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# Use of Recycled Plastics in Asphalt

## Opportunities, Challenges, and NCAT Research

Fan Yin, Ph.D., P.E.

ASCE Montgomery Branch

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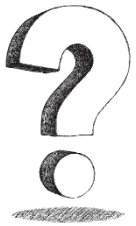
# Background

- In late 2016, media reports in the U.S. started to advertise the use of recycled plastics in asphalt
  - Eliminate the growing amount of waste plastics
  - Improve the performance of asphalt pavements



- Since then, the “plastic roads” concept has gained increasing attention

- What’s missing?

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# Literature Review

- What has been done in the past?
- What needs to be done in the future?

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# Literature Review

- Arguably the most comprehensive literature review thus far
  - 110+ documents in English (1991 to 2020)
- Classification by topics
  - Laboratory testing (87)
  - Field project (28)
  - Literature review (5)
  - Cost analysis (4)
  - Pavement design (3)
  - Production introduction (3)
  - Accelerated pavement testing (1)
  - Agency specification (1)


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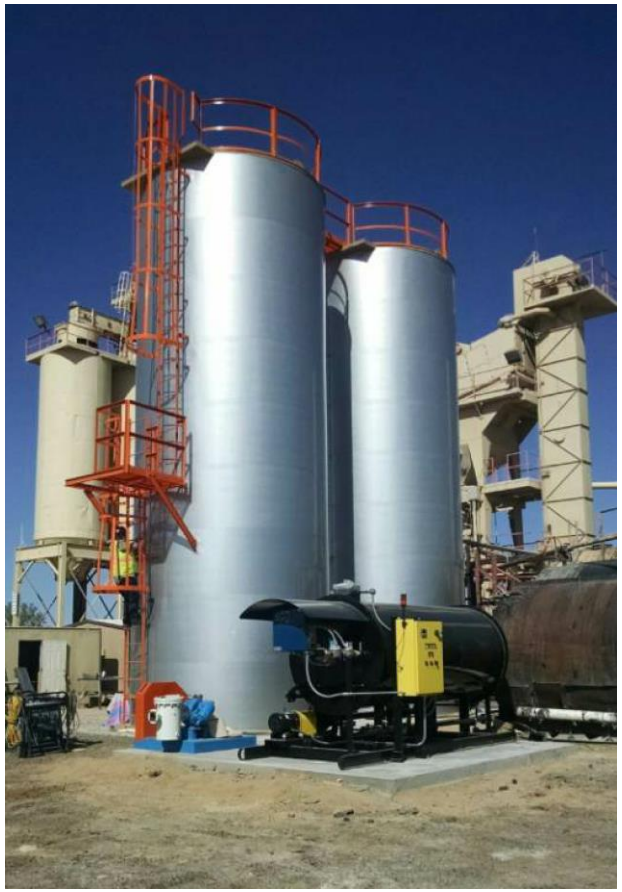
# Methods of Adding Plastics

- Wet Process
  - Polymer modifier or binder replacement
  - 2 to 8% by weight of asphalt binder
  - Low melting point needed



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# Methods of Adding Plastics

- Wet Process
  - Polymer modifier or binder replacement
  - 2 to 8% by weight of asphalt binder
  - Low melting point needed
- Dry Process
  - Aggregate replacement
  - Mixture modifier
  - Aggregate modifier
  - 0.2 to 1% by weight of aggregate

