NATIONAL ACADEMIES
Sciences
Engineering
Medicine

TRB TRANSPORTATION RESEARCH BOARD

TRB Webinar: The Jury is Still Out—The Latest on Recycled Plastic Waste in Asphalt

March 16, 2023

12:30 – 2:00 PM

PDH Certification Information

1.5 Professional Development Hours (PDH) – see follow-up email

You must attend the entire webinar.

Questions? Contact Andie Pitchford at TRBwebinar@nas.edu

The Transportation Research Board has met the standards and requirements of the Registered Continuing Education Program. Credit earned on completion of this program will be reported to RCEP at RCEP.net. A certificate of completion will be issued to each participant. As such, it does not include content that may be deemed or construed to be an approval or endorsement by the RCEP.

ENGINEERING
RCEP
REGISTERED CONTINUING EDUCATION PROGRAM

Purpose Statement

Plastic waste is an ongoing concern for our environment. Agencies and industry are keenly interested in the use of recycled plastic waste in asphalt, which holds potential to both improve asphalt pavements' performance and reduce the amount of plastic waste. This webinar will include up-to-date engineering information pertaining to recycled plastic waste in asphalt pavements.

Learning Objectives

At the end of this webinar, you will be able to:

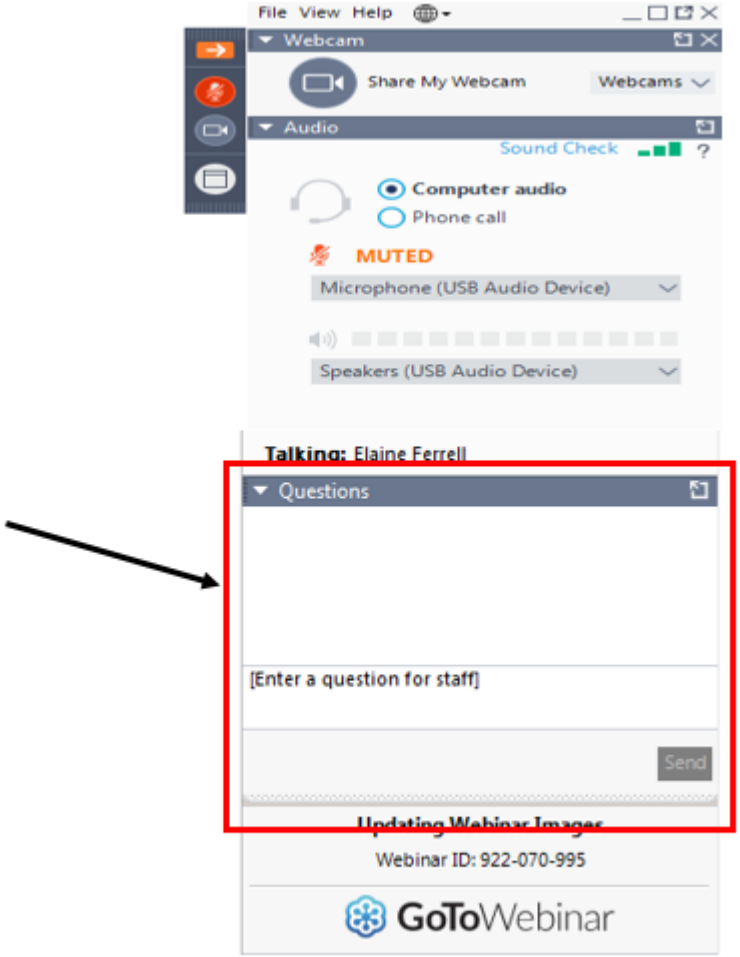
(1) Identify the state-of-the-practice regarding current knowledge and utilization of waste plastic in asphalt, including concerns and research gaps

(2) Develop an awareness of ongoing and upcoming research efforts to investigate concerns and research gaps

(3) Point to examples of waste plastic use in asphalt outside of the U.S., including successes, challenges, and concerns

Questions and Answers

- Please type your questions into your webinar control panel
- We will read your questions out loud, and answer as many as time allows

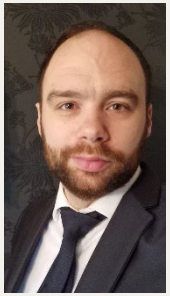


Today's presenters

Ben Cox
benjamin.c.cox@usace.army.mil
U.S. Army Corps of Engineers

Richard Willis
rwillis@asphaltpavement.org
National Asphalt Pavement Association

Fan Yin
fzy0015@auburn.edu
National Center for Asphalt Technology



Matthew Waning
Matthew.Waning@cumbria.gov.uk
Cumbria County Council

Orlando Walters
Orlando.Walters@wsp.com
WSP

NATIONAL ACADEMIES *Sciences Engineering Medicine*

THE JURY IS STILL OUT:
THE LATEST ON PLASTIC WASTE IN ASPHALT

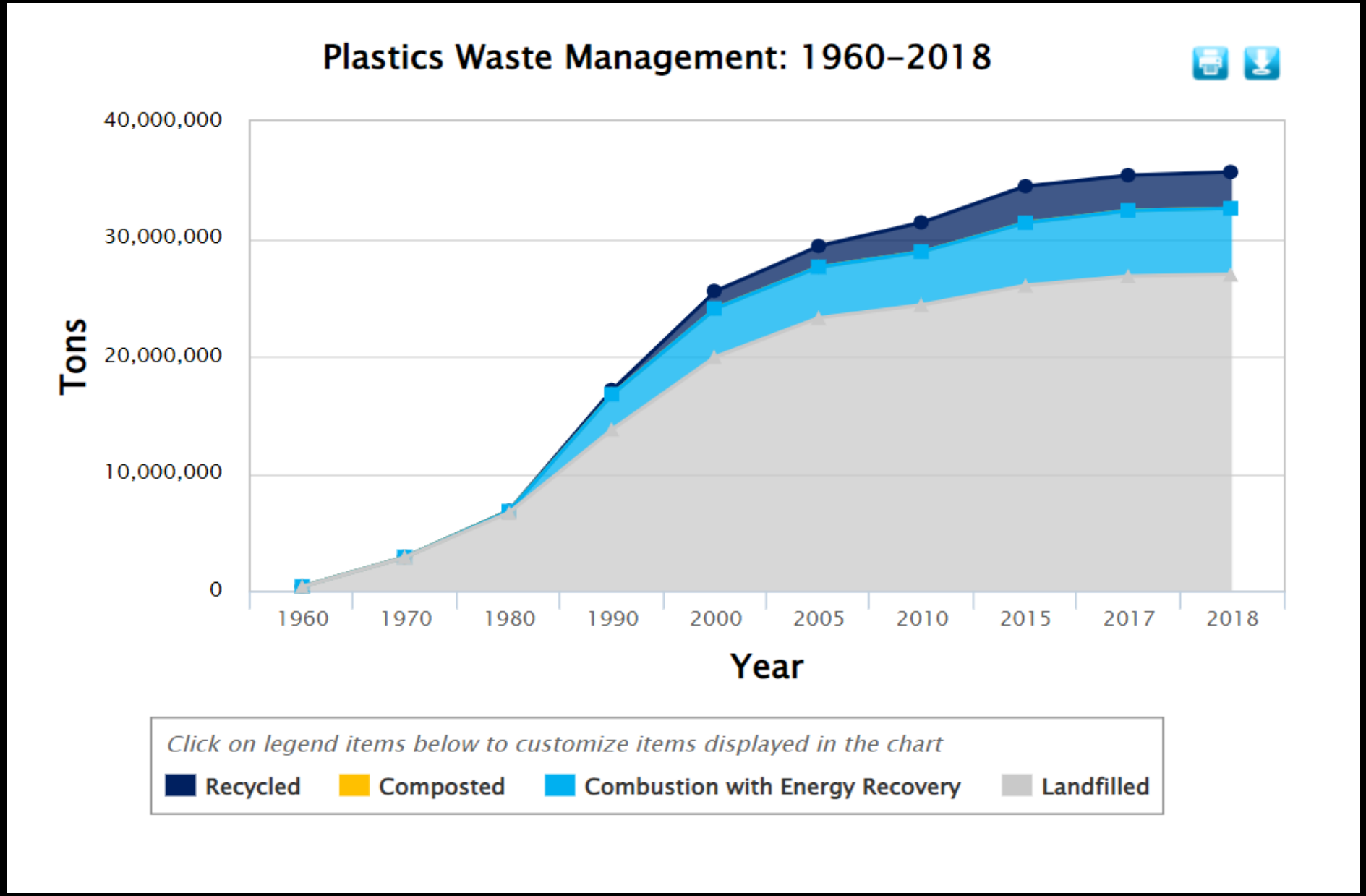
NAPA
NATIONAL ASPHALT
PAVEMENT ASSOCIATION

