RMA: State-of-Knowledge and Specification Landscape

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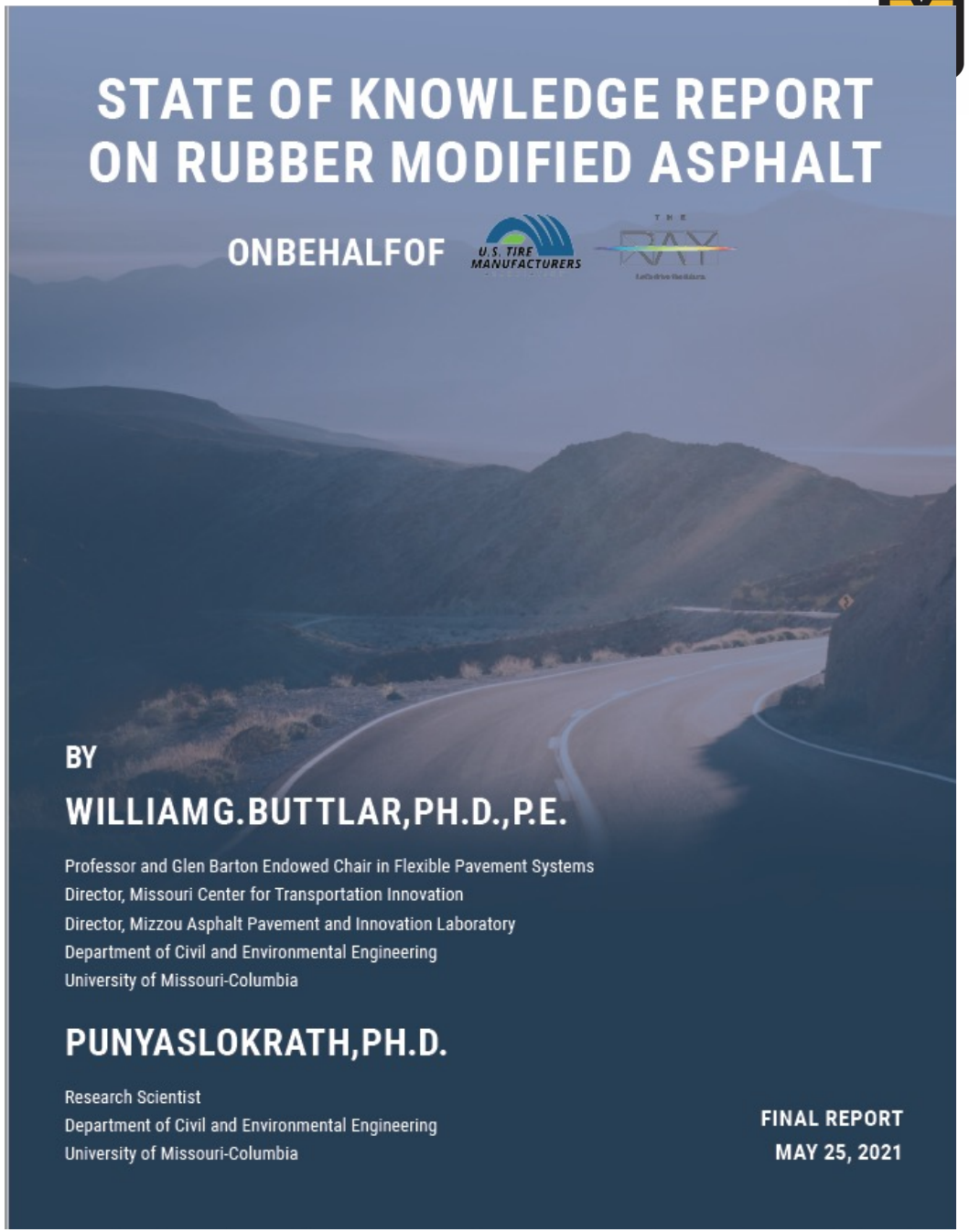
University of Missouri

RMA SOK Study

- Conducted at the University of Missouri-Columbia in Partnership with USTMA and The Ray
- Over 300 Articles Reviewed
- Survey of State Highway Agencies Conducted
- Peer-reviewed by Panel of Experts from Academia, Industry and Various State and Federal Agencies
- SOK Report Aggregates Knowledge and Identifies Gaps



Terminal Blend

vs.

Wet Process

vs.

Dry Process

Terminal Blend

Wet Process

Both require care and expertise in storage and handling to avoid settlement, clogging, and proper mixing (shearing, time, temperature)

Dry Process

ENGINEERED
CRUMB RUBBER

SHIPPED IN BULK
BAGS

TRANSPORTED TO FEEDER

MODIFIED FIBER MACHINE

INJECTED THROUGH RAP COLLAR

Requires care and expertise in mix design, plant feeding, silo storage (time for uptake of binder and swelling of rubber)

Dry Process RMA

- After ISTEA mandate (USA, 1990s), common perception is that rubber modification doesn't work
- Why?
  - Bad Engineering Rollout
    - Failure of PlusRide-era projects
    - Failure to understand/control wet process technology
  - Lack of clear process controls
    - Oversized rubber grains
    - Poor process temperature control
  - Unfavorable economics

Modern Dry Process RMA

- Use of much finer grains, -30 mesh (<0.600 mm)
- Chemical modification to increase binder uptake
- Workability additives
- ASTM and ISO certified process controls to produce consistent rubber grains
- One of the most common dry process RMA products used in US right now is **Engineered Crumb Rubber (ECR)**
  - >8 million tons of asphalt mix on ground
  - Shows comparable performance to polymer-modified mixes (next slides)

SOK Executive Summary – RMA Benefits

Environment/Sustainability

- Reduces Environmental Impact
  - CO_2 Emission (-34%)
  - Ozone Depletion (-38%)
  - Human Toxicity (-27%)
  - Water Depletion (-30%)
- Reduces Leaching Potential (-85%)
- Reduces Tire Tread Emissions
- Reduces Roadway Noise, Rolling Resistance (Saving Fuel)

Performance/Safety

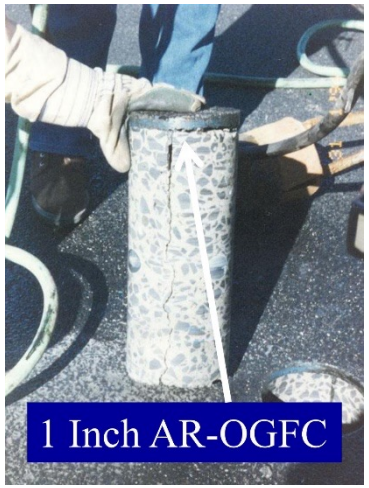
- Extends Pavement Life
  - Reduced Cracking
  - Reduced Rutting
  - Up to 2X Life Extension
- Improved Tire Grip (Skid Resistance)
- Improved Pavement Smoothness
- Often Used in Open-Graded Friction Courses, Safer for Travel during Heavy Rain Events

