Welcome to the Webinar

The State of Knowledge on Rubber Modified Asphalt (RMA)

Today's Speakers

Sarah Amick
Vice President EHS&S and Senior Counsel
U.S. Tire Manufactures Association

Allie Kelly
Executive Director
The Ray

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University of Missouri

What we will cover

- Overview of USTMA
- Overview of the Ray
- The need for a state of knowledge on rubber modified asphalt
- Overview of report findings
- Q&A

USTMA Members

USTMA Sustainability Vision

USTMA members have the goal that all scrap tires enter sustainable end use markets.

USTMA's 2019 scrap tire market summary report measures our progress towards meeting our sustainability vision.

The Ray:

A Publicly-Accessible Living Laboratory

A Proving Ground for the Transportation Infrastructure of the Future

Wildlife Conservation | Changing Attitudes | Life Safety | Pollution Remediation | Resource Efficiency

@TheRayHighway

Rubberized Asphalt on The Ray

- I-85 : GA-AL state line → Exit 13 (2019)

  4 lane-miles + rest area parking lot

  12.5mm OGFC, 12.5mm SMA

  Dry process + additive requirement

  42,240 pounds of scrap tires

  - ✓ Extended pavement life + crack resistance
  - ✓ Wet weather road safety
  - ✓ Noise reduction

@TheRayHighway

Why conduct a state of knowledge on RMA?

- A single inventory of the best-in-class safety, performance, environmental and economic research did not previously exist
- Identify existing data gaps
- Advance the circular economy for scrap tires and infrastructure
- Answer the question – Does RMA present a sustainable infrastructure solution?

U.S. TIRE MANUFACTURERS ASSOCIATION

THE RAY
Let's drive the future.

Mizzou
University of Missouri

State of Knowledge Report on Rubber Modified Asphalt (RMA)

Webinar Presentation

July 22, 2021

Bill Buttlar, PhD, PE

University of Missouri-Columbia

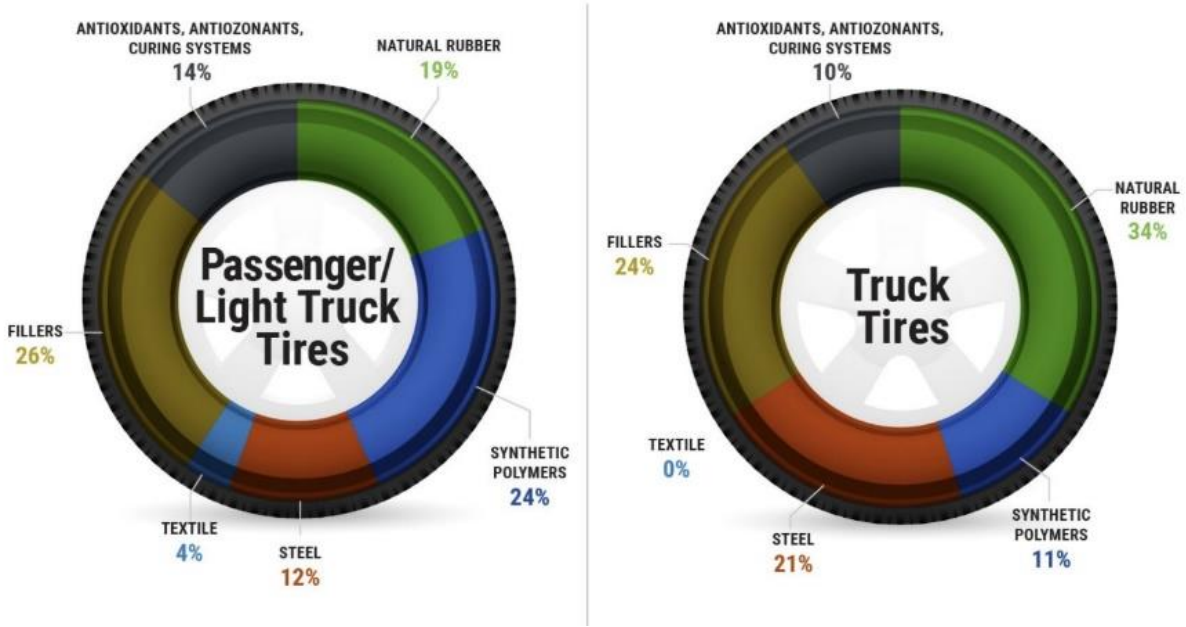
Recycling - Why Do We Care?

- 260 million scrap tires are generated in the U.S. annually

- Rubber is an incredibly tough and durable material…so durable in fact that it can pose considerable end-of-life challenges

Can these materials be re-used in America's infrastructure to eliminate single use and promote a more circular economy???

RMA – What is it?



