Cost-Effective County Road Reclamation in Northeast Indiana

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Overview

Noble County Highway
- Road Selection
- Constraints / Approach
- Method / Specifications
- Typical Section
- Construction Method
- Cost Breakdown

Levy Technical Laboratories
- Steel Slag
- CIR
- DOT Specs
- Test Results
  - Tensile Strength
  - CBR
  - Proctor
  - Unconfined Compression
  - Triaxial Data
Synopsis

Traditional methods of reconstructing rural roads are not feasible without the typical annual highway budget for counties.

A low cost reconstruction solution is needed in order to repair a large number of roads in poor condition, while also being constrained by the annual budget. (8-10 miles annually, ~$500k)

Candidate Selection

- Poor Condition
  - PASER 4 or less
  - Structural Failure
- Existing Conditions
  - 6” of Existing Material
  - Rural Use and AADT
Constraints / Approach

Constraints
- Permanent solution, 20+ years with only minor maintenance.
- Cost Effective, 8-10 miles annually with a budget of $500,000.
- No full road closures, road remains open daily to local traffic.
- All work is to be completed using the existing right of way, typically 40’ on center.

Approach
- Fix the root of the problem.
  - Drainage
  - Road Base
- Maximize in-house or local resources that provide good value.
  - Recycle existing roadway
  - Highway Department staff and equipment
  - Locally sourced materials
Method / Specifications

Method

- Drainage
- Roadway
  - Uniform Base Section
  - Increased Strength
  - Compaction
    - Gradation
    - Moisture Content
    - Construction Method
  - Depth of Subbase (core samples)

Specifications

- Material Selection
  - Steel Slag (Duraberm) Similar to #53 / #73
  - Pavement Recycle with Slag Blend (~30%)
  - Calcium Chloride (38%) at 0.75 gal/SYS
    - 0.5 gal for base, 0.25 gal for surface cure

Noble County Highway Dept.
Typical Section

Partial Depth Reclamation

- ~8" Reclaimed Base
- 1" Chip and Seal
- Length: 40'-0"
Construction Prep

- Drainage
  - Replace Crossing Culverts
    - Regulated Drains
  - Reestablish Roadside Ditches
    - Replace Driveway Culvert
  - Road Lifts in Low Spots

- Signage
  - Road Construction
  - Loose Gravel
Construction Method

Phase 1

- Add Material
  - Tailgate Material (2.5”)
    - Construction stakes for tonnage per ¼ mile
  - Preliminary Grading

- Alternative
  - First Pass with Grinder on Existing Roadway
  - Preliminary Grading
  - Tailgate Material (2.5”)
Phase 2

- Additive
  - Apply Calcium Chloride
    - 0.5 Gal / SY

- Grinder
  - Bomag MPH 125 Recycler
    - Rental

- Three passes

- Center pass last

- Roller
  - Bomag BW213PD Sheepsfoot
    - Rental

- As many passes as possible
Phase 3

- Preliminary Grade
  - Edge to Center
- Pneumatic Roller
  - Even Compaction
- Final Grade
- Steel Drum Roller
- Additive
  - Apply Calcium Chloride
    - 0.25 Gal / SY
- Cure 4-6 weeks
  - Weather Dependent

Noble County
Highway Dept.
Surface Treatment

- Road Prep
  - Patch / Fill Soft Areas
  - Broom loose stone
- HMA Surface
- Chip and Seal (triple)
  - Sealing Asphalt or Emulsion
    - BM-90S (P)
  - First Course - 0.34 gal /SYS
    - Limestone, Gravel or Slag #9’s
  - Second Course - 0.29 gal /SYS
    - Limestone, Gravel or Slag #9’s
  - Surface Course 0.25 gal /SYS
    - Limestone, Gravel or Slag #11’s
  - Fog Seal - 0.12 gal /SYS
Construction Complete

Noble County
Highway Dept.
## Cost Breakdown

<table>
<thead>
<tr>
<th>Material</th>
<th>Unit Cost</th>
<th>Unit Rate</th>
<th>Per Mile (20’ Width)</th>
<th>Total Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duraberm (2.5”)</td>
<td>$4.00 / ton</td>
<td>2 tons / CYS</td>
<td>1630 tons / mile</td>
<td>$6,520</td>
</tr>
<tr>
<td>Grinder Rental</td>
<td>Average cost per mile for rental and carbide teeth.</td>
<td></td>
<td></td>
<td>$3,809</td>
</tr>
<tr>
<td>Calcium Chloride</td>
<td>$0.834 / gal</td>
<td>0.75 gal / SYS</td>
<td>8,800 gal / mile</td>
<td>$7,339</td>
</tr>
<tr>
<td>Sealing Asphalt</td>
<td>$2.192 / gal</td>
<td>0.88 gal / SYS</td>
<td>10,442 gal / mile</td>
<td>$22,633</td>
</tr>
<tr>
<td>#9 Aggregate</td>
<td>$17.50 / ton</td>
<td>2 x 27.3 lb / SYS</td>
<td>320 tons per mile</td>
<td>$5,600</td>
</tr>
<tr>
<td>#11 Aggregate</td>
<td>$18.50 / ton</td>
<td>19.6 lb/ SYS</td>
<td>115 tons per mile</td>
<td>$2,128</td>
</tr>
<tr>
<td>Fog Seal</td>
<td>$1.35 / gal</td>
<td>0.12 gal / SYS</td>
<td>1,408 gal /mil</td>
<td>$1,900</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>$49,930</strong></td>
</tr>
</tbody>
</table>
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Aggregate Additions
DSA: Driving Surface Aggregate (PSU)

