Effectiveness of Quality Control on Geomembrane Installations, based on ELL Surveys

Carl Charpentier[1], Arnaud Budka[2], Thierry Jacquelin[3] & André Rollin[4]
Groupe Alphard, 4560B St-Laurent Blvd, Suite 202, Montreal (Qc), Canada H2T 1R3

ABSTRACT: The use of geomembrane has spread over the world. Standards are now produced and followed everywhere around the globe for selection, installation, quality control and quality assurance. This paper will focus on two (2) areas: quality control of geomembrane installation and leak location surveys. What is the goal of leak location on geomembranes? Prove that the method is working effectively by finding tiny holes? That step is over now, as proofs it can be very precise are easily obtainable. Patch holes to get a lined job as impervious as possible? It sure does. But apart from finding holes, analysing the types of holes, locations, frequency and so should help us getting a better understanding of what's happening out there, and should be used to enhance and improve common practices, such as quality-control of geomembrane installation on-site. Are the QC programs that efficient?

This article aims at sharing a specific operational knowledge earned over the years and to propose improvements or adaptations of geomembrane installer methods. A summary of common mistakes left on the field will be established for the leak location team and for quality assurance companies in order to promote the prevention of specific problems rather than find holes and patch them.

Keywords: Leak location, geomembrane, quality control, best practices

[1] *E-mail: ccharpentier@groupe-alphard.com*

[2] *E-mail: abudka@groupe-alphard.com*

[3] *E-mail: tjacquelin@groupe-alphard.com*

[4] *E-mail: andre.rollin@sympatico.ca*

1 QUALITY CONTROL AND QUALITY ASSURANCE

To help clarify the terms used in this paper, the term "quality control", or QC, will be used to describe the inspection of the quality of the geomembrane installation, including repairs and testing, performed by the installer and included in a standard lining job. The term "quality assurance", or QA, will be used to describe the same tests and measurements used on the geomembrane and repairs, made by an independent third party company.

On The Geosynthetics Institute's (GSI) website, Construction Quality Control (CQC) is defined as:

"A planned system of inspections that is used to directly monitor and control the quality of a construction project. Construction quality control is normally performed by the geosynthetics installer, or for natural soil materials by the earthwork contractor, and is necessary to achieve quality in the constructed or installed system. Construction quality control (CQC) refers to measures taken by the installer or contractor to determine compliance with the requirements for materials and workmanship as stated in the plans and specifications for the project."

In other words, QC, or CQC, represents all the measurements performed on the field to ensure the imperviousness of the geomembranes. It can be directly related to leaks, as when pressurizing an air channel or validating a patch, or it may be related solely to project control, as when noting the serial numbers of geomembrane rolls, or measuring panels. This paper will focus on the field tests performed to locate and repair holes.

2 COMMONLY USED QC METHODS FOR TESTING A GEOMEMBRANE SEAM

The air channel test is performed on thin geomembranes, such as polyethylene (HDPE, LDPE), polyvinyl chloride (PVC), and others. Two panels are welded together using a double-fusion welder, which creates an air channel between the two tracks of the seam. The installer must then obstruct each end of the seam by means of one of multiple ways; the first is to use special clamps on either end. Although fast and reliable, this method often requires that the ends of the seams be cut so as to access the top and bottom of it, therefore requiring those areas to be patched afterward. Another method is to grind the air channel and cap it with an extrusion bead, however before pressurizing the seam, the installer must wait a few minutes after performing the extrusion to allow it to cure, otherwise the cap will break.

Once the air channel is sealed, the quality control technician then inserts a needle through the top liner, straight into the channel, and builds up the pressure inside the seam, to verify that both tracks of the seam are airtight. If the test fails (exceeds a prescribed loss of pressure during a specified length of time), the installer can either try to find the location of the leak (by listening to the air flow in the channel) or extrude the entire tested seam.

The spark test is another method for testing the imperviousness of a seam. It is performed on extrusion welds on polyethylene geomembranes. The installer grinds the geomembrane as usual, however a thin copper wire is then installed lengthwise along the middle of the grind, which is then extruded over (covered). Using a high voltage probe, the installer can survey over the extrusion. A spark will reach the wire if there are any un-welded areas. This way, the installer verifies both sides of an extrusion weld.

The vacuum box is another commonly used device for testing seams. To test leaks in the seam, the vacuum box is placed over the weld, and air is suctioned through any leaks in the weld due to a pump or a shop-vac. The top of the vacuum box is transparent, so the installer is able to see the weld. The geomembrane surface must first be soaked with soap so that any air passing through an un-welded area will produce bubbles that are observable by the quality control technician.

