Applications of Engineered Turf Cover and Revetment Systems in Landfill Closures

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Outline

- Introduction of ClosureTurf and HydroTurf
- ClosureTurf Weather Performance
  - UV Radiation
  - Freezing Temperatures
  - Historic Rain Events
  - Strong Winds
  - Lightning and Fire
- Landfill Gas Management for ClosureTurf
Introduction of ClosureTurf and HydroTurf
ClosureTurf System Components

- ClosureTurf is a three-component final cover system comprised of a structured geomembrane, an engineered turf, and a specified infill.

<table>
<thead>
<tr>
<th>System Components</th>
<th>Functions</th>
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</thead>
</table>
| **Structured Geomembrane:** HDPE or LLDPE geomembrane | • **Barrier layer** – reduces infiltration  
• **Drainage layer** (with integrated drainage studs) – provides internal drainage and minimizes hydraulic head on liner |
| **Synthetic Turf:** HDPE synthetic grass blades tufted into two layers of PP geotextile backing | • **Protection layer:**  
  • covers and protects the underlying geomembrane from UV degradation and wind uplift  
  • minimizes wind and water erosion of sand infill  
• **Post-closure aesthetics** – blends in with natural surroundings |
| **Infill:** Sand with or without a binder | • **Protection layer:**  
  • covers and protects underlying geotextile backing and geomembrane from UV radiation  
  • provides ballast for wind uplift protection  
  • improves vehicle drivability  
  • provides fire protection |
ClosureTurf System Components

Structured HDPE or LLDPE Geomembrane

*AGRU MicroSpike* (40 mil)

*AGRU MicroDrain* (50 mil)

*AGRU Super GripNet* (50 or 60 mil)

Selection of geomembrane is typically based on slope (interface friction), drainage (hydraulic shear of sand), and cost.
ClosureTurf System Components

Engineered Turf

100% Green

100% Tan

Blend (e.g., 75% Green + 25% Tan)
First ClosureTurf installation completed in 2009 at the LaSalle-Grant Landfill in Louisiana
To date, ~1,500 acres installed or being installed at 40+ sites in 20+ states
Project size ranging from several acres to over 150 acres
Municipal and industrial waste landfills and coal ash impoundments
Warm and cold climates and severe weather conditions (hurricanes, storms, snows, and strong winds)
HydroTurf can be used with the ClosureTurf final cover system or traditional soil covers for landfill downchutes and drainage channels.
HydroTurf Flexibility

Besides the exceptional hydraulic performance, it is flexible to accommodate differential settlement.
HydroTurf Landfill Downchute

HydroTurf Downchute with Soil Cover at a CCR Landfill Site
(Left: before vegetation; Right: after vegetation)
HydroTurf Landfill Downchute with Soil Cover at a MSW Landfill Site
HydroTurf Landfill Downchute

HydroTurf Downchute with Soil Cover at an Industrial Waste Landfill Site
HydroTurf Perimeter Channel

HydroTurf Perimeter Drainage Channel at a Mine Site
ClosureTurf Weather Performance
UV Radiation

- Geomembrane (covered by the engineered turf and infill): **400+ years**
- Engineered Turf: **100+ years**
  - Real world testing conducted on the engineered turf at the Atlas Weathering Facility in New River, AZ
    - Direct Exposure 45° South
    - ASTM G147 and G7
  - Ten years of data collected: 1.3 years, 5 years, 7 years and 10 years

[Image of Atlas Weathering Laboratory in New River, AZ]
[Graph showing half-life projections and field data]

