Pretreated Rubber Technologies

Arizona Pavements/Materials Conference
Arizona State University
Tempe, AZ
Nov 19-20, 2014

Doug Carlson
VP Asphalt Products
What is it?

- Recycled Tire Rubber
- 10 minus (1.8 mm and smaller) or 30 minus (0.6 mm) in size
- Value added technology included in and on rubber
- Or, has been pre-reacted, pre-swelled, “activated”, or pelletized
• Increased use of RAP has lead to mix acceptance testing
• Instead of tasting the batter before you bake the cake, taste the cake
The main objective of this study was to evaluate and compare the effects of two treated RTR technologies that can be added at the asphalt mix plant (dry process) versus adding the RTR untreated to the asphalt binder (wet process) in mix performance testing on dense graded and a gap graded mixtures.

Conducted by:
Dr. Walaa Mogawer
Highway Sustainability Research Center
Project Scope

Two Types of Mixtures

Dense Graded Mixture

Gap Graded Mixture

Added to Binder (Wet Process)

Added to Mixture During Mixing (Dry Process)

Northeast Asphalt User Producer Group Meeting
Portsmouth, NH ♦ October 23rd, 2013
1. Design a 9.5 mm Superpave and a 9.5 mm gap graded asphalt mixture using RTR modified asphalt binder.

2. Redesign the same two mixtures using two types of treated RTR added during the mixing process.

3. Determine the effect of using the RTR in a wet process versus adding treated RTR in a dry process on the mixture stiffness, performance (rutting, moisture damage, low temperature cracking, reflective cracking, and fatigue cracking), mixture workability and draindown characteristics.
Experimental Plan

9.5 mm Dense Graded Superpave Mixture

9.5 mm Gap Graded Mixture

Incorporate RTR into Mixtures

Control Mixture without RTR

Mixture Design

Wet Process
RTR Added to the Binder

Untreated

Testing

Dry Process
RTR Added to the Mixture

Treated A

Treated B

1. Untreated #30 Mesh
2. Treated #30 Mesh - A
3. Treated #30 Mesh - B
Experimental Plan

Testing

Mastic

Rutting Performance
Multiple Stress Creep Recovery (MSCR)

Fatigue Performance
Linear Amplitude Sweep (LAS)

Mixture Performance

Low Temperature Cracking
Thermal Stress
Restrained Specimen Test

Reflective Cracking
Texas Overlay Tester

Fatigue Cracking
Beam Fatigue

Mixture Stiffness
Dynamic Modulus |E*|

Rutting / Moisture Susceptibility
Hamburg Wheel Tracking Device

Workability
Asphalt Workability Device

Draindown
The untreated Liberty Tire Recycling #30 mesh RTR was sent to two different research groups (Sonneborn LLC and Polymer Consultants Inc.) who then treated the RTR. This yielded two distinct treated RTR to be incorporated into the mixture through a dry process.

- Sonneborn LLC = Treated RTR A
- Polymer Consultants Inc = Treated RTR B
### Mixture Design

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>9.5 mm Superpave Dense Graded</th>
<th>9.5 mm Superpave Specification</th>
<th>9.5 mm Gap Graded</th>
<th>9.5 mm Gap Graded Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.5 mm</td>
<td>100.0</td>
<td>100 min</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>9.5 mm</td>
<td>97.1</td>
<td>90-100</td>
<td>92.4</td>
<td>91-95</td>
</tr>
<tr>
<td>4.75 mm (No. 4)</td>
<td>66.8</td>
<td>90 max</td>
<td>44.2</td>
<td>40-45</td>
</tr>
<tr>
<td>2.36 mm (No. 8)</td>
<td>47.8</td>
<td>32-67</td>
<td>25.9</td>
<td>22-26</td>
</tr>
<tr>
<td>1.18 mm (No. 16)</td>
<td>33.5</td>
<td>-</td>
<td>17.3</td>
<td>-</td>
</tr>
<tr>
<td>0.600 mm (No. 30)</td>
<td>23.0</td>
<td>-</td>
<td>12.0</td>
<td>9-12</td>
</tr>
<tr>
<td>0.300 mm (No. 50)</td>
<td>13.3</td>
<td>-</td>
<td>8.0</td>
<td>6-8</td>
</tr>
<tr>
<td>0.150 mm (No. 100)</td>
<td>7.1</td>
<td>-</td>
<td>6.1</td>
<td>-</td>
</tr>
<tr>
<td>0.075 mm (No. 200)</td>
<td>4.4</td>
<td>2-10</td>
<td>4.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Binder Content, %</td>
<td>6.0%</td>
<td>-</td>
<td>7.5%</td>
<td>6.0% Min.</td>
</tr>
</tbody>
</table>
Conducted to determine changes in mixture stiffness due to wet and dry process RTR utilized.

