SMA – High Performance for a Demanding Public

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2019 Pennsylvania Asphalt Pavement Association (PAPA)
Hershey, PA

Stone Matrix Asphalt (SMA)

- Gap graded aggregate blends with cubical shaped aggregate
- Mastic of polymer-modified asphalt binder, mineral filler and fibers
- When produced and placed correctly, known for outstanding performance

Quoting Dr. Ray Brown (NCAT Report 425)

"SMA is a simple idea. Find a hard, durable, quality stone, fracture it into roughly cubical shape and of a size consistent with the proposed layer thickness, and then glue the stones together with a durable, moisture-resistant mortar of just the right quantity to give stone-to-stone contact among the coarse aggregate particles. For the asphalt technologist, the trick is getting the various parameters right."

A Quick "More Recent" SMA History in NJ

A "More Recent" History of SMA in NJ

- Prior to 2005, SMA use was limited in NJ
  - Rt 78 E, MP 28.58 to 30.8 – 9.5 mm NMAS SMA
  - Rt 1 N & S, MP 11.3 to 11.8 – 12.5 mm NMAS SMA
- In 2005, NJDOT advertised project for I295 (9.5 mm SMA)
  - To help industry, Rutgers organized an SMA & OGFC Workshop
  - Larry Michaels (MDSHA)
  - Randy West and Don Watson (NCAT)
  - Jeff Graf (Maryland Paving)

SMA/OGFC Design and Construction Workshop

March 8^{th} and 9^{th}, 2006
South Brunswick Courtyard by Marriott
420 Forsgate Drive
Cranbury, NJ 08512

Sponsored by:
The Center of Advanced Infrastructure and Transportation at Rutgers University (CAIT)
The New Jersey Department of Transportation (NJDOT)

Purpose: To provide an interactive workshop for policy makers, engineers, and the asphalt industry regarding the use of Stone Mastic Asphalt (SMA) and Open-graded Friction Course (OGFC) mixes. The workshop will combine a training course developed and taught by industry professionals from the National Center for Asphalt Technology (NCAT), as well as personal experience and research studies of experts in the field of SMA and OGFC. The workshop will equip participants with: 1) a better understanding on the design, construction, and performance of SMA and OGFC mixes 2) a collection of resource materials, including presentation notes, and relevant reports, and; 3) an understanding of the state-of-the-art in SMA and OGFC structural and functional performance that can be anticipated when using these specialty hot mix asphalt mixes.

Target Audience: Hot mix asphalt industry members, Local, State, and Federal agency engineers (design, maintenance, materials, and research), and consulting engineers.

Workshop Registration: A fee of $100.00 is required to confirm registration. All checks should be made out to Rutgers University. The fee will cover; handout materials, continental breakfast and lunch. Please RSVP to Janet Leli via email, telephone or fax. In the event that you are unable to attend the conference for any reason, please note that it is a departmental policy that a registered attendee must withdraw at least 72 hours in advance of the start of a course (first day of the course). If a written, faxed withdrawal is not received by our department in this manner, the full program fee is owed and non-refundable.

jleli@rci.rutgers.edu or Ph: (732) 445-5236 or Fax: (732) 445-5636

Hotel Registration: Rooms are being held at the South Brunswick Courtyard by Marriott. The hotel phone number is (800) 321-2211 or (609) 655-9950.

Additional Information: For additional information or any questions regarding the workshop, please contact:

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A "More Recent" History of SMA in NJ

- Next SMA project did not come until 2007
- Rt 30 E & W, MP 13.2 to 13.9
  - 12.5 mm NMAS
  - Composite pavement overlay
  - 8 years before overlay
- Rt 278 E & W, MP 0.0 to 0.9
  - 9.5 mm NMAS
  - Flexible pavement
  - PMS showed good performance for 9 years
- 2 projects in 2007 and 2008
- After 2008, 8+ SMA projects per year

NJDOT SMA Specifications

NJDOT SMA Specifications

- NJDOT SMA specifications generally follow AASHTO M325 recommendations
  - 4% air voids @ Ndesign = 75 gyrations
  - Polymer modified PG64E-22 (PG76-22)
  - 0.3 to 0.4% cellulose fibers; 0.4 to 0.6% mineral fibers

Table 902.05.02-2 SMA Mixtures Volumetrics For Design and Plant Production

Property	Production Control Tolerances	Requirement
Air Voids	±1%	3.5%
Voids in Mineral Aggregate (VMA)	–	17.0% minimum
VCA_{mix}	–	Less than VCA_{dry}
Draindown @ production temperature	–	0.30% maximum
Asphalt Binder Content (AASHTO T 308)[1]	±0.40%	6% minimum
Tensile Strength Ratio (AASHTO T 283)	–	80% minimum

1. Asphalt binder content may not be lower than the minimum after the production tolerance is applied.

NJDOT SMA Specifications

- NJDOT SMA specifications generally follow AASHTO M325 recommendations

Table 902.05.02-1 SMA Specification Band (% passing) nominal-maximum aggregate size

Production Control Tolerances from JMF[1]	Sieve Size	19 mm % Passing	12.5 mm % Passing	9.5 mm % Passing
0%	1"	100	100	100
±2%	3/4"	90-100	100	100
±5%	1/2"	50-88	90-100	100
±5%	3/8"	25-60	50-80	70-95
±3%	No. 4	20-28	20-35	30-50
±2%	No. 8	16-24	16-24	20-30
±4%	No. 16	–	–	0-21
±3%	No. 30	–	–	0-18
±3%	No. 50	–	–	0-15
±2%	No. 200	8.0-11.0	8.0-11.0	8.0-12.0
	Coarse Aggregate Fraction	Portion Retained on No. 4 Sieve	Portion retained on No. 4 Sieve	Portion retained on No. 8 Sieve
	Minimum Lift Thickness	2 inches	1 1/2 inch	1 inch

