HSRC
Highway Sustainability Research Center

Innovative Research in Asphalt Pavements

# Effect of Binder Modification on the Performance of an Ultrathin Overlay Pavement Preservation Strategy

NEAUPG

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# Research Team

| Name | Institute |
| --- | --- |
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# Overall Study Focus

**Polymer Modified Asphalt (PMA)**

**OR**

**WITH &**

**WITHOUT**

**Warm Mix Asphalt Technology -Wax Based**

**=**

***Ultrathin Overlay (UTOL) Pavement Preservation Strategy***

**Asphalt-Rubber (AR) Binder**

# Background

- A common goal of FHWA "Every Day Counts" initiative is to improve the environmental sustainability of roads.
- RIDOT acting on the initiative's goal by incorporating sustainable and environmentally friendly technologies, GTR and WMA, into engineered asphalt mixtures used for pavement preservation strategies including high performance ultra-thin lift overlays (UTOL).
- UTOL have a thickness of one inch or less and are used in applications requiring higher levels of rutting and fatigue cracking resistance.

# Background

- Agencies in Arizona, Maryland, Michigan, New Jersey, New York, and Ohio have developed specifications for high performance thin overlays used in pavement preservation.

- These specifications normally require the use of Polymer Modified Asphalt (PMA) binder.

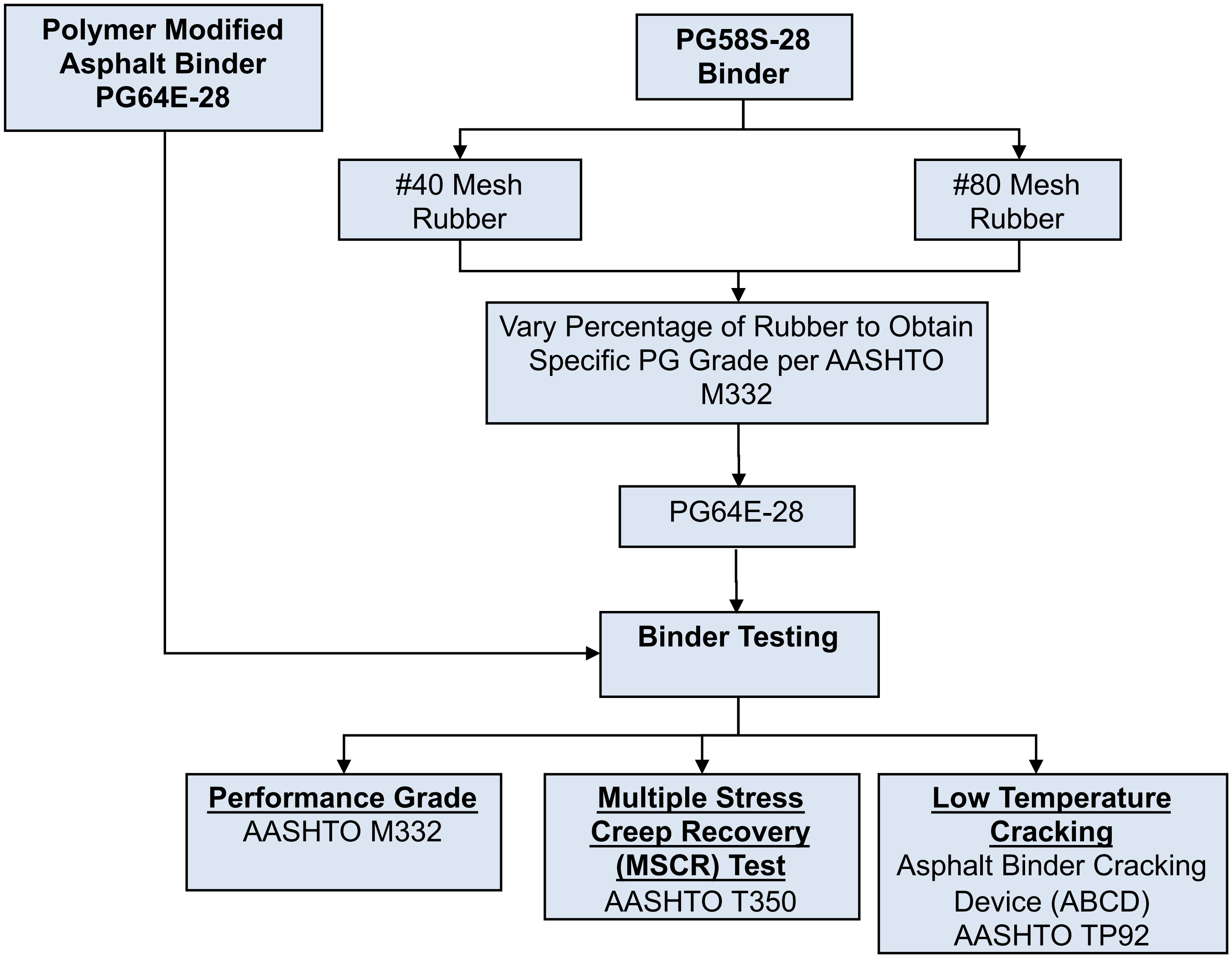
# AR Binders

- A PG58-28 base binder from a local supplier in Massachusetts was used for development of the AR binder.
- The GTR utilized was obtained in mesh sizes of #40 and #80 mesh and used to fabricate the AR binders through a wet process.
- GTR dosage was varied for each mesh size in order to obtain a resultant AR binder with properties comparable to the PMA binder.

