Advancements in Leak Location Technologies for the Control of Geomembranes
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Abstract

Electrical Leak Location (ELL) technologies have proved to be an effective method for locating holes in geomembrane liners. Geomembrane liners are employed throughout the world for large-scale waste or liquid containment. This paper summarizes the capabilities of different leak location methods to locate holes in installed geomembranes and introduces a novel method for also localizing poor subgrade locations in tandem with a leak location survey. Poor subgrade locations attributed to rocks under the geomembrane can lead to breaches in the liner by causing localized stresses as the overburden pressure increases. Even with a rigorous construction quality assurance (CQA) program in place, rogue winds and dragging geomembranes during placement can cause rocks to be deposited on the prepared geomembrane foundation layer. The penetration of rocks through geomembranes has been statistically shown to be the leading cause of holes in geomembranes. By performing the water puddle method (ASTM D7002-03) unacceptable subgrade locations can be found and remedied as part of the water puddle survey for locating existing leaks. The authors' field experience with locating poor subgrade locations during leak location surveys is discussed. Risk analysis for the potential of holes to be formed by poor subgrade has been assessed through puncture testing (ASTM D4833-07) performed by the authors. Puncture testing results are reported for varying subgrade conditions and the implications for geomembrane liner integrity are discussed.

Introduction

ELL surveys can locate holes in installed geomembranes when exposed or covered with water or a relatively thin layer of soil. This technology, developed over twenty five years ago and applied commercially for over twenty years, continues to advance for improved CQA measures. Currently, two survey methods have associated ASTM methods (ASTM D7002-03 and ASTM D7007-03) and are increasingly required by regulatory agencies as a final CQA step for the control of liner integrity in containment facilities. Both survey methods including a technical description and their limitations are described in this paper. In addition to the accepted methods, ELL technology continues to evolve to provide more opportunities for increased CQA. This paper introduces the concept of deep fill surveys, which could expand ELL services to encompass the forensic control of geomembrane leaks in existing deep fill containment facilities. In addition, the control of unacceptable subgrade locations in tandem with a water puddle survey is proposed. The importance of controlling rocks deposited on the subgrade is illustrated by providing the results of puncture testing performed by the Authors. Even a rigorous CQA program does not completely control rocks deposited on the subgrade and the results of the puncture testing presented herein shows that the integrity of a geomembrane can be seriously compromised under high loading conditions.

Dipole Method – ASTM D7007-03

The dipole method is employed for installed geomembranes covered with water or earth material. A DC voltage is applied to the material covering the geomembrane and the power source is grounded to the earth beneath it. The survey area must be isolated from the surrounding ground so that the applied voltage can only travel through holes in the geomembrane in the survey area. In order to locate the sources of electrical leakage, voltage measurements are taken throughout the survey area in a grid pattern. The magnitude of horizontal measurements of voltage potential will increase sharply when approaching a hole location due to the sudden drop in voltage caused by the electrical leakage. The sensitivity of the survey dictates the hole size capable of being located, which can vary from several millimeters to a centimeter for surveys with soil as a cover material, while pinhole leaks can typically be located with water as a cover material. The survey sensitivity is dependent upon the site conditions, but can be increased by the development of survey equipment technology as discussed below.

The success of a dipole survey depends heavily on the conductivity of the material above and below the geomembrane, the thickness of the soil cover material and the boundary conditions. If covered with water, a geomembrane can be surveyed for leaks with a very high sensitivity due to the high conductivity of water. In water, the ELL equipment can be weighted and dragged along the surface of the geomembrane under any depth of liquid. If soil is used as a cover material, the moisture content of the cover material must be monitored to ensure sufficient conductivity. Very compact or clayey soils tend to have a higher conductivity than loose, granular, and non-clayey soils. The thickness of the cover soils is also pivotal for the current survey method, since it relies on horizontal measurements of voltage potential. Once the cover soils reach a certain thickness, the voltage isopotential lines are no longer visible on the surface of the cover soils. The boundary conditions of the survey area are critical because the loss of current through the edges will create a preferential path for current flow and likely prevent current flow through the holes in the geomembrane; essentially the holes become invisible to the ELL operator. Current methods require any soil access roads to be removed or electrically isolated with a geomembrane flap before the performance of a dipole survey.

