Asphalt Rubber – Experience & Specification Development

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Massachusetts Department of Transportation
Highway Division

NEAUPG - Portsmouth, NH - October 25, 2013

Asphalt Rubber

- Asphalt Rubber – ASTM D6114 Type 2.
- SAMI – 1986 Standard Specifications
  - Rubber Chip SAMI– DOT
  - Wooden Bridge Decks SAMI/Surface- DOT
  - Surface Treatment - Municipals
- 1991 ISTEA Rubber Mandates
- "Generation 1 AR HMA"
  - 1992 Project – Rt 140 Freetown
    - Dense "Recipe" HMA Mixture
  - 1996 – MassDOT Participated in a NIOSH Study
  - I-95 Foxboro Southbound (1997)
    - Dense "Recipe" Mix and 3/8" OGFC-AR.

Terminal Blend GTR

- 2004 – "Pavement Preservation" Thin Overlays
  - "Terminal Blends" GTR & Polymer (PGAB 76-34)
    - "RI Mix"
    - I-91 Bernardston-Greenfield (2005)
    - Rt 146 Uxbridge-Milville (2006)
    - Rt 2 Gardner-Westminster (2006)
- "Terminal Blends" OGFC
  - I-395SB Webster (2006)
    - GTR clogged plant screens/filters for AC pump
    - Low Binder Control Strip high speed lane – left in place
      - 5% rather than 6.2% AC
      - Still performing adequately.
      - No discernible performance impact to date.
- I-295 Attleboro-North Attleboro Terminal Blend vs Asphalt Rubber Project.

Asphalt Rubber HMA – "2'nd Generation"

- I-295 Attleboro-North Attleboro
- Terminal Blend - Asphalt Rubber demo.
  - Asphalt Rubber Gap Graded (ARGG) PG 58-28
  - Terminal Blend – "RI Specification" PG 76-34.
  - Bonded Ultrathin Overlay w/PG 64-28
  - Bonded Ultrathin Overlay w/PG 58-28 + AR
- Availability of Terminal Blend GTR Binder
  - Supply/Contractor concerns
- Bid 2007 - Built 2008
- Construction Changes – Advera WMA ARGG mix substituted for Terminal Blend PG76-34.

ARGG – Specification Development?

- DOT Needs
  - T/O Maintenance Mix
  - OGFC Maintenance Mix
  - Dense/Gap Graded/Open Graded
- Looked to other States for specs…
  - Arizona.. California.. Texas…
- Developed Draft Volumetric Mix Design Specification working with UMASS Dartmouth – HSRC.
  - Dr. W. Magower at UMass Dartmouth's HSRC instrumental in specification Development.

Specification

- Section 450 HMA Quality Assurance Spec's.
- Five Quality Criteria
  - Acceptance, Incentives & Disincentives
  - Statistical Percentage within limits for:
    - Plant Air Voids
    - Binder Content
    - Compacted Thickness
    - Density (by cores)
    - Ride Quality (IRI)
- Demo Projects – QA for informational purposes.

Specification (cont.)

- Density for Typical Dense HMA
  - 95.0% Target Density
  - ± 2.5% Specification Limits
  - ± 3.0% Engineering Limits
  - Spec's had little information on density requirements
  - Other DOT's believed there was a relationship between low density prior failures.
- ARGG? Minimum 92.0 on initial projects
  - Objective was to benchmark field density.
  - How uniform and repeatable?
  - Standard Deviation – same as HMA?

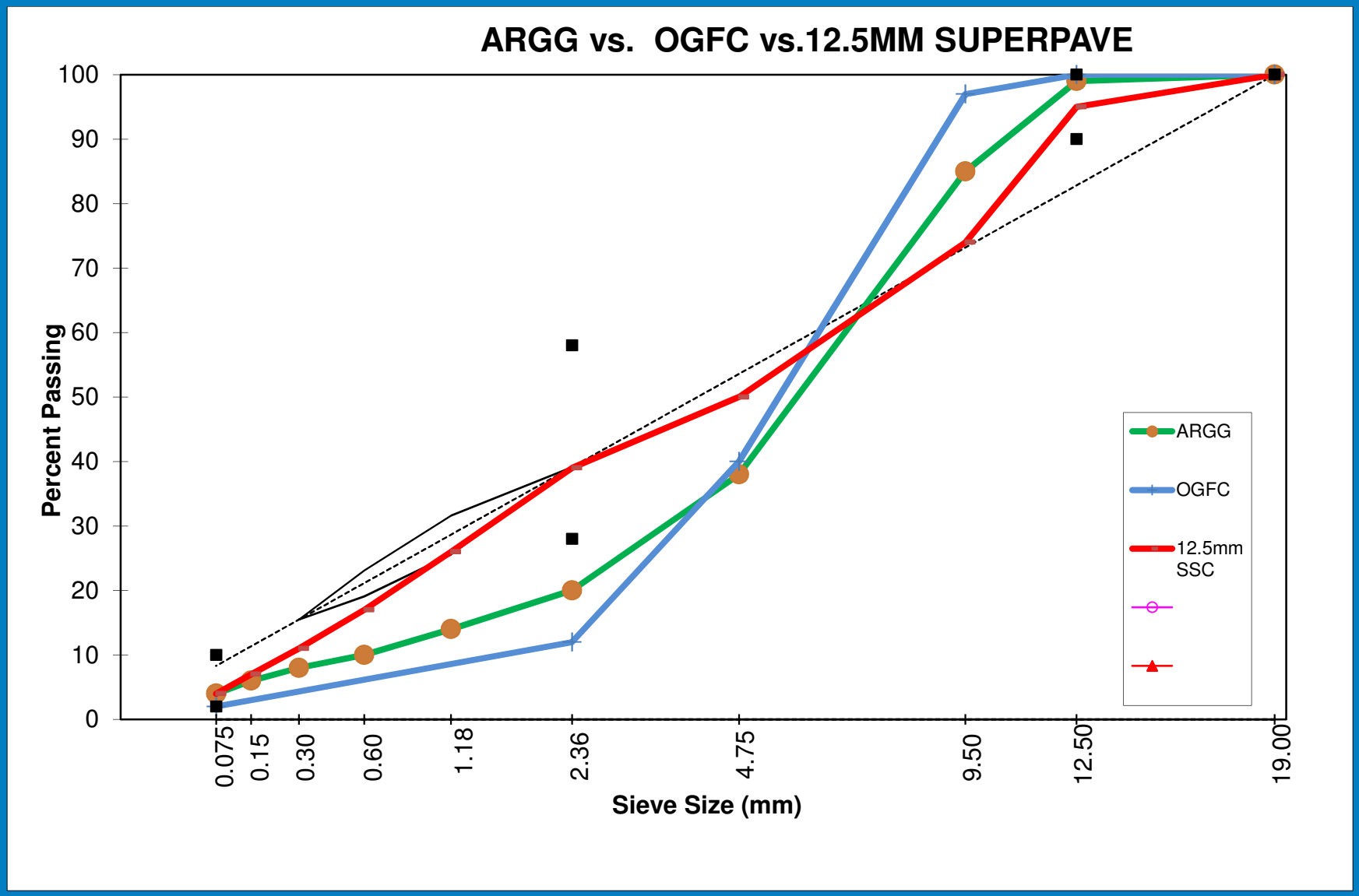
Specification(cont.)

- Plant Air Voids
  - 4% Target
  - ± 1.5% Specification Limits
  - ± 2.0% Engineering Limits
- Thickness
  - 1.25” Specified
  - Not subject to statistical analysis.
- Binder Content
  - Target = Mix Design (6.5% min. later = 7.6%)
  - ± 0.3% Specification Limits
  - ± 0.4% Engineering Limits

Specification (cont.)

- Ride Quality
  - Target IRI = 65 in/mi.
  - Surface courses ≤ 1.5” not subject to ride.
- Contractor must place Control Strip on first night production
  - 600-1800 tons.
  - Contractor and DOT QC must each perform random sampling (3x locations)
  - Must meet specified PWL before proceeding to full paving.

Gap Graded?


ARGG vs. OGFC vs.12.5MM SUPERPAVE
Percent Passing
100
90
80
70
60
50
40
30
20
10
0
0.075
0.15
0.30
0.60
1.18
2.36
4.75
9.50
12.50
19.00
Sieve Size (mm)
ARGG
OGFC
12.5mm SSC

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%**

Post-Construction Spec.“Adjustments”

- Plant Air Voids seemed erratic.
  - Control Strip Nights
    - 6 Tests for plant air voids inconsistent.
    - Tests Taken in short production night.
    - Specimens removed from mold “hot”.
    - Visible swelling in mixes.
    - Cause for concern?
- Field Densities were good
  - 92% minimum achieved.
  - Consistent.
  - Need target and tolerances
- Ride Quality
  - 50-60in/mile.

Post Construction Spec. "Adjustments"

- "Borderline" Tests for binder content.
  - Binder content near specification limits.
    - Ignition ovens required correction for AR.
    - Ignition ovens required more frequent cleaning.
    - Black residue could sometimes be seen after burn.
      - Carbon black?
- **Adjusted binder content tolerances.**
  - Increased Spec Limits from ±0.3% to ±0.4%
  - Increased Engineering Limits from ±0.4 to ±0.6.
- **Eliminated plant air void testing for QC.**
- **Required Ride (IRI) testing for thin lifts.**
- **Target Density Later Increased to 94%.**

I-95 Attleboro "Before"

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- I-95 Attleboro (2008)
- 4.57± miles (37.56 lane miles)
- 3 lanes + Breakdown lane & Shoulder
- Distress
  - Ravelling & Weathering OGFC
  - Delamination & Thermoplastic
  - Longitudinal Joints & Plow Damage
- Rehab
  - Micromill & 1.25" ARGG Thin Overlay
- Bid $3,022,045.35
  - Clearing & Grubbing
  - Frames/Grates (lockdowns)
  - Guardrail repairs & Safety items
  - Traffic Control, Striping, etc.
- Cost $82.6K/lane mile

Pre-Construction Ride Statistics

ROUTE	FROM	TO	LIRI	RIRI	AVG IRI	COMMENTS	COLLECTION YEAR	PROJECT #
0095N	0.00	4.57	74.65	85.84	80.25	No Bridge	2008	54309

I-95 Attleboro

Ride Statistics

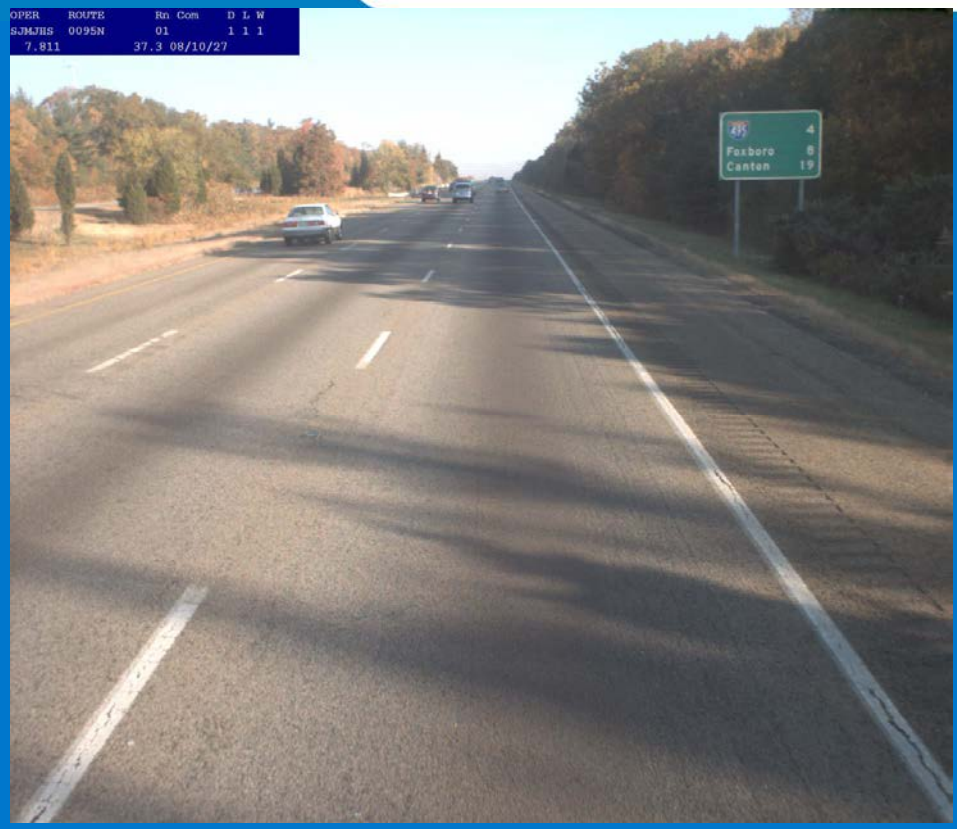
ROUTE	FROM	TO	LIRI	RIRI	AVG IRI	COMMENTS	COLLECTION YEAR	PROJECT #
0095N	0.00	4.57	74.65	85.84	80.25	Before	2008	54309
0095N	0.00	4.57	40.57	56.07	48.32	After	2009	54309

