Overview of CR Mix Designs – Current & Future Directions

Stephen A Cross, PhD, PE
Technical Director, ARRA
Professor, Oklahoma State University
CR Mix Designs

► From: Typical Emulsion Contents
   (No Mix Design)
► To: Surface Area Methods
► To: Task Force 38
   (50-75 Blow Marshall)
► To: Road Science & Predecessor's
   ■ CR (CIR, CCPR)
   ■ FDR
Mix Design Methods

- Procedures can be found as Supplemental Specifications on many DOT web sites
  - Kansas, Montana, Missouri, Utah
- Simplified Procedures have been adopted by many
  - ARRA
  - CFLHD
  - PCCAS
  - Some DOTs
Foam Mix Designs

► Developed by Wirtgen/Loudon International
► Developed for FDR
► Applicable to CR
  ■ Basically same procedure/requirements for CR & FDR
► Appendix 1, Wirtgen Cold Recycling Technology
Foam vs. Emulsion

► Foam is a Binding Technology
► Emulsions are a Coating Technology
► For Binding Technology to Work, most Literature Recommends:
  - 5-20% Fines (-No. 200)
  - 100% RAP < 5% Fines (-No. 200)
  - Active filler (1% cement)
Basic CR Emulsion Procedure

1. Obtain cores from pavement.
2. Remove portion of core to be recycled and crush to create RAP.
3. Determine binder content and recovered aggregate gradation of select cores.
4. Determine RAP Gradation and batch samples to desired gradation.
Basic CR Emulsion Procedure

5. Select type and grade of asphalt emulsion and any additives.
6. Mix samples at different emulsion contents and compact.
7. Cure samples.
8. Test trial mixtures:
   a) Basic mix properties,
   b) Final cure mix properties,
   c) Moisture sensitivity.
   d) Other tests
Basic FDR Procedure
(Foam or Emulsion)

1. Obtain cores and aggregate base from pavement
2. Crush cores to create RAP.
3. Determine binder content and recovered aggregate gradation of select cores.
4. Determine gradation of aggregate base.
5. Blend RAP and aggregate base to selected percentages from job.
7. Select type and grade of stabilizing agent and any additives
8. Perform Modified Proctor (AASHTO T 180 Method D) and determine optimum moisture content and maximum dry density of blended material
Basic Procedure

9. Mix samples at different stabilizing agent contents, perform initial cure and compact.

10. Initial Cure Testing

11. Final cure samples

12. Test trial mixtures:
   a) Mix properties
   b) Indirect Tensile Strength
   c) Moisture sensitivity

13. Establish Job Mix Formula
## Comparisons

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Emulsion CR</th>
<th>Emulsion FDR</th>
<th>Foam CR &amp; FDR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Opt. Moisture</td>
<td>1.5-3.0%</td>
<td>T 180 or 3%</td>
<td>T 180</td>
</tr>
<tr>
<td>Cure before compaction</td>
<td>None</td>
<td>30 min @ 40 C</td>
<td>None</td>
</tr>
<tr>
<td>Compaction</td>
<td>30 gyrations SGC 75-Blow Marshall</td>
<td>30 gyrations SGC 75-Blow Marshall</td>
<td>75-Blow Marshall Modified T 180 - 4 layers, 55 blows</td>
</tr>
<tr>
<td>Curing After Compaction</td>
<td>Constant mass @ 60 C, 16-48 hrs.</td>
<td>Constant mass @ 60 C, 16-48 hrs.</td>
<td>72 hrs. @ 40 C</td>
</tr>
<tr>
<td>Bulk Gravity</td>
<td>T 166</td>
<td>T 166</td>
<td>Volumetrically</td>
</tr>
<tr>
<td>Rice Gravity</td>
<td>T 209</td>
<td>T 209</td>
<td>T 209</td>
</tr>
<tr>
<td>Air Voids</td>
<td>Required (% Sat.)</td>
<td>Required (% Sat.)</td>
<td>Not required</td>
</tr>
</tbody>
</table>
## Comparisons – Marshall Stability

