MnROAD Phase 3 Concrete Pavement Construction Update

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NCC Fall Meeting, Minneapolis, MN

9/20/2017
MnROAD Facility

MnROAD

- Full-scale, cold climate pavement test facility near Albertville, MN
- 3.5 mile (5.6 km) “Mainline” section with diverted interstate I-94 traffic
- 2.5 mile (4 km) “Low Volume Road” closed loop test track
- Multiple pavement test sections
  - Asphalt
  - Concrete
  - Overlays
- Operation began in 1994
  - Beginning Phase 3 experiments

Provides opportunities for bold ideas
MnROAD History

• MnROAD Phase 1 (1994-2007)
  ➢ Funded by MnDOT, Mn LRRB and FHWA
  ➢ Experiments determined by MnDOT and Minnesota LRRB

• MnROAD Phase 2 (2007-2015)
  ➢ Funded by MnDOT, Mn LRRB and FHWA,
    Pooled fund partners (state DOTs)
  ➢ Experiments determined by MnDOT, Mn LRRB,
    Pooled fund partners (state DOTs)

• MnROAD Phase 3 (2015-?)
  ➢ Research and operation funded by National Road Research Alliance (NRRA)
    [6 states, MnLRRB]. Construction $ = MnDOT
  ➢ Experiments determined by NRRA members (includes input from 30 industry and academia members)
MnROAD Staff

Responsible for site operations

• Install and maintain supporting infrastructure
• Install sensors
• Conduct load tests
• FWD testing
• Distress surveys
• Provide loading on Low Volume Road
• Assist with non-pavement related studies
MnROAD Phase 3 - Round 1
Primary PCC Studies

• **Fiber-reinforced Concrete Pavement**
  - Thin overlays
  - Thin slabs on grade

• **Long-Term Impacts of Early Opening of Concrete Pavements to Traffic**
  - New pavements
  - Repairs

• **Reduced Cementitious Content Concrete Mixtures**
  - Current limits
  - How low can you go?

• **(Long Term Effects of Diamond Grinding on PCC and Impact of Sealers)**
  FUTURE?

• **(Compacted Concrete Pavement)**
  FUTURE?
Fiber Reinforced Concrete Study

Objectives

- Determining contribution of fibers in reducing panel fatigue cracking

- Determining contribution of fibers in mitigating joint faulting

- Determining optimal panel size
Fiber Reinforced Unbonded Concrete Overlay

- **MnROAD Cells 705, 805** (Mainline interstate traffic)
  - Fiber content: 20% RSR (ASTM C1609)
  - Non-woven geotextile fabric interlayer
  - Cell 705: 14’W x 12’L, 12’x12’ panels
  - Cell 805: 6’Wx12’L & 8’Wx12’L panels
  - 3’ wide passing lane PCC shoulder
Fiber Reinforced Concrete On Grade

- **MnROAD Cells 506, 606, 706, 806**  
  *(Mainline interstate traffic)*
  - All cells: 6’ x 6’ panels
  - **Fiber content:**
    - Cell 506: No fibers (control)
    - Cell 606: 20% RSR (ASTM C1609)
    - Cell 706: 30% RSR (ASTM C1609)
    - Cell 806: 0.75% by volume

<table>
<thead>
<tr>
<th>5&quot; Fiber Reinforced Concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td>11&quot; Drainable aggregate base</td>
</tr>
<tr>
<td>3&quot; Existing Class 5 base</td>
</tr>
<tr>
<td>Clay subgrade</td>
</tr>
</tbody>
</table>
Ultra-thin Fiber Reinforced Concrete On Grade

- **MnROAD Cells 139, 239**  
  (Low Volume Road traffic)

  - All cells: 6’ x6’ panels

  - **Fiber content:** 30% RSR (ASTM C1609)

```plaintext
<table>
<thead>
<tr>
<th>3&quot; Fiber Reinforced Concrete</th>
<th>4&quot; Fiber Reinforced Concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td>6&quot; Class 5</td>
<td>6&quot; Class 5</td>
</tr>
<tr>
<td>4&quot; common borrow (silty-clay)</td>
<td>4&quot; common borrow (silty-clay)</td>
</tr>
<tr>
<td>Clay subgrade</td>
<td>Clay subgrade</td>
</tr>
</tbody>
</table>
```
Objectives

