Does Balanced Mixture Design (BMD) Work? You Bet Your Asphalt! NJ's Experience

Presented By:

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  - Wayne Byard, Mike Jopko, Keith Sterling
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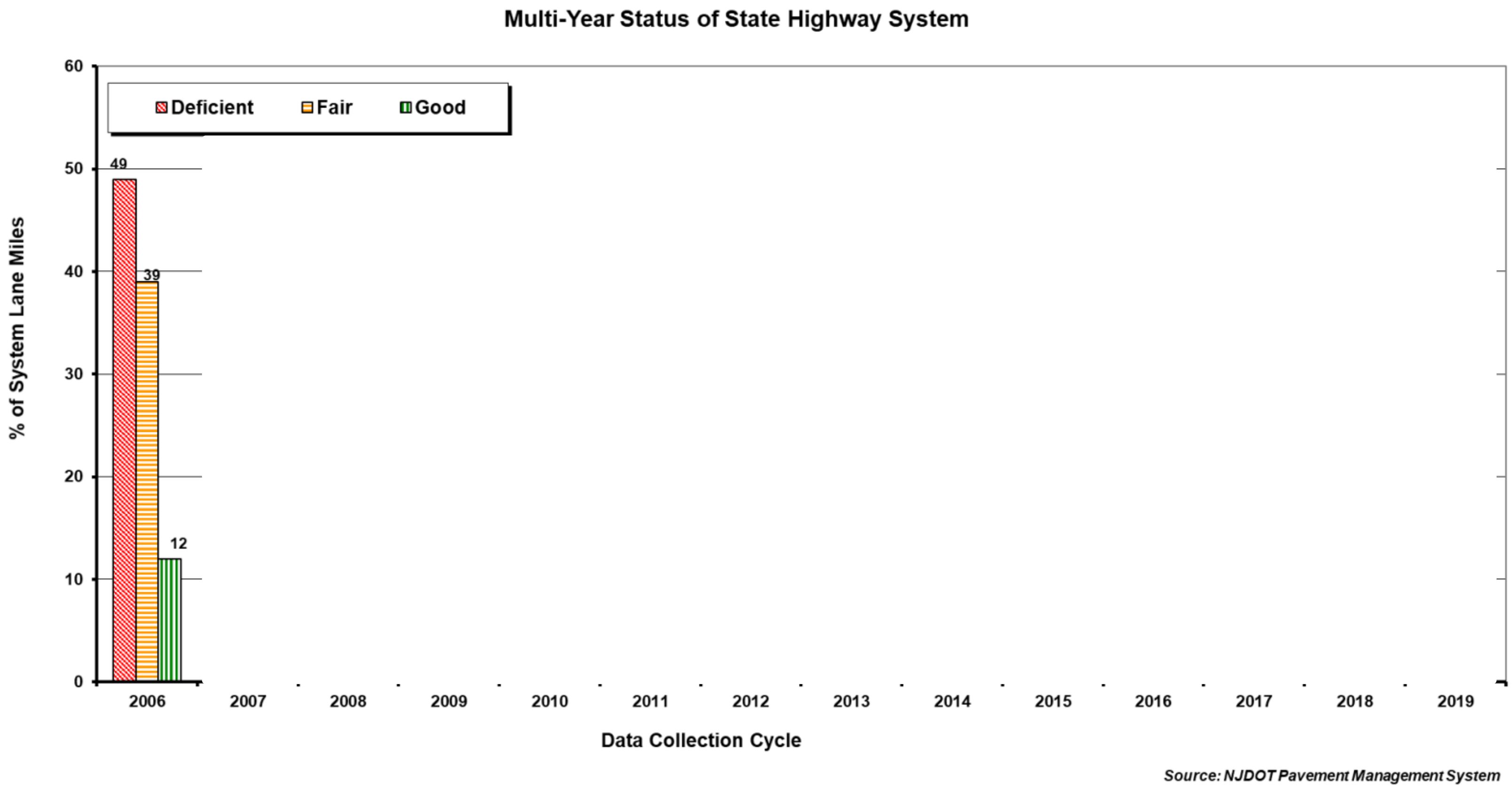
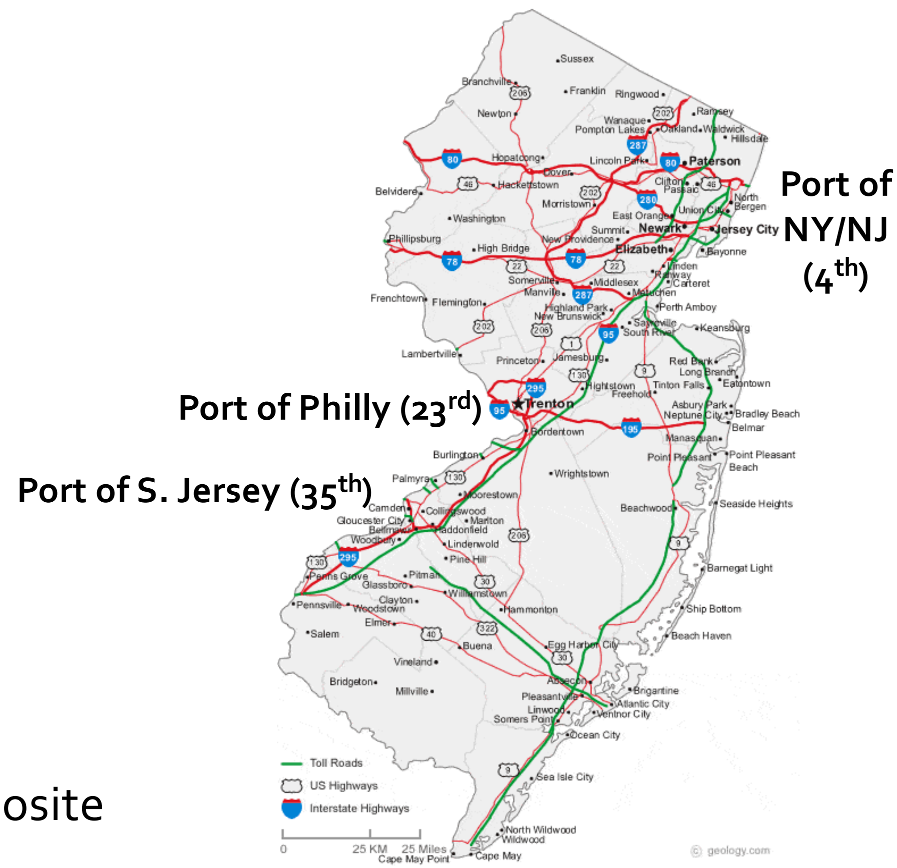
  - Ed Wass, Ed Haas, Chris Ericson, Darius Pezeshki

Where It Started!



