Performance Summary of NJ's SMA

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2018 Northeast Asphalt User Producer Group (NEAUPG)
Atlantic City, NJ

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 8th and 9th, 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

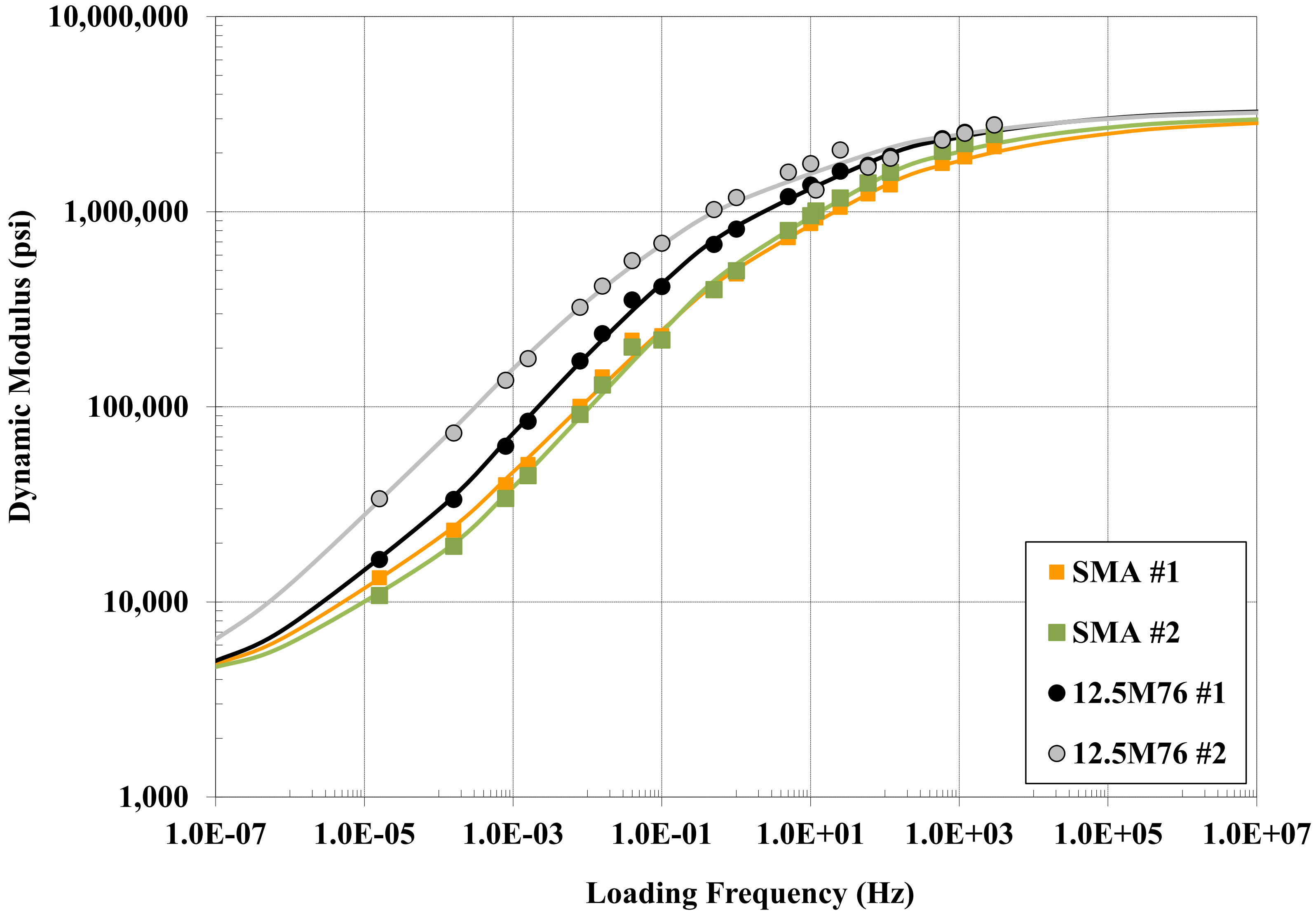
SMA Laboratory Performance – Stiffness and Permanent Deformation

- Dynamic modulus and some permanent deformation tests will show SMA "softer" than HMA
  - SMA higher effective asphalt content than HMA
    - Thicker film thickness
  - No RAP allowed
  - E* (small strain stiffness) strongly a function of binder stiffness
- 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



SMA High Temperature Lab Performance

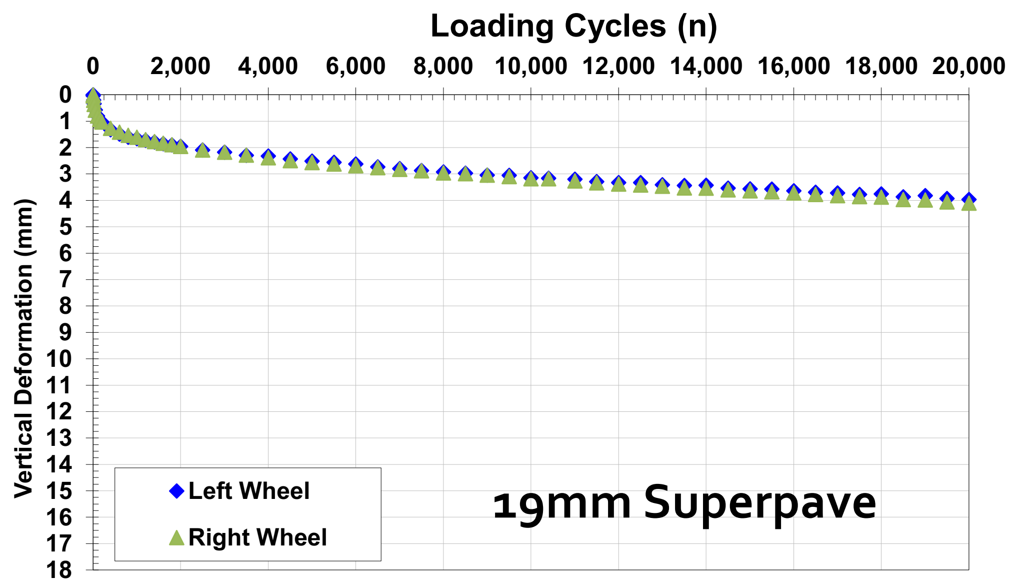
- AMPT Flow Number strongly related to binder stiffness properties and asphalt content

