Leak location liner system in environmental containments - China experience

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ABSTRACT: A proper geomembrane installation and associated construction quality assurance (CQA) are always crucial to the long-term performance of geosynthetic lining system. Traditional geomembrane CQA program focuses only on quality of welded seams through destructive and non-destructive tests. To ensure the sealing integrity of installed geomembranes, leak tests and field monitoring are designed to locate leaks in installed geomembranes during and after construction, and even when the facilities are in operation. A new generation leak location liner system has been developed, successfully tested and verified as a reliable and effective technology that significantly enhances the quality of liner leak detection surveys at post-installation and long term monitoring of installed geomembranes during operation. This paper presents two environmental containments located at southwest China that using leak location liner system. The first project is a hazardous waste landfill designing with double liner system, and the other is a demonstration pad carried out at an industrial waste facility. Field investigations performed by third party surveyors have successfully and accurately located the holes that are either occurred during installation process or intentionally placed. Results from the field surveys performed at the two projects in China demonstrated again that the improved leak location liner system associated with electrical liner integrity survey and permanent leak monitoring technology can further reduce the risk of loss of containments, potentially enhances environmental and economy sustainability of geomembrane lined facilities.

Keywords: (geomembrane CQA, leak location liner system, electrical liner integrity survey, permanent leak monitoring)

1 INTRODUCTION

Two environmental containments in Southwest China presented in this paper have the following common features: the waste facilities were lined with high density polyethylene (HDPE) leak location liner (also known as electrically conductive geomembrane) as the primary barrier, associated with electrically spark testing (as per ASTM D7240) conducted on installed liners at field primarily for inspection of post-installation mechanical damage. This is then following with Electrical Liner Integrity Surveys (ELIS) performed on geomembrane covered with shallow soils or water, and a permanent Liner Integrity Monitoring System (LIMS) throughout the operation of the facilities.

The first case study is located at Qujing, a city that is rich with valuable minerals under the ground in Yunan Province, China. To balance the rapid development of the local economy and environment risk, a hazardous waste treatment facility has been planned for several years and it finally started construction in the middle of 2016 and completed in the following year. Two landfill cells, each with total storage capacity of 1 million m^3, have been designed within the facility. The first waste landfill cell has been put into operation recently, and will be receiving non-ferrous metal smelting waste, medical waste of the city and the surrounding areas after the waste has been treated by either solidification or incineration, which are all rated as hazardous wastes.

The second case study is a state owned enterprise that operates a large manufacturing facility in Guizhou province, China. Several industrial chemicals are produced there and the facility includes a large fertilizer (phosphogypsum) processing operation with a gypsum stack of approximately 20 hectares and an average depth of nearly 100 meters. Over the past decades, the area has experienced significant groundwater and surface water contamination. This has therefore attracted attention by the local government. In October 2015, a demonstration pad was constructed on an existing phosphate gypsum stack in Fuquan, Guizhou Province. Phosphate gypsum, a waste containing calcium sulfate generated during the production of phosphorus fertilizer, should be properly contained due to environmental concerns. Owned by a local phosphorus chemical corporation, several large canyon disposal facilities in this mountainous region lined with HDPE geomembrane have been constructed and operating for almost 10 years, and most of which have an average waste height of nearly 100 meters. The existing storage capacity that contains gypsum stack is expected to reach its capacity and hence plans are underway to build vertical expansions that combine two existing gypsum stacks into one, however leak prevention is a challenge to the design engineers in this particular karst geological site condition. It was then decided to construct a test pad to demonstrate the current best available technology and to acquire necessary engineering parameters for inclusion of this liner system in the final design of the site expansion.

2 GEOMEMBRANE PERFORMANCE & ELECTRICAL LINER INTEGRITY SURVEYS (ELIS)

Polyethylene geomembranes have been widely used as primary barriers in environmental containments for more than four decades. Many researches have shown that well-stabilized PE geomembranes perform satisfactorily for decades if they are protected from mechanical aggressions. A proper geomembrane installation and associated construction quality assurance (CQA) are always crucial to the long-term performance of lining system. Many case studies revealed that a well-planned and well-executed CQA produces a high quality containment system. On the contrary, geomembrane will lose parts or all of its functions due to poor CQA. The leakage analysis shows that the installation of a geomembrane with high quality liner installation associated with a complete CQA program reduces liquid losses by 92% at different hydraulic heads over that of poor installation without an effective CQA program. Also, an important note regarding geomembrane liners with "low quality" installations: data and in-house surveys suggest that over 30% of such systems experience a failure that requires either a substantial reconstruction or complete replacement of the system (Beck et al. 2009).