- Surface Wearing Course developed specifically for Unpaved Roads.
- Unique particle size distribution
  - Maximize packing density
  - Durable road surface
  - 1 ½” X 0
- PENNDOT approved as of 2006 (publication 447)
Pavements

Typically comprised of several layers with each layer having its own function and purpose. The most important part of a roadway is the subgrade / sub-base condition. If this layer is good a smaller asphalt cross-section is required to provide a stable pavement section. If this supporting layer is poor a thicker asphalt section is required.

MINIMUM PAVEMENT THICKNESS – ASPHALT/AGGREGATE

<table>
<thead>
<tr>
<th>Layer</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface</td>
<td>2.5&quot;</td>
</tr>
<tr>
<td>SM-9.5</td>
<td>2.0&quot;</td>
</tr>
<tr>
<td>Base IM-19:0</td>
<td>1.5&quot;</td>
</tr>
<tr>
<td>Aggregate Base 21B</td>
<td>6&quot;</td>
</tr>
</tbody>
</table>

- Good (DCBR >10)
- Fair (DCBR 6-10)
- Poor (DCBR 3-6)
Improved Foundation = Added Strength / Life

Reclamation

Surface
6 – 14” FDR
Subgrade

Overlay

HMA
Base / Sub-base
Subgrade

Mill & Fill

Mill & Fill
HMA
Base / Sub-base
Subgrade

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Cost-Effective County Road Reclamation in Northeast Indiana
Why Use Steel Slag?

- **Europe**
  - The use of steel slag in pavement structure courses would be acceptable from both economic and environmental standpoints: (Građevinar; 1/2012)
  - The main aim of the work was to determine whether a weathered BOF slag could be used as a main constituent in hydraulic road binder. (Mahieux, Aubert, and Escadeillas; 9/2009)

- **Australia**
  - The material has been blended at a rate of about 40% with existing base materials to rehabilitate existing pavements where the EA FS increased the wet/dry strength value, decreased the Plasticity Index and modified the pavement materials such that it now conforms to a DGB20 specification in accordance with RMS Specification 3051.

- **Stabilization**
  - Mechanical / Chemical
  - Purdue
Steel Slag Characterization

- Non-Liquid / Non-Plastic
- LA Abrasion: 18 to 30
- Sodium Sulfate Soundness: <12%
- Crush Count: Highly Irregular (80+ Two Face)
- Gradation: Meets ASTM (D1241) and FHWA (Type 1 or 2) Requirements
- Binding Potential: Free Lime in Excess of 6%*

There are various types of Steel Slag. Not all have the ability to act as a binder in these applications. Proper characterization is essential.
Steel Slag Characterization

- Chemical Properties
  - pH
  - Chemical Analysis by various methods
  - Calcium Carbonate Equivalency (CCE)
  - Free Lime

- Physical Properties
  - Gradation
  - Moisture
  - Specific Gravity and Absorption
  - Unit Weight
  - Expansion / Disruption
## Gravel Roads Maintenance and Design Manual

### Gradation for Aggregate Surface Course

<table>
<thead>
<tr>
<th>Sieve</th>
<th>No.1</th>
<th>No.2</th>
<th>IN-53</th>
<th>IN-73</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 ½&quot;</td>
<td></td>
<td>100</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>1&quot;</td>
<td>100</td>
<td>100</td>
<td>80-100</td>
<td>100</td>
</tr>
<tr>
<td>¾&quot;</td>
<td>70-90</td>
<td></td>
<td>90-100</td>
<td></td>
</tr>
<tr>
<td>½&quot;</td>
<td>55-80</td>
<td></td>
<td>60-90</td>
<td></td>
</tr>
<tr>
<td>3/8&quot;</td>
<td>50-85</td>
<td>60-100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>#4</td>
<td>35-65</td>
<td>50-85</td>
<td>35-60</td>
<td>35-60</td>
</tr>
<tr>
<td>#8</td>
<td>25-50</td>
<td>40-70</td>
<td>25-50</td>
<td></td>
</tr>
<tr>
<td>#30</td>
<td>15-30</td>
<td>24-45</td>
<td>12-30</td>
<td>12-30</td>
</tr>
<tr>
<td>#200</td>
<td>8-15</td>
<td>8-15</td>
<td>5.0-10.0</td>
<td>5.0-12.0</td>
</tr>
</tbody>
</table>
Reclamation

