Mix Designs for FDR, CIR, and HIR

Southeast States In-Place Recycling Conference
Atlanta, Georgia

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Kevin McGlumphy, P.E.
Outline

- Purpose and other considerations for mix designs
- FDR
- CIR
- HIR
- Summary
Purpose of a Mix Design

- Increase the probability of a successful project
- Additive type determination and check compatibility
- Determine additive quantities and other requirements such as water
- Is add-rock or a secondary material required?
- Provide QC targets
Other considerations

• Provide guidance on or be involved with sample collection
• Will the road be widened?
• Are multiple designs required for the project?
• Determine if pavement design parameters are achieved (i.e. structural coefficients)
Other considerations

- Dealing with fabric
- Is there a stripped layer?
- Saw-cut to depth and remove non-recycled layers
- Correctly proportion materials
Full Depth Reclamation
# Suggested Additives for Full Depth Reclamation – Blend of existing bituminous and base / soil

<table>
<thead>
<tr>
<th>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>
<th>Silt, Silt with sand</th>
<th>Lean clay</th>
<th>Organic silt / organic lean clay</th>
<th>Elastic silt</th>
<th>Fat clay, fat clay with sand</th>
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<tbody>
<tr>
<td>USCS</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>
<td>ML</td>
<td>CL</td>
<td>OL</td>
<td>MH</td>
<td>CH</td>
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<tr>
<td>AASHTO</td>
<td>A-1-a</td>
<td>A-1-a</td>
<td>A-1-b</td>
<td>A-1-b or A-2-6</td>
<td>A-1-b</td>
<td>A-3 or A-1-b</td>
<td>A-2-4 or A-2-5</td>
<td>A-2-6 or A-2-7</td>
<td>A-4 or A-5</td>
<td>A-6</td>
<td>A-4</td>
<td>A-5 or A-7-5</td>
<td>A-7-6</td>
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<tr>
<td>Emulsion FDR / GBS</td>
<td>Best if SE &gt; 30 and P200 &lt; 20 (100% base to 100% RAP)</td>
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<tr>
<td>Foamed asphalt P200 &gt; 5 to 20% and follow max. density grad.</td>
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<tr>
<td>Portland cement PI&lt;10</td>
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<tr>
<td>Lime PI&lt;10 and P200&lt;25 or PI 10-30 and P200&gt;25, SO4 in clay &lt; 3000 ppm</td>
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</table>
FDR Additive Contents - typical

- Asphalt emulsion (2% to 6%)
- Foamed asphalt (1% to 3%) + cement
- Portland cement (3% to 6%)
- Fly ash (8% to 14%)
- Lime (2% to 6%)
FDR Mix Design Methods

- Asphalt emulsion – Industry-adopted and agency-specific (i.e. PennDOT) mix designs
- Foamed asphalt – Foamed Bitumen Mix Design Procedure Using the Wirtgen WLB 10
- Portland cement – PCA EB052, Soil-Cement Laboratory Handbook
- Fly ash – American Coal Ash Association
- Lime – National Lime Association
## FDR Tests

### Common Tests
- Moisture density relationships
- Gradation analysis, liquid limit, plastic limit

### Bituminous
- High shear mixer
- Superpave gyratory compactor or Marshall
- Strength (indirect tensile, Marshall)
- Moisture-conditioned strength
- Short-term strength
- Modulus for pavement design
- Thermal cracking

### Chemical
- Unconfined compressive strength
- Wet-dry and freeze-thaw durability tests
Adjustments for FDR performance

Applies more to bituminous

• **Strength**
  ▫ Add rock, add small amount of cement or lime, lower binder content

• **Moisture-conditioned strength**
  ▫ Add small amount of cement or lime, higher binder content

• **Setting characteristics (short-term strength)**
  ▫ Solventless emulsion, add small amount of cement

• **Modulus (structural coefficient)**
  ▫ Same as strength

• **Thermal cracking**
  ▫ Softer or more binder
Cold in-place recycling
CIR Mix Design Methods

- Industry-adopted or state specific (i.e. PennDOT) procedures
CIR Mix Design

- Mix design
  - RAP crushed to defined gradations
  - Emulsion formulated
    - Climate & project needs
    - Controlled break, cohesion, coating/adhesion
  - Superpave Gyratory Compactor (SGC) or Marshall compaction at field moisture content
- Performance-related tests
Milling & Crushing, Screening & Sizing

Lab

Field
Lab RAP Analysis

• Lab
  ▫ Field cores crushed to 2 gradation bands
  ▫ A design for both gradations

• Field
  ▫ Field gradation depends upon multitude of factors: milling, weather, etc.
  ▫ Gradation compared to lab tested band
  ▫ Emulsion rate based on applicable gradation
Density Compaction Effort
Superpave Gyratory Compactor
Performance-Related Tests

- Raveling
- Strength – Marshall stability, indirect tension test, or APA
- Moisture susceptibility
- Thermal cracking
Raveling Test

Engineered CIR Specimen (AZ project)
1% loss after 15 minutes

Conventional CIR Specimen (MN project)
11% loss after 10 minutes
Adjustments for CIR performance

- **Strength**
  - Add rock, add small amount of lime

- **Moisture-conditioned strength**
  - Add small amount of lime, higher emulsion content

- **Setting characteristics (short-term raveling test)**
  - Solventless emulsion, change emulsion formulation

- **Thermal cracking**
  - Softer or more binder
Hot in-place recycling

- Surface recycling
- Repaving
- Remixing
HIR Additives

• Rejuvenating agent – blending charts for type and amount
• Asphalt emulsion with rejuvenating agent and polymer
• New aggregate or HMA
HIR Mix Design Methods / Tests

- Mix design effort ranges from as little as additive selection only to as much as a full mixture analysis
- Industry-adopted or other procedures
- Thicker -> Mix design more important
  - Marshall and SGC compaction
  - Volumetrics, Marshall strength, indirect tensile strength, APA, resilient modulus, thermal cracking
Adjustments for HIR performance

- Adjustment of additive / formulation
- Adjustment of other added materials
## AASHTO Structural Coefficients

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Coefficient</th>
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<tbody>
<tr>
<td>Aggregate base</td>
<td>&lt;0.10 to 0.14</td>
</tr>
<tr>
<td>Cement treated base / soil cement</td>
<td>0.14 to 0.23</td>
</tr>
<tr>
<td>Bituminous FDR</td>
<td>0.20 to 0.25</td>
</tr>
<tr>
<td>Emulsion CIR</td>
<td>0.28 to 0.33</td>
</tr>
<tr>
<td>HIR</td>
<td>0.40</td>
</tr>
<tr>
<td>HMA</td>
<td>0.40 to 0.44</td>
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Coefficients dependent on original material quality and local experience
Summary – Mix Designs for FDR, CIR, and HIR

• Increase the probability of success
• Determine additive type and check compatibility
• Determine primary additive quantities and the need for secondary additives (i.e. new aggregate)
• Determine if modulus or strength is achieved to meet pavement design requirements
  ▫ Consider dynamic modulus - MEPDG
Questions?

Thank you!

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