Sampling, Testing and Instrumentation of Ponded CCR Impoundments

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Presentation Outline / Overview

Safety Share and Outline of Site Condition Assessment Framework

Surface Impoundment Technical Considerations for Closure

Sampling & Testing of Ash Ponds

- Sampling & Testing for Closure
- Sampling & Testing for Potential Ash Harvesting
- Site Conditions & Equipment Platforms
- Economic Considerations
- Access Planning & Safety Considerations
- Investigation and Sampling Methods
- Importance of Monitoring and Potential Verification Testing

Monitoring Case Studies

Planning & Evaluation for Potential Future Harvesting
Safety Share -
CCR Pond Construction Access
Evaluation, Monitoring, and Proofing
Methods
Unique Challenges & Safety Risks Working in and Over Ash

- Balance Safety Risks with Data Needs
- Spatial Variation/Segregation of Ash
- Chemical Effects (Class C, F, Bottom, Gypsum,)
- Repetitive Motion Concerns (Liquefaction Risks)
CCR Pond Construction Access Evaluation, Monitoring, and Proofing Methods

World of Coal Ash 2017
May 11, 2017

Gregory Hebeler, PhD, PE
Grant Martin, EIT
Mitigating Risks – One Potential Framework

1. Assess Risks
2. Evaluate Ash Pond Conditions
3. Engineer Controls
4. Verify Efficacy of Controls

Mitigation of Risks

Acceptable Risk Level

Risk Level

Base Case  Assess  Evaluate  Engineer  Validate

Repeat Framework
Surface Impoundment Closures
Technical Design Drivers
Surface Impoundments – Technical Considerations for Closure

Material Characterization

Stability Evaluations

Settlement & Capping

Liquefaction Potential

DeWatering

Future Harvesting
Geotechnical Investigation Objectives
Sampling and Testing Needs for Closure

• What are we dealing with?
  • CCR (Pond / Stack / Combination)
  • Quantity & Type of CCR
  • Embankments
  • Foundations

• How will material behave?
  • Additional / Reduced static load
  • Additional dynamic load
  • Changes in water levels
  • Long-term settlement
  • During construction & Interim Conditions

• How best to investigate? Access issues?
  • Focus Testing on Critical Design Areas
  • Do you have the data to evaluate PFMs and Interim Conditions?
Engineering Design Drivers for CCR Closures

- **Water Levels and Control** are **Keys to Design and Monitoring** of these Systems

- Sluiced and Uncompacted Materials can show significant strength when dried but **retain risk of return to low strengths and liquefaction / flow susceptibility** if saturated and containment is lost

- Obtain **Enough Data to Evaluate PFM and Potential Critical Interim Conditions**

- **Economic & Risk Trade offs** Between: Material and Placement Controls & Engineering and Monitoring Controls.
Beneficial Reuse Characterization Objectives

• Evaluate the CCR Resource
  • Quantity – Develop Volumetric Estimates / Models by Material Type
  • Resource Map the CCR Unit
• Quality of CRR for reuse
  • Material Variability Vertically and Laterally
  • Disturbed samples typically fine for Beneficial Use Evaluations
• Application / Use Options Evaluations (Concrete, Fill, other)
• Define the Market, Transportation, and Other Conditions

• Is Beneficiation Required?
  • What kind (Carbon control, drying, material separation, thermal, etc.)
  • Constraints on use opportunities

• Leverage operations, construction activities, and other investigation programs to systematically obtain samples for beneficial use characterization.

• Can closure be situated / staged to improve potential future harvesting?
Beneficial Use Evaluations
Sampling & Testing at Ash Ponds
CCR Distinctives

- Soil-like
- **Traditional correlations don’t always apply**
- Spherical particles
- Small size, but relatively high permeability
- Light weight
- Can be lightly / heavily cemented
- Highly erodible
CCR Distinctives

SEM Images

Compacted Ash Zones

Top

Bottom
Conditions often vary often short distances based on current and historic operations
Bottom Ash Stringers / Lenses

CCR Sampling – Material and Deposition Considerations
Site Conditions & Equipment Platforms
CCR Sampling - Field Exploration

Range of CCR Sampling Conditions:

- Compacted / Stacked / Landfills
- Saturated / Loose / wet
- Supernatant Pond Areas
Range of Site Conditions

**Stacked Conditions**
- Capable of supporting all types of equipment

**Soft Conditions**
- Surface will support small loads and LGP equipment

**Open Water Conditions**
- Free water within the unit is generally navigable by marine equipment

- **Small Hand Operation Equipment / Platforms**
  - Truck or ATV Mounted Equipment / Platforms
  - Track Mounted Equipment / Platforms
  - Amphibious Equipment / Platforms