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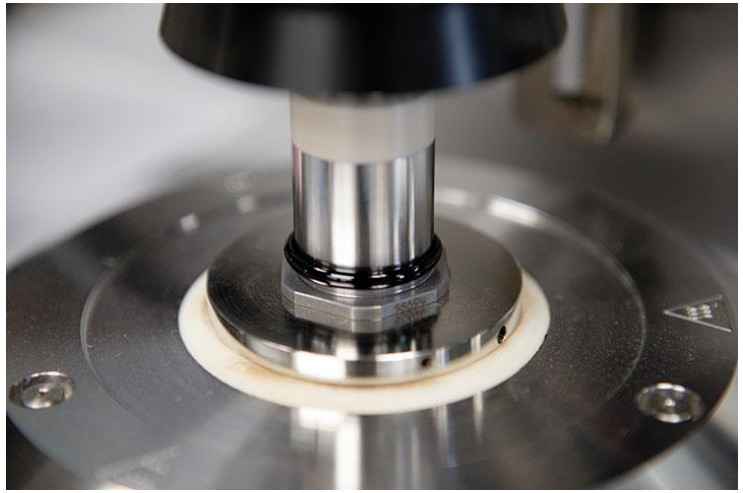
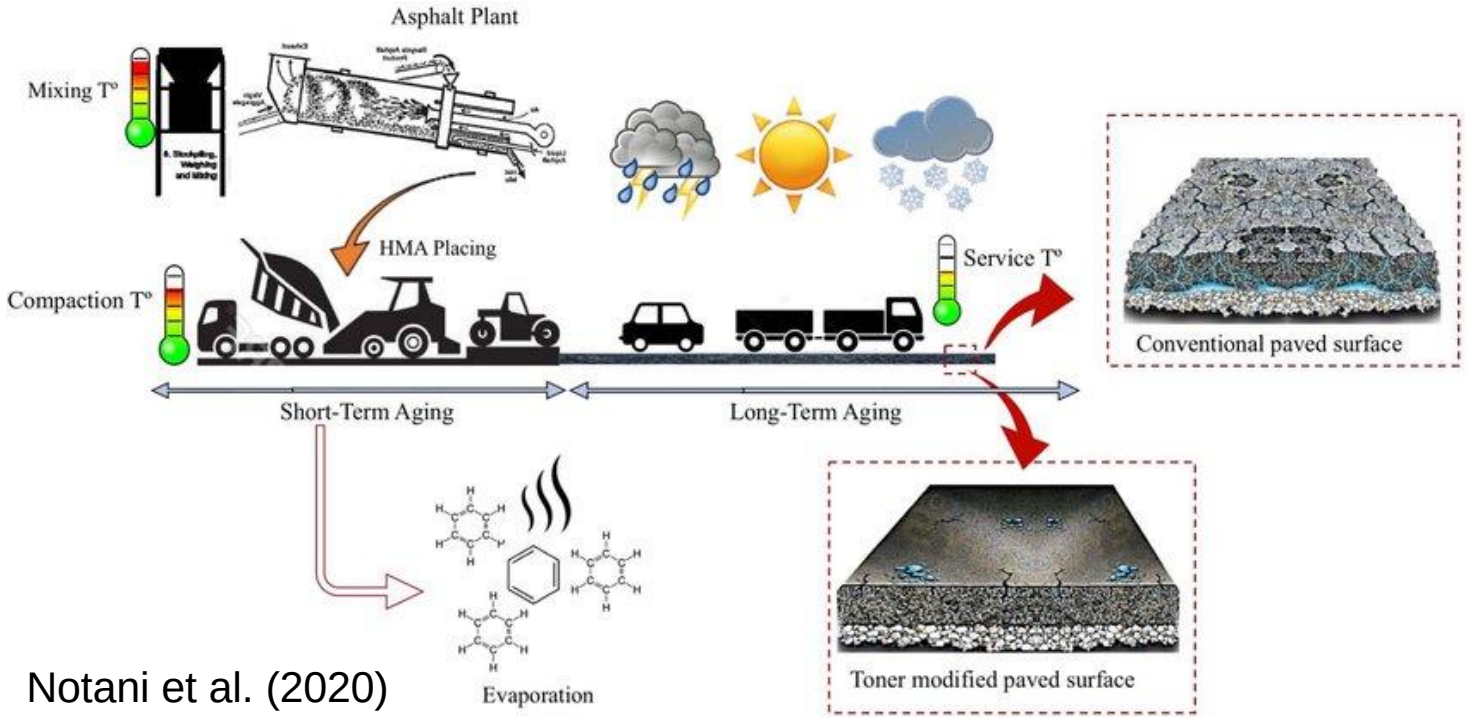
# Asphalt Binder Characterization

- Binder properties
  - Plastic stiffens asphalt binder
  - Better rutting resistance
  - Very little data on fatigue, low-temperature, and aging resistance

