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Design and Installation of an Exposed Geomembrane Landfill Final Cover in Louisiana

D. J. Romero[1], R. C. de Abreu[1], and J. E. Deamer[1]

[1]*Fourrier & de Abreu Engineers, L.L.C., Baton Rouge, United States of America*

dustin@fdaengineers.com, ricardo@fdaengineers.com, joyner@fdaengineers.com

ABSTRACT

The Tangipahoa Regional Solid Waste Facility (TRSWF) is a municipal solid waste (MSW) landfill located in Independence, Louisiana, U.S.A. which recently installed a relatively new type of geosynthetic final cover consisting of a high-density polyethylene (HDPE) exposed geomembrane anchored with percussive driven earth anchors (PDEA's). This new system was used to close an approximate 10-hectare disposal cell of the TRSWF. In 2014, two other cells were closed also using a synthetic final cover system, however, an artificial turf system was installed at that time. Geosynthetic final covers have been the preferred method for landfill cell closure at the facility due to the steep slopes, highly erodible clays, and low pH topsoil. The authors designed the exposed final cover to account for the several forces acting on the geomembrane such as self-weight, wind suction, anchor pull-out resistance, and landfill gas pressure. One of the main environmental advantages of exposed geomembranes systems is that by not having soils as components, surface runoff is expected to have better quality than the runoff of other cover systems. Performance of both final cover systems installed at the facility (the artificial turf system and the exposed geomembrane system) are currently being monitored. In this study, the authors wanted to demonstrate that exposed geomembrane final cover systems can be designed and installed even under very adverse conditions, such as in the case study presented herein.

Keywords: landfill, geosynthetics, final cover, percussive driven earth anchors, exposed geomembrane

1 INTRODUCTION

Throughout the world, landfills have conventionally been designed following the premise of encapsulating solid wastes within a contained and controlled airspace to avoid the migration of potential contaminants from the waste to the environment (de Abreu, 2003). Under this concept, low-permeability barriers are constructed on the bottom and on the top of the landfill to minimize the release of contaminants to the water, air, and natural soils. The top barrier, known as the final cover, is usually constructed upon closing a disposal cell or the landfill. It is designed to minimize the infiltration of rain and snow as well as to avoid the uncontrolled escape of gases generated by the biological and chemical decomposition of the refuse, while being resistant to weathering and other internal and external elements.

Final cover systems for MSW landfills in the United States are regulated under Subtitle D of the Resource Conservation and Recovery Act (RCRA) and specific regulations from each state. The Louisiana Administrative Code (LAC) requires that final cover systems for MSW landfills be installed with a recompacted clay layer with thickness of at least 61 cm and hydraulic conductivity lower than $1x10^{-7}$ cm/s and overlain with a geomembrane. A geomembrane is usually not required for slopes that are steeper than 1(V):4(H). A minimum of 15 cm of topsoil capable of support vegetative grow is required to be placed as the top part of the cover. It is important to note that although regulations often prescribe the minimum component layers that the final cover must have, it is usually necessary to design additional layers for the successful installation and performance of the cover. According to Koerner (1998) and Qian et al. (2002), additional components of a final cover may include a gas collection layer, a surface water drainage layer, and a protection layer.

Alternative design for landfill final covers, including the utilization of exposed geomembranes, can also be approved by the state's environmental agency, the Louisiana Department of Environmental Quality

(LDEQ), if the alternative cover can provide equivalent or superior performance when compared to the traditional cover.

Exposed geomembranes have been used as landfill cover in the United States for more than 15 years. The use of exposed geomembranes as final cover offers several advantages when compared to traditional covers, including easier installation, less maintenance, airspace savings, and overall cost savings (de Abreu and Franklin, 2014). One of the main environmental advantages of exposed geomembranes systems is that by not having soils as components, surface runoff is expected to have better quality than the runoff of other cover systems. The main concerns regarding the use of exposed geomembranes by environmental regulatory agencies are weathering and wind uplift. Other concerns include aesthetics, increase in surface water run-off, potential for physical damage, and eventual seepages being more difficult to be detected. On the other hand, traditional covers may suffer from stability issues, such as differential settlement causing cracks and increasing the hydraulic conductivity of the low-permeability clay layer, soil erosion, and veneer sliding of layers. Figure 1 presents a visual comparison between the components of a traditional and an exposed geomembrane final cover. The figure depicts the minimum layers thicknesses as required by the State of Louisiana.

