Motivation in Arkansas for Full Depth Reclamation (FDR)

- Increase of heavy traffic on rural Arkansas’ highways
  - Natural gas drilling (fracking) and logging
- Roads not designed for unanticipated heavy loads
- Traditional maintenance/rehabilitation strategies not adequate or prohibitively expensive
  - Chip seal
  - Two-inch overlay
  - Mill and fill with two-inch overlay
  - Remove and replace

FDR is a potential solution
FDR overview

- FDR reclaims, stabilizes, and compacts 8-14” of in-place bound, unbound, and subbase material
- Material stabilized by adding asphalt emulsion, asphalt foam, or Portland cement
- After mixing complete, material compacted and a surface course is placed

Can lead to decrease in virgin materials, and economic/environmental savings

Life Cycle Cost Analysis Procedure
Federal Highway Administration

1. Establish alternative pavement design strategies for analysis period,
2. Determine performance periods and activity timing,
3. Estimate agency costs,
4. Estimate user costs,
5. Develop expenditure stream diagrams,
6. Compute Net Present Value (NPV),
7. Analyze results and reevaluate design strategies.

Relatively straight forward: steps 1-5, 7
6. Compute NPV warrants more discussion
Net Present Value (NPV) =

\[
\text{Initial Cost} + \sum_{0}^{t_n} \left( \frac{\text{Maintenance Cost}}{(1 + r)^{t_n}} \right) + \sum_{0}^{t_n} \left( \frac{\text{Rehabilitation Cost}}{(1 + r)^{t_n}} \right) - \left( \frac{\text{Salvage Cost}}{(1 + r)^{t_n}} \right)
\]

t = time period (yrs)
n = year of analysis
r = discount rate (%)

Salvage Cost =

\[
\text{CLR} \times \frac{\text{Remaining Life of Last Resurfacing}}{\text{Service Life of Last Resurfacing}} + \text{CRI}
\]

CLR = cost of the last resurfacing
CRI = cost of the lower asphalt layers remaining from the initial construction

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Alternative pavement design strategies (maintenance schedule)

- **Traditional in Arkansas**
  - Chip seal (6 years)
  - Two-inch overlay (11 years)
  - Mill and fill with two-inches of asphalt concrete (11 years)
  - Removal and replace (11 years)

- **FDR rehabilitation techniques**
  - Asphalt emulsion (6 years)
  - Asphalt foam (6 years)
  - Portland cement (6 years)

50-year design analysis (assume non-surface layers structurally sound with no deterioration)

Deterioration curves for chip seal and two-inch overlay

Performed on four Arkansas Highways:
AR98, AR134, AR36, AR5
Increase in traffic and bound layer thickness from left to right
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Agency costs – 2014 weighted averages from Arkansas (cost per lane mile $1,000s)

- Chip seal: emulsion, aggregate ~12
- Two inch overlay: 5% asphalt binder, 95% aggregate ~65
- Mill and fill: cold milling, asphalt binder, aggregate ~77
- Remove and replace: cold milling, base course, asphalt binder, aggregate ~264 – 502
- FDR: stabilization process, cement/emulsion, tack coat + chip seal or two inch overlay ~78-218

Ranges from different structural numbers
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User costs – function of auto delay, truck delay, production rate (cost per lane mile $1,000s)

- Chip seal: emulsion, aggregate ~4-63
- Two inch overlay: 5% asphalt binder, 95% aggregate ~5-76
- Mill and fill: cold milling, asphalt binder, aggregate ~21-315
- Remove and replace: cold milling, base course, asphalt binder, aggregate ~264 –502
- FDR: stabilization process, cement/emulsion, tack coat + chip seal or two inch overlay ~78-218

Ranges from different highway traffic
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LCCA of two traditional agency costs ($/lane-mile): 5% discount rate

<table>
<thead>
<tr>
<th>Year</th>
<th>Chip Seal</th>
<th>Two-inch overlay</th>
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<tbody>
<tr>
<td>Year 0 - Initial Price</td>
<td>$11,990</td>
<td>$65,175</td>
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<tr>
<td>Year 6</td>
<td>$8,947</td>
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<td>Year 11</td>
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<td>$38,107</td>
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<td>Year 12</td>
<td>$6,677</td>
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<td>Year 18</td>
<td>$4,982</td>
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<td>Year 22</td>
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<td>$22,280</td>
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<td>Year 24</td>
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<td>$7,616</td>
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<td>Year 48</td>
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<tr>
<td>Year 50 - Salvage value</td>
<td>$1,074</td>
<td>$5,985</td>
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</tbody>
</table>
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Agency and user costs for AR98

Lowest traffic, least bound – FDR highly competitive

Highest traffic, highest bound – FDR moderately competitive
Influence of user costs for FDR – chip seal surface

User costs dominate on higher traffic roads:
AR98 – 310 ADT
AR5 – 4,460 ADT

1993 AASHTO structural number
ESAL prediction: chip seal and overlay

FDR more appropriate for roadways with initial thinner bound layers
Conclusions

• FDR versus traditional maintenance and rehabilitation techniques
  – More competitive: lower traffic, thinner bound layers
  – Less competitive: higher traffic, thicker bound layers

• Adding days of user delay increased the cost of FDR significantly
  – User costs: ¼ to 5 times agency costs

• Traffic capacity of FDR increased rapidly at reclaiming depths > 10 inches

Thank you, questions?