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Edward C. Levy Co.  
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Purdue Road School**

**Secondary Road Reclamation  
Utilizing  
Sustainable Steel Slag Products**



# Maintenance Issues

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## Urban Sprawl

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# Rehabilitation Options

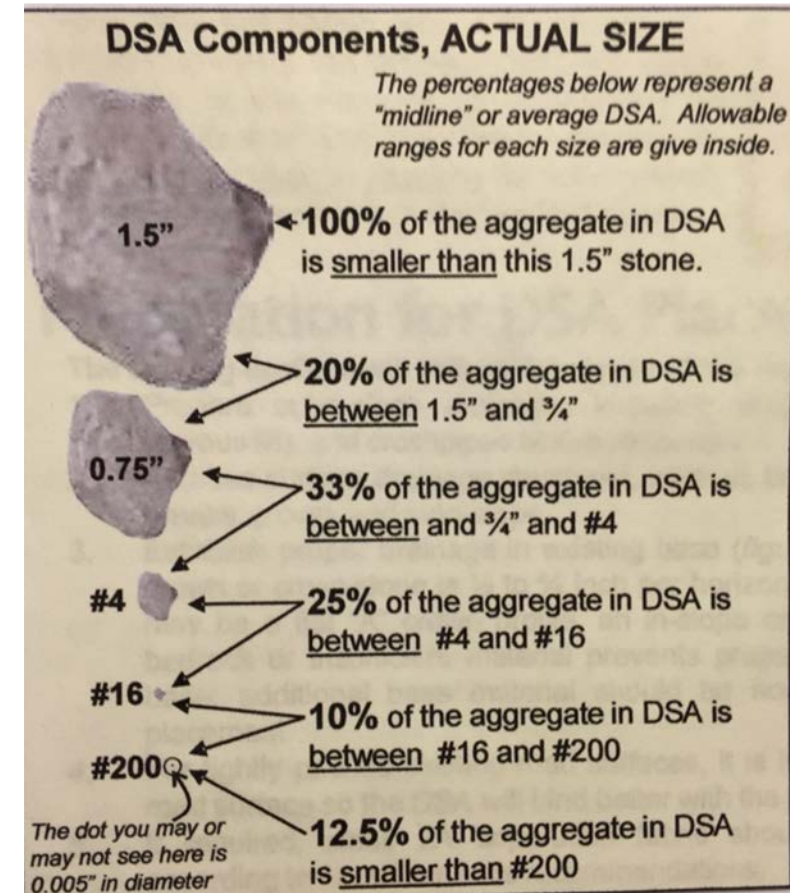
- Gravel Roads
  - Grading
  - Aggregate Addition / Stabilization
- Paved Roads
  - Chip and Seal
  - Resurfacing
- Re-Construct
- Reclamation



# Aggregate Additions

## DSA: Driving Surface Aggregate (PSU)

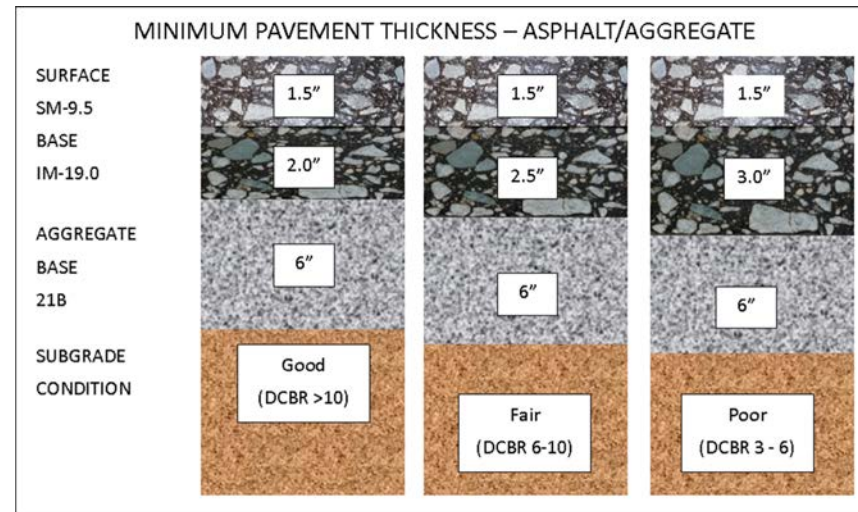
- Surface Wearing Course developed specifically for Unpaved Roads.
- Unique particle size distribution
  - Maximize packing density
  - Durable road surface
  - 1 ½ " X 0
- PENNDOT approved as of 2006 (publication 447)



# Pavements

Typically comprised of several layers with each layer having it's 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.

