GROUND TIRE RUBBER (GTR) IN PAVEMENTS

massDOT
Massachusetts Department of Transportation
Highway Division

Increasing the use of recycled content in road & infrastructure workshop

NOVEMBER 17, 2020

Ground Tire Rubber

- Ground Tire Rubber (GTR) in MassDOT Pavements
- What is Asphalt Rubber”
  - Benefits
- Asphalt Rubber Pavement Performance
  - Asphalt Rubber & Recycled Asphalt Pavement
  - Asphalt Rubber & Warm Mix
- Sample Projects
  - HMA-ARGG
  - Stress Absorbing Membrane Interlayer (SAMI)
- Issues

Ground Tire Rubber – MassDOT Usage (in Pavements)

- Crack Sealants & joint Sealants(some products)
- Rubber Chip Seal Surface Treatment
- Stress Absorbing Membrane Interlayer (SAMI)
- HMA Pavement Surface (HMA-ARGG)
  - (HMA-ARGG-12.5)
  - (HMA-ARGG-9.5) special provision.
- HMA Open Graded Friction Course
  - HMA-OGFC-AR
  - HMA-Porous Pa
- Ultra-Thin Bonded Overlay
  - UTBO-AR
- Etc….

Asphalt Rubber

- **What is Asphalt Rubber???**
  - It's a blend of hot liquid asphalt and ground tire rubber.
  - 80% Asphalt
  - 20% Ground Tire rubber
- First developed in Arizona in the 1960's
- Initially used in Surface Treatments (SAM and SAMI's)
- Now used in HMA Surface Courses – "Thinner Overlays"
- ASTM D-6114 Binder Specification
- **Not Proprietary**
- **Thin Overlays, Open Graded Friction Courses & Pavement Preservation Activities are the biggest market for Ground Tire Rubber in Pavements.**

How is AR made?
ASTM D6114
Type II (aka "Wet Process")

- **15-20% Crumb Rubber**
  - #30-#40 Mesh
  - Processed from Scrap Tires
- **Performance Graded Asphalt**
  - PG58-28 (or)
  - PG64-22
- **Requires On Site blending or at a nearby facility**
- **Reaction process**
  - Elevate Temperature of Liquid Asphalt
  - Mix for 1 hour
    - Rubber particles swell
    - Suspension in Asphalt


350D
2009/06/16

GTR Asphalt Products

Asphalt-Rubber Binder

Terminal Blend Binder

Why Asphalt Rubber?

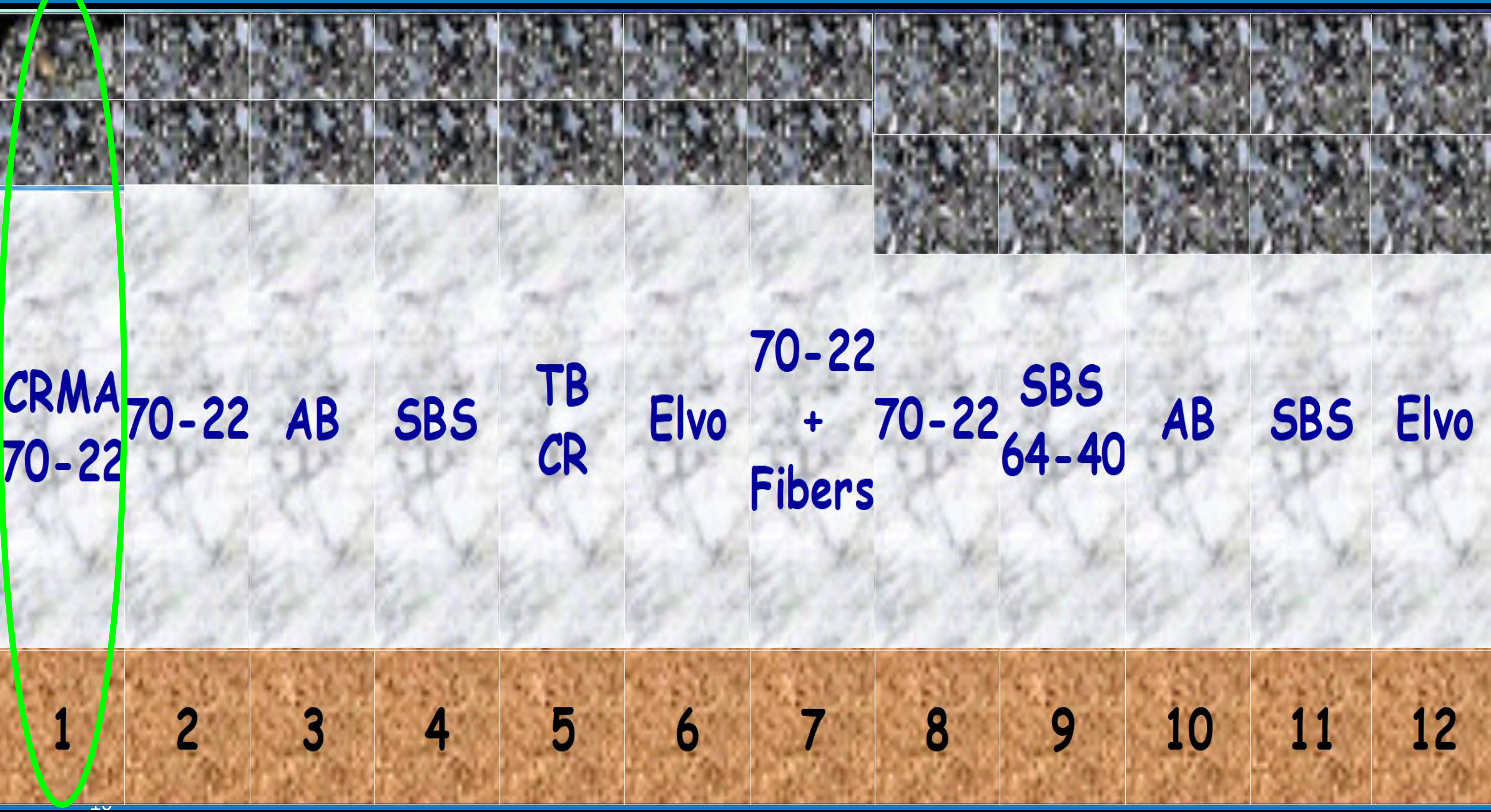
Rubber contains polymers which…

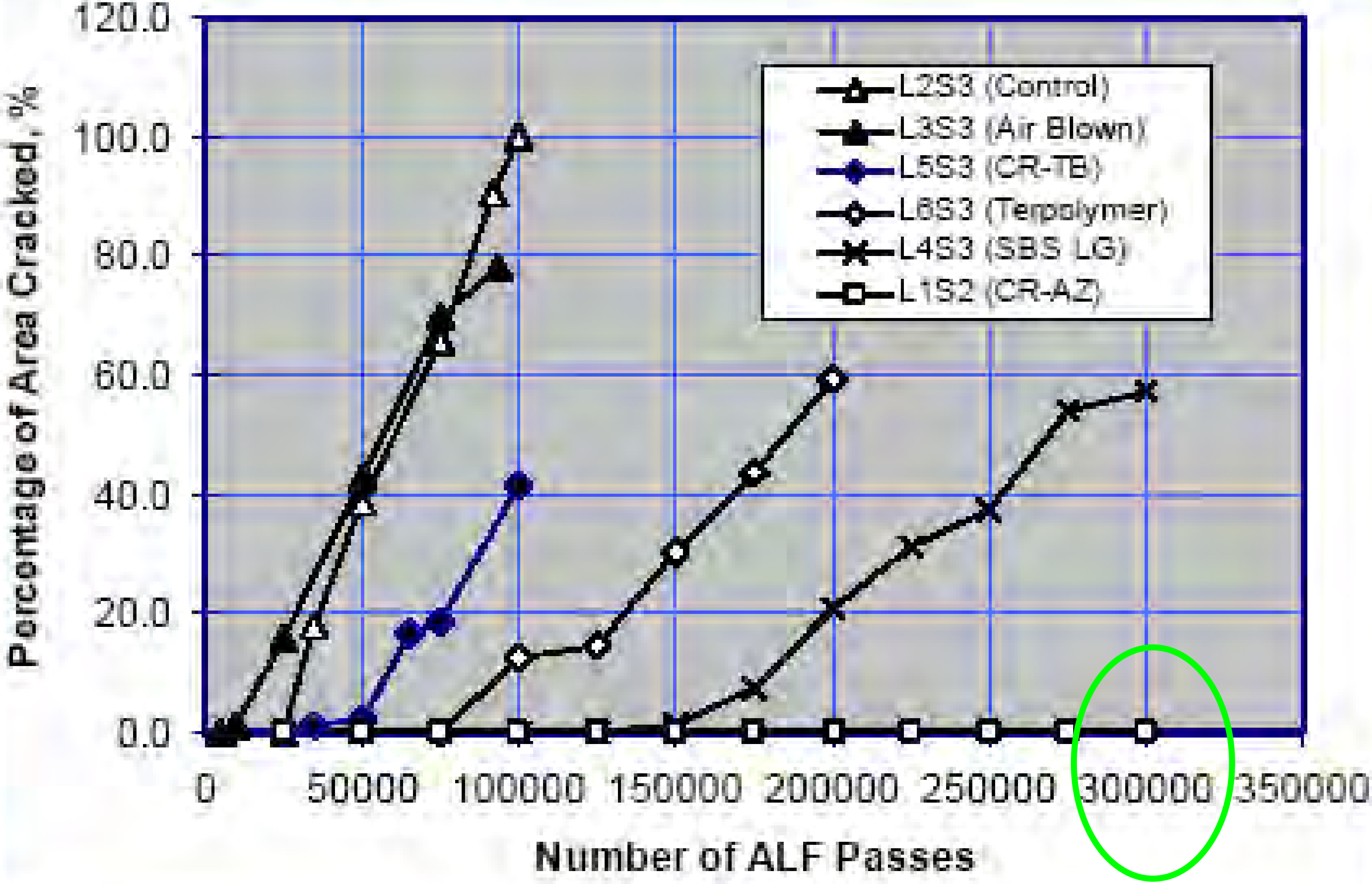
- Raises softening point to above 140º F.
  - Resistant to rutting and shoving
  - Resistant to asphalt migration and drain-down
- Increases low temperature flexibility.
  - Resistance to cracking
- Increases high temperature viscosity.
  - Thicker film coatings on aggregate particles
  - More asphalt = greater resistance to oxidation
  - Increased long term durability
  - Top PG Grading above 80 = Stability

Why AR Mixes?

