Development of Design and Construction Specifications of Full-Depth Reclamation with Emulsified and Foamed Asphalt for NJDOT

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In This Presentation...

- Background
- Goal & objectives
- Summary of literature review
- Performance evaluation of FDR mixes
- Survey questionnaire
- Preliminary recommendations for NJDOT FDR design and construction specification
Background

➢ **Full-depth reclamation (FDR)** is a rehabilitation process consisting of reclaiming deteriorated asphalt pavement to a depth of up to 14 in.

➢ Similar benefits to CIR: economical, environmental, and construction-based.
Design and construction specifications for FDR is not available for several highway agencies and state DOTs.

NJDOT allows only the use of cement for FDR.

Several mix design methods have been developed to improve the performance of FDR by introducing bituminous additives.

The outcomes of these studies can be used to update the current NJDOT specification for FDR.
Goal and Objectives

➢ **Goal**: Review, research & enhance the existing NJDOT Full Depth Reclamation (FDR) specifications

➢ **Specific Objectives**

➢ Conduct a thorough review pertaining to FDR

➢ Evaluate the laboratory performance of FDR with and without bituminous additives

➢ Distribute a survey questionnaire to FDR subject matter experts (SMEs)

➢ Recommend edits to the current NJDOT FDR design and construction specification.
Selection of FDR Stabilizing Agents

To improve their long-term performance, FDR is stabilized using:

1. Chemical stabilization
2. Mechanical stabilization
3. Bituminous stabilization
Selection of FDR Stabilizing Agents

Selection of the stabilization method depends on:
- Condition of the asphalt pavement to be rehabilitated using FDR
- Material availability
- Projected traffic level

Example
1. When reclaimed aggregate base is clay and/or silty materials and Plasticity Index > 10 → chemical stabilization is recommended
2. When the thickness of the pulverized unbound base is high with large aggregates → bituminous stabilization is recommended
Selection of FDR Stabilizing Agents

Criteria for selecting stabilizing agents vary between states:

- **PennDOT**: properties of RAP and soils, such as Plasticity index (PI), gradation, and percent passing sieve no. 200 sieve ($P_{200}$).

- **California DOT**: gradation of aggregate base, plasticity indices of both subgrade and base, and the R-value of the subgrade.

- **MnDOT**:
  - 50% RAP and 50% aggregate base (Emulsion is recommended)
  - 67% RAP and 33% aggregate base (Only cement)
# Selection of Stabilizing Agents for FDR Based on the Properties of Pulverized Material

<table>
<thead>
<tr>
<th>Stabilizing Agent</th>
<th>Properties of Pulverized Material</th>
<th>Pulverized Material</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Well graded gravel</td>
<td>Poorly graded gravel</td>
</tr>
<tr>
<td>Emulsion</td>
<td>PI &lt; 6 and P&lt;sub&gt;200&lt;/sub&gt; &lt; 20%</td>
<td>Yes</td>
</tr>
<tr>
<td>Foamed Asphalt</td>
<td>PI &lt; 10 and P&lt;sub&gt;200&lt;/sub&gt; &lt; 20% and P&lt;sub&gt;200&lt;/sub&gt; &gt; 5%</td>
<td>Yes</td>
</tr>
<tr>
<td>Portland Cement</td>
<td>PI &lt; 20 and SO&lt;sub&gt;4&lt;/sub&gt; &lt; 3000 ppm</td>
<td>Yes</td>
</tr>
<tr>
<td>Lime</td>
<td>PI &gt; 25 and SO&lt;sub&gt;4&lt;/sub&gt; &lt; 3000 ppm</td>
<td>-</td>
</tr>
</tbody>
</table>
Field Sampling

Characterize Reclaimed Materials

<table>
<thead>
<tr>
<th>Test</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture content</td>
<td>AASHTO T265</td>
</tr>
<tr>
<td>Sieve analysis</td>
<td>PTM 616 (AASHTO T27)</td>
</tr>
</tbody>
</table>

- **Emulsion** (Compaction of Mixtures): Emulsion (3%) or PG 64-22, PG 58-22, or PG 58-28 foamed asphalt (2%, 3.5%, 5%, increment, by weight).

- **Curing**: Curing materials finer than No. 200 sieve (1%, by weight) when bituminous additives are used, else (3% through 8%, by weight).

