Air Channel Test ASTM D 7177 Eliminates Water Balance Test of PVC Geomembrane Lined Surface Impoundment

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ABSTRACT: This paper will present a detailed description of the installation quality control and engineering quality assurance programs implemented on the 73,000 square meter (787,800 Ft^2) PVC geomembrane lagoon system installed at the Village of Manton Wastewater Treatment Lagoon improvement project in Manton, MI USA. Air channel strength testing of dual track thermal welds of PVC geomembranes has been developed to provide quality assurance testing for the full length of PVC geomembrane field welds. This method effectively peel tests every inch of a field weld and eliminates the need for cutting holes in the liner to remove samples in order to perform destructive peel testing on only a small portion of the seam. The testing method was adopted as ASTM D 7177 Standard Specification for Evaluation of Polyvinyl Chloride (PVC) Dual Track Seamed Geomembranes in June 2005 and was first used extensively in the 2006 construction season. The designers at Fleis & Vandenbrink Engineers worked with the Michigan Department of Environmental Quality to eliminate the outdated and obsolete water balance test by requiring air channel testing for PVC geomembrane field seams. The success of this project has provided the basis for implementing this new testing technology in lieu of the water balance test, saving customers precious time and ultimately precious funding for construction of PVC lined surface impoundments.

INTRODUCTION

There is an old cliché about spending more initially for a quality product and saving money in the long run. This paper provides information about how quality PVC geomembrane welding and testing can provide immediate cost savings today to owners, operators and communities.

Thermal welding of PVC material is not a new development. The process has been used for many years in all types of PVC fabrication. However over the past 5 years or so, there have been new developments and improvements in the equipment and techniques for thermal welding of thin, flexible PVC films used as geomembranes. In the process of developing these new techniques and working countless hours in the field with new equipment, it became very apparent to the authors that air channel testing of PVC dual track welded seams was also a strenuous test of the strength and quality of the full length of every weld. While heat welding any thermoplastic geomembrane today is relatively simple, welding long lengths of seam without the slightest imperfection in its peel strength is still quite challenging. This came to light on some of the first projects while developing these PVC air channel testing techniques. For instance, a field seam that had a destructive sample removed (and that sample passed independent laboratory peel testing) failed when air channel tested along its entire length. A large section of that same tested seam had not bonded completely, had passed air lance testing, but began to split open when air channel tested. It was then that the authors were more convinced than ever that air channel testing of PVC geomembranes could in fact measure the strength, and therefore the quality, of the entire length of a weld.

The authors also discovered that thermal welding long lengths of seam (> 60-100M) (200 – 300 ft.) that easily passes an air lance test, would invariably fail an air channel test in some small area, unless the operator was thoroughly trained and the welding machine properly set up. Temperature, speed, and contact pressure are critical to developing a consistent weld in any geomembrane. Welding too hot and traveling too fast are the major detriments to the successful, consistent welding of PVC. They also discovered that too much air pressure at very high sheet temperatures would cause failure in an otherwise passing PVC weld. This is not the case in testing HDPE geomembranes.

Persisting in their belief that air channel testing could provide real time strength testing of PVC welds led others into this research and the eventual development of ASTM D 7177 Standard Specification for Air Channel Evaluation of Polyvinyl Chloride (PVC) Dual Track Seamed Geomembranes. This procedure only applies to the air channel strength testing of PVC geomembrane welds. While there have been serious attempts to develop a similar procedure for testing the full length of other thermoplastic geomembrane welds (i.e. HDPE), none have been successful or standardized.

The Manton project recognized that superior testing of the PVC geomembrane seams by checking both the continuity and strength would render a costly and time consuming water balance test unnecessary. (Not to mention that a water balance test does not identify the defect – it only tells you the lagoon is leaking, but not where.) The project specifications required the Minnesota Water Balance Test be conducted, if all the requirements of the air channel testing were not met to the satisfaction of the Owner. The water balance test essentially consists of filling each lagoon with clean water and measuring any change over a 30 day period. Any water level changes are compared against a control to determine the integrity of the lagoon liner system. The control is typically a barrel placed in or near the lined area or a weather station.

