Active LFG Control: An Unreliable Aid to Veneer Stability

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Typical Geosynthetic Final Cover System
Typical Piggyback (Waste Over Waste) Liner System

Diagram:

- Geosynthetic Rain Cover
- Protective Cover
- Drainage Geocomposite (Leachate Collection)
- 60 Mil Textured HDPE Geomembrane
- Geosynthetic Clay Liner (GCL)
- Drainage Geocomposite (Leak Detection)
- 40 Mil Textured LLDPE Geomembrane

Waste
Slope Stability: LFG Related

\[ FS = \frac{(W - u_{LFG}) \cos \beta \tan \phi + a}{W \sin \beta} \]  
Eq. 1

The variables in Equation 1 are defined as follows:

\[ W = \text{weight of final cover system above the GM (psf)}, \]
\[ u_{LFG} = \text{LFG pressure (psf)} \]
\[ \beta = \text{slope angle (degrees)} \]
\[ \phi = \text{interface friction angle (degrees)} \]
\[ a = \text{interface adhesion (psf)} \]
LFG Pressure at Limit of Sliding Stability

Maximum LFG Pressure, Sliding FS = 1.0
2-ft (60 cm) Soil Cover

Interface Friction, degrees

-10 -5 0 5 10 15 20 25 30 35
LFG Pressure, Inch H2O

- 14 Degree, a = 0
- 4H:1V Slope
- 18.4 Degree, a = 0
- 3H:1V Slope
- 14 degrees, a = 25 psf
- 18.4 Degree, a = 25 psf
Passive LFG Relief/Collection Systems (vs. Active LFG Systems)

While active LFG systems rely on a regularly spaced network of gas wells……..

Passive LFG systems are systems that rely on gravel “French drains” or area collectors placed at/near the surface of the waste.
Passive LFG Relief/Collection Systems (vs. Active LFG Systems)

Things to Note:

• Passive LFG systems are commonly empirically designed as there is typically a high degree of uncertainty about LFG generation rates.

• Active LFG wells typically have solid piping extending 10 to 20 feet below the final cover system in order to limit air intrusion.
  – Thus, by design, the effectiveness of an active LFG system to minimize pressure on the final cover veneer is limited.

• For the wrong combinations of slope, interface shear strength, gas pressure, etc. failures have resulted…….
Case Study: Failure During Construction

Final Cover System on 4H:1V slope with components (top-down):
- 1.5-ft topsoil and vegetative soil;
- 1-ft sand drainage layer;
- PVC geomembrane;
- GCL having nonwoven side down, slit film side up;
- 1-ft thick LFG relief layer of fine sand; and
- Interim cover/structural layer immediately over waste.
Case Study: Failure During Construction

• Failure occurred along PVC geomembrane/GCL interface before placement of final 1.5-ft of soil.

• PVC GM/GCL interface (\(\phi = 16\) degrees; \(a = 11\) psf) (not very robust) theoretically stable (\(FS > 1.0\)) at < 10 inch-\(H_2O\) LFG pressure.

• Average LFG pressure of 6.6 inch-\(H_2O\) and a maximum LFG pressure of 16 inch-\(H_2O\) were measured after failure.
Case Study: Failure During Construction

PVC-GCL Interface Shear Strength

Maximum LFG Pressure, Sliding FS = 1.0
2-ft (60 cm) Soil Cover

Maximum LFG Pressure
- 14 Degree, a = 0
- 18.4 Degree, a = 0
- 14 degrees, a = 25 psf
- 18.4 Degree, a = 25 psf

LFG Pressure, Inch H2O
Interface Friction, degrees
Case Study: Failure During Construction

- The 1-ft thick sand LFG relief layer was found to have been saturated during construction so this layer provided little to no capacity for LFG transmission.
  - Thus, it’s critical to construct LFG relief layers from free draining materials – especially since LFG contains significant moisture.

- The sand LFG relief layer was retrofitted with strip drains spaced at 29-ft in the cover reconstruction.
Case Study: Post-Construction Failure

Final Cover System on 3H:1V slope with components (top-down):
• 2-ft topsoil and vegetative soil;
• 8 oz/sy nonwoven geotextile
• Text. LLDPE geomembrane (spikes on bottom/drain surface on top);
• GCL having nonwoven side down, woven side up; and
• 1-ft interim soil cover immediately over waste.
Case Study: Post-Construction Failure

- Failure occurred along LLDPE geomembrane/GCL within a few months of completion of the final cover system. The LLDPE geomembrane used was a structured product with conical spikes on the bottom and a studded drain layer (in conjunction with the nonwoven geotextile) on top.