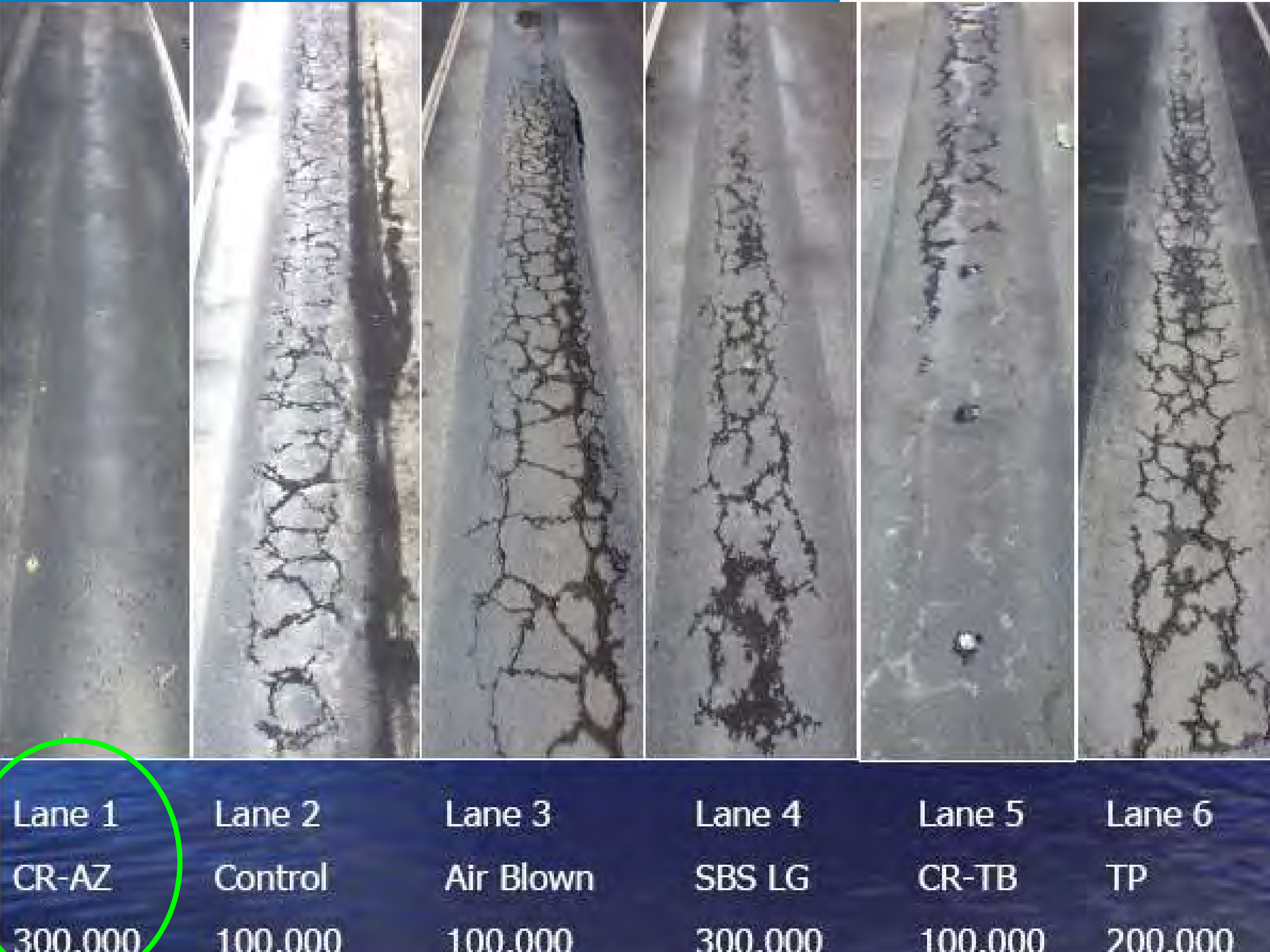
- **Benefits**
  - Longer Pavement Life
    - Reduced Rutting
      - AR = Higher Softening Point of PG Binder
    - Reduced Oxidation
      - Thicker Film Coatings = More Binder in Mix
    - Reduced Cracking
      - AR Properties = Greater Flexibility at Cold Temperatures
    - Increased Long Term Durability
    - Reduced Thickness
  - Noise Reduction
    - **AR Properties Absorb Tire Noise**
    - Economic Alternative to Sound Barriers
  - ***"Green" Process***
    - ***Reuses Scrap Tires***

ALF Project Test Sections





Percentage of Area Cracked vs. ALF Wheel Load Passes


Lane 1
CR-AZ
300,000
Lane 2
Control
100,000
Lane 3
Air Blown
100,000
Lane 4
SBS LG
300,000
Lane 5
CR-TB
100,000
Lane 6
TP
200,000

MassDOT GTR Background

- SAMI – 1986 Standard Specifications
  - Rubber Chip Seals as wearing courses (SAM)
  - Stress Absorbing Membrane Interlayers (SAMI) to mitigate cracking SAMI.
- 1991 “ISTEA” Rubber Mandates
  - “Generation 1 AR HMA”
    - 1992 Project – Rt 140 Freetown
      - Conventional HMS
    - 1996 – MassDOT Participated in a NIOSH Study
    - 1997 - I-95 Foxboro Southbound
      - Open Graded HMA (permeable pavement)
  - These designs were not gap graded or modified to take advantage of the AR film thickness.

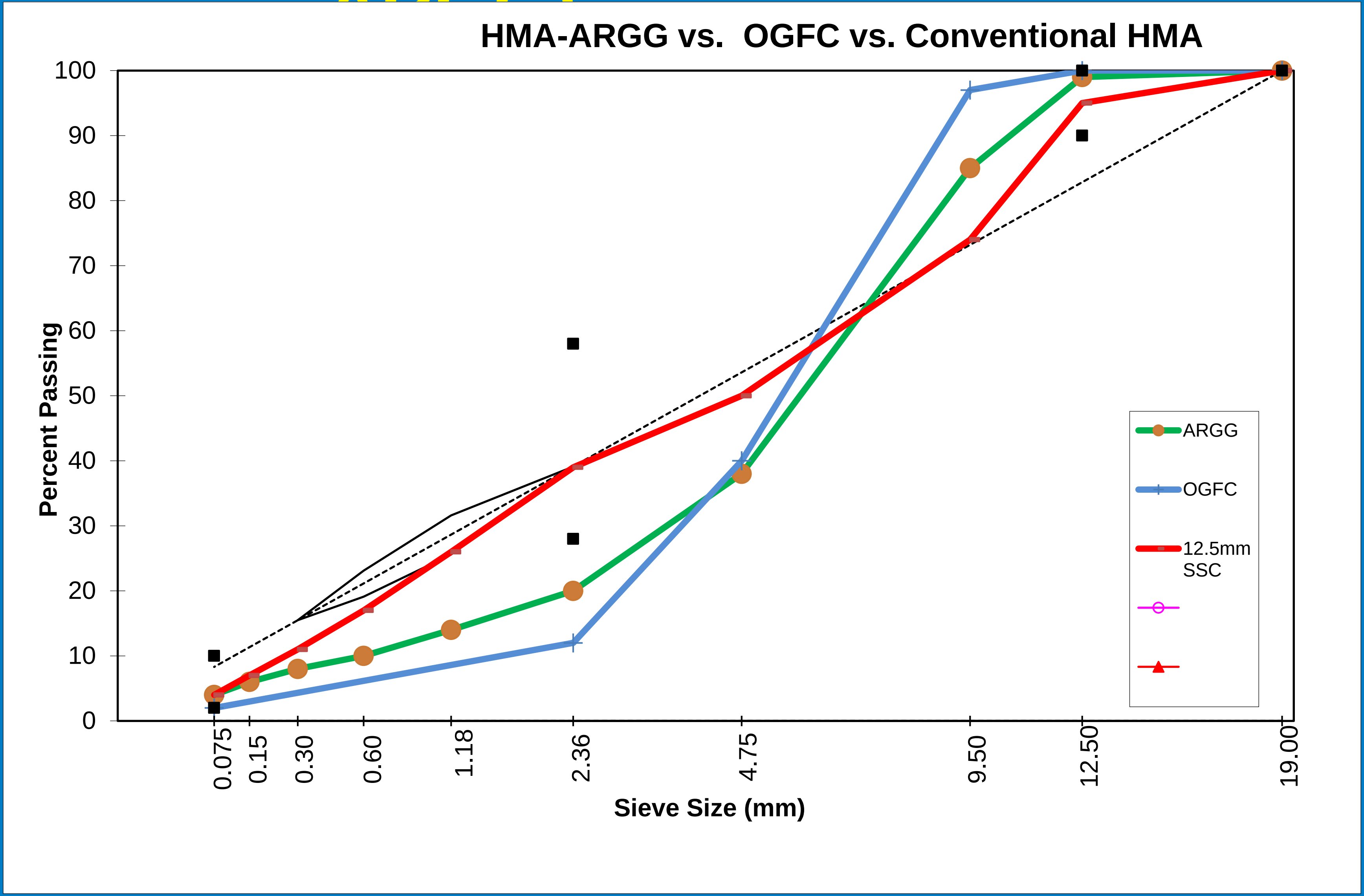
"Generation 2" GTR

- Terminal Blend – typically less than 10% GTR and are produced at an asphalt terminal.
  - 2004 – "Pavement Preservation" Thin Overlays
  - "Terminal Blends" GTR & Polymer (PGAB 76-34)
    - I-91 Bernardston-Greenfield (2005)
    - Rt 146 Uxbridge-Milville (2006)
    - Rt 2 Gardner-Westminster (2006)
    - I-395SB Webster (2006) OGFC
      - GTR clogged plant screens/filters for AC pump
      - Low Binder Control Strip high speed lane – left in place
        - 5% rather than 6.2% Asphalt Content.
        - Despite low asphalt content, it outperformed the "control" section
- Asphalt Rubber vs Terminal Blend Demonstration Project
  - I-295 Attleboro-North Attleboro
  - HMA-ARGG and UTBO-AR.

