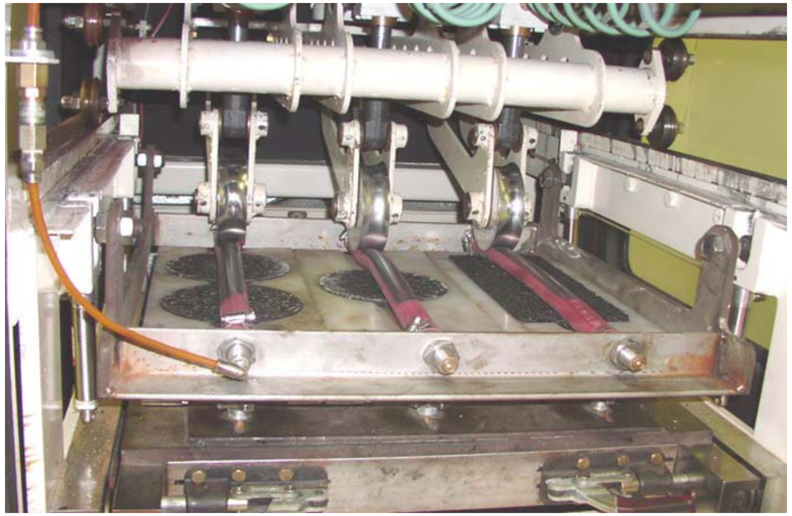
- Minimum of 20% RAP in Surface Course
- Minimum of 30% RAP in Intermediate/Base
- Lab design and plant produced material must meet rutting (APA) and cracking (Overlay Tester) requirements

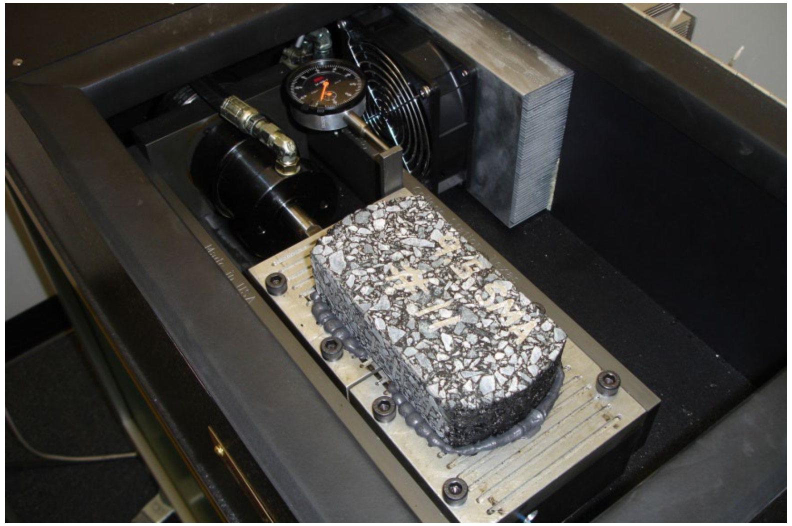
Table 902.11.03-2 Performance Testing Requirements for HMA HIGH RAP Design

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)	> 200 cycles	> 275 cycles	> 100 cycles	> 150 cycles

NJDOT Performance Related Specifications (PRS)

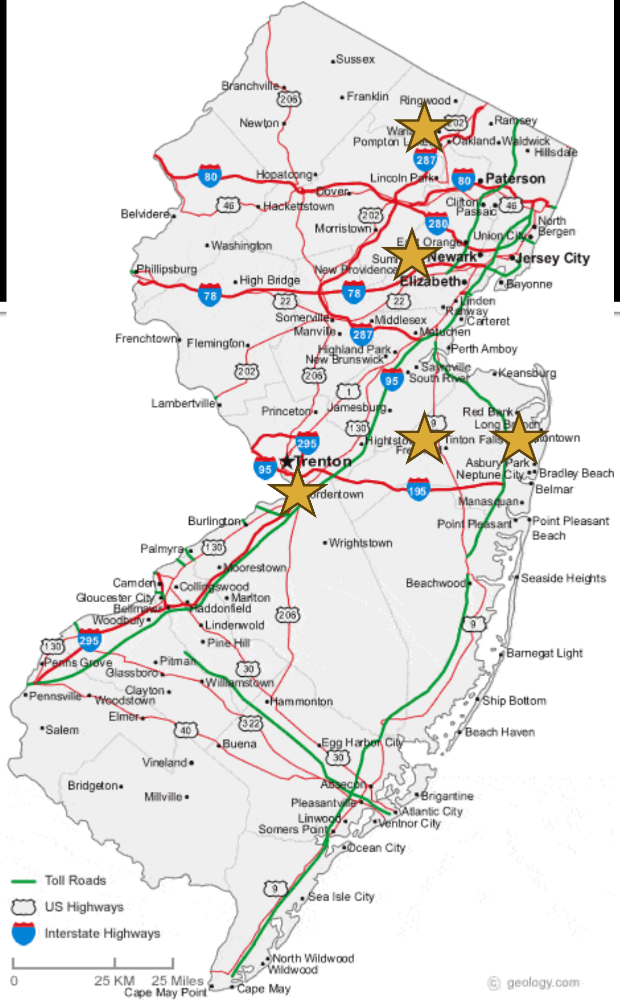
- NJDOT developed PRS using the Asphalt Pavement Analyzer (AASHTO T340) and Overlay Tester (NJDOT B-10)
  - Flexural beam fatigue used for BRBC and BDWSC mixes
- Criteria established for different mixes based on research and field performance history





NJDOT 2012 HRAP Projects

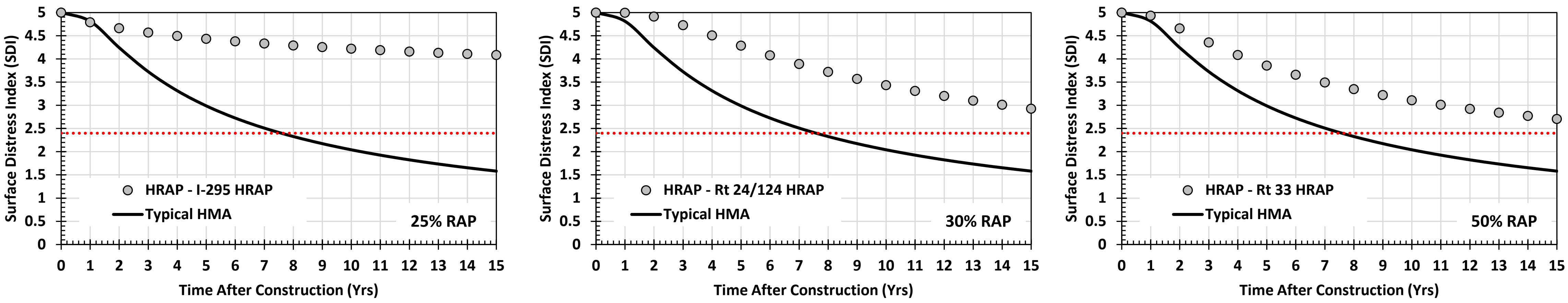
- I295 *(14 Yrs)*
  - 25% RAP Surface, Engineered Binder
  - 35% RAP Intermediate, Engineered Binder
- Rt 24/124 - 30% RAP, Engineered Binder *(10 Yrs)*
- Rt 15/23 - 30% RAP, RA *(10 Yrs)*
- Rt 33 - 50% RAP, RA *(7 Yrs)*
- Rt 36 - 50% RAP, RA *(7 Yrs)*
- Projects used a combination of "strategies" to overcome aged/oxidized asphalt binder of RAP
  - NJDOT requires 1% increase in VMA to increase effective asphalt content (i.e. – Reduced RBA of RAP)



NJ Route	HRAP Strategy		
	RA	Reduce RBA	Subs. Binder
I295		X	X
Rt 9 & 36	X	X	
Rt 15 & 23	X	X	
Rt 24 & 124		X	X
Rt 33	X	X	

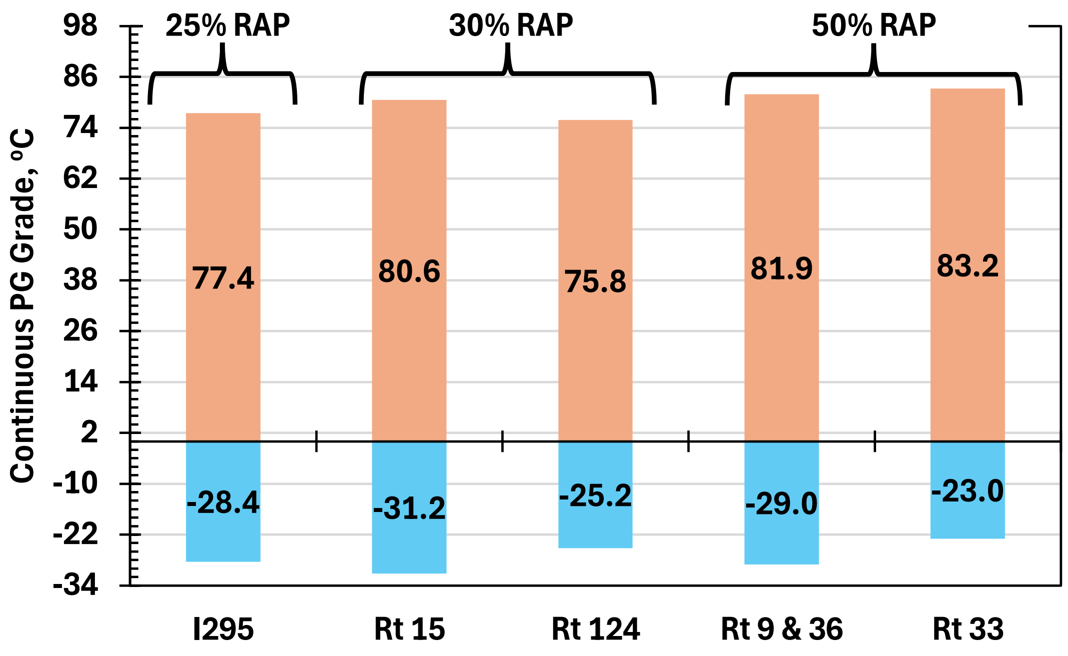
NJDOT 2012 HRAP Projects

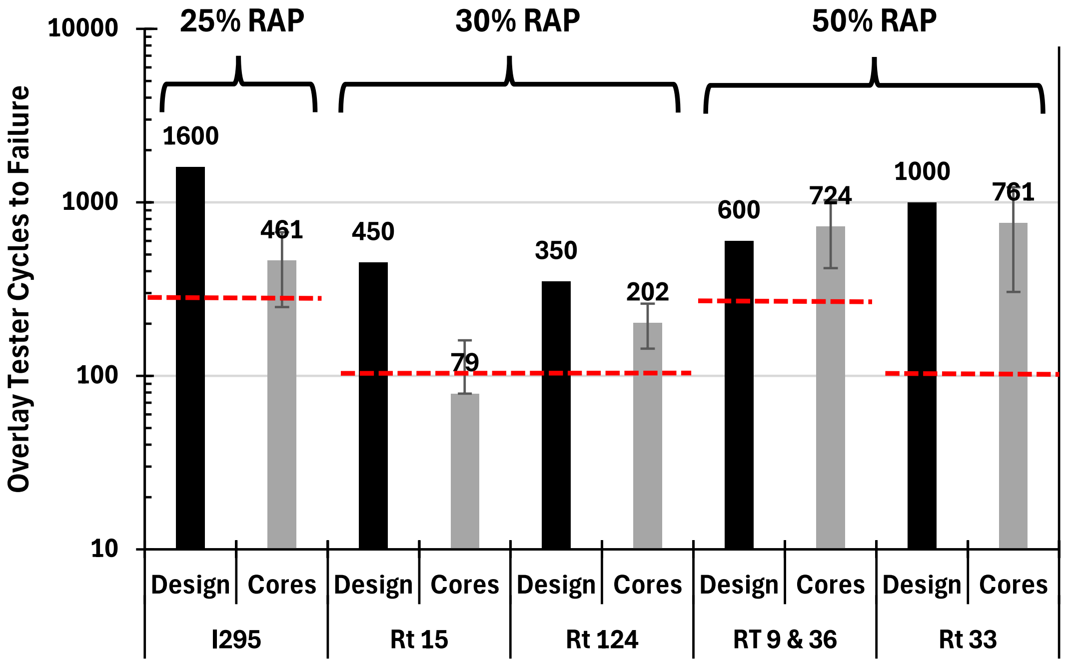
- Pavement Management System (PMS) data used to assess predicted pavement performance vs conventional HMA
  - 2025 PMS data showed that the use of the HRAP specification provides improved pavement performance over conventional HMA
    - Improved service life predicted to be from 7 to conservatively 12 years over conventional HMA



NJDOT 2012 HRAP Projects

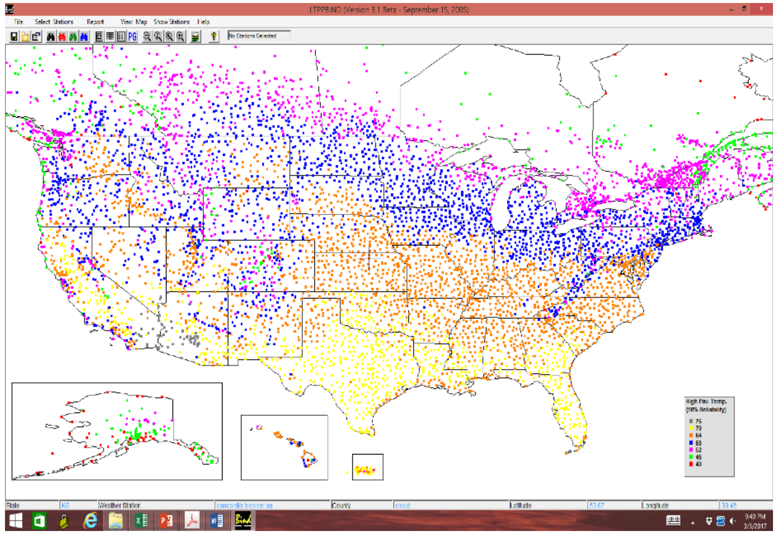
- Field cores recovered and evaluated in Fall 2024 for asphalt mixture and binder performance
  - Recovered binders (top ½") still met low temp PG grade of -22°C
  - Performance criteria (red line) was easily achieved during initial production
  - Only Rt 15 cores had value "below" threshold for cracking

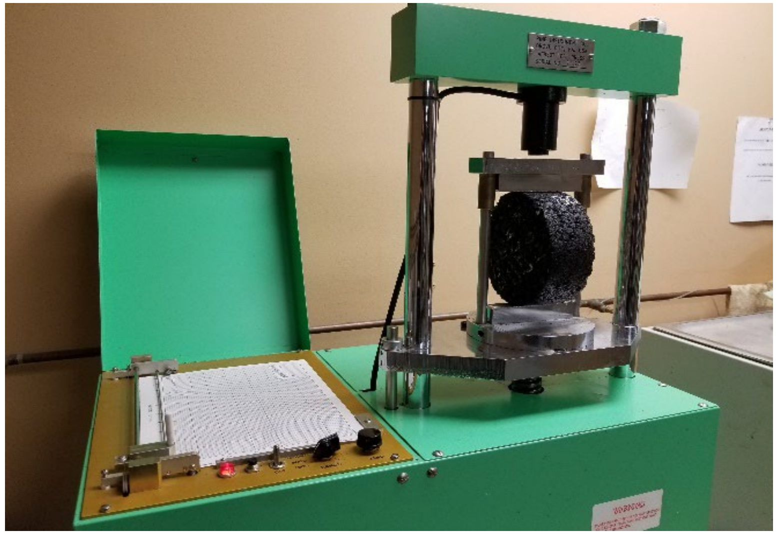




NJDOT HRAP 2024 – Rutting: High Temperature IDT, HT-IDT

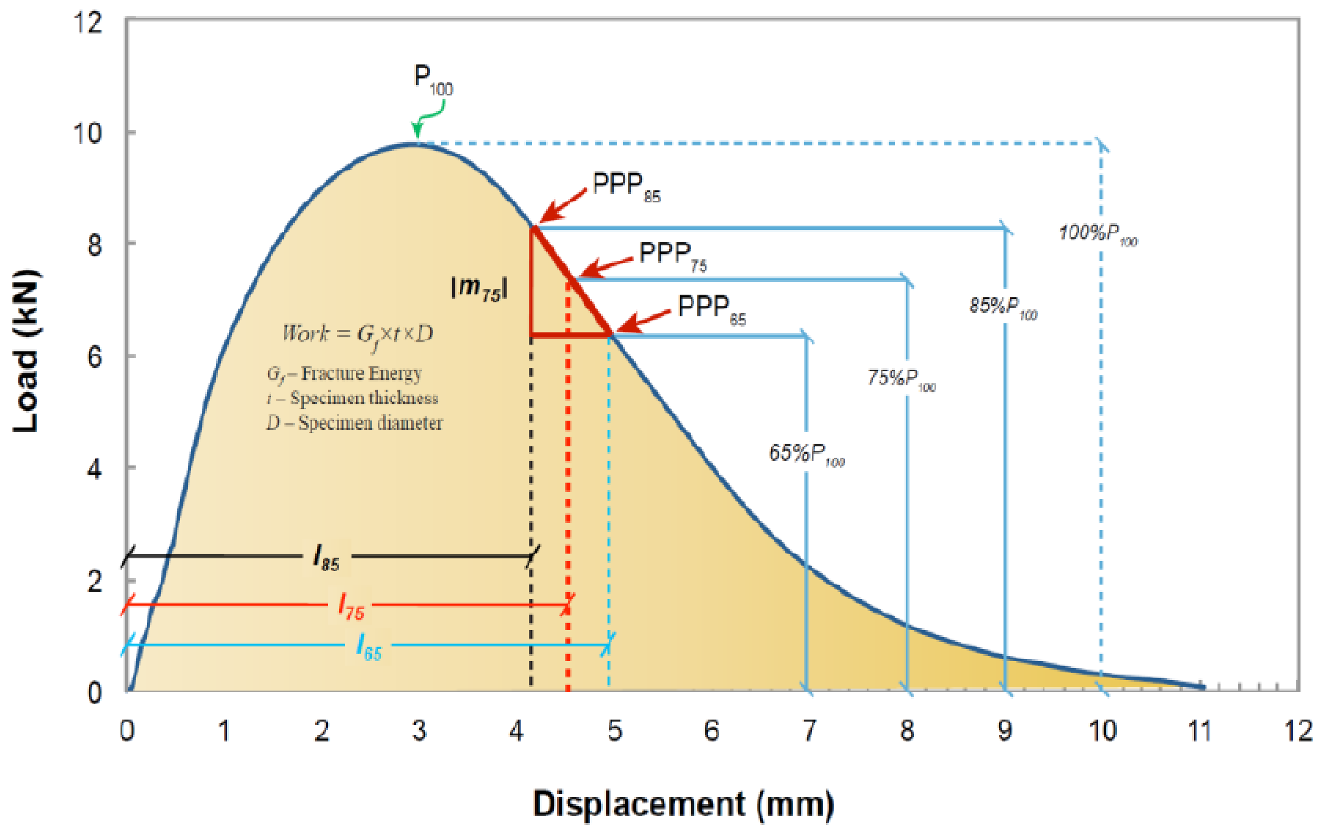
- High temperature IDT (NCHRP 9-33 Recommendations)
  - Uses TSR IDT frame with Lottman head (used for TSR; AASHTO T283)
  - Gyratory compacted samples (set air void level to specified)
  - 50 mm/min (2 inch/min) deformation rate
  - Test temperature is 10°C lower than local climate (LTPPBind 3.1, 98% Reliability, 20 mm below surface, not corrected for traffic or vehicle speed)
    - For NJ = 44°C





NJDOT HRAP 2024 - Fatigue Cracking: IDEAL-CT

- Fatigue Cracking (ASTM D8225)
  - Uses TSR IDT frame with Lottman head (used for TSR; AASHTO T283)
  - Gyratory compacted samples (set air void level to specified)
  - 50 mm/min (2 inch/min) deformation rate
  - Test temperature is 25°C

