CHEMICALLY ENGINEERED CRUMB RUBBER (ECR)

DRY PROCESS RUBBER MODIFICATION OF ASPHALT PAVEMENTS

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PRESENTATION GOALS

- BRIEFLY DISCUSS HOW RUBBER MODIFIES ASPHALT
- DESCRIBE THE DRY PROCESS
- UNDERSTAND OPERATIONAL AND FIELD REALITIES OF THE DRY PROCESS
- DISCUSS INTEGRATION OF DRY PROCESS RUBBER WITH BALANCED MIX DESIGN
- UNDERSTAND THE MODIFICATION PROCESS
- UNDERSTAND THE ECONOMIC BENEFITS OF DRY PROCESS USE
TWO RUBBER ASPHALT MYTHS

- RECYCLED TIRE CRUMB RUBBER “MELTS” IN HOT ASPHALT BINDER
- CRUMB RUBBER MODIFICATION IS THE SAME AS POLYMER MODIFICATION OF ASPHALT
WHAT HAPPENS TO DRY PROCESS CRUMB RUBBER IN HOT ASPHALT?

- CRUMB SURFACE PORES ABSORB LIGHTER ENDS OF BINDER
- BINDER VISCOSITY INCREASES
- RUBBER SWELLS, BECOMES STICKY
- MINIMAL DEPOLYMERIZATION AND LIMITED RELEASE OF SOME TIRE PROCESSING OILS
- VIRTUALLY ALL RUBBER REMAINS IN GRANULAR FORM
- EXTENDED HEATING RELEASES LIGHT ENDS, REDUCES VISCOSITY

REACTION OF RUBBER AND HEATED BINDER
WHAT HAPPENS WHEN CRUMB RUBBER IS ADDED TO AN ASPHALT MIX?

- BINDER ABSORBED BY RUBBER
- BINDER VISCOSITY/RUTTING RESISTANCE INCREASES
- SLIGHT INCREASE IN MIX FLEXIBILITY
- MECHANICAL INTERFERENCE IN CRACK PROPAGATION
- MORE RUT AND CRACK RESISTANCE
GTR-modified binder is made by mixing GTR particles with asphalt in high shear for 30 mins.

90 mins at room temp and 30 mins at -15°C later...

After 2 hrs of conditioning in DC(T) chamber at PG low temperature...

Test is run at a rate of 0.2 mm/min.

Note: a) This test was a trial run to test the data acquisition capabilities of the machine. This was run at 1 mm/min.
b) CMOD gage points are missing in this video.
Polymer-modified Binder CT Specimen
Brittle Failure

Load vs CMOD

PG 64-22

PG 64-22 + 5% GTR

PG 64-22 + 10% GTR

PG 64-22 + 15% GTR

PG 64-22 + 20% GTR

PG 76-22 Polymer-Modified
Fracture Energy ($J/m^2$) =

\[
\text{Area under Load} - \text{CMOD Curve} \quad \frac{\text{Lig. Length} \times \text{Thickness}}{}
\]
TWO GENERAL TYPES OF CRM ASPHALT: TERMINAL BLEND AND DRY PROCESS BLEND
LET’S TAKE A LOOK AT THE “DRY PROCESS”
ENGINEERED CRUMB RUBBER

- Recycled Tire Rubber
- Chemically Engineered Bond on Rubber Surface
- ISO-Compliant Manufacturing Process
- Controlled Reactive Surface Area
- Ambient or Cryo Rubber
- Reliable Dry Flow Characteristics

ELASTIKO®
PRECISION PNEUMATIC INJECTION SYSTEM

- MODIFIED FIBER MACHINE
- LOSS-IN-WEIGHT FEEDER
- 2 MIN. ACCURACY: +/- 2%
- 500 MEASUREMENTS/DAY CAPABILITY
- TIED TO BINDER PUMP SPEED
- MAX PLANT OUTPUT: 400 TPH
- ADJUSTABLE FEED RATE FOR ALL MIX DESIGNS
THE DRY PROCESS IN PRODUCTION
HOW DOES DRY PROCESS RUBBER WORK IN PRODUCTION?