FHWA Recycling Policy

- Three E’s
  - Engineering
  - Economics
  - Environment

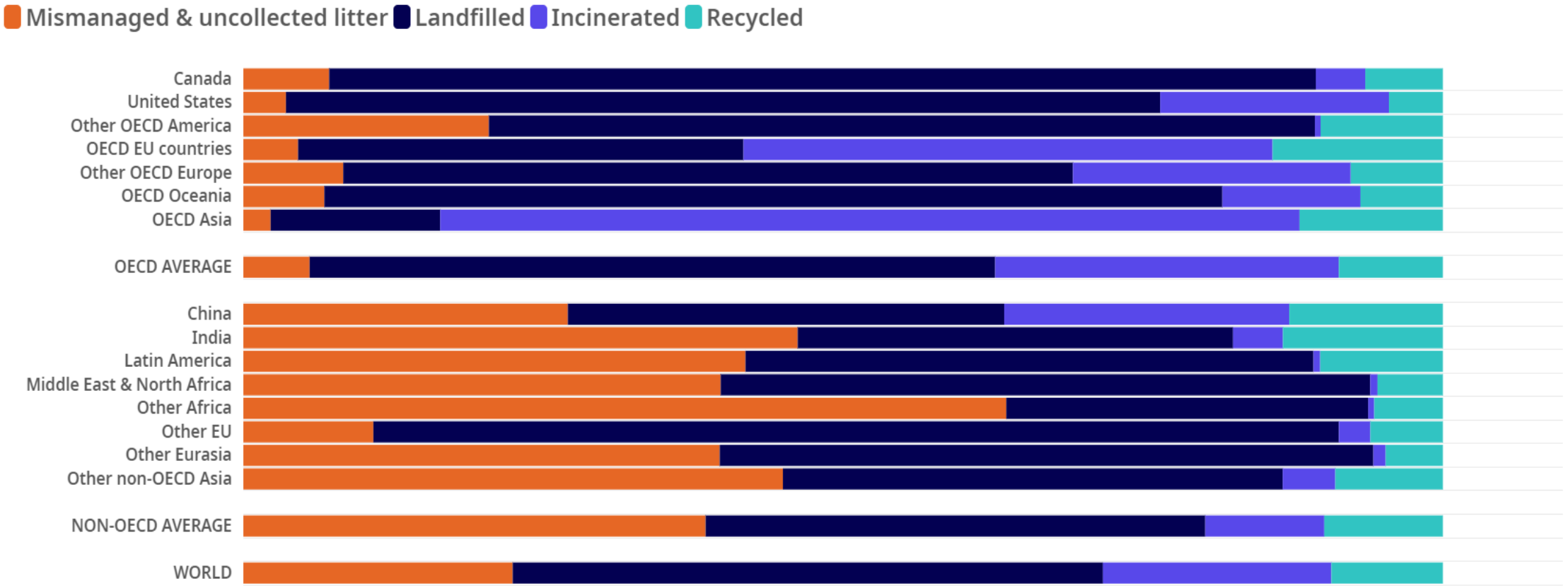
- FHWA, 2015

https://www.fhwa.dot.gov/legsregs/directives/policy/recmatpolicy.htm#:~:text=The%20FHWA%20policy%20is%3A,of%20engineering%20and%20environmental%20suitability



https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/plastics-material-specific-data

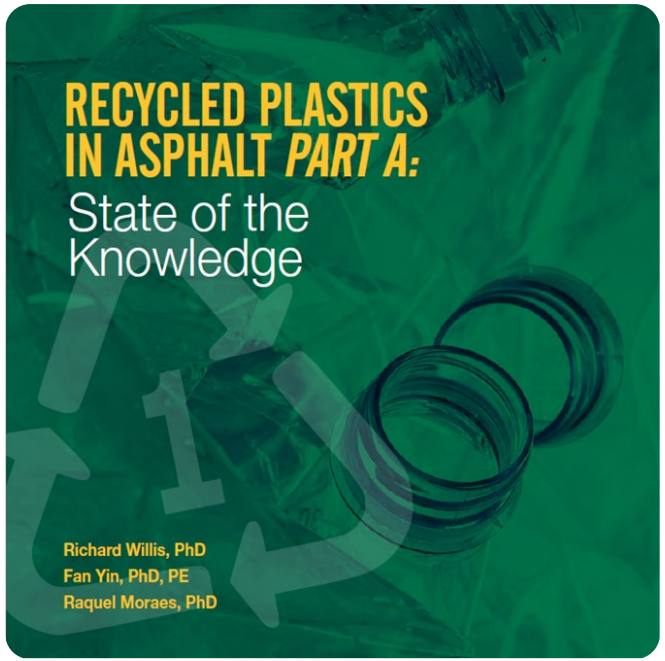
Share of plastics treated by waste management category, after disposal of recycling residues and collected litter, 2019

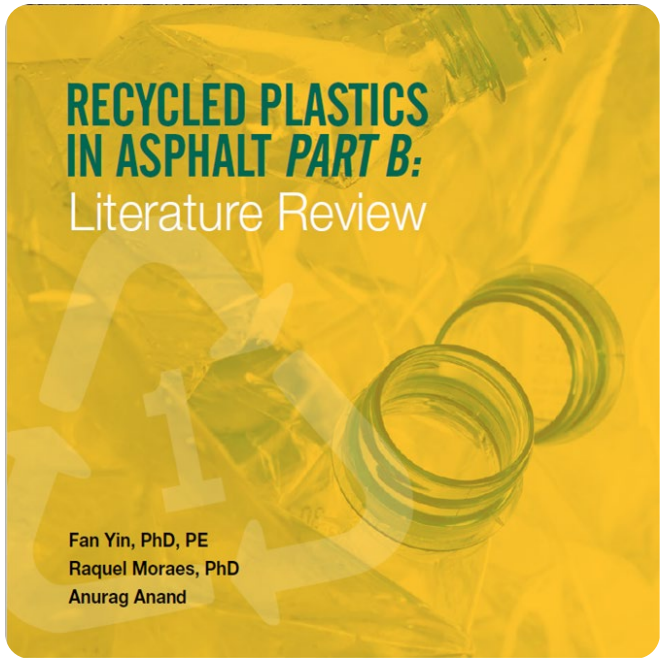


Source: OECD Global Plastics Outlook Database

OECD

Recycling Responsibly





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

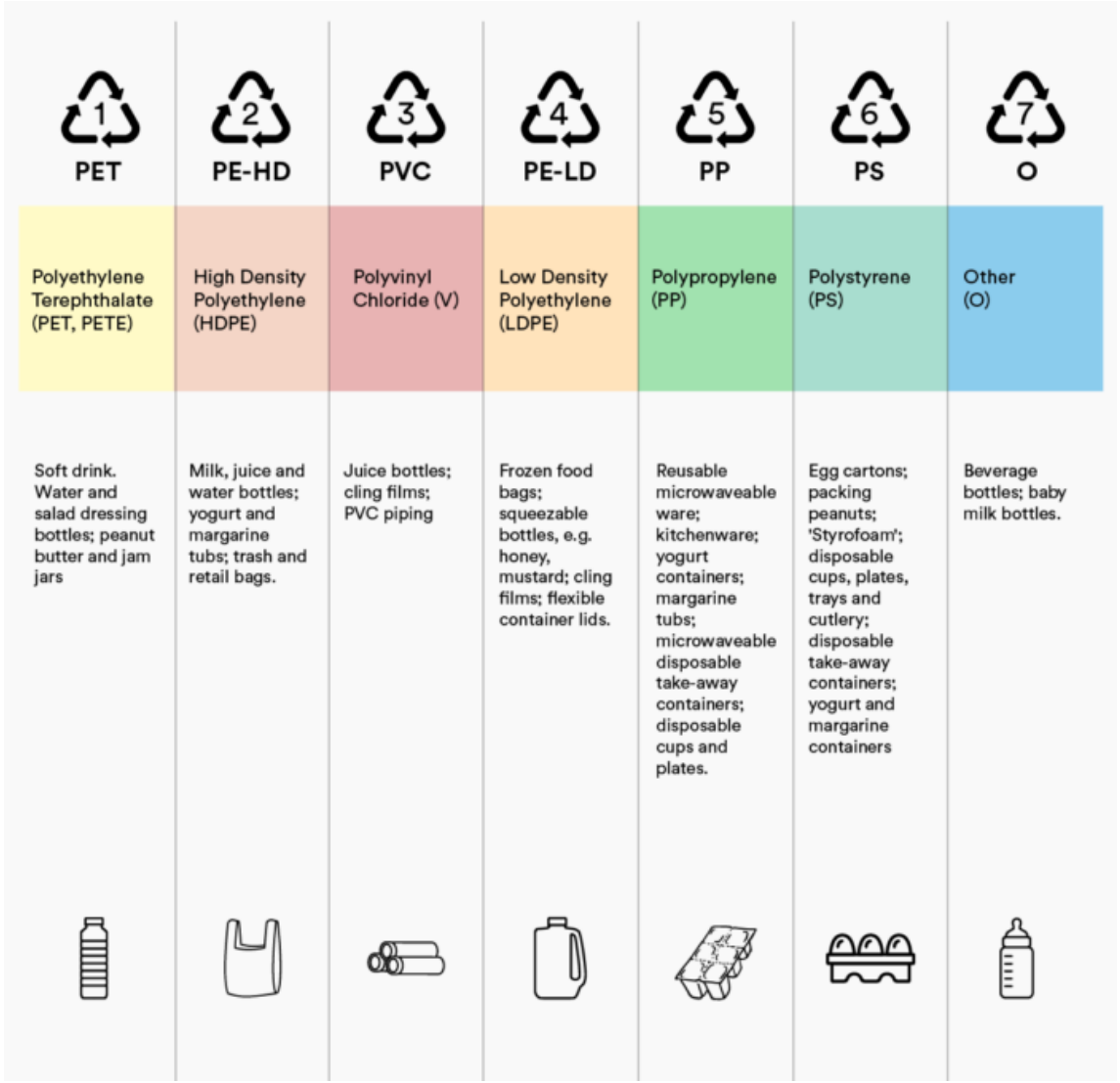
- Over 150 documents from 1991 to 2021
  - Journal and conference papers
  - Technical reports
  - Trade publications
  - Newsletter and magazine articles
  - Personal email communications