Regression for Field Data:
\[ y = -10.32\ln(x) + 105.48 \]
# UV Radiation

## CLOSURE TURF LLC - LANDFILL COVER SYSTEM

### RETAINED TENSILE STRENGTH VS. WEATHERING TIME

**Desert Weathering VS. Salle Project Site Weathering**

<table>
<thead>
<tr>
<th>Weathered ClosureTuff ***</th>
<th>Weathered Conditions</th>
<th>Test Specimen</th>
<th>Weathering Time</th>
<th>Tensile Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>(year)</td>
<td>(hours)</td>
</tr>
<tr>
<td>1</td>
<td>Desert weathering, New River, Arizona</td>
<td>Top Portion</td>
<td>1.3</td>
<td>11280</td>
</tr>
<tr>
<td>2</td>
<td>Direct 45 deg South with plywood packing</td>
<td>2&quot; long green yarn</td>
<td>5.0</td>
<td>43800</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>2&quot; long green yarn</td>
<td>7.0</td>
<td>61320</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>3&quot; long green yarn</td>
<td>10.0</td>
<td>87600</td>
</tr>
<tr>
<td>5</td>
<td>Salle project site exposure</td>
<td>Top Portion</td>
<td>7.0</td>
<td>61320</td>
</tr>
<tr>
<td>6</td>
<td>facing south on slope</td>
<td>3&quot; long green yarn</td>
<td>8.0</td>
<td>70080</td>
</tr>
</tbody>
</table>

**NOTE (1) control strength determined from the trench sample from the same site.**

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**DATE REPORTED** 10/27/2016

**FIGURE NO.** 1

**PROJECT NO.** SGI16014

**DOCUMENT NO.**

**FILE NO.**
Freezing Temperatures

- ClosureTurf Deep Freeze Experiment by Dr. George Koerner, Geosynthetic Institute on September 25, 2018

1. Block of Dry Ice top (Turf) and bottom (Agru LLDPE Geomembrane)
2. Propanol flood
3. One hour incubation
4. -60 Degree Celsius minimum temperature
5. Accura TSX wagon (1 ton, 26 psi tire pressure, 8” wide wheel)
6. Two passes (i.e. forward & back)
7. Observation

The experiment procedure and photos were provided to Watershed Geo by Dr. George Koerner, Geosynthetic Institute.
Freezing Temperatures

- ClosureTurf Deep Freeze Experiment by Dr. George Koerner, Geosynthetic Institute
Freezing Temperatures

- ClosureTurf Deep Freeze Experiment by Dr. George Koerner, Geosynthetic Institute
Freezing Temperatures

**Site:** Central Landfill  
**Owner:** Rhode Island Resource Recovery Corporation  
**Location:** Johnston, RI  
**Completed:** 2017  
**Closure Area:** 18 acres

Winters bring severe winds and lots of heavy snows.
Freezing Temperatures

Winter storm, Skylar, brought high winds and over a foot of snow in March 2019 as the third Nor’easter to strike the northeast this winter.
Historic Rain Events

Rainfall Simulation – ClosureTurf with Sand Infill

- TRI facility in South Carolina (ASTM D-6459 and ASTM D-6460)
- 3H:1V Slope, 8’ x 40’
- Tests replicate rain induced forces @ 2”, 4” and 6” per hour
- Zero infill movement at 2” and 4” rain events per hour; 0.03 tons per acre of movement at 6” rain event
- Clearly outperforms prescriptive cover systems which allow for 5 - 10 CY (~7 to 14 tons) per acre per year
Historic Rain Events

- ClosureTurf with HydroBinder / HydroTurf
  - Hydraulic test performed at Colorado State University - Engineering Research Center
  - System maxed out test facility capacity without reaching performance threshold
    - Flow velocity > 40 ft/sec (fps)
    - No instability or damage of system
    - No erosion of subgrade soil
  - Results conclude that the system outperforms hard armor technologies, such as riprap, articulated concrete blocks, etc.
Historic Rain Events

Hurricane Michael, October 2018

Hurricane Irma, September 2017

Hurricane Matthew, October 2016
Historic Rain Events

**Site:** Saufley Field Road Landfill  
**Owner:** Escambia County  
**Location:** Pensacola, FL  
**Completed:** 2013  
**Closure Area:** 25 acres
The site received over 22 to 26 inches of rain in 24 hours on April 29th and 30th, 2014 (a 500-yr storm event).

