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 reusing 100% RAP, with the resulting recycled pavement usually opened to traffic at the end of the work day.

**CIR Definition**

Pavement Design for In-Place Recycling

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Outline

• Purpose of pavement design
• Pavement evaluation
• Pavement design procedures
• Material characteristics
• Structural coefficients / GE values
• Example structures
• Summary and conclusions
Purpose of Pavement Design

• Evaluate the existing pavement to determine the viability for the in-place recycling process
  – Input needed for design
  – Assess the pavement for equipment support (i.e. CIR train)
• Determine LCCA options
• Determine the thickness of recycled layers and overlay, if needed
Pavement Evaluation

• Coring
  – Needed for mix design
  – Delaminated / stripped layers
  – Dynamic cone penetrometer option

• More important for CIR & FDR:
  – Deflection testing
    • Falling weight deflectometer (FWD)
    • Dynaflect
  – Ground penetrating Radar (GPR)
Material characteristics

• HMA industry tests have been adapted for bituminous CIR and FDR mix designs (exceptions – raveling, cohesion) and HIR

• Bituminous CIR and FDR can have slightly lower modulus than HMA
  – Cement FDR acts like a weak PCC
  – Mechanical FDR acts like granular base

• HIR acts like HMA
Material characteristics

Typical quantities

- **CIR** - 1.5 to 3.5% emulsion (65% residue)
- **FDR**
  - 3 to 6% emulsified asphalt
  - 1 to 3% foamed asphalt
  - 3 to 6% cement
- **HIR**
  - < 1% recycling agent
Pavement design procedures

  - Rehab design: $SN_{OL} = SN_f - SN_{eff}$
- Caltrans Flexible Pavement Rehabilitation Manual
- Mechanistic Empirical Pavement Design Guide
  - NCHRP study underway for CIR and FDR
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.
### Structural coefficients / granular factors

<table>
<thead>
<tr>
<th>Treatment (and thickness)</th>
<th>AASHTO coefficient range</th>
<th>Caltrans $G_f$</th>
</tr>
</thead>
<tbody>
<tr>
<td>HMA / HIR (3/4” to 2.5”)</td>
<td>0.40 – 0.44</td>
<td>1.9</td>
</tr>
<tr>
<td>Aggregate base (6-14+)</td>
<td>0.10 – 0.12</td>
<td>1.1</td>
</tr>
<tr>
<td>Mechanical FDR (6-10”)</td>
<td>0.10 – 0.12</td>
<td></td>
</tr>
<tr>
<td>Bituminous FDR (4-8”)</td>
<td>0.20 – 0.28 (0.25)</td>
<td>(1.4 – 1.6)</td>
</tr>
<tr>
<td>Chemical FDR (8-10”)</td>
<td>0.14 – 0.23</td>
<td>1.2 – 1.6 (PC)</td>
</tr>
<tr>
<td>CIR (2-5”)</td>
<td>0.28 – 0.33 (0.30)</td>
<td>1.5 – 1.7</td>
</tr>
</tbody>
</table>

Dependent on agency design philosophy and experience, quality of materials, and stabilizer type and amount.
Structural coefficients / granular factors

Determined from resilient modulus testing of cores, lab-prepared specimens, or in-place deflection measurements (preferred)

\[ y = 0.1681\ln(x) - 1.7535 \]

\[ R^2 = 0.9963 \]

Bituminous – Refer to Figure 2.5 of 1993 AASHTO guide (Chapter 2)
Pavement design

- The pavement structure – depth of recycling and overlay thickness – is primarily influenced by:
  - Traffic – especially trucks
  - Subgrade type and properties
  - Aggregate base or stabilized base thickness, type, and quality / condition
  - Deflection measurements
  - Additive properties used in recycling
  - Climate
  - Design life
Example as-built structures

• CIR
  – Preservation product with some structural improvement
  – Leaves a portion of existing asphalt pavement in place
  – Does not treat the base or subgrade

• FDR
  – Of the three treatments, has the most structural improvement
  – Treats the entire depth of asphalt pavement
  – Possibly treats the subgrade

• HIR
  – Preservation product
  – Leaves a portion of existing asphalt pavement in place
CIR examples

• Nevada DOT CIR designs
  – For Category 4 or 5 (< 1,600 ADT), 3” CIR with double chip seal
  – For Categories 1 to 3 (>1,600 ADT), calculate ESALs for CIR design. >10,000 ADT with overlay

• Virginia I-81 (Augusta County) – left lane
  – 21,000 AADT and 28% trucks
  – Before: 12” HMA over 11” aggregate base
  – After: 4” new HMA over 5” CIR with foamed asphalt over remaining HMA over aggregate base
CIR examples

- **Washington Road, Tazewell County, Illinois (2001)**
  - Up to 4600 AADT and 15% trucks
  - Before: 12” HMA over 12” gravel base
  - After: 3” new HMA over 3” CIR with emulsified asphalt over 9” remaining HMA over base

- **Maple Lake, MN Municipal Airport Taxiway**
  - Average 57 aircraft / day (general aviation)
  - Before: 6” HMA on clay subgrade
  - After: 3” new asphalt over 3” CIR (with 25% aggregate added and emulsified asphalt)
FDR examples

• Washington Ave. in Las Vegas, NV
  – 15,000 AADT and 3% trucks. Curbed city street – 5 lanes
  – Before: 5” HMA over 15” aggregate base
  – After: Mill off old HMA. 5” new HMA over 6” FDR with emulsified asphalt over existing base

• Fairburn, Georgia
  – 4260 AADT, two lanes
  – Before: 4” HMA over 7” aggregate base
  – After: Widened road. 3.25” HMA over 6” FDR
FDR examples

• CR 52 in Long County, Georgia
  – 3,375 AADT and 15% trucks
  – Before: 1.25” HMA over 6” sand clay base
  – After: 1.5” new HMA over 6” FDR with cement over existing base

• Lancaster, California
  – Up to 5,900 AADT with 11% trucks
  – Before: 3” HMA over 6” aggregate base
  – After: 4.5” HMA over 4.5” FDR
HIR examples

• Milwaukee, WI (68th Street)
  – Four lanes, city street traffic (residential)
  – Before: 3” HMA over concrete
  – After: 2” HIR (final surface) over remaining HMA
HIR examples

- Oklahoma Turnpike (Turner)
  - 28,000 AADT and 20% trucks
  - After: \( \frac{3}{4} \)” new UTBWC over 2” HIR over full depth asphalt
Summary and Conclusions

- Evaluate the pavement carefully for design inputs
- Ensure proper project selection for treatment
- Evaluate different pavement design alternatives and finalize choice
- Perform a mix design with a reliable method
- Verify structural coefficient or granular factor if new to the process
Resources

Valuable resources if more information is needed...

• 1993 AASHTO Guide for Design of Pavement Structures
• Caltrans Flexible Pavement Rehabilitation Manual
• Recycling and Reclamation of Asphalt Pavements Using In-Place Methods, NCHRP Synthesis 421, 2011
• Recycling seminars
• Asphalt Recycling and Reclaiming Association – Basic Asphalt Recycling Manual
• www.arra.org
Thank You!

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