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

Bill Buttlar  
Glen Barton Chair in Flexible Pavements, P.E.  
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 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


  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?
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)

RMA Pavement on Illinois Tollway

Conventional Paving Equipment/Process

GTR Mixed With Asphalt by Wet or Dry 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
  - CO₂ 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
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

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.
H.R.2950 - Intermodal Surface Transportation Efficiency Act of 1991

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.
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.

<table>
<thead>
<tr>
<th>Impact category</th>
<th>Impact of Rubberized road with respect to Conventional road</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate change (kg CO₂ eq)</td>
<td>-34%</td>
</tr>
<tr>
<td>Ozone depletion (kg CFC-11 eq)</td>
<td>-38%</td>
</tr>
<tr>
<td>Human toxicity (kg 1,4-DB eq)</td>
<td>-27%</td>
</tr>
<tr>
<td>Photochemical oxidant form. (kg NMVOC eq)</td>
<td>-34%</td>
</tr>
<tr>
<td>Terrestrial acidification (kg SO₂ eq)</td>
<td>-35%</td>
</tr>
<tr>
<td>Freshwater eutrophication (kg P eq)</td>
<td>-20%</td>
</tr>
<tr>
<td>Terrestrial ecotoxicity (kg 1,4-DB eq)</td>
<td>-37%</td>
</tr>
<tr>
<td>Freshwater ecotoxicity (kg 1,4-DB eq)</td>
<td>-26%</td>
</tr>
<tr>
<td>Water depletion (m³)</td>
<td>-30%</td>
</tr>
<tr>
<td>Fossil depletion (kg oil eq)</td>
<td>-37%</td>
</tr>
</tbody>
</table>

Bartolozzi et al., 2015
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 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

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

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**
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).
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>
<thead>
<tr>
<th>Mixture Type</th>
<th>Skid Resistance (British Pendulum Number)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>65.6</td>
</tr>
<tr>
<td>SBS</td>
<td>62.8</td>
</tr>
<tr>
<td>Crumb Ruber (10%)</td>
<td>82.0</td>
</tr>
<tr>
<td>Crumb Rubber (15%)</td>
<td>76.4</td>
</tr>
<tr>
<td>Crumb Rubber (20%)</td>
<td>71.0</td>
</tr>
</tbody>
</table>

**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 vs. On-Board Sound Intensity Level, dBA

<table>
<thead>
<tr>
<th>Mixture Type</th>
<th>On-Board Sound Intensity Level, dBA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asphalt Rubber Friction Course (ARFC)</td>
<td>97.6</td>
</tr>
<tr>
<td>Asphalt Concrete Friction Course (ACFC)</td>
<td>100.2</td>
</tr>
<tr>
<td>Stone Mastic Asphalt (SMA)</td>
<td>100.6</td>
</tr>
<tr>
<td>Porous Asphalt Concrete Friction Course (P-ACFC)</td>
<td>100.9</td>
</tr>
<tr>
<td>Porous Eyrpean Mixture (PEM)</td>
<td>101.7</td>
</tr>
</tbody>
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## Sacramento County Public Works (1999)

<table>
<thead>
<tr>
<th>Route</th>
<th>Mixture Type</th>
<th>Time of measurement (post-construction)</th>
<th>Change in noise (dB Leq)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alta Arden Expressway</td>
<td>Rubberized</td>
<td>1 month</td>
<td>-6 dB</td>
</tr>
<tr>
<td></td>
<td></td>
<td>16 months (1 year, 4 months)</td>
<td>-5 dB</td>
</tr>
<tr>
<td></td>
<td></td>
<td>72 months (6 years)</td>
<td>-5 dB</td>
</tr>
<tr>
<td>Antelope Road</td>
<td>Rubberized</td>
<td>6 months</td>
<td>-4 dB</td>
</tr>
<tr>
<td></td>
<td></td>
<td>60 months (5 years)</td>
<td>-3 dB</td>
</tr>
<tr>
<td>Bond Road</td>
<td>Conventional</td>
<td>1 month</td>
<td>-2 dB</td>
</tr>
<tr>
<td></td>
<td></td>
<td>48 months (4 years)</td>
<td>0 dB</td>
</tr>
</tbody>
</table>
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 People, Pocketbooks, and the Planet. 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.