- **Small Open Water Equipment / Platforms**
- **Medium Open Water Equipment / Platforms**
- **Large Open Water Equipment / Platforms**
Dry conditions are easily managed with traditional investigation and sampling platforms that are tracked (left), truck (middle), or ATV (right) mounted.
Open water site conditions can be investigated using platforms ranging from a canoe/kayak (left) and skiffs (middle), to moderately sized barges (right).
Simple Overwater Sampling – Jon Boat with Moon Hole
Small Jack-Up Barges Effective for Sampling up to 30 to 40 feet of water depth... other solutions needed for sampling / profiling deeper water
Soft conditions require amphibious equipment (left & middle) or investigation and sampling equipment mounted on an amphibious platform (right).
Amphibious Platforms & Support Equipment
Use of cribbing/mats to distribute the load (left) or construction of a working platform (right) provide a means of mobilizing traditional rubber-tired equipment over soft site conditions.
Case Study – Geotech Access Evaluation

3 Phase Evaluation:
• Hand Probing + Hand Augering
• CPTu
• Proof Rolling

\[ q_{ult} \approx \frac{q_t}{3} \]
Case Study – Geotech Access Evaluation

- Bearing pressure of rig compared to allowable from CPTu
- Point A near historical sluice spigot
- Crust degrades with distance from spigot

\[
FS = \frac{q_{ult}}{q_{rig}}
\]
Case Study – Geotech Access Evaluation
Case Study – Investigation and Construction Access Guidelines

• From data collected, recommended:
• Progressive Access Proofing for Investigation and Construction
• Water Management During Construction:
  • Well Point System
  • Stormwater Diversion Berms / Ditches
  • Deep wells
• Verified with piezometers and observation methods
Investigation and Sampling Methods
CCR Sampling & Testing Methods – Hand Sampling Techniques
CCR Sampling & Testing Methods – Drilling Techniques
## CCR Sampling & Testing Methods – Drilling Techniques

<table>
<thead>
<tr>
<th>Drilling Methods</th>
<th>Moisture</th>
<th>Density</th>
<th>Material Type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Wet</td>
<td>Moist</td>
<td>Dry</td>
</tr>
<tr>
<td>Solid Auger</td>
<td>X</td>
<td>✓</td>
<td>maybe</td>
</tr>
<tr>
<td>Hollow Stem Auger</td>
<td>ok, may need to charge augers</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Sonic</td>
<td>ok, may cause material to flow</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Mud-Rotary</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>
CCR Sampling & Testing Methods – Drilling Samplers & Tests

Standard Penetration Test (SPT)
- Widely available
- Disturbed sample obtained
- Quantitative density/strength indicator
- Less repeatable
- Correlations developed for natural soils and require calibration for use in CCR

Vane Shear Test (VST)
- Undrained shear strength
- Peak and Residual Strengths
- Correlate to CPT and lab testing
- Perform in conjunction with sampling

Piston Sampler
**CCR Testing Methods – CPT**

- **Capping Soil**
- **Compacted CCR**
- **Sluiced CCR**
- **Underlying Foundation Soils**

![Diagram](image_url)

**Cone Penetration Test (CPT)**

*per ASCE 5170 procedures*

- $f_c$ - sleeve friction
- $u_p$ - porewater pressure
- $A_s$ - net area ratio (from tip calibration)
- $q_m$ - measured tip stress or cone resistance
- $q_c$ - corrected tip stress = $q_m - (1-A_s)u_p$

1. Saturate cone tip cavity and placement of pre-saturated polyurethane blanket
2. Obtain borehole readings for tip, sleeve, parameter transmitter and inclinometer channels

*Continuous Hydraulic Push at 30 mps; Add rod every 1 m.*

*Courtesy of Paul Mayne*
Example CPT Interpretation of CCR
CCR Behavior

**Stacked**
Generally achieves good strengths & is not prone to liquefaction

**Sluiced, then dried**
CRR that remains dry also exhibits significant peak strengths but maintains low residual & post liquefied strengths

**Sluiced and still wet**
CCR typically exhibits residual strengths close to NC behavior and very small strength increases with depth (cemented structure)

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Theoretical NC Undrained Strength Ratio $\frac{S_u}{\sigma'_{v0}} = 0.22$
In-Situ STATE

**Stacked** Typically Dilative and with Negative State Parameter

**Sluiced & Dried** Typically dilative and with slightly Negative State Parameter

**Sluiced & Wet** Typically contractive in-situ with Positive State Parameter
Example CPT Interpretation of CCR – Evaluation of Compaction / Density

- Compacted / Stacked Ash
- Difficult / Weak Sluiced Ash Layer
Direct Push Geoprobe sampling techniques allow for rapid and continuous sampling from various platforms making it a potential method for most site conditions.
CCR Sampling Methods – Geoprobe

Geoprobe investigations can be conducted from various platforms making it a potential method for most site conditions.
Electrical Resistivity Imaging (ERI) Field Investigation Process Illustration
Geophysical equipment for land, marine, and amphibious applications provide a means to profile and delineate the bottom of a CCR Unit over long linear distances.
CCR Pond Sampling, Testing, & Construction Access

Assessment, Evaluation, Engineering Controls, Monitoring, and Proofing Methods
Assessment of Risks

Key Questions
- Who/What needs access?
- Where is access needed?
- What do we know about the ash pond?
- Emergency Action Plans (EAP)?
- Resources to deal with emergencies?