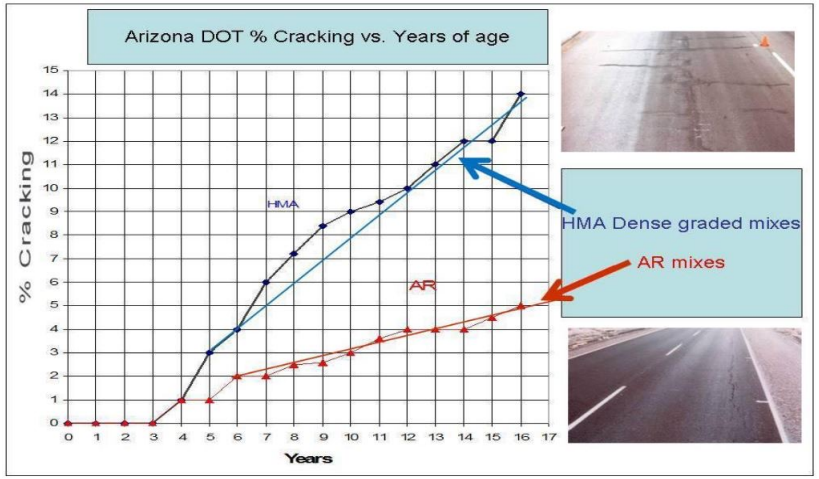
Economics

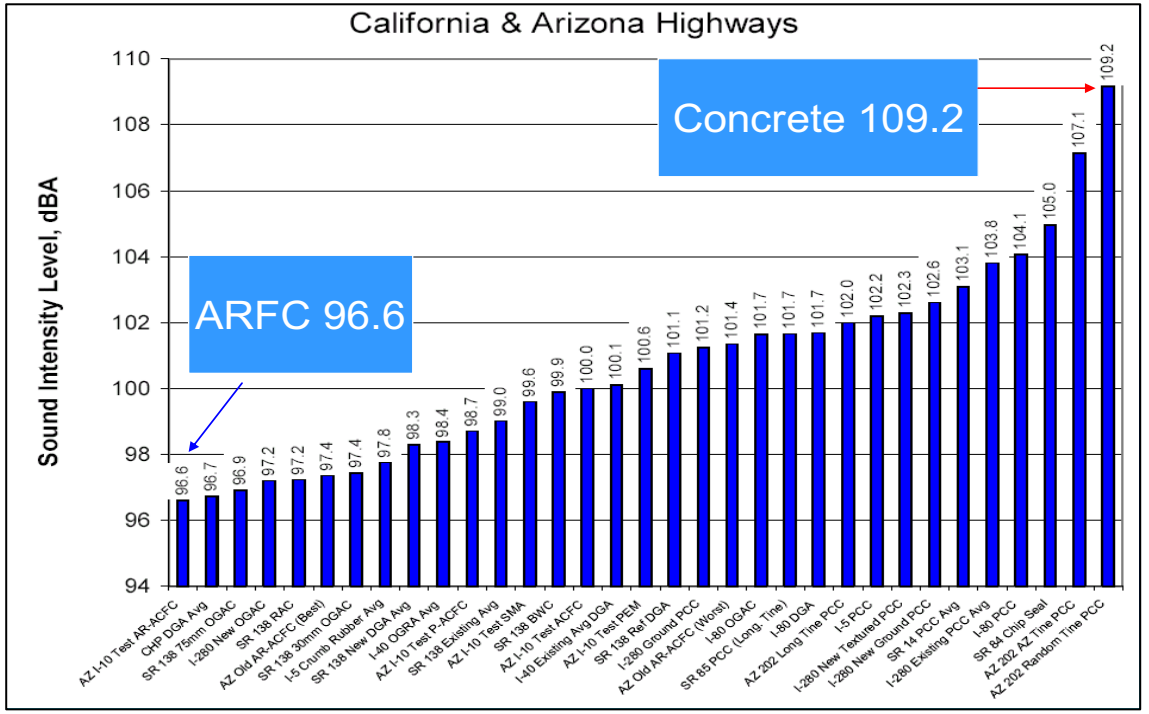
- Dry Process is Less Expensive than Traditional Polymer-Modified Asphalt, w/ Comparable Performance
- Thinner Designs Provide Comparable Performance to Traditional Asphalt, at Lower Cost (40-50% Reduction)

RMA - Performance

- RMA is able to provide performance and functional benefits including **longer service life**, **lower noise**, and **better ride** quality, and **increased skid resistance**





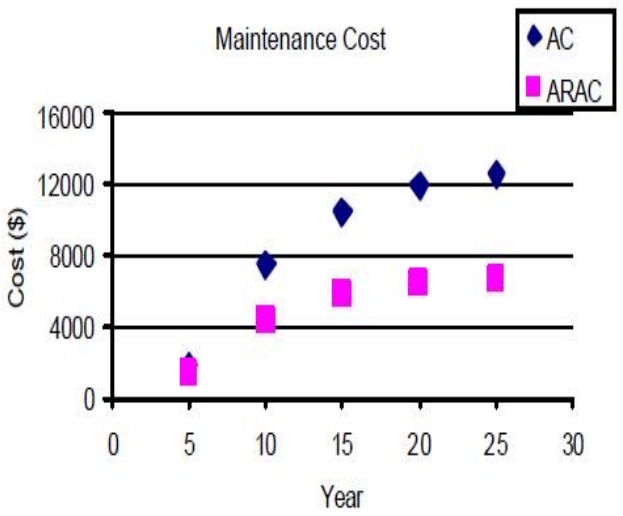


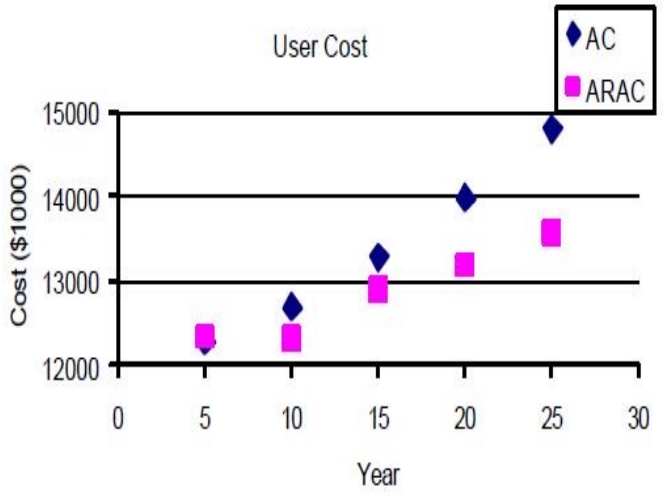
RMA Performance Benefit Examples:

