Full Depth Pavement Reclamation Using Coal Combustion Products in Marquette Country

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Michigan County Engineers Workshop
February 21, 2006
Coal Combustion Products (CCP)

- Fly ash
- Bottom ash
- Boiler slag
- Flue gas desulfurization material
  - FGD wet scrubber materials
  - FGD gypsum
  - Dry scrubber materials
- Fluidized bed combustion materials
- Integrated Coal Gasification by-products
  - Slag
  - Sulfur
  - Sulfuric Acid
- Recovered coal ash

Coal ash is calcined and melted inorganic soils that are within coal
Fly ash is a pozzolan

A pozzolan is primarily a siliceous or siliceous and aluminous material, in a finely divided form and in the presence of water, chemically reacts with calcium hydroxide (lime) at ordinary temperatures to form compounds possessing cementitious properties.

U.S. CCP Production and Utilization

► Approximately 50% of US electricity is generated by coal-fueled power plants
► In 2005, over 123 million tons of CCP were produced
► 40% beneficially used (50 mill. tons)
Rules regulating the use of CCP

► CCP is a RCRA D Non-hazardous material regulated by each state
► Use of fly ash in concrete is allowed in every state
► Most states exempt CCP from solid waste regulations if beneficially used
  ▪ Wisconsin: Self implementing rules for five categories of byproducts that allow 12 types of exempted uses
  ▪ Illinois: Exempted uses
  ▪ Michigan: Exempted uses per statute and now drafting self-implementing rules

Environmental Benefits of CCP Use

► Reduce greenhouse gas emissions
  ▪ 1 ton of fly ash that replaces cement in concrete offsets about 1 ton of CO₂
► Reduce the amount of CCP landfilled
► Conserve natural resources
► Reduce the need for mining Improve roads and buildings
► More durable materials
► Reduce life-cycle impacts and costs
Today fly ash is an essential component for durable concrete
CCP is stored to supply seasonal and market demands

QC/QA includes physical and chemical testing
Controlled Low Strength Material (CLSM)

CLSM using high carbon Class F fly ash and cement

CLSM using Class C fly ash and sand

Bottom ash subbase and structural bases
Soil Stabilization

Increase the structural capacity of subgrades using cementitious fly ash

Cold In-Place Recycled Pavement (Full Depth Reclamation)

Make better roads using fly ash binder for recycling asphalt or concrete pavements to make base course.
Benefits of Full Depth Reclamation

► Reduce life cycle costs
► Reduce construction schedules
► Less impact on traffic during construction
► Increase structural capacity
► Improve durability and reduce rutting
► Improve cross sections and drainage
► Resource conservation

Costs for Full Depth Reclamation

► Typical cost range $3.00/sy to $4.25/sy
► Depends on:
  ▪ Depth of pulverization
  ▪ Amount of binder
  ▪ One or two pulverization passes
  ▪ Water truck
  ▪ Size of project
Structural Benefits: Falling Weight Deflectometer
Pavement Evaluation

- Falling Weight Deflectometer
- Seven Sensors: 0, 12”, 18”, 24”, 36”, 48”, and 60” from the center of loading
- Impact Load = 40KN (9000 lbs)
- Performed in the outer wheel path every 100’

Pavement Deflection

![Graph showing pavement deflection over time with data for 2001 and 2002.]
Structural Number Distribution

Tests Number

Structural Number

Fly Ash Content vs. Resilient Modulus

Fly Ash Content (%)

Resilient Modulus (ksi)
Marquette County Presque Isle Power Plant Project Overview

► 3.6 mile Landfill Haul Road
  - One existing asphalt pavement section
  - Two existing gravel sections
► Full Depth Reclamation incorporating Bottom Ash, Class C Fly Ash and Cement Kiln dust
  - Bottom ash addition 3” to 4” (used 3,100 tons)
  - Fly ash binder addition: 11% application rate (used 1,900 tons of fly ash)
  - Cement Kiln dust (CKD) also evaluated
  - Generally did not add water – conditions were close to the optimum moisture at 8% to 9%
► Showed good stabilization
Pre-existing Road Conditions

- Fly Ash from Presque Isle Power Plant (PIPP) in Marquette, MI
- Less than 5% sulfur reduces swelling potential
- Prefer low unburned carbon content in fly ash

Fly Ash Composition

<table>
<thead>
<tr>
<th>PIPP Fly Ash</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Silica, Aluminum, Iron</td>
<td>63.8%</td>
</tr>
<tr>
<td>Silicon Dioxide</td>
<td>39.0%</td>
</tr>
<tr>
<td>Aluminum Oxide</td>
<td>18.9%</td>
</tr>
<tr>
<td>Iron Oxide</td>
<td>5.8%</td>
</tr>
<tr>
<td>Sulfur Trioxide</td>
<td>2.4%</td>
</tr>
<tr>
<td>Calcium Oxide</td>
<td>18.9%</td>
</tr>
<tr>
<td>LOI</td>
<td>1.0%</td>
</tr>
</tbody>
</table>
Mix Design

► Samples analyzed to determine maximum densities of various mix combinations
  ▪ Higher dry unit weight/ fills voids with particles
► Optimum moisture content needed for maximum compressive strength
  ▪ Moisture content range 7% - 14.9%
    ▶ Target was 9%
  ▪ Moisture was adjusted in the field to reach optimum compressive strength