End of Life Tire Recycling

Ground Tire Rubber (GTR)

GTR Mixed With Asphalt by Wet or Dry Process

Conventional Paving Equipment/Process

RMA SOK Study

- Over 300 Articles Reviewed
- Survey of State Highway Agencies Conducted
- Focus on **Environment/ Sustainability**, **Performance/Safety**, and **Economics**
- Peer-reviewed by Panel of Experts from Academia, Industry and State/ Federal Agencies
- Goals: **Aggregate Knowledge**, **Identify Gaps**

Executive Summary – RMA Benefits

Environment/Sustainability

- Reduces Environmental Impact
  - CO_2 Emission (-34%)
  - Ozone Depletion (-38%)
  - Water Depletion (-30%)
- Reduces Leaching Potential (-85%)
- Reduces Tire Tread Emissions (30-50%)
- Reduces Roadway Noise, Rolling Resistance (Fuel Savings)

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 (Reduced Hydroplaning)

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)

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)

Survey Results (1/2)

- 54% of the responding SHAs reported **no current usage** of RMA in their states.
  - This tracks with previous surveys. Majority of states do not use RMA at this point.
- 73% of respondents consider **lack of contractor/agency experience in RMA** as main barrier
- 65% reported complexity and variability introduced in materials storage, handling, and stability as barrier

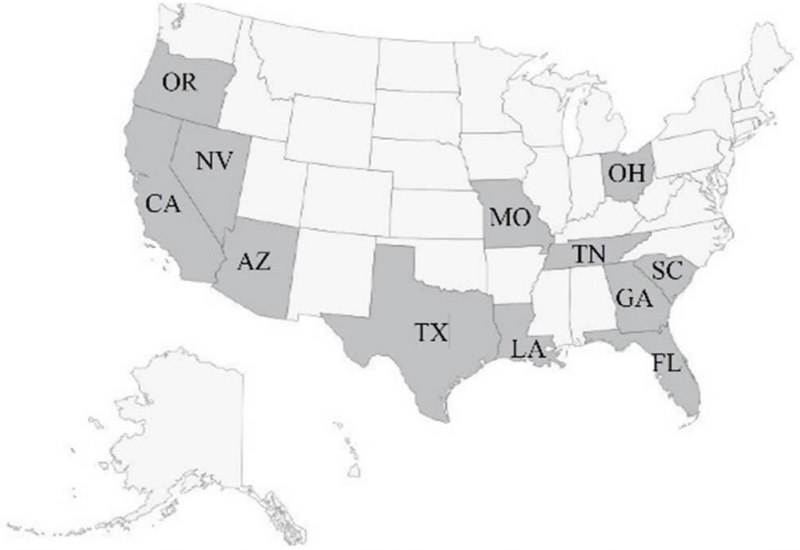


Figure 4. Map. States allowing GTR-modified usage in current specifications. (Source PTSi)

From: 'Resource Responsible Use of Recycled Tire Rubber in Asphalt Pavements,' PTSi = Paragon Technical Services, Inc.

Survey Results (2/2)

- 50% reported higher initial cost in low bid environment as barrier
- Only 28% of respondents cited the past field experiences of RMA to be a barrier in its adoption.
- Key point: In the past, RMA has been reported as cost-prohibitive. Failed government mandates in the 1990s negatively affected adoption throughout the 2000's, even after market forces led to cost decreases. More on next slide…

→ **These are far from insurmountable barriers**

RMA Mandate – 1990's

H.R.2950 - Intermodal Surface Transportation Efficiency Act of 1991102nd Congress (1991-1992)

Requires each State, beginning on January 1, 1995, and annually thereafter, to certify to the Secretary that such State has satisfied the minimum utilization requirement (stated as a percentage of the total tons of asphalt laid in such State and financed in whole or part by any assistance pursuant to Federal highway provisions: five percent for 1994; ten percent for 1995; 15 percent for 1996; and 20 percent for each year thereafter) for asphalt pavement containing recycled rubber, subject to specified requirements, waivers, and penalties.

This requirement was deleted in a 1995 amendment

Lessons learned: Early technology mandates usually don't work. Instead, rigorous technical vetting, field performance data and market forces need time to develop. Fortunately, **RMA has now successfully completed this lengthy vetting process**.

RMA – Environment and Sustainability (1/3)

