A True Green Closure

A Sustainable and Reliable Approach Using Structured Membrane and Synthetic Turf

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ABSTRACT

As a response to numerous failures and poor performance of environmental closures at landfills, engineers have looked at new approaches in establishing a more physically stable and environmentally sound solution. Traditional landfills require large amounts of soil for their construction, and many experience on-going erosion and sedimentation issues. Traditional covers are highly reliant on trucking soils, heavy civil construction and on-going maintenance and repairs in order to maintain their integrity. New methods are needed to lower the impact on the environment throughout the capping construction process.

A potential solution to landfill closure failures and construction and operation environmental impacts has been the implementation of exposed geomembranes. However there are disadvantages to these systems such as: accessibility, lack of membrane protection, wind uplift issues and aesthetics. The latest approach presented here builds off of the success of using exposed geomembranes with a number of improvements to address the disadvantages of exposed systems. This system incorporates high interface friction materials, and multiple layers of protection provide by a turf system. The system is ballasted with sand infill to provide wind resistance and accessibility. Like other exposed membrane caps there is no soil and vegetative layer. This system also provides for a stable and rapid installation which allows for the capture of landfill gas emissions at earlier phases of development.

INTRODUCTION

Sustainability for landfill closures has a dual meaning. One meaning relates to the physical stability and long-term performance and maintenance, which is a problem that has long-plagued the landfill industry. The other meaning is associated with the reduction of carbon footprint and minimizing other impacts on the environment.

Many traditional soil cover systems are destined to fail on steep landfill slopes as a result of excessive erosion, gas pressure buildup, earthquake loads, poor maintenance and/or inadequate post-closure oversight. Closures have shown to lose the integrity of its intended function after site closure and in absence of onsite personnel. The initial construction and reconstruction an activity of the cover destroys land to obtain borrow, creates sedimentation issues, consumes significant fuel, and produces significant emissions from trucking and operation of heavy equipment.

The goal of an improved closure system should be to first increase the performance and reliability of its intended function of protecting the environment from groundwater releases and landfill gas emissions. Sacrificing functional integrity for the sake of environmental sustainability is pointless or even harmful from the macro goal of protecting the environment.

A step in the right direction has been some engineers' reliance on exposed geosynthetics. Exposed geomembrane cover systems (EGCS) have been successfully used for closures at landfills in the United States for several years. The EGCS represents a positive development in landfill cover system's design and construction. The use of EGCS minimizes veneer stability issues and eliminates the impacts associated with a soil cover. However, covers using just an exposed geomembrane can have negative aesthetics and require numerous anchor trenches to resist wind uplift. Access can also be very difficult on top of the membrane during post-closure care operations.

This new cover system deals with similar concepts as the EGCS but goes a step further by combining the impermeable liner with a multiple geosynthetic layers with a synthetic turf yarn. The approach is to utilize the benefits of an EGCS and eliminate the negative aspects of frequent anchoring, poor accessibility and aesthetic issues. This is achieved by providing additional layers of protection, higher friction angles, and homogeneous ballast (as opposed to point loads at anchor trenches) with high drainage capacities. The turf simply serves as aesthetically pleasing, uniform ballast that also provides accessibility, membrane protection and surface water control.

This new approach has all of the positive sustainability characteristics of the EGCS but also provides an opportunity to obtain "earlier" control of surface emissions. Maximizing control of landfill gas is one of the major goals of the industry and can contribute significantly to the reduction of green house gasses.

The system also provides for a new approach in landfill gas collection (LFG) by using a geocomposite material at the foundation layer (i.e., below the EGCS) to direct and relieve gas pressure to collection points. This approach has the potential to dramatically improve the landfill gas collection efficiency early in the life of the facility

Another environmental advantage of this system is providing better options for post-closure uses. A new trend for post-closure use is solar collection. These fields will employ the use of rigid panels that operate at the highest efficiencies currently available.

IMPROVING PERFORMANCE

It is common for engineers to design traditional synthetic and soil covers with a very low factor of safety against veneer failure (factors of safety of 1.1 are many times accepted under dynamic conditions). The post-closure maintenance period also accepts the fact that the system is heavily-reliant on replacing soil loss, re-vegetation, fertilization and storm water repairs. Simply improving the performance from this standard traditional design is in of itself adding to the environmental sustainability of the cover. The design approach presented here uses synthetic turf and structured geomebranes for final landfill covers. The system requires minimal anchoring and provides a drainage system that can handle intense wind and rain. The components also work together to allow for traffic access during post-closure care and provide for an aesthetically pleasing surface. Comparison of this new approach with prescriptive traditional closures is shown in Figure 1.