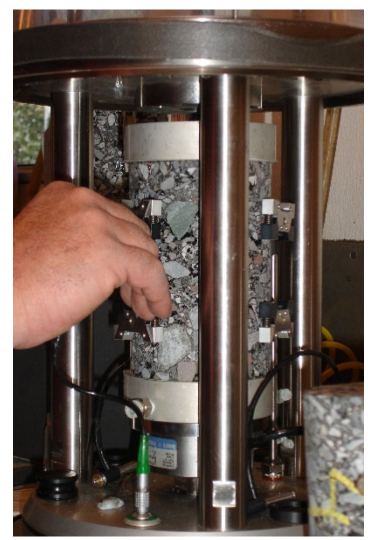
SMA Laboratory Performance

SMA Laboratory Performance – Stiffness and Permanent Deformation

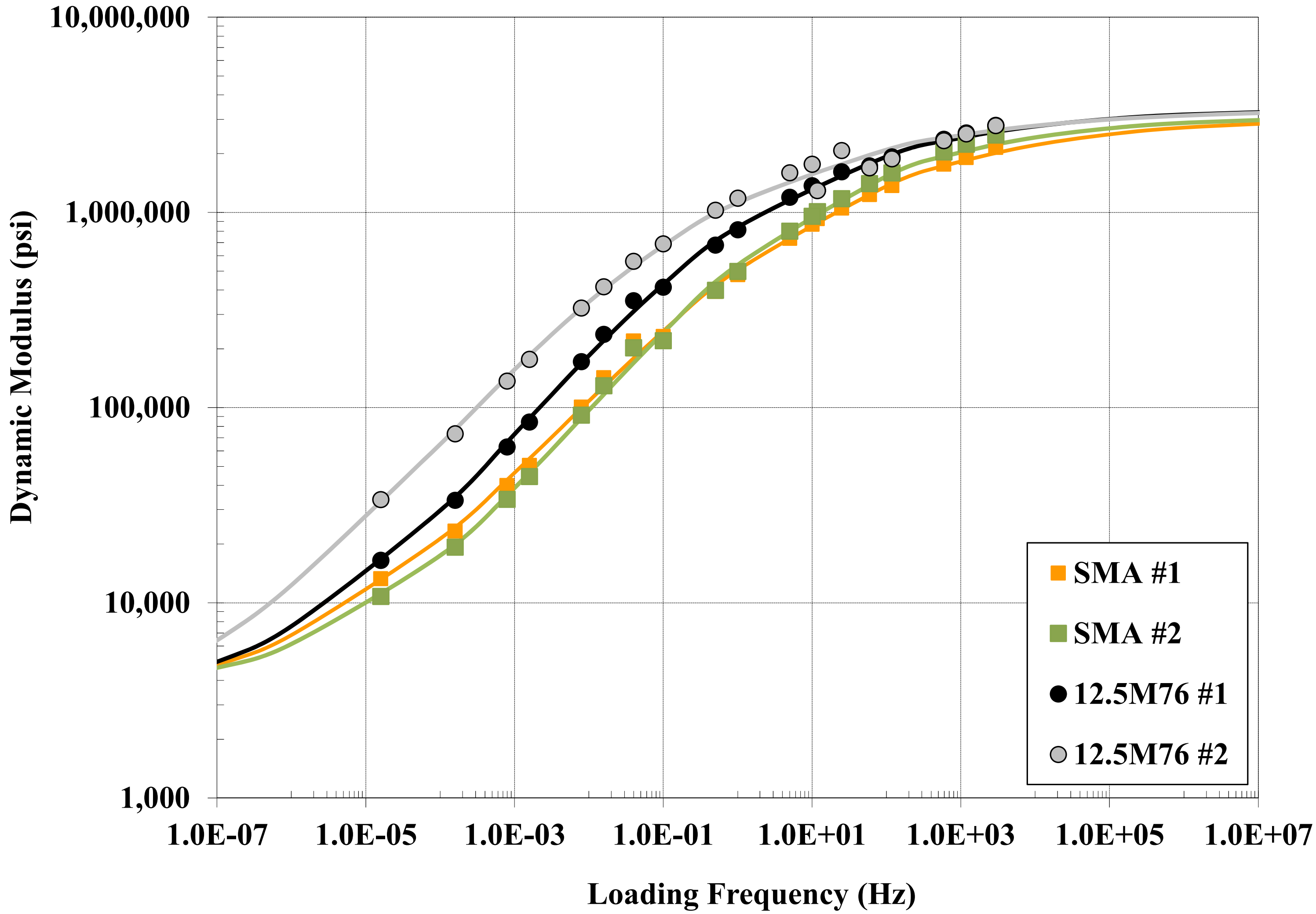
- Dynamic modulus and some permanent deformation tests may show some SMA mixes to be “softer” than HMA
  - SMA higher effective asphalt content than HMA
    - Thicker film thickness
  - No RAP allowed (for NJ)
  - E* (small strain stiffness) strongly a function of binder stiffness & effective binder volume
- Aggregate skeleton (stone-on-stone) difficult to mobilize without properly applied confinement

Mixture Stiffness – Dynamic Modulus

- Asphalt mixture stiffness properties determined using Asphalt Mixture Performance Tester (AMPT)
- Test method determines the material stiffness properties at different test temperatures and loading frequencies
- Results provide a "master stiffness curve" used in pavement design procedures



Dynamic Modulus Comparisons (NJ Mixtures)



SMA High Temperature Lab Performance

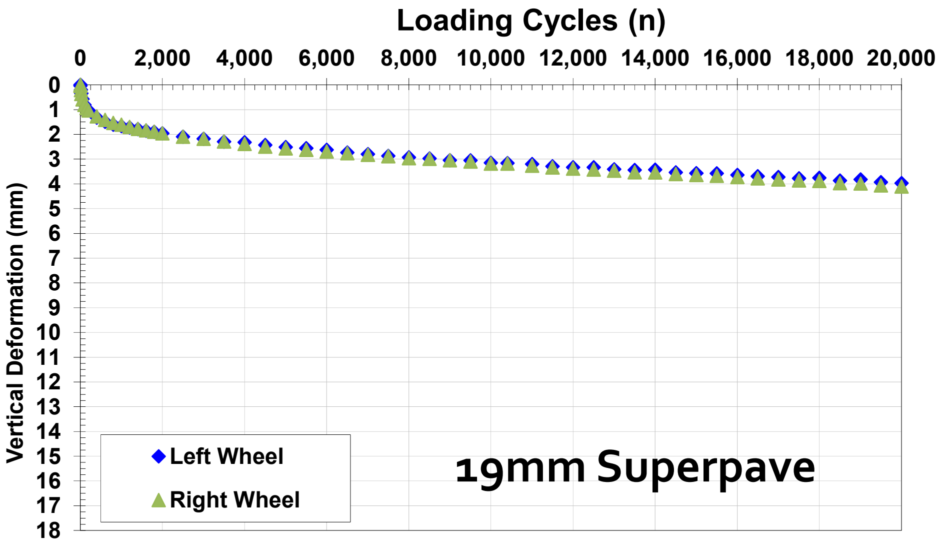
- AMPT Flow Number strongly related to binder stiffness properties and asphalt content

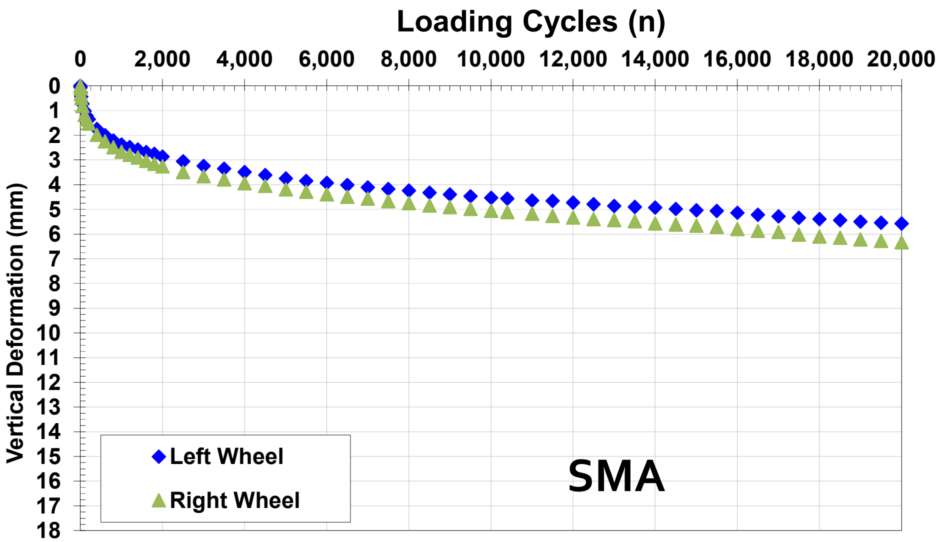
Mix Type	Flow Number (cycles)	AC Content (%)	High Temp PG	Jnr	% Rec
12.5M76 #1	1022	5.32	88.7	0.056	69.7
12.5M76 #2	4263	5.19	92.6	0.03	76.5
SMA #1	613	5.98	81.8	0.15	69.1
SMA #2	522	6.14	81.2	0.23	55.6