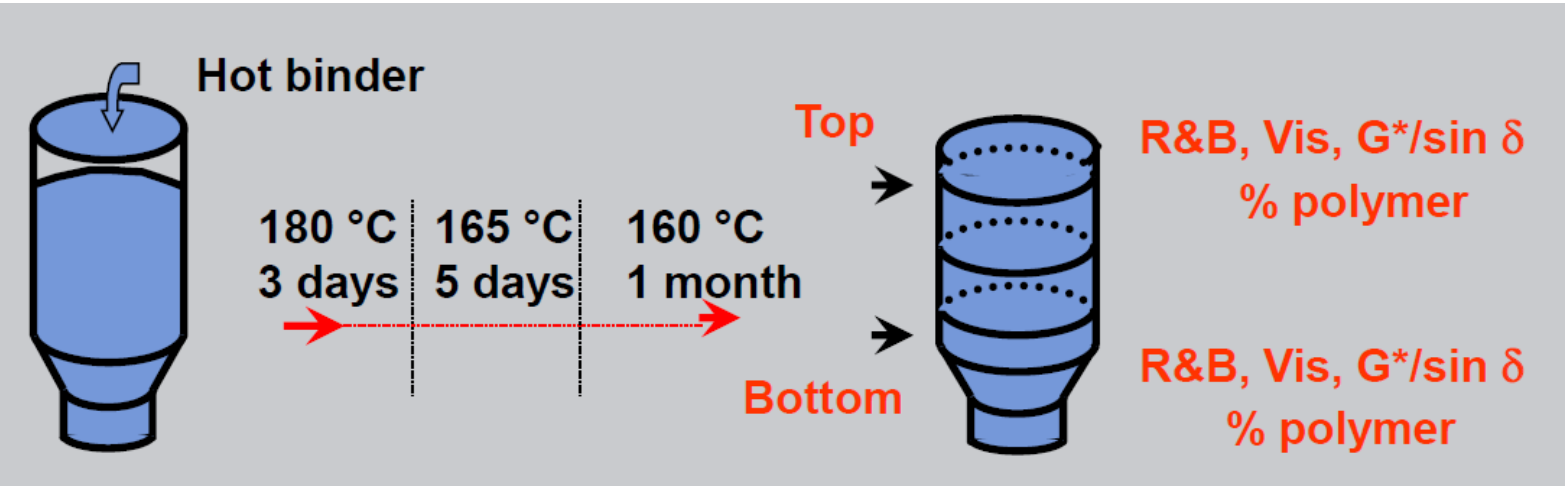


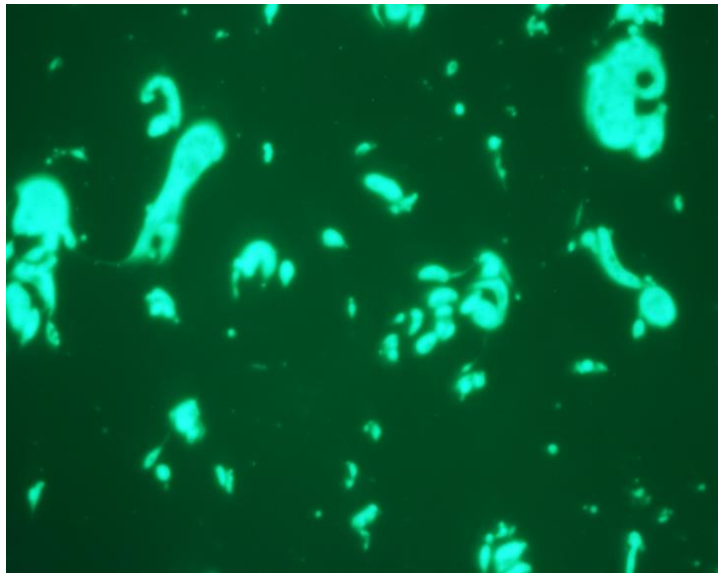



Notani et al. (2020)

# Asphalt Binder Characterization

- Phase separation issue
  - Cigar tube test
  - Fluorescence microscopy



(Baumgardner and Planche, 2020)

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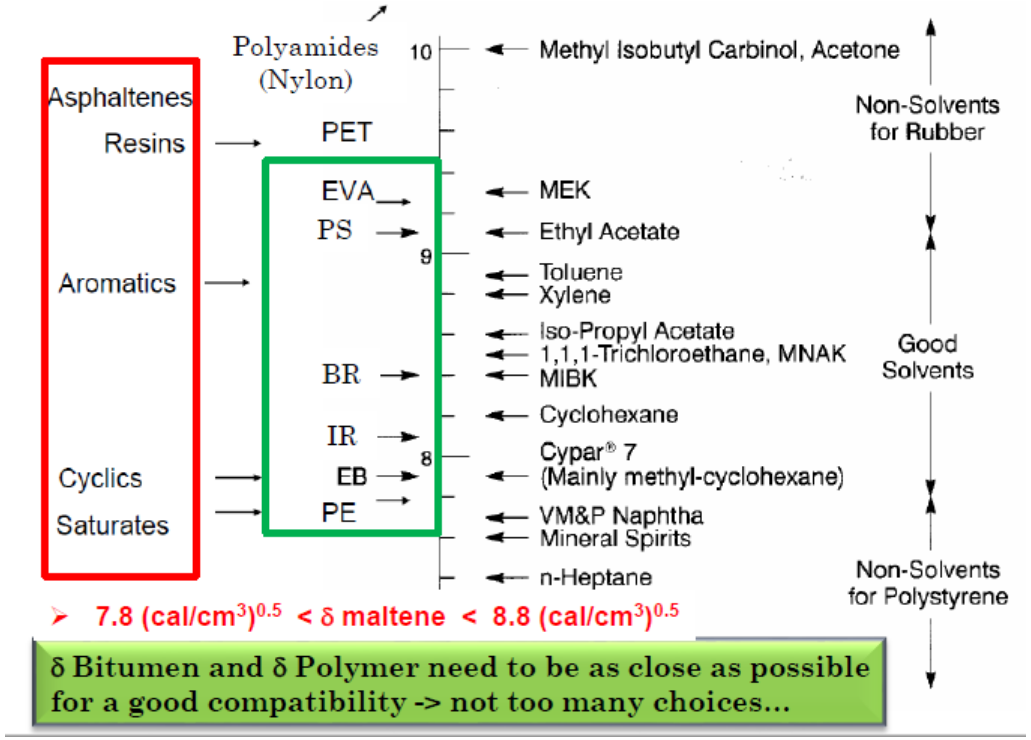
# Asphalt Binder Characterization

- Phase separation issue
  - Incompatibility due to solubility difference
  - Stokes' law, separation tendency = f (density difference, viscosity)
  - Additives or plastic modification may help




**Sedimentation, under the force of gravity, of small particles, in a fluid**

- Settling velocity of droplets

$$dx/dt = 2r^2(\rho_2-\rho_1)g/9\eta$$

- $r$ = radius of the droplets
- $\rho_1$ = density of the external fluid
- $\rho_2$ = density of the droplets
- $\eta$ = viscosity of the matrix

(Baumgardner and Planche, 2020)

