2016 FDR Symposium

Sustainability of FDR and ARRA Resources
Macon, Georgia
May 15-16, 2018

Stephen A (Steve) Cross, PhD, PE
Technical Director
Asphalt Recycling & Reclaiming Association
Industry Segments

- Cold Planing
- Hot In-Place Recycling
- Cold Recycling
  - CIR & CCPR
- Full Depth Reclamation
- Soil Stabilization
Pavement Management

Seal Coats
Slurry Seals
Hot In-Place Recycling (HIR)
Cold Recycling (CIR & CCPR)
Full Depth Reclamation (FDR)
Full Depth Reclamation

Improves existing materials in-place to provide greater structural support and reduction of imported material.
Types of FDR

- Pulverization
- Mechanical Stabilization
  - Corrective Aggregate
  - RAP
- Bituminous Stabilization
  - Emulsified Asphalt
  - Foamed Asphalt
- Chemical Stabilization
  - Cement, CKD
  - Lime, LKD
  - Calcium Chloride
  - Class C Fly Ash
Full Depth Reclamation Construction Sequence

Old Asphalt

Base

Sub-base

Existing road

Pulverization to design depth

Pulverized

Sub-base

Removal of excess material (if necessary) and shaping

Pulverized

Sub-base

Addition of stabilizing agents, mixing & compacting

Stabilized

Sub-base

New Surfacing

Stabilized

Sub-base

Final surface course
FDR must be surfaced

► FDR layers can be surfaced with any type of pavement material.
  - HMA
  - Seal Coats
  - PCCP

► Typical AASHTO Structural Layer Coefficient 0.15 – 0.25.

► Not best way to design FDR with cement
FDR Engineering Properties

Strength is built into a pavement structure with FDR

- Corrects pavement defects
- Increases structural capacity

<table>
<thead>
<tr>
<th>3” worn HMA</th>
<th>SN_h = 0.2 x 3 = 0.60</th>
<th>SN_{FDR} = 0.25 x 6 = 1.50</th>
</tr>
</thead>
<tbody>
<tr>
<td>10” aggregate base</td>
<td>SN_a = 0.11 x 10 = 1.10</td>
<td>SN_a = 0.11 x 7 = 0.77</td>
</tr>
<tr>
<td>SN_t = 1.70</td>
<td>SN_t = 1.70</td>
<td>SN_t = 2.30</td>
</tr>
</tbody>
</table>
Strength is built into a pavement structure with FDR

- Corrects pavement defects
- Increases structural capacity

### 3” worn HMA

- $SN_h = 0.2 \times 3 = 0.60$
- $SN_a = 0.11 \times 10 = 1.10$
- $SN_t = 1.70$

### 2” new HMA

- $SN_h = 0.42 \times 2 = 0.84$
- $SN_{FDR} = 0.25 \times 6 = 1.50$
- $SN_a = 0.11 \times 7 = 0.77$
- $SN_t = 3.11$

### 6” FDR

### 7” aggregate base
Sustainability

20 ton load of cement at 5% treats 400 tons material

1-way haul

► 50 - 67 truckloads
► 27 - 31 truckloads
► 19 - 20 truckloads
► 19 - 20 truckloads
**FDR vs. New Base**

1 mile, 24-foot wide, 6-inch base (PCA)

- Number of trucks needed: 12 vs. 180
- New roadway material—tons: 300 vs. 4,500
- Material lanfilled—cubic yards: 0 vs. 2,700
- Diesel fuel consumed—gallons: 500 vs. 3,000

New Base vs. Full Depth Reclamation
PPRA Website
(www.RoadResource.org)

► Joint Venture of
  ■ ARRA
  ■ AEMA
  ■ ISSA

► Resource for Pavement Preservation &
In-place Recycling
  ■ Treatment Selection
  ■ Technical Resources
  ■ Sustainability
  ■ Network Resources
Which treatment is right for my road?

Pavement Criteria & Photo Selector

- Pavement Condition
- Primary Distress
- Road Type
- Surface Type

*This tool is designed to help explore possible solutions but should *not* be regarded as a formal recommendation for your pavement. Contact a supplier or contractor near you for a specialized consultation.*
How do I ensure treatment success?

Treatment Resource Center

FOR PAVEMENT CONDITIONS C-D-F (PCI of less than 70)

A cost-effective, long-lasting, greener alternative to conventional maintenance and rehabilitation techniques. Cold in-place recycling (CIR) is a process that cold mills and recycles the top 2-5 inches of asphalt using a continuous train operation. Through the complete reuse of existing material, CIR greatly reduces trucking, time and natural resources to significantly lower project costs. Generally, any road that is a candidate for mill & fill is a candidate for CIR.