Traditional geomembrane CQA program focuses only on quality of welded seams through destructive and non-destructive tests at field. To ensure the sealing integrity of installed geomembranes, field monitoring and leak integrity tests are required to serve as verification during and after construction, and even when the facilities are in operation. A case study of a landfill in Victoria Australia indicated that 57 holes and 350 dimples were found on the installed HDPE geomembrane through electrical survey at post-installation even though a strict construction quality assurance program has been put in place (Bogoda et al. 2014).

Survey data on occurrence of liner defects reveals that 24% of total amount comes from preliminary construction phase (geomembrane deployment, seam welding, etc.), 73% is related to final construction phase (backfill on geomembrane), defects occurrence at post-construction, early operational phase only takes 2% (Nosko 1996). Figures 1 and 2 are classic examples of such defects. In addition, traditional CQA program is only able to examine the liner quality during preliminary construction phase. These statistical data clearly indicates that to ensure the liner integrity and long term performance, it is crucial to carry out electrical liner integrity survey (ELIS) on the entire installed geomembrane, and this will be an effective supplement to the traditional CQA program. Electrically spark testing on exposed geomembrane (ASTM D 7240) and dipole survey on covered geomembrane (ASTM D 7007) are proven technologies for such surveys performed at the final construction stage. Leak location liner is the geomembrane product that has been tested and verified to be able to enhance the efficiency and accuracy of Electrical Liner Integrity Surveys (ELIS). The combination of leak location liner and combi-modules is the state-of-the-art technology for permanent leak monitoring of the engineering containments.

Figure 1 Defect caused by welding process

Figure 2 Hole caused by oversized aggregates

3 QUJING HAZARDOUS WASTE LANDFILL

3.1 *Description*

The first landfill cell was constructed in June 2017. It is sited and built in a relatively flat area in a mountain region. A double liner system with geo-composite leak detection layer in between was designed for the facility. Single layer liner area exceeds 30km^2. Figure 3 illustrates detailed liner configuration of both bottom and side slope and Figure 4 is an overview of the job site. This is a demonstration project in the region and local government would like to set up a model in order to serve a reference for design and construction of similar hazardous waste containments in future. A 2.0mm white surface leak location liner was selected as the primary liner for accommodating a more effective and accurate leak inspection using electrical liner integrity survey at post installation and after the liner has covered with gravelly soils.

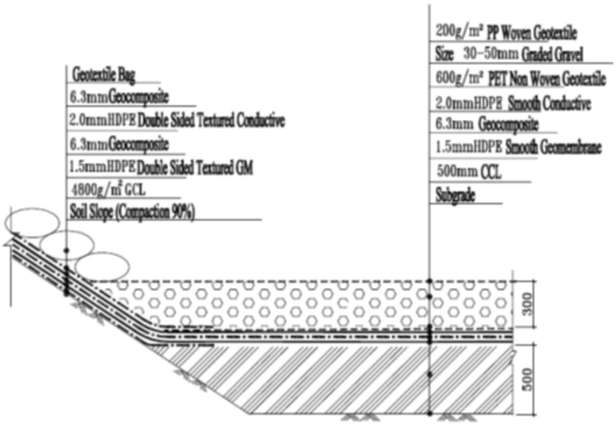

Figure 3 Cross section of liner configuration

Figure 4 Job site overview

3.2 *Leak location liner installation*

Leak location liner has a thin integrated conductive layer at the bottom surface that is usually installed facing down. The installation process of leak location liner is essentially identical with the standard non-conductive geomembrane installation guidelines, with additional measures to be taken to ensure the geomembrane have a well-connecting electrically conductive bottom and a proper isolation of the dual track wedge welded conductive edges, which are generally the key factors to the success of ELIS and LIMS. The following are few important guidelines:

- Use ISOlation-Wedge (Iso-Wedge) for welding the leak location liner. The Iso-Wedge is an improved fusion wedge that breaks the conductivity of the exposed flap from the rest of the sheet at the welded seams so as to avoid false positive signals when performing ELIS. One just needs to replace the standard wedge with Iso-Wedge prior to seam welding and perform trial welding to verify that the Iso-Wedge functions as required (Figures 5 to 7).