- 85% reduction in rut depth (Vahidi et al. 2014)
- Up to 12 dB reduction in noise (Way 2012)

RMA - Economics

- **Heavy traffic applications**: Modern RMA mixtures are **less expensive than polymer-modified asphalt mixtures** and provide **comparable performance**
- **Light traffic applications:** Life cycle cost studies generally find RMA to be **more cost effective than conventional mixtures**





RMA Economic Benefit Examples:

- 43% savings in life cycle cost (Buttlar and Rath 2020)
- 40% savings in maintenance costs (Jung et al., 2002)

RMA – Environment and Sustainability (1/3)

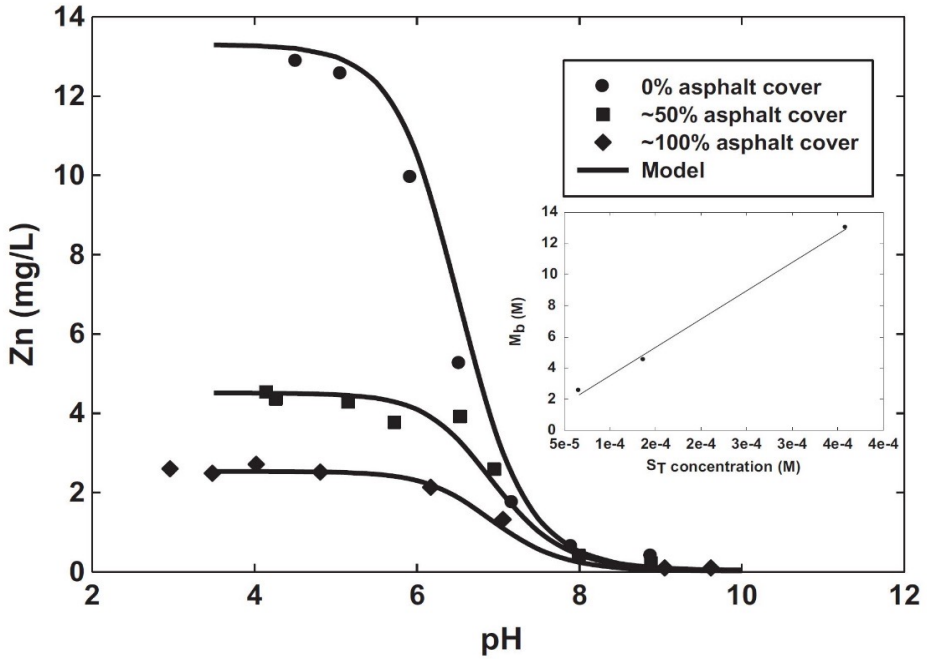
- The most comprehensive LCA studies show **reductions in environmental impact when using RMA**, ~30% reduction
- A research gap still exists in this area – more emphasis on **consequential** Life Cycle Analysis (LCA) studies is needed. Most studies in the literature are based on more limited, **attributional** LCA frameworks.

Impact category	Impact of Rubberized road with respect to Conventional road
Climate change (kg CO_2 eq)	-34%
Ozone depletion (kg CFC-11 eq)	-38%
Human toxicity (kg 1,4-DB eq)	-27%
Photochemical oxidant form. (kg NMVOC eq)	-34%
Terrestrial acidification (kg SO_2 eq)	-35%
Freshwater eutrophication (kg P eq)	-20%
Terrestrial ecotoxicity (kg 1,4-DB eq)	-37%
Freshwater ecotoxicity (kg 1,4-DB eq)	-26%
Water depletion (m^3)	-30%
Fossil depletion (kg oil eq)	-37%

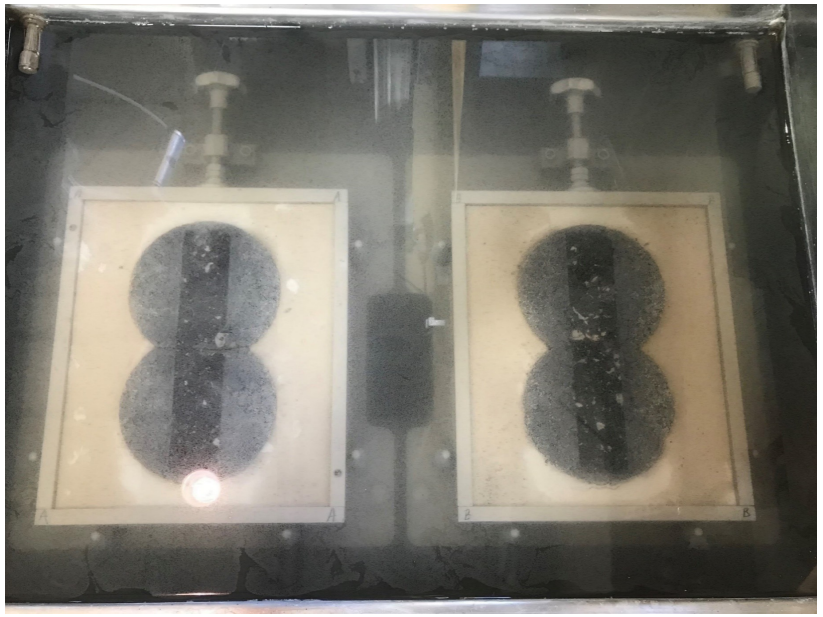
Bartolozzi et al., 2015

RMA – Environment and Sustainability (2/3)

- Entombment of rubber particles in asphalt results in **significant decrease in leaching** ~85% reduction
- Research gaps exist in this area
  - A number of the reported leaching studies are ~ 20 years old; field validation studies are needed
  - Microparticle release from RMA is thought to be very limited, but needs to be verified experimentally



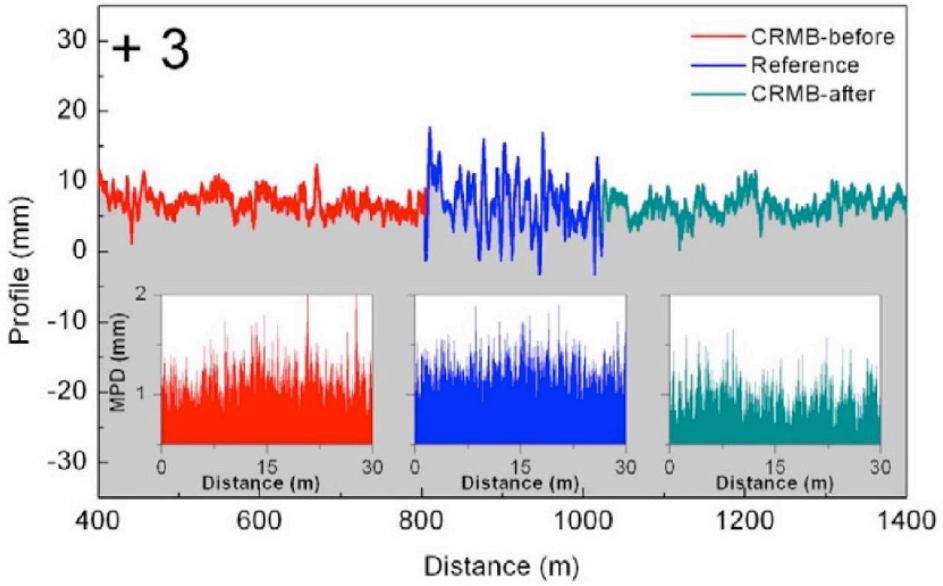
Liu et al., 2018



Microparticle analysis in accelerated wheel tracking test at Mizzou (Hamburg)

