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Portable methods of locating leaks in liners and their integration

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ABSTRACT: The conventional applied electric potential method of locating leaks in geomembrane lining systems loses its effectiveness when there is direct contact between soils above and beneath the liner, such as around the periphery of an umbrella-type landfill cap, and where an underwater seal to a concrete structure is made with a steel batten strip. In such cases infrared spectroscopy (tracer gas monitoring), acoustic, natural/self potential, and vacuum methods are complementary methods that can contribute to an effective survey.

1 INTRODUCTION

The conventional applied potential method of locating leaks in geomembrane liners requires the following boundary conditions for optimum sensitivity: (1) a conductive medium above the liner, (2) a conductive medium through the leaks being sought, (3) a conductive medium below the liner, from wherever there might be a leak to wherever the ground (current return) electrode is placed, and (4) electrical isolation between the media above and below the liner. In many cases the last is not achieved so other methods have been developed to enable effective surveys to be performed.

2 APPLIED POTENTIAL METHOD

This conventional technology (Laine and Darilek, 1993, Nosko et al, 1996) can be used on liquid-covered and soil-covered liners, and even waste-covered liners (Peggs, 2002). However, problems occur in single liners when a soil cover on top of the liner is in contact with subgrade soil around the periphery of the cell or pond. A similar situation occurs in a landfill cap that is not welded to the bottom liner. The current generated by the potential applied across the liner flows around the edges of the liner rather than through the leaks being sought. The overall sensitivity of the survey is thus compromised, particularly towards the edges where the large background signal of the large current flowing around the edge may swamp and obliterate the much smaller signal from a significant leak. In one case nothing less than a 100 mm diameter hole could be detected in the center of a 36 ha reservoir due to extensive soil contact around the periphery. In another case a 600 mm L-shaped tear about 30 m from the edge could not be detected.

One solution to this situation, of course, is to dig a narrow trench that exposes the geomembrane around the full periphery of the cell or pond. This can be costly and can cause significant damage to the liner.

A similar loss of sensitivity occurs at metal pipe penetrations, pipe penetrations through concrete slabs, at batten strip seals, and even at booted plastic pipes when the water in the pipe is in contact with a metal valve some way down the pipe. The last, however, can easily be resolved with an inflatable rubber plug in the pipe. Other survey techniques are available to complement the applied potential method in the other situations.

3 NATURAL/SELF POTENTIAL METHOD

The NP method is applicable when a geomembrane is placed directly over a soil or concrete layer. When water flows through a mineral layer it strips electrons from the soil particles so generating an electron gradient, thus a current flow, and therefore a potential gradient. The result is a potential low at the start of the flow. Thus, water flowing through a leak in a liner and then through the subgrade soil, generates a potential low at the hole in the geomembrane. A survey probe passed through the water close to the liner can detect these potential lows often from distances of 1 m or more.

This technique has been used to locate leaks in a landfill cap geomembrane which, along one edge became the bottom liner of a narrow strip (~5 m) of wetlands (Figure 1).

Figure 1. Narrow wetlands. Landfill on right, river on left.

The liner was fastened with a metal batten strip to metal sheet pilings that separated the landfill from an adjacent river. Therefore the conventional applied potential technique could not be successful due to the soil and water of the wetlands being connected through the sheet pilings to the soil underneath the liner. Instead, the natural potentials were measured every meter along the edge of the landfill cover stone, along the center of the narrow strip, and about 600 mm from the sheet piling. A reference electrode was placed on the soil surface in the center of the wetlands strip. Several potential lows were found, as shown in Figure 2. Unfortunately none of these locations has yet been excavated.

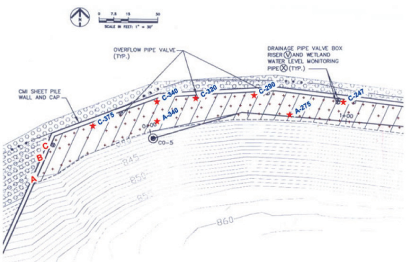

Figure 2. NP survey results.