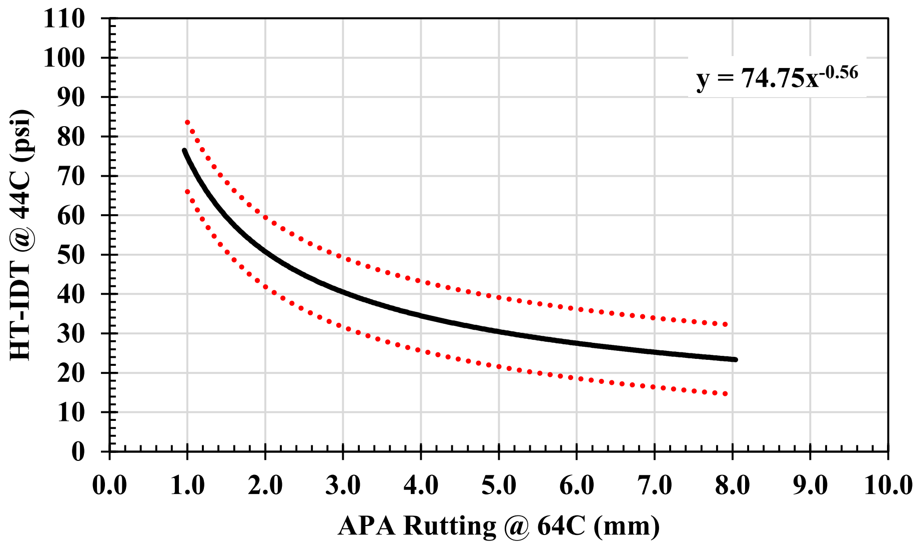


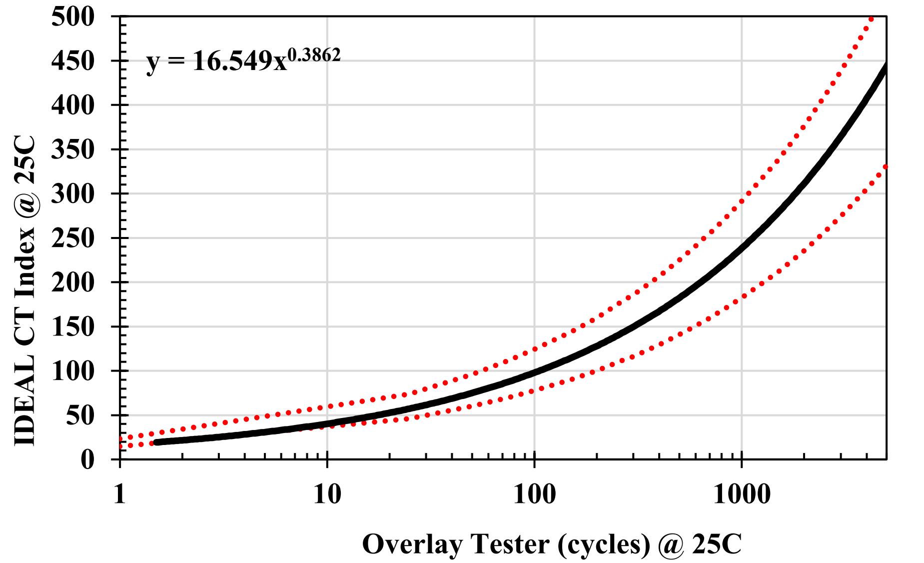
For 62 mm thick specimens: $CT_{Index} = \frac{G_f}{|m_{75}|} \times \left(\frac{l_{75}}{D}\right)$

For non-62 mm thick specimens: $CT_{Index} = \frac{t}{62} \times \frac{G_f}{|m_{75}|} \times \left(\frac{l_{75}}{D}\right)$

NJDOT HRAP – 2024 Revisions

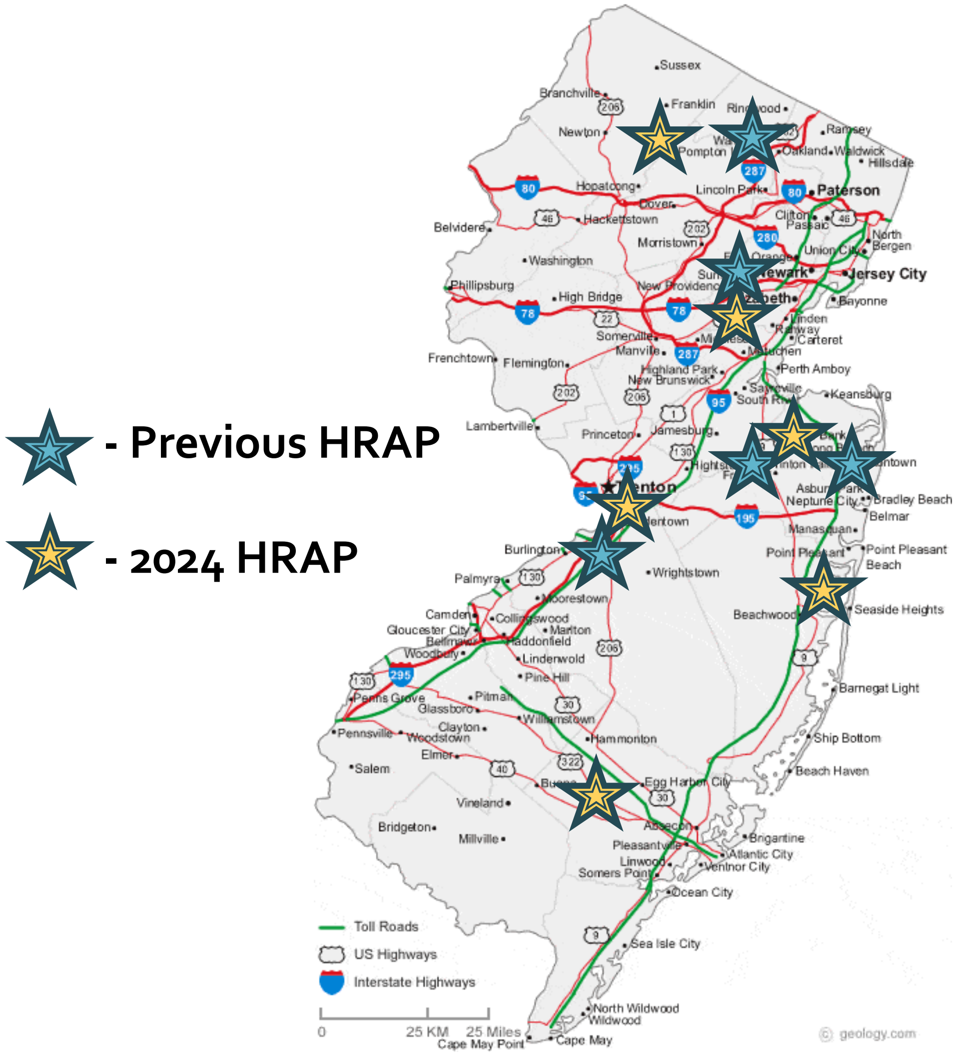
- Performance Testing (BMD)
  - Test specimens 6 to 7% AV
  - Rutting (n = 132)
    - APA Rutting @ 64C ≈ HT-IDT Strength @ 44C
  - Fatigue Cracking (n = 185)
    - Overlay Tester @ 25C ≈ IDEAL-CT Index @ 25C
  - If failing IDT tests occur, additional samples tested for Overlay Tester and APA for verification





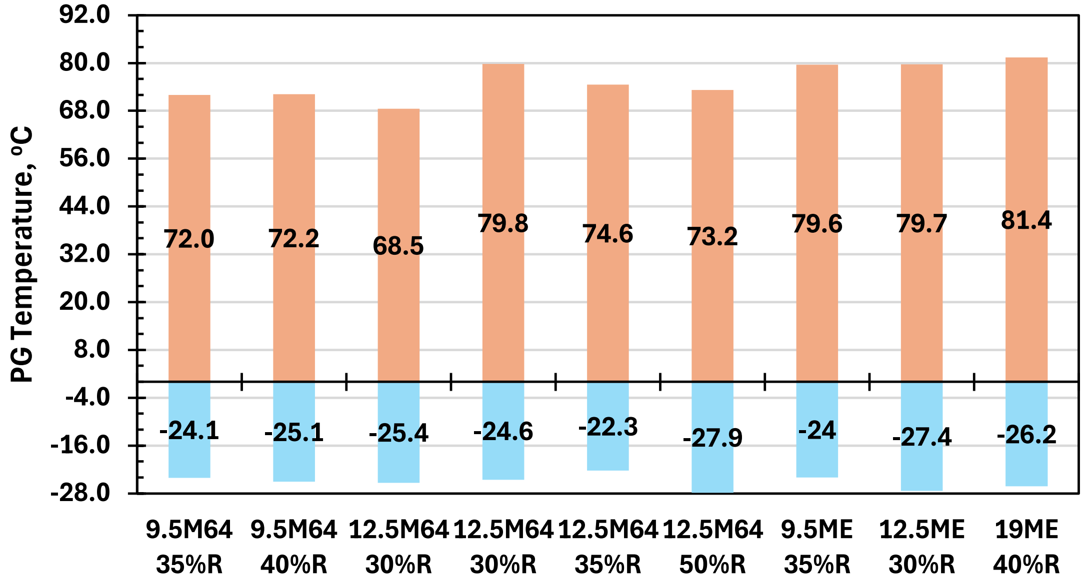
NJDOT HRAP – 2024 Projects

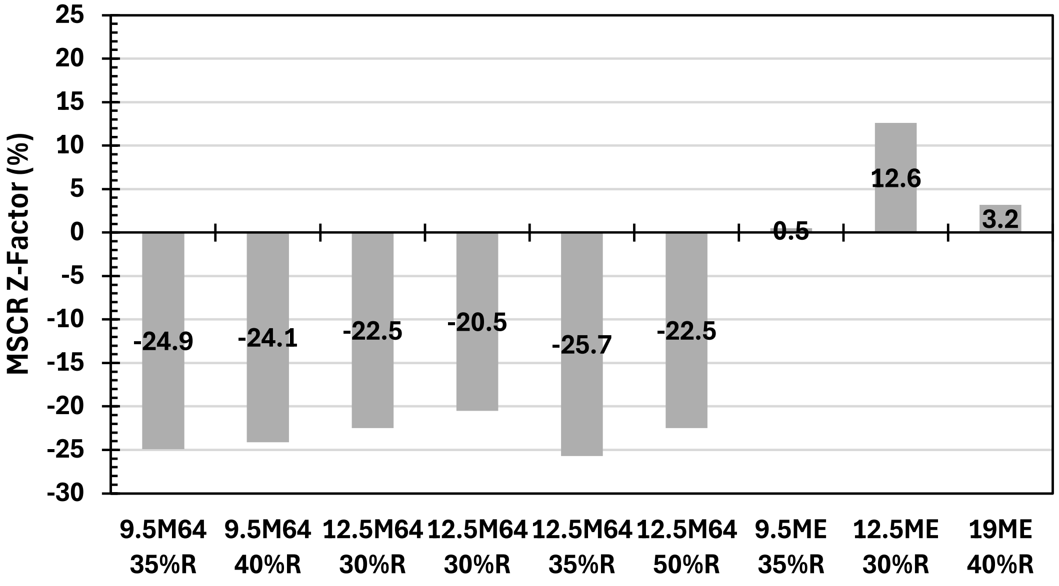
- 6 projects advertised for 2024 for HRAP
  - 2 projects per NJDOT region (North, Central, South)
  - Sampling and specimen compaction was conducted at plant
    - Sampling occurred every 700 tons to coincide with plant's QC testing
      - Lot #1 – Samples 1, 2, 3
      - Lot #2 – Samples 4, 5, 6
      - Random numbers generated to select 3 specimens for rutting & 3 specimens for cracking
    - Performance testing every 1400 tons or at least per night (whichever comes first)



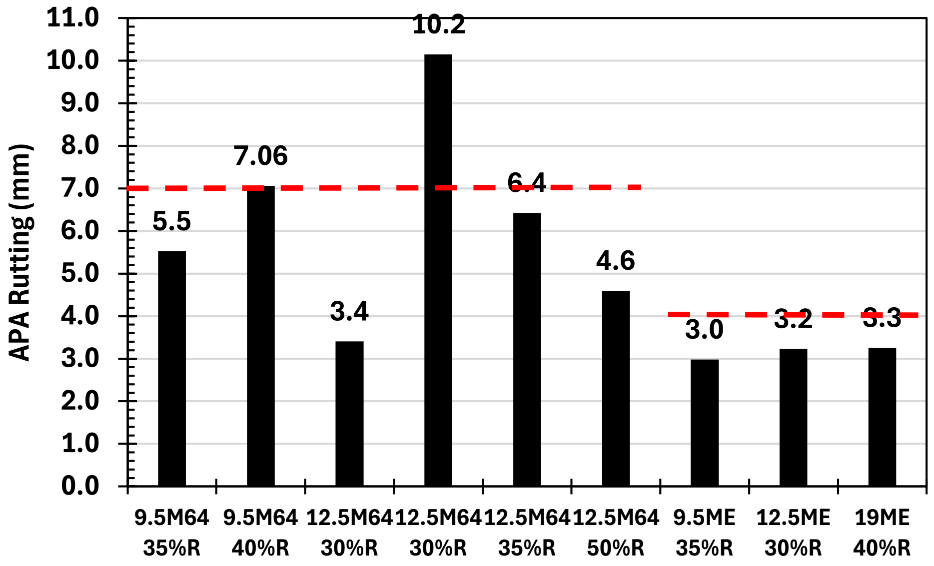
Recovered Binder Properties

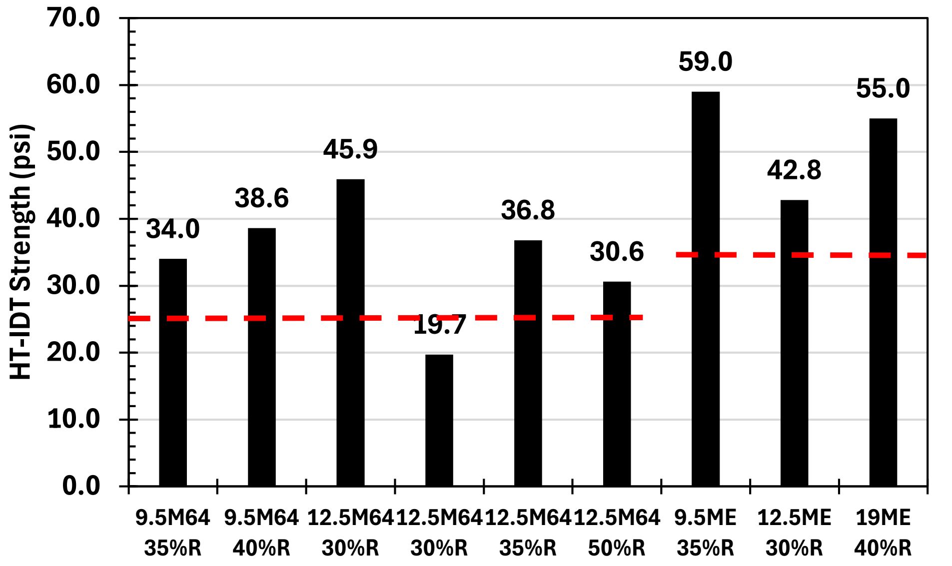
- Binder recovered from sampled loose mix
  - Produced met specified
    - Average PG grade of RAP sources: **PG94-10**
  - Polymer mixes showed reduction in elastomeric response
    - Z-factor = 20 to 24% for PG64E binders provided to NJ

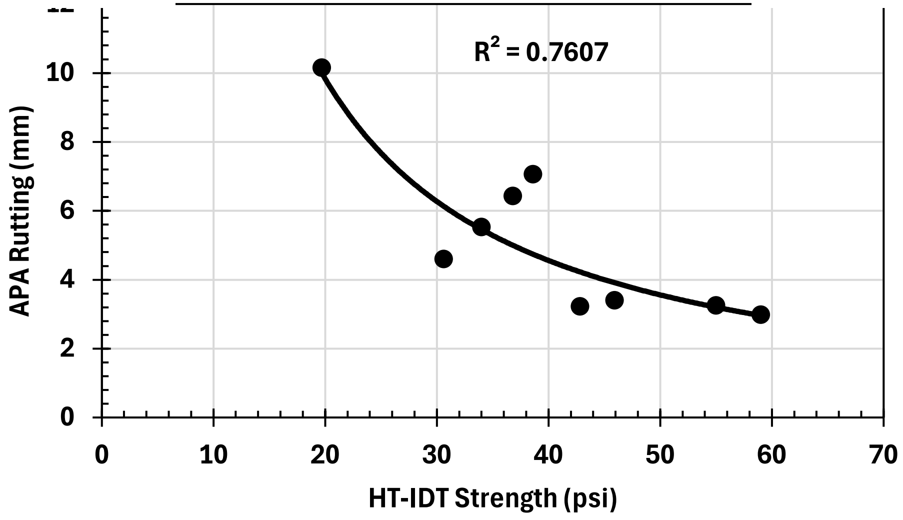




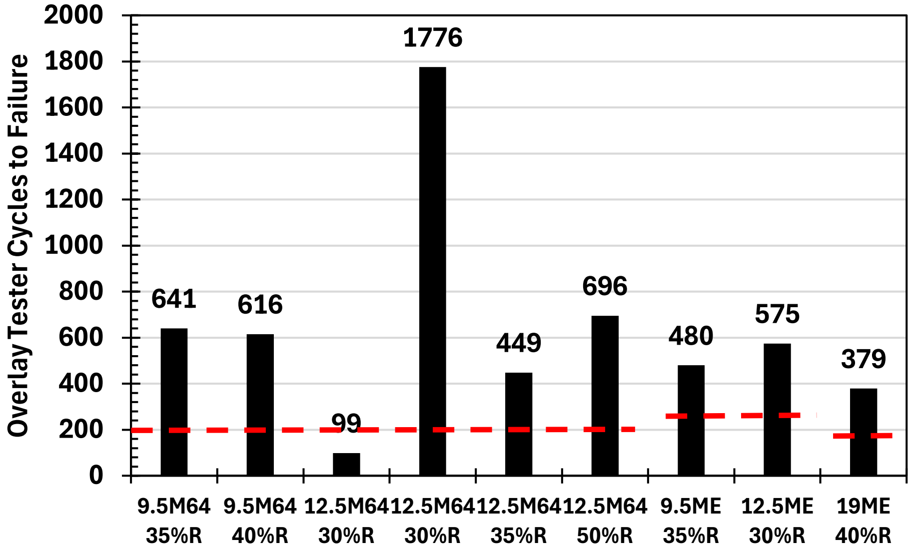
Rutting Mixture Performance

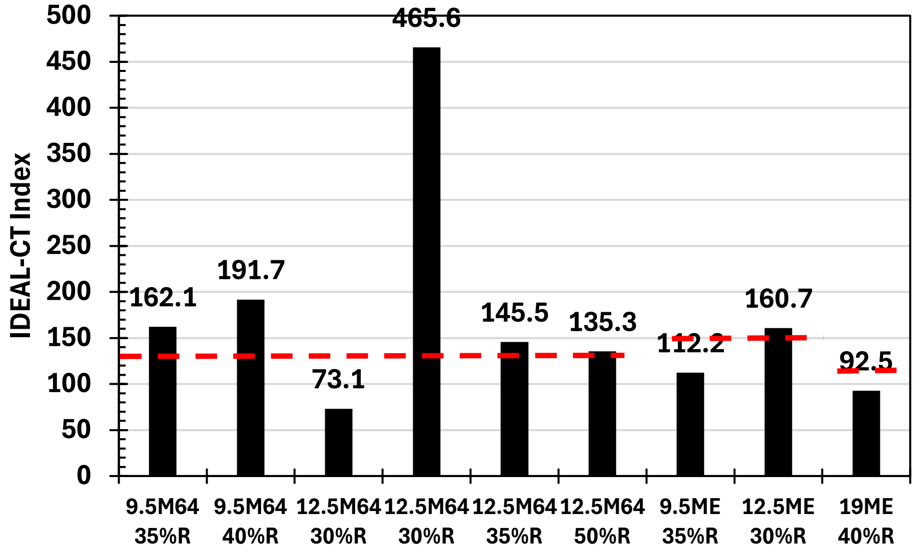


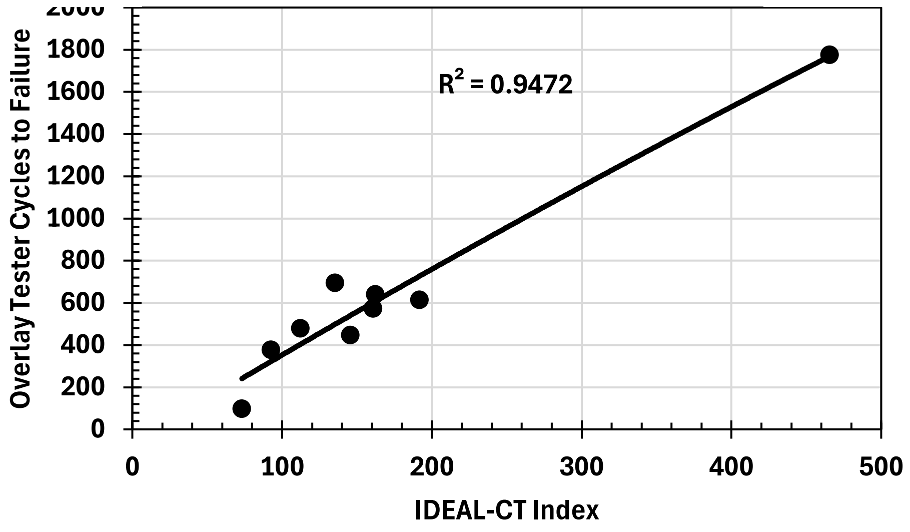




Cracking Mixture Performance







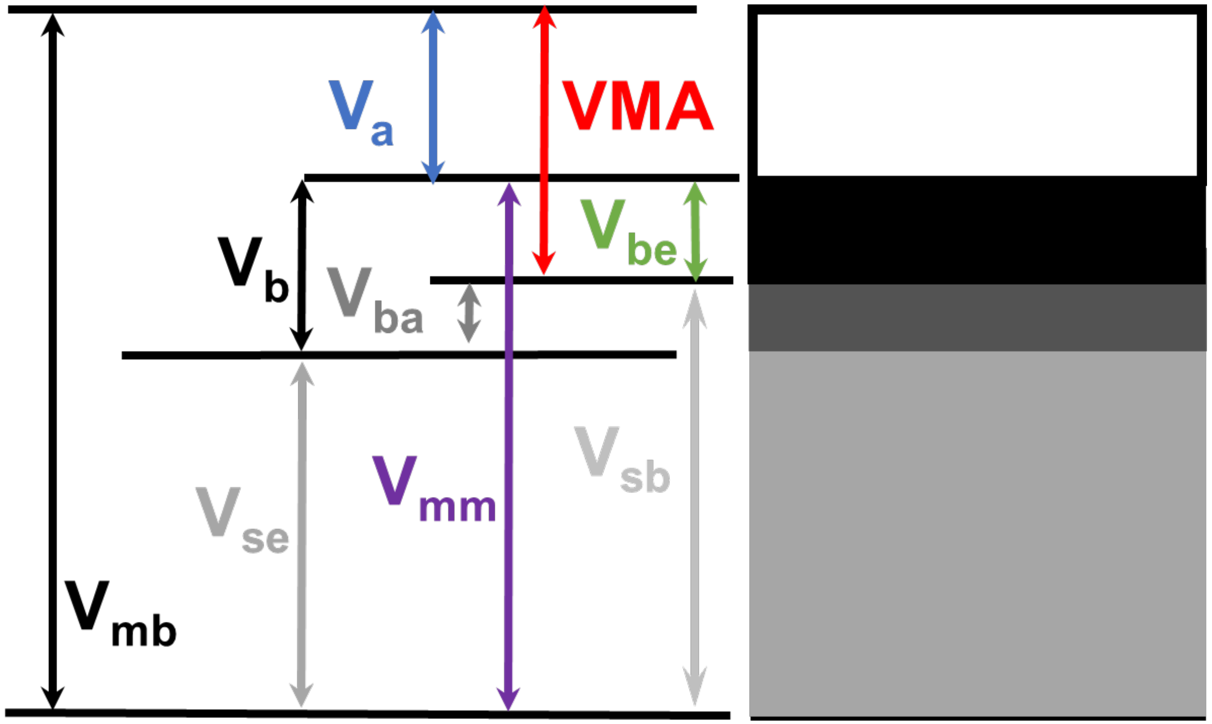
Plant Mix Performance vs Plant Volumetrics

