Advances in Geomembranes : Leak Location Liner Geomembrane Barrier Systems with Increased Integrity

GEOQuébec 2015
Challenges from North to South
Des défis du Nord au Sud

Vincent Diviacchi & Boyd J. Ramsey
GSE Environmental LLC, Houston, Texas, USA

ABSTRACT
In recent years, several developments and advances have been made in geosynthetic barriers, particularly barriers in exacting difficult and high risk applications. These developments have advanced the capabilities of geosynthetics and improved the performance of barrier systems. In particular, two applications have changed significantly. On December 19, 2014 the US EPA published the regulations that will be imposed on the storage of coal ash and coal combustion residuals in the United States. In the two years prior to that, a series of advances in leak detection methods and efficiency, leak location techniques and equipment and the materials that facilitate more accurate and rapid leak detection surveys have been fully commercialized and successfully applied to multiple installations around the world. This includes the ability to easily provide continuous monitoring for leakage through geosynthetic systems. This combination of regulations and technology has significantly improved the performance capabilities and potential for geosynthetic barriers. These technologies are reported, case history examples are presented, and projections are made for current and future usage of these materials and techniques.

RÉSUMÉ
Au cours des dernières années, plusieurs développements et progrès ont été réalisés dans le domaine des géomembranes, en particulier concernant les applications à risque élevé. Ces développements ont accru les possibilités d'utilisation des géosynthétiques et l'amélioration de la performance des barrières. En particulier, deux applications ont considérablement changé. Le 19 décembre 2014, la US-EPA a publié les règlements qui seront imposés sur le stockage des cendres de charbon et les résidus de combustion du charbon aux États-Unis. Dans les deux années avant cela, une série de progrès dans les méthodes de détection des fuites et d'efficacité, les techniques de localisation des fuites et de l'équipement, ainsi que les matériaux qui facilitent les campagnes de détection des fuites plus précises et plus rapides, ont été commercialisés et appliqués avec succès dans plusieurs installations à travers le monde. Cela inclut la possibilité de fournir facilement une surveillance continue des fuites à travers des systèmes géosynthétiques. Cette combinaison de règlements et de technologie a considérablement amélioré les capacités de performance et le potentiel des géomembranes. Ces technologies sont décrites, des exemples sont présentés, et des projections sont faites pour l'utilisation actuelle et future de ces matériaux et techniques.

1 INTRODUCTION

Geosynthetics have become an integral piece in designs of containment systems. Geosynthetic liners have increasingly become the product of choice for barriers as bottom liners and for closures. As demand for these liners continually increases so has the demand for better performing products. The formulation of the base resin in geomembrane liners can be improved for longer life in exposed and buried applications. Modifying the formulation can also yield a more flexible product for applications where subgrade deformation or waste consolidation is a long term concern. These and more properties of the geomembrane liner can be enhanced for a better performing product. The variable manufacturing process for geomembrane liners results in a wide variety of geosynthetics that can be tailored specifically for a project design and its unique site conditions. In an increasing amount of containment designs the demand for higher quality products with higher quality installations has given the geomembrane manufacturers a chance to provide their clients with new product innovations.

One of the latest product innovations with the geomembrane liners is the ability to locate defects over the entire surface. The ability to test the geomembrane liner itself significantly increases the ability to find defects and leaks in the geosynthetic containment liner system. "How much do you want your liner to leak?" is a question that is rarely asked of the owners, engineers and other participants in the installation of a geosynthetic barrier system, yet it is a critical question. With the latest geomembrane product innovation an owner can now feel confident that the latest technology in geomembranes is significantly reducing the amount of defects on the geomembrane before the site goes into operation.

2 BACKGROUND DEDSIGN AND ASSSOCIATED PRODUCTS

In discussing the use of the latest technologies it is important to understand the background of best practice containment systems. The most efficient and effective barrier system is a composite liner system using a primary geomembrane (GMB) liner, most commonly manufactured from High Density Polyethylene (HDPE) with some form of clay, either a compacted clay liner (CCL) or a Geosynthetic Clay Liner (GCL), although other variations exist. These system(s) have a great history of success as documented by several investigations, most prominently the US EPA study titled “Assessment and Recommendations for Improving the Performance of Waste Containment Systems” by “Boneparte, et.al. (2002).” Figure 1 illustrates the effectiveness of composite liners as indicated by lower leakage rates.