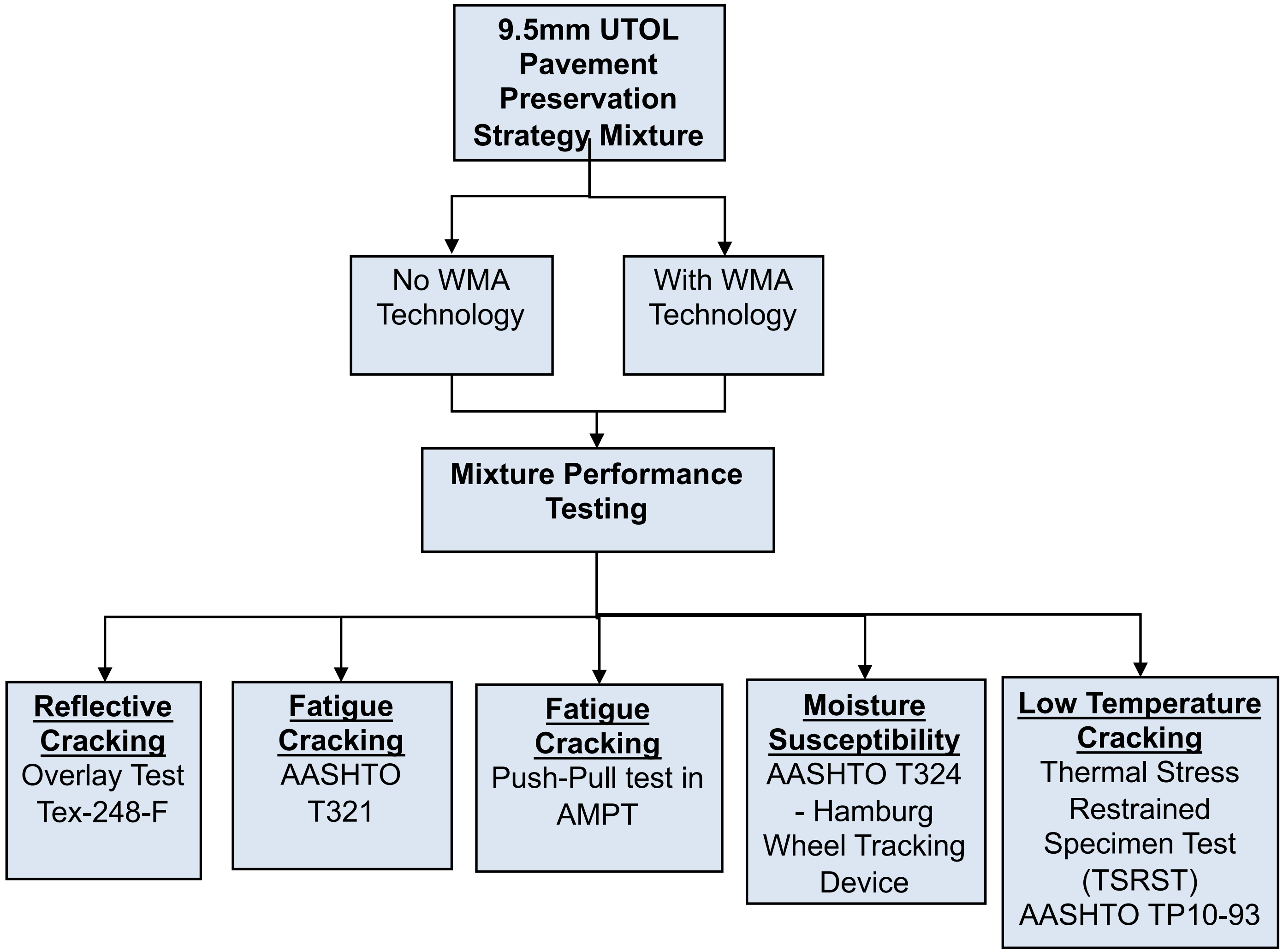
# Objectives

- Determine if AR binders used in conjunction with and without WMA will provide similar or better performance as compared to a PMA binder used with and without WMA in a high performance UTOL mixture.

# Experimental Plan - Binder



# Experimental Plan - Mixture



# PMA Binder

- The PMA binder selected for the study was a PG64E-28 which has been previously utilized by RIDOT for their Paver Placed Elastomeric Surface Treatment (PPEST) preservation mixture.
- The PG64E-28 designation confirms the polymer modification of the binder and the "E" designation indicates the binder is suitable for an extremely heavy expected traffic level and loading rate.

# WMA Technology

- The Warm Mix Asphalt technology utilized for this study was chosen from the Northeast Asphalt User Producer Group (NEAUG) approved list.
- An organic based WMA technology known as SonneWarmix was used at a dosage rate of 0.75% by weight of binder.
- The mixing and compaction temperature for mixtures using the WMA was reduced approximately 30°F for mixing and 23°F for compaction as compared to the HMA mixtures.

# AR Binder Development

- The PMA binder was graded to be a PG64E-28.
- By trial and error, AR binders were prepared using each mesh size at varying GTR contents until the grade of the resultant AR binder matched the PMA binder grade of a PG64E-28.
- For each mesh size, 15% GTR was required to attain the PG64E-28 grade.