Until recently, ELL survey technology and equipment has been a closely guarded secret by very few companies offering ELL services. Emerging companies typically hire independent electrical engineers to fabricate equipment for their exclusive use. Now that ELLs are increasingly mandated by regulatory agencies, the demand for equipment has reached the level where it can be a dedicated business. Emerging equipment developers are quickly discovering the closely guarded ELL trade secrets. For example, deep fill surveys have never been commercially available in the United States, though the technology is known to exist to successfully locate leaks under several tens of meters of cover material thickness. Dedicated ELL equipment developers have discovered an AC technology capable of locating leaks. Once commercially available, the AC technology will enable ELL surveys to pinpoint leaks in containment facilities already filled with waste, or heap leach pads in the mining industry that have already begun operations. These leaks would otherwise continue to compromise the surrounding environment and in the case of a heap leach pad, cause valuable solution loss. In addition, ELL equipment developers have discovered a tool for correcting poor boundary conditions by placing "mirror" charges where there is an electrical leak. This tool could enable surveys where permanent conductive pipes, for example, previously precluded a successful survey. AC filter technology in tandem with a typical dipole survey per ASTM D7007-03 will also enable the ELL operator to filter out background noise to create a more sensitive survey, ultimately locating smaller holes than with a DC survey. Although currently in development, it is estimated that the new technology will be commercially available by the end of 2009.

