BENEFICIAL REUSE OF COAL COMBUSTION BYPRODUCTS AS GEOTECHNICAL CONSTRUCTION MATERIAL

July 29, 2009
<table>
<thead>
<tr>
<th>Time</th>
<th>Agenda Item</th>
<th>Presenter(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12:00 - 12:30</td>
<td>Lunch, Introductions, Agenda Review</td>
<td>Bob Spoerri &amp; Eric Schaeffer</td>
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<tr>
<td>12:30 - 12:50</td>
<td>History and current utilization of CCPs as Geotechnical Construction Material</td>
<td>Tom Adams</td>
</tr>
<tr>
<td>12:50 - 1:20</td>
<td>Technical overview of CCP use as Geotechnical Construction Material</td>
<td>Dr. Craig Benson</td>
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<tr>
<td>1:20 - 1:40</td>
<td>Perspective on Wisconsin's experience with CCPs, including NR538 regulatory structure</td>
<td>Paul Koziar</td>
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<td>1:40 - 2:00</td>
<td>Experience with CCP use as Geotechnical Construction Material in the Midwest and Southeastern US</td>
<td>Bob Spoerri and Bob Waldrop</td>
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<td>2:00 - 2:15</td>
<td>Break (Time Permitting)</td>
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<td>2:15 - 3:00</td>
<td>Presentations Q&amp;A</td>
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<tr>
<td>3:00 - 3:45</td>
<td>Discussion of standards framework for using CCPs as Geotechnical Construction Materials</td>
<td></td>
</tr>
<tr>
<td>3:45 - 4:00</td>
<td>Next steps, Summary and Close</td>
<td>Bob Spoerri &amp; Eric Schaeffer</td>
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</tbody>
</table>
WHY FIND BENEFICIAL USES FOR CCPS?

Thomas H. Adams
Executive Director
American Coal Ash Association
Background

- Coal fueled generation will continue for the foreseeable future
- Byproducts of the generating process create mineral resources that must be disposed – or used
- Historically both production and beneficial use have increased each year in the last ten years
- EPA, DOE and industry have set the goal of 50% utilization of all CCPs by the year 2011
Production and Use over the Years

Why Find Beneficial Uses for CCPS – ACAA
Constituents in CCPs

- CCPs contain the same heavy metals as found in coal, but in slightly more concentrated forms.
- The concentrations are comparable to other products, such as portland cement, lime, etc.
- CCPs create no greater risks than commonly used products found in commercial applications.
- The metals are very similar to the ranges found in soils, typically in low parts per million.
Sample Concentrations in FA

Why Find Beneficial Uses for CCPS - ACAA

Comparison Trace Metals - Soil v. Fly Ash v. West VA Coal (ppm)

Parts Per Million (ppm)

Soil Avg ppm
Ash Avg ppm
WV Coal ppm

Arsenic Barium Boron Cadmium Copper Lead Mercury Nickel Selenium Zinc

Why Find Beneficial Uses?

- If not used, then new or expanded landfill space will be required.
- The characteristics of CCPs allow them to be widely substituted for natural materials – conserve these materials for other uses.
- Recycling these residuals conserves energy required for extraction and processing of other materials.
Other Considerations

- Properly characterized and placed using environmentally appropriate procedures will not cause adverse impact.
- By beneficial use, this industry DOES NOT mean disposal by another name.
- It is essential for this nation to wisely use its available mineral resources, including recycling industrial residues.
- We need to reduce our carbon footprint by sound beneficial use.

Why Find Beneficial Uses for CCPS – ACAA
Disposal Will Continue

- Not all CCPs are useable with current technologies
- Depending on location, transportation options and competition, applications may be limited
- Plant by plant, utilization vs. disposal must be evaluated
- Almost certainly, additional landfill space will be required to address new byproducts from plant scrubber systems unless appropriate beneficial uses can be identified
Conclusions

- U.S. CCP industry is evaluating future options as regulations and technologies change
- Conservation of natural resources through recycling CCPs makes environmental and technical sense
- Building understanding with government agencies, NGOs, academia and industry is one path toward addressing diverse viewpoints
- In times of economic challenge, ash reuse makes $ense
Conclusions

- Beneficial use of CCP should be encouraged to lessen the need for disposal
- Properly *engineered* and *managed* applications will achieve desired physical, environmental, economic and social results
- We cannot ignore the impacts of inefficient resource management on our environment and society
- Zero-waste target – done safely
Thank You

AMERICAN COAL ASH ASSOCIATION

Thomas H. Adams, Executive Director

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thadams@acaa-usa.org
CCPs as Geotechnical Construction Materials