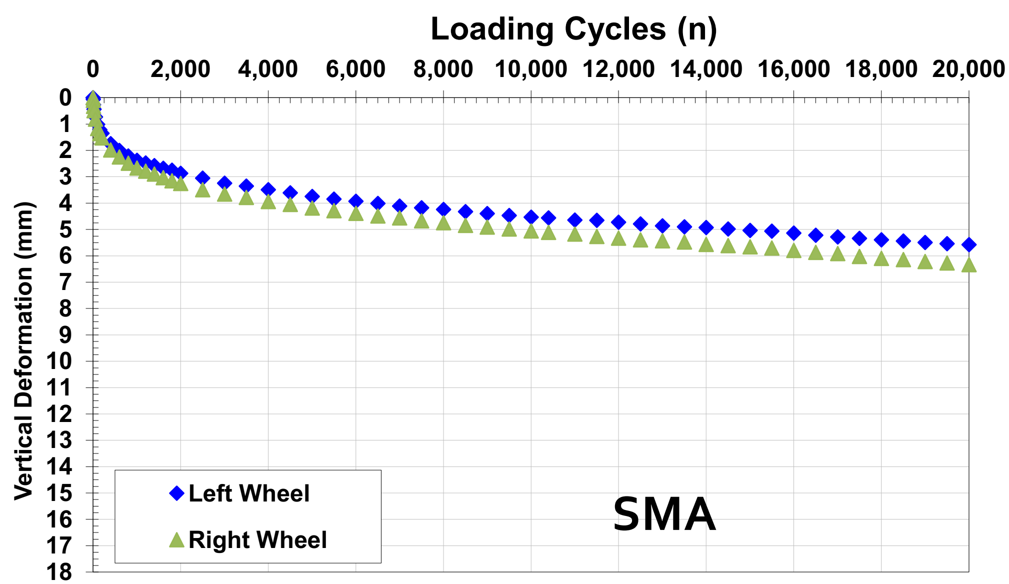
Mix Type	Flow Number (cycles)	AC Content (%)	High Temp PG	Jnr	% Rec
12.5M76 #1	1022	5.32	88.7	0.056	69.7
12.5M76 #2	4263	5.19	92.6	0.03	76.5
SMA #1	613	5.98	81.8	0.15	69.1
SMA #2	522	6.14	81.2	0.23	55.6