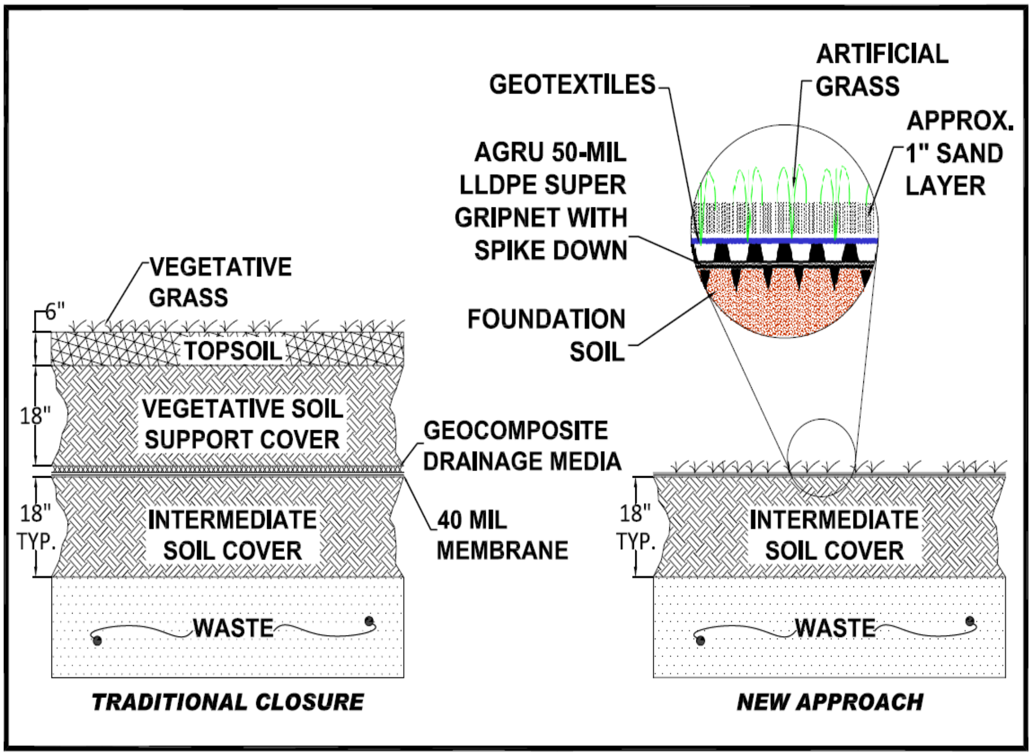

Figure 1. Traditional cover compared to new approach

The cover system of this approach is designed from the bottom up with a lower impermeable layer placed over the soil intermediate cover comprising of: (1) a drain liner geomembrane or textured geomembrane liner and a geonet drainage media, or alternatively a drain liner with studs incorporated in the linear low density polyethylene sheet that serves as the transmissive layer (AGRU US SuperGripNet); (2) the synthetic turf that is engineered with polyethylene fibers with a length of 1.5 to 2.0 inches tufted into two fabrics of woven polypropylene geotextiles, and; (3) a sand layer approximately 0.5 to 0.75 inches that is placed as infill to ballast the material and protect the system against wind uplift. This system has a U.S. patent and is referred to in the industry by the trade name of Closure Turf™.

This design approach has a top porous sand ballast layer that resists significant wind uplift forces and disturbs the free stream wind flow. The internal friction angle of the system components provide for a highly stable system without expensive anchor trenching.

Presented in Figure 2 is a diagram that illustrates the multiple forces an exposed cover system must withstand to remain stable. Each force and condition, such as wind loads, seismic, slope angles and rain intensity should be evaluated under severe or worst case conditions as dictated by the design (degree slope and soil sub grade classification) or local climate (wind and rain).