Measurements are taken for four weeks and compared with atmospheric gains and losses to determine the lagoon leakage rate. The downside of the water balance test is the cost of the time it takes, as well as the cost of pumping clean water to fill the lagoons to six feet in depth, and then discharge it again.

CASE STUDY

The Village of Manton in northwest lower Michigan has a wastewater treatment facility utilizing three ponds. The ponds were originally constructed using clay soil as a liner. In 2006 it became necessary to rehabilitate the lagoons and reduce the amount of leakage from the ponds. Elmer's Crane & Dozer, Inc. of Traverse City, MI USA was selected as prime contractor for the project. They performed all of the earth work on the site.

Elmer's selected Environmental Protection, Inc. (EPI) of Mancelona, MI USA to fabricate and install the PVC geomembrane liner system. STS Consultants, Inc. was retained as the independent third party construction quality assurance (CQA) firm to oversee liner installation and testing. 73,000 M^2 of 40 mil PVC geomembrane was required to completely line the lagoons. EPI fabricated the 40 Mil PVC into panels as large as 1,400 M^2 (15,000 square feet -75 feet wide & 200 feet long). These large custom sized panels were used to reduce the amount of field seams required.

The existing lagoon system was made up of three large ponds. The new design would require two of the existing lagoons be renovated to include two settling lagoons (lagoons number two and four) and one aeration basin (lagoon 1a). The third existing lagoon would be removed from service but left intact for future expansion.

In succession, the lagoons were each drained, dewatered, and sludge removed, then excavated down to the original clay liner. Since this project was a rehabilitation of existing lagoons, the engineer also designed a gas venting system into the subgrade that would allow any gases from organic degradation to vent outside the liner and not be trapped below the liner system. A sand cushion layer was then placed over the clay subgrade in preparation for the PVC geomembrane.

The sequence was essentially the same for each lagoon. Once the PVC geomembrane was installed and all testing had been completed, the excavation contractor began placing one foot of cover soil over the entire liner system using heavy equipment and GPS guided bulldozers for finish grading. The side slopes were also covered with rip rap to maintain the cover soil and minimize erosion. Once the excavation, liner placement, and cover soil phase was completed, each individual lagoon was placed back into service prior to beginning work on the next lagoon. The use of the air channel strength test instead of the 30 day water balance test also saved a minimum of one month between the completion of one lagoon and the start of draining the next. This sequence allowed the Village of Manton to continue uninterrupted service during the rehabilitation process.

WELDING

Once the lagoon subgrade was completed, the PVC geomembrane panels were deployed and welded together using Leister Twinny hot air welding machines that produce a dual track weld with an un-bonded air channel between the welds. Fig. 1 provides a close up view of the nip rollers and hot air nozzle that create the two parallel welds with an un-bonded air channel between.

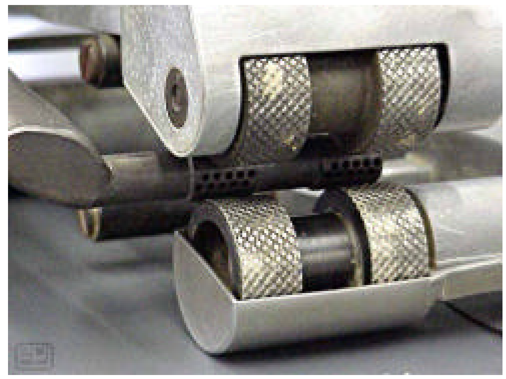

FIG 1: Dual Track Hot Air Welder

Prior to production welding, each machine was configured and trial welds were made. Minimum required peel strength was 2.6 kN/M (15 lb/in width) of specimen and the shear strength requirement was 14 kN/M (77.6 lbs/in width). All trial welds and destructive samples were tested according to ASTM D 6392 Standard Test Method for Determining the Integrity of Nonreinforced Geomembrane Seams. There was approximately 3,700 lineal meters (12,000 feet) of field seam produced on this project. The CQA Engineer removed 26 destructive samples (> 1 sample per 150 M of seam). All destructive samples were tested in EPI's lab, and 50% of the samples (13) had a portion also sent to an independent laboratory (TRI / Environmental, Inc., Austin, TX). All samples met specification requirements when tested according to ASTM D 6392.

