LEA Objectives

- Reduce energy consumption
- Reduce GGE
- Equal or improved mix performance
- Minimize equipment costs/plant modifications
Energy Equation – No Change of State

\[ \Delta H = M \times c_p \times (T_f - T_i) \]

where:

- \( M \) = mass in kg
- \( c_p \) = specific heat in J/(kg*°C)
- \( T_i \) = initial temperature (°C)
- \( T_f \) = final temperature (°C)
Energy Equation – Physical Change of State

\[ \Delta H = L_v (M_{vf} - M_{vi}) \]

where:

- \( L_v \) = latent heat of vaporization in J/kg
- \( M_{vi} \) = initial mass of vapor in kg
- \( M_{vf} \) = final mass of vapor in kg
Thermal Properties

\( C_{agg} \) – specific heat of aggregate = 0.837 kJ/kg/°C
\( C_{bitumen} \) – specific heat of bitumen = 2.093 kJ/kg/°C
\( C_{water} \) – specific heat of water = 4.185 kJ/kg/°C
\( L_v \) – latent heat of vaporization = 2256 kJ/kg
\( C_{vap} \) – specific heat of water vapor = 1.830 kJ/kg/°C

Thus, the vaporization of 10 kg of water requires 22.5 MJ, as much energy as required to heat 154 kg of coarse aggregate from 22 °C to 197 °C.
Coarse Aggregates are coated by all of the asphalt

**PHASE 1**
120°/150°C

**PHASE 2**
170°C

**PHASE 3**
Dry, Hot Coarse Aggregates

**PHASE 4**
Hot Asphalt + Additive

**PHASE 5**
Coarse Aggregates are coated by all of the asphalt

Moisture from fine aggregates triggers asphalt foaming

Foamed asphalt encapsulates fine aggregates

Thermal equilibrium reached. All aggregates uniformly coated

120°/150°C

170°C

100°C

90°C
Heat Transfer Thermogram During Mixing

![Graph showing heat transfer thermogram during mixing.](image)

- **Coarse core**
- **Coarse surface**
- **AC**
- **Fines water**
- **Fines**

**Temperatures, in °C**

**Time, in seconds**
Additive Injection System
Polkville Stone
Moisture Control
Performance
Rt. 11 – Just south of Polkville
Laboratory Compaction – LEA vs. HMA control - 2006

Low Energy Asphalt vs. Hot Mix Compaction Curves
Standard Test Specimen (115mm)
Laboratory Compaction – LEA vs. HMA control - 2006

Low Energy Asphalt vs. Hot Mix Compaction Curves
TSR Samples (95mm)
Laboratory Compaction – LEA vs. HMA control - 2006

Low Energy Asphalt vs. Hot Mix Compaction Curves
Dynamic Modulus Specimens (185mm)
### TSR Results – Mixed Warm - 2006

**Project**: POLKVILLE WARM MIX 2006 - RT. 11

**Asphalt**:  
**Additive**:  
**Dosage**:  
**Compaction**: PINE INST. GYRATORY COMPACTOR  
**Effort**:  
**Date Tested**: 9-21-06  
**By**: JACOB EGGLESTON / JASON DIMARE

<table>
<thead>
<tr>
<th>Sample #</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
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<tbody>
<tr>
<td>Diameter</td>
<td>D</td>
<td>3.937</td>
<td>3.937</td>
<td>3.937</td>
<td>3.937</td>
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<tr>
<td>Thickness</td>
<td>t</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2.868</td>
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<tr>
<td>Dry Mass In Air</td>
<td>A</td>
<td>1224.3</td>
<td>1223.2</td>
<td>1225.0</td>
<td>1223.8</td>
</tr>
<tr>
<td>SSD Mass</td>
<td>B</td>
<td>1228.3</td>
<td>1227.1</td>
<td>1229.4</td>
<td>1228.1</td>
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<tr>
<td>Mass In Water</td>
<td>C</td>
<td>678.5</td>
<td>674.8</td>
<td>677.3</td>
<td>676.9</td>
</tr>
<tr>
<td>Volume, (B-C)</td>
<td>E</td>
<td>549.7</td>
<td>552.3</td>
<td>552.1</td>
<td>551.2</td>
</tr>
<tr>
<td>% Air Voids, (100(G-F)/G)</td>
<td>H</td>
<td>7.0</td>
<td>7.5</td>
<td>7.4</td>
<td>7.3</td>
</tr>
<tr>
<td>Volume Air Voids, (HE/100)</td>
<td>I</td>
<td>38.5</td>
<td>41.6</td>
<td>40.6</td>
<td>40.2</td>
</tr>
<tr>
<td>Load (lbs)</td>
<td>P</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1080</td>
</tr>
</tbody>
</table>