Craig H. Benson, PhD, PE
Wisconsin Distinguished Professor
Director, Recycled Materials Resource Center
University of Wisconsin-Madison
chbenson@wisc.edu
Applications

• Fly ashes
  – Structural fill (e.g., embankments)
  – Drying agent for wet soils (e.g., wet subgrades)
  – Strengthening agent for subgrades and bases

• Bottom ashes
  – Structural fill (e.g., retaining wall backfill)
  – Base course for pavements
  – Drainage layers
## Structural Fill

![Diagram of Structural Fill](image)

- **125 mm AC**
- **115 mm Crushed Aggregate Base**
- **140 mm Salvaged Asphalt Base**

### Bottom Ash

- **600 mm Bottom Ash Subbase**

### Control

- **840 mm or more Excavated Rock Subbase**

### Fly Ash

- **300 mm Fly Ash Stabilized Subbase**

---

## Pavements

- **125 mm AC**
- **115 mm Crushed Aggregate Base**
- **140 mm Salvaged Asphalt Base**

### Control

- **Subgrade**

### Fly Ash

- **Subgrade**

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*CCPs as Geotechnical Construction Materials – Dr. Craig Benson*
Why use CCPs in Lieu of Earthen Materials or Chemical Stabilizers?

- Many behave like soils
- Avoid borrow source problems
- Reduced energy consumption
- Lower greenhouse gas emissions
- Improved performance and service life
- Cost savings
Two Byproducts → High Quality Product

RPM + High Carbon Fly Ash
= high modulus and durable base

CCPs as Geotechnical Construction Materials – Dr. Craig Benson
Creating a Superior Roadway with CCPs

- **LWD, 7 days**
- **DCP, 7 days**
- **DCP 21 days**
- **FWD, 21 days**
- **SSG, 21 days**

**Modulus from LWD, MPa**

- **RPM**
- **Crushed Aggregate**
- **RPM+FA**

*CCPs as Geotechnical Construction Materials – Dr. Craig Benson*
Life Cycle Analysis – Energy and GHG Emissions

Initial Energy Consumption [MJ]

<table>
<thead>
<tr>
<th>Process</th>
<th>Energy Consumption [MJ]</th>
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</thead>
<tbody>
<tr>
<td>Processes (Equipment)</td>
<td>80,000</td>
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<tr>
<td>Materials Transportation</td>
<td>20,000</td>
</tr>
<tr>
<td>Materials Production</td>
<td>40,000</td>
</tr>
</tbody>
</table>

Life Cycle CO2 Emissions [Mg] and Global Warming Potential

<table>
<thead>
<tr>
<th>Process</th>
<th>CO2 Emissions [Mg]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Processes (Equipment)</td>
<td>8.000</td>
</tr>
<tr>
<td>Materials Transportation</td>
<td>2.000</td>
</tr>
<tr>
<td>Materials Production</td>
<td>4.000</td>
</tr>
</tbody>
</table>

CCPs as Geotechnical Construction Materials – Dr. Craig Benson
What about impacts to ground water?

- CCPs elute a variety of trace elements, as do nearly all granular construction materials.

- Systematically evaluate whether use of materials impacts the environment.

- Code vs. site-specific analysis.
Wisconsin NR 538 Code

Chapter NR 538

Beneficial Use of Industrial Byproducts

1. Evaluate byproducts based on total elemental analysis and water leach tests.

2. Define byproduct categories based on test data.

3. Define suitable application based on category.
# Applications Based on Category

## Table 4

<table>
<thead>
<tr>
<th>Beneficial Use Methods</th>
<th>Industrial Byproduct Category</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5</td>
</tr>
<tr>
<td>(1) Raw Material for Manufacturing a Product</td>
<td>X</td>
</tr>
<tr>
<td>(2) Waste Stabilization / Solidification</td>
<td>X</td>
</tr>
<tr>
<td>(3) Supplemental Fuel Source / Energy Recovery</td>
<td>X</td>
</tr>
<tr>
<td>(4) Landfill Daily Cover / Internal Structures</td>
<td>X</td>
</tr>
<tr>
<td>(5) Confined Geotechnical Fill</td>
<td>X</td>
</tr>
<tr>
<td>(a) commercial, industrial or institutional building subbase</td>
<td></td>
</tr>
<tr>
<td>(b) paved lot base, subbase &amp; subgrade fill</td>
<td></td>
</tr>
<tr>
<td>(c) paved roadway base, subbase &amp; subgrade fill</td>
<td></td>
</tr>
<tr>
<td>(d) utility trench backfill</td>
<td></td>
</tr>
<tr>
<td>(e) bridge abutment backfill</td>
<td></td>
</tr>
<tr>
<td>(f) tank, vault or tunnel abandonment</td>
<td></td>
</tr>
<tr>
<td>(g) slabjacking material</td>
<td></td>
</tr>
<tr>
<td>(6) Encapsulated Transportation Facility Embankment</td>
<td>X</td>
</tr>
<tr>
<td>(7) Capped Transportation Facility Embankment</td>
<td>X</td>
</tr>
<tr>
<td>(8) Unconfined Geotechnical Fill</td>
<td>X</td>
</tr>
<tr>
<td>(9) Unbonded Surface Course</td>
<td></td>
</tr>
<tr>
<td>(10) Bonded Surface Course</td>
<td></td>
</tr>
<tr>
<td>(11) Decorative Stone</td>
<td></td>
</tr>
<tr>
<td>(12) Cold Weather Road Abrasive</td>
<td></td>
</tr>
</tbody>
</table>