Asphalt Rubber HMA – “2’nd Generation”

- I-295 Attleboro-North Attleboro Pilot Project
- Terminal Blend - Asphalt Rubber “showdown”.
  - Asphalt Rubber Gap Graded (ARGG) PG 58-28
  - Asphalt Rubber Gap Graded (ARGG-WMA) PG 58-28
  - Bonded Ultrathin Overlay w/PG 64-28
  - Bonded Ultrathin Overlay w/PG 58-28 + AR
- Availability of Terminal Blend GTR Binder
- Bid 2007 - Built 2008
- Construction Changes – Warm Mix .

Asphalt Rubber-Gap Graded (HMA-ARGG)



ARGG - Specifications

Sieve Designation	Percent by Mass Passing	Tolerances
19.0 mm (3/4”)	100	± 0
12.5 mm (1/2”)	90-100	± 6
9.5 mm (3/8”)	83 – 87	± 6
4.75 mm (#4)	28 - 42	± 6
2.36 mm (#8)	14 – 22	± 4
1.18 mm (#16)	-	-
0.075 mm (#200)	0 – 6	± 1

Property	Criteria
Air Voids	3 - 6 %
Voids in Mineral Aggregates (VMA)	18 - 23 %
Draindown	0.3 % maximum
% Binder content*	7.6 % minimum
PGB Content – Specification limits**	±0.4%
PGB Content – Engineering limits**	±0.6%

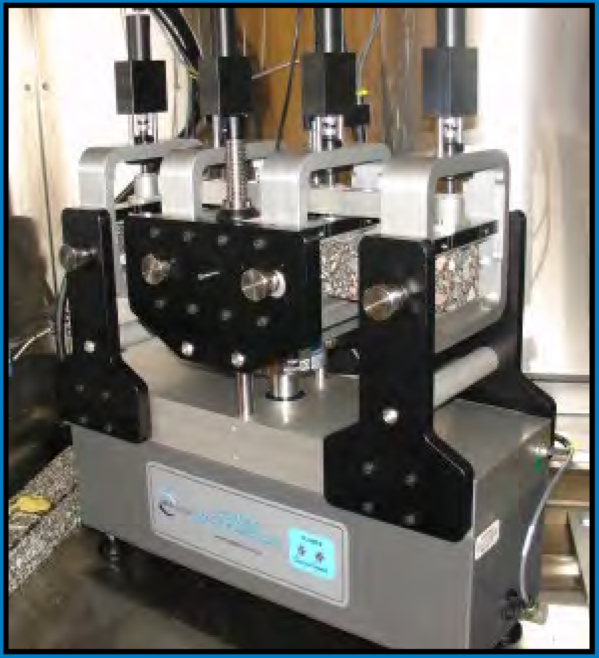
Warm Mix Asphalt & Recycled Asphalt Pavement (RAP)

- Warm Mix Asphalt (WMA)
  - Additive which Lowers Production & Compaction Temps
- I-295 Attleboro Demo Project
  - Advera (Zeolite WMA)
- Rt 3 Plymouth Late Season Paving (35 F)
  - Sonnewarm WMA
    - Increased compaction time
    - No impact to stability or moisture damage
    - No temperature reduction attempted.
- **I-495 HAMS – questioned why “no-RAP”???**
  - Performance Questions using WMA & RAP.
  - Task under ISA with UMASS Dartmouth HSRC.

UMass Dartmouth HSRC Plant Produced Mixture Comparison

- DOT assigned a task to UMASS HSRC for comparison of plant produced ARGG mixture to 12.5mm Superpave and a latex modified control mix.
- Testing included:
  - Beam Fatigue
  - Dynamic Modulus
  - Flow Number
  - Hamburg Wheel Tester
  - Overlay Tester
  - TSRST.

Fatigue – Four Point Flexural Beam

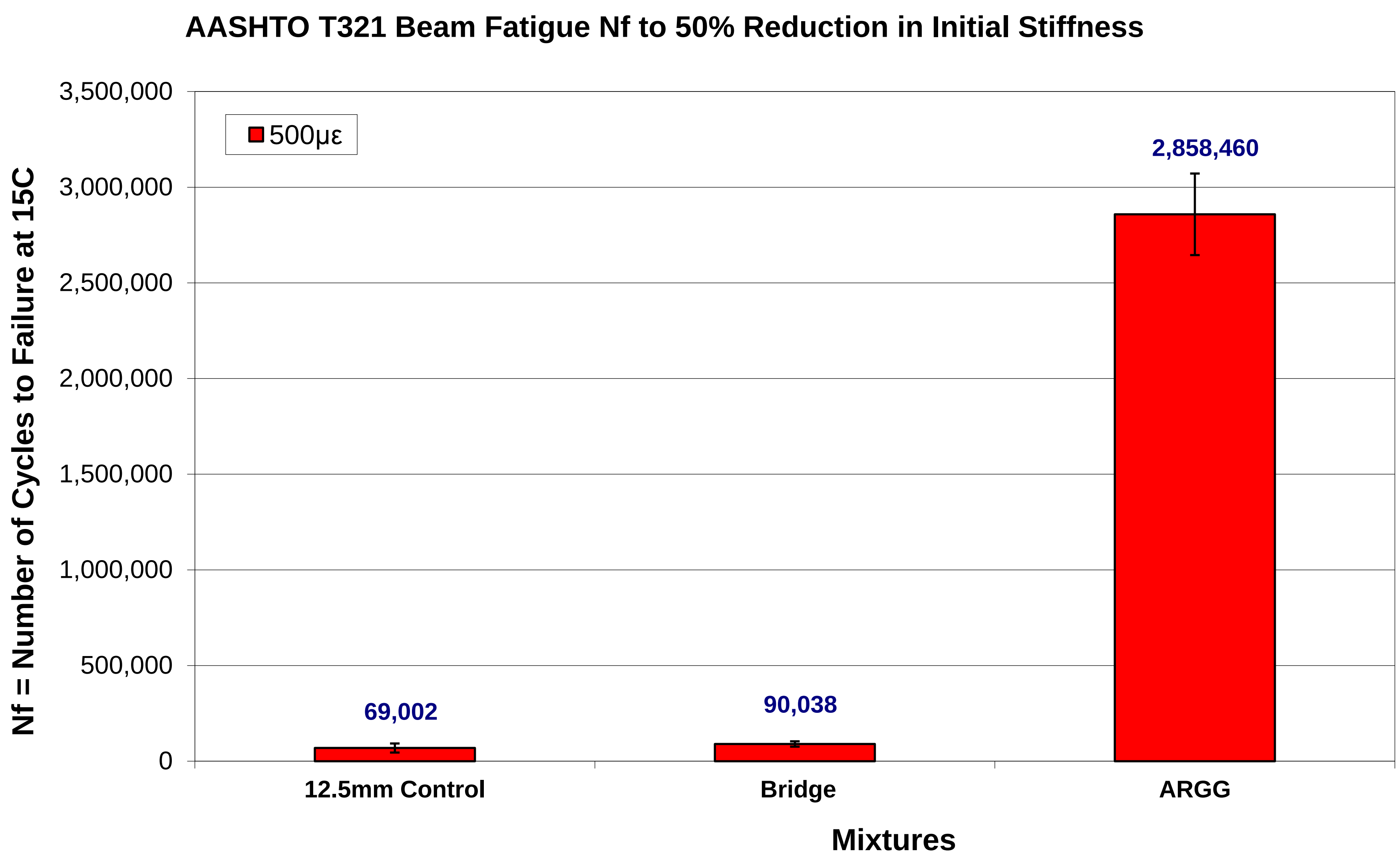


Testing in Accordance with AASHTO T321

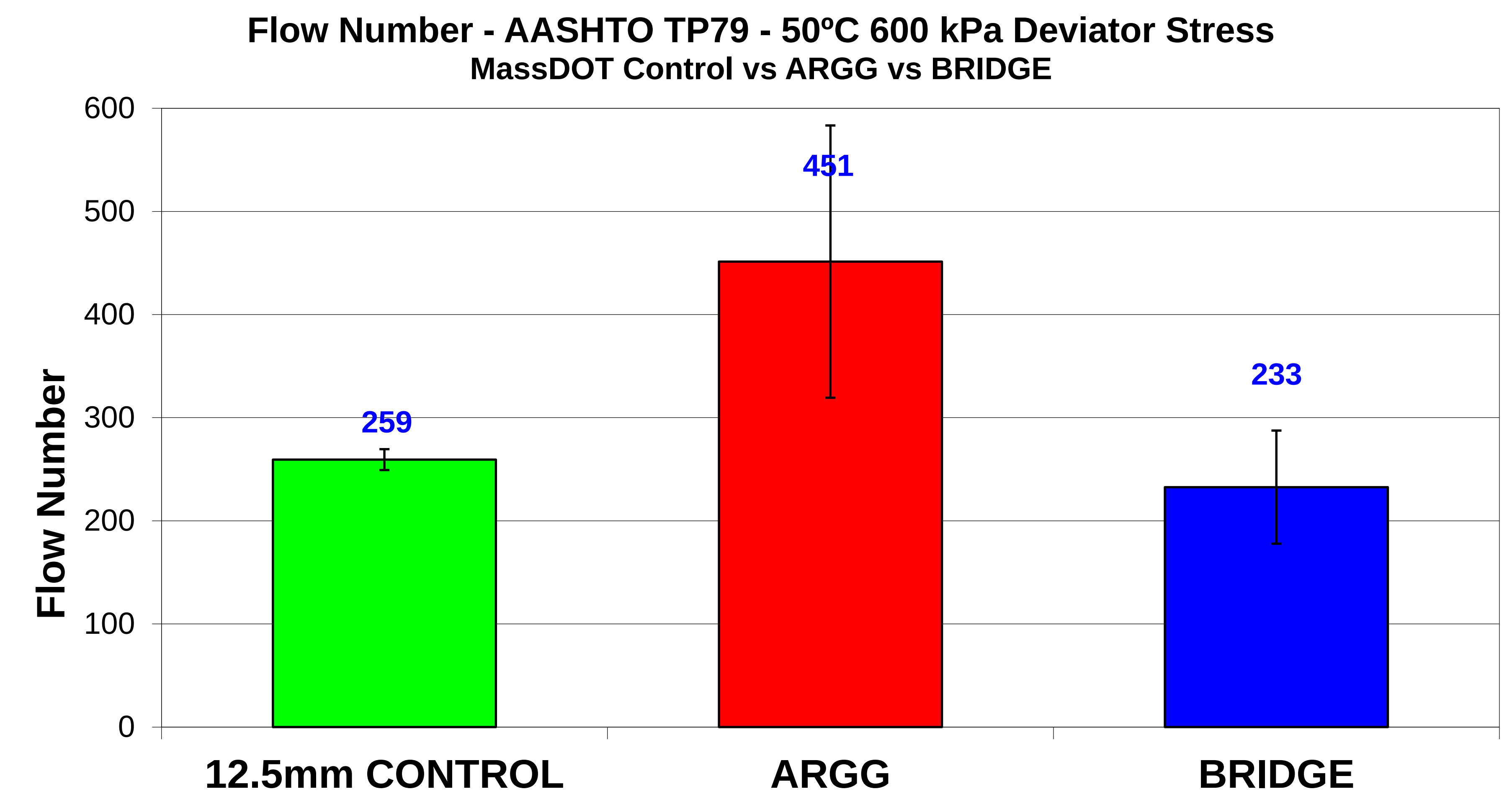
- Specimens are fabricated at a target air void level of 7.0 ± 1.0%
- Testing conducted in strain control mode
- Loading Frequency = 10Hz
- Sinusoidal Wave Form
- Failure Criteria = 50% reduction in initial stiffness per AASHTO T321 method