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>4°C</td>
<td>10 Hz, 1Hz, 0.1Hz</td>
</tr>
<tr>
<td>20°C</td>
<td>10 Hz, 1Hz, 0.1Hz</td>
</tr>
<tr>
<td>40°C</td>
<td>10 Hz, 1Hz, 0.1Hz, 0.01Hz</td>
</tr>
</tbody>
</table>

Specimens were fabricated at a target air void level of 7.0 ± 1.0%.
Mixture Master Curves – Dense Graded

9.5mm Superpave Dense Graded Mixtures

Dynamic Modulus $|E^*|$, ksi

Reduced Frequency, Hz

- DG Control
- DG Control + Untreated GTR Added to Binder (Wet)
- DG Control + Treated GTR A Added to Mixture (Dry)
- DG Control + Treated GTR B Added to Mixture (Dry)
9.5mm Gap Graded Mixtures

- GG Control
- GG Control + Untreated GTR Added to Binder (Wet)
- GG Control + Treated GTR A Added to Mixture (Dry)
- GG Control + Treated GTR B Added to Mixture (Dry)

Dynamic Modulus $|E^*|$, ksi

Reduced Frequency, Hz
The control mixture had the lowest stiffness.

Generally, wet process mixtures yielded the highest increase in stiffness at all testing temperatures relative to the control mixtures with no RTR.
Rutting/Moisture Susceptibility

HWTD testing conducted in accordance with AASHTO T324

Water temperature of 50°C (122°F)

Test duration of 20,000 cycles
Stripping Inflection Point (SIP)

Northeast Asphalt User Producer Group Meeting
Portsmouth, NH ♦ October 23rd, 2013
## Rutting/Moisture Susceptibility

<table>
<thead>
<tr>
<th></th>
<th>RTR Introduction Method</th>
<th>Stripping Inflection Point</th>
<th>Rut Depth at 10,000 Passes (mm)</th>
<th>Rut Depth at 20,000 Passes (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dense Graded Mixtures</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DG Control</td>
<td>n/a</td>
<td>5,300</td>
<td>&gt;20</td>
<td>&gt;20</td>
</tr>
<tr>
<td>DG Control + Untreated RTR (Wet)</td>
<td>Added to Binder</td>
<td>NONE</td>
<td>0.70</td>
<td>0.85</td>
</tr>
<tr>
<td>DG Control + Treated RTR A (Dry)</td>
<td>Added to Mixture</td>
<td>NONE</td>
<td>1.22</td>
<td>2.00</td>
</tr>
<tr>
<td>DG Control + Treated RTR B (Dry)</td>
<td>Added to Mixture</td>
<td>NONE</td>
<td>1.60</td>
<td>2.76</td>
</tr>
<tr>
<td><strong>Gap Graded Mixtures</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GG Control</td>
<td>n/a</td>
<td>3,100</td>
<td>&gt;20</td>
<td>&gt;20</td>
</tr>
<tr>
<td>GG Control + Untreated RTR (Wet)</td>
<td>Added to Binder</td>
<td>NONE</td>
<td>1.76</td>
<td>2.31</td>
</tr>
<tr>
<td>GG Control + Treated RTR A (Dry)</td>
<td>Added to Mixture</td>
<td>14,750</td>
<td>2.93</td>
<td>&gt;20</td>
</tr>
<tr>
<td>GG Control + Treated RTR B (Dry)</td>
<td>Added to Mixture</td>
<td>16,400</td>
<td>3.35</td>
<td>9.01</td>
</tr>
</tbody>
</table>
For dense graded mixtures, the wet and dry process RTR mixtures passed the test.

