2003 International Ash Utilization Symposium, Center for Applied Energy Research, University of Kentucky, Paper #21. 

# Bottom Ash Use in Utility Joint Trench Operation

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## I. Abstract

The use of Bottom ash in backfilling utility joint trenches is the combined efforts of several departments working together to solve two different problems. First problem, find a cheaper alternative to sand; second problem, find cheaper disposal means for bottom ash.

The electric distribution arm of The Cincinnati Gas & Electric Co (CG&E), subsidiary of Cinergy Corp., has used sand for years in backfilling joint trench utilities of gas, electric, telephone, and CATV. New regulations were going to require more sand to be used increasing the cost of the joint trench operation.

The By-Products arm of CG&E is always looking for lower cost disposal of its bottom ash.

These two groups have been working on other projects together for years and at an erosion control meeting the two groups were talking about sand when the idea was created, why not use bottom ash in place of sand?

After much testing, discussion and a few trials, it was determined bottom ash was a safe and cheaper alternative to sand in the use in utility joint trenching saving over $7/ton versus using sand.

This project was compiled as part of an initiative to investigate the beneficial use of bottom ash as a replacement for sand. The principal sponsors of the bottom ash initiative were Rick Mack, Operations Services & Applied Technology; Dave Fries, Joint Trench Operations; Dave Beck, Bill Kraemer, & Dave Thiem, By-Products Management; Randy Born, Environmental Water Quality and Waste. The research and compilation of this report were done by the following departments -- Joint Trench Operations, By-Products Management, Engineering Standards and Support, Water Quality and Waste, Operational Services, and Applied Technologies. Without each department's hard work and support this effort would not have been possible.

## II. Introduction

Changes to the NESC code requirement will impact the way electrical underground residential distribution (URD) systems are installed. The new ruling will require separation distances for URD systems to increase from 6” to 12” separations. When ratified, the changes in separation requirements will significantly increase the amount of sand needed in the multi-utility trench.

Realizing that large increases in future sand purchases were looming, efforts were made to locate a suitable and economical replacement for sand. Discussions between departments internally to the company led to the investigation of testing bottom ash for the replacement to sand.

The multi-utility (joint) trench refers to the method used in all new subdivisions and developments for installing all utilities in one underground trench. The utilities include electric, gas, telephone, and CATV. This trench is then backfilled with sand. The sand is used in place of the native soil to help in dissipate heat generated from the electric cable, which is the deepest utility in the trench.

Bottom ash refers to the coal ash byproduct, formed in pulverized coal furnaces, which are too large to be carried in the flue gases and therefore fall to the bottom of the furnace into a dry bottom ash hopper. As the bottom ash is removed from the hopper, it is then passed through a grinder for size reduction, and resembles course sand in size and shape. The major components of the bottom ash material are silicon (Si), aluminum (Al), iron (Fe) and calcium (Ca). Bottom ash is often used in place of natural aggregates in many applications, including backfill and pipe bedding for underground pipes and leachate lines.

Cincinnati Gas & Electric (CG&E) currently produces over 130,000 tons of bottom ash at their pulverized coal-burning power plants each year. The majority of the waste byproduct is disposed of in structural fills throughout greater Cincinnati, with an average disposal cost of $5/ton. Using bottom ash as a replacement for sand would allow substantial savings as a beneficial use of the bottom ash and avoided costs for not buying sand.

The bottom ash had to meet the same standards as the sand for thermal resistivity and meet the State of Ohio EPA Guidelines for beneficial use standards. The potential savings were over $7/ton for the CG&E for each ton of bottom ash used to replace sand.

## III. Objectives and Research

### A. Environmental Factors

The reuse of coal combustion products are not specifically authorized under Ohio law or regulations, but the reuse of non-toxic bottom ash is authorized under a policy document issued by the Ohio Environmental Protection Agency’s (OEPA) Division of

Surface Water, on November 7, 1994 titled "*Beneficial Use of Nontoxic Bottom Ash, Fly Ash, and Spent Foundry Sands and Other Exempt Waste"* (DSW 0400.007). This policy allows for the use of non-toxic bottom ash to be used as pipe bedding, for uses other than potable water.