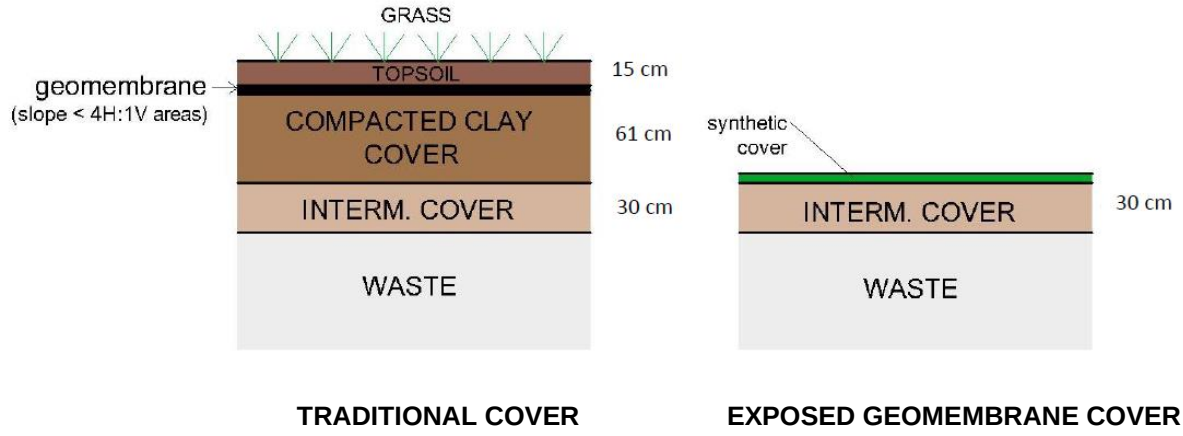


Figure 1. *Comparison between components of traditional and exposed geomembrane final covers as regulated by the State of Louisiana*

The present study demonstrates that even under adverse conditions, the use of exposed geomembranes as final covers can exceed the performance of traditional final covers.

2 FINAL COVER SYSTEMS FOR THE TANGIPAHOA REGIONAL SOLID WASTE FACILITY

2.1 The facility

The TRSWF is a permitted MSW landfill located in south Louisiana approximately 90 km northwest of the city of New Orleans. The landfill is owned by the Tangipahoa Parish Government and has been in operation by the local government since 1987. The facility currently receives approximately 500 metric tons of waste daily for final disposal. Fifteen disposal cells were constructed for waste disposal over the years, with twelve of them now closed. In November 2013, Cells 10 and 11, which are approximately 9 hectares, were closed using the artificial turf final cover system. In mid-2022, Cell 12, which is approximately 10 hectares in area, was closed using exposed geomembrane cover. Installation of the PDEA's was completed in September of 2022. The exposed geomembrane system is further described in Section 2.2. A site plan is shown as Figure 2.

2.2 Description of the exposed geomembrane final cover system

The layers of the final cover system for Cell 12 at the TRSWF consist of a 1.5 mm double-textured green high-density polyethylene (HDPE) geomembrane over a 30-cm thick interim cover layer. One of the challenges that the authors had to carefully consider when designing the final cover for Cell 12 was the recently installed Gas Collection and Control System (GCCS), which required an innovative solution for

the exposed geomembrane anchoring system. Traditional anchoring methods, such as anchor trenches, were not feasible due to the significant number of underground interferences of the existing GCCS. Underground interferences included gas lines, force main lines, and air lines close to the surface. The authors ultimately decided on the selection of percussive driven earth anchors (PDEA's) as the anchoring system for the exposed geomembrane. In total 6,139 PDEA's were installed as part of the anchoring system. To ensure that the exposed geomembrane system was protected against water intrusion, geomembrane patches were installed and extrusion-welded over each PDEA. Although the existing GCCS system could still be damaged due to installation of the PDEA's, the authors were able to avoid this by incorporating the as-built GCCS location data into a precise geometric design of anchor locations and by carefully surveying each of the 6,139 anchor locations.