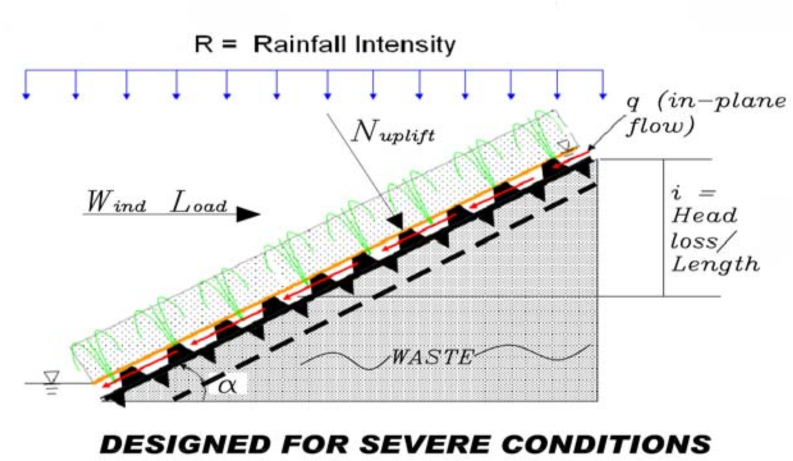

Figure 2. Forces acting on cover

The new system does not present stability issues from sudden failures such as sliding and washout, or from long-term failures caused by soil and wind erosion since there is no vegetated cover. Facility owners and operators of these closures can potentially realize significant cost savings by constructing a cover system with the synthetic grass that does not require the vegetative maintenance, soil grading and replacement that are common with traditional closures.

The amount of sand infill will be based on the wind velocities for the region. The sand will also provide additional protection of the geotextiles against UV light. The polyethylene yarns durability against UV light, coupled with having infill cover and an upper “sacrificial” geotextile also lends itself well to long-term performance of a closure cover. Field samples taken from covers installed in southern Arizona and central Louisiana have shown that the underlying geotextiles have experienced no identifiable loss of tensile strength ASTM D4595 since the initial installation 3 years ago. The exposed portions of the yarn (that serve aesthetics only) will maintain the required strength well beyond minimum regulatory post-closure periods. Weatherometer ASTM G147(02) tests performed on the exposed portion of the yarn show less than 10 percent tensile strength loss after 20 years.

Through the combination of these unique geosynthetics components, the landfill operator can achieve a more reliable and stable cover along with a more environmentally friendly cover system during construction and post-closure maintenance.

OPTIMIZING SUSTAINABILITY IN CONSTRUCTION

Unlike the traditional soil and geosynthetic composite closures, the system provides a sustainable approach to closing landfills by eliminating soil, removing the need for vegetative maintenance, fertilization and the inherent erosion issues associated with a soil and vegetative cover.

As is the case with exposed geomembrane covers, this composite system also eliminates the destruction of land for borrow and minimizes the need for on-going maintenance, as is required by a vegetated soil cover (particularly problematic on steep side slopes). Just as is the case on large civil projects and in drainage systems, geosynthetics can provide an opportunity to significantly reduce CO_2 emissions. Figure 3 below presents a comparison in CO_2 emissions for a traditional cover construction and the proposed cover described in this paper.