Temperature	Strain Level
15°C (59°F)	με

Plant Mix Beam Fatigue (500 μstrain)



Plant Mix Flow Number



Rutting / Moisture Susceptibility - HWTD

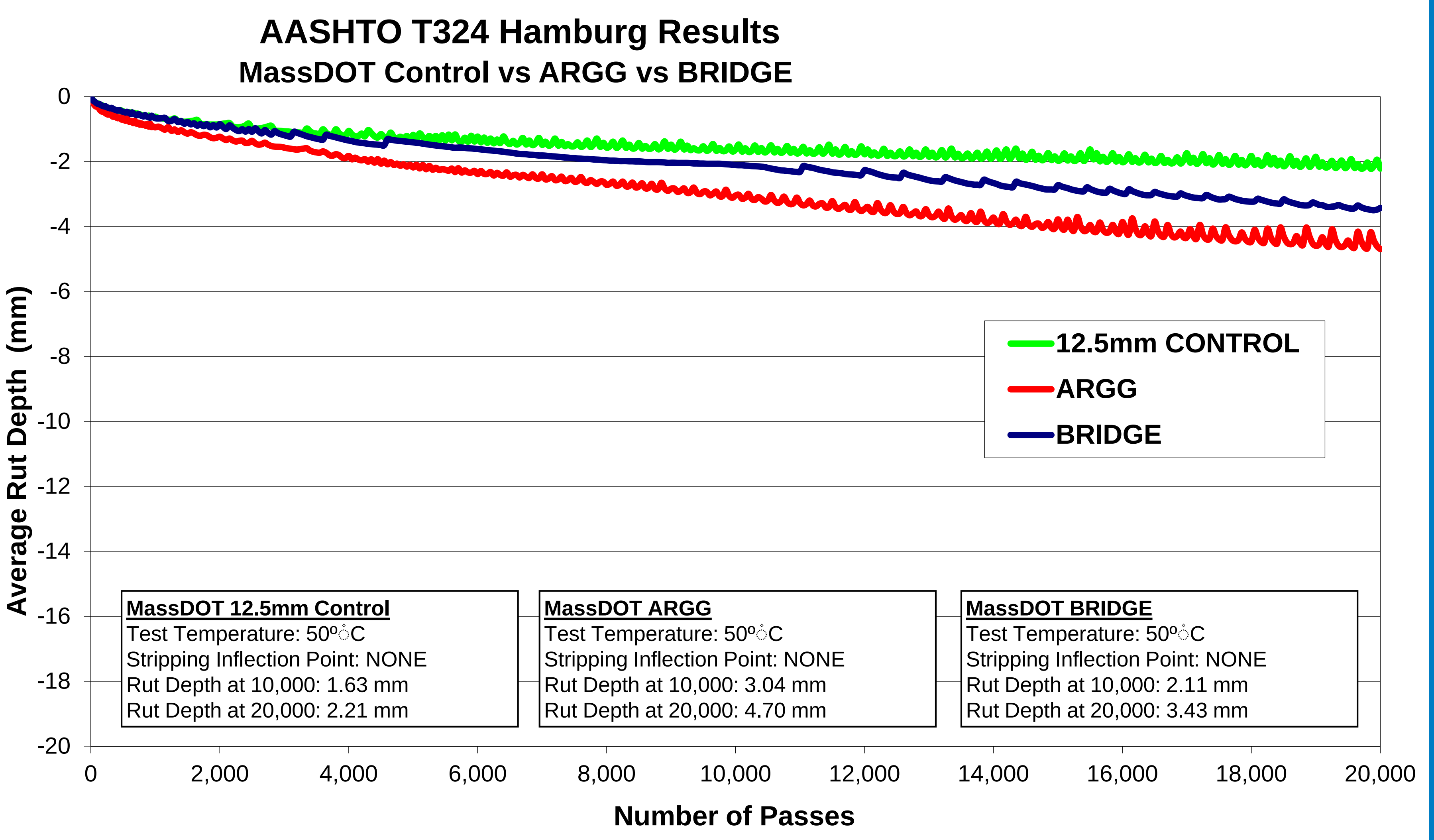
AASHTO T324:Standard Method of Test for Hamburg Wheel-Track Testing of Compacted Hot Mix Asphalt (HMA)

Water at 45ºC (113ºF) • Duration of 20,000 passes • SGC specimens at 7.0±1.0% air voids

<u>MassDOT Pass/Fail Criteria</u>

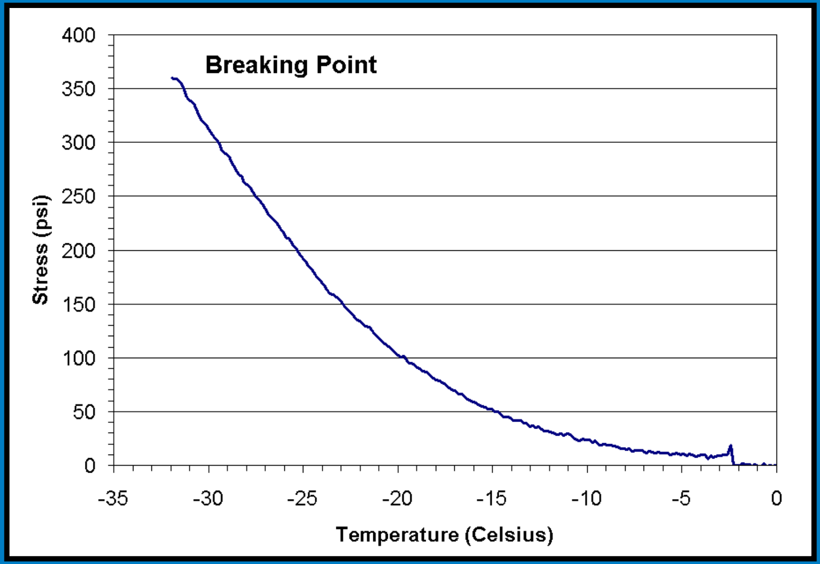
Maximum rut depth of 12.5 mm after 20,000 passes combined with no SIP before 15,000 passes.