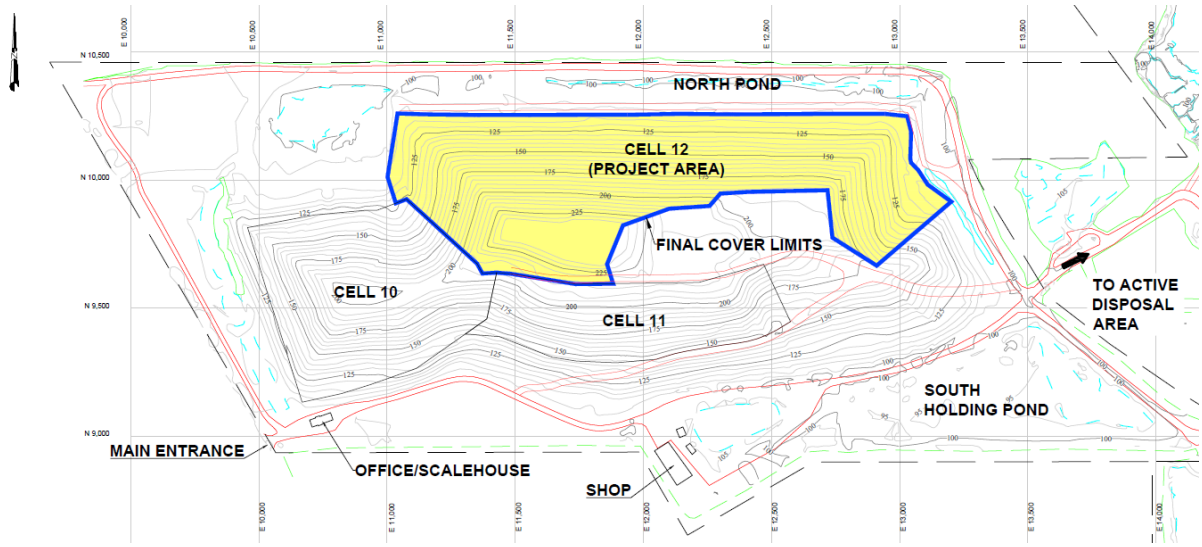


Figure 2. *Site plan (Contour line elevations are shown in feet, NGVD)*

The PDEA's utilized in this project consisted of non-corrosive materials: hard anodized aluminum alloy anchors with lower terminations and wire tendons made of stainless steel and met the criteria of a design life of 20 years.

3 DESIGN CONSIDERATIONS

3.1 Weathering

During the design phase of the exposed geomembrane, the authors had to consider the effects of weathering to ensure that the exposed geomembrane could withstand the degradation effects of precipitation, ultraviolet (UV) radiation, and erosive forces. These constraints have the potential to compromise the structural integrity of exposed geomembranes by breaking down the chemical and physical properties of the geomembrane thus lowering strength and endurance properties and reducing service life. To address those concerns, the authors utilized the performance requirements for HDPE geomembranes in accordance with the GM13specifications of the United States Geosynthetic Research Institute (GRI) for the geomembrane acceptance. In addition, it was also required that textured, green-colored HDPE geomembranes were utilized in the project.

According to Koerner (2012), since their introduction, geosynthetics have made progress in their formulations and manufacturing and an exposed lifetime of 30 years or greater is currently achievable, even in hot climates, as indicated in laboratory studies conducted by the Geosynthetic Institute (GSI). GSI states that conventional polymer practice considers the half-life of geosynthetics to be the effective lifetime value. The half-life is the timeframe over which geosynthetics retain 50% of their strength and endurance properties after being exposed to weathering conditions. Although the half-life of geomembrane depends on the specific polymer formulation, studies conducted in Phoenix, Arizona by GSI predict that half-life for HDPE (high-density polyethylene) geomembrane could be 97 years for strength parameters and 91 years for elongation parameters. The life expectancy of exposed geomembranes can be difficult to predict and is largely dependent on the specific formulations used in the production of the HDPE geomembrane and specific site conditions. However, studies such as the

one performed in Phoenix by GSI suggest that modern HDPE geomembranes can withstand prolonged exposure to UV radiation which is the major cause of degradation to the organic materials contained in exposed geomembranes (Koerner et al., 2017).