**Saturated 7 sec. @ 30 °Hg**

| Minimum Mass Required for 55% Saturation | 1245.5 | 1246.1 | 1247.3 |
| SSD Mass | B' | 1257.4 | 1252.8 | 1249.7 |
| Mass In Water | C' | 706.4 | 698.3 | 696.3 |
| Volume, (B'-C') | E' | 551 | 545.4 | 553.4 |
| Vol. Abs. Water, (B'-A) | J' | 33.1 | 29.6 | 24.7 |
| % Saturation, (100J'/I) | 88.0 | 71.2 | 60.8 |
| % Swell, (100(E'-E)/E) | 0.24 | 0.40 | 0.24 |

**Conditioned 24 h In 140F Water**

| Thickness | t" | 2.818 | 2.828 | 2.824 |
| SSD Mass | B" | 1263.4 | 1259.4 | 1259.6 |
| Mass In Water | C" | 710.2 | 703.1 | 702.6 |
| Volume, (B"-C") | E" | 552.2 | 556.3 | 557 |
| Vol. Abs. Water, (B"-A) | J" | 39.1 | 36.2 | 34.6 |
| % Saturation, (100J"/I) | 101.5 | 87.1 | 85.2 |
| % Swell, 100(E"-E)/E | 0.64 | 0.72 | 0.89 |
| Load (lbs) | P" | 850 | 870 | 860 | 860 |

**Dry Strength, 2P/(3.14)Dt**

| Std | Avg. 60.9 | 63.7 | 72.9 | 65.8 |
| Wet Strength, 2P"/(3.14)Dt" | 48.8 | 49.8 | 49.3 | 49.3 |

**Visual Moisture Damage**: some some some  
**Crack/Break Aggregate**: some some some

**AVERAGE TSR = 74.8 %**
# TSR Results – Reheat - 2006

**PROJECT:** POLKVILLE WARM MIX 2006 - RT. 11 (REHEATED)

**ASPHALT:**

**ADDITIVE:**

**COMPACTION:** PINE INST. GYRATORY COMPACTOR

**DATE TESTED:** 9-21-06

**BY:** JACOB EGGLESTON / JASON DIMARE

<table>
<thead>
<tr>
<th>Sample #</th>
<th>Diameter</th>
<th>Thickness</th>
<th>Dry Mass In Air</th>
<th>SSD Mass</th>
<th>Mass In Water</th>
<th>Volume, (B-C)</th>
<th>Bulk Sp. Gr., (A/E)</th>
<th>Max. Sp. Gr.</th>
<th>% Air Voids, (100(G-F)/G)</th>
<th>Volume Air Voids, (HE/100)</th>
<th>Load (lbs)</th>
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<tbody>
<tr>
<td>A</td>
<td>3.937</td>
<td>-</td>
<td>1221.5</td>
<td>1227.5</td>
<td>677.2</td>
<td>E</td>
<td>2.020</td>
<td>2.395</td>
<td>7.3</td>
<td>40.3</td>
<td>P</td>
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<tr>
<td>B</td>
<td>3.937</td>
<td>-</td>
<td>1221.0</td>
<td>1226.0</td>
<td>676.0</td>
<td>F</td>
<td>2.020</td>
<td>2.395</td>
<td>7.3</td>
<td>40.2</td>
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<tr>
<td>C</td>
<td>3.937</td>
<td>-</td>
<td>1220.8</td>
<td>1226.0</td>
<td>675.3</td>
<td>G</td>
<td>2.020</td>
<td>2.395</td>
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<td>2.395</td>
<td>7.35</td>
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</table>