I-95 Attleboro "After"

Ride Quality Improvement								
ROUTE	FROM	TO	LIRI	% REDUCED	RIRI	% REDUCED	AVG IRI	% REDUCED
0095N	0.00	4.57	34.09	45.7%	29.77	34.7%	31.93	**39.8%**

I-95 North Attleboro – Foxboro "Before"

- I-95 North Attleboro-Foxboro (2008)
- 6.39± miles (51.12 lane miles)
- 3 lanes + Breakdown & Shoulder
- Distress
  - Ravelling & Weathering OGFC
  - Delamination & Thermoplastic
  - Longitudinal Joints & Plow Damage
- Rehab
  - Micromill & 1.25" ARGG Thin Overlay
- Bid $6,008,093.25
  - Bridge Repairs, ramp & interchanges ($0.9M)
  - Clearing & Grubbing
  - Frames/Grates (lockdowns)
  - Guardrail repairs & Safety items
  - Traffic Control, Striping, etc.
- Cost $ 117.5K/lane mile



Pre-Construction Ride Statistics

ROUTE	FROM	TO	LIRI	RIRI	AVG IRI	COMMENTS	COLLECTION YEAR	PROJECT #
0095N	4.57	8.22	77.91	88.53	83.22	Before	2008	58178
0095N	9.38	12.12	70.29	67.50	68.90	Before	2008	58178

I-95 North Attleboro - Foxboro

Construction Ride Statistics

ROUTE	FROM	TO	LIRI	RIRI	AVG IRI	COMMENTS	COLLECTION YEAR	PROJECT #
0095N	4.57	8.22	55.39	65.49	60.44	After	2009	58178
0095N	9.38	12.12	41.82	65.64	53.73	After	2009	58178

I-95 North Attleboro - Foxboro

Reduction In IRI After Project Completion								
ROUTE	FROM	TO	LIRI	% REDUCED	RIRI	% REDUCED	AVG IRI	% REDUCED
0095N	4.570	8.220	22.52	28.9%	23.04	26.0%	22.78	**27.4%**
0095N	9.380	12.120	28.48	40.5%	1.86	2.8%	15.17	**22.0%**

I-495N Milford – Southborough "Before"

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- I-495N Milford - Southboro (2008)
- 11.12± miles (44.48 lane miles)
- 3 lanes + Breakdown & Shoulder
- Distress
  - Ravelling & Weathering OGFC
  - Delamination & Thermoplastic
  - Longitudinal Joints & Plow Damage
  - Structural Cracking north of I-90
- Rehab
  - Micromill & 1.25" ARGG Thin Overlay
  - Added 1.75" pavement structure north of I-90
- Bid $4,800,781.00
  - Clearing & Grubbing
  - Frames/Grates (lockdowns)
  - Traffic Control, Striping, etc.
- Cost $ 107.9.5K/lane mile

Pre-Construction 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

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 "Today"

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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%**

Rt 24 Brockton – Raynham "Before"

- 12.38± miles (99.04 lane miles)
- 3 lanes + Breakdown & Shoulder
- Distress
  - Ravelling & Weathering OGFC
  - Delamination & Thermoplastic
  - Extensive temporary patching
  - Structural Cracking at bridges only!
- Rehab
  - Micromill & 1.25" ARGG Thin Overlay
  - Added 2" pavement structural inlay at bridge approaches.
- Bid $12,275,737.50
  - Extensive Bridge Work
  - Clearing & Grubbing
  - Frames/Grates (lockdowns)
  - Traffic Control, Striping, etc.
  - Major Interchange work at I-495.
- Cost $ 123.9K/lane mile

Pre-Construction Ride Statistics								
ROUTE	FROM	TO	LIRI	RIRI	AVG IRI	COMMENTS	COLLECTION YEAR	PROJECT #
0024N	21.43	33.81	80.06	68.28	74.17	Before	2010	61791

Rt 24 Brockton – Raynham

Ride Statistics

ROUTE	FROM	TO	LIRI	RIRI	AVG IRI	COMMENTS	COLLECTION YEAR	PROJECT #
0024N	21.43	33.81	80.06	68.28	74.17	Before	2010	61791
0024N	21.43	33.81	65.34	56.96	61.15	After	2011	61791

Rt 24 Brockton – Raynham "Today"

Reduction In IRI After Project Completion

ROUTE	FROM	TO	LIRI	% REDUCED	RIRI	% REDUCED	AVG IRI	% REDUCED
0024N	21.43	33.81	14.72	18.4%	11.32	16.6%	13.02	17.6%

RT 24 Avon Stoughton "Before"

- 4.02± miles (31.16 lane miles)
- 3 lanes + Breakdown & Shoulder
- Distress
  - Ravelling & Weathering OGFC
  - Delamination & Thermoplastic
  - Thermoplastic markings gone
- Rehab
  - Micromill & 1.25" ARGG Thin Overlay
- Bid $4,349,096.25
  - Bridge Patching & Repairs
  - Clearing & Grubbing
  - Frames/Grates (lockdowns)
  - Traffic Control, Striping, etc.
  - Guardrail repairs & interchanges.
- Cost $ 139.5K/lane mile

Pre-Construction Ride Statistics

ROUTE	FROM	TO	LIRI	RIRI	AVG IRI	COMMENTS	COLLECTION YEAR	PROJECT #
0024N	33.82	37.84	74.61	85.76	80.18	Before	2009	59128

RT 24 Avon - Stoughton

Post-Construction Ride Statistics

ROUTE	FROM	TO	LIRI	RIRI	AVG IRI	COMMENTS	COLLECTION YEAR	PROJECT #
0024N	33.82	37.84	37.58	42.58	40.08	No Bridge	2010	59128

RT 24 Avon Stoughton "After"

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Reduction In IRI After Project Completion								
ROUTE	FROM	TO	LIRI	% REDUCED	RIRI	% REDUCED	AVG IRI	% REDUCED
0024N	33.82	37.84	37.03	49.6%	43.17	50.3%	40.10	**50.0%**

Asphalt Rubber, WMA & RAP

- I-295 Attleboro Demo Project
  - Advera (Zeolite WMA)
- Rt 3 Plymouth Late Season Paving
  - PaveCool and Wax-based WMA
    - Increased compaction time
    - No impact to stability or moisture damage
    - No temperature reduction.
- I-495 HAMS – questioned “no-RAP”
- Performance Questions using WMA & RAP.
  - Task under ISA with UMASS Dartmouth HSRC.

RAP & WMA AR Mixtures

- UMASS HSRC 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

Concerns with RAP&WMA AR Mixtures

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- Higher amounts of RAP
  - Mixture may become too stiff and may be more prone to failure
  - RAP/virgin binder blending at higher RAP contents unknown
  - Potential reduction in compactability and workability
- WMA
  - May increase mixture moisture susceptibility

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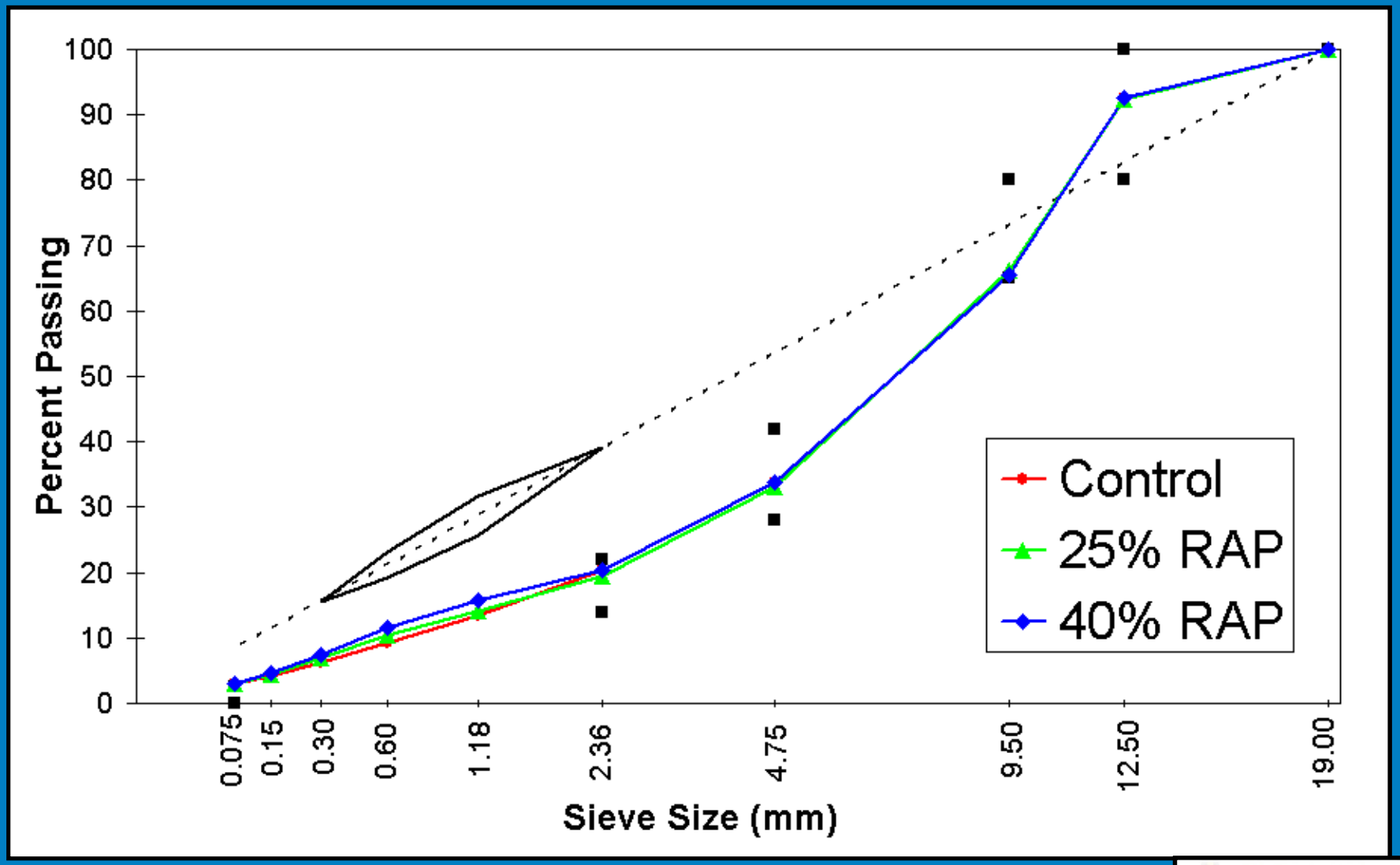
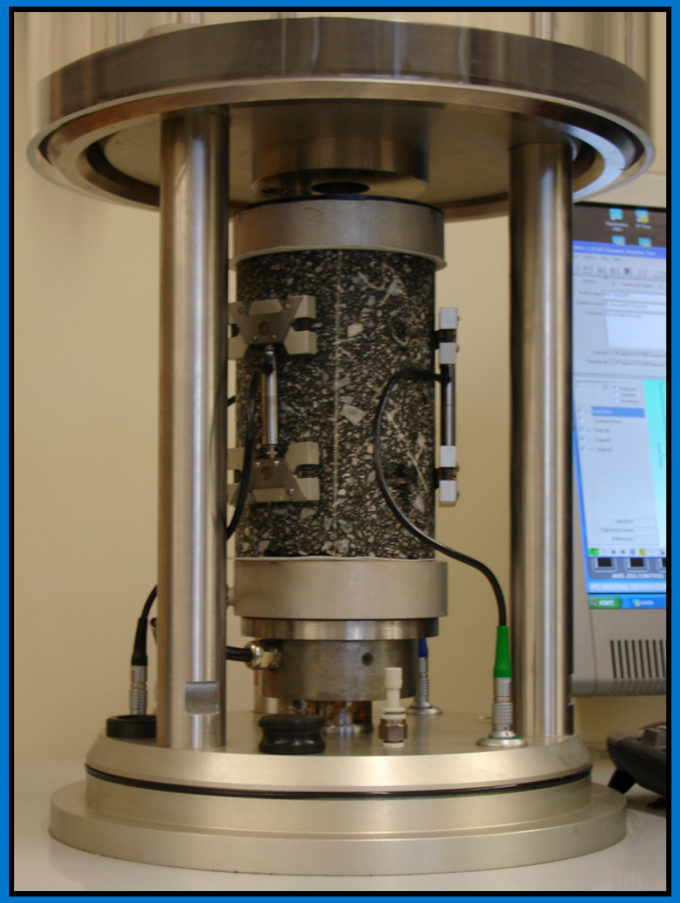
Binder & WMA

- PG58-28 base binder + 17% rubber
- Conformed to ASTM D 6114 Type II specifications
- Mixing temperature = 177ºC (351ºF)
- Compaction temperature = 154ºC (309ºF)
- SonneWarmix™ added at a dosage rate of 1.0% by weight of total binder (Virgin +RAP).
- Reduced mixing and compaction temperatures for WMA mixtures corresponded to temperatures that the asphalt rubber supplier had been using when producing similar mixtures with the same WMA technology.

