Performance of Full Depth Reclamation (FDR) and Cold In-place Recycle (CIR) Projects in Columbus, Indiana
Session 132: 2018 Purdue Road School

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Heritage Research Group
Acknowledgments

- City of Columbus
  - Engineering Department
- Applied Research Associates (ARA)
Full Depth Reclamation (FDR)

- Deepest Recycle Treatment
  (5 - 10 in.)
- Entire asphalt pavement and portion of underlying materials
- Two step process:
  - Pulverize and shape;
  - Stabilize and compact
- Results in stabilized base course when recycling agents are used
  - Asphalt Emulsion
  - Cement
- Requires Wearing Course
Cold In-place Recycling (CIR)

- Pulverize existing HMA pavement (3 – 5 inches)
- Engineered emulsion mixed with millings
- Single step process
- Laydown with Paver
- Compaction
- Requires Wearing Course
Background Information

- City of Columbus began experimenting with FDR in 2011
- In 2014, city had performed more pavement recycling
  - FDR in industrial parks and minor collectors
  - CIR on 3 pavement sections
- Co-presented implementation experience at 2015 Road School
Presentation Highlights

- FDR used on industrial park pavements
- Projects successfully scoped, bid and constructed
  - Reconstruction estimate: 4.6M
  - FDR w/ drainage improvements: 1.46 M
- CIR experimented on sections
  - When & where does patching end?
  - Economical vs. deeper mill and fill treatments
# Columbus, Indiana Project Experience

## Road Sections

<table>
<thead>
<tr>
<th>Section</th>
<th>Road</th>
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<th>Type</th>
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Columbus, Indiana Project Experience

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<th>Road</th>
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Objective

- Determine performance of recycled pavements
  - How are the FDR sections performing structurally?
    - Are strengths of FDR layers as expected?
  - How are the pavements performing?
    - Distress Surveys
Scope

- How to accomplish the objectives
- 1. Falling Weight Deflectometer Testing (FWD)
  - Analyze layer strength on multiple FDR Sections
- 2. Visual Distress Surveys
  - Quantify condition
  - Surface vs Structural Distress
How strong are the FDR sections?

- **Falling Weight Deflectometer**
  - Non-destructive
  - Drops known weight onto surface
  - Measures deflection of pavement at different locations
  - Deflection data used to backcalculate estimated layer stiffness values
FWD Testing

- Contracted work by ARA
- FWD Performed May 2017
- Various pavement sections selected
  - Different ages
  - Different loadings
    - Industrial Park versus Urban Collectors
- Built by different contractors
  - Multiple FDR and HMA contractors
FWD Analysis

- Pavement Sections Analyzed
  - Unimproved sections on Cunningham and Poshard

<table>
<thead>
<tr>
<th>Road</th>
<th>Section Limits</th>
<th>Construction Year</th>
<th>Layer Thickness (in.)</th>
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<td>Interlake Rd. to Inwood Dr.</td>
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<td>Cunningham</td>
<td>River to Central</td>
<td>2014</td>
<td>3</td>
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<td>Poshard-1</td>
<td>Central to Middle</td>
<td>2014</td>
<td>3</td>
</tr>
<tr>
<td>Poshard-2</td>
<td>Middle to Marr</td>
<td>2015</td>
<td>3</td>
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<tr>
<td>Middle Rd.</td>
<td>Cessna to Hawpatch</td>
<td>2014</td>
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Due to changes in layer thickness, Norcross and Poshard sections were respectively broken into subsections designated as 1 and 2.
FWD Deflection Basins

- Loads drop on pavement at $D = 0$
- Sensors measure deflection at points out to 60 in.
- At 60 inches, deflection about the same
  - Controlled by subgrade

**Diagram: Cunningham Average Deflection under 9k Load**

- Graph shows deflection (mils) vs. offset (in.)
- Two lines represent unimproved and improved conditions.
- deflection increases with offset.
FWD Data: Improved vs Unimproved

- Observations
  - Lower Deflections in improved section
  - No change in D48 and D60 sensors
    - Subgrade not touched
  - D0 through D36 sensors, reduction in deflection
    - FDR and Overlay strengthened upper layers

Figure 6. Cunningham FWD peak deflections under 9-kip target load.
FWD Analysis

- How was analysis approached?
  - Pavement cross section divided into layers (3 layers)
  - Remaining aggregate layer grouped with subgrade
  - Concern over thin depths and consistency of aggregate layer

![Graph showing pavement cross section]

*Figure 1. Typical pavement cross section of Columbus pavement sites*

*Figure 10. FDR pavement cross section used for static backcalculation analysis.*
FWD Deflection Basin to Modulus Data

- Deflection data is established as baseline
- Pavement thickness input into model
- Model chooses multiple stiffness values of all three layers until...
- Calculated deflection is as close as possible to measured deflection basin

Figure 11. Measured and backcalculated deflection basin from static analysis (CR 175W SB station 4305, RMSE = 1.8%).
Discussion of FWD Results

- **HMA FWD Stiffness**
  - Ranges: 529 ksi to 3907 ksi
  - Outliers above 1000 ksi
  - Average: 651 ksi

- **FDR FWD Stiffness**
  - Ranges: 70.6 ksi to 215 ksi
  - Outliers below 100 ksi
  - Correspond with high HMA
  - Average: 178 ksi

### Table 2. Layer Moduli from the static analysis (HMA and FDR at field temperatures)

<table>
<thead>
<tr>
<th>Road</th>
<th>Parameter</th>
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Discussion of FWD Results

![Graph showing modulus values for different pavement sections.]