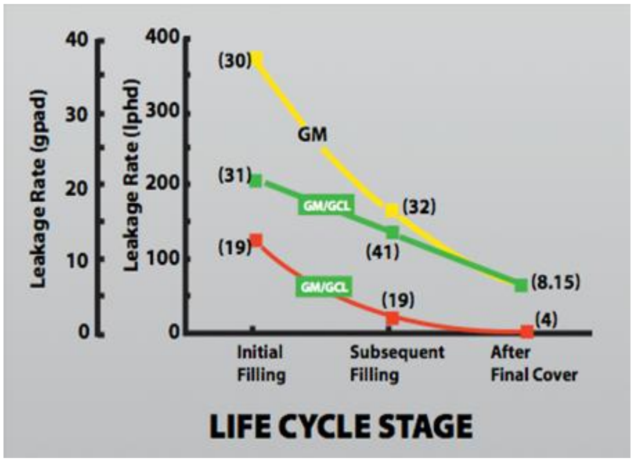

Figure 1. Leakage rates of GMB alone (top) and composite liners (CCL and GCL, respectively) after Boneparte (Appendix E)

This and other data leads to formulas used to predict the leakage of liquids through the composite liner systems. “Giroud and Bonaparte” (1989), and “Giroud et al.” (1992) presented equations for calculating steady-state leakage rates through holes in the geomembrane component of composite liners, respectively; these are commonly called the Giroud leakage equations. These equations address both the number and size of holes in the primary geomembrane liner; and the “contact factor” addressing the degree of intimate contact between the primary geomembrane and the clay component of the composite liner. The more intimate and complete the contact, the greater the “composite action” and lower the leakage rate.

The GMB and CCL or GCL composite liner system provide an excellent barrier layer to prevent leakage. But they do not address the construction activity that occurs after the liners are installed. Once liner installation is complete the earthworks contractor begins work with placement of earthen cover soil. This is where the bulk of damage to the liner system can occur. The best detailed assessment of holes location and probable cause identification was published by “Nosko & Touze-Foltz” (2000). That investigation clearly identified holes made by stones on the flat surfaces of the sites (as contrasted with slopes) as responsible for an overwhelming majority of holes/leakage; nearly ¾ of the total. That work also identified and proposed a method for assessing the impact of wrinkles which relate directly to the “contact factor” from the Giroud leakage equations.

As a majority of the holes in a liner are caused by rocks/stones and the placement of cover soil is at least half of the rock/soil/stone contact, it is very important to keep the CQA function operational through cover soil placement. In fact, if one could only have CQA during a single phase of construction, cover soil placement is the best selection. The Construction Quality Assurance (CQA) process of geosynthetic construction is a powerful piece to address. The proposition is that despite the best of intentions, everyone does a better job when their work is being monitored and evaluated; this applies to geosynthetics as well.

Figure 2. Poor cover soil placement (note the lack of a distribution pattern) without CQA.

Too often, a quality geosynthetic liner is installed and perhaps even verified by liner integrity testing, only to be severely damaged during cover soil placement by either rock/stone impact on the geosynthetic, or as has been often seen, the impact of tracked vehicles operating on a liner with no cover soil.

Figure 3. Tracked vehicle damage on partially exhumed geomembrane (courtesy A. Beck)

3 LEAK LOCATION METHODS

Do you know one thing you can do make your site over 20,000 times less likely to exceed a standard Action

Leakage Rate of 200 liter/hectare/day? *If both a surface and post cover soil placement Liner Integrity Survey, are specified and properly conducted, a site is 22,000 times less likely to exceed a ALR of ~200. liter/hectare/day (~ 20 gallons/acre/day. (Beck, 2012a).*

Generally the answer to this question only receives intelligent consideration when some sort of regulatory limit is being applied to the project and operation. This is generally manifest in an "Action Leakage Rate" above which the project is impacted with altered operations, up to and usually including shutdown of one or more aspects of the operation. Some owners and applications are not really concerned with leakage; water storage in non-arid environments is usually not critical. However, the increasing value of water resources and the use of geosynthetics to contain both valuable and hazardous liquids (heap leach mining is a prime example) are combining to make the question "How much do you want your liner to leak?" and the answers, very critical to the construction of a geosynthetic barrier system. Utilizing proper testing techniques and construction, an owner can have a geosynthetic barrier system with as little leakage as possible and without dramatically increasing the project cost. The ability to test the liner while it is exposed, and then again after cover soil is placed over top can provide immeasurable value.