Plant Mix
Hamburg Wheel Testing

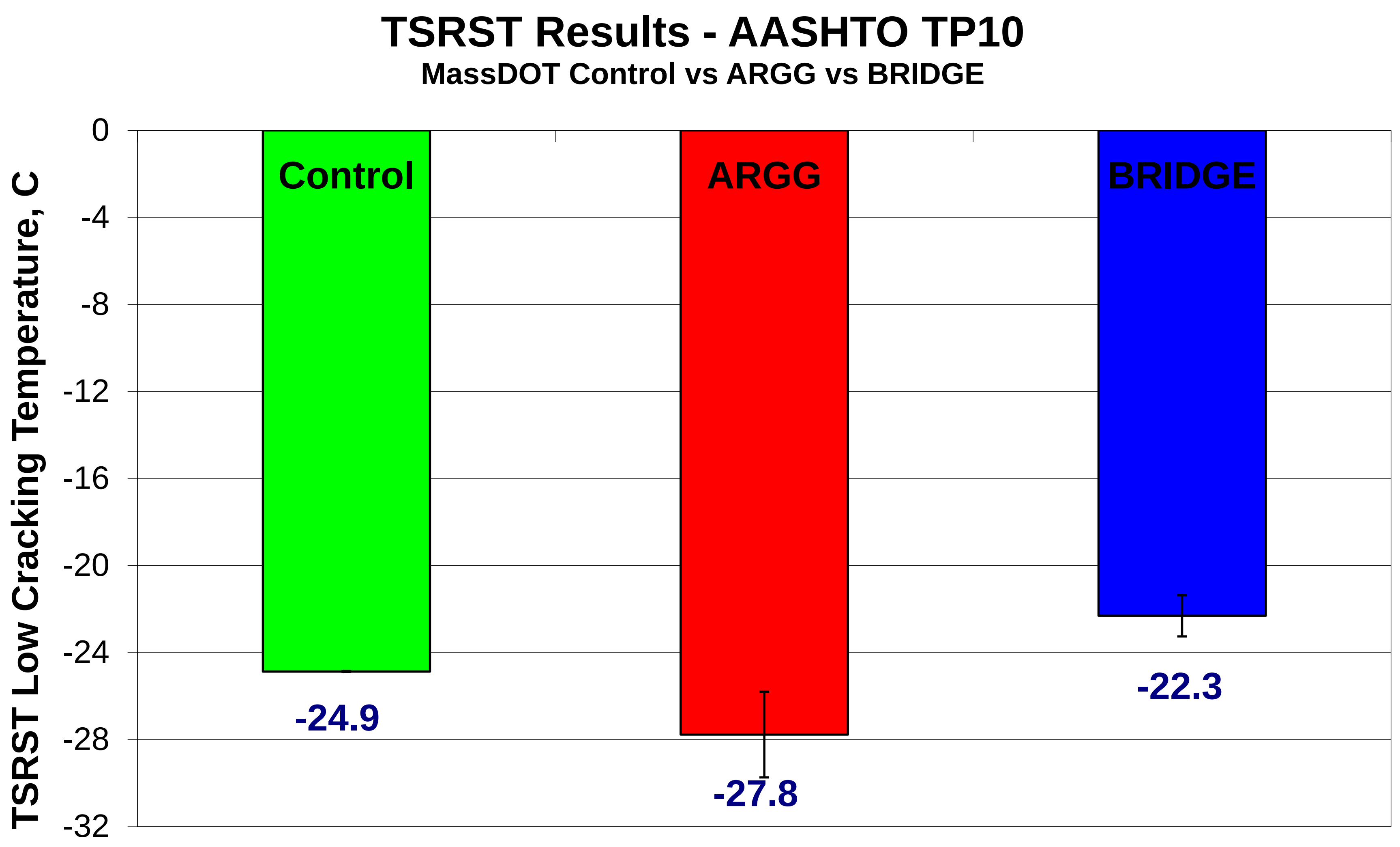


Thermal Cracking Test – TSRST

- Superpave gyratory specimens utilized.
- Cooling Rate of -10ºC/hour.
- Testing in accordance with AASHTO TP10-93.



Plant Mix TSRST Results



Reflective Cracking – +Overlay Tester

- Test Temperature = 15ºC (59ºF)
- Test Termination at 1,200 cycles or 93% Load reduction
- Testing in accordance with Tex-248-F

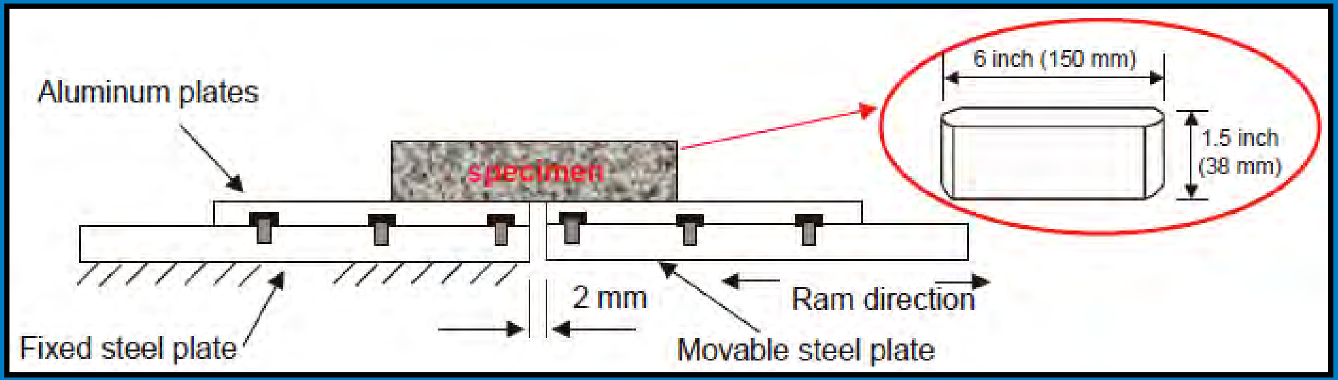
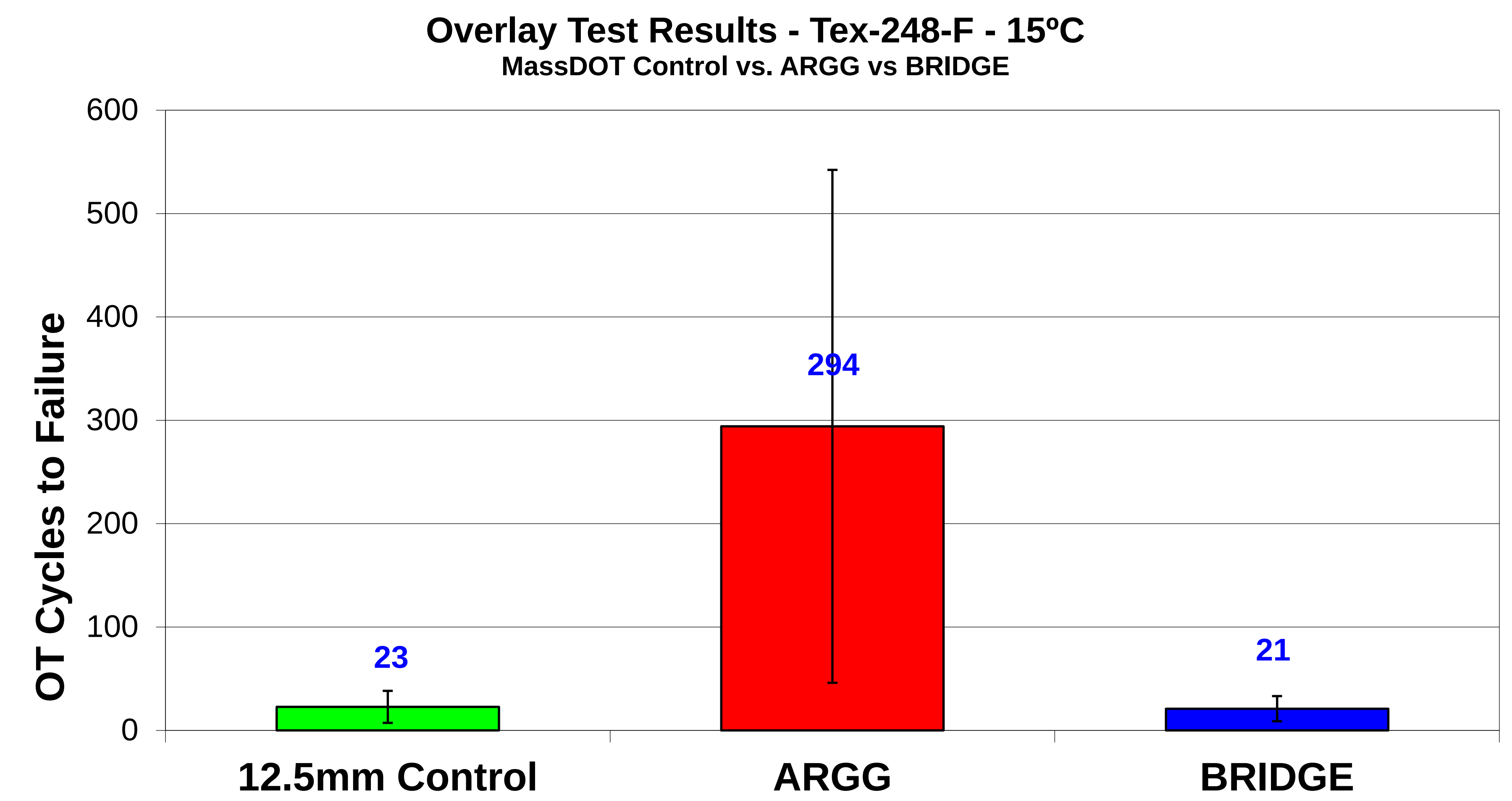


Diagram from: Zhou et al. "Overlay Tester: Simple Performance Test for Fatigue Cracking" Transportation Research Record: Journal of the Transportation Research Board, No. 2001, Transportation Research Board of the National Academies, Washington, D.C., 2007, pp. 1–8.

Plant Mix
Overlay Test Results



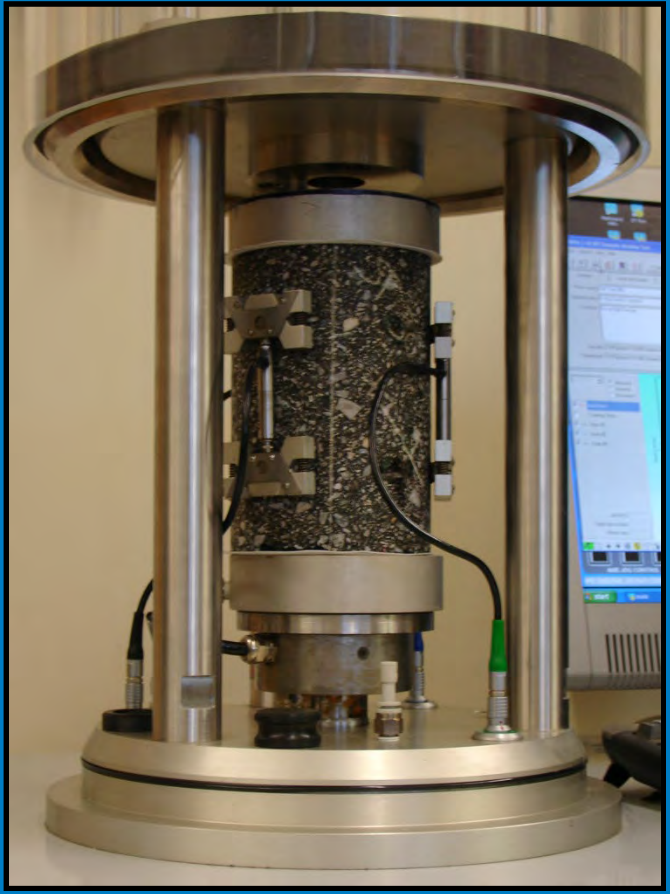
RAP & Warm Mix Asphalt AR Mixtures

Massachusetts Department of Transportation Highway Division

- UMASS Highway Sustainability Research Center undertook an extensive Research Project evaluating use of RAP & WMA with AR.
- WMA - Lower production/placement temperatures, reduced emissions and odors, decreased energy consumption for production & improved environmental working conditions
- Higher binder content for ARGG mixtures may improve mixture cracking resistance, improve rutting performance, and resist aging/oxidation
- Meet the DOT/ industry goal of producing a sustainable, cost effective, and environmentally friendly mixture

HSRC Highway Sustainability Research Center

Mixture Stiffness – Dynamic Modulus



AASHTO TP62 in Asphalt Mixture Performance Tester (AMPT)

Conducted to determine changes in mixture stiffness due to the incorporation of RAP and WMA Technology.