# Binder Grading Results

| | PG58-28 Virgin Binder | PMA Binder | AR – 15% #40 Mesh | AR – 15% #80 Mesh |
|---|---|---|---|---|
| **Rolling Thin-Film Oven Residue (T240)** | | | | |
| Multiple Stress Creep Recovery (MSCR) Test Temperature, °C | 58 | 64 | 64 | 64 |
| $J_{nr\ 3.2}$ | 2.602 | 0.1586 | 0.4301 | 0.4907 |
| Loading Designation | S | E | E | E |
| **Final AASHTO M332 Grade** | **58S-28** | **64E-28** | **64E-28** | **64E-28** |

# Binder Low Temperature Cracking Performance

- The Asphalt Binder Cracking Device (ABCD) was used to determine the low temperature cracking resistance of the PMA and AR binders with and without WMA in accordance with AASHTO TP92-14.

# Binder Low Temperature Cracking Performance Results

| Binder | Average ABCD Cracking Temperature, °C |
|---|---|
| PMA Binder | -37.8 |
| AR Binder 15% #40 Mesh | -37.8 |
| AR Binder 15% #80 Mesh | -44.9 |
| | |
| PMA Binder + WMA | -36.0 |
| AR Binder 15% #40 Mesh + WMA | -40.9 |
| AR Binder 15% #80 Mesh + WMA | -44.9 |

# Mixture Design

- The mixtures were developed using the RIDOT Paver Placed Elastomeric Surface Treatment (PPEST) specification

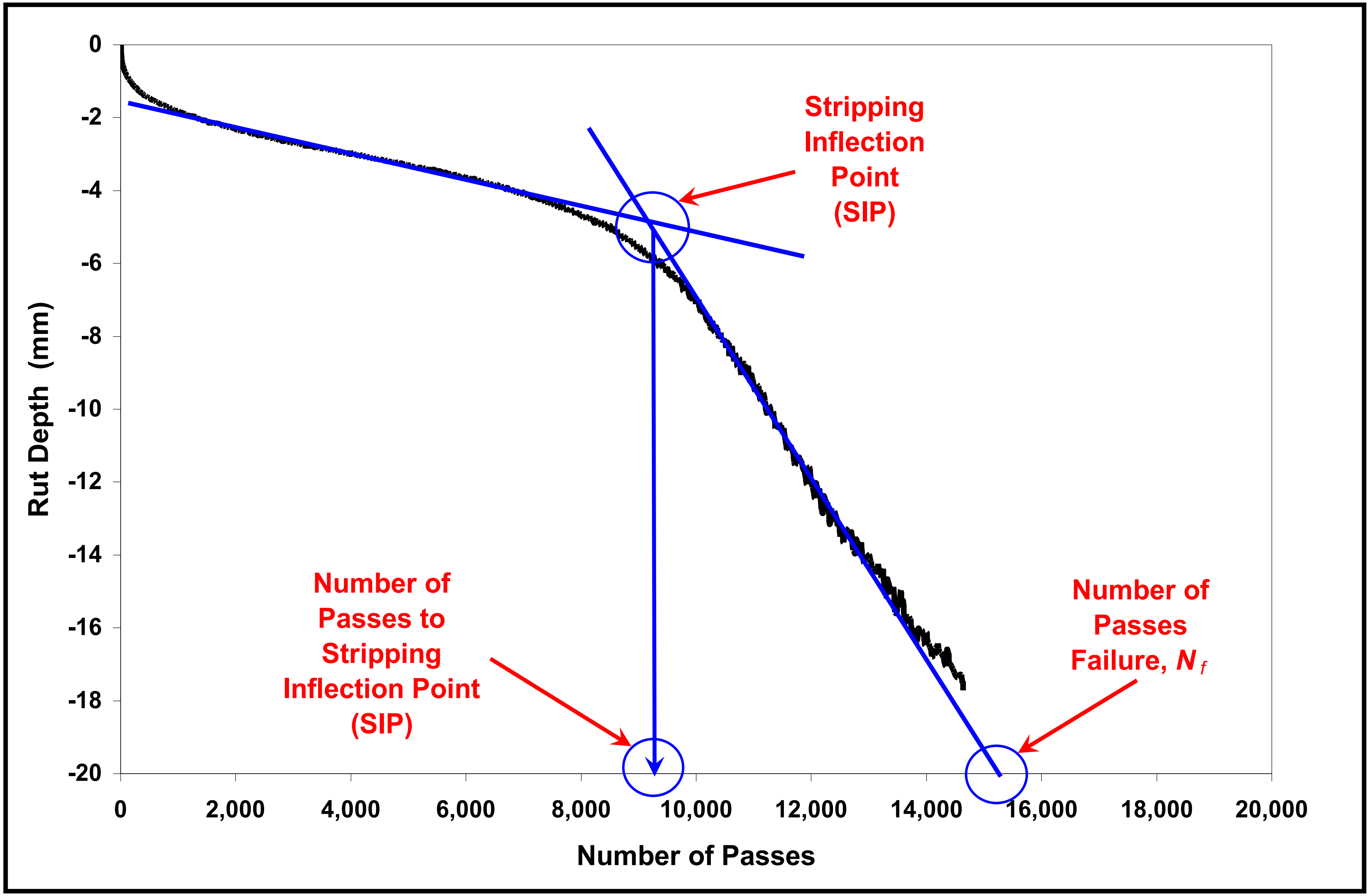
| Sieve Size | 9.5 mm Mixture Gradation | 9.5 mm PPEST Gap-Graded Specification |
|---|---|---|
| 12.5 mm | 100 | 100 |
| 9.5 mm | 93.0 | 91-95 |
| 4.75 mm (No. 4) | 42.5 | 40-45 |
| 2.36 mm (No. 8) | 24.0 | 22-26 |
| 1.18 mm (No. 16) | 16.0 | - |
| 0.600 mm (No. 30) | 10.5 | 9-12 |
| 0.300 mm (No. 50) | 7.0 | 6-8 |
| 0.150 mm (No. 100) | 5.0 | - |
| 0.075 mm (No. 200) | 4.0 | 4.0 |
| Binder Content, % | 6.75% | 6.0% Min. |