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

- 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

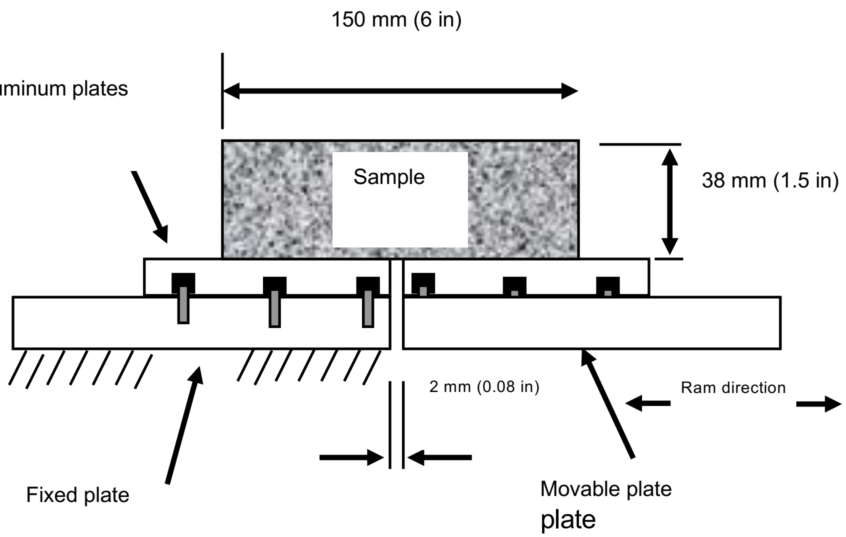




SMA High Temperature Lab Performance

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

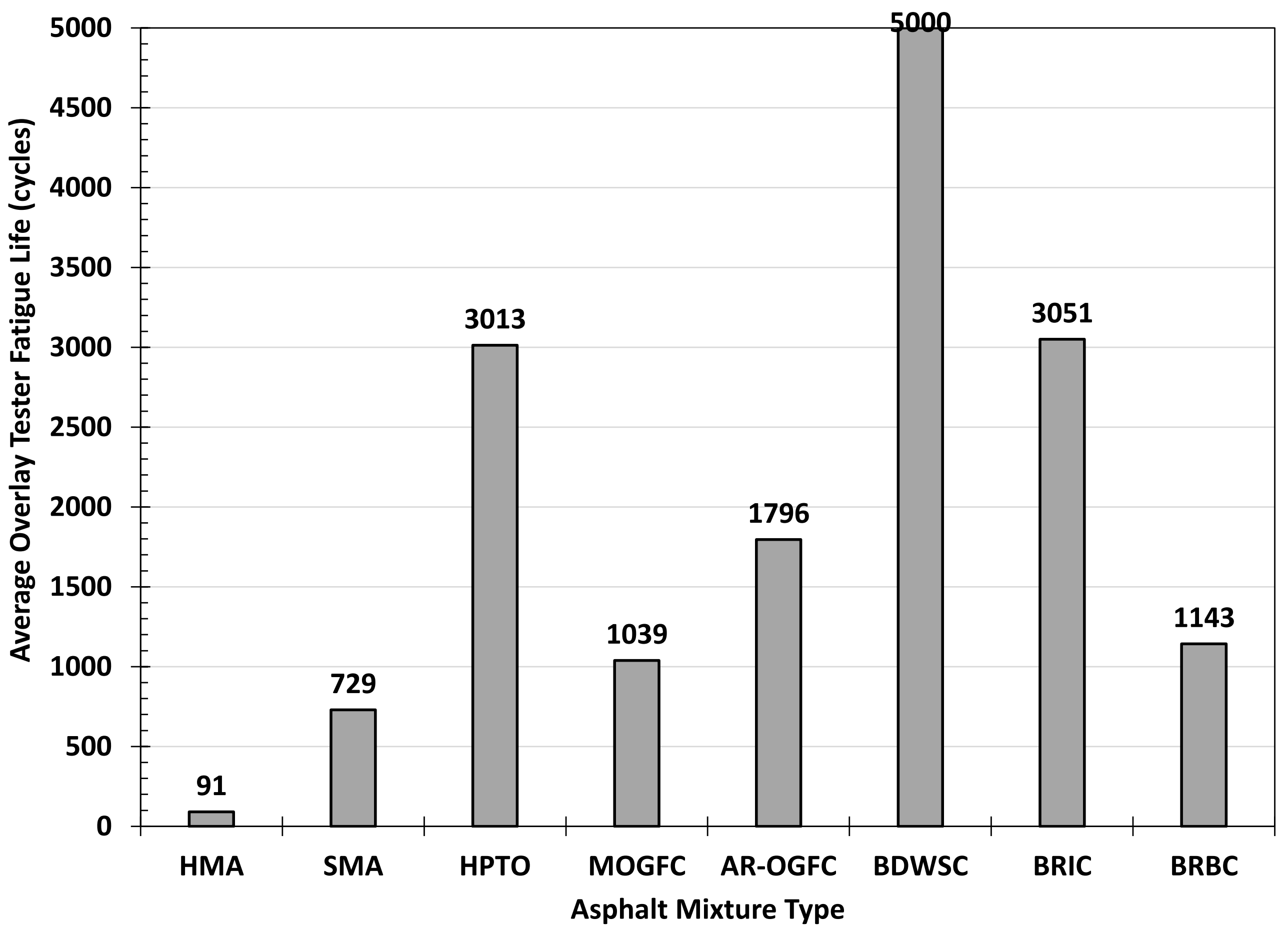
Overlay Tester



- 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

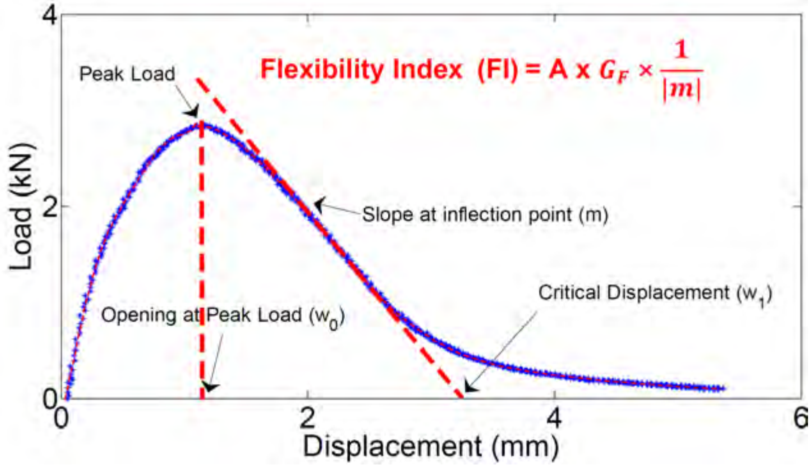
Overlay Tester

- "High Performing" asphalt mixtures in NJ generally have Overlay Tester > 600 cycles



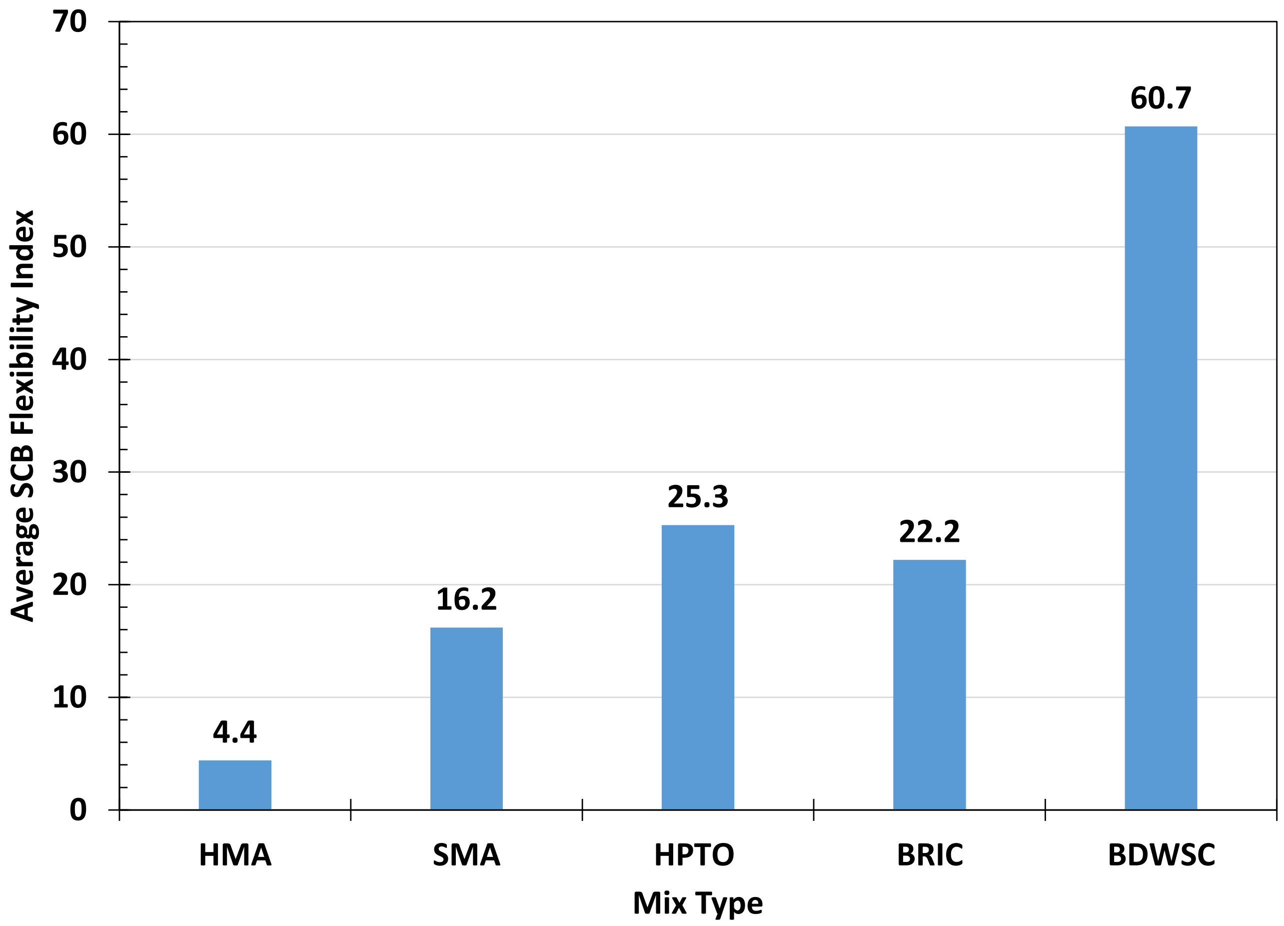
Semi-circular Bend (SCB) Test

- 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



SCB Flexibility Index

- “High Performing” asphalt mixtures in NJ generally have SCB Flexibility Index > 15 cycles



