BASE STABILIZATION GUIDANCE AND ADDITIVE SELECTION FOR PAVEMENT DESIGN

Renae Kuehl, PE, SRF Consulting Group
Dan Wegman, PE, Braun Intertec Corporation

November 2, 2017
Who is the LRRB?

Serves local agencies to:
• Research local agency specific issues
• Develop new initiatives
• Apply new knowledge
• Implement new technologies
What was the Issue?

**Issue:** High level education on the selection of base stabilization additives

**Intended Audience:** City and County Engineers
What was the solution?

Guidebook that addresses:

- Base Stabilization
- Base Modification
- In Place Pavement Recycling Methods
- Stabilization Additives
- Stabilization Additive Selection
- Steps to Successfully Stabilize a Road
- Stabilization Troubleshooting
- Laboratory Mix Design
- Proprietary Products
- Research on Why Stabilization Works
In-place Recycling: Most Common Bituminous Recycling Options

Cold In-Place Recycling

Full Depth Reclamation
Chemical Stabilization:
Incorporation of stabilizers that either react chemically with the material being stabilized (e.g., lime reacts with clays) or react on their own to form cementing compounds (e.g., cement)

- Cement: Portland or hydrated
- Lime: hydrated or quick lime
- Fly-ash: by-product of coal combustion and can be in the form of self-cementing Class C or Class F (when used in combination with other additives)
- Cement Kiln Dust (CKD): by-product of cement production
- Lime Kiln Dust (LKD): by-product of lime production
Bituminous Stabilization:
Incorporation of a bituminous material that alters the surface chemistry of the aggregate particles

- **Asphalt emulsion** which is an emulsion of asphalt binder, water, and emulsifier.
- **Foamed asphalt** is a mixture of compressed air and a small amount of cold water that’s injected into hot asphalt binder (140C to 170C).

*Foamed asphalt adheres to fine particles (mainly passing No. 200 sieve) creating an asphalt bound filler that acts as mortar binding the coarse aggregates together.*
SFDR Process
SFDR Can Address...

- All forms of cracking including fatigue, edge, slippage, block, longitudinal, and reflective
- Reduced ride quality due to swells, bumps, sags, patches, and depressions
- Permanent deformations including, rutting, corrugations, and shoving
- Loss of bond between pavement layers
- Moisture damage (stripping)
- Loss of surface integrity due to raveling, potholes, and bleeding
- Inadequate structural capacity
- Subgrade instability by increasing structural capacity of the base and surfacing layers
Base Stabilization Can Improve...

- Shear strength
- Modulus (stiffness)
- Resistance to moisture
- Stability
- Durability
- Resistance to fatigue
- Resistance to rutting
- Grade change restrictions
Stabilized Full Depth Reclamation

- A Full Depth Reclamation through pulverization of a bound surfacing layer, blending the pulverized/reclaimed material with underlying aggregates and a stabilization additive to produce a homogeneous base material.
Many products exist to stabilize base materials for roadway construction, but it is not always clear which product is the right one to use! ????
Stabilization/Modification Options

- Cutbacks/Roadmix
- Proprietary Products – (206 +)
- Engineered Emulsion
- Lime/chlorides
- Foamed Asphalt
- Flyash/Cement
- Combinations of above
Stabilization/Modification Options

- Cutbacks/Roadmix
- Proprietary Products – (206 +)
- Engineered Emulsion
- Lime/chlorides
- Foamed Asphalt
- Flyash/Cement
- Combinations of above
More on Base Stabilization...

- Base Stabilization refers to permanent improvements made to a base aggregate layer resulting in a bound structural pavement layer with measurable elastic and strength characteristics.

- A laboratory mix design is required to optimize the type and quantity of additive to be incorporated.
Why Stabilization Works?

- Transfers maximum horizontal tensile strains from the bottom of the hot mix asphalt (HMA) layer deeper into the pavement structure.
Key to improved performance

- Max Tensile Strain
- 50% less on HMA
MnRoad I-94 Albertville

- **Cell 2**
  - 50% RAP
- **Cell 3**
  - 75% RAP
- **Cell 4**
  - 100% RAP
MnRoad Cells 2-4

1" UTBWC

2 Zone To 3" of High Compression

High Modulus Rut Resistant Material

Max Tensile Strain

Flexible Fatigue Resistant Material 6 - 8"

Pavement Foundation
MnRoad Cells 2-4
Design Life: 3.5 M ESAL (SEM Materials)

Estimated traffic (I-94): Feb.09 – fall 16: ~ 6.0 M ESAL
MnRoad Cells 2,3,4

Fatigue Cracking Origins: Material Factors

- **Initiation**
  - Microscopic defects and incompatibilities amplify applied stress and microcracks form

