Evaluation of Partial Depth Pavement Repairs on Routes Heavily Traveled by Amish Horse and Buggies

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Create for Good.
The researchers would like to thank the Ohio Department of Transportation (ODOT), the Federal Highway Administration (FHWA), and the Ohio’s Research Initiative for Locals (ORIL) for sponsoring this study.

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Finally, the researchers would like to express their appreciation to Ms. Jacquelin Martindale Ms. Vicky Fout for their time and assistance.
Background

- ODOT performs routine repairs on roadways in Ohio to maintain comfortable and safe travel of the public.
- Roadways in Ohio with heavy Amish buggy traffic see more frequent partial depth repairs as it encounters more damage.
- Calks, or cleat like welds, that are placed on the horseshoes to provide adequate traction for the horses are believed to be the main cause of pavement damage.
Objectives

- Develop longer lasting repairs for roadways in Ohio particularly those with high buggy traffic.
- Identify changes to horseshoes to reduce the Amish buggy damage.
- Develop a cost benefit analysis that can be used to evaluate the cost effectiveness of the improved processes and alternatives and compare them to processes currently being used.
Phase 1 Overview

- Survey of ODOT Current Practices
- Literature Review
- Provide an Analysis of Repair Cycles for Amish Routes
- Develop a Matrix of Alternatives & Evaluate Cost Effectiveness
- Provide Recommendations for Changes in Horseshoes
- Prepare and Submit Final Report
Repairs on Amish Buggy Routes

- Scarring and rutting are the main issues in repairs on Amish buggy routes
Aggregate at depth of 1.75 inch to 2.5 inch from surface were cracked.
Cost Analysis

- **Non Amish Route**
  - EUAC($): $2,000

- **Amish Route**
  - EUAC($): $10,000

410% increase
The main distress in repairs on Amish buggy routes was scarring and rutting of the surface layer(s).

The life cycle costs of partial depth repairs on routes with heavy Amish buggy traffic were about three times more expensive than those of routes without Amish buggies.

Several alternatives were proposed to improve the rutting resistance of asphalt mixtures used in partial depth repairs on Amish buggy routes, which included using alternative: mix design procedure, asphalt binder type, aggregate structure, and aggregate type.

Proper compaction of asphalt mixtures during partial depth repairs is essential to ensure satisfactory field performance.
Conclusions-Phase 1

- Vibratory steel roller compactor should be used for compaction of asphalt mixtures in partial depth repairs and density should be monitored.
- The results of LCCA analysis indicated that the alternative repair mixtures/method can be much more cost effective than the current mixture and method.
- Using screw-in studs that are made from hard polymer and have larger contact area as well as horse boots might be two good solutions that can help reduce pavement damage caused by Amish buggies.
- The Amish community were receptive to trying the screw-in studs and horse boots and using them in the future if they are proven to be cost effective and are not rejected by their horses.
Phase 1 - Recommendations

Amish Buggy Traffic

- < 5 buggies per hour
  - No change to current practice
  - Repair >50 CY
    - No
    - Yes
      - Monitor Compaction

- 5-10 buggies per hour
  - Monitor Compaction
  - Repair >50 CY
    - No
    - Yes
      - Use vibratory roller & 70-22 mix if available

- > 10 buggies per hour
  - Urban
    - Repair >50 CY
      - No
      - Use vibratory roller & 70-22 mix
      - Yes
      - Use vibratory roller & mix with optimal performance based on Phase 2 results
  - Rural
    - Repair >50 CY
      - No
      - Use vibratory roller & 70-22 mix
      - Yes
Phase 2 - Overview

1. Conduct Laboratory Study To Design Mix
2. Implementing Lab Recommendations into Field Trials
3. Evaluate of Field Trials
4. Provide an Analysis of Repair Cycles for Amish Routes
5. Quantify The Reduction In LPA Roadways Damage Due To Alternative Horseshoes
6. Evaluate The Effectiveness Of New Horseshoes Alternative
7. Evaluate The Effects Of New Horseshoes Alternative On Horse Hoof
8. Evaluate the Effectiveness of using GTR Mixes on Amish Buggy Routes
9. Prepare and Submit Final Report
Phase 2 - Mix Design & Evaluation

A comprehensive laboratory study was conducted to design mixes that have better resistance to damage caused by horseshoes:

1. Mixtures designed using Airport mixes’ design procedure
2. Mixtures designed using Airport mixes’ design procedure but with aggregate structure modified based on Bailey’s method.
3. Mixtures designed using Airport mixes’ design procedure but with aggregate structure modified based on Bailey’s method and had steel slag.
4. Mixtures designed using Airport mixes’ design procedure but with aggregate structure modified based on Bailey’s method and had PG 88-22.
5. Mixtures were designed using Airport mixes’ design procedure but with aggregate structure modified based on Bailey’s method and include ground modified tire (GTR) modified binder.