Mixture Gradations



Mixture Stiffness – Dynamic Modulus



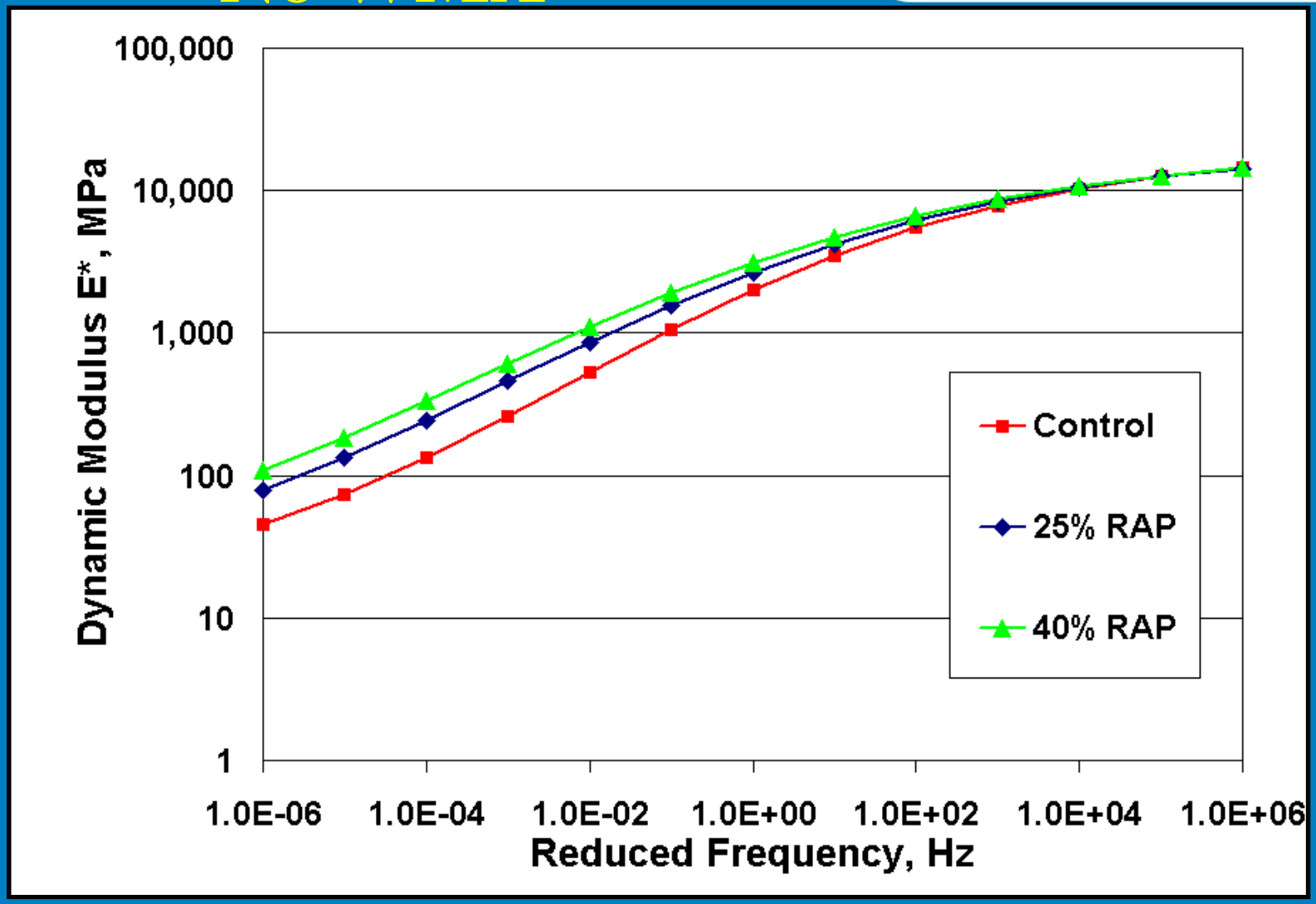
AASHTO TP62 in Asphalt Mixture Performance Tester (AMPT)

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

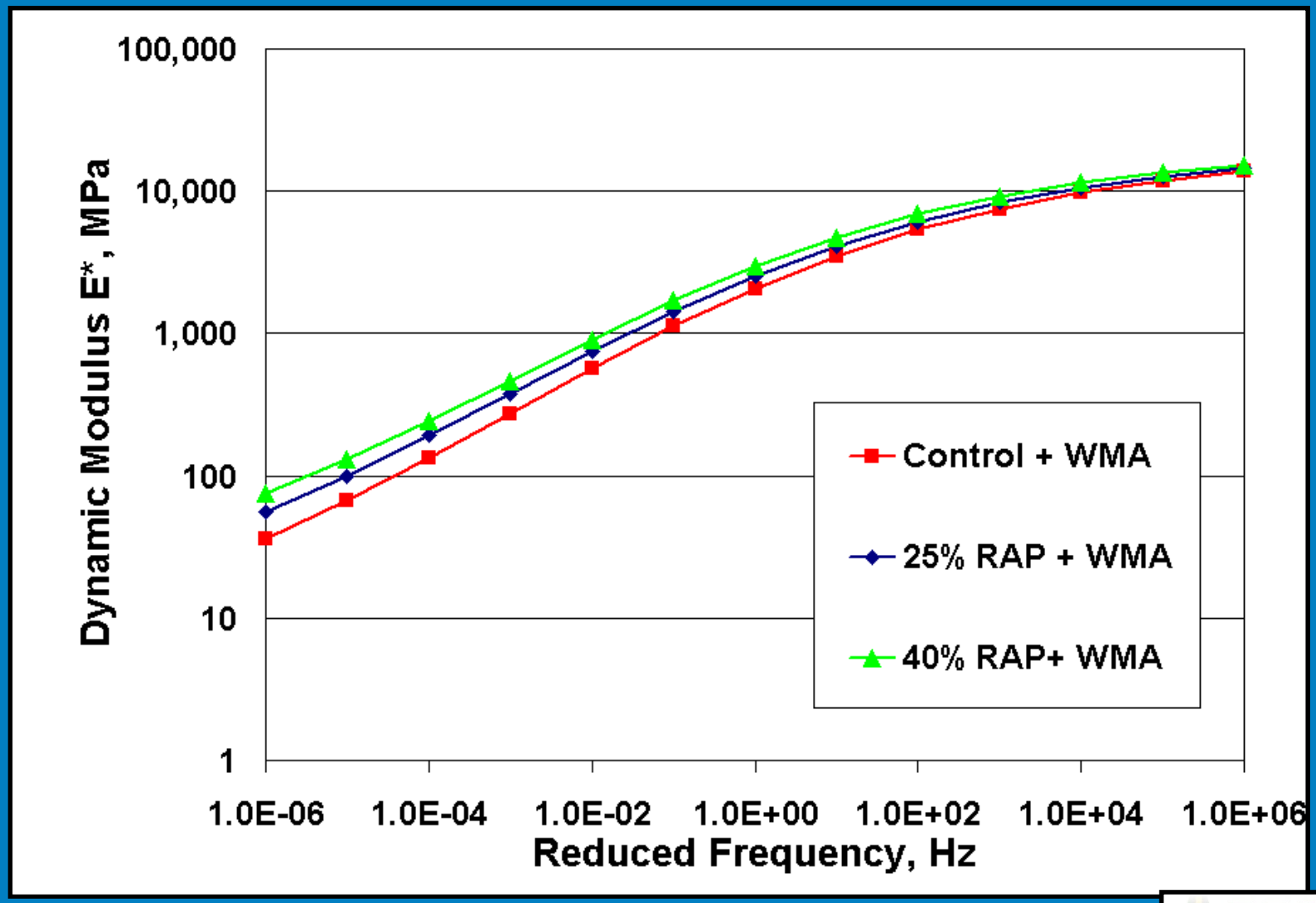
Temperature	Frequency
4°C	10 Hz, 1Hz, 0.1Hz
20°C	10 Hz, 1Hz, 0.1Hz
40°C	10 Hz, 1Hz, 0.1Hz, 0.01Hz