- 20%–50% less expensive than conventional maintenance and reconstruction methods
- Reduce Greenhouse emissions by Up to 90%
- Reuses 100% of existing materials
- 20%–40% faster construction times
- Adds 15–20 years (combined with appropriate wearing course)
- Most agencies use SLCs between 0.30–0.38 (Recent research indicates values from 0.36–0.44 may be more appropriate)

ISSUES ADDRESSED
- Frequent, severe, non-load distresses in top lift of hot mix
- All distresses within the recycling depth (2-5 inches)
- Reflective cracking from below CIR layer
- See all

ATTRIBUTES
- Eliminates defects within the recycling depth
- Blocks or slows reflective cracking
- Reuses existing material in place
- Replaces 1 or 2 lifts of hot mix
- Allows for road widening where desired

COMMON COMBINATIONS
- CIR + hot mix overlay (most common)
- CIR + Single or Double Chip Seal
- CIR + Micro or Slurry Surfacing
- CIR + CCIP to increase treatment depth
Can recycling and reclamation treatments achieve the same structural gains as conventional methods?

**Structural Comparison Calculator**

<table>
<thead>
<tr>
<th>Layer Type</th>
<th>Depth (in)</th>
<th>Coefficient</th>
<th>Cost/SY</th>
<th>SN</th>
</tr>
</thead>
<tbody>
<tr>
<td>HMA Wearing Course</td>
<td>2</td>
<td>0.44</td>
<td>$7.17</td>
<td>0.44</td>
</tr>
<tr>
<td>HMA Base Course</td>
<td>3</td>
<td>0.40</td>
<td>$19.57</td>
<td>1.20</td>
</tr>
<tr>
<td>Remaining Asphalt (Existing)</td>
<td>3</td>
<td>0.20</td>
<td>-</td>
<td>0.60</td>
</tr>
<tr>
<td>SubBase/Granular Base</td>
<td>8</td>
<td>0.10</td>
<td>-</td>
<td>0.80</td>
</tr>
</tbody>
</table>

**Conventional Approach**

Total Structural Number: **3.04**

50,000 SY × $26.74/SY = $1,337,000 total

<table>
<thead>
<tr>
<th>Layer Type</th>
<th>Depth (in)</th>
<th>Coefficient</th>
<th>Cost/SY</th>
<th>SN</th>
</tr>
</thead>
<tbody>
<tr>
<td>HMA Wearing Course</td>
<td>1.5</td>
<td>0.44</td>
<td>$10.76</td>
<td>0.66</td>
</tr>
<tr>
<td>CIR</td>
<td>3.5</td>
<td>0.35</td>
<td>$9.21</td>
<td>1.25</td>
</tr>
<tr>
<td>Remaining Asphalt (Existing)</td>
<td>2</td>
<td>0.20</td>
<td>-</td>
<td>0.40</td>
</tr>
<tr>
<td>SubBase/Granular Base</td>
<td>8</td>
<td>0.10</td>
<td>-</td>
<td>0.80</td>
</tr>
</tbody>
</table>

**Optimized: Recycling First Approach**

Total Structural Number: **3.085**

50,000 SY × $19.97/SY = $998,500 total

By choosing the recycling first approach...

**25% / $338,500**

**Total Optimized Strategy Cost Savings**

- Reduce GHG emissions by 80%
- Reuse 100% of materials in place
- Speed construction time by 20-40%
- Eliminate 98% of hauling to/from site
Cost & Structural Comparison

Conventional: Reconstruction

Many agencies are learning that the use of limited funds toward a “worst first” approach accelerates the decline of their overall network, as miles of good roads go untreated each year.

<table>
<thead>
<tr>
<th>Layer Type</th>
<th>Depth (in)</th>
<th>Co-Eff</th>
<th>S/SY</th>
<th>SN</th>
</tr>
</thead>
<tbody>
<tr>
<td>HMA</td>
<td>4</td>
<td>0.44</td>
<td>$21.26</td>
<td>1.76</td>
</tr>
<tr>
<td>Granular Base</td>
<td>8</td>
<td>0.14</td>
<td>$17.75</td>
<td>1.12</td>
</tr>
</tbody>
</table>

Cost/SY: $39.01
Overall Structural Number: 2.88

Optimized: Full Depth Reclamation

Consider an Optimized approach, which reallocates funds across more efficient strategies to keep good roads good and help you get ahead of the curve.

<table>
<thead>
<tr>
<th>Layer Type</th>
<th>Depth (in)</th>
<th>Co-Eff</th>
<th>S/SY</th>
<th>SN</th>
</tr>
</thead>
<tbody>
<tr>
<td>HMA</td>
<td>3</td>
<td>0.44</td>
<td>$15.94</td>
<td>1.32</td>
</tr>
<tr>
<td>FDR w/ Cement</td>
<td>8</td>
<td>0.20</td>
<td>$9.50</td>
<td>1.6</td>
</tr>
<tr>
<td>Granular Base (Existing)</td>
<td>4</td>
<td>0.10</td>
<td>-</td>
<td>0.40</td>
</tr>
</tbody>
</table>

Cost/SY: $25.44
Overall Structural Number: 3.32
Why shouldn’t I address my worst roads first?

Life Cycle Cost Calculator

By choosing an optimized treatment strategy...

Optimized Strategy  
Total Savings  
$29,500,000

Net Present Value: $0.00/SY  
Total Life Cycle Cost: $0.0M

Cost/SY Over 50 Years: $28.65

Cost/SY Over 50 Years: $48.00

Conventional Approach  
Optimized Strategy
How do I Improve the overall health of my network?