6. Mixes used to repair state routes in Holmes County.
Phase 2 - Mix Design & Evaluation

Design Asphalt Mixtures

Conduct Laboratory Testing

Durability

AASHTO T283

Rutting

Flow Number

APA

Field Evaluation
Flow Number (F_N) Test Results

- **Airport Mix 1**
- **Airport Mix 2-PG 76-22**
- **Airport Mix 2-PG 88-22**
- **Slag Mix**
- **Typical Surface Mix**
- **Holmes county 101G Mix**
Field Test Sections
Changes to Horseshoes
Changes to Horseshoes

- Horseshoes with different calk designs were obtained from Amish farriers in different counties.
  - Horseshoes A
  - Horseshoes B
  - Horseshoes C
  - Horseshoes D
  - Horseshoes E

- Those designs represent the ones used by different farriers in these counties.
- The area and shape of the cleat differed among these designs,
# Changes to Horseshoes

<table>
<thead>
<tr>
<th>Cleat #</th>
<th>Depth (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7.20</td>
</tr>
<tr>
<td>2</td>
<td>6.87</td>
</tr>
<tr>
<td>3</td>
<td>6.68</td>
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</tbody>
</table>

![Image of horseshoe with labeled cleats]
# Changes to Horseshoes

<table>
<thead>
<tr>
<th>Cleat#</th>
<th>Depth (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8.65</td>
</tr>
<tr>
<td>2</td>
<td>8.52</td>
</tr>
<tr>
<td>3</td>
<td>9.09</td>
</tr>
<tr>
<td>4</td>
<td>8.58</td>
</tr>
<tr>
<td>5</td>
<td>9.2</td>
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</tbody>
</table>

[Image of a horseshoe with labeled cleats]
Changes to Horseshoes

<table>
<thead>
<tr>
<th>Cleat#</th>
<th>Depth (mm)</th>
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<tbody>
<tr>
<td>1</td>
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</tr>
<tr>
<td>2</td>
<td>5.64</td>
</tr>
<tr>
<td>3</td>
<td>5.45</td>
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</table>

Shoes "D"
## Changes to Horseshoes

<table>
<thead>
<tr>
<th>Cleat#</th>
<th>Depth (mm)</th>
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<tbody>
<tr>
<td>1</td>
<td>4.38</td>
</tr>
<tr>
<td>2</td>
<td>4.55</td>
</tr>
<tr>
<td>3</td>
<td>5.30</td>
</tr>
</tbody>
</table>
Changes to Horseshoes

- A method using a new carbonite coating technology was evaluated to obtain the needed traction for the horse but without causing the same damage.
- The method involves spraying carbide on the horseshoes uniformly.
- The method provided good traction but poor wearing resistance.
Changes to Horseshoes

- Another method for applying carbide particles has been evaluated.
- To date, the method provided good traction but relatively good wearing resistance.
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Quantify Reduction In Road Damage
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The graph shows the relationship between Penetration Depth (mm) and Blows, with data points for Point 1, Point 2, and Point 3.
Quantify Reduction In Road Damage

Maximum Penetration (mm)

Horseshoe

A  C  D  E
Quantify Reduction In Road Damage

<table>
<thead>
<tr>
<th>Horseshoe</th>
<th>Blows to 4mm penetration</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>13</td>
</tr>
<tr>
<td>C</td>
<td>9</td>
</tr>
<tr>
<td>D</td>
<td>6</td>
</tr>
<tr>
<td>E</td>
<td>30</td>
</tr>
</tbody>
</table>
Quantify Reduction In Road Damage

A new design for horseshoes is currently under evaluation.
Quantify Reduction In Road Damage
Mixtures designed using Airport mixes’ design procedure but with aggregate structure modified based on Bailey’s method and had PG 88-22 showed better field performance to date than other mixes.

Proper compaction of mixtures used for partial depth repairs is important to ensure the adequate performance and service life.

The calks area, depth, and shape significantly affect the damage that horseshoes cause to roadways.
Questions?