- Statistical analysis indicated that;
  - IDEAL-CT Index correlated strongest to VFA at the plant (higher VFA, higher IDEAL-CT Index
    - Plant AV (lower AV, higher IDEAL-CT Index)
    - Plant AC% (higher AC%, higher IDEAL-CT Index)
    - RAP % (lower RAP, higher IDEAL-CT Index)
  - HT-IDT Strength correlated strongest to PG Grade and Jnr
    - Plant VFA (lower VFA, higher HT-IDT)
    - ¾", ½", and 3/8" Sieves (lower % passing, higher HT-IDT)
  - However, as binder/mix stiffness increased, poorer the correlations to mixture volumetrics

Mixture Performance Testing & Balanced Mixture Design (BMD)

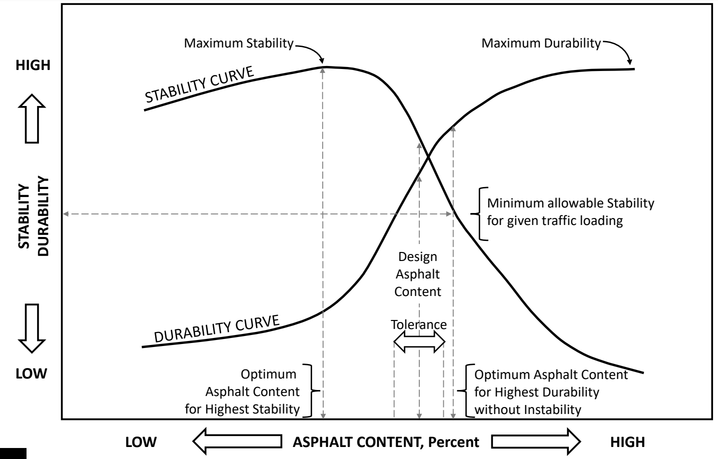
Binder in the Volume Matters!

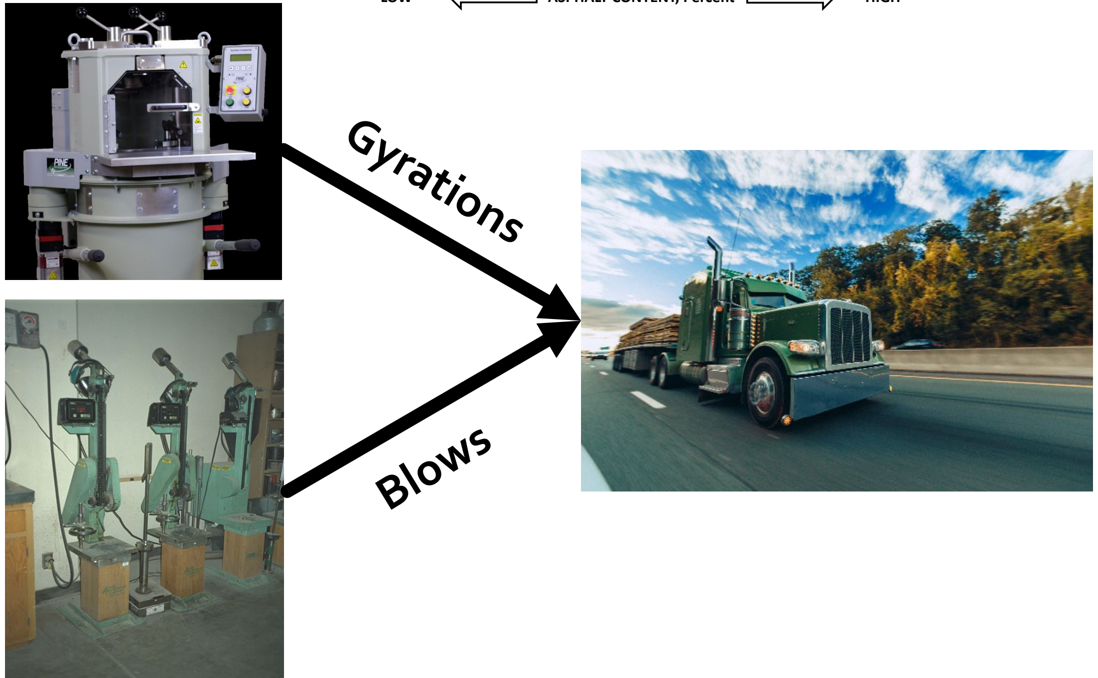
- We relied heavily on volumetrics for an idea on mix performance
  - "Easier" to test during production
  - In the past, mix constituents were simpler
- Current materials show a far greater range in volume stiffness
  - Neat to modified binders, RAP/RAS
- Our current mixture response is highly impacted by what is now in this volume



Design Air Voids – Where Did They Come From?

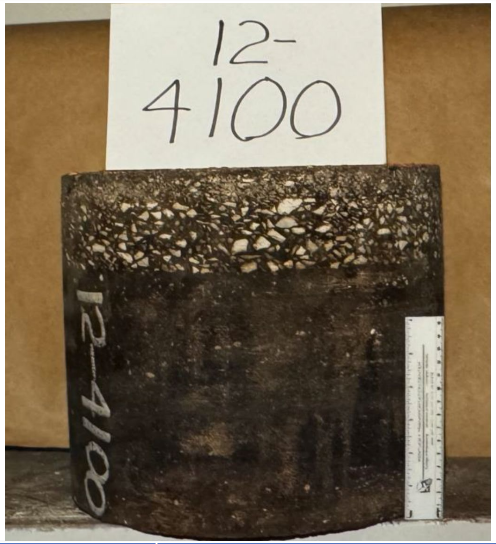
- Design AV% determine opt AC% (obviously influences Vbe)
- They were intended to represent in-place density in wheelpath after densification finished for "well performing" pavements
  - Hveem – less emphasis on air voids and more emphasis on stability but recognized importance of air voids on durability
  - Marshall (USACE) – calibrated laboratory compaction effort to densification that occurred with accelerating loading sections
    - General approach taken today where field densification levels are "calibrated" to gyrations

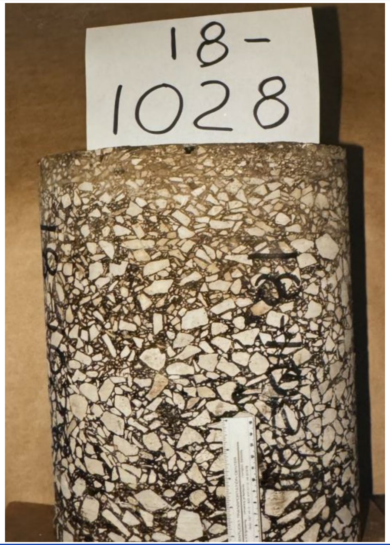




Design Air Voids & Gyration Table

- Superpave used methodology to develop Gyration Table
- Cored large number of in-service pavements
  - 12″ diameter cores
  - Determined Gmb and Gmm
  - Recovered binder and aggregates
  - Recompacted at identical proportioning using different gyration levels
  - Determine # of gyrations to achieve in-place density
    - Phil Blankenship M.S. Thesis!



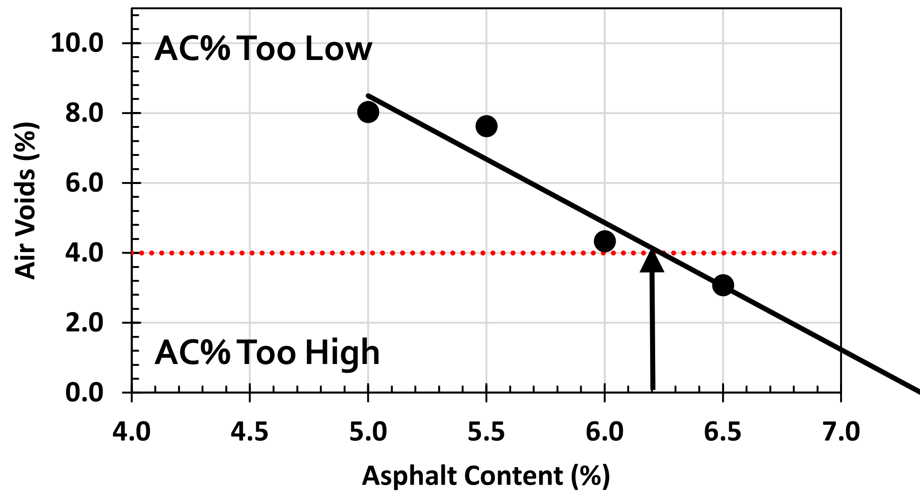


Design ESALs (millions)	Environment								
	Cool (<32°C)			Warm (32 – 38°C)			Hot (>38°C)		
	N_{ini}	N_{des}	N_{max}	N_{ini}	N_{des}	N_{max}	N_{ini}	N_{des}	N_{max}
<0.3	6	50	90	7	**72**	137	7	82	159
0.3 - 1	6	55	100	7	**81**	157	8	93	184
1 - 3	6	61	113	8	**92**	181	8	105	211
3 – 10	7	67	126	8	**103**	206	9	119	244
10 – 30	7	74	141	9	**118**	241	9	135	282
30 – 100	7	84	163	9	**136**	284	10	153	325
>100	8	93	184	10	**155**	330	10	172	372

SHRP Report, SHRP-A-408 (1994)

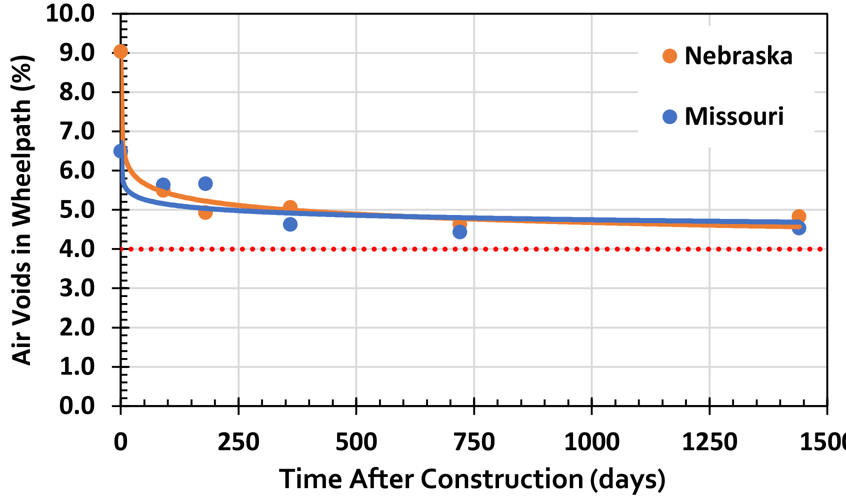
Design Air Voids & Wheelpath Densification

- Wheelpath Densification
  - Mix design assumes we want to optimize asphalt content to provide <u>stable and durable mix</u> after densification has taken place (i.e. ≈ 4% air voids)
    - Increase asphalt content when voids high – decrease asphalt content when voids low



Example: NCHRP 9-9A (2000 – 2006)

State	Initial AV%	4 Yr ΔAV%
Nebraska	9.0	-4.8%
Missouri	6.5	- 2.0%



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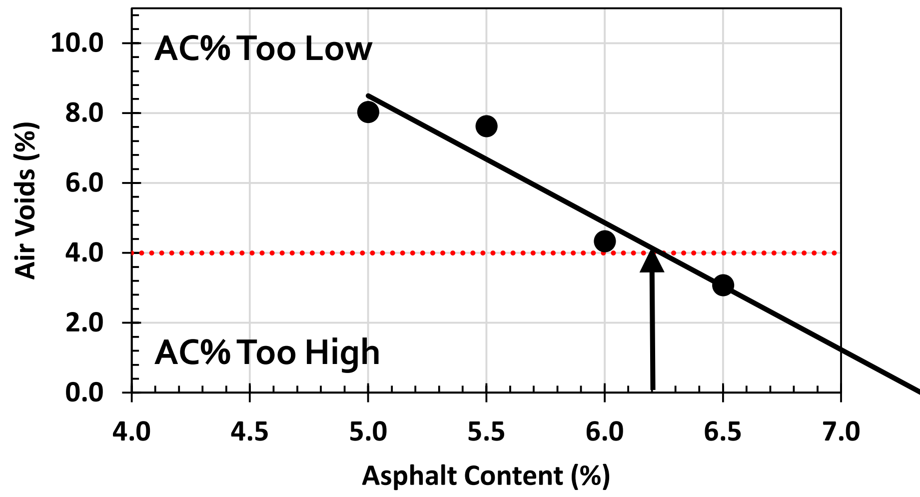
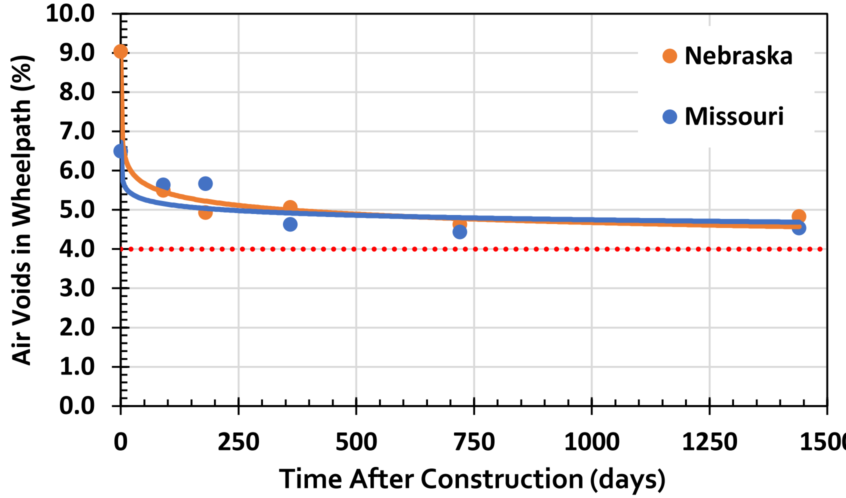
  - Mix design assumes we want to optimize asphalt content to provide <u>stable and durable mix</u> after densification has taken place (i.e. ≈ 4% air voids)
    - Increase asphalt content when voids high – decrease asphalt content when voids low



Example: NCHRP 9-9A (2000 – 2006)

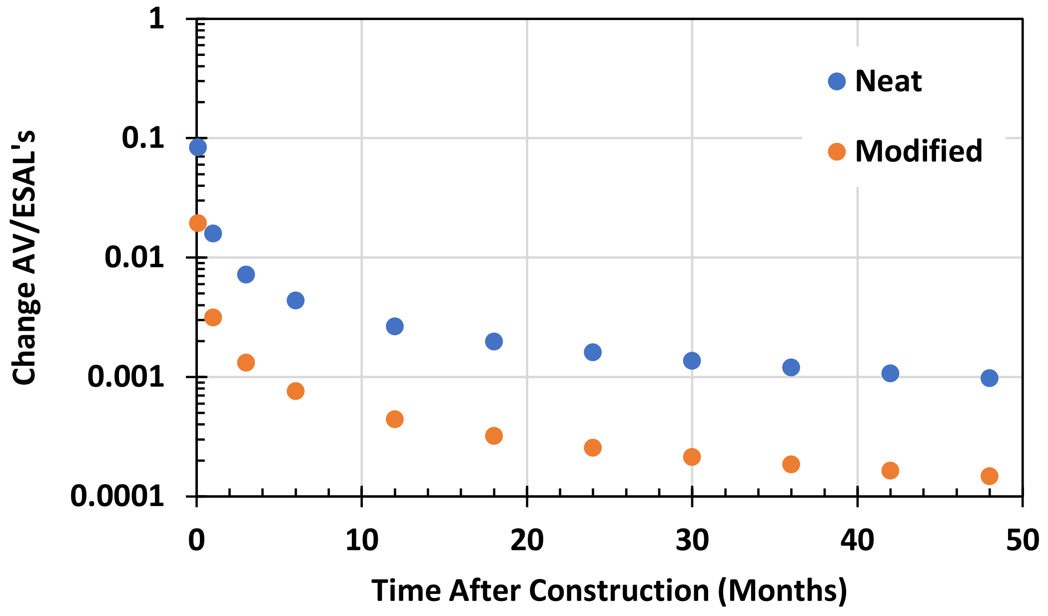
State	Initial AV%	4 Yr ΔAV%	4 Yr MESAL
Nebraska	9.0	-4.8%	0.068
Missouri	6.5	- 2.0%	8.4

Unmodified
PMA



Design Air Voids & Wheelpath Densification

- NCHRP 9-9A Data (Brian Prowell's Ph.D. thesis)
  - Pavements with neat binders consolidated at a rate 6 times more than modified binders (40 projects)
    - PMA densified less – analogous to densification from lower traffic or lower gyrations
  - According to volumetric mix design rules, if air voids above 4% after compaction, additional asphalt binder needed
    - For **same aggregate gradation**; lower gyration level ≈ increased AC
    - We do not take into consideration stiffness of binder with respect to densification
      - Equi-viscous temperature for mix design!