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

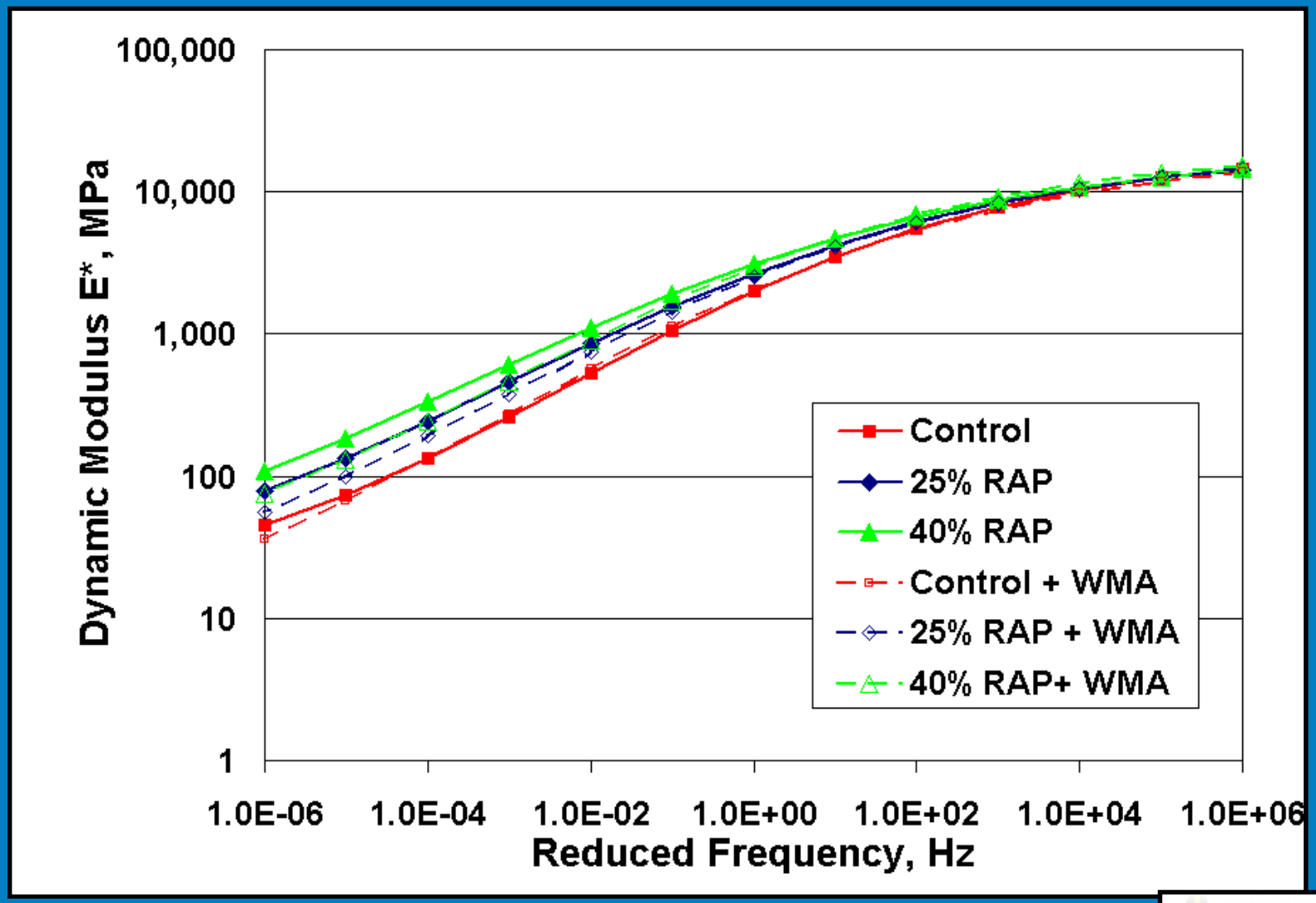
Master Curves – No WMA



Mixture Master Curves – with WMA



Mixture Master Curves - ALL



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

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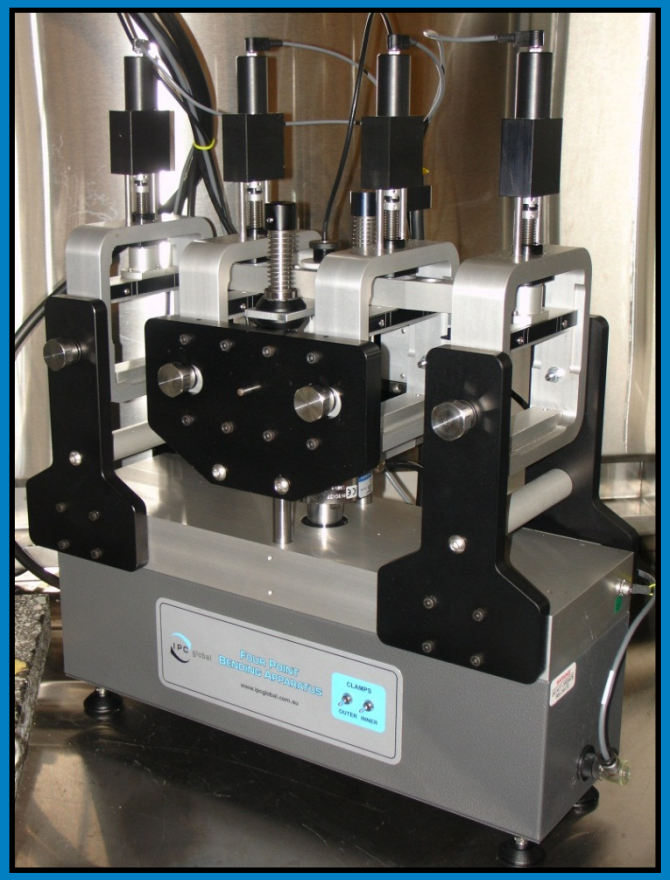

Testing in Accordance with AASHTO T321

- Specimens were 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 Levels
15°C (59°F)	300με, 500με, 700με & 900με

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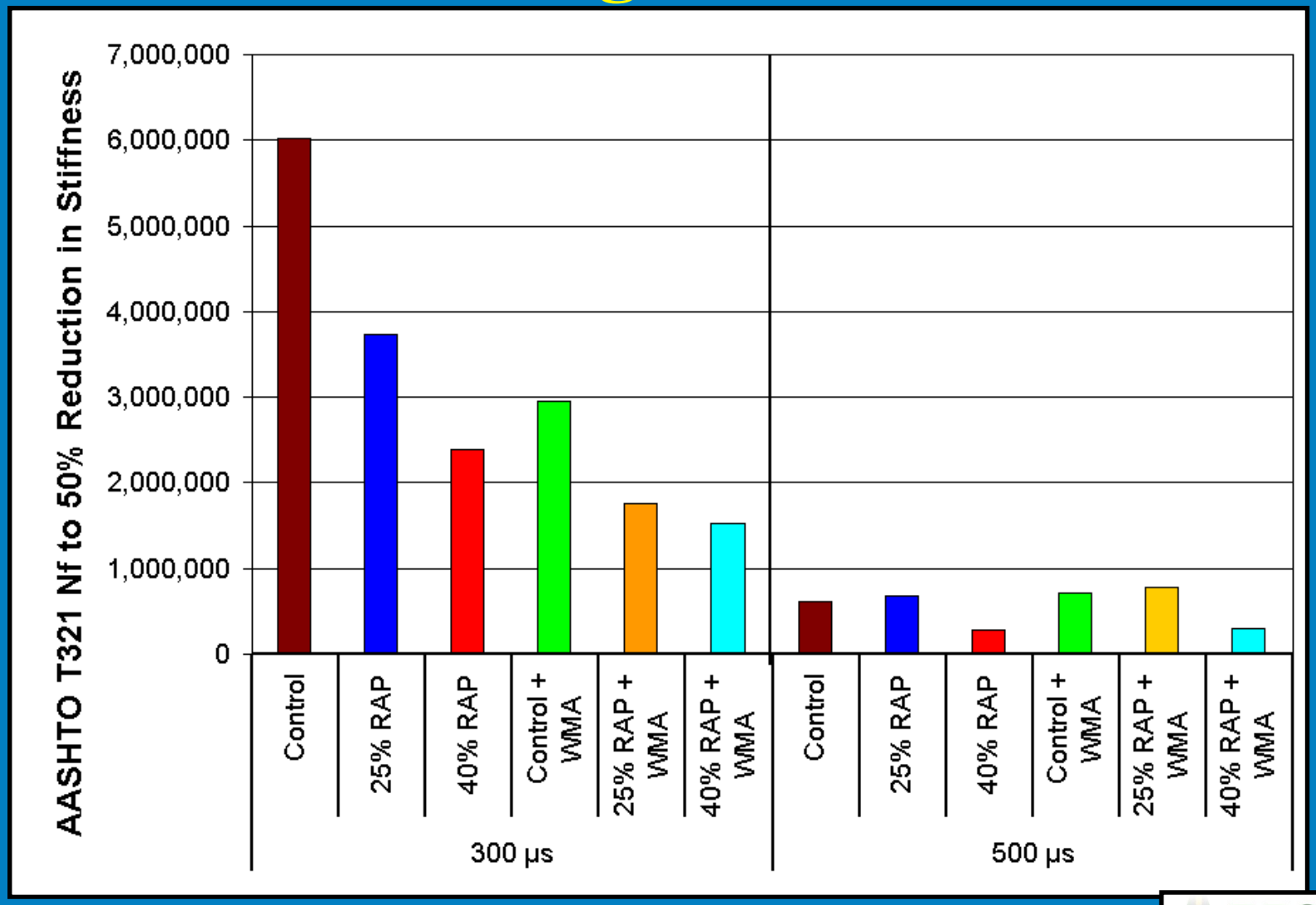
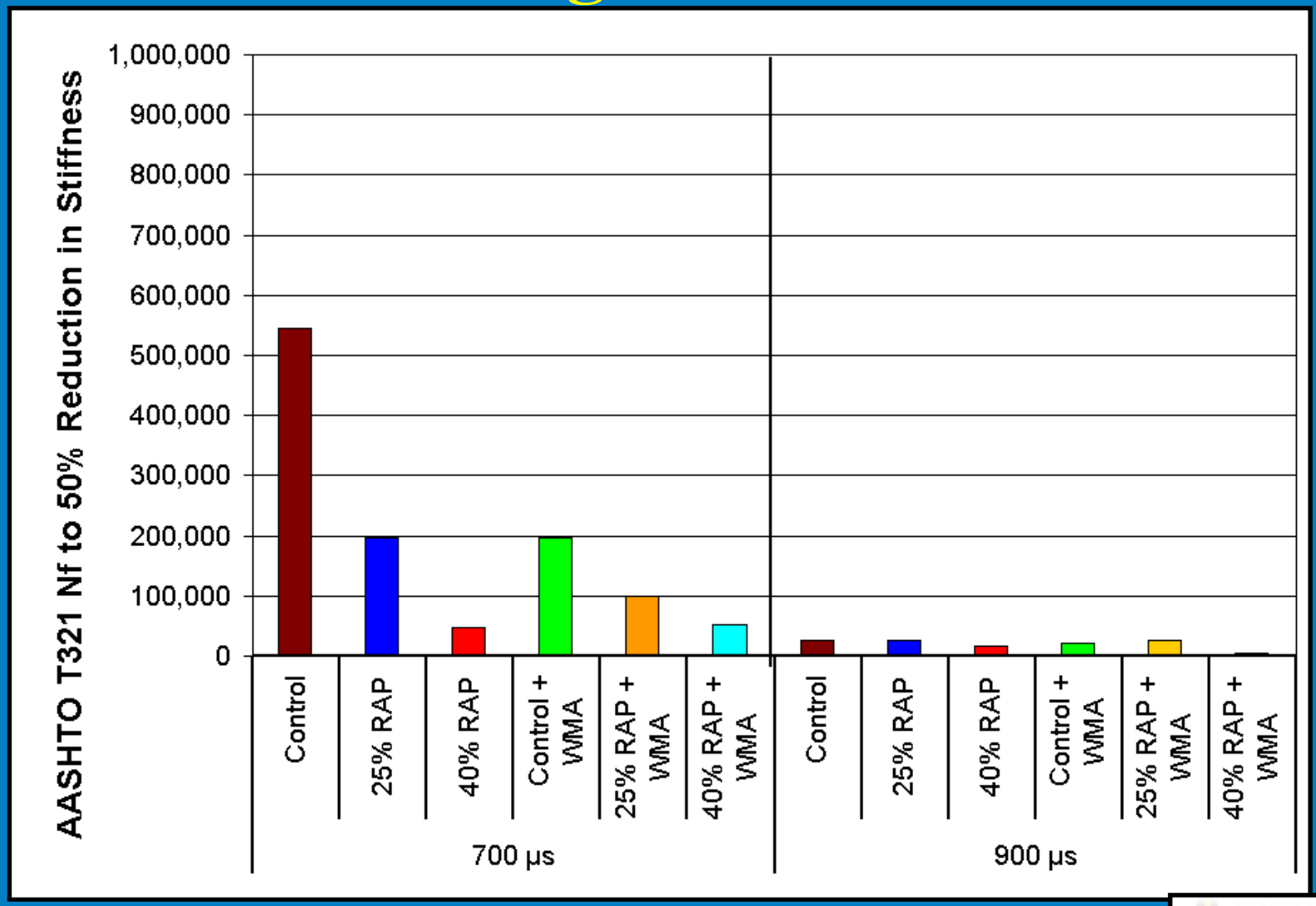
Fatigue – Four Point Bending Beam

	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



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

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

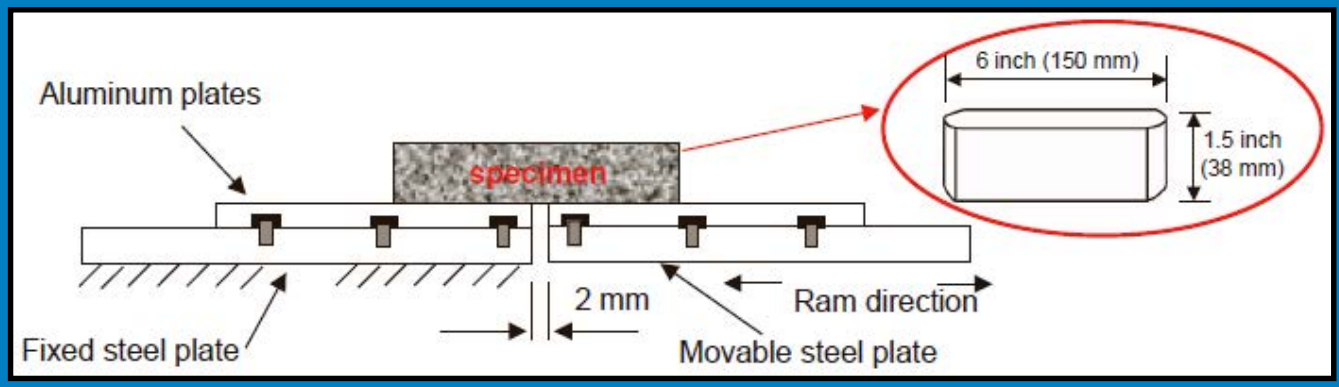


Diagram from: Zhou et al. "Overlay Tester: Simple Performance Test for Fatigue Cracking" Transportation Research Record: Journal of the Transportation Research Board, No. 2001, Transportation Research Board of the National Academies, Washington, D.C., 2007, pp. 1–8.

Reflective Cracking – Overlay Tester

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

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.