The Beneficial Use of Nontoxic Bottom Ash, Fly Ash, and Spent Foundry Sands and Other Exempt Waste policy defines non-toxic bottom ash as the "bottom ash generated by fuel burning operations which burn fuel, primarily coal, where the leachate does not exceed thirty (30) times the levels specified in O.A.C. Rule 3745-81-11(B) for any parameter listed in the following table". The toxicity levels for CG&E produced bottom ash fall well below the published Drinking Water Standards, and are listed in table 1 for comparison.

| Parameter | **Drinking Water Standards, or DWS (mg/L)** | **Nontoxic Criteria = 30x Standard (mg/L)** | **Cinergy Generated Bottom Ash (mg/L)** |
|---|---|---|---|
| **Arsenic** | 0.05 | 1.5 | 0.012 |
| **Barium** | 2.00 | 60.0 | 0.06 |
| **Cadmium** | 0.005 | 0.15 | 0 *** |
| **Chromium** | 0.1 | 3.0 | 0 ** |
| **Lead**** | 0.050 | 1.5 | 0 ** |
| **Mercury** | 0.002 | 0.06 | 0 *** |
| **Selenium** | 0.05 | 1.0 * | 0 ** |

**Table 1.** Ohio Primary Maximum Contaminant Levels - O.A.C. Rule 3745-81-11(B)

* For bottom ash to be considered nontoxic, the selenium concentration in the leachate may not exceed 1.0 mg/L.

** Detectable limit is equal to 0.005 mg/L.

*** Detectable limit is less than or equal to 0.002 mg/L.

**** For purposes of this policy, this number will be referenced as a drinking water standard (DWS).

According to Ohio's "Beneficial Use" policy, the bottom ash to be generated at CG&E power plants for use in underground residential distribution (URD) systems are considered Category 1 material. Category 1 materials are defined as those beneficial uses, indicated with an "x" in Table 2: Types of Beneficial Uses, which do not require Ohio EPA review or notification. The bottom ash, classified as Category 1 material, is not subject to annual reporting, isolation distance requirements, or other criteria applicable to all Category 2, 3, and 4 classified material. The "*General Requirements Applicable to All Beneficial Use Projects*" are the only conditions relevant to CG&E's underground residential distribution (URD) systems.

| Types of Beneficial Use | RW or OEW | Non-Toxic | | 20x DWS | | 10x DWS | | 5x DWS | | DWS | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | FA | BA | FA | BA | FA | BA | FA | BA | FA | BA |
| Manufacturing another product | x | x | x | x | x | x | x | x | x | x | X |
| Stabilization of other wastes | x | x | x | x | x | x | x | x | x | x | X |
| In composting process | x | x | x | x | x | x | x | x | x | x | X |
| Subject to procurement guidelines | | x | x | x | x | x | x | x | x | x | X |
| With ODNR approval | | x | x | x | x | x | x | x | x | x | X |
| Anti-skid agent/road surface prep | | | x | | x | | x | | x | | X |
| Soil blending ingredient | | | | | | | | x | x | x | X |
| Daily cover @ landfill | | | x | | x | | x | | x | | X |
| Structural fill | | | | xx (600-30k Tons)<br>o (< 600 Tons) | | | | xx (600-30k Tons)<br>o (200 Tons - < 600 Tons) | | xx (>30k Tons)<br>o (600-30k Tons)<br>x (<600 Tons) | |
| **Pipe bedding** | | | | | | | | **x** | **x** | **x** | **X** |
| Roads/parking lots | | | | | | | | x | x | x | X |
| Commercial uses (general) | | | | | | | | x[1] | x[1] | x[1] | x[1] |
| Generator give-away | | | | | | | | | | x[2] | x[2] |
| Borrow pits | | | | o[1] | o[1] | o[1] | o[1] | x[1] | x[1] | x | X |

**Table 2.** Types of Beneficial Uses and Categorization

FA = Fly ash; BA = Bottom Ash; RW = Residual Waste; OEW = Other Exempt Waste
Note: Phenol, Cyanide, and Fluoride criteria only apply to spent foundry

x Category 1 = No Ohio EPA review or notification.
o Category 2 = Annual Report, isolation distances, other criteria.
xx Category 3 = (30) Thirty-day prior notification to Ohio EPA; isolation distances, other criteria.