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Emulsion CR</th>
<th>Emulsion FDR</th>
<th>Foam CR &amp; FDR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry Stability</td>
<td>Min 1250 lbs. @ 40 C</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Wet Stability</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Vacuum Sat.</td>
<td>55-75%</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Soak</td>
<td>23 hrs. @ 25 C, 1 hr. @ 40 C</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Stability Ratio</td>
<td>Min. 0.70</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>
## Comparisons – Indirect Tensile Strength

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Emulsion CR</th>
<th>Emulsion FDR</th>
<th>Foam CR &amp; FDR</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dry ITS</strong></td>
<td>Min. 45 psi @ 25 C</td>
<td>Min. 40 - 45 psi @ 25 C</td>
<td>Min 225 kPa (32.6 psi) @ 25 C</td>
</tr>
<tr>
<td><strong>Wet ITS</strong></td>
<td>N/A</td>
<td>Min. 20 - 25 psi @ 25 C</td>
<td>Min. 100 kPa (14.5 psi) @ 25 C</td>
</tr>
<tr>
<td><strong>Conditioning</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vacuum Sat.</td>
<td>55-75%</td>
<td>55-75% or &gt; 55%</td>
<td>N/A</td>
</tr>
<tr>
<td>Water Soak</td>
<td>24 hrs. @ 25 C</td>
<td>24 hrs. @ 25 C</td>
<td>24 hrs. @ 25 C</td>
</tr>
<tr>
<td>TSR</td>
<td>Min. 0.70</td>
<td>N/A</td>
<td>If &lt; 0.60 requires active filler</td>
</tr>
</tbody>
</table>
Additional Tests

- Raveling ASTM D7196
- High Temperature Validation
- Thermal Cracking AASHTO T 322
- Recovered Binder Tests
- Other Tests
  - Hamburg or APA Rut Test
  - Fracture Energy Test
  - Air Void Requirements
  - Field Tests
Raveling Test - ASTM D 7196
(CR Emulsion Only)

► Evaluates curing / breaking time to prevent raveling
► Tested at Optimum EAC
► Cure @ 50 F at 50% relative humidity for 4 hours
► Abrade samples for 15 min
► What % Loss (2-7%)
High Temperature Validation
(CR Emulsion Only)

- At high temperatures (> 85°F) CR mixtures can compact to higher density
- Often require less recycling agent for optimum performance
- Procedures to validate effect of reducing recycling agent content 0.25 – 0.50% on strength, retained strength and raveling at high temperatures
High Temperature Validation

- Test for Marshall stability/tensile strength and raveling on samples mixed 0.50% less RA than optimum.
- Mix and compact at 104°F (40°C).
- Cure and test Marshall stability/tensile strength and retained strength using normal parameters.
- Test for raveling after 4-hour cure at 77°F and 50% relative humidity.
Presence of unusually soft or high asphalt content existing binders can affect recycling agent selection and CR pavement performance.

If their presence is expected can test recovered binder
- AASHTO T 319
- AASHTO T 164 and T 170

Recovered pen > about 30 you have an active binder
Low Temperature Validation (AASHTO T 322)

- Crack initiation temperature must be less than expected low pavement temp. CR mix
- Select base asphalt of recycling agent to meet AASHTO M 320 low temperature requirement for project location.
Proposed Tests

- Hamburg Rut Test AASHTO T 324
- Asphalt Pavement Analyzer AASHTO T 340
- Fracture Test (Semi-Circular Bend Test) AASHTO TP 105
- Air Void Requirements
- Field Curing/Stability Tests
Hamburg or APA Rut Test

- CDOT has experimented with Hamburg
- What temperature?
- What threshold value?
- What effects on performance if I pass?
- Need to calibrated to actual performance
Fracture Energy Tests

- Semi-Circular Bend Test
- AASHTO TP105
- Measures fracture energy
- Related to cracking?
- Might help prevent brittle mixtures with use of additives
- Has potential

Thanks Instrotek
Air Void Requirements

► What air void content do you want?
► How do I control it?
► Where and how do we measure it?
► What effect does VTM have on CR and FDR performance?
Air Void Requirements

► With HMA I Control Air Voids by:
  ■ VMA
    ● Gradation of Aggregate
    ● Compactive effort
  ■ Asphalt content
► I want 3-5% VTM in field after traffic so I design for 4% in the Lab
► What & where do you want VTM with CR & FDR and when?
RAP Gradation

