Evaluation of Winter Pothole Patching Methods

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Outline

- Background
- Objectives
- Project Overview
- User Survey
- Equipment Selection and Training
- Field Evaluation Program
- Field Evaluation Results
- Conclusions
- Recommendations for Implementation
- Questions
Background
Background

- Potholes are one of the most aggravating forms of pavement deterioration due to:
  - Danger to travelling public
  - Potential damage to vehicles
- They generally form during the winter months due to freeze-thaw cycles.
**Step One:** Pavement Deflects Excessively

- Shoulder
- Weak area deflects
- Asphalt surface
- Stabilized base layer
- Subbase layer
- Compacted subgrade

**Step Two:** Crack forms and water enters

- Shoulder
- Cracks
- Asphalt surface
- Stabilized base layer
- Subbase layer
- Compacted subgrade

**Step Three:** Water freezes, pieces pop out

- Shoulder
- Pieces pop out
- Asphalt surface
- Stabilized base layer
- Subbase layer
- Compacted subgrade

**Step Four:** Pavement erodes into base layer

- Shoulder
- Pothole
- Asphalt surface
- Stabilized base layer
- Subbase layer
- Compacted subgrade
Background

Several pothole patching methods have been used in Ohio:

- Throw and roll (most common)
- Semi-permanent method
- Edge seal method
- Spray injection method
Background

- The conventional throw and roll may be effective when hot mix asphalt is used.
- However, potholes generally form during the winter when asphalt plants are closed.
- Therefore, cold asphalt mixtures are typically used instead of hot mix asphalt during the winter.
- The use of cold asphalt mixtures may lead to premature patch failure due to:
  - Reduced adhesion
  - Formation of a cold joint along the interface between the pavement surface and the patching material
In recent years, a tow-behind combination infrared asphalt heater/reclaimer system has been used to improve the performance of pothole patches.
Background

- Installation of infrared pothole patch
  - Heating
Background

- Installation of infrared pothole patch
  - Heating
Background

- Installation of infrared pothole patch
  - Heating
Background

- Installation of infrared pothole patch
  - Scarifying
Background

- Installation of infrared pothole patch
  - Adding reclaimed material
Background

- Installation of infrared pothole patch
  - Compaction
Background

- In spite of the potential benefits of the infrared pothole patching method, no research has been conducted to evaluate its advantages and disadvantages.

- Therefore, research is needed to determine:
  - Performance and survival rate of patches installed using this method.
  - Efficiency and cost-effectiveness of this method as compared to other patching methods.
  - Optimum weather conditions that the infrared heater/reclaimer system can be used at.
Objectives
Objectives

- Evaluate the performance and longevity of pothole patches installed using three methods:
  - Throw and roll
  - Spray injection
  - Infrared pothole patching

- Compare the cost-effectiveness of the three pothole patching methods.

- Determine the advantages and limitations of the three pothole patching methods.
Objectives

- Select the most suitable infrared asphalt heater/reclaimer system for use in Ohio.
- Provide recommendations on the incorporation of the tow-behind combination infrared asphalt heater/reclaimer system into ODOT’s pavement maintenance program.
- Develop a deployment strategy for the use of the tow-behind combination infrared asphalt heater/reclaimer system in Ohio.
Project Overview
Literature Review

User Survey

Purchase Infrared Heater/Reclaimer System

Design Test Matrix

Field Evaluation

Data Analysis

Cost-Effectiveness Analysis

Recommendations for Implementation
User Survey
User Survey

- A 10-question survey containing primarily multiple-choice type questions was developed.
- A copy of the survey was sent for review to ODOT technical panel members.
- The survey was then implemented using SurveyMonkey for distribution as a web survey.
- The survey was sent to 28 users, and a total of 12 responses (43%) were received.
- The following slides present a summary of the survey results.
User Survey

Did you notice any improvement in the pothole patching performance/survival when using infrared heater/reclaimer?

- Significant
- Marginal
- No
User Survey

Did you find the infrared heaters/reclaimer more cost effective than other techniques used for pothole patching?

