Geosynthetics for CCR Applications

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Fabricated Geomembrane Institute
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Outline of Presentation

• Review of CCR Rule Language
• Bottom Liner Systems
  • Design Scenarios
  • GCL Hydraulic Conductivity Testing
  • Additional Design Considerations
• Cover Systems
  • Design Scenarios
  • Design Considerations
• Constructability
  • Geocomposite Drainage Outlets
  • Tie-ins at Structures and Pipe Penetrations
  • Geomembrane Deployment
  • Electrical Leak Detection
• Questions
• Published – Friday, April 17, 2015
  - Additional Documentation
  - Additional Analysis
  - Improvements
  - Design Changes

- Both State and Federal Regulations
• Result:
  - Closures of inactive/ not needed facilities.
  - Force reviews of existing facilities
  - Require regular inspections and annual review by Professional Engineer
  - Changes future construction and new designs

• 257.70 and 257.72:
  - Design Criteria for Bottom Liner System for Landfills and Surface Impoundments

• 257.102:
  - Design Criteria for closure of Landfills and Surface Impoundments
• Bottom Liner System
• (257.70 – Landfills, 257.72 – Surface Impoundments)
  ➢ Composite Liner:
    • Geomembrane (GM) / Compacted Clay Liner (CCL)
    OR
    • GM/equivalent liner to CCL (i.e. Geosynthetic Clay Liner)

Leachate Collection System (Typ. 2 feet)

Compacted Clay Liner (Typ. 3 feet)

CCL Only (non-CCR Rule)
Examples

- **Leachate Collection System (Typ. 2 feet)**
  - Compacted Clay Liner (Typ. 3 feet)

- **Geomembrane**
  - **Leachate Collection System (Typ. 2 feet)**
  - Compacted Clay Liner (2 feet)

- **CCL Only (non-CCR Rule)**

- **Composite Liner**
  - **Leachate Collection System (Typ. 2 feet)**
  - Geomembrane

- **Alternative Composite Liner**
  - Geosynthetic Clay Liner
Bottom Liner System

• Compacted Clay Liner (CCL)
  ➢ 24 inches thick
  ➢ Maximum permeability 1E-07cm/s
    • Lab testing
    • Test pads
    • In-situ Shelby tube sampling
Bottom Liner System

- Geomembrane
  - 30 mil (0.76 mm) minimum thickness

Fabricated Geomembrane Deployment
Bottom Liner System

• Alternative Composite Liner
• GM/Lower Component
  ➢ Was added in response to comments
    • Clay availability in different areas of country
  ➢ Demonstrated with Darcy’s Law:
    • $\frac{Q}{A} = q = k \left( \frac{h}{t} + 1 \right)$
    • $k$ – hydraulic conductivity of alternative liner
    • $h$ – hydraulic head above the liner
    • $t$ – thickness of alternative to clay liner
Bottom Liner System

• Hydraulic Conductivity of GCL
  - Perm – Minimum Average Roll Value (MARV)
    • Average (–) 2 standard deviations
    • 97.7% - degree of confidence values will be achieved
    • Typically reported as $5 \times 10^{-9}$ cm/s for standard GCL’s

  - Per Darcy’s Law - Requires $\sim 3E-09$cm/s for equivalency to 24 inch CCL

• What is the Solution?
  • GCL manufacturers have developed new polymer modified GCL’s for reduced hydraulic conductivity values
Bottom Liner System

• Other Bottom Liner Requirements:

  - Interface shear resistance on all interfaces
  - Placed on a foundation capable of providing support to the liner.
  - Cover all surrounding ground in contact with waste
  - Need appropriate chemical properties and strength to resist affects of leachate
• Case Study:

- *GCL Chemical Compatibility Testing with CCR Landfill Leachate*
- Authors: Jason Ross, P.E. and Mike Rowland, P.E.
- World of Coal Ash Conference, May 2017
- Available: www.flyash.info
GCL Hydraulic Conductivity

• CCR Landfill

• Designed and Permitted over a decade prior to construction.