Actions
- Limit access (where, who, and what)
- Gather historical and aerial photographs, construction and operation records, interviews with plant operators, etc.
- Develop EAP in case equipment or personnel become stuck in ash
Field Evaluation of Ash Conditions

Main Data of Interest
- Strength of Ash
- Water Level Within Ash
- Depth / Limits of Ash

Observational Methods
- Hand Auger and Hand Probe
- Geoprobe
- Test Pit
- Proofing Methods

Quantitative Methods
- Manual Tools
  (Hand Vane Shear Test, DCP, HPT)
- CPTu
- Vane Shear Test (VST)
- SPT

Re-evaluate Conditions After Rain Events, Other Changed Conditions, Incrementally Through Construction for Critical Areas
Engineering Controls

• **Water Management**
• Geosynthetics / Crane Matting
• Monitoring & Verification Hold Points
• Excavation & Cut Slope Guidelines & Restrictions
• Dewatering and Filling Rate Limits
• Undercutting and Replacement of Known Trouble Areas
• Use Technologies to Limit the Need to have people and equipment in harm’s way – Remote Monitoring & Drone’s, etc.
Construction Verification Testing
Location #1 -
See very distinct changes in CPT pore pressure response and correspondent large increases in correlated friction angle and undrained shear strength over the dewatered zone.
Pre & Post Dewatering CPT Testing

Location #2 -

More moderate reductions in CPT pore pressure response and corresponding more moderate increases in correlated friction angle and undrained shear strength over the dewatered zone.
Pre & Post Dewatering CPT Testing

Location #3 -
Removal of 15-20 feet of ash via excavation – very minor changes in CPT pore pressure response and corresponding minor to no change in correlated friction angle and undrained shear strength over the dewatered zone.
Key Take Aways

• **Focus Testing and Sampling on Objectives and Areas of Higher Consequence** – Sampling and Testing Data not needed everywhere, but sufficient coverage to adequately evaluate range of PFMs and focused in areas of critical infrastructure and/or consequence.

• **Dewatering Systems** – Water Levels Often Key to Stability, Surface Water Controls Key to Successful Dewatering, Well Designs Can Typically be Aggressive

• **Monitoring & Verification of Design Assumptions Ahead of & During Construction** – Water Level Tracking, Assessment of Material Behavior Changes with Dewatering, Loading (Stacking) and Unloading (Excavations), Confirmation Testing Before and During Construction – CPT a quick and effective tool for both, Remote Monitoring Tools.
Construction Monitoring Examples
Manual Inclinometer
For Each Sensor

In-place Inclinometer

Sensor  Wheels  Gauge Tube
Telemetry

VM

Atlas

Computer

Email
Slope Monitoring Instrumentation – VW Piezometers and Inclinometers

No Vertical Exaggeration
Water Level Monitoring

Porewater Elevation

- P1 VW-1 759 (Elev)
- P2 VW-2 794 (Elev)
- P2 VW-3 779 (Elev)
- P2 VW-1 759 (Elev)
- P2 VW-2 782 (Elev)
- P3 VW-1 803 (Elev)
- P3 VW-2 770 (Elev)
- P3 VW-3 781 (Elev)
- P4 VW-1 774 (Elev)
- P4 VW-2 751 (Elev)
- P5 VW-1 775 (Elev)
- P5 VW-2 785 (Elev)
- P5 VW-3 815 (Elev)
- P6 VW-1 761 (Elev)
- P6 VW-2 763 (Elev)
- P7 VW-1 803 (Elev)
- P7 VW-2 783 (Elev)
Slope Inclinometer Monitoring
Working on Saturated Ash
Pore Water Pressure Monitoring

Data ties back to Safety Plan.
• Yellow Zone in areas where pore water pressures are reading 200 – 400 psf.
• Red Zone…No equipment in areas where pore water pressures are reading above 400 psf or where there is a sudden rapid increases over 75 psf.
Cover Monitoring Techniques
Light-Weight Cover Systems
Test Strip
Thermal Evaluation
Potential for Future Harvesting
Beneficial Use Evaluations
Beneficial Use Evaluation Dashboard
Beneficial Use – LOI & Particle Size Profiling
Beneficial Use Index Property Profiling

MEDIAN PARTICLE SIZE, LOSS ON IGNITION, & MOISTURE CONTENT

- Median Particle Size, D50 (μm)
- Loss On Ignition - LOI (%)
- Moisture Content (%)

![Graphs showing data for median particle size, loss on ignition, and moisture content.](image-url)