Mix Design

Mix combinations used-

- 25% Bottom Ash + 11% Class C Fly Ash + Reclaimed Asphaltic Material
- 25% Bottom Ash + 11% Class C Fly Ash + Recycled Gravel Material
- 25% Bottom Ash + 11% Cement Kiln Dust + Reclaimed Asphaltic Material
- 11% Class C Fly Ash + Reclaimed Asphaltic Material

% are by mass for fly ash and by depth of overall stabilization for bottom ash

One area was treated twice with fly ash and re-pulverized and re-compacted due to wet conditions
Construction Sequence

- Bottom ash delivery, spreading and grading
- Fly ash delivery and spreading
  - Use of vane spreader
  - Berm prevents fly ash from “flowing” off the pavement
- Pulverization and mixing
- Water addition (when necessary)
- Compaction

Bottom Ash Delivery Via Live Bottom Dump Truck
Bottom Ash Spreading and Grading

Vane Spreader Minimizes Dusting and Regulates Volume of Fly Ash
Vane Spreader

Why Construct a Berm?
Transfer fly ash via tanker truck to vane feeder or directly from silo

Reclamation/ Pulverization

- Water can be added to obtain optimal moisture content and mixed in with the pulverizer.
- Pulverized to 6-10 in.

*Taken from ARRA 2001
Pulverization and Mixing

Pulverization during rain
Stabilizing 1 foot off pavement edge

Pulverizer’s enclosed mixing chamber
Pulverization and Compaction

Sheepsfoot roller compacted in vibratory mode (5-8 passes) then graded immediately.

After final grading 2-3 passes with steel drum roller.

Compaction between 89.6% - 98.8%.
## Water addition

![Water addition image](image)

## Compressive Strengths

<table>
<thead>
<tr>
<th>No.</th>
<th>Mixture/Composition</th>
<th>Moisture Content Range (%)</th>
<th>Dry Density (pcf)</th>
<th>% Compaction Range</th>
<th>7/28/56 Days Compressive Strength Range (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>25% BA (1-6) + 11% FAC + RAM</td>
<td>8.9 - 14.9</td>
<td>116.5/ 128.4</td>
<td>89.6/98.8</td>
<td>7 days 250 – 310, 28 days 260 – 290, 56 days 300 – 320</td>
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<tr>
<td>2</td>
<td>25% BA (1-6) + 11% FAC + RGM</td>
<td>7.7 - 9.1</td>
<td>122.5/ 125.4</td>
<td>94.5/96.5</td>
<td>7 days 240 – 340, 28 days 290 – 330, 56 days 340 – 400</td>
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<tr>
<td>3</td>
<td>25% BA (1-6) + 11% CKD + RAM</td>
<td>10.5 - 11.5</td>
<td>124.8/ 127.1</td>
<td>96/97.7</td>
<td>7 days 240 – 280, 28 days 410 – 540, 56 days 510 – 580</td>
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<tr>
<td>4</td>
<td>11% FA + RAM</td>
<td>8.1 - 8.3</td>
<td>126.8/ 128.2</td>
<td>96.9/98.6</td>
<td>7 days 450 – 460, 28 days 360 – 490, 56 days 390 – 460</td>
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</tbody>
</table>
PIPP Haul Road
Full Depth Reclamation Compressive Strength

Field QC /QA

Moisture and density
Molding cylinders for compressive strength using standard proctor equipment
Asphalt Pavement

► Light rain for three days during project
  ▪ Work was able to continue
  ▪ Water repelled on stabilized soil similar to a paved surface
► This allowed soils to be ready for paving when weather was conducive to paving

Asphalt Pavement

► Fly ash Section 3 1/2 in. of asphalt pavement
► Non-fly ash stabilized section 4 in. of asphalt pavement
► Thinner placement because structural coefficient increased from .14 to .28-.30
► Stabilized shoulders allowed loads at outer edges of the pavement to be uniformly supported
Regulations

► Allowed under paved roads - considered part of structural pavement
► Blending done quickly after fly ash was placed to keep fly ash from spreading outside of road
► Dust kept to a minimum – drop height of fly ash was minimized on vane truck

Regulations

► 100 tons Coal Combustion Products (CCPs) and CKD allowed per project outside of structural pavement
► Total CCP’s and CKDs used = 5160 tons
► On unpaved section (shoulder) = 210 tons
► Equals 70 tons in each section (project) which is within the limit
Summary

► Pilot projects used fly ash, bottom ash and kiln dust;
► Reduced use of new materials and reuses material
► We Energies will seek source exemption from DEQ for use beyond edge of pavement

Summary

► Showed increased dry density
► Increased load bearing capacity
► Increased savings using fly ash over cement or lime
► Overall viable option when designing roadways
► Accelerates construction schedule
► Contractors were able to construct with little difficulty
Website References

- American Coal Ash Assoc.  www.acaa-usa.org
- Michigan Tech  www.imp.mtu.edu
- UW-Milwaukee  www.cbu.uwm.edu
- Univ. North Dakota Energy & Environmental Research Center  www.undeerc.org/carrc
- DOE National Energy Technology Laboratory  www.fetc.doe.gov
- Univ. of Kentucky Center for Applied Energy Research  www.caer.uky.edu
- We Energies  www.we-energies.com/environmental/recycle_coalash.htm

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