DISCUSSION TOPICS

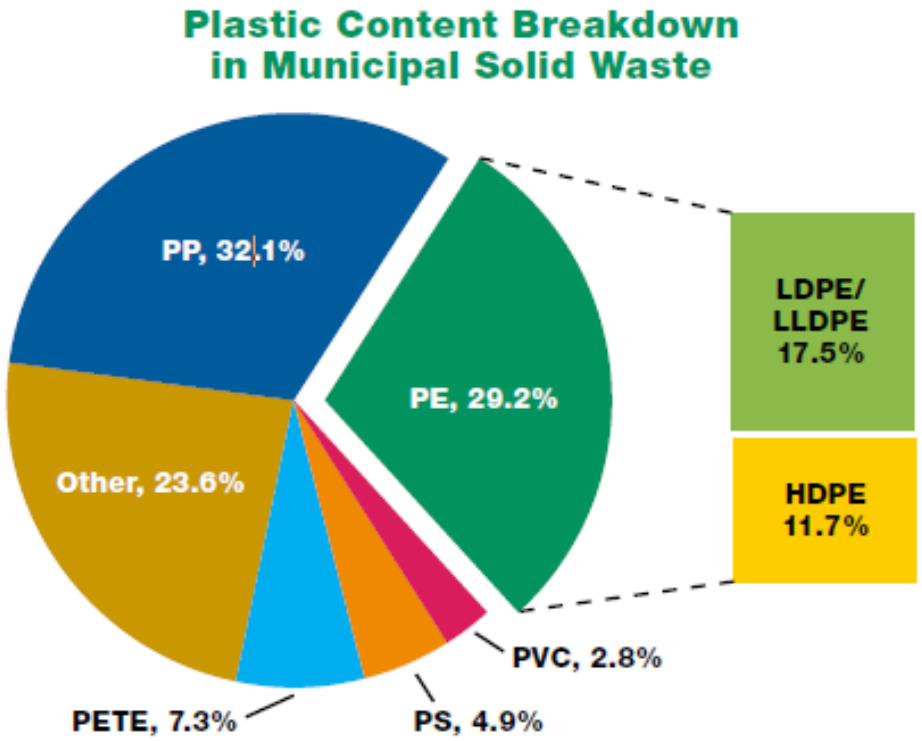
- Type of recycled plastics
- Methods of adding recycled plastics
- Laboratory binder characterization
- Laboratory mixture characterization
- Plant operations
- Construction
- Health and safety concerns
- Environmental impact
- Field projects

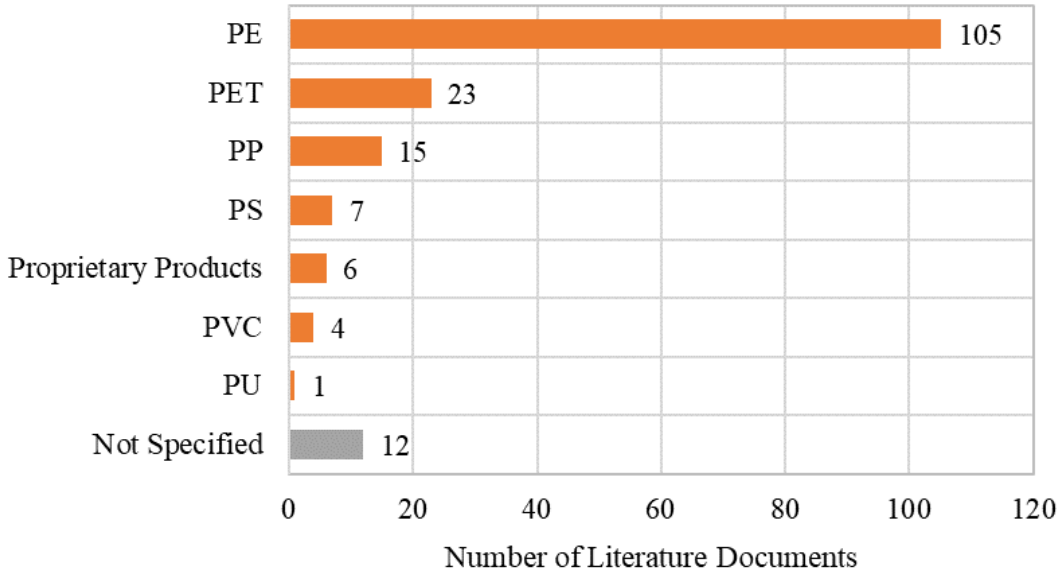
TYPE OF RECYCLED PLASTICS

- Key properties for asphalt application
  - Commonly reported: specific gravity, melting temperature, particle size
  - Others: melt flow index, degree of crystallinity, ash content
- How do they affect the performance properties of recycled plastic modified (RPM) asphalt binders and mixtures?



TYPE OF RECYCLED PLASTICS





(DuBois, 2020)

TYPE OF RECYCLED PLASTICS

- No robust specifications on acceptance limits of recycled plastics for use in asphalt
  - Unprocessed, partially processed, or fully processed
  - Degree of consistency and cleanliness
  - Post-consumer recycled (PCR) versus post-industrial recycled (PIR)




METHOD OF ADDING RECYCLED PLASTICS

- Wet Process
  - Polymer modifier or binder replacement
  - 1 to 12% by weight of asphalt binder
  - Low melting point needed