Temperature	Frequency
4°C	10 Hz, 1Hz, 0.1Hz
20°C	10 Hz, 1Hz, 0.1Hz
40°C	10 Hz, 1Hz, 0.1Hz, 0.01Hz

Specimens were fabricated at a target air void level of 7.0 ± 1.0%.

Mixture Stiffness Conclusions

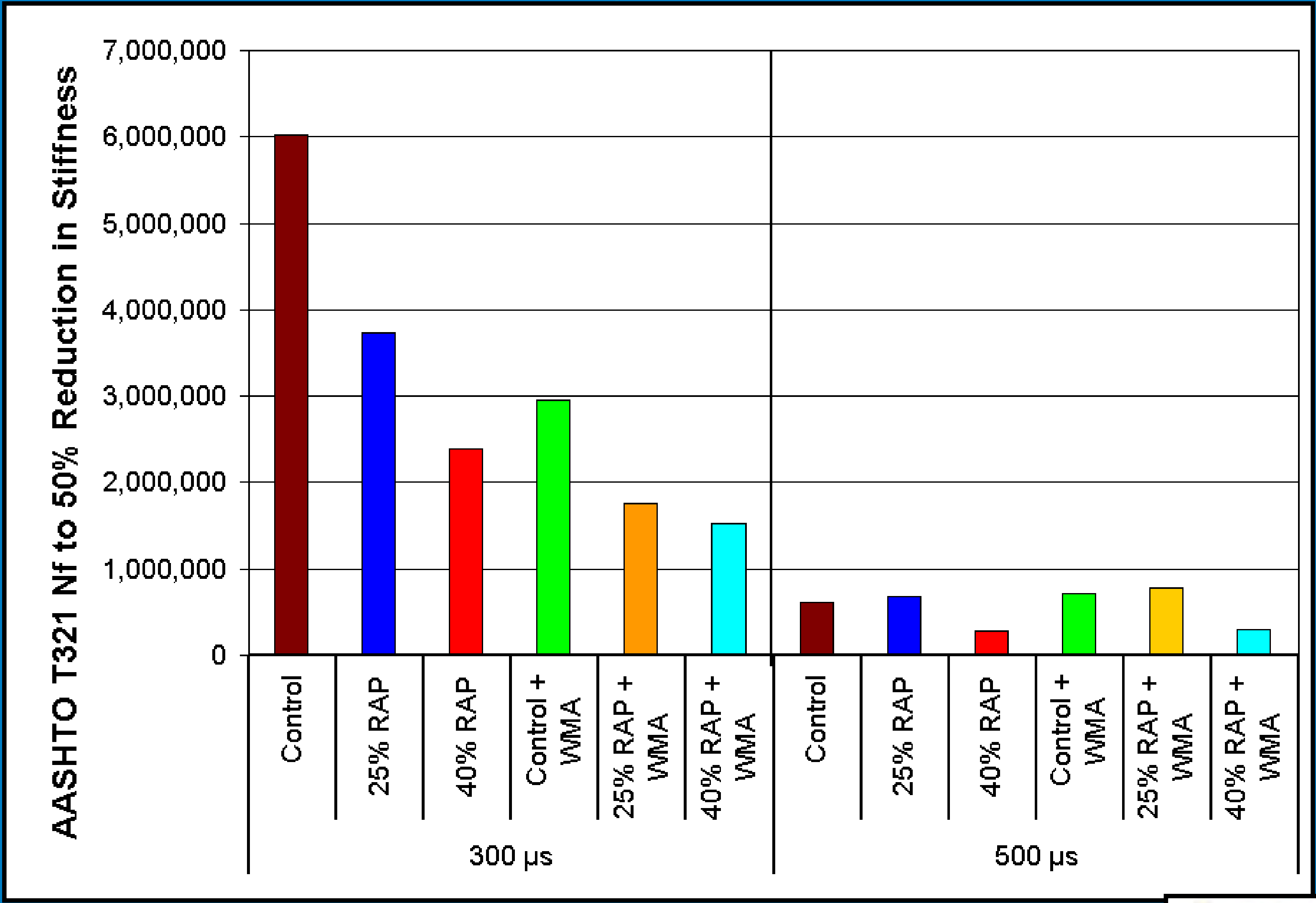
- The addition of RAP to the control mixture resulted in an increase mixture stiffness.
- The stiffness increase in the mixtures containing RAP was mitigated through the use of a WMA technology and corresponding reduced aging temperatures.
- The addition of the WMA technology to the control mixture had little to no effect on the stiffness of the mixture.

Fatigue – Four Point Bending Beam

	Number of Cycles to 50% Initial Stiffness, N_f		
Strain Level, με	Control	Control + 25% RAP	Control + 40% RAP
300	6,025,590	3,724,655	2,390,822
500	614,053	677,983	289,898
700	544,687	197,625	46,895
900	25,567	24,984	16,255

	Number of Cycles to 50% Initial Stiffness, N_f		
Strain Level, με	Control + WMA	Control + 25% RAP + WMA	Control + 40% RAP + WMA
300	2,946,065	1,759,123	1,526,473
500	705,290	775,690	306,746
700	196,372	99,901	51,134
900	21,616	27,026	4,697

Fatigue – Four Point Bending Beam



Four Point Bending Beam - Conclusions

- The resistance to fatigue cracking decreased with the incorporation of RAP. The same trend was also apparent with the incorporation of the WMA technology.
- At each strain level, the number of cycles to failure for each mixture was reduced when WMA was incorporated.
- For the mixtures incorporating WMA, the mixing and compaction temperatures were dropped 17°C and 13°C respectively. This drop in the temperature might have caused the RAP and AR binders not to comingle sufficiently.

Reflective Cracking – Overlay Tester

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Mixture	Average OT Cycles to Failure
Control	351
25% RAP	43
40% RAP	54
Control + 1% WMA	275
25% RAP + 1% WMA	64
40% RAP + 1% WMA	21

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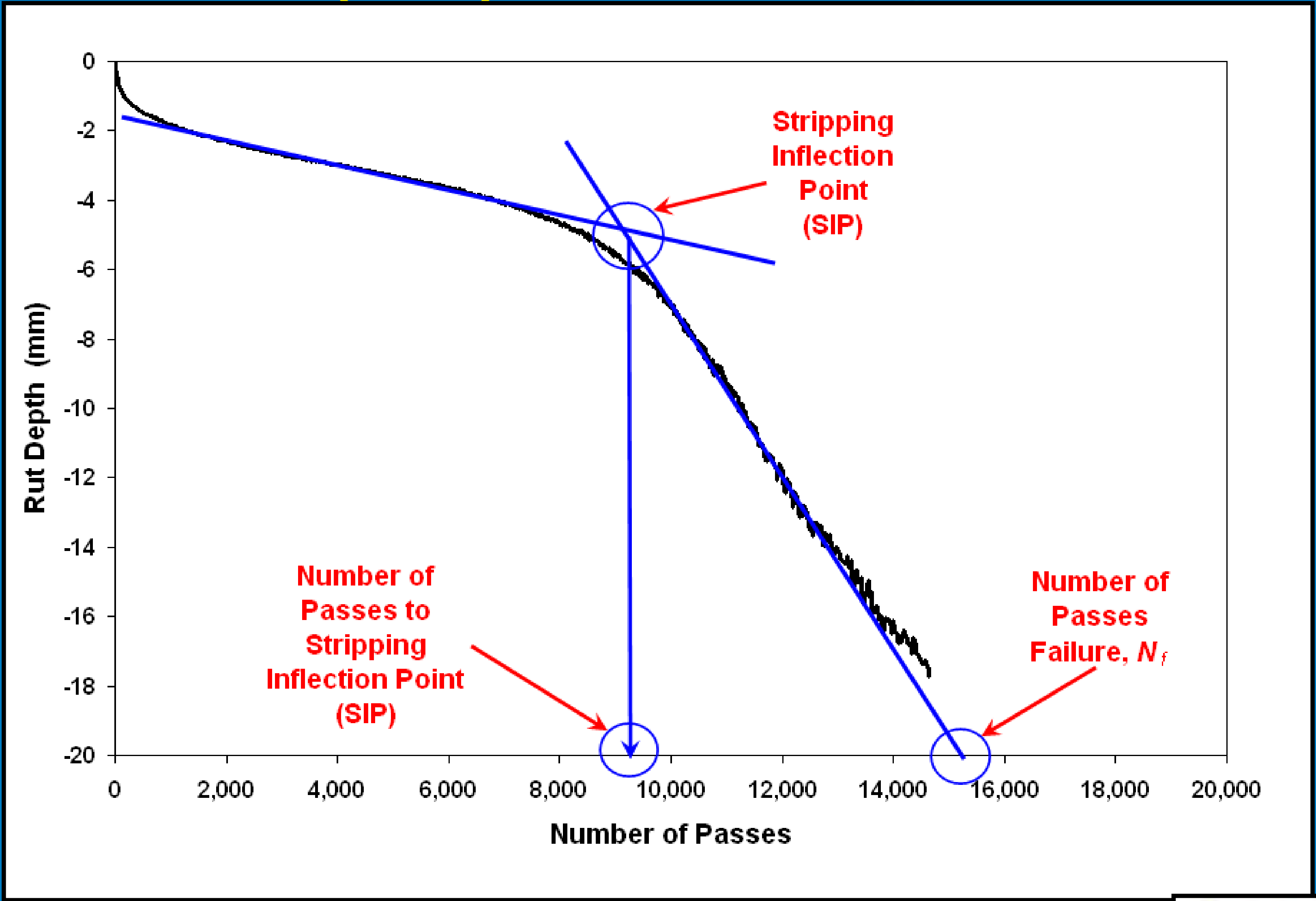
Highway Sustainability Research Center

Overlay Tester – Conclusions

- The reflective cracking resistance of the mixture decreased with the incorporation of higher amounts of RAP. The same trend was apparent when WMA was incorporated.
- Generally, the OT data agreed with the results of the beam fatigue which showed a reduced cracking resistance for the mixture incorporating WMA.