3.2 Wind uplift

Due to the location of the facility, wind uplift was considered one of the most important and critical design aspects of this project. Wind uplift for exposed geomembranes is caused by the development of suction forces at the geomembrane surface, as discussed by Giroud (1995). These suction forces are directly proportional to the wind speed and must be counterbalanced to prevent the failure of the geomembrane. This consideration was extremely important since the facility is located in an area prone to hurricanes, known as the Atlantic Hurricane Belt. Due to the facility's location within the Atlantic Hurricane Belt, high wind events at the facility are a common occurrence. Not only can the geomembrane become torn or pulled from its anchor trench during high wind events, but uplift can also cause the geomembrane to become repositioned causing wrinkling and tension of the geomembrane. To prevent wind uplift, the PDEA system was implemented. During the design phase, the authors calculated the magnitude of wind uplift and the anchor spacing required to counteract the wind uplift forces. The wind uplift calculations were performed using the methods of PDEA system design provided by Giroud et al. (1995), which were later updated by Zornberg and Giroud (1997).

3.2.1 Effective suction calculation

To determine the required spacing of the earth anchors, the authors calculated the magnitude of effective suction that must be counteracted by the earth anchors. Zornberg and Giroud (1997) recommend the following equation for calculation of the effective suction due to wind:

$$S_e = 0.050(\lambda)V^2 e^{(-1.252 \times 10^{-4})\, z} - 9.81\mu_{GM}$$

Where S_e is the effective suction (Pa); λ is the dimensionless suction factor; V is the wind velocity (km/h); z is the site elevation (m); and μ_{GM} is the mass per unit area of geomembrane (kg/m^2)

The effective suction (S_e) was calculated using an assumed wind velocity of 153 km/h, based on local construction standards. The average facility elevation, based on the North American Vertical Datum of 1988 (NAVD 88), is approximately 73 meters above sea level. The mass per unit area of geomembrane was provided by the manufacturer's technical data sheet. The diagram provided below shows how the suction factor is determined based on the location of analysis on the slope. The suction factors used in the calculations are based on the work by Kashiwayanagi and Sato, 2006, which suggests that the suction factors presented by Giroud et al. (1995) are overly conservative. The suction factors presented by Giroud et al. (1995) do not consider the suctions forces present below the geomembrane during a wind uplift event. The effective suction for each section as calculated using the parameters provided above are provided in Table 1, in general locations as shown on Figure 3.

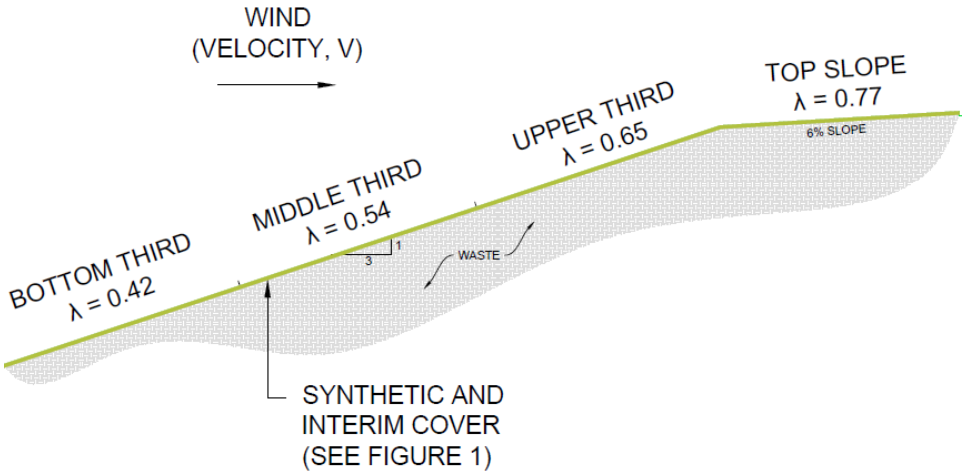


Figure 3. *Diagram showing the selection of suction factors*

Table 1 *Calculated effective suctions*

	Effective suction, S_e (Pa)
Bottom third	474
Middle third	613
Upper third	741
Top slope	879