SMA Laboratory Performance in NJ

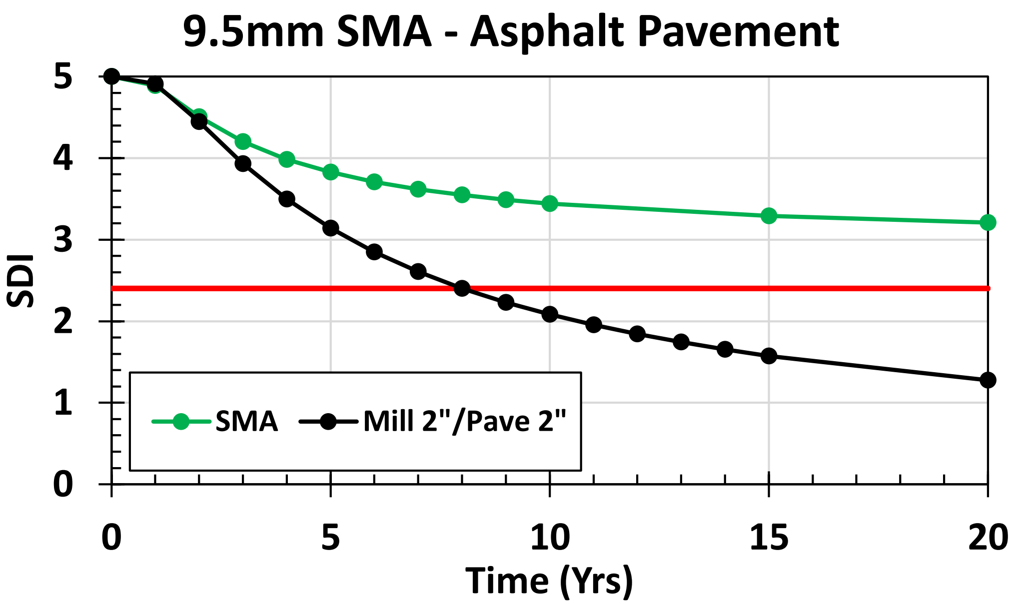
- In general, SMA obtains excellent laboratory performance
  - May show to be "softer" than HMA at high temperatures due to higher effective asphalt contents and no RAP
    - Lower high temperature stiffness/more permanent deformation in AMPT and loaded wheel testers
    - Difficult to mobilize stone-on-stone rutting resistance without applied confining pressure
  - SMA far superior in fatigue cracking resistance than HMA
    - Fatigue cracking resistance directly related to effective asphalt content

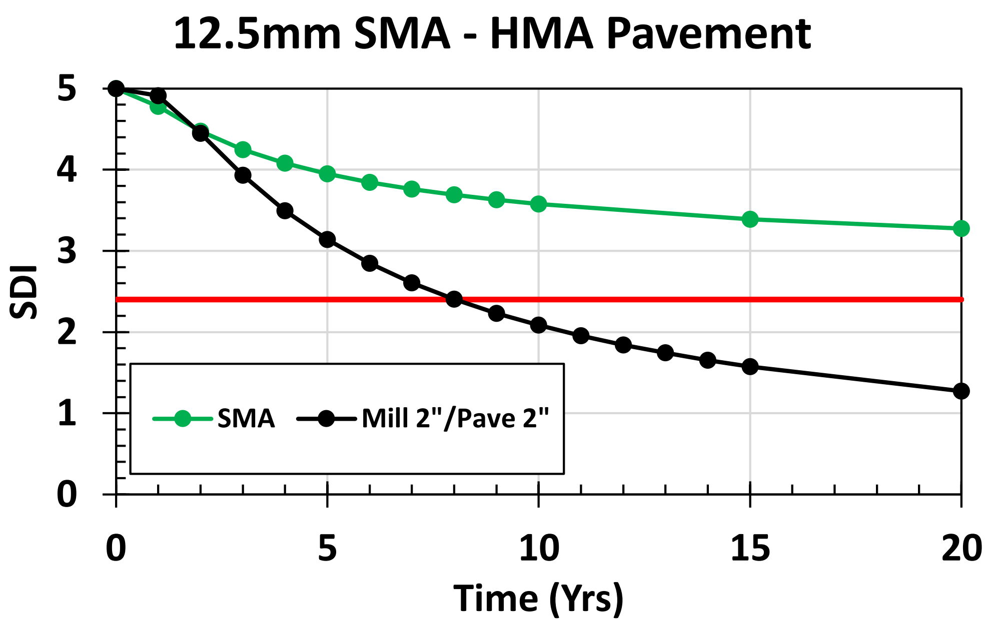
SMA Field Performance

SMA Field Performance

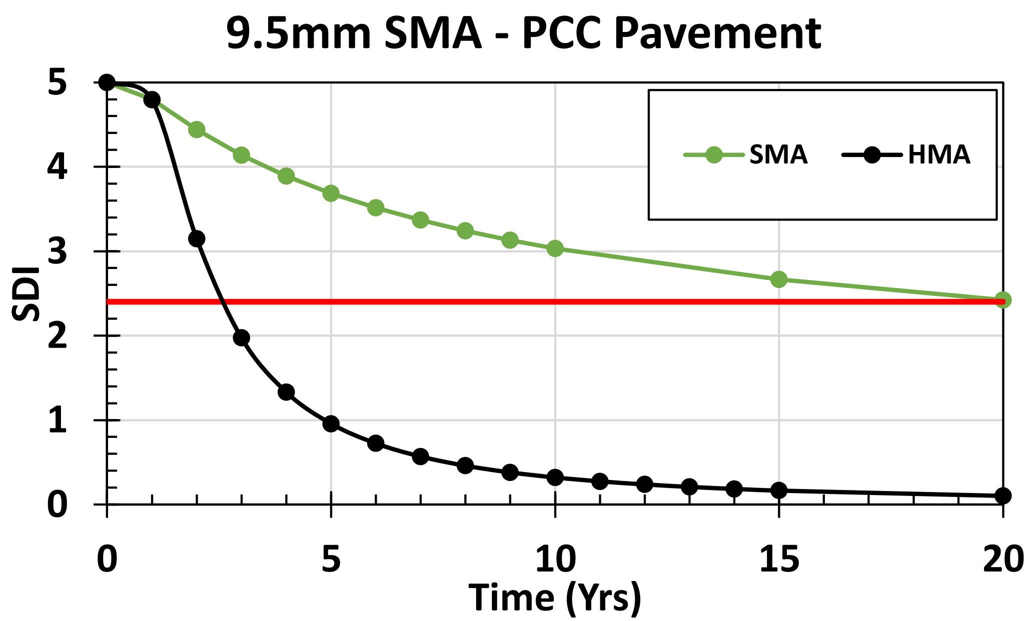
- NJDOT PMS was mined to extract the SMA performance since 2007.
  - Surface Distress Index (SDI) used to monitor "life" of the pavement
  - SDA < 2.4 trigger for pavement rehabilitation
- Approximately 100 SMA pavement sections were evaluated
  - Minimum of 3 years of performance
  - 9.5 mm and 12.5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