# Rutting/Moisture Susceptibility -
## Hamburg Wheel Tracking Device (HWTD)

- HWTD testing conducted in accordance with AASHTO T324

- Water temperature of 50ºC (122ºF)
- Test duration of 20,000 cycles

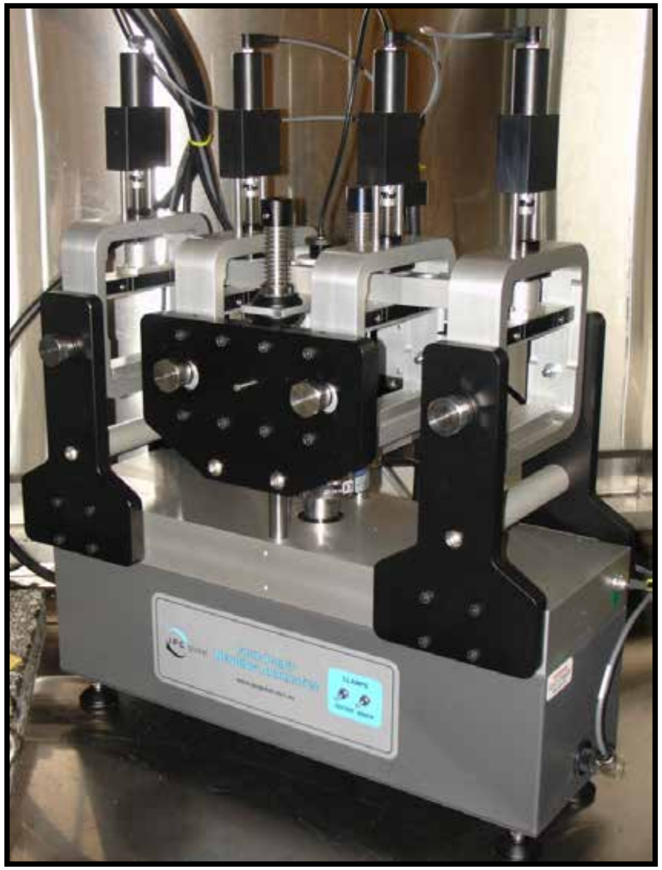
# Stripping Inflection Point (SIP)



# HWTD Results

| | PMA | | AR #80 Mesh | | AR #40 Mesh | |
|---|---|---|---|---|---|---|
| **HMA or WMA** | **HMA** | **WMA** | **HMA** | **WMA** | **HMA** | **WMA** |
| Stripping Inflection Point | NONE | NONE | NONE | NONE | NONE | NONE |
| Rut Depth at 10,000 Passes (mm) | 0.75 | 3.63 | 2.18 | 3.88 | 1.86 | 2.39 |
| Rut Depth at 20,000 Passes (mm) | 0.97 | 4.28 | 2.66 | 5.22 | 2.36 | 3.97 |