3.2.2 Anchor spacing calculation

After determining the effective suction on the exposed geomembrane, the required anchor spacing could be calculated. The following equation was used to calculate the number of anchors required:

$n = (S_e \times A)/(P \times FS)$

Where n is the number of anchors required; S_e is the effective suction (Pa); A is the area being analysed (m^2); P is the ultimate load of the anchors (N); and FS is the factor of safety.

The ultimate load of the anchors as suggested by the manufacturer was approximately 9,800 N. That value assumes that the subgrade conditions of landfill covers are approximately equal. Although this is generally a valid assumption, it does not cover all subgrade conditions experienced by the authors in different landfills. Twenty pull-out tests were performed throughout the project area to evaluate that the design loads were adequate. A factor of safety of 0.9 was used in the calculations. The effective suction calculations are provided in Section 3.2.1. These parameters were used in the equation above with the respective area for each section (top slope, upper third, middle third, and bottom third) to calculate the number of anchors required. The resultant calculations are provided in Table 2 below.

Table 2 *Calculated maximum anchor spacing*

	Anchor spacing (m)
Bottom third	4.6
Middle third	4.0
Upper third	3.7
Top slope	3.4

3.2.3 Alternate method for effective suction calculation

Li et al. (2019) suggest that the earlier design methodology for calculating the effective suction of an exposed geomembrane presented by Giroud et al. (1995), and later extended by Zornberg and Giroud (1997), was overly conservative due to the fact that the earlier design methodology did not account for the suction forces below the exposed geomembrane caused by the GCCS system and the limited exchange of air across the geomembrane due to its low permeability. Li et al. (2019) suggest the following equation for calculation of the effective suction:

$$S_e = S - 9.81\mu_{GM} + p = 0.05(\lambda)V^2e^{(-1.252 \times 10^{-4})\, z} - 9.81\mu_{GM} + p$$

Where S_e is the effective suction (Pa); λ is the dimensionless suction factor; V is the wind velocity (km/h); z is the site elevation (m); μ_{GM} is the mass per unit area of geomembrane (kg/m^2); and p is the pressure underneath geomembrane (Pa).

Note that the difference between the revised design methodology proposed by Li et al. (2019) and the conventional design methodology by Giroud et al. (1995) is the inclusion of the term “p” which represents the suction forces that occur beneath the geomembrane and counteract uplift.

The authors believe that the methodology proposed by Li et al. (2019) is promising, since likely the effects of the negative pressure beneath the geomembrane should be somehow considered. However, given the critical location of the facility, within the Atlantic Hurricane Belt, and the current lack of additional practical data points to validate the theory, the authors decided instead to use the earlier designed methodology for conservativism.

3.3 Cover veneer slope stability

Over the past 30 years there have been dozens of veneer cover slope stability failures in the United States (Thiel, 2008). In fact, veneer cover slope failures occur more frequently compared to slope failures of bottom liner systems. Therefore, veneer slope stability is an important concept that must be considered in the design of any final cover system. Traditional veneer cover systems employ the use of soils as a ballast system introducing an interface between the soils and the underlying geomembrane which is susceptible to failure. However, use of exposed geomembrane offers a unique benefit for veneer slope stability since they do not require the use of soils as a ballast system. The PDEA/exposed geomembrane cover system offers protection against veneer slope stability through strong textured geomembrane/soil interface shear strength as well as added protection from the anchoring forces of the PDEA's, which hold the geomembrane tight against the underlying interim cover. The utilization of PDEA's will also lead to a more stable soil mass. The inclusion of tensile reinforcing members in a soil may significantly increase its strength and load bearing capacity much the same way that placing rebars in concrete increases its strength (Coduto, 2001). This increase in soil strength may contribute to an increase in stability of the surficial layer of the slope. Due to the interface friction of the textured HDPE geomembrane, combined with the PDEA's, a slope stability failure of the veneer cover system is not likely to occur for this type of final cover system.