A unique testing method must be used for bituminous liners to validate the 20 cm wide overlap seam. The quality control is performed with an ultra-sound tool that monitors the contact between the two geomembranes to find air bubbles in the seam. Any air bubbles found indicates a poor weld, and the area would need to be repaired (patched), to ensure the imperviousness and strength required. This method is not used to validate an entire seam; only spot checks are performed, mostly where wrinkles are visible or where the geomembrane does not appear to be uniformly welded.

3 LEAK LOCATION METHODS (METHODS USED THROUGHOUT THE YEARS THAT LED TO THIS ARTICLE)

3.1 *Water Puddle Technique*

The water puddle geoelectrical method (as described in ASTM D7002) uses the intrinsic insulation properties of a geomembrane to locate perforations that enable water to pass from one side of the liner to the other (see following figure). A continuous DC voltage is applied into the metallic water lance structure, while a grounded electrode is placed outside of the geomembrane limits in order to intercept any current passing through a perforation. In this case, a visual and auditory signal indicates the presence of a leak. This technique requires only a thin film of water on the surface of the geomembrane and provides a validation of the entire exposed surface.

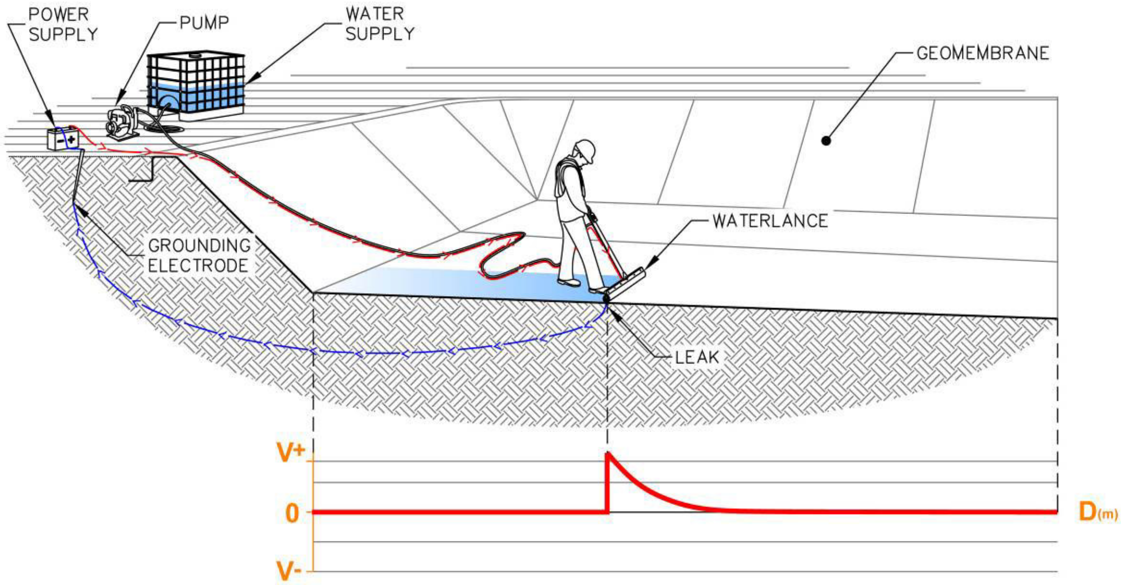

Figure 1. Water puddle schematic

3.2 *Dipole Method*

The dipole geoelectrical method (as in ASTM D7007 standard practice) uses the intrinsic insulation properties of geomembranes to localise perforations that enable water to go from one side of the liner to the other (see following figure). A current of about 500 V is injected into the covering material and a grounding electrode is placed outside the geomembrane limits. Thus, the current must pass through a leak in order to reach the ground (electrode), which generates a distinct electrical field that can be identified and located by a specialized technician.

When applied to covered geomembrane, the dipole method requires that the covering material to be moist enough to allow the electric current to penetrate from above the geomembrane to underneath it in the presence of a leak. Should the calibration of the surface indicate that the material is not sufficiently humid, the surface must be sprayed with water prior to prospection. In order to have a good quality signal, it is also important that the extremities of the covering materials are electrically isolated from the ground outside the limits of the geomembrane, otherwise the diameter of the size of leak that can be detected becomes larger the closer the technician is to the perimeter of the survey area.

Since the dipole method uses geoelectrical properties of the ground, the survey is impossible to perform if the covering or the foundation material is frozen, and less effective if the thickness of the covering material exceeds 1 m.