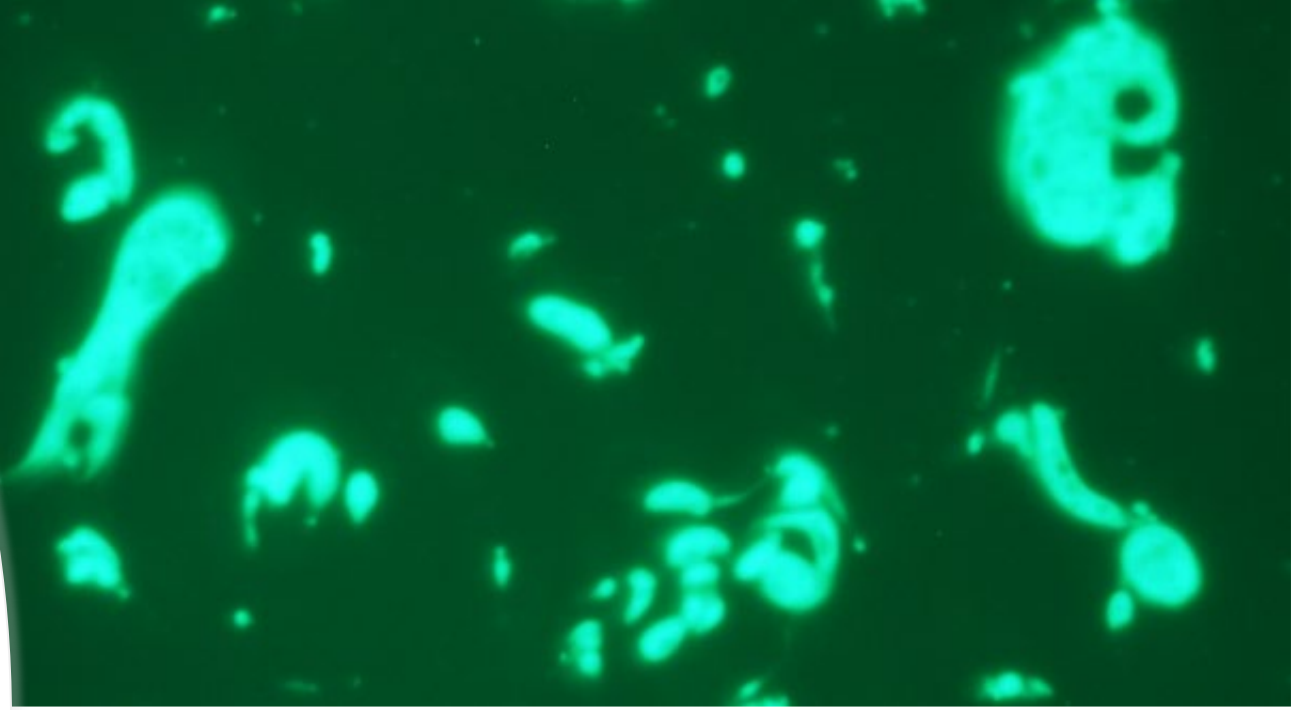
METHOD OF ADDING RECYCLED PLASTICS

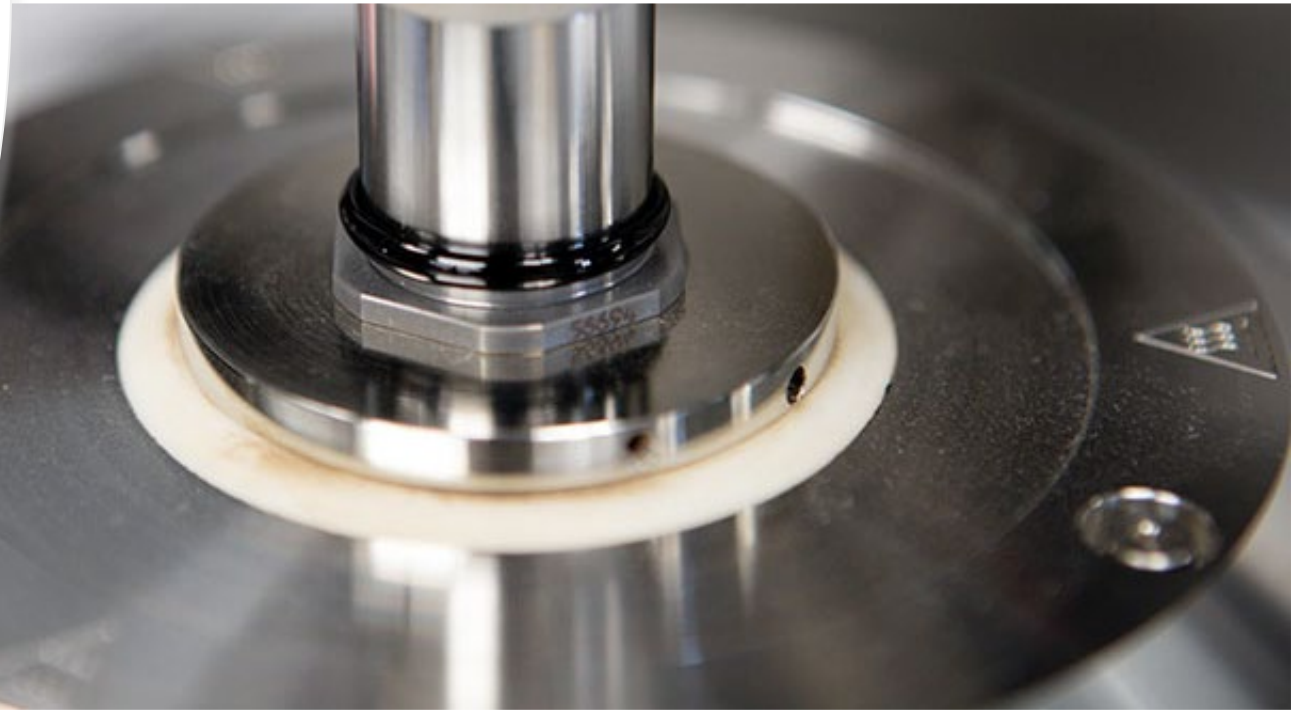
- Dry Process
  - Aggregate replacement
  - Mixture modifier
  - Binder modifier
  - Combination of the above
  - 0.2 to 6% by weight of aggregate

(Photo courtesy of Jean-Paul Fort)

LABORATORY CHARACTERIZATION

- Binder properties
  - Stiffening effect
- Phase separation issue
- Little mixture information for cracking





KNOWLEDGE GAPS

- Sourcing
- Modifier or replacement
- Performance properties
- Operations
- Health & Safety
- Environmental
- Field performance

MOVING FORWARD

- Patience
- Partnership
- Communication

National Center for Asphalt Technology

NCAT

at AUBURN UNIVERSITY

TRB Webinar: The Jury is Still Out

The Latest on Recycled Plastic Waste in Asphalt

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

March 16, 2023

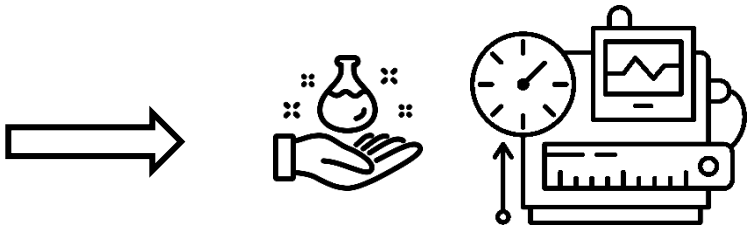
Additive Group (AG) Experiment

- New experiment to comprehensively evaluate sustainable and resilient pavement technologies
  - **Recycled plastic**
  - Rubber
  - Synthetic fiber
  - Reactive polymer

- NCAT Test Track to address fatigue cracking
- MnROAD to address reflective cracking

Experiment Scope

State DOTs commit to sponsoring the AG experiment



NCAT conducts Phase I lab study to evaluate additive products

NCAT shares Phase I results with state DOTs

State DOTs select additives for Phase II field study

Construct AG test sections on Test Track and MnROAD

Trafficking of Test Sections

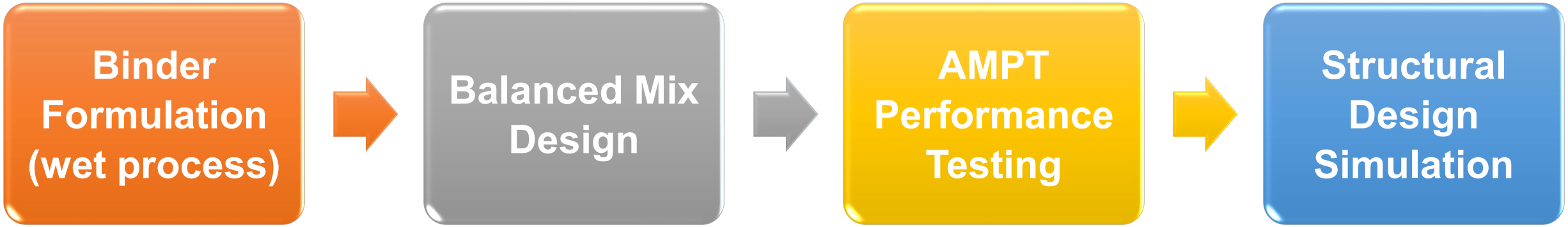
Assess Performance

Plastic-in-Asphalt Technologies

- Wet process – binder modification
  - Post-consumer recycled (PCR) LLDPE and reactive ethylene-based terpolymer (RET) as compatibilizer
  - Chemically modified PE wax (P)
- Dry process – mixture modification
  - PCR LLDPE
  - HDPE-based plastic additive (P)
  - Plastic additives processed from recycled carpets (P)

*Notes: *P = proprietary technologies*

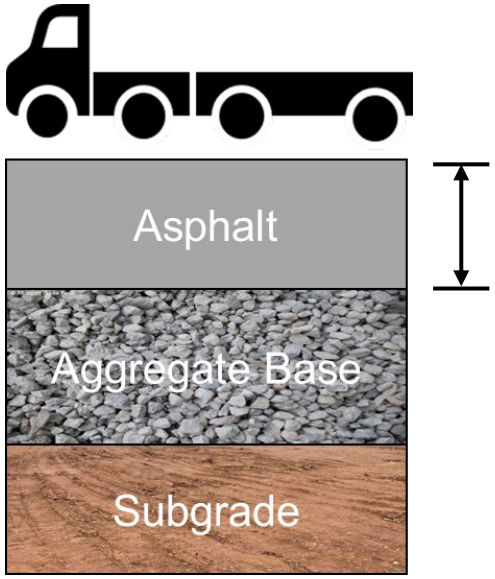
Phase I Lab Study

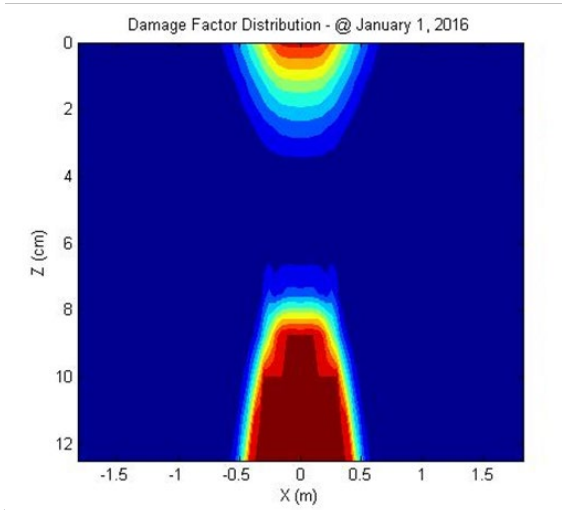


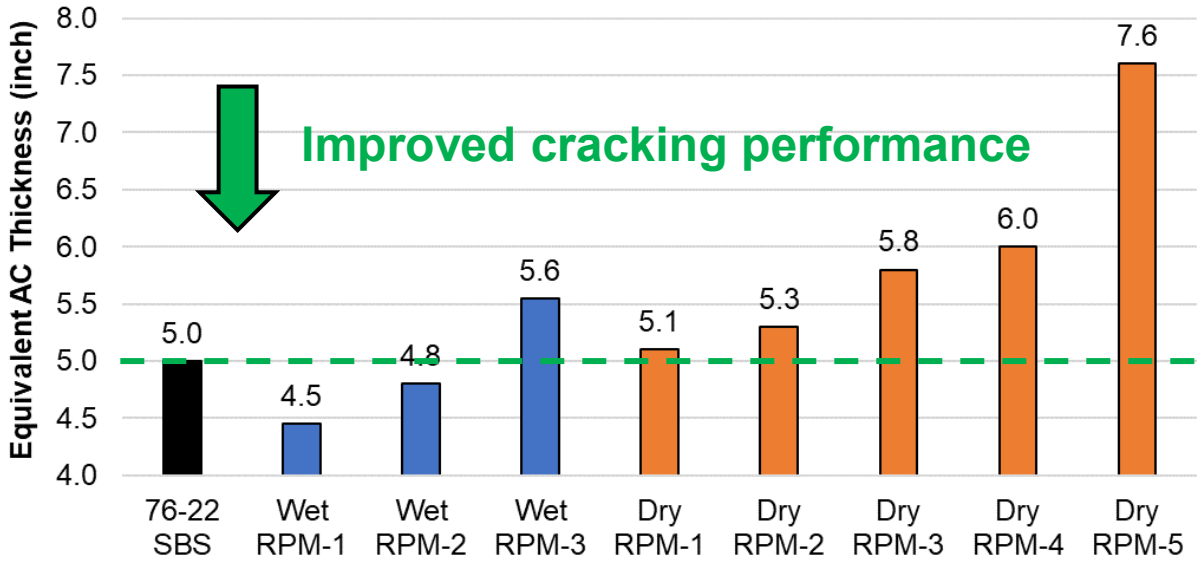
- Polymer separation, PG, and MSCR
- IDEAL-CT and HWTT
- AMPT E* and Cyclic Fatigue
- FlexPAVE™ simulations

