Secondary Road Reclamation Utilizing Steel Slag and LWD

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Edw. C. Levy Co.
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County Roads: Doing more than designed for
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)

[Diagram showing DSA Components, Actual Size]
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.
Insufficient Base
Adequate Base
Improved Foundation = Added Strength / Life

**Reclamation**
- **Surface**: 6 – 14” FDR
- **Subgrade**

**Overlay**
- **Overlay**: HMA
- **Base / Sub-base**: Subgrade

**Mill & Fill**
- **Mill & Fill**: HMA
- **Base / Sub-base**: Subgrade
What is secondary road stabilization?

• Removes deep pavement cracks
• Allows for adjustments to the road profile
• Road can be opened to traffic prior to placement of final road surface
• Equivalent to traditionally reconstructed roadway in terms of expectancy, wear and load bearing characteristics (Better Road 2001)
• Less traffic interruption
• Environmentally Friendly
• Reduced cost of construction
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
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 EAaFS 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
Purdue / I-65; 2010 > 2016

Yildirim, Prezzi; Purdue 2009

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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
<table>
<thead>
<tr>
<th>Sieve</th>
<th>No.1</th>
<th>No.2</th>
<th>IN-53</th>
<th>IN-73</th>
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<tbody>
<tr>
<td>1 ½”</td>
<td></td>
<td></td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>1”</td>
<td>100</td>
<td>100</td>
<td>80-100</td>
<td>100</td>
</tr>
<tr>
<td>¾”</td>
<td></td>
<td>70-90</td>
<td>90-100</td>
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<tr>
<td>½”</td>
<td></td>
<td>55-80</td>
<td>60-90</td>
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<tr>
<td>3/8”</td>
<td>50-85</td>
<td>60-100</td>
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<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>
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</table>
# PennDOT Project: FDR/SLAG 2016/2017

## Project Details

<table>
<thead>
<tr>
<th>County</th>
<th>McKean Co.</th>
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<tbody>
<tr>
<td>Project Length</td>
<td>4.65 Miles</td>
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<tr>
<td>Estimated Project Cost</td>
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<tr>
<td>Cost per mile</td>
<td></td>
</tr>
<tr>
<td>Average Daily Truck Traffic</td>
<td>1,035</td>
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<tr>
<td>Average Daily Truck Traffic</td>
<td>376</td>
</tr>
<tr>
<td>Estimated Project starting Date</td>
<td>Fall 2016</td>
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</table>

**Scope of repairs proposed:**

12” 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” Binder & 1.5” Wearing course at 22’. Guiderail safety upgrade, tree trimming and some drainage will be addressed.
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

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PennDOT - Construction
PennDOT - Construction
PennDOT – Finished Reclamation/Stabilization
PennDOT – Highway 46
Noble County, IN

- 800+ miles of County Roads to Maintain (Does not include city streets or State Roads)
- 200-500 vehicles per day
- Utilizing Partial Depth Reclamation to reduce costs and extend lifespan of county roads.
California Bearing Ratio

- Noble County 2016
- Results

<table>
<thead>
<tr>
<th></th>
<th>0.1 Penetration</th>
<th>0.2 Penetration</th>
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</thead>
<tbody>
<tr>
<td>Initial</td>
<td>25.1 PSI</td>
<td>33.3 PSI</td>
</tr>
<tr>
<td>Final</td>
<td>60.8 PSI</td>
<td>81.1 PSI</td>
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</table>

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## Triaxial Data

<table>
<thead>
<tr>
<th></th>
<th>Unconfined Compression</th>
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<tbody>
<tr>
<td></td>
<td>No Aging</td>
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<tr>
<td>Existing Roadway</td>
<td>23.0 psi</td>
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<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>
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</table>
Duraberm Blend Trials

CBR Values at 0.2 Penetration for Varying CaCl Additions

County Road Location

- 200 S (Gravel Road)
- 500 S
- 100 E
- Duraberm, 0% CaCl

- Duraberm, 0% CaCl
- 3% CaCl @0.2
- 5% CaCl @0.2
- 7% CaCl @0.2
- 40% DB Blend, 0% CaCl

Secondary Road Reclamation Utilizing Steel Slag and LWD – Purdue Road School 2019
Noble County, IN Secondary Stabilization in Action
Secondary Stabilization in Action
Secondary Stabilization in Action
Secondary Stabilization in Action
Secondary Stabilization in Action
How do you know you’ve done a good job?
Light Weight Deflectometer (LWD)