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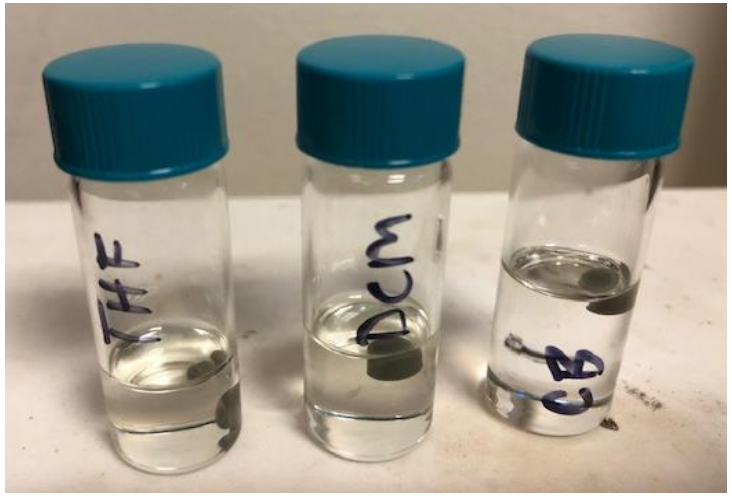
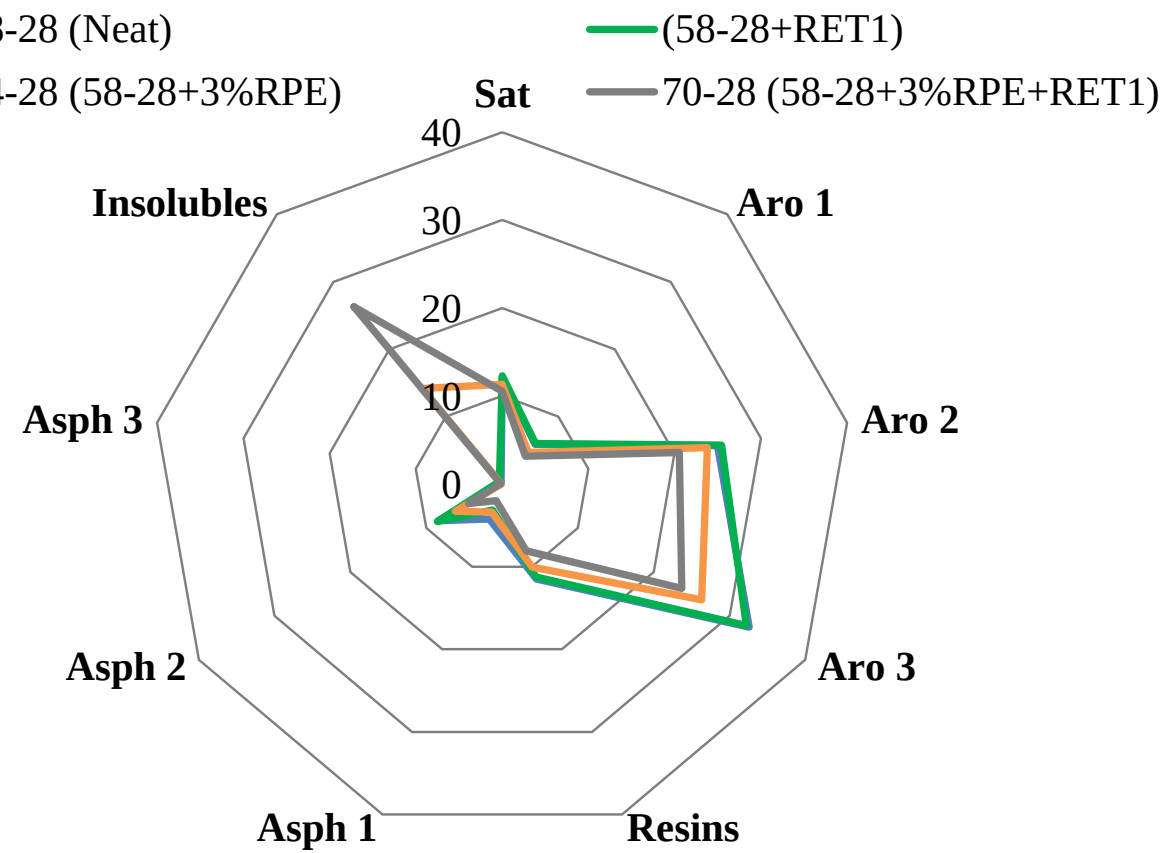
# Asphalt Binder Characterization

- Polyethylene (PE) insoluble in many solvents
- Insoluble fraction in SAR-AD analysis
  - Saturate
  - Aromatic
  - Resin
  - Asphaltene




(Example Data)



# Asphalt Mixture Characterization

- Marshall stability
  - Increased Marshall stability
- Increased stiffness and rutting resistance
  - Wet – stiffer binder
  - Dry – increased aggregate friction and/or quality
- Very little information on cracking and moisture resistance
- High modulus mixture applications
  - Potential pavement thickness reduction benefits

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# Other Challenges

- Plant operations
  - High-shear blending unit for wet process
  - Additive feeding system for dry process
- Construction
  - Reduced mixture workability
  - Increased temperature susceptibility due to polymer crystallization below $T_{melt}$
- Health and safety concerns
  - Leaching of toxic components
- Environmental impact
  - Release of microplastics
  - Re-recyclability of asphalt pavements