- Highly cost effective: 58.3%
- Somewhat cost effective: 33.3%
- I do not know: 8.3%
- Not cost effective: 8.3%
- Other (please specify):
User Survey

What factors were found to affect the infrared heater/reclaimer improvement? (Please select all that apply)

- Weather condition during patch installation: 80%
- Pothole size: 20%
- Pavement type: 40%
- Patching Material: 60%
- Traffic conditions at pothole location: 20%
- None: 0%
- Others: 0%
User Survey

What type of asphalt mixture typically used for patching with infrared heaters/reclaimer? (Please select all that applies)
User Survey

What are the major drawbacks that you found for using infrared heaters/reclaimer? (Please select all that applies)

- Cost
- Complexity of Operation
- Safety
- Traffic Control
- Repair Time
- Other Equipment Maintenance
- Labor Intensive
- None
- Others
User Survey

Did you use the infrared heater systems for pavement maintenance applications other than pothole patching? (Please select all that applies)

- Utility cuts: 80%
- Expansion joints: 60%
- Catch basins: 50%
- Trenches: 80%
- Others: 20%
User Survey

- Infrared heater systems can significantly improve the performance as well as longevity of pothole patches and can be cost-effective if proper installation procedures are followed.

- Weather conditions during pothole patching was the main factor:
  - Rain adversely affects the capabilities of the infrared asphalt heaters if water accumulates in the pothole.
  - Wind and very low temperatures prolong the heating time.
Equipment Selection & Training
Equipment Selection

- Three main infrared asphalt heater systems:
  - Ray-Tech Mini Combo (Ray-Tech)
  - KASI Minuteman (KASI)
  - HDE 750-MT (Heat Design Equipment)

- The HDE 750-MT infrared asphalt heater/reclaimer system has similar features but is significantly more expensive than the other two systems.

- Based on consultation with the technical panel members, it was decided to focus on the other two systems.
Equipment Selection

- **Compatibility with ODOT existing Equipment**
  - KASI is compatible with ODOT truck, while Ray-Tech is not

- **Operational Costs**
  - KASI has 2/3 the operational cost of Ray-Tech

- **Safety & Ease of Operation**
  - KASI has features that make it easier and safer to use than Ray-Tech

- **Durability and Maintenance Needs**
  - KASI was found to more durable and needed less maintenance
Equipment Selection

- Therefore, the research team recommended purchasing the KASI Minuteman system to be evaluated in this project.
- The KASI system was delivered to the Warrensville Garage in ODOT District 12 on December 17, 2012.
Training

- Training was held at the Warrensville Garage.

- Training included:
  - A 60-minute presentation provided by the KASI General Manager
  - A field training session for ODOT Districts 12 and 2 maintenance crews
Field Evaluation Program
Data Collection

Installation Evaluation

- Patch IDs: [Field]

- General
  - Evaluated By: [Field]
  - Date of Installation (mm/dd/yyyy): [Field]

- Project Information
  - Location:
    - Highway Type: [Select One]
    - Highway Number: [Field]
    - Mile Post: [Field]
    - Longitude: [Field]
    - Latitude: [Field]
    - Pavement Type: [Select One]
    - Pavement Structure: [Field]

- Weather and Pavement Information
  - Weather Information:
    - Weather Conditions: [Select Options]
    - Air Temperatures: [Field]
  - Pavement Information:
    - Pavement Temperature: [Field]
    - Pavement Condition: [Select One]

- Patch Information
  - Patching Method
    - Patching Method: [Select One]
    - Patching Materials: [Select One]
    - Patching Crew (List): [Field]
  - Patch Equipment (List): [Field]
  - Patch Information
    - Infrared Only: Temp. of Patching Material in Infrared Container (°F): [Field]
    - Infrared Only: Temp. at the Bottom of the Pothole Before Heating (°F): [Field]
    - Infrared Only: Temp. 6 inch from the Edge of the Pothole Before Heating (°F): [Field]
    - Infrared Only: Start Time of Heating (h:mm): [Field]
    - Infrared Only: End Time of Heating (h:mm): [Field]
    - Infrared Only: Heating Duration (Minutes): [Field]
    - Infrared Only: Temp. at the Bottom of the Pothole After Heating (°F): [Field]
    - Infrared Only: Temp. 6 inch from the Edge of the Pothole After Heating (°F): [Field]
    - Infrared Only: Before and After Compaction:
      - Infrared Only: Temp. of Patching Material Immediately Before Compaction (°F): [Field]
      - Infrared Only: Temp. of Patching Material Immediately After Compaction (°F): [Field]
    - Picture Taken for Pothole After Installation? [Select Options]
  - Overall Patch Quality: [Select One]

- Comments: [Field]
Field Evaluation Program

Six sites were selected for the pothole patching field evaluation program:

- Interstate 480 (East Bound) – District 12
- US Highway 422 (East Bound) – District 12
- Ohio State Route 168 – District 12
- Ohio State Route 67 – District 2
- Ohio State Route 18 – District 2
- Ohio State Route 635 – District 2
Field Evaluation Program
I-480
Forty five (45) manmade potholes were drilled into the pavement surface and patched on January 9, 2013.