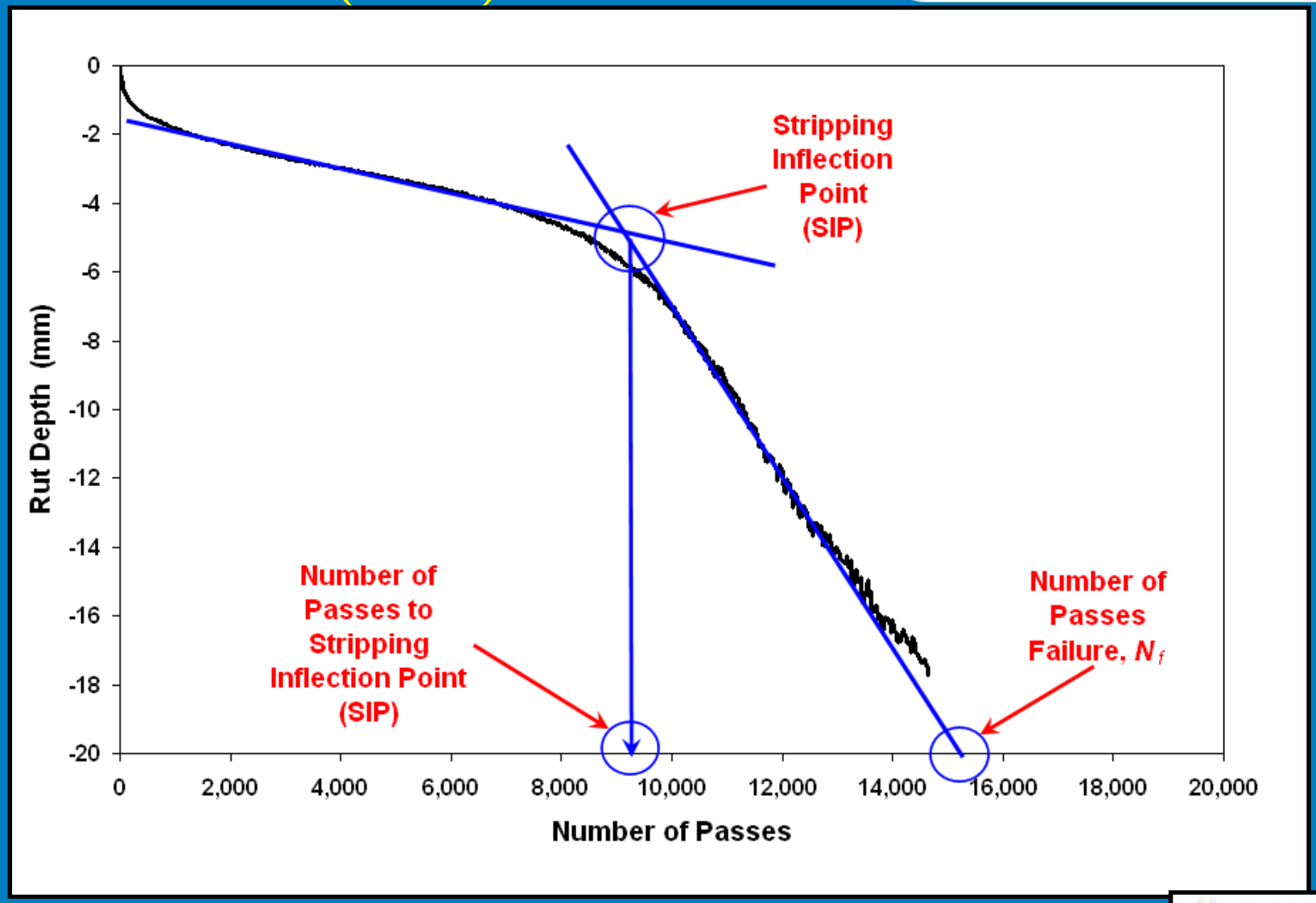
Moisture Susceptibility & Rutting - Hamburg Wheel Tracking Device (HWTD)

- HWTD testing conducted in accordance with AASHTO T324

- Water temperature of 50ºC (122ºF) during testing

- Test duration of 20,000 cycles

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

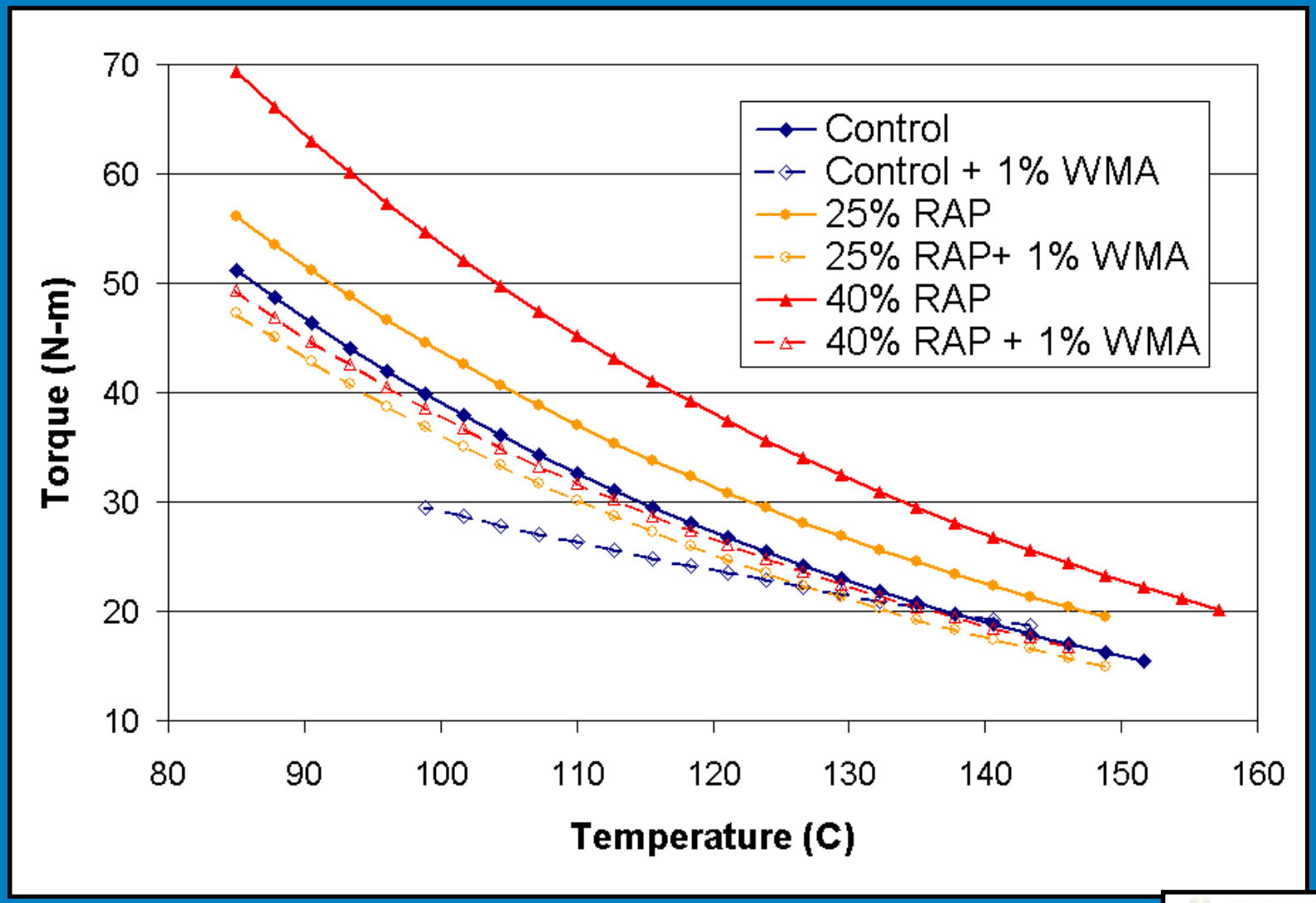
- Mixture workability evaluation was conducted to determine the impact of RAP, AR and/or WMA on mixture workability.
- Workability evaluation was conducted using prototype device designed and built by UMass Dartmouth known as the Asphalt Workability Device (AWD).
- The AWD operates on the torque measurement 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).
- 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.

Implementation of RAP & WMA in AR Mixes..

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

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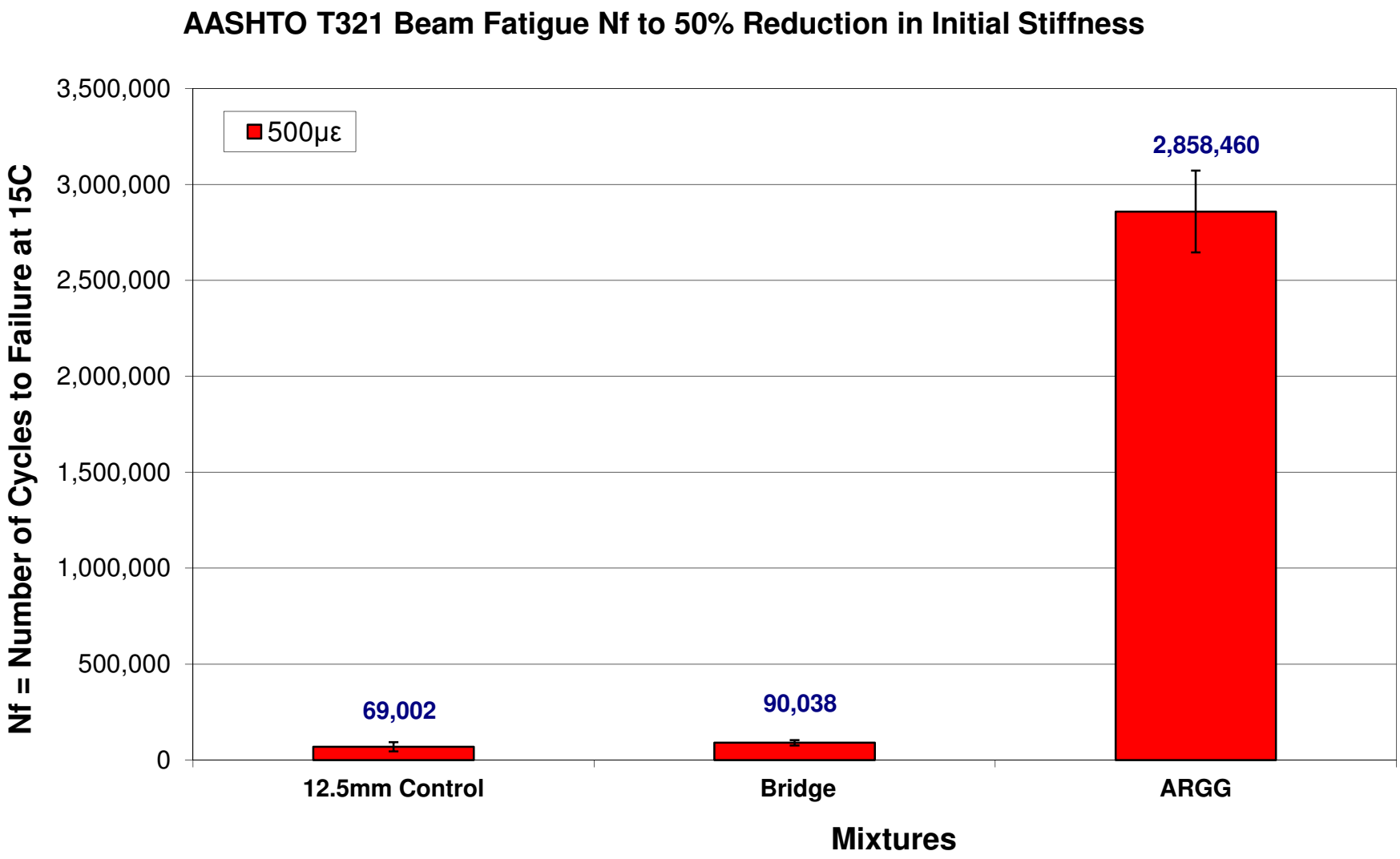
Hot Mix Asphalt- ARGG

