Cold in-place recycling (CIR) is the on-site recycling process to a typical treatment depth of 3 to 5 inches, using a train of equipment (tanker trucks, milling machines, crushing and screening units, mixers, a paver, and rollers), an additive or combination of additives (asphalt emulsions, lime, fly ash, cement), generating and using 100% RAP, with the resulting recycled pavement usually opened to traffic at the end of the work day.
Outline

• Purpose of mix design
• Sampling
• Mix design tests and emulsions
• Pavement design
• Summary and conclusions
Purpose of Mix Design

- Determine emulsion content – provide guidance on low and high contents for construction
  - Impact on project cost
- Determine emulsion properties to meet mix and job requirements
- Look for problem materials and ways to correct for them
Sampling

• Ideally, sample locations are determined by construction and maintenance records or in-place testing (FWD, GPR)

• Samples should represent the width and length of the project to provide an overall “picture” of layer thickness values
Sampling

- Cores may identify thin areas that are insufficient for CIR or where new material could be added
- Other testing, such as DCP, can be performed at the time of coring to evaluate the aggregate base and subgrade for strength and train support
Sampling

- Overall quantity depends on specification and job requirements

- Bottom line – The mix design must plan on variability in materials and thicknesses
Mix design – material preparation and evaluation

- Saw-cut material that will not be used
- Look for signs of stripping, fabric, delamination, etc.
  - Don’t leave stripped layers in place
- Excessive thickness of chip seals may give lower strength
  - High binder content
Mix design – material preparation and evaluation

- Round aggregates may give lower strength
- Consider lime or cement for stripping or new aggregate for strength
- Recovery of asphalt
  - Gradation
  - Penetration and PG grading
Mix design – key tests

<table>
<thead>
<tr>
<th>CIR</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Grinder / crusher</td>
<td>➢ Simulate milling</td>
</tr>
<tr>
<td>• Mixer</td>
<td>➢ Simulate mixing</td>
</tr>
<tr>
<td>• Raveling test</td>
<td>➢ Adequate setting</td>
</tr>
<tr>
<td>• Marshall stability</td>
<td>➢ Long-term strength</td>
</tr>
<tr>
<td>• Retained strength</td>
<td>➢ Key performance indicator</td>
</tr>
<tr>
<td>• Thermal crack</td>
<td>➢ Non-load cracking</td>
</tr>
</tbody>
</table>
Mix design – grinder or crusher to simulate milling

- Miniature lab milling machine or jaw crusher to simulate expected field gradations
Mix design – mixing

- Recommend using a mechanical mixer to better simulate mixing that occurs in field equipment.
Mix design – compaction and curing

• Superpave gyratory compactor. Some agencies specify Marshall compaction.

• Cure at 60°C from 16 to 48 hours (except raveling) after compaction
Mix design – raveling test

- Indicator of emulsion breaking and setting properties
- California considering three temperatures
- Criteria being considered – 5% max. (tentative)
Mix design – Marshall stability and retained stability

- 1,250 pounds Marshall stability at 40C
- 70% retained stability after vacuum saturation
  - Key performance indicator
Mix design – Thermal cracking

• Not an issue for Bay Area
  – Considered for high altitudes and cold climates
• AASHTO T-322
Mix design – summary

<table>
<thead>
<tr>
<th>Test</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gradation</td>
<td>Report</td>
</tr>
<tr>
<td>Asphalt content</td>
<td>Report</td>
</tr>
<tr>
<td>Air voids</td>
<td>Report – Typically 9 to 14%</td>
</tr>
<tr>
<td>Raveling test</td>
<td>5% max. (tentative, TBD)</td>
</tr>
<tr>
<td>Marshall stability at 40C</td>
<td>1,250 lbs min.</td>
</tr>
<tr>
<td>Retained stability</td>
<td>70% minimum</td>
</tr>
<tr>
<td>Emulsion</td>
<td>In order to meet mix and project requirements</td>
</tr>
</tbody>
</table>
Mix design – typical emulsion rates

Typical emulsion quantities for CIR
• 1.5 to 3.5% or higher CSS-1/1h (special)
• Depends on how “active” the asphalt in the RAP is
• Ratio of emulsion residue to cement or lime of 1.8 (minimum) – if used
Mix design – summary

- HMA industry tests have been adapted for CIR mix designs (except raveling)
- CIR acts like a slightly lower modulus HMA material
Pavement design – surface courses

- WMA / HMA binder and wearing courses
- Rubberized asphalt concrete
- Ultra-thin bonded wearing course
- Surface treatments – micro surfacing or chip seal, etc.
- Dense-graded cold mixes

The recycled layer must be covered by at least a bituminous treatment (i.e. micro surfacing or chip seal). The specific treatment needed will depend on pavement design and ride expectations.
Pavement design

- The pavement structure – depth of recycling and overlay thickness – are primarily influenced by:
  - Subgrade type and properties
  - Aggregate base or stabilized base thickness, type, and condition
  - Deflection measurements
  - Additive properties used in recycling
  - Traffic – especially trucks
  - Design life
Pavement design

- Caltrans Flexible Pavement Rehabilitation Manual
  - Section 4-40: Cold Recycled Asphalt Concrete Pavement
  - Deflection – Dynaflect – is primary method of design
  - Tolerable deflection at surface (TDS) based on TI
  - If Dynaflect $D_{80} >$ TDS, rehab is needed
  - Deflection at milled depth (DM) is determined
  - Percent reduction in deflection at milled depth (PRM) determined
Pavement design

- Caltrans Flexible Pavement Rehabilitation Manual
  - GE is determined from PRM and TI
  - Thickness saved as compared to DGAC should be at least 0.10 foot
  - Gravel factor $G_f$ for asphalt concrete is 1.9 (rehab)
  - $G_f$ for CIR is 1.7 (1.5 Caltrans manual)
Pavement design - example

- Caltrans Flexible Pavement Rehabilitation Manual
  - Mill depth planned 0.30 ft
  - GE needed is determined to be 0.82 ft
  - GE of CIR = (0.30 ft) (1.7) = 0.51 ft
  - GE of DGAC = 0.82 – 0.51 = 0.31 ft
  - Thickness of DGAC = 0.31 / 1.9 = 0.16 ft
  - Rounded to 0.20 ft
Summary

• Proper sampling is critical
• Test methods are in place to ensure a successful project, determine the binder content, and the need for additives
• Consider a $G_f$ of 1.7 for CIR
Resources

Valuable resources if more information is needed...

- ARRA Basic Asphalt Recycling Manual
- Caltrans Flexible Pavement Rehabilitation Manual
- Recycling and Reclamation of Asphalt Pavements Using In-Place Methods, NCHRP Synthesis 421, 2011
- Cold In-Place Recycling and Full Depth Recycling with Asphalt Products, Illinois Center for Transportation, Series No. 09-036, March 2009
- Cold In-Place Recycling in New York State, Contract 6764F-2, New York State DOT, July 2010
- Recycling seminars
- wwwARRA.org
Questions?

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