As discussed above, the cover soil operation leads to many of the liner system defects and identifying these defects is key. Liner Integrity Surveys or Electronic Leak Location Surveys have been a tool to identify these defects for many years. However, improvements in the testing equipment and geosynthetic materials can result in a more accurate and sensitive survey of the containment system. It is important that the geosynthetic installation plan ahead for both post-installation/exposed, pre-cover soil placement survey (commonly done utilizing ASTM D 7240 or ASTM D 7002) AND a post soil cover survey (commonly done utilizing ASTM D 7007). Proper execution of these surveys and protocols can be dramatically enhanced with proper materials selection in advance of construction.

"Bare" geomembrane testing is most often done using either the water lance method (ASTM D7002) or testing of a geomembrane with a conductive layer (ASTM D 7240), although other methodologies may be used. Clearly the availability and value of water is a contributing factor in this decision. Sufficient water/ moisture must be present in the subgrade for ASTM 7002 type testing to be effective. An additional issue is the requirement to remove the water as necessary to enact repairs should a leak be found. Use of a conductive geomembrane and ASTM D 7240 both eliminates these considerations and in the opinion of the author and others allows for a more rapid and accurate liner integrity survey to be completed.

Since we know soil cover placement is the activity that is the most likely to cause damage to the geomembrane, a test following cover soil placement is a key component. The dipole method (ASTM 7007) is the best and most effective method for determining liner integrity. It has previously been effective at identifying and locating damage as slight as a 4 cm cut through both 1 meter of soil and an overlying geocomposite drainage blanket. The same survey method can be completed over containment structures that are filled or partially filled with liquids.

Figure 4. Detected damage on partially exhumed geomembrane (Ramsey et.al., 2012)

The most effective use of these tests (ASTM D7240 and ASTM D7007) is in a complimentary fashion. As reported by Beck, when both bare geomembrane is tested prior to soil placement and a liner integrity survey is also completed after soil placement, the site is over 20,000 times less likely to exceed a standard Action Leakage Rate of 200 liters per hectare per day.

4 LATEST LEAK LOCATION TECHNOLOGIES

Selection of an electrically conductive geomembrane and installation utilizing the most modern and correct methodologies will increase the speed, reduce the costs and improve the accuracy of any leak location survey. A manufacturer with significant experience producing electrically conductive geomembranes is important. Poor formulations of the conductive layer can lead to ineffective geomembrane sheets to conduct a current. The manufacturer must also produce an electrically conductive layer for the entire lower surface, not just portions of it. If the conductive layer does not extend through to the edges of the roll then you are left with strips of non-conductive material where defects cannot be discovered with a leak location survey.

This effort extends not only to the material selection, but also the installation welding. There is new equipment and welding techniques available to prevent the capture of "false-positive" results from a liner integrity survey. Before this new welding equipment became available, the seam presented a problem area during Electronic Leak Location Surveys. The electrical current induced in the overlying cover soil would travel through the upper flap of a welded seam and register as a defect. Every seam in the installation, or every 6.7m of liner installed, would read as a defect in the liner system. That made performing leak location surveys with the geomembrane counterproductive. Isolation of the welding "flap" of a dual track extrusion weld in order to minimize and hopefully eliminate the “false-positive” results became very important to achieve an accurate leak location survey.

In researching a solution to this seam problem, GSE developed the IsoWedge. The IsoWedge is a patented heating element that is part of all dual tracked wedge welders. The IsoWedge eliminates the false positive readings in leak location surveys found at every seam of an electrically conductive geomembrane installation. Use of state of the art welding techniques, proper isolation of appropriate areas/sections of the projects for testing, and other details can be simply and inexpensively addressed during installation, but will prove to be expensive and complicated to recreate if a leak is discovered after the facility has been placed into service. These test and techniques are best applied before the act of installation.

5 CASE HISTORY EXAMPLE

Hundreds of sites around the world have utilized bare geomembrane testing and covered leak location surveys to enhance quality control and find defects on the liner system before going into service. Example sites include heap leach pads, coal ash impoundments, municipal solid waste landfills, industrial waste landfills, vertical storage tanks, and agricultural waste lagoons. A recent test pad for a soil fertilizer mining company in North America was built to witness the accuracy of an electrically conductive geomembrane. The test pad was for containment of processed gypsum waste. It was built utilizing the electrically conductive geomembrane installed with the patented GSE IsoWedge seaming technology.