Warm Mix Asphalt– ARGG

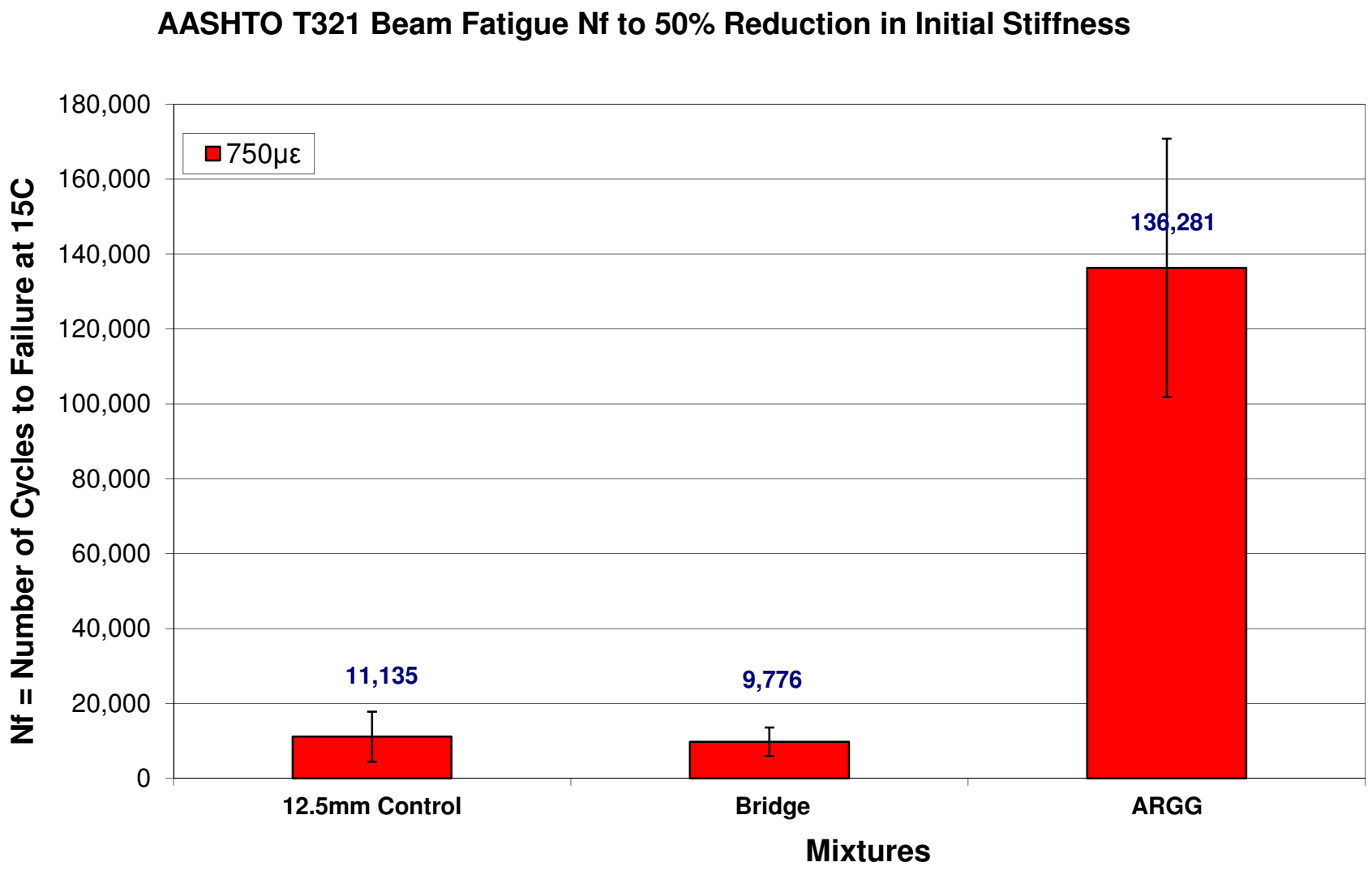
UMass Dartmouth HSRC Plant Produced Mixture Comparison

- DOT assigned a task to UMASS HSRC for comparison of plant produced ARGG mixture to 12.5mm Superpave.
- Use this testing for AASHTO ME Design Analysis.
- Testing included:
  - Beam Fatigue
  - Dynamic Modulus
  - Flow Number
  - Hamburg Wheel Tester
  - Overlay Tester
  - TSRST.

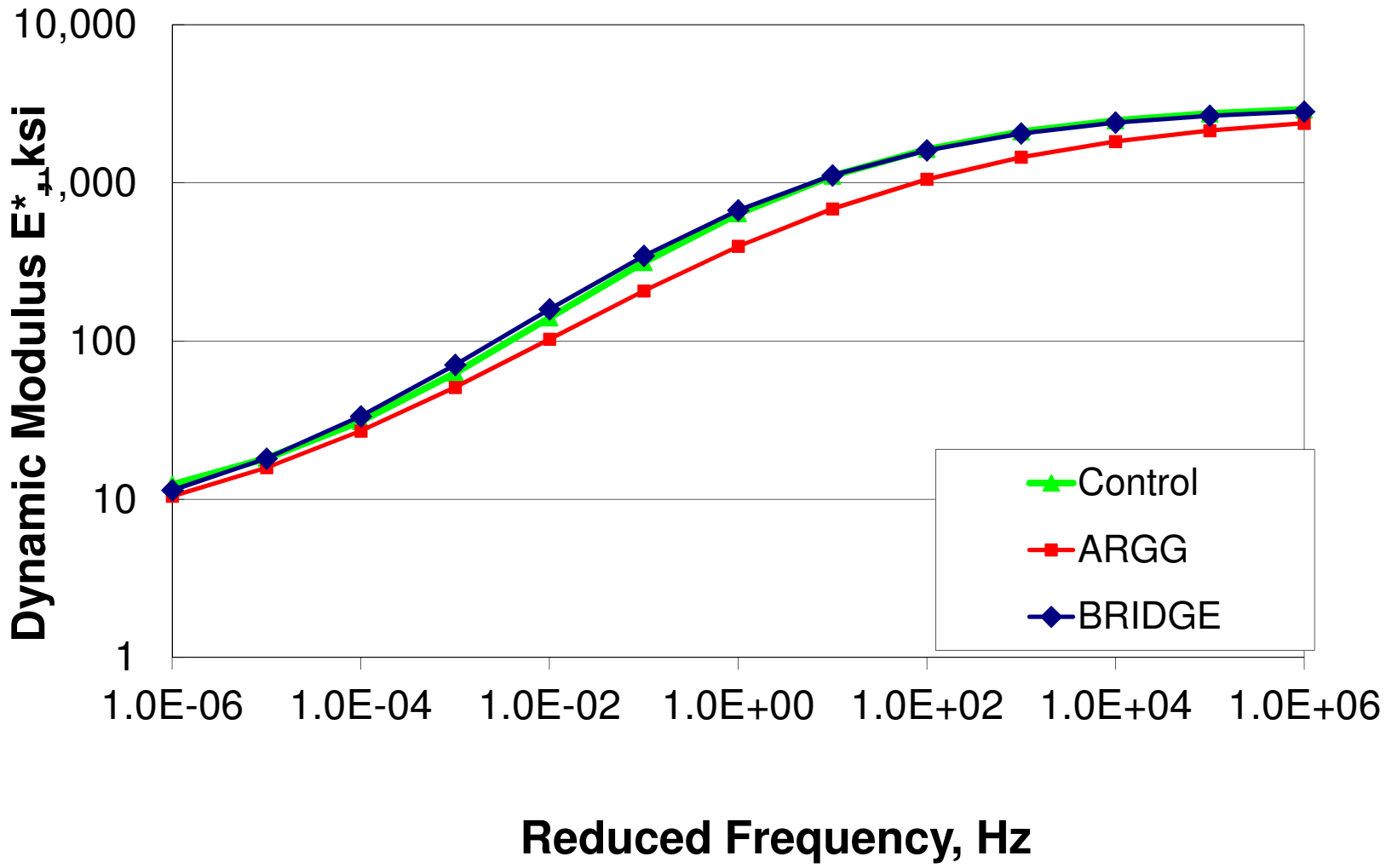
Plant Mix
Beam Fatigue (500 µstrain)



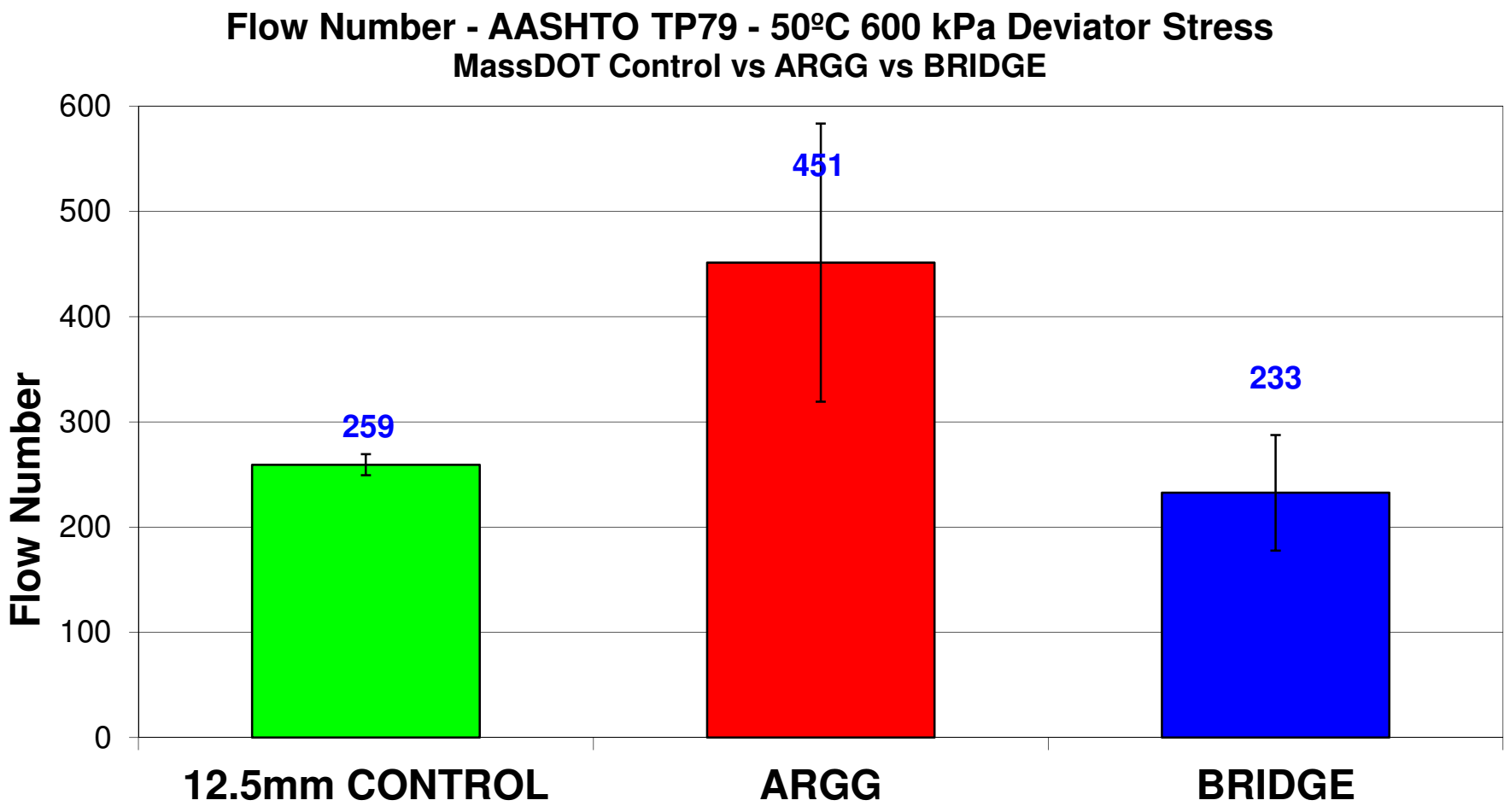
Plant Mix
Beam Fatigue (750 µstrain)