• Geosynthetic Bottom Liner System:
  - GCL (standard bentonite), Geomembrane, Geotextile

• CCR’s placed into Landfill:
  - FGD, Fly Ash
  - *Trona used periodically in pollution control process
GCL’s with CCR Landfill Leachate
(Benson, Edil, Shackleford and others)

• Bentonite swelling – lowers hydraulic conductivity

• High ionic strength of landfill leachate
  ➢ reduces swell capabilities
  ➢ FGD and trona ash = highest ionic strengths

• Results in higher hydraulic conductivity for GCL
Response from manufacturer’s:
- Add polymer blends to the bentonite
  - Polymer ‘coats’ the bentonite and helps it resist cation/anion exchange

- Development of these products continues
- Interface shear strength considerations
- Project specific testing


- Scenarios I and II (saturation)
- Methods A, B or C (falling head/constant head)
GCL Hydraulic Conductivity

• Representative sample

• Existing leachate collection system
  ➢ same site
  ➢ same waste
  ➢ same bottom liner system

➢ Tested for:
  • Ca, Mg, Na, K, SO₄, ph….
GCL Hydraulic Conductivity

• Products selected based on manufacturer’s recommendations

• Index testing of GCL products for conformance to project requirements.

• Tested using low confining pressures (<5 psi)

• 4 GCL Products (3 polymer modified)
Termination Criteria:
- Passing results for 6 months
  (Permitting recommendation for this specific case)
- pH and electrical conductivity
- 6766: hydraulic conductivity consistent, 2 pore volumes
Results up to 20 days of testing
• Full results to 6 months of testing

GCL Hydraulic Conductivity

Permeability (cm/s)

Time (days)

GCL 1 - No Polymer
GCL 2 - Polymer Modified
GCL 3 - Polymer modified
GCL 4 - Polymer Modified
Permeability Target (3E-09cm/s)
CONCLUSIONS

• Chemical compatibility was achieved and documented.

• Chemical compatibility testing of GCL’s is recommended, regardless of the type of CCR materials (fly ash only, FGD, trona, gypsum...).

• A sudden increase in hydraulic conductivity of a polymer-modified GCL was observed after 3 months of passing test results.
CONCLUSIONS

• Periodic re-verification of compatibility may be warranted – changing pollution controls.

• Permit documents should allow future consideration of new products and procedures.

• Testing requires early planning to ensure that multiple GCLs are pre-qualified when obtaining construction bids.

• Industry Needs – Construction conformance testing for polymer products
Bottom Liner System

- Design Considerations
- Interface shear strength
Bottom Liner System

• Design Considerations
• Interface shear strength

- ASTM D5321 – Soil-Geosynthetic and Geosynthetic-Geosynthetic Interfaces
  - ‘Faster’ shearing rates allowed (1 mm/min), quicker loading

- ASTM D6243 – Internal and Interface Shear of Geosynthetic Clay Liners
  - Slower shear rates (0.1 mm/min), slower loading requirements.
Cover Systems
Cover Systems

• Cover System (257.102)

• Requirements:
  - Perm ≤ bottom liner system
    • (1E-05 cm/s maximum)
  - 18-inch earthen layer to minimize infiltration
  - 6-inch earthen layer capable of supporting vegetation to minimize erosion.
  - Accommodate settling and subsidence

  - Alternative Cover System – allowed provided that a PE can demonstrate all the requirements are met.
**Cover System**

- **Examples: Cover System**

  **Scenario 1:**
  No Bottom Liner or Soil liner = $1E-05$ cm/s

  Waste/Cover Soil

  Infiltration Layer (18-inch thickness)  
  Perm ≤$1E-05$ cm/s

  Vegetative Layer (6-inch thickness)

  **Scenario 2:**
  Compacted Clay Liner in Bottom Liner

  Frost Protection

  Compacted Clay Liner (Perm ≤$1E-07$ cm/s)

  Infiltration Layer (18-inch thickness)

  Vegetative Layer (6-inch thickness)

  Waste/Cover Soil
Cover System

- Examples: Cover System

Cover System with Frost Protection Layer
Cover Design – Must have effective drainage above the geomembrane

Scenario 3: Geomembrane in Bottom Liner System
Cover System

• Main take-aways:

  ➢ Bottom Liner determines cover requirements

  ➢ Interface shear strength – project specific testing
      • How low can we assign a normal stress?