For gap graded mixtures, the wet process mixture was more effective in improving the moisture and rutting resistance and as compared to the dry process treated RTR mixtures.
Mixture Low Temperature Cracking - TSRST

Cooling Rate of -10°C/hour

Testing in accordance with AASHTO TP10-93

Northeast Asphalt User Producer Group Meeting
Portsmouth, NH ♦ October 23rd, 2013
## TSRST Low Temperature Results

<table>
<thead>
<tr>
<th>Dense Graded Mixtures</th>
<th>RTR Introduction Method</th>
<th>TSRST Specimen Temperature at Failure, °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>DG Control</td>
<td>n/a</td>
<td>-24.3</td>
</tr>
<tr>
<td>DG Control + Untreated RTR (Wet)</td>
<td>Added to Binder</td>
<td>-28.7</td>
</tr>
<tr>
<td>DG Control + Treated RTR A (Dry)</td>
<td>Added to Mixture</td>
<td>-26.8</td>
</tr>
<tr>
<td>DG Control + Treated RTR B (Dry)</td>
<td>Added to Mixture</td>
<td>-29.3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gap Graded Mixtures</th>
<th>RTR Introduction Method</th>
<th>TSRST Specimen Temperature at Failure, °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>GG Control</td>
<td>n/a</td>
<td>-24.3</td>
</tr>
<tr>
<td>GG Control + Untreated RTR (Wet)</td>
<td>Added to Binder</td>
<td>-28.0</td>
</tr>
<tr>
<td>GG Control + Treated RTR A (Dry)</td>
<td>Added to Mixture</td>
<td>-25.2</td>
</tr>
<tr>
<td>GG Control + Treated RTR B (Dry)</td>
<td>Added to Mixture</td>
<td>-28.5</td>
</tr>
</tbody>
</table>
The wet process mixtures low cracking temperatures were significantly colder than those for the control and Treated RTR A mixtures.

The wet process and Treated RTR B mixtures were not significantly different. This indicates that the wet and dry process could be comparable.
Test Temperature = 15°C (59°F)

Test Termination at 2,000 cycles or 93% Load reduction

Testing in accordance with Tex-248-F
Overlay Tester Results – Dense Graded

Overlay Test Results - 9.5mm Superpave Dense Graded Mixtures

Mixtures:
- Control
- Control + Untreated GTR Added to the Binder (Wet)
- Control + Treated GTR A Added to the Mixture (Dry)
- Control + Treated GTR B Added to the Mixture (Dry)

OT Cycles to Failure:
- Control: 1,200
- Control + Untreated GTR: ~1,400
- Control + Treated GTR A: ~1,600
- Control + Treated GTR B: ~1,800

Graph shows the comparison of OT cycles to failure for different mixtures.
Overlay Tester Results – Gap Graded

Overlay Test Results - 9.5mm Gap Graded Mixtures

- Control
- Control + Untreated GTR Added to the Binder (Wet)
- Control + Treated GTR A Added to the Mixture (Dry)
- Control + Treated GTR B Added to the Mixture (Dry)

Mixtures

OT Cycles to Failure

2,100
1,800
1,500
1,200
900
600
300
0
For both mixture types, the control and Treated RTR B mixtures exhibited the most cycles to failure which correlated well with the mixture stiffness testing. Mixture stiffness testing indicated that these were the least stiff mixtures.
Fatigue – Four Point Bending Beam

- Specimens were fabricated at a target air void level of 7.0 ± 1.0% 

- Testing conducted in strain control mode

- Loading Frequency = 10Hz

- Sinusoidal Wave Form

- Failure Criteria = 50% reduction in initial stiffness per AASHTO T321 method

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Strain Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>15°C (59°F)</td>
<td>900με</td>
</tr>
</tbody>
</table>
## Beam Fatigue Results