Traffic Level *Million ESALs*	**Minimum Flow Number** *Cycles*	**General Rut Resistance**
< 3	---	Poor to Fair
3 to < 10	200	Good
10 to < 30	320	Very Good
≥ 30	580	Excellent

SMA High Temperature Lab Performance (PA Mixes)

- Loaded wheel test procedures (APA and Hamburg) will also show similar trends to E* and Flow Number
  - Example:
    - Same aggregate source
    - Same asphalt binder source





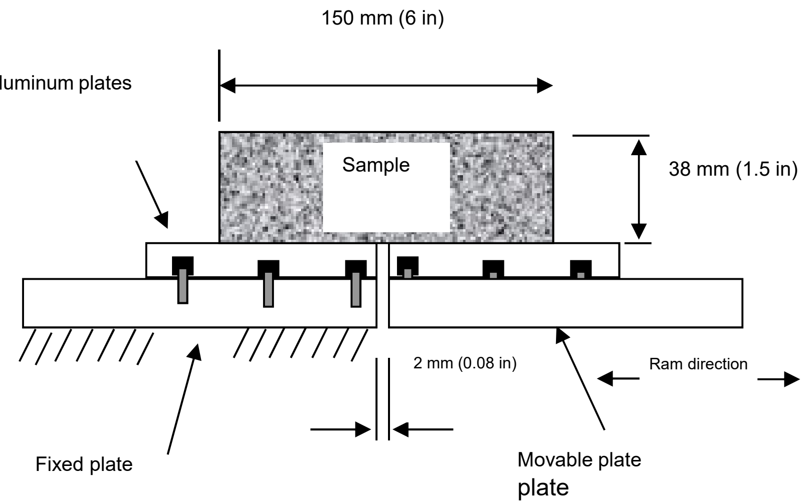
SMA High Temperature Lab Performance

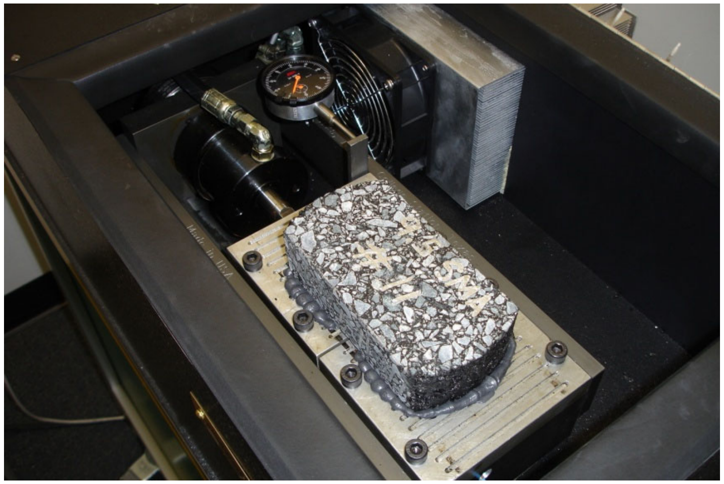
- Although SMA mixtures achieve excellent permanent deformation performance in the field, may not show as well as some HMA in the lab
  - SMA aggregate skeleton difficult to mobilize without applying proper confining pressure
  - SMA stiffness will appear "softer"
    - Higher effective asphalt content (higher film thickness)
    - Typically no RAP in SMA
    - PAVEMENT-ME?

SMA Laboratory Performance – Cracking Performance

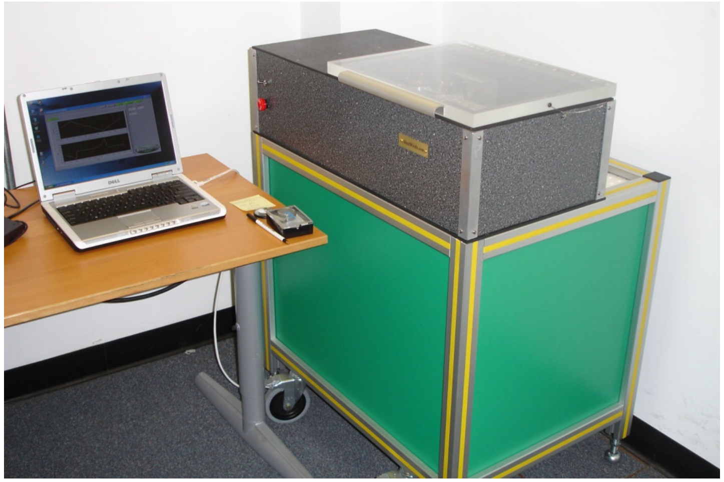
- In contrast to the permanent deformation, due to higher effective AC, SMA mixtures typically outperform dense graded HMA in laboratory fatigue tests
- Examples from
  - Overlay Tester
  - Flexural Beam Fatigue
  - SCB Flexibility Index

Overlay Tester



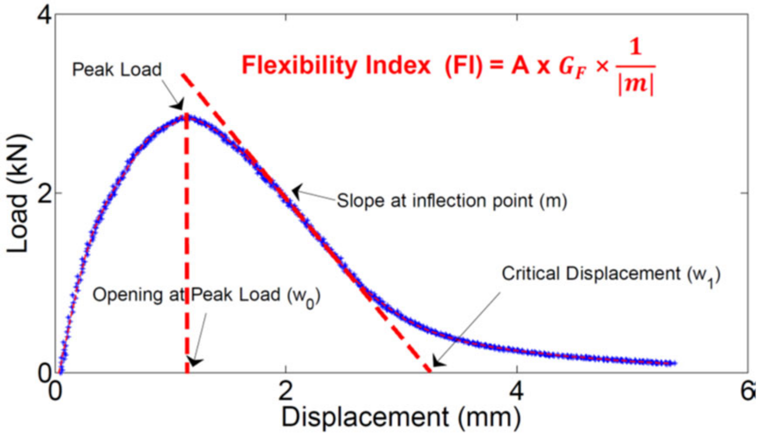


- Sample size: 6" long by 3" wide by 1.5" high
- Loading: Continuously triangular displacement 5 sec loading and 5 sec unloading
- Definition of failure
  - Discontinuity in Load vs Displacement curve