- Modulus values range from 0 to 4000 ksi.
- Sections include Deaver, CR 175W, Norcross 1, Norcross 2, Cunningham, etc.
- Two modulus types are indicated: FDR Modulus and HMA Modulus.
Visual Distress Surveys

- How can visual distress surveys be completed...
  - Boots on the ground survey
  - Automated data survey vehicle (DSV)
    - Collect high resolution pictures
    - Manually rate in the office
  - Automated distress identification and rating
  - State of the Art Equipment

Source: ARA, NACE 2016
Wanted for Visual Distress Surveys

- Another Option
- Quick Collection
- Data in the Cloud
- GPS Referenced
- Automated
- Economical
- Pavision from ARA
How Does Pavision Work?

- System attached to vehicle
- Components
  - Forward Camera
  - Down Facing Camera
  - Roughness Accelerometer
  - GPS Unit
- Controlled with laptop
  - Login Site
  - Cloud Based
How Does Pavision Work?

Forward Image Example
How Does Pavision Work?

Downward Image Example
How Does Pavision Work?

Automated Distress Analysis Available
How Does Pavision Work?

Google Map Overlay/Interface
Pavement Condition Index

- Pavision automated distress evaluation performed well in ranking the sections
- Additional quality control needed for accuracy
- Pavision collected images used for manual distress survey
- ASTM D6433
CR 175W

- Converted County Highway
- Chip Seals over 7” HMA
- Block Cracking
- Transverse/ Longitudinal

- 8 in FDR treatment (2014)
- Two 1.5 in HMA lifts
- PCI = 96.5
- Smoothness = 61.4
Cunningham Rd

- 4.0 – 5.0” Full Depth HMA
- Fatigue Cracking/ Potholing
- Transverse/ Longitudinal

- 6 in FDR treatment (2014)
- Two 1.5 in HMA lifts
- PCI = 74
- Smoothness = 80.6
Deaver Rd

- 7.5” HMA over Aggregate Base
- Age Related Cracking
- Block Cracking
- Wheelpath Fatigue Cracking

- 8 in FDR treatment (2015)
- Two 1.5 in HMA lifts
- PCI = 96.4
- Smoothness = 69.4
Norcross Dr (2011)

- 1st FDR Section in Columbus
- Age Related Cracking
- Block Cracking
- Fatigue Cracking
- Drainage Issues
- 8 in FDR treatment (2011)
- Two 1.5 in HMA lifts
- PCI = 78
- Smoothness = 83
Norcross Dr (2014)

- 7.5” HMA over Aggregate Base
- Age Related Cracking
- Pavement Patching
- Edge Cracking

- 8 in FDR treatment (2014)
- Two 1.5 in HMA lifts
- PCI = 65.6
- Smoothness = 64.5
Poshard Dr (2014)

- 3.0 - 4.75” HMA over Agg Base
- Age Related Cracking
- Pavement Patching
- Edge Cracking/ Potholing

- 6 in FDR treatment (2014)
- Two 1.5 in HMA lifts
- PCI = 71.8
- Smoothness = 84.3
Poshard Dr (2015)

- 6.0 – 8.0” HMA over Agg Base
- Age Related Cracking
- Pavement Patching
- Edge Cracking/ Potholing
- 8 in FDR treatment (2014)
- Two 1.5 in HMA lifts
- PCI = 97.7
- Smoothness = 57.2
Middle Rd

- 5.0 – 6.0” HMA over Agg Base
- Transverse/ Age Cracking
- Pavement Patching
- Edge Cracking/ Potholing

- 7 in FDR treatment (2014)
- Two 1.5 in HMA lifts
- PCI = 59.2
- Smoothness = 132.8
What Is Going on with Middle Rd?

- Condition worse than others
- Longitudinal Cracking
- Are they structural?
  - Shouldn’t be?
  - FWD Data
  - FDR Modulus 173 ksi

- Collect cores to find out
Middle Rd Coring Investigation

- Samples Collected on February 13, 2018

Top of FDR
Does Pavement Strength Influence PCI

- Backcalculated Modulus plotted vs PCI
- No visible trend exists
- Condition influenced by condition of HMA overlay
- Too early in age
  - Structural distress not appearing
  - What will happen later?
  - Fatigue properties of FDR?
Cold In-place Recycle

- Not as many sections to evaluate
- Initial scope not completed because of timing constraints
  - No FWD data available on CIR sections
  - Only one evaluated for PCI
Indianapolis Rd

- Composite Pavement
- Transverse/ Longitudinal Cracking
- Milling for ride at joints
Indianapolis Rd

- CIR performed in 2015
- 4 in CIR treatment
- 3.0” Total HMA cover
- PCI = 98.4
- Smoothness = 59.4
Indianapolis Rd
Closing Remarks

- FDR and CIR projects performing well
  - No Structural Issues to Date
- FWD data suggests FDR strengths in the 100 – 200 ksi range
  - Some outliers high and low
  - Quality of the model
- Pavement Distress Data mixed
  - Some related to Surface Distresses
  - Others performing extremely well
    - PCI > 90
Contact Information

- Thank you!
- Questions and Comments

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- Heritage Research Group
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