Per Ohio EPA's guidelines there presents no reason to not use the bottom ash in place of sand as long as the bottom ash is used in the following manners:

1. Does not create a nuisance condition or used in a manner that is likely to cause an adverse impact to public health or the environment.
2. Storage piles should not create a nuisance and erosion control practices shall be used.
3. Not be used, without a permit, in projects that would include placing the bottom ash in a streambed, wetland, or well field.

**B. Technical Factors**
Altering the parameters of an underground residential distribution (URD) system can cause the problem of derating the cable's ampacity limit. Changing the soil surrounding the electrical cable can negatively impact the amount of current that can safely flow through the cable.

### 1. Cable Ampacity

Cable ampacity determines the current carrying limits (ampacity) of an electrical cable. Power losses in the conductors of the electric cable, dielectric losses in the insulation and eddy currents in the sheath all generate heat. The amount of heat buildup in the cable material and its ability to dissipate the heat directly determines the current rating for the cable. While many factors influence the cable ampacity rating, the *key variables* in underground cable ampacity are – *installation depths, cable separation, soil temperature, installation method, and soil thermal resistivity*.

The key factors of thermal resistances:

1. **Installation Depth** – deeper cable depths increases the total soil resistance.
2. **Cable Separations** – adjacent cables contribute heat and may induce more losses.
3. **Soil Temperature** – warmer soils can absorb less heat.
4. **Soil Thermal Resistivity** – a measure of how well the soil carries away heat.
5. **Installation Method** – direct-buried cable, dissipates heat better than a cable within duct.

| Variables | Value | Effect on Ampacity |
|---|---|---|
| Installation Depth | Deeper | Less Ampacity |
| Cable Separation | Smaller | Less Ampacity |
| Soil Temperature | Higher | Less Ampacity |
| Soil Thermal Resistivity | Higher | Less Ampacity |
| Installation Method | Duct, rather than direct-burial | Less Ampacity |

**Table 3.** Key Variables for Underground Cable Ampacity

### 2. Soil Thermal Resistivity

Thermal resistivity is a specialized measurement that quantifies how well a material can dissipate heat. The thermal resistivity of the surrounding soil is the principle factor determining how much heat the URD cable is able to release. An "ideal" soil is one of low thermal resistivity; the lower the soil thermal resistivity value the better the soil is for heat dissipation.

American Electric Power (AEP) conducted the soil thermal resistivity tests at the AEP Dolan Technology Center located at 1 Riverside Plaza in Columbus, OH. These tests were performed as prescribed by the IEEE standard 441-1981 -- *Guide for Soil Thermal Resistivity Measurement*. Each sample was tested "as received" and at approximately 15% moisture content. The results of the soil thermal resistivity tests are recorded in Table 4.

| | **Washed Sand** | **Beckjord Unit 5** | **Beckjord Unit 6** | **Miami Fort Unit 7** | **Miami Fort Unit 8** | **Zimmer** |
|---|---|---|---|---|---|---|
| **Thermal Resistivity As received** | 89 | 128 | 140 | 133 | 132 | 159 |
| **% Moisture** | 5.7 | 24.0 | 43.8 | 23.5 | 30.4 | 9.2 |
| | | | | | | |
| **Thermal Resistivity @ 15%** | 29 | **119** | 158 | **116** | 136 | **125** |
| **% Moisture** | 15.0 | 14.7 | 15.1 | 15.5 | 15.9 | 15.0 |