3.4 Surface water drainage design

Since the primary function of an exposed geomembrane is to create a low-permeability layer, significant increase in surface runoff was expected due to the extreme reduction in the infiltration and evapotranspiration components. During the design phase, the authors were required to consider the effects of a significant decrease in the Manning's roughness coefficient and reduction in the time of concentration for the watershed of the project area. Louisiana's solid waste laws and regulations require stormwater management systems at solid waste facilities to be designed to withstand, at a minimum, the surface runoff from a 24-hour 25-year rainfall event.

The authors designed diversion earth berms and excavated let-downs, installed beneath the geomembrane, which are used to control and convey stormwater to the pond located immediately north of the project area – the North Pond. The facility is currently increasing the capacity of the North Pond to allow storage of a 24-hour/25-year rainfall event (the design storm). Having the capacity to store the design storm is critical to minimize negative impacts on the environment, receiving water bodies, and downstream floodplains.

Surface water drainage design with artificial turf systems requires designers to consider the effects of sheet flow and the resultant shear forces on the ballasting sand. Since the exposed geomembrane system does not require the use of ballasting sand, the authors were able to reduce the number of diversion berms required for the surface water drainage system.

4 INSTALLATION CONSIDERATIONS

4.1 General anchor and patch installation procedure

The general anchor installation procedure involved driving the anchors using a demolition hammer (see Figure 4) and subsequent tensioning the anchor tendon using a hydraulic pump. Anchors were driven to a depth of approximately 1.6 meters. Once the anchors were driven to the required depth, the anchor tendon was clamped to the hydraulic pump apparatus, and the anchor was tensioned to the required load. After loading the anchor, installers recorded the date, anchor ID, drive depth, load, and extension (the distance the tendon was required to be pulled to reach the required load) on the geomembrane (see Figure 5). Upon completion of anchor installation, a geomembrane patch was placed on top of the anchor and extrusion welded to the primary exposed geomembrane. The geomembrane patches were then non-destructively tested using a vacuum box. Each anchor load test and vacuum box test was observed by construction quality assurance (CQA) personnel to ensure the project specifications were satisfied.



Figure 4. *Installation of PDEA using demolition hammer*



Figure 5. *Post-tensioned PDEA with anchor installation information*

4.2 Existing GCCS system

Extreme care was necessary to be taken during anchor installation to avoid damaging the existing GCCS system of Cell 12. As-built survey data was used to determine the location of each anchor. This process was especially challenging since the spacing requirements calculated in Section 3.2.2 needed to be satisfied while simultaneously avoiding the existing components of the GCCS system. A unique anchor ID was assigned to each one of the 6,139 anchors and subsequently surveyed using GPS surveying equipment. After the locations were surveyed, the geomembrane was marked using marking paint. The method used for determining the location of and surveying each anchor gave the authors and the installers confidence that the existing GCCS system would not be damaged. All 6,139 anchors were installed with no impact to the underlying GCCS system.



Figure 6. *CQA representative surveying PDEA locations*



Figure 7. *Existing GCCS System Extraction Well*

4.3 Geomembrane expansion and contraction

Geomembranes tend to expand and contract as their temperature fluctuates. Whenever ambient temperatures are low, geomembranes become contracted and may develop “trampolining”, especially in stormwater diversion berms. At extremely low temperatures, a geomembrane can even be stressed to failure if not enough slack is provided. Whenever ambient temperatures are high, geomembranes may form wrinkles. To optimize the final cover’s performance, the geomembrane must be installed with sufficient slack while also minimizing wrinkles. During the summer months ambient temperatures routinely rise to over 35° C with the geomembranes being hotter than the surrounding air. Since installation of the Cell 12 exposed geomembrane took place primarily during the summer months of the North Hemisphere, management of geomembrane wrinkles became a considerable challenge for the installers.