# Fatigue – Four Point Flexural Beam

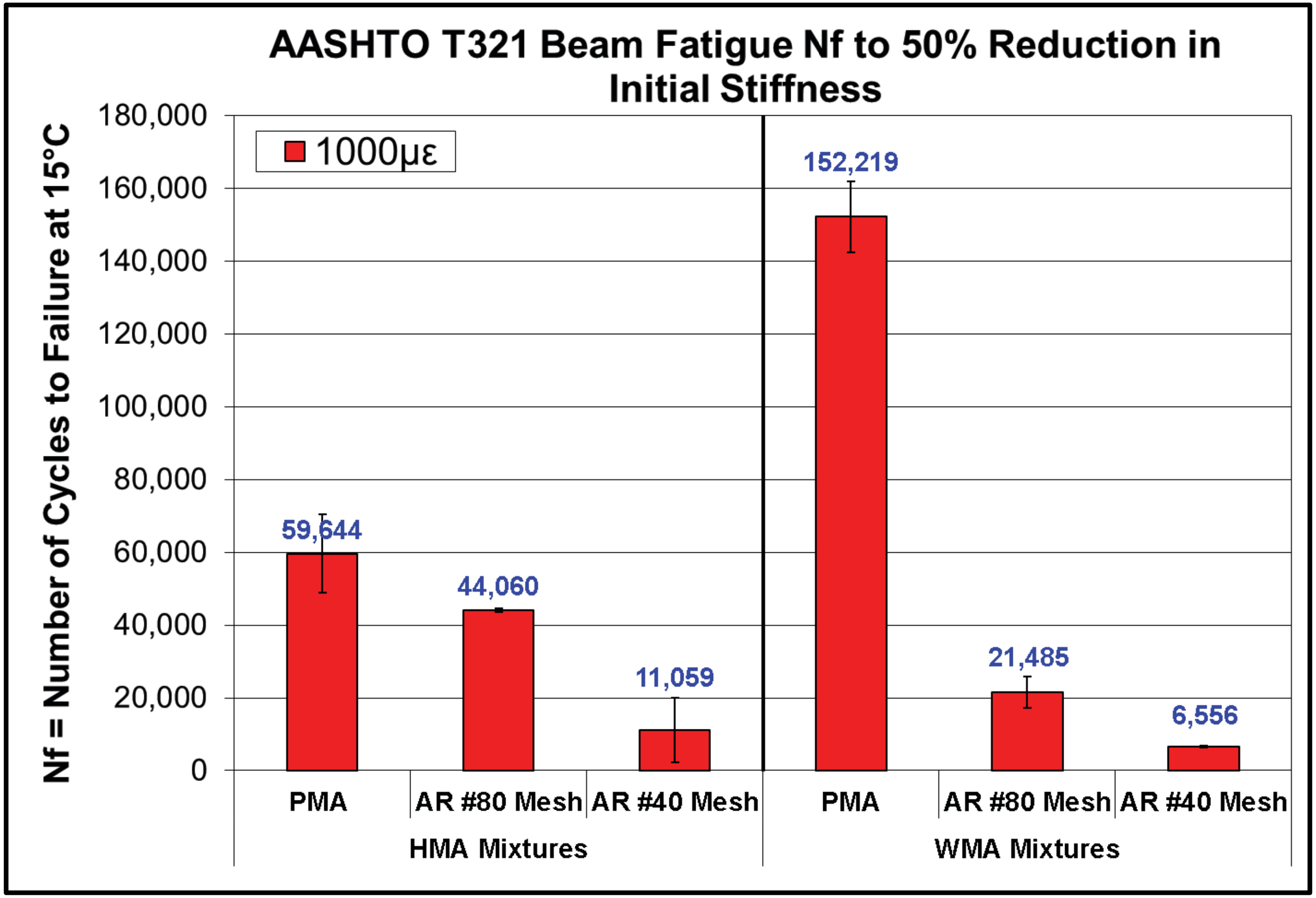


Testing in Accordance with AASHTO T321

- 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) | 1,000$\mu\varepsilon$ |

# Beam Fatigue Test Results



# Cyclic Tension Fatigue Test in the AMPT

Uniaxial Cyclic Tension Fatigue (Pull-Pull)

| Temperature | Strain Levels (με) |
|---|---|
| 15°C | 250, 500 & 750 |

Dynamic modulus test → LVE

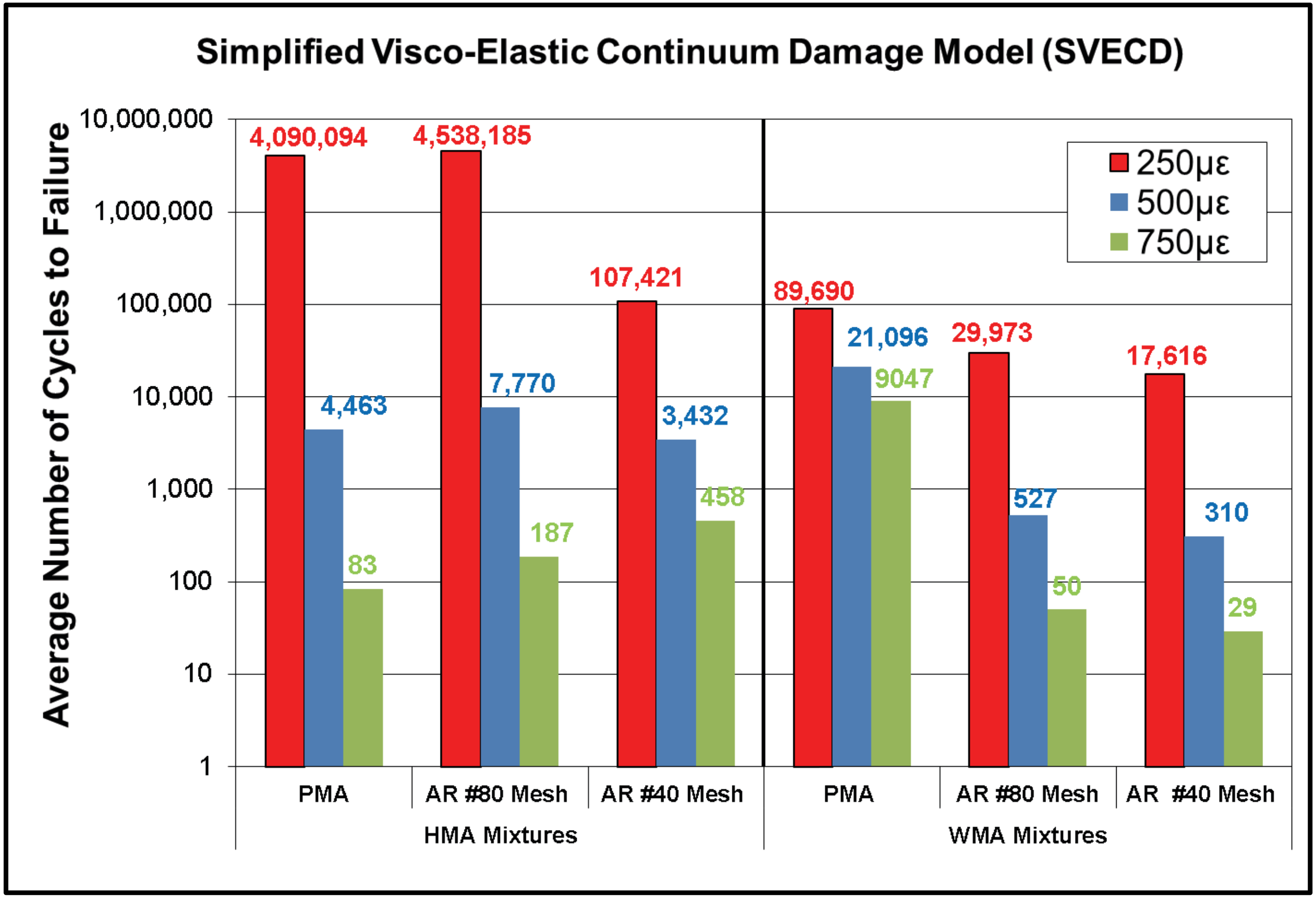
Constant cyclic displacement test → Number of cycles to failure ($N_f$) based on reduction in phase angle