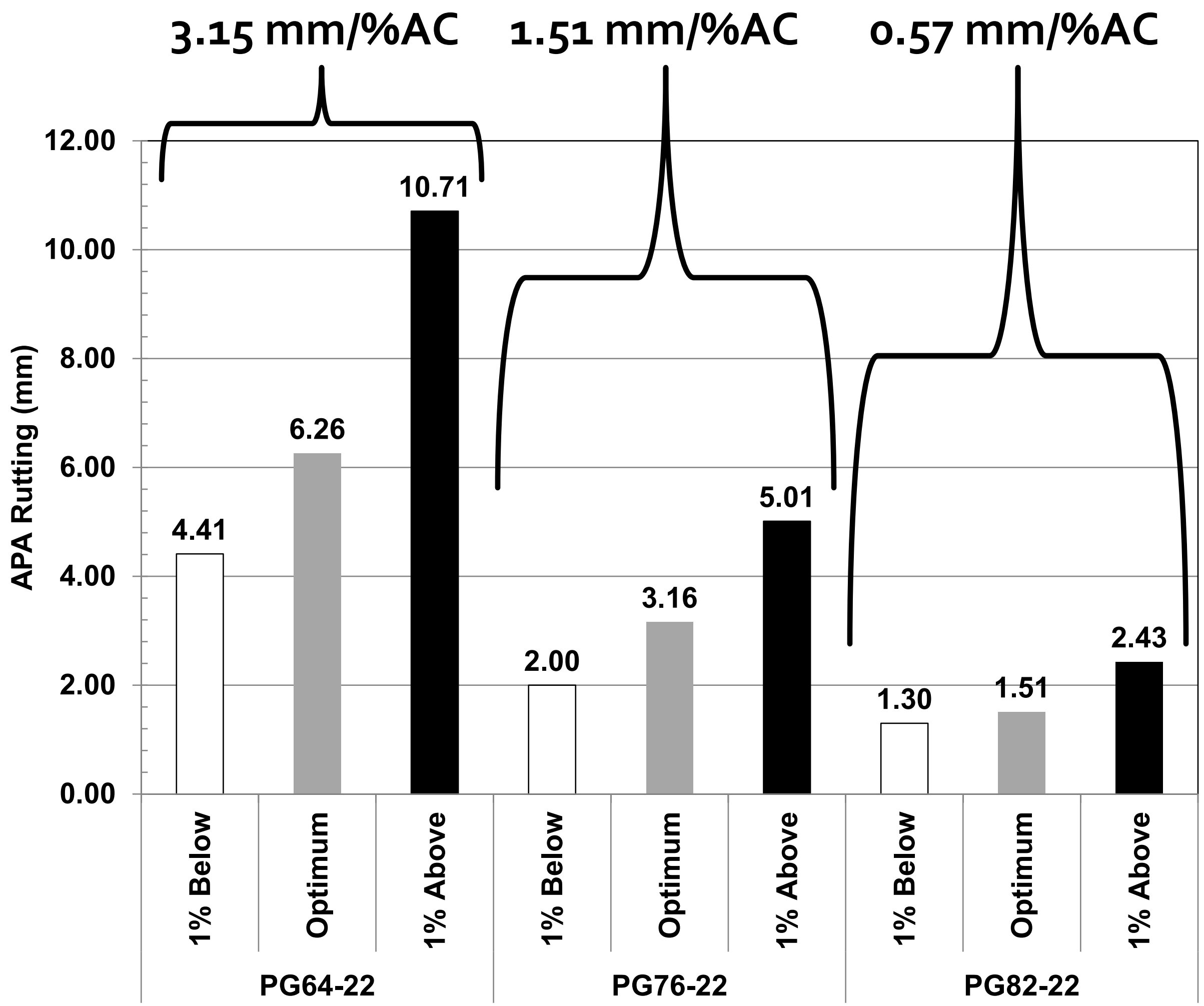


20 Yr MESAL's	N_{des} (<PG76)	N_{des} (>PG76)
< 0.3	50	N.A.
0.3 to 3	65	50
3 to 30	80	65
> 30	100	80

(Prowell & Brown, 2007)

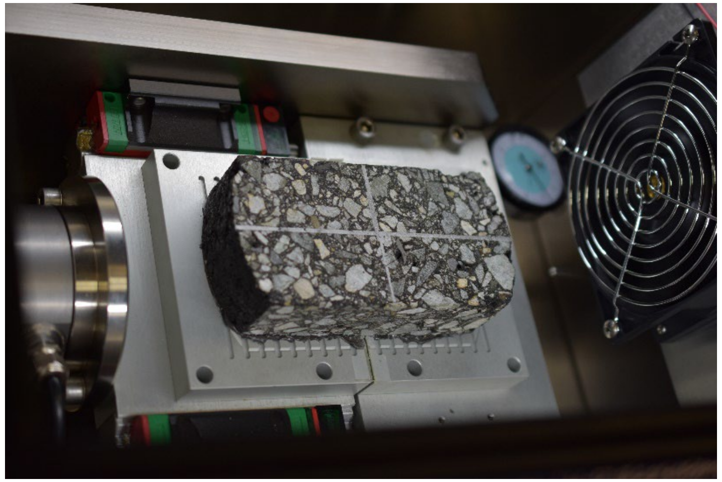
Early NJ BMD Research

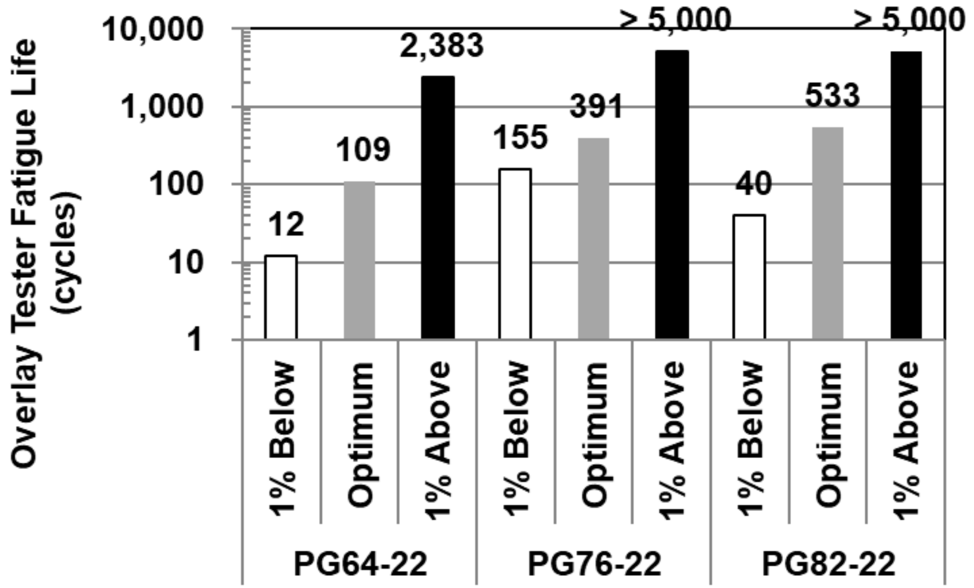
- Asphalt Pavement Analyzer Rutting (AASHTO T340)
  - As binder content increased, rutting increased
  - But magnitude lessened when binder grade improved
    - Volume (Vbe) of binder the same but what made up the volume was different (i.e. – stiffer binder in relationship to the test temperature)



Early NJ BMD Research

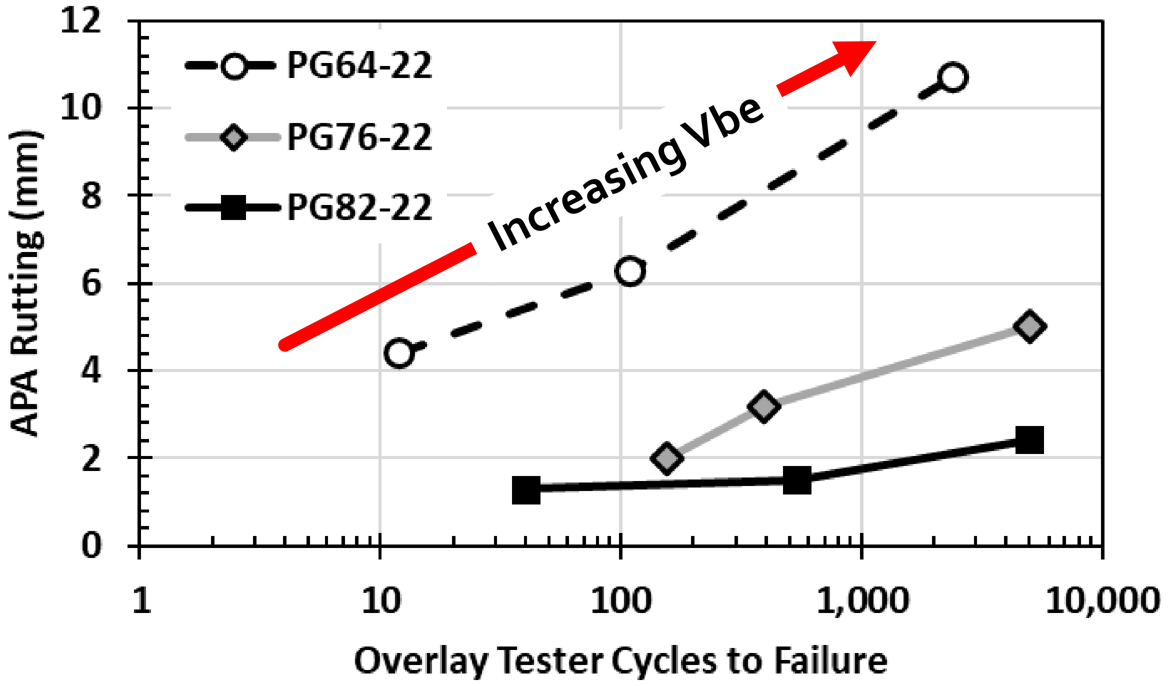
- Overlay Tester Cracking (NJDOT B-10)
  - As binder content increased, resistance to fatigue cracking improved
  - At low Vbe, all 3 binders were consistently poor in cracking performance
  - At higher Vbe, performance improved with PMA better than neat even at identical Vbe



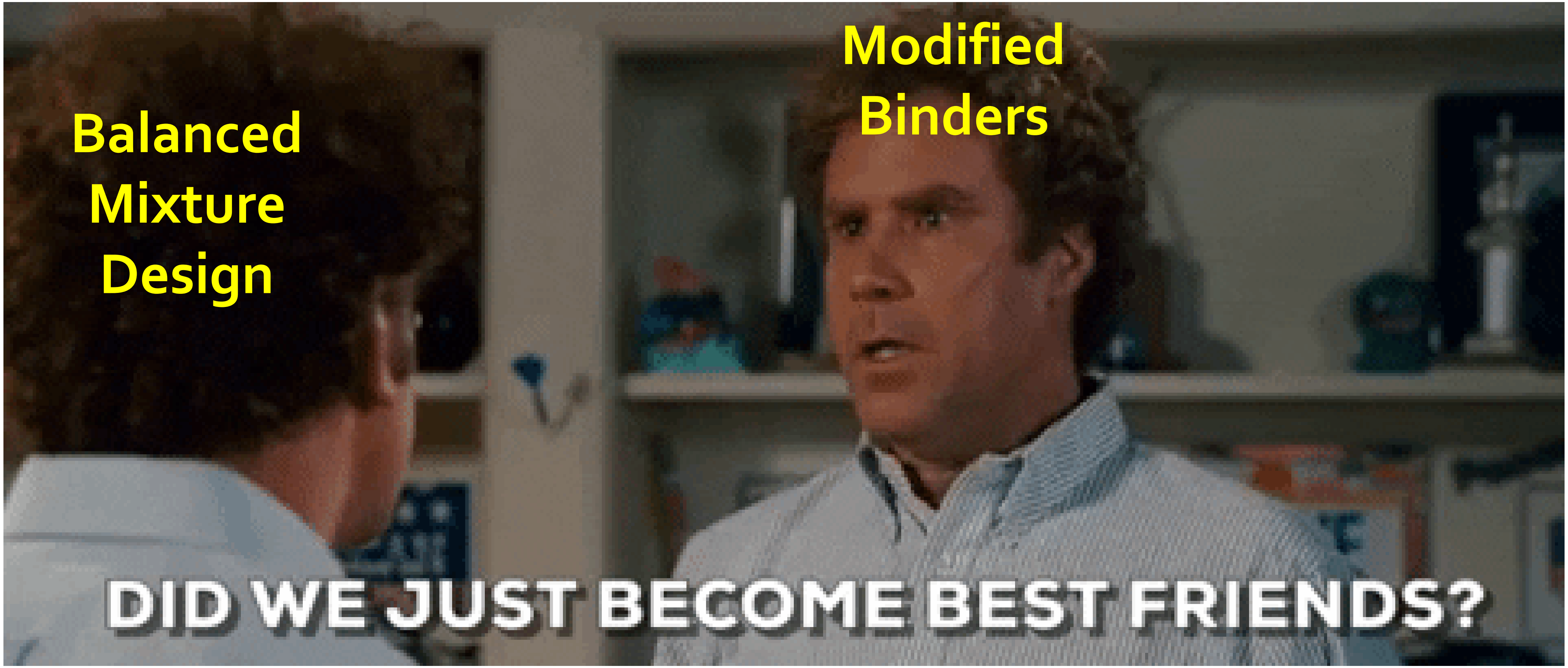


Early NJ BMD Research

- Mixture performance
  - To improve mixture performance, an increase in Vbe required to improve cracking resistance
  - In order to minimize potential for rutting, PMA (i.e. – stiffer binder) utilized
    - "BMD Cheat Code"



BMD and Modified Binders – Perfect Together!



Volumetric Criteria & Mixture Performance

Related Distress	Low End of Range	Volumetric Parameter	High End of Range	Related Distress
Bleeding/ Stability	1.5	AV% (Production)	5.0	Durability/ Rutting
Durability	Minimum	VMA (Production)	+2.0% of Min. (M323)	Rutting/ Stability
Durability	65	VFA (Design)	85	Rutting/ Stability/ Bleeding
Stability	0.6	#200/Pbe (Production)	1.3	Durability

Flexibility of Future BMD Specifications

- Flexibility comes with confidence!
- Aggregate Properties
  - Consensus and Source properties
- Asphalt Binder Properties
  - High Temperature
  - Low Temperature
  - Intermediate/Cracking(?)
- Volumetrics
  - Effective Binder properties, air voids

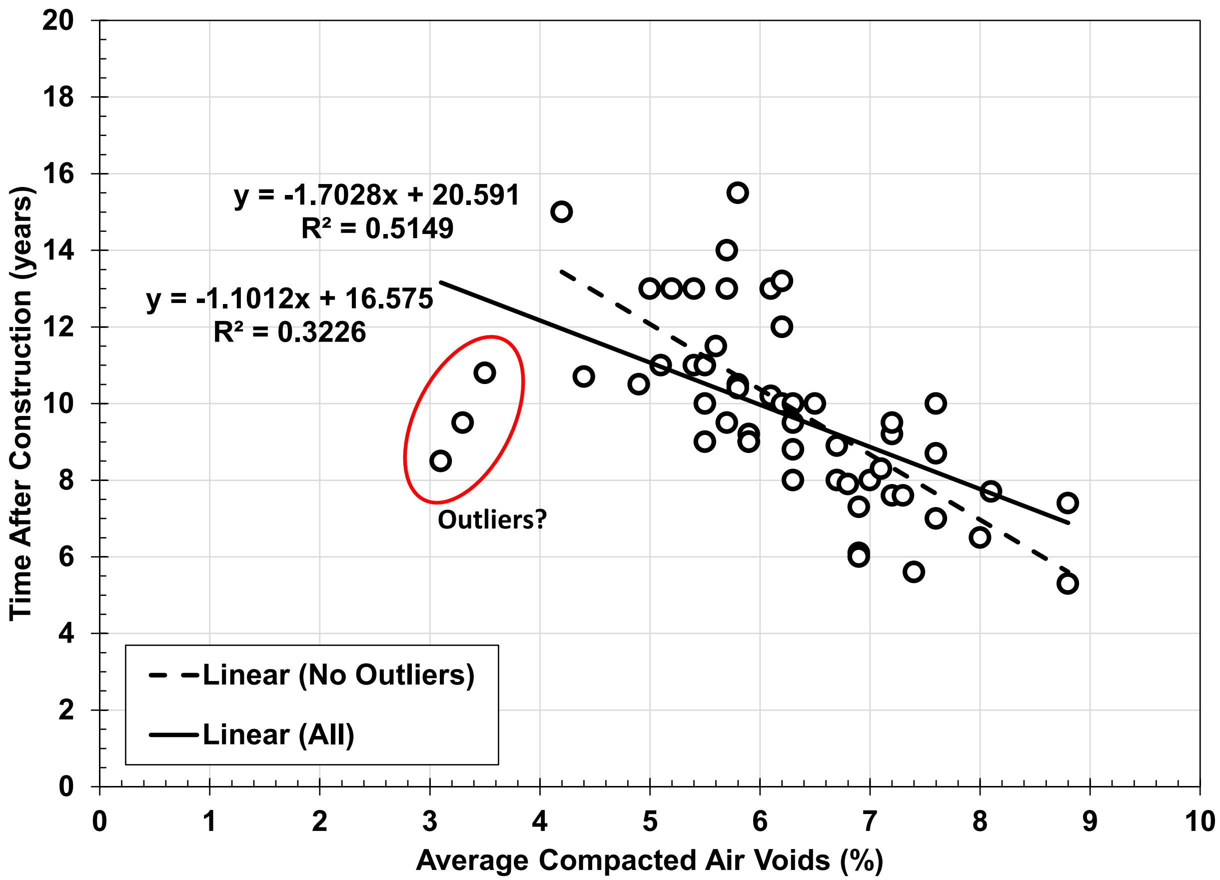
NAPA BMD IWG

Property		Example #1	Example #2	Example #3
Aggregates	FAA (T 304)	Min.	Report only	Report only
	CAA (T 335)	Min.	Min.	Report only
	Flat and Elongated Particles (ASTM D4791)	Max.	Max.	Max.
	Sand equivalent (T 176)	Min.	Min.	Min.
	LA abrasion (T 96)	Max.	Max.	Report only
	Polish Value (ASTM D3319)	Min.	Report only	–
	Natural sand content	Report only	–	Report only
Binder	Delta Tc (T 387)	Min.	Min.	Report only
	PGHT (M 320)	Min.	Min.	Report only
	PGLT (M 320; M 332)	Max.	Max.	Max.
	GRP (T 315)	Max.	Max.	Max.
	MSCR recovery (R 92)	Min.	Min.	Min.
Additives	Polymer content	Min.	Report only	Report only
	Antistrip type and dose	Min.	Report only	Report only
Design gyrations by traffic level (R 35)		Value	Value	Value
Va (M 323)		Range	Min.	–
VFA (M 323)		Max.	Report only	Report only
VMA (M 323)		Min.	Min.	Report only
$P_{0.075}/P_{be}$ (M 323)		Range	Range	Report only
Aggregate gradation		Report only	Report only	Report only
Design asphalt binder content		Report only	Report only	Report only
Design Va		Report only	Report only	Report only
Gmm (T 209)		Report only	Report only	Report only

“New” Paving Technologies & Trackless Tack

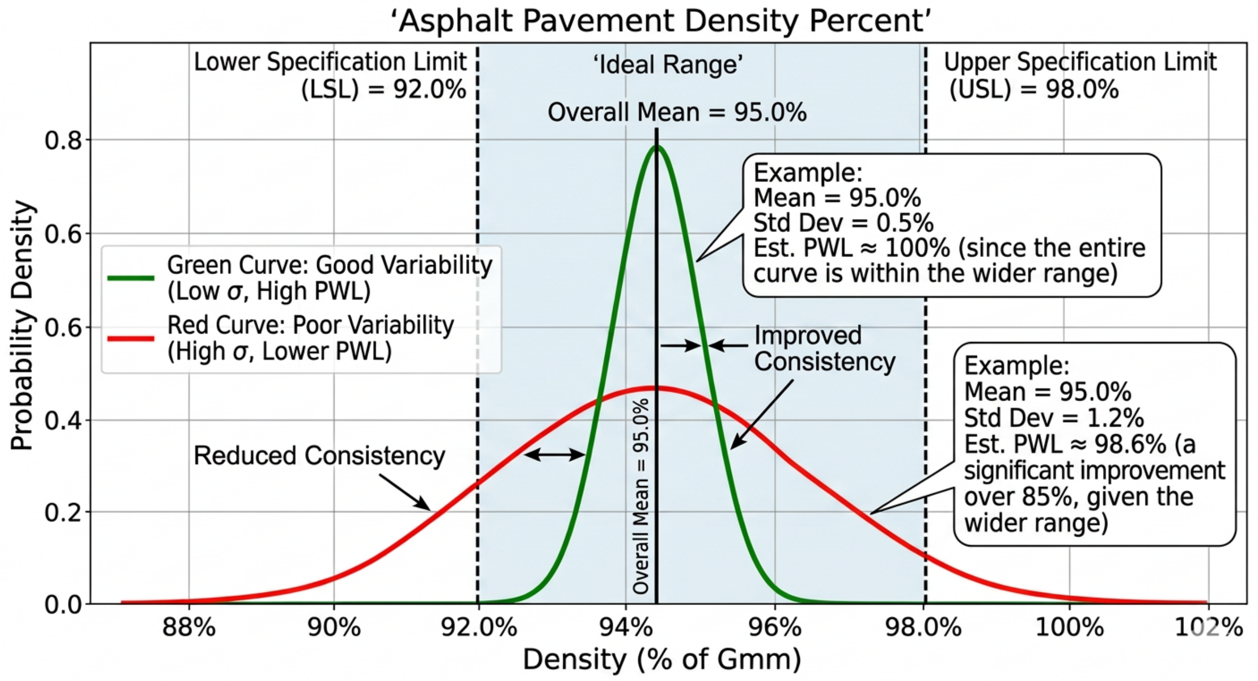
Improved Density for Improved Pavement Life

- In-place air voids has direct impact on pavement life
  - NJDOT study showed over 1 year of service life change per 1% air void level!
  - 2020 NJDOT study on field cores
    - 9.5 mm NMAS
      - Ave = 6.3% (Std Dev = 2.08%)
      - 18.7% of cores with air voids > 8%
    - 12.5 mm NMAS
      - Ave = 5.3% (Std Dev = 1.81%)
        - 6.6% of cores with air voids > 8%



In-Place Density Spec – Percent Within Limits (PWL)

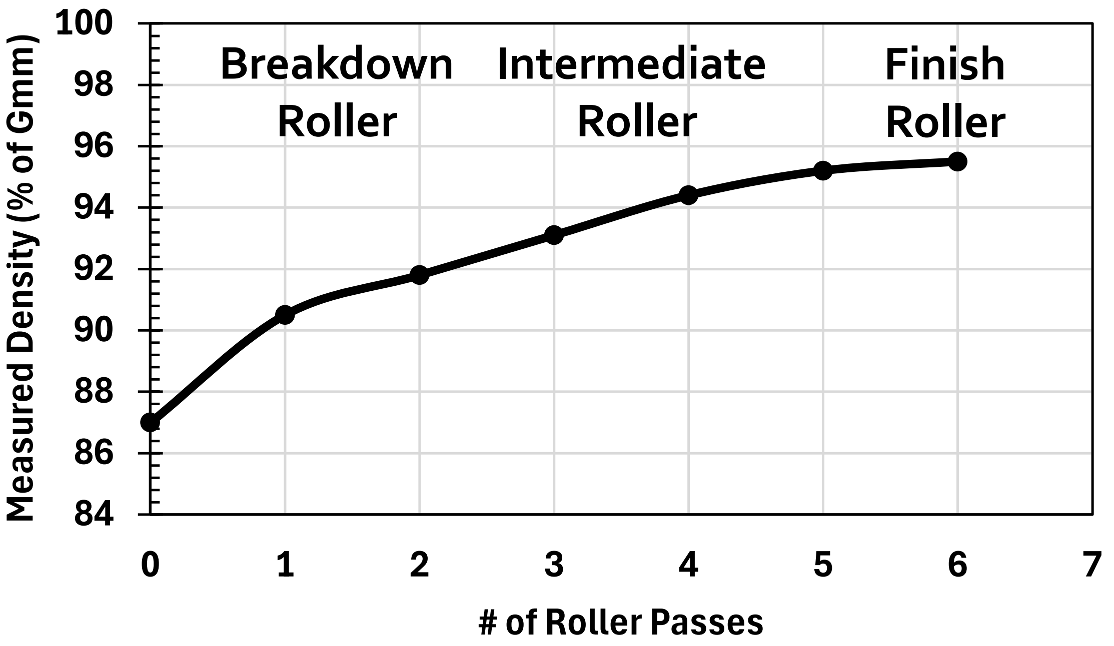
- In-place density requirements are based on achieving a desired value (mean) while minimizing variability (standard deviation, σ)
  - For pay adjustment, while achieving the same mean;
    - More consistency = better pay adjustment = **more $$**