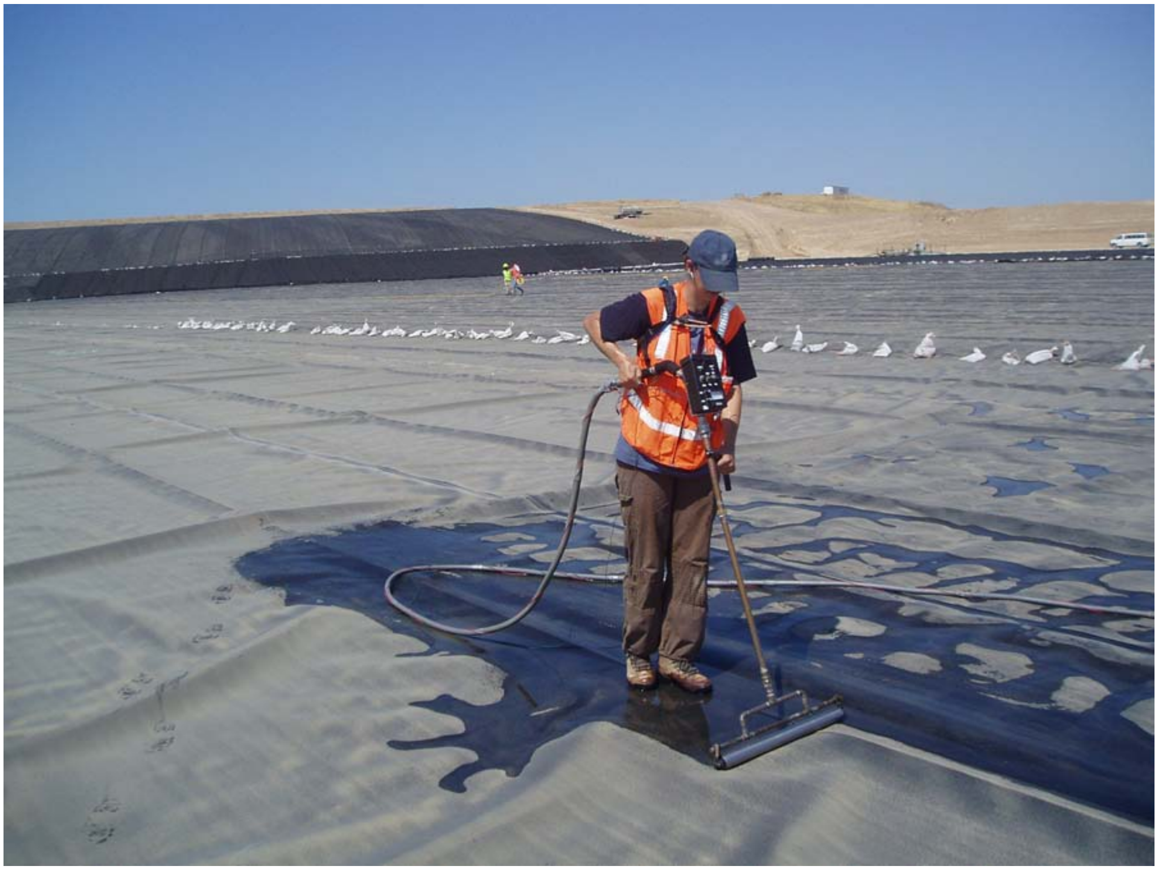
Water Puddle Method – ASTM D7002-03

The water puddle method is employed for exposed geomembranes. It is an extremely sensitive survey capable of locating pinhole leaks. Water charged with a DC voltage is sprayed over the bare geomembrane and the power source is grounded to the earth beneath the liner. ELL equipment consists of an ammeter in series with the DC circuit. If a hole is present through the geomembrane, the circuit will close and the ELL equipment will detect the flow of current through the circuit.

The success of the water puddle method depends on the flow of the applied water through the hole in the geomembrane and intimate contact of the geomembrane to the earth. This is best achieved when the liner is flat, or free from the wrinkles that typically develop during the afternoon in a hot climate. The survey is best performed at night or in overcast conditions. The survey area must also be isolated so that the applied water cannot flow out of the survey area. This would ground out the circuit so that a hole though the liner cannot be located. The current ASTM method does not specify the type of equipment, called a water lance, applying water to the geomembrane. Different types of water lances are employed, from simple water streams to squeegees to metallic contact bars. The water puddle method is not as sensitive on extreme side slopes, since water tends to flow down the surface of the slope rather than through a hole in the liner.

The Author has discovered through field experience the additional benefit of locating poor subgrade locations in tandem with a water puddle survey. A metallic roller bar at the end of the water lance was designed to apply additional pressure to the liner without creating a source of friction that could cause damage to the liner. This enables the operator of the ELL equipment to locate rocks under the geomembrane because the roller is sharply arrested once it encounters the perturbation. In one large-scale project, dozens of hole locations were found along with several hundreds of rocks under the geomembrane. These locations have the potential to become holes once overburden pressure is applied. The metallic roller bar is shown in Figure 1 during a water puddle survey. Several sizes of roller bars are used and the larger, heavier rollers tend to provide superior contact with the subgrade.

Figure 1. Small metallic roller bar assembly during a survey



Although CQA activities require a thorough inspection of the subgrade to provide a smooth and unyielding surface for the installation of a geomembrane, experience has shown that rocks are frequently encountered under installed geomembranes. Rocks can be deposited on the prepared subgrade by high winds, especially during gravel placement operations, or they can be carried from the outside of the construction area when a geomembrane is dragged along the ground during installation. Typical statistics report that most holes located during dipole surveys are caused by rocks against the geomembrane. The puncture testing required in the design of a containment facility is performed using the design specific soil materials, compacted and prepared according to design specifications. Heap leach pads are currently being designed with record high overburden pressures, making the geomembrane puncture performance critical.

Laboratory puncture testing according to ASTM D4833-07 was performed by the Authors to assess the performance of geomembranes in the presence of rocks deposited on the subgrade when subjected to high overburden pressure. 40-mil and 60-mil samples of geomembrane were subjected to a load of approximately 3,400 kPa. The subgrade and overliner material used in the puncture testing were taken from a mining project and prepared similarly to design specifications for a heap leach pad facility. Three rocks were placed on the prepared subgrade of the testing apparatus within the size and type typically found by the authors in poor subgrade locations, as shown in Figure 2. Both tests resulted in punctures of the geomembrane where rocks were present. This is mainly caused by the thinning of the liner to conform to the shape of the rock and extreme pressure restricted to a point on the rock. In areas of the samples without rock placement, the geomembrane exhibited more acceptable deformation behavior. Figures 3 and 4 show the geomembrane samples after subjected to puncture testing. Holes greater than 1 mm were found on the points and edges of the rocks along with a significant thinning and deformation of the geomembrane around the rock locations. These results show that rocks on the subgrade significantly increase the risk of geomembrane perforation during the service life of a containment facility. Therefore, increased control of rocks on the subgrade is necessary, especially when the geomembrane will be subjected to high overburden pressures.