RMA – Environment and Sustainability (3/3)

- RMA results in smoother pavement surfaces over lifespan*, **increasing driver comfort** and **reducing vehicle repair costs**
- The smoother, stiffer, and more elastic surface of RMA is expected to **conserve fuel**
- Travel over gap-graded RMA leads to 1.4 to 2.0 times **reduced tire tread wear and tire particle emissions** as compared to driving on concrete (Allen et al., 2006)
- Research gaps in this area include need to quantify fuel savings for motorists and to quantify tread wear reduction for other RMA pavement types
- RMA also results in **higher skid resistance** compared to unmodified and polymer-modified mixtures (measured recently in Cooper County, MO)

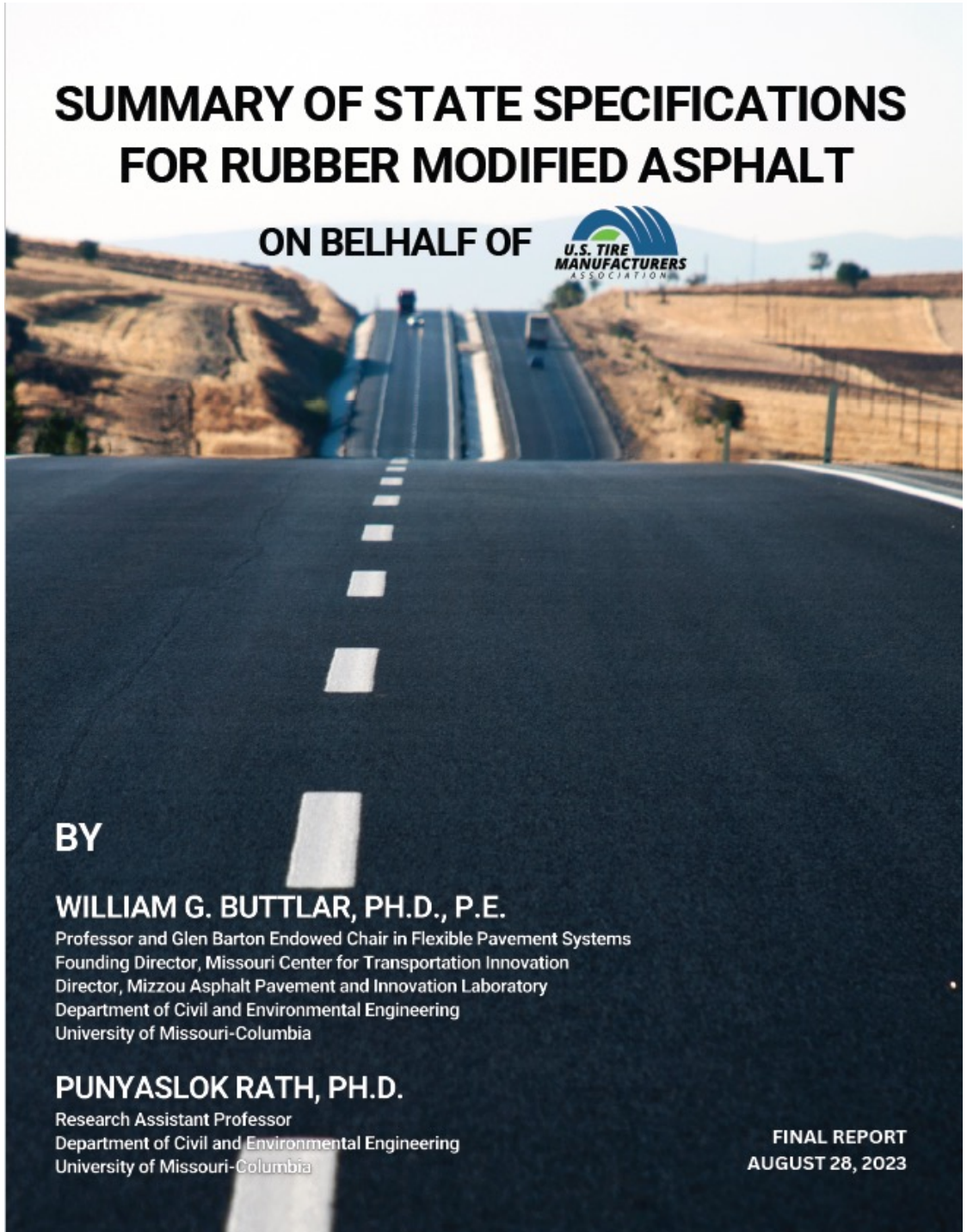