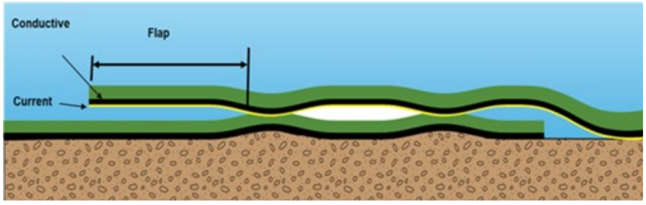

Figure 5 Welding with traditional welding machine

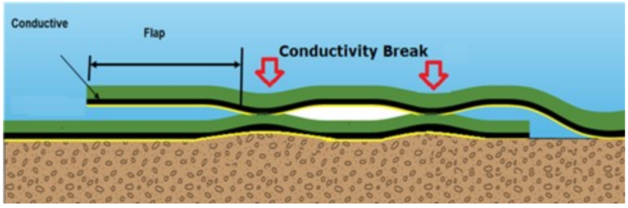

Figure 6 Welding with modified Iso-Wedge machine

Figure 7 Iso-Wedge trial welding

- Place an extra piece of 1m x 1m leak location liner at every 15 meters interval under the welding seam with the conductive layer facing up. This is to enhance the electrical connectivity of two adjacent panels.

The deployment and installation of geosynthetic liner system was carried out a local experienced geosynthetic installer. It took almost 40 days to complete the installation of the liner system. Figure 8 shows thermal welding of Leak Location Liner was in progress at site.

Figure 8 Leak location liner field welding in progress

3.3 *Spark testing and dipole test*

Historically, leak location liner is a specialty polyethylene geomembrane that incorporates an electrically conductive layer and can be utilized for post-installation inspection, i.e., spark testing as per ASTM D7240. To perform spark testing, a high electrical voltage of negative polarity (neoprene pad) is applied to the membrane sheet to be tested, and an electrode of positive polarity (test wand and brush) is then passed over the geomembrane. Any voids in the geomembrane will establish continuity and allow a spark to pass between the geomembrane and the electrode (wand and brush) and trigger the power source alarming. This technology can be used for electrically spark testing of synthetic polyethylene geomembrane for defects and pin holes during manufacturing process (Youngblood et al. 2009). With the development of a specialty geomembrane having an integral outer layer of conductive material, an electrically conductive geomembrane can be electrically spark tested in the field to inspect for post-installation mechanical damage. With the improvement of installation techniques, today the specialty geomembrane also enables ELIS to be effectively performed over entire geomembrane and even with shallow cover soils or water. ELIS as detailed in ASTM D7007 are performed using the concept that if there is a sufficiently conductive medium both above (cover material) and below (subgrade soil or a conductive geomembrane layer) an insulating barrier (geomembrane) and each of these conductive mediums are oppositely electrically charged, electric current will flow towards and through any location where the integrity of the insulating barrier has been compromised. This current flow can then be detected using equipment that measures voltage drop between two measuring points. By taking these voltage drop measurements in a predetermined grid on the cover soil, holes can be pinpointed by finding locations where the current reverses direction (H.B. Ng et al. 2015).

For a conventional non-conductive geomembrane, the conductive mediums must be in intimate contact with the geomembrane so that an electrical connection can be made through any holes in the geomembrane. For single-lined system using nonconductive traditional liner, an electrical liner integrity survey can only be performed successfully provided that the liner is in intimate contact with the subgrade soil that maintains sufficient natural moisture content. However, in most of the applications, that is not always a guaranteed condition to perform an electrical liner integrity survey on traditional geomembrane liner. In addition, covered ELIS cannot be performed easily on a double lined pond where the primary geomembrane liner is separated from the conductive subgrade by a geonet and a secondary liner. Similarly, even in a single lined pond, a hole that is located at the peak of a wrinkle in the liner is unlikely to be detected by ELIS on the traditional liner because the electrical connection is broken by the lack of intimate contact between the hole and the subgrade soil. In addition, in cases where there is a dry subgrade or encapsulated geosynthetics clay liner (GCL), the material beneath the nonconductive traditional liner may not be sufficiently conductive to perform the leak survey (Peggs 2007). However, when using leak location liner, the conductive layer in the geomembrane will serve as the conductive medium at the base of geomembrane and the aforementioned issues are no longer the concerns.

At Qujing hazardous waste landfill job site, leak testing was carried out by a local third party surveyor at post-installation and after the liner has been covered with gravelly soil. Spark testing was performed at the side slope on the installed leak location liner, and the leak integrity dipole test was performed at the base of containment where leak location liner has been covered with a layer of 30cm thick graded gravel. Water was sprayed on the area to be tested in order to enhance the conductivity of gravelly soils placed above the liner. It took about one week to finish the leak testing and integrity survey (Figure 9 and 10).

