ARC Deliverables/Products Presentation and Workshop

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Western Regional Superpave Center (WRSC)
University of Nevada, Reno

ARC Deliverables/Products Presentation and Workshop
University of Nevada, Reno


11:35 – 12:00:  Rutting Performance of Asphalt Mixtures Under Critical Conditions.

1:00 – 1:25:  Mix Design for Cold in-Place Recycling (CIR).

ARC Deliverables/Products Presentation and Workshop
Mix Design for Cold In-Place Recycling
Superpave Mix Design for CIR Mixture

- No performance-related mix design
  - Proctor test, Hveem procedure, Marshall stability.

- No fully established mix design procedure using Superpave Gyratory Compactor.

- Initial water and emulsion contents based on experience.

- Moisture sensitivity test and raveling test are the most common performance tests.
Proposed CIR Mix Design Method

1. Selection of Reclaimed Asphalt Pavement (RAP).
2. Selection of emulsified asphalt.
3. Determination of theoretical maximum specific gravity.
4. Determination of required number of gyrations.
5. Determination of curing time.
6. Determination of Optimum Emulsion Content (OEC) and Optimum Water Content (OWC).
7. Evaluation of moisture susceptibility.
Number of Gyrations

- Select initial water and emulsion content
- Target AV = 13±1%; height = 115±5mm

Approach
- Trial samples to reach target air voids & height
  - Initial water content: 2 – 6%
  - Emulsion content: 1 – 3%
  - Compacted to 100 gyrations
- The required number of gyrations was selected to reach the target specimen height and air voids.
  - If the target specimen height is not achieved at the target air void, the weight of the mixture is adjusted.
Curing Time for CIR

- Time to reach a constant mass $\approx 0.025\%$ mass loss/hr
- 24 hrs curing at 60°C.

![Curing curve at 60°C for graded RAP with CMS-2s emulsion](image)
OEC and OWC

- 4 levels of emulsion content (1.0, 1.5, 2.0, 2.5)
- 4 levels of water content (1.0, 2.0, 3.0, 4.0)
- Allow ± 0.5% of OWC for variations in the field
- Select 2 Combinations that best meet the criteria
<table>
<thead>
<tr>
<th>Type of Mixes</th>
<th>Type of Emulsion</th>
<th>No of gyration for Mix Design</th>
<th>Design Emulsion Content, %</th>
<th>Design water Content, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graded RAP with 1.5% lime</td>
<td>CMS-2s</td>
<td>30</td>
<td>1.5</td>
<td>3.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.5</td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td>Engineered emulsion for CIR</td>
<td>10</td>
<td>2.0</td>
<td>3.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Non-graded RAP with 1.5% lime</td>
<td>CMS-2s</td>
<td>35</td>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2.0</td>
<td>3.0</td>
</tr>
<tr>
<td></td>
<td>Engineered emulsion for CIR</td>
<td>20</td>
<td>2.0</td>
<td>3.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2.5</td>
<td>3.0</td>
</tr>
</tbody>
</table>
Moisture Susceptibility of CIR Mixtures

![Graph showing the tensile strength of CIR mixtures with and without lime under dry and wet conditions.](image-url)

**Tensile Strength (kPa)**
- **TS Dry without lime**
- **TS Dry with lime**
- **TS wet without lime**
- **TS wet with lime**

**Tensile strength ratio, TSR (%)**
- **TSR without lime**
- **TSR with lime**

The graph illustrates the tensile strength and tensile strength ratio of CIR mixtures with and without lime, under dry and wet conditions. The mixtures are graded CIR with CMS-2s, graded CIR with EE, non-graded CIR with CMS-2s, and non-graded CIR with EE.
Resistance to Raveling and Cohesion Development

- **Resistance to Raveling (ASTM D7196)**
  - 150mm diam. by 70±5mm SGC samples
  - Compacted to 20 gyrations
  - Cured for 4 hrs at ambient condition
  - Abraded for 15 mins
  - Measured mass loss