There was no impact on the surrounding community, no damage to report, and no immediate attention required.
Historic Rain Events

HydroTurf Downchute at Saufley Field Road Landfill after the Historic Rain Event (photo taken October 2014)

Comparison to Failure of a Riprap Downchute at a Landfill Site
Historic Rain Events

Runoff Before ClosureTurf

Runoff After ClosureTurf

Saufley Field Road Landfill
Historic Rain Events

Site: Berkeley County Landfill
Owner: Berkeley County
Location: Moncks Corner, SC
Completed: 2013
Closure Area: 12 acres
Historic Rain Events

- ClosureTurf survived around 26 inches of rain over a four-day period from October 1\textsuperscript{st} to 5\textsuperscript{th}, 2015 (1-in-1000 event).

- No maintenance was required post event: small amount of sand migration to the bottom of the slope. Because there was enough coverage of sand, the sand did not have to be redistributed or replaced.
Historic Rain Events

Perimeter Channels of Closure
Turf Versus Soil Cover
(Photos taken on Nov. 2018)
Strong Winds

Wind Tunnel Testing at Georgia Tech Research Institute (up to 120 mph), July 2010

The measured uplifting force was less than the weight of ClosureTurf and changed to downward force as the turf blades bent towards the ground by wind.
Strong Winds

There has been no report of ClosureTurf damage due to wind uplift.

Figure 1. Maximum design wind velocities.

Lightning and Fire

- There has been no report of ClosureTurf damage due to lightning or fire.

- A lightning strike on ClosureTurf is very unlikely because the sand infill, engineered turf, and geomembrane are all poor conductors.

- Fire resistance test of ClosureTurf demonstrated that fire on ClosureTurf did not propagate.

- Any damage due to lightning or fire, if occurs, will be limited to local areas and can be easily identified and repaired.
Landfill Gas Management for Closure Turf
(Comparison with Soil Cover)
Landfill Gas Management

- Like a traditional soil cover with a geomembrane barrier layer, ClosureTurf is subject to gas uplift if landfill gas is generated from the waste and gas pressure builds up beneath the geomembrane layer.

Gas Uplift of Soil Cover  
Gas Uplift of ClosureTurf
Landfill Gas Management

- Gas uplift can cause slope failure of a soil cover, which results in disruption of landfill operations and significant cost of repairs; while gas uplift of ClosureTurf may result in wrinkles that may not need to be repaired or can be repaired at a much lower cost, if needed.
- Gas uplift of a soil cover is hard to detect until the cover starts failing; while gas uplift of Closure is visible immediately as an early warning of malfunction of the landfill gas system.

Reference: The Design of Geosynthetic Final Cover Systems & Future Alternatives, presentation by Pieter K. Scheer, P.E., Richardson Smith Gardner & Associates, Inc., 2016. The presentation is available online at the link below:
Landfill Gas Management

• For both soil cover and ClosureTurf, it is critical to:
  • design and install an adequate active landfill gas collection and control system (GCCS) or passive gas venting system;
  • for an active GCCS, install sufficient gas relief valves to relieve gas pressure in case the system malfunctions; and
  • maintain a robust GCCS with minimal flare shutdowns.
• For ClosureTurf, it is easier to retrofit the gas system by adding more pressure relief valves, if needed.

Landfill Gas Management

- Regulatory Considerations

When landfill sites are required to install active gas collection and control systems (GCCS) under the federal New Source Performance Standards (NSPS) there are certain restrictions that “by-pass valves” may not be included in the system. This provision essentially bottles up the LFG in complete contrast to the desires of the design engineer and as demonstrated above, can cause catastrophic failure of the veneer cover system. Therefore, the proposed relief valve system is offered as a compromise since the valve can be designed to only vent at a critical pressure considered in the design immediately below the GM and independent of the gas GCCS. Furthermore, the destruction of the LFG can continue if coupled with a solar vent flare that will only fire when gas is present, commonly used as an odor control measure today. These components can be addressed in the GCCS Design Plan as associated with the final cover components more specific to each landfill situation. The NSPS standards are currently under review and should consider these situations in their final form to better integrate the cover system design limitations with the intent of the air regulations.

THANKS!