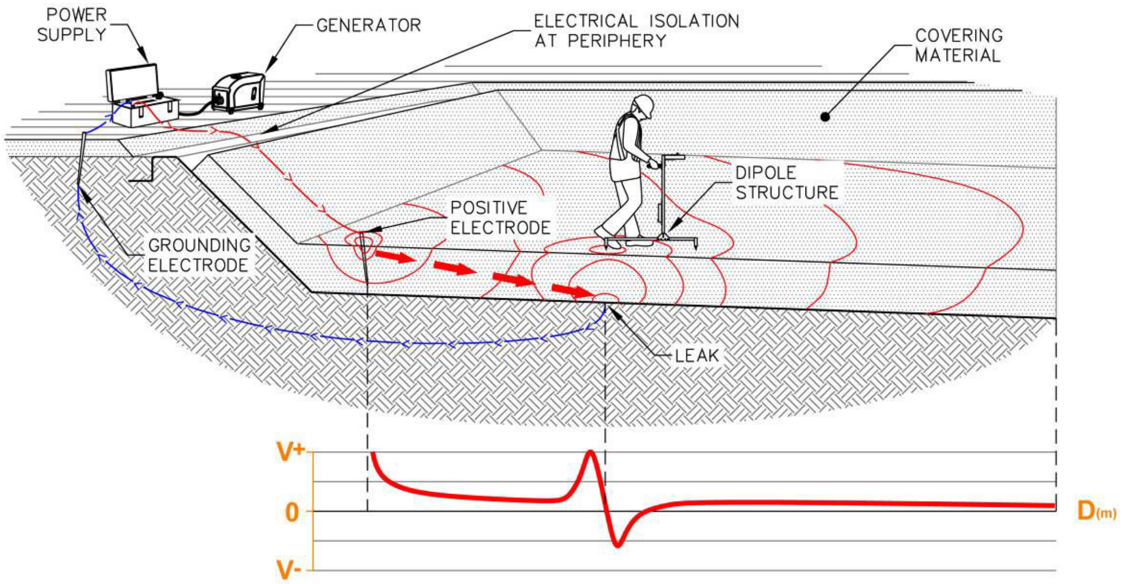

Figure 2. Dipole schematic

4 LEAK LOCATION (ELL), OR LINER INTEGRITY SURVEY OVER QUALITY CONTROLLED AREAS

Electrical Leak Location allows for 100% of the surface to be surveyed. Areas already identified by the QC can be double-checked, and the rest of the surface can be surveyed to find any factory defaults or damage due to transportation or installation. As mentioned in “Lessons Learned from 10 Years of Leak Detection Surveys on Geomembranes by Forget B, Rollin A.L. and Jacquelin T. (2005c)”, approximately 30% of leaks are found at seam edges, and 70% are found on the panels. In the following paragraphs, the defects found using quality control methods will be addressed.

Past results support that the air channel test is effective; it is a fast and reliable technique for testing the quality of the double-fusion seam. It is however, very important to perform it properly. The installer must wait the prescribed amount of time after pressurizing the seam (3 or 5 minutes), make a small cut in the air channel at the far end of the seam, and either hear the air flow out of the seam or see the gage meter needle drop to zero, to ensure that the air channel is not blocked. It should be noted that electrical leak location methods rarely finds leaks in double-fusion seams, because both tracks of the seam must be opened for the water (water lance, water puddle) or the spark (arc tester) reach the subgrade. A single opening in the air channel will not trigger any alarms, as the welding might still be impervious.

As illustrated by Figures 3 and 4, even with a successful air channel test, un-seamed areas and leaks along the edges of the seam can still be present. The origins of such defects can be various: for example, if the geomembrane overlap is too wide, it is forced into the welding machine, which compresses both geomembrane panels and creates a small ripple (Figure 5). As soon as the geomembrane exits the welding machine, it is no longer compressed. As the movement is very rapid and the liner very hot, the geomembrane can tear along the seams, which has been observed in Canada and in France on multiple projects. Other parameters should be considered, like ambient temperature changes, welding fusion temperature and welding machine speed.