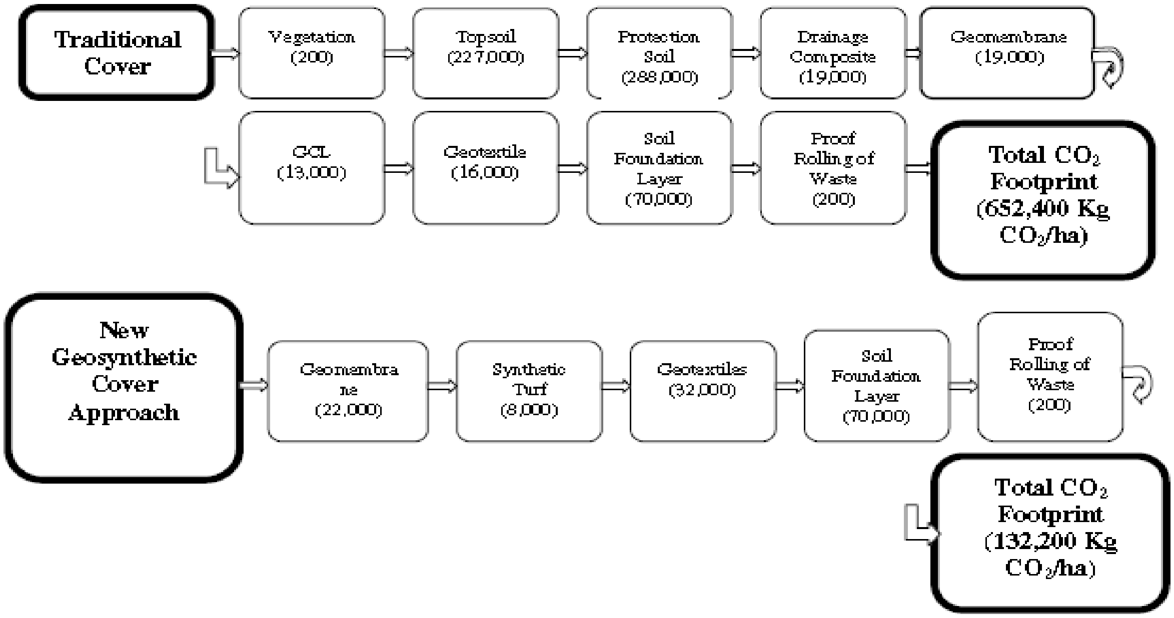

Figure 3- Comparison of carbon footprints

OPTIMIZING SUSTAINABILITY THROUGH CLOSURE PHASING

In addition to saving soil, the proposed new cover can be constructed much faster than traditional covers. The lower construction costs and simplicity of the installation allow the operators to close in smaller increments (3 to 5 acres at a time) once the final grades have been achieved. This results in earlier collection of the landfill gases as opposed to waiting a longer period of time to close large areas (20 to 50 acres) in order to obtain economies-of-scale. Typically, it is impractical for operators to mobilize heavy equipment and procure soil borrow to construct less than 20 acres of closure. The proposed new closure can be installed in an economical way in an area as small as 3 acres because of the low mobilization costs and the minimal earthwork required.

According to the EPA there is approximately 10% loss of collection efficiency through emissions when a gas collection and control system (GCCS) is installed. Without a GCCS in place the amount of landfill gas escaping into the atmosphere can be many times greater. Based on the EPA's emission loss estimates, and Riley, Park Hayden and Associates experience across the Southeast U.S., it can be reasonably assumed that 2 to 4 cubic feet per minute per acre of surface emissions escape into the atmosphere with a well-operating GCCS with no final cover system in place. Based on these assumptions and typical landfill phasing, the annual and cumulative emission reduction provided by earlier closures using the new cover concept would be significant.

The estimate below is based on 5-acre incremental closures versus a typical 20-acre incremental closure and assuming a typical landfill filling sequence. An airspace depletion rate of 25 years is used in the total equivalency calculation. Although there are many variables affecting the actual surface emissions, such as the gas generation curve and waste fill depths, a general approximation is provided below to demine the degree of potential positive impact when implementing more frequent closure phases:

Greenhouse Gas Reduction Estimate

LFG Flow Rate per acre = 2 (assumed) scfm
LFG Flow Rate per acre= 1,051,200 scfm/year
LFG Methane Content= 50%
Net Methane GWP= 21.00 (estimates range from 21 to 23)

Direct GHG Emissions Reduction 10 metric tons of CH_4 *per ac/yr*
(24.7 metric tons of CH_4 *per hectare/yr)*

or, 209,000 kg of CO_2 *Equivalent (*TCO_2E*) per acre*
(516,230 Kg of CO_2 *per hectare)*

The total estimated reduction in CO_2 *emission through smaller, incremental closures can be estimated by assuming a yearly average of 7 acres of additional closure area. An airspace deletion time frame of 25 years is used in the calculation.*

209,000 Kg of CO2 per ac/ yr x 7ac x 25 yr = 36,575,000 of CO_2 *Equivalent*

OPTIMIZING SUSTAINABILITY THROUGH END USES

The lack of mowing and vegetation maintenance, such as fertilization and periodic soil replacement will result in a reduction of emissions and improve water quality. However a more significant, positive environmental impact can be realized through the addition of a solar collection facility. There is a going trend to use landfills as solar collectors and the Environmental Protection Agency (EPA) has performed analysis and support the initiative through the office of Solid Waste and Emergency Response. The EPA is encouraging the reuse of closed landfills for siting clean renewable energy facilities.

Placement of renewable energy systems at closed landfills is a relatively new practice. There are a number of challenges that are unique to installing photovoltaic (PV) panels on top of landfills, such as impacting the integrity of the system, stability, maintenance, efficiency losses from dust and shadowing. The closure system presented in this paper helps developers overcome many of these challenges.

There are three types of PV cell materials used in the solar industry. The most efficient are the polycrystalline and monocrystalline. However, these materials are also the heaviest and require mounting in a rigid frame tied to a foundation (typically concrete footings or pad). There are other type of solar cells that are lighter, normally called thin-film, but they are often less efficient. However it is a pliable material and is much lighter in weight and therefore is better suited to meet the engineering challenges of settlement and integration into an exposed geomembrane. Some of the available PV options are presented in Table 1 below provided by the EPA.