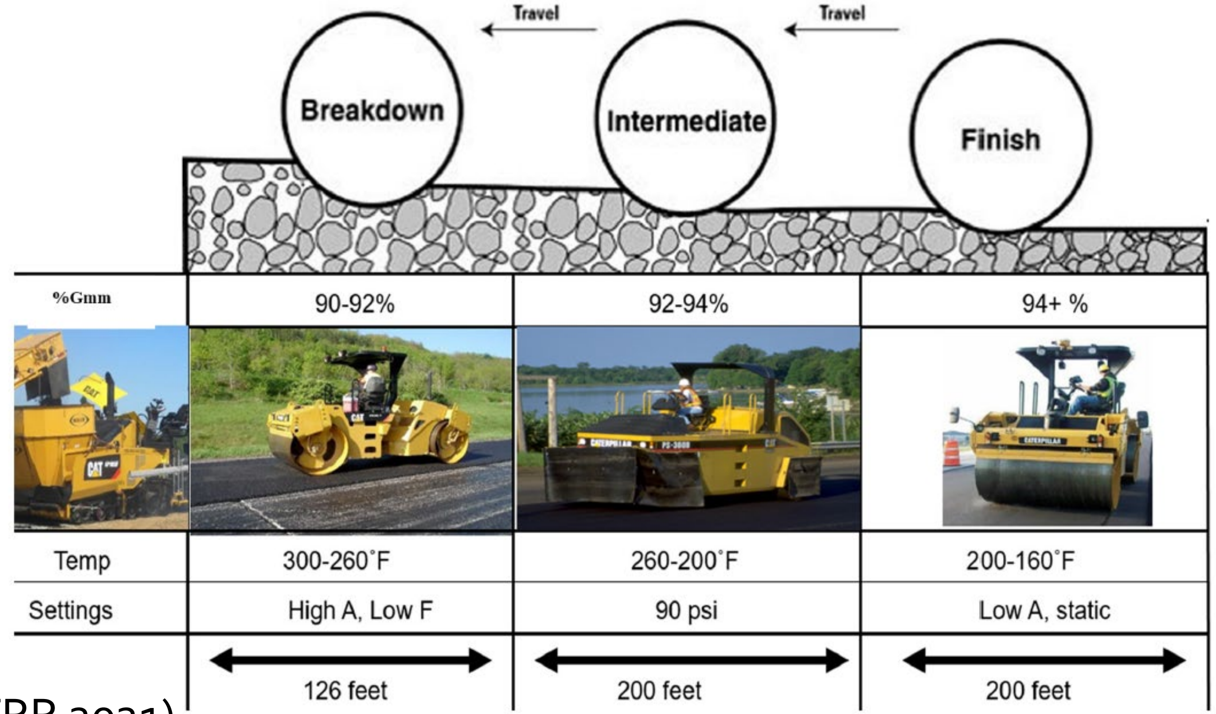
Improved Density for Improved Pavement Life

- Compactive energy important to achieve required in-place density
  - Typically 2 to 8% air voids (98 to 92% of Gmm)

Test Strip



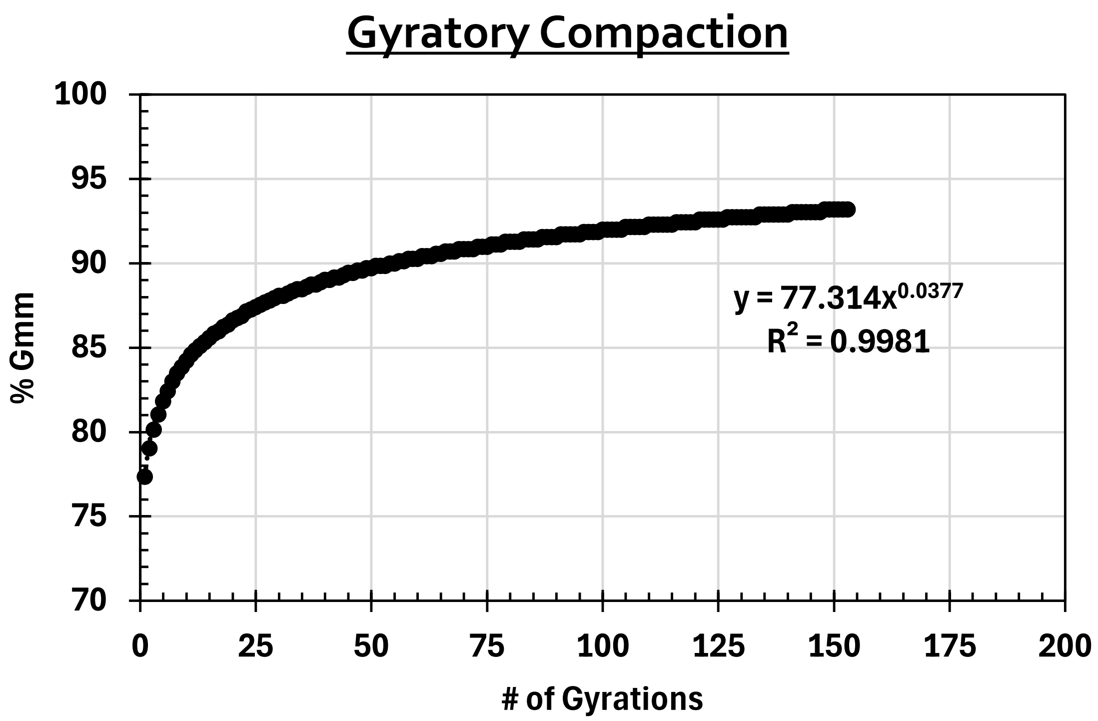
Test Strip



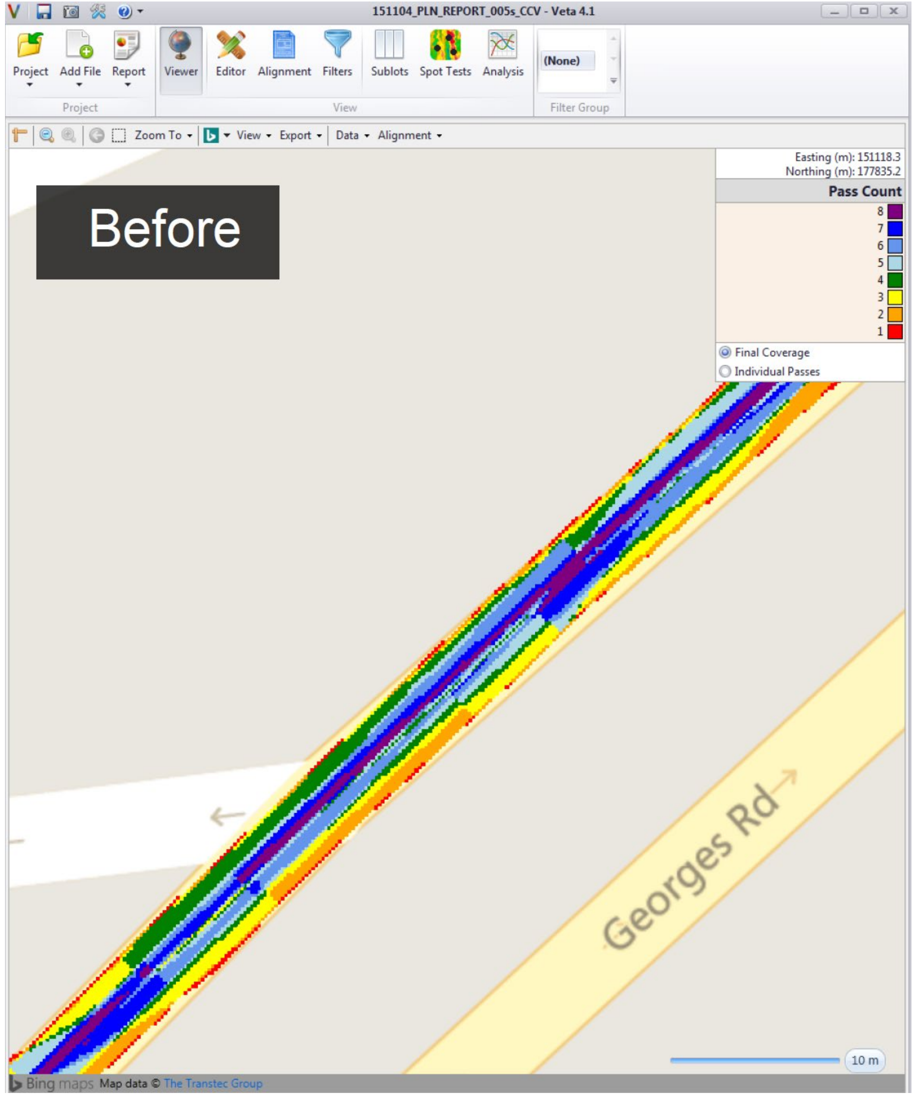
Hand et al. (TRR 2021)

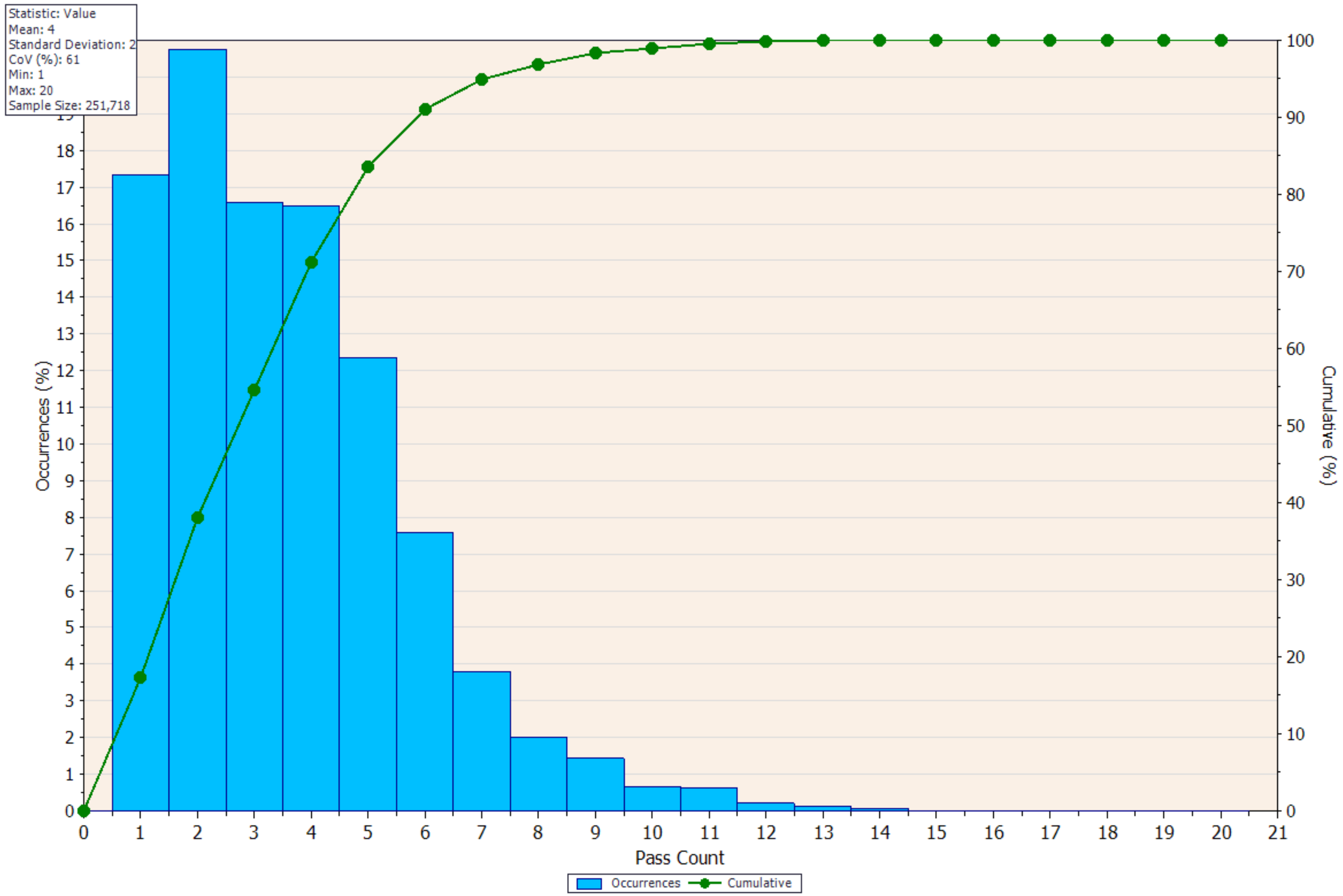
Improved Density for Improved Pavement Life

- Compactive energy important to achieve required in-place density
  - Design gyrations based on anticipated traffic



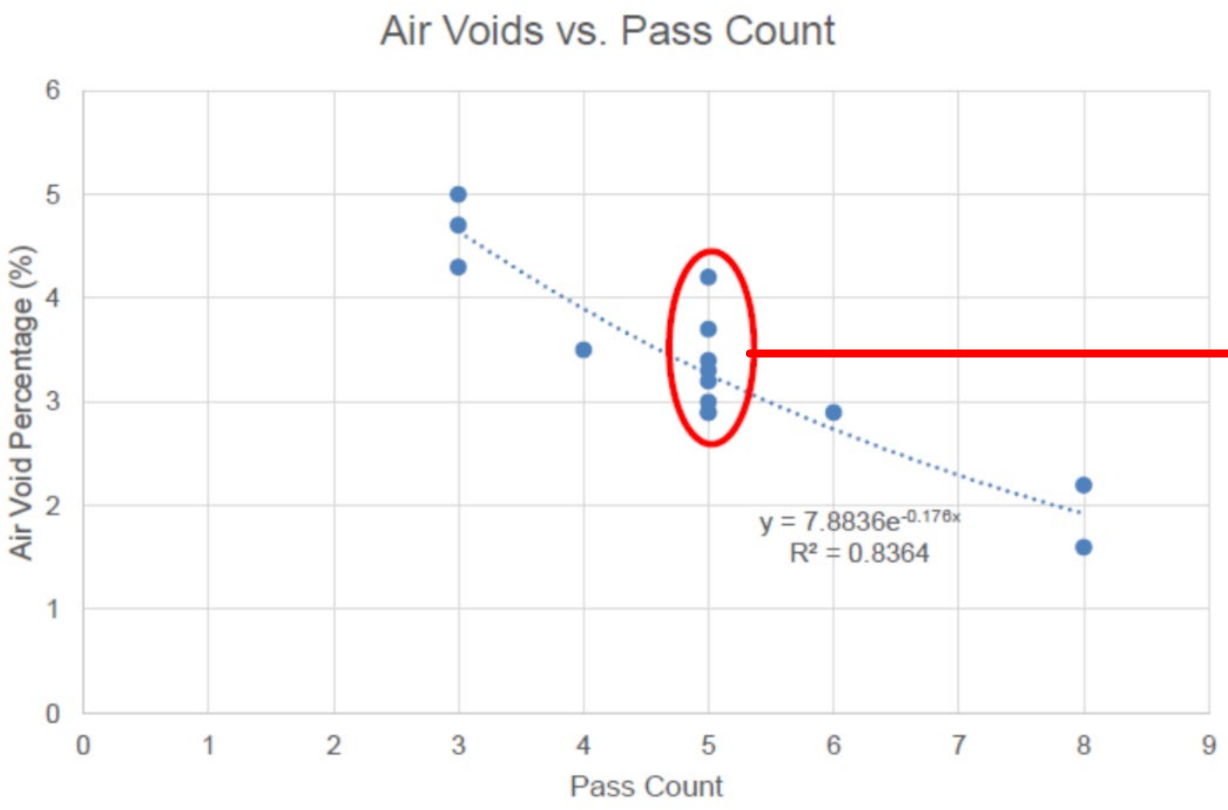
Intelligent Compaction (IC) to Monitor Compactive Energy (2016 NJDOT Study)

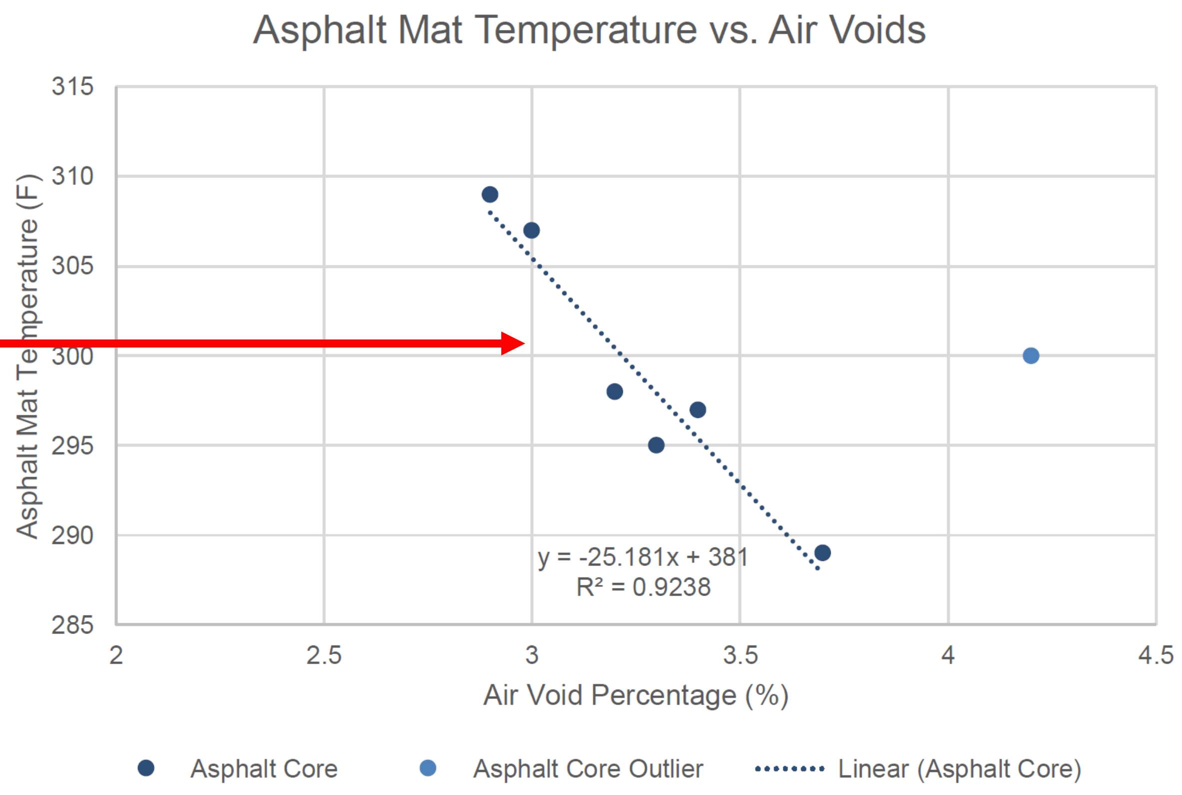




Intelligent Compaction (IC) to Monitor Compactive Energy (2016 NJDOT Study)

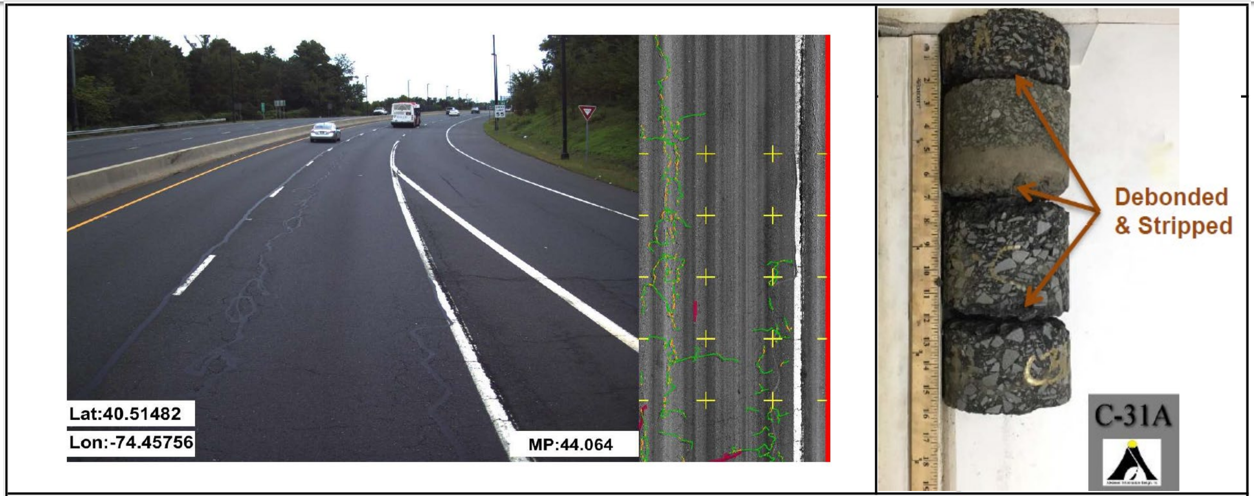
- Encourage industry to embrace benefits of intelligent compaction