Vazquez et al., 2016

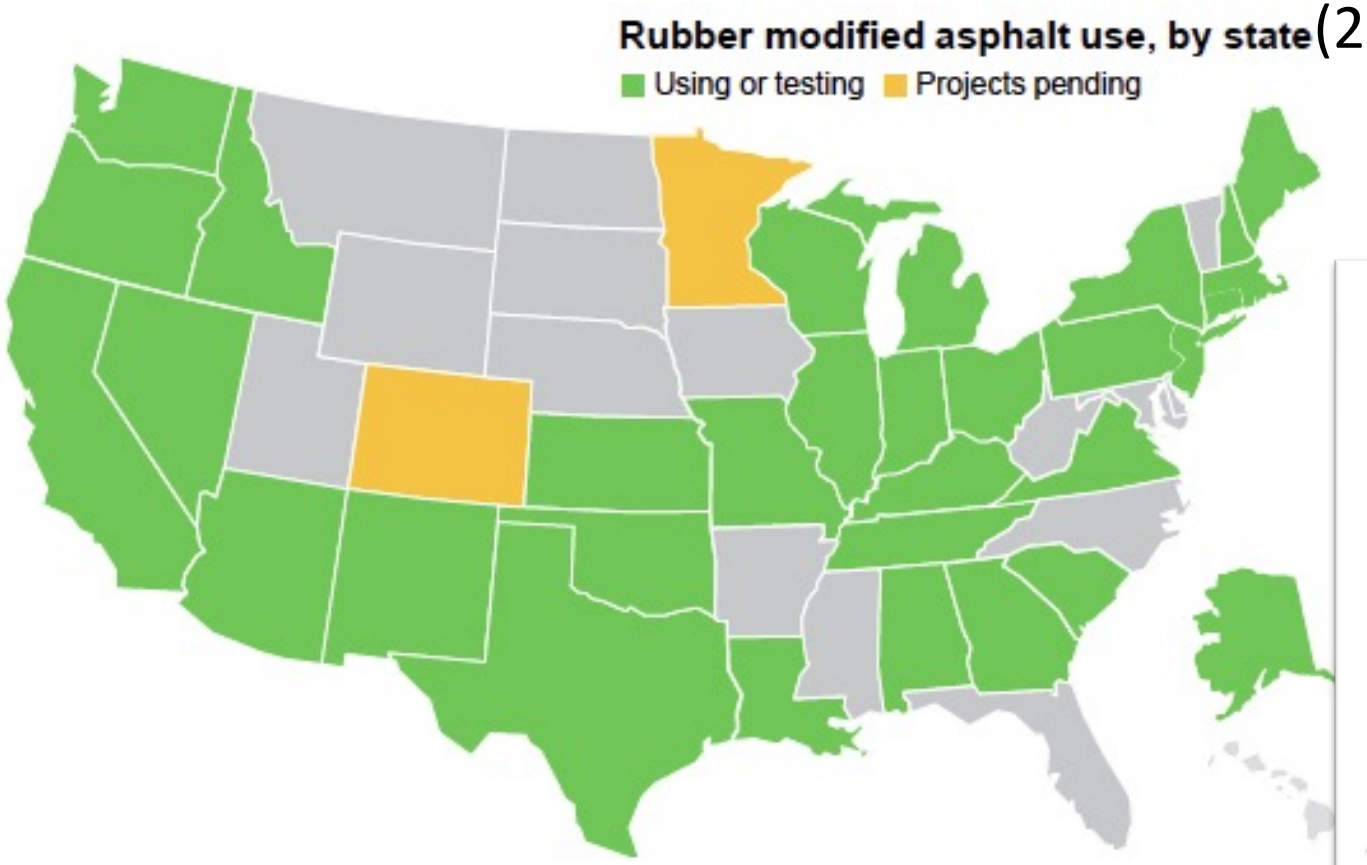
*Irfan et al. (2017); Irfan, Ali, Ahmed, & Hafeez (2018); Cooper et al. (2007); Willis et al. (2014); Vazquez et al. (2016)

RMA State Specifications Study

- Conducted at the University of Missouri-Columbia in Partnership with USTMA
- Survey of State Highway Agencies Conducted
- Literature Review of All 50 State Highway Agency, Public-Facing Online Specifications Reviewed
- Summarizes Publicly Available State Specifications Involving Wet and Dry Process GTR Pavements
- Identifies Gaps and Their Probable Causes
- Identifies Key Opportunities across US

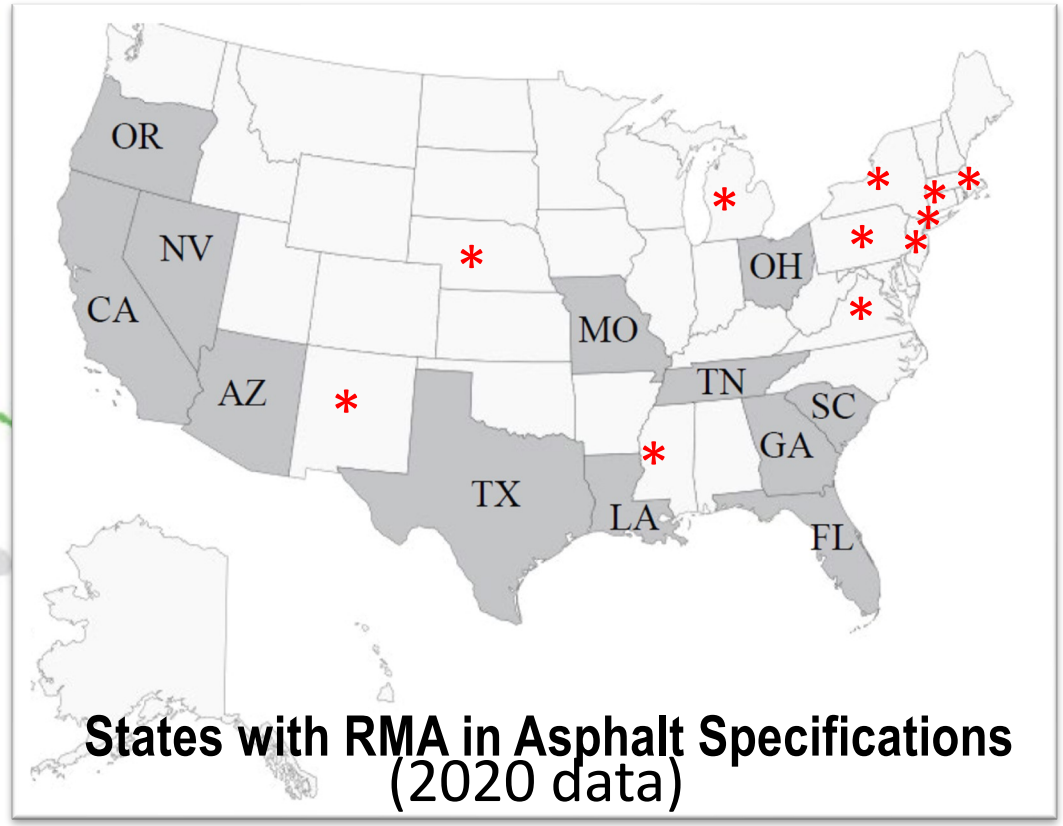


Previous Findings, RMA Usage Circa 2020



(2020 data)

