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Air-channel testing landfill geomembrane seams

Results from a recent workshop help minimize destructive testing

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Thermal welding of polyvinyl chloride (PVC) geomembranes is an efficient and cost-effective method of field seaming. PVC geomembranes possess excellent thermal welding characteristics, such as a wide thermal seaming range and a lack of residual stresses or stress cracking. Also, as if with materials such as high-density polyethylene geomembrane, there is no required surface preparation (e.g., grinding). Fully automated welding systems can thermally weld PVC geomembranes as thin as 0.5 mm (20 mil). These welding systems allow the operator to adjust welding speed, nip-roller pressure, and welding temperature to create the best quality single- or dual-track thermal seams. This facilitates field seaming, though PVC geomembranes already call for as many as 80% fewer field seams than for polyethylene geomembranes.

Photo 1. Wedge welding and air-channel testing area at the PGI workshop.

PVC affords the installation contractor the luxury of using three proven seaming methods: chemical fusion, hot wedge or hot air welding. The hot wedge and hot air welding can be performed using a single- or dual-track wedge. Each seaming method has proven itself viable in the field. This versatility of PVC within all of the industries that it has serviced over the past four decades makes PVC geomembrane attractive to the specifying community. For applications such as landfill liner and cover systems where the quality assurance (QA)/quality control (QC) requirements are stringent, dual-track wedge welding may be the engineering community's preferred method because the seam can be air-channel-tested.

On 11 October 2004, a number of PVC Geomembrane Institute (PGI) members assembled at the Colorado Lining International facility near Denver to develop a consensus on the procedure for efficient field dual-track welding and air-channel testing of PVC geomembrane seams for landfill liner and cover systems. The participants in the PGI workshop included PVC geomembrane manufacturers, fabricators, installers, equipment suppliers and landfill designers. The recommended procedure presented herein is most applicable to the extensive QA/QC required by the landfill industry. It is anticipated that this procedure will facilitate third party QA personnel in verifying and documenting the integrity of field PVC geomembrane seams for landfill liner and cover systems. It is not anticipated that the air-channel testing procedure described herein will be required for other PVC geomembrane applications, such as wastewater, golf, decorative or recreational ponds. However, the procedure could be used for these other applications if the QA/QC procedure requires the testing, or if the fabricator/installer desires to utilize the technology.

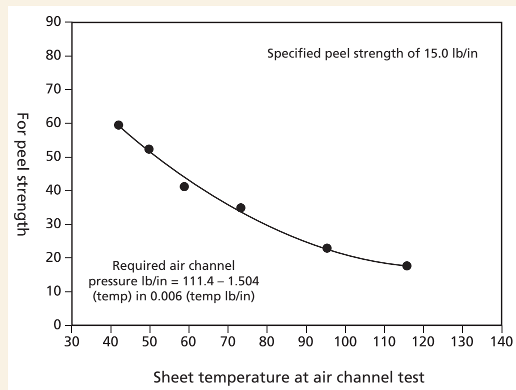

Figure 1. Relationship between the air-channel pressure required to verify a specified field peel strength of 2.6 N/mm and 15.0 lb./in. at various sheet temperatures, from Stark et al. (2004).

Figure 1 shows the welding and air-channel testing being performed under field conditions to ensure the practicality of the welding and testing procedure presented below. The main objective of the PGI welding workshop was to develop a consensus for implementing the relationship

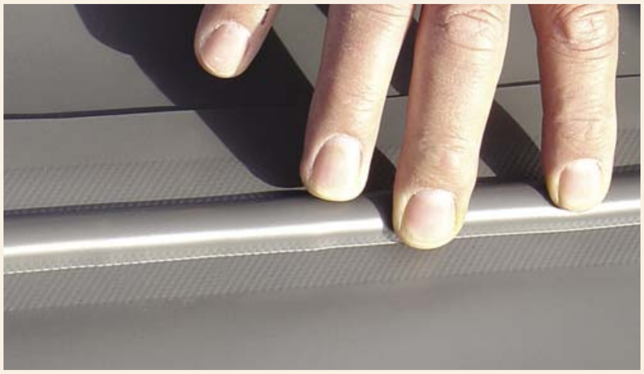

Photo 2. Inflated field seam in 0.75 mm (30 mil) PVC geomembrane.

Photo 3. Air-channel testing of T seam in 30 mil sheet.

between the air-channel pressure—2.6 N/mm (15 psi)—required to verify the PGI-specified seam peel strength (PGI 2004) presented in Stark et al. (2004) and shown in **Figure 1**. The main advantage of the relationship in **Figure 1** is that seam peel strength can be verified from field air-channel nondestructive testing instead of through destructive tests. This leads to a substantial reduction in the destructive sampling of installed PVC geomembrane, as discussed below for the Crown Vantage Landfill in Michigan.

