LEAK MONITORING FOR A DOUBLE LINER SEPARATED BY A NOVEL CONDUCTIVE GEOTEXTILE

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ABSTRACT: A critical double lining system in an anaerobic digester of a waste water treatment plant required assurance of there being no leaks through the primary high density polyethylene (HDPE) liner. Three different types of leak location surveys and monitoring techniques were proposed for implementation prior to filling the basin with water. To enable such surveys to be effective a novel conductive geotextile was placed between the primary geomembrane and the otherwise non-conductive geonet leak detection layer. A permanent in-situ system of sensors was used for the continuous in-service monitoring of the system. Prior to filling the basin, spark testing, wading, and water lance surveys were performed on the primary liner. The few leaks found were repaired. Since filling, through 11 months of service, the liner, under 8 m of water, has recorded zero leakage.

1 INTRODUCTION

There was a massive failure shortly after installation of the geomembrane liner in an anaerobic digester of the wastewater treatment plant at a potato processing facility. Leakage through the bottom liner resulted in gas generation forming a whale in the bottom liner that lifted the floating cover. It was necessary to build a replacement digester for the continued operation of the plant.

2 DIGESTER DESIGN

The new digester was designed and built (Figure 1) with a double 2 mm thick high density polyethylene (HDPE) bottom liner with a geonet leakage detection system. Subsequently a 1.5 mm linear low density polyethylene (LLDPE) floating cover would be installed. The prepared soil subgrade floor was approximately 63 m by 150 m. The 2H:lV compacted soil side slopes were 13 m long with a 2 m high concrete wall at the top. There was no bench at the top of the slopes. The liner was to be taken over the top of the wall and attached with batten strips to the outside of the wall.

Due to the previous liner failure and possible inconvenience of having to remove the floating cover in the event of a liner problem, much regulatory attention was focused on the new liner. Consequently the owner, owner's engineer, and design/build liner contractor were anxious to demonstrate that there were no leaks in the primary geomembrane before the facility was filled with water. This would be a particular challenge due to the presence of many pipe penetrations through the slopes and many concrete pedestals to support influent and effluent pipes placed on top of the liner. A protective strip of liner was placed under each pipe run, and each concrete pedestal was placed on a geotextile pad (Figure 2).

Figure 1. General view of basin

When water was initially placed on the liner it was noticed that there was a bubble of air (Figure 3) under the high end of the protective strip since it had been completely welded to the primary geomembrane. To prevent the possibility of the seam rupturing and tearing theliner under the higher operating hydrostatic head a vent hole was placed in the strip.

To ensure that there would be no leaks in the primary liner it was planned to perform electrical integrity surveys prior to filling with water. In most cases, in order to provide an electrically conductive layer immediately under the primary geomembrane, geonet-only leak detection layers are back-filled with water. This is not too difficult to do on the flat floor of a deep basin, but it is impractical on side slopes. And in this case there were no means provided for removing large amounts of water from between the two liners

Figure 2. Pipe support blocks

Figure 3. Bubble at end of protective strip.

It was planned to install a system of sensors under the primary geomembrane to monitor the occurrence and locations of leaks during basin filling and operation. A total of 430 HDPE sensors were placed on an orthogonal grid pattern with a spacing of 5 m. To facilitate the operation of the installed sensors and to facilitate additional leak survey technologies by providing a required conductive medium directly under the primary geomembrane, a new 360 g/m^2 conductive nonwoven geotextile was placed above the geonet.

Prior to filling the basin the geosynthetic layers were simply draped over the top of the peripheral wall. Sandbags were used to prevent the geosynthetics from slipping back into the basin and, as shown in Figure 1, to push the liner components into the angle between the top of the slope and the base of the wall. This was not very successful due to the rigidity and expansion and contraction of the HDPE geomembrane. The ultimate objective was to allow the rising water to progressively confine the liner against the slope, to push the liner into the corner (while not tensioned), and to confine it against the wall before the liner was battened to the outside of the wall. In this way there would be no danger of the liner bridging (under tension) the angle between slope and wall as the water reached that level, with resultant stressing of the liner under the hydrostatic head.

3 CONDUCTIVE GEOTEXTILE

This is a nonwoven PP staple fiber needlepunched geotextile that is made conductive by mixing the resin with carbon black. This also improves the geotextile's resistance to UV radiation. Electrical resistance (ISO/DIS 10965 at 16 kPa) is less than 10^5 Ohms. Whilst rolls can simply be overlapped to achieve conductivity throughout the layer, in the present project the joints were thermally bonded for maximum electrical conductivity. The geotextile was also draped over the tops of the walls between the primary geomembrane and the geonet.

Prior to placement of the primary geomembrane the in-situ sensors were attached to the geonet with cable ties, then the geonet was overlain by the conductive geotextile and the primary geomembrane. The sensors are conductive HDPE rods cast on to the ends of HDPE-insulated wires as shown in Figure 4. These sensors do not corrode nor do they damage the geomembrane.