- Gradation affects VMA
- Most Mix designs use 1 to 3 standard gradations
- How well do these match what we actually produce?
- These gradation bands were based on full CIR trains, not single unit trains
- Gradation can easily be verified
Compactive Effort

► SGC Compaction

- Ndes = 30 gyrations
- Based on 6 sites over 16 years ago (TRR 1819 vol. 2)
- remove 1 site Ndes increased 10 gyrations
- Do better job now – need to validate

► 75- Blow Marshall

- How good is this?
Gmm: AASHTO T 209

- Dry-Back procedure (sec. 11) is required to account for uncoated particles.
- How accurate is this, especially with foam?
Gmm: ASTM D 6857 (Optional)

- Does the CoreLok procedure work any better?
- Other methods?
Due high air voids, water absorption of AASHTO T 166 will exceed 2.0%. Use AASHTO T 331? Most procedures do not.

Foam uses volumetric

How well do lab voids compare to field voids?

Performance appears to not be a function of void content but how much my voids change in the field.
Verification of Field Mix Properties

- Sample age and temperature can have pronounced affect on measured mix properties
- Sealing uncompacted samples in containers does not appreciably help
- Must specify maximum compaction delay and sample temperature
- Usually requires compaction on-site
## Results QA Testing CIR

<table>
<thead>
<tr>
<th>Test</th>
<th>No Delay</th>
<th>Delay</th>
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</thead>
<tbody>
<tr>
<td>Lab Molded Voids</td>
<td>13.3%</td>
<td>20.6%</td>
</tr>
<tr>
<td>Dry Tensile Strength</td>
<td>74.5 psi</td>
<td>72.1 psi</td>
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<tr>
<td>Wet Tensile Strength</td>
<td>55.9 psi</td>
<td>64.9 psi</td>
</tr>
<tr>
<td>TSR</td>
<td>0.75</td>
<td>0.90</td>
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<tr>
<td>E* 20 C, 1 Hz</td>
<td>456,000 psi</td>
<td>355,000 psi</td>
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NCHRP Fiscal Year 2017

- Project 09-62, Problem # D-13
- Quality Assurance and Specifications for In-Place Recycled Pavements Constructed Using Asphalt-Based Recycling Agents
- 3-year, $1 M, Last step for approval
- Could be a big help in moving technology forward
Basic Asphalt Recycling Manual

2nd Edition

- Chapters on:
  - Preconstruction Activities (project selection)
  - Mix Design
  - Construction
  - QA Sampling & Testing

- For CP, HIR, CR & FDR
ARRA Guidelines

► 100 Series - Recommended Construction Guidelines
► 200 Series - Recommended Mix Design Guidelines
► 300 Series - Recommended Quality Control Sampling and Testing Guidelines
► 400 Series – Recommended Project Selection Guidelines
<table>
<thead>
<tr>
<th>Series</th>
<th>Cold Planing</th>
<th>Cold Recycling</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Milling</td>
<td>Micro Milling</td>
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<tr>
<td>100 Series Construction</td>
<td>Final Review</td>
<td>Final Review</td>
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<td>200 Series Mix Design</td>
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<td>300 Series QC</td>
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<tr>
<td>400 Series Project Selection</td>
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# Status of ARRA Guidelines

<table>
<thead>
<tr>
<th>Series</th>
<th>Full Depth Reclamation (FDR)</th>
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<tbody>
<tr>
<td></td>
<td>Bituminous</td>
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<tr>
<td>100 Series Construction</td>
<td>Complete</td>
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<tr>
<td>200 Series Mix Design</td>
<td>Under Development</td>
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<tr>
<td>300 Series QC</td>
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<td>400 Series Project Selection</td>
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Stephen A. Cross, PhD, PE
Technical Director, ARRA
steve.cross@okstate.edu
405-744-7200

Magnitude 3.0 Earthquakes

<table>
<thead>
<tr>
<th>Year Range</th>
<th>Number</th>
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<tbody>
<tr>
<td>1975 - 2008</td>
<td>6</td>
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<tr>
<td>2008 - 2012</td>
<td>42</td>
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<td>2013</td>
<td>109</td>
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<tr>
<td>2014</td>
<td>106</td>
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