Analyzed for damage characteristic curve (S-VECD Model)

Simulated fatigue lives using pseudo energy failure criterion

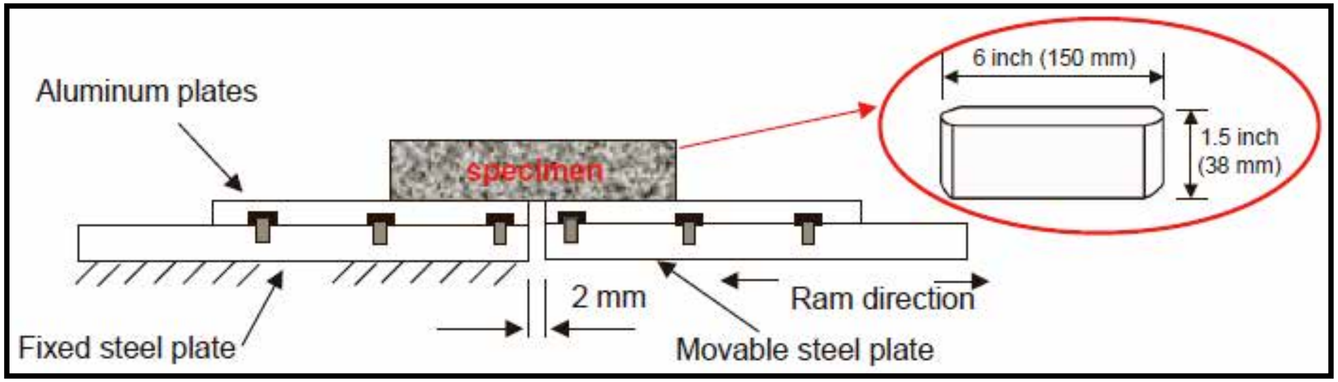
Input to pavement fatigue analysis (not performed in this study)