Stripping Inflection Point (SIP)



HWTD Results

Mixture	Stripping Inflection Point	Average Rut Depth at 10,000 Passes (mm)	Average Rut Depth at 20,000 Passes (mm)
Control	NONE	0.88	1.09
25% RAP	NONE	0.41	0.51
40% RAP	NONE	0.23	0.28
Control + 1% WMA	NONE	0.45	0.65
25% RAP + 1% WMA	NONE	0.14	0.23
40% RAP + 1% WMA	NONE	0.85	0.96

NONE = Mixture passed 20,000 cycle test with no SIP.

HWTD Conclusions

- All mixtures evaluated passed the moisture susceptibility testing in the HWTD.
- The magnitude of the average total rut depth observed at the end of each test was less than 1.10 mm (0.043 inch).

Workability Evaluation

- Mixture workability evaluation was conducted to determine the impact of RAP, AR and/or WMA on mixture workability.

- Workability evaluation was conducted using prototype device designed and built by UMass Dartmouth known as the Asphalt Workability Device (AWD).

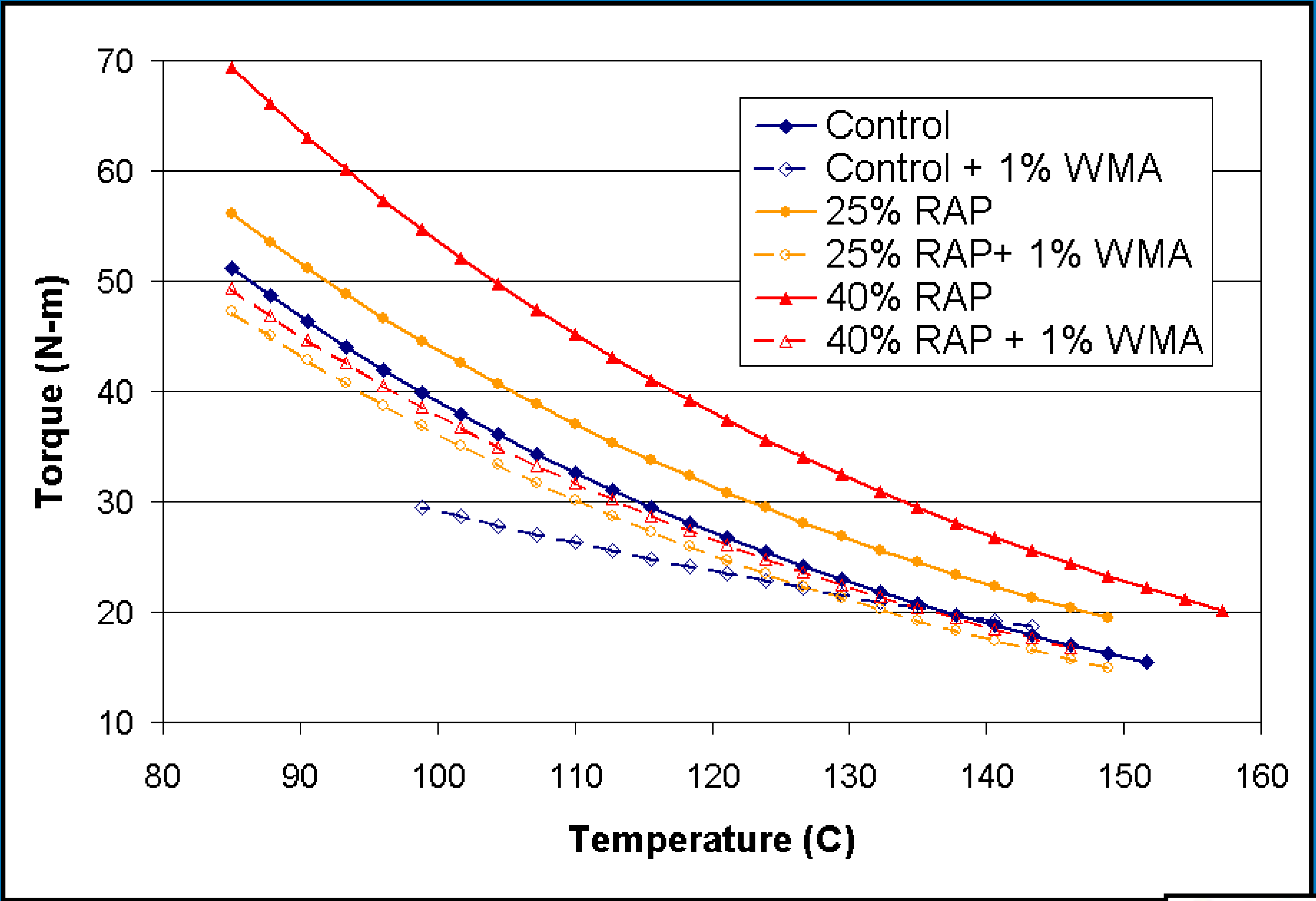
- The AWD operates on the torque measurement principles.

Workability Evaluation

UMass Dartmouth AWD

AWD Paddle Configuration

Workability Results



Workability Conclusions

- Mixtures without the WMA technology showed that as the amount of RAP incorporated into the mixture was increased there was a corresponding decrease in mixture workability (i.e. increase in torque).

- <u>Overall, the addition of the WMA improved the workability of the mixtures with RAP to a level similar to the control mixture without RAP and WMA.</u>

Implementation of RAP & WMA in AR Mixes..

- How were any results from the Study Implemented by the DOT?
  - WMA required in all Asphalt Rubber Mixtures.
  - <u>10% RAP Permitted in ARGG!</u>
  - Must be capable of lowering production temperatures to 280F.
  - DOT has waived its initial temperature requirement of 55F for placement of ARGG.

Hot Mix Asphalt- ARGG

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Warm Mix Asphalt– ARGG

As a result of this research..

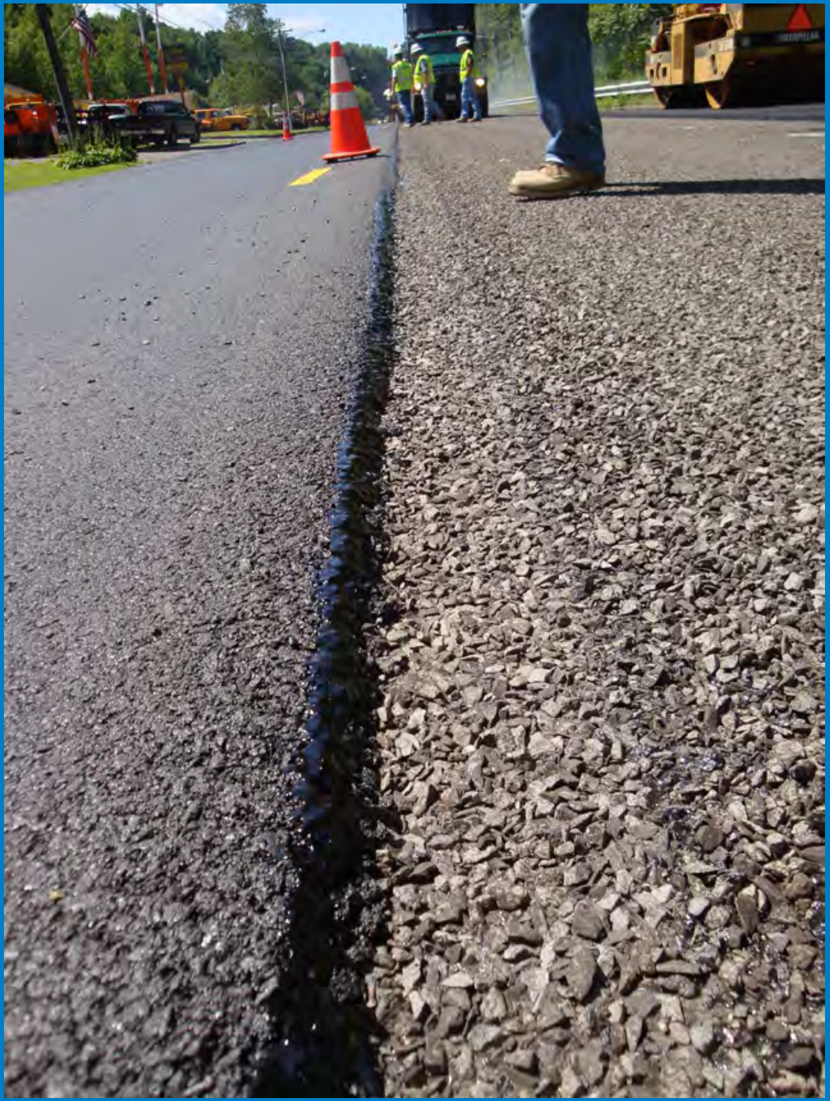
- Specified ARGG as an overlay on Composite (HMA over Jointed PCC Roadways.
- Specified ARGG on some of the most critical roadways requiring high levels of pavement performance.
- OGFC-AR used on dozens of miles of Interstate Highways.
- Full-Depth Porous Pavement containing AR and shingles for highway median.
- Millions of tons of Asphalt Rubber mixtures placed statewide.

