Resource Responsible Use of Recycled Tire Rubber in Asphalt Pavements

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FEDERAL HIGHWAY ADMINISTRATION (FHWA)
“DEVELOPMENT AND DEPLOYMENT OF INNOVATIVE ASPHALT PAVEMENT TECHNOLOGIES” COOP AGREEMENT WITH UNIVERSITY OF NEVADA, RENO

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II. Background

III. Specifications and Testing of GTR-Modified Asphalt Binders

IV. Asphalt Mixture Considerations

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Presentation Overview

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Introduction

- Recycling: Process of converting waste materials into new materials or objects.
- Alternative to conventional waste disposal, saves material and reduces environmental impact.
- Recycling of rubber from waste tires into asphalt pavements is an attractive alternative addressing engineering, economic, and environmental issues.

Triune Benefits of Recycling and Reuse
The Federal Highway Administration (FHWA) Recycled Materials Policy:
Established in 2006.
Recycling and Reuse offers triune benefits of engineering, economic, and environmental impact.
Comparatively, (ASCE), sustainability is made up of environmental, social, and economic needs, collectively referred to as the “Triple Bottom Line.”

In-service asphalt pavement performance affects every facet of the FHWA recycled materials policy.

Federal Highway Administration (FHWA) project: “Deployment and Development of Innovative Asphalt Pavement Technologies. (DDIAPT)"
- Resource Responsible (RR) use of Materials for Flexible Pavement
- Technical Report – Resource Responsible Use of Recycled Tire Rubber in Asphalt Pavements
  https://scholarworks.unr.edu/handle/11714/7484
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Background

- Tire Components
- Waste Tire Issue
- Historical Perspective
- Current Usage of GTR-Modified Binders and Mixtures
- Rubber-Modified Asphalt Processing and Technologies
  - Wet Process – AR Technology
  - Wet Process – RMB Technology
  - Dry Process
- Summary of Technologies
**Typical Tire Components**

Production of pneumatic tires for passenger cars, trucks, airplanes, etc. uses large quantities of polymers:
- Natural Rubber (NR),
- Synthetic Styrene Butadiene Rubber (SBR),
- Ethylene Propylene Diene Monomer (EPDM) Rubber,
- Butyl Rubber (BR)

<table>
<thead>
<tr>
<th>Component</th>
<th>Typical Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural rubber (NR)</td>
<td>14 to 27 percent</td>
</tr>
<tr>
<td>Synthetic rubber</td>
<td>14 to 27 percent</td>
</tr>
<tr>
<td>Carbon black</td>
<td>28 percent</td>
</tr>
<tr>
<td>Steel, fabric</td>
<td>14 to 15 percent</td>
</tr>
<tr>
<td>Processing oils and additives</td>
<td>16 to 17 percent</td>
</tr>
</tbody>
</table>