Each pothole measured approximately 3 to 4 ft in width, 3 to 5 ft in length, and 3 to 4 inches in depth.

Fifteen (15) potholes were patched using each of the three pothole patching methods evaluated in this study.

Ten (10) potholes were located along the right wheel path and five (5) potholes were located at the middle between the two wheel paths.
I-480

Infrared

Spray Injection

Throw and Roll
I-480 (Infrared)

- There were problems with igniting the infrared heater for the first time in very cold weather. This problem might be solved by proper storage of the equipment.
I-480 (Spray Injection)

- While the operator of spray injector coated the surrounding top surface with binder, he did not coat the side of potholes completely.
I-480 (Throw and Roll)

- The material for most throw and roll patches was contaminated with many leaves, incompletely coated aggregates (grayish colored), and uncoated big rocks.
US 422
US 422
US 422
US 422
US 422
US 422
Ohio SR 168

- This site is located in Geauga County in ODOT District 12.
- The infrared heater system was used to install spot patches to repair the damage from horseshoes worn by horses that pull Amish buggies.
Ohio SR 67

- This site is located in Seneca County in District 2.
- The objective was to demonstrate and evaluate the ability of the infrared heater to repair pavement surfaces due to settlement in wide trenches.
Ohio SR 67

- During patching, it was very difficult to maintain the same surface level along the entire patched area as the infrared chamber needed to be moved several times to heat the entire area.
Ohio SR 67

- For the first trench, the asphalt mixture was obtained from an asphalt plant.
- It was found that the infrared asphalt reclaimer should be emptied of the asphalt mixture at the end of the patching day.
The patching material should be stored in small piles about 1.5 ft by 1.5 ft under a shed.
Ohio SR 18

- The infrared was used to repair pavement surface due to settlement in three trenches located on SR 18 in District 2.
- The width of the trenches at this site ranged between 3 ft to 6 ft.
- No problems were observed during patching of the trenches.
Ohio SR 635

- The infrared system was used to repair shoving in the pavement surface that occurred near an intersection in District 2.
- Some difficulties were encountered during patching as the surface had chip seal that was burned during heating and was difficult to scarify and compact.
Field Evaluations

- Evaluation was done after 29, 66, 99, 161 and 188 days.
- It was based on the procedure recommended and used in Strategic Highway Research Program (SHRP) studies.

- Survival data
- Distress data
  - Bleeding
  - Cracking
  - Dishing
  - Edge Disintegration
  - Missing Patch
  - Raveling
  - Shoving
Field Evaluations

- Evaluation was done after 29, 66, 99, 161 and 188 days
- It was based on the procedure recommended and used in Strategic Highway Research Program (SHRP) studies.
- Two types of data were collected
  - Survival data
  - Distress data
    - Bleeding
    - Cracking
    - Dishing
    - Edge Disintegration
    - Missing Patch
    - Raveling
    - Shoving
Field Evaluations

- Each patch was rated using the obtained distress data based on the guidelines that was developed as part of the SHRP program for pothole patches.
Field Evaluations
Field Evaluations

Spray Injection

Infrared

0 days

188 days
Results
Installation Time

- Infrared
- Spray Injection
- Throw and Roll

Time (min)

- With
- Without
Installation Time

Productivity (tons/day)

- Infrared
- Spray Injection
- Throw and Roll
Installation Time

Temperature (°F)

- Pavement Temperature After Heating
- Pavement Temperature Before Heating
Performance Results: I-480

Infrared
Spray Injection
Throw and Roll
### ANOVA Results: I-480

<table>
<thead>
<tr>
<th>Effect</th>
<th>F Value</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patching Method</td>
<td>146.57</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Evaluation date</td>
<td>4.13</td>
<td>0.0034</td>
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<tr>
<td>Location</td>
<td>6.68</td>
<td>0.0107</td>
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<tr>
<td>Size</td>
<td>2.16</td>
<td>0.1437</td>
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<tr>
<td>Patching Method*Evaluation date</td>
<td>0.11</td>
<td>0.9987</td>
</tr>
<tr>
<td>Location*Evaluation date</td>
<td>0.02</td>
<td>0.999</td>
</tr>
<tr>
<td>Location*Patching Method</td>
<td>36.8</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>Size*Evaluation date</td>
<td>0.04</td>
<td>0.9967</td>
</tr>
</tbody>
</table>
## Post-ANOVA Results: I-480