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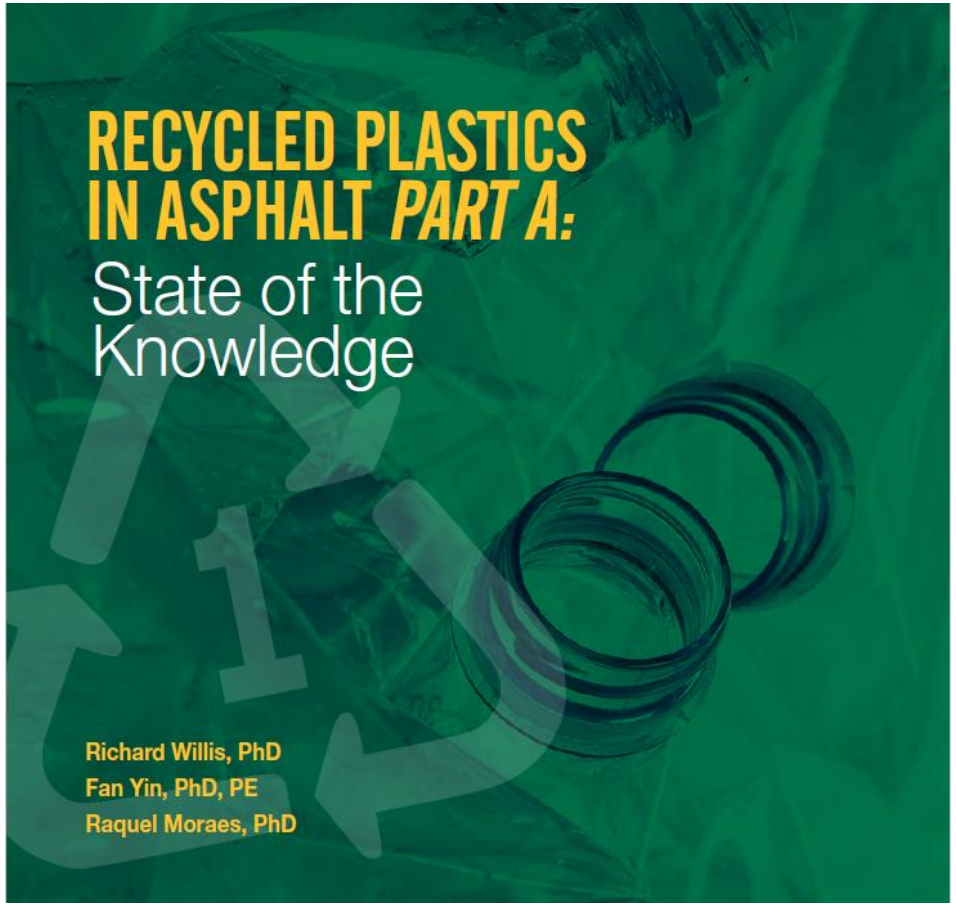
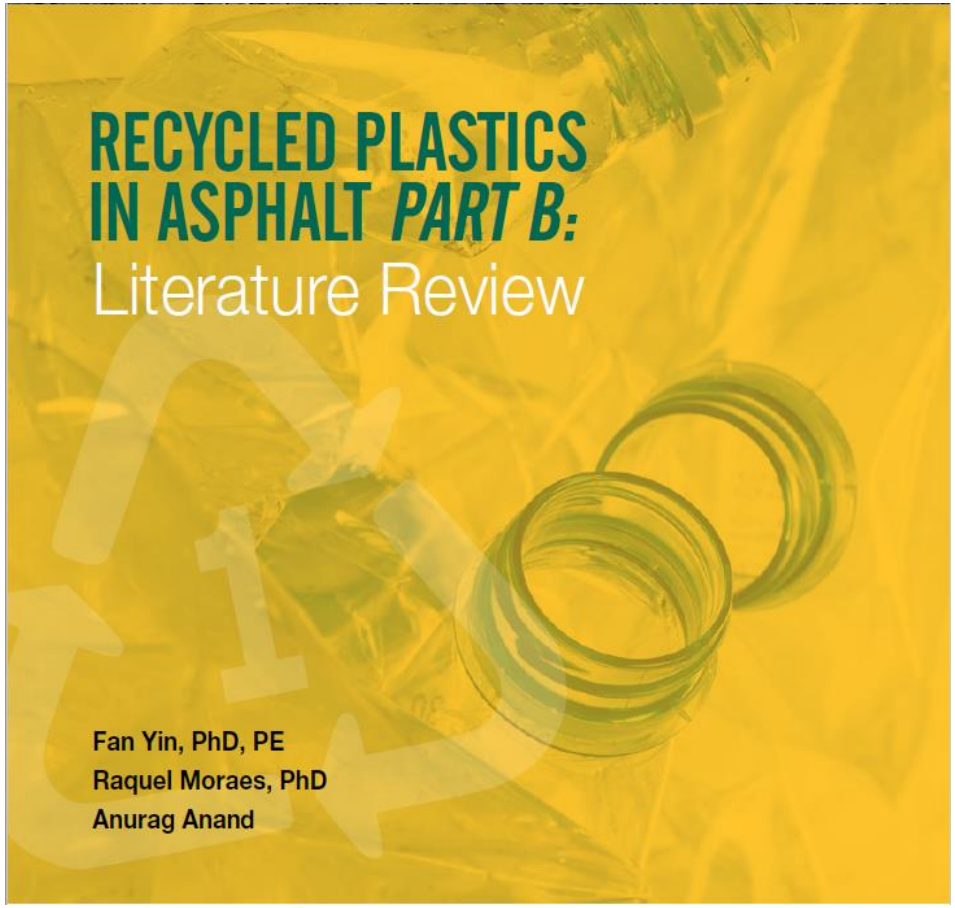
# NAPA-IS-142 Documents

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# RPM Field Sections Since 2018