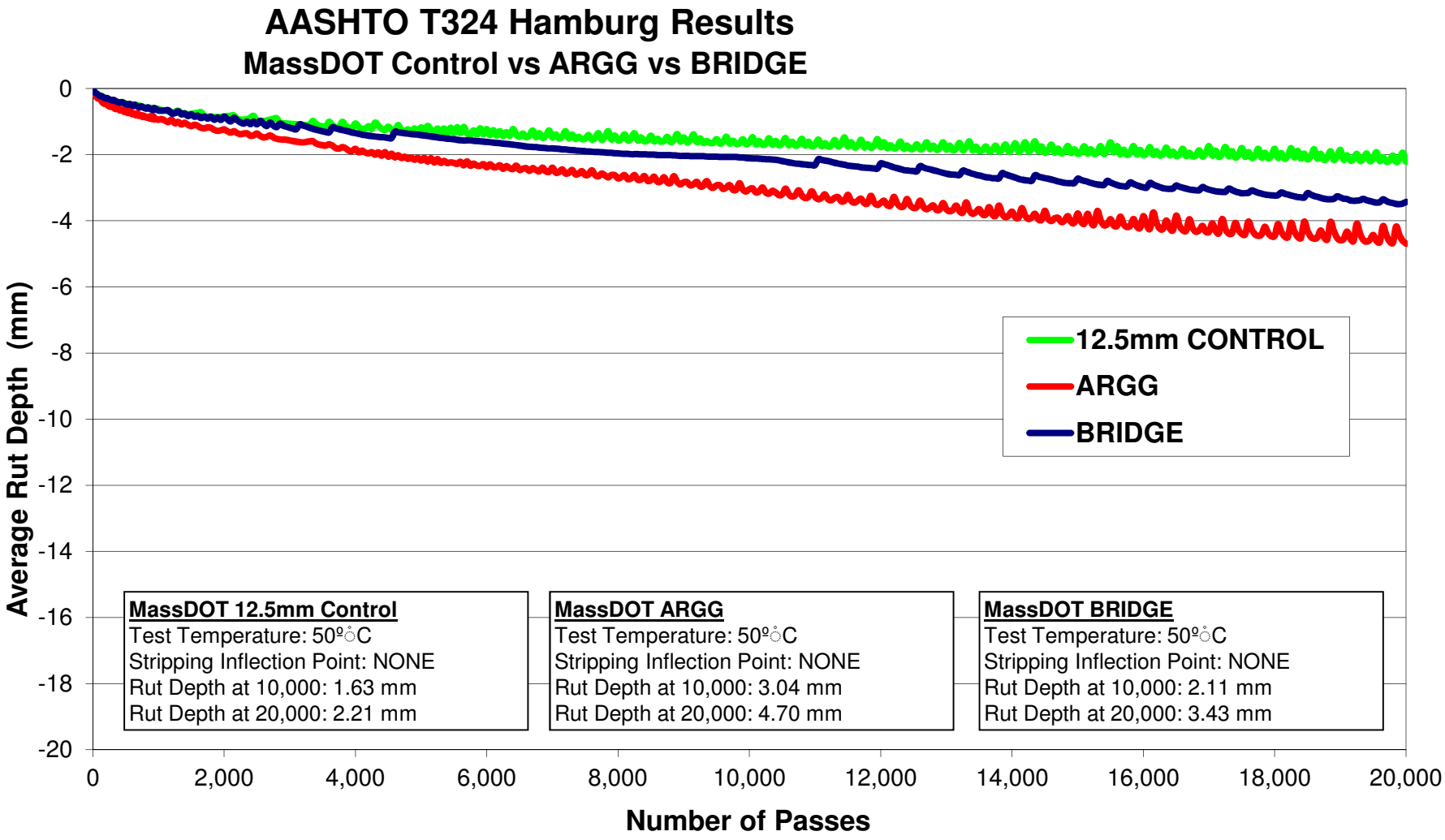
Plant Mix
Dynamic Modulus



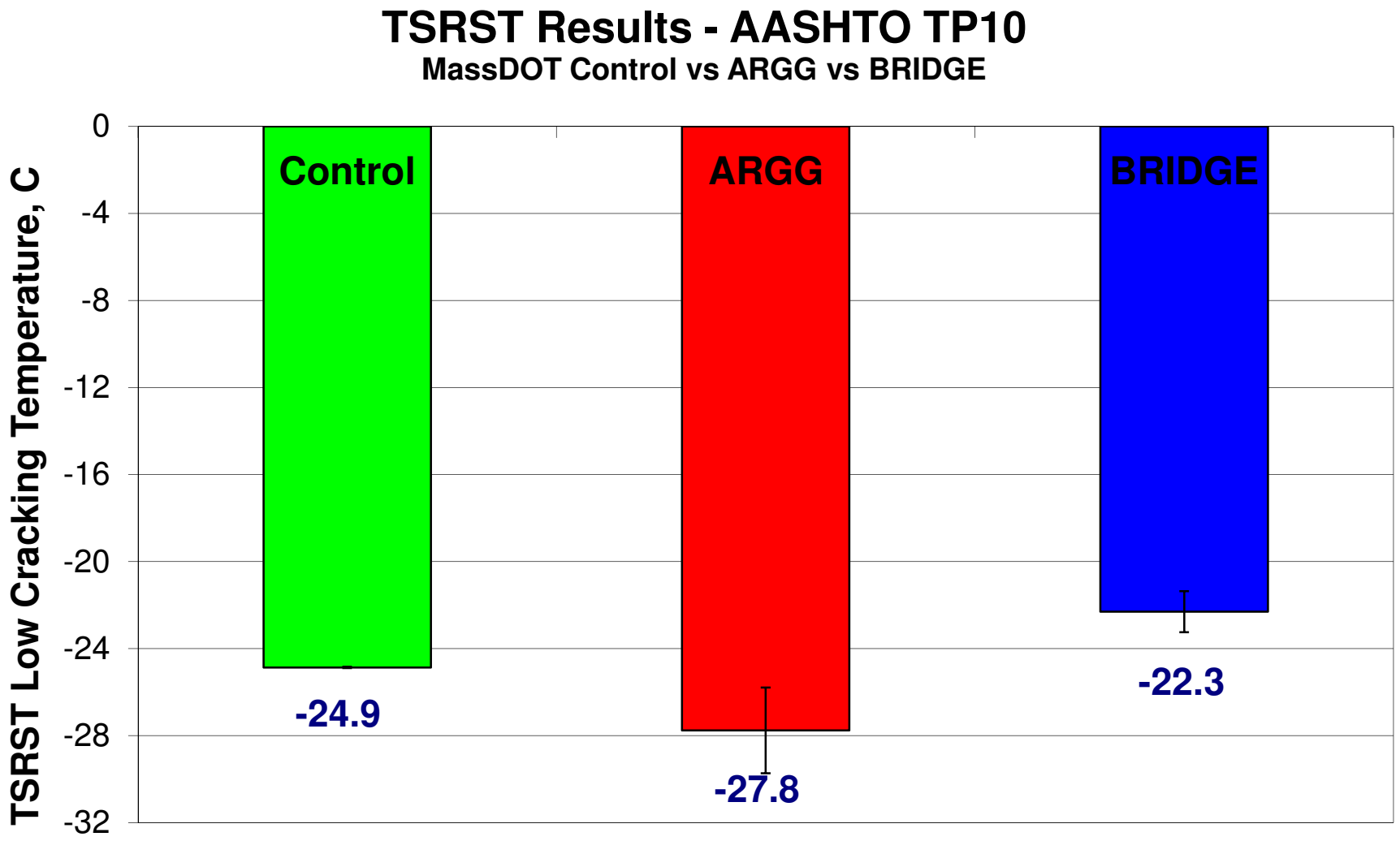
Plant Mix Flow Number



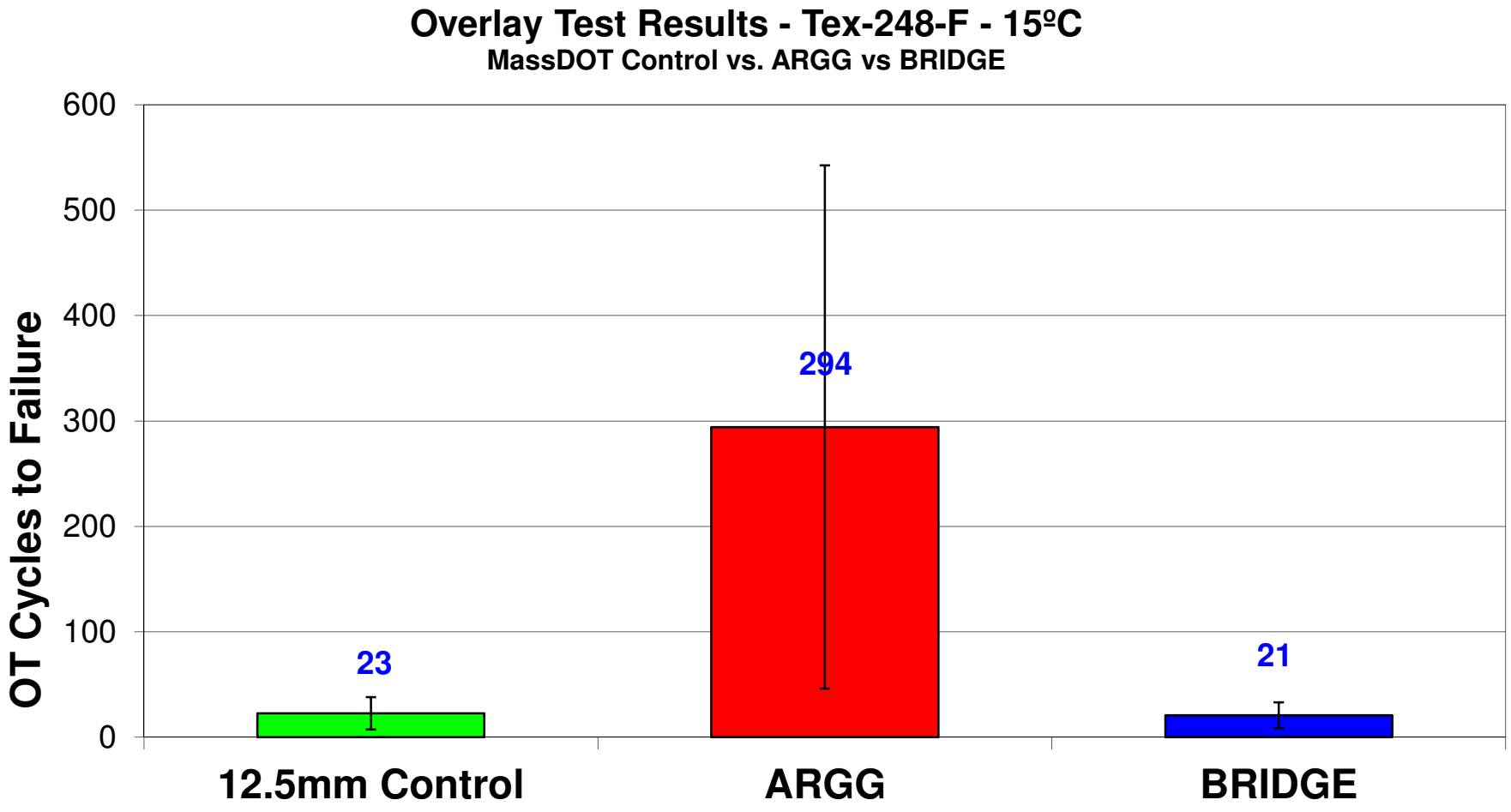
Plant Mix Hamburg Wheel Testing



Plant Mix
TSRST Results



Plant Mix
Overlay Test Results



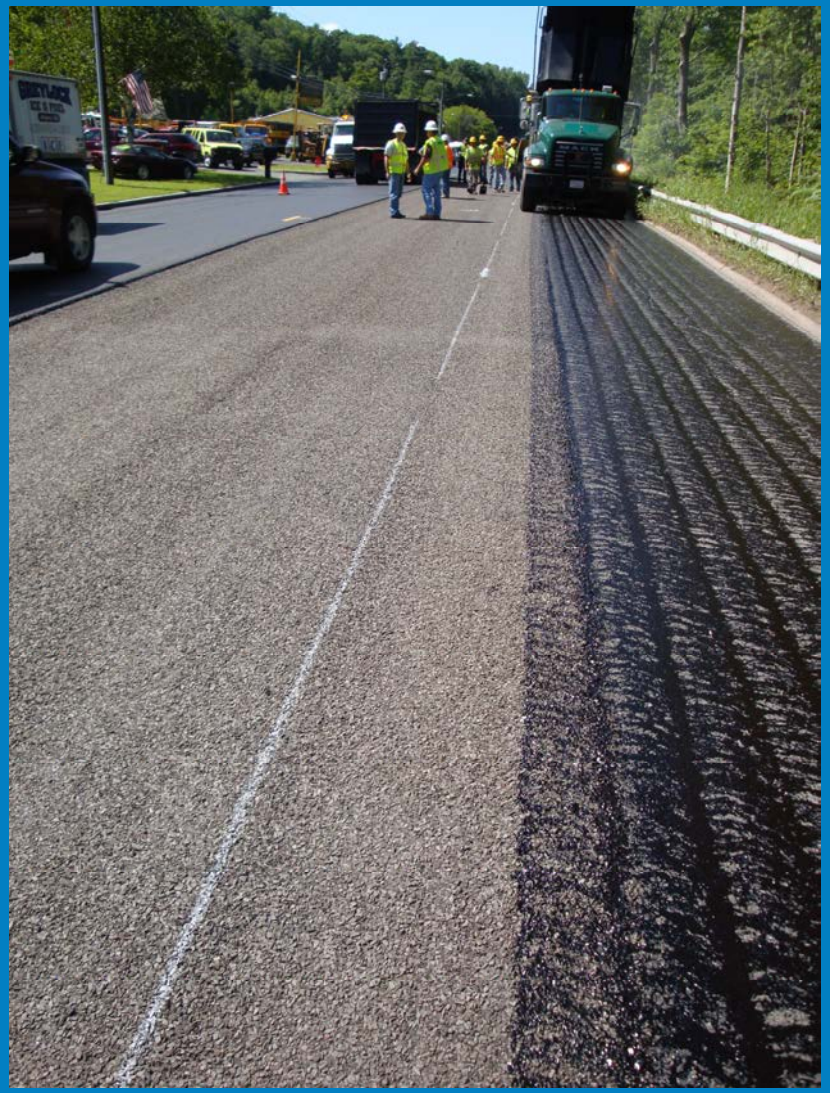
UMass Dartmouth HSRC Plant Produced Mixture Comparison

- Currently evaluating how overlay thicknesses can be impacted by using ARGG.
- Specified ARGG as an overlay on Composite (HMA over Jointed PCC Roadways.
- Specified ARGG on I-90 Weston in toll-plaza area.
- Two OGFC-AR Projects that we will be looking at.
- Full-Depth Porous Pavement containing AR and shingles for highway median.
- We'll be running these specifications and mixtures through HSRC for verification and other testing.