*Lower category number provides more stringent limits on leaching characteristics.*
### Water Leach Test Criteria – NR 538

<table>
<thead>
<tr>
<th>Standard (mg/L)</th>
<th>Parameter</th>
<th>Ferrous Foundry Excess System Sand</th>
<th>Ferrous Foundry Slag</th>
<th>Coal Ash</th>
<th>Other¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.03</td>
<td>Antimony (Sb)</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>0.25</td>
<td>Arsenic (As)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
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<tr>
<td>10</td>
<td>Barium (Ba)</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>0.02</td>
<td>Beryllium (Be)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
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<tr>
<td>0.025</td>
<td>Cadmium (Cd)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>2500</td>
<td>Chloride (Cl)</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>0.5</td>
<td>Chromium, Total (Cr)</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>6.5</td>
<td>Copper (Cu)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
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<tr>
<td>1</td>
<td>Total Cyanide</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
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<tr>
<td>20</td>
<td>Fluoride (F)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Iron (Fe)</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>0.075</td>
<td>Lead (Pb)</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>0.5</td>
<td>Manganese (Mn)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
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<tr>
<td>0.01</td>
<td>Mercury (Hg)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
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<tr>
<td>0.5</td>
<td>Nickel (Ni)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>Nitrite &amp; Nitrate (NO₂⁻-NO₃⁻-N)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>Phenol</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
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<tr>
<td>0.25</td>
<td>Selenium (Se)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>0.25</td>
<td>Silver (Ag)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>2500</td>
<td>Sulfate</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>0.01</td>
<td>Thallium (Tl)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>Zinc (Zn)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

¹ As provided under s. NR 538.06 (1), the testing program for materials other than ferrous foundry system sand, ferrous foundry slag and coal ash must be approved by the department prior to characterization. For other materials the department may modify the list of parameters required to be analyzed for and may establish standards on a material-specific basis for additional parameters.

**Note:** All testing is to be conducted on a representative sample of a single industrial byproduct prior to commingling with other materials, unless otherwise approved by the department.

- Contaminants of concern depend on byproduct being considered.
- Category 1 has the most test requirements.
No Code / Site-specific Analysis

- Are leached concentrations higher than those from accepted construction materials?
  - No: use CCP without further analysis
  - Yes: conduct additional analysis to evaluate impact
    - Leach testing
    - Predictive modeling
    - Monitoring

CCPs as Geotechnical Construction Materials – Dr. Craig Benson
Methods to Assess Leaching

• Batch tests (TCLP, SPLP, WLT):
  - solid and liquid in a vial
  - tumbled to ensure well mixed
  - supernatant analyzed for contaminants of concern

• Column tests:
  - flow through experiment simulating field scenario
  - effluent analyzed for contaminants of concern.
Laboratory Column Leach Tests

Provides flow-through data simulating field.

CCPs as Geotechnical Construction Materials - Dr. Craig Benson
Typical Output: Se Concentration - 10 yr

After 10 yrs

Results

CCPs as Geotechnical Construction Materials – Dr. Craig Benson
Typical Output: Se Concentration - 45 yr

Results

CCPs as Geotechnical Construction Materials – Dr. Craig Benson
Predictions at Edge of Right of Way

POC = 20 m

Elution Concentration $C_o$

Maximum Concentration within 100 years ($\mu g/l$)

Depth Below Ground Surface (m)

CCPs as Geotechnical Construction Materials – Dr. Craig Benson
What do we see in the field?