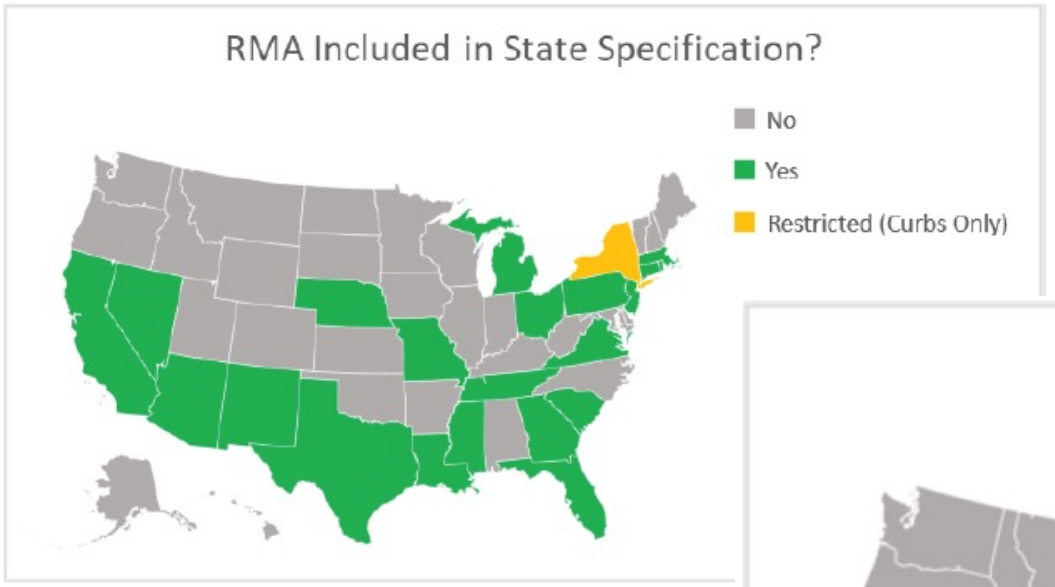
Newly Identified Specifications(*)

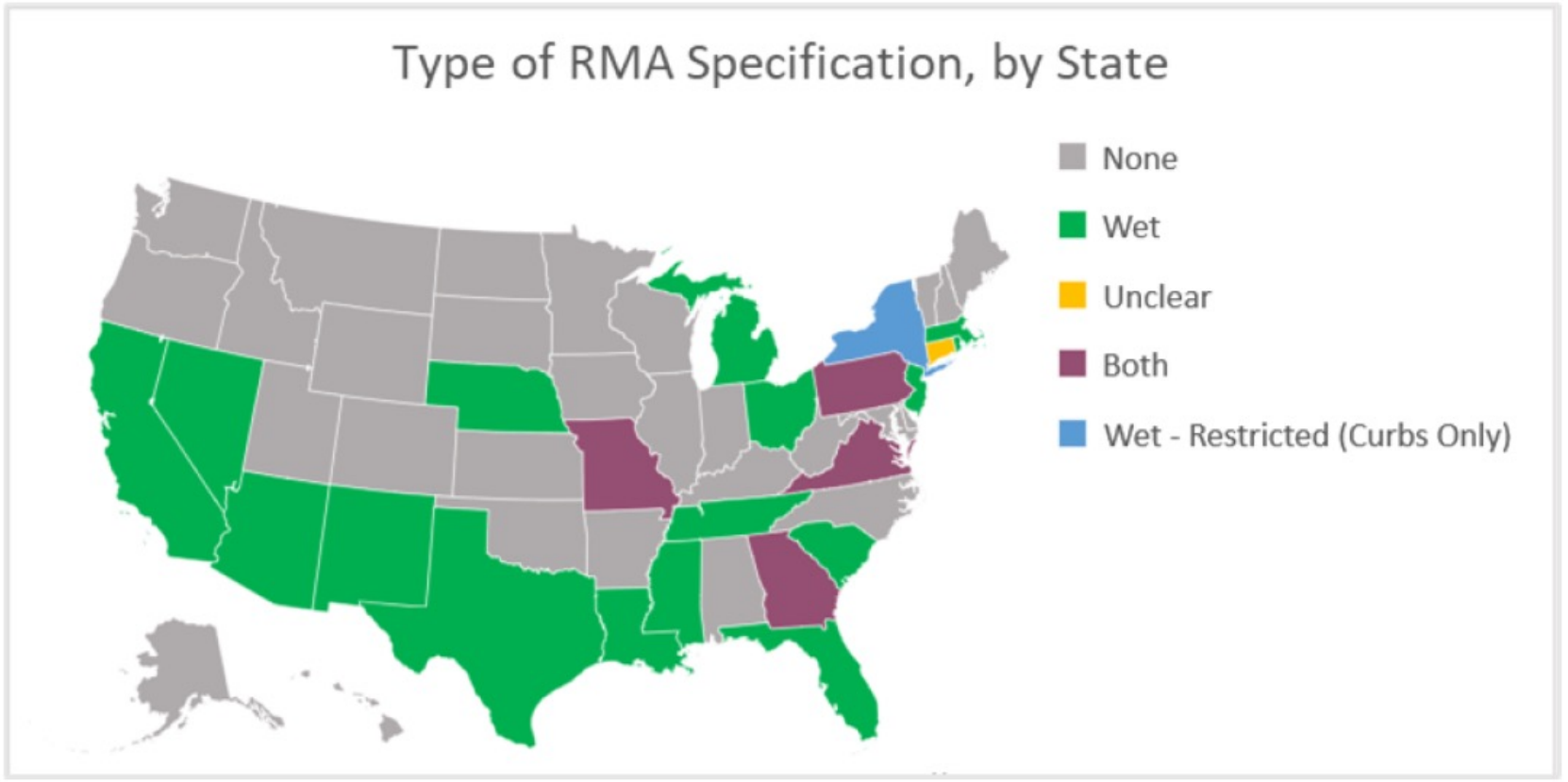


States with RMA in Asphalt Specifications
(2020 data)

Source: *Resource Responsible Use of Recycled Tire Rubber in Asphalt Pavements*, FHWA-HIF-20-043, 2020

State Specification Summary – As of 2023





RMA Spec Updates – SE USA (1 of 2)

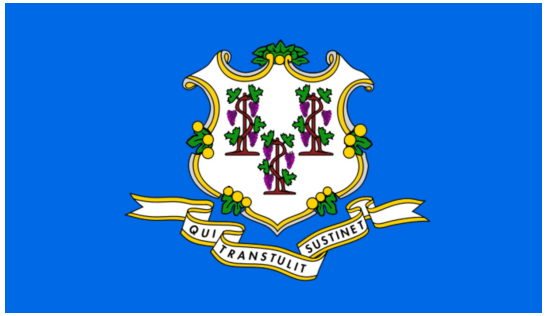
- **Virginia** - Provisional specifications for both dry and wet process RMA
- **Tennessee** - Allows use of terminal blend rubber (section 904.01)
- **South Carolina** – A supplemental specification took effect in Jan 2019 that includes an addendum to section 401.2.1.1 of their specification, entitled ‘asphalt binder *additives*.’ Only terminal blend GTR is allowed, at a minimum additional rate of 7% by wt. of binder. The spec also states that when GTR binder is being used in SMAs, fibers are not required.