- **Cohesion development**
  - Cohesion tester (for slurry and chip seals)
  - Pneumatically actuated 25mm rubber foot
  - Pressure of 193 kPa
  - Torque applied by turning wrench by 90°-120°
  - Time required to reach 20 kgcm
# Resistance to Raveling and Cohesion Development

<table>
<thead>
<tr>
<th>Type of mix</th>
<th>Raveling, after 4hrs</th>
<th>Raveling after 20kgcm of torque in cohesion tester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graded CIR with CMS-2s emulsion</td>
<td>4.4%</td>
<td>2.4%</td>
</tr>
<tr>
<td>Graded CIR with engineered emulsion</td>
<td>1.6%</td>
<td>1.6%</td>
</tr>
<tr>
<td>Non-graded CIR with CMS-2s emulsion</td>
<td></td>
<td>6.8%</td>
</tr>
<tr>
<td>Non-graded CIR with engineered emulsion</td>
<td></td>
<td>1.8%</td>
</tr>
<tr>
<td>Non-Grade CIR with engineered emulsion</td>
<td>3.9%</td>
<td>1.1%</td>
</tr>
</tbody>
</table>

Typically, a max raveling of 2.0% is recommended.

<table>
<thead>
<tr>
<th>Time required to reach cohesion criteria, hrs</th>
<th>5.0</th>
<th>4.5</th>
<th>5.5</th>
<th>4.5</th>
</tr>
</thead>
</table>

Raveling, %

- Graded CIR with CMS-2s emulsion: 4.4%
- Graded CIR with engineered emulsion: 1.6%, 1.6%
- Non-graded CIR with CMS-2s emulsion: 6.8%, 1.8%
- Non-Graded CIR with engineered emulsion: 3.9%, 1.1%

Typically, a max raveling of 2.0% is recommended.
Performance Properties of CIR Mixes

Stiffness

<table>
<thead>
<tr>
<th>Type of CIR mixes</th>
<th>4°C</th>
<th>20°C</th>
<th>40°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graded CIR with CMS-2s</td>
<td>4,369</td>
<td>4,112</td>
<td>5,108</td>
</tr>
<tr>
<td>Graded CIR with EE</td>
<td>2,318</td>
<td>2,377</td>
<td>2,646</td>
</tr>
<tr>
<td>Non-graded CIR with CMS-2s</td>
<td>943</td>
<td>981</td>
<td>1,075</td>
</tr>
<tr>
<td>Non-graded CIR with EE</td>
<td>3,076</td>
<td>1,298</td>
<td>5,524</td>
</tr>
</tbody>
</table>

Notes: Cured for 48hrs at 60°C; Target air voids of 10.0 ± 1.0%
Performance Properties of CIR Mixes
Rutting Resistance

- Cured for 48hrs at 60°C
- Target air void of 10.0±1.0%
- Temperature: 45, & 58°C
- $\sigma_d = 70$psi; $\sigma_c = 10$psi
- Pulse time: 0.1s; Dwell time: 0.6s

<table>
<thead>
<tr>
<th>Type of CIR mixes</th>
<th>Flow number at 58°C, FN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graded CIR with CMS-2s</td>
<td>220</td>
</tr>
<tr>
<td>Graded CIR with EE</td>
<td>320 (±)</td>
</tr>
<tr>
<td>Non-graded CIR with CMS-2s</td>
<td>195</td>
</tr>
<tr>
<td>Non-graded CIR with EE</td>
<td>296</td>
</tr>
</tbody>
</table>
Findings & Recommendations

- Addition of 1.5% of lime by weight of RAP improved moisture resistance and reduced resistance to raveling.
- CIR mixes had similar moduli values and were comparable to conventional HMA.
- CIR mixes showed good resistant to rutting when designed appropriately.
- Non-graded mixes showed big variations in test results.
Findings & Recommendations

• The proposed CIR mix design method can potentially be used for designing performance-related CIR mixes.
  • The mix design is being validated.

• The curing time of dynamic modulus/RLT samples need to be standardized to represent either early or the later part of the CIR pavement life.

• Fatigue performance and low temperature performance of CIR mixes need to be evaluated.
Thank You!

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Thank You!