The technique has also been applied (Peggs, 2002) to a GCL-only liner that could not, since it is not an electrical insulator, be surveyed by the applied potential method. The GCL decorative pond liner was covered by a monolayer of stones which generated an inadequate confining pressure – one of the reasons for its leaking. Potential measurements were made every 600 mm along parallel lines about 1.7 m apart.

Leaks in the GCL itself (such as complete erosion and loss of bentonite, Figure 3), loss of bentonite at overlaps, and through missing sections of batten strip, were found at all suspect locations examined.

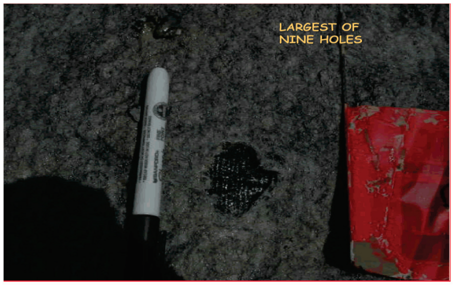

Figure 3. Bentonite erosion in GCL.

The NP technique would also be applicable to locate leaks in the upstream faces of earthen dams and in geomembranes placed on concrete dams.

4 INFRARED SPECTROSCOPY (IRS)

IRS (Peggs and McLaren, 2002) is most applicable for locating leaks in umbrella-type landfill caps. The equipment consists of a portable multi-channel analyzer that is tuned to detect parts per million (ppm) and parts per billion (ppb) concentrations of a characteristic gas, such as methane, carbon dioxide, nitrogen, and sulfur hexafluoride. It is essentially a portable FTIR carried on an all terrain vehicle (ATV). Methane is the obvious signature gas when surveying landfill caps.

The air approximately 100 mm above the soil surface is continuously sampled at ATV speeds up to about 10 km/h. The gas is pulled into a sampling tube and an IR beam passed through the gas to identify the appropriate gas concentration. Methane is analyzed to less than 1 ppm two times every second. The results are plotted in real time on a laptop computer that also displays a GPS map of the path followed. Typically, parallel paths about 2 m apart would be followed. When a high concentration of gas is exactly located the equipment can be used by hand to direct the excavation in the direction of the highest concentration, for with roads, culverts and slopes, the actual leak may be some distance from the peak concentration on the surface. This is quite similar to the influence of pipes, trenches, and corners on the signal generated in the applied potential method. For instance, in an applied electric potential survey, two 250 mm diameter pipes just above the toe of slope produced a peak leak indication signal about 750 mm from the actual location close to the pipes.

In one IRS survey a linear maximum signal about 5 m long (Figure 4) was found, obviously related to a seam in the geomembrane cap. The 600 mm of soil cover was removed to reveal a double wedge seam as expected, but there was no leak at the seam.

The maximum concentration in the excavation was found and the excavation was extended about 300

Figure 4. Linear peak signal (line) on surface.

mm sideways to a large smooth 250 mm rock in the sand drainage layer. The rock had made two holes, about 8 mm and 3 mm diameter in the liner (Figure 5) but the rock was directing the escaping methane towards the seam where it collected under the loose flap and spread along the length of the seam. From the underside of the flap it then moved upwards through the soil to generate the linear defect observed on the surface.

Figure 5. Smooth rock and two holes in cap.

A plot of the GPS track and the leaks found in a 6 ha cap in only 1.5 days are shown in Figure 6. This includes leaks found only a few meters away from the edge of the cap and downwind of an uncapped section of the landfill. In comparison the applied potential method is capable of surveying about 0.8 ha/day with one set of equipment.

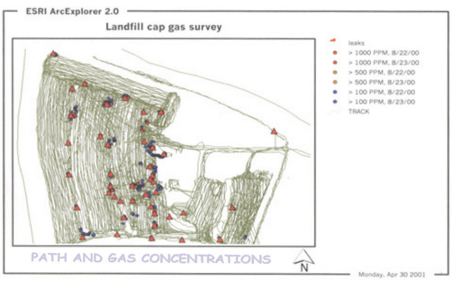

Figure 6. GPS survey track and leak locations.