- MATERIAL ADDED LIKE A DRY AGGREGATE
- CRUMB DIFFUSES IN MIX LIKE FINE AGGREGATE (NO SETTLING)
- RUBBER INTERACTS WITH HEATED BINDER DURING MIXING, SYSTEM DWELL TIME
- RUBBER SOFTENS, SWELLS, ABSORBS LIGHTER ENDS OF BINDER
- BINDER STIFFENS: RUT RESISTANCE
- SOFT RUBBER GRAINS POPULATE BINDER RUBBER INTERFACE
- SOME INCREASE IN MIX FLEXIBILITY
- MECHANICAL INTERFERENCE WITH CRACK PROPAGATION
- CAN INCREASE TOLERANCE FOR ABR
- RUBBER RETAINS ITS CHARACTER THROUGH GENERATIONS OF PAVEMENT
WHY USE THE DRY PROCESS?

- CHEAPER MIX MODIFICATION
- EASE OF DESIGN
  - STANDARD ASPHALT
  - REDUCED ADDITIVE NEEDS
  - OPTIONS FOR ABR
- EASE OF PRODUCTION
  - NO SPECIAL TANKS
  - NO MULTIPLE BINDERS
  - ON-OFF MODIFICATION CONTROL
  - STANDARD INJECTION EQUIPMENT
  - HANDLES LIKE REGULAR HOT MIX
  - REDUCED WASTE
- EASE OF LAYDOWN
  - EASY UNLOAD
  - FLOWS THROUGH PAVER
  - WARM MIX PERFORMANCE
  - NO STICKING TO ROLLERS, TOOLS
  - REDUCED ROLLER PASSES
  - PROPER COMPACCTION
  - MINIMAL WASTE GENERATION
  - CREWS LIKE IT
- GOOD FIELD PERFORMANCE
DOES THE DRY PROCESS “WORK” IN THE PLANT AND IN THE FIELD?
ILLINOIS TOLLWAY SYSTEM

APPROACHING 300 MILES OF HEAVY-USE INTERSTATE TOLL HIGHWAY
TOLLWAY EXPERIMENTAL PAVING PROGRAM

- Primary mix designs: SMA and Dense-Graded
- Aggressive push for improved performance
  - “Test track” perspective
- Push for improved sustainability
- Work with rubberized asphalt
  - Terminal blend down since 2008
  - Trial efforts with dry process, hybrid terminal blends
  - Multiple experiments with higher ABR mixes
- Changeover to balanced mix design
HAMBURG/DCT MIX DESIGN PLOT

- **Stiff Mix, Failing**
- **Super Mix, Passing**
- **Low**
- **Med**
- **High Traffic**
- **Poor Mix, Failing**
- **Soft Mix, Failing**

**Hamburg Rut Depth (mm)**

**DC(T) Fracture Energy (J/m²)**

- 400
- 460
- 690
- 12.5
ILLINOIS TOLLWAY AUTHORITY DRY PROCESS PAVING PROJECTS

- IN 2015: SHOULDER WORK: DENSE-GRADED, SMA
- IN 2016: MAINLINE SMA PAVING
  - VARIOUS MIX DESIGNS
  - HIGH ABR, SOFT BINDERS
- IN 2017: SPECIFICATION FOR DRY PROCESS ISSUED
  - PMA, TERMINAL BLEND RUBBER, DRY PROCESS ALLOWED
  - DENSE-GRADED, SMA, LEVELING MIXES, FRICTION AND BASE
- IN 2018 TO PRESENT: PRODUCERS DECIDE BEST PROCESS FOR THEIR PROJECT
PHASE ONE DRY PROCESS TRIALS