Monitoring Sites:
- Waseca, MN (1)
- Chisago Cty, MN (1)
- Lodi, WI (10)
- Cross Plains, WI (1)
- Ft. Atkinson, WI (3)
- MnROAD (5)

CCPs as Geotechnical Construction Materials – Dr. Craig Benson
Lysimeter Layout: STH 60

West to Prairie du Sac, WI

East to Lodi, WI

Legend

- Lysimeter
- Collection Tank

(Not to scale)

CCPs as Geotechnical Construction Materials - Dr. Craig Benson
Wisconsin STH 60 Lysimeters: Selenium (Se)

- Se higher from fly-ash stabilized soil initially
- Se comparable within 3 yr.
- Se always below MCL

CCPs as Geotechnical Construction Materials – Dr. Craig Benson
Wisconsin STH 60 Lysimeters: Chromium (Cr)

- Cr higher from fly-ash stabilized soil initially
- Cr from fly ash comparable or lower within 3 yr.
- Cr always below MCL

Fly Ash Stabilized Soil
Fly Ash Stabilized Soil (BDL)
Control - Crushed Stone
Control - BDL
MCL

State Highway 60
Cr - Chromium

CCPs as Geotechnical Construction Materials – Dr. Craig Benson
Wisconsin STH 60 Lysimeters: Cadmium (Cd)

- Cd higher from control initially
- Cd comparable within 3 yr.
- Cd above MCL initially, esp. for control

State Highway 60
Cd - Cadmium
UNH Colebrook Embankment

Precipitation

CFA

Natural Berm

O Porewater Monitoring Locations

CCPs as Geotechnical Construction Materials – Dr. Craig Benson
Colebrook Arsenic Concentrations

CCPs as Geotechnical Construction Materials – Dr. Craig Benson
Colebrook Mercury Concentrations

Natural Aggregate
• 0.70 ng/L, 0.51 ng/L

Coal Fly Ash
• 0.44 ng/L, 1.08 ng/L

MCL = 2 μg/L

Mercury eluted from coal fly ash is not different from natural aggregate, and well below MCL.
Mercury in MnROAD Leachate  

Mercury from conventional aggregate (CA) and recycled pavement material (RPM) higher than from fly ash section.

CCPs as Geotechnical Construction Materials – Dr. Craig Benson
Final Remarks

CCPs can be used to make geotechnical construction more sustainable (energy, emissions, life cycle) ... it’s not just about getting rid of ash.

CCPs can elute elements of concern like nearly all construction materials. Evaluate potential impact in a systematic manner in context of accepted risks.

Need to develop consistent codes, methods of chemical analysis, and evaluation techniques that can be applied nationwide to ensure safe and wise use of CCPs in geotechnical construction.

CCPs as Geotechnical Construction Materials – Dr. Craig Benson
Wisconsin’s Industrial
Byproduct Beneficial
Use Program

Presented by:
Paul Koziar
Paul Koziar Consulting LLC
Overview of Presentation

- Historical Development of WI Program
- Key Elements of the Program (Chapter NR 538)
- Example of the Geotechnical Fill Requirements
- Review of reuse under NR 538
Chapter NR 538
Program Development

- Case-by-case approvals prior to 1998
- Ch. NR 538 Wis. Adm. Code
  - Technical Advisory Committee
NR 538 Program Summary

Key Program Elements

- Applicable to 2 major industrial byproducts

- Establishes 5 categories for industrial byproducts

- Categories established through the comparison of the results of waste characterization tests and existing groundwater and direct contact standards.

- Specifies beneficial uses allowed for each category matching their suitability for placement in the environment.
Key Program Elements
Geotechnical Construction Material

- Self-implementation for projects < 5000 cu yds. after initial waste characterization
- General and specific engineering and environmental standards for each type of geotechnical fill based on the category from 1 to 5
- Storage and transportation standards
- Notification and approval by WDNR for projects > 5000 cu yds
- Public notification and opportunity public input
- Property owner notification for geotechnical fill projects
- Environmental monitoring of large projects
Example of Geotechnical Fill Construction Under Chapter NR 538

TRANSPORTATION FACILITY ROADWAY DESIGN STANDARDS
WISCONSIN DEPARTMENT OF TRANSPORTATION
INDUSTRIAL BYPRODUCT USE UNDER NR 538.10(6)

HMA SURFACE COURSE
GRAVEL BASE COURSE
GRANULAR SUBBASE

SLOPE

VEGETATED SIDE SLOPE

1FT COVER SOIL INCLUDING 4" MIN. TOPSOIL

2FT THICK RECOMPACTED CLAY LINER

INDUSTRIAL BY-PRODUCT MATERIAL

3FT THICK RECOMPACTED CLAY LINER

IN-SITU MATERIAL

RECOMPACTED CLAY (SEE SPECIFICATIONS)