NJ's Reasoning for BMD
("Performance Based Mix Design")

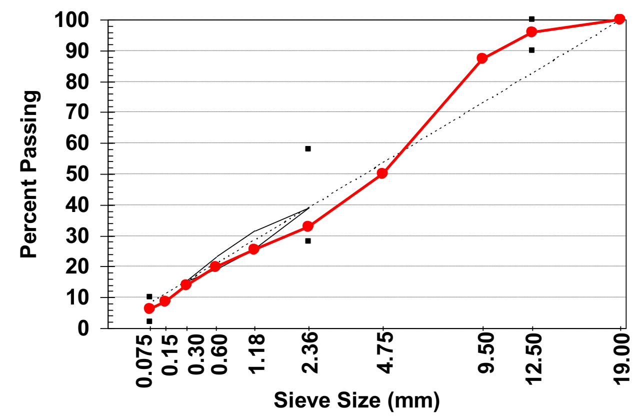
- Existing asphalt mixtures
  - Early 125 and 100 N_{des} mixes were dry
  - Significant cracking issues
    - Flexible (top-down); Composite (transverse)
- Traffic conditions
  - 29% increase from 1990 to 2006
  - 30% projected from 2006 to 2025
    - 99 billion miles traveled
- Climate conditions
  - Precipitation: 43 to 48 inches per year
  - Air Temperature: > 30 days over 90F;
    > 80 days less than 32F
- Pavement conditions
  - Over 60% of NJDOT pavements are composite



Balanced Mixture Design Performance

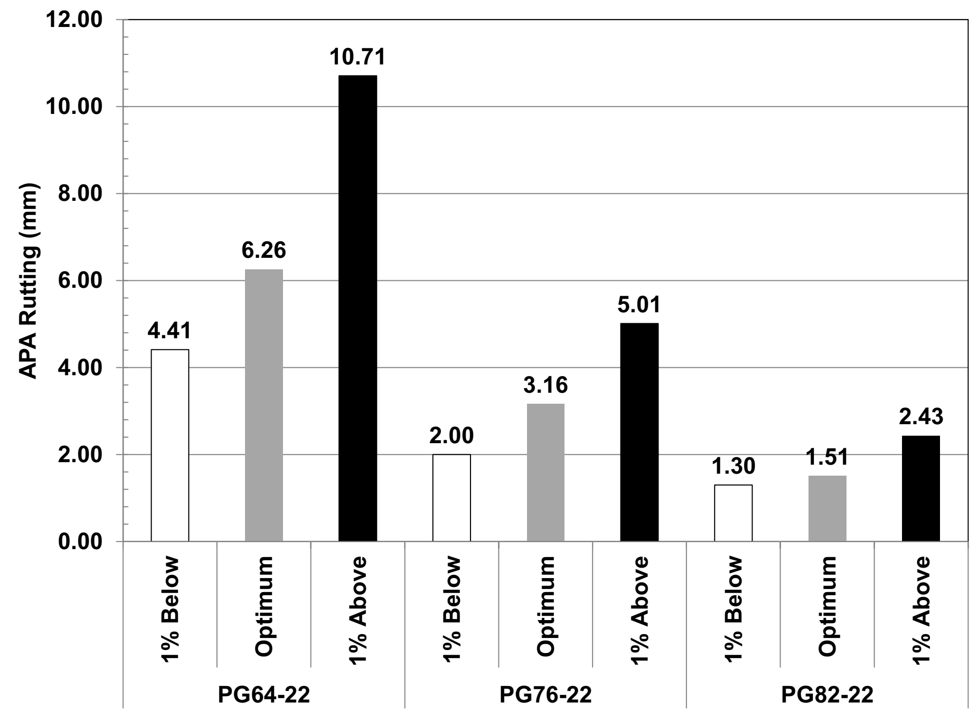
- NJDOT began utilizing performance testing in mixture design in 2006
  - BMD Approach A
- Starting evaluating BMD after reading AAPT paper by Zhou et. al, (2007)
  - Asphalt content below, at, and above volumetric optimum
  - Different binder grades

Binder Content (%)	4.9%
VMA (%)	14.9%
G_{mm} (g/cm^3)	2.712
G_{sb} (g/cm^3)	2.91
Percent Passing	
19mm	100
12.5mm	95.9
9.5mm	87.3
4.75mm	50.1
2.36mm	32.9
1.18mm	25.5
0.6mm	19.9
0.3mm	13.9
0.15mm	8.7
0.075mm	6.2