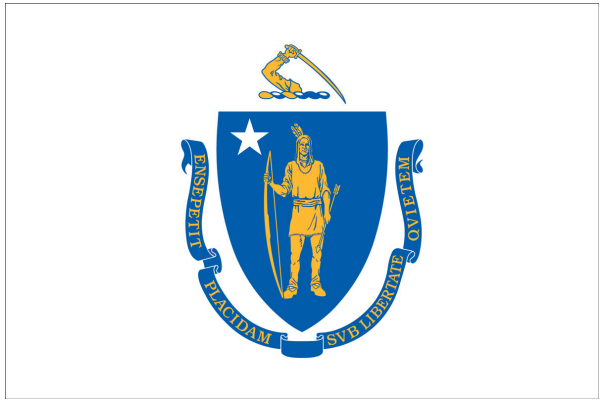
RMA Spec Updates – SE USA (2 of 2)

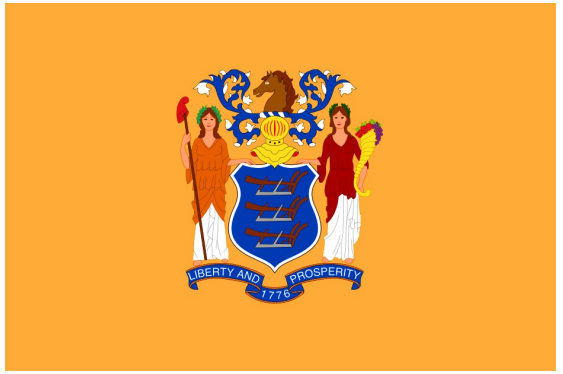
- **Georgia** - Crumb rubber is allowed in lieu of polymer modification. Both dry and wet process RMA is allowed (section 820)
- **Mississippi** - Terminal blend GTR allowed in lieu of polymer (section 702.08.3). GTR modified emulsified asphalt (cationic) also allowed (section 702.07.4).
- **Florida** - Section 919.2.2 states that GTR is allowed for use (‘asphalt rubber binder’). Pelletized asphalt rubber is permitted as well for binder modification.

RMA Spec Updates – NE USA (1 of 2)

- **Connecticut** - Addition of crumb rubber allowed in bituminous concrete (section 4.06.02), but material specifications in section M.04 state that polymer modified binder can solely be modified with SBS. No other mention of crumb rubber in material specification.
- **Massachusetts** - Allows use of asphalt rubber (>15% by weight of binder) in gap-graded mixtures, and in SAMIs; see M.03.01 B.
- **New Jersey** - Allows wet process modification of asphalt binder with GTR to be used in their specified AR-OGFC mix. See 902.07. The spec has extensive guidelines on blending (section 1009.03).

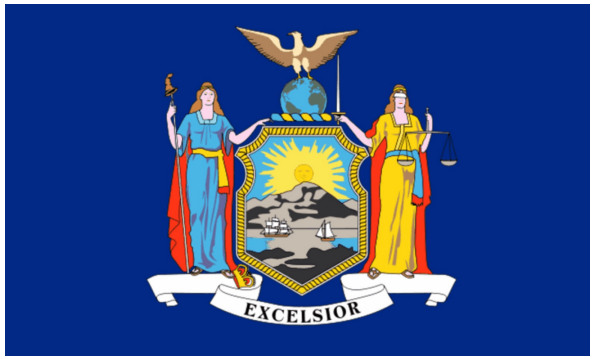


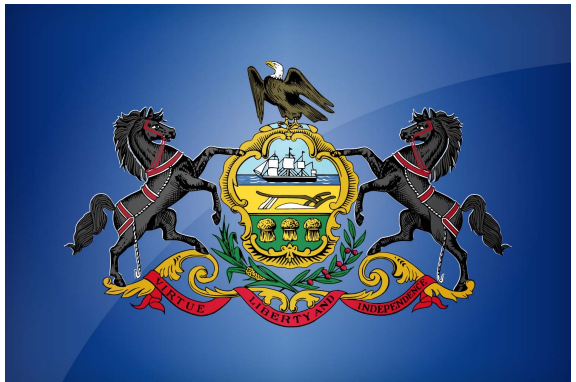




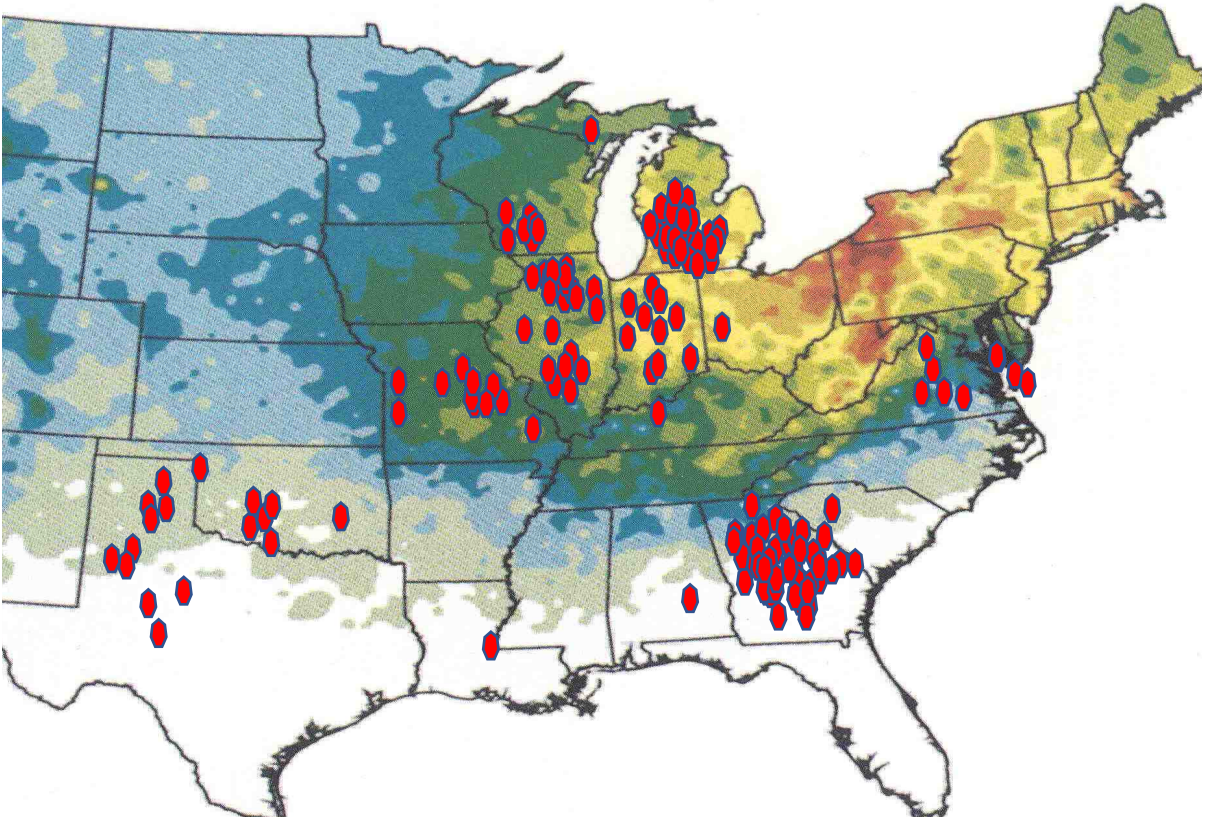
RMA Spec Updates – NE USA (2 of 2)