**Wet process (9)**

**Dry process (7)**

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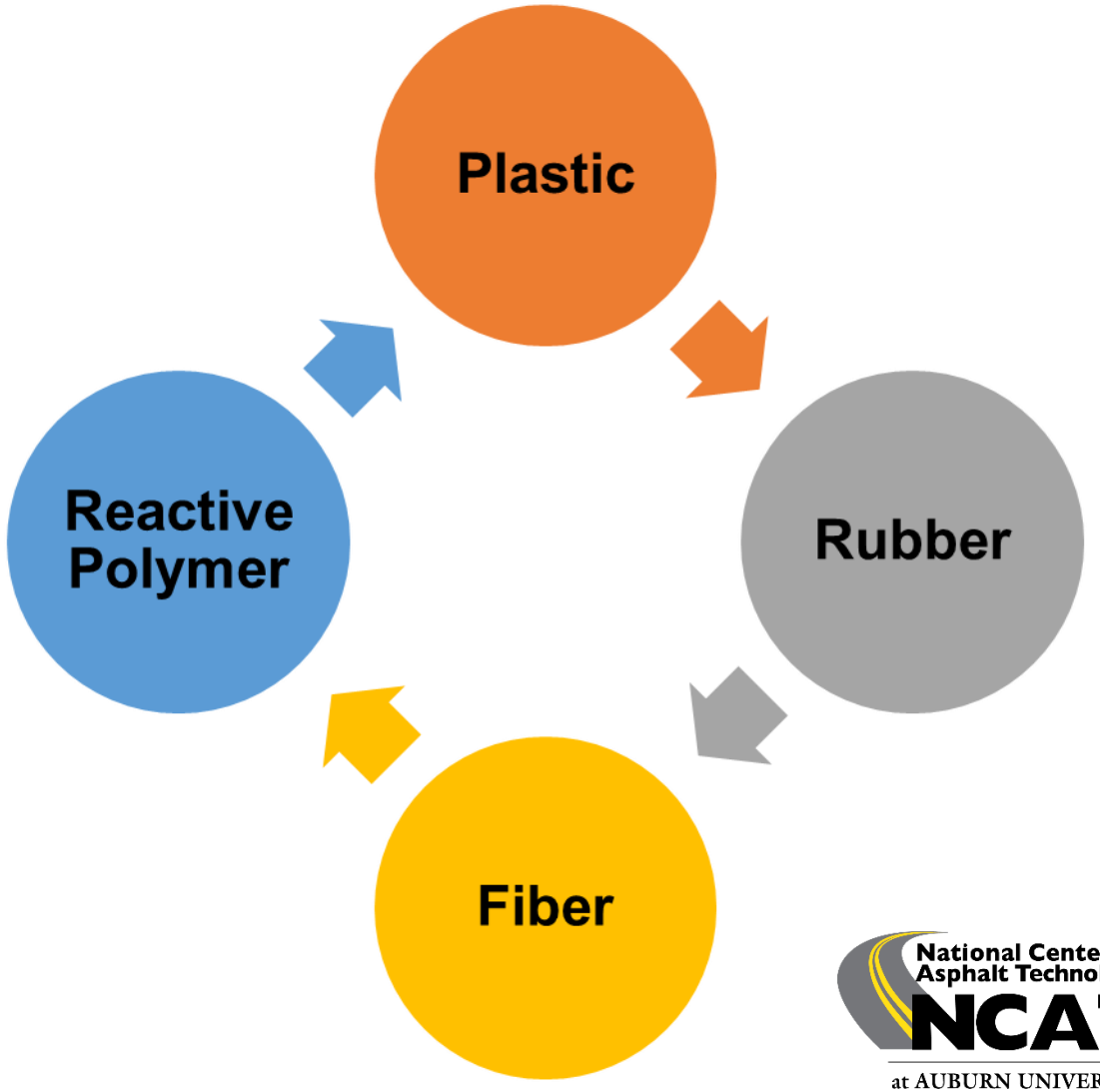
# Additive Group (AG) Experiment

- New experiment to comprehensively evaluate **sustainable and resilient pavement technologies**
- Continuation of NCAT-MnROAD partnership to address national needs

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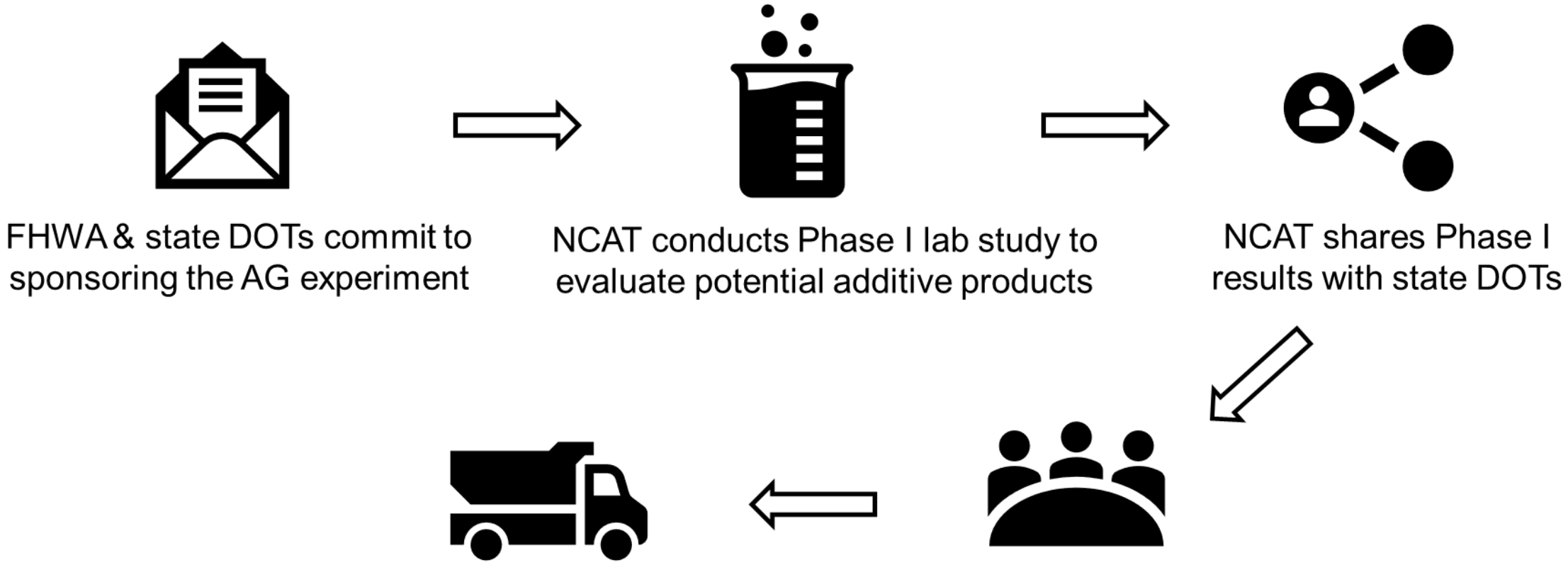
# Experiment Scope