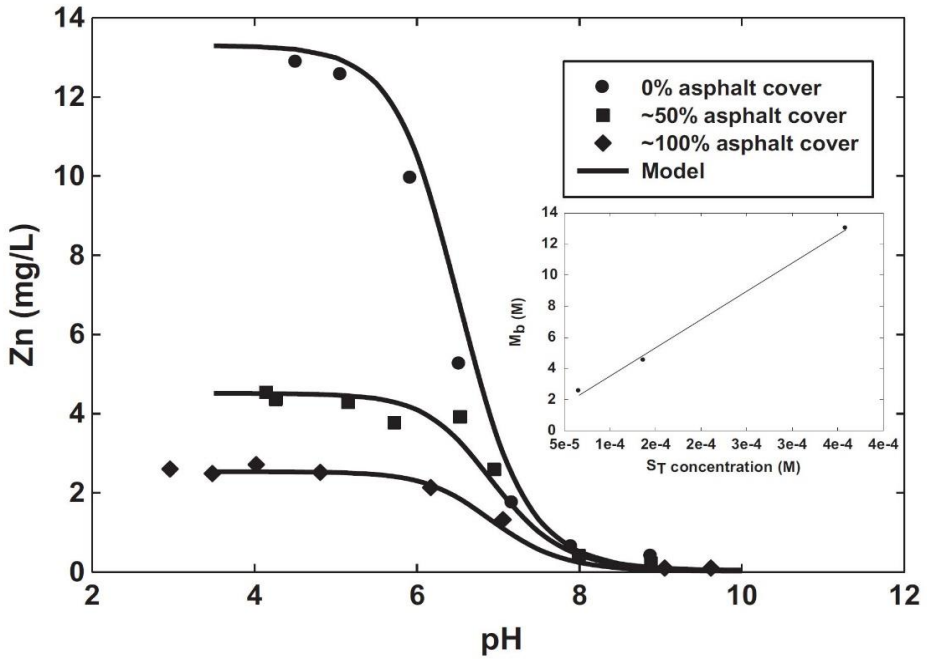
- The most comprehensive LCA studies show **reductions in environmental impact when using RMA**, ~30% reduction
- A research gap still exists in this area – more emphasis on **consequential** Life Cycle Analysis (LCA) studies is needed. Most studies in the literature are based on more limited, **attributional**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

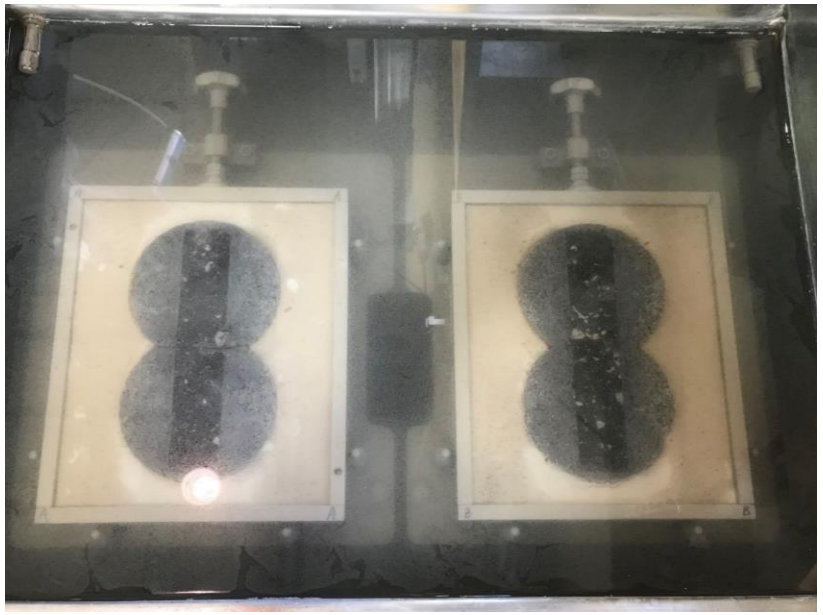
Bartolozzi et al., 2015

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



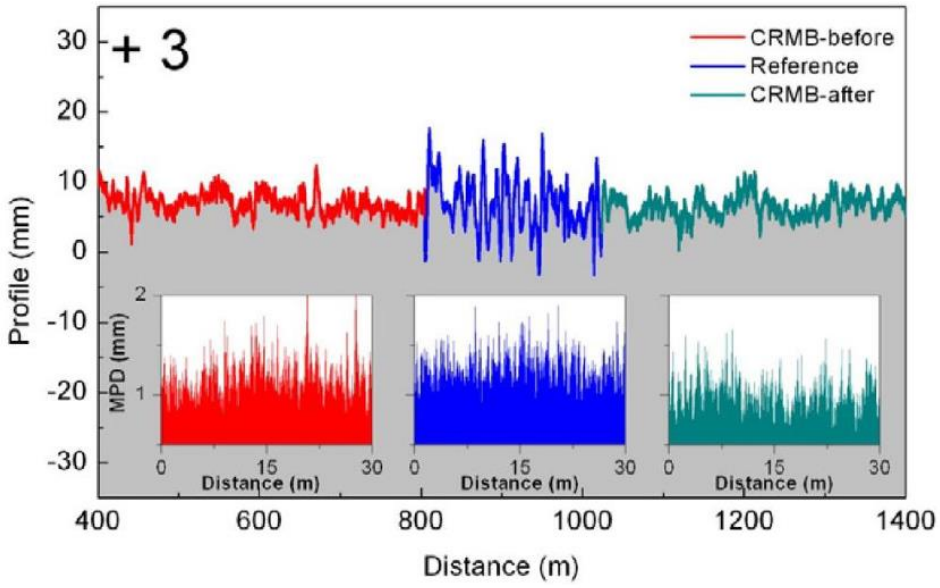
Liu et al., 2018



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

RMA – Environment and Sustainability (3/3)