<table>
<thead>
<tr>
<th>Patching Method</th>
<th>Rating Estimate</th>
<th>Letter Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infrared</td>
<td>7.8</td>
<td>A</td>
</tr>
<tr>
<td>Throw &amp; Roll (TH)</td>
<td>3.6</td>
<td>B</td>
</tr>
<tr>
<td>Spray Injection (SP)</td>
<td>2.3</td>
<td>C</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Location</th>
<th>Patching Method</th>
<th>Rating Estimate</th>
<th>Letter Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between wheel path</td>
<td>Infrared</td>
<td>8.2</td>
<td>A</td>
</tr>
<tr>
<td>On wheel path</td>
<td>Infrared</td>
<td>7.4</td>
<td>A</td>
</tr>
<tr>
<td>Between wheel path</td>
<td>TH</td>
<td>4.8</td>
<td>B</td>
</tr>
<tr>
<td>On wheel path</td>
<td>SP</td>
<td>3.1</td>
<td>C</td>
</tr>
<tr>
<td>On wheel path</td>
<td>TH</td>
<td>2.3</td>
<td>C</td>
</tr>
<tr>
<td>Between wheel path</td>
<td>SP</td>
<td>1.6</td>
<td>C</td>
</tr>
</tbody>
</table>
Performance Results: US 422

The patches installed at US highway 422 demonstrated the ability to repair large pavement areas using the infrared method.
Performance Results: SR 168

- Patches showed good performance after one month.
- It is recomended to utilize the infrared to repair the damages in pavement surface that resulted from grinding and skidding actions of the horseshoes worn by horses.
The patches showed excellent performance with no signs of raveling or any type of distresses after one month of installation.

It is recommended using the infrared method to repair settled areas of pavement surface for trenches that are up to 8 ft wide.
Results: Survivability Analysis

- Survival analysis was conducted using LIFETEST procedure in SAS Software on data collected for pothole patches installed on I-480.
- In this analysis, the patch was considered to fail when the performance rating became less than 3 or if it was re-patched.

<table>
<thead>
<tr>
<th>Patching method</th>
<th>Total</th>
<th>Failed</th>
<th>Censored</th>
<th>Percent Censored</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infrared</td>
<td>15</td>
<td>1</td>
<td>14</td>
<td>93</td>
</tr>
<tr>
<td>Spray Injection</td>
<td>15</td>
<td>13</td>
<td>2</td>
<td>13</td>
</tr>
<tr>
<td>Throw and Roll</td>
<td>15</td>
<td>11</td>
<td>4</td>
<td>27</td>
</tr>
<tr>
<td>Total</td>
<td>45</td>
<td>25</td>
<td>20</td>
<td>44</td>
</tr>
</tbody>
</table>
The infrared method have much higher survival probability than the other two methods.
## Results: Cost Analysis

<table>
<thead>
<tr>
<th>Input</th>
<th>Infrared Method</th>
<th>Spray Injection Method</th>
<th>Throw and Roll Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material Cost ($/ton):</td>
<td>99.5</td>
<td>203.3</td>
<td>101.8</td>
</tr>
<tr>
<td>Initial Need (tons):</td>
<td>1000</td>
<td>1000</td>
<td>1000</td>
</tr>
<tr>
<td>Repair Crew Wages ($/day):</td>
<td>1079.6</td>
<td>890.6</td>
<td>701.5</td>
</tr>
<tr>
<td>Traffic Control Wages ($/day):</td>
<td>319.9</td>
<td>319.9</td>
<td>319.9</td>
</tr>
<tr>
<td>Repair Equipment cost ($/day)</td>
<td>335.3</td>
<td>1180</td>
<td>147.3</td>
</tr>
<tr>
<td>Traffic Control Equipment Cost ($/day):</td>
<td>26.0</td>
<td>26.0</td>
<td>26.0</td>
</tr>
<tr>
<td>Productivity (tons/day):</td>
<td>5.6</td>
<td>13.4</td>
<td>22.1</td>
</tr>
<tr>
<td>Estimated Average Repair Life (months):</td>
<td>Analysis period</td>
<td>2.1</td>
<td>3.5</td>
</tr>
</tbody>
</table>
Results: Cost Analysis

Infrared
Spray Injection
Throw and Roll

Cost ($)
Analyses Period (Month)
Conclusions
Conclusions: Equipment Selection

- Several infrared asphalt heaters/reclaimer systems are available in the market.
- The main factors that were considered in the selection of most suitable equipment included:
  - Price
  - Compatibility with ODOT trucks
  - Maintenance needs
  - Operational costs
  - Safety features and ease of use
- The KASI Minuteman was found to be the most suitable equipment to be purchased and evaluated in this study.
Conclusions: User Survey

- The majority of the infrared asphalt heater/reclaimer users indicated that it can significantly improve the performance and longevity of the pothole patches and is cost-effective when proper installation procedures are followed.