<table>
<thead>
<tr>
<th>Dense Graded Mixtures</th>
<th>RTR Introduction Method</th>
<th>Average Number of Cycles to 50% Initial Stiffness, $N_f$</th>
</tr>
</thead>
<tbody>
<tr>
<td>DG Control</td>
<td>n/a</td>
<td>900με</td>
</tr>
<tr>
<td>DG Control + Untreated RTR (Wet)</td>
<td>Added to Binder</td>
<td>56,756</td>
</tr>
<tr>
<td>DG Control + Treated RTR A (Dry)</td>
<td>Added to Mixture</td>
<td>25,042</td>
</tr>
<tr>
<td>DG Control + Treated RTR B (Dry)</td>
<td>Added to Mixture</td>
<td>79,836</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gap Graded Mixtures</th>
<th>RTR Introduction Method</th>
<th>Average Number of Cycles to 50% Initial Stiffness, $N_f$</th>
</tr>
</thead>
<tbody>
<tr>
<td>GG Control</td>
<td>n/a</td>
<td>900με</td>
</tr>
<tr>
<td>GG Control + Untreated RTR (Wet)</td>
<td>Added to Binder</td>
<td>60,972</td>
</tr>
<tr>
<td>GG Control + Treated RTR A (Dry)</td>
<td>Added to Mixture</td>
<td>30,791</td>
</tr>
<tr>
<td>GG Control + Treated RTR B (Dry)</td>
<td>Added to Mixture</td>
<td>88,176</td>
</tr>
</tbody>
</table>
The wet process and Treated RTR B dry process mixtures had similar fatigue cracking performance. This suggests that a wet or dry process can provide comparable fatigue characteristics of the mixtures.
## Draindown Results

<table>
<thead>
<tr>
<th>Gap Graded Mixtures</th>
<th>RTR Introduction Method</th>
<th>Draindown at Mixing Temperature</th>
<th>Draindown at Mixing Temperature +15ºC</th>
</tr>
</thead>
<tbody>
<tr>
<td>GG Control</td>
<td>n/a</td>
<td>1.1%</td>
<td>1.3%</td>
</tr>
<tr>
<td>GG Control + Untreated RTR (Wet)</td>
<td>Added to Binder</td>
<td>0.1%</td>
<td>0.1%</td>
</tr>
<tr>
<td>GG Control + Treated RTR A (Dry)</td>
<td>Added to Mixture</td>
<td>0.1%</td>
<td>0.2%</td>
</tr>
<tr>
<td>GG Control + Treated RTR B (Dry)</td>
<td>Added to Mixture</td>
<td>0.1%</td>
<td>0.1%</td>
</tr>
</tbody>
</table>
The draindown using the wet process was 0.1% which was much lower than the control mixture. This might be due to the viscous gel that the RTR forms when added to the asphalt binder.

The draindown for the dry process was 0.2% or less which was also much lower than the control mixture.

This might indicate that the dry process using the two treated RTR led to the same formation of a viscous gel in the mixture.
Overall, the data analysis indicated that treated RTR added in a dry process can yield mixtures that have similar performance characteristics to the same mixtures designed using the wet process.
Gap Graded Test Road Section Construction

St. Petersburg
October 06, 2013
What Is This?

- RTR
- Bitumen ~20%
- Heat ~350 F
- Mineral Additive
- Cooled – reaction suspended
- Kind of a micro-pellet
TEST ROAD SECTION LOCATION AND CONSTRUCTION INFORMATION

Project Location: St. Petersburg, Russia, Ringway (south)
Date and time: 06/10/2013 13:00-15:00
Producer and contractor: "Asphaltobetonny Zavod N1"
Plant: BENINGHOFEN
Pug Mill Capacity – 4 tones
Length of section: 300 m
The layer thickness: 5 cm
Type of mixture: GAP Grade
  Bitumen content: 5,6%
  RuBind content: 3,4%
Ambient temperature: +7C to +9C
Temperature of the mixture:
  at the plant: 180C
  during compaction: 160C
MIX PRODUCTION
PLACEMENT AND COMPACTION
## PHYSICAL-MECHANICAL PROPERTIES OF ASPHALT CONCRETE MIX