AIR CHANNEL TESTING

Air channel testing of the dual track field seams was conducted immediately after the welding was completed and the material had cooled to ambient temperatures. The specifications for this project required all seams be air channel tested according to GRI Test Method GM6. ASTM D 7177 testing requirements specify a minimum pressure for each particular geomembrane sheet temperature. On this project, the ASTM requirements correlated to the GRI GM6 test requirement (GM6 was actually slightly lower than the ASTM requirements.) In addition, the ASTM D 7177 test method will verify seam peel strength, as well as continuity. EPI used the minimum requirements of the ASTM D 7177 method since they were more specific to PVC geomembrane than the requirements of GM6, and provided more confidence to the CQA.

When the air channel is inflated (FIG. 2) to the appropriate test pressure for the material temperature, a peel stress equivalent to 2.6 kN/m (15 lb/in width) is applied to the interior of BOTH sides of the dual track weld. Thus both welds are being tested at the same moment. The peel stress from the interior of the weld is similar to the stress applied to a test specimen in a tensiometer when it is peel tested from the exterior of the weld channel.

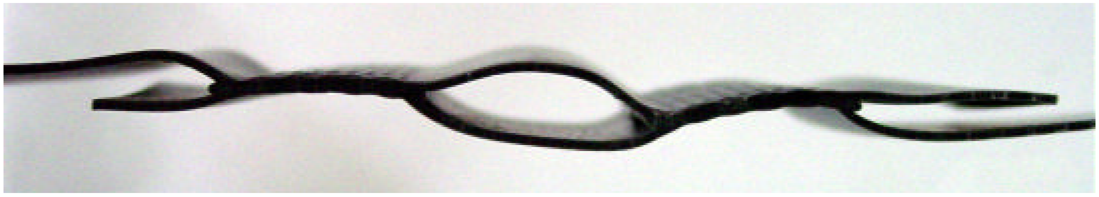

FIG. 2. Exaggerated view of an inflated dual track PVC geomembrane thermal weld produced with a Leister Twinny hot air welder.

Significant research was done on this test method comparing air channel peel pressures to actual laboratory peel specimen test results. "Air Channel Testing of Thermally Bonded PVC Seams", by Thomas, et al. (2003) describes the testing used to develop the relationships between air pressure in the PVC channel and the temperature of the PVC material at the time of testing. These field tests results were then correlated with laboratory test results to develop a relationship between air channel pressures and peel strength of the weld. Further refinements involved testing in cold temperatures with very stiff material, and testing at very high material temperatures. The resulting information produced the following Table 1 which is referred to in ASTM D 7177:

Table 1. Pressure Required to Verify 2.6 kN/M (15 lb/in) Peel Strength for PVC

Sheet Temperature °C	Sheet Temperature °F	Air Pressure KPa	Air Pressure PSI	Hold Time (seconds)
4.5	40	345	50	30
7	45	324	47	30
10	50	310	45	30
13	55	290	42	30
15.5	60	276	40	30
18	65	262	38	30
21	70	241	35	30
24	75	228	33	30
26.5	80	214	31	30
29.5	85	193	28	30
32	90	179	26	30
35	95	165	24	30
37.5	100	152	22	30
40.5	105	138	20	30
43.5	110	131	19	30

The air channel pressures used for this project were between 138 and 214 KPa (20 psi and 31 psi) and typically on the higher end at 165 to 193 KPa (24 psi to 28 psi). Given the sheet temperatures at the time of the tests, the pressures used would ensure the seam strength of the entire length of seam according to ASTM D 7177. Any seam that did not hold the required pressure was investigated to find the leak point and then tested in each direction from the leak. The leak point was then capped with a repair patch after the air channel testing was completed. That repair patch was then tested using the air lance method according to ASTM D 4437.