In addition, regulatory agencies (e.g., New York Department of Environmental Quality) are proposing to eliminate destructive sampling and testing for PVC geomembranes if the procedure presented in this article is utilized. Some states, such as Michigan and Minnesota, are considering the same arrangement. This change in regulation is possible because of the relationship between thermally welded seam burst strength and the seam peel strength (ASTM D6392) for a given sheet temperature (**Figure 1**).

An important advantage of the peel strength/burst pressure relationship in **Figure 1** is the ability to test the entire seam length instead of a 1 m coupon. Thus, a peel test is essentially being conducted over the entire length of the seam to ensure the continuity and integrity of the entire seam. The relationship in **Figure 1** is applicable to 0.75 mm (30 mil) thick PVC geomembranes of different colors, e.g., gray and black.

Another important aspect of this air-channel testing is that the flexible nature of a PVC geomembrane allows visual inspection of the entire, inflated seam. This differs from air-channel testing on more rigid types of geomembrane; for those, the inflated channel cannot be as clearly seen. With PVC, the technician can view the seam inflate as pressure migrates along it. The inflated channel resembles somewhat an inflated inner tube; this distinctive behavior is referred to as "tubing." If a weak spot is encountered and results in a leak, the air pressure may not fully inflate beyond that spot. **Photo 2** shows a 0.75 mm (30 mil) thick PVC geomembrane with an inflated air-channel. Note the readily visible, inflated air-channel, how it maintains the air pressure.

Another objective of this workshop was to refine the procedures for welding and air-channel testing of T or butt seams. **Photo 3** shows the air-channel pressurized across the T seam (see arrow). The T seam does not have a detrimental effect on the inflated air-channel.

Another benefit of air-channel testing of PVC seams is that problematic seams are readily visible. For example, **Photo 4** shows a seam "aneurysm" that was discovered during the workshop. It's clearly visible to field personnel.

PVC geomembrane thickness	Maximum allowable air-channel pressure drop kPa (psi)
0.50 mm (20 mil)	35 (5)
0.75 mm (30 mil)	35 (5)
1.00 mm (40 mil)	30 (4)
1.25 mm (50 mil)	30 (40)
1.50 mm (60 mil)	20 (3)

Table 1. Air pressure inflation and maximum pressure drop schedule for PVC geomembranes.

Recommended test procedure

This section presents a detailed procedure for conducting air-channel tests on field PVC seams. To facilitate dual-track welding and, thus, air-channel testing, it is recommended that the subgrade be smooth- drum rolled prior to placement of the PVC geomembrane.

Before pressurizing the air-channel, a wedge-welded seam should be allowed to cool for five minutes. A hot air welded seam should be allowed to cool for about 10 minutes. These times are usually not problematic for production seams because of the length of typical production seams. However, these times may require some waiting for short or trial seams. If the seam is pressurized before it cools, the seam may not be able to accommodate the required air-channel pressure (**Figure 1**). The waiting periods will likely be less in colder temperatures. In addition, care should be taken to ensure that no one stands or walks on a hot seam, as this might cause a blockage that prevents the entire seam length from inflating.

After pressurizing the air-channel, the pressure in the seam should be allowed to stabilize before beginning the test. This stabilization period is usually one to two minutes long. After stabilization, the air channel should hold the pressure indicated by **Figure 1** for at least 30 seconds to ensure that the seam satisfies the required peel and shear strengths. The required air-channel pressure is obtained by measuring the sheet temperature using a thermo-couple or laser/infrared thermometer to obtain the required air-channel pressure in excess of a 2.6 N/mm (15 lb/in) seam peel strength. The air-channel pressure obtained from **Figure 1** is a minimum value.

Of course, the air-channel can be pressured beyond the required value. Because of changes in weather conditions during the test and low elongation of the PVC material that can occur during the test, the air-channel pressure can change 35 kPa (5 psi) during the 30 second or greater holding period for a 30 mil PVC geomembrane. **Table 1** presents the allowable air-channel pressure drop for other thicknesses of PVC geomembrane.

Recommended repair procedure

Defects

If the air-channel does not hold the required pressure, a remedial measure must be applied to the field seam. The location of a leak can usually be readily determined by watching the air-channel inflate from the source to the clamped end of the seam. When the pressure reaches the defect, the channel may have difficulty inflating further.

After the leak is located, the leak is repaired using the following procedure.

- The geomembrane is cut to remove the leak.
- The air channel is tested in both directions from the defect to verify the integrity of the remainder of the seam.
- If the seam passes the test in both directions, a patch is applied over the area of the leak.
- The patch should extend 15 cm on all sides of the leak. The patch can be adhered to the PVC geomembrane using a hot air welder (**Photo 5**) or a solvent weld.
- The patch should be tested using the air lance procedure as described in ASTM D4437.

Photo 4. Aneurysm in 30 mil PVC geomembrane seam.