It is strongly recommended that earth anchors be installed whenever the geomembrane is reasonably smooth and wrinkle-free. To satisfy this requirement, anchor installers implemented an alternate schedule which allowed the earth anchors to be installed during the early morning hours before the geomembrane temperature rose and excessive amounts of wrinkles developed. Using the alternate schedule, the anchor installers were able to take advantage of the low ambient temperatures of the early morning hours and install the anchors in the relatively unwrinkled exposed geomembrane. Sufficient slack was ensured by maintaining the required overlap length of approximately 13 cm at panel seams.

Not only did wrinkles present challenges for installation of the earth anchors but also for the patch installers. Since each patch required extrusion welding, patch installers were presented challenges while attempting to extrusion weld the geomembrane patches over the wrinkles. Due to the challenges observed during patch installation, the patch installers also implemented an alternate schedule – a night shift. The night shift, which took place between the hours of 18:00 to 6:00, allowed the patch installers to take advantage of the relatively low ambient temperatures and relatively unwrinkled geomembrane. This resulted in better welds and increased production due to the cooler working environment. Figures 8 and 9 below show night shift activities taking place for patch installation.



Figure 8. *Crew preparing for night shift*



Figure 9. *Extrusion welding during night shift*

5 PERFORMANCE EVALUATION

The facility and the designers are currently evaluating the performance of the installed artificial turf and the exposed geomembrane final cover systems. At the time of the writing of this article, approximately four months passed since installation of the exposed geomembrane final cover system at the Tangipahoa RSWF.

5.1 Visual performance

Since installation of the exposed geomembrane, no signs of weathering or significant damage have been observed. The facility plans to perform quarterly visual inspections to check for damage and to evaluate if any additional measures regarding maintenance or minor repairs are needed following installation of the exposed geomembrane. During the routine inspections, inspectors will also observe the patches which were installed over the PDEA's to ensure that they are still in good condition and have maintained a watertight barrier around all PDEA's.

All anchors were visually inspected after installation to ensure they were tensioned to the required load. Since the installation of the earthen anchors, no signs of loose anchors were observed.

The exposed geomembrane final cover system was installed over silty and sandy clays originated at the facility's borrow source. No signs of erosion underneath the exposed geomembrane have been observed since installation of the final cover system.

With the increase in surface water runoff, the designers want to evaluate how the exposed geomembrane final cover system performs during rain events. As expected, the water drains quickly down the steep slopes and follows the diversion berms and let-down chutes before draining into the North Pond. Some rainwater gathers in the flowline of some diversion berms forming shallow puddles on the liner that dry relatively quickly with sufficient sunlight.

5.2 Surface water run-off quality performance

The TRSWF, like other landfills in North America, has a water discharge permit and is required to monitor and sample surface water runoff that leaves the facility and discharges off from the property through outfalls. These outfalls are regularly tested for parameters such as total suspended solids (TSS), chloride, common metals, and pH to determine water quality against strict effluent limits enforced by the LDEQ. A major reason for the designers selecting an exposed geomembrane final cover system was the lack of contact stormwater runoff with soils which should result in a better quality of stormwater runoff discharging through the outfalls. The facility is currently analyzing the quality of stormwater runoff for the three separate types of covers at the landfill: (1) the artificial turf synthetic final cover system used to cover Cells 10 and 11; (2) the exposed geomembrane final cover system used to cover Cell 12; and (3) an interim cover consisting of a minimum of 0.3 m of a silty of sandy clay placed directly on top of waste. The analysis of the various types of cover systems consists of the collection of samples and laboratory analysis for parameters such as Turbidity, Total Suspended Solids (TSS), pH, Total Organic Carbon (TOC), and Total Iron. Only one sampling event has been performed so far, therefore a final conclusion cannot be drawn at the present time. Table 3 presents the results of the first sampling event just as an initial reference. The facility's effluent limits are shown on the table as well.