Understanding the relationship of air pressure to material sheet temperature is critical in testing flexible PVC geomembranes. If the pressure is not high enough, the only test is of continuity, so the pressure needs to be high enough to stress the weld in a peel mode. Conversely, if the pressure is too high (which is often the case at very high material temperatures, i.e. above 32 °C) a passing seam can be compromised. With excessive air pressure in the PVC channel at very high sheet temperature, we are expecting the weld to have much higher peel strength than the standard specification requires, and we cause a seam to “fail” an air channel test when it would normally pass a destructive peel test. There is an inverse relationship of material sheet temperature to air channel pressure when testing PVC geomembrane peel strength.

The ideal scenario would be to have every seam be leak free and without defects over 100% of its length prior to testing. However, the ideal is tough to deliver under field conditions. Rain, dirt, wind, operator error, burn outs… all contribute to problems welding a perfect seam. On this project 71% of the seams were welded and tested over their complete length, welded error free, without holes. As operators and equipment improve, this rate will also improve.

AIR CHANNEL TESTING “T-SEAMS”

ALL field seams must be tested and T-seams can be difficult if not welded properly. T-seams are defined as a point in the seam where three layers of material overlap each other. This occurs at the point that a dual track field weld crosses a factory seam, usually at a 90 degree angle. The PVC geomembrane factory welded panels on this project were made up of strips of PVC material 193 cm (76 inches) wide.

Referring to Fig.3, each panel is made up of 12 strips of 193 cm (76 inch) wide PVC, each 61 M (200 feet) long. The factory seams are vertical in Fig.3. There are eleven factory seams in each panel. The lines shown on Fig. 3 are the field seams. There is approximately 1,200 M (4,000 feet) of simple two panel overlap field seam in this lagoon (the vertical field seams shown). Approximately 400 M

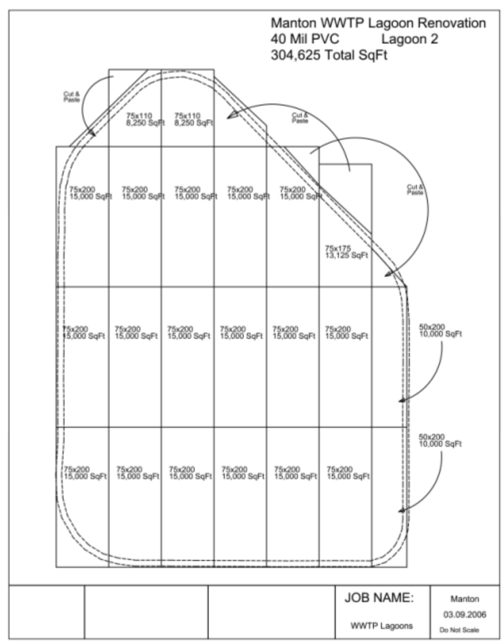

FIG. 3. Panel Layout Dwg – Lagoon 2

(1,225 feet) of seam (the horizontal seams shown in Fig. 3) are typical T-seams where the end of one factory panel over laps the end of another factory panel. Since the

