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
Slope Stability: LFG Related

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

Eq. 1

The variables in Equation 1 are defined as follows:

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

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

- 14 Degree, $a = 0$
- 18.4 Degree, $a = 0$
- 14 degrees, $a = 25$ psf
- 18.4 Degree, $a = 25$ psf

4H:1V Slope
3H:1V Slope
Passive LFG Relief/Collection Systems (vs. Active LFG Systems)

Passive LFG systems are systems that rely on gravel “French drains” or area collectors placed at/near the surface of the waste.

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

LFG Pressure, Inch H2O

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

Maximum LFG Pressure
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-$H_2O$ 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-$H_2O$ 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

Interface Friction, degrees

LFG Pressure, Inch H2O

14 Degree, a = 0
18.4 Degree, a = 0
14 degrees, a = 25 psf
18.4 Degree, a = 25 psf

Specified Strength Allowable = 15”
Measured Strength Allowable = 9”

3H:1V Slope
Case Study: Post-Construction Failure

- To evaluate 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 H$_2$O, 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

100’ Spacing

LFG Collector Trench

NOTE:
1. Excavate trench such that existing cover is breached or to a maximum depth of 4 feet.
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/flares.

4. Interface shear strength may be reduced by installation technique, i.e. dragging geomembrane.
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