Lime in Asphalt

Lime Association of Texas Workshop
Houston, TX
April 9, 2014
Outline

- Background
- Types of Distress
- Benefits of Lime
- Summary
Long Life Pavement
(5 to 40 Years Increase in Life)

- Minimize Premature Pavement Distress
- Minimize Rehabilitation and Maintenance
- Minimize User Inconvenience (Customer Focused Construction)
- Todays Technology/Materials/Contractors
- Safe Driving Surface
Design Considerations

- Safety
- Thickness
- Mixture
Safety

- Work Zone
- Surface Properties
  - Friction
  - Drainage
  - Splash and Spray
  - Noise
Thickness Design

- Fatigue Limit
- Select Mixture for Different Depth in Pavement Structure

Thin

- Asphalt Mixture < 4”
- Flexible Base
- Subgrade

Tire Load

Thick

- Asphalt Mixture > 6”
- Flexible Base
- Subgrade

Tire Load
- Friction/Splash/Spray/Noise
- Permanent deformation
- Thermal cracking
- Water Susceptibility
- Stiffness
- High RAP/RAS
- Permanent deformation
- Fatigue resistance
- Water susceptibility
MIXTURE DESIGN

- Mixture design test parameters use for structural design input
- Designs for different traffic level and climates
- Specific mixtures for different layers in pavement
- Nominal maximum aggregate size
- Proper use of recycled materials
- Lab mix-lab compacted vs plant mix-field compacted
Mixture/Structural Design

- Stiffness
- Rutting
- Fatigue
- Thermal cracking
- Water susceptibility
- Aging
- Lab mix-lab compacted vs plant mix-field compacted
Recycled Materials

- RAP/RAS binder stiffness
- Uniformity of RAP/RAS
- Cracking-fatigue, thermal, reflection
- Aging
Lime in Asphalt

- Several states require lime in all asphalt mixtures
- 5-10% of all asphalt mixtures contain lime
- 150,000 tons of lime used in asphalt mixture per year
Summary-Design

- Safe surfaces: friction, drainage, splash-spray, noise
- Specific mixtures for different layers
- Proper use of recycled materials
Outline

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- **Types of Distress**
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Pavement Performance Problems

- Raveling
- Bleeding/Flushing
- Rutting/Shoving
- Alligator Cracking
- Transverse Cracking
- Longitudinal Cracking
- Reflection Cracking
- Localized Distress
Raveling
Raveling
Bleeding
Bleeding
Permanent Deformation

High T, Large Load,
Sustained/Slow Loading (Large t)
Decreases w/Aging
Rutting and Shoving
Shoving
Fatigue Cracking
Fatigue Cracking
Fatigue Cracking

Intermediate T, Repeated Loading, Fast Loading (Small t) Increases w/Aging
Thermal Cracking

Low T, Large $\Delta T$, Rapid Loading (Small $t$) Increases w/Aging
Thermal Cracking
Longitudinal Cracking
Crack Sealing
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Benefits of Using Lime

- Reduce Water Susceptibility
- Reduce Aging
- Increase Stiffness of Mixture
- Reduce Plastic Index
Loss of Bond
Loss of Strength

- Water sensitivity
- Water susceptibility
- Stripping
Stripping

- Loss of adhesion between aggregate surface and asphalt cement in the presence of moisture
Stripping Potential Controlled by:

- Asphalt cement properties
- Aggregate properties
- Mixture characteristics
- Climate
- Traffic
- Construction practices
- Pavement design consideration
Asphalt Cement Properties

- Physical properties
- Viscosity
- Temperature
- Adhesive ability
- Chemical properties
Aggregate Properties

- Shape and surface texture
- Gradation
- Fines content & properties
- Coating
- Absorption
- Surface chemistry
Mixture Characteristics

- Asphalt cement content
- Aggregate gradation
- Air voids content
- Strength
Hot-Wet

Southeast US

- High temperature-low viscosity
- Moisture in summer
- Bleeding
- Blistering
Cold-Dry