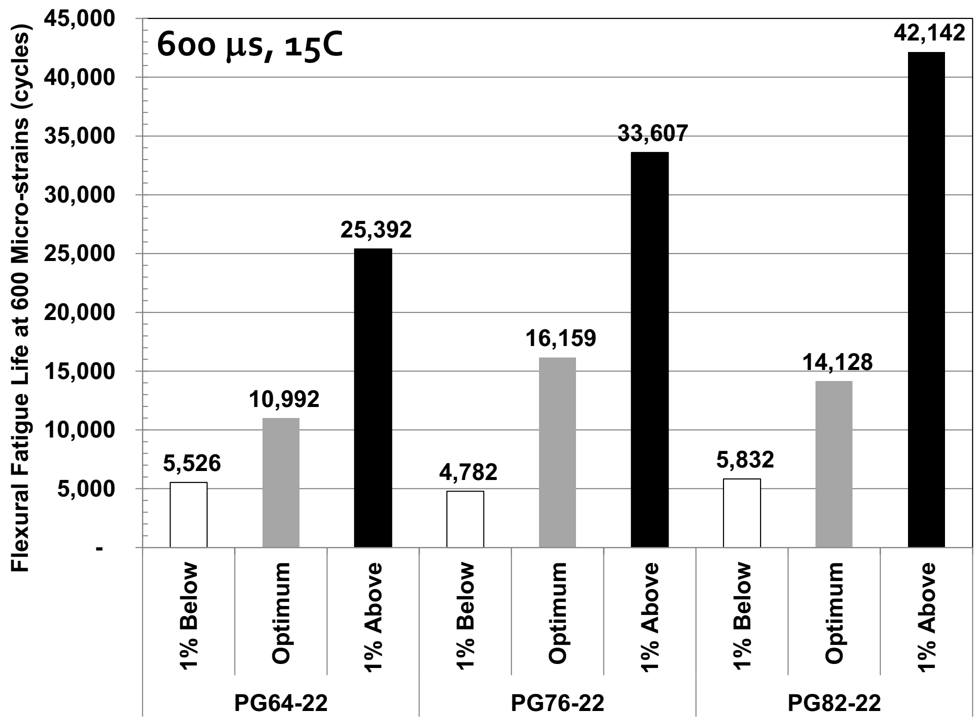


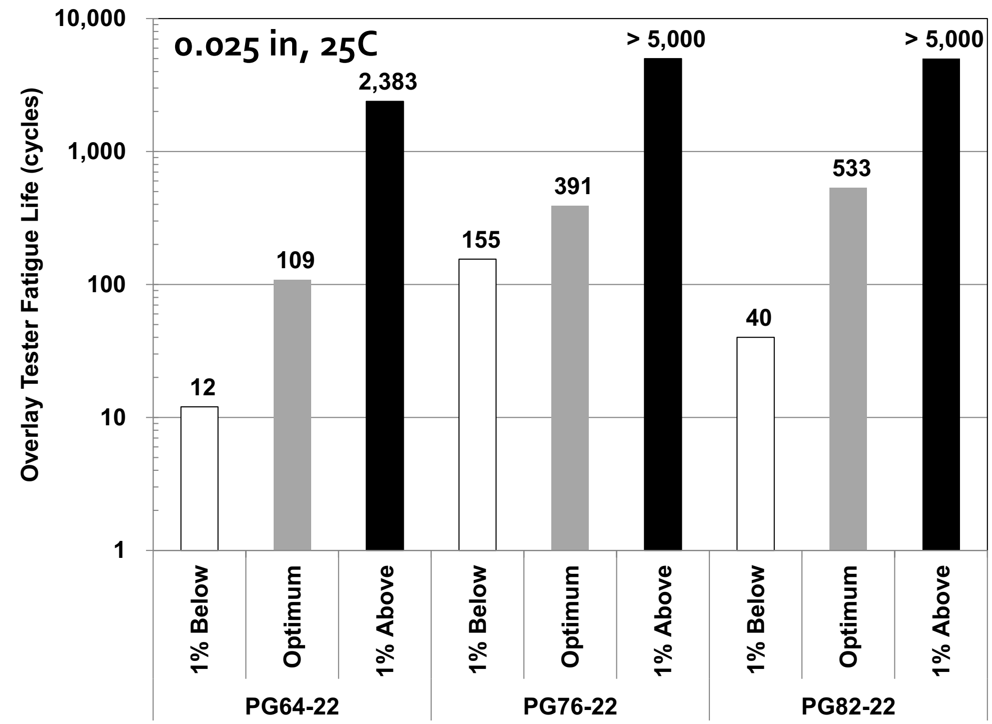
Early NJ BMD Research (2006)

- Rutting (AASHTO T340)
  - As binder content increased, rutting increased
  - But magnitude lessened when binder grade improved
- Cracking (AASHTO T321 & NJDOT B-10)
  - At below volumetric optimum and at optimum, similar fatigue properties were observed
  - At above optimum, significant improved



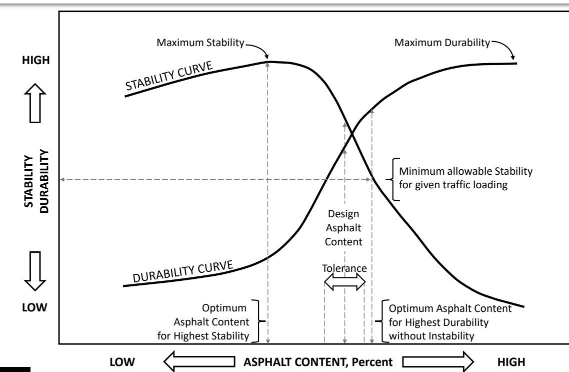
Early NJ BMD Research (2006)

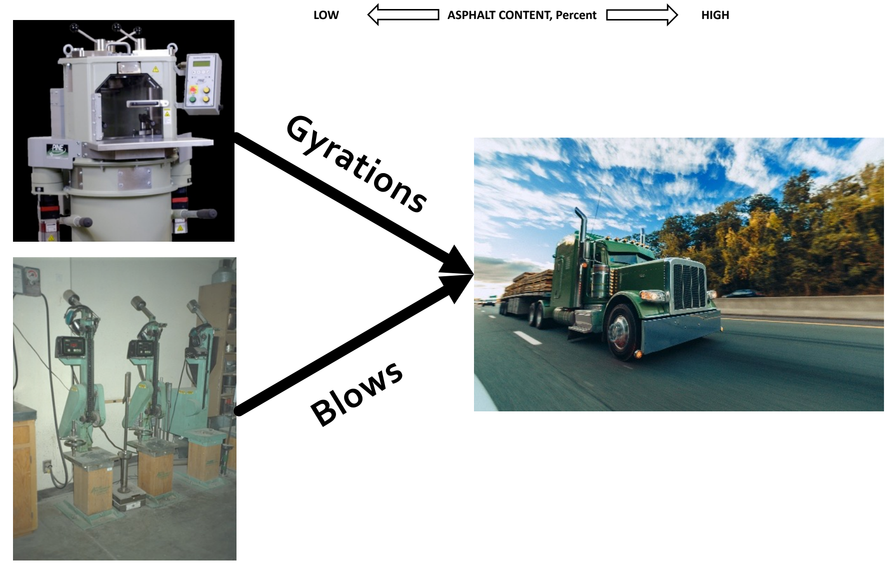




Question?

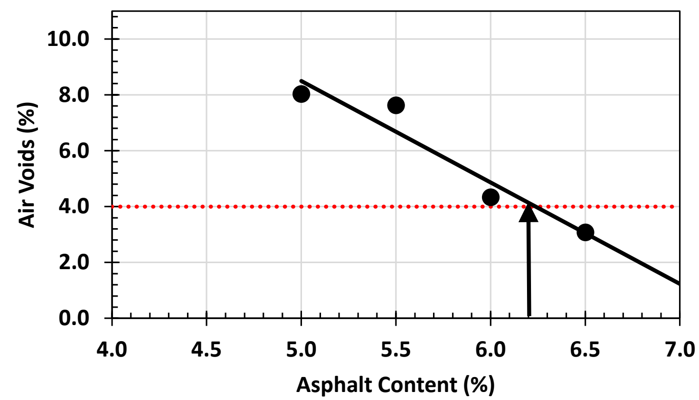
- Have we been doing asphalt mixture design incorrectly for modified asphalt binders?
- NCHRP 9-9A
  - Hveem – less emphasis on sample air voids and more emphasis on stability but recognized importance of air voids on durability.
  - Marshall (USACE) – calibrated laboratory compaction effort to densification that occurred with accelerated loading sections
    - General approach taken today where field densification levels are "calibrated" to gyrations
      - ***But what if we have binders that are more resistant to field densification than others?***