**Table 4.** Thermal Resistivity Results of Tested Bottom Ash & Sand Samples

### 3. Thermal Resistivity Assessment

Engineering Standards and Support evaluated the effects of using bottom ash, with its higher thermal resistivity, for underground residential distribution URD) systems installed in 2-inch PVC conduit. The calculations indicate that cable ampacity will fall slightly (< 5%) in URD systems using bottom ash as a replacement for sand. While the cable ampacity ratings would decrease slightly, CG&E Engineering Standards and Supports will allow bottom ash to be used as replacement for sand under certain conditions:

1. Only materials with a thermal resistivity value of 125 or less at 15% moisture content may be used. Based on the test reports, only bottom ash from Beckjord Unit #5, Miami Fort Unit #7, and Zimmer may be used for backfill around URD cables, therefore only 100,000 tons of the 150,000 produced can be used.
2. This material must NOT be used for any installations where feeder cables with conductor sizes greater than #4/0AL are installed -- *substation exits, mainline*

*dips, mainline underground installations done by commercial or industrial developers*.

3. Periodic re-testing of the thermal resistivity is suggested to insure that the materials are staying within acceptable limits.

**4. Economic Factors**

**a. Joint Trench Operations** buries 450 to 500 thousand feet of multi-utility trench each year. The most expensive component in laying the trench is the purchase and placement of the sand material. CG&E currently pays $7.50/ton to purchase and haul the sand material from the aggregate suppliers to the various project sites. Joint Trench purchases 90 to 100 thousand tons of sand each year. With the proposed 12-inch separation requirement, the annual cost for sand could increase by $350,000.

**b. By-Products Management** manages the disposal of 100,000 tons of acceptable bottom ash each year. This bottom ash is currently disposed of in structural fills averaging a cost of $5/ton for hauling and placing.

**c. Cost Structure**

Using bottom ash as a replacement for sand in URD systems can significantly reduce the cost Joint Trench pays for the pipe bedding material and the cost ByProducts pays for disposal of the bottom ash. The current arrangement is that each department pays half of the transportation of the bottom ash to each joint trench site. These sites range in 5 to 45 miles from the Generating Stations. The maximum cost to each department should not be greater than $3/ton, providing significant savings to both departments. Material needs and current costs are summarized in table 5.

| Process Owner | Current Trenching | Trench Fill Material | Current Costs |
|---|---|---|---|
| **Joint Trench Usage** (6-inch separation) | 450,000-500,000 ft/yr | 90,000-100,000 tons (needed) | $675,000-$750,000 @ $7.50/ton |
| **By-Products Management** (Bottom-Ash Produced) | | 100,000 tons (produced) | $5/ton |

**Table 5.** Annual amount of trench material needed / bottom ash produced.

**d. Combined Savings**

Significant economic savings can be achieved by using bottom ash as a replacement for sand in the URD system. The combined savings in lower material costs and reduced landfill expenses are $600,000 each year. The cost of the material would remain fairly static, eliminating CG&E's exposure to variations in aggregate costs. Current costs, proposed costs, and estimated savings are summarized in table 6.

| Process Owner | Current Cost (2001) | Proposed URD Usage | Estimated Annual Savings* |
|---|---|---|---|
| **Joint Trench** | $600,000<br>@ $7.50 /ton | $200,000<br>@ $2.5 /ton | $400,000 |
| **By-Products Management** | $400,000<br>@ $5 /ton | $200,000<br>@ $2.5 /ton | $200,000 |

**Table 6.** Current costs, Future costs, and estimated savings.

* All calculations based on 80,000 tons bottom ash per year.

## IV. Conclusions

Through testing and certain restrictions it has been determined that two-thirds of CG&E's bottom ash can be used for backfill in URD installations in place of sand providing savings to both Joint Trench and By-Products departments. Savings are estimate to be $7.5/ton for each ton of bottom ash used. Original estimates are that 80,000 tons of bottom ash will be used annually providing CG&E with $600,000 in annual savings.