Figure 3. Double fusion seam with an obstructed air channel and a large opening missed by the QC

Figure 4. Overlap removed to show numerous holes along the edge of a positively tested air channel

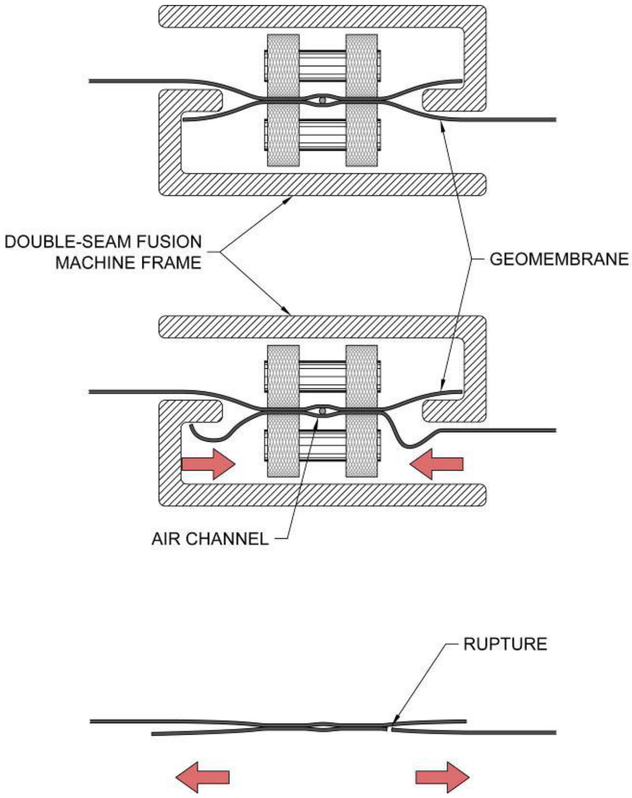

Figure 5. Scheme of a wide overlap squeezed in a double seam fusion machine

Extrusion seams and patches should be controlled using a vacuum box.

The vacuum box technique is widely used, as it is a simple, cheap and relatively reliable test that can occasionally locate defects. Based on past experience however, two major downsides have been identified: the first is that proper suction can only be achieved on an absolutely flat surface. It is very difficult to use this technique at the heel of a slope, or around accessories (pipes) that penetrate the liner without the use of pre-fabricated crossings made from pieces of pre-welded geomembrane. The other downside is that the vacuum box dirties very quickly, as it sucks in air from the sides, which mixes with water, soap and often dirt or sand. As such, the visibility through the box becomes rapidly compromised. Constant cleaning of inside of the vacuum box is mandatory.

Figure 6: VTOK stands for Vacuum Test OK, written 15 cm from a pin-sized hole

The vacuum box test cannot be considered as an absolute verification of a seam; it should be used in conjunction with an ELL survey. Whereas the vacuum box test can detect holes that were not detected during an ELL survey, likewise the ELL survey can detect holes that were not detected during the vacuum box test. It should be noted that the vacuum box test requires the full attention and dedication of the technician, as this method is based on visual observations. It is difficult to sustain the required concentration over an extended period of time; therefore this method should only be used on specific and limited areas such as repairs and extrusions.

The water puddle method uses water as an electrical bridge to reach the subgrade, whereas the vacuum box test uses air. While both methods are used on exposed geomembrane, they are very different, and as such preferentially detect different types of defects. For example, if the subgrade is wet and water was present while repairing an area, or there is water underneath the geomembrane creating a positive pressure, it is easy to locate holes using the water puddle technique. If there is a defect on a steep slope or the repair is dry, and the defect is the result of a poor installation job, the vacuum box has a greater probability of identifying it.

As previously mentioned, the spark test method is used for testing extruded seams. This technique's main limitation is related to the installation of the copper wire. If the copper wire is misplaced (not located in the middle of the seam), a spark will be emitted, regardless of the presence of a leak, forcing the installer to fix the seam. It is imperative that the copper wire be carefully placed to prevent any unnecessary repairs.

A final topic that is related to quality control, but is not an imperviousness test, is the calibration of the welding apparatus. Every installer should have specifications to achieve with regards to the seam strength (peel and shear). A calibration of the welding device is systematically needed to define the welding parameters (temperature, pressure and speed) required to reach the specifications. Non-destructive test methods are not sufficient to determine the seam's properties. For example, tension on the seam, due to the placement of the protective layer of natural materials, or the load applied by trucks circulating over the covered membrane, can cause the seam to peel apart. Figure 7 shows an example of this, which was detected using the dipole method.

Figure 7: Adhesion failure after placement of the protective layer

The ultrasound test is used to find air space (or bubbles) in bituminous geomembrane seams. This method is very sensitive, and results can vary depending on the angle of the device, the pressure on the geomembrane and other survey parameters.