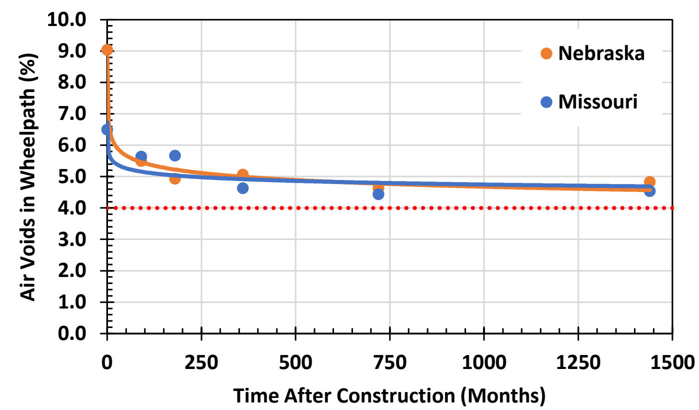
Wheelpath Densification

- Wheelpath Densification
  - Mix design assumes we want to optimize asphalt content to provide stable and durable mix after densification has taken place (i.e. ≈ 4% air voids)
    - Example: NCHRP 9-9A (Nebraska & Missouri)



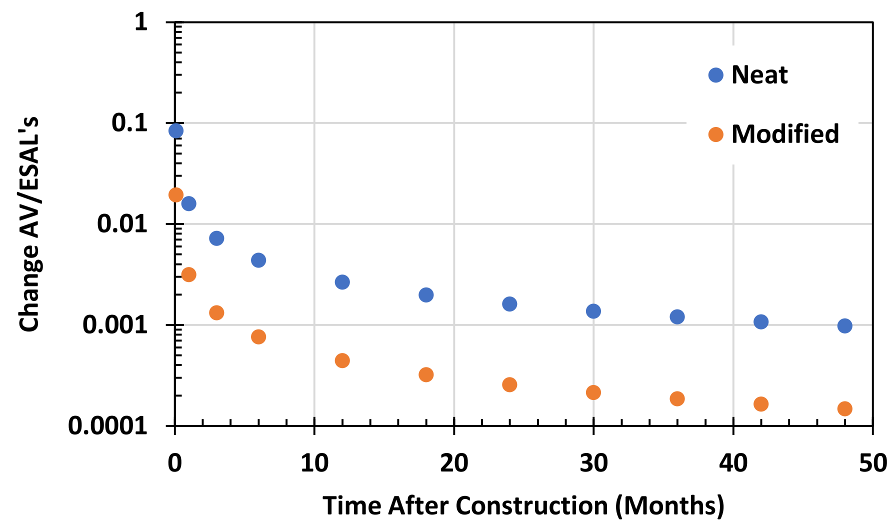
State	Initial AV%	4 Yr ΔAV%	4 Yr MESAL
Nebraska	9.0	-4.8%	0.068
Missouri	6.5	- 2.0%	8.4

Unmodified PMA



Wheelpath Densification

- NCHRP 9-9A Data
  - Pavements with neat binders consolidated at a rate 6 times more than modified binders (40 projects)
  - According to volumetric mix design rules, if air voids above 4% after compaction, additional asphalt binder added
    - For same aggregate gradation; lower gyration level ≈ increased AC



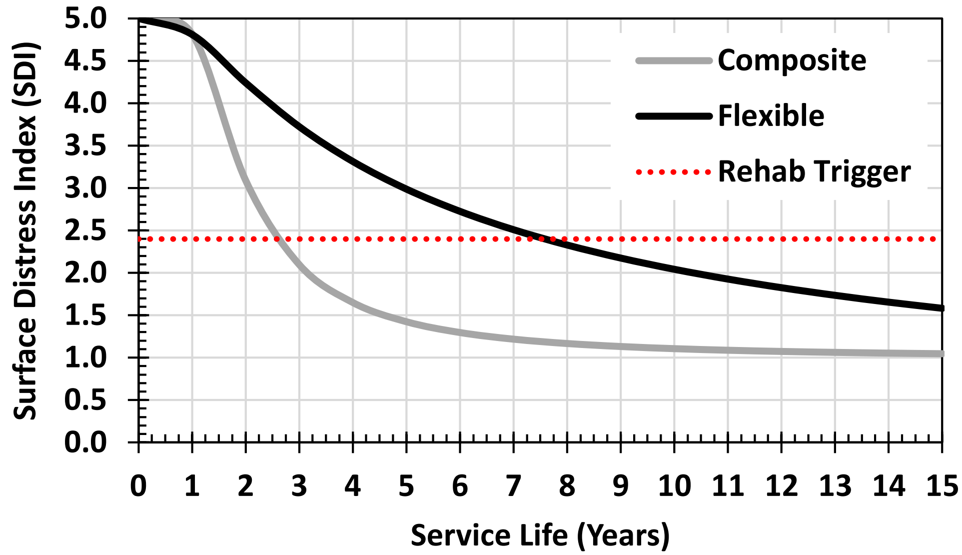
20 Yr MESAL's	N_{des} (<PG76)	N_{des} (>PG76)
< 0.3	50	N.A.
0.3 to 3	65	50
3 to 30	80	65
> 30	100	80

(Prowell & Brown, 2007)

NJDOT Efforts

NJDOT – Field Performance Comparisons

- Change in Mix Design Practice
  - Clear that performance could be improved if using modified binders with mix design procedures/criteria to encourage higher asphalt contents
- Implementation
  - Started in 2007 with performance criteria initially developed using mix testing database and "engineering judgement"
    - Tackled one issue at a time



$$SDI = SDI_0 - e^{\left(A - B \cdot C^{\ln\left(\frac{1}{Age}\right)}\right)}$$

NJDOT High Performance Thin Overlay (HPTO)

- Volumetric
  - Design AV = 4%
  - N_{des} = 75
  - VMA ≥ 14%
  - VFA 65 – 78%
  - RAP ≤ 15%
  - No performance test requirements

1" Thick Lift with or without milling

- HPTO
  - Design AV = 3.5%
  - N_{des} = 50
  - VMA ≥ 18%
  - Min AC% ≥ 7%
  - No RAP
  - APA Rutting ≤ 4.0mm
  - Overlay Tester ≥ 600 cycles