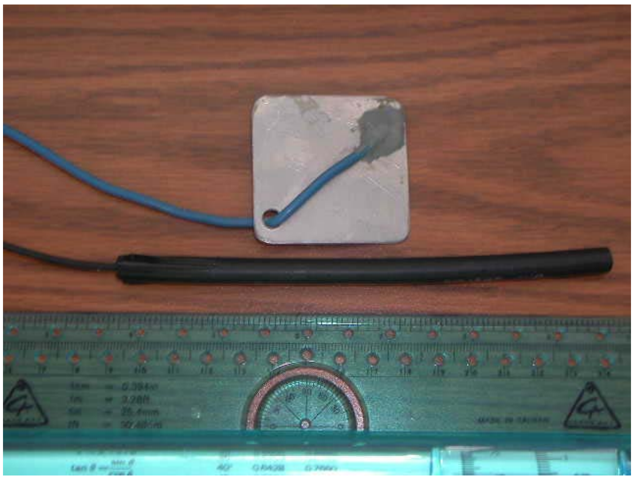

Figure 4. Leak monitoring sensor

4 SURVEY METHODOLOGY

To gain access to the basin an inverted U-shaped welded aluminum ladder was placed over the top of the wall and the liner components. The in-basin end of the ladder reached almost to the bottom of the peripheral wall. A wooden-rung rope ladder was shackled to the bottom of the aluminum ladder to transit the slopes and for performing the electrical surveys on the slopes. The survey was performed to within about 750 mm of the top of the wall.

4.1 *Spark Survey*

Prior to filling the basin, but before all construction work on the liner was completed and the basin filled with water, a preliminary spark survey was performed for the owner over the complete surface of the liner. A potential of 15 kVDC was applied between an electrode clamped to the geotextile outside the wall and a brass brush electrode used to sweep the surface of the primary geomembrane. When a spark discharge was seen or heard the local area was searched for the exact location of the hole. Six leaks were found varying from 1 mm diameter to 60 mm long. All leaks were repaired.

4.2 *Wading and Water Lance Survey*

When all the work had been completed in the basin a combined wading and water lance survey was performed on behalf of the design/build contractor. While a water lance survey could have been performed over the complete liner surface a wading survey has the advantage of forcing the geomembrane into good contact with the conductive substrate and it also induces some service stresses into the liner. This is particularly useful at corners and pipe boots.

The wading survey was performed with approximately 300 mm of water on the floor. A 48 VDC power supply was connected between metal plates clamped to the geotextile at the outside of the wall (Figure 5) and an electrode placed in the water. A handheld adjustable-spacing dipole probe was used to measure the potential gradients in the water, searching for any characteristic high signals above a leak. The balance of the floor, the pipe boots, the slopes, and the walls, were surveyed with the water lance. In this case the positively charged water on the floor was pumped to the water lance directing a solid stream of water on the liner. When the water penetrated a hole and contacted the negatively charged geotextile, current flowed through the water stream between two electrodes in the water lance and was recorded. The leak could be exactly located from the different signals obtained when the water stream was on the dampness around a hole, when the peripheral water was washing over the hole, and when the full stream was directly over the hole. The signal, of course, is proportional to the cross sectional area of the water pathway between the hole and the water lance.

Figure 5. Electrode clamped to conductive geotextile.

5 CALIBRATION

Prior to performing the wading and water lance surveys the equipment was calibrated in several stages.

1) One side of an acrylic calibration cell was sealed with a piece of geomembrane containing a 1 mm diameter hole – a simulated leak. Inside the cell there was an electrode simulating the current return electrode under the actual liner. The cell was filled with water and placed in the basin water. Thus, current injected into the basin water would flow through the calibration hole to the current return electrode in the cell. The survey meter controls were set up to detect this hole quite easily from a distance of 2 m. Therefore, the parallel grid pattern for the wading survey was established with a spacing of 2 m so that the survey probe would pass within 1 m of all holes in the liner.

2) The calibration cell was then placed on dry liner and the equipment calibrated using the water lance. When the water stream fell on the hole a clear signal was obtained. In fact, after the liner around the calibration cell had been wetted the remaining dampness on the liner allowed the hole to be identified from a distance of about 1.5 m.

3) Having shown that the equipment was working satisfactorily, two holes were placed in the primary liner itself to confirm the correct functioning of the conductive geotextile. One hole was a 2 mm diameter hole placed on the flat floor of the basin, while the second hole was 5 mm knife slit on the top of a wrinkle. Both defects were immediately clearly signaled confirming the excellent performance of the geotextile.