### Actual Savings

Through the first three months of using bottom ash in place of sand have provided the following results in table 7.

| Process Owner | Actual URD Usage (Aug '02– Aug '03) | Actual Costs | Estimated Annual Savings* |
|---|---|---|---|
| **Joint Trench** | 48,411 tons bottom ash | $127,662<br>@ $2.64 /ton | $235,277 |
| **By-Products Management** | | $127,662<br>@ $2.64 /ton | $114,250 |

**Table 6.** Actual usage for last 12 months.

The combined savings are $349,527 for using 48,411 tons of bottom ash for the first 12 months of the program. During these 12 months only about 3/4 of the projects were implemented using bottom ash as Joint Trench was doing a phase in approach to the operation and there was an outage on Miami Fort #7.

## V. Keywords

Bottom Ash
Underground Utilities
Joint Trench
Underground Residential Distribution (URD)

## VI. References

Ohio Environmental Protection Agency, 1994, Beneficial Use of Nontoxic Bottom Ash, Fly Ash, and Spent Foundry Sand, and Other Exempt Waste, Division of Surface Water policy (DWS 0400.007), November 7, 1994.

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# Bottom Ash Use in Utility Joint Trench Operation

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2003 International Ash Utilization Symposium

October 2003

# Bottom Ash Use in Utility Joint Trench Operation

- Cinergy produces 150,000 tons/yr of bottom ash in the Greater Cincinnati area
  - Many marketers have tried to market the bottom ash without success
    - Block plants – too friable
    - Aggregates – too much competition from sand and gravel
    - Anti skid – not enough snow and too many large particles
  - Mainly used in structural fills and backfills
    - Average cost of $5-6/ton
- Cinergy's ByProducts Group continuously looks for cheaper bottom ash uses

# Bottom Ash Use in Utility Joint Trench Operation

- Employees idea of trying to replace sand with bottom ash in underground utilities trench
  - All new subdivisions use underground utilities
    - Done by Cinergy's Joint Trench Department
    - Utilities are electric, gas, cable tv, and telephone
      - All are buried in one trench and backfilled with sand
      - 90-100,000 tons of sand are used each year
      - Sand was used as it has better thermal dissipating capabilities than soil  - to allow the electric cables to not overheat

# Bottom Ash Use in Utility Joint Trench Operation

- Group was put together to investigate benefits and risks
- Benefits
  - Savings in not buying sand
    - Sand cost ~$7.50/ton delivered
  - Savings in bottom ash disposal costs
    - Costs are $5-6/ton
  - Total savings of $600,000 per year
- Risks
  - Thermal conductivity of bottom ash vs. sand
    - Could cause electric cables to overheat, lowers cable ampacity
    - Thermal conductivity of sand is 29 C cm/W
    - Thermal conductivity of bottom ash ranged from 119 to 158 C cm/W

# Bottom Ash Use in Utility Joint Trench Operation

- Risks (continued)
  - Thermal Conductivity (continued)
    - It was determined that bottom ash with thermal conductivity of less than 125 C cm/W could be used and not cause overheating
      - **About 100,000 tons of bottom ash meet the <125 C cm/W limit.**
  - Environmental concerns
    - Does it meet beneficial use guidelines?
      - **Meets Ohio EPA guidelines as pipe bedding**
      - **Meets Kentucky statue as structural fill**
    - Dusting
      - **Bottom ash is used within 1-2 days, eliminating drying out and dusting concern**

# Bottom Ash Use in Utility Joint Trench Operation

- Actual Results:
  - For the last 12 months, 48,411 tons of bottom ash were used at a total cost of $5.28/ton
  - Savings to Generation plants was $2.36/ton
  - Savings to Joint Trench Operations was $4.86/ton
  - Total savings of $349,527 in the last 12 months
    - Reasons for less usage
      - Miami Fort #7 outage in spring 2003 for 7 weeks
      - Economy slowdown – less housing and development
      - Cold winter caused freezing of bottom ash, stopped for about 6 weeks

# Bottom ash being loaded at Miami Fort Station

# Bottom ash being delivered to site

# Bottom ash at site

# Cables being installed from pole

# Cables in underground trench

# Bottom Ash being placed in trench

# Bottom Ash being placed in trench