Performance Evaluation of Asphalt Pavements with Full-depth Reclaimed Base

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Minnesota Pavement Conferences
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Background

- Full depth reclamation (FDR)
  - A widely used method for pavement rehabilitation
  - Pulverize the entire pavement surface layer and blends it with a portion of granular base/sub-base material (typically 50-50).
- Eliminate all distress areas.
- Eliminate potential for reflective cracking.
Stabilized FDR (SFDR)

- Counties have started to use

- Add stabilizer to FDR
  - Engineered emulsion, base I and fly ash.

- Increase stiffness of base --- reduce HMA overlay thickness.
  - Significant cost saving
Research Project

Objective

Evaluate performance of stabilized full-depth reclamation materials used for pavement base layer.
Selected Projects

- MnROAD three test sections
  - Cooperative research project between Road Science LLC. and Mn/DOT
  - I-94 (Feb. 09)
Several county project

<table>
<thead>
<tr>
<th>County</th>
<th>Road</th>
<th>Project Limits</th>
<th>Stabilizer</th>
<th>Stabilizer Content</th>
<th>Year Constructed</th>
<th>thickness (inches)</th>
<th>Stabilized Depth</th>
<th>Aggregate Depth</th>
<th>Subgrade Soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>LeSueur</td>
<td>CSAH 2</td>
<td>CSAH 11 to S. Jct. CSAH 5</td>
<td>Class C fly ash</td>
<td>6%</td>
<td>2008</td>
<td>6</td>
<td>12</td>
<td>0.0</td>
<td>Plastic</td>
</tr>
<tr>
<td>LeSueur</td>
<td>CSAH 13</td>
<td>CSAH 13 to 0.5 mile S. of CSAH 12</td>
<td>Emulsion and Class C fly ash</td>
<td>3.5% 2% fly ash</td>
<td>2008</td>
<td>6</td>
<td>7</td>
<td>1-3</td>
<td>Plastic Class 4 (sand-gravel)</td>
</tr>
<tr>
<td>Pope</td>
<td>CSAH 28</td>
<td>CR 79 to TH 55</td>
<td>T15 Base One .004 gal./yd2/lir</td>
<td>2007</td>
<td>3.5</td>
<td>4</td>
<td>4</td>
<td>(sand-gravel)</td>
<td></td>
</tr>
<tr>
<td>Pope</td>
<td>CSAH 29</td>
<td>TH 104 to TH 55</td>
<td>none</td>
<td>n/a</td>
<td>2004</td>
<td>3.5</td>
<td>n/a</td>
<td>8</td>
<td>(sand-gravel)</td>
</tr>
<tr>
<td>Goodhue</td>
<td>CSAH 30</td>
<td>TH 56 to CSAH 1</td>
<td>Fortress</td>
<td>4.50%</td>
<td>2008</td>
<td>stabilized 2.5&quot; and 1.5&quot; HMA on</td>
<td>6&quot; w. Fortress, 6&quot; unstabilized</td>
<td>8</td>
<td>n/a</td>
</tr>
<tr>
<td>Olmsted</td>
<td>CSAH 13 W. County Line to CSAH 3</td>
<td>Fortress</td>
<td>3.85%</td>
<td>2005</td>
<td>4</td>
<td>6</td>
<td>5.75</td>
<td>n/a</td>
<td></td>
</tr>
</tbody>
</table>
Empirical Equation to estimate GE:

\[ R = (0.41 + 0.873 \times \text{Mr})^{1.28} \]

\[ \log(\text{BB}_{80}) = 2.65 - 0.016 \times \text{GE} - 0.56 \log(R) \]

Mn/DOT uses granular equivalence (GE)

- Granular material (Class5): GE=1
Some preliminary results

- Olmsted CSAH 13
  - 4"HMA, 6" SFDR (7.75"HMA+ 2.5"Agg +3.85%Em)
    Effective GE = 24; GE (SFDR) = 1.9

- Pope CSAH 29 and CSAH 28
  - CSAH 29: 3.5” HMA; 8” FDR (50-50)
  - CSAH 28: 3.5” HMA; 4” SFDR (Base One); 4”FDR
    CSAH 29: Eff. GE=17; GE (FDR) = 1.6
    CSAH 28: Eff. GE=18; GE(SFDR) = 1.9
LeSueur CSAH 2 and CSAH 13
- CSAH 2: 6" HMA over 12" SFDR (6% Fly ash) over subgrade.
- CSAH 13: 6" HMA over 7" SFDR (3.5% emulsion & 2% fly ash) over 3" non-stabilized agg. base.

GE of CSAH2 SFDR is about 1.8
GE of CSAH 13 SFDR is about 2.1 ??