FlexPAVE™ Simulation Results

- Wide range of performance among different RPM mixtures
  - Most did not perform as well as SBS control
  - Wet-process RPM with elastomer appeared promising
- Need to engineer binder formulation and mix design to perform



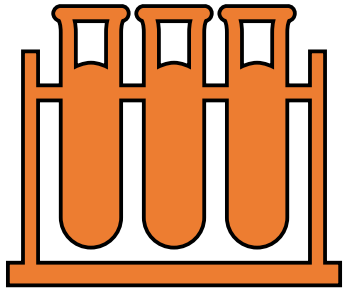




Equivalent AC thickness to yield the same damage as SBS control

Phase II Field Study (2021 to 2024)

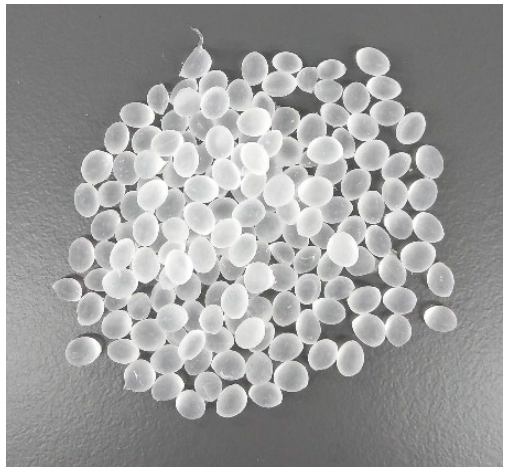
- Instrumented structural test sections with 5.5-inch AC over 6-inch aggregate base and subgrade
- PG 76-22 SBS control
- Dry-process RPM
  - SBS control + 0.5% PCR LLDPE (by weight of aggregate)



- 95% retained on #4 sieve
- Ash content: 0.4%
- melt flow rate: 2.5g/10-min at 190°C
- Crystallization onset temperature: 110°C
- Odor/fume potential: low (4.5 ug/g VOC)

Phase II Field Study (2021 to 2024)

- Instrumented structural test sections with 5.5-inch AC over 6-inch aggregate base and subgrade
- PG 76-22 SBS control
- Dry-process RPM
- Wet-process RPM
  - Same as control, except for using a PG 76-22 modified binder with 1.0% PCR LLDPE, 1.5% RET, and 0.32% PPA (by weight of virgin binder)



Dry-process RPM Mix

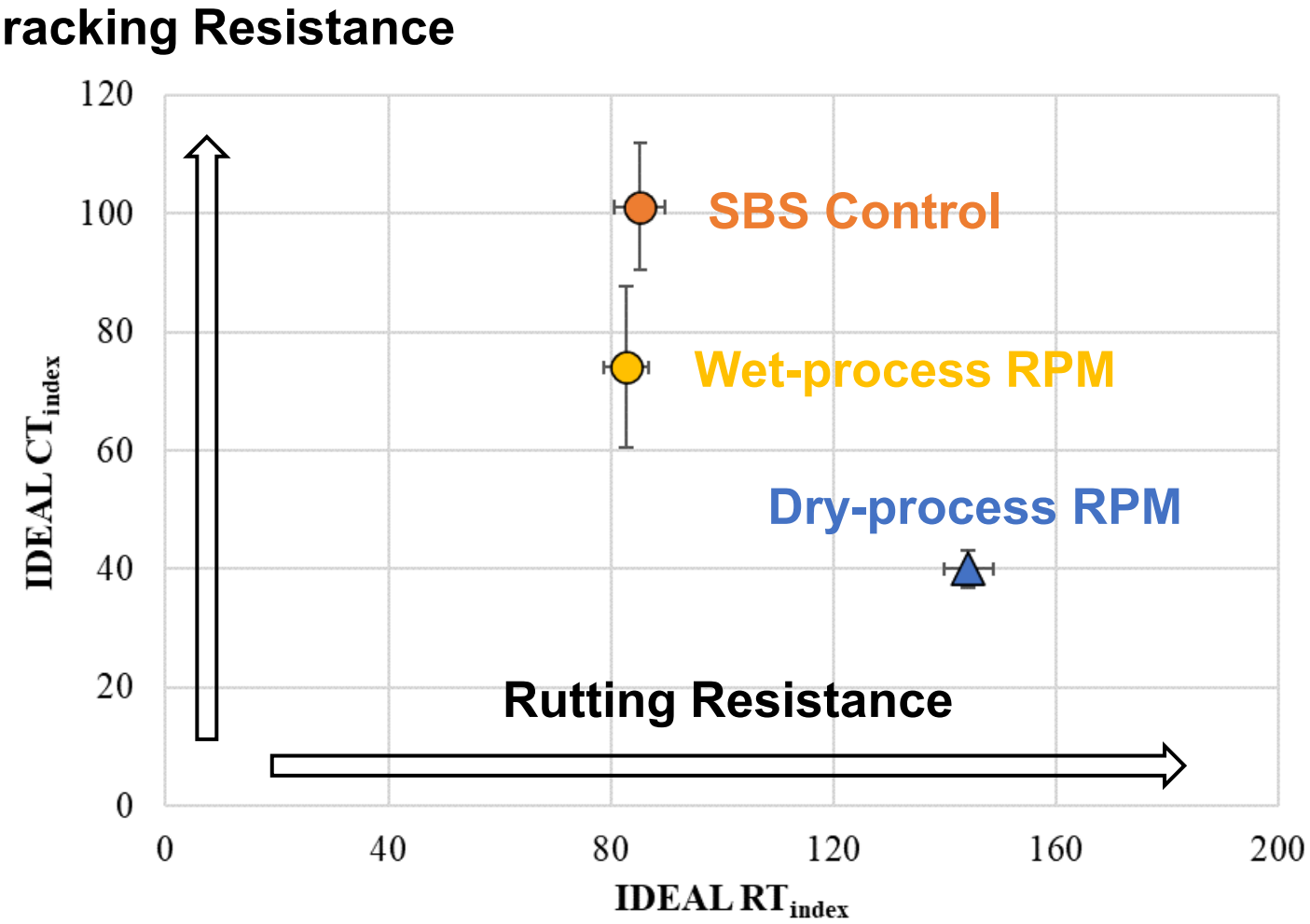






BMD Testing during Production

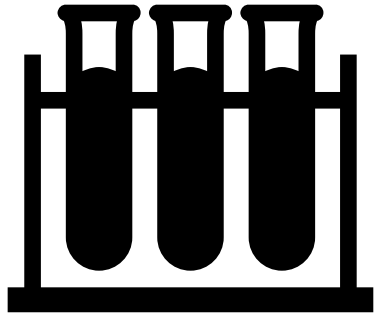
IDEAL-CT



IDEAL-RT

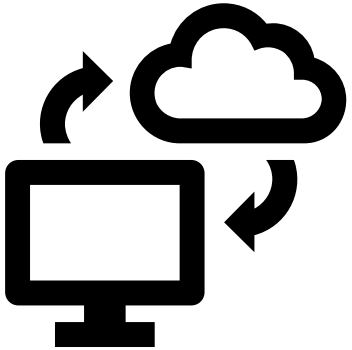
Performance Testing & Simulations

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



A comprehensive process to evaluate asphalt additives without test sections

- WESLEA
- Pavement ME Design
- FlexPAVE™



Field Performance after 4.5 million ESALs

- No cracking
- Minimal rutting (< 0.2 inches)
- Steady IRI
- Measured strains are high, so fatigue cracking is expected
- Corrected microstrain at 20°C
  - Dry RPM < SBS control < wet RPM

MnROAD AG Experiment

- BOB (bituminous over bituminous) test sections
  - 2-inch AC over 4.0-inch milled AC with full-depth transverse saw cuts
- PG 49-34 unmodified control
- PG 58H-34 SBS control
- Dry-process RPM
  - Unmodified control + 0.5% PCR LLDPE by weight of aggregate
- Wet-process RPM
  - Same as both controls, except for using a PG 58H-34 modified binder with 1.1% PCR LLDPE, 1.4% RET, and 0.4% PPA (by weight of virgin binder)
- Construction completed in July 2022
- Comprehensive lab & field testing underway

Summary

- Significant research efforts ongoing – most on performance characterization and microplastics
- Lessons learned…
  - Much more complicated than “it’s just plastic”
  - Some plastics having high odor/fume potential
  - Challenging to maintain storage stability
  - Improved rutting resistance, reduced cracking resistance
  - Feasible to design good-performing RPM mixtures, but cost-effective?
  - Microplastics not likely an issue
- Many knowledge gaps remaining – plastic sourcing & characterization, re-recyclability, LCA, long-term field performance, etc.