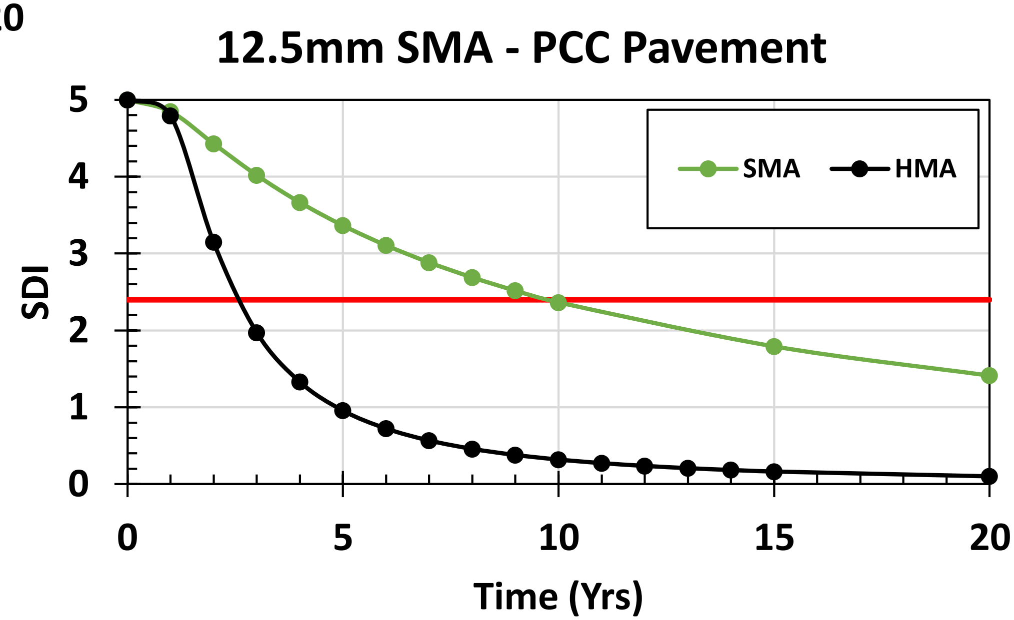
SMA Field Performance – Flexible Pavement





SMA Field Performance – Composite Pavement





SMA Field Performance Summary

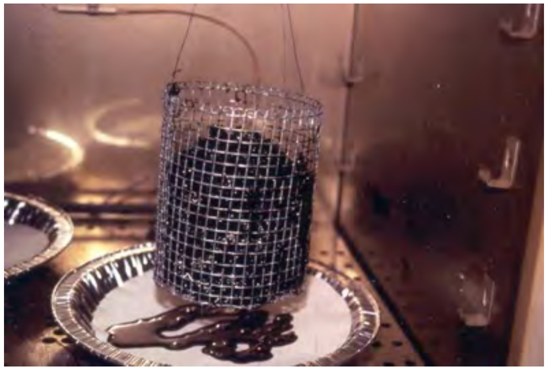
- Flexible Pavements
  - Pavement distress curves indicate SMA should outperform HMA by 10+ years for flexible pavements
- Composite Pavements
  - Pavement distress curves indicate SMA should outperform HMA by 7+ years for composite pavements
  - NJDOT also includes a Bituminous Rich Intermediate Course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

Fiberless SMA

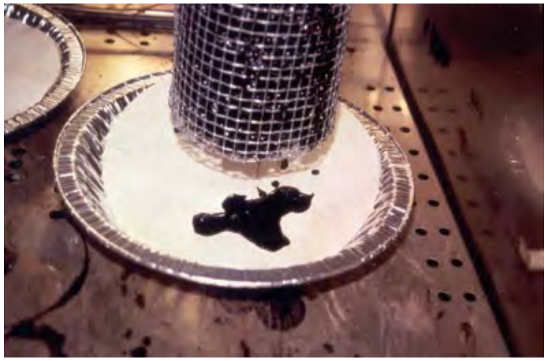
Design of SMA Mixes

- To help reduce the potential of draindown, polymer-modified asphalt (PMA) and fibers used with SMA and OGFC
  - PMA results in better adhesion to aggregate at higher temps than Neat binders (generally higher viscosity)
  - Fibers increase stiffness of mastic by increasing surface area

Neat



PMA



PMA + Fibers

Issues with Fibers

- Cost – fibers and rental equipment
- Fibers need to be separated or "fluffed" prior to addition or clumping can occur
- Metering required and should have "sight glass" to ensure fibers flowing
- Fibers must be included in ignition oven correction factor determination
  - Impossible to separate AC and Fiber changes during production from ignition oven testing

Fiberless SMA Concept

- The inclusion of fibers used to increase the viscosity of the mastic (binder, fines, fibers)
  - Increased mastic viscosity will stick to aggregate better and resist draindown
- Utilizing an asphalt binder with higher viscosity can help increase mastic viscosity
  - As temperature decreases, binder viscosity increases
- Reduction in mixture temp will create compaction issues
  - Must couple mixture temp reduction with WMA additive
  - **WMA technology that does not influence binder viscosity**

Fiberless SMA "Mixture Design"

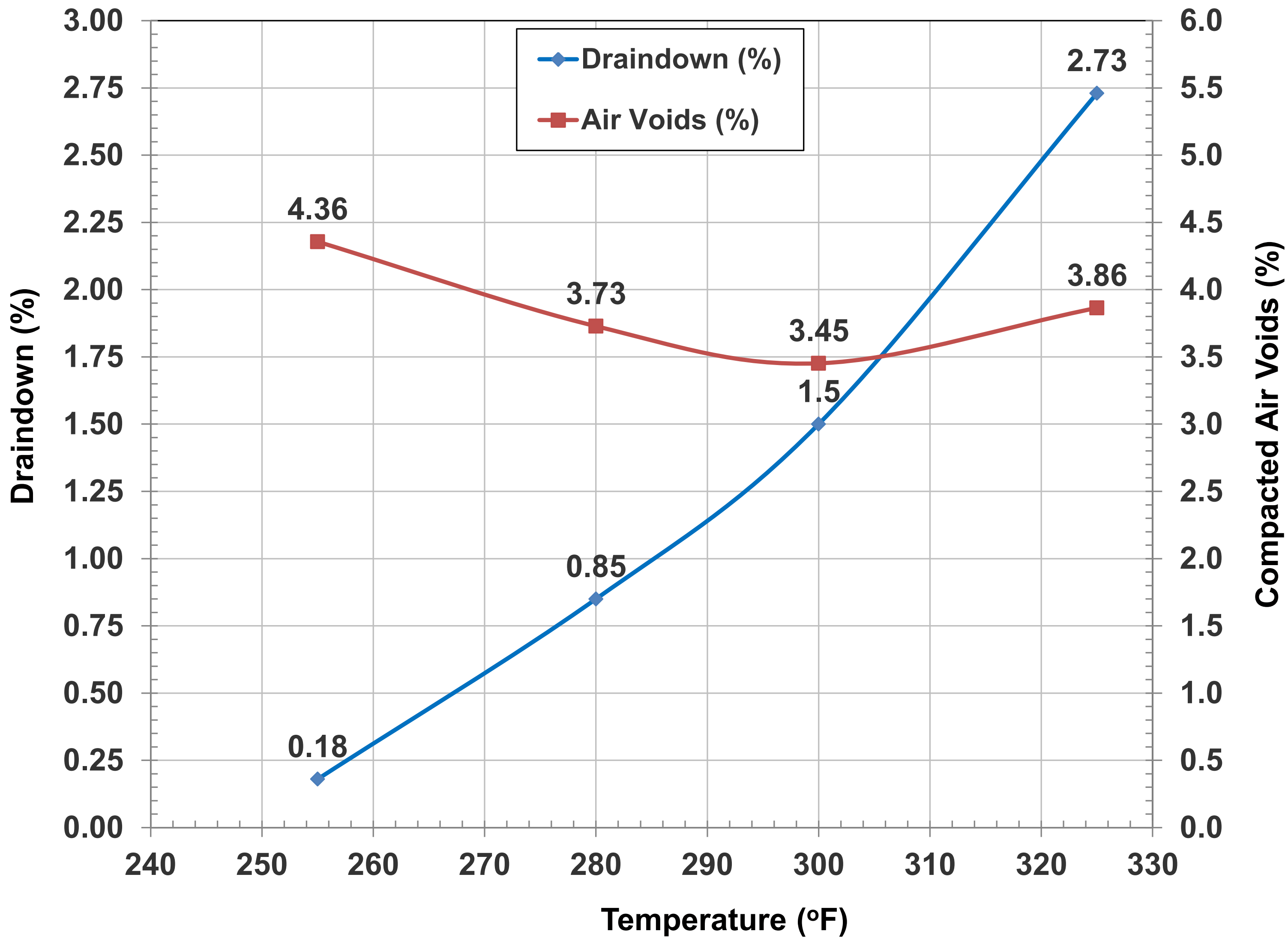
- General methodology
  - Utilize existing SMA design as your starting point (i.e. – asphalt content, aggregate blend)
  - Determine Draindown (AASHTO T305) and compacted air voids after reducing mixture temperature
    - Example: 325, 300, 280, 255°F
    - Compare draindown and compacted air voids
  - Examine mixing process to ensure coating is taking place
  - Make slight mixture adjustments if necessary