Freeze-Thaw Cycles

- Several days of moisture
- Daily freeze-thaw cycles
- Water expansion
- Brittle asphalt
Traffic

- Volume – ADT
- Heavy vehicles
Construction Practices

- Quality control
- Compaction - air voids
- Joint density & segregation
- Time of year
Overlay AC

Dense Graded AC

Fabric Chip Seal

Water
Water Susceptibility

- Water sensitivity
- Stripping
- Water damage
- Loss of Strength in the presence of moisture
  - Adhesion between asphalt binder and aggregate
  - Loss of strength in asphalt binder
Anti-Strip Agents

- Liquids-amines/di-amines
- Solids-lime/portland cement/by-products
Antistrip Additives

Liquid Antistrip Agents

- Chemical Compounds Containing Amines (Basic Compounds Derived from Ammonia)
- Heat Stability
- 0.5 % Generally
- May Change AC Properties (Soften)
- Heat AC, Add Liquid Antistrip, Mix for 2 Min
Antistrip Additives
Lime

- Hydrated Lime - Ca(OH)
- Bonding of the Calcium with the Silicates in Aggregate
- And/or Interaction or Modification of the Acidic Portions of AC
- 1 to 1.5% Generally
- Dry Mixed w/ Hot Aggregate or Damp Aggregate Immediately before AC Added and Mixed
Water Sensitivity - Tests

- Boil Test (ASTM D3625) (Tex-503-C)
- Immersion Compression (ASTM D1075)
- Tensile Strength Ratio (AASHTO T 283)
- Hamburg (Tex-242-F)
TSR and Hamburg

- AASHTO T283 Modified Lottman Test (TSR)
  - 1 Freeze-Thaw (F/T) Cycle

- Resilient Modulus Test ($M_R$)

- Hamburg Wheel-Tracking Device (HWTT)
Resilient Modulus Test Results
University of Nevada, Reno Study

Resilient Modulus 77F (Ksi)

Truckee, CA
Grass Valley, CA

Percent Hydrated Lime (%)

Before Lottman
After Lotmann

0 1 2

0 50 100 150 200 250 300
Resilient Modulus Test Results
University of Nevada, Reno Study

Resilient Modulus 77F (Ksi)

Mammoth, CA

Moreno, CA

Percent Hydrated Lime (%)

0 1 2

Before
Lottman

After
Lotmann

54
Types of Lime Added to Dry Aggregate
University of Nevada, Reno Study

Resilient Modulus 77F (Ksi)

Before Lottman
After Lotmann

Control  Hyd. Lime I  Hyd. Lime II  Quicklime  Dolomitic
Deeth Reconstruction
State of Nevada Test Results

Resilient Modulus (KSI)

No PCC, 5.5% FA, 5.5% AC
1.5% PCC, 5.5% AC
1.5% PCC, 3.0% FA, 6.0% AC
2.0% PCC, 2.5% FA, 6.0% AC

Original
Vacuum Saturated
Lottman
Water Sensitivity

- After asphalt chemistry
- After aggregate surface chemistry
- After coatings
After Aggregate Surface

- Initial coating
- Long term coating
- Adhesion cohesion
Hamburg Test Results (Nebraska Study)

B1_1.0% Screenings-1st Pair
B1_1.0% Screenings-2nd Pair
B1_1.0% Screenings-Average
B2_1.0% Dry Lime-1st Pair
B2_1.0% Dry Lime-2nd Pair
B2_1.0% Dry Lime-Average
B3_1.0% Lime Slurry-1st Pair
B3_1.0% Lime Slurry-2nd Pair
B3_1.0% Lime Slurry-Average

B1 Stripping Point approx. 1,800 passes
B3 Stripping Point approx. 2,200 passes
B2 Stripping Point approx. 4,300 passes

Maximum Impression (mm)

No. of Passes

0 1000 2000 3000 4000 5000 6000 7000 8000
Moisture Sensitivity Dynamic Modulus (E*)