Figure 9 Spark testing at slopes

Figure 10 Dipole test at bottom

Figure 11 Example of leak detected

Several holes and defects with diameter ranging from 5mm to 50mm were detected and located using the leak location survey (Figure 11). It is believe that these defects and damages were caused during the geomembrane installation and soil backfilling process. All the damages were then repaired with extrusion welds and tested with non-destructive seam vacuum box test before covering back the gravelly soils.

4 FUQUAN PHOSPHATE GYPSUM DEMONTRATION PAD

4.1 *Demonstration pad*

A demonstration test pad of 30m x 30m was constructed on top of an existing gypsum stack. The test pad was prepared with depth of about 30cm and side slope gradient of 4H: 1V. A 60cm deep trench was also constructed to anchor the geomembrane around the peripheral of test pad. The subgrade was properly compacted and levelling before receiving the white surface leak location liner. Figure 12 shows the cross section of the demonstration pad and Figure 13 is an overview of the prepared test pad.

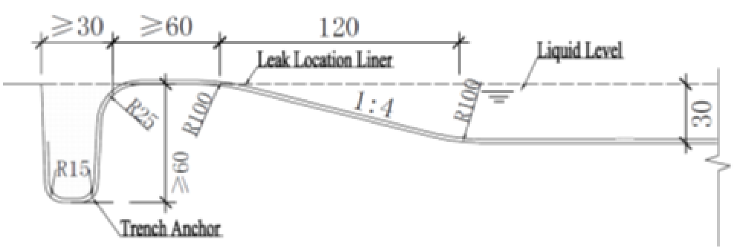

Figure 12 Pad cross section

Figure 13 Overview after liner installation

4.2 *Leak location surveys*

2.0mm white leak location liner used for this demonstration project was deployed and welded according to conductive geomembrane installation guidelines as described in section 3.2 of the paper. Leak location surveys, in the order of spark testing, permanent liner integrity monitoring and dipole test, were implemented on the demonstration pad to verify the effectiveness of every technique means. Spark testing on the entire geomembrane surface completed within few hours. Several installation defects were found and repaired with extrusion welds (Figure 14).

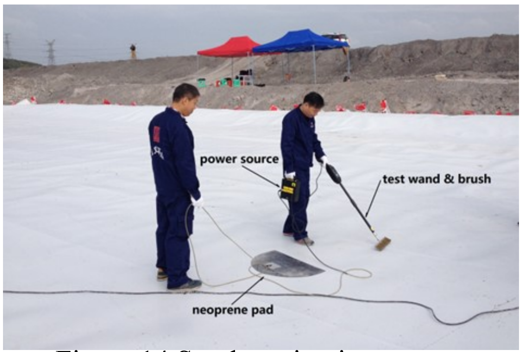

Figure 14 Spark testing in progress

A dipole test (quadrapole) was conducted by a third party surveyor after two "blind" holes were placed by local EPA personnel and test pad was filled up with 30cm thick gypsum (Figure 15). The survey took about one and a half hour to complete and identified leaks that were intentionally placed as the outcome of a 15 minute data review. One of the holes, nearer to the center of the site than the other was very accurately located to a distance of just a few centimeters. The other leak was closer to the edge of the liner and because of some edge distortion effects the accuracy was not quite as good, but still within a 20 to 30 centimeter radius. Figure 16 is the dipole test electric potential diagram with two leaks being detected.