- The survey identified weather conditions, pavement type, and properties of patching material as the main factors affecting the patch performance.

- The main applications of the infrared asphalt heater/reclaimer include: utility cuts, expansion joints, trenches, catch basins, spider web and facial cracks, water pockets, and curbing.
Conclusions: Installation

- The infrared had much lower productivity than the throw and roll and spray injection pothole patching methods.
- The existing pavement surface should be heated to 275-350°F prior to scarifying.
  - A heating duration of 5 to 10 minutes was needed depending on the initial pavement surface temperature.
- The infrared burners in the heater chamber should be placed approximately 10 inches above the pavement surface:
  - The surface may be burned and the material underneath won’t be sufficiently heated if the burners are too close to the surface.
Conclusions: Material & Storage

- The temperature of the pavement surface should be approximately 250°F prior to compaction.
- The properties of the asphalt mixture used in the infrared method affect the performance of the patches.
- The storage procedure of the asphalt mixture has considerable effect on the performance of the infrared patches.
- Improper storage of the infrared heater/reclaimer system will lead to problems in igniting the infrared heater especially in the winter.
Conclusions: Performance

- Most of the deterioration in the pothole patches occurred in the first month of installation and continued at a much slower rate.
- The infrared patches had significantly better performance than the other patches.
- The main distress in the infrared patches was raveling, while it was dishing for the throw and roll and the spray injection patches.
- Patches installed by leaving a crown of asphalt of about 0.25 to 0.5 inch above the pothole surface performed better and did not exhibit significant dishing.
Conclusions: Longevity

- The patches installed using the infrared method had better survivability and longevity than those installed using the other two methods.
- The results of the statistical survivability analysis showed that the infrared patches are expected to survive at least 14 times the expected life of throw and roll and spray injection patches.
- The throw and roll patches had a slightly better average service life than the spray injection patches. However, both methods had statistically similar survival curves.
Conclusions: Cost-Effectiveness

- The infrared method might be more cost-effective than the throw and roll method especially for medium size (2 ft to 3 ft) and large size potholes (more than 3 ft in dimensions).
- For smaller potholes, the throw-and-roll method will probably be more cost-effective than the infrared pothole patching method.
Conclusions: Infrared Applications

- The infrared equipment has the ability to repair large areas of pavement surface, which typically could not be patched using the conventional throw and roll method.
- The infrared method can be used to repair the damage in pavement surface that results from the horseshoes worn by horses.
- The infrared method was successfully used to repair the damage in pavement surface due to settling in trenches that are up to 8 ft wide.
Recommendations for Implementation
Recommendations for Implementation

1- Equipment Purchase

- It is recommended that each ODOT district assesses its need for purchasing the tow-behind infrared heater/reclaimer based on the results of this report.
- The factors used in this study should be considered in the selection of most suitable unit.
- A one-day training session should be conducted for every district that purchases the tow-behind infrared heater/reclaimer equipment to train the maintenance crew on the proper operation procedure as well as storage and maintenance needs for the equipment.
Recommendations for Implementation

2- Equipment Storage

- Proper storage of the infrared heater/reclaimer system is essential for its effective use and to eliminate any problems that can occur during patching in the winter.

- The equipment should be parked in a garage, except during the reclaiming process.

- If it is not possible to park the equipment inside a garage or under a shed, the infrared heater should be lowered all the way down.

- If the equipment is exposed to rain, the manifolds at the bottom of the infrared chamber should be drained.
Recommendations for Implementation

3- Patching Material

- The asphalt mixture used in the infrared patching method should have the following properties:
  - Asphalt content: between 6.2% and 6.7%
  - Asphalt binder type: neat asphalt binder PG 64-22
  - Aggregate type: low absorption aggregate with a nominal maximum aggregate size ½ inch (12.5 mm)
  - Reclaimed Asphalt Pavement (RAP) content: up to 30%

- The asphalt materials should be stored in small blocks or piles under a shed.
Recommendations for Implementation

4- Installation Procedure

- Appendix D provides a detailed step-by-step procedure for installing patches using the tow-behind infrared heater/reclaimer system.

- The key step in the installation is achieving proper pavement temperatures for scarifying and compaction.
  - The temperature should be 275-375°F for scarifying.
  - The temperature should be ~250°F for compaction.

- The infrared chamber should be placed so that the infrared burners are 10 inches above the pavement surface.
Questions?