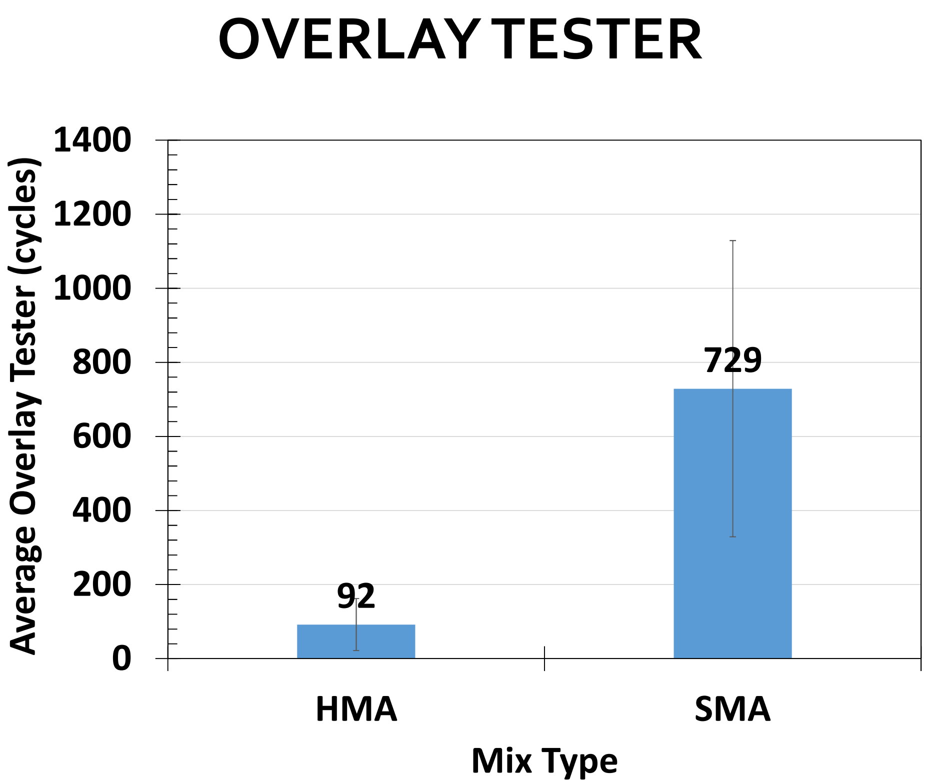


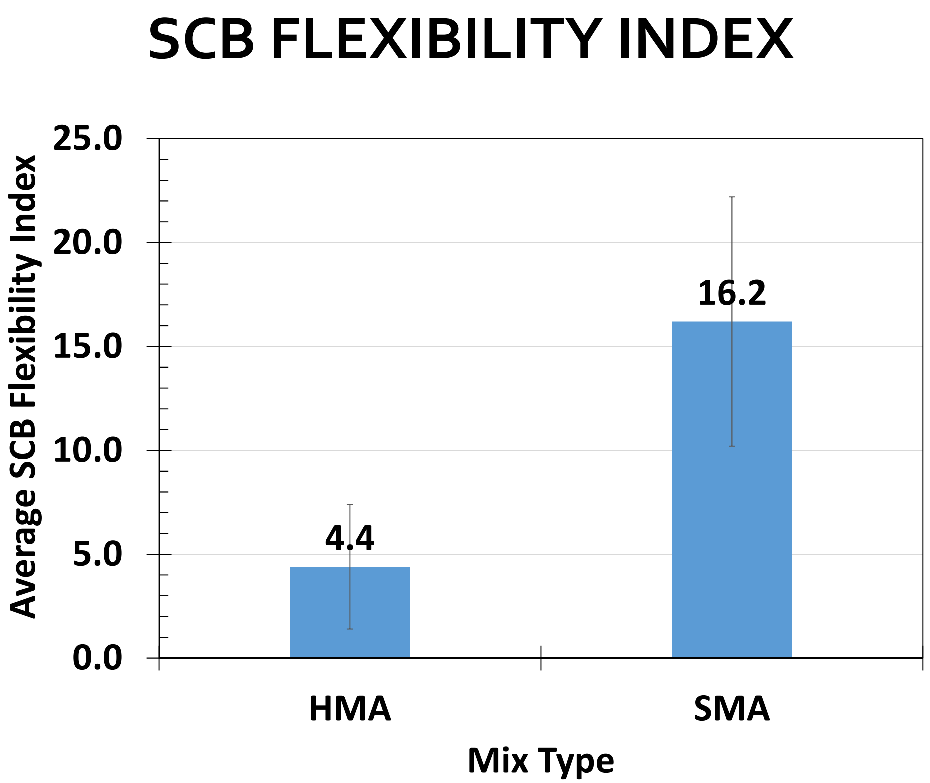
Semi-circular Bend (SCB) Test

- Uses 3-point bending on a semi-circular asphalt sample
- Can use same equipment at AASHTO T283 (50 mm/min)
- Notch cut to initiate cracking
- Test evaluates the energy required to fracture the specimen and propagate a crack at the notch
  - Work of Fracture
- Additional analysis was used to calculate the Flexibility Index (FI)
  - Post peak response



Fatigue Cracking – SCB FI and Overlay Tester Averages (n > 10)