Source PTSi
Waste Tire Issue

- At the end of serviceable life, discarded waste tires contain as much as 99% of the total rubber used in tire construction.
- Environmental concern as polymeric materials do not decompose easily.
- Two major challenges:
  - Waste of valuable rubber,
  - Environmental pollution due to disposal of waste tires.
<table>
<thead>
<tr>
<th>Market or Disposition</th>
<th>Thousands of Tons</th>
<th>Millions of Tires</th>
<th>% of Total to Market</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tire-Derived Fuel (TDF)</strong></td>
<td>1,736.3</td>
<td>105.9</td>
<td>50.9</td>
</tr>
<tr>
<td>Cement Kilns</td>
<td>805.9</td>
<td>49.2</td>
<td>23.6</td>
</tr>
<tr>
<td>Pulp &amp; Paper</td>
<td>503.1</td>
<td>30.7</td>
<td>14.8</td>
</tr>
<tr>
<td>Industrial Boilers</td>
<td>427.3</td>
<td>26.1</td>
<td>12.5</td>
</tr>
<tr>
<td><strong>Ground Tire Rubber (GTR)</strong></td>
<td>1,013.3</td>
<td>61.8</td>
<td>29.7</td>
</tr>
<tr>
<td>Civil Engineering (CE)</td>
<td>316.0</td>
<td>19.3</td>
<td>9.3</td>
</tr>
<tr>
<td>Exported</td>
<td>109.8</td>
<td>6.7</td>
<td>9.3</td>
</tr>
<tr>
<td>Electric Arc Furnace</td>
<td>39.2</td>
<td>2.4</td>
<td>3.2</td>
</tr>
<tr>
<td>Reclamation Projects</td>
<td>44.0</td>
<td>2.7</td>
<td>1.2</td>
</tr>
<tr>
<td>Agricultural</td>
<td>7.1</td>
<td>0.4</td>
<td>1.3</td>
</tr>
<tr>
<td>Baled Tires/market</td>
<td>14.6</td>
<td>0.9</td>
<td>0.2</td>
</tr>
<tr>
<td>Punched/ Stamped</td>
<td>22.5</td>
<td>1.4</td>
<td>0.4</td>
</tr>
<tr>
<td>Other</td>
<td>108.5</td>
<td>6.6</td>
<td>0.7</td>
</tr>
<tr>
<td><strong>Total to Market</strong></td>
<td><strong>3,411.3</strong></td>
<td><strong>208.1</strong></td>
<td><strong>100.0</strong></td>
</tr>
<tr>
<td><strong>Generated</strong></td>
<td>4,189.2</td>
<td>255.6</td>
<td>–</td>
</tr>
<tr>
<td>% to Market/Utilized</td>
<td>81.4%</td>
<td>81.4%</td>
<td>–</td>
</tr>
<tr>
<td><strong>Landfill Disposal</strong></td>
<td>646.8</td>
<td>39.5</td>
<td>–</td>
</tr>
<tr>
<td>% Managed (Includes Markets, Baled, and Landfill)</td>
<td>96.9%</td>
<td>96.9%</td>
<td>–</td>
</tr>
</tbody>
</table>

Source USTMA
In 2017 Scrap Tire Markets consumed 81.4 percent of the estimated 4.3 million tons of scrap tires generated annually.

- Tire-Derived Fuel: 50.9%
- Ground Tire Rubber: 29.7%
- Civil Engineering: 9.3%

Source: PTSi
The GTR market is reported at slightly more than 1.0 million tons or about 62 million scrap tires.
Historical Perspective

- More than 50 years of success in GTR modification of asphalt binders.
- GTR modification of asphalt binders ranks second among polymer modifiers.
- Modern GTR asphalt modification began in the early 1960s,
  - Asphalt Rubber (AR) modified chip seal Phoenix, AZ,
  - AR expanded into greater chip seal usage, crack relief interlayers and open-graded friction courses (OGFC)
  - During 1960s through 1970s AR proved useful in asphalt pavements and pavement maintenance.
Historical Perspective

- During 1960s through 1970s dry mixture addition of GTR emerged.
- More issue with early dry mixture addition than dry addition today
  - Rubber Modified Asphalt Concrete (RUMAC) – 10 mesh at 3 percent by weight of mix.
    - PlusRide™
    - TAK™
- Dry addition of GTR to mixtures today consists of smaller sized rubber and lower rubber content – 30 mesh at 0.5 percent by weight of mix (10 percent of binder based on 5.0 percent binder content)
- Dry addition technology today generally employs co-additives
Current Usage

State DOT published specifications revealed that only twelve States currently publish specifications allowing GTR-modified asphalt binders for use in construction of asphalt pavements.
<table>
<thead>
<tr>
<th>State</th>
<th>Tons of GTR Used</th>
<th>% of Total Tons of GTR Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arizona</td>
<td>4,303</td>
<td>21.4</td>
</tr>
<tr>
<td>Arkansas</td>
<td>5</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>California</td>
<td>13,412</td>
<td>66.7</td>
</tr>
<tr>
<td>Delaware</td>
<td>10</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>Florida</td>
<td>136</td>
<td>0.7</td>
</tr>
<tr>
<td>Georgia</td>
<td>378</td>
<td>1.9</td>
</tr>
<tr>
<td>Illinois</td>
<td>750</td>
<td>3.7</td>
</tr>
<tr>
<td>Massachusetts</td>
<td>710</td>
<td>3.5</td>
</tr>
<tr>
<td>Michigan</td>
<td>55</td>
<td>0.3</td>
</tr>
<tr>
<td>Missouri</td>
<td>260</td>
<td>1.3</td>
</tr>
<tr>
<td>Texas</td>
<td>98</td>
<td>0.5</td>
</tr>
<tr>
<td>Total</td>
<td>20,117</td>
<td>100.0</td>
</tr>
</tbody>
</table>
Processes and Technologies

Currently there are two primary processes of incorporating GTR into asphalt binders and mixtures referred to as either the “wet” or “dry” process.