Figure 15 Dipole (quadrapole) test in progress

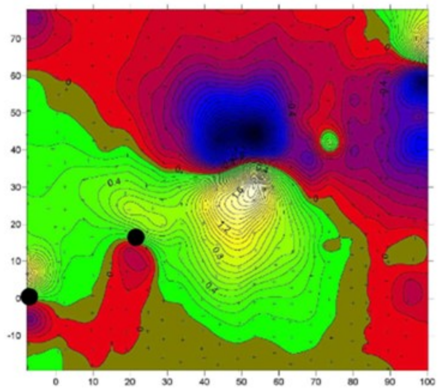

Figure 16 Dipole test electric potential diagram

4.3 *Permanent liner integrity monitoring system*

By integrating combi-modules into the leak location liner as shown in Figure 17, field tests have demonstrated that it is a state-of-the-art technology capable of continuous monitoring and permanent quality control of geomembrane liners during the operation of the facility. Combi-Module is an electronic device that functions both as energy source and sensor. It is rare metal plated and encapsulated into a HDPE casing, thus can last as long as the geosynthetic liner even in the harshest environment. The combi-module is embedded in the liner, for doing so, a hole which is slightly smaller than the combi-module is cut off in the membrane sheet and the sensor's flange is inserted and fixed by extrusion welding along the edge. As shown in Figure 18, an integrated cable wire is assembled on top of the liner and connected with the central monitoring unit placed at the border of the facility (usually indoor environment). The plugged-in central computer unit is responsible for collecting and analyzing data from the combi-modules located at different positions, meanwhile supplies power and activates them (Figure 19).

Figure 17 Combi-Module embedded in leak location liner

Figure 18 Combi-module and cable wire after installed

Figure 19 Central monitoring unit

In the early field test that was performed to ensure the synergies between the leak location liner and combi-module, it was found that when a hole was drilled on the liner, an electrical circuit between the energy source and sensor was formed, and the combi-module closest to the hole received the most significant levels of energy. It was concluded that the conductive layer of leak location liner, independent from the subgrade soil conductivity, provides "electrical super highway" to the generated current, geomembrane welds does no effect on the survey data, and data is complete reproducibility (Weiss et al. 2014).

In the demonstration pad, three combi-modules were designed and integrated into the installed leak location liner. Leak as tiny as 1mm^2, that falls within the triangle area formed by the three combi-modules can be pinpointed. After the installation of leak location liner and combi-modules, and the set -up, calibrations of the central computer unit, a background state was established first. As shown in Figure 20, the site was then flooded with acid water to a depth of between 10-25 centimeters, and officers from local EPA punched a hole, approximately 1.5 centimeters in diameter, through the liner with the absence of all surveyors. The fact is the central computer unit responds quickly within less than 30 seconds after the hole is drilled, receiving data from the three combi-modules to assist in locating the "blind" hole. From the measured data and the subsequent data analysis, the system detected the location of the blind hole with an estimated accuracy within a 1 meter diameter. This calculated location was compared with the actual measured location and was found varied by about 68 centimeters (Figure 21).

The amount and layout of combi-modules designed for leak monitoring depend on the site geometry and the required detection accuracy. When using leak location liner, the area monitored by one combi-module is able to cover up to 3,000m^2, which will provide a substantial reduction in numbers of combi-modules used for the leak monitoring and hence allowing a more cost-effective solution.

Figure 20 Test pad flooded with acid water

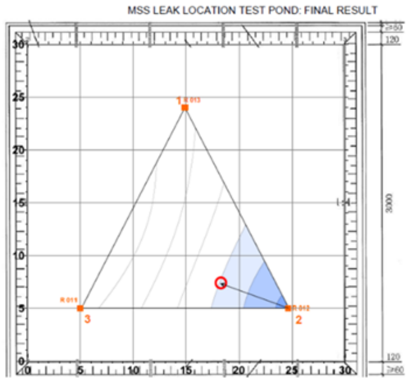

Figure 21 Leak location result

5 SUMMARY AND CONCLUSIONS

A series of leak tests has been successfully performed or demonstrated at two environmental containments in Southwest China. Each leak testing was essential at different construction stages, from the initial deployment to the final construction and operation phases. A few defects on the liner were located accurately, both damages during construction and other intentionally placed damages. Completion of the field leak survey has demonstrated the ability of leak location liner (electrically conductive geomembrane) to be used to facilitate an ELIS and permanent LIMS. Leak surveys at Qujing hazardous waste landfill improved the overall installation quality, minimized the potential leakage through the lining system and contamination to the ground water. Local EPA officers, project owner and design engineers are satisfied with the outcome of the Fuquan gypsum demonstration pad, which provides them a complete solution for the leak prevention at their future gypsum stack projects located at the karst topography landscape. Parameters and methodologies obtained from the demonstration project will be served as a reference for future design and construction of environmental containments in the region.

Leak location liner system, characterized by the patented welding and installation techniques, facilitates a comprehensive liner integrity tests, inclusive of spark testing on exposed leak location liner, dipole test to be performed after the liner has covered with shallow soils or water, and permanent liner integrity monitoring at post-installation and even during the operation of the facility. The new generation leak location liner system has been successfully demonstrated and verified as a reliable and effective technology that significantly enhances the quality of liner leak testing and ensures a safeguard containment system that potentially improves environmental and economy sustainability of geomembrane lined facilities.

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