- Evaluate visible and non-visible immediate damage caused by early age loading
- Quantify the effect of early loading damage on long-term performance
- Determine minimum strength at opening or other measurable variables associated with this parameter
- Recommend strategies for minimizing or avoiding early loading damage detrimental to long-term performance
Early Opening to Traffic

• MnROAD Cell 124
  (Low Volume Road Traffic)

  ➢ Standard panel size 12’W x 15’L
  ➢ Standard concrete mix
  ➢ Doweled joints
  ➢ Early sequential traffic loadings
    ➢ Based on maturity
  ➢ Vehicle driven across concrete before full set to cause visible damage
Early Opening of Repairs

- MnROAD Cells 7 & 8
  (Mainline interstate traffic)

  ➢ Full panel replacements, full-depth joint repairs, and partial-depth repairs

  ➢ Various repair materials
    - MnDOT spec. 3U18M
    - MnDOT spec. 3U58
    - Contractor design high early mix
    - Internal cure mix
    - Roller Compacted Concrete
      - 1 and 2 lifts

  ➢ Early sequential traffic loadings
Reduced Cementitious Content Concrete Study

Objectives

- Investigate the early-age characteristics of concrete paving mixes containing low and lower cementitious content
- Assess causes of, or potential for, durability issues with very low cementitious content
- Identify effect of reduced cementitious content on long term serviceability and economics of concrete pavements
- Develop recommended specifications, mixing and placement practices for the use of low cementitious content concrete mixes
Reduced Cementitious Content Mixes

• **MnROAD Cells 138, 238**
  (Low Volume Road traffic)

  ➢ All cells: 12’W’ x 15’L panels

  ➢ Cell 138: Cementitious content = 500 lb/cy
  ➢ Cell 238: Cementitious content = 470 lb/cy
Concrete Repair Product Evaluations

- I-94 MnROAD Bypass (1900 ft) (intermittent interstate traffic)
  - 44 year JRCP (27’ long panels)
  - Partial-depth joint and mid-panel repairs
  - Various repair materials
    - 15 early-set materials
    - Installed by MnDOT maintenance workers
    - Guided by manufacturer/supplier reps
Concrete Mix Designs

### Contractor Mix Design - Specialty Concrete (JMF)

#### Use for:
- Job Specific Concrete using a JMF
- Paving Projects 3,500 CY or greater
- High Performance Bridge

<table>
<thead>
<tr>
<th>Name/Mill/Plant</th>
<th>MnDOT Abbreviation</th>
<th>Type/Class</th>
<th>SP.G / Dosage</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>Holcem Ste. Gen.</td>
<td>STGBLMO</td>
<td>I/II</td>
<td>3.15</td>
</tr>
<tr>
<td>Fly Ash</td>
<td>Headwaters Coal Creek</td>
<td>COCUNND</td>
<td>F</td>
<td>2.50</td>
</tr>
<tr>
<td>Slag</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other CM</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pit #</th>
<th>Size</th>
<th>Class</th>
<th>SP.G</th>
<th>ABS</th>
<th>Agency Contact</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Estimated Batch Weights - Pounds (Dry)