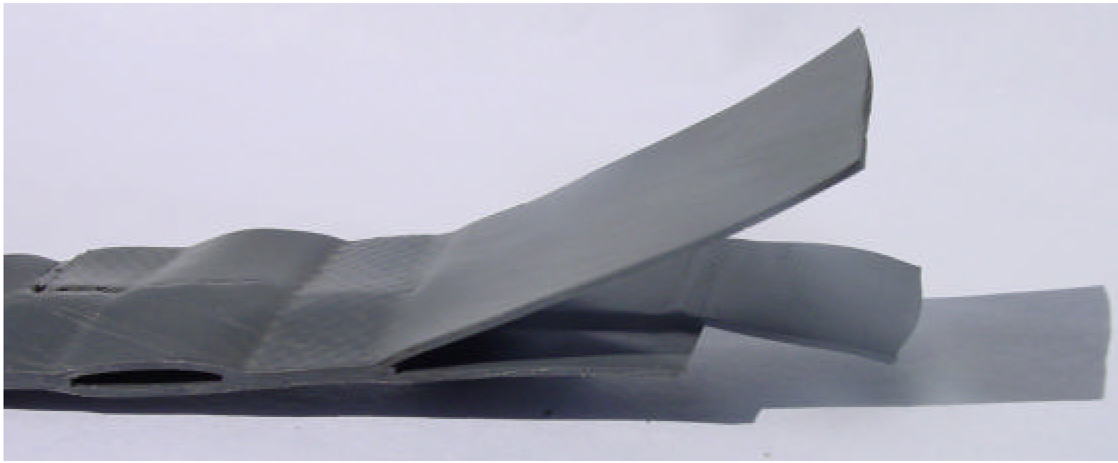

FIG. 4. Specimen from PVC geomembrane T-Seam

factory seams don't normally line up exactly from the end of one panel to the end of the next panel, one of these horizontal seams could have a potential of 146 T's in that weld. There is an additional T-seam created at the end of each field seam. The field T-seam must be specially prepared so that there is no un-bonded edge where the welder crosses the previously welded field seam.

The air channel test over each "T" requires great care in welding (FIG. 4) in order to eliminate leaks and be able to proficiently perform air channel testing. There is a potential at each "T" to have a very tiny hole at the junction of the three layers of material. This is another key reason why air channel testing of every seam is critical to the integrity of the liner system – finding and eliminating these holes. Special care is taken by the welding technicians when setting up the welder to make sure this type of overlap is completely sealed, so the air channel test can be used to verify strength and continuity of these seams also.

On this project the factory seams had no loose edge, so the process for welding T-seams in PVC was relatively easy. Slowing the welding machine's rate of travel allowed the melted PVC material to flow together at the junction of the three layers of material, providing the necessary seal and weld strength. If there is a loose edge on the factory seams, then each loose edge will need to be trimmed, similar to the process used on field welds which intersect other seams. On this project all factory panel end seams were tested over their entire length.

CONCLUSIONS

The downside of the water balance test is the cost of the time it takes, as well as the cost of pumping clean water to fill the lagoons, and then discharging it again. If the test indicates that the pond is leaking, there is no way to know where the leak may be. On the Manton project, eliminating the water balance test of each lagoon saved at least 90 days from the construction schedule and the pumping millions of gallons of water.

Air channel testing for continuity and peel strength on all PVC field welds gives the regulators, engineers and owner the assurance that every inch of field seam exceeds the minimum specified strength requirements. Investing in a superior welding and weld testing system saved the community of Manton significant construction time and significant real dollars.

REFERENCES

ASTM D 7177. Standard Specification for Air Channel Evaluation of Polyvinyl Chloride (PVC) Dual Track Seamed Geomembranes, *American Society for Testing and Materials*, West Conshohocken, Pennsylvania, USA.

ASTM D 4437, Standard Practice for Determining the Integrity of Field Seams Used in Joining Flexible Polymeric Sheet Geomembranes, *American Society for Testing and Materials*, West Conshohocken, Pennsylvania, USA.

ASTM D 6392. Standard Test Method for Determining the Integrity of Nonreinforced Geomembrane Seams Produced Using Thermo-Fusion Methods, *American Society for Testing and Materials*, West Conshohocken, Pennsylvania, USA.

GRI Test Method GM6. Standard Practice for Pressurized Air Channel Test of Dual Seamed Geomembranes, *Geosynthetic Research Institute*, Folsom, Pennsylvania, USA.

Thomas, R.W. and Stark, T. D., "Air Channel Testing of Thermally Bonded PVC Seams," September 4, 2002

Thomas, R. W., Stark, T. D., and Choi, H., "Air Channel Testing of Thermally Bonded PVC Seams," *Geosynthetics International Journal*, Industrial Fabrics Association International (IFAI), Vol 10, No. 3, October 2003, pp. 645-659.

Thomas, R.W. and Stark, T. D., "Air-Channel Testing of Thermally Bonded PVC Geomembrane Seams," *Geotechnical Fabrics Report*, Industrial Fabrics Association International, Vol 20, No. 8, October 2003, p. 10.

Stark, T. D., Choi, H., and Thomas, R. W., "Low Temperature Air Channel Testing of Thermally Bonded PVC Seams," International Association of Geosynthetic Installers, Industrial Fabrics Association International (IFAI), Vol 4, Issue 1, Winter 2004, pp. 5-7.