- **New York** - Allows use of coarse recycled tire rubber only in HMA curbs (Section 714-06).
- **Pennsylvania** - Allows Crumb Rubber as 'stabilizers' in SMA mixtures (along with cellulose fibers, mineral fibers), section 419.2. 0.3 , where 1.0% CR by mix weight is allowed. PennDOT has ***special provisions*** for ***dry and wet process rubber*** use in asphalt mixtures (c04481 ITEM 9448 and c04491 ITEM 9449, respectively)
- **Rhode Island** - Allows thin overlays with wet process RMA (PG76-34), via section 411.02.1. Sec 411 describes a paver-placed elastomeric surface treatment or PPEST, which is a 1" thin overlay, gap graded, 3/8" nominal max aggregate size.





Modern Dry Process RMA Footprint: USA and EU (~2022)



- Wide array of mix designs in wide array of climates
- Good performance and lower investment cost

Image Credits: Asphalt Plus LLC. website. Note: the images on the right are modified to show various modern dry process products such as ECR and RARX

Key Findings – State Specs Summary

- 21-of-50 states have some form of published RMA specification (i.e., wet and/or dry process specifications)
- A number of the states using RMA are concentrated in the Southwest, Southeast, and a handful of Midwestern and East Coast states
- Of the 21 states with RMA specifications, 17 have published wet process specifications, while only four (GA, MO, VA, and PA) have published both wet and dry process RMA specifications
- Eight states have formal specifications for rubberized chip seal

Insights and Opportunities

- Considerable effort needed to scale the use of RMA across the US, especially in areas such as the Northwest.
- Sharing of best practices, for instance, at regional asphalt user-producer group meetings, and taking advantage of new federal funds being made available for green engineering projects may help in the scaling up of RMA use in the US.

Recommendations (page 1-of-2)

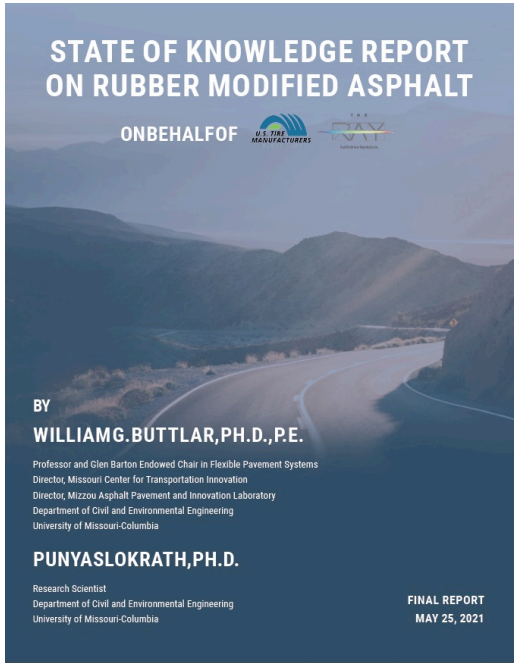
(1) Investment in regional demonstration projects, scrap tire recycling infrastructure, and hot-mix asphalt plant recycling infrastructure to facilitate RMA usage, particularly in areas with little-to-no current RMA usage should be given priority. Significant opportunities exist for both states co-located in regions of expertise with dry and wet process RMA (SW, SE, Midwest, NE USA), and for regions such as the upper Midwest and Western states where little-to-no RMA is currently used.

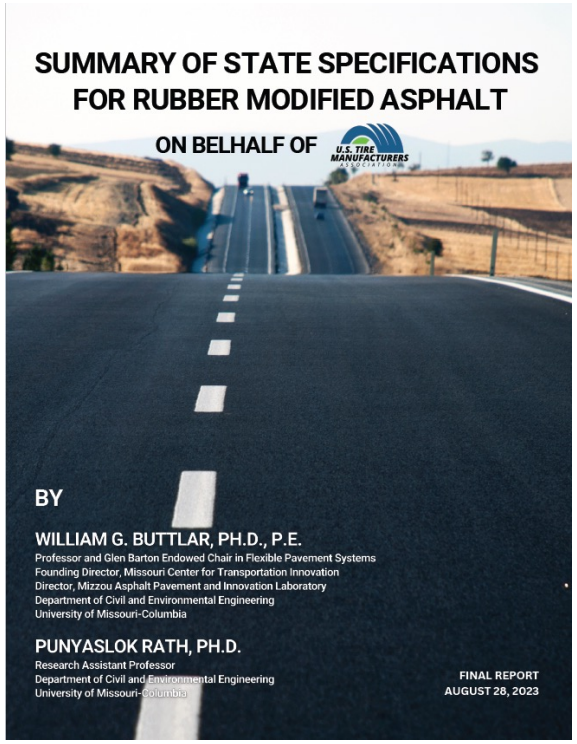
(2) Gaps in knowledge with respect to RMA performance testing, modern performance specifications, and integrated pavement/materials design should be addressed with an eye towards national standardization, bolstered by a national clearinghouse of test results, field performance data, improved performance prediction models, and templates for new RMA construction and materials specifications.

Recommendations (page 2-of-2)

(3) A national steering group should be established, which can help develop and coordinate national research priorities and studies for RMA and can provide oversight to a center of excellence for RMA research. The steering group can also help to prioritize and coordinate regional demonstration projects, strategic investments in recycling infrastructure, and provide overall industry leadership and advocacy towards increased pavement sustainability, resiliency, and circular economy solutions involving RMA.

Questions?





Acknowledgments:

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US Tire Manufacturer's Assoc.

The Ray

Thank You!

https://MAPIL.missouri.edu/state-of-knowledge-report-on-rubber-modified-asphalt/

Other Gaps and Opportunities

- The possibility of using thinner lifts with use of RMA has not been thoroughly explored
  - California did some work in the early 90s showing very promising results
  - A more recent Missouri study also showed positive results
- Asphalt industry is moving towards EPDs but most LCA studies available for RMA are severely outdated; NAPA's PCR identifies this as a gap
  - Most EPD efforts are heading towards cradle-to-gate analyses; however, EPDs need to include the use-phase in order for RMA and other mixes with recycled polymers to receive the proper 'environmental credit'
  - Comparable performance of modern RMA mixtures to polymer modified mixtures is not yet taken into account in any of the published LCA studies that have included the use-phase
- Can we more directly leverage tire disposal/environmental fees to grow RMA usage?
- Can the paving industry access new federal funding sources to grow RMA usage, such as the $2 billion Low Carbon Transportation Materials grants?