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>Requirements of GOST 31015-2002</th>
<th>actual values</th>
<th>GAP Grade with RuBind</th>
<th>Common used SMA 15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density, g/cm³</td>
<td>-</td>
<td>2,51</td>
<td>2,64</td>
<td></td>
</tr>
<tr>
<td>Porosity,% by volume</td>
<td>1,0-4,0</td>
<td>2,0</td>
<td>2,1</td>
<td></td>
</tr>
<tr>
<td>Compressive strength, MPa, at temperatures:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>+20°C</td>
<td>≥2,2</td>
<td>6,1</td>
<td>2,8</td>
<td></td>
</tr>
<tr>
<td>+50°C</td>
<td>≥0,65</td>
<td>1,0</td>
<td>0,8</td>
<td></td>
</tr>
<tr>
<td>Draindown, %</td>
<td>≤0,2</td>
<td>-</td>
<td>0,20</td>
<td></td>
</tr>
<tr>
<td>Water resistance/long-term water resistance</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abrasive wearing by the Prall method, ml, EN 12697-16)</td>
<td>-</td>
<td>11</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>The rut depth after 20,000 wheel passes, mm (+60°C) EN 12697.22</td>
<td>-</td>
<td>1,2</td>
<td>3,8</td>
<td></td>
</tr>
</tbody>
</table>
PelletPAVE™

Providing Asphalt-Rubber Technology for Pavement Maintenance

Cost Effective and Convenient
# Moisture Susceptibility Testing / AASHTO-T-283

## PelletPAVE ITS / TSR Analysis

<table>
<thead>
<tr>
<th>Sample</th>
<th>Load</th>
<th>ITS, psi</th>
<th>AVG ITS, psi</th>
<th>TSR, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry 1 (F)</td>
<td>5676</td>
<td>163.8</td>
<td>171.8</td>
<td></td>
</tr>
<tr>
<td>Dry 2 (F)</td>
<td>6224</td>
<td>179.8</td>
<td></td>
<td>100.2</td>
</tr>
<tr>
<td>Wet 1 (F)</td>
<td>6027</td>
<td>173.7</td>
<td>172.1</td>
<td></td>
</tr>
<tr>
<td>Wet 2 (F)</td>
<td>5909</td>
<td>170.5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

![Graph showing ITS and TSR comparison between Pave Pellets and Type A (PG 76-22)]
Recent Projects with Pellet Pave

• Clark County Nevada 2013
  – 100% of binder from pellets

• New York City Oct 2014
  – Half of the Project used Pellets
  – 700 mix tons where pellets 100% of binder
  – 700 mix tons of A-R
October 2014 Demo Near New York City
There is Science in Everything!
**Ooey-gooey:** Add 2 cups more flour.

**A nice tan:** Set the oven higher than 350 degrees Fahrenheit (maybe 360). Caramelization, which gives cookies their nice brown tops, occurs above 356 degrees.

**Crispy with a soft center:** Use 1/4 teaspoon baking powder and 1/4 teaspoon baking soda.

**Chewy:** Substitute bread flour for all-purpose flour.

**Just like store-bought:** Trade the butter for shortening. Arias notes that this ups the texture but reduces some flavor; her suggestion is to use half butter and half shortening.

**Thick (and less crispy):** Freeze the batter for 30 to 60 minutes before baking. This solidifies the butter, which will spread less while baking.

**Cakey:** Use more baking soda because, according to Nyberg, it "releases carbon dioxide when heated, which makes cookies puff up."

**Butterscotch flavored:** Use 3/4 cup packed light brown sugar (instead of the same amount of combined granulated sugar and light brown sugar).

**Uniformity:** If looks count, add one ounce corn syrup and one ounce granulated sugar.

**More flavor:** Chilling the dough for at least 24 hours before baking deepens all the flavors
Asphalt Costs Have Surpassed RTR Costs

Asphalt Costs-Aug 1990 to Feb 2014

Liquid Ton

Asphalt Prices

RTR Costs
Reduce Costs for Asphalt Mix Producers