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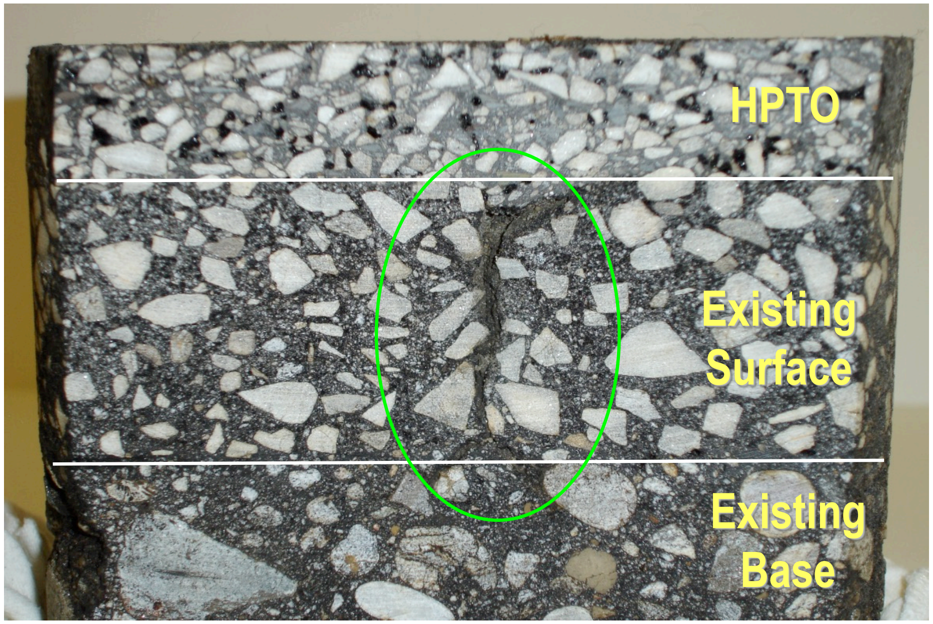

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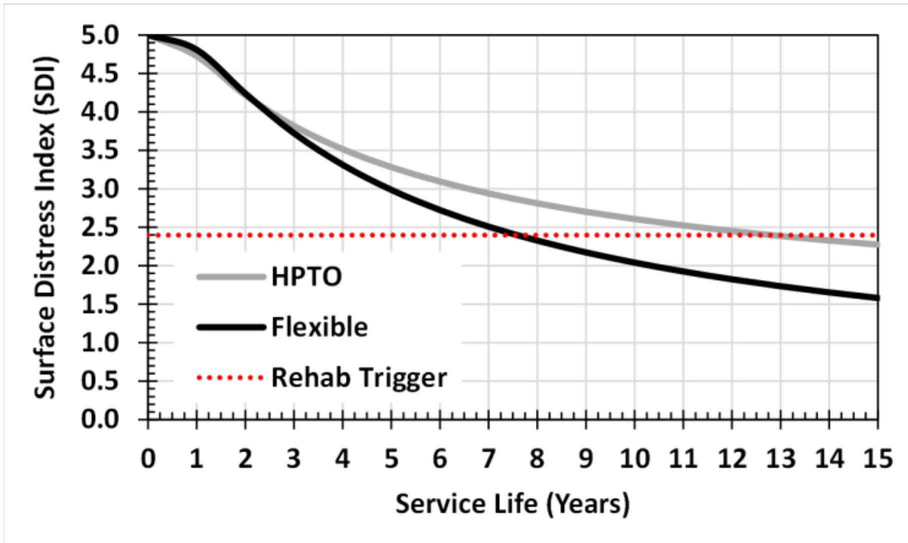

Improvement of > 5 Years of Service Life

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Stone Matrix Asphalt (SMA) with Bituminous Rich Intermediate Course (BRIC) for Composite Pavements

- Volumetric
  - Design AV = 4%
  - N_{des} = 75
  - VMA ≥ 14%
  - VFA 65 – 78%
  - RAP ≤ 15%
  - No performance test requirements

- SMA
  - Design AV = 3.5%
  - N_{des} = 75
  - VMA ≥ 17%
  - Min. AC% ≥ 6%
  - No RAP
- BRIC

Over 60% of NJDOT Pavements are Composite

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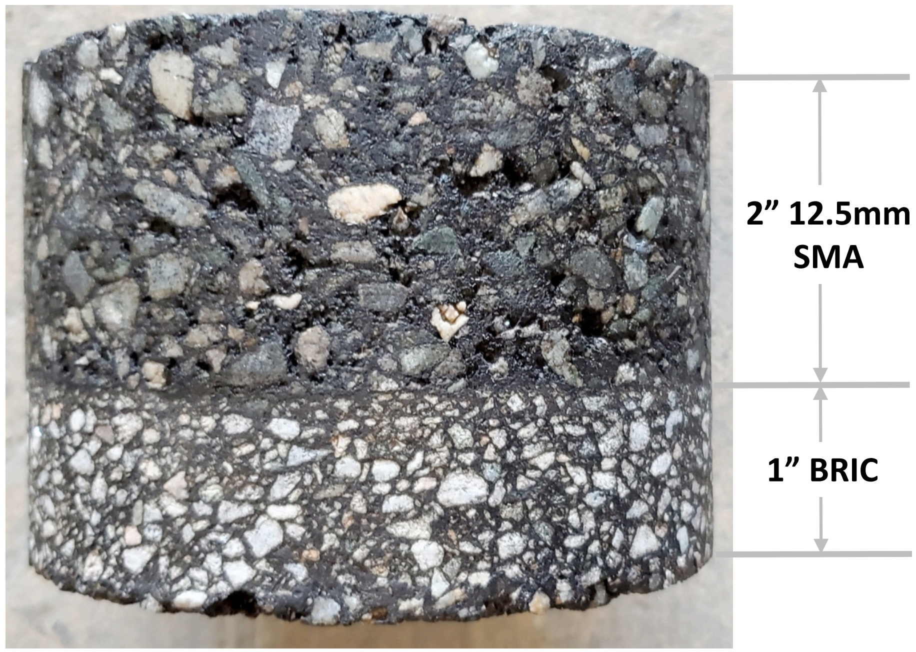

Combining modified asphalt mixtures as system to mitigate reflective cracking

- SMA
- BRIC
  - Design AV = 2.5%
  - N_{des} = 50
  - VMA ≥ 18%
  - Min AC% ≥ 7%
  - No RAP
  - APA Rutting ≤ 6.0mm
  - Overlay Tester ≥ 700 cycles