# SVECD Results

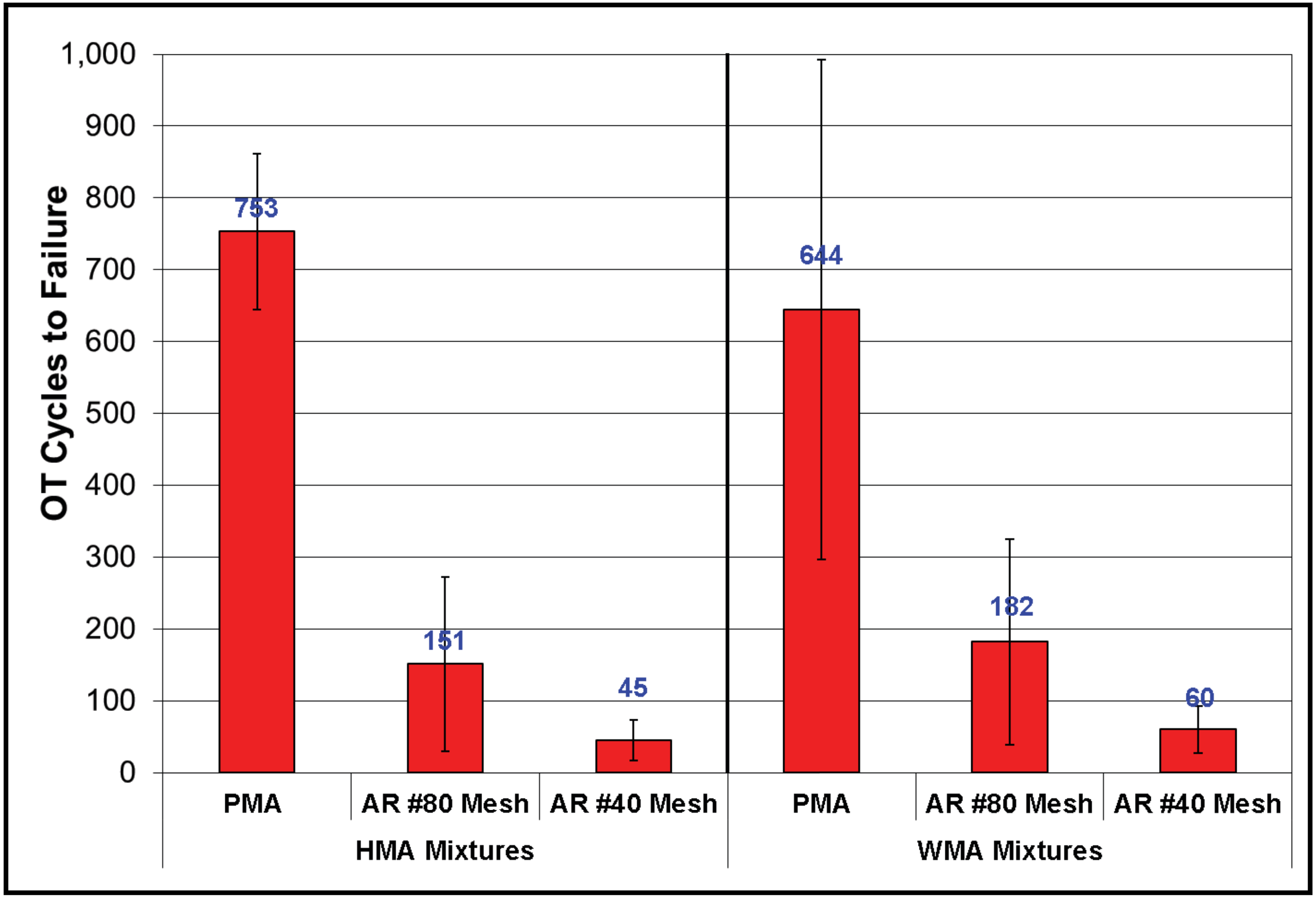


# Reflective Cracking - Overlay Tester

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

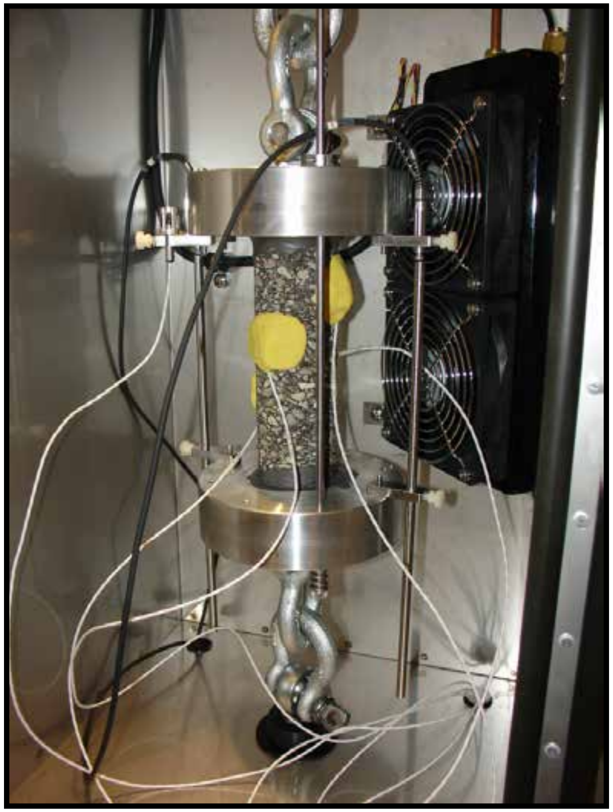


# OT Results

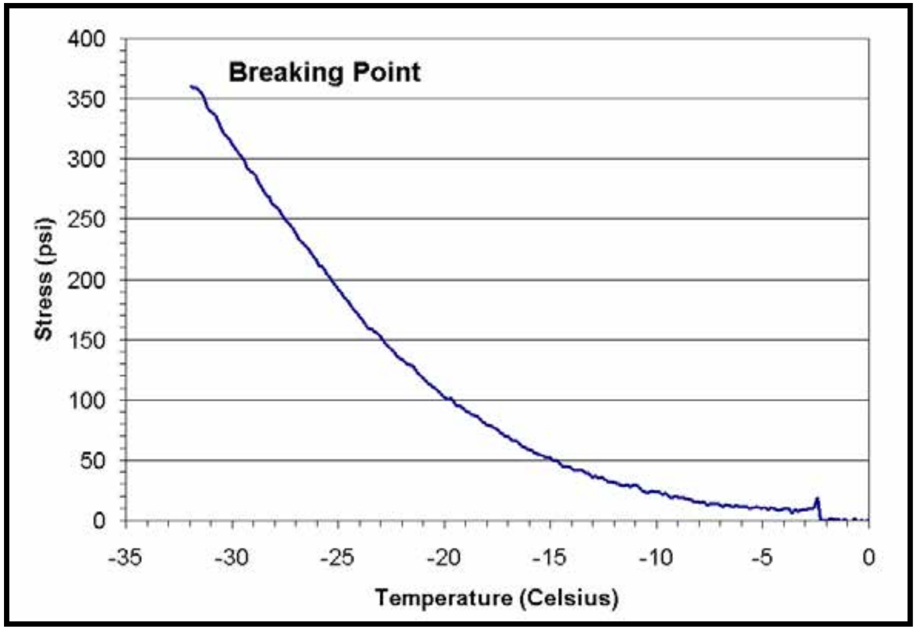


1,000
900
800
700
600
500
400
300
200
100
0
OT Cycles to Failure
753
151
45
644
182
60
PMA
AR #80 Mesh
AR #40 Mesh
PMA
AR #80 Mesh
AR #40 Mesh
HMA Mixtures
WMA Mixtures