Figure 2. Rocks placed on prepared subgrade

Figure 3. 40-mil geomembrane sample results

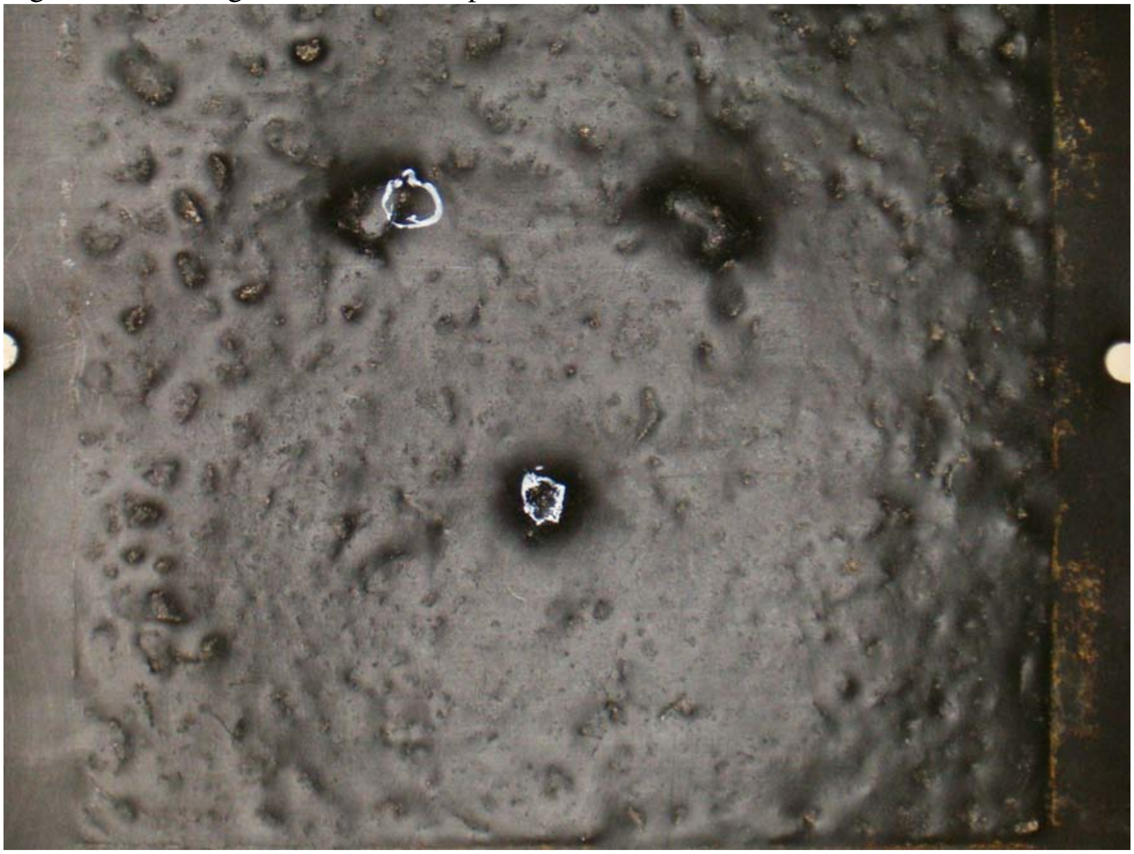


Figure 4. 60-mil geomembrane sample results

Conclusions and Recommendations

Current ELL technology has been successfully locating holes in geomembranes since its inception. Currently, ELL surveys are used almost exclusively for the CQA of new containment facility construction, with the exception of filled ponds. In addition, it has been restricted to simply locating holes rather than controlling subgrade quality. With upcoming advancements in leak location equipment, deep fill surveys will soon be possible. This will expand the capabilities of an ELL survey to encompass existing containment facilities known to contain leaks, but which would be unfeasible to excavate. The addition of subgrade quality control to a water puddle survey is as simple as modifying existing project specifications. When specifying a water puddle survey for a containment facility project, design engineers can simply add an additional request of the ELL contractor to also point out areas of poor subgrade. Since an ELL operator literally covers every square foot of liner during a survey, this adds a large improvement to CQA quality while adding very little extra cost if any. It would then be dependent on the ELL contractor to make sure the water lance equipment is of the type to be able to easily locate rocks deposited on the subgrade.

References

ASTM D 7007, Standard Practices for "Electrical Methods for Locating Leaks in Geomembranes Covered with Water or Earth Materials".

ASTM D 7002, Standard Practices for "Leak Location on Exposed Geomembranes Using the Water Puddle System".