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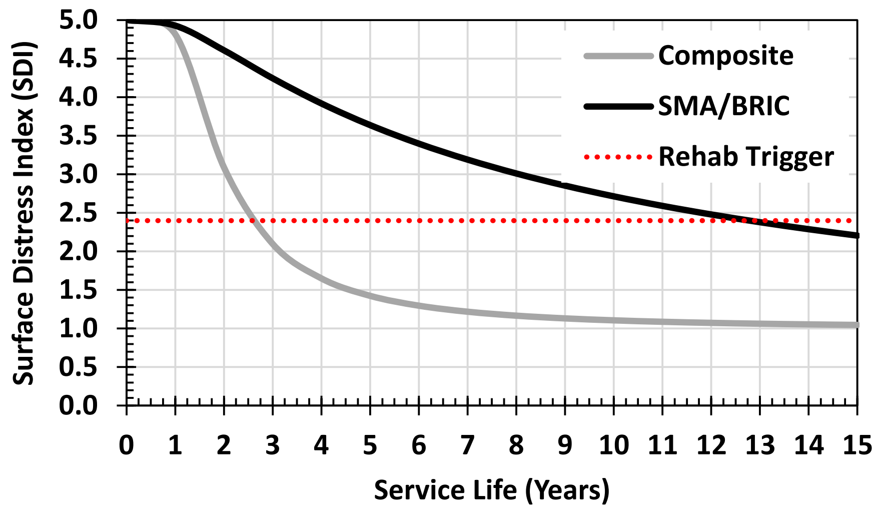

Improvement of > 10 Years of Service Life

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  - No RAP
  - APA Rutting ≤ 6.0mm
  - Overlay Tester ≥ 700 cycles

High Recycled Asphalt Pavement (HRAP) Mixtures

- Volumetric
  - Design AV = 4%
  - N_{des} = 75
  - VMA ≥ 14%
  - VFA 65 – 78%
  - RAP ≤ 15%
  - No performance test requirements

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

Performance criteria based on 0% RAP mix

- HRAP
  - Design AV = 4%
  - N_{des} = 75
  - VMA ≥ 1% over Volumetric
  - VFA 65 – 85%
  - Unlimited RAP%
  - Modified binders, WMA, Recycling Agents

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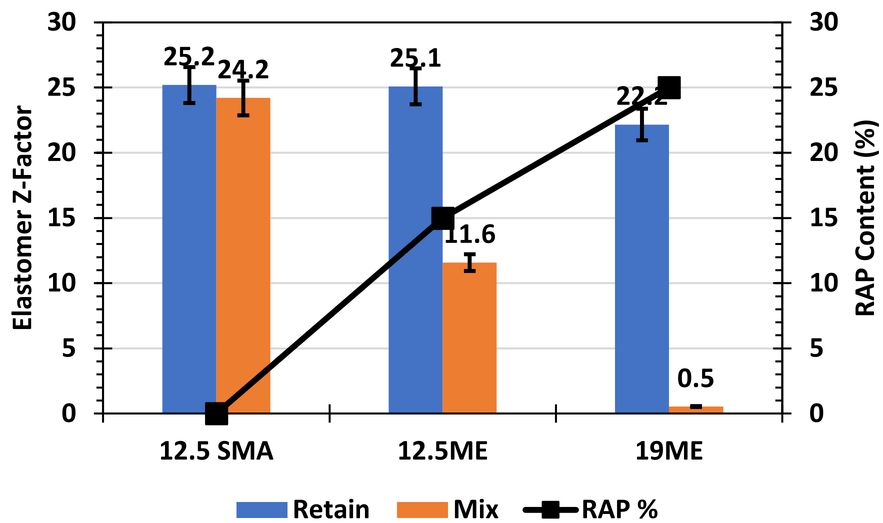

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Addition of RAP reduces elastomeric properties. Need to increase VBE to include more virgin liquid. Compensates for lack of RAP binder transfer to virgin aggregate.

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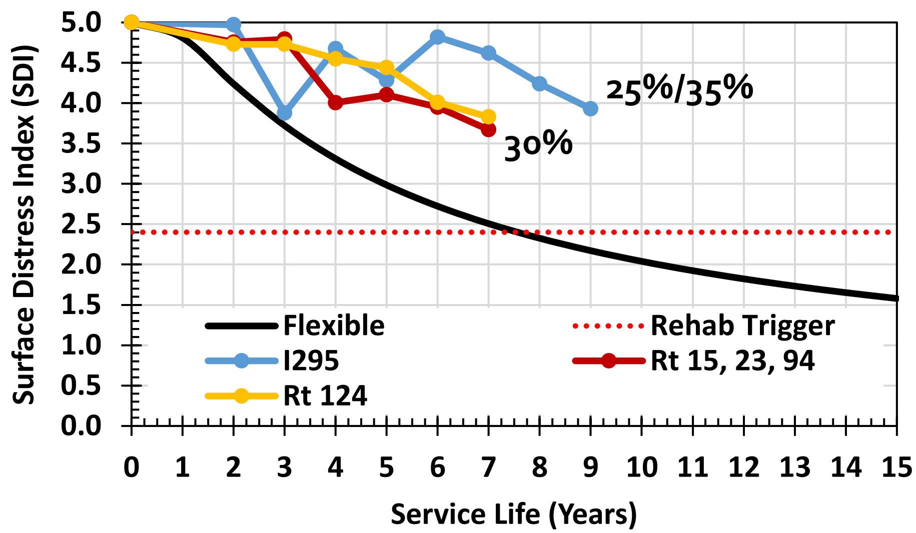

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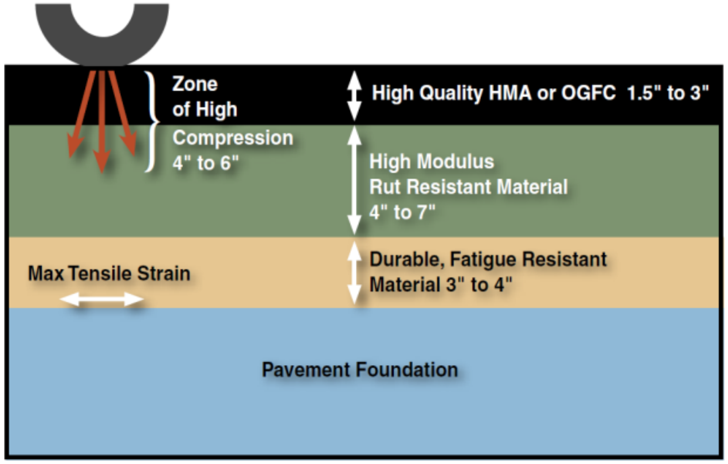
Only 3 projects with significant field performance, but projected 5 to 8 years benefit

Bituminous Rich Base Course (BRBC)