MnROAD (Cell 2,3 and 4)
- Cell2: FDR – 50-50 (4.25% Em); GE = 1.5
- Cell3: FDR – 75-25 (3.5% EM); GE = 1.8
- Cell4: FDR – 100RAP (3.25% EM); GE=1.4
- Interstate traffic (I-94): 1.2 M ESAL
  - Feb.09 – Jan. 11
- No cracks
- Normal consolidation
MnROAD Test Section (Cell 2, 3, 4)

TERRA Cooperative Research Project

- Road Science LLC and Mn/DOT

* Study how the emulsion-stabilized FDR in the different sections affects pavement performance in an accelerated loading scenario (interstate)

• Demonstrate viable rehabilitation options for flexible pavements

• Demonstrate how stabilization is optimized based on quantity of RAP and depth
Mix Design

- Increase the probability of a successful project
- Additive type determination and check compatibility
- Determine additive quantities and other requirements such as water
- Is add-rock or a secondary material required?
- Provide QC targets
- Sampling is very important
Mix Design

- Mixing with multiple contents – Engineered Emulsion
- High shear mixer for thorough mixing
- Superpave Gyratory Compaction – 30 gyrations
- Curing to simulate short-term or long-term strength
- Testing
## Mix Design

<table>
<thead>
<tr>
<th></th>
<th>Cell 2</th>
<th>Cell 3</th>
<th>Cell 4</th>
<th>Shoulder</th>
<th>Specs</th>
</tr>
</thead>
<tbody>
<tr>
<td>RAP/base blend</td>
<td>50 / 50</td>
<td>75 / 25</td>
<td>100% RAP</td>
<td>50 / 50</td>
<td>--</td>
</tr>
<tr>
<td>Design emulsion, %</td>
<td>4.0</td>
<td>3.0</td>
<td>0.75</td>
<td>4.5</td>
<td>--</td>
</tr>
<tr>
<td>Air voids, %</td>
<td>10.2</td>
<td>9.3</td>
<td>13.2</td>
<td>10.0</td>
<td>--</td>
</tr>
<tr>
<td>Short-term strength</td>
<td>241</td>
<td>276</td>
<td>430</td>
<td>225</td>
<td>175 g/25 mm, min.</td>
</tr>
<tr>
<td>ITS at 25°C</td>
<td>52</td>
<td>59</td>
<td>51</td>
<td>59</td>
<td>40 psi, min.</td>
</tr>
<tr>
<td>Conditioned ITS at 25°C</td>
<td>25</td>
<td>30</td>
<td>33</td>
<td>25</td>
<td>25 psi, min.</td>
</tr>
<tr>
<td>Critical cracking temp.</td>
<td>-32°C</td>
<td>-42°C</td>
<td>-31°C</td>
<td>-46°C</td>
<td>-27°C at 2 inches</td>
</tr>
</tbody>
</table>
Dynamic Modulus (AASHTO TP-62)

- E* test -- Mn/DOT and Road Science
- Input for all layers to predict deflection when a load is applied – estimation of pavement response
Fatigue – Road Science

![Graph showing the relationship between microstrains and number of cycles to failure. The graph includes data points and equations for Cell 2 and Cell 3.]

- **Cell 3**: 
  - Equation: \( y = 1382.3x^{-0.1382} \)
  - \( R^2 = 0.9728 \)

- **Cell 2**: 
  - Equation: \( 1938.3x^{-0.1725} \)
  - \( R^2 = 0.8801 \)
## Construction

<table>
<thead>
<tr>
<th>Cell 2</th>
<th>Cell 3</th>
<th>Cell 4</th>
<th>Shoulder</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 inch TBWC</td>
<td>1 inch TBWC</td>
<td>1 inch bonded 64-34 HMA</td>
<td>Micro surfacing</td>
</tr>
<tr>
<td>2 inches 64-34 HMA</td>
<td>2 inches 64-34 HMA</td>
<td>2 inches 64-34 HMA</td>
<td>4 inches FDR-EE (50/50 blend)</td>
</tr>
<tr>
<td>6 inches FDR-EE (50/50 blend)</td>
<td>6 inches FDR-EE (75/25 blend)</td>
<td>8 inches FDR-EE (100% bituminous)</td>
<td>36” base (Cells 2 &amp; 3) 5” base (Cell 4)</td>
</tr>
<tr>
<td>6 inches untreated FDR (50/50 blend)</td>
<td>2 inches untreated FDR (75/25 blend)</td>
<td>9 inches Class C fly-ash treated clay</td>
<td>Clay</td>
</tr>
<tr>
<td>26” Class 4 base</td>
<td>2” Class 5 base over 33” Class 3 base</td>
<td></td>
<td>Clay</td>
</tr>
<tr>
<td>Clay</td>
<td>Clay</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Construction

- Reclaimer used for pre-pulverization, emulsion addition, and fly ash stabilization of Cell 4 subgrade
Construction

- Padfoot compactor for breakdown compaction, followed by motor grader
- Followed by finish rollers
- Normally opened to rolling traffic after finish rolling
Construction

- Crushed RAP placement in Cell 4. The HMA surface had been removed for fly ash stabilization.
- After RAP placed back down, it was reclaimed with emulsion.
Construction

- Placement of HMA on emulsion-stabilized base
- Normally a few days to a week of curing before overlay. Measure in-place moisture.
Construction

- Micro surfacing being placed on shoulder
Current Performance

- No cracking as of last fall.
- Normal deformation of 0.15 inch
- Currently ~1/2 of design ESALs
Summary and Conclusions

- SFDR seems a good pavement rehabilitation option that can be used in cities, county roads, or state highways.
  - Initial testing shows SFDR is stronger.

- SFDR sections at MnROAD are performing very well so far.
Summary and Conclusions

- Mix design procedures have been developed and have good track record
- Construction needs
  - Project selection
  - Sampling
  - Water content
  - Emulsion content
  - Compaction
  - Time to overlay