Landfill 101
Geosynthetics Design and CQA

NC SWANA - Spring Conference - Asheville, NC

April 25, 2018

Presenters:
Pieter K. Scheer, P.E.
John R. Fearrington, P.E.
Geosynthetics Design
**Overview**

geosynthetic, n – a planar product manufactured from polymeric material used with soil, rock, earth, or other geotechnical engineering related material as an integral part of a man-made project, structure, or system. (ASTM D4439)

- Typical Liner/Final Cover Cross Sections
- Materials/Function(s)/Design Considerations
  - Geomembranes
  - Geosynthetic Clay Liners
  - Drainage Geocomposites
  - Geotextiles
  - Other Geosynthetics
Typical Landfill Liner System

- Leachate Collection System and Protective Cover
- Type GT-C Geotextile or Drainage Geocomposite
- 60 Mil Textured HDPE Geomembrane
- Geosynthetic Clay Liner (GCL)
- Compacted Soil Liner
- Prepared Subgrade or Structural Fill
Typical Landfill Final Cover System

- Vegetative Soil Layer
- Drainage Geocomposite
- 40 Mil Textured LLDPE Geomembrane
- Intermediate Cover
- Waste

Minimum 2.0' thickness
Nominal 1.0' thickness
**Function:** Barrier to Liquids or Gas

- Very low permeability (HDPE: water-vapor transmission rates in range of $10^{-12}$ to $10^{-15}$ m/sec)

- In conjunction with a soil liner or GCL, forms a composite liner:

  For MSW Landfills, Subtitle D (40 CFR 258.40) defines composite liner as:

  “a system consisting of two components; the upper component must consist of a minimum 30-mil flexible membrane liner (FML), and the lower component must consist of at least a two-foot layer of compacted soil with a hydraulic conductivity of no more than $1 \times 10^{-7}$ cm/sec.”

  Further…… “FML components consisting of high density polyethylene (HDPE) shall be at least 60-mil thick.”

**Geomembrane, n** – an essentially impermeable geosynthetic composed of one or more synthetic sheets. (ASTM D4439)
Why HDPE for MSWLF Liner System Geomembranes?

- Excellent chemical resistance compared with other materials (LLDPE, Polypropylene, PVC, EPDM, etc.)
- Industry has solid understanding of HDPE geomembranes
- Life expectancy is anticipated to be hundreds of years

Why 60-mil thickness if HDPE?

- Can be difficult to properly seam thinner HDPE geomembranes
Why LLDPE for Final Cover System Geomembranes?

- Better flexibility than HDPE
- Better resistance to localized strains (LLDPE: 8-12% max. vs. HDPE: 4-8% max.)

What Thickness?

- Rules typically require 30-mil minimum
- Due to durability and difficulties in seaming, 40-mil more often specified
HDPE and LLDPE geomembranes may be smooth or textured (most common)

- Flat die or blown film process

Smooth geomembranes have low interface shear strength

Texturing used to enhance interface shear strength

- **Texturing Options:**
  - Co-extrusion (blown film)
  - Structuring (flat die)
  - Impingement/Lamination (Not Common)
Design Considerations Include:

- Protection (installation stresses, point loads (i.e. rock), long-term loads)
- Interface shear strength (consider pore pressure (liquid) and/or uplift pressure (gas))
- Details: sumps, anchor trenches, tie-ins, penetrations
- Long-term strains due to settlement
- Maintaining positive slope after settlement
- Special strain cases (piggyback landfills, potential for voids/subsidence)
Function: Barrier to Liquids

- Low permeability when hydrated (< $5 \times 10^{-9}$ cm/sec)
- Used as supplement and/or replacement of compacted soil liner
- Most often used in conjunction with and beneath a geomembrane (composite liner)
- Can be used as a single liner (not typical for lined MSWLFs)
- Self healing if punctured or cut
- Flexible and conformable to subgrade
- Self seaming at overlaps (with bentonite addition as needed)

**Geosynthetic Clay Liners (GCLs)**

*geosynthetic clay liner, n* – a manufactured hydraulic barrier consisting of clay bonded to a layer or layers of geosynthetic materials. (ASTM D4439)
Types:

- Typically needle-punched GCLs are used for landfill applications (due to low shear strength of bentonite).
- If both sides are non-woven geotextiles use scrim reinforcement on one side (minimizes chance for loss of overlap if left with minimal cover).
Design Considerations Include:

- Internal and interface shear strength
- Details: sumps, anchor trenches, tie-ins, penetrations
- Special waste compatibility (i.e. CCR)
- Special strain cases (piggyback landfills, potential for voids/subsidence)
**drainage geocomposite**, *n* – a product comprised of two or more materials, at least one of which is a geosynthetic, manufactured for the purpose of planar flow of liquids or gases.