Aneurysms

Photo 4 shows an aneurysm that can develop from the pressurized air intruding into the welded material. In most cases, the channel will still pressurize and maintain the required air pressure. However, to ensure the long-term integrity of the seam, it is recommended that the amount of incursion of the air-channel into the weld seam be measured and the remedial measure, if any, be a function of the percent intrusion into the weld. The intrusion is calculated by dividing the length of intrusion by the width of the unintruded weld.

The following guidelines are presented for repairing an aneurysm:

- If air-channel incursion is less than or equal to 25% of the weld width, no remedial measure is required.
- If air-channel incursion is greater than 25%, the exposed flap of the geomembrane should be welded down to isolate the aneurysm. The flap should be sealed for a length of 15 cm on all sides of the aneurysm. The sealed flap can be tested using the air lance test described in ASTM Test Method D4437.
- The flap on the underside of the liner does not have to be seamed because the liquid will not reach the underside of the liner.

Photo 5. Hot air welding the upper flap of the geomembrane six inches above and below (see small tic mark near arrow) an aneurysm (large mark on sheet).

Case history

One project at which the air-channel testing of PVC geomembrane seams significantly reduced the number of destructive samples required from the completed liner is the Crown Vantage Landfill in Parchment, Mich. The project involves a 186,050 m^2 (2,000,000 ft.^{2}) final cover system for two cells of a paper mill landfill (**Photo 6**). The first cell was an ash fill requiring 55,650 m^2 (598,040 ft.^{2}) of 0.75 mm (30 mil) thick PVC geomembrane. The geomembrane was placed directly on the fine, black ash material that was compacted on 3H:1V slopes of the cell. The second area was a waste cell that had been covered with 2 ft. of sandy soil. This cell required 130,825 m^2 (1,408,190 ft.^{2}) of PVC geomembrane. The liner was placed directly on the sand layer over the waste on slopes that varied from 5H:1V to 3H:1V.

Photo 6. **Two cells at Crown Vantage Landfill were lined with PVC geomembrane. The seams were air-channel tested using the procedure described in this article.**

The smaller cell required 32 prefabricated panels to cover the footprint. The use of prefabricated panels resulted in only 2,500 meters of field seams for this cell. The Michigan Department of Environmental Quality (MDEQ) requires a destructive sample for every 150 m of completed seam for seams thermally welded in the field. MDEQ requires shear and peel testing on the destructive samples by a third party laboratory. Because air-channel testing was being conducted on this project and the relationship between air-channel pressure and seam peel strength (**Figure 1**) was available, MDEQ required only trial welds be performed by each machine at the start and conclusion of each welding session. This meant trial welds at start up in the morning, before shut down at noon, at start up after any break in welding, and before shut down at the end of the day. Only one destructive sample per day for seam shear and peel strength testing was required regardless of the number of welders being used and regardless of the lineal meters of field seam completed in the day. This large reduction in the amount of destructive samples resulted in a better barrier because of the reduction in the number of patches.

The much larger cell required 72 prefabricated panels to cover the 130,825 m^2 waste pile. Most of the panels for both cells were 30 m wide and 60 m long. Over 7,000 meters of field seam were required to weld the 70 together for the cell. While this amount of field seaming is significant, the length is about 70% less than the approximately 22,875 meters that would have been required if polyethylene membranes had been used. Air-channel testing of the dual-track PVC welds resulted in about 200 fewer destructive samples. That extraordinary reduction has resulted in a better completed barrier.

Cell caps

Ambient temperatures during construction of the smaller cell cap varied from 18 to 33° C (64–91° F). Sheet temperatures varied from 16 to 63° C (61–145° F) during welding operations.

The larger cell cap was constructed in October, when the ambient temperatures ranged from 2° to 28° C (36–81° F). Sheet temperatures also varied greatly from a high of 4 to 49° C (39–120° F). Welder temperatures were set between 200 and 220° C (390–430° F) and welder speeds ranged from 1.5 to 2.5 meters per minute, depending on the sheet temperature.

There were no destructive seam test failures on this portion of the project. The combination of rigorous trial weld testing and air-channel testing of the entire length of every field seam resulted in confidence that every meter of field seam exceeds the minimum strength specifications. Also, there were no air-channel test failures due to below-standard peel strength. The limited air-channel test failures that did occur were confined to holes in T seams where the loose flap of the intersecting field seam had not been trimmed properly.

Conclusion

The purpose of this article is to present a comprehensive procedure for air-channel testing of field PVC geomembrane seams for landfill liner and cover systems. The basis of the air-channel test procedure is the relationship between the required air-channel pressure to satisfy the specified peel strength (i.e., 2.6 N/mm) and the sheet temperature during air-channel testing presented by Stark et al. (2004). The procedure specifies the times for cooling of the thermally welded seam and stabilization of the air-channel pressure. The article also presents procedures for remediating seam defects and aneurysms. It is anticipated that this comprehensive procedure will facilitate the use of air-channel testing for field PVC geomembrane seams in landfill liner and cover systems. GFR

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