The wet process blends GTR with asphalt with one of two technologies:

- Wet Process
- Terminal Blend

The dry process incorporates GTR directly into the asphalt mixture during production.

<table>
<thead>
<tr>
<th>Material</th>
<th>Process</th>
<th>Technology</th>
<th>Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground Tire Rubber</td>
<td>Wet</td>
<td>Continuous Blend</td>
<td>GTR Modified Binder (Asphalt Rubber or Rubber Modified Binder)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1960's - Arizona</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>McDonald Process</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1992 - Arizona</td>
<td>Generic Dry-Process</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Terminal Blend</td>
<td>GTR Modified Hot-Mix Asphalt Mixture</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1989 - Florida</td>
<td></td>
</tr>
<tr>
<td>Dry</td>
<td></td>
<td>Plus Ride RUMAC, TAK</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1960's - Sweden</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Generic Dry-Process</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1990's - Kansas</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Asphalt Plus SmartMix</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2010's - Georgia</td>
<td></td>
</tr>
</tbody>
</table>
Asphalt Rubber (AR)

<table>
<thead>
<tr>
<th>Technologies Included in This Process</th>
<th>Technology Definition</th>
<th>Other Names of the Technology</th>
</tr>
</thead>
</table>
| Asphalt Rubber (AR)                   | “An asphalt binder in various types of flexible pavement construction including surface treatments and asphalt mixtures consisting of a blended asphalt binder, ground tire rubber (GTR), and certain additives in which the rubber component is at least 15 percent by weight of the total blend and has reacted in the asphalt binder sufficiently to cause swelling of the rubber particles.” | • McDonald Process  
• Arizona Crumb Rubber  
• Wet Process Rubber  
• Recycled Tire Rubber Modified Bitumen (RTR-MB)  
• Asphalt Rubber Binder (ARB)  
• Bitumen Rubber Binder  
• Crumb Rubber Binder  
• Batch Blending |
## Rubber Modified Binder (RMB)

<table>
<thead>
<tr>
<th>Technologies Included in This Process</th>
<th>Technology Definition</th>
<th>Other Names of the Technology</th>
</tr>
</thead>
</table>
| **Rubber Modified Binder (RMB)**     | “A version of the wet process where ground tire rubber (GTR) is blended with asphalt binder at the refinery or at an asphalt binder storage and distribution terminal and transported to the asphalt mix plant or job site for use. These blends may contain from 5 to 12 percent GTR by total asphalt binder mass. Some hybrid RMB binders may contain polymers such as styrene-butadiene-styrene (SBS) in addition to GTR.” | • Terminal Blend  
• Terminal Blended Rubberized Asphalt (TBRA)  
• Recycled Tire Rubber Modified Bitumen (RTR-MB)  
• Rubber Modified Binder (RMB)  
• Hybrid Rubber Binder  
• Wright Process |
Dry Process Rubber

<table>
<thead>
<tr>
<th>Technologies Included in This Process</th>
<th>Technology Definition</th>
<th>Other Names of the Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dry Process</strong></td>
<td>“A process where hot-mix asphalt mixture is modified with ground tire rubber (GTR) using GTR as an aggregate/binder modifier which is incorporated into the aggregate prior to mixing with asphalt binder producing a GTR-modified hot-mix asphalt mixture. GTR used in this technology is generally less than 0.6mm (30 mesh).”</td>
<td>• Dry process rubber</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Belt add modifier (BAM)</td>
</tr>
</tbody>
</table>
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Specifications and Testing of GTR-Modified Asphalt Binders – Wet Process

- Agency specifications may vary in format and extent of the specification, but generally have common components describing the type of product or process, materials (including specifications and test methods), construction requirements, methods of measurement, and basis for payment.

- Acceptance specifications for GTR-modified asphalt binders primarily include:
  - Characterization of stiffness of binder with respect to expected end use conditions
  - Tests to ensure safety, consistency and retention of properties with aging
  - Agencies specifying modified asphalt binders with AR technology tend to follow empirical specifications based on their experiences
Specifications and Testing of GTR-Modified Asphalt Binders – Wet Process

- The Superpave asphalt binder specification (AASHTO M 320 *Standard Specification for Performance-Graded Asphalt Binder*) encourages wider use of rheology-based testing of GTR-modified asphalt binders using the wet process and either the AR or RMB technology.