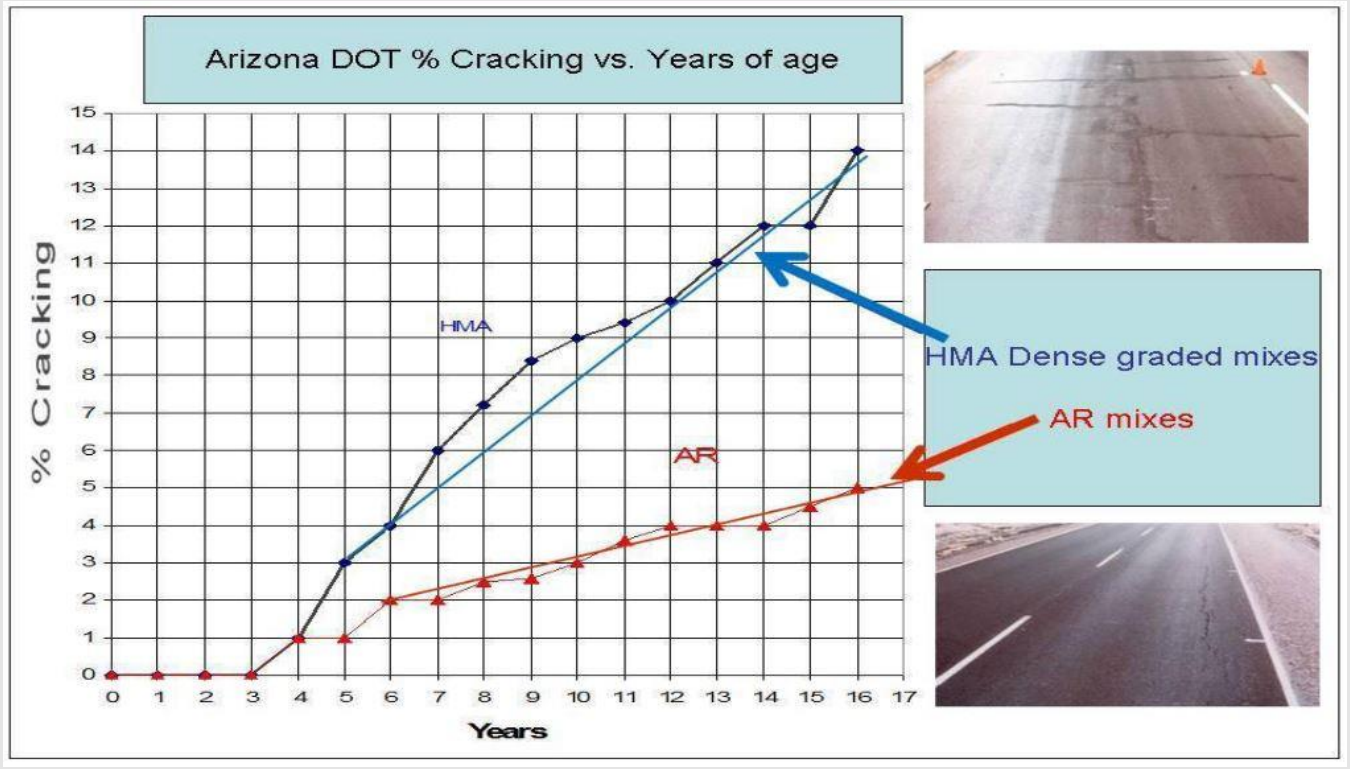
- RMA results in smoother pavement surfaces over lifespan*, **increasing driver comfort** and **reducing vehicle repair costs**
- The smoother, stiffer, and more elastic surface of RMA is expected to **conserve fuel**
- Travel over gap-graded RMA leads to 1.4 to 2.0 times **reduced tire tread wear and 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