Thank You

Questions?

f-yin@auburn.edu

National Center for Asphalt Technology
NCAT
at AUBURN UNIVERSITY

March 15, 2023

The Jury is Still Out

Live Labs – CCC Plastic Roads

Matt Waning – Project Manager, Cumbria County Council

Orlando Walters – Project Manager, WSP

Cumbria Live Labs Project

Map data © 2023 Google, GeoBasis-DE/BKG (©2009)

Live Labs Programme

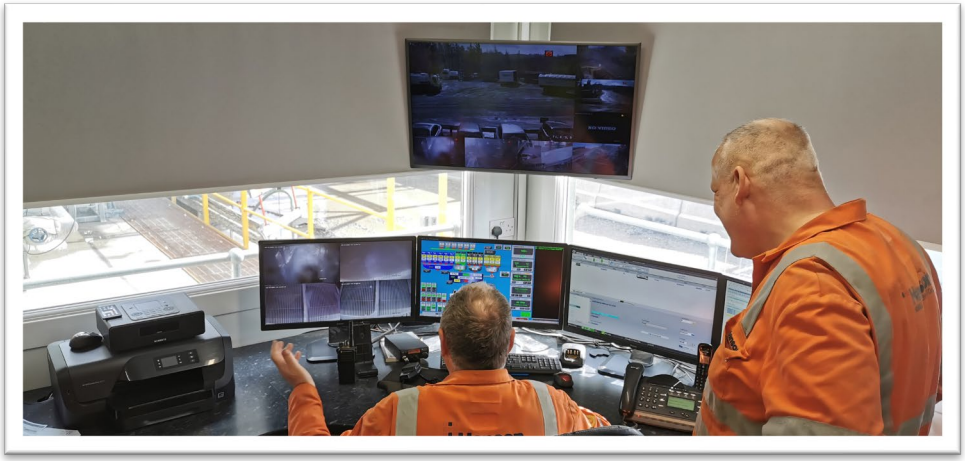
- The **ADEPT SMART Places Live Labs Programme** is a two-year, £22.9m project funded by the Department for Transport (DfT).
  - Buckinghamshire
  - Bedfordshire
  - **Cumbria (CCC)**
  - Kent/Staffordshire
  - Reading
  - Solihull and Birmingham
  - Suffolk

Cumbria Live Labs Project – Aims

- Investigate the sustainability and suitability of utilising a waste plastic additive
- Determine benefits of adopting ‘plastic roads’ as a standard design

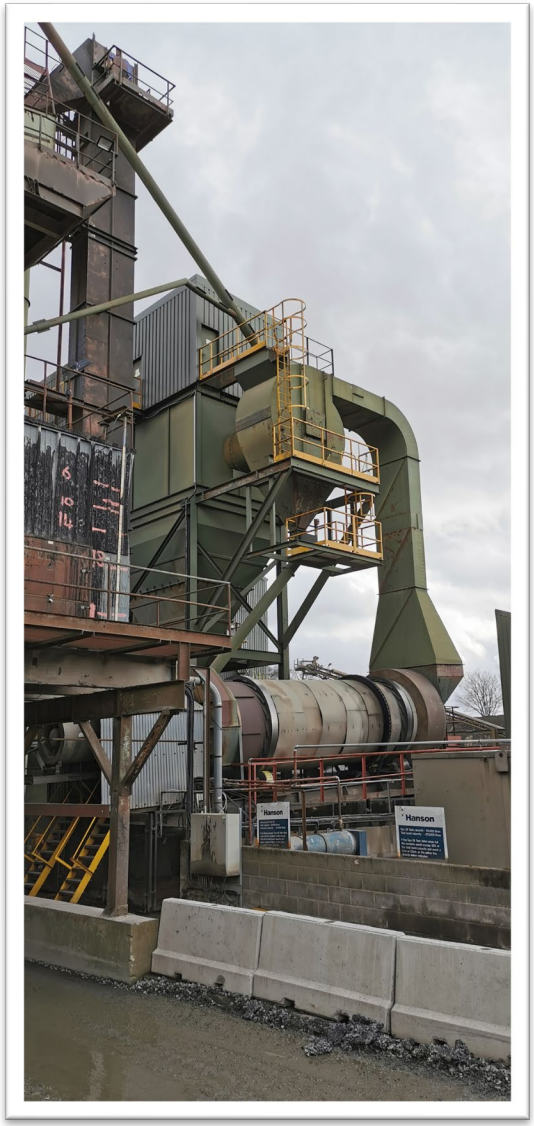
Detailed Project Objectives

- Can plastic additives can provide a more resilient road network whilst conveying a local waste for local roads ethos?
- Investigate positive benefits such as reduced construction depth.
- Determine the optimum pavement design /specification when plastic additive is used.



Detailed Project Objectives

- Investigate workability of material.
- Determine financial benefits
- Produce a business case to adopt a circular economy of waste and construction.



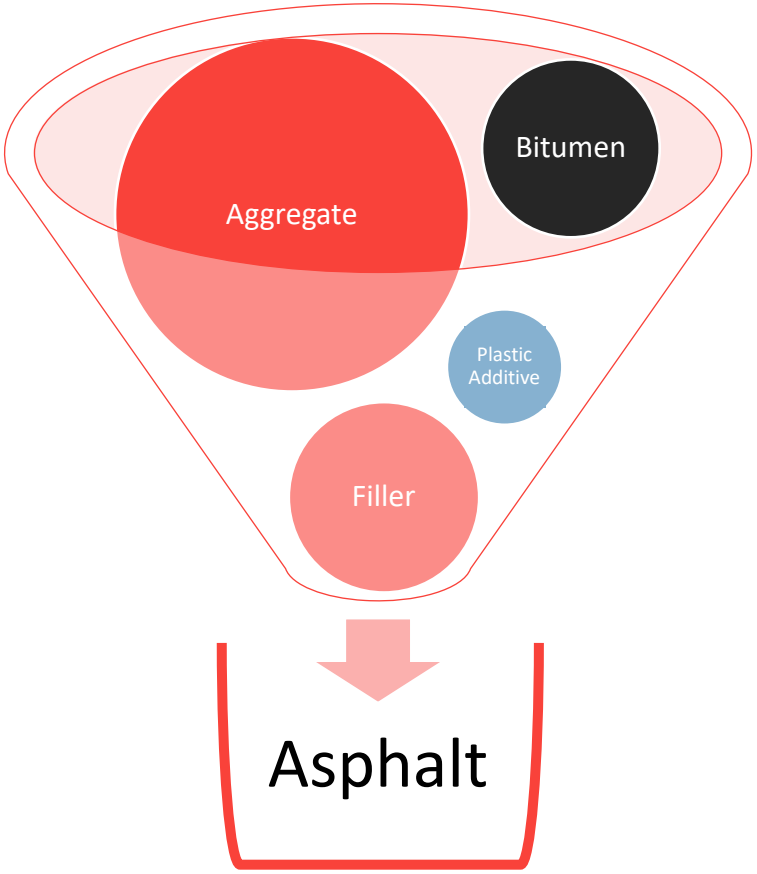
Detailed Project Objectives

- Ensure that the use of plastic in asphalt does not pose a risk to the environment or people.

- Develop partnerships across other highways authorities where plastic additives have been used.

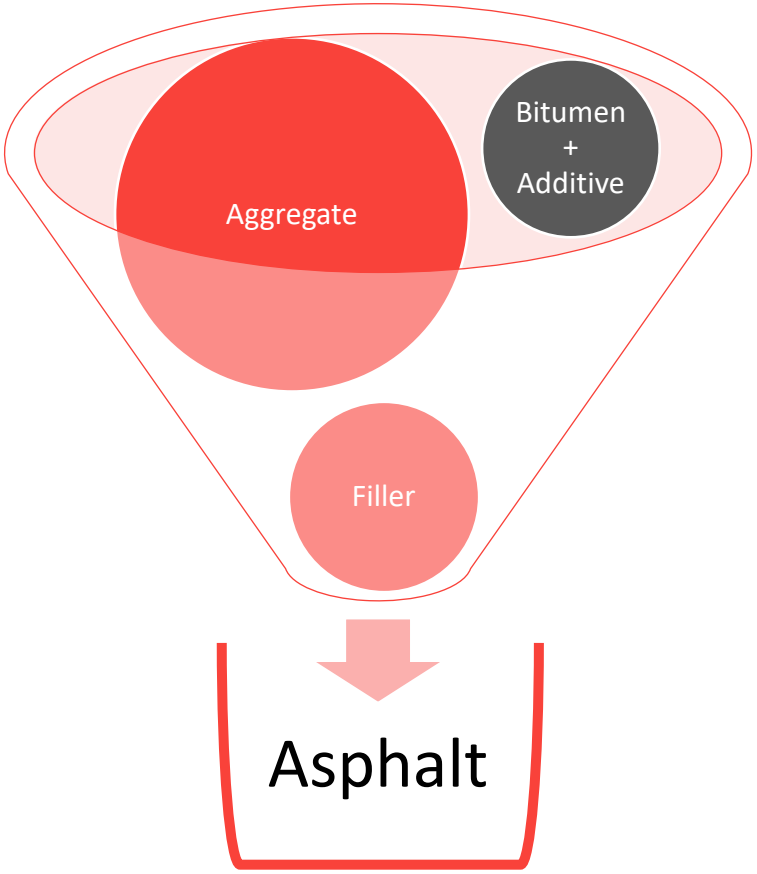
Development in Project Brief

- Originally examining “dry process” plastic additives.