VEGETATED SIDE SLOPE

SLOPE

HEADWELL MONITOR

2FT THICK RECOMPACTED CLAY LINER

1FT COVER SOIL INCLUDING 4" MIN. TOPSOIL

Wisconsin’s Industrial Byproduct Beneficial Use Program – Paul Koziar
Review of reuse under NR 538

- Reuse rate for Coal ash > 80%
- Specific requirements for environmental and engineering controls have encouraged more reuse
- Concrete/cement and geotechnical fills largest uses
- To date, most geotechnical fills for roadways and airports
- Approximately 100 projects for coal ash
- Required monitoring of large projects has shown no potential detrimental effect on groundwater quality
- New air emission controls changing the physical character of coal ash
Beneficial Reuse Management

Bob Spoerri
CEO
212 W. Superior, Suite 402
Chicago, IL 60654
• **Concept:** Create partnerships between industrial companies that generate materials suitable for beneficial reuse and land owners and others that can utilize these materials in compliance with regulatory and technical requirements

• **Current Materials:** Foundry sand, coal ash, FGD Gypsum and paper processing residuals

• **Current Types of Projects:**
  - Sub-grade fill for a wide variety of construction projects such as new buildings, road and parking lot construction, and roadside sight & sound barriers
  - Agricultural and horticultural applications including soil amendment and manufactured soils

• **Benefits to:**
  - **Industrial Partners:** Reduced costs relative to the alternative cost of land fill disposal. Reduced need for expanded wet impoundments.
  - **Project Partners:** Reduced costs versus using new virgin materials.
  - **The Environment:** Conservation of natural resources, preservation of landfill space, and Reduced CO2 emissions
  - **The Economy:** Enhanced economic viability for public projects, small business expansion, agricultural infrastructure & property development. Conversion of marginal land into productive, taxable use. Creation of new jobs.

*Beneficial Reuse Management – Bob Spoerri*
Beneficial Reuse Management has completed more than 200 beneficial reuse projects and has diverted more than 2 million tons of industrial byproducts from landfills.
The Process

Feasibility
- Materials testing and technical evaluation
- Project/Product identification
- Evaluation of reuse economics

Design and Approval
- Project design and engineering
- Regulatory submittal, review and approval
- Project permits, notices and public meetings

Implementation
- Subcontractor selection and contract negotiation
- Project Management & Oversight
- Project documentation and completion

Beneficial Reuse Management – Bob Spoerri
TYPICAL CROSS SECTION OF UNCONFINED FILL (CATEGORY 2 & 3 MATERIAL)

TYPICAL CROSS SECTION OF CONFINED FILL (CATEGORY 4 MATERIAL)

Beneficial Reuse Management – Bob Spoerri
Business Expansion
Indianapolis Power & Light/TKO Graphics - Indianapolis, Indiana

Before

During

Completed Project:
30,000 Yd³ Coal Ash

Beneficial Reuse Management – Bob Spoerri
Public Infrastructure
Midwest Generation/Chicago Land Speedway – Joliet, IL

Before

During

Completed Project:
12,000 tons Coal Ash

Beneficial Reuse Management – Bob Spoerri
Agricultural Infrastructure
Xcel Energy/Grubisic Farms, Inc. – Mason, WI

Beneficial Reuse Management – Bob Spoerri
Full Circle Solutions, Inc.
35 North Main Street, Suite A
Jasper, Georgia 30143

Bob Waldrop
Executive Vice President
20 + Years of Service to:
- Independent Power Producers
- Small Coal-Fired Industries
- Utilities

Over 10 Million Tons of CCPs Beneficially Reused
CCP GEOTECHNICAL FILL
TYPICAL CROSS-SECTION

VEGETATIVE SUPPORT LAYER
(SOIL)
INfiltration Layer
(SOIL)
Barrier Layer
(COMPACTED CCP)
Permeability: $1 \times 10^{-8}$ cm/sec
Placed CCP
Separation Fabric
Drainage Layer
(Granular Material)
Prepared Subbase
(Natural Ground)
Seasonal High Water Table
Groundwater
(Natural Aquifer)
Perforated Drainage Pipes to Stormwater Basin for On-Site Use

0' minimum
1' minimum
1' minimum
Variable Thickness
2' minimum
2' minimum
2' minimum

Note: Top slope 2% minimum.
Sideslopes 3:1 maximum.

Full Circle Solutions – Bob Waldrop
CCP GEOTECHNICAL
FILL
TYPICAL CROSS-SECTION

TYPICAL CROSS-SECTION
NOT TO SCALE

Full Circle Solutions – Bob Waldrop
THANK YOU