Design Example

- Determine Optimal Temperature for WMA-SMA
  - 12.5 mm NMAS SMA
  - 6.5% Asphalt Content
    - PG76-22
  - 0.2% Cellulose Fibers
  - 0.04% Draindown at Design

Washed Gradation		
Screen		% Pass
2"	50.00	100
1 ½"	37.50	100
1"	25.00	100
¾"	19.00	100
½"	12.50	96
3/8"	9.50	80
#4	4.75	34
#8	2.36	21
#16	1.18	17
#30	0.600	15
#50	0.300	13
#100	0.150	12
#200	0.075	9.3

Compacted Air Voids vs Draindown



Design Example - Results

- Final Result
  - Optimal temp range for mixture between 265 and 255°F.
  - In that range;
    - Air voids slightly above 4%
    - Draindown around 0.2 to 0.25% (specification is 0.3%)
    - Dust to Effective Binder below allowable
- Final Recommendation
  - Maintain asphalt content and increase dust content
    - Increase dust will help close up air voids and reduce draindown
  - Received phone call from contractor saying project went great and they are planning to bid all future SMA projects the same way

Project #1 – New Jersey

- First project to look at fiberless SMA with WMA
- Location: Rt 1 in New Jersey
- 12.5mm SMA
  - 6.4% AC content
  - PG76-22
  - 0.3% cellulose fibers

Washed Gradation		
Screen		% Pass
2"	50.00	100
1 ½"	37.50	100
1"	25.00	100
¾"	19.00	100
½"	12.50	94
3/8"	9.50	63
#4	4.75	28.2
#8	2.36	19.8
#200	0.075	8.8

1st Project – Supplier did own assessment of compacted air voids

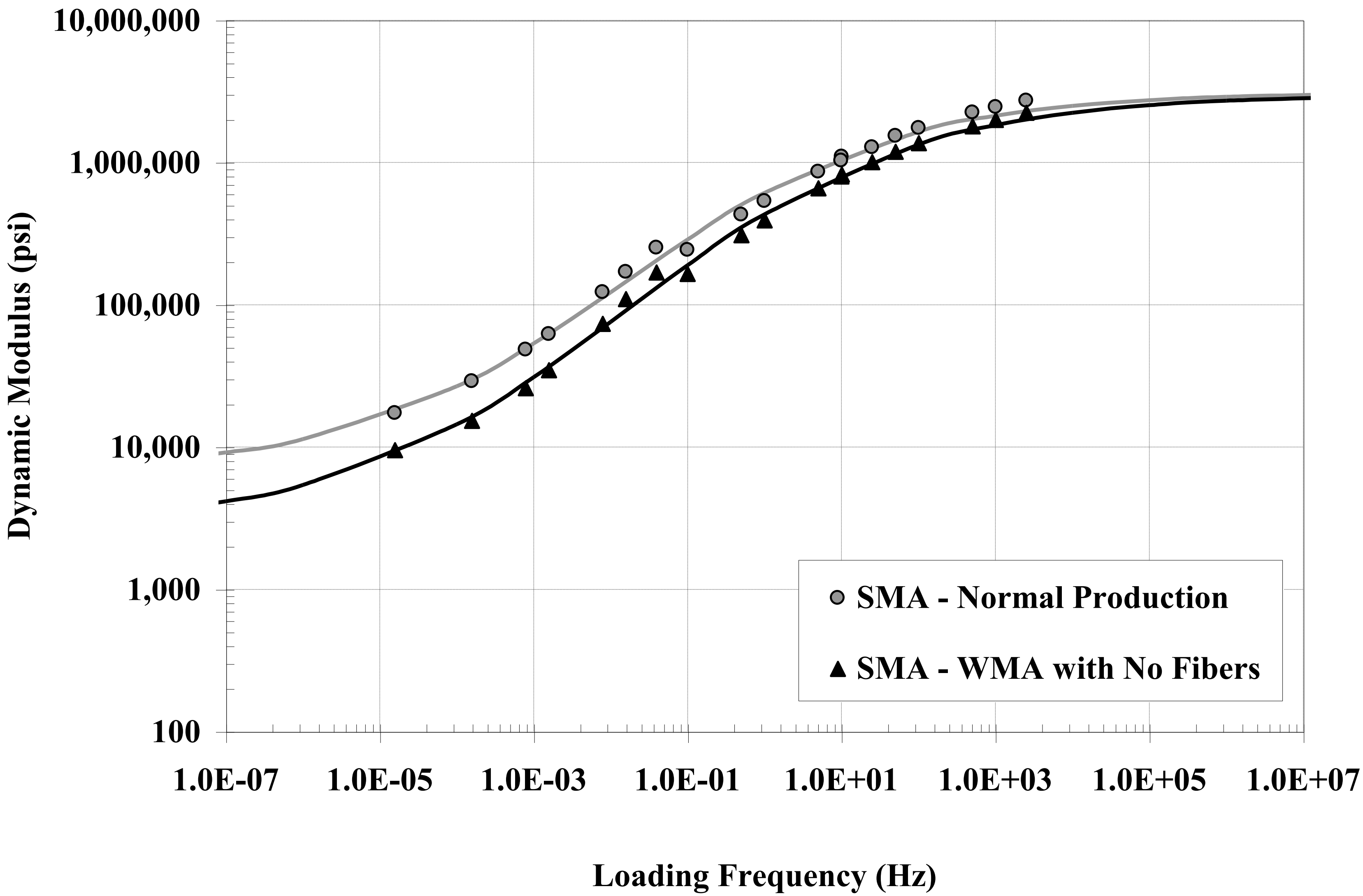
Project #1 – New Jersey

Mixture ID	Temperature (F)		Percent Draindown
	Mixing	Testing	
Normal SMA	325	325	0.08
WMA SMA #1 (No Fibers)	325	325	0.19
WMA SMA #2 (No Fibers)	290	290	0.08
WMA SMA #3 (No Fibers)	255	255	0.06