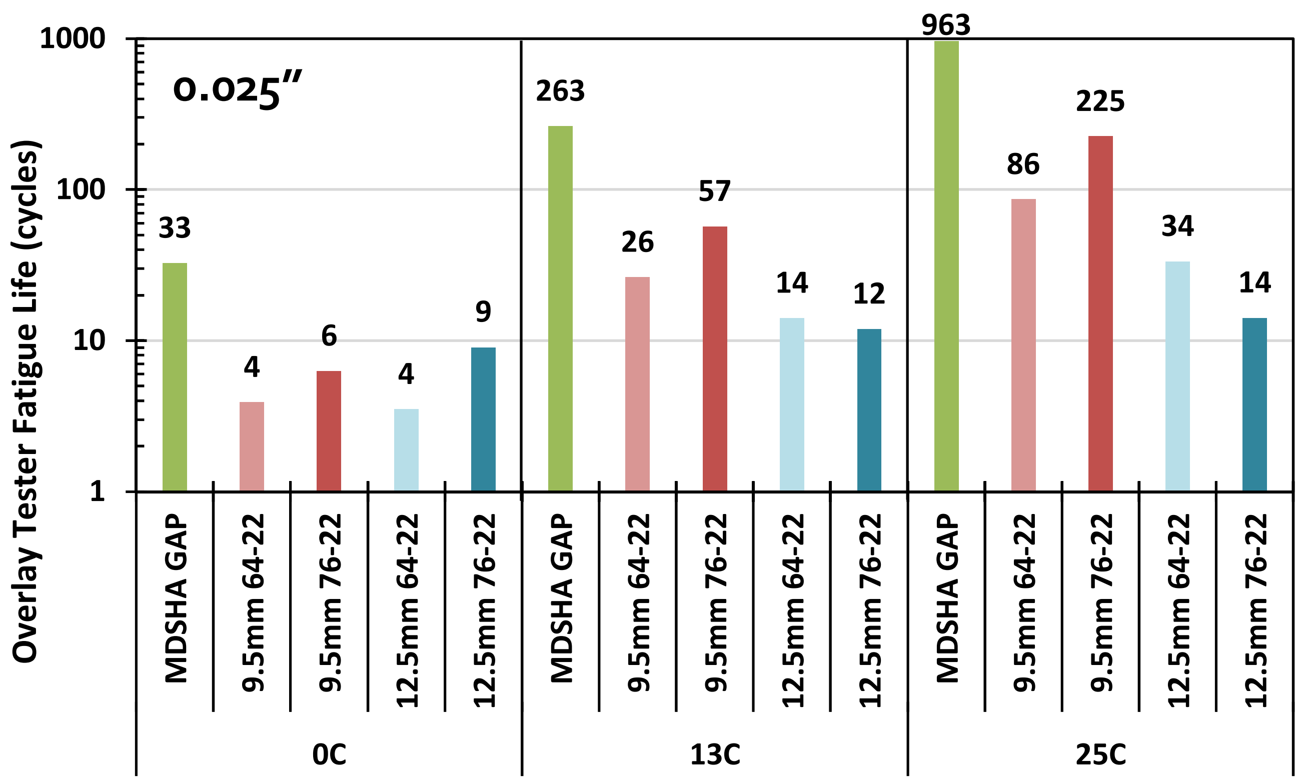




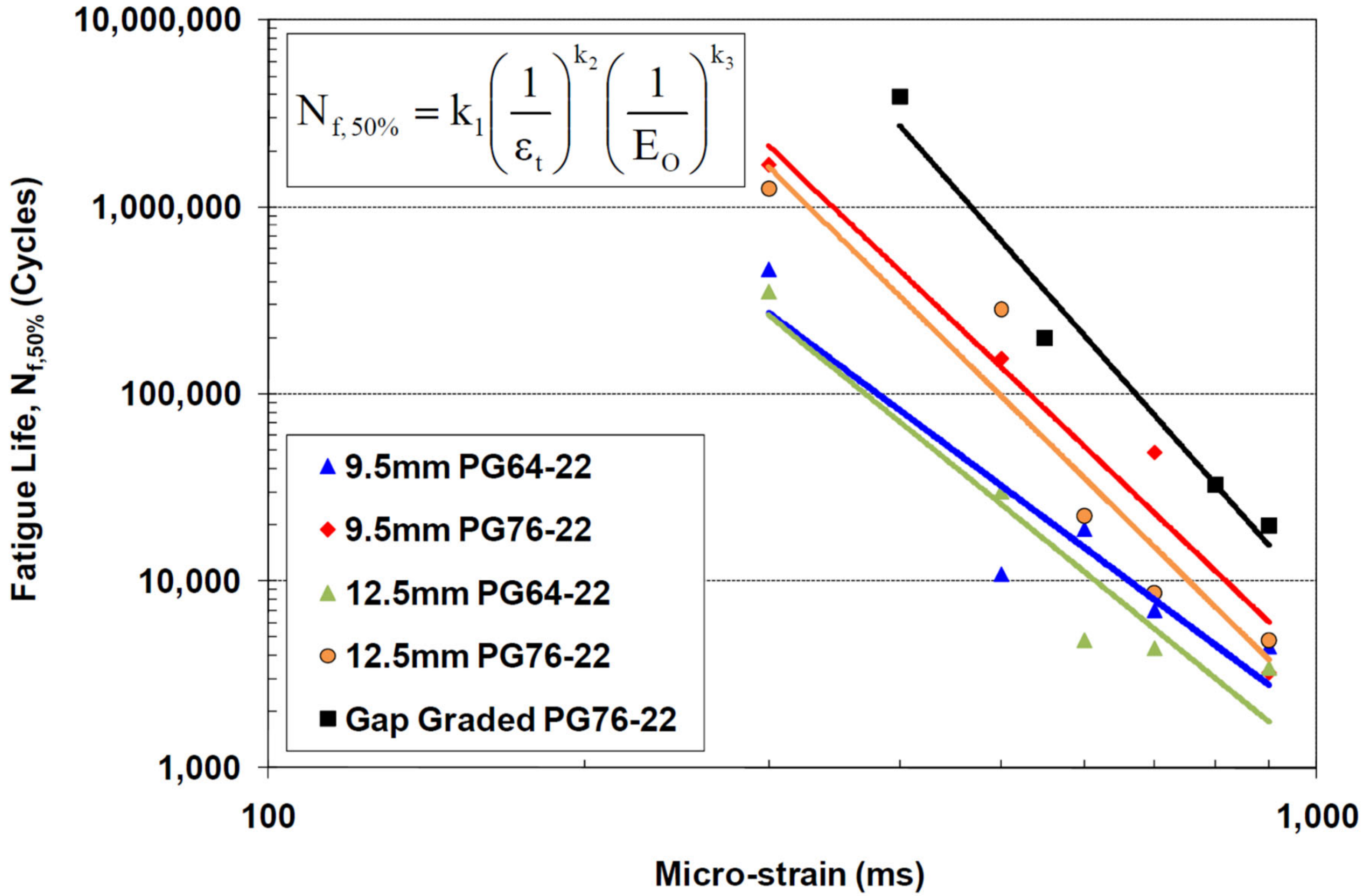
Error bars represent standard deviation for all mixes tested – not test variability

Overlay Tester (MDSHA Study)

- Conducted at different test temperatures and displacements



Flexural Beam Fatigue (MDSHA Mixes)



SMA Laboratory Performance in NJ

- In general, SMA obtains excellent laboratory performance
  - May show to be "softer" than HMA at high temperatures due to higher effective asphalt contents and no RAP
    - Lower high temperature stiffness/more permanent deformation in AMPT and loaded wheel testers
    - Difficult to mobilize stone-on-stone rutting resistance without applied confining pressure
  - SMA far superior in fatigue cracking resistance than HMA
    - Fatigue cracking resistance directly related to effective asphalt content
    - For NJ, RAP is not allowed in SMA