In fact, the signal from a small hole would pulse when the stream was removed from the hole, as air bubbles built up over the hole (no signal) then collapsed and the bubble water would run through the hole (signal). This was a graphic demonstration of the sensitivity and response of the technique.

During the production survey the owner's representative used a nail to punch a hole in the liner then asked for the water lance survey to be done in that area. No leak was indicated. The liner was cleaned and probed but no penetrating hole could be physically or visually identified. It was concluded that the nail had not punctured the liner. The engineer made an obvious hole, about 3 mm diameter, in the same area and this was clearly identified.

Towards the end of the complete survey a gouge mark was observed in the liner where the liner was raised off the subgrade between the top of the slope and the base of the wall. Parts of the gouge had clearly been strained beyond the yield point of the HDPE geomembrane. However, no leak signal was generated at the gouge. The installer used a knife to place a definite 7 mm long slit in a yielded section of the gouge. This was clearly signaled as a leak.

Thus the effectiveness of the survey and the conductive geotextile were clearly confirmed.

6 OBSERVATIONS

During the wading and water lance surveys six leak signals were generated over the 1.1 ha area of the liner by or at the following features:

1. A puncture by a 6 mm diameter nail head under the liner
2. An L-shaped cut about 4mm x 6 mm
3. At a pipe boot extrusion weld
4. At another pipe boot
5. At an air pressure test needle hole in a double track fusion seam
6. A 40 mm long deep grinding gouge penetration not covered by extrusion bead at a pipe boot peripheral weld

Leak indication 5 was consistently obtained at the hole (Figure 6). However, a second air pressure test confirmed there to be no leak in the seam. The only explanation is that some fibers from the geotextile had been fused in the weld and were exposed in the air channel. The hole was beaded and the signal no longer present.

Figure 6. Needle hole in fusion seam (right of top of battery)

Indications 3 and 4 were felt not to be leaks to the secondary liner due to the structure of the pipe boot that had several enclosed compartments between the outer weld bead and the geotextile between the liners on the slopes. There were effectively more than two boots to the pipe. It was concluded that the water lance stream had penetrated a hole in the weld bead and contacted the copper wire installed in the bead to facilitate spark testing. When the water contacted the wire the local change in conductivity would generate a change in signal equivalent to a small leak. In both cases the beads were repaired and the signals disappeared. A similar leak-type signal occurred when the stream contacted the aluminum ladders or the wet ropes of the rope ladder that were attached to the aluminum ladders

Worthy of note are two other sites involving composite liners where leaks were indicated through the geomembrane, but vacuum box tests and visual examination were not able to identify the actual leaks. However, when the exposed area was patched in one case, and a T-weld rewelded in the other case, liner leakage stopped. Clearly, if the geomembrane and clay of a composite liner are in intimate contact it is quite possible that a vacuum box test will not draw air up through the leak – it will just make a better seal between clay/GCL and geomembrane. This has been graphically shown for a I mm hole in a geomembrane placed on a GCL that was hydrated overnight before performing the unsuccessful vacuum box test.

7 IN-SITU SURVEYS

During the wading and water lance surveys 5 HDPE electrodes were being attached to the top of the primary geomembrane to complete the in-situ monitoring system. Prior to filling the basin all of the sensors were connected to an on-line data collection monitoring system located outside the peripheral wall. All sensors were confirmed to be functioning correctly and were calibrated. During construction copper wires had been connected to the geotextile at the 3, 6 and 9 m water depth levels to provide an alarm and to record when the water reached these levels. The five sensors above the primary geomembrane acted as one current injection or current return sensor. The in-situ sensors would record the time at which any leakage started and would also facilitate the leak's location by monitoring potentials between the sensors above and below the geomembrane The potential gradients between the sensors above the liner and those closer to the leak below the liner are lower than those to the sensors further away from the leak.

Treated secondary effluent water was first pumped into the pond in October 2002. The lagoon level was slowly raised to a depth of 3 m and no leakage was detected by the system. Once the correct approvals were obtained the lagoon was completely filled in December 2002. In January 2003 the contents of the old lagoon were pumped to the new lagoon system and the lagoon gas cover was installed. The system was brought to full operation in February 2003. Monitoring wells were installed around the periphery of the lagoon to provide secondary leak detection in the event that the in-situ system failed.

There is no specified action leakage rate for the primary liner. However, the liner is considered to be functioning as intended since neither the in-situ leak detection system nor the monitoring wells are showing any signs of leakage.

8 CONCLUSIONS

The new conductive geotextile performs exceptionally well over significant distances and facilitates the performance of elecgtric leak location/integrity surveys on the primary liner of double geomembrane liners separated by a geonet, or other non-conductive leak detection layer, that otherwise could not be surveyed

Leak detection surveys are appropriate and effective as the final stage of liner construction quality assurance (CQA). For the final stage of CQA such surveys would better be termed electrical “integrity” surveys.

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