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>
</tr>
</thead>
<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>
</tr>
</tbody>
</table>

**Emulsion FDR / GBS**
- Best if SE > 30 and P200 < 20 (100% base to 100% RAP)

**Foamed asphalt**
- P200 5 to 20% and follow max. density grad.

**Portland cement**
- PI-10

**Lime**
- PI-10 and P200: 25 or PI 10-30 and P200: 25. SO₂ in clay < 3000 ppm
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

Lab

Field
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>
</tr>
</tbody>
</table>

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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