- **Coalescence**
  - Microcracks grow and coalesce into macrocracks

- **Propagation**
  - Macrocracks move through the asphalt concrete ultimately showing up as visible flaws on pavement surface

Fatigue Cracking Origins: Material Factors

- **Initiation**
  - Microscopic defects and incompatibilities amplify applied stress and microcracks form

- **Coalescence**
  - Microcracks grow and coalesce into macrocracks

- **Propagation**
  - Macrocracks move through the asphalt concrete ultimately showing up as visible flaws on pavement surface
Base Stabilization Types

• **Chemical Stabilization:**
  Incorporation of stabilizers that either react chemically with the material being stabilized (e.g., lime reacts with clays) or react on their own to form cementing compounds (e.g., cement)

  - Cement: Portland or hydrated
  - Lime: hydrated or quick lime
  - Fly-ash: by-product of coal combustion and can be in the form of self-cementing Class C or Class F (when used in combination with other additives)
  - Cement Kiln Dust (CKD): by-product of cement production
  - Lime Kiln Dust (LKD): by-product of lime production
More on Base Stabilization

- Strength gain should be in a range that provides increased strength and stability without creating a rigid brittle blend that can induce cracking of the overlying pavement surface.
Base Modification

• **Base Modification** refers to the incorporation of additives to base materials that provide **short term improvements** intended to facilitate construction as a **compaction aid**.

• The base layer is thought to remain essentially unbound.

• Modifiers including proprietary products, do not have design procedures and laboratory and field verification testing.
Base Stabilization Additives

- **Base Stabilization**
  - **Chemical Stabilization**
    - Cement
    - Lime
    - Fly-ash
    - Cement Kiln Dust (CKD)
    - Lime Kiln Dust (LKD)
  - **Bituminous Stabilization**
    - Asphalt Emulsion
    - Foamed Asphalt
## Additive Selection

<table>
<thead>
<tr>
<th>Reclaimed Material Type</th>
<th>Well-Graded Gravel</th>
<th>Poorly Graded Gravel</th>
<th>Silty Gravel</th>
<th>Clayey Gravel</th>
<th>Well-Graded Sand</th>
<th>Poorly Graded Sand</th>
<th>Silty Sand</th>
<th>Clayey Sand</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>USCS</strong>&lt;sup&gt;(1)&lt;/sup&gt; Classification</td>
<td>GW</td>
<td>GP</td>
<td>GM</td>
<td>GC</td>
<td>SW</td>
<td>SP</td>
<td>SM</td>
<td>SC</td>
</tr>
<tr>
<td>Asphalt Emulsion</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$S_E^{(3)}&gt;30$ or $P_l^{(4)}&lt;6$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$P_{200}^{(5)}&lt;20%$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foamed Asphalt</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$P_l&lt;10$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$5%&lt;P_{200}&lt;20%$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cement, CKD, and Fly-ash</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$P_l&lt;20$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lime, LKD</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$P_l&gt;20$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$P_{200}&lt;25%$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Not recommended
- Recommended
- Highly recommended
Additive Selection

- **Well-Graded Gravel/Poorly Graded Gravel**
  - Emulsion

- **Silty Gravel/Clayey Gravel**
  - Foamed Asphalt
  - Cement/CKD/Fly-ash

- **Well-Graded Sand/Poorly Graded Sand/Silty Sand**
  - Cement/CKD/Fly-ash

- **Clayey Sand**
  - Lime/LKD
  - Cement/CKD/Fly-ash
Full Depth Reclamation (SFDR)
Keys to Success – Strength & Flex

Stabilization Considerations

- Cutbacks or Road Mix (Prone to Rutting)
- Proprietary Products
- Engineered Emulsion
- Foam Asphalt or Lime
- Fly Ash or Cement (Prone to Cracking)

Flexible
Granular
Organic Clay
Stiff
• In foamed asphalt, binder goes through a short-term aging which could adversely affect the mixture fatigue performance.
• With foamed asphalt some fine particles are needed, generally about 5 to 20 percent passing 200 sieve.
• Asphalt emulsion does not require heat during the stabilization process and therefore is not expected to age the asphalt.
• Asphalt emulsion is a safer product than foamed asphalt since no heat is needed.
Chemical Stabilization Highlights

- Incorporation of an excessive amount of additive increases rigidity of the base layer with the potential to induce cracking.
- Cement, Cement Kiln Dust (CKD), and fly-ash typically are limited to aggregate materials where the plasticity index is less than 20.
- Lime and/or Lime Kiln Dust (LKD) are more often recommended for aggregate materials with a plasticity index of about 20 or greater.
- Some variability in by-product stabilization additives (fly-ash, Cement Kiln Dust (CKD), and Lime Kiln Dust (LKD)) should be expected.
CCPR Test Sections at MnRoad
Questions?