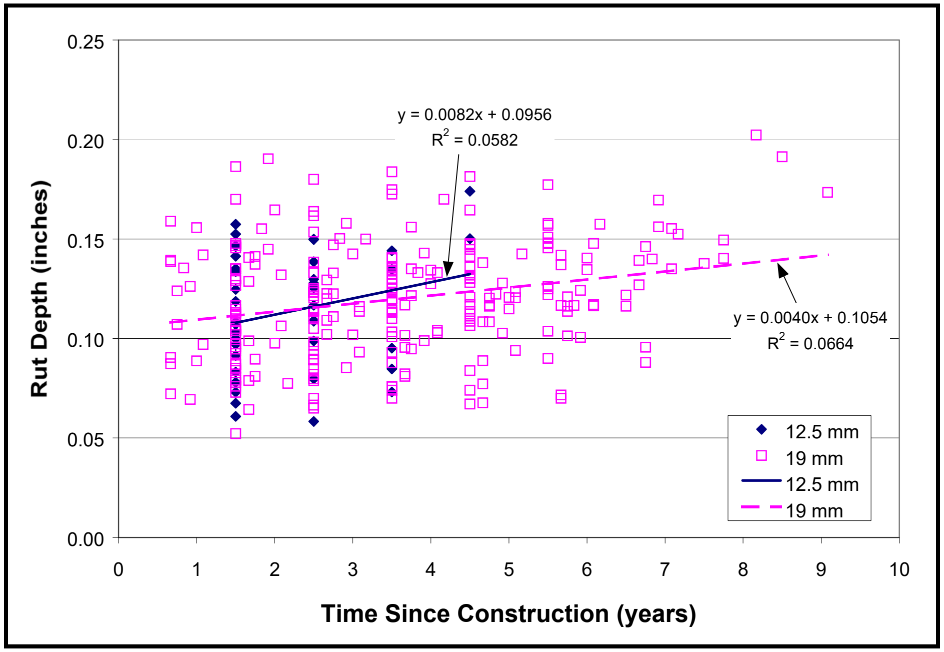
SMA Pavement Performance

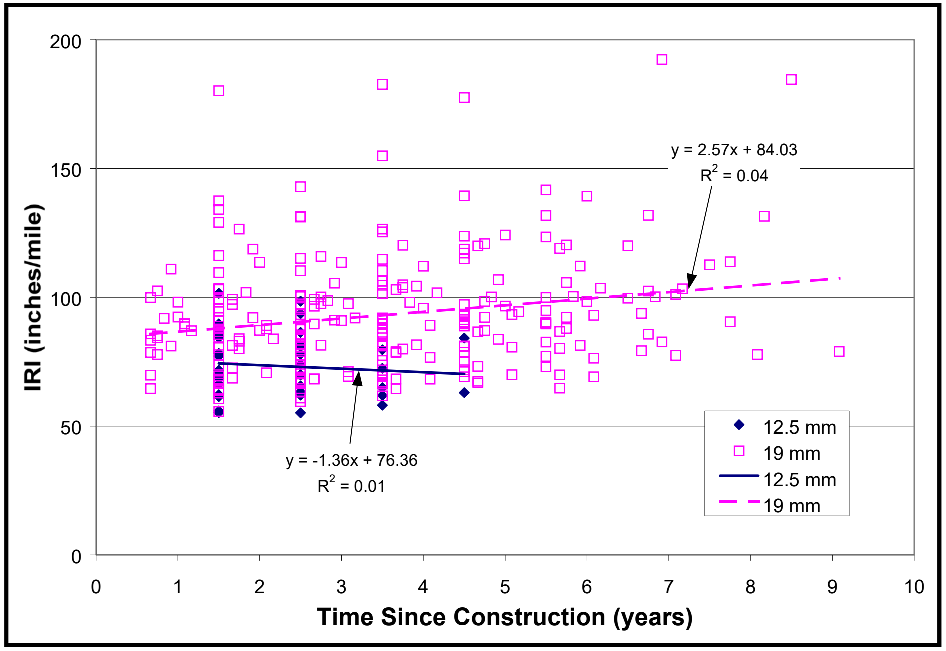
Early SMA in United States - Maryland

- Documented in AAPT, Vol 72 (2003)
  - Michael, Burke, and Schwartz
- 10 years of pavement performance starting in 1993
  - 86 different projects
  - > 1300 lane miles
  - >80% interstates
  - 9.5, 12.5, and 19 mm NMAS

Early SMA in United States - Maryland

- Excellent performance
  - Rutting: 0.04 inches/yr (average)
  - Roughness (IRI): 3.2 in/mile per year (average)

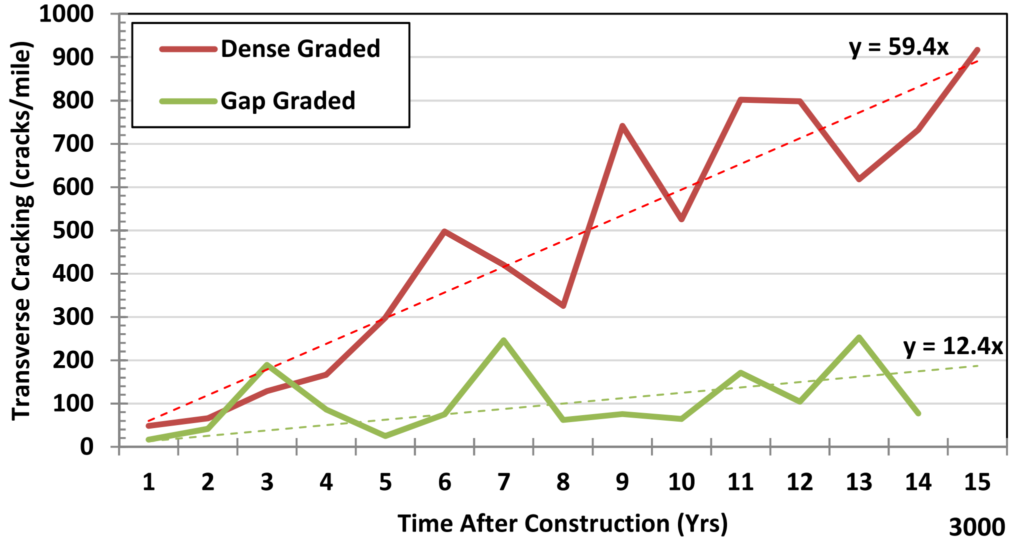




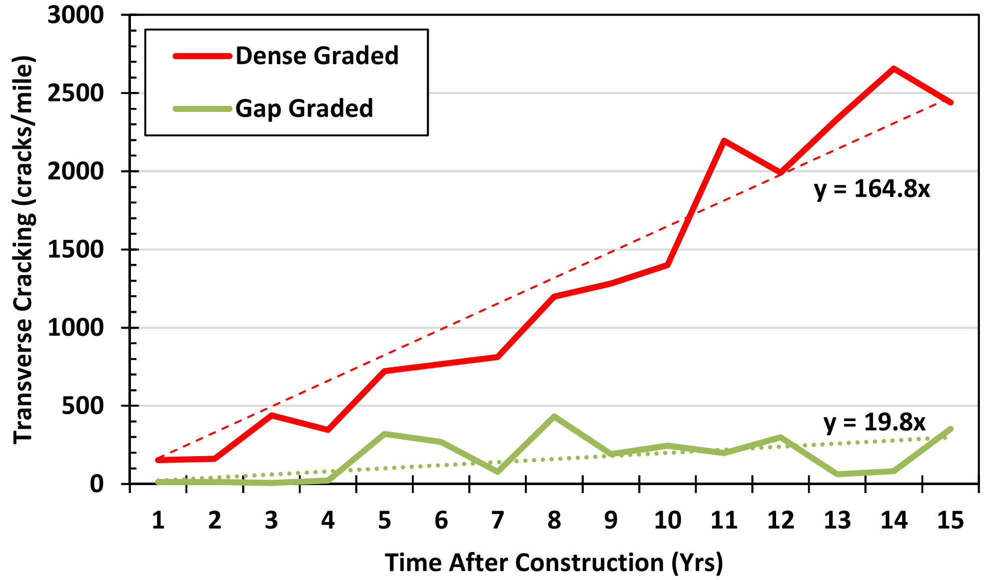
Maryland Performance – 2008/2010

- Rutgers worked with MDSHA to evaluate performance of different HMA mixes for composite pavements
  - Asphalt mixture performance shown earlier
- Utilized PMS to assess impact of surface course mix type on reflective cracking
  - Two separate roadways where both SMA (Gap Graded) and dense graded HMA placed

Maryland Performance – 2008/2010



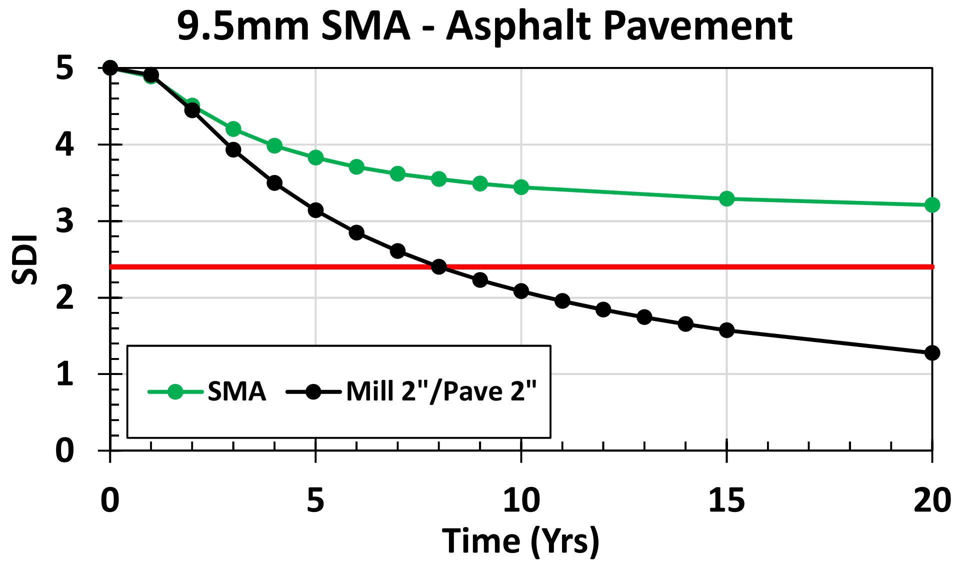
Cracking rate of SMA (Gap-Graded) was 5 to 8 times lower than HMA!