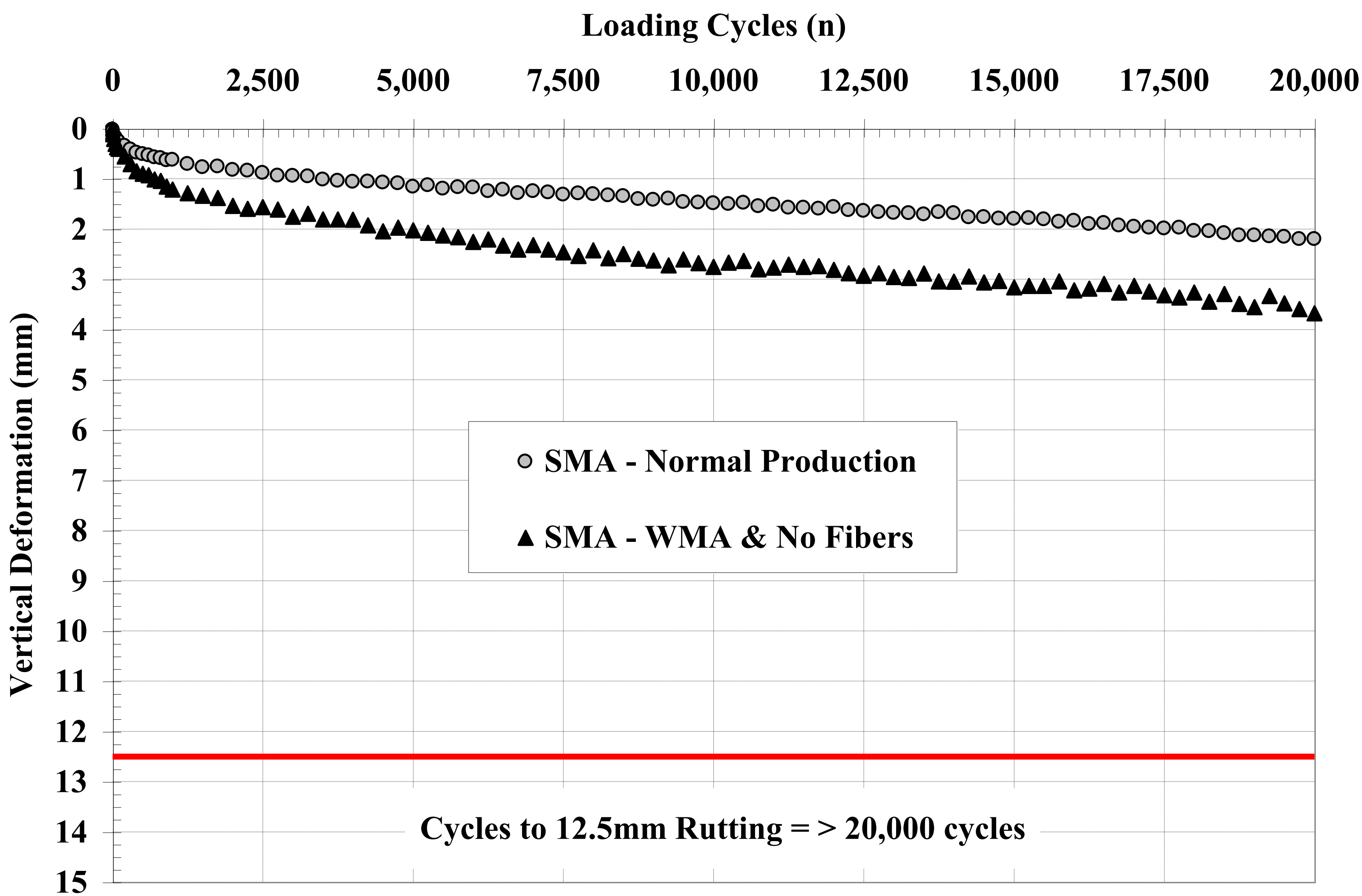
Rt 1 SMA - Testing of Materials

- Field Core Density
  - Normal SMA Density = 5.13% air voids
    - Produced over 315F
  - WMA SMA Density = 5.12% air voids
    - Produced under 280F

Dynamic Modulus – Mixture Stiffness



Hamburg Stripping Potential



Overlay Tester – Cracking Potential

SMA - WMA with No Fibers			
Sample ID	**Temp (F)**	**Displacement (inches)**	**Fatigue Life (cycles)**
# 1	77 F	0.025"	10,472
# 2			27,855
# 3			16,255
Average (Trimmed Mean) =			**18,194**

SMA - Normal Production			
Sample ID	**Temp (F)**	**Displacement (inches)**	**Fatigue Life (cycles)**
# 1	77 F	0.025"	2,126
# 2			2,425
# 3			1,458
Average (Trimmed Mean) =			**2,003**