- **Water**: 3%

- **Performance Testing**:
  - Height Mode using SGC (PennDOT)
  - Gyratory Mode using SGC (30 gyrations) or 75 blows per face (PennDOT, VDOT, TxDOT)
  - 40°C at 72 hours (PennDOT)
  - Indirect tensile strength (PennDOT)
  - Marshall stability
Best Practices for FDR Construction

1. Project Selection & Pavement Preparation
2. Pavement Pulverization
3. Cement Placement
4. Bituminous stabilization (Optional)
5. Placement of the Mix and Compaction
6. Curing & Maintenance
Pulverization Depth

- Pulverization depth for FDR rehabilitation of flexible pavements: thickness of the existing asphalt layer.
- Typical pulverization depth ranges between 6 and 9 inches and rarely exceeds 12 inches.
- **ARRA:** pulverization depth - 4 to 12 inches depending on the thickness of the asphalt layer.
- **MnDOT:** most FDR projects consist of reclaiming the asphalt overlay along with 1 to 4 inches of the underlying aggregate base.
Asphalt overlay is relatively thick:

- Milling machine can be used to mill up to 4 inches of the asphalt layer to allow for the FDR reclaimer to pulverize the pavement to the desired depth.

Asphalt overlay is thin or the aggregate base layer is relatively thick:

- Stabilizing agents (e.g., emulsified and foamed asphalt) are applied to the top 3 to 5 inches of the reclaimed aggregate base.
Recommendations

- IOWA-DOT and NJDOT recommend the use of Portland cement with or without corrective aggregates.
- NYSDOT, Penn DOT, MnDOT and VDOT allow the use of more stabilizers along with cement (e.g., *Portland cement* and *hydraulic cement*) such as lime, fly ash, emulsified asphalt, or foamed asphalt.
- NYSDOT, MnDOT, and PennDOT:
  - Recommend the addition of emulsified asphalt to the reclaimed material to improve cohesion and
  - Maximize the load bearing capacity of FDR mixtures
Performance Evaluation of FDR Mixes
Material Selection

Materials (obtained from Asphalt Paving Systems Inc.)

- Reclaimed Asphalt Pavement (3 in.) and Soil (7 in.)
- Portland Cement
- CSS-1h Emulsion
- PG 64-22 Asphalt for foaming
Determine the Characteristics of RAP and soil

Mix RAP and soil with stabilizing agents

Compact using SGC at 30 gyrations

Allow to cure for 72 hours at 140°F

Determine air void level using Corelok

Evaluate the performance of FDR specimens
FDR Mixtures

Goal: Evaluate the impact of bituminous additives on FDR mixtures typically used in New Jersey

Mix A: Only Cement
- Cement: 4%, 4.5, & 5% by weight
- Water: 3%, by weight
- Curing: 1 Week at Room Temperature

Mix B: Cement + Emulsion
- Cement: 1%, by weight
- Water: 3%, by weight
- Emulsion: 3%, 4%, and 5%, by weight
- Curing: 3 days at 140°F

Mix C: Cement + Foamed Asphalt
- Cement: 1%, by weight
- Water: 3%, by weight
- Foamed Asphalt: 3%, 4%, and 5%, by weight
- Curing: 3 days at 140°F
Sieve Analysis

Average Gradation of DryRAP & Soil
Average Gradation of Dry RAP
Maximum Density Line
RAP Binder Content: 4.95%

Cumulative Percent Passing (%) vs. Sieve Size (mm)
Foaming Characteristics

<table>
<thead>
<tr>
<th>Temperature (°C)</th>
<th>Half-Life (s)</th>
<th>Expansion Ratio</th>
<th>OWC (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>160</td>
<td>7</td>
<td>8</td>
<td>2.5</td>
</tr>
<tr>
<td>170</td>
<td>11</td>
<td>12</td>
<td>2.5</td>
</tr>
<tr>
<td>180</td>
<td>7</td>
<td>10</td>
<td>3</td>
</tr>
</tbody>
</table>

NJDOT: Half-life- 8s, Expansion ratio-10

Foaming Machine

Foamed Asphalt
FDR Specimen Production

FDR at 4% cement and 3% water (Mix A)

FDR at 1% cement, 3% Emulsion and 3% water (Mix B)
Air Voids

![Graph showing air void levels for emulsified and foamed asphalt at different binder content percentages.](image-url)

- **Emulsified Asphalt**
  - Binder Content 3: 12.2%
  - Binder Content 4: 9.8%
  - Binder Content 5: 4.4%