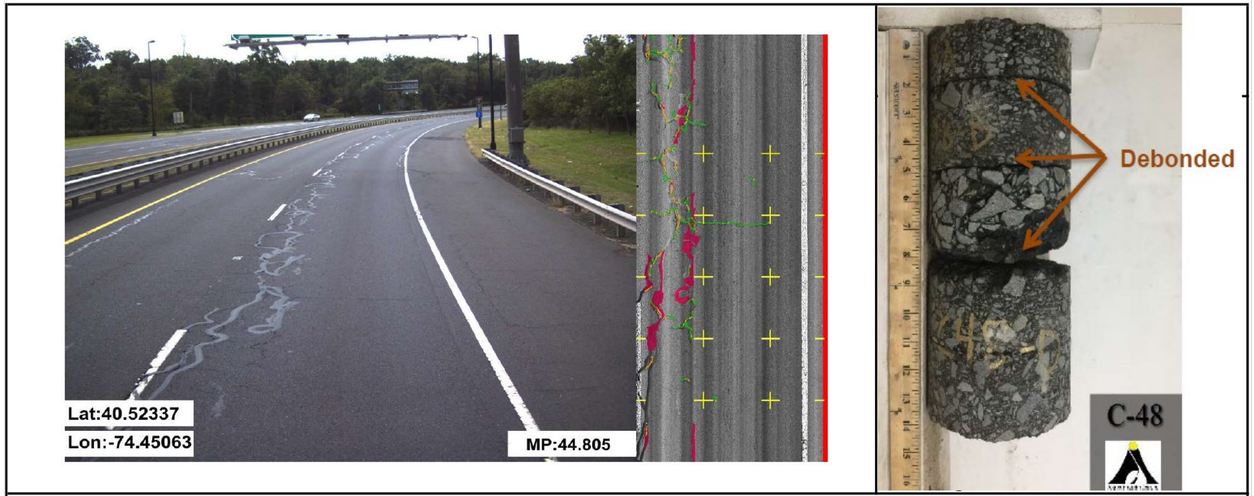


Bonding of Pavement Layers

- Literature indicates that even a 10% reduction in interlayer bond strength can reduce pavement life by 50%
  - NJDOT concerned with bonding on milled surfaces
    - Research study from 2021 to 2022 showed bond shear strength of milled surfaces approximately ½ of paved surfaces
    - Majority of recovered cores from distressed areas show debonding and on-set of stripping



Description: L-Longitudinal Cracking between lanes; L-Transverse Cracking; M-Fatigue Cracking in Lane 2



Description: L-Longitudinal Cracking between lanes; M-Fatigue Cracking in Lane 2; L-Transverse Cracking; L-Block Cracking

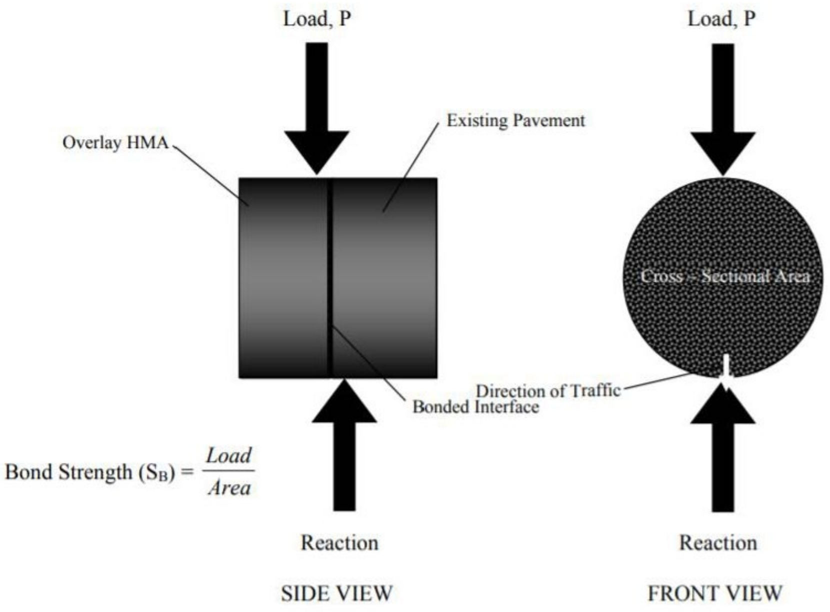
Basic Comparison of NTT vs Conventional Tacks

- NTT's performance is a function of its stiffness after the emulsion breaks
  - Higher stiffness at field/ construction temperatures less likely to pickup and track
- Comparison of NTT vs CRS-1H indicates
  - Lower penetration
  - Lower residue
    - NTT will have lower residual rate when using same application rate as CRS-1H

Distillation Properties (Post Application)		
Property	**CRS-1H**	**NTT (PennDOT)**
Penetration, 25C, 100 g, 5 s, 0.1 mm	40 to 90	10 to 60
% Residue	≥ 60%	≥ 50%
Softening Point (Ring & Ball), °C	N.A.	≥ 45°C

Laboratory Testing of Bond Strength

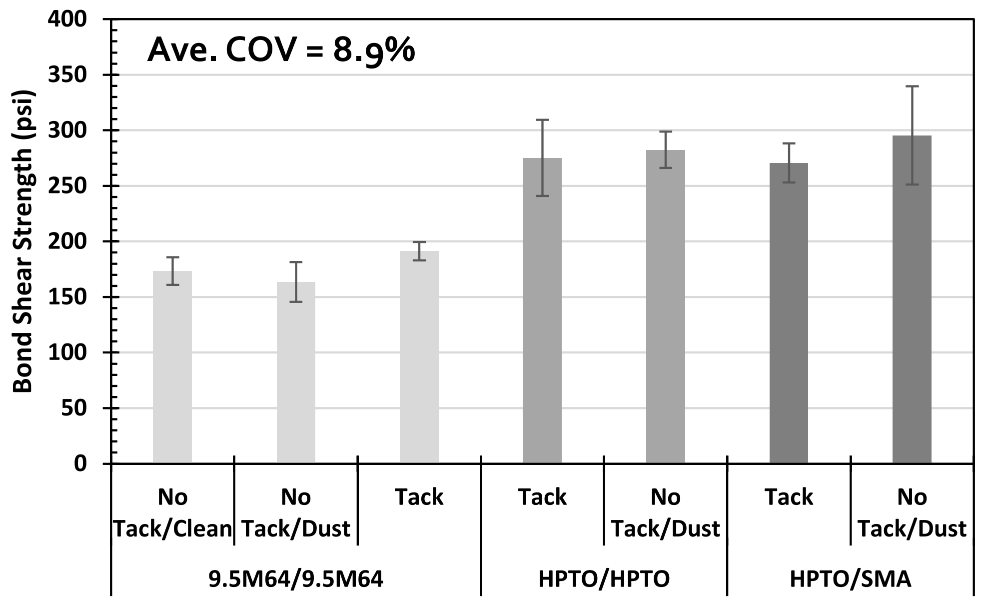
- NJDOT B-14
  - Based on ALDOT-430
  - 6″ diameter specimens
  - 25°C test temperature
  - Loading rate of 50 mm/min
  - Positioned to shear in same direction as milling/paving/traffic
  - Final value is Bond Shear Strength



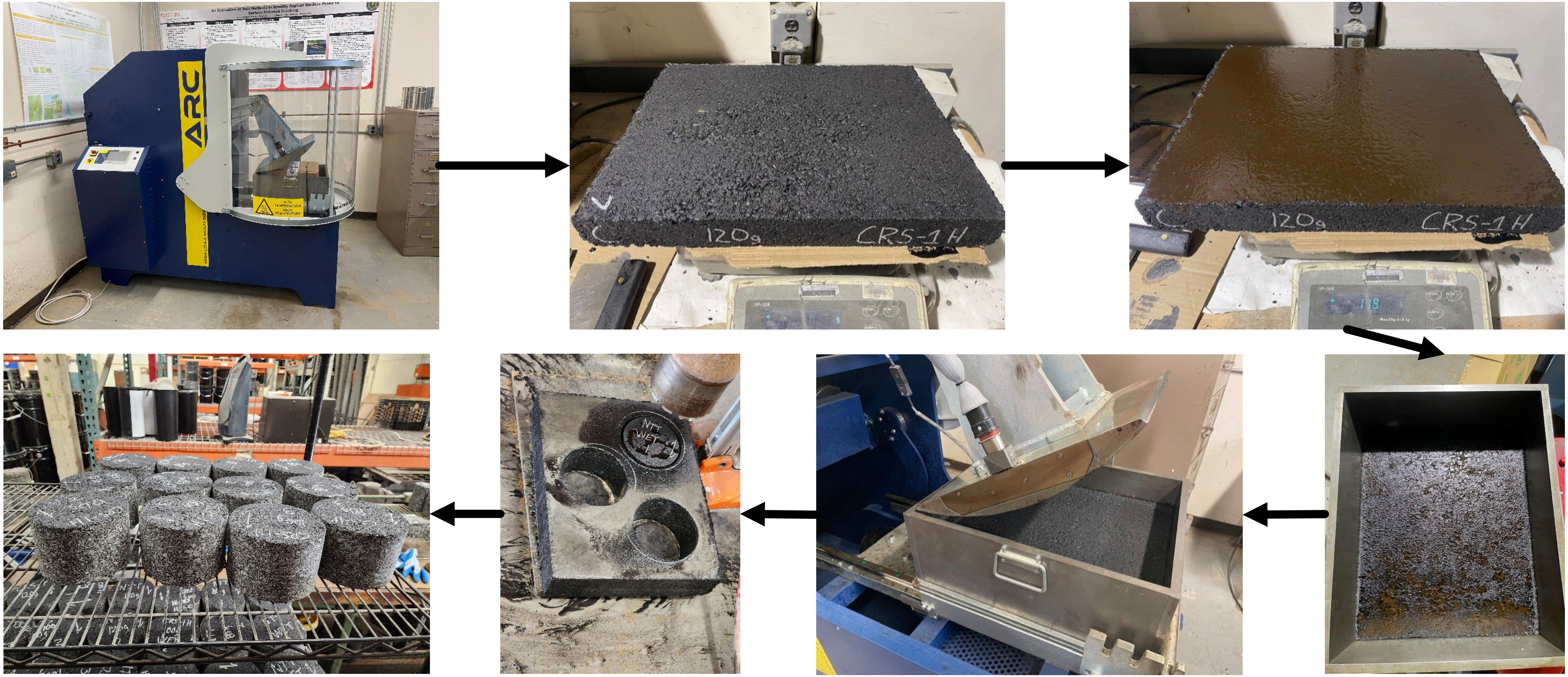
Laboratory Characterization of Bond Strength

- Laboratory specimens followed recommendations from AASHTO TP114, *Determining the Interlayer Shear Strength (ISS) of Asphalt Pavement Layers, Section 8.3*
  - Compact lift in gyratory, coat surface, place back in mold, compact next lift on top of tacked surface
- Although it may be good to assess variability of Bond Shear Strength test, trend in results did not match field observations nor showed sensitivity to surface conditions

Surface Layer	Bottom Layer	Interface Condition	Ave Bond Strength (psi)	Std Dev (psi)
9.5M64	9.5M64	No Tack/Clean	173.3	12.4
9.5M64	9.5M64	No Tack/Dust	163.5	17.8
9.5M64	9.5M64	Tack	191.3	8.3
HPTO	HPTO	Tack	275.2	34.4
HPTO	HPTO	No Tack/Dust	282.5	16.4
HPTO	SMA	Tack	270.5	17.6
HPTO	SMA	No Tack/Dust	295.4	44.3

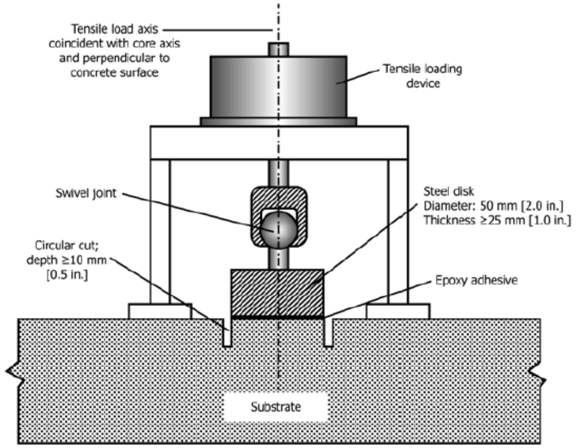


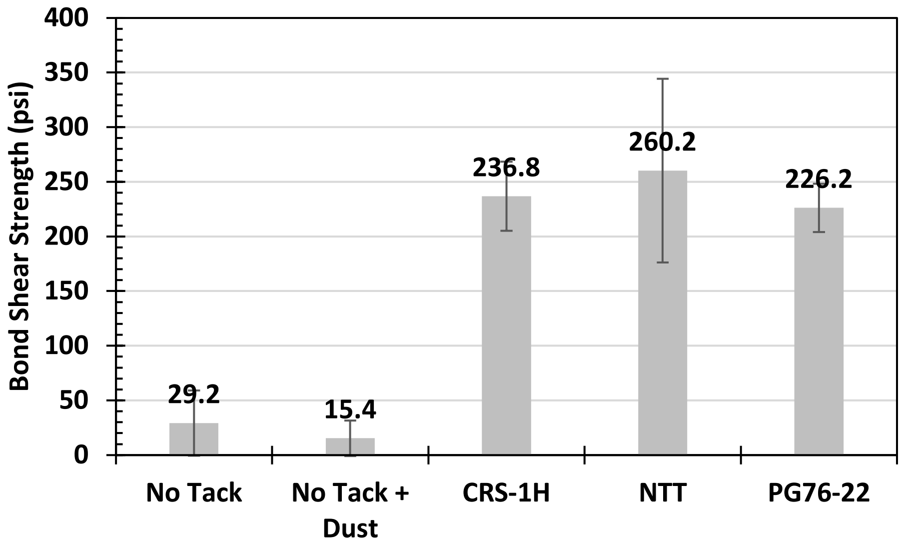
Laboratory Characterization of Bond Strength

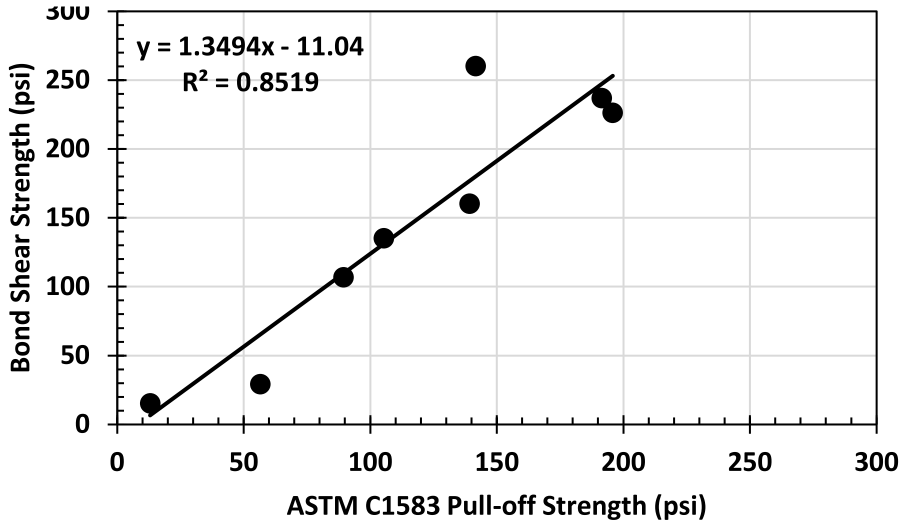


Laboratory Characterization of Bond Strength

- Slab specimens more consistent with observed testing of field cores
  - Sensitive to both surface condition, tack type, and application rate
- Bond Shear Strength correlated well with Pull-off Strength (ASTM C1583)

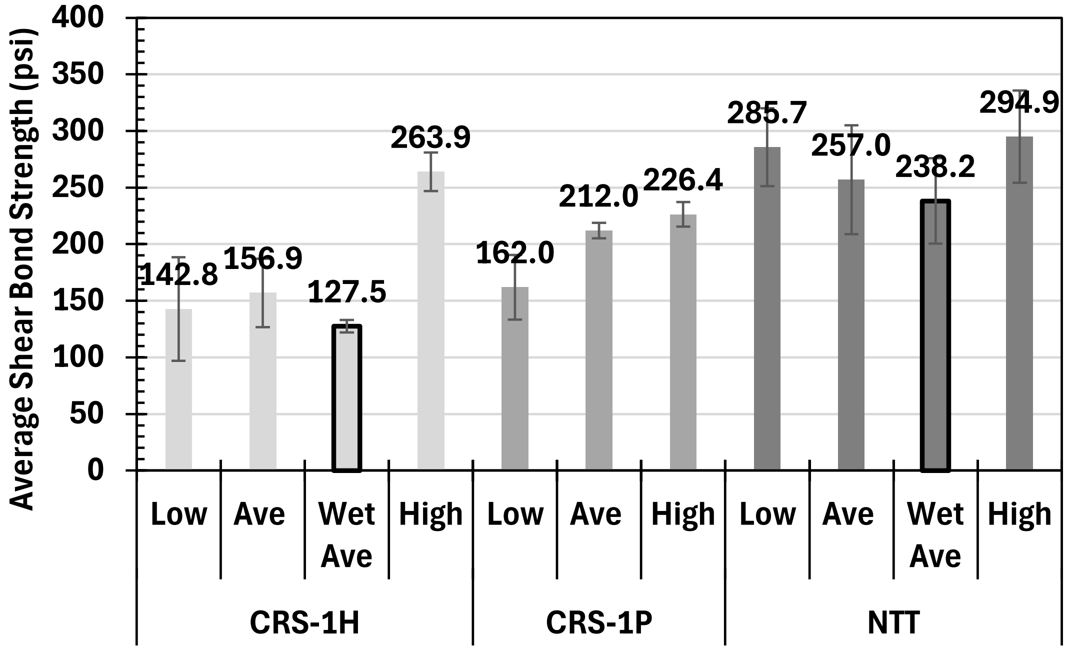




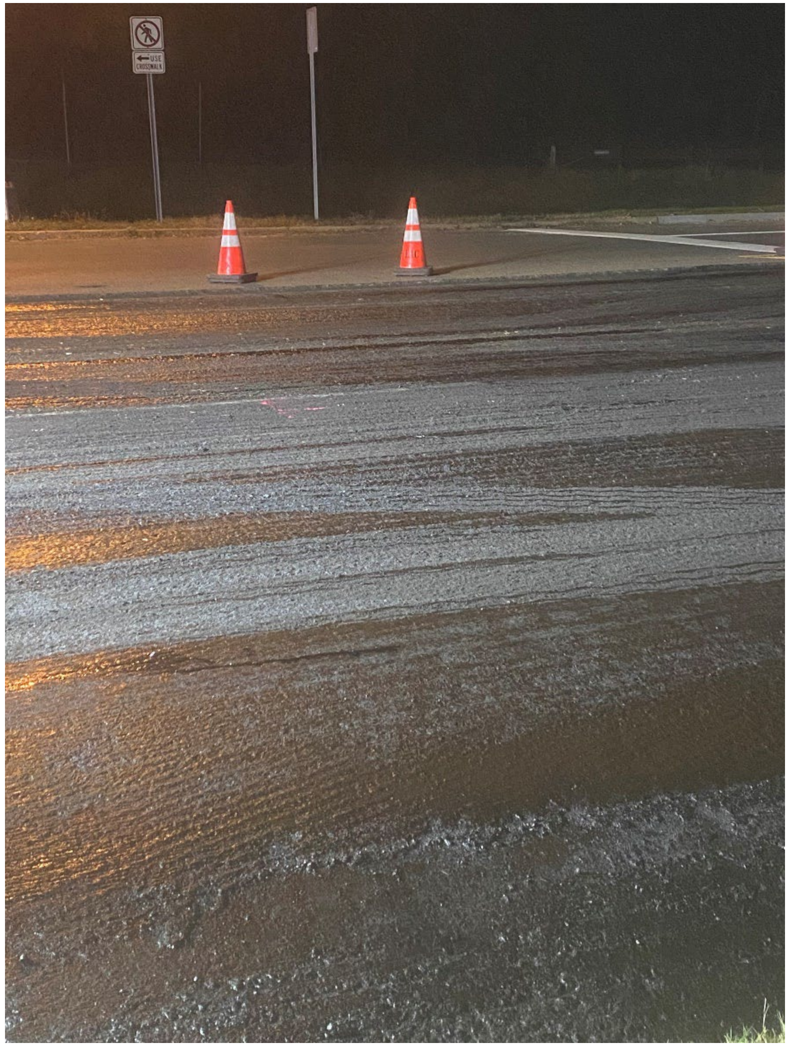


Laboratory Characterization of Bond Strength

- 2024 work looked at locally supplied CRS-1H, CRS-1P and NTT
  - Middle of spec application rate and -20% and + 20%
- Method shows NTT provided highest bond shear strength
- "Wet" specimens produced by not allowing tack to break before overlay
  - Reduces bond shear strength by 10 to 15%