- Aging concrete pavements, when applicable, rubblized
- Utilized as base aggregate course for perpetual pavement design
  - Option #1
    - Design and construct the pavement to achieve a high stiffness, resulting in a pavement structure with minimal deflections/strains
      - Traditionally done with excessive thickness and cement treated base/subbase and subgrades
  - Option #2
    - Design/construct the asphalt materials, especially the base course, to be strain tolerant (i.e. – design the asphalt material to bend without cracking under resultant tensile strains)



Changing Design Methodology – Design Materials to Meet Structural Needs of Pavement ("Design Role Reversal")

- Evaluated maximum tensile strain with selected HMA thickness over rubblized PCC
  - Used JULEA software – same in MEPDG
- Used methodology in NCHRP Report 646
- Conduct flexural beam fatigue at 400 and 800ms
  - 3 samples each
- Use 95% confidence interval with a selected # of repetitions
  - Designing HMA to meet pavement performance needs – "Role Reversal"

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- BRBC
  - Design AV = 3.5%
  - N_{des} = 50
  - VMA ≥ 13.5%
  - No RAP
  - PG76-28
  - APA Rutting ≤ 5.0mm
  - Flexural Beam Fatigue (Based on project needs)

Example: NJ I295, MP45 to 57.3; 23 Overpass Structures Requiring Undercutting

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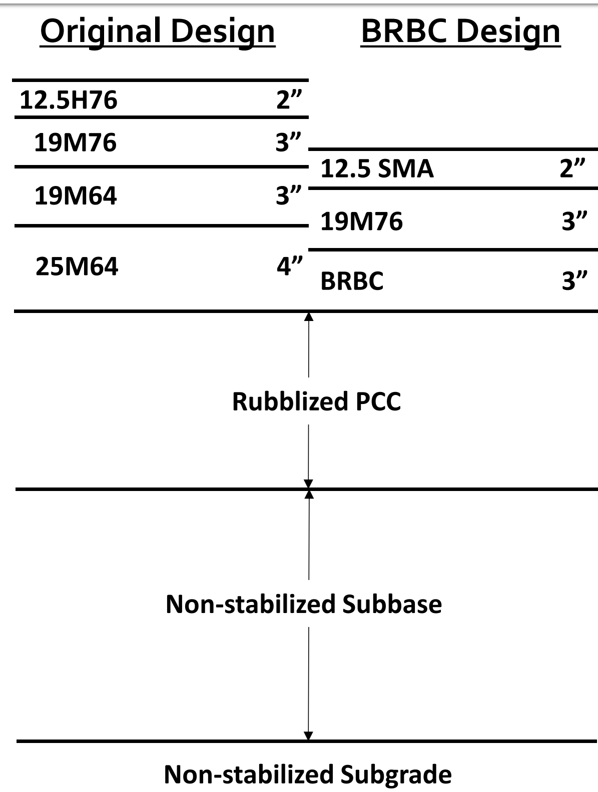

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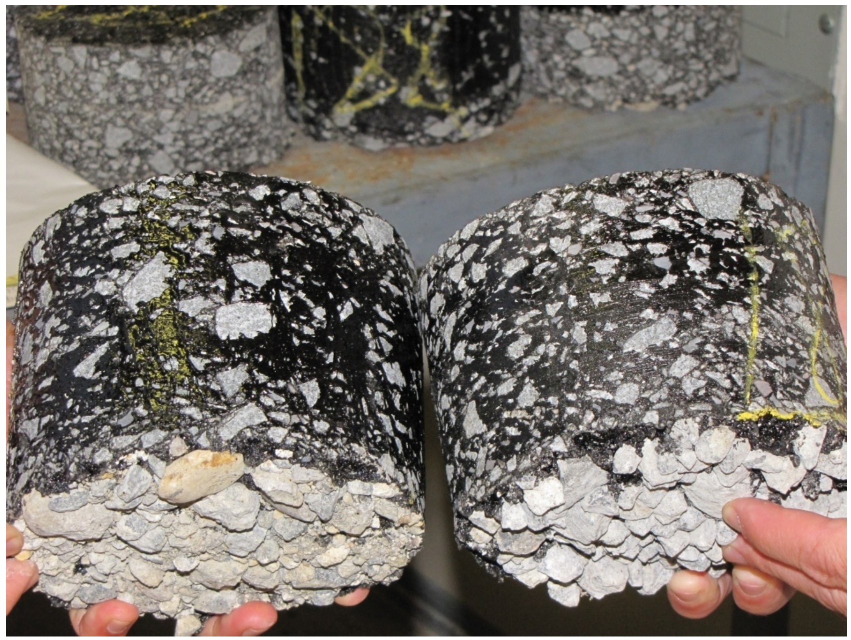

Project Saved:

- **Over 170,000 tons HMA**
- **Over 2700 round trips of delivery trucks**
- **Approximately $7 million**

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ASPHALT PAVEMENT ALLIANCE

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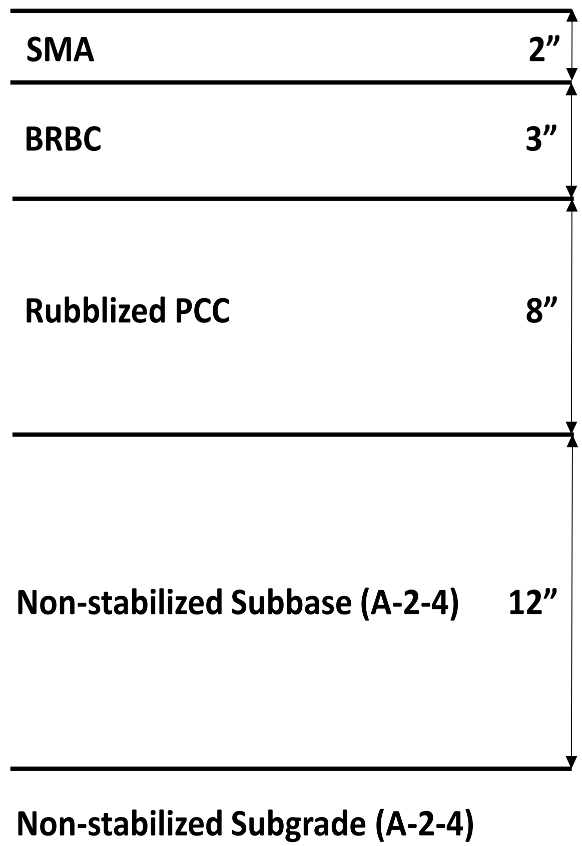
Example: NJ I295, MP45 to 57.3