Vazquez et al., 2016

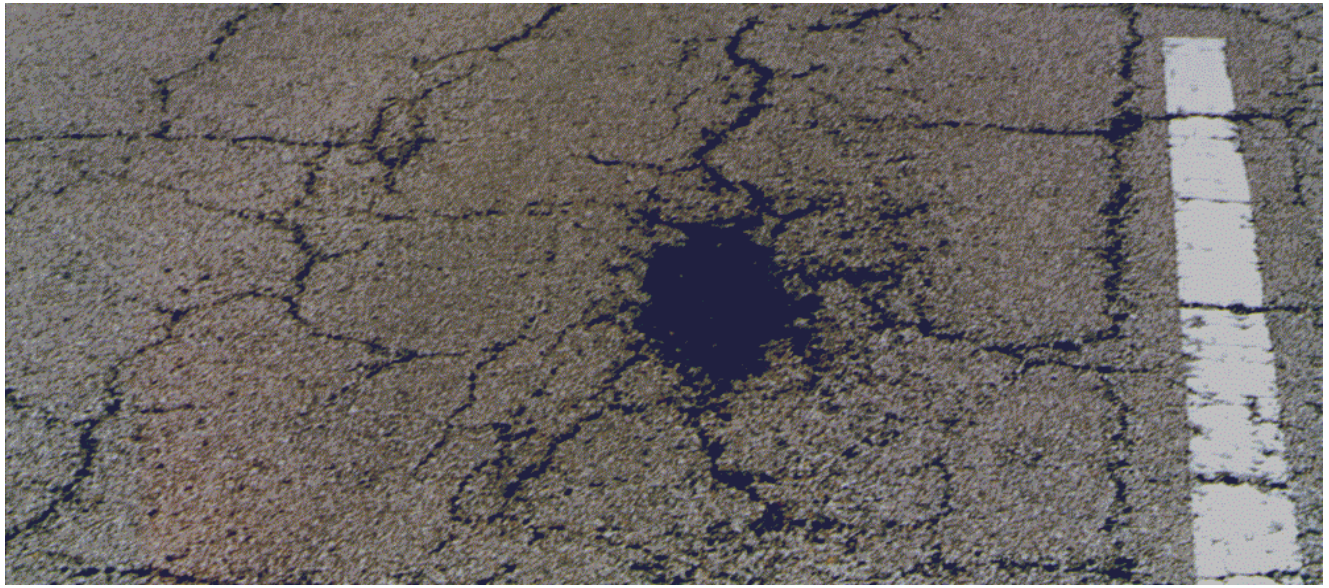
*Irfan et al. (2017); Irfan, Ali, Ahmed, & Hafeez (2018); Cooper et al. (2007); Willis et al. (2014); Vazquez et al. (2016)

RMA – Performance - Cracking



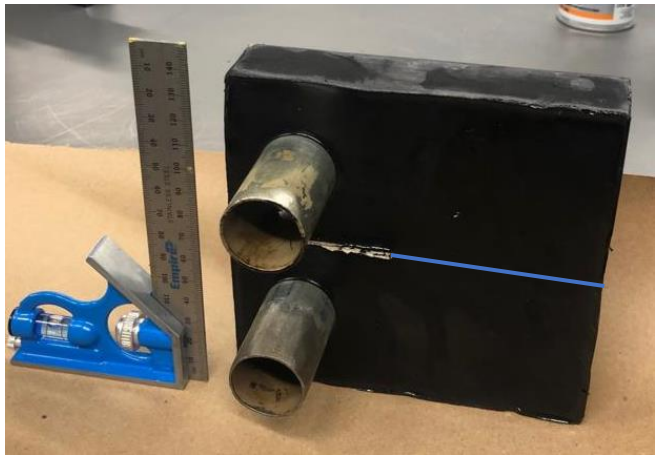
- RMA Performance Benefit Examples:
- - Greater than 50% reduction in field reflective cracking
- - 85% reduction in rut depth (Vahidi et al. 2014)
- - 15 other studies reported rut depth reductions with RMA

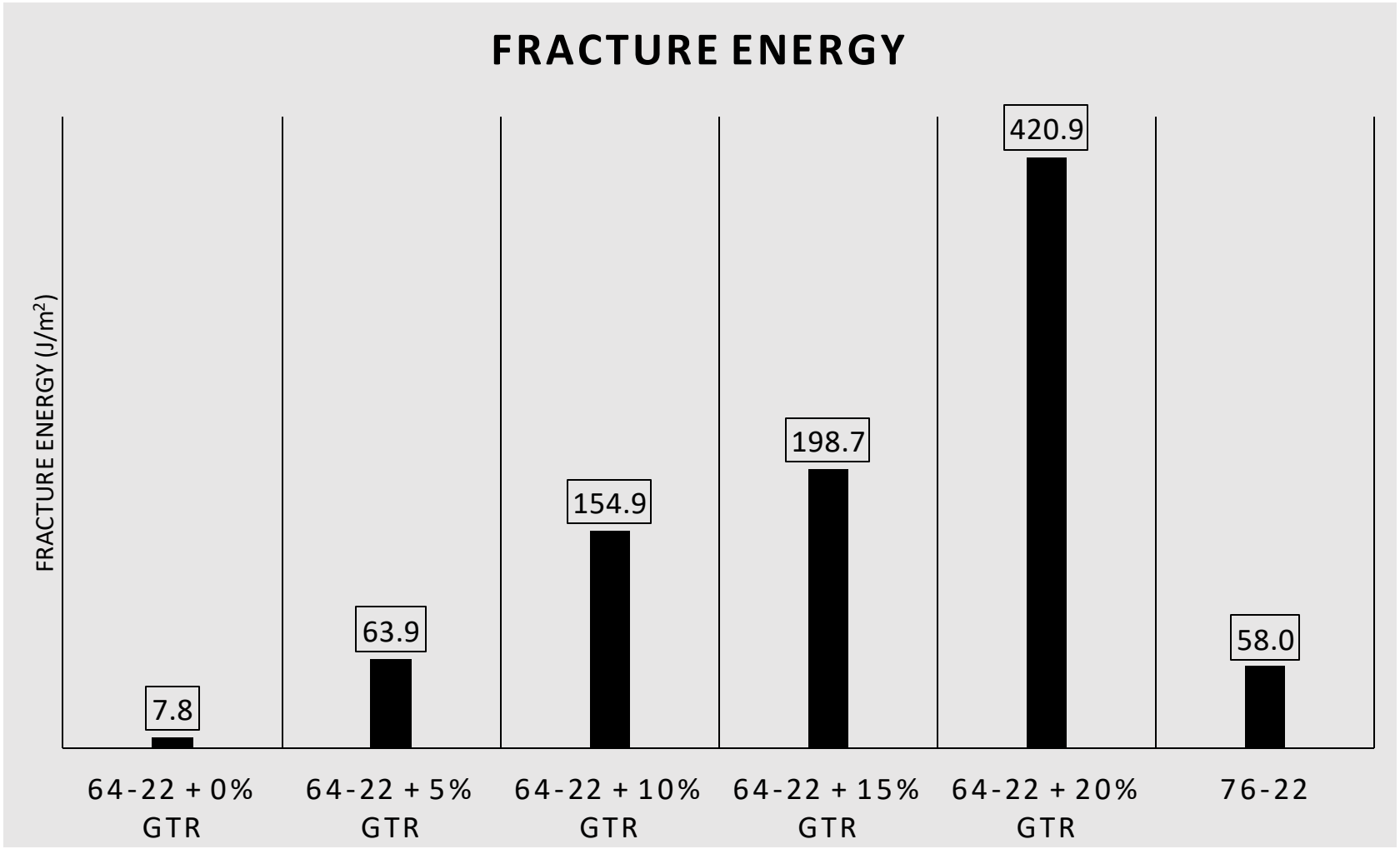
Low-Temperature Cracking Study at Mizzou



