Design Criteria and Testing for Cold In-Place Recycling

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Presentation Topics

• CIR description
• Project selection criteria for CIR
• Mix design
• Pavement design
CIR Description

• Typical treatment depth of 2 to 4 inches
• Train of equipment (tanker trucks, milling machines, crushing and screening units, mixers, a paver, and rollers)
• An additive or combination of additives (asphalt emulsion, lime, fly ash, cement) mixing with 100% RAP
• Resulting recycled pavement usually opened to traffic at the end of the work day
CIR Description

Can be placed on ground or directly in paver hopper

Diagram: Center for Transportation Research and Education, June 2007, Iowa State University
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Project selection criteria

Generalized pavement deterioration curve

Pavement Condition Index

Excellent
Good
Fair
Poor
Very poor
Failed

Time, years (exact values vary depending on traffic, materials, etc.)

- New
- Minor aging
- Micro cracks
- Minor raveling
- Minor cracking
- Minor roughness / friction loss
- Moderate cracking
- Moderate roughness
- Rutting
- Major cracking
- Patching
- Major roughness
- Crack Sealing
- Chip Seal/Scrub Seal
- Slurry / Micro surfacing
- Thin overlay /
- HIR or thin mill & fill
- Ultra-thin bonded
- Full depth reclamation
- Cold in-place recycling
- Reconstruction
Project selection criteria

- Highways, county roads, city streets, airports
- Any asphalt-surfaced road, including composite pavements, with adequate thickness for the process
- Pavements with functional or minor structural distresses
- Treats the bituminous layer but not the base or subgrade
Project selection

- Minor structural upgrades for current or future traffic
- Good surface drainage and internal drainage
- Up to 20-year service life, or more, with preventative maintenance
- Generally an alternative to mill and fill
Challenges and limitations

- Steep grades are processed down-hill
- Longitudinal profile problems
- Tight curves
- Manholes and other utilities require special handling
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Purpose of Mix Design

• Determine emulsion content – 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
Mix Design

- HMA industry tests have been adapted for CIR mix designs (except raveling)
- CIR acts like a slightly lower modulus HMA material
Sampling and Preparation

• Samples to represent length and width
• Ensure uniformity or design around variability
• Look for paving fabrics
• Look for stripping or delaminated layers
Mix design – key tests

- Grinder / crusher ➢ Simulate milling
- Early-cure strength ➢ Adequate setting
- Marshall stability or tensile strength ➢ Long-term strength
- Retained strength ➢ Key performance indicator
- Hamburg WT ➢ Alt. strength or retained
- Thermal crack ➢ Non-load cracking
Mix design – grinder or crusher

- Miniature lab milling machine or jaw crusher to simulate expected field gradations
- Alternate – field milling if same equipment as job
Mix design – mixing

- Use a mechanical mixer to better simulate mixing that occurs in field equipment
Compaction and curing

• Superpave gyratory compactor. Some agencies specify Marshall compaction
• Cure at 60°C from 16 to 48 hours (except raveling) after compaction
Strength and Retained Strength

• Marshall strength (40°C) or indirect tensile strength (25°C)
• 70% retained stability after vacuum saturation and soak
Mix design – Thermal cracking

• AASHTO T-322
• To meet the low temperature requirements for the project
Mix design – typical emulsion rates

Typical emulsion quantities for CIR
- 1.5 to 3.5% or higher CSS-1/1h (special) and 1 to 3% HFMS-2
- Depends on how “active” the asphalt in the RAP is
- Ratio of emulsion residue to cement or lime of 1.8 or 2.0 (minimum) – if used
Mix design

While there is no nationally accepted mix design procedure yet for CIR, engineered mx design procedures used by many agencies have given more confidence in the process.
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Pavement design – surface courses over CIR

- 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
Pavement Design for Rehab

- Basic equation: \( S_{NOL} = S_{Nf} - S_{Neff} \)
  - \( S_{Nf} \) - AASHTO Sec. II, Fig. 3.1 nomograph
    - Soil modulus by testing (sampling) or FWD
  - \( S_{Neff} \) - 2 options
    - From deflection data (FWD - recommended)
    - From condition data
**SN_{eff} from Deflection Data**

- Falling weight deflectometer (FWD) is one common device
- Estimate soil modulus
- Quantify variability along road
$SN_{\text{eff}}$ from Condition Data

- $SN_{\text{eff}} = a_1 D_1 + a_2 D_2 m_2 + a_3 D_3 m_3$

  - $D_1, D_2, D_3 =$ Thickness values of existing layers

  - $a_1, a_2, a_3 =$ Layer coefficients corresponding to the current condition

  - $m_2, m_3 =$ Drainage coefficients corresponding to the current condition
Overlay Thickness

- $S_{NL} = SN_f - SN_{eff}$

- Overlay $S_{NL} = D_{OL} a_{OL}$

- $D_{OL} = (SN_f - SN_{eff}) / a_{OL}$
How to apply equation for CIR?

- \( SN_{OL+CIR} = SN_f - SN_{eff} \)
  - CIR will remove part of the asphalt layer and its structural contribution
    - CIR coefficient ranges from 0.28 to 0.35 (0.30 is typical)
  - \( SN_f \) is calculated the same way as for overlays
  - \( SN_{eff} \) should consider the following:
Pavement Design

\[ SN_{OL+CIR} = SN_f - SN_{eff} \]

- \[ SN_{OL+CIR} = a_{OL}D_{OL} + a_{CIR}D_{CIR} \] (Solve for overlay thickness, keeping CIR thickness fixed)

- \[ SN_f = \text{AASHTO Sec. II, Fig. 3.1} \]

- \[ SN_{eff} = a_{AC}D_{AC} + a_2D_2m_2 + a_3D_3m_3 \] (condition data, etc.)

NCHRP study for CIR using MEPDG
Summary

- Representative sampling and laboratory material processing is critical.
- Test methods are in place to ensure a successful project, determine the binder content, and the need for additives.
- A coefficient for CIR as high as 0.35, but more like 0.30, can be considered with proper mix design and construction procedures in place.
Resources

Valuable resources if more information is needed...

• ARRA Basic Asphalt Recycling Manual
• Recycling and Reclamation of Asphalt Pavements Using In-Place Methods, NCHRP Synthesis 421, 2011
• 1993 Guide for Design of Pavement Structures, AASHTO
• ARRA / FHWA recycling seminars
• www.arrar.org
Thank You!

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