- At the time of discovery of the failure, the active gas recovery system had been down for about one week for maintenance.
Case Study: Post-Construction Failure

- Pre-construction testing of LLDPE GM/GCL interface (phi = 29 degrees; a = 0 psf) theoretically stable (FS > 1.0) at < 15 inch-H$_2$O LFG pressure.

- Post-failure testing of LLDPE GM/GCL interface (phi = 23.5 degrees; a = 0 psf) theoretically stable (FS > 1.0) at < 9 inch-H$_2$O LFG pressure.

- The significantly lower interface shear strength was attributed to dragging of the geomembrane downslope during deployment. The dragging reduced the asperity height of the spikes (i.e. dulled the tip of the spike).
Case Study: Post-Construction Failure

Maximum LFG Pressure, Sliding FS = 1.0
2-ft (60 cm) Soil Cover

Measured Strength Allowable = 9”

Specified Strength Allowable = 15”

LFG Pressure, Inch H2O

3H:1V Slope

Interface Friction, degrees

-10
-5
0
5
10
15
20
25
30
35
16 18 20 22 24 26 28

14 Degree, a = 0
18.4 Degree, a = 0
14 degrees, a = 25 psf
18.4 Degree, a = 25 psf
Case Study: Post-Construction Failure

- To evaluated the effect of the active LFG system shutdown, a single recovery well was removed from an active LFG system and the subsequent increase in LFG observed.

- From an initial vacuum of 9-inch H₂O, it took only one hour to achieve a zero pressure. Over the next five (5) hours, the LFG pressure increased to 1.5-inch.

- Thus, over a 10-inch increase in LFG pressure required less than six (6) hours. This increase occurred despite the presence of adjacent LFG wells that remained in service and under the full operational vacuum.
Case Study: Post-Construction Failure

- Conservative design would assume that **full LFG pressures would develop in less than two (2) days** if the entire active LFG system shuts down.
Contingent Passive Venting Systems: Piggyback Liner System

LFG Collector Trench

100’ Spacing
Contingent Passive Venting Systems: Final Cover System

- Limit LFG release under normal operations.
- Allow venting of positive LFG pressures.
Summary Points

1. It’s critical to construct LFG relief layers with free draining materials – especially since LFG contains significant moisture.

2. LFG pressure increases during shutdown of active recovery systems can lead to slope failure.
   - Conservative design would assume that full LFG pressures would develop in less than two (2) days if the entire active LFG system shuts down.

3. A passive contingent LFG system with relief valves must be installed in landfills using active LFG recovery systems lacking backup compressors/flare.

4. Interface shear strength may be reduced by installation technique, i.e. dragging geomembrane.
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Carbon Credit Projects -
A Verifiers Perspective
Beginning a Carbon Offset Project

- Identify the program that works for you.
- Know the rules
Verification Process

**DOCUMENT, DOCUMENT, DOCUMENT**

- Cutoff start date for methane destruction
  - System operation must occur after a specified date (e.g., January 1, 1999 under CCX)
  - Destruction before this date may need to be subtracted from the total.
  - E.g., 100 scfm (pre-1999) - 200 scfm (post-1999) = 100 scfm verifiable flow, under CCX
- Small “vent” flare installation dates are hard to document, and flow meter data is typically not available.
Eligibility depends on voluntary status

- No credit for carbon reductions mandated by law.
- Provide permitting files **AND** related correspondence.
  - Design Capacity
  - Tier 1 & 2 NMOC Reports
- States may be more stringent than EPA.
- Sites required to control methane may still be eligible.
  - Solid waste permit may require migration control, but does not specify collection and flaring.
  - Credits from early system expansions may be verifiable.
Conclusion

• Landfills are largest US emitters of methane.
• Carbon trading may reduce the impacts of global warming.
• Several trading programs available to landfills.
• Verification process is not easy or automatic.
• Documentation is critical to successful verification.
For More Information:

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