The owner has installed geosynthetic products on many areas of their project sites. They were interested in the latest geomembrane technology to ensure their containment systems were properly installed before going into operation. The electorally conductive HDPE geomembrane and the IsoWedge technology gave them the option.

The electrically conductive geomembrane was installed and then spark tested per ASTM D7240 to locate any defects from the geomembrane installation. The geomembrane was then covered with gypsum waste over the entire surface. A third party performed the leak location survey and located several defects, simulated and real, which then uncovered and inspected prior to repair.

This simple test pad constructed with the latest material and geomembrane welding technology showed the owner what can be achieved with an improved containment system.

6 CASE HISTORY EXAMPLE

As more engineers and owners become aware of these materials and techniques there will be greater interest in recommending them to improve the quality of liner containment system installations. Environmental stewardship is a driver for many companies and these

Figures 5-7. Simple test pad construction

advanced installation techniques give the forward looking companies a level of quality that far exceeds current industry standards. Sites that fall under regulatory and public scrutiny will be eager to utilize this technology and show they are designing site with best practices in mind.

Improved accuracy in leakage calculations also continues to grow with increasing research. New methods to calculate leakage has shown that the quality of the installation is ever more important. “Rowe and Hosney” (2010) describe the effects of wrinkles in geomembranes and how defects on these wrinkles substantially contribute to excessive leakage rates. Winkles in geomembranes are interconnected, reduce contact between the composite liner systems, obstruct leachate flow paths, and are more susceptible to damage by cover soil placement. Identifying these defects with an electrically conductive geomembrane becomes even more valuable.

"Beck" (2012b) has done excellent and the most recent analysis of anticipated leakage rates and measurement of past performance. The analysis of a significant data set (132 sites) from the state of New York is addressed in "A Statistical Approach to Minimizing Landfill Leakage". The recommendations are clearly stated: *"…if both leak location methods are specified, the water puddle method after geomembrane installation and the dipole method after cover soil placement to ensure that no major damage occurs during cover soil placement, the chance of exceeding the ALR becomes essentially zero.*

7 CONCLUSION

The benefits in barrier performance that can be obtained by utilizing conductive geomembrane with leak location survey testing completed both prior to and after soil placement have been evaluated. Additional barrier performance is obtained by using a composite geosynthetic system with a geomembrane and geosynthetic clay liner demonstrating the best performance over a range of conditions. Beyond proper material selection it is crucial to select qualified geosynthetic installers, maintain Construction Quality Assurance (through cover soil placement), require electrical isolation of both weld flaps, and the use of liner integrity surveys can all improve the performance of the geosynthetic systems by multiple orders of magnitude.

It is difficult to separate the contributions of geosynthetic installer selection, CQA, the selection of materials that contribute to and the conduction of liner integrity surveys and other factors that positively affect the performance of geosynthetic barrier systems, as these are generally used in combination. Once an owner, engineer, general contractor or risk management participant understands the contribution of proper geosynthetic selection and installation, <u>all</u> of the described components tend to be used. This is particularly common as the materials being contained become increasingly valuable or hazardous. However, when the costs of remediation and impact of a potential failure are considered, the benefit of these techniques and materials are obvious.

REFERENCES

ASTM D5820 - 95(2011) Standard Practice for Pressurized Air Channel Evaluation of Dual Seamed Geomembrane, American Society for Testing and Materials, West Conshohocken, Pennsylvania, USA.

ASTM D7002 – 10 (2010), Standard Practice for Leak Location on Exposed Geomembranes Using the Water Puddle System", American Society for Testing and Materials, West Conshohocken, Pennsylvania, USA

ASTM D 7007 – 09 (2009), "Standard Practices for Electrical Methods for Locating Leaks in Geomembranes Covered with Water or Earth Materials", American Society for Testing and Materials, West Conshohocken, Pennsylvania, USA.

ASTM D7177-05(2010) Standard Specification for Air Channel Evaluation of Polyvinyl Chloride (PVC) Dual Track Seamed Geomembranes, American Society for Testing and Materials, West Conshohocken, Pennsylvania, USA.