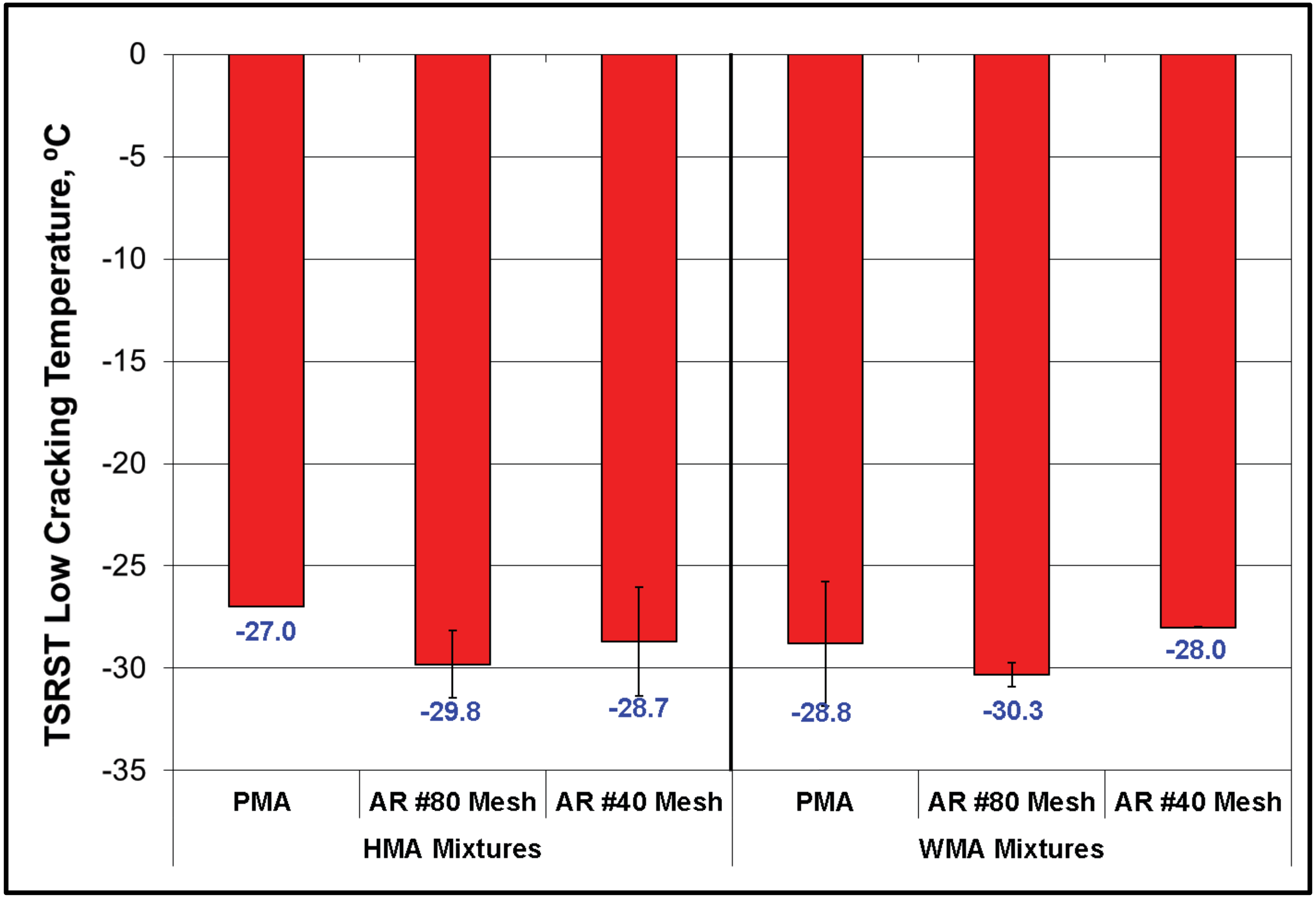
# Mixture Low Temperature Cracking - TSRST



- Cooling Rate of -10°C/hour
- Testing in accordance with AASHTO TP10-93



# TSRST Results



# Conclusions

- All mixtures tested provided comparable rutting, moisture damage, and low temperature cracking performance.
- The HMA mixtures with the PMA binder had more resistance to fatigue cracking than the two HMA mixtures with the AR binders according to the beam fatigue test.
- The addition of WMA increased the mixture fatigue performance using the PMA binder but decreased beam fatigue performance using the two AR binders.

# Conclusions

- The results of the fatigue test using SVECD did not always agree with the results from the beam fatigue test. In regards to the use of WMA, the only consistent result was that it decreased performance using the AR binders.

- The HMA mixture with the PMA binder had a greater resistance to reflective cracking than the HMA mixtures with the two AR binders. The effects of WMA were regarded to be insignificant.

# Acknowledgements

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# Thank you!

# AR Binders

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- The GTR utilized was obtained in mesh sizes of #40 and #80 mesh and used to fabricate the AR binders through a wet process.
- GTR dosage was varied for each mesh size in order to obtain a resultant AR binder with properties comparable to the PMA binder.

# AR Binders – Wet Process

- The virgin binder was heated to 374ºF (190ºC). Blending was conducted using a Silverson L4RT-W bench top laboratory high shear mixer at a speed of 5,000 RPM. Blending of the virgin binder and GTR continued for 60 minutes at 374ºF (190ºC).
- This process was used to ensure that the complex shear modulus of the binder reached an almost constant value which was considered to be a sign of complete reaction between the rubber particles and the binder.

# Future Work

- Concentrate on improving the fatigue and reflective cracking performance provided by AR binders along with evaluating mixture tests used to measure fatigue cracking performance for these types of high performance UTOL mixtures.

# Conclusions

- The two AR binders did not perform as well as the PMA binder in the high performance UTOL mixture in regards to (1) fatigue cracking as measured by the beam fatigue test and (2) reflective cracking.

- Results from the beam fatigue test were not always supported by the fatigue test using SVECD which were variable.

- The only detriment to performance provided by WMA was that it decreased fatigue cracking performance using the AR binders.

# Experimental Methodology

- A PMA binder was selected that had shown field success in a pavement preservation strategy.
- AR binders were developed by varying both the percentage and the mesh size of the GTR to determine a combination that provided a similar binder PG as the PMA binder in accordance with AASHTO M332 (MSCR requirements).
- This AR binder and the selected PMA binder were then utilized to design the high performance UTOL.