Project #1 – New Jersey

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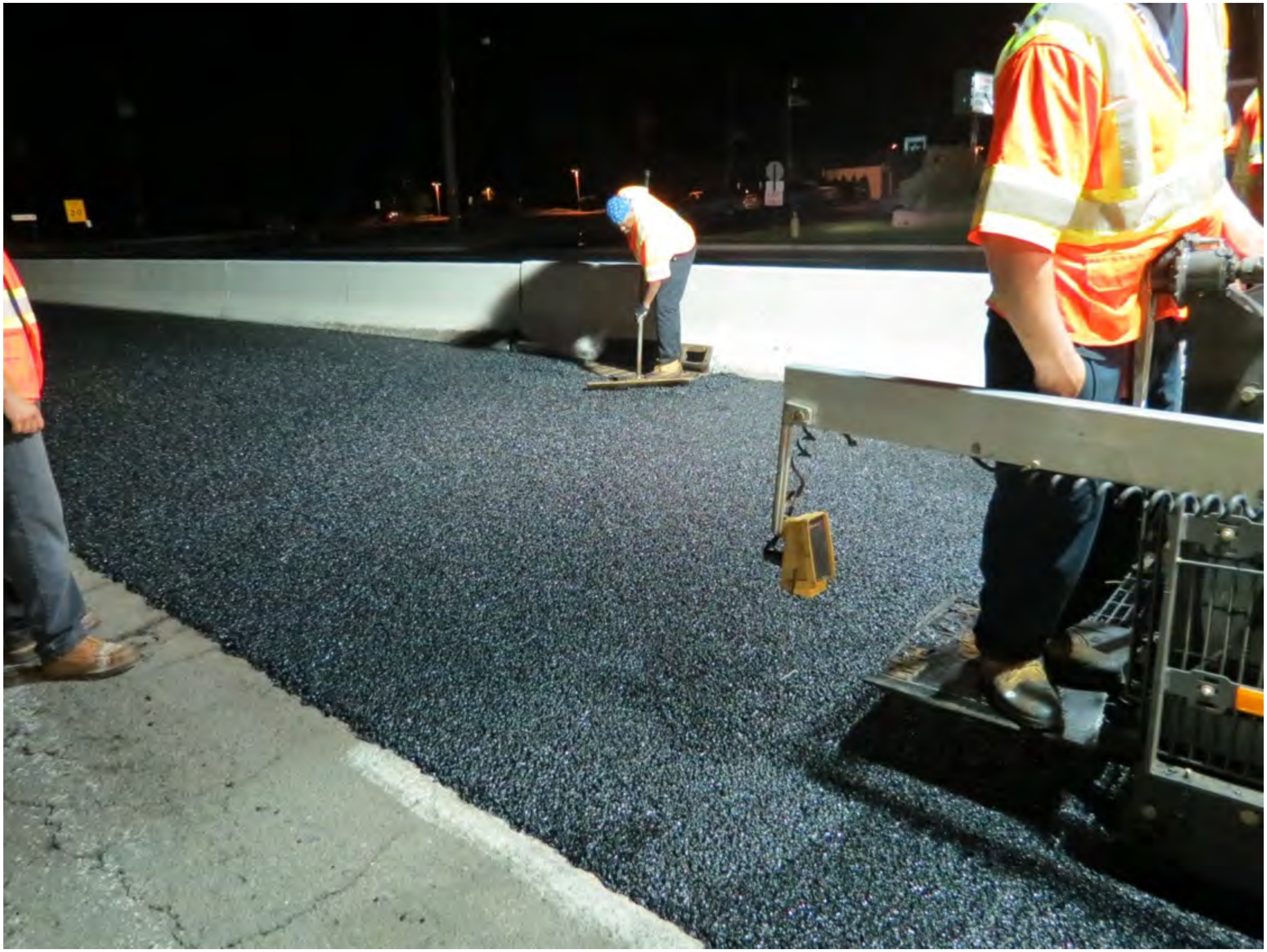
Project #1 – New Jersey

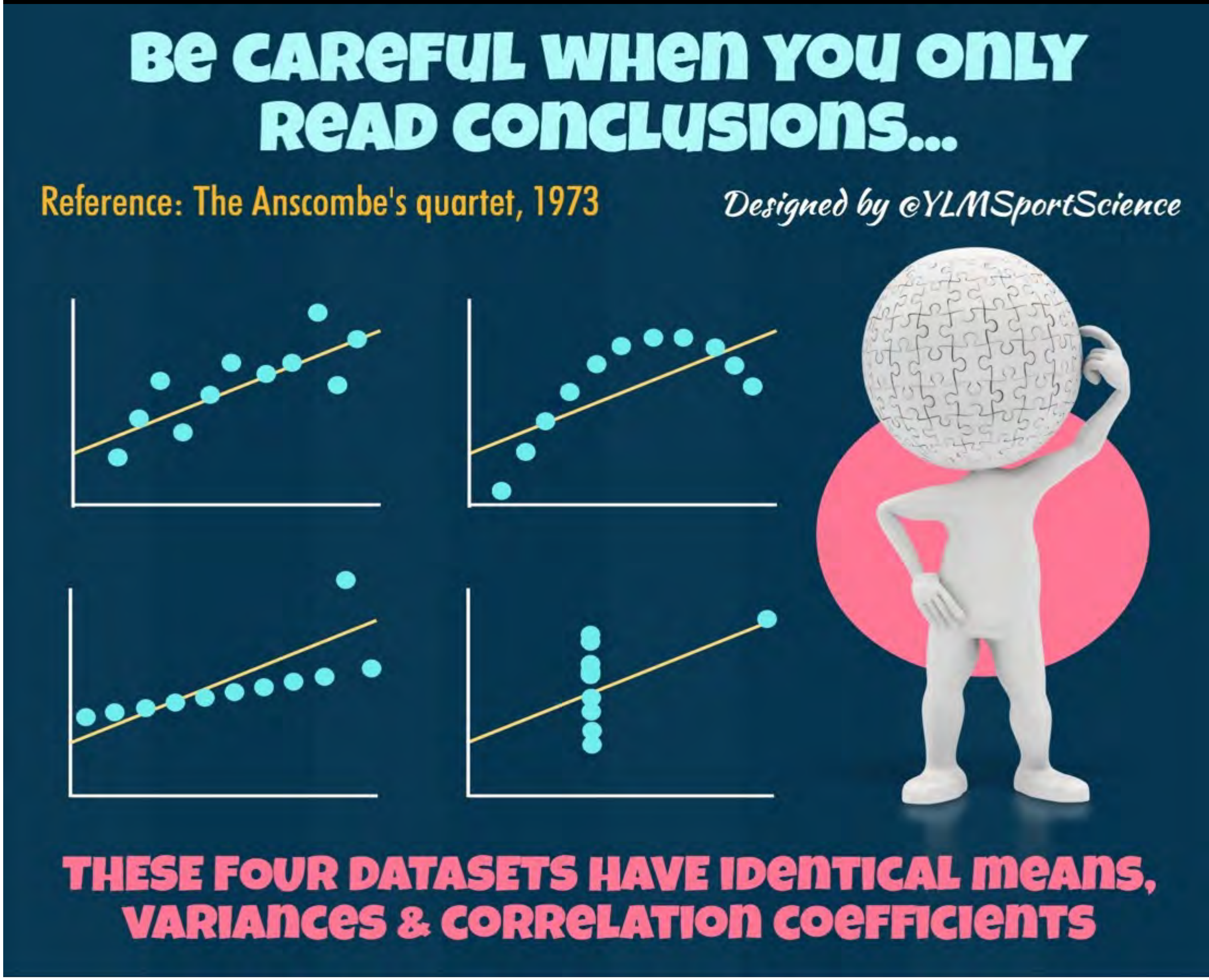


Project #1 – New Jersey Rt 1

- For initial pilot, reduction in production temp successfully reduced draindown when fibers eliminated
  - Produced @ 275 to 285°F
  - Laydown @ 270 to 280°F
- Field densities of with and without fibers statistically equal
- Mixture performance looked good
  - Lower production temps not aging binder as normal
    - Stiffness slightly lower
    - Large increase in fatigue resistance (higher effective AC?)

One Complaint!

Thank you for your time! Questions?



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