ASTM D7240 - 06(2011), "Standard Practice for Leak Location using Geomembranes with an Insulating Layer in Intimate Contact with a Conductive Layer via Electrical Capacitance Technique (Conductive Geomembrane Spark Test)", American Society for Testing and Materials, West Conshohocken, Pennsylvania, USA.

ASTM D 7703 – 11 (2011), "Standard Practice for Electrical Leak Location on Exposed Geomembranes Using the Water Lance System", American Society for Testing and Materials, West Conshohocken, Pennsylvania, USA.

Beck, A. (2012) "A Statistical Approach to Minimizing Landfill Leakage", Solid Waste Association of North America,
Washington D.C. Conference Proceedings.

Beck, A., (2012) Beck. "How Much Does my Landfill Leak?" Waste Advantage Magazine,

Bonaparte, R, Daniel, D.E. and Koerner, R.M., "Assessment and Recommendations for Improving the Performance of Waste Containment Systems", EPA/600/R-02/099 EPA National Risk Management Research Laboratory, http://pbadupws.nrc.gov/docs/ML1217/ML12179A248.pdf

Bonaparte, R., Othman, M.A., Rad, N.S., Swan, R.H., and Vander Linde, D.L. (1996) "Evaluation of Various Aspects of GCL Performance", Appendix F in Report of 1995 Workshop on Geosynthetic Clay Liners, D.E. Daniel and H.E. Scranton, authors, EPA/600/R-96/149, EPA National Risk Management Research Laboratory, Cincinnati, OH, pp. F1-F34.

Darilek, Glenn. (2013). "Specifying Allowable Geomembrane Leakage Rates Based on Available Technology", Geosynthetics 2013 Proceedings, , IFAI, Roseville, MN, USA

Forget,B.,Rollin, A.L., and Jacquelin, T. (2005) "Lessons Learned from 10 Years of Leak Detection Surveys on Geomembranes", Proceedings of Sardinia 2005, Sardinia, Italy

Giroud, J.P. and Bonaparte, R. (1989) "Leakage Through Liners Constructed with Geomembranes, Part II: Composite Liners", Geotextiles and Geomembranes, Vol. 8, No. 2, pp. 77-111.

Giroud, J.P., Badu-Tweneboah, K., and Bonaparte, R. (1992) "Rate of Leakage Through a Composite Liner Due to Geombrane Defects", Geotextiles and Geomembranes, Vol. 11, No. 1, pp. 1-28.

GRI GM14: Standard Guide for Selecting Variable Intervals for Taking Geomembrane Destructive Seam Samples Using the Method of Attributes., The Geosynthetic Institute, Folsom, PA USA

GRI-GM20 Standard Guide for Selecting Variable Intervals for Taking Geomembrane Destructive Seam Samples Using Control Charts., The Geosynthetic Institute, Folsom, PA USA

Harpur, W. A., Wilson-Fahmy, R. F., and Koerner, R. M. (1993). "Evaluation of the contact between geosynthetic clay liners and geomembranes in terms of transmissivity," Proceeedings of GRI Seminar on Geosynthetic Liner Systems, Geosynthetic Research Institute, Drexel University, Philadelphia, PA. 143-154.

Koerner, R.M. and Koerner G., (2012) GSI White Paper #26 : “Need for and Justification of Quality Management Systems for Successful Geosynthetic Performance”, The Geosynthetic Institute, Folsom, PA USA.

Laine, D.L., and Darilek, G.T. (1993) "Locating Leaks in Geomembrane Liners of Landfills Covered with Protective Soil", Proceedings, Geosynthetics '93 Conference, Vancouver, B.C., Vol. 3, pp. 1403-1412.

Ramsey, B., Peggs, I. et.al (2012) “New Electrically Conductive Geomembrane For Post Installation Liner Integrity Surveys”,
Proceedings of the Fifth European Geosynthetic Conference, Valencia , Spain, Volume 2, pp-251-256.

Nosko, V., and Touze-Foltz, N., (2000) “Geomembrane Liner Failure: Modelling of Its Influence on Contaminate Transfer”, Proceedings of the Second European Geosynthetic Conference, Patron Editore, Bologna, Italy, pp-557-560.

Rowe, R.K. and Hosney, M.s., (2010) “A Systems Engineering Approach to Minimizing Leachate Leakage from Landfills”, 9th International Conference on Geosynthetics, Brazil 2010, pp. 501-510.