The reclamation process removes deep pavement cracks thereby eliminating the potential for reflective cracking. The process allows for cross-slope and profile grade adjustments. If specific conditions dictate that the final surface treatment will be applied at a later date, the road can be opened to traffic once the compactors complete their pass. A roadway rehabilitated utilizing the full depth reclamation process is equivalent to a traditionally re-constructed roadway in terms of life expectancy, wear and load-bearing characteristics (Better Roads, 2001). However the process has less interruption of traffic, is environmentally friendly, and is completed at a fraction of the cost.
Reclamation Benefits

- Reduced Costs of Construction
- Conservation of Aggregates and Binders
- Preservation of Existing Pavement Geometrics
- Preservation of the Environment
- Conservation of Energy
- Less User Delay
- No need to remove materials

Kandhal and Mallick 1997
Full Depth Stabilization
CIR/Partial Depth Stabilization
Cost-Effective County Road Reclamation in Northeast Indiana

Noble County Highway Dept.

Yildirim, Prezzi; Purdue
2009 05/20/2010
### PennDOT Project: FDR/SLAG 2016/2017

<table>
<thead>
<tr>
<th>County</th>
<th>McKean Co.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Length</td>
<td>4.65 Miles</td>
</tr>
<tr>
<td>Estimated Project Cost/ Cost per mile</td>
<td></td>
</tr>
<tr>
<td>Average Daily Truck Traffic</td>
<td>1,035</td>
</tr>
<tr>
<td>Average Daily Truck Traffic</td>
<td>376</td>
</tr>
<tr>
<td>Estimated Project starting Date</td>
<td>July 2016, (Pending on A-409 Funds)</td>
</tr>
<tr>
<td>Scope of repairs proposed:</td>
<td>12&quot; Full-depth reclamation (FDR) to widen the base from 20’ to 24’. Approximately 100,000 Cubic feet / 6,500 ton of slag is to be used as the aggregate to obtain the necessary structure for widening. Overlay with 3&quot; Binder &amp; 1.5&quot; Wearing course at 22’. Guiderail safety upgrade, tree trimming and some drainage will be addressed.</td>
</tr>
</tbody>
</table>

Noble County Highway Dept.

Cost-Effective County Road Reclamation in Northeast Indiana
PennDOT – Material Characterizations

Stability vs % CSS-1h (Slag 2A Type Aggregate)

Specific Gravity vs % CSS-1h (Slag 2A Type Aggregate)
PennDOT – Material Characterizations, cont.

**Pub 242 RT 46 Slag Section Design**
*DRY ITS VS % Emulsion*

**Pub 242 RT 46 2A Design Section**
*DRY ITS VS % Emulsion*

**Pub 242 RT 46 Slag Design**
*% TSR VS % Emulsion*

**Pub 242 RT 46 2A Design**
*% TSR VS % Emulsion*
PennDOT - Construction

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PennDOT - Construction

Cost-Effective County Road Reclamation in Northeast Indiana
PennDOT – Finished Reclamation/Stabilization

Cost-Effective County Road Reclamation in Northeast Indiana
PennDOT – Highway 46

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Cost-Effective County Road Reclamation in Northeast Indiana
Indirect Tensile Strength
California Bearing Ratio
Unconfined Compression
## Triaxial Data

<table>
<thead>
<tr>
<th></th>
<th>Unconfined Compression</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No Aging</td>
</tr>
<tr>
<td>Existing Roadway</td>
<td>23.0 psi</td>
</tr>
<tr>
<td>W/ 30% Blend</td>
<td>26.4 psi</td>
</tr>
<tr>
<td>W/ 40% Blend*</td>
<td>39.5 psi</td>
</tr>
<tr>
<td>W/ 50% Blend</td>
<td>57.5 psi</td>
</tr>
<tr>
<td>W/ 60% Blend</td>
<td>61.8 psi</td>
</tr>
</tbody>
</table>
References:

- FHWA: Gravel Roads Maintenance & Design Manual
- FHWA –HIF-036, Full Depth Reclamation
- USDA Forest Service: Stabilization Selection Guide for Aggregate & Native-Surfaced Roads
- USACE: UFGS Section 32 15 00 – Aggregate Surface Course
- New York DOT GEM-27, “Full Depth Reclamation of Asphalt Pavement”
Acknowledgements:

- Zack Smith / Noble County Highway Department, Indiana
- Jennifer Sharkey & Emmett Heller / Steuben County Highway Department, Indiana
- Michael Barton / Whitley County Highway Department, Indiana
- Pennsylvania DOT
Thank You

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