- Hand held portable falling weight device
- Measures deflection and indicates compaction level
- Modulus – measure of stiffness
  - Helps optimize performance
  - Increased modulus > increased life span of pavement
  - Helps predict performance of recycled materials
- Cost Effective
  - Inexpensive
  - Efficient – short testing time (~2 minutes per test)
- Correlate Deflection to Modulus
- QA / QC for Quick Field Determination of compaction
Example LWD Data
History of LWD

• Germany 1981
  – Developed by Federal Highway Research Institute and HMP Company in Germany
  – In Situ Testing device

• United States
  – Growing interest in use as in situ spot-testing device for QC / QA of earthwork compaction

• Egypt 2008
  – Testing natural subgrade and compacted fill commercially in field work

• India 2016
  – Low Volume road QC tool
International Research

• Comparative studies of lightweight deflectometer and Benkelman beam deflectometer in low volume roads - India
  – Portable and cost effective method
  – QA / QC and Structural Evaluation

• The use of lightweight deflectometer for in situ evaluation of sand degree of compaction - Egypt
  – Compaction and QC of soil-surfaced roads, embankments and fill
  – Relationship of Density/Unit Weight to LWD

![Graph 1](image1.png)

![Graph 2](image2.png)
Research: NCHRP 10-84

• Modulus Based Devices Evaluation
• Survey – States interested in “implementing a practical modulus-based specification.”
  – Not incorporating laboratory resilient modulus
• Proposed AASHTO Specification
• Validated the proposed AASHTO Specification through five field projects located in different regions of the country.
AASHTO

- Standard Test Methods for Estimating Modulus of Embankment and Unbound Aggregate Layers with Portable Falling Weight Devices
ASTM

• E 2835-2015: Standard Test Method for Measuring Deflections using a Portable Impulse Plate Load Test Device
INDOT Test Methods

• ITM 508
  – Field Determination of Deflection Using Light Weight Deflectometer

• ITM 514
  – Test Section for Aggregates and Recycled Materials – Section 8.0 for Aggregates

• INDOT Standard Specifications
  – 203.24 Method of Making Strength, Stiffness and Density Test
## InDOT

### Maximum Allowable Deflection

<table>
<thead>
<tr>
<th>Material Type</th>
<th>Max. Allowable Deflection (mm)</th>
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<tbody>
<tr>
<td>Lime Modified Soil</td>
<td>0.30</td>
</tr>
<tr>
<td>Cement Modified Soil</td>
<td>0.27</td>
</tr>
<tr>
<td>Aggregate Over Lime Modified Soil</td>
<td>0.30</td>
</tr>
<tr>
<td>Aggregate over Cement Modified Soil</td>
<td>0.27</td>
</tr>
</tbody>
</table>
Why LWD?

• Modulus, a measure of stiffness, is a better predictor of performance than density.

• Modulus is one material property that directly relates to long-term performance of pavements.

• Agencies face continued and increasing pressure to deploy limited resources effectively.
2018 Testing Protocol

• Testing
  – Cores
  – Grindings
  – Mix

• Gradation, Moisture, Plasticity, Proctor, CBR
  – Target Moisture: 7%

• Add LWD testing during/after compaction

ITM 514 Test Section
In Field, Real Time
Noble County Improvements

Road Compaction before and after Secondary Road Stabilization

Road location, Noble County

Compaction value, Mpa

Before

After

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County Improvements

Before Stabilization

After Stabilization
County Improvements

Before Stabilization

After Stabilization
County Improvements

Before Stabilization

After Stabilization
Identifying Potential Issues
Measuring Success
Light Weight Deflectometer

• Cost Effective
  – Inexpensive
  – Efficient – short testing time (~2 minutes per test)

• Hand Held - Portable

• In Field – Real Time data

• Quality Control
  – Modulus
  – Compaction
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”
- NCHRP Project 10-84: Modulus-Based Construction Specification for Compaction of Earthwork and Unbound Aggregate
- Comparative Studies of Lightweight Deflectometer and Benkelman Beam Deflectometer in Low Volume Roads – Guzzarlapudi et al.
- The Use of Light Weight Deflectometer for In Situ Evaluation of Sand Degree of Compaction – Elhakim et al.
- INDOT Specification Handbook
Acknowledgements

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Questions?