Noble County

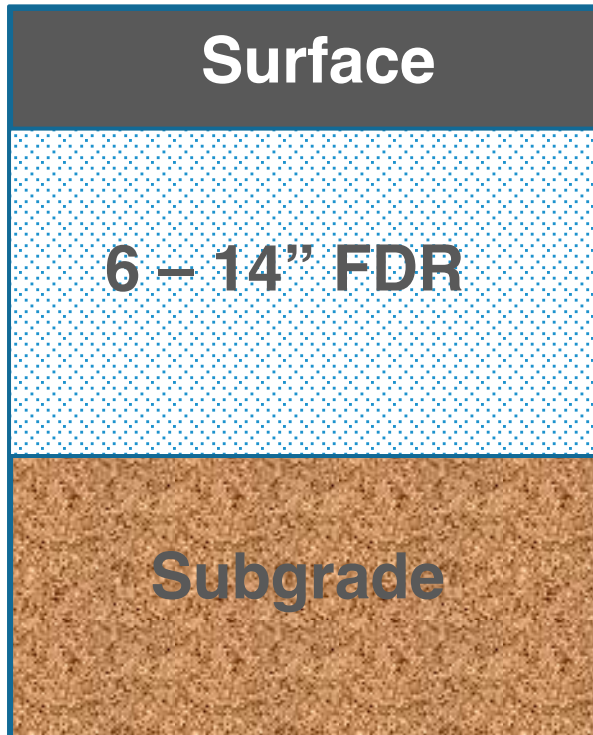


Steuben County

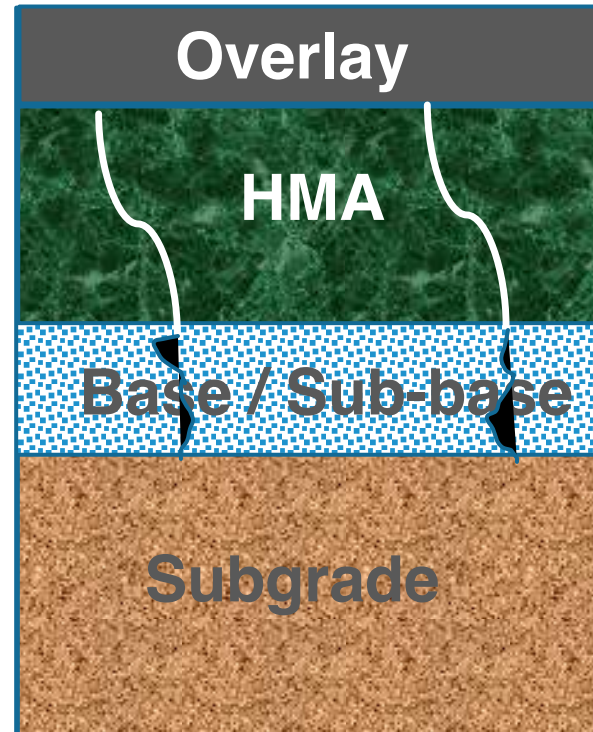
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## Improved Foundation = Added Strength / Life

### Reclamation



### Overlay



### Mill & Fill



# Full Depth Reclamation

The full depth reclamation process is applicable to depths up to 12 to 16", with typical applications in the range of 6 to 9". It 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

# Typical Aggregate Specification Requirements

- Key Physical Properties
  - Liquid Limit: Max 35
  - Plasticity Index: 4 to 9
  - LA Abrasion: Max 50
  - Soundness: Sodium Sulfate 12% Max @ 5 Cycles
  - Crush Count: 75% One Face
  - Gradation

# FHWA (Gravel Roads Maintenance and Design Manual)

GRADATION FOR AGGREGATE SURFACE COURSE			
Percent passing			
<u>Sieve</u>	<u>No. 1</u>	<u>No. 2</u>	<u>FDR</u>
1"	100	100	
3/8"	50-85	60-100	
#4	35-65	50-85	
#10	25-50	40-70	
#40	15-30	24-45	
#200	8-15	8-15	

# 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 EAFS 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

# Stabilization - Mechanical

## ➤ Compacting and Blending

- Mixing 2 or more soils to obtain desired gradation
- Placing non chemical material in or on a soil to provide strength

## ➤ Various materials

- Crushed Aggregate
- Asphalt Pavement Millings
- Crushed Concrete
- Crushed Slag