- **Function:** Intercepting and Conveying Liquids or Gas
- Typically installed on top of barrier layer (limits head acting on barrier = less leakage potential)

- **Types:**
  - Geonet (bi-planar or tri-planar) with or without non-woven geotextile(s) (typically heat laminated)
  - Multi-linear – utilizing small diameter piping
  - Structured geomembrane (used with adjacent geotextile or geomembrane)
Design Considerations Include:

- Determining required transmissivity (short and long-term)
  - Long-term reduction factors (biological, chemical, creep)
- Protection of geomembrane (cushion design)
- Filtration (adjacent soil/aggregate)
- Internal and interface shear strength
**geotextile**, *n* – a permeable geosynthetic comprised solely of textiles. (ASTM D4439)

**Functions:**
- Separation
- Filtration
- Cushioning
- Drainage/gas transmission
- Reinforcement

- Majority are made from polypropylene fibers
- Standard textile manufacturing is used
- Characterized by an open and porous structure
- Mechanical and hydraulic properties vary widely
Types:

- Non-woven (needle punched or spunbonded)
- Woven (slit film, monofilament or multifilament) (Not Commonly Used) (Exception: Scrim Reinforcement of GCLs)

Design Considerations Include:

- Protection of geomembrane (cushion design)
- Interface shear strength
- Use caution with geotextile/geotextile interfaces
- Filter design (adjacent soil/aggregate)
Other Geosynthetics Used in Landfills:

- Geosynthetic rain covers
- Alternative closure products:
  - ClosureTurf®
  - LiteEarth™
- Geogrids (Reinforcement for steep slopes or MSE walls)
Geosynthetics may introduce low strength surfaces within the liner system – interface between various geosynthetic/soil materials

Assessment of minimum interface shear strength requirements is critical:

- Perform veneer stability calculations for liner and final cover system interfaces (generally 3H:1V maximum slope)
- Evaluate block failure surfaces for critical interim and final fill conditions (typically for worst case cross sections)
- Consider pore/gas pressures and seismic factors as applicable
- Consider residual interface shear strength values as applicable

Specify requirements for testing during construction
Landfill Cell Construction w/ GCL and a 60-mil HDPE Geomembrane

Landfill Closure Event w/ Drain Tube and a 40-mil LLDPE Geomembrane
Geosynthetics CQA

Overview

- Purpose of CQA
- Testing/Installation of Geosynthetics
- Placement of Overlying Layers
Landfill Liner
- Prevent leachate seepage into groundwater
- Prevent landfill gas migration

Landfill Final Cover
- Prevent infiltration
- Reduce landfill gas emissions
## Calculated Leakage Rates due to Pinholes and Holes in a Geomembrane

<table>
<thead>
<tr>
<th>Defect Diameter (in)</th>
<th>Water Depth on top of the Geomembrane (FT)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.01</td>
</tr>
<tr>
<td>Permeation</td>
<td>N/A</td>
</tr>
<tr>
<td>Pinholes</td>
<td>0.004</td>
</tr>
<tr>
<td></td>
<td>0.012</td>
</tr>
<tr>
<td>Holes</td>
<td>0.08</td>
</tr>
<tr>
<td></td>
<td>0.445</td>
</tr>
</tbody>
</table>

Leakage Rate in Gallons per Acre per Day (GPAD)

Definitions

- Construction Quality Assurance (CQA)
- Construction Quality Control (CQC)
- CQA Engineer
- CQA Technician
- CQA (Certification) Report
Geosynthetic Institute (GSI)
Pre-Construction Testing
Installation and Testing
Leak Location Survey
Geosynthetic Specifications

- Geomembranes
- Geosynthetic Clay Liners
- Drainage Geocomposites
- Geotextiles
- Geosynthetic Rain Covers
- Turf Reinforcement Mats
CQC and CQA Laboratory Testing

Ply Adhesion (ASTM D 1505) (Drainage Geocomposite)

Peel Strength (ASTM D 6496) (GCL)

Photos courtesy of Geotechnics, East Pittsburgh, PA.
CQC and CQA Laboratory Testing

Interface Shear (ASTM D 5321) (Drain Tube to Soil shown)

Grab Tensile (ASTM D 4632) (Geotextile)

Photos courtesy of Geotechnics, East Pittsburgh, PA.
Pre-Installation Testing

Field Tensiometer

Trial Seam (Extrusion)
Typical Geomembrane Welds
Geosynthetics CQA
Testing/Install of Geosynthetics

Non-Destructive Testing of Geomembrane

Air Pressure Testing (Double Wedge)

Vacuum Box Testing (Extrusion)
Destructive Testing of Geomembrane

Photos courtesy of Geotechnics, East Pittsburgh, PA.
Geosynthetics CQA
Case Study: Machine Calibration

CQA Technician observed high wheel pressure on dual track fusion welds.

By lifting the weld flap, holes were observed on the lower membrane along the weld track.
What happens when a test fails?

- Bound the Failing Test
- Re-test until passing results
When the installation and QC program are followed, mistakes can still happen.
Survey can be completed on exposed geomembrane or after protective cover placement.

Leak Location Surveys
The most damage to a liner system occurs after installation.
GSI White Paper No. 27: Maintaining geomembrane contact with underlying materials by controlling wrinkles.

QUESTIONS