- Rubber Found to **Significantly Boost Low-Temperature Cracking Resistance**
- RMA Greatly Outperformed Unmodified Asphalt
- RMA **Outperformed Polymer-Modified Asphalt**
- Presence of Rubber in Fractured RMA Specimens was Clearly Observed**, Whereas Polymer Exhibited More Glassy/Brittle Failure**

Compact Fracture Test Specimen

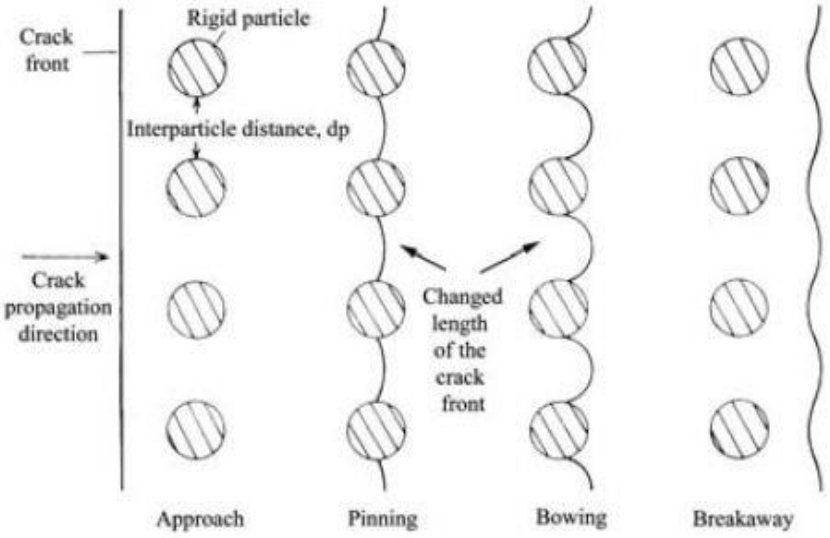


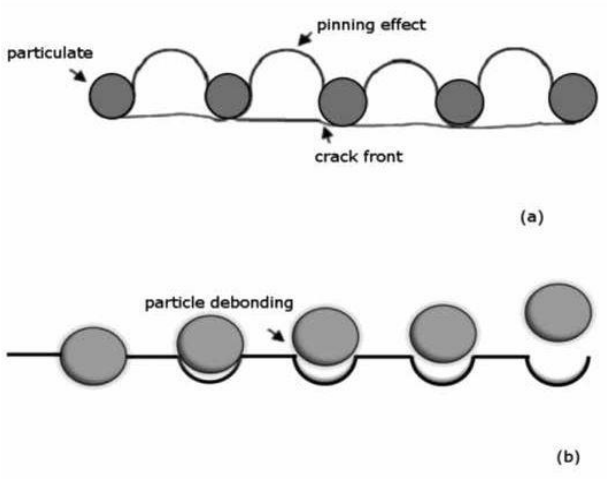


Unmodified PG64-22	10% Rubber-Modified	Polymer Modified PG76-22
		

Crack Pinning Exists in RMA…

…Leads to **extended pavement life**, **smoother pavements**, **lower maintenance costs**