## ➤ Benefits

- Improve Gradation
- Increase Structural Stability
  - Improve Interlock
- Don't have to sacrifice thickness by adding material:
  - Correct cross-slope and/or profile grade
  - Widen
- Can use with other stabilizing additives
  - Bituminous
  - Chemical

# Stabilization - Chemical

## ➤ Traditional Stabilizers

- Cement
- Lime
- Fly Ash
- Calcium Chloride
- Bituminous materials

## ➤ Amount Matters

- Less = Modify
- More = Improve

## ➤ Benefits

- Modify on-site materials to be stronger for structural base or sub-base.
- Reduces/eliminates need to do full depth repairs or total reconstruction.
- Noble County: "...the moisture ... activates the lime in the Duraberm resulting in lime hardening ( $\text{CaO} + \text{H}_2\text{O} > \text{Ca}(\text{OH})_2$ )."

# Purdue / I-65; 2010 > 2016



Yildirim, Prezzi; Purdue  
2009

05/20/2010

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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



# Steel Slag Characterization Environmental Considerations

- Quality Roads
- Environmental Contaminations
- Land Applications
- EPA, State, and other regulatory bodies



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# Construction

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# Evaluation

- Step 1 – Evaluate existing Pavement
  - Gather Information
    - Depth of existing Surface / Base?
    - How many pavement layers and what types are each?
    - What's the expected traffic levels?
    - Level of Deterioration?
  - Test the pavement to know the composition and thickness of the existing layers.
    - Cores – Center and Edges, Various Locations
    - Gradation, PL/LL
  - Interpret the results to determine proper technique

# Key Decisions

- Available Equipment
- Blend / Depth (Traffic Levels)
  - 50/50 blend?
  - Milling Depth 10 to 14”?
- Binder
  - Emulsion
  - Cement
  - Lime

## Triaxial Data

	Unconfined Compression	
	No Aging	28 Day
<b>Existing Roadway</b>	23.0 psi	46.5 psi
<b>W/ 30% Blend</b>	26.4 psi	80.9 psi
<b>W/ 40% Blend</b>	39.5 psi	85.3 psi
<b>W/ 50% Blend</b>	57.5 psi	90.3 psi
<b>W/ 60% Blend</b>	61.8 psi	96.0 psi

# Construction

- Step 1 – Mixture
  - Blend Ratio / Type of Binder
  - Target
- Step 2 - Geometry
  - Surface drainage, elevation, etc.
- Step 3 - Placement
  - 3-8” uncompacted
    - Consider traffic and budgets
- Step 4 – Blend / Stabilize
  - Binder
  - Final depth 6” to 14”
- Step 5 – Compact
- Step 6 – Finish (Surface)