Cost-Benefit Value & Remaining Service Life

**Cost-Benefit Value**

With limited funding, how do I prioritize my projects?

CBV offers roadway engineers a way to prioritize projects while accounting for the variables relevant to you and the realities of traffic, cost, and life extension.

\[
CBV = \frac{\text{(Traffic + Constraint Factor) \times (Life Extension)}}{\text{(Unit Cost) \times (PCI)}}
\]

Two road comparison: Which road should I treat first?

**ROAD 1**

- Worst First Reconstruction
- AADT 5000
- PCI 30
- \[\left(\frac{5000 \text{ AADT}}{4 \text{ ap}}\right) \times (20 \text{ years})\] = 33 CBV

**ROAD 2**

- Pavement Preservation Chip Seal
- AADT 5000
- PCI 75
- \[\left(\frac{5000 \text{ AADT}}{4 \text{ ap}}\right) \times (5 \text{ years})\] = 41 CBV

**CRITICAL CONCEPT**

For equal traffic, preservation has a higher benefit.

**Compare Network Approaches**
Part 5: Full Depth Reclamation
Chapters 14-17

FHWA –HIF-14-001
# Table 15-1: Stabilizing Agent Selection Guide for FDR Mixtures Including RAP

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>USCS</strong></td>
<td>GW</td>
<td>GP</td>
<td>GM</td>
<td>GC</td>
<td>SW</td>
<td>SP</td>
<td>SM</td>
<td>SC</td>
<td>ML</td>
<td>CL</td>
<td>OL</td>
<td>MH</td>
<td>CH</td>
</tr>
<tr>
<td>AASHTO</td>
<td>A-1-a</td>
<td>A-1-a</td>
<td>A-1-b</td>
<td>A-1-b</td>
<td>A-2-6</td>
<td>A-3 or A-1-b</td>
<td>A-2-4 or A-2-5</td>
<td>A-2-6 or A-2-7</td>
<td>A-4 or A-5</td>
<td>A-6</td>
<td>A-4</td>
<td>A-5 or A-7-5</td>
<td>A-7-6</td>
</tr>
<tr>
<td>Emulsified Asphalt</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SE &gt; 30 or PI &lt; 6 and</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
P<sub>20%</sub>               |                   |                      |             |              |                 |                   |           |             |                   |           |                           |            |                            |
| Foamed Asphalt              |                   | X                    | X           | X            | X               | X                 |           |             |                   |           |                           |            |                            |
| PI < 10 and P<sub>20</sub> 5 to 20% |       |                      |             |              |                 |                   |           |             |                   |           |                           |            |                            |
| Cement, CKD or Self-Cementing Class C Fly Ash | X     | X                    | X           | X            | X               | X                 | X         | X           | X                  | X         |                           |            |                            |
| PI < 20                      |                   |                      |             |              |                 |                   |           |             |                   |           |                           |            |                            |
| SO<sub>4</sub> < 3000 ppm   |                   |                      |             |              |                 |                   |           |             |                   |           |                           |            |                            |
| Lime/LKD                     |                   |                      |             |              |                 |                   |           |             |                   |           |                           |            |                            |
| PI > 20 and P<sub>20</sub> > 25% |             |                      |             |              |                 |                   |           |             |                   |           |                           |            |                            |
| SO<sub>4</sub> < 3000 ppm   |                   |                      |             |              |                 |                   |           |             |                   |           |                           |            |                            |
ARRA Developed Best Practice Guidelines to Complement BARM

- 100 Series - Recommended Construction Guidelines
- 200 Series - Preconstruction Sampling & Mix Design
- 300 Series - Recommended Quality Control Sampling and Testing Guidelines
- 400 Series – Project Selection Guidelines
## ARRA Best Practice Guidelines

<table>
<thead>
<tr>
<th></th>
<th>100 Series Const.</th>
<th>200 Series Mix Design</th>
<th>300 Series Quality Control</th>
<th>400 Series Project Selection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold Planing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Milling</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Micro Milling</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cold Recycling</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cold Central Plant</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Cold In-Place</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Full Depth Reclamation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bituminous</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Cementitious</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Lime</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

**Available at** www.ARRRA.org  **Under Development**
Education Resources

► Pavement Preservation Application Checklist Series
► Updated HIR & CIR, New FDR
► www.arrar.org & www.fhwa.gov
Where to find?
www.ARRAn.org
www.ARRRA.org
Transportation Curriculum Coordination Council (TC3)

Web Based Inspector Training Courses on:
- HIR
- CIR
- FDR

Hosted by AASHTO
Free at Checkout
Consist of Modules Covering
- Introduction
- Pre-Production Activities
- Full Production
- Post Construction Activities
Full Depth Reclamation (FDR) Module 1: Introduction

The presentation is available as an attachment from the paperclip icon in the bottom right-hand part of the screen.
Thank You

Stephen A Cross, PhD, PE
Technical Director
ARRA
steve.cross@okstate.edu
405-744-7200