- TWO MIX DESIGNS: TOLLWAY SMA AND WIDOT DENSE-GRADED
- MODERATE ABR, 58-28 BINDER, 1.5 MILE SHOULDER STRIPS
- PAVED IN 40 F TEMPS, MIX TEMP OUT OF PAVER AS LOW AS 238 F
- NO COMPACITION ISSUES
- MIX LAB PERFORMANCE GOOD. FIELD PERFORMANCE GOOD
PHASE ONE LAB RESULTS FOR TOLLWAY SMA AND DENSE-GRAD

<table>
<thead>
<tr>
<th>90WMA1523 IL 12.5 N80 SMA F Surface</th>
<th>Volumetrics</th>
<th>Performance Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquid AC</td>
<td>Gmb, Gmm, Voids %</td>
<td>Hamburg Rut Depth (mm)</td>
</tr>
<tr>
<td>PG 70-28</td>
<td>2.52, 2.612, 3.5</td>
<td>2.06 @ 20,000</td>
</tr>
<tr>
<td>PG 58-28 w/GTR</td>
<td>2.51, 2.613, 3.9</td>
<td>2.51 @ 20,000</td>
</tr>
</tbody>
</table>

*Not same design but a similar blend

<table>
<thead>
<tr>
<th>CURDE15003 WIS E-3 12.5 N75 Surface</th>
<th>Volumetrics</th>
<th>Performance Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquid AC</td>
<td>Gmb, Gmm, Voids %</td>
<td>Hamburg Rut Depth (mm)</td>
</tr>
<tr>
<td>PG 58-28</td>
<td>2.401, 2.501, 4.0</td>
<td>8.17 @ 10,000 passes</td>
</tr>
<tr>
<td>PG 58-28 w/GTR</td>
<td>2.373, 2.487, 4.6</td>
<td>3.42 @ 20,000 passes</td>
</tr>
</tbody>
</table>

DCT: DISC SHAPED COMPACT TENSION TEST
**PHASE 2 TRIALS: GTR PRODUCTS EVALUATED**

<table>
<thead>
<tr>
<th>TERMINAL BLEND GTR</th>
<th>DRY PROCESS ENGINEERED CRUMB RUBBER (ECR)</th>
<th>RUBBER-POLYMER HYBRID</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Finely ground rubber; #30 - #100</td>
<td>• Shipped in totes</td>
<td>• Rubber and polymer pellets</td>
</tr>
<tr>
<td>• Terminal blended</td>
<td>• Continuous feed into drum</td>
<td>• End result PG Grade formulation</td>
</tr>
<tr>
<td></td>
<td>• Dry (non-liquid)</td>
<td>• Terminal blended</td>
</tr>
</tbody>
</table>
## TOLLWAY PHASE 2 TRIAL MIX DESIGNS

**TARGET PERFORMANCE:** COMPARABLE TO 70 -28 BINDER BASE

<table>
<thead>
<tr>
<th>PLACEMENT</th>
<th>PRODUCT</th>
<th>BASE MIX</th>
<th>SOFTER AC</th>
<th>SOFTER MIX MORE ABR</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAINLINE</td>
<td>TERMINAL GTR</td>
<td>GTR</td>
<td>58 -28 + 12%</td>
<td>46 -34 +12%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>GTR</td>
<td></td>
</tr>
<tr>
<td>MAINLINE</td>
<td>DRY GTR</td>
<td>GTR</td>
<td>58 -28 + 10%</td>
<td>46 -34 +10%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>GTR</td>
<td></td>
</tr>
<tr>
<td>SHOULDER</td>
<td>TERM. HYBRID GTR</td>
<td>58 -28+ 10% ADD</td>
<td>46 -34 +10%</td>
<td>46 -34 +10%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>ADD</td>
<td></td>
</tr>
</tbody>
</table>