## Insufficient Base





**Adequate Base**

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# Placement



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Tailgating

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Grading

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## Placement / Grading

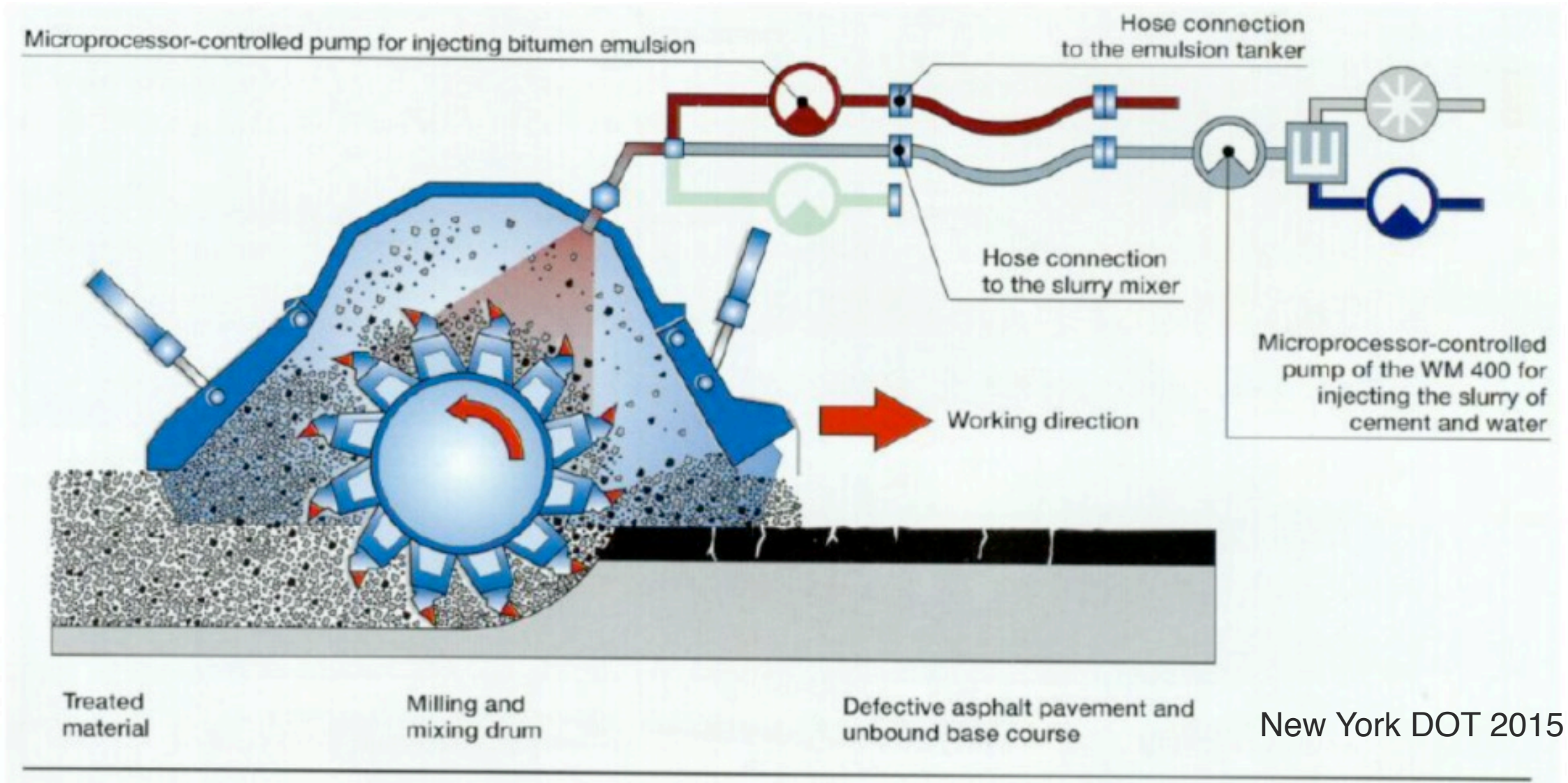
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Blending



05/20/2010

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New York DOT 2015



Blending / Liquid Binder

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Compaction

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**Secondary Road Reclamation Utilizing Sustainable Steel Slag Products**

**Cost: \$150,000 > \$300,000 / Mile**



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# Cost Breakdown

- 8" Depth with 0.5 gal CaCl / sq. yd.
- Base
  - \$29,442 / mile (22' wide)
- With Triple Chip and Seal / Fog Seal
  - \$67,323 / mile
- With 1.5" Overlay
  - \$90, 774 / mile

- 8"Depth with 1 gal emulsion / sq. yd.
- Base (4" add)
  - \$50,000 / mile (3 miles, 20' wide)
- With Double Chip and Seal
  - \$75,000 / mile

Traditional FDR

\$200,000 - \$300,000 / mile

Traditional Reconstruction

\$300,000 - \$500,000 / mile

# Typical Surface Treatments



- Chip and Seal
- Double Chip and Seal
- Cold Mix Asphalt
- Hot Mix Asphalt

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## Chip & Seal

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A large orange asphalt paving machine is shown from a rear perspective, moving along a road. Four workers in orange safety vests are positioned around the machine: one on the left holding a long-handled broom, one on the machine's platform, one on the right, and one further right. The machine is spreading a dark, smooth layer of asphalt. The road is flanked by trees with green and some autumn-colored leaves. A red car is visible in the distance on the left. The scene is set on an overcast day.

## Asphalt Paving

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5/2/06

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# 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
- Minnesota DOT: Design Guide for Low-Volume Aggregate Surfaced Roads
- ASTM: D1241 – Specification for Materials for Soil-Aggregate Subbase, Base and Surface.
- 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 / Whitely County Highway Department, Indiana
- Pennsylvania DOT



## PBE FDR/SLAG Project FY: 2016/2017

County	McKean Co.
Project Length	4.65 Miles
Estimated Project Cost/ Cost per mile	
Average Daily Truck Traffic	1,035
Average Daily Truck Traffic	376
Estimated Project starting Date	July 2016, (Pending on A-409 Funds)
Scope of repairs proposed:	12" Full-depth reclamation (FDR) to widen the base from 20' to 24'. Approximately 100,000 Cubic feet / <b>6,500 ton of slag</b> 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.



# Thank You

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