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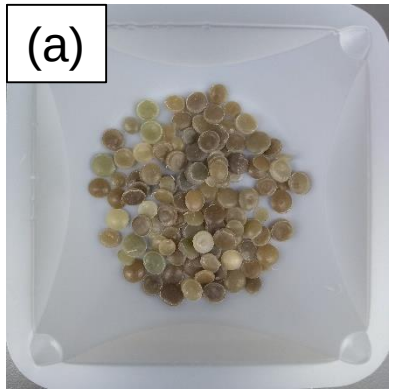
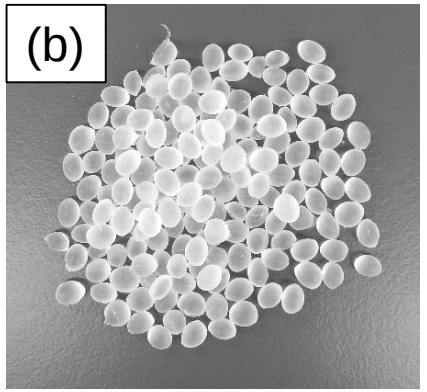
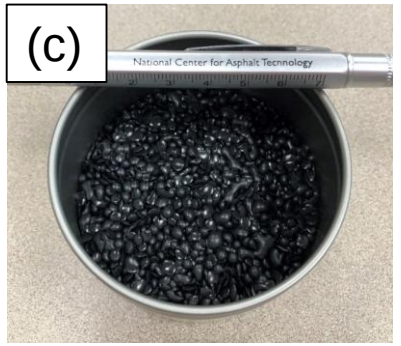
# Phase I Study

- Laboratory material characterization study to "screen" different asphalt additives for NCAT Test Track experiment

- Recycled plastic technologies
  - Binder modification with LDPE-rich PCR and reactive elastomeric terpolymer (RET)
  - Binder modification with SBS and chemically modified PE wax
  - Mixture modification with LDPE-rich PCR
  - Non-disclosure technologies




(a) LDPE-rich PCR
(b) RET (photo courtesy of Dow)
(c) PE Wax

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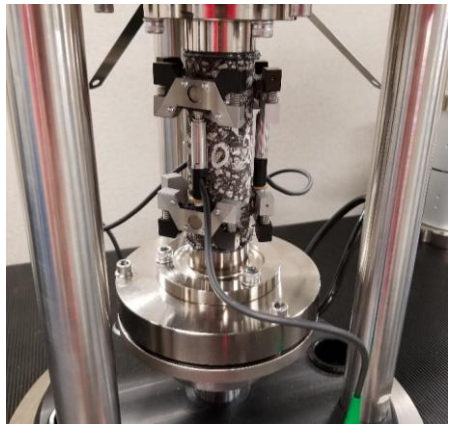
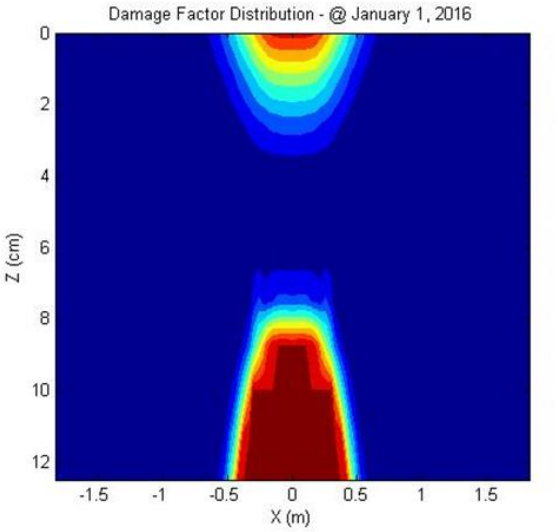
# Phase I Study