Development in Project Brief

- Extended to incorporate a “wet process” plastic additive pre-blended into bitumen



New additive – Wet Process

- End of life plastic waste
- Processed using a patented catalytic depolymerisation process to produce waxy substances
- Potential for better miscibility in bitumen than unprocessed plastic creating stable bitumen products
- Added benefit of lowering asphalt production and laying temperatures
- Enabling CO_2 reduction in asphalt production

Initial steps

- Reviewed large body of technical reports, papers and data
- Undertook gap analysis
  - Trials of dry process additives often lack detailed technical information
  - No control sections
  - Laboratory trials based around “wet mixing” process rather than “dry mixing” actually used at full-scale
- Developed a Trial Site selection process

Material types and additives

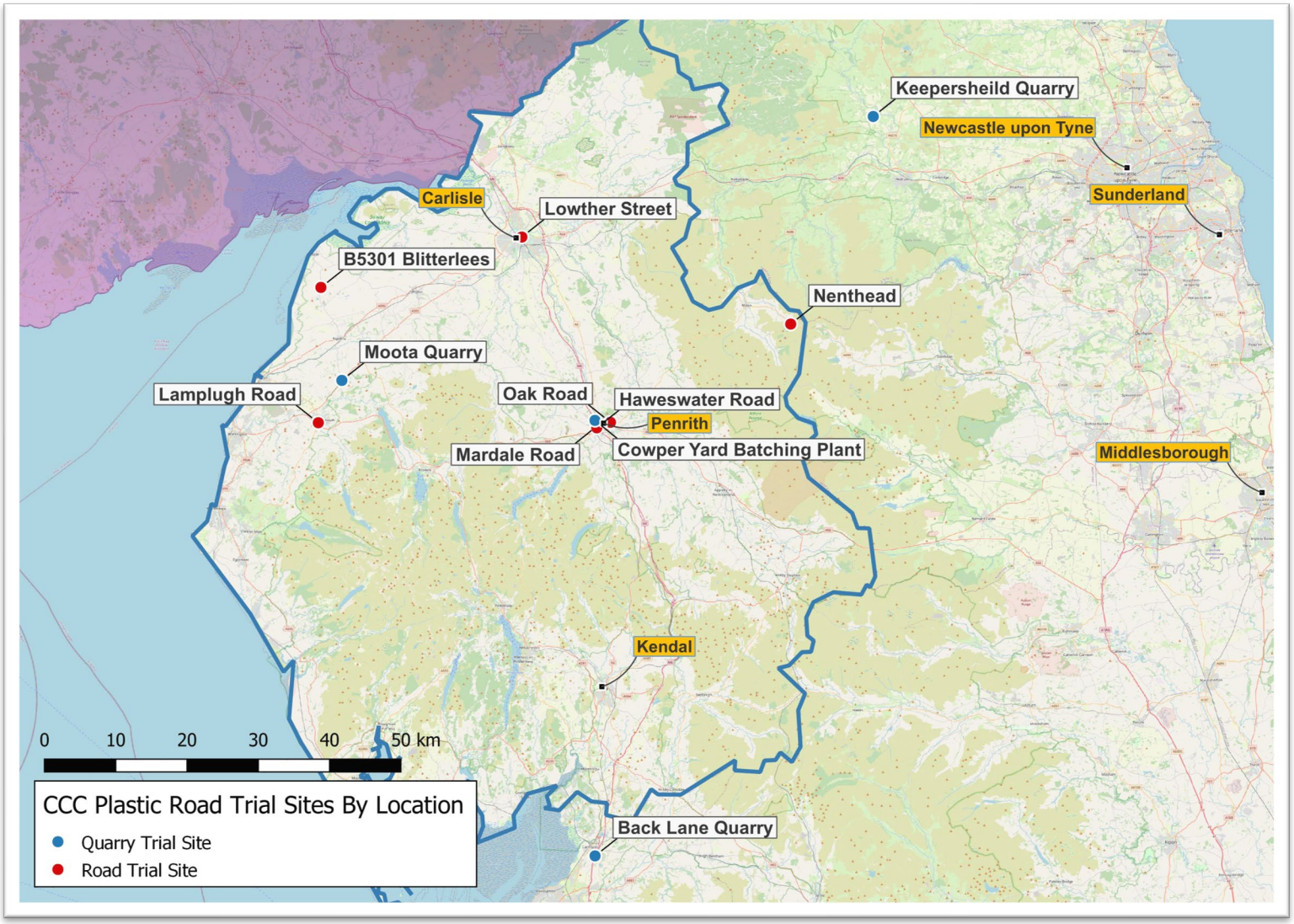
- 3 additives installed in Trials:
  - **Additive 1:** Dry process additive, marketed as an alternative to PMBs for TSCS and performance HRA
  - **Additive 2:** Dry process additive, marketed as bitumen extender for all asphalt materials
  - **Additive 4:** Wet process modified bitumen marketed as a ‘Warm Mix’

* Including a trial of very thin material (25mm)

Site Trials

- Essential to incorporate a control
- Multiple site parameters to consider –
  - trafficking volume
  - speed
  - urban/rural
  - exposed/sheltered,
  - mainline/junctions
- Dry Process 7 trials (4 road and 3 quarry)
  - (Additive 1 and 2)
- Wet Process 5 trials (4 road and 1 quarry)
  - (Additive 4)

Trial Locations



Design of Site Trials

- Pre-construction condition information provided obtained before road trials constructed
- Control sections created to enable performance comparisons, and allow a future monitoring
- Standard compliance tests were conducted
- Additional laboratory testing of mixtures from quarry trials
- Mixture samples collected for “Blind” specialist testing at University of Nottingham (Prof Gordon Airey)

Testing

- Mixture Testing:
  - Grading / Binder content
  - Voids
  - Wheel Tracking
  - Stiffness

- Binder Testing (Rheology)
  - Empirical: penetration, softening point viscosity.
  - Dynamic Shear Rheometer (DSR).
  - High temperature flow properties (MSCR) Test).
  - Intermediate temperature fatigue properties (LAS).
  - Intermediate temperature fracture strength and cracking resistance (DENT).
  - Low temperature stiffness, stress relaxation and cracking resistance (BBR)

What was Learnt – the good

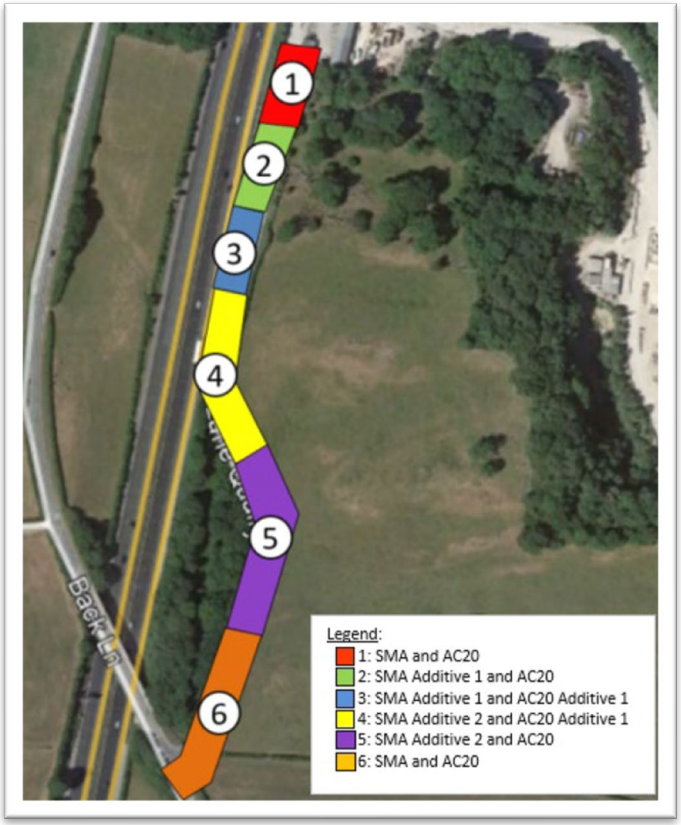
- Road trials have proved to be an excellent way to evaluate performance of new materials
- In two years, new ideas have come along and were included where possible
- All our Live Labs project partners shared an appetite to be innovative and push boundaries
- Impartial research

What was Learnt – the challenges

- Legal and procurement challenges
- Being respectful of pressures faced by a commercial partner organisation
- The importance of clear communication with all partners
- International Literature review highlights more research required

Successes

- Delivery of a fully independent research project
- Working with Live Labs nationally has helped with decarbonisation goals and established networking partnerships
- Funding secured for future years monitoring and testing



Conclusions

- Successfully installed 7 highway trials with control sections
- No significant performance issues to date
- Potential issues were identified with introducing “dry process” additive
- Challenges with identifying locally sourced plastic waste within trials due to confidentiality/NDAs
  - Possible H&S issues with dry process plastic additives
  - Concerns over potential presence of PVC
  - Ensuring that Material Safety Data Sheets are comprehensive and accurate

Conclusions

- Results from material testing:
  - General increase in stiffness but also increased range in stiffness distribution
  - Rheological testing does not explain the increased mixture stiffness
  - Does not exhibit the behaviour traditionally seen for a bitumen that has been polymerically modified.

Recommendations

- Further testing required to assess the degree of dispersion.
- Monitor performance of trial sites

Questions?