  ➢ Drainage of water from liner interface is critical
Cover System

• Design Considerations:
  ➢ Veneer Stability
    • Provide required transmissivity value
    • Project specific testing
Construction Considerations
• Additional Construction Considerations

• Geocomposite Drainage Outlets –
  - Ineffective drainage/clogged drainage can lead to sliding cover soils
  - Clogging of outlets due to maintenance (grass clippings etc…)

Geocomposite Drainage Net Deployment
• Additional Considerations

• Geocomposite Drainage Outlets –
  ➢ Overlap lengths of Geocomposite drainage nets along slopes

Zip tie connection of drainage net core

Sewing and Overlap of Geotextiles
Constructability

• Design and Construction Considerations:
  ➢ Tie-ins to Structures
  ➢ Boots and Attachments

➢ Reference: Guidance on the Design and Construction of Leak-Resistant Geomembrane Boots and Attachment to Structures
  • IFAI Conference Geo, 2009 Conference, Salt Lake City, February 2009

➢ Authors:
  • Richard Thiel, Thiel Engineering,
  • Greg DeJarnett, Envirocon
  • Available: www.rthiel.com
Constructability

- Design and Construction Considerations:
  - Thiel and DeJarnett covers:
    - Pre-fabricated vs. field fabricated boots
    - Boot gaskets
    - Spark Test
    - Clamping Options
    - Concrete Collars with embedded Geomembrane
    - Batten Strip details
    - Examples of bad and good installations, with photos
  
  - Extremely practical reference for design and construction of geosynthetics – the tricky details that are difficult to get right.

  - Penetrations and attachments require the greatest oversight on a construction project.
Constructability

• Geomembrane Deployment

• Fabricated vs. Non-Fabricated Geomembranes

• Non-Fabricated Geomembranes – arrive to site in rolls

• Fabricated Geomembranes:
  ➢ Arrive to site in panels and/or factory fabrication of the manufactured rolls
  ➢ Faster deployment and less testing once on-site
Constructability

- Geomembrane Deployment – Off-Site Fabrication
Constructability

Fabricated Geomembrane Deployment – 1 Panel!
Deployment halted due to weather.

- Removal and recompaaction of subgrade.
- Additional density testing
- Re-survey
- Then it rains again
- Fabricated Geomembranes can pay off.
Constructability

• Electrical Leak Detection

• Exposed Geomembrane Surveys
  ➢ Water Puddle Method (D7002)
  ➢ Water Lance Method (D7703)
  ➢ Conductive-Backed Geomembrane Spark Testing (D7240)
  ➢ Arc Testing Method (D7953)

• Covered Geomembrane Surveys
  ➢ Dipole Method – Soil Covered Geomembrane (D7007)
  ➢ Dipole Method – Water Covered Geomembrane (D7007)
Constructability

- Electrical Leak Detection

Dipole Method
• Electrical Leak Detection

Excavator bucket striking the liner.
• Electrical Leak Detection

Able to find small defects

Ductile Iron Pipe Outlet

Knife Slices
Liner Defect found from Electrical Leak Detection
Conclusions

• Use of geosynthetics in CCR Applications is still growing and evolving.

• Learn from past failures and modify our designs.
• Stay current with best practices in construction.

• These facilities will be around for generations.
Questions???

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Insane in the Geomembrane: The Story Behind Coal Combustion Residual (CCR) Surface Impoundment Liners

Tuesday, August 6, 2019 at Noon CDT
Free to Industry Professionals
1.0 PDH

Presenters:
Harold (JR) D. Register, P.E. (Consumers Energy)
Andrew B. Bittner, P.E. (Gradient)
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