Balanced Mix Design

AMPT Performance Testing

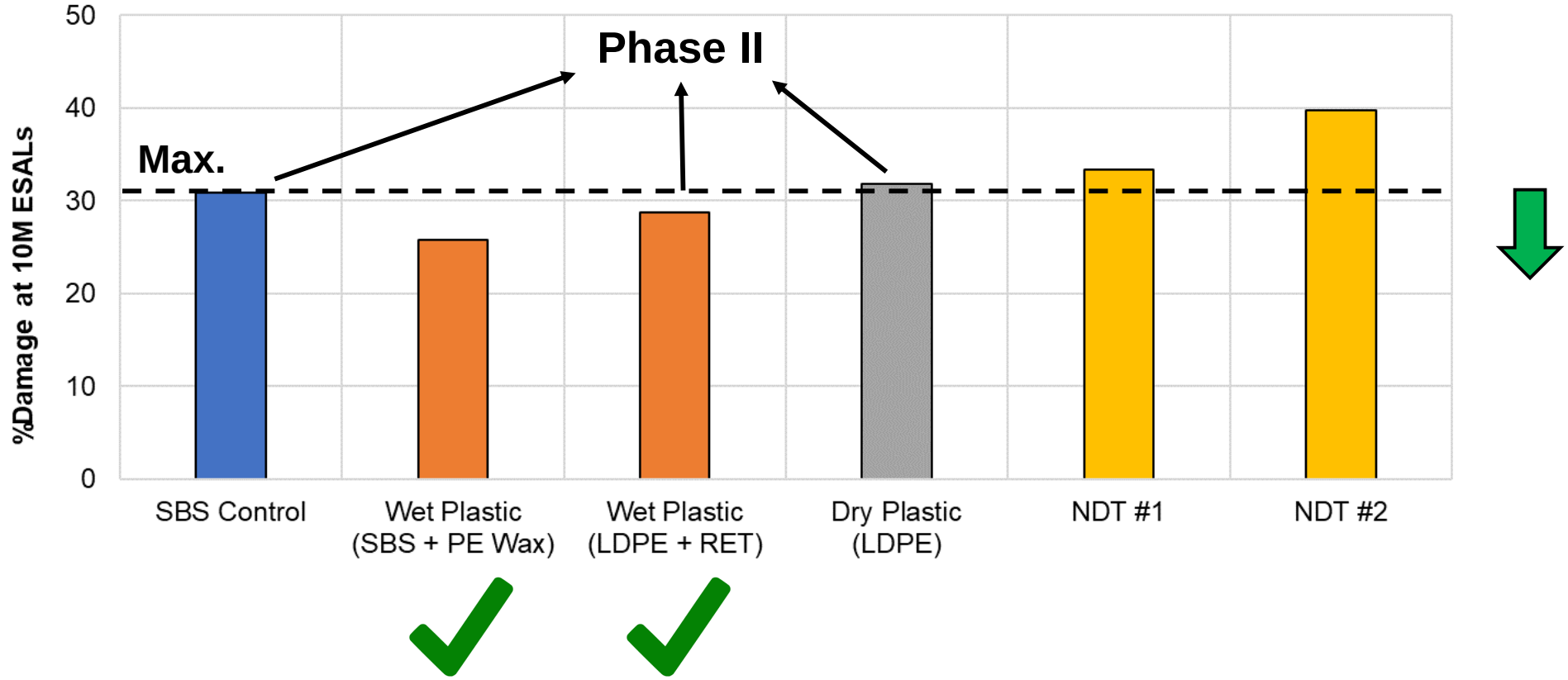
FlexPAVE™ Cracking Performance Prediction





# FlexPAVE™ Predicted %Damage

- Adding recycled plastics did not always yield favorable results
- Wet-process plastic technologies (with elastomers) appeared promising
- **Engineer binder formulations and mix designs to ensure performance**



# Phase II Study

- 6 structural test sections focusing on fatigue cracking
  - 2 on recycled plastics
- Companion test sections at MnROAD focusing on reflective cracking

**Completed**






**Ongoing**





# Test Sections, Mix Design, and Production

- Structural test sections
  - 5.5 in. AC (one lift) + 6.0 in. aggregate base + Track subgrade
  - Full instrumentation with strain gauges, pressure plates, and temp. probes
- Mix Design
  - 12.5mm NMAS dense-graded mix with 20% RAP
  - Balanced rutting and cracking performance
- Production
  - Wet-process RPM mix: terminal-blended LDPE+RET modified binder
  - Dry-process RPM mix: plastic pellets fed into the drum using a HiTech feeder
  - No production and construction issues

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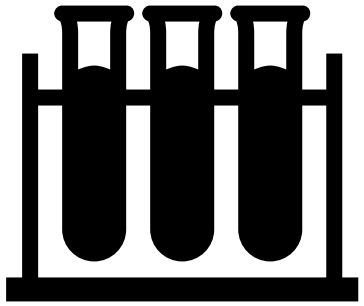
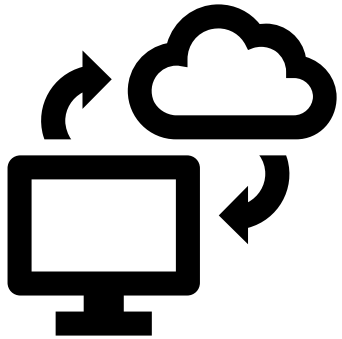
# Performance Testing and Simulations

- BMD (IDEAL-CT, HWTT, IDEAL-RT, and HT-IDT)
- Bending beam fatigue
- AMPT cyclic fatigue

- WESLEA
- Pavement ME Design
- FlexPAVE™

**A comprehensive process to evaluate asphalt additives without test sections**





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# Summary

- ‘Use of recycled plastics in asphalt’ is a HOT topic but remains at an early stage in terms of technology development and implementation
  - Comprehensive literature review available
  - Potential economic, environmental, and engineering benefits
  - Many knowledge gaps to address
- NCAT-MnROAD AG experiment
  - Evaluate mixture performance and pavement structural responses
  - Phase I study: adding recycled plastics did not always yield favorable results, but wet-process technologies (with elastomers) appeared promising
  - Engineer binder formulation and mix design to ensure performance

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# Thank You

Questions?

f-yin@auburn.edu

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