**Dry Strength, 2P/(3.14)Dt Std**

<table>
<thead>
<tr>
<th>Visual Moisture Damage</th>
<th>Crack/Break Aggregate</th>
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<tr>
<td>some</td>
<td>some</td>
</tr>
<tr>
<td>some</td>
<td>some</td>
</tr>
</tbody>
</table>

**AVERAGE TSR = 78.0 %**
Dynamic Modulus (MPa)
Legend number denotes test temperature (C)

Hz

MPa

S-W-4
S-W-10
S-W-20
S-W-30
S-W-35
S-H-4
S-H-10
S-H-20
S-H-30
S-H-35
What did we learn in 2006?

- LEA mixtures can be placed in the rain (not the preferred method) and compacted in the temperature range as low as 60°C.
- LEA mix workability is compatible with current equipment.
- LEA mixtures look the same as conventional HMA but without the odors.
- LEA seems to clean out the transport equipment.
- Moisture susceptibility properties of LEA mixtures are equal to or improved when compared to conventional HMA.
<table>
<thead>
<tr>
<th>Section</th>
<th>Total Cracking lin. ft./lane mile</th>
<th>% of Total Cracking in driving lane</th>
<th>% of Total Cracking in shoulders</th>
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<tbody>
<tr>
<td>HMA Control</td>
<td>842</td>
<td>39</td>
<td>61</td>
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<tr>
<td>LEA</td>
<td>125</td>
<td>33</td>
<td>67</td>
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</table>
What else do we know?

- LEA offers the greatest potential in terms of reduction of fuel consumption.
- This allows LEA to offer the most environmental gains with reductions in GGE in excess of 50%.
Unknowns

**Design Concerns**
- How do we short term condition the mix samples?
- Do we need to adjust our PG grade of asphalt?
- What will our TSR values be?
- Do we need to change the number of gyrations typically used in our HMA designs?
- What should the mix volumetrics be for LEA?
- How do we determine compaction temperatures?
- How will LEA perform with other mix types or other aggregates?
- Can we use polymer modified asphalt for LEA?

**QC/QA Concerns:**
- How do we condition the mix for sample repeatability?
- How sensitive is LEA to aggregate/mix moisture?

**Plant Concerns:**
- Will there be any negative effects on the bag house?
- Drum vs. Batch plants - any differences?
- Can we add RAP to the LEA mixtures?
- What is the flexibility of the location for addition of wet sand? For additive?
- What are the actual energy savings in our plants when producing LEA?
- What are the actual air quality improvements in our plants when producing LEA?

**Field Concerns:**
- Do we need to change our compaction techniques?
- How low can the LEA temperature be and still achieve density?
- How can we improve workability of the LEA mix?
- What is the relationship between field compaction and mix moisture content?

**Performance Concerns:**
- Is there a potential for rutting, flushing, moisture damage, etc.?
- How can we prevent these types of failures in LEA?
- What about rideability of LEA mixtures?
- How can quantify possible performance advantages of LEA?
QC Plan