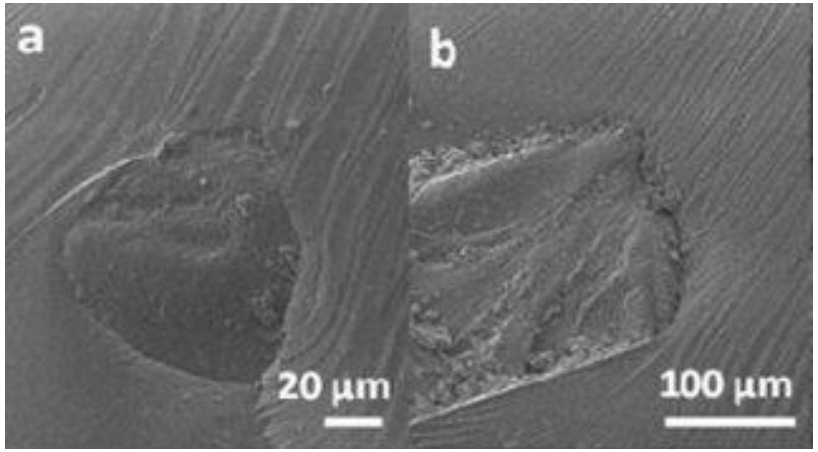


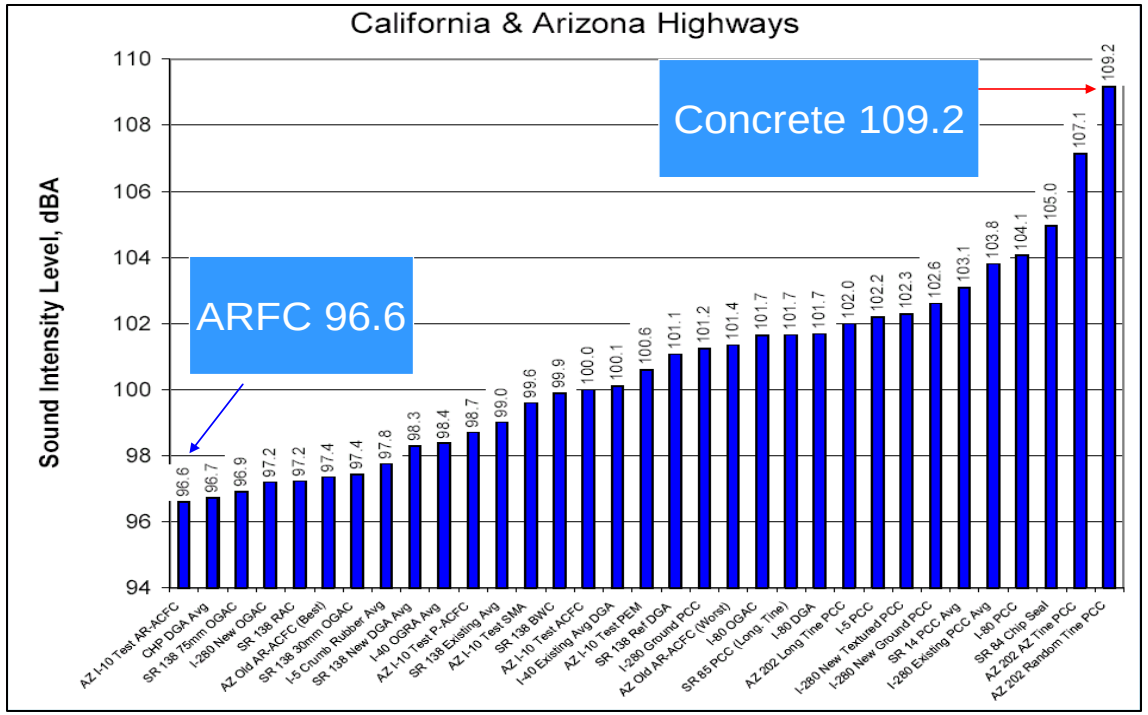
Image Credits: Chaudhary et al. (2015). Toughening of Epoxy with Preformed Polyethylene Thermoplastic Filler, Polymer-Plastics Technology and Engineering 54(9).
Ramadan et al. (2017). Behaviour of Hybrid SiC/Jute Epoxy Composites Manufactured by Vacuum Assisted Resin Infusion, Polymers and Polymer Composites 25(5):333-344.

RMA – Performance (cont.)