<table>
<thead>
<tr>
<th>Mix #</th>
<th>% Air</th>
<th>Water</th>
<th>Cement</th>
<th>Fly Ash</th>
<th>Slag</th>
<th>Other CM</th>
<th>% Fly Ash</th>
<th>% Slag</th>
<th>% Other CM</th>
<th>% Ternary</th>
<th>Total CM</th>
<th>W/C Ratio</th>
<th>FA#1</th>
<th>FA#2</th>
<th>CA#1</th>
<th>CA#2</th>
<th>CA#3</th>
<th>Volume</th>
<th>Th. Unit Wt.</th>
<th>Slump Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>MR-3A21</td>
<td>7.0</td>
<td>228</td>
<td>400</td>
<td>170</td>
<td>30</td>
<td></td>
<td>30</td>
<td></td>
<td></td>
<td></td>
<td>570</td>
<td>0.40</td>
<td>1173</td>
<td>562</td>
<td>1015</td>
<td>305</td>
<td>305</td>
<td>27.0</td>
<td>142.7</td>
<td>1/2-3&quot;</td>
</tr>
<tr>
<td>MR-3A21A</td>
<td>7.0</td>
<td>197</td>
<td>353</td>
<td>117</td>
<td>25</td>
<td></td>
<td>25</td>
<td></td>
<td></td>
<td></td>
<td>470</td>
<td>0.42</td>
<td>1242</td>
<td>595</td>
<td>1075</td>
<td>323</td>
<td>323</td>
<td>27.0</td>
<td>144.5</td>
<td>1/2-3&quot;</td>
</tr>
<tr>
<td>MR-3A21B</td>
<td>7.0</td>
<td>210</td>
<td>375</td>
<td>125</td>
<td>25</td>
<td></td>
<td>25</td>
<td></td>
<td></td>
<td></td>
<td>500</td>
<td>0.42</td>
<td>1218</td>
<td>584</td>
<td>1054</td>
<td>317</td>
<td>317</td>
<td>27.0</td>
<td>143.8</td>
<td>1/2-3&quot;</td>
</tr>
</tbody>
</table>

#### % Aggregate Proportion by Volume

<table>
<thead>
<tr>
<th>Mix #</th>
<th>% Aggregate Proportion by Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>MR-3A21</td>
<td>39</td>
</tr>
<tr>
<td>MR-3A21A</td>
<td>18</td>
</tr>
<tr>
<td>MR-3A21B</td>
<td>33</td>
</tr>
<tr>
<td>MR-3A21B</td>
<td>10</td>
</tr>
</tbody>
</table>

**Low Cementitious Cells (138-238)**

Table courtesy of American Engineering Testing
# Concrete Mix Designs

## Fiber Reinforced Concrete Cells
- **Fiber type:** FORTA-FERRO
- **20% RSR = 5 pcy; 30% = 8 pcy; 0.75% vol = 11.66 pcy**

*Table courtesy of American Engineering Testing*
Table 1 – Summary Test Results – ASTM C1609 – 28 days

<table>
<thead>
<tr>
<th>Specimen Dimension</th>
<th>5 pcy</th>
<th>8 pcy</th>
<th>11.7 pcy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Width (in.)</td>
<td>6.15</td>
<td>6.10</td>
<td>6.20</td>
</tr>
<tr>
<td>Depth (in.)</td>
<td>6.05</td>
<td>6.05</td>
<td>6.00</td>
</tr>
<tr>
<td>Initial Deflections</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\delta_1$ - Deflection at First Crack (in.)</td>
<td>0.0017</td>
<td>0.0019</td>
<td>0.0019</td>
</tr>
<tr>
<td>$\delta_P$ - Deflection at Peak Load (in.)</td>
<td>0.0019</td>
<td>0.0020</td>
<td>0.0021</td>
</tr>
<tr>
<td>Loads</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$P_1$ - First Crack Load (lbf.)</td>
<td>7,928</td>
<td>9,011</td>
<td>8,257</td>
</tr>
<tr>
<td>$P_P$ - Peak Load (lbf.)</td>
<td>8,109</td>
<td>9,433</td>
<td>8,866</td>
</tr>
<tr>
<td>$P_{150}^{600}$ - Load at L/600 (lbf.)</td>
<td>1,492</td>
<td>2,522</td>
<td>3,782</td>
</tr>
<tr>
<td>$P_{150}^{150}$ - Load at L/150 (lbf.)</td>
<td>1,322</td>
<td>2,437</td>
<td>3,528</td>
</tr>
<tr>
<td>Stress</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$f_1$ - First Crack Stress (psi)</td>
<td>635</td>
<td>730</td>
<td>660</td>
</tr>
<tr>
<td>$f_P$ - Peak Stress (psi)</td>
<td>650</td>
<td>765</td>
<td>710</td>
</tr>
<tr>
<td>$f_{150}^{600}$ - Stress at L/600 (psi)</td>
<td>120</td>
<td>205</td>
<td>305</td>
</tr>
<tr>
<td>$f_{150}^{150}$ - Stress at L/150 (psi)</td>
<td>105</td>
<td>195</td>
<td>285</td>
</tr>
<tr>
<td>Toughness</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$T_{150}^{150}$ - Toughness (in-lbs)</td>
<td>187</td>
<td>327</td>
<td>460</td>
</tr>
<tr>
<td>$f_{T,150}$ or $Fe_{3mm}$ (psi)</td>
<td>126</td>
<td>221</td>
<td>307</td>
</tr>
<tr>
<td>$R_{T,150}$ or $Re_{3mm}$ (%)</td>
<td>20.1</td>
<td>30.3</td>
<td>46.6</td>
</tr>
</tbody>
</table>