- **Foamed Asphalt**
  - Binder Content 3: 6.3%
  - Binder Content 4: 7.0%
  - Binder Content 5: 9.4%
Rutting Performance (AASHTO T340)
Cracking Performance (ASTM D6931)
Increasing the cement content from 4% to 5% improved:

- Rutting performance by 86% (reduction of rut depth by 1.1 mm)
- Cracking resistance by 76% (increase of ITS by 20 psi)
Summary of Findings

The addition of bituminous additives has different impacts on FDR performance:

- Emulsion improves the performance of FDR mixes
- Foamed asphalt has a minor effect on FDR performance
Summary of Findings

➢ Rutting performance of emulsion FDR improved by 90% compared to control at the lowest content of emulsion (3%);

➢ Cracking resistance of emulsion FDR improved by 85% compared to control at the lowest content of emulsion (3%);

FDR with 5% cement - 3% emulsion and 1% cement is recommended.
Survey Questionnaire
The topics covered by this survey questionnaire include
- FDR use across the US and worldwide
- Mix design process (with/without bituminous additives)
- Selection of FDR stabilizing agents
- Construction practices including pavement investigation and selection of the depth of pulverization
- Additional details to equipment requirements
- Field monitoring and performance evaluation
- Lessons learned?
38. List the challenges, if any, encountered during the construction process of FDR (e.g., project selection, milling, paving, compaction, etc...).

39. How do you overcome these challenges?

40. In one or few sentences, what are the main lessons learned from the FDR projects conducted in your agency?
Prepare a list of Subject Matter Experts (SME) of highway agencies

The list will include all the states (in the US) and some countries using FDR as a rehabilitation method of asphalt pavements (e.g., Canada, Spain, Belgium and Brazil)

Prepare the survey in Qualtrics and distribute
# Preliminary Results

<table>
<thead>
<tr>
<th>Information</th>
<th>Georgia</th>
<th>Pennsylvania</th>
<th>Virginia</th>
<th>Indiana</th>
<th>Florida</th>
<th>Nevada</th>
<th>New York</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost savings per lane mile using FDR</td>
<td>-</td>
<td>$10,000-$30,000</td>
<td>Over $50,000</td>
<td>Over $50,000</td>
<td>-</td>
<td>No savings</td>
<td>-</td>
</tr>
<tr>
<td>How is RAP and aggregate base collected</td>
<td>Coring, crushing</td>
<td>Coring, backhoe</td>
<td>Reclaiming/pulverization, coring, crushing</td>
<td>Coring, crushing</td>
<td>Coring</td>
<td>Reclaiming/pulverization, coring, crushing</td>
<td>Coring, asphalt pavement block samples and underlying materials (3x3 ft)</td>
</tr>
<tr>
<td>Depth of pulverization when rehabilitating</td>
<td>7-10 in.</td>
<td>10-14 in.</td>
<td>10-14 in.</td>
<td>10-12 in. for cement FDR</td>
<td>7-10 in.</td>
<td>7-10 in.</td>
<td>7-10 in.</td>
</tr>
<tr>
<td>What is used as chemical additives?</td>
<td>Cement</td>
<td>Cement 3-8%</td>
<td>Cement 4-6%</td>
<td>Cement 5-7%</td>
<td>Cement 1-1.5%</td>
<td>Cement 2-3%</td>
<td>Cement (hydraulic cement and kiln dust)</td>
</tr>
<tr>
<td>What is the typical percentage of water?</td>
<td>5-12%</td>
<td>3%</td>
<td>2-3% depending on conditions</td>
<td>Within -1% to +2% of optimum mix design moisture content</td>
<td>2-3%</td>
<td>Determined by site conditions</td>
<td>AASHTO T180 Method D</td>
</tr>
</tbody>
</table>
# Preliminary Results

<table>
<thead>
<tr>
<th>Information</th>
<th>Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>State</strong></td>
<td>Georgia</td>
</tr>
<tr>
<td>Bituminous additive(s) used?</td>
<td>-</td>
</tr>
<tr>
<td>What are the ranges of FDR optimum contents of these stabilizing agents?</td>
<td>-</td>
</tr>
<tr>
<td>Quality control requirements the contractor is mandated to perform</td>
<td>Layer thickness, gradation</td>
</tr>
<tr>
<td>Measures followed to ensure the quality of FDR by the state/agency</td>
<td>In-Place Density, layer thickness, cement content, proof roll</td>
</tr>
</tbody>
</table>
Thank You!

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