After 10 years, 2022 saw 1st Pavement Preservation treatment

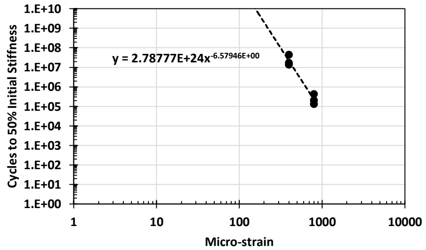
2019 BRBC – Rt 70 (Pinelands Conservation Commission)

- More aggressive design/ construction on NJ Rt 70 through conservation preserve
  - Greatly limited overlay thickness due to runoff regulations
  - Completed in 2020 and performing very well



Test Data

Sample ID	Micro-Strain	Fatigue Life (Nf)
#12	400	42,514,195
#14	400	13,202,300
#15	400	16,830,701
#3	800	421,489
#16	800	201,036
#17	800	127,461



Final Thoughts and Conclusions

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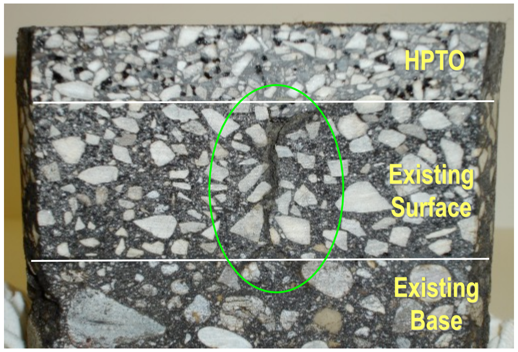
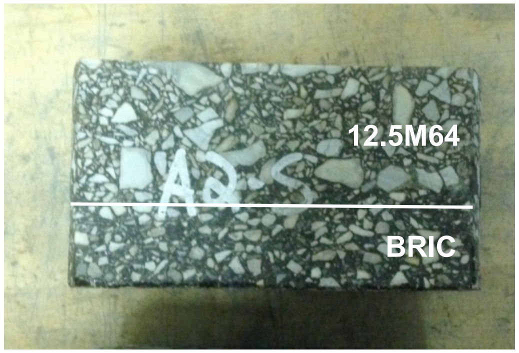
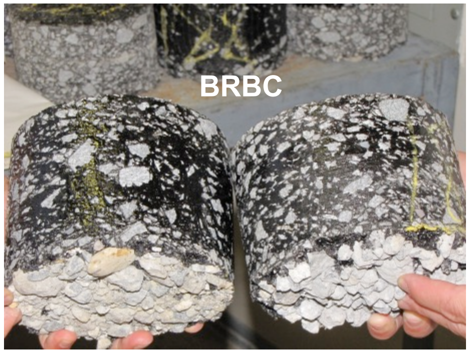
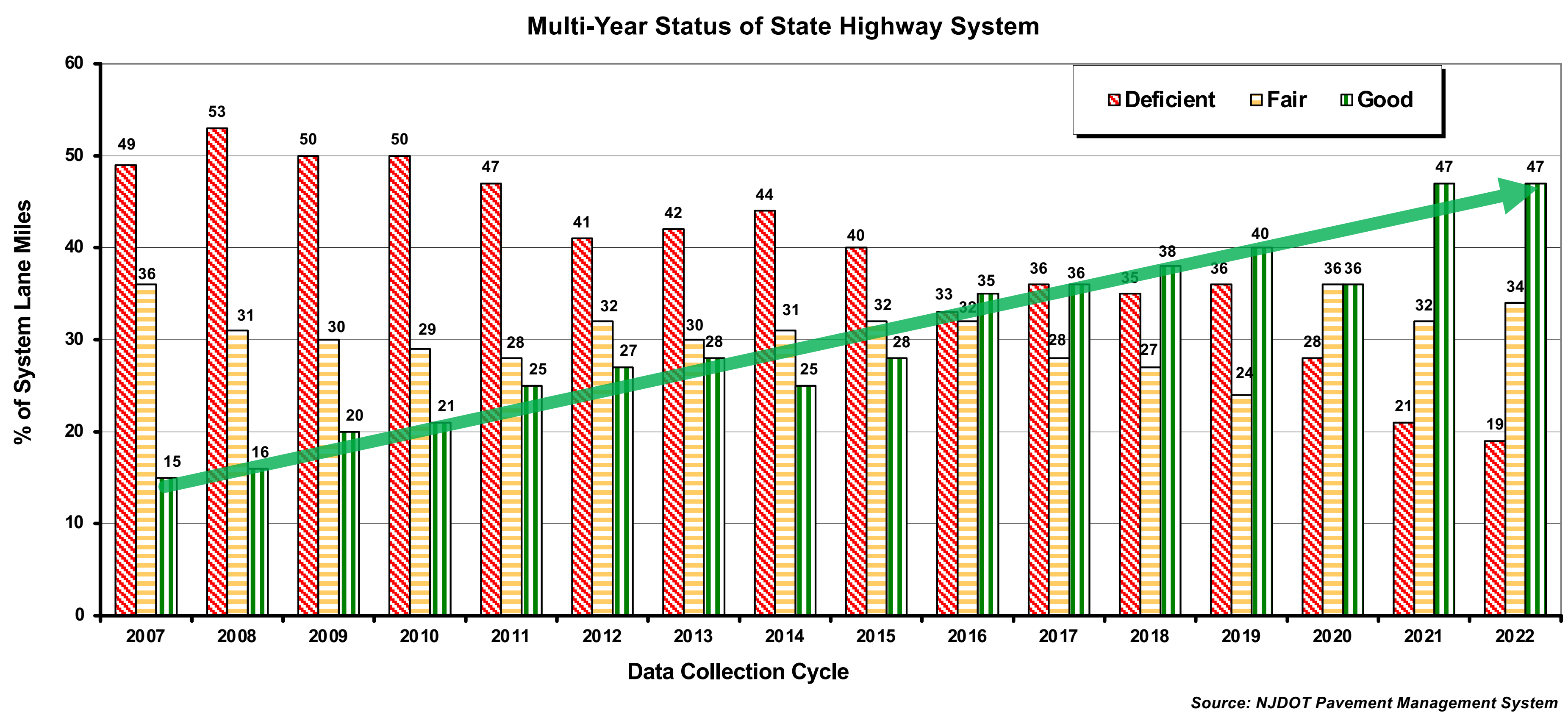
- Implementation of BMD (Approach A) in NJ has:
  - Resulted in improved field performance
    - Increase 5 to 10 years of service life!
  - The increase service life provides;
    - A more sustainable system
    - Allocate $ sooner for preserving Good pavements
    - Allocate $ rehab/reconstruct Average to Poor
- Where is it going?







Where It's Going!



As Ted Lasso reminded us..
"Be curious, not judgmental…"

Thank you for your time!

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