Route 8 Cheshire Lanesboro Stress Absorbing Membrane Interlayer Demo Project

- MassDOT specifies Stress Absorbing Membrane Interlayers (SAMI) to mitigate reflective cracking in some applications. Item #466.
- SAMI can be placed independent of an overlay and left open to traffic.
- Four test sections were constructed on Route 8 in the towns of Cheshire- Lanesboro.
- Two Sections included a Rubber Chip Seal SAMI.
  - SAMI & HMA Overlay
  - SAMI & Bonded Thin Overlay

Route 8 Cheshire Lanesboro Construction

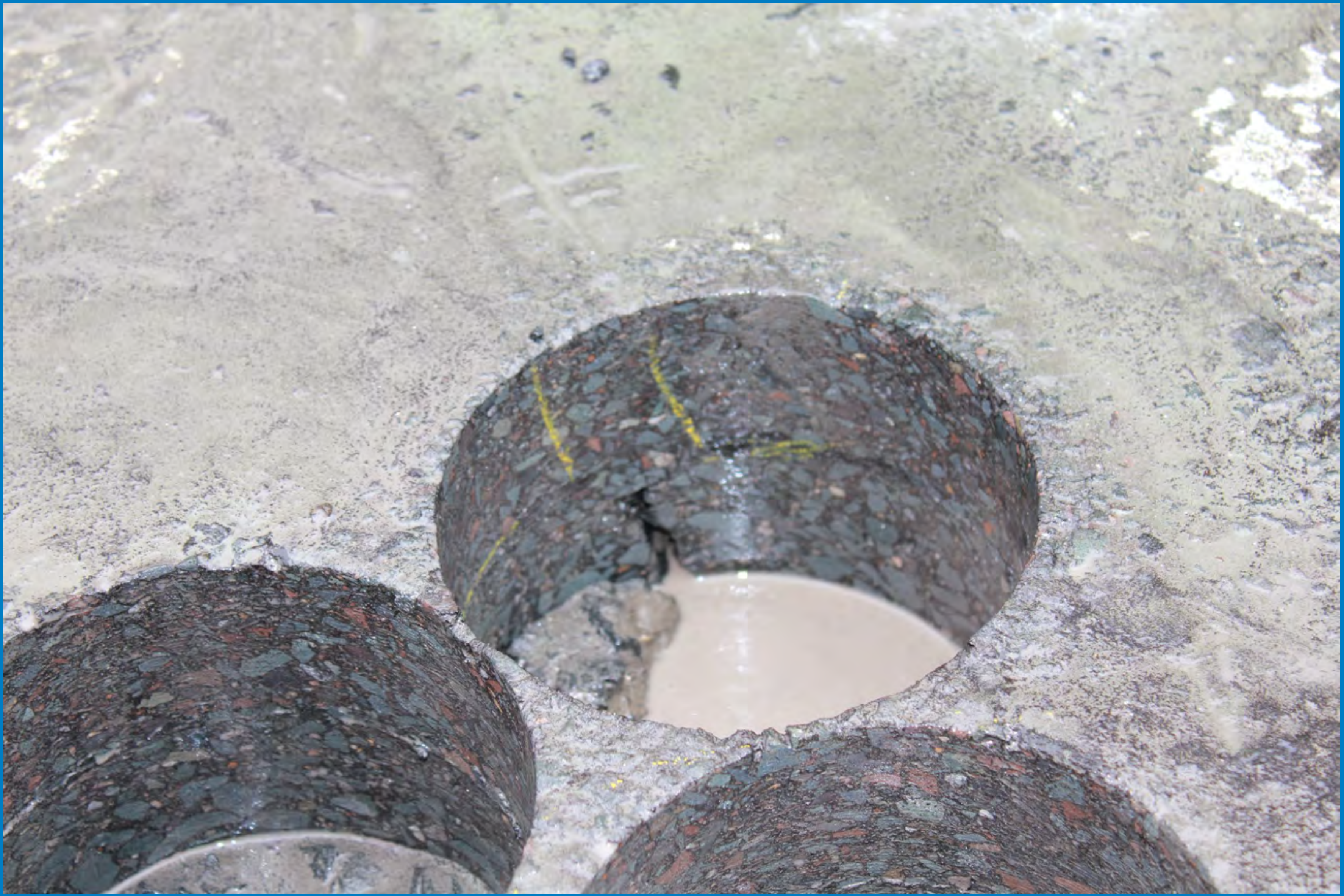
Route 8 Cheshire Lanesboro Construction



Cheshire-Lanesboro – Two Years Later
HMA Overlay on Shoulder – No SAMI

Cheshire Lanesboro – Two Years Later
No SAMI - Core

Cheshire Lanesboro
HMA over SAMI



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Cheshire - Lanesboro
HMA over Rubber Chip Seal
SAMI

- First Core on shoulder – no SAMI
- Second Core through SAMI
- Effective on most longitudinal cracking
- Effective on less light to moderate transverse cracking

Cheshire Lanesboro
HMA over Rubber Chip Seal SAMI

Route 8 Cheshire Lanesboro

- HMA over Rubber Chip Seal SAMI
- Crack stops at SAMI.
- Effective on most longitudinal cracking.
- Effective on less severe transverse cracking.

Cheshire Lanesboro Bonded Thin Overlay on Rubber Chip SAMI

Kernwood Drawbridge
Salem, MA

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Kernwood Drawbridge
Salem, MA

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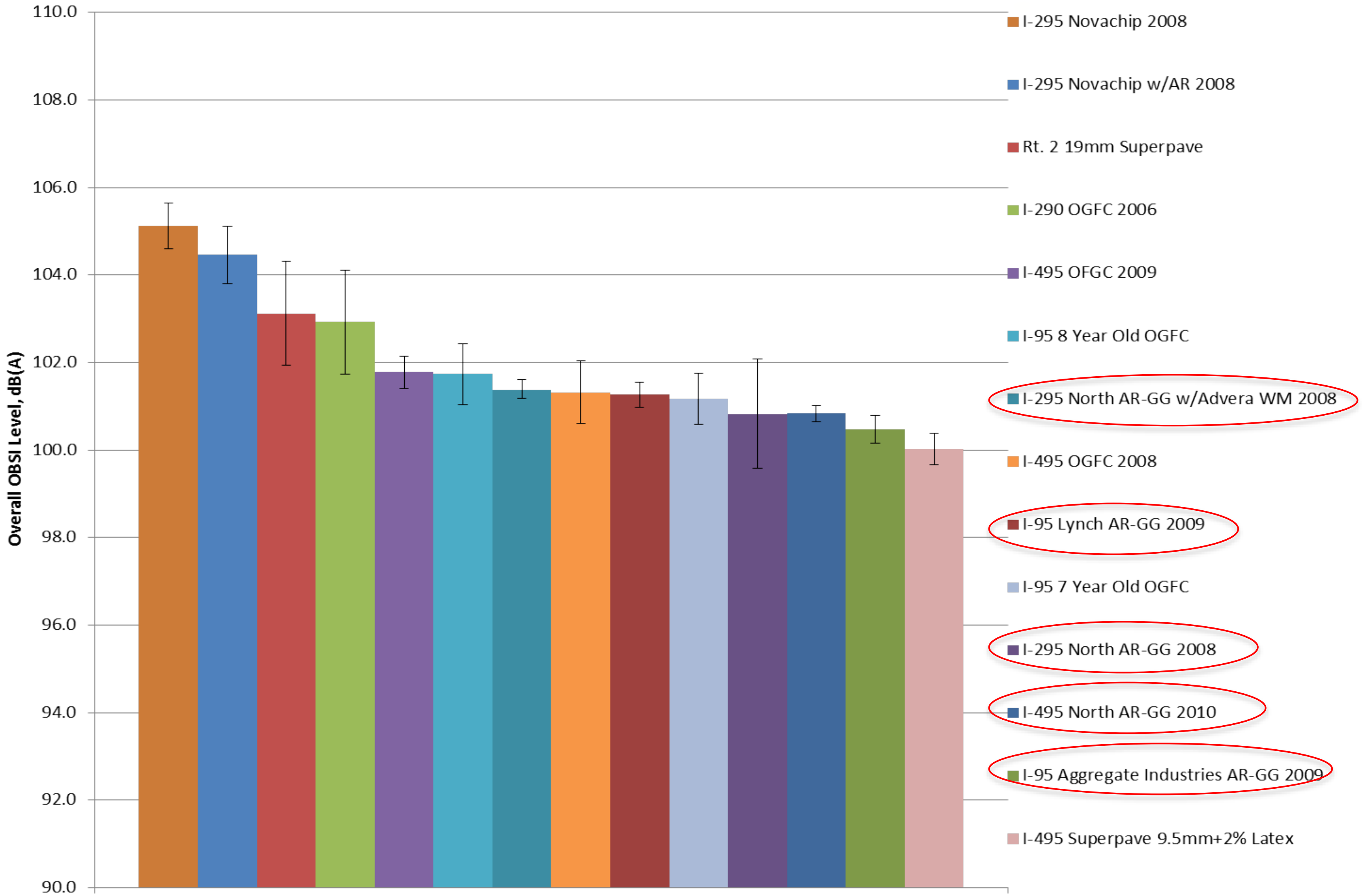
I-495N Milford – Southborough

Ride Statistics								
ROUTE	FROM	TO	LIRI	RIRI	AVG IRI	COMMENTS	COLLECTION YEAR	PROJECT #
0495N	50.55	61.67	83.94	81.17	82.55	Before	2008	54488
0495N	50.55	61.67	37.89	52.86	45.37	After	2009	54488

I-495N Milford–Southborough "10 Years Later"

Reduction In IRI After Project Completion								
ROUTE	FROM	TO	LIRI	% REDUCED	RIRI	% REDUCED	AVG IRI	% REDUCED
0495N	50.55	61.67	46.05	54.9%	28.31	34.9%	37.18	**45.0%**

Overview of Tested Materials in MA



Which Highways have projects using Ground Tire Rubber?

- **Rt 1, Rt 2, Rt 3, Rt 8, Rt 9, Rt 23, Rt 24, Rt 32, Rt 44, Rt 68, Rt 128, Rt 140, Rt 213, etc…**

- **I-84, I-90, I-91, I-93, I-95, I-190, I-195, I-290, I-291, I-295, I-391, I-395, I-495**

Issues?

- Yes, but fortunately not related to performance.
- Even with Warm Mix, AR mixtures require higher production temperatures than unmodified mixtures.
  - Modified asphalts have an odor (GTR, SBS, SBR, etc..).
  - Elevated production temperatures have an odor.
  - HMA Plants need to work with DEP and local officials to address any issues (not just AR).
  - MassDOT has bid AR mixes using a SSC-HP Specification having performance targets.
- Mobilization of AR blending equipment and connecting to an HMA plant has an added cost.
- AR mixtures are more costly than unmodified mixtures.

Summary

- Hopefully, this presentation has conveyed the pavement research and testing we perform prior to using new technology.
  - Dr. Walaa Mogawer at the UMass Dartmouth Highway Sustainability Resource Center (HSRC) has provided years of testing, expertise and support of these efforts.
- GTR recycled into roadways because it improves pavement performance.
  - Tire disposal considered ancillary benefit.
  - Increased costs of AR pavement offset by improved performance.
- MassDOT is implementing specifications which establish minimum standards for many of the performance tests shown on these slides.

Thank You!!

Questions??

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