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

Table 4. Skid resistance results from Shirini et al. (2016)

Mixture Type	Skid Resistance (British Pendulum Number)
Control	65.6
SBS	62.8
Crumb Ruber (10%)	82.0
Crumb Rubber (15%)	76.4
Crumb Rubber (20%)	71.0



RMA Performance Benefit Examples (cont.):

- Skid resistance improvement ~ 25% (Shirini 2016)
- Up to 12 dB reduction in noise (Way 2012)

Additional Noise Study Findings

Mixture Type	On-Board Sound Intensity Level, dBA
Asphalt Rubber Friction Course (ARFC)	97.6
Asphalt Concrete Friction Course (ACFC)	100.2
Stone Mastic Asphalt (SMA)	100.6
Porous Asphalt Concrete Friction Course (P-ACFC)	100.9
Porous Eurpean Mixture (PEM)	101.7

Donavan and Janello (2018)

Sacramento County Public Works (1999)

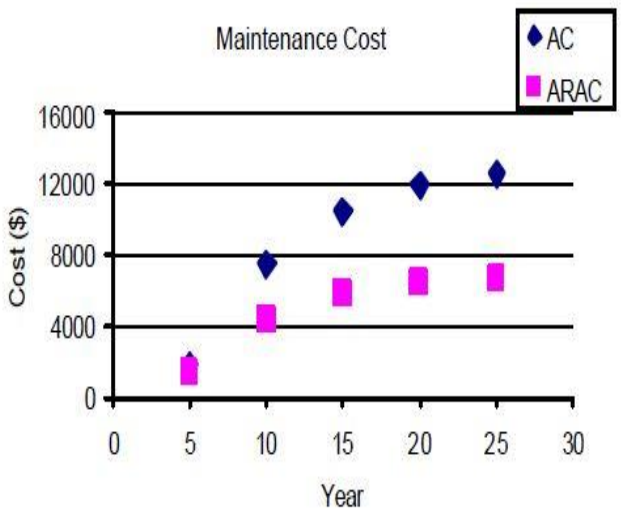
Route	Mixture Type	Time of measurement (post-construction)	Change in noise (dB Leq)
Alta Arden Expressway	Rubberized	1 month	-6 dB
		16 months (1 year, 4 months)	-5 dB
		72 months (6 years)	-5 dB
Antelope Road	Rubberized	6 months	-4 dB
		60 months (5 years)	-3 dB
Bond Road	Conventional	1 month	-2 dB
		48 months (4 years)	0 dB

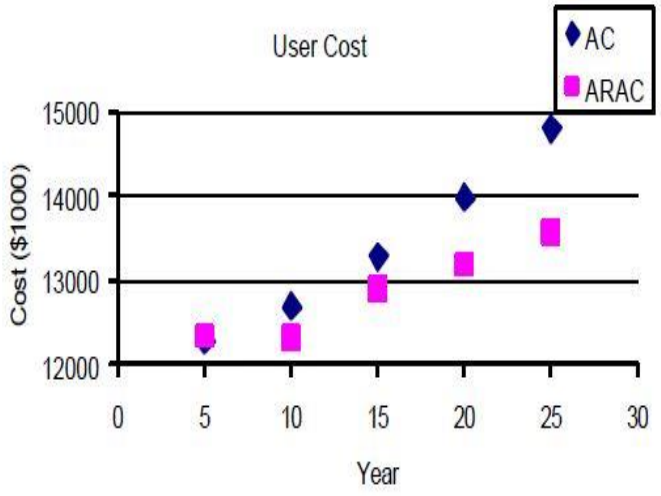
RMA Noise Reduction – Bottom Line

- The literature reported a 1 to 12 dB reduction in sound emanating from RMA as compared to other pavements
- Reduced noise **improves driver comfort** and **safety**, creates **more livable urban communities**, **reduces cost of sound barriers**
- Research gap: a deeper understanding of the mechanisms underlying noise reduction in RMA as compared to non-rubberized asphalt and concrete pavements is needed

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)

Knowledge Gaps Identified

- Most states have limited-to-no-experience in RMA
- Modern asphalt mixture tests and specifications were not developed considering RMA - This could be a barrier in producing specifications in many states, hindering RMA adoption
- Pavement design software needs a national-level effort to incorporate adequate design guidelines/factors for RMA
- Existing leaching studies are becoming dated, entombment efficacy is not well understood; field validation studies are needed

Knowledge Gaps Identified (cont.)

- Studies to quantify microparticle release from RMA are needed
- Assumptions adopted in LCA studies need to be updated considering modern RMA technologies to adequately capture the environmental costs and benefits of RMA, more work on consequential LCA needed
- A deeper understanding of the mechanisms underlying noise reduction in RMA as compared to non-rubberized asphalt and concrete pavements is needed, rolling resistance fuel savings
- Now is the time for the industry to come forward and establish an Environmental Product Declaration (EPD) for RMA

Thank You!

- **Bottom Line:** We are not fully reaping the benefits of RMA for **P**eople, **P**ocketbooks, and the **P**lanet. Even though research gaps still exist, RMA is a proven, ready technology (40+ years) with attractive **environmental, performance and economic benefits**.

- **Recommendation:** **A coordinated national effort** is critically needed to bridge knowledge gaps, to disseminate best practices, to demonstrate performance, and to share data and specifications to substantially increase RMA usage.