Field Projects – Rt 166 (Milled Surface)



Southbound

Rt 166 - CRS-1H Section			
Station	Core #	Bond Strength (psi) (Individual)	Bond Strength (psi) (Ave. All)
664+31	1	26.62	9.8
	2	22.26	
	3	0	
	4	0	
	5	0	
689+27	1	56.54	24.9
	2	37.84	
	3	9.16	
	4	20.88	
	5	0	
Project Average =		**17.3**	

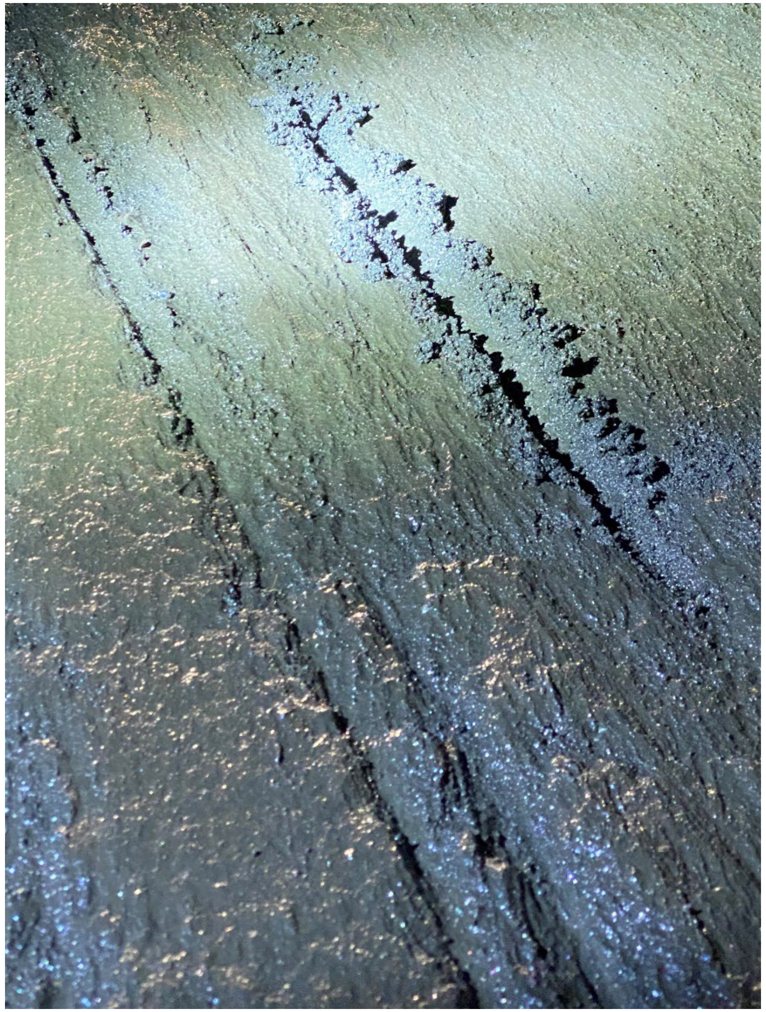
Northbound

Rt 166 - NTT Section			
Station	Core #	Bond Strength (psi) (Individual)	Bond Strength (psi) (Ave. All)
696+66	1	57.58	65.2
	2	49.66	
	3	67.6	
	4	85.66	
	5	65.6	
704+46	1	12.43	43.0
	2	45.16	
	3	59.12	
	4	63.52	
	5	34.73	
Project Average =		**54.1**	

Field Projects – Rt 166 (Milled Surface)

Left: Milled and swept (2 passes)

Right: Adjacent, old travel lane



Field Projects – I295 (Paved Surface)

- Paved Surface
  - Tack applied between intermediate course and surface course
  - Optimal condition: paved surface, warm weather construction
- In NJ, finding significant differences in bond strength for milled vs paved surfaces

I295- CRS-1H Section			
Station	Core #	Bond Strength (psi)	
		(Individual)	(Ave. All)
812+32	1	139.61	159.3
	2	90.7	
	3	257.32	
	4	209.11	
	5	99.69	
766+32	1	72.36	143.8
	2	94.27	
	3	207.3	
	4	188.82	
	5	156.21	
814+97	1	170.02	162.3
	2	214.62	
	3	180.6	
	4	160.61	
	5	85.41	
760+39	1	158.01	181.5
	2	202.76	
	3	204.97	
	4	175.42	
	5	166.16	
Project Average =		161.7	

I295 - NTT Section			
Station	Core #	Bond Strength (psi)	
		(Individual)	(Ave. All)
729+35	1	69.74	116.1
	2	102.18	
	3	52.03	
	4	163.46	
	5	193.2	
776+92	1	199.24	205.3
	2	174.91	
	3	159	
	4	252.24	
	5	241.02	
726+50	1	350.17	212.2
	2	254.92	
	3	175.85	
	4	153.42	
	5	126.87	
823+79	1	155.29	179.1
	2	175.81	
	3	286.42	
	4	193	
	5	85.17	
Project Average =		178.2	

NJDOT Shear Bond Strength Study

- Between 2021 and 2022 (CRS-1H only)
  - 6 milled surfaces
  - 2 paved surfaces
  - Different contractors
  - Different times of construction
  - 3 labs provided testing to assess variability
    - Remember: Bond Shear Strength test showed 8.9% COV with laboratory produced specimens

Milled Surfaces (6 Projects)

Average Bond Strength 1 to 3 Days After Paving

Laboratory	Wheelpath		Non-Wheelpath	
	Ave	Std Dev	Ave	Std Dev
NCAT	119.0	42.8	90.1	20.0
NJDOT	91.7	22.7	86.9	31.3
Rutgers	101.4	27.5	92.4	34.0

Average Bond Strength 15 to 30 Days After Paving

Laboratory	Wheelpath		Non-Wheelpath	
	Ave	Std Dev	Ave	Std Dev
NCAT	105.5	33.2	112.1	20.7
NJDOT	105.9	22.2	73.8	47.0
Rutgers	119.1	27.1	86.4	28.7

Paved Surfaces (2 Projects)

Average Bond Strength 1 to 3 Days After Paving

Laboratory	Wheelpath		Non-Wheelpath	
	Ave	Std Dev	Ave	Std Dev
NCAT	218.8	8.6	178.0	72.3
NJDOT	232.1	54.4	199.2	89.5
Rutgers	208.9	40.6	158.9	64.2

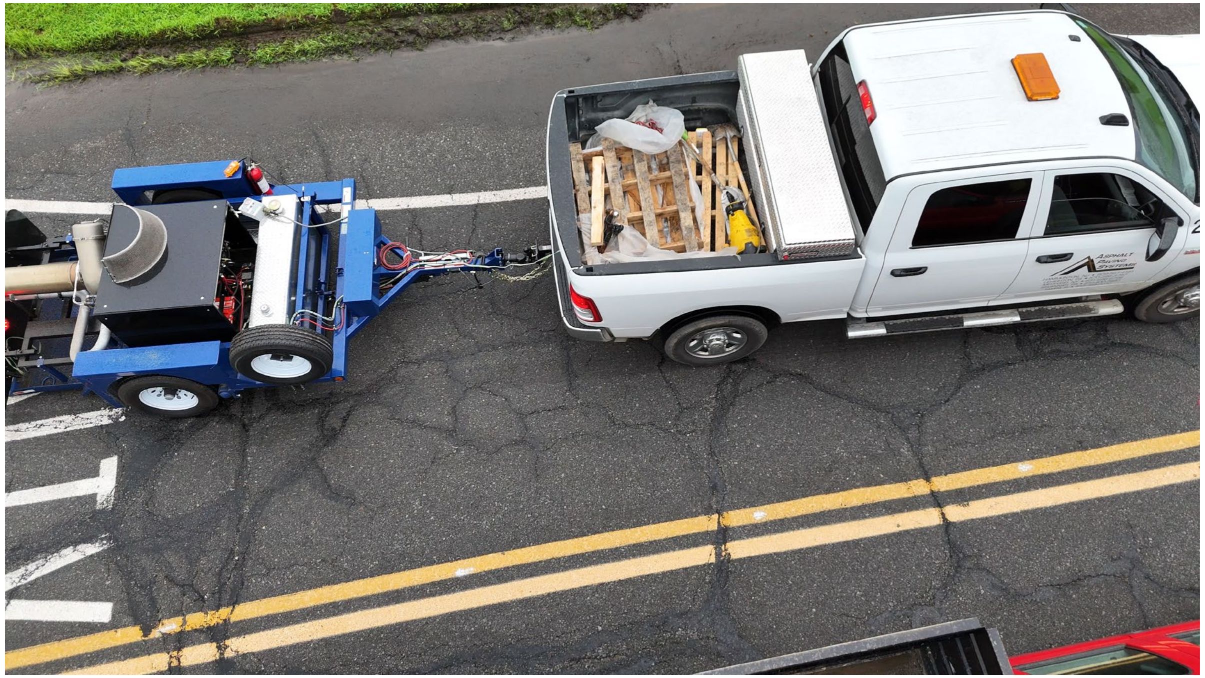
Average Bond Strength 15 to 30 Days After Paving

Laboratory	Wheelpath		Non-Wheelpath	
	Ave	Std Dev	Ave	Std Dev
NCAT	248.1	38.8	205.6	55.9
NJDOT	270.6	31.1	204.9	85.8
Rutgers	233.3	23.4	186.5	47.1

Milled Surfaces COV% = 47%
Paved Surfaces COV% = 28%

Bonding of Pavement Layers

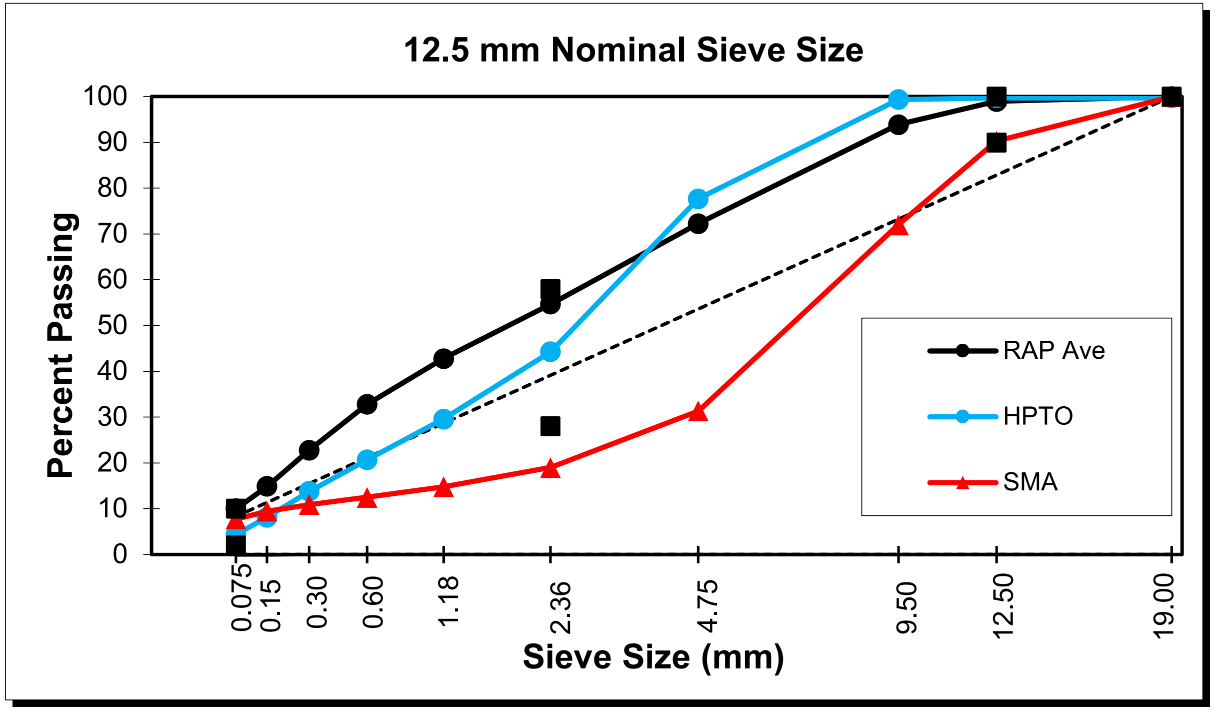
- More work needs to be put into surface preparation before any new tack material proposed and used
  - Pavement surface drier, fine/micro milling drums, better broom/vacuum sweepers to provide a cleaner, smoother texture for paving
  - Change in NJDOT allowable construction practices



On-going Research Activities at Rutgers

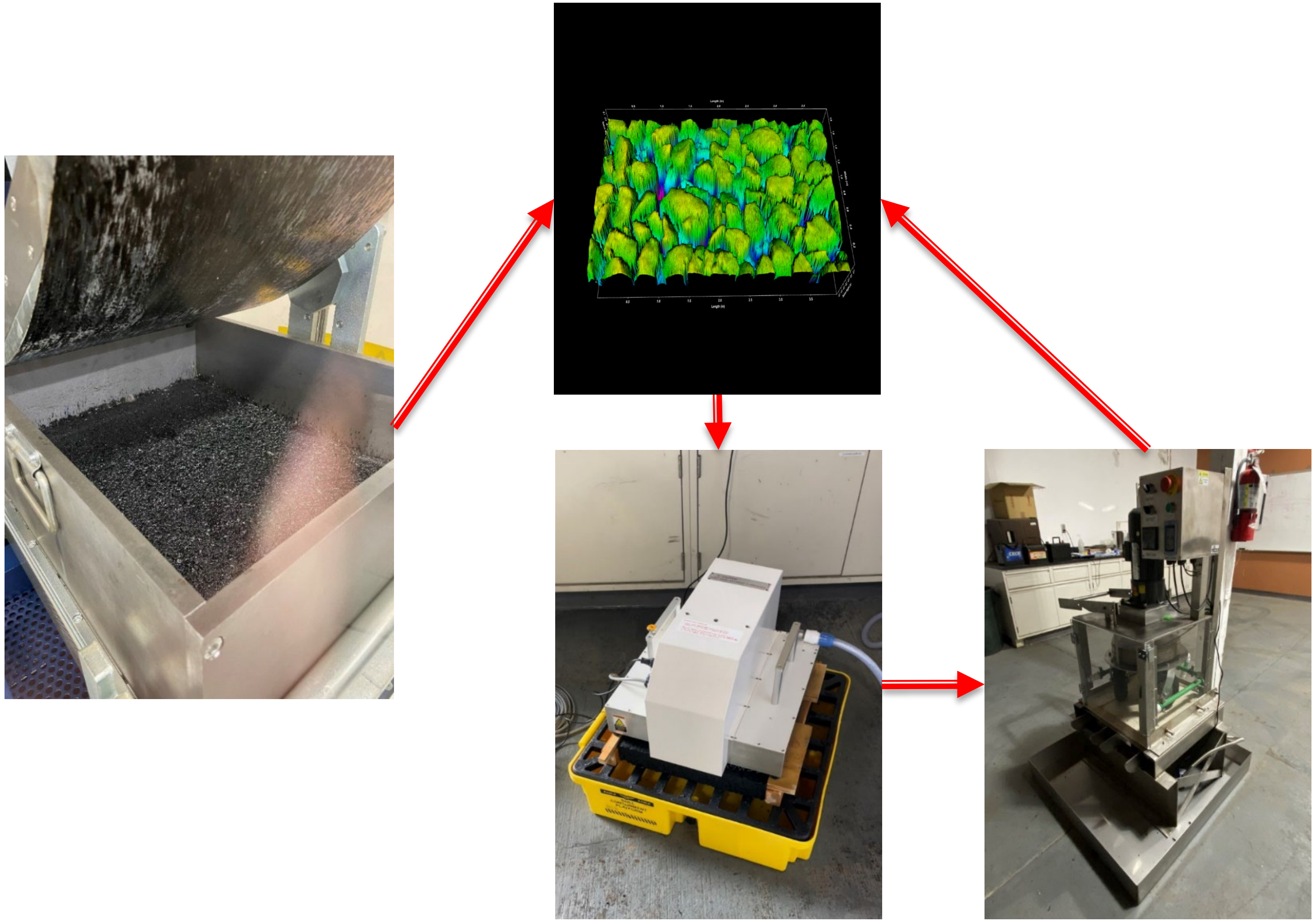
New Jersey Department of Transportation (NJDOT)

- Evaluating Potential Inclusion of RAP in NJDOT’s HPTO and SMA Asphalt Mixtures
  - Considerations:
    - RAP sizing requirements
    - RAP aggregate properties (F&E; Gsb)
    - Determining Voids in Coarse Aggregate (VCA)
    - Potential inclusion of performance testing to guard against decrease in cracking performance



New Jersey Department of Transportation (NJDOT)

- Evaluating Improvement in Frictional Properties of NJDOT's HPTO
  - Looking at how different designs/constituents impact friction and texture properties
    - Field to lab calibration
    - Recommend future changes to direct better friction properties while maintain/ improving structural properties



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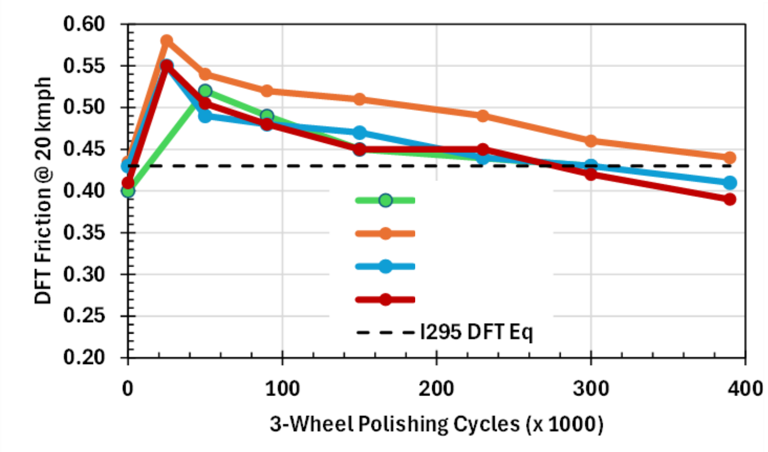
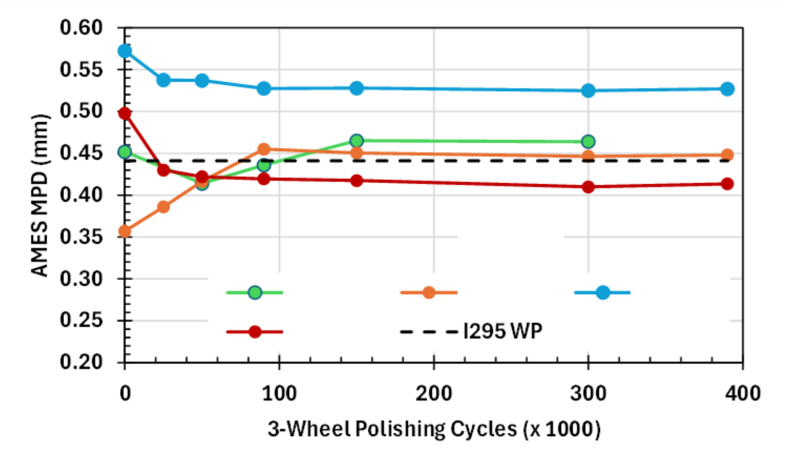
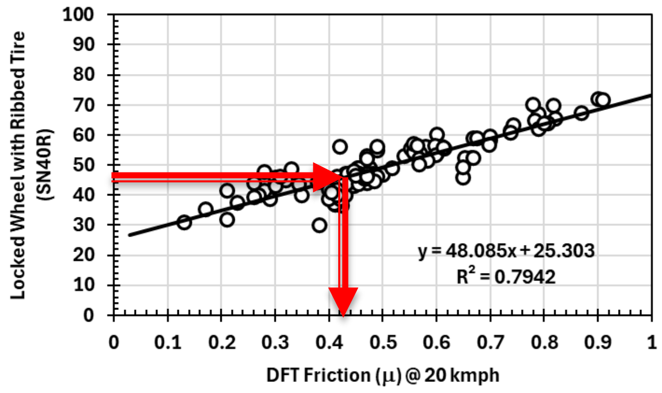
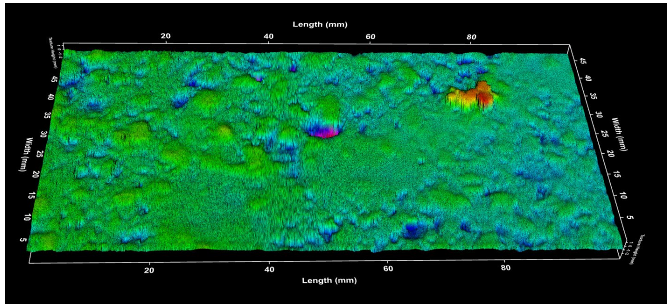