* INCREASE ABR TO 47%, ALL OTHERS 34%
TOLLWAY PHASE 2 FIELD RESULTS TO DATE

- BEGINNING 4TH YEAR OF SERVICE IN 2019
- BINDERS EXTRACTED WITH RUBBER SHOWED ALL MIXES IN THE 70 -28 RANGE
- SEVERE WINTER COLD IN EARLY 2019
- MAINLINE PAVING SHOWED NO THERMAL OR REFLECTIVE CRACKING
- SIGNIFICANT CRACKING SEEN IN SHOULDER MIXES (MINIMAL BASE)
- TOLLWAY RELEASED A SPECIFICATION FOR DRY PROCESS WITH UP TO 51% ABR
BALANCED MIX PERFORMANCE PLOT: IL DRY PROCESS SMA RUBBER PROJECTS FIELD DATA
MARKET, PRICING RESPONSE TO TOLLWAY DRY PROCESS SPECIFICATION

- In 2018, Tollway reported an SMA quoted pricing range of between $92 and $80 per ton.
- Dry process was at bottom of range.
- Approx. 300,000 mix tons on ground or in process.
- 50% of Tollway asphalt (friction and leveling course) used dry process.
- In 2019 to date, approximately 75% of carryover and bid work for Tollway (as reported) plans to use dry process rubber with high ABR.
- Part of savings from higher ABR, big modification savings too.
TOLLWAY DRY PROCESS PROJECTS
UNDERSTANDING THE DRY PROCESS MODIFICATION PROCESS

- NOT THE SAME PROCESS AS CROSS-LINKED RUBBER
- SEGREGATION STIFFENS BINDER
- FLEXIBILITY/RECOVERY EFFECTS ARE SMALL
- RUBBER CHANGES MECHANICAL INTERACTION WITH PROPAGATING CRACKS (DEFLECTING, PINNING)
- NET EFFECT IN FIELD: SIMILAR PERFORMANCE TO PMA
- OBSERVATIONS BASED ON MULTIPLE PROJECTS WITH POLYMER CONTROL PAVEMENTS
TOLLWAY IFIT SCB TESTING

IFIT SCORE

0 1 2 3 4 5 6 7

IFIT

SCORE

TERMINAL BLEND

DRY PROCESS

HYBRID GTR
NATIONAL DRY PROCESS FOOTPRINT GROWING:
> 3 MILLION ELASTIKO® MIX TONS PLACED

MORE THAN 1,000 MILES OF INTERSTATE
5,000 MILES OF STATE HIGHWAY
MULTIPLE SIDE-BY-SIDE POLYMER/DRY PROCESS FIELD COMPARISONS OVER LAST 13 YEARS

- WET, DRY, HOT, COLD ENVIRONMENTS
- COMPARABLE LIFE-CYCLE PERFORMANCE
- LOWER DRY PROCESS UP FRONT, LIFE CYCLE COST
IMPROVED QUALITY CONTROL IMPACTS

- NO PRODUCT LOSS DURING TRANSPORT
- NO SETTLING/SEPARATION
- ACCURATE, DIGITAL LOAD RATE TRACKING
- RUBBER CONTENT RECOVERY AFTER PRODUCTION
  - SOLVENT RECOVERY
  - RUBBER OXIDATION
US MODIFICATION ECONOMICS OVERVIEW

COST COMPARISON: TWO-GRADE BUMP

PRODUCER COST IN DOLLARS PER BINDER TON
CONCLUDING REMARKS

- MOVING THE LOCUS OF MODIFICATION HAS ECONOMIC BENEFITS
- COMPARABLE PAVEMENT PERFORMANCE WITH PMA
- DIFFERENT MODIFICATION PROCESSES
- DRY PROCESS WELL-SUITED FOR TRANSITION TO BALANCED MIX DESIGN
- SUBSTANTIAL BODY OF FIELD DATA IN A WIDE ENVIRONMENTAL RANGE, WIDE ARRAY OF MIX DESIGNS
- STRONG EVIDENCE OF CUSTOMER/MARKET ACCEPTANCE
THANK YOU!
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