- The Multiple-Stress Creep and Recovery (MSCR) (AASHTO M 332 *Standard Specification for Performance-Graded Asphalt Binder Using Multiple Stress Creep Recovery (MSCR) Test*) testing may also be employed.
Specifications and Testing of GTR-Modified Asphalt Mixtures –
Dry Process

- Specification and certification of mixtures modified with GTR using the dry process is not as straightforward as when the wet process is used.
- Some agencies have specified the GTR-modified asphalt binder be evaluated and certified via asphalt binder extraction, recovery, and subsequent testing of recovered asphalt binder when the dry process is used.
Extracted asphalt binder testing poses one of two, possibly both, concerns:
- Is GTR/GTR modified asphalt binder totally recovered from the mixture,
- does solvent interaction incorporate rubber and asphalt binder in a manner not achieved in the in-place mixture.

Specification of the mixture using the dry process is possibly more appropriately based on mixture testing schemes such as the balanced mixture design (BMD) approach.
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Three general asphalt mixture types are used for production of GTR-modified asphalt pavements:
- dense-graded,
- gap-graded,
- and open-graded.

Volumetric mixture designs alone may not provide mixtures with desired overall performance.

The BMD approach to mixture design may be more appropriate for design and evaluation of GTR-modified systems.
Addition of GTR, specifically the wet process using AR and RMB technologies, generally raises optimum asphalt binder content and lowers laboratory stability results in dense-graded asphalt mixtures, regardless of mix design methodology.

Use of AR binders, with higher GTR concentration, in DGA is not common but may occur.

GTR used in DGA mixtures is typically in the form of AR binder technology with reduced GTR concentration (maximum 10 percent) or RMB technology of a similar GTR concentration.
Gap-graded asphalt mixtures are typically used in place of dense-graded mixtures with AR technology at higher GTR concentrations (15 to 22 percent)

Fine aggregates is removed to allow room for the rubber particles within the gradation.

Gap-graded mixes with AR binders are designed to have binder contents in the 6 to 8 percent range.

Marshall, Hveem, or Superpave mix design methods have been used for mixture design, with design air voids varying based on agency specifications.
Asphalt Mixture Considerations
Wet Process – Open-Graded (OGFC) Mixtures

- Open-graded asphalt mixtures represent one of the most common uses of wet process GTR-modified asphalt binder, especially with high GTR concentration AR technology.
- An asphalt binder drain down test is used to make sure the asphalt binder does not flow off the aggregate during normal production, placement, and compaction operations.
- Binder stabilizing agents such as cellulose fibers may be used to aid in resistance to asphalt binder drain down.
Dry process GTR-modified asphalt mixtures have been designed using standard Marshall, Hveem, and Superpave methods, but the criteria for selecting optimum asphalt binder content are different than typically used with these methods.

Laboratory designed asphalt mixtures are prepared by pre-blending heated dry aggregate and rubber followed by addition of asphalt binder.

Laboratory stability and stiffness values of dry-process modified asphalt mixtures are significantly lower than values of conventional mixtures.
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Summary

- Lacking the ability to recycle old tires into new tires, there are several common repurposing methods to effectively reuse rubber.
- Recycling of rubber from old tires may include but is not limited to:
  - Tire Derived Fuel (TDF),
  - Ground Tire Rubber (GTR),
  - and Civil Engineering (CE) applications.
- GTR is the second highest consumer of RTR with uses in:
  - Molded and extruded products,
  - Playground and mulch applications,
  - Sports surfacing,
  - Asphalt binder modification,
  - Automotive uses.
Addition of GTR to asphalt binder and mixture is an accepted practice in asphalt production and consumes about 12 percent of the total GTR market today.

Modification of asphalt binders with GTR is well established and can provide high performance pavements that aid in reduction of the number of waste tires disposed of in landfills and elsewhere.

Growth in use of GTR-modified asphalt pavements can be credited to successful construction of high-performance asphalt pavements.

Dry-process addition of GTR to asphalt mixtures is somewhat in its infancy but have generated promising reports.
Resource Responsible Use of Recycled Tire Rubber in Asphalt Pavements

THANK YOU
QUESTIONS/DISCUSSION?