Route 8 Cheshire Lanesboro Ongoing Monitoring

- 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

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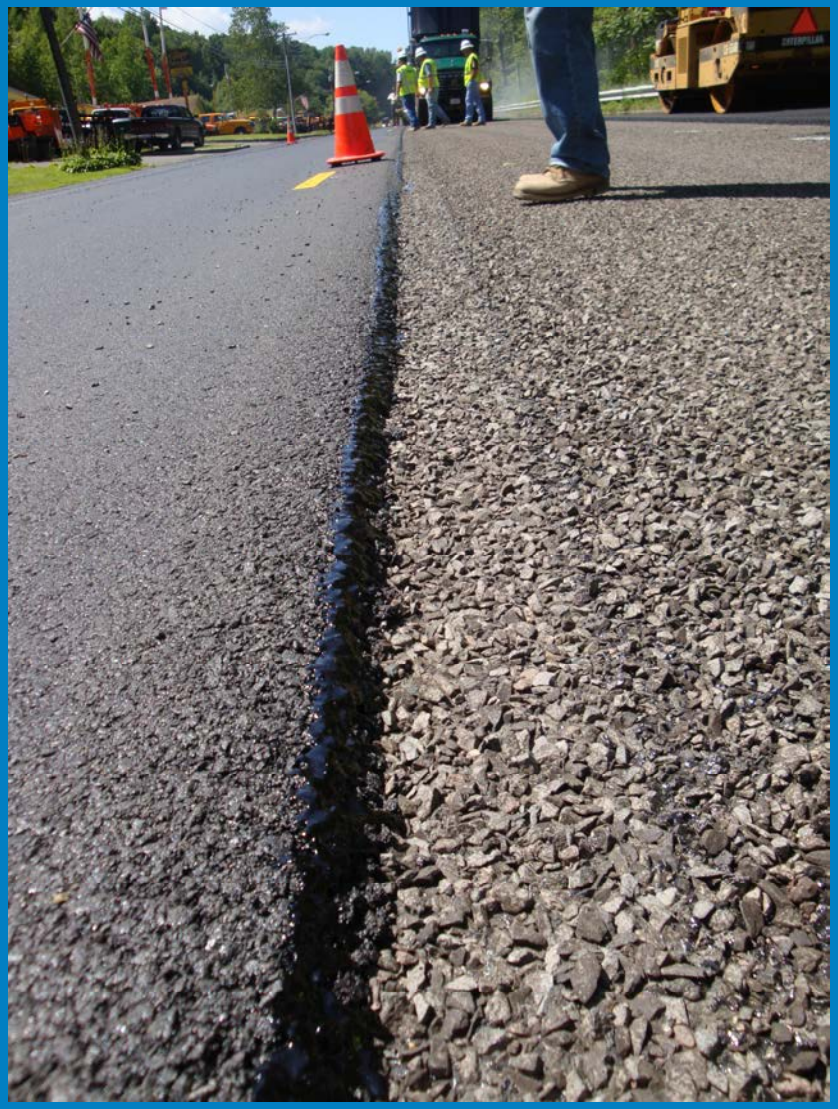
Massachusetts Department of Transportation
Highway Division



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

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Highway Division

Cheshire Lanesboro – Two Years Later
No SAMI - Core

Cheshire Lanesboro
HMA over SAMI

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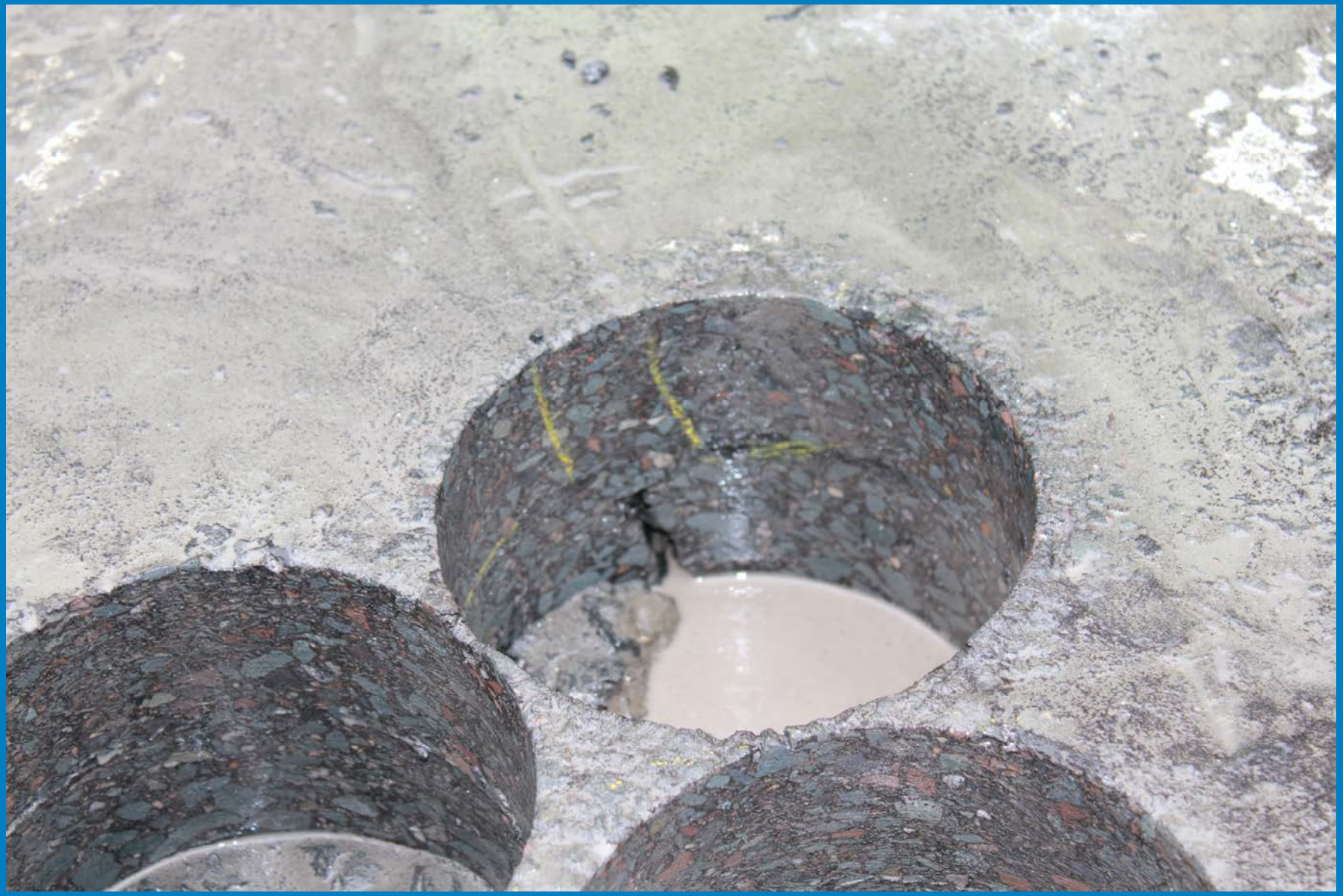

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Highway Division

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.

- Route 8 Cheshire Lanesboro
- Bonded Thin Overlay on Asphalt Rubber SAMI
- Light Reflective Cracking visible
- SAMI and core appear intact.

Cheshire Lanesboro
Bonded Thin Overlay on Rubber Chip SAMI

Kernwood Drawbridge
Salem, MA

Kernwood Drawbridge
Salem, MA

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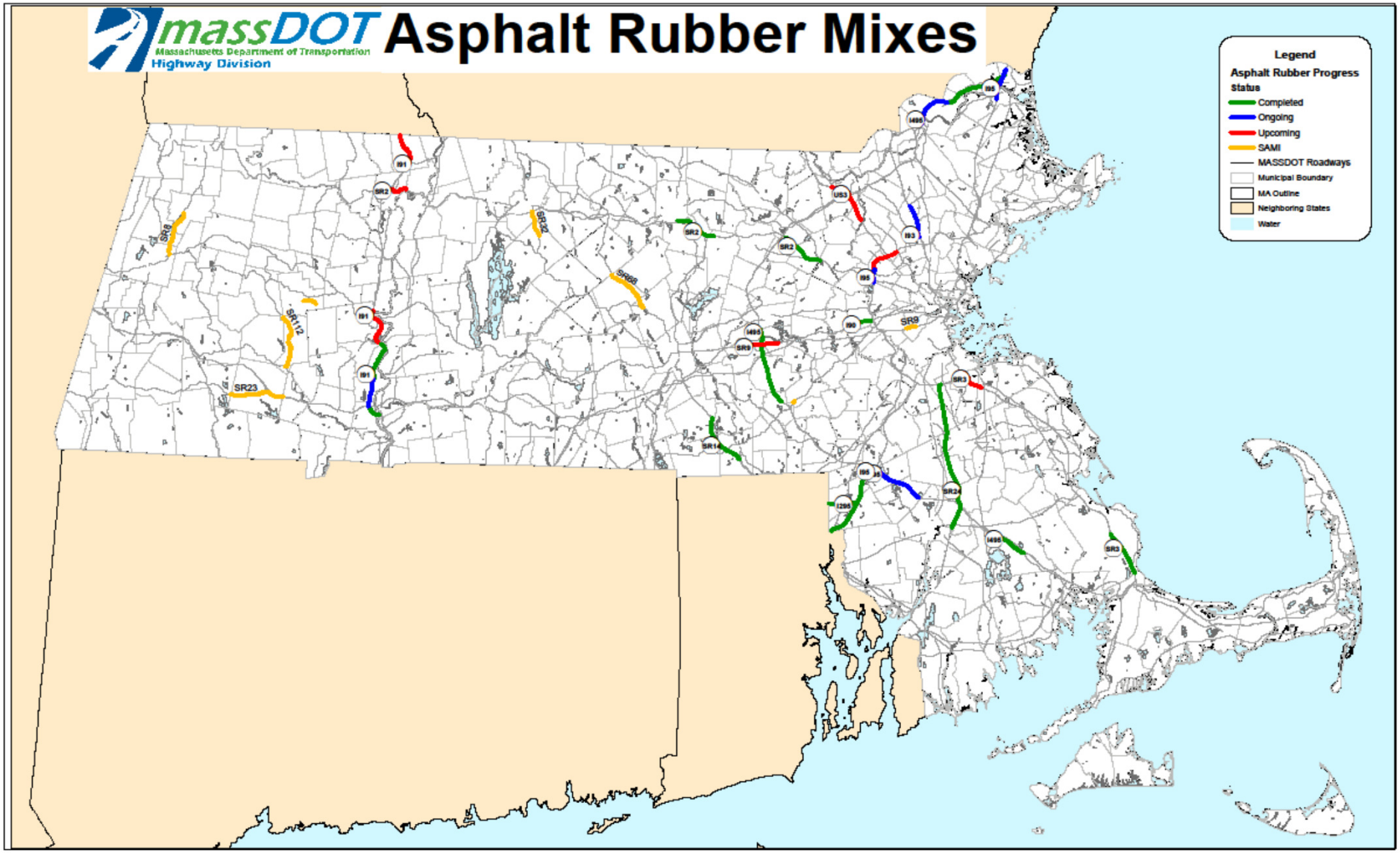
Massachusetts Department of Transportation
Highway Division

Asphalt Rubber Locations



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