Our final report is published on the Adept website:

https://www.adeptnet.org.uk/cumbria-live-lab-plastic-additives-asphalt

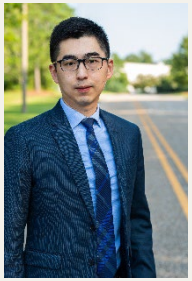
Today's presenters

Ben Cox
benjamin.c.cox@usace.army.mil

ERDC
ENGINEER RESEARCH & DEVELOPMENT CENTER

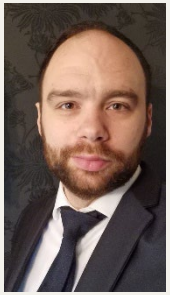
Richard Willis
rwillis@asphaltpavement.org

NAPA



Fan Yin
fzy0015@auburn.edu

National Center for Asphalt Technology
NCAT
at AUBURN UNIVERSITY



Matthew Waning
Matthew.Waning@cumbria.gov.uk

Cumbria
County Council

Orlando Walters
Orlando.Walters@wsp.com

wsp

NATIONAL ACADEMIES
Sciences
Engineering
Medicine

Upcoming events for you

March 30, 2023

TRB Webinar: Successes & Challenges—The First 4 Years of Federal Performance Management

April 4, 2023

TRB Webinar: Performance of Concrete Overlays on Asphalt Pavement

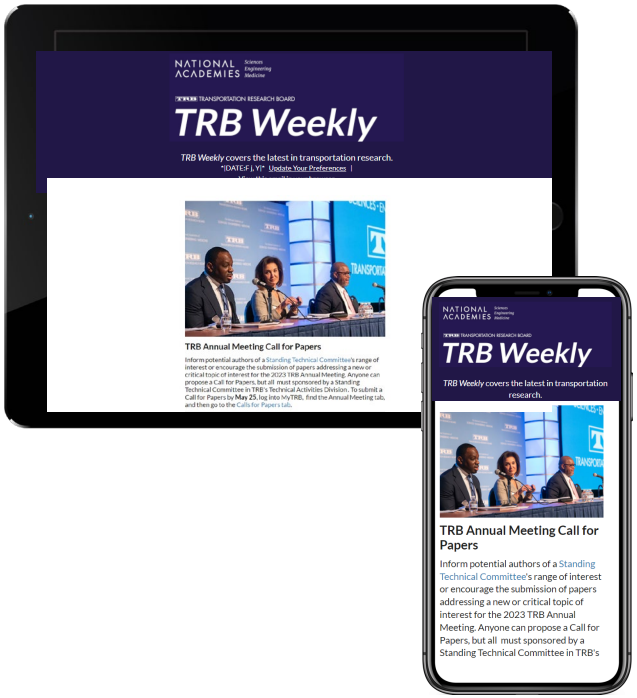
https://www.nationalacademies.org/trb/events

Subscribe to *TRB Weekly*

If your agency, university, or organization perform transportation research, you and your colleagues need the *TRB Weekly* newsletter in your inboxes!

Each Tuesday, we announce the latest:

- RFPs
- TRB's many industry-focused webinars and events
- 3-5 new TRB reports each week
- Top research across the industry



Spread the word and subscribe!
https://bit.ly/ResubscribeTRBWeekly

Discover new TRB Webinars weekly

Set your preferred topics to get the latest listed webinars and those coming up soon every Wednesday, curated especially for you!

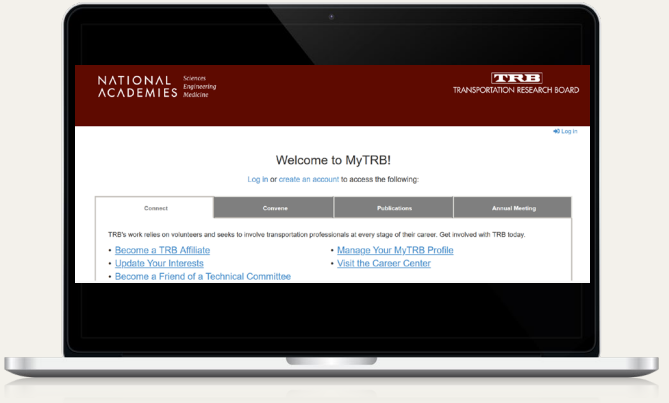
https://mailchi.mp/nas.edu/trbwebinars

And follow #TRBwebinar on social media

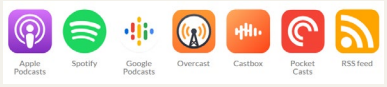
@NASEMTRB
@NASEMTRB
Transportation Research Board

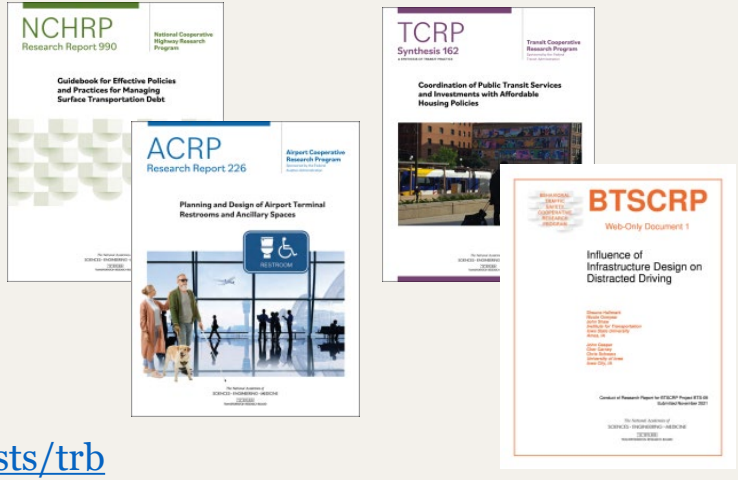
Get involved

https://www.nationalacademies.org/trb/get-involved



- **Become a Friend of a Standing Technical Committee**
  Network and pursue a path to Standing Committee membership
- **Work with a CRP**
- **Listen to our podcast**

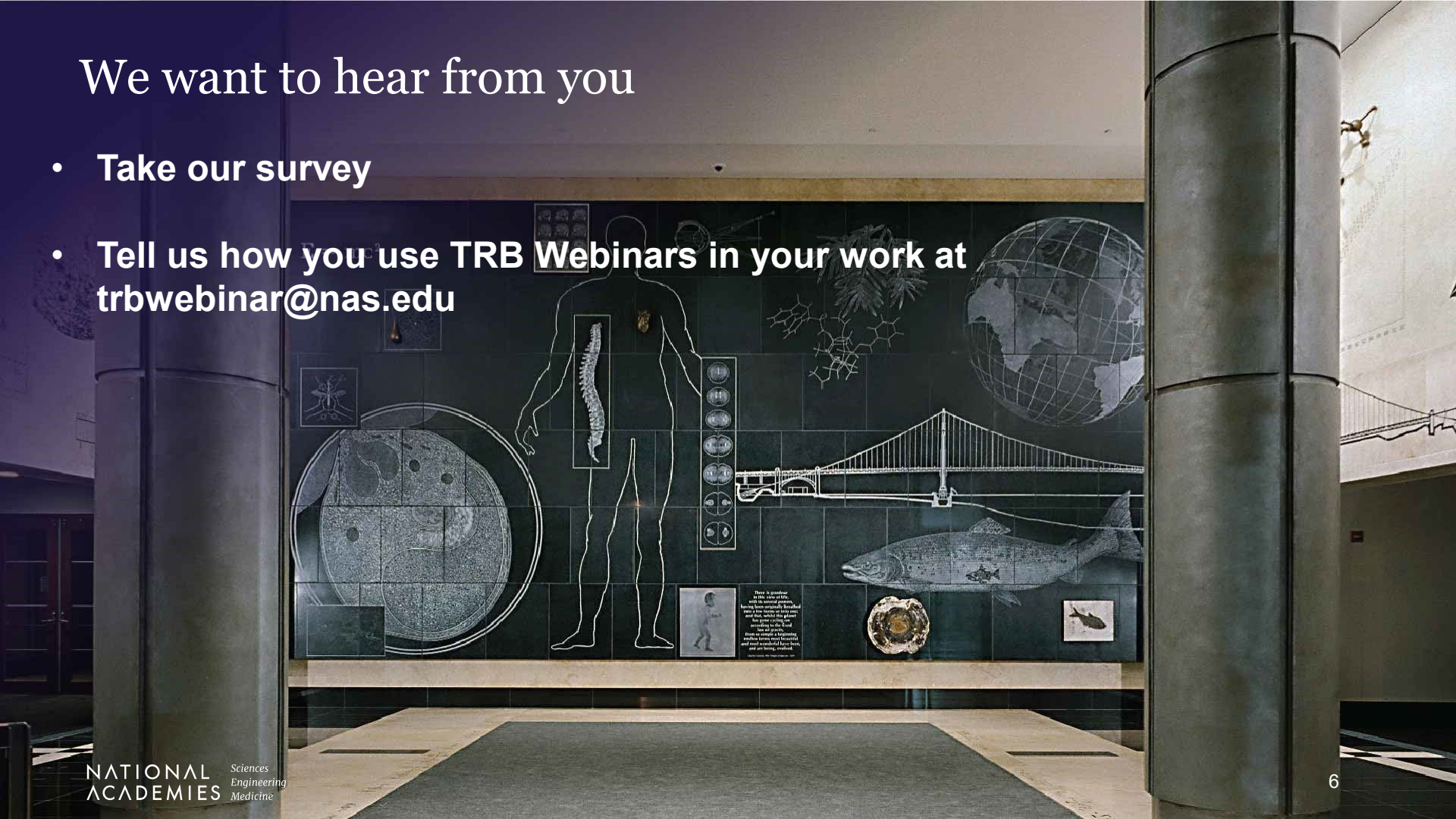




https://www.nationalacademies.org/podcasts/trb

We want to hear from you

- **Take our survey**
- **Tell us how you use TRB Webinars in your work at trbwebinar@nas.edu**



NATIONAL ACADEMIES Sciences Engineering Medicine