Table 3 *Sampling Results from 2nd & 3rd of August 2022*

Parameter	Artificial Turf	Exposed Geomembrane	Interim Cover	Water Quality Discharge Limit
Turbidity (NTU)	12	11.9	632	35
TSS (mg/L)	<4.0	19	261	27
pH (Std. Units)	8.0	6.4	5.9	6.0 (minimum) 9.0 (maximum)
TOC (mg/L)	1.2	<1.0	5.3	50
Total Iron (mg/L)	<0.05	0.302	31.7	1.0

6 CONCLUSIONS

The Tangipahoa Regional Solid Waste Facility recently installed an exposed geomembrane final cover to close a 10-hectare MSW waste disposal cell in September 2022. As of February 2023, the design and installation of the exposed geomembrane final cover system has been demonstrated to function as intended. The LDEQ requires that the final cover be maintained for 30 years, which makes the durability of the final cover extremely important. The writers designed the final cover system to withstand various forces acting on the geomembrane such as self-weight, wind suction, anchor pull-out resistance, and landfill gas pressure. The design of the exposed geomembrane final cover system contains 3 components: a 30 cm thick interim earthen cover placed on top of the waste, a 1.5 mm thick textured HDPE geomembrane, and percussive driven earth anchors, securing the liner in-place. All components were installed under supervision of the writers. During installation, field tests, written logs and visual observations were recorded to document and ensure the quality and the workmanship of the final cover system withstands the test of time. The exposed geomembrane final cover system passed all design considerations and was successfully installed without damaging the interim cover, the underlying GCCS, or the geomembrane itself. Quarterly inspections will be conducted on the final cover system throughout its lifetime. In addition to the durability of the final cover system, the writers are keen to see the quality of the stormwater runoff discharging from the exposed geomembrane final cover. The stormwater runoffs from three separate liner systems are currently being evaluated for regular effluent parameters. Despite the various challenges, the exposed geomembrane final cover system was successfully installed at the Tangipahoa Regional Solid Waste Facility. The methodology presented herein can also be extended to other landfills as long as the design requirements for exposed geomembranes outlined

under this study are met. Moreover, this project demonstrates that exposed geomembranes can be implemented at landfills as an effective option to more traditional final covers.

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REFERENCES

Coduto, D. P. (2001). *Foundation design: Principles and practices*. Prentice Hall.

de Abreu, R. C. 2003. Facultative bioreactor landfill: an environmental and geotechnical study, Ph.D. Dissertation, University of New Orleans, USA.

de Abreu, R. C. and Franklin J. 2014. Synthetic final covers and a new approach to landfill gas collection, Presentation to the 2014 Louisiana Solid Waste Association Conference, Lafayette, Louisiana, USA.

Giroud, J.P., Pelte, T., & Bathurst, R.J. 1995. Uplift of geomembranes by wind. Geosynthetics International. 2, 897-952.

Kashiwayanagi, M., Sato, M., & Takimoto, J. 2006. Six-year performance of synthetic-rubber-sheet facing for the upper pond of seawater pumped storage hydropower plant. In: Proceedings of the Eighth International Conference on Geosynthetics, Yokohama, Japan, vol. 2. Pp. 607-610.

Koerner, R.M. 1998. *Designing with Geosynthetics*. 4th Edition. Prentice Hall, Upper Saddle River, USA, 761 pp.

Koerner, R.M. 2012. Traditional vs. exposed geomembrane landfill covers. Geosynthetics Magazine, October 2012.

Koerner, G.R., Koerner, R.M., & Hsuan, Y.G. 2017. The durability of exposed geomembrane covers. Geosynthetics Magazine, 12 January 2023, https://geosyntheticsmagazine.com/2017/10/01/the-durability-of-exposed-geomembrane-covers.

Li, C., Espinoza, D., & Morris, J. 2019. Wind-induced uplift of exposed geomembrane covers: A proposed revision to conventional design approaches. Geotextiles and Geomembranes 48 (2020) 24-31.

Qian, X., Koerner, R.M., & Gray, D.H. 2002. *Geotechnical aspects of landfill design and construction*. Prentice-Hall, Upper Saddle River, USA.

Thiel, R. 2008. Slope stability sensitivities of final covers. Geosynthetics Magazine, 12 January 2023, https://geosyntheticsmagazine.com/2008/08/01/slope-stability-sensitivities-of-final-covers.

Zornberg, J.G., & Giroud, J.P. 1997. Uplift of Geomembranes by Wind-Extension of Equations. Geosynthetics International. 4, 187-207, 521-522.