It was interesting to note that while, in some instances, the location of a leak was evidenced by dead vegetation, in other leak locations the grass appeared quite healthy.

Clearly, the opportunity exists for injecting a characteristic gas under the liner to detect leaks, as has been done with smoke, but this would depend on the topography of the liner, the permeability of the layer under the liner, and the sensitivity of the IRS to the gas used. Sulfur hexafluoride, with detection sensitivity in the parts per billion range would be a good candidate. There also exists the potential for spreading a slow gas (nitrogen?) release chemical on the subgrade prior to placement of the liner over very large areas, such as a heap leach pad or a large evaporation pond, for the very rapid location of leaks, approximately 50 ha/day.

5 ACOUSTIC METHOD

At batten strips and pipe boots, acoustic methods using a very sensitive waterproof microphone can be used to listen for the noise of turbulent water flowing through a leak.

A concrete basin reservoir with many concrete columns supporting a concrete roof was leaking at an unacceptable rate. The liner was attached with a large hose clamp to each of the round concrete columns about 300 mm above the floor. Applied potential surveys were performed with the water level just above the boots and again just below the boots. Some signals were found around the weld at the column/floor corner welds. The follow-up acoustic survey found new leaks at the batten strips, some on the vertical weld of the boot, and some additional ones in the corner weld. It also confirmed the ones previously found, Interestingly, but not surprisingly, in a few cases the location of the acoustic peak was not the same as the electrical peak because the electrical survey locates the opening of the leak on the water side, while the acoustic survey locates the water pouring out of the leak on the underside of the liner. Some leak passages were found to be about 25 mm long.

The acoustic technique can run into background noise problems where there is noise from pumps and other mechanical equipment and where there is water flowing in drains under the liner.

Segmented double lining systems (Robertson, 1990) have also been developed to facilitate vacuum methods of leak detection and location, but have not been widely used.

6 SUBDRAIN FILLING

A GCL-only liner of a waste water treatment plant lagoon was covered by 450 mm of stony soil. On first filling, the lagoon could not be filled to higher than 2.2 m of its designed 3.5 m operating water level. This was before the NP method had been applied to nonconductive liners. Due to high groundwater level, when the pond was emptied water was seen welling upwards through a hole left by a sample in the GCL that had been removed at the low end of the floor. There was an efficient underdrain system to take care of high groundwater levels and the floor of the lagoon had a reasonable slope.

With the demonstration that what can leak down will also leak up, the underdrain system was pumped dry then the groundwater allowed to re-fill the system. The ballast soil on the liner was wet and muddy. As the groundwater filled the system it pushed air ahead of it which exited the system through leaks in the GCL which then bubbled up through the muddy soil/ water cover layer (Figure 7). It was not necessary to have the groundwater itself rising through the leaks.

Figure 7. Air bubbles above GCL leak.

Over 50 leaks were found in a liner area of approximately 1.25 ha (Peggs, 2002). Clearly this approach will only work on specific lining systems.

7 SUMMARY

While the conventional applied potential method of performing liner leak location and integrity surveys is applicable to most lining systems, particularly now that lining systems are being designed so that such surveys can be effectively performed, there are some liner conditions under which it cannot be performed and which therefore may provide a false sense of security. Recollect that there are no signals when there are no leaks. Unfortunately, there are several conditions other than a lack of leaks that will result in no signal being generated, the most common one being connection of cover soil to subgrade soil around the periphery of the liner. Fortunately, there are complementary technologies available that allow effective surveys to be performed under such adverse conditions. And in the case of a landfill cap, whether or not conditions are suitable for the applied potential technique, use of the IRS technique can increase the survey rate from about 0.8 ha/d to about 6 to 15 ha/ d depending on topography.

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