Table 1 – US EPA table of photovoltaic panel options

Brand	**Model**	**Watts**	**Weight (lbs)**	**Watts/Pound**	**Dimensions (inches)**	**Cell Type***
Uni-Solar	PVL-68	68	8.7	7.82	112.1x15.5x0.2	A
Uni-Solar	PVL-144	144	17	8.47	216x15.5x0.2	A
Kaneka	G-SA060	60	30.2	1.99	39x39x1.6	A
SolarWorld	SW175	175	40	4.38	63.9x32x1.6	M
SunWize	SW150	150	44	3.41	66.61x30.27	M
REC Solar	SCM 210WP	210	48.4	4.33	66.55x39.01x1.69	P
Sanyo	190BA3	190	33	5.75	52x35x1.8	P
	HIT Power N 215N/HIP-215NKHA5	215	35.3	6.10	63.2x32x72.8	P
Mitsubishi	MF120EC4	120	25.4	4.72	56.1x25.4x2.2	P
	MF185UD5	185	43	4.30	65.3x32.6x1.81	P
Kyocera	KC 50T	50	10	5.00	25x26	P
Kyocera	KC 130GT	130	26.8	4.85	56.1x25.7x2.2	P
Kyocera	KD 180 GX-LP	180	36.4	4.95	52.8x39x1.4	P

*P = polycrystalline; M= monocrystalline; A= amorphous thin film

Integrating the heavier more efficient PV systems with the new proposed closure system is a challenge currently being met by developers who have designed solar fields on top of landfills utilizing the heavier system. Characteristics of the closure system and the surface conditions in which the solar fields are to be developed minimizes many of the issues mentioned above; which may further the goal of the EPA and leaders in the renewable energy industry.

The most recent closure incorporating the new closure system is located at Crazy Horse Canyon Landfill in Salinas, California. The system, scheduled for installation in the summer of 2011, uses non-penetrating foundations on the top deck of the landfill. Some of the reasons the developer chose to site a solar filed on this cover system are:

- Protection provided by the turf components allowing for use of the heavier but more efficient PV system.
- New frame technology that eliminates fixed anchor points and distributes the stress on the geomembrane below.
- Accessibility for maintenance and panel replacement.
- Differential settlement can be corrected if it occurs to the degree that affects the system.
- The stability provided by the spikes located on the underside of the geomembrane.
- Relatively dust free environment promoting efficient solar collection.

Approximately 2,000 panels of monocrystalline cells are designed for a total output of approximately 1.0 Megawatt. Currently under evaluation is the use of a PV panel racking system on the south side slope that has potential to expand the output by 0.2 Megawatt. The side-slope installations present an additional challenge of designing against sliding failure. The unique membrane incorporated into this system produces a very high interface with the soil foundation layer, thus providing resistance to sliding failure. A trial location has been under evaluation in Tucson Arizona. The trial consists of rigid panels attached to the impermeable synthetic turf system installed on a 2:1 slope. After two years of evaluation there has been no measurable sliding of the rigid PV units.

The new geosynthetic cover system provides an opportunity for the solar fields to operate in a clean, very low particulate environment that allows the PV panels to operate at its highest possible efficiency. The nature of the system provides for accessibility, maintenance and replacement of PV panels that have exceeded their service life or be replaced with newer technology panels.

Establishing a renewable energy project such as solar power is a positive trend that can benefit landfill operators and the community. Solving the unique technical challenges of developing on top of the landfill, and hopefully continued trend of more favorable pricing of PV systems, will result in a practical post closure use that has long evaded the waste industry.

CONCLUSION

New geosynthetic applications can improve the reliability and performance of landfill closures. In particular, adding a specialized synthetic turf component to an exposed geomembrane cap can significantly improve membrane protection, accessibility, wind resistance uplift and aesthetics. Additionally, the turf provides for a combination of savings on upfront construction cost and post closure maintenance cost when compared to traditional cover systems.

From a sustainability point of view, the new synthetic closure turf system results in substantial reductions in CO_2 emissions from the construction and potential earlier capture of surface emissions.

The geosynthetic system discussed in this paper provides the ability to integrate the heavier more efficient photovoltaic panels. The advancement of panel frame design and the accessibility provided by the specialized synthetic turf may allow developers to produce solar electricity in a more competitive manner by extending the life of the solar field through panel replacement, and receiving competitive costs through the multiple panel options.

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