- Six (6) gyratory specimens will be prepared and checked for density at 65 gyrations (Ndes) – three (3) of which will be conditioned at 95°C +/- 3°C (203°F +/- 5.4°F) for 30 minutes (+/- 5 minutes) before compaction and three (3) of which will be conditioned at 95°C +/- 3°C (203°F +/- 5.4°F) for 2 hours (+/- 5 minutes) prior to compaction. All specimens will be prepared according to AASHTO T-312-04.
- Two (2) gyratory specimens will be prepared and checked for density at 95 gyrations (Nmax) after 2 hours (+/- 5 minutes) of conditioning at 95°C +/- 3°C (203°F +/- 5.4°F). All specimens will be prepared according to AASHTO T-312-04.
- Two samples will be conditioned for 2 hours (+/- 5 minutes) at 95°C +/- 3°C (203°F +/- 5.4°F), prepared, and tested to determine the mix maximum specific gravity according to AASHTO T-209-05.
- Six (6) gyratory specimens will be compacted, following a 2 hour (+/- 5 minute) at 95°C +/- 3°C (203°F +/- 5.4°F) conditioning period, to 7% air voids for moisture susceptibility testing. Testing will be done according to AASHTO T-283-03.
- Six (6) gyratory specimens will be compacted immediately after sampling to 7% air voids for moisture susceptibility testing. Testing will be done according to AASHTO T-283-03.
- Three (3) gyratory samples will be compacted immediately after sampling to 65 gyrations (Ndes) and tested using the apparatus from AASHTO T-283-03.
- Three (3) gyratory samples will be compacted, following a 2 hour (+/- 5 minute) at 95°C +/- 3°C (203°F +/- 5.4°F) conditioning period, to 65 gyrations (Ndes) and tested using the apparatus from AASHTO T-283-03.
- Three (3) gyratory specimens will be compacted, following a 2 hour (+/- 5 minute) at 95°C +/- 3°C (203°F +/- 5.4°F) conditioning period, to 7% air voids for Dynamic Modulus testing. All sample preparation and testing shall be done according to the current AASHTO Proposed Standard Test Methods.
- One sample of mix taken from the plant will be tested for moisture content according to AASHTO T 329-05 with the exception that readings will be taken every 10 minutes (+/- 1 minute) and the temperature will be at 95°C. This will then tested for asphalt content and gradation by means of ignition oven (burnoff) according to AASHTO T-308-05.
- One sample of mix taken from the plant will be tested for moisture content after being conditioned for 4 hrs. at 163°C. This will then tested for asphalt content and gradation by means of ignition oven (burnoff) according to AASHTO T-308-05.
- One sample of mix taken from the field will be tested for moisture content after being conditioned for 4 hrs. at 163°C. This will then tested for asphalt content and gradation by means of ignition oven (burnoff) according to AASHTO T-308-05.
- PG binder will be sampled and tested for compliance with PG specs according to AASHTO M-320-05.
QC Plan

- Density monitoring
- Mixture discharge temperature
- Mix temperature in the trucks.
- Natural gas usage.
- Baghouse temperatures.
- Slat conveyor amperage.
- Pugmill amperage.
- Wet aggregate moisture content*
- Additive rates*
- Stack emissions

* - appears on 5 minute recordation
## 2007 Projects

<table>
<thead>
<tr>
<th>DATE</th>
<th>ROUTE</th>
<th>NMAS</th>
<th>GYR</th>
<th>ESAL'S</th>
<th>BINDER</th>
<th>RAP</th>
<th>TYPE</th>
<th>METRIC TONS</th>
<th>HMA CONTROL</th>
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<td>9.5</td>
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<td>64-28PPA</td>
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<td>T &amp; L</td>
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<td>8/22 – 9/5</td>
<td>NYSDOT RT. 13</td>
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<td>WEAR</td>
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<td>9.5</td>
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<td>64-22</td>
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<td>WEAR</td>
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</table>
Effect of Mix Time on Moisture Content - 35% Wet Fines

- 30 sec. mix time - 300°F - 4.5% Moisture
- 60 sec. mix time - 300°F - 4.5% Moisture
- 30 sec. mix time - 300°F - 6.5% Moisture
- 60 sec. mix time - 300°F - 6.5% Moisture
- 30 sec. mix time - 345°F - 4.5% Moisture
- 60 sec. mix time - 345°F - 4.5% Moisture
Laboratory Compaction – LEA (lab) Aged 2 hrs.@95°C vs. HMA

LEA vs. HMA Compaction Curves
Standard Test Specimen - 115mm
Comparison of Gmb vs. Time of Conditioning

Gmb, Conditioned 30 Minutes @95C Prior to Compaction

Gmb, Conditioned 2 Hrs. @95C Prior to Compaction
Dry Strengths (TSR) - Aged vs. Unaged

Dry Strength, unaged vs. Dry Strength, aged 2hrs.@95C
Tensile Strength Ratio - Aged vs. Unaged
Comparison of Indirect Tensile Strengths - Peak Loads - Aged vs. Unaged