5 OTHER SIGNIFICANT TYPES OF LEAKS IDENTIFIED DURING ELL SURVEYS

ELL methods can locate various types of defects, including unbounded areas on bituminous geomembranes and structural objects, such as piping and walls (Rollin A.L., Fournier J-F. (2001) Biogas Barrier Beneath Buildings: Case Studies Using Geomembranes, geosynthetics'01). The following section reviews the types of perforations most frequently detected and offers recommendations to avoid their occurrence.

Transportation is a huge source of punctures and scratches to the rolls and panels. This is especially true for thick liners, as the rolls and the rolled panels are very heavy. During installation, particular attention should be given to the first few meters of each roll, which should be inspected while freshly installed and still clean.

Knife cuts that penetrate the installed geomembrane are very often found near patches. To avoid the risk of slicing the installed geomembrane, patches should be prepared outside the geomembrane installation area or on a solid and smooth board. Along with cutting patches, knife cuts often occur when knives are dropped on the ground, or when blades are changed and are disposed of improperly, such as on a sandbag where it can easily fall off if the sandbag is moved.

The water puddle method also detects many kinds of scratches that are deep enough to penetrate the geomembrane. Angular or aggressive elements can be introduced onto the geomembrane surface when all-terrain vehicles drive over dirty areas and rocks and then over the geomembrane. If an all-terrain vehicle is needed to transport drains or pipes onto the geomembrane, the transported materials as well as the all-terrain vehicle and the geomembrane should be cleaned of any stone or aggressive element. Rocks can easily damage the geomembrane when dragged across it. Damage can also occur due to more inconspicuous items, such as a power generator that is missing a plastic tip on a leg, toolboxes, or any item in contact with the geomembrane. A person with mud or dirt on their boots can have a stone impeded there, which could scratch the liner. Unnecessary movement on the geomembrane should be kept to a minimum to lower the risk of dropping items or scratching the membrane.

Fusion holes - another category of perforations – are created when the geomembrane melts due to high temperatures. Installers use numerous hot tools, which can slowly melt the geomembrane if they are too close. This can occur if the hot tools (such as an extruder, hot wedge or hot air hand tool) are accidentally misplaced or moved.

Prior to extruding, the HDPE in the extrusion welder must be heated. The heated extrudate must be placed on a board, in a sandbag, or even in a water puddle, so as not to be placed in contact with the geomembrane. The hot residues can easily melt the geomembrane, or fuse to it and then be ripped off, damaging the liner underneath.

Geomembrane can be damaged easily, and any debris is a potential hazard to the integrity of the liner. Defects can originate from nails used to build grade measure tools on the material covering, broken needles from sewing machines (geotextile installation) or even frozen sandbags thrown carelessly. One should always be cautious to ensure that nothing harms the geomembrane.

6 CONCLUSION

The goal of this article was to deliver and present field experiences to illustrate the advantages and drawbacks of commonly used QC tools and methods. If no electrical leak location survey is planned, a strict CQA procedure must be implemented.

This article also illustrates the main potential hazards to the integrity of the geomembrane, which are often easily avoidable, in order reduced the damage to the geomembrane at the source. A leak location survey that finds no holes should be seen as a great accomplishment for the installation crew.

The integrity of the entire surface of the geomembrane cannot be accurately controlled by visual inspection alone. It is nearly impossible to spot defects when the geomembrane is wet or dirty. Additionally, holes can be located under overlaps, or be so tiny that the eye cannot see them.

Are there more quality control test methods still to be developed, new technologies that would make for better and more efficient quality control? For example, on bituminous geomembrane, a new type of ultrasound (or equivalent) device that could verify the whole 20 cm-wide seam would be interesting to develop. Mounted on a calibrated mobile frame with adjustable speed, it could validate the full length of the bituminous seam.

To test for imperviousness, other possibilities aside from geoelectrical surveys should be considered. For example, it can be difficult to perform common leak location surveys on double-lined systems that have geocomposite drainage net between the two layers, even when the secondary layer is flooded. Another way to find holes in a case like this could be to weld both geomembrane layers together along their periphery, to create a type of “sealed geomembrane bag”. Air pressure could be pumped in through an opening in the top geomembrane and then through the geocomposite with a vacuum truck. There are tools available that amplify sound in a very specific direction that could act as detectors, and a trained technician could find air leaks in the top geomembrane.

It is important continuously push test methods and technology further, and to challenge current standards in order to find new ways to improve the quality control performed by the installers, the quality assurance performed by the third parties, and the electrical leak location surveys conducted by the specialised firms.

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