Dynamic Modulus \( E^* \) at \( 104^\circ \) F and 10Hz, ksi

- **Un-Treated Unaged**
- **Liquid-treated Unaged**
- **Lime-treated Unaged**

- **California**
- **Texas**

\[ \sigma = \sigma_0 \sin(\omega t) \]

\[ \varepsilon = \varepsilon_0 \sin(\omega t - \varphi) \]
...But without Embrittlement at Low Temperature

No negative effect on cracking

Beneficial effect on rutting

70/100 bitumen versus temperature data from Wortelboer et al. (ESHA/LCPC), E&E 1996
APA (under Water) Test Results

APA Rutting Failure Criteria

Rut Depth (mm)

Strokes

- B0_No Additive
- B1_1.0% Screenings
- B2_1.0% Dry Lime
- B3_1.0% Lime Slurry (Concentration Ratio = 0.33)
- B4_1.0% Lime Slurry (Concentration Ratio = 0.22)
- B5_1.0% Lime Slurry (Concentration Ratio = 0.13)
Hydrated lime added to the bitumen has a substantially greater impact in reducing the softening point of asphalt binder than does filler from graywacke or limestone source. Why?
Aging Index
Western Research Institute

Log Aging Index

- Boscan
- Ca. Central
- W. Texas Maya
- N. Slope Mays

Legend:
- 0%
- 10%
- 20%
Additive Effect on the Hardening of Asphalt
Utah DOT – Field Study

![Graph showing the additive effect on the hardening of asphalt over time in years for viscosity at 140F. The graph compares two conditions: No Additive and Hydrated Lime. The viscosity levels increase over time, with the Hydrated Lime condition showing a slower increase compared to No Additive.](image-url)
Hydrated Lime Improves Mixture Stiffness at High Temperature

Stiffening effect = better rutting resistance

![Graph showing rut depth vs. loading cycles for AC 14 35/50 and AC 14 35/50 + 1.25% lime.](image)

- AC 14 35/50
- AC 14 35/50 + 1.25% lime
Comparison of Fatigue Life

\[ N_f = A(\text{strain})^{-B} \]

- AAD-1
- AAM-1
- AAD-1+HL
- AAD-1+LS
- AAM-1+HL

Strain (%) vs. Fatigue life
## Resistance to Thermal Cracking

Thermal Stress Restrained Specimen (TSRST)

<table>
<thead>
<tr>
<th>State</th>
<th>Mix</th>
<th>0 F-T</th>
<th>6 F-T</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fracture Stress (psi)</td>
<td>Fracture Temp (°C)</td>
<td>Fracture Stress (psi)</td>
</tr>
<tr>
<td>AL</td>
<td>Un-treated</td>
<td>368</td>
<td>-24</td>
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<tr>
<td></td>
<td>Liquid-treated</td>
<td>345</td>
<td>-26</td>
</tr>
<tr>
<td></td>
<td>Lime-treated</td>
<td>406</td>
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<tr>
<td>CA</td>
<td>Un-treated</td>
<td>303</td>
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<td>Lime-treated</td>
<td>404</td>
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<td>Un-treated</td>
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<td></td>
<td>Lime-treated</td>
<td>426</td>
<td>-18</td>
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</tbody>
</table>
## Resistance to Thermal Cracking

**Thermal Stress Restrainted Specimen (TSRST)**

(Cont’d)

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<tr>
<th>State</th>
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<th>0 F-T Fracture Stress (psi)</th>
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<tr>
<td>SC</td>
<td>Un-treated</td>
<td>292</td>
<td>-19</td>
<td>126</td>
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<tr>
<td></td>
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<td>287</td>
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<td>-20</td>
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<td>Lime-treated</td>
<td>353</td>
<td>-17</td>
<td>377</td>
<td>-18</td>
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Summary

- Improve Performance
- Balance Pavement Thickness Design and Mixture Design
- Lime offers some help
## Pavement Distress Lime Benefits

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<td>Raveling</td>
<td>• Reduce Aging</td>
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<td>• Increased Stiffness</td>
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