*Table courtesy of American Engineering Testing/Testing, Engineering & Consulting Services, Inc.*
Box Test

After 30 minutes

Low cementitious mix

20% RSR Fiber mix

Photos courtesy of American Engineering Testing
Removal of Previous Test Cell

PASSRC Interlayer after 9 years

Cell 405
Removal of Previous Test Cell

Cell 406
Instrumentation
Instrumentation
Paving
Paving

Cell 139, 3” FRC
Sampling
Construction Issues

• FRC Cell 606 paved 1” too thick

• Passing lane sawed 1 foot narrower than planned on Cells 705/805

• Spongy/non-uniform base under LVR cells

• Damage to Cell 139 from construction traffic
# Early loading of Cells 124-424

## Cell x24 Early Loading Sequence

<table>
<thead>
<tr>
<th>Maturity (Deg-Hr)</th>
<th>Flexural (psi)</th>
<th>Loads applied to lanes</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>73</td>
<td>1st Load on Cell 124 (forward and back)</td>
</tr>
<tr>
<td>200</td>
<td>196</td>
<td>1st Load on Cell 224, 2nd load on Cell 124</td>
</tr>
<tr>
<td>300</td>
<td>267</td>
<td>1st Load on Cell 324, 2nd load on Cell 224, 3rd load on Cell 124</td>
</tr>
<tr>
<td>400</td>
<td>318</td>
<td>1st Load on Cell 424, 2nd load on Cell 324, 3rd load on Cell 224, 4th load on Cell 124</td>
</tr>
</tbody>
</table>

Starting Day 2, 5 passes per day for first week

![Compressive and Flexural Graph](image)
Early Loading of Cell 624
Early Loading of Cell 624
Early loading of Cells 124-424

4,000 lb axle vs 14,000 lb axle loads (1st Cell @ 3hrs)
Post Paving Activities

- Profile (Lightweight profiler)
- Mix uniformity mapping (MIRA)
- Slab thickness (MITScan T2)
- Transverse joint deployment
  - Edge observations before shoulder placement
- Warp and curl (ALPS2 laser profiler)
- Install joint opening sensors and pins
- FWD Tests (after shoulder placement)
- Initial load testing with MnROAD truck
- Compile PCC strength and durability specimen results
Warp and Curl Profiling
Early Transverse Joint Deployment

All 6’ x 6’ panels on base

Observation on 7-5-17, Age range: 5 to 9 days
Early Loading Damage

Cell 139, 3” FRC, Loaded with construction traffic @ 2 weeks old
Early Loading Damage

Cell 139, 3” FRC
Early Loading Damage

Cell 139, 3” FRC
Early Loading Damage

Cell 139, 3” FRC
Remaining Activities

- Partial-depth concrete repairs on parallel WB- I-94
  - 15 fast set mixes
  - Same repair pattern

- General repairs of older MnROAD mainline PCC cells

- Repairs (with early loading) in Cells 7 and 8 (25 years old)
  - Partial depth repairs with MnDOT 3U18M and 3U58
  - Full-depth joint replacements with high early strength mix
  - Full panel replacements
    - Internal cure mix
    - RCC (compacted with small maintenance roller)
      - Driving lane 2 lifts
      - Passing lane 1 lift
Questions?

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