Indirect Tensile Strength, Peak Load in lbs., Unaged

Indirect Tensile Strength, Peak Load in lbs., Aged 2 Hrs. @ 95C

Indirect Tensile Strength, Peak Load in lbs., Unaged
Test Condition

Dynamic Modulus, ksi

Route 11 HMA 64-28 Acid
Route 11 LEA 64-28 Acid
Route 13 LEA 70-22
Actual Fuel Savings

- Ranged from 33 – 47%
## Amperage

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<thead>
<tr>
<th></th>
<th>Slat Conveyor</th>
<th>Pugmill</th>
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<tr>
<td>HMA – PG 64-28PPA</td>
<td>42 - 50</td>
<td>26 – 38</td>
</tr>
<tr>
<td>LEA – PG 64-28PPA</td>
<td>42 - 50</td>
<td>27 – 34</td>
</tr>
<tr>
<td>LEA – PG 64-28P</td>
<td>44 - 60</td>
<td>38 – 40</td>
</tr>
<tr>
<td>LEA – PG 70-22</td>
<td>46 - 56</td>
<td>30 – 40</td>
</tr>
<tr>
<td>LEA – PG 64-22</td>
<td>42 - 50</td>
<td>27 – 40</td>
</tr>
<tr>
<td>LEA – PG 64-22 w/10% RAP</td>
<td>44 - 50</td>
<td>35 – 41</td>
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# Baghouse Temperatures

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<th>Inlet Temperature, F</th>
<th>Outlet Temperature, F</th>
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<tr>
<td>HMA</td>
<td>345 - 385</td>
<td>260 – 305</td>
</tr>
<tr>
<td>LEA</td>
<td>295 - 335</td>
<td>225 - 275</td>
</tr>
</tbody>
</table>
QC Air Voids

LEA % Air Voids @ Plant - QC Data

23 out of 29 days the plant received a bonus – no days resulted in a penalty
LEA Mix Moisture

Date

% Mix Moisture


Plant Sample - A  Plant Sample - B  Field Sample  Specification Limit
## Field Density

<table>
<thead>
<tr>
<th>Mix</th>
<th>Avg. Gmb</th>
<th>Avg. %Gmm</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>HMA control – Rt. 96B</td>
<td>2.278</td>
<td>94.1</td>
<td>1.43</td>
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<tr>
<td>LEA control – Rt. 96B</td>
<td>2.298</td>
<td>95.6</td>
<td>0.51</td>
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</table>
Field Density

- 4 readings were taken every 60 meters
- A PTD is determined to be 95.5% of Gmm
- Running average of last 10 must stay at least 98% of PTD
- No single location can be above 1.03*PTD or below 0.96*PTD
- A new test strip was never required
2008 Projects

- 58,625 tons placed (to date 94,135)
- Many mix types – with and without RAP
- NYSDOT
- 4 counties
- 2 cities
- 6 towns
- 3 villages
- 3 plants (1 more in the next few weeks)
  - Trailer
Gernatt Asphalt Products

- Delevan NY plant
- Astec Double Barrel
- 27% wet fraction - % moisture > 7%
- Mix moisture < 0.4%
- 4741 tons – 25.0 mm w/o RAP in one day
- 3419 tons – 25.0 mm w/13.5% RAP
- 2857 tons – 9.5 mm w/13.5% RAP
King Road Materials

- NYSDOT Region 1 – Rt. 43
- Cedar Rapids Plant
- 908 tons – 9.5 mm w/o RAP
- 533 tons – 9.5 mm w/15% RAP
- Mix moisture <0.25%
Continued Work

- Workability/compactability
  - Improved chemistries
- Reduced Binder Aging
- High Rap Mixes
- NYSERDA Research Contract
Acknowledgement

- **NYSDOT**
  - Stan Birchenough – Resident Engineer – Cortland/Tompkins County Residency
  - Tom McPhilmy – Region 3 Materials Engineer
  - Russ Theilke – Materials Bureau – Albany
  - Greg Wichser – Region 1 Materials Engineer
- All of the plant and field personnel at Suit-Kote
Questions?

Watch for more information on our website:

www.mcconnaughay.com