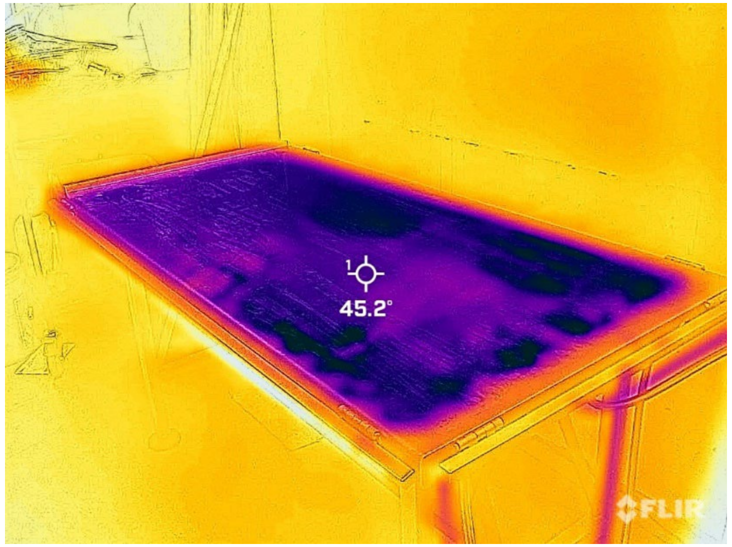


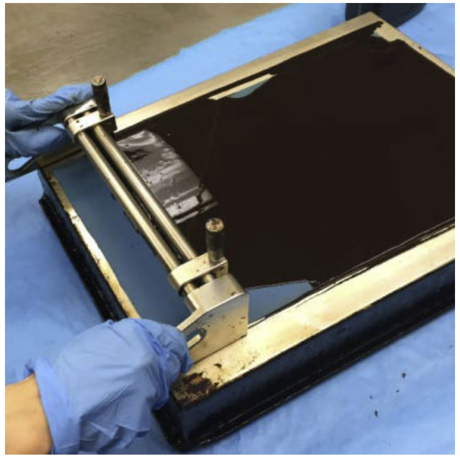


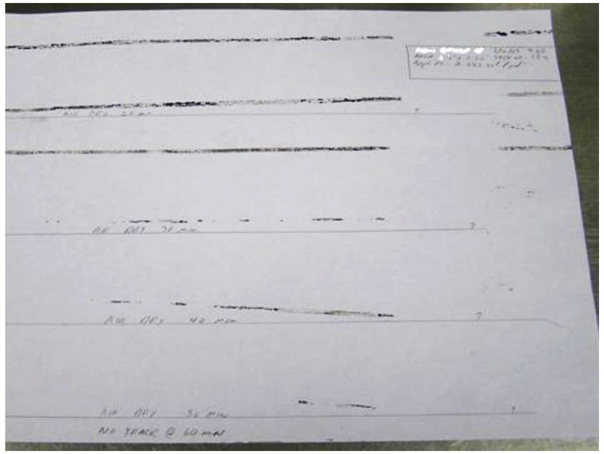


New Jersey Department of Transportation (NJDOT)

- Tack Coat and Emulsion Evaluation for Pavement Preservation and Tack Coats
  - Tracking Test Methods for Better Characterization
  - Binder Recovery Practices from Emulsions Using Low Temperature Evaporation

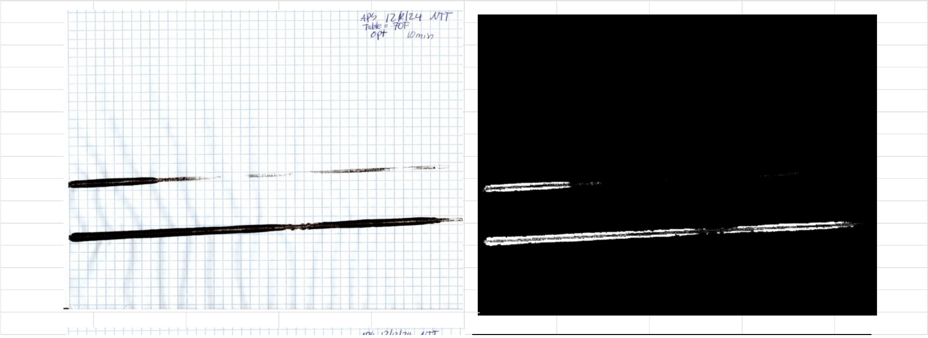


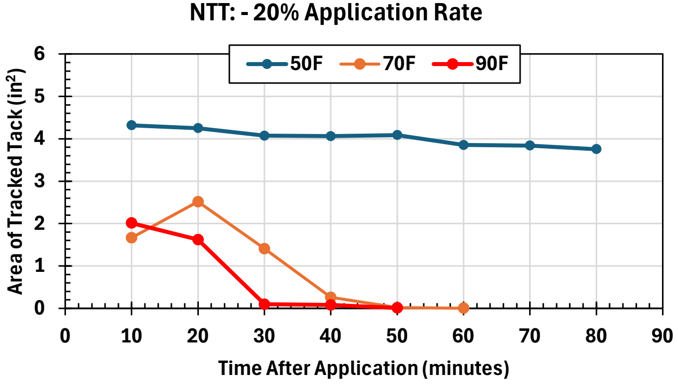


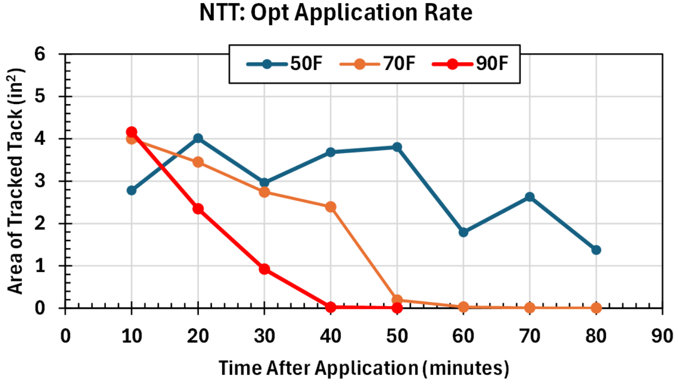


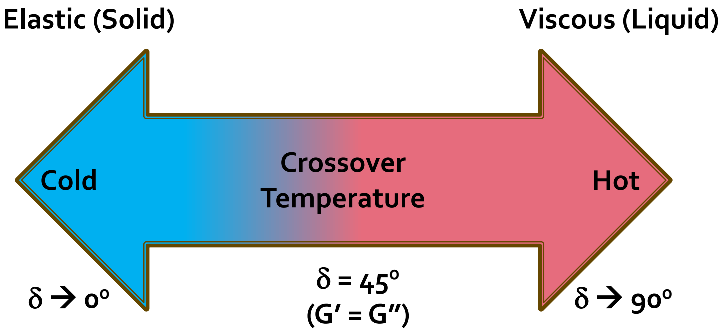
New Jersey Department of Transportation (NJDOT)

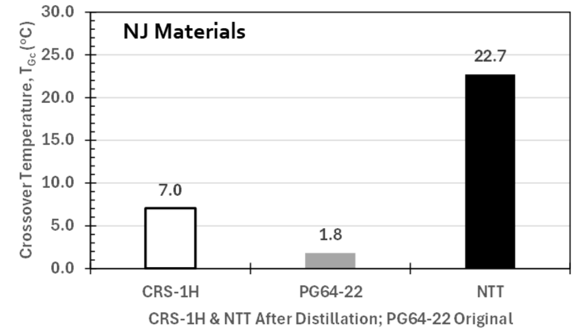
- Tack Coat and Emulsion Evaluation for Pavement Preservation and Tack Coats
  - Tracking Test Methods for Better Characterization
  - Binder Recovery Practices from Emulsions Using Low Temperature Evaporation









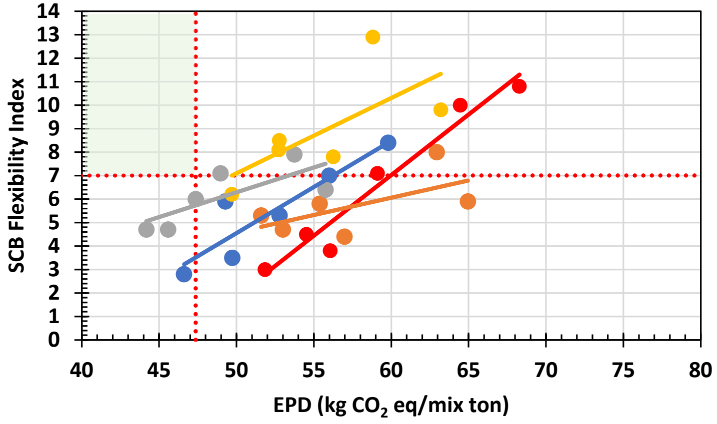


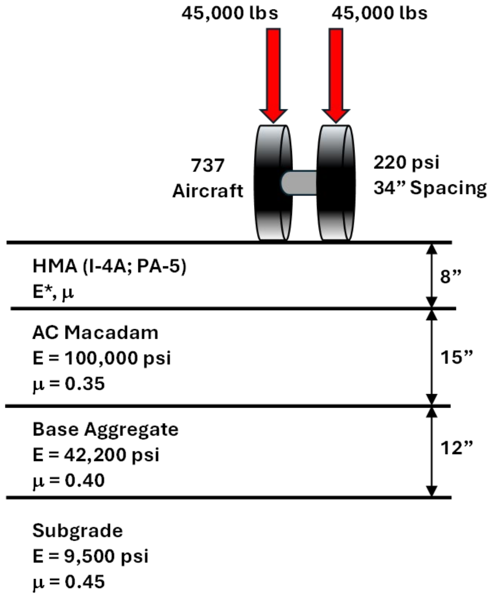
New Jersey Department of Transportation (NJDOT)

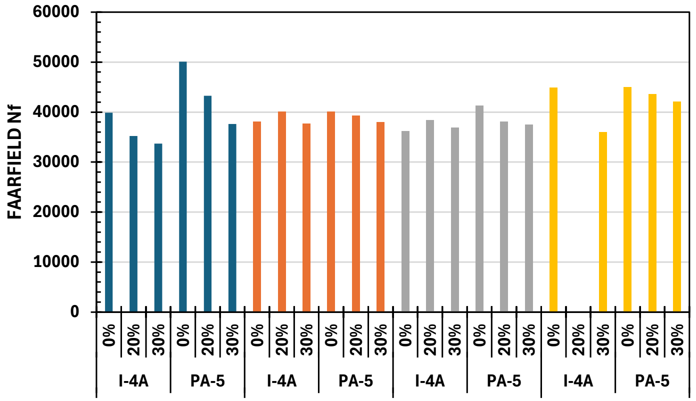
- Other projects under the NJDOT Pavement Support Program
  - Enhanced Friction Overlays
  - Pavement Management Support activities
    - PMS Software Support, Equipment Verification Program
  - Pavement Design Support activities (AASHTO's PAVEMENT-ME)
  - Benefit-Cost Analysis of Overlay Strategies and Specialty Mixes
  - Training Activities

Port Authority of NY/NJ (PANYNJ)

- Relationship Between EPD & PANYNJ Mix Performance
  - Internally, PANYNJ was pushed to reduce EPD's of asphalt mixtures
  - Currently RAP no used
    - No recycling agents approved
  - How does inclusion of RAP impact mix EPD and mix performance?
    - Rutting
    - Cracking

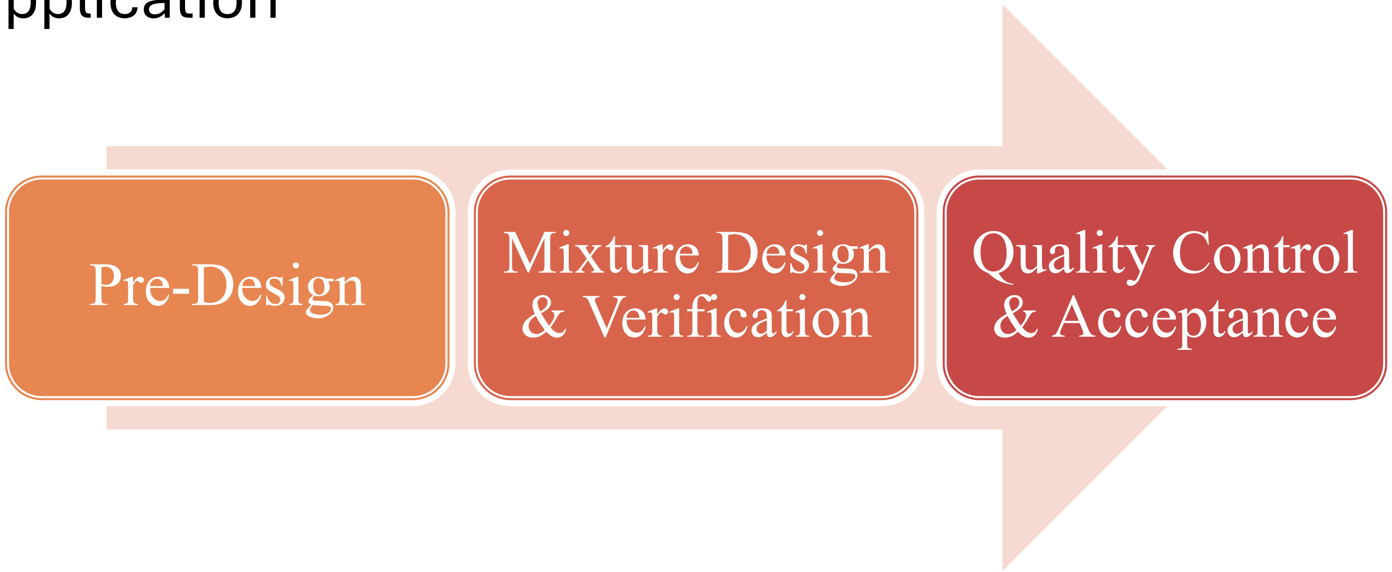






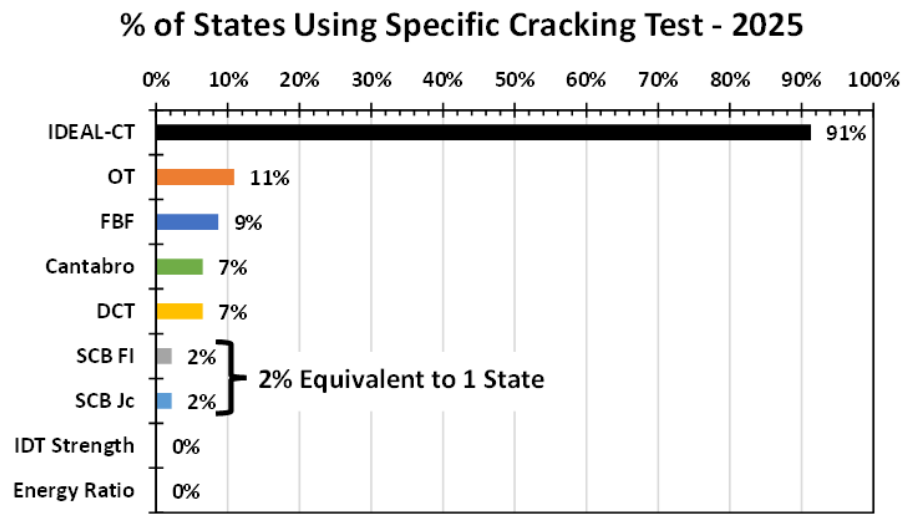
National Cooperative Highway Research Program (NCHRP)

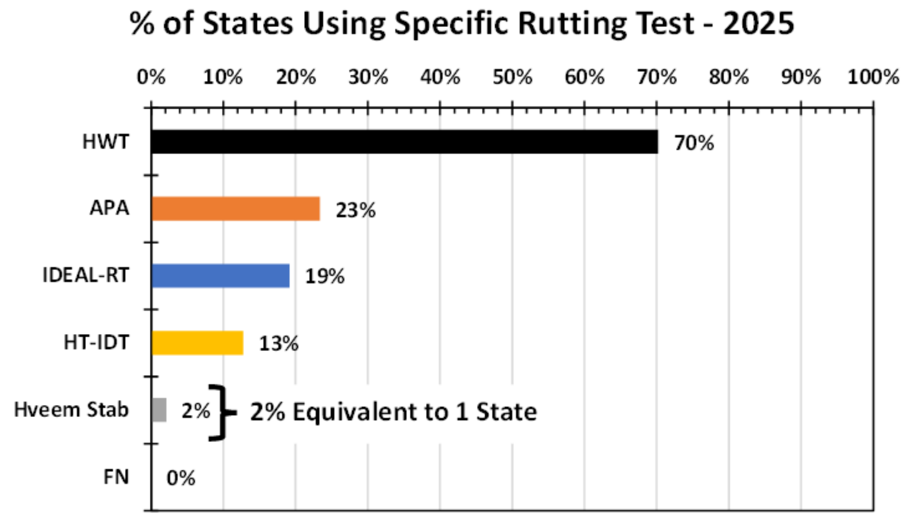
- NCHRP Project 9-71
  - Framework for Design, Production, and Placement of Balanced Asphalt Mixtures
    - Focus on enhancing the BMD design process, address the different applications of asphalt mixtures, and delineate the set of performance tests and procedures required for each application



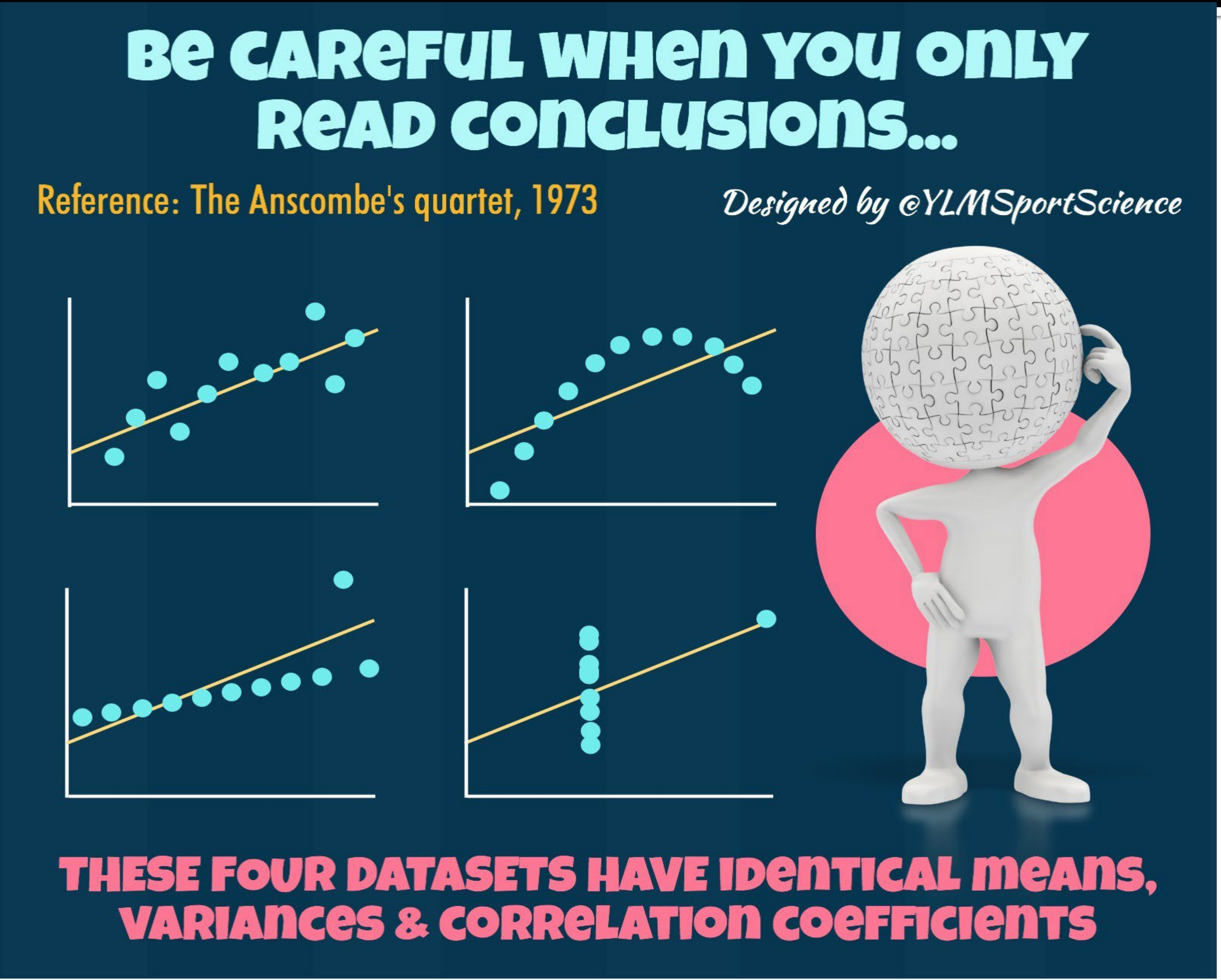
National Cooperative Highway Research Program (NCHRP)

- NCHRP Project 9-72
  - Sensitivity Evaluation of Balanced Mix Design Performance Tests
    - Evaluating the sensitivity of rutting and cracking performance tests to
      - Mixture constituent properties
        - Aggregate angularity, PG grade, neat vs PMA, effective binder, RAP content and stiffness
      - Plant production parameters
        - Plant production, silo storage time, RAP source changes, binder source changes (same PG grade), binder content from target, aggregate gradation primary control sieve (PCS) from target





Thank you for your time!
Questions?



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