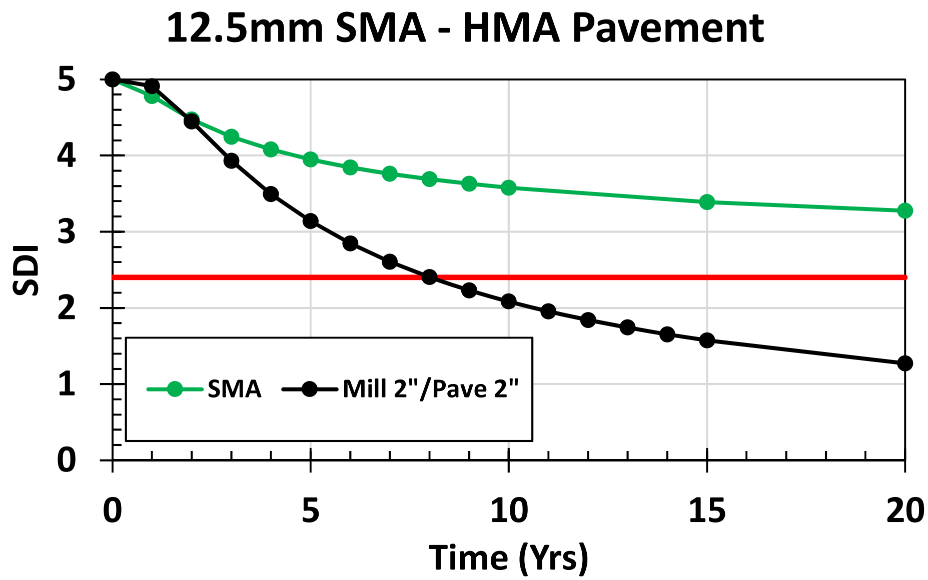


SMA Field Performance - NJ

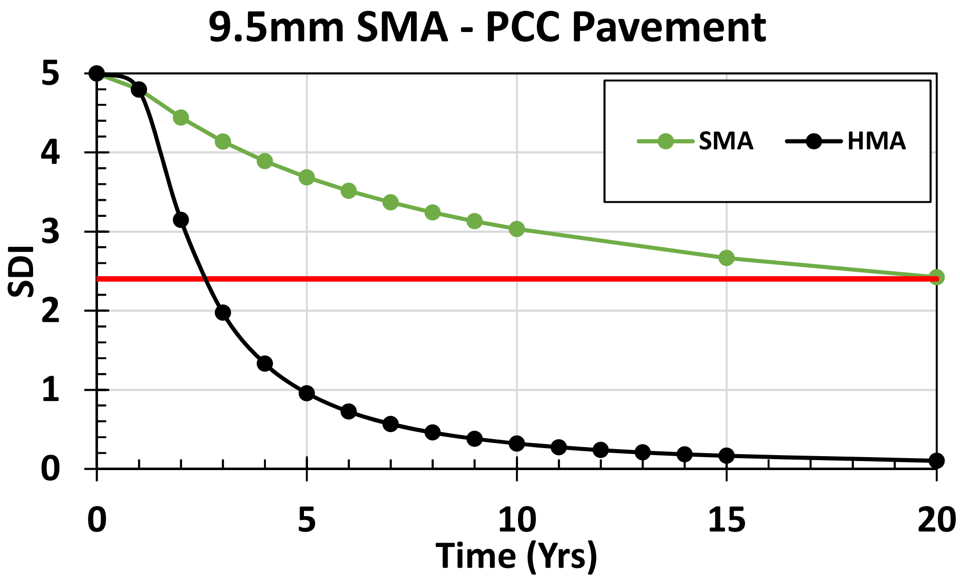
- NJDOT PMS was mined to extract the SMA performance since 2007.
  - Surface Distress Index (SDI) used to monitor "life" of the pavement
  - SDI < 2.4 trigger for pavement rehabilitation
- Approximately 100 SMA pavement sections were evaluated
  - Minimum of 3 years of performance
  - 9.5 mm and 12.5 mm NMAS
  - Flexible and composite pavement overlays
  - Performance compared to mill 2"/pave 2" HMA

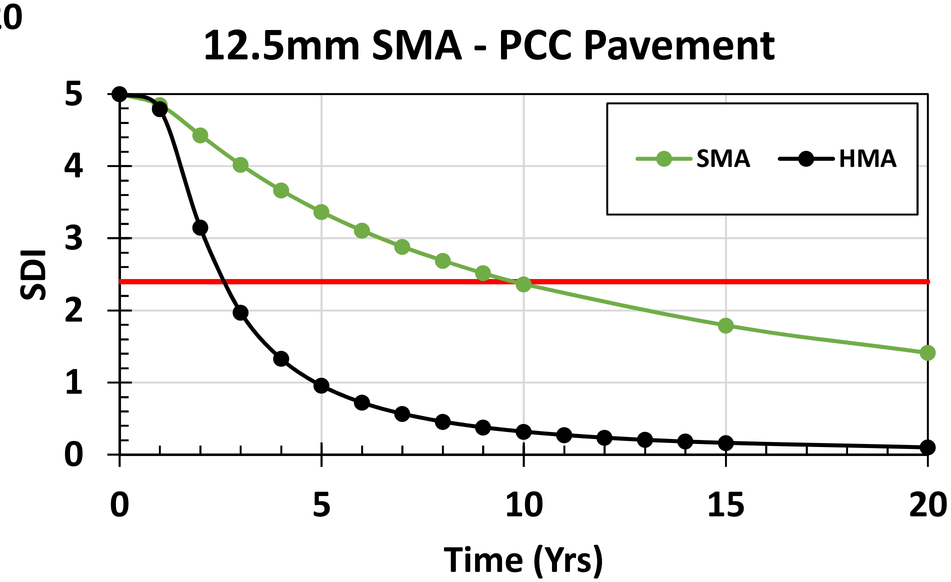
SMA Field Performance – NJ Flexible Pavements





SMA Field Performance – NJ Composite Pavements



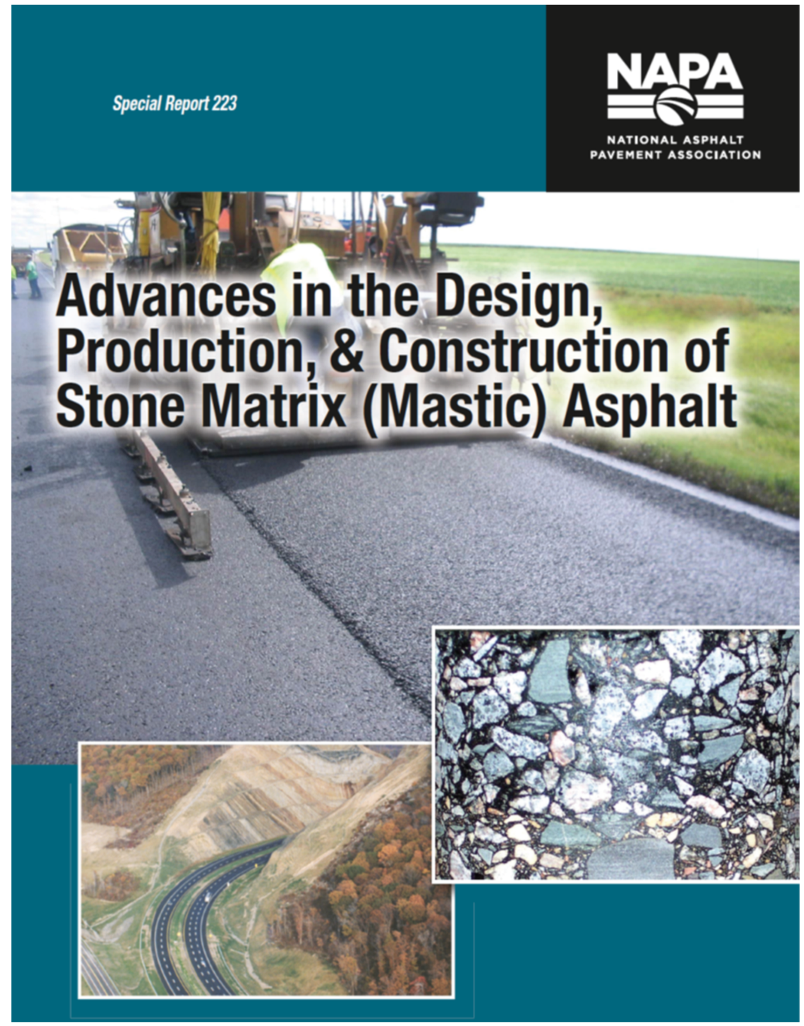


SMA NJ Field Performance Summary

- Flexible Pavements
  - Pavement distress curves indicate SMA should outperform HMA by 10+ years for flexible pavements
- Composite Pavements
  - Pavement distress curves indicate SMA should outperform HMA by 7+ years for composite pavements
  - NJDOT also includes a Bituminous Rich Intermediate Course (BRIC) to provide even greater life expectancy

SMA vs Dense Graded – NCAT Study

- 13 state agencies provided PMS data
- Predicted service life using each individual state agency's procedures
- SMA had average of **31.4% (3.9 years) increase** in predicted service life over dense graded HMA



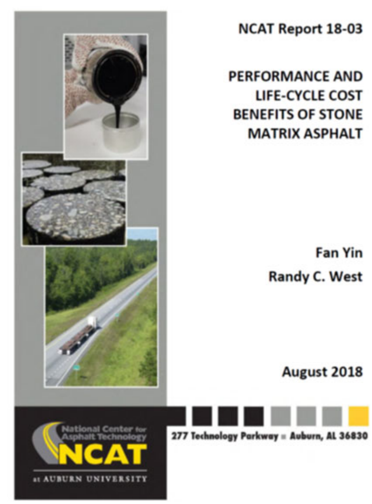
Pavement Prediction with PAVEMENT-ME

- NCHRP 1-47 indicated distress predictions highly sensitive to E* (except thermal cracking)
- The PAVEMENT-ME dependency on E* may make SMA look “soft”
  - Higher permanent strains for rutting
  - Potentially higher deflections = higher tensile strains
- Before use, should look at calibrating models for HMA and SMA separately
- NCAT Report 18-03 attempted to use lab tests

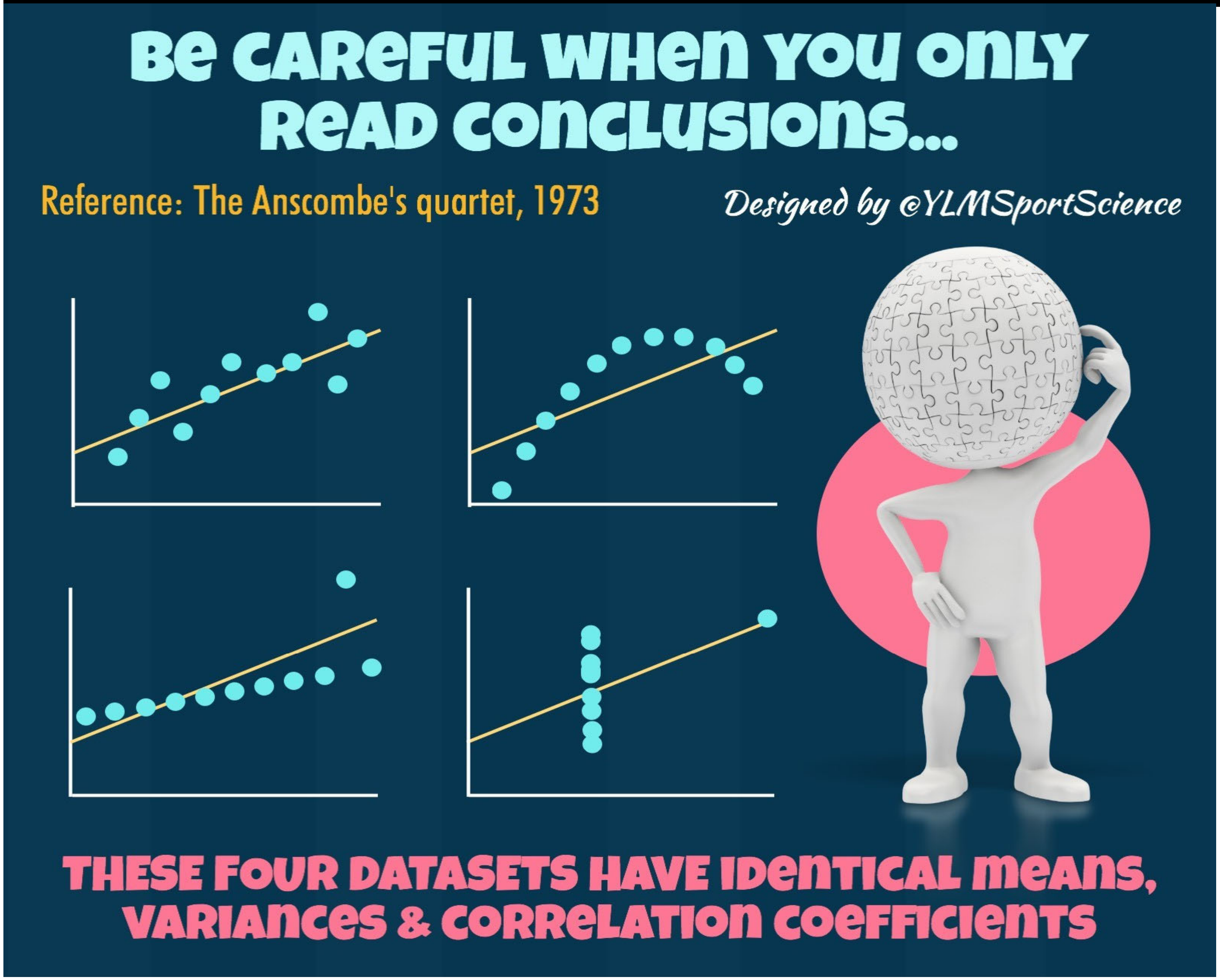
$$\log E^* = 3.750063 + 0.02932\rho_{200} - 0.001767(\rho_{200})^2 - 0.002841\rho_4 - 0.058097V_a - 0.802208\left(\frac{V_{eff}}{V_{eff}+V_a}\right) + \frac{3.871977 - 0.0021\rho_4 + 0.003958\rho_{38} - 0.000017(\rho_{38})^2 + 0.005470\rho_{34}}{1+e^{(-0.603313-0.313351\log(f)-0.393532\log(\eta))}}$$

Where:

E^*	= Dynamic Modulus, psi
η	= Bitumen viscosity, 10^6 poise
f	= Loading frequency, Hz
V_a	= Air voids content, %
V_{eff}	= Effective bitumen content, % by volume
ρ_{34}	= Cumulative % retained on the 3/4-in sieve
ρ_{38}	= Cumulative % retained on the 3/8-in sieve
ρ_4	= Cumulative